HOW TO ELIMINATE MAN-MADE INTERFERENCE

46RH-1

PIONEER HOME STUDY RADIO SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 46

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 4. **Answer Lesson Questions and Mail Your Answers to NRI for Grading.**

☐ 5. **Start Studying the Next Lesson.**

NPC6M750 1950 Edition Printed in U. S. A.

How To Eliminate Man-Made Interference

A GROWING PROBLEM

THE radio public is today being supplied with receivers of greater sensitivity than ever before; short-wave reception of foreign as well as local programs is an accepted feature of the modern home receiver, and listeners are gradually becoming conscious of the superior performance of high fidelity receivers. These three important factors make the problem of man-made interference more and more important as new receivers reach the hands of the public.

Radio receiver manufacturers are now capable of building receivers which create only a negligible amount of interference within themselves; older receivers which develop internal noise can readily be repaired by the Radio-Trician, but still program-spoiling interference increases.

Oil burners, electric power-generating systems, refrigerators, motor-driven appliances, medical equipment, electric signs and scores of other new electrical appliances are man's contributions to radio receiver interference. Thus man creates more interfenence at the same time that he builds radio receivers which are more sensitive to interference; profitable work for the serviceman trained in interference elimination is the result. Remember that no radio installation is complete and satisfactory until it is as free from interference as is humanly possible. The man who can render this interference elimination service efficiently and intelligently will "cash in" on an opportunity for profit and prestige which grows bigger every day.

NOISE NOT DUE TO RECEIVER DEFECTS

We know that when noise is heard in a receiver, the first step is to eliminate receiver defects as possible causes of the trouble. A line filter is inserted in the power line of the receiver, the antenna and ground leads are disconnected from the receiver, and antenna and ground binding posts are shorted together; if, when this is done, the noise disappears or is reduced an appreciable amount, the trouble is definitely not a receiver defect. It is, therefore, an external disturbance which can or cannot be eliminated, depending upon its nature.

External noise disturbances which cannot be eliminated may be divided into two groups: (1), those due to *local* electrical storms or lightning; (2), those due to the accumulated effects of distant electrical storms, sun disturbances and disturbances created by distant industrial or electro-medical equipment.

The new frequency modulation system of broadcasting almost completely eliminates atmospheric interference, but both broadcasting systems (f.m. and a.m.) have serious man-made interference problems.

The accumulated noise disturbance is often referred to as background noise; * this has a definite level (microvolts per meter) which will vary with the antenna location. Industrial towns and cities will usually have a high noise level, this being exceptionally high near factories and shopping centers. The only remedy in such cases is to cut down the sensitivity of the receiver or confine tuning to broadcasts whose intensities are much greater than the noise level. In localities of high noise level the customer should be taught to listen only to local or high-powered stations.

When receivers having automatic volume control are tuned off a broadcast signal, the AVC acts to boost the gain, and background noise becomes disturbingly prominent. This has led to the development and use of inter-carrier noise suppressors, found on a number of receivers.

Man-made static, usually of local origin and having an intensity comparable with that of the normal received signal, is often so annoying that the usefulness of a receiver is destroyed. It is the purpose of this text to show the origin of such disturbances and suggest ways and means of eliminating or at least greatly reducing such interference. The "cure" is generally applied in two steps: first, by seeking to keep the noise signal out of the receiver; and second, by "killing" the interference at its source.

ORIGIN AND NATURE OF NOISE SIGNALS

Wherever there is an electric spark or arc, there you will find a source of possible noise interference. The spark need not be large or even visible to create a disturbing effect. Contrary to general belief, the spark itself does not radiate interference, nor is it generally true that the spark creates a broadcast band radiation.

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* This background noise should not be confused with noise originating within the receiver due to thermal agitation of the electrons in the conductors and to the impact or shot effect of electrons as they hit the plates of vacuum tubes. It is this noise which is heard when antenna and ground terminals of a high quality receiver are shorted and the gain turned up.

A spark is accompanied by a sudden current change in the circuit where it originates, the change being transmitted to all parts of the circuit. This sharp current change gives rise to a fundamental audio frequency noise signal whose frequency depends upon the duration of a single disturbance, and a large number of audio and super-audio frequency harmonics of this fundamental. These noise signals may reach the receiver by conductive, magnetic or capacitive coupling, and may either affect the audio stages directly or, more likely, enter a resonant R.F. circuit. The latter is more troublesome, for through shock-excitation it results in the formation of an R.F. current which is modulated with the original noise signal. Because the original noise signal wave form is not destroyed or altered, the expert is usually able to judge, after listening to the noise emitted from the loudspeaker, what the probable source of interference may be.

When a spark occurs in an electric circuit, the current surge is transmitted through the connecting wires, away from the origin of the spark, in both directions * and out of phase. In a power transmission circuit this means that a large area—several blocks—will be affected. This disturbance will continue to travel until it is dissipated by the system. If the circuit contains transformers or other circuit-changing components, part of the disturbance will be reflected back to the origin at the first of these points, be reflected again at the disturbance source, and continue to travel back and forth until the losses in the circuit wipe out the disturbance. The remainder of the surge passes through the first obstacle and out over the line to the next, where it in turn is partially reflected, partially transmitted.

Whenever the surge of current meets an electrical obstacle in the line, be it a transformer, a change in wiring construction, or even a noise-eliminating filter introduced into the line improperly by an untrained radio man, the surge moves back and forth between its origin and this point, creating a standing wave or ultra high frequency oscillation whose frequency is determined by the line length. This wave is radiated through space in much the same way that R.F. currents are radiated by a transmitter antenna.

Sparks in auto ignition systems are typical examples; because the ignition wires are short, the natural wavelength of the radiation is somewhere between 1 and 10 meters. This explains why 5 to 10 meter ultra short-wave reception is so greatly affected by auto ignition disturbance.

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* If you were to drop a stone in a long trough filled with water, the disturbance would likewise travel away from the source to both ends of the trough, and then would be reflected back to the origin of the disturbance.

Bear in mind that a spark or arc produces a current surge or impulse which is fundamentally of an A.F. or super-audio frequency. Because the circuit in which this impulse is created has reflecting points ultra high frequency radiations are produced. The original A.F. impulse currents, flowing along the transmission lines, also produce strong magnetic and electrostatic lines of force which may travel an appreciable distance through space. Magnetic and electrostatic interference fields of this nature get into the radio receiver through the aerial and ground, over the power supply lines or directly through the chassis. As these impulse fields induce strong impulse voltages in the R.F. or I.F. oscillatory circuits, forced oscillations modulated by the original noise currents are produced.

A study of Fig. *1*, which shows a typical "man-made static" problem, will bring out many of the facts just discussed. An electric motor, located in a house, is sparking at *S*, one of the brushes. Impulse current, therefore, passes out of the feeder line to points marked *1*, where a part divides to flow to points *2* and *4*, and the remainder is reflected back to the motor to produce a radiation whose wavelength is determined by the distance between *S* and *1*. At point *2* the impulse current will again divide, a part going to house *B* before being reflected back. The radio antenna on house *B* picks up noise radiation from all electric wires in the house and from the power line system, and the radio receiver itself receives the impulse current directly through the power line. A radio in house *B*, therefore, picks up more interference than a radio in house *C*, which is unwired and therefore receives noise signals only through space.

It would appear that because of the parallel power leads in this system, out-of-phase impulse currents in the two wires would produce canceling fields. This is not true, because spark *S* is rarely produced in the electrical center of the disturbing device. In this example, where sparking is occurring at one brush, one impulse passes directly into the line while the other passes through the armature and the other brush first. The inductance of the armature thus reduces the strength of one of the impulse current signals and prevents cancellation of the currents. It is safe to say that any line which is connected electrically to a spark source will send out an interfering induction field.

Reflection of the current impulses at points *1*, *2*, *3*, and *4* produces standing waves on the line; radio waves modulated with noise signals are, therefore, radiated by the line to create troublesome interference in all-wave receivers.

REDUCING MAN-MADE INTERFERENCE

In tackling any interference-elimination job, the practical aspects of the problem must be carefully considered, and even human nature itself must not be overlooked. Broadly speaking, however, the interference-eliminating procedure may be divided as follows: *1*, eliminate or reduce the sparking, if possible; *2*, prevent the interfering current impulses from leaving the disturbing device; *3*, prevent the various interfering signals from reaching and affecting the radio receiver. It is generally conceded that elimination of interference at its source is the best procedure, but in cases where this is impractical, filters and other devices which will keep the signal out of the radio receiver must be used.

Reducing the interference at its source is not always the simplest

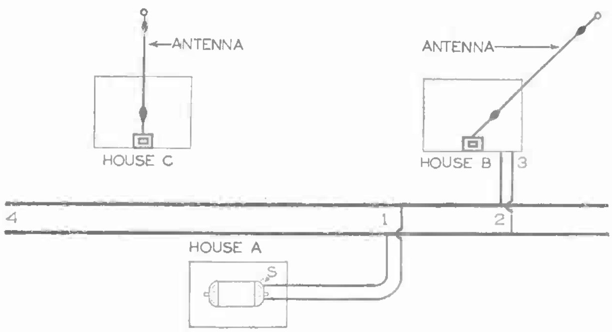


FIG. 1. Diagram illustrating how interference created by sparking brush *S* on motor in house *A* can reach radio sets in vicinity.

procedure, nor is it always permitted by the owner of the disturbing device. If a customer calls you on an interference job and you can directly trace the trouble to some device in the customer's home, the logical procedure is to kill the interference at its source. On the other hand, where your tests show that the interference is being created outside of the customer's home, you must decide whether to search for the location of the interfering device or prevent the interference from affecting your customer's receiver; remember that once a disturbing device is located you must convince its owner that there is a need for interference-eliminating work, and that this work will make his own receiver more free from interference.

After proving to yourself that the chassis of the receiver in question is not picking up noise directly (which of course includes trying a line filter to prove that the interference is not coming in over the power line), your next important move is to install a noise-reducing antenna. You cannot, of course, guarantee that this will entirely eliminate noise interference troubles in the receiver, but you can be sure that it will improve radio reception as well as give a worth-while reduction in interference pick-up. Always make this perfectly clear to a customer who is ordering a noise-reducing antenna. Then, if the antenna fails in its primary purpose, you will not be blamed by the customer for something which is beyond your control, and you will be allowed to tackle the more difficult procedure of locating and eliminating the source of interference.

NOISE-REDUCING ANTENNAS

You are already sufficiently familiar with noise-reducing antennas, so they will not be discussed in detail in this lesson. The type of antenna which you select for a job depends upon the type of receiver encountered, the antenna location, and to some extent upon your personal preferences gained through experience with the products of different manufacturers. An all-wave receiver calls for an all-wave antenna, while a broadcast band antenna should be put up where only American broadcast band stations are to be received. The length of the antenna and lead-in wires will vary according to the space available.

The effectiveness of any noise-reducing antenna depends upon your ability to locate this antenna in a position where it will pick up a minimum of noise interference. You can determine the ideal position with a battery receiver, using a loop or pole antenna and moving the set about until you locate a zone where the least noise is heard, but these three general rules for locating noise-reducing antennas will often allow you to "spot" a good location at a glance: *1*, Place the antenna as high as is reasonably possible, keeping all unshielded vertical wires short; *2*, keep the horizontal or straightaway portion of the antenna at a maximum distance from known sources of interference; *3*, place the horizontal portion at right angles to nearby trolley lines, main power lines or transmission lines. The antenna on house *C* in Fig. *1*, for example, is at right angles to the main power line running from points 2 to 4; the antenna on house *B* is not at right angles to this line, and is, according to the general rule, incorrectly placed. This antenna may actually give better results than an antenna which is perpendicular to the power line, for oftentimes interference radiated from various points will cancel itself in certain regions. If an antenna erected according to general rules fails to reduce the noise sufficiently.

try it in various directions. An antenna located in a noise-free zone, with the shielded or twisted leads correctly balanced and grounded, may be expected to prevent pick-up of noise signals.

In a few instances it may be necessary to locate the exposed portion of the antenna at distances as great as 1,000 feet from the receiver, in order to get the antenna into a noise-free zone. Very little signal strength is lost by a long lead-in such as this, provided that both the antenna and the receiver are correctly impedance-matched to the lead-in, using shielded R.F. transformers for this purpose. Quite often, as in locations near railroad tracks along which run high tension power lines, or in locations near high power cross-country transmission lines, the placing of the antenna at a remote point is the only practical solution to the problem of interference elimination.

SUPPRESSING NOISE AT THE SOURCE

Assuming for the moment that the disturbing device has been located, you will invariably find it to be a spark, an arc or a rubbing condition. (All conductors such as pipes in homes acquire electrical charges; rubbing together of two of these pipes results in current impulses which cause interference.) If the spark or arc is not essential to the operation of the device, it should be eliminated or reduced in intensity. Rubbing parts should either be completely insulated from each other or bonded together with flexible metallic braid or stranded wire.

When the sparking can neither be eliminated nor reduced, the logical procedure is to prevent the current impulses from flowing any distance away from the device. For this purpose filters consisting of condensers alone, or combinations of condensers with choke coils, are available and in general use. The correct sizes for these condensers and choke coils are usually quite difficult to determine in advance: it is necessary to try different values and use the smallest electrical sizes which satisfactorily stop the interference.

The most commonly used coil-and-condenser combinations for filtering or blocking impulse currents are shown in Fig. *2*. That shown at *A*, consisting simply of a condenser connected across the power line as close as possible to the noise source, is often quite effective as a filter. The shunt capacity provides a low impedance path back to the noise source for the high frequency component of the impulse current, lessening the tendency for this current to flow out over the power line. When this condenser is installed on a vacuum cleaner, for example, it should preferably be connected to the terminals of the motor and not across the outlet plug terminals on the wall. If possible, try grounding the metal frame of the offending device; a *short* ground lead oftentimes reduces interference appreciably. All condensers used for filtering purposes on 110- or 220-volt A.C. power lines should have peak voltage ratings of between 600 and 1,000 volts, for these units must withstand high voltage surges caused by impulse currents.

When trying various filter combinations, it is important that some one listen to the receiver to note the effectiveness of each combination when the disturbing device is not within "ear shot" of the receiver. Oftentimes the customer will be only too glad to listen to the receiver for you, but better results can generally be obtained with a trained assistant. If you are working alone, it is wise to set up a portable battery receiver near the location of the disturbing device, using headphones rather than a loudspeaker if the interference noise proves too annoying to those nearby.

With the filter shown at *A* in Fig. *2*, there is no assurance that the impulse currents will pass to ground; the balanced condenser filter, having its center points grounded as shown at *B*, is therefore more effective.

When condensers of a reasonably high capacity, such as 1-mfd. units, fail to give satisfactory noise reduction when used alone, a combination condenser-and-choke filter like that shown at *C* should be tried. This is essentially a brute filter which allows only very low frequency currents to pass through to the power line. The higher the electrical values of the coil and condenser, the better is the filtering action. Always use the smallest commercially available size which gives satisfactory results, for purposes of economy. The condenser may be connected either to the load side of the choke coil (*C*) or to the line side of the choke coil (*D*). As a rule, however, the closer the choke is to the source of interference (*D*), the better is the impulse filtering action. Try the choke coil in one power lead first, then the other, to ascertain which position gives the better reduction in noise.

Two choke coils and one condenser connected either as at *E* or *F* will often give improved results, while the grounded combinations shown at *G, H* and *I* are even better filter combinations. Where several different parts of a device are sparking, such as in commutator type switches for signs or groups of contacts on a relay, then each line which carries impulse currents should be filtered in the manner shown at *J*. A choke coil is inserted in each line, and a suitable condenser connected from the load side of each line to ground.

Improved suppression of interference is often obtained by using a balanced filter having a ground connection which can be electrically varied in the manner shown at *K;* this circuit is otherwise essentially the same as those shown at *G* and *H*. The same balancing scheme can be used with the simple two-condenser filter shown at *B;* a 100-ohm potentiometer, with its variable tap grounded, is connected between the two condensers.

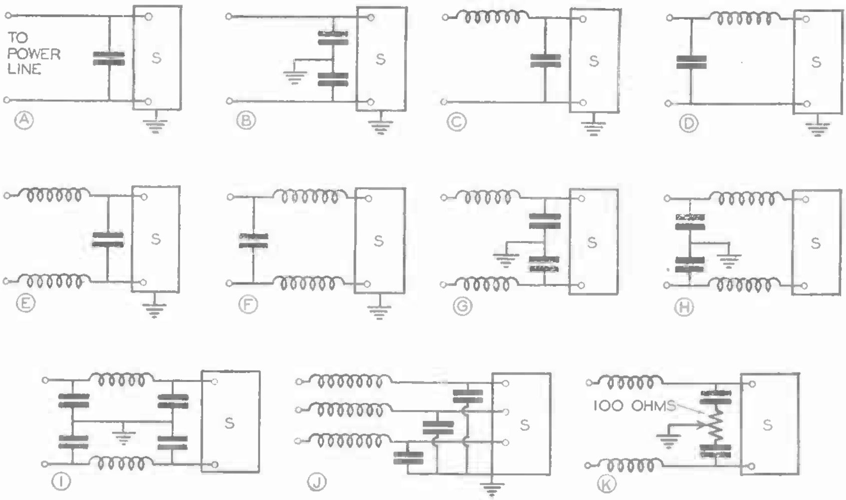


FIG. 2. Condenser filters and condenser-coil filters are here arranged approximately in the order of their effectiveness, the circuit at *I* being the most effective for interference eliminating purposes. Circuit *J* is used with devices which have three make-and-break contacts or with a three-phase load, while circuit *K* is a variation of circuit *G*, which permits adjustment of the ground point. Grounding of *S*, the disturbing device, is optional in circuits *A* through *F*.

A TEST DEVICE FOR DETERMINING THE MOST EFFECTIVE FILTER

Any serviceman, having located an interference-producing device, can almost always secure an effective cure by installing an expensive filter like that shown at *I* in Fig. *2*. But cost to the customer must also be considered in a successful noise elimination job. If noise-free reception costs too much, many people will forego the use of their receivers or endure the noise, rather than pay the price; this is clearly not an encouraging condition for the radio sales and service business. Experience has proven that a satisfactory job done at the lowest possible cost to the customer—a charge which gives a fair profit—is one of the most important requirements for success in radio servicing. This means that the simplest and lowest cost filtering devices should always be tried first, working up gradually to the more complicated and more expensive combinations until the lowest cost unit is found which gives satisfactory filtering.

A variable filter combination system which gives a choice of circuit combination *A, B, C, D, G* or *H* in Fig. *2* simply by changing the setting of a rotary switch and changing connections to the unit is shown schematically in Fig. *3*. All condensers used here should preferably have working voltage ratings of between 600 and 1,000 volts, while the choke coils should be capable of handling at least 5 amperes. Use non-inductive paper type condensers mounted in metal cases which can be grounded. Notice that two outlet receptacles, each having a plug-in cap with insulated alligator clips attached to flexible leads, are used for the input and output connections. A ground connection is made by means of a flexible lead having at one end a prong

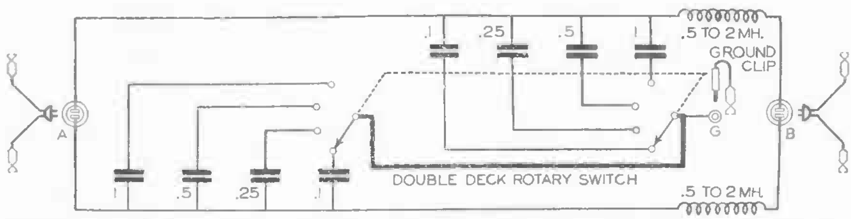


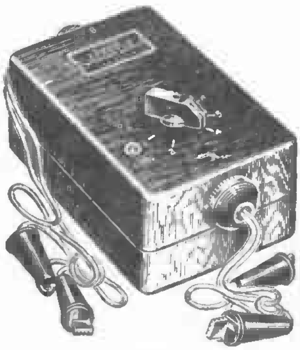
FIG. 3. Circuit diagram of a variable filter combination system which you can easily make for use in determining the most effective filter combination for an interference-creating device. Connections are made by plugging into standard electrical receptacles at *A* and *B*, and by plugging test prong into pup jack *G*. Mount parts in box of convenient size. Be sure power is off before making connections. The filter circuits provided here are those most generally used.

which plugs into a "pup" jack on the unit; at the other end of this lead is an alligator clip which is to be attached to the frame of the interfering device or to a grounded object.

When side *A* of this variable filter circuit is connected to the offending device, the condensers are next to the source of noise; when side *B* is connected to the device, the choke coils are closest to the source of noise. Single condenser connections and single choke and condenser filters are obtained by using one lead at *A*, one at *B* and the ground connection. When using condensers alone, always start with the lowest capacity, increasing the capacity up to 1 mfd. before resorting to choke coils. In making this test filter, be sure to use only those parts which can be readily obtained from radio supply houses at any time, for once the best filter setting is found, you must duplicate the parts used at that setting.

The method just described for using a variable filter combination system to determine the correct filter for a given job was first introduced by the Sprague Products Company; the interference analyzer which they developed for this purpose is shown in Fig. *4A,* while the circuit diagram of their analyzer appears in Fig. *4B*. This device is used in much the same way as that which was just described. The condensers and choke coils used in the Sprague Analyzer are exactly the same as the units supplied by the Sprague Products Company for use in interference filters; several of these are shown in Fig. *5*. The choke coil is capable of handling currents up to 10 amperes; where larger currents must be filtered, larger capacity chokes can be obtained.

When the condensers and choke coils required for a noise elimination job cannot be readily installed inside or on the disturbing device, it is wise from the standpoint of eliminating fire hazards, securing a shock-proof installation and improving the general appearance of the installation, to mount the condensers and chokes in a standard electrical cut-out box such as is shown in Fig. *6*. This procedure is compulsory for heavy-duty electrical devices which must pass fire underwriters' specifications and the regulations of local electrical inspectors.



COURTESY SPRAGUE PRODUCTS CO.

FIG. 4A. This Sprague Interference Analyzer is one of the serviceman's most effective weapons in the war against man-made radio interference. The knob on top controls the circuit-selecting rotary switch.

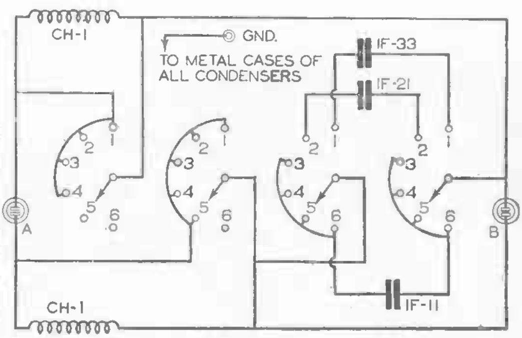
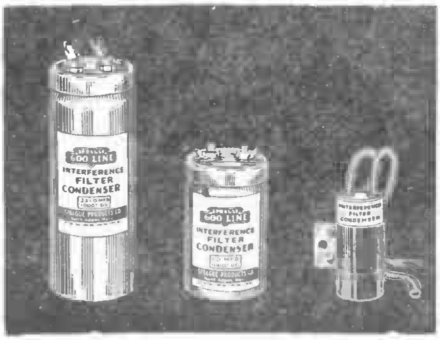


FIG. 4B. Circuit diagram of Sprague Interference Analyzer; numbers alongside condensers and choke coils refer to special interference elimination condensers and chokes sold by the Sprague Products Company, and shown in Fig. 5. A four-deck switch with six contacts per deck gives six different combinations of filtering units. Connections are made by inserting standard connecting plugs into the receptacles at A and B, and by plugging a test prong into the pup jack marked GND. Condenser IF-11 is of the dual-unit type, with the metal case serving as the common grounded connection. Positions 3 to 6 give balanced condenser filters.

As you already know, a filter unit must be placed as close as possible to the source of sparking if it is to be effective in reducing noise. When a cut-out box is used, the leads connecting it to the source of disturbance should be run through BX conduit or iron pipes, this conduit being permanently clamped at one end to the cut-out box and at the other end to the disturbing device; if necessary, a separate ground wire should be clamped or soldered to the conduit. This shielding procedure will prevent the standing waves, formed on the connecting wires, from radiating modulated disturbance waves of low wavelengths, which might cause interference in ultra high frequency receivers.

As a rule, interference filters have little effect upon the sparking or arcing itself, and serve only to prevent the current impulses from getting into the power line. Quite often the sparking at relay contacts, switch contacts and other make-and-break contacts can be greatly reduced by using a resistor in series with a single filter condenser connected across the spark source. This connection is especially



Courtesy Sprague Products Co.

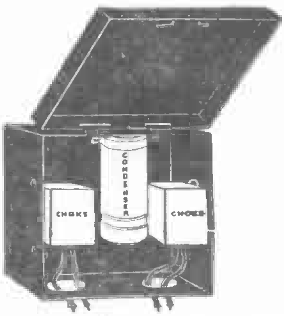
FIG. 5. Typical interference elimination units. Left to right: Sprague Type IF-11 dual 1 mfd., 600 volt condenser with metal can serving as common terminal; Sprague Type IF-50 single 1 mfd., 1,000 volt condenser unit with two terminals; Sprague Type IF-33, 1,000 volt rating condenser with two flexible leads, available in two capacities; Sprague Type CH-1 special interference eliminating choke coil (above), rated to carry 10 amperes and mounted in a metal case which should always be grounded.

worthwhile if you wish to prevent sparking contacts from pitting badly and producing even more serious disturbances at a later date.

THE NOISE DETECTIVE

You now know what to do once an interference-producing device is located; locating the offending device itself is another problem, however, and one which often calls for systematic thinking and even detective work. A well-trained interference-elimination technician can listen to the noise coming in over a radio receiver, ask a few questions of the customer and from these observations get clues which will permit rapid isolation of the offending device. Just as a detective asks questions when searching for a criminal, so should the Radio-Trician ask questions when on an interference job. When was the noise last heard? At what time of the day or night is it usually heard? Is the noise always the same in character? When was the noise first heard? These are questions whose answers may give you clues to the solution of the problem. The opinion of the customer as to the source of the trouble is also of value. Ask if the noise began about the time that some one in the neighborhood bought an electric refrigerator, a vacuum cleaner, fruit juice extractor, or other electrical appliance; try to associate the beginning of the interference noise with the arrival of a new neighbor, the installation of traffic lights at the corner, or the installation of a new neon sign in a nearby store. Neighborhood gossip can provide useful tips for the noise detective.

The value of knowing the time when interference noises are heard can easily be demonstrated. For example, interference heard for a



Courtesy Sprague Products Co.

FIG. 6A. The required combination of interference eliminating chokes and condensers should be mounted in a steel cut-out box like this, with all wires to the sparking device being run through BX conduit or pipe to meet fire underwriters' regulations and give a more efficient installation.

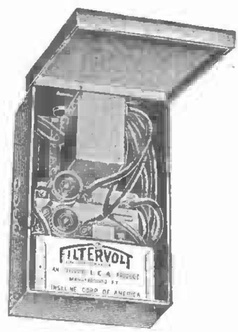


FIG. 6B. Another arrangement of filter units in a steel cut-out box. It is a good practice to place a fuse in series with each condenser, as is done here, for breakdown and short-circuiting of a condenser would otherwise place a direct short across the power line.

little while around breakfast time and perhaps occasionally late in the evening at a time when you know that the neighbors are having a party, may be produced by a fruit juice extractor; noise heard at intervals fifteen to thirty minutes apart may be due to an oil burner, a refrigerator, an air compressor in a nearby beer parlor or any other device which is operated only for short periods of time and is automatically controlled. Interference which is heard only when a street car or train is passing near the house gives an obvious clue; interference heard in apartments when the elevator is in operation proves that the trouble is in the elevator motor. Clicking noises heard when lights are turned on in the house tell their story at once. Your questioning of the customer, once you suspect a possible cause of the trouble by listening to the noise yourself, should result in a quick isolation.

If the interference can be picked up by the radio receiver at the time when you call, give special attention to any peculiarities of the sound; note whether the interference is heard with the same intensity at all frequencies. With a little experience you will be able to make very good guesses as to the causes of different types of interference noises. Until you have gained this experience, use the following suggestions which have been prepared by the Tobe Deutschmann Corporation of Canton, Massachusetts, as your guide in recognizing the sources of interference noise which you hear.

Whirring, crackling, buzzing, humming, droning and *whining* sounds are characteristic of motors and generators. When motors start, the pitch of the whine increases until it reaches a steady value. This is especially true of commutator type motors. Repulsion starting single-phase induction motors may have a sputtering, whirring, crackling, buzzing or humming sound. When such sounds are heard, look for such electrically operated equipment as:

Adding Machines
Air Conditioning Units
Automatic Towel Rollers
Barber Clippers
Beauty Parlor Devices
Billing Machines
Cash Registers
Dental Engines
Dishwashers
Dough Mixers
Drink Mixers
Electric Addressing Machines
Electric Computators
Electric Elevators
Electric Refrigerators
Electric Vibrators
Fans
Farm Lighting Plants
Floor Polishers
Generators
Hair Dryers
Humidifiers
Massage Machines
Motor-Generators
Portable Electric Drills
Printing Presses
Sewing Machines
Shoe Dryers
Small Blowers
Telephone Magnetos
Toy Electric Trains
Vacuum Cleaners
Valve Grinders
Washing Machines

Rattles, buzzes and *machine-gun fire* sounds indicate interference from buzzers, telephone dials or doorbells. These noises are usually intermittent, starting and stopping at irregular intervals. Short machine-gun firing sounds indicate telephone dialing interference. Look for such interfering devices as:

Annunciators
Automobile Ignition Systems
Buzzers
Dental Laboratory Motors
Dial Telephones
Doorbells
Elevator Controls
Sewing Machines
Switchboards
Vibrating Rectifiers

Violent heavy buzzing or *rushing* sounds are often heard over a large area or even a whole town, the sounds being at times so loud that they drown out the radio program. They may be louder at one end of the tuning scale of the receiver, indicating high frequency noise-modulated radiation; they may be heard only on certain bands of all-wave receivers. These sounds may be traced to:

Air Purifiers
Battery Chargers
Diathermy Machines
Doctors' Apparatus
Flour Bleaching Machinery
High Frequency Apparatus
Insulation Testers
Neon Signs
Ozone Devices
Spark Transmitters
Spark Ignition in Oil Burners
Violet Ray Apparatus
X-Ray Machines

Crackling, sputtering, snapping, short buzzes or *scraping* sounds indicate loose connections; if in the house, they will be especially noticeable when walking about; if outside, heavy traffic or street cars may increase the intensity of the sounds. Look for:

Defective Light Sockets
Flimsy Elevator Controls
High Tension Lines
Power Lines Grounded to Trees
Street Cars
Wet Line Insulators
Loose connections in floor lamps and appliance cords; broken heater elements in household appliances. Unbonded rubbing metal contacts in houses, such as adjacent water pipes.

Clicking sounds are a definite indication of some sort of make-and-break connection essential to electrically operated industrial equipment, such as:

Elevator Controls
Flashing Signs
Heaters, Automatic
Heating Pads
Incubators
Irons
Mercury Arc Rectifiers
Electric Typewriters
Ovens
Percolators
Shaving Mug Heaters
Soldering Irons
Telegraph Relays
Thermostats
Traffic Signals
Safe Time Clocks

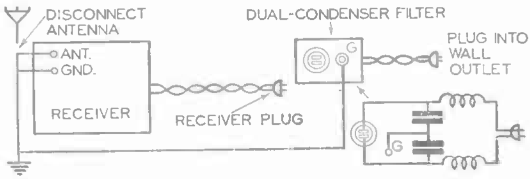
Heavy violent buzzing sounds, usually of short duration, are characteristic of heavy sparking or arcing across a gap. Such sounds are traceable to:

Arc Lights
Automobile Ignition
Breaks in Third Rails
Electric Car Switches
Electric Elevators
Motion Picture Projectors
Pole Changer (Telephone Interrupter)
Street Car Switches
Street Lights
Toy Electric Trains

TRACING THE ORIGIN OF INTERFERENCE

After making a survey of an interference problem, the Radio-Trician is generally able to tell whether the interference noise heard is produced in the customer's house or outside the house; in an apartment building he can readily tell whether devices in the customer's apartment are at fault. When the source of noise can be quickly located, a simple filter will remedy the trouble at minimum expense to the customer.

When, however, locating the offending device involves a search through many apartments in a building or many houses in a neighborhood, by all means give the noise-reducing antenna first considera-



Make this simple test with a condenser-choke filter of the plug-in type to determine whether interference is reaching the receiver directly over the power line. If interfering noises are still heard when the set is connected as shown, with the dual condenser line filter inserted in the power line, you have proved that the receiver itself is creating the noise; if no noise is heard but noises return with full intensity when the filter is removed, the interference is coming in over the power line. The remedy in this case is obvious: Install a line filter. The circuit diagram for the line filter recommended for this test is shown at the lower right.

tion, after you first try a line filter across the power leads of the receiver. Occasionally noise signals get in by this route.

Before actually installing a noise-reducing antenna, make sure that direct chassis pick-up of the noise signal is not involved, either by making the usual test with antenna disconnected and the receiver input terminals shorted, or by operating another receiver in the same location. Direct chassis pick-up is ordinarily encountered only in older types of receivers which have a number of unshielded parts.

Interference Originating in the Customer's Location. A quick test which will rule out the customer's location as the source of interference can be made with a portable battery receiver of the type which uses a loop or fish-pole antenna and no ground connection. The interfering noise should be heard on the battery receiver when it is placed in operation near the customer's receiver; if the noise is not heard, check the customer's antenna and ground system for poor joints and exposed wires which are rubbing against a tree or building. Assuming that the interference noises are heard on the battery receiver, have some one open the main power switch which controls the entire electrical system in the house or apartment. If the noise disappears or is greatly reduced when this is done, at least one of the offending devices is in the place.

Locating the Noise-Producing Device in the Home. In small homes or in apartments this is easiest done by switching each of the electrical appliances off and on while the customer's receiver is in operation. In large homes this is done more quickly by having an assistant remove the fuses for each electrical circuit in the house in turn, while you note the effects on the customer's receiver. When the noise stops, you have isolated the defective device to one particular circuit; there remains only the checking of each part, device and connection in this circuit. The following procedure has proven very effective for isolating noise-producing sources:

1. Check the antenna, lead-in and ground for loose or poor connections.
2. Be sure that none of the service wires which enter the house are rubbing against the branches of trees or against the building.
3. Make certain that the service conduit containing the supply wires leading into the house is grounded.
4. The wiring in the house should be grounded as provided by the accepted local electrical code. Have a licensed electrician check this if there is any doubt in your mind.
5. Be sure that all switches in the distribution system make firm contact. All line fuses should be firmly in place, with clean contacts. No temporary fuses or fuse shorts should be allowed. Fuses should be checked, as a loose connection between the fusing material and the contact cap will create arcs.
6. Inspect all connections in switch boxes, distribution boxes and fuse boxes for looseness, tightening terminal screws where necessary.
7. Examine all lamp bulbs used in the house and make sure that they are firmly screwed into their sockets. Turn on each lamp and tap it on the side for loose elements and poor base connections. Question the socket.
8. Check all lamp extensions and attachment plugs to every appliance, looking for loose contact. Shake extension cords, listening to the radio for signs of poor internal connections while the device connected to the cord is turned on. Extension cords with knots and kinks, as well as worn cords, are prolific sources of interference.
9. Repair or replace snap switches which do not open quickly.
10. Water and gas pipes or electric conduit pipes rubbing against each other may discharge their electrostatic charges. Bond the pipes together at the rubbing joint or insulate the contact surfaces. Quite often the turning on of a water faucet, walking through the house, use of household appliances or the operation of oil burners or refrigerators will start such electrostatic interference. With experience you will be able to distinguish electrostatic noises from those produced by electrical apparatus.

In checking these items the receiver should be turned on, with your assistant or even the set owner listening to the receiver, while you check various things in the house. A broom handle may be used for probing or knocking against pipes; when the region surrounding the noise source is probed, noise will be clearly heard in the receiver.

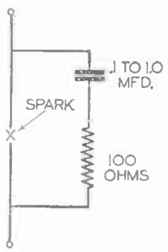
Interference Outside the Customer's Home. When your tests show that the noise source is not in the customer's home, and the installation of a noiseless antenna proves inadequate, then the defective device must be isolated by means of an "interference locator." A portable receiver with self-contained batteries may be employed. The receiver should be sensitive, employing three to four R.F. pentode stages if a T.R.F. set; a portable superheterodyne may also be used. If the receiver is not already well shielded, it should be built into a heavy aluminum box. Inexpensive and sensitive portable battery receivers may be purchased from large radio mail order houses. In addition to the headphones used as an output indicator, a copper oxide rectifier type 0-5 volt voltmeter having a 1,000 ohm per volt sensitivity should be permanently connected to the output. Thus both aural and visual output indications are available. Whatever receiver is used, it must *not* have A.V.C., for this would tend to conceal changes in interference intensity.

The pick-up system may be a 7-foot collapsible aluminum pole or a loop antenna. In the latter case the antenna coupler in the receiver must be disconnected and the input condenser arranged to tune the loop. For an .00035 mfd. input variable condenser a box type loop containing 24 turns spaced ⅛ inch apart on a 20-inch square form will be needed to cover the broadcast band. Use No. 18 or 20 gauge D.C.C. wire. Both pole and loop antennas may be used by installing a D.P.D.T. change-over switch. The pole antenna is preferred where there are many overhead wires in the vicinity of the home; the loop antenna performs best in open spaces.

In locating a noise source, first listen to the noise signal on the portable receiver, with the tuning dial set to a frequency where broadcasts are not heard. Using the loop antenna, rotate the loop until a maximum output meter reading is obtained. The noise origin will be in the plane of the loop (along a horizontal line parallel to and passing through the top of the loop), but may be either ahead or behind the loop. Walk in the direction which gives increased output readings. Where overhead supply wires exist (we assume that the investigation is started outdoors, as everything in the house has been checked), the greatest noise signal will be evident when the loop is *parallel to* the overhead wires. This does not identify the source, however. Where overhead wires do not exist, then the direction of interference may be identified from two positions about 200 feet apart and, by following the two directions to their apparent intersections, the approximate location is obtained.

With the pole antenna use the "hot-and-cold" method, walking in the direction which gives increased noise in the phones or an increased output meter reading. Where an overhead power line is involved, follow the line for maximum output. The loop antenna may also be used in the above "hot-and-cold" method. Always point the loop in the direction of greatest output and follow the direction of maximum output indication. Follow overhead lines with the loop parallel to the line.

If some indication of the direction of the interference is secured from the customer, increased output should be obtained when moving



A condenser and resistor in series, connected as shown, will reduce the intensity of a spark at make-and-break contacts.

the interference locator toward the suspected point. For instance, if you are told that noise started when the neighbor installed a new refrigerator, walking to the neighbor's home when the noise commences should show increased noise output.

The independent interference man must realize that in locating a fault he may have to trespass on private property. Where the trouble originates in a home or building, it should not be difficult to obtain permission, once he identifies himself. In case the trouble is traceable to power lines and line equipment, the power service superintendent should be informed; he will without doubt have his engineers cooperate in the matter and make the necessary corrections. Most power companies and public utilities have engineers who specialize in interference work. This text does not consider interference troubles peculiar to public utilities; where the trouble is traced to telephone equipment, street railway lines or other public service equipment, explain the situation to the customer and suggest that he notify the company in question.

Once the noise has been localized to some house or business establishment, first secure permission from the tenant or owner, then proceed to isolate the defective device in the same manner which you would use in the customer's home. If the noise is traced to a point some distance away from the customer's home, it is probably due to a device which draws considerable power; thermostat contacts, electric light switches, and electrostatic sources of interference can generally be ruled out in a case like this.

COMMON INTERFERENCE CONDITIONS

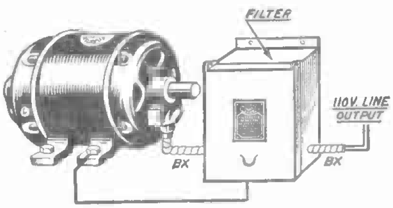
A study of a few common interference-producing conditions which may arise in various types of electrical equipment will help to clarify this important problem of interference elimination.

Electric Motors and Generators. Any electric motor, especially the D.C. and universal A.C. motors which employ commutators, should be suspected as a source of noise interference. Probable causes of trouble here include sparking at the commutators due to poor contact with the brushes, and dirty or uneven commutator segments. Sparking causes pitting and burning of the commutator segments, and the interference situation rapidly grows worse; before attempting to clean up the motor, connect the interference analyzer and determine whether a simple filter combination will completely eliminate the present interference. If the combination of filters required proves excessive in cost, repeat the analyzer test after you have remedied the sparking; a less-expensive filter should now prove sufficient. For motors try the filter combination shown at *B* in Fig. *2* first; if this is insufficient, add two choke coils as shown at *G* in Fig. *2*, making sure that the coils used will carry continuously the full load current of the motor. For 110 volt motors figure 10 amperes per horsepower; estimate 5 amperes per horsepower for 220 volt motors.

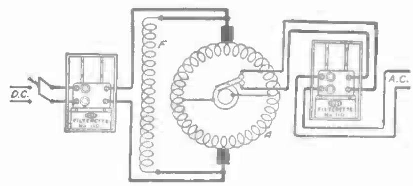
No interference-remedying job on a motor can be considered complete unless the cause of the trouble is removed or at least rectified. The commutator should first be cleaned and made smooth with fine sandpaper, and the brushes then reshaped if necessary to fit the commutator better. It is common practice to smooth the commutator, where it is not too badly worn, by wrapping or tacking sandpaper to a flat block of wood and applying this while the motor or generator is revolving. Brushes can be reshaped with the motor or generator at rest; slip a piece of sandpaper under a brush, with the cutting surface facing the brush and the sandpaper pressed against the commutator. Rock the commutator back and forth slowly until the brush takes its proper curvature. When you have finished, wipe off the brushes and the commutator carefully and apply a very small amount of vaseline over the surface of the commutator.

Oftentimes sparking at brushes can be reduced by shifting the positions of the brushes to get improved commutation. Rock the brushes slowly back and forth a very short distance until minimum sparking is observed; this should be done while the machine is operating at normal load if best results are to be obtained. With generators, moving brushes *in the direction of rotation* ordinarily reduces sparking; with motors the opposite holds true.

Make-and-Break Contacts. With simple make-and-break contacts such as are found in switches, temperature control thermostats, automatic electric irons, electric water heaters and similar devices, a filter consisting of a single condenser or a condenser in series with a



Combination choke-condenser filters mounted in metal cut-out boxes are often necessary to stop interference created by medium and large sized motors. Connections between motor and filter box must be run through flexible BX conduit, as shown here.



Both input and output leads of a rotary converter must be filtered, using choke-condenser units mounted in cut-out boxes and mounted as close as possible to the machine. F represents field coil, A the armature of the converter, which here changes D.C. to A.C.

resistor will usually prove sufficient to eliminate the interference. It is always a good plan to clean and adjust the contacts, in order to prevent a prolonged arc which would prove destructive to the contact points and cause even more severe interference than before.

Oil Burners. Interference produced by oil burners can usually be traced to the high tension ignition circuit, to automatic switching devices, or to the motor. Some burners use a gas pilot light, eliminating ignition systems as a possible source of interference; this you can easily confirm by inspection. If the interference noise is continuous for the period during which the burner is operating, the motor is clearly at fault; if the noise is heard only for a short period when the burner starts, the ignition system, one of the relay devices or the starting mechanism in the motor is at fault. Trouble at the motor can usually be eliminated by installing a filter as close as possible to the brushes.

Ignition system troubles are remedied by shielding all high tension wiring either with metal conduit, with flexible metal loom, or with metal braid, the shield being well grounded at each end in all cases. Some servicemen recommend that the frame of the oil burner be bonded to the boiler and to ground with heavy wire or metal braid, to prevent radiation. Try a coil and condenser type filter across the input leads of the ignition transformer; try simple condenser filters across thermostat contacts and relay contacts. Oftentimes it is necessary to place a wire shield around the ignition electrode in gun-feed type oil burners and ground this shield to prevent ultra high frequency radiation.

Here are a few practical suggestions concerning oil burners. If the noise elimination job on a burner appears at first inspection to be a rather involved affair, it is well worth while to contact the local distributor of that burner. Similar interference conditions will have been encountered in other installations, and often the distributor can make suggestions or supply special equipment which will remedy the trouble in short order. Once you prove that you can eliminate interference on that type of burner, the distributor may even refer similar jobs to you. Remember that all filters should be placed in metal housings to conform with underwriters' regulations.

Electric Refrigerators. The motor is the usual source of trouble in electric refrigerators; its treatment has already been taken up. Static charges accumulating on the compressor-motor belt sometimes cause trouble; the remedy here is bonding the motor frame and the compressor frame either to the refrigerator frame, to some large metal mass in the unit or to ground. Refrigerator mechanisms are usually mounted on spring supports; occasionally you will find that a spring has weakened, allowing a make-and-break contact between the refrigerator frame and the part in question; in this case install a new spring. If the interference is traced to a sparking thermostat, it is wise to call in a refrigerator serviceman; adjustments on refrigeration control devices such as this require specialized knowledge.

Electro-medical Apparatus. X-ray machines, violet ray apparatus and diathermy machines can cause a great deal of annoying interference; these may prove the most stubborn cases which you will encounter. Most of the equipment now being marketed is designed to create a minimum of interference, but older models are trouble-makers. Modern vacuum tube type diathermy machines create interference at only one frequency in the short-wave region; this interference can be eliminated only by placing the machine in a screened room.

With medical apparatus in general, the first step involves placing a choke-condenser filter in the supply line to the device. If this is insufficient, the only recourse is to place the apparatus in a screened room. The frame of the room can be either of metal or wood; this is then covered with either iron or copper screening, preferably both inside and outside of the framing, and the screening is well bonded together at all joints. The door must be so constructed that it makes firm electrical contact with the remainder of the screen when closed. Filters should be placed on all power lines which enter or leave this screened room, for otherwise interference would be conducted outside and there radiated; the filters should be placed as close as possible to the exact points where the lines pass through the screen.

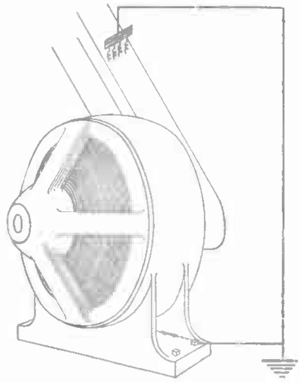
Courtesy Tobe Deutschmann Corp.

When electromedical apparatus is creating noise interference a grounding screen cage like this must often be used. All joints must either be soldered or continuously bonded in some way. Filter units must be attached to all power lines at the points where they enter the cage. All devices and filter units inside the cage should be grounded to the screen; connect the screen to a nearby ground if this gives an additional reduction in interference.

Flashing Signs, Traffic Lights and Neon Lights. In general, interference from these three sources can be spotted by visual inspection and by studying the nature of the sound heard in the receiver. For example, if a steady choppy noise is heard in synchronism with the flashes of a yellow blinker light up the street, the defect is immediately isolated. If a steady rolling or clicking sound is heard, and you note in the vicinity a sign having a continuous change of light, perhaps around the border, that sign is very likely the offender. Whenever there is some question as to the source of trouble, use the portable receiver to localize the trouble. The next step is a study of the device in question to determine the simplest filtering procedure.

Simple flashing signs which have a single make-and-break flasher require only a filter condenser connected directly across the contacts; the closer the condenser is to the contacts, the more effective it will be. Motor-driven contactors are generally used in signs which create the effect of motion; the first step with these is to filter the motor supply leads, then the main supply leads to the electric lights. If this fails, it is then necessary to connect a filter to each contact on the contactor. The condenser should be connected from the contact to the common terminal for all circuits, which is ordinarily easily located. In severe cases of interference it is necessary to place a choke coil in each lead to the lights, the condenser being connected from the contact side of the coil to the common power lead. Short connections are essential here to prevent high frequency radiation.

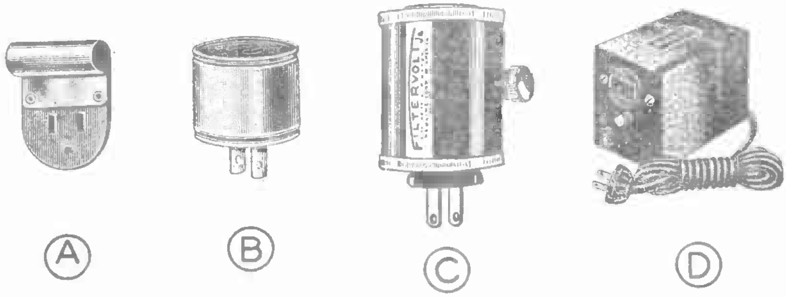
Flashing traffic lights are treated in much the same manner, using condenser filters across the contacts and line filters where necessary. This work must naturally be done under the supervision of the proper authorities.



Moving belts and belt conveyers are sources of static discharges, not only creating noise interference but actually endangering the lives of nearby persons and the insulation in the machinery. A grounded metal comb with flat or coil springs rubbing on the belt will discharge this static electricity harmlessly to ground and at the same time stop the radio interference. Use a good ground which is carefully erected. In any industry where static electricity is produced, all fixed and movable parts of machinery should be grounded.

Neon signs of the non-flashing type do not as a rule cause interference troubles; where interference is positively traced to these signs, about the only remedy is the installation in the primary leads of the high tension transformer of a condenser-coil filter of the type shown at *G* and *H* in Fig. *2*. When a rotating contactor is used in the primary circuit of a number of neon transformers to switch from one group of tubes to another, filters must be connected to each contact and to the motor of the contactor. Where the rotating contactor is in the secondary circuit, switching high tension currents from one to another of a number of small sections of neon tubing, condenser filters are out of the question because of the high voltages involved. Try inserting 10,000 to 25,000 ohm spark suppressor resistors in each high tension lead; choke coils inserted in these leads may also reduce the interference. In certain severe cases the only remedy may be a complete change-over of the sign-operating mechanism, which will place the rotating contactor in the primary circuit and provide a separate transformer for each section of tubing; such an arrangement is more readily treated for noise suppression, but the cost of making the change-over is generally so high that the job of filtering is given up.

Quite often neon tubing will accumulate an electrostatic charge which leaks off to the nearest metal objects or at points of support; try placing mica sheets at these points. The two chains which sometimes support neon signs in show windows often acquire a difference in potential; insulating each chain from the neon tubing or using a non-metallic type of support will effect a remedy. Neon signs should be kept as far away from glass windows as possible, to prevent ac-



Examples of typical commercial filter units for interference-creating electrical appliances. At *A* is a single condenser unit which may be slipped over the prongs of the appliance plug; *B* is a similar unit, but of larger capacity, for insertion between appliance plug and wall outlet; *C* is a dual condenser filter with a midpoint terminal which can be grounded; *D* contains a condenser and coil combination designed for use with larger appliances. These devices are generally carried by those servicemen who do not make a specialty of interference elimination; by trying each device in turn, they can generally find one which will give satisfactory noise reduction where there is only mild interference. Never connect condensers larger than 1 mfd. directly across an A.C. line for filtering purposes; the power losses in larger condenser units are often high enough to cause excessive heating on continuous duty, resulting in failure of the condenser.

cumulations of static charges on the glass. Quite often a general overhauling of the neon sign, done by a sign expert, will greatly reduce the interference and make ordinary filtering procedures effective. This involves cleaning of all insulators and all tubing, to prevent high tension currents from leaking over dust-covered glass surfaces.

Thus you can see that the elimination of interference, once the source has been located, calls for "horse sense" and a certain amount of "trial and error" work, as well as a knowledge of the causes of interference and the technique of filtering.

Radio Noise Survey. Although the results of any survey made of causes of radio interference noises will vary with the locality, the following data taken from one such survey gives a general indication of the frequency with which various noise complaints occur. Out of

9,000 complaints, about 30 per cent were traced to power companies and public utilities, about 30 per cent to apparatus owned by the general public, about 15 per cent to defective radio sets and the remainder to transient or unlocateable conditions. Of the 30 per cent traced to devices owned by the public, motors and motor-operated devices accounted for 10 per cent, defects in wiring of building—6 per cent, switches and interrupter apparatus—5 per cent, electro-medical apparatus and neon signs—3 per cent, and miscellaneous—6 per cent.

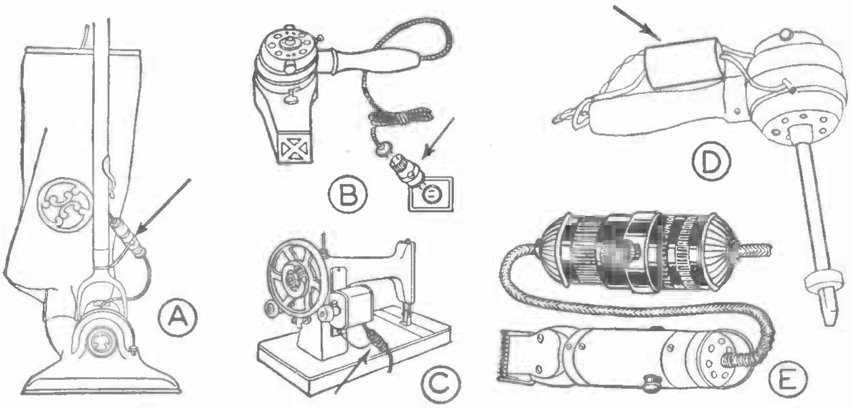
SECURING INTERFERENCE ELIMINATION BUSINESS

Noise is as old as civilized man, but radio has made the public more noise-conscious today than ever before. Noise ruins the entertainment value of radio programs, changing the radio receiver from a luxury to a nuisance in the customer's mind. Interference elimination is so much a community affair that many towns and cities have passed ordinances which compel those people owning interference-creating devices either to eliminate the noise or to cease using the offending device; as the public demands better and better radio programs, laws become more widespread. With laws such as this in your favor, the securing of interference elimination business is comparatively simple, but even if you must first sell the idea of noise elimination to a customer, there are enticing profits awaiting you in this field. In addition, this side-line of servicing will bring more regular service jobs to your shop.

Always make inquiries about possible interference on each radio receiver service call which you make; bringing noise interference to the attention of the public and stressing the fact that practically all noise can be eliminated, will eventually produce many interference elimination jobs for you. If you plan to become a specialist in noise elimination, it is a wise plan to select a certain section of your town, preferably in the immediate neighborhood of your shop, for complete noise elimination. It may take weeks or months to locate and remedy all noise sources in this section, but once all noise has been eliminated, your reputation will spread throughout the town, and your work in other sections will prove more easy. Then, too, the experience gained will be of great value in solving similar problems elsewhere.

Be sure to contact the trouble-shooting department of your local power company, and the same department in any other nearby public utility. These firms constantly receive complaints of interference; once you have shown that you can handle this work, they will welcome you with "open arms" and even send jobs your way. Whenever you encounter an interesting or particularly successful job, always call your local newspaper; anything with a little human interest makes a good story for the newspaper and gives profitable publicity to you.

Having selected a six or eight-block square section of your town as a starting point, the best approach is to announce that you are making a "radio interference survey." Visit the homes and business establishments in this section, preferably during your spare time,



Courtesy Tobe Deutschmann Corp.

Examples of filter installations on small electric appliances which are creating interference because of sparking or arcing. *A*—vacuum cleaner motor interference can generally be cured by inserting a dual condenser filter in the connecting cord, not more than six inches away from the motor, and grounding the midpoint terminal to the frame of the appliance; arrow points to filter. *B*—interference created by the blower motor of a small hair dryer can often be satisfactorily reduced by placing a condenser filter of the plug-in type between the wall outlet and the hair dryer plug. *C*—plug-in type dual condenser filter inserted in sewing machine motor cord, as close as possible to motor, gives a neat interference-reducing installation where it is not feasible to make connections directly to motor terminals. *D*—condenser filter connected directly to terminals of a small mixer; this is not an ideal installation, for the filter interferes with the use of the appliance. *E*—plug-in type condenser filter inserted in cord of barber clippers, close to motor, gives satisfactory elimination of interference in most cases. Always try plug-in filters at wall outlet first, to avoid unnecessary cutting of appliance cord. Ground midpoint of filter to frame of appliance or nearby ground wherever possible.

explain what you are doing and ask if they have noticed any radio interference noises. Secure their permission, if possible, to turn on their radio receiver so you can listen for the noise yourself. By starting in a section where you are known, opposition to such a survey will be at a minimum. Keep your eyes open for regular service jobs while making the survey, and put in your bid for the job either at the time of the call or at a later date.

After each call, when making the survey, write your observations on a small card, perhaps of the three by five-inch size. With these cards arranged in geographical order, a study of them should show you where interference is a maximum; your first efforts should be concentrated in this region. Secure permission to check on all suspected devices, and apply the interference-isolating technique which has already been explained.

If you hesitate to make a sales talk in each home in order to explain your purpose, send printed post-cards or letters explaining what you intend to do; this will tend to offset possible objections or the need for lengthy explanations when you make your call. A cartoon or drawing on the card or letter will attract attention to the purpose of your message and thereby give better results for you. Literature like this can also be used to explain why certain devices cause interference and why this interference should be eliminated at its source; this literature, by calling to the attention of customers man-made interference situations which they may not have recognized as such, will make it easier for you to sell filters and interference-elimination services at a later date.

LINE FILTER CONSTRUCTION DATA

Line Filters for Radio Sets. Get two .5 mfd. tubular paper condensers rated at 600 volts D.C. working voltage, one bakelite coil form about 6 inches long and 3 inches in diameter, and a half pound of ordinary No. 18 bell wire. Unwind the wire and cut into two pieces of equal length.

Drill two holes (each about 1/8 inch in diameter) at one end of the coil form, locating them about a half inch in from the edge of the form and about one inch apart. Anchor each wire by looping it once or twice through its hole, leaving about 6 inches projecting for connections. Proceed to wind the two wires side by side on the coil form in a single layer, with turns as close together as possible. When all but about 6 inches of the wire has been wound in this manner, drill two more holes about one inch apart and loop the ends through these holes for anchorage. This will give you two coils of approximately 35 turns each, wound on a single coil form.

Insert this filter choke in the radio set power cord, either at the wall plug or at the radio set. In other words, cut the two wires of the radio set cord at the desired location, connect one pair of cut wires to the leads at one end of the choke, and connect the other pair of cut wires to the two leads at the other end of the choke. Now connect one terminal of each .5 mfd. condenser to one of the leads at the *receiver* end of the choke coil; connect the remaining two condenser leads together and provide a means for grounding this common condenser connection (to a convenient water pipe or to the radio set ground if you know that to be good). Cover all exposed connections with friction tape. This completes the filter itself, but you will probably want to mount it in a wood or metal box so no dangerous 110 volt A.C. terminals will be exposed. The circuit of this filter is like that shown on page *16* (with the receiver connected and plugged into the outlet on the filter), or like that in Fig. *2G* if *S* represents the receiver.

General Filter Construction Hints. The same general filter construction described above will serve for practically any line filter application *if the wire used in winding the choke is the same size as the power cord wire used for the appliance being filtered.* In other words, if you are filtering an electric tor having No. 14 wire in its line cord, wind the choke with about 35 turns coil (70 in all) of No. 14 insulated wire; No. 14 tinned solid copper push-k wire will do nicely, or you can use the same size of double cotton-covered e and apply a coating of insulating varnish to the completed choke. To his number of turns, you will have to order about 60 feet of wire in what-ize is required. Naturally you will need a longer coil form for heavier ince the choke must be in a single layer. The condenser size specified ight for all cases; in general, the condensers should be connected to d of the choke which will make the interfering signals go through the efore they reach the condensers.

TEST QUESTIONS

e sure to number your Answer Sheet with the *number* appear- the front cover underneath the title of this text.

lace your Student Number on every Answer Sheet.

Never hold up one set of lesson answers until you have another to send in. Send each lesson in by itself before you start on the sson. In this way we will be able to work together much more ely, you'll get more out of your Course, and you will receive the possible lesson service.

What effect does a tone control, which cuts off the high audio frequencies, have on static noises?

In locating the best position for the straightaway portion of a noise-reducing antenna, what three rules would you follow?

What type of filter would you try if simple condenser filters using 1-mfd. units failed to give satisfactory noise reduction?

What should be the peak voltage rating of condensers used on ordinary 110 or 220 volt A.C. power lines for filtering purposes?

5. What are the probable causes of noise interference in D.C. motors?
6. What type of filter would you use on a make-and-break contact?
7. When interference-producing apparatus is located in a completely screened room or cage, where should the line filters (which are placed on all power lines entering the room) be placed?

When using a pole antenna with an interference-locating receiver, how can you tell when you are approaching the source of noise?

If interference noise traced to an oil burner is continuous for the period of operation of the burner, what is the cause?

10. What should be the current-carrying capacity of a choke coil which is to be used in filtering the power leads to a 220 volt, one horsepower motor?

INITIATIVE

The man who does only the routine tasks, the ordinary jobs in his profession, always waiting for the other fellow to take the lead, can expect only moderate returns for his labors. He who is continually on the alert for new ideas and new uses for his talents—who is alert to grasp each new opportunity—gets the greatest profits. The immediate financial returns from work in a new and specialized branch of your profession may not be great, but the reputation which you gain for progressiveness will soon result in more profitable routine jobs. It all boils down to these simple facts—you must do out-of-the-ordinary things, stand above the crowd in some way, to attract favorable attention. People remember you first for the unusual, then for your ability to do ordinary work well.

J. E. Smith

HOW TO CHOOSE AND INSTALL REPLACEMENT PARTS

47RH-2

PIONEER HOME STUDY RADIO SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE No. 47

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

FM6M1250 1951 Edition Printed in U.S.A.

Replacement Parts

WHILE the final steps in making a repair — removing the defective part and obtaining and installing a replacement—are purely mechanical, it is possible to waste a great deal of time in taking these steps unless you know what to buy, where to buy it, and how to install it. We will give you this important information in this lesson, along with a number of hints on testing parts. Let's start by learning something about the kinds of radio parts which are usually available.

KINDS OF REPLACEMENT PARTS

Replacement parts fall into three groups: exact duplicate replacements; universal replacements; and general replacement parts.

Exact Duplicate Parts. These parts are exact duplicates of the originals, both physically and electrically.

Universal Parts. There are a number of universal radio parts so designed that, with minor physical or electrical alterations, they can be used as replacements for a wide variety of radio parts. For example, volume controls come with extra-long shafts. Once you have chosen a control of the proper electrical characteristics, you can make it fit the receiver by cutting off the shaft to the required length. Thus, the same control can be used in any receiver which its electrical characteristics will fit.

As another example, output transformers come with tapped secondaries; by choosing the proper taps, you can match practically any loudspeaker to almost any output tube (or tubes).

General Replacement Parts. Finally, we have parts, such as tubes, resistors, and condensers, which can be used in any receiver as long as the proper electrical characteristics are chosen and as long as there is sufficient room for the parts.

We include, among these, parts not designed for the particular radio, but which can be used by making some slight change in the original circuit to "fit" the new part characteristics. Changes of this kind are rare, as the widespread distribution of exact duplicate and universal replacement parts generally makes it possible to make a direct replacement.

STOCKING RADIO PARTS

You can start a radio service business with a surprisingly small stock of parts. However, you will want to build up your stock gradually, both so you can cut down the number of trips or orders to the parts suppliers and so you can render the fastest possible radio service.

When you start in business, you will need a kit of resistors, a small number of electrolytic, paper, and mica condensers, a stock of tubes, an assortment of pilot lights, and a certain amount of hook-up wire and hardware. With this small stock as a beginning, you can increase gradually the amount and variety of these parts. Also, you can add items like universal output transformers, a volume control kit, i.f. transformers, tube sockets, dial cords and belts, and an assortment of knobs.

Some servicemen make the mistake of acquiring too large a stock. It is not wise to invest much money in slow-moving parts. Increase the quantity and variety of your stock only as your service experience indicates the need for such expansion. At the beginning, ask your local distributor to help you choose parts which, according to his sales records, move rapidly in your area. This is particularly important in the case of tubes. There are about a thousand different types of radio tubes, yet perhaps in your district only seventy-five to one hundred types are widely used.

WHERE TO BUY RADIO PARTS

There are many sources of supply available to the serviceman. Perhaps the best known are the large mail-order radio parts suppliers, who carry very complete stocks of parts and who can usually obtain any special parts you may need. In large cities there are also radio parts supply houses and distributors who carry a wide selection of radio parts.

In addition, there are distributors scattered throughout the country who handle various popular makes of radio receivers. Exact duplicate parts for these receivers can be obtained through these distributors. Where there are no distributors, parts can sometimes be obtained directly from the factory. Also, many *parts* manufacturers (condenser and resistor manufacturers, etc.) deal directly with servicemen, although in recent years, mail-order and local parts supply houses have acted as distributors for these lines.

Collecting Service Data. All servicemen collect wholesale parts catalogs, both to locate sources of supply and to obtain information on the electrical and physical characteristics of different parts. Be sure to collect all the volume control guide booklets, vibrator replacement guides, transformer replacement guides, tube charts, and other service data which are available from your local distributors or supply house. Many of these are free, while others are sold for just a few cents.

► While we are on the subject of collecting information—try to get all possible information on radio receivers themselves. You will find that your parts distributor will help you obtain service manuals.

Many set manufacturers publish their own manuals, which are kept up to date by supplements or come out in yearly editions. You may find it desirable to get those covering any particular brands of receivers which predominate in your locality.

Let us turn now to certain specific radio parts and learn more about the problems of obtaining the proper replacement and installing it quickly. We shall deal chiefly with transformers, condensers, resistors, and loudspeakers, as other parts—line cord resistors, tubes, batteries, etc.—are replaced most generally by exact duplicates.

Power Transformers

There are two ways in which a transformer can fail: *1*, a winding may open; or *2*, a short circuit may develop.

The first is rare, as electrolysis seldom occurs in a sealed transformer, and an open is seldom caused by an overload. If an open occurs, the fact is obvious, since one of the secondaries will not deliver voltage. A continuity check with an ohmmeter will lead you to the defective winding.

Watch particularly for an open center tap. You may still have continuity across the entire winding, so make a check to the center tap from each end of the winding.

► A short circuit is the usual transformer defect, and it is invariably caused by excessive heat. If too much current is drawn from a transformer winding—that is, if the transformer is overloaded—so much heat will be produced in it that the paper insulation between the layers of wire in the winding will char (carbonize). Since carbon is a fairly good conductor, the winding, or part of it, will be short-circuited. Once an internal short has developed, the transformer must be rebuilt or discarded. Under normal conditions, it is not economical to rebuild, so a replacement would be installed.

CHECKING FOR AN OVERLOAD

Your nose will first discover a short circuit or an overload. The pungent odor of burning enamel and paper insulation is unmistakable. Smoke may come from the transformer, and perhaps some tar or wax sealing compound will boil out of it.

These symptoms indicate that the transformer is overheated, but not necessarily that it is damaged. Simple tests will show where the trouble lies.

► When you find an overheated or smoking transformer, turn off the set and remove all the tubes, including the rectifier. Now turn the set back on and wait to see if the transformer cools off.

If the transformer *does* cool and stop smoking, it has been overloaded but is probably not seriously damaged. The overload was probably caused by a B supply defect, the effects of which were stopped by removing the rectifier tube. Repairing the defect will usually restore normal operation.

► On the other hand, if the transformer continues to overheat with the tubes out, it is being *overloaded* by shorted secondary leads or by a filament circuit short, or else it has been *damaged* by: *1*, a B supply defect; *2*, operation on the wrong power line frequency; or *3*, by an internal transformer defect.

If you live in a district with 25-cycle power, check the receiver label to see if the transformer is meant for 60-cycle operation. Such a transformer will draw too much primary current from a 25-cycle line, and eventually will be ruined. The only cure is to replace it with a transformer designed to operate on 25-cycle power.

Shorted Leads. Next, remove the chassis from the cabinet. Then, with the tubes out, turn the set on and examine the bottom of the chassis for signs of arcing between the transformer secondary leads. Push the wires around with an insulated probe or stick. If you see or hear an arc, the insulation probably has become frayed on the wires. Tape or replace the leads in order to cure this.

Also, examine the rectifier tube socket. An arc may have occurred between a plate terminal and the chassis, between the two plate socket terminals, or from one of the rectifier filament socket terminals to the chassis. Often the arc can be seen or its charred path can be observed on the bottom of the socket.

If the rectifier has a wafer socket, the arc path may be between the two wafers of the socket and so may be invisible. If the transformer continues to overheat, disconnect the leads going to the rectifier socket to see whether this removes the overload.

Replace any socket which shows evidence of arcing, as the carbonized path is sure to give further trouble.

If there are no apparent shorts but the transformer continues to overheat, it is probably damaged.

A Transformer Short Checker. If you have taken the set to your shop, you can test the transformer with the simple checker shown in Fig. *1*. This device consists of a 60-watt lamp bulb in a socket wired in series with a power cord and an outlet. To use it, remove the tubes and pilot lamps from the radio and plug the set into the outlet. The lamp then will be in series with the primary of the power transformer and will indicate the amount of primary current.

Under these conditions, if the set is normal there will be so little drain on the power transformer that the lamp will barely glow—if it lights at all. If the lamp burns brightly, however, there is a short circuit between the high-voltage wires or in the rectifier socket, or else the transformer itself is defective. Examine the high-voltage wiring for shorts, then disconnect the leads going to the rectifier tube socket to see if the lamp glow decreases. If it does, the socket is defective. If not, the transformer itself is defective.

Circuit Defects. Whether you have an overheated transformer or a damaged one, be sure to clear up any overload conditions existing in the radio. Otherwise, the transformer (or its replacement) is certain to be damaged.

► Short circuits in the filament circuits are rare, as the low voltage is not likely to cause insulation breakdowns and there are usually no condensers in these circuits. One possibility of a short circuit is a grounded pilot light socket in a receiver which has a grounded center tap on the filament winding. This shorts half the filament winding. (However, many modern receivers use the chassis as *one side* of the filament circuit, so the pilot light is deliberately grounded to complete the circuit. Don't confuse this intentional ground with a short circuit.)

► On the other hand, the high voltages in the B supply cause frequent breakdowns, particularly of by-pass and filter condensers.

To check the B supply circuit, first test all the tubes, looking especially for shorted elements in the rectifier and power tubes. Then, *with the set turned off*, check the resistance from the *cathode* terminal of the rectifier socket to the chassis with an ohmmeter. Be sure to observe polarity. The *positive* ohmmeter terminals must go to the B+ side of the circuit. (When in doubt, reverse the leads after taking a reading. Then, the polarity permitting the *higher resistance* reading is the correct one.)

The receiver diagram will show what the resistance should be. Usually, the resistance between B+ and B— should be only the leakage of the electrolytic filter condensers (over 100,000 ohms).

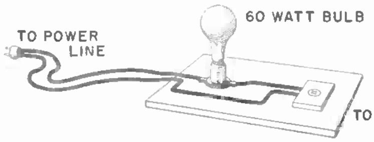


FIG. 1. A simple lamp device, used to check for shorted power transformer windings.

(Some receivers have bleeder resistors which reduce the reading to some value between 5,000 and 25,000 ohms.) If the reading is less than that which is expected, look for a short. Such a short could overload the transformer and also could be the cause of a shorted rectifier tube. The electrolytic filter condensers, the most likely sources of trouble, should be checked first.

CHOOSING THE REPLACEMENT

When you have determined definitely that the transformer is defective and have cleared up any overload conditions, the next step is to make the replacement—preferably with an exact duplicate transformer. Such a transformer may be obtained from the distributor of the receiver, from the manufacturer, from a wholesale mail-order house, or from one of the large transformer manufacturers who specialize in exact duplicate replacements. When you order, give the following information:

1. The make of the receiver.
2. The model number of the receiver.
3. A complete list of the tubes used in the receiver.

If your customer does not wish to wait while you send for an exact duplicate, or if none is available, you must choose a universal or general-purpose replacement transformer which has physical and electrical characteristics similar to the original.

ELECTRICAL REQUIREMENTS

To choose a suitable universal replacement transformer, you need to know the ratings of the windings on the old transformer. You can usually learn this from the service information on the receiver, from your parts distributor, or from catalogs of transformer manufacturers. They list receivers by make and model number and recommend as replacements specific transformers of their line. (If you cannot obtain the recommended transformer, its characteristics, given in the manufacturer's listing, at least will give you the information you want.)

Check these points to see that the proper transformer is obtained:

1. Primary. The transformer must be designed for the power line voltage and frequency. The frequency rating is usually given in the data on the primary winding.

The original transformer may have had taps on the primary to adjust it for a power line voltage range of, say, 100 to 125 volts. Most universal replacements will not have these taps; if not, wire the replacement primary directly to the power line terminals.

2. Wattage Rating. If the proper voltages and currents are delivered, you need not worry about the wattage of a transformer. Just ascertain that *each* winding is properly rated for the load it must carry.

3. Filament Windings. There will be from one to four filament windings, each with a voltage and current rating. The voltage rating depends on the types of tubes to be connected to the winding, and the current rating depends on the total current drawn by them.

Both the voltage and current demand for a winding can be found by determining *which* tubes are connected to it, whether they are in series or parallel, and (from a chart) what the requirements are for each tube. When tube filaments are in *parallel*, the filament winding must supply the voltage required for any *one* of the parallel tubes, while the current will be the *sum* of all of the current ratings of that group of tubes. When tube filaments are in *series*, the voltage required is the *sum* of all the voltage ratings (plus any series resistance drops), while the current rating will be that of a single tube in the group.

Of course, the current rating of the winding can be any amount equal to or *above* the current drawn by the tubes—this rating just gives the *maximum current* the winding can deliver without overheating.

► Most universal replacement transformers come with center taps on some of the filament windings. If the original transformer has no corresponding center tap, just cut this tap off or wrap the end with tape.

► Some very old receivers used a center tap on the rectifier tube filament winding as the B+ connection. Generally, replacement transformers will not have such a center tap, but you can make the B+ connection to either side of the rectifier tube filament circuit.

► It is perfectly all right to use a transformer having extra filament windings.

Just tape the extra leads or ignore the terminals on the transformer.

4. The High-Voltage Secondary. The high-voltage secondary must furnish sufficient voltage to give the proper B and C voltages, and must have a current rating equal to or greater than the amount drawn by the tubes and any bleeders.

► You'll have to be careful in figuring the proper voltage rating for this winding. If the voltage is too high, it may damage the filter and by-pass condensers and introduce excessive regeneration, while a voltage below normal may lower the sensitivity and output of the receiver.

Many universal replacement transformers are designed for average receiver conditions, and you need know only the number and types of tubes to get approximately the right transformer. For example, you can buy a transformer designed for a 5- or 6-tube receiver and the rating of the high-voltage secondary usually will be close to the requirements for the receiver.

It is better, though, to compute the rating from the normal operating voltages for the tubes used. Radios differ somewhat in their actual applied voltages, but a tube chart will show you the probable voltages used. Any set with 71A, 6G6, or 6A4 output tubes will need plate voltages of about 180 volts. If the output tubes are 42, 6F6, 6V6, or 6L6, the voltage may be 250 volts, but can be higher (depending upon whether the output is class A, AB, or B). Certain special class B tubes take voltages up to 400 volts. Most other common power tubes take 250 volts as the plate supply.

When the output tubes are triodes, the C bias voltage will be 40 or 50 volts and should be added to the plate voltage supply. You can ignore the bias requirements for pentode and beam power tubes.

If the speaker field is used as a choke in the B supply circuit, allow about 100 volts as the drop across it. Adding this value to the plate voltage requirement gives the d.c. voltage needed at the filter input, which is approximately equal to the a.c. peak voltage when a condenser input filter is used. Since transformers are rated in r.m.s. values, multiply this filter input voltage by .7 to get the approximate r.m.s. rating necessary to give this peak value. Then, add about 50 volts to this r.m.s. value to approximate the rectifier and transformer secondary drops. The total will be the r.m.s. rating for one-half the high-voltage winding.

For example, if we need 250 volts for the plate supply and 100 volts for the field, we need 350 volts d.c. The r.m.s. voltage needed is 350 × .7, or about 245 volts. Adding 50 volts to this gives a rating of about 300 volts for one-half the high-voltage winding, or 600 volts for the entire winding. This is a common rating for average size receivers.

The current requirement for the high-voltage winding can be found by adding the plate and screen grid currents of all the tubes except the rectifier. If a bleeder resistor is used, add about 20 milliamperes to this value. The total will be near the proper rating for the high-voltage winding. To be safe, you can choose a transformer with a current rating higher than this value if one is available.

MECHANICAL REQUIREMENTS

Several typical transformer mountings are shown in Fig. *2*. The type shown at *A* is mounted above the chassis, with the leads going down through chassis holes. The important dimensions are the height (if the cabinet is small) and the mounting centers. (By mounting centers we mean the distance between the centers of the holes through which pass the bolts holding the transformer case to the chassis.) This measurement may be made with a pair of calipers by spreading them until their points reach to the centers of each pair of holes, then checking the spread on a ruler.

The types shown in *B* and *D* mount through a large hole so part is above and part below the chassis. The dimensions of the cut-out area on the chassis are important, as well as the mounting centers. When the replacement listing does not give the "window" size needed, check the mounting centers and core sizes. If they are similar, then the winding dimensions will probably be similar.

Figs. *2A* and *2C* are two views of an above-chassis type with universal mounting brackets. These can be put on any of the transformer bolts in such a way that many mounting center distances can be accommodated.

TRANSFORMER INSTALLATION

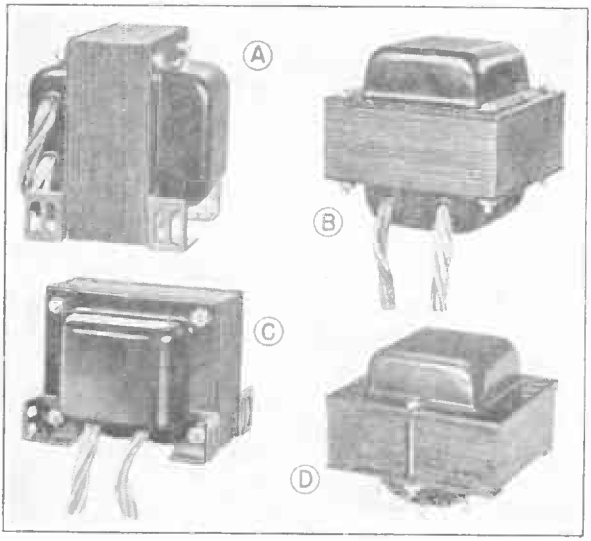
Don't remove the defective transformer until you've obtained the replacement. This will make it much easier to identify the connection.

When you are ready to take out the defective unit, make a sketch of the leads, showing their colors and their connections. Then, to be sure you get the new leads on the right places, cut the old transformer leads near the transformer, leaving the other ends of the leads still connected in the radio. If the transformer is a lug type like that in Fig. *2D*, unsolder the leads at the lugs. Some servicemen fasten marked slips of paper to the leads to identify them.

► If you have an exact duplicate transformer, the replacement will be easy. Just unfasten the original transformer, put the new one in place, and make the proper connections. If the new transformer has leads, they will be colored the same as those of the original, and you can easily find the proper connections from the leads you left in the radio. Remove identifying pieces of wire as you solder the new leads in place.

If the replacement has lugs, the lug positions will be the same as those of the original, and your sketch showing the colors of the wires connected to each lug will aid in your making the proper connections.

Universal Replacements. If the re-



Courtesy Thordarson Elec. Mfg. Co.

FIG. 2. Typical replacement power transformers. The style shown at A, B, and C is a universal type; it may be mounted in many positions by moving the mounting feet to the proper corners. The style at D represents a "half-shell" transformer, which is mounted so that the lugs pass through a large chassis cut-out.

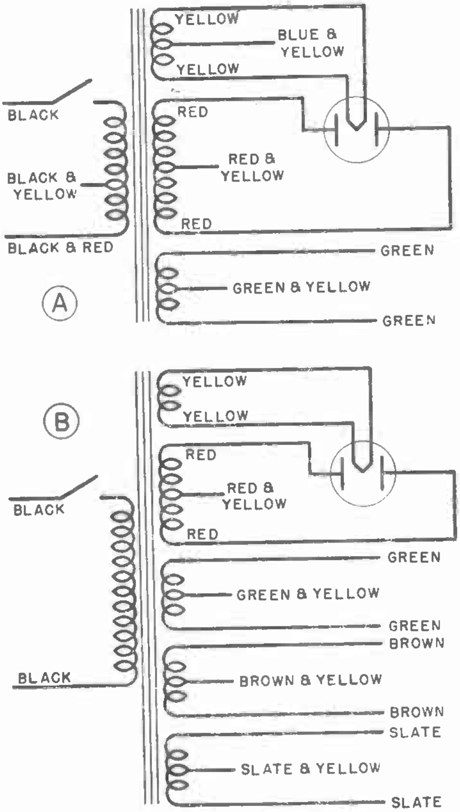


FIG. 3. The RMA standard color code for power transformer leads. Not all transformers have their leads colored according to this code, so watch for those having different arrangements.

placement is not an exact duplicate, mounting and connecting it may be more of a problem.

First, cut off the leads near the defective transformer and make an identification sketch of the connections, then remove the defective transformer and set the new one in its place. If the new transformer has universal mounting brackets, see if you can place it so the brackets fit over the original mounting holes. If not, you will have to drill new holes.

► A universal transformer may be entirely different from the original in the color code of its leads or in its terminal arrangement. There should be a slip packed with the transformer which will identify its terminals, and your sketch of the original transformer connections will show the proper connecting points. Any extra terminals can be ignored. Extra leads, such as unused center tap connections or extra filament windings, can be insulated with tape and tucked out of the way.

IDENTIFYING LEADS

If you have no lead identification slip for your transformer, you may be able to identify the leads from the standard R.M.A. color code for power transformers shown in Fig. *3*—especially if it is a universal type made within recent years. However, there are many variations in the color codes used, particularly in transformers used in earlier receivers.

► If the color code is not helpful, you can identify the windings of an unmarked transformer with an ohmmeter and a simple lamp testing device.

First, use the ohmmeter to discover which leads show continuity to each

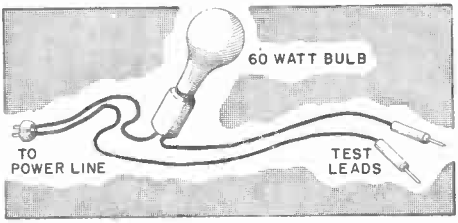


FIG. 4. A simple continuity tester.

other; these leads go to the same winding. Next, put a 60-watt light bulb in series with a power cord and test leads, as shown in Fig. *4*. Separate the transformer leads so that their ends do not touch, then touch the test leads to each pair of wires which show continuity. When you put the test leads across filament windings, you will have a full, bright light; across the high-voltage winding, no light; and across the primary, a faint glow.

Once you have identified the primary, connect it to the 110-volt a.c. line and measure the voltages developed by the secondaries. This will identify each winding. Since you know from the lamp test which is the high-voltage winding, you need not measure its voltage unless you want to know what it is.

Remember that the voltages produced by a transformer with no load connected to it may be somewhat higher than the rated voltages. Thus, a 6.3-volt filament winding may produce 7 to 7.5 volts with no load, while a 5-volt filament winding may produce 5.5 to 6 volts.

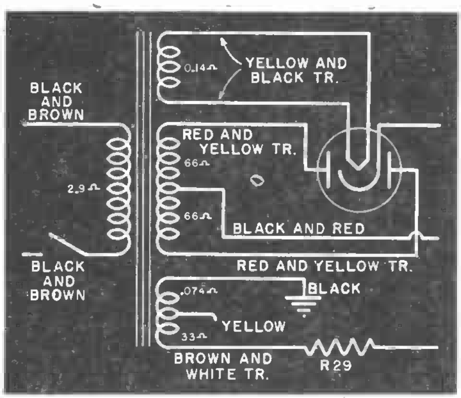


FIG. 5. A typical example of a transformer which is not color-coded according to the RMA code. Notice the special filament winding. Only an exact duplicate transformer can be used to replace this one.

► When the resistance values are given on a diagram, as in Fig. *5*, you can identify the windings with an ohmmeter. Notice that the transformer shown in Fig. *5* has a tapped filament winding. (A check of the circuit diagram of the receiver in which it was used shows that the tube filaments operate from the 6.3 volts produced by the .074-ohm winding, while a special tuning circuit indicator uses the total voltage produced by this secondary.) Also notice that the color code **is not** the standard R.M.A. code.

Another example is given in Fig. *6*. Here, two of the filament windings have about the same resistance, so the ohmmeter reading only identifies them as filament windings. If you did not have a wiring diagram to show the connections or voltages, you would have to measure the voltages to identify these windings.

AUTO-SET TRANSFORMERS

As the transformer, vibrator, and buffer condenser of an auto radio are usually designed to "work together," and since the transformer is usually in a shielded compartment of limited size, it is best to use an exact duplicate replacement. However, universal types are available. The auto-set transformer has only one secondary, and its voltage and current ratings are the only ones to consider. Follow the same rules as for the high-voltage winding of a power line transformer. Remember that the plate voltages range from 180 to 250 volts, and that the speaker field is never used as a choke.

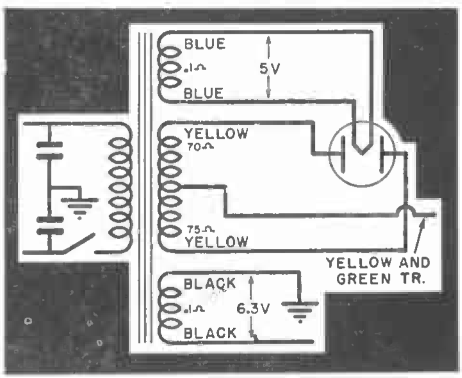


FIG. 6. Filament windings have such low resistances that an ohmmeter is not reliable as a means of distinguishing between these windings. Voltage measurements should be made to complete the identification.

Iron-Core Chokes and Audio Transformers

FILTER CHOKES

A properly moisture-proofed filter choke will rarely open or otherwise become defective unless subjected to a severe overload, such as one caused by shorted or leaky filter or by-pass condensers.

If possible, order an exact duplicate for ease in mounting. Simply ask for a filter choke for the make and model number of the receiver on which you are working. If you cannot get an exact duplicate, order one with about the same physical dimensions and mounting centers. If the original choke was shielded the replacement should also be shielded.

The resistance of a power supply filter choke is not important unless it is in the negative side of the circuit and the voltage drop across it is used for biasing. In this latter case, the resistance of the replacement should be approximately the same as that of the original part (which you may find on the wiring diagram).

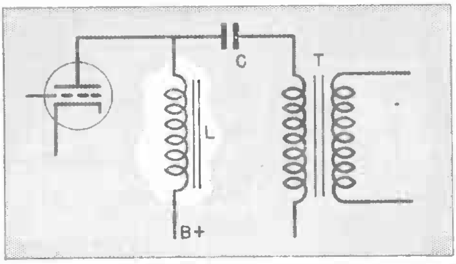


FIG. 7. A high-inductance choke, used as a plate load.

Since high-capacity electrolytic condensers are now used universally in filter systems, an inductance of 10 henrys (or more) is satisfactory. Remember, however, that the choke inductance is figured for a particular d.c. current, and will be lowered if the current rating is exceeded. Thus, if a 60-ma., 10-henry choke is used in a 100-ma. circuit, the inductance may drop to 2 or 3 henrys, and the choke may overheat. You must use a replacement with a current rating equal to or somewhat higher than the actual current flow in the circuit to obtain a proper inductance value.

You can compute the current roughly by adding the normal cathode currents of all tubes (get these from a tube chart) with the exception of the rectifier. Add on 20 ma. if a bleeder system is used. Receivers using a power transformer and about six tubes will require a 60- or 70-ma. choke. Larger receivers will need a choke rated at 100 ma. or more.

In general, satisfactory chokes for a.c.-d.c. sets are obtained just by asking for a choke to use in an a.c.-d.c. set.

AUDIO CHOKES

High-inductance chokes are sometimes found in impedance-coupled a.f. amplifiers and in stages where a coupling transformer or load device is isolated as in Fig. 7. These chokes must have high inductance to pass on low audio frequencies and, like other chokes, the amount of inductance will depend on the d.c. current flow.

If an exact duplicate is not available, use a choke intended to operate in the plate circuit of the particular tube used in the stage, or choose one which has a current rating above the normal d.c. value of that tube.

The higher the inductance of your choke, the better the low-frequency response will be. However, remember that a high inductance means many turns, and the distributed capacity may reduce high-frequency response.

If the original choke was shielded,

the replacement should be also (to minimize hum pick-up).

INTERSTAGE AUDIO TRANSFORMER REPLACEMENTS

An interstage a.f. transformer is one which is used to couple two audio stages together. The windings may open, short, or become noisy. In such cases it is best to use an exact duplicate, for then the response of the receiver will be unchanged and mounting difficulties will be eliminated. When ordering, state the make and model number of the receiver and the position of the transformer in the circuit (first a.f. or second a.f. transformer).

If a duplicate is not available, use an a.f. transformer with a step-up turns ratio of 3:1. The receiver tone quality and hum level may be affected by the change in transformer characteristics, but may even be improved if you use a good quality replacement. As a practical hint—don't deliberately try to change the tone quality unless the receiver owner indicates a desire for a change. He may like the tone quality and be dissatisfied with any change, no matter how much better it may sound to you.

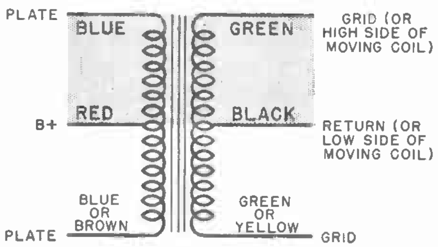


FIG. 8. The RMA color code for audio transformer leads. The shaded upper half is the code for an interstage transformer.

To replace the defective transformer, first cut its leads close to the case (leaving the other ends of the leads connected in the chassis for identification), then remove it. The transformer may be held to the chassis by screws, bolts, or rivets, or by turned-over ears which project through holes in the chassis. Cut off rivet heads with side-cutting pliers, or drill out the rivets. Straighten turned-over ears with a heavy screwdriver.

Next, solder the leads from the new transformer into their proper places, removing each old lead when it has served its purpose as an identifier. The standard color code for a.f. transformers is shown in Fig. *8*. Be sure that you follow any instructions accompanying the replacement.

Turn on the set and listen for excessive hum. Should the hum be abnormally high, see if you can rotate the new transformer to a position where the hum disappears or is at a minimum. If you find such a position, bolt the transformer to the chassis there—if not, bolt it in the most convenient location.

Bear in mind that hum might be caused by other defects—isolate the hum to the new transformer, as described elsewhere in the Course, before you consider special mounting angles or positions.

Emergency Repairs. If a replacement is not readily available for an a.f. transformer with an open winding, you can make a temporary repair by changing to impedance coupling. Shunt the open winding with a resistor and connect a coupling condenser between the plate and grid leads of the transformer. Fig. *9* shows this arrangement for a transformer with an open primary. The resistor used across an open primary should have a value of from 50,000 ohms to 100,000 ohms, while a 250,000- to 500,000-ohm resistor can be used to shunt an open secondary. A condenser of from .01 to .05 mfd., rated at 600 volts, will be a satisfactory coupling condenser.

This is usually a temporary repair,

to be used only while you are waiting for a replacement transformer. It will change the tone quality, and it may decrease the volume so much that the set will be unsatisfactory. Be careful to cut the leads going to the *defective* section (*a* and *b* for the primary, or *c* and *d* for the secondary in Fig. 9) to prevent it from "coming alive" and causing noise.

If the transformer is noisy, cut both the primary and secondary out of the circuit and use resistors in place of both windings. This, with the coupling condenser, gives ordinary resistance-capacitance coupling.

REPLACING INPUT PUSH-PULL TRANSFORMERS

Input push-pull transformers have the same troubles as interstage types —shorts, opens, and noise. If an exact duplicate is not available, you must first determine the class of operation of the output stage. Sometimes, looking up the output tubes in a tube chart will tell you this. Several tubes—type 46's, for example—are used only in class B amplifiers.

If the output tubes are triodes and are not class B types, you are usually safe in assuming that the stage is a class A amplifier. However, if the output tubes are pentodes or beam-power tubes, such as types 42, 6F6, 6V6, or 6L6, they may be operated as class A, class AB, or class B.

You can sometimes tell the type of operation from the operating voltages. Sometimes, also, class B stages are driven by a power tube. For example, a pair of 42 tubes operated from a single 42 tube acting as the driver would probably mean class B operation.

If the secondary winding is not open, you can tell the transformer class by checking the secondary resistance. A class B input transformer will have

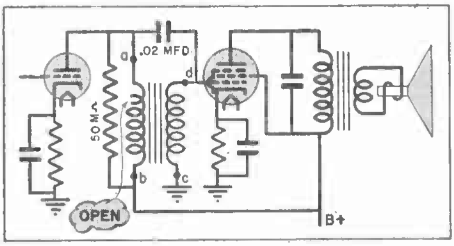


FIG. 9. How to change to resistance-capacitance coupling when there is an open transformer winding.

very low secondary resistance, usually between 100 and 300 ohms. On the other hand, a class A input transformer may have a secondary resistance of from 1500 to 3000 ohms.

► Any high-grade input push-pull transformer which fits the space available will make a satisfactory replacement in a class A output stage. These transformers usually have ratings of 3 to 1.

On the other hand, a duplicate input transformer is necessary for a class AB or B stage. These transformers are designed to work from a particular driver tube into the grid circuit of particular class AB or B stages.

► Hum pickup caused by the transformer's being too near the power transformer, speaker field, or filter choke may make it necessary occasionally to change the position of the replacement.

► Temporary repairs can be made if the primary of an input push-pull transformer opens. Simply shunt the open primary with a .5-watt resistor of between 50,000 and 100,000 ohms, and connect a .01- to .05-mfd., 600-volt condenser from the plate lead of the transformer to either (not to each) of the grid leads. The secondary will then act as an auto-transformer and will deliver equal signal voltages, 180° out of phase, to each push-pull grid.

Phase Inverters. If your customer is interested in improved tone quality (at additional expense) and the output stage is class A, you may suggest using a phase inverter stage in place of the original input push-pull transformer.

The before-and-after circuits for making this conversion are shown in Figs. *10A* and *10B*. Since the phase inverter is self-balancing, no adjustments should be necessary. The phase inverter tube (a dual triode in a single envelope) must operate at the same filament potential as the original tube VT_1.

OUTPUT TRANSFORMERS

The primaries of output transformers frequently burn out. While an exact duplicate replacement is preferable, universal output transformers will give very good results in ordinary class A output stages. These transformers are equipped with tapped primaries and secondaries, which make it possible to match either single or push-pull output tubes to any of the common voice coil impedances.

While complete instructions are packed with each transformer, the general procedure is to connect the primary first. For push-pull operation, the two outside leads go to the plates and the center tap to B+. For a single output tube, follow the instructions. In some cases, the center tap is not used, and one of the outside primary leads goes to B+ and the other to the plate of the tube. In other cases, half of the primary is used.

Then, solder the correct secondary leads to the points from which the original secondary leads were removed. If you know the voice coil impedance, the instructions will tell you which two of the secondary leads can be used. If you don't, you can calculate the voice coil impedance roughly by measuring its d.c. resistance with a low-range ohmmeter. The impedance will be about 1.5 times the d.c. resistance. Modern speakers usually have voice

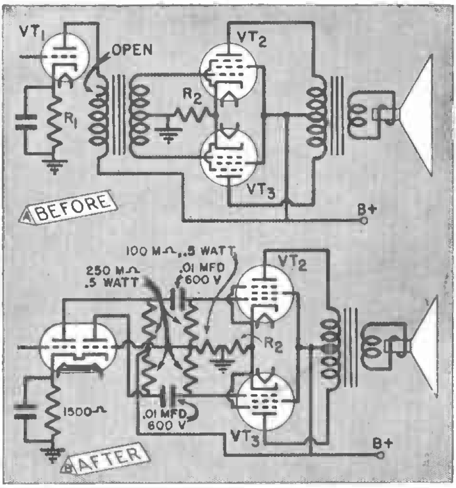


FIG. 10. Substituting phase inversion for an input push-pull transformer.

coil impedances of 6 to 8 ohms, but others range from 2 to 15 ohms.

A slight mismatch is unimportant. However, a large mismatch will decrease the volume to some extent and will cause a noticeable change in response(the high notes will be either too weak or too strong). If the reproduction does not sound normal *(with the receiver in its cabinet)*, try different taps, listening for best response.

If the set has pentode or beam-power output tubes, *don't disconnect the secondary leads while the set is turned on.* Removing the load this way can damage the output tube.

Of course, turning off the set each time you try another secondary tap makes it hard to compare results, since by the time you've connected a tap, you'll probably have forgotten how the set sounded when the previous tap was used. To avoid this difficulty, some servicemen use a test output transformer and "shorting" switch combinations like that shown in Fig. *11*. This switch will not break contact with one point before making contact with another, so there will always be a load on the transformer. Clips are used to connect to the output tubes and to the

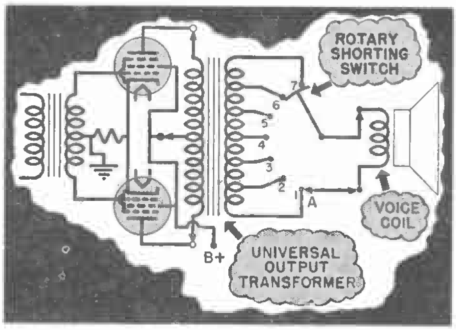


FIG. 11. An arrangement for determining the proper impedance-matching taps on a universal transformer.

voice coil. The lead *A* also has a clip, and is fastened to one of the transformer terminals. The switch then can be rotated to various taps and responses can be compared rapidly. If optimum results are not obtained, lead "*A*" can be clipped to another terminal and a new combination tried. Thus, starting on *1*, we can compare the outputs using terminals 1-2, 1-3, 1-4, 1-5, etc. Then, with *A* on *2*, we can compare the outputs of 2-3, 2-4, 2-5, etc. (The set should be turned off while *A* is being moved, and the switch should not be set on the same terminal as *A*, to avoid removing the load.) The impedance of the taps which give the best output can be found on the chart furnished with the transformer. Now, knowing the proper impedance to use, you can install a transformer having this rating, or can find the proper terminals to use on another universal transformer.

► A universal transformer should not be used in high-fidelity receivers, p.a. systems, high-power circuits (here the types of output tubes are a clue), or if class B operation is used. For such circuits, order a replacement (if you can't get a duplicate) by stating the type numbers of the output tubes, the model number and make of the loudspeaker, and its d.c. voice coil resistance.

► In some receivers, the secondary of the output transformer is tapped to provide inverse feedback. Use an exact duplicate here if possible. Should howling occur when a duplicate is installed, the feedback is causing regeneration rather than degeneration; reverse the connections to the primary of the output transformer. This will reverse the phase of the voltage across the secondary.

If such a transformer must be replaced by a universal transformer, disconnect both ends of the lead which ran to the tap on the old transformer. If the lead is left connected in the circuit, even though it is not connected to the new transformer, it may provide a feedback path and so cause instability and howling.

R.F. and I.F. Transformers

I.F. windings require more frequent replacement than r.f. coils, but their replacement is usually simpler. Both have opens, noise, and lowered Q as their troubles. Short circuits are not so common, but do occur in multi-layer windings. Let's run through the problems for both transformer types.

R.F. TRANSFORMERS

In any receiver, the r.f. (tuning) coils must have equal inductance and distributed capacity values so that they will track when they are used with identical ganged condensers. This means the tuned secondaries must be held to close tolerance values, so most servicemen use exact duplicate replacement coils when anything is wrong with the tuning winding.

If a duplicate is not available, you can: *1*, have one wound by a coil manufacturing company (your supply house will forward your order to one if you do not wish to order direct); *2,* get a universal coil with an adjustable inductance; or *3,* replace all the r.f. coils with a matched set. Let's consider these steps in order.

Case 1. In ordering coils, give the following information:

1. Name and model of radio.
2. Number of chassis and any chassis identification such as a series or code number.
3. Name of coil or of circuit in which it is used (antenna, 1st or 2nd r.f.).

This is usually enough information if the receiver is a popular brand, as coil winding firms know the specifications on these coils and can wind a du-

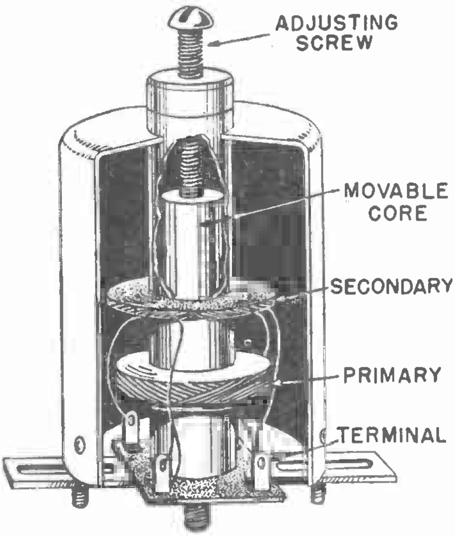


FIG. 12. A universal r.f. transformer.

plicate. However, if the coil is removed from an "orphan" or unidentified chassis, send a schematic diagram of the section of the circuit in which it was used. If requested, send in the defective coil as a sample. (When ordering from a distance, it is a good idea to send the defective coil in as a model, whether requested or not.) If any lugs, leads, or mounting brackets are missing, make a note of their locations. If a shield is used, give its dimensions.

If the coil is one of an identical series of coils, such as are found in a t.r.f. set, a good coil can be sent in as a sample, but be sure to request that it be returned to you.

Case 2. The inductance of a universal coil can be varied over a wide range by an adjusting screw, so if its distributed capacity is not too far off, a universal coil can be made to track reasonably well. Fig. *12* shows a cutaway view of such a coil.

It's easy to adjust a universal antenna or r.f. coil in a t.r.f. receiver. Use a condenser of about 200 mmfd. (.0002 mfd.) as a dummy antenna; connect it between the hot side of a signal generator and the antenna connection of the receiver. Connect an output meter to the receiver, tune the signal generator and the receiver to 600 kc., and rotate the adjusting screw of the coil until you obtain maximum output. Next, tune the receiver and signal generator to 1400 kc. and align the circuits by adjusting the trimmers on the gang for maximum output. This may throw the adjustment at 600 kc. off somewhat, so retune the signal generator and receiver to this frequency and reset the screw for maximum output. Continued adjustment of the 600-kc. and 1400-kc. adjustments usually will give reasonable tracking over the band. However, if the responses are very unequal, or adjusting one throws the other completely off, the distributed capacity of the universal coil winding is widely different from that of the other coils; you should then use an exact duplicate coil or a matched set of coils.

► A slightly different procedure must be followed when you replace an antenna or r.f. coil on a superheterodyne, since the 600-kc. and 1400-kc. receiver dial settings depend upon the receiver oscillator, rather than upon the coil being replaced. First install the new coil, then adjust the oscillator high-frequency trimmer and the low-frequency padder, if one is used, so that the receiver tracks its dial. Next, adjust the new coil inductance at 600 kc. and its trimmer at 1400 kc. for maximum output. Repeat the low- and high-frequency adjustments for the new coil just as for a t.r.f. set. Do not adjust any of the other trimmers on the gang at this time—only the one for the new coil. Complete realignment can be made after the inductance of the replacement coil is satisfactory.

Case 3. When you have an a.c.-d.c. t.r.f. set using a single stage of r.f., in which either the antenna or r.f. coil is defective, simply order a matched antenna coil and an r.f. coil. Specify that they are to be used in an a.c.-d.c. midget. Get shielded coils if the originals were shielded. In most cases shields are not used, the antenna coil being mounted above the chassis and the r.f. coil under the chassis. The instructions which come with the coils will facilitate their installation, but of course you should identify each lead on the old coils before unsoldering them. Fig. *13* shows a typical pair of replacement coils.

Defective Primaries. The foregoing procedures are necessary if the secondary or tuned winding is defective. However, the secondaries seldom fail; it is the primaries, which carry appreciable amounts of plate current, that usually open up. The primaries of antenna coils (these are also called r.f. coils) are sometimes burned to a crisp by lightning or by a customer's carelessly plugging the aerial and ground leads into a lower line outlet rather than an antenna outlet.

Most servicemen replace the entire coil if the primary is defective, particularly when a replacement is easy to obtain. However, the inductance of the primary is not critical, so it is possible to use a replacement primary winding which can be slipped on the coil form and wired in the circuit to replace the original.

Since r.f. coils vary in physical size you should have an assortment of these windings on hand if you intend to use them. Both low- and high-impedance types are available, but most modern radios use the high-impedance types.

The replacement primary is slipped over the secondary as shown in Fig. *14*. Be sure to follow the manufacturer's instructions carefully, for the position and direction of the winding are important. If it is necessary to disconnect the transformer to get the primary on, be sure to make a connection sketch.

OSCILLATOR COILS

An open primary is the usual defect of an oscillator coil. It is best to install an exact duplicate rather than a new primary, because the primary controls the amount of feedback.

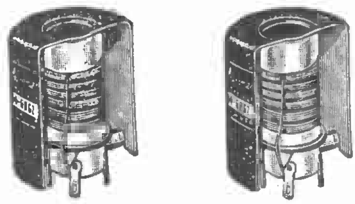


FIG. 13. A cut-away view of a set of shielded, matched r.f. transformers. These are also available unshielded.

If necessary, the coil can be repaired by one of the firms specializing in this business. If you send a coil off to be repaired, include a schematic diagram of the circuit in which it is used, give the make and model number of the receiver, the intermediate frequency, the type number of the oscillator tube, and state if the oscillator section of the condenser gang has specially shaped plates.

Be certain that you draw and keep a diagram of the exact connections to the coil lugs—so you'll have no trouble in making the new installation.

Universal oscillator coils are available, but their installation and adjustment is quite a problem, particularly if the padder adjustment has been disturbed. If you get a universal coil, be sure to follow the detailed instructions furnished by its manufacturer.

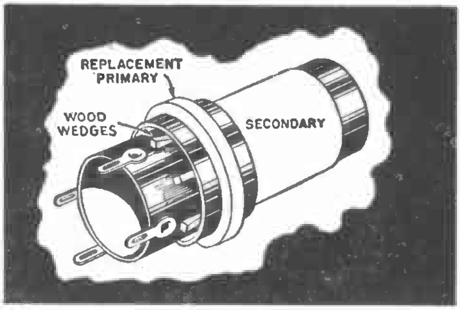


FIG. 14. How a replacement primary winding is installed.

Multi-Band Coils. When the receiver has several wave bands and uses a tapped coil or multiple windings on the same form, either an exact duplicate or a rewinding job is necessary. Matched sets of coils with taps for the police band are available for a.c.-d.c. receivers, but these are almost the only exceptions.

I.F. TRANSFORMERS

The i.f. transformer assembly includes the coils and their tuning condensers. Occasionally the trimmers will short or become leaky, or a high-resistance joint will develop. Generally, though, the trouble is an open coil, which you can repair by installing either a replacement coil or a complete transformer assembly. If a new transformer is available, use it in preference to new windings, since far less time will be spent in making the replacement.

Any large coil manufacturer can furnish either duplicate or satisfactory universal replacements. Sometimes, mounting holes for the new shield will have to be drilled in the chassis. When you order a replacement transformer, state the make and model number of the receiver, the i.f., and the position occupied by the transformer in the circuit. For example, if two i.f. transformers are used they are spoken of as the first (or input) i.f. transformer and as the second (or output) i.f. transformer. If three i.f. transformers are used, the first is called the input i.f. transformer, the second is called the interstage i.f. transformer, and the third is called the output i.f. transformer. It is very important to get transformers which are designed to work with the *number of i.f. stages* used. Transformers designed for a *single* i.f. stage have very high gain, and if they are placed in a set using *two* stages of i.f. amplification, the amplifier will be unstable and may oscillate.

Try to get a replacement with the same physical dimensions—give the size of the transformer shield and the mounting centers.

The leads on the replacement transformer may have a different color code than the original transformer leads had. Replacement i.f. transformers use the color code shown in Fig. *15* unless otherwise specified.

The blue (plate) lead and the green (diode or control grid) lead should be kept as far as possible from each other, and away from other grid and plate leads. The position of the original leads is usually a reasonable guide, but if the new transformer has a higher gain than the original, it may be necessary to separate the leads more to prevent oscillation.

In general, the blue and green leads should be as short as possible. The

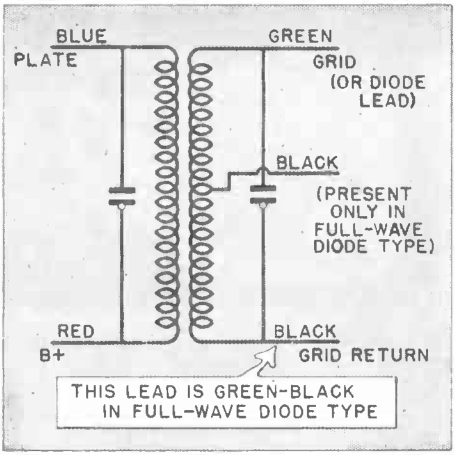


FIG. 15. RMA color code for i.f. transformer leads.

length and routing of the red (B+) lead is ordinarily unimportant. The length and route of the black lead is important only in output transformers; in them, this lead carries i.f. to the diode load and is quite "hot," so should be kept short.

► If you can't get a replacement i.f. transformer which will fit on the chassis, install replacement coils—preferably exact duplicates. Again, your order must identify the receiver by make and model number and also identify the i.f. transformer. If an exact duplicate is not available, order a replacement designed to operate at the intermediate frequency of the receiver and equal or close to the original in physical dimensions. Typical replacements are shown in Fig. *16*.

► The spacing between the primary and secondary coils is important, but is usually factory-adjusted. Should you get a set of coils with adjustable spacing, however, measure the distance between the original coils before removing them, and use the same spacing on the replacements. This will give average satisfactory results.

An exact adjustment can be made by getting a response curve for the transformer with a c.r.o. and a frequency-modulated (wobbulated) oscillator in the manner you learned earlier in your Course. If the coils are somewhat overcoupled the curve will be flat; if they are very much overcoupled it will be double-humped. If the coils are undercoupled the curve will be "low." Overcoupling causes poor selectivity; undercoupling results in poor sensitivity. You should adjust the spacing of an ordinary i.f. transformer so that the response curve just starts to flatten at resonance. An adjustable band-expanding transformer should have no flattening of the response curve in the sharp or selective position, but in the broad or "fidelity" position the curve should have a flat top or even a double-hump. High-fidelity transformers (which are usually factory-adjusted) will be overcoupled and should have a broad flat-top or double-hump characteristic.

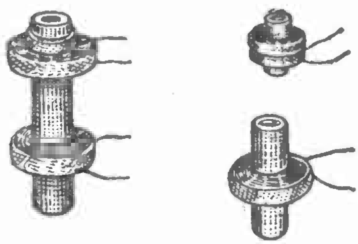


FIG. 16. Typical replacement i.f. windings.

Once you've found the right spacing, cement the coils in place with coil dope.

Some i.f. transformers have three windings, for band-pass operation. Use a duplicate instead of a universal replacement for these.

Replacing Condensers

You may have to replace all kinds of condensers—even tuning condenser gangs. However, you will usually carry only an assortment of paper and electrolytic types, and perhaps a few fixed mica condensers in stock. Let's take up condenser replacements according to type.

PAPER CONDENSERS

The most important ratings for any condenser are the capacity and the working voltage. The rating of the original part usually can be found from the schematic diagram or from the condenser label, but an exact duplicate replacement is seldom needed for a defective paper condenser. A wide variation in capacity is usually permissible.

If you don't know the original capacity, use .01 mfd. to .1 mfd. for r.f. and i.f. by-passing, .25 mfd. to 1 mfd. for a.f. by-passing, .00025 mfd. for grid leak detectors, .002 mfd. to .05 mfd. for a.f. coupling condensers, and .001 mfd. to .05 mfd. for buffer condensers. This gives a clue to the sizes you should stock. A few each of the .01, .05, .1, .25, and .5-mfd. sizes will be adequate for practically all by-pass and audio coupling purposes.

A more important factor is the condenser working voltage rating, *which should always be greater than the voltage across the terminals to which the condenser is connected.* Many servicemen never use a paper condenser with less than a 600-volt rating (space permitting) even if the condenser is to be used in a low-voltage circuit. It costs only a few cents more and is excellent insurance against a call back. Buffer condensers in vibrator power supplies should be rated at 1600 volts or more. Filter condensers of the paper type (very rare today) should have a 600-volt to 1000-volt rating.

Sometimes one end of a tubular paper condenser will have a black ring on it and be marked "outside foil" or "ground." The foil connected to the lead at this end of the condenser is the final outside layer and surrounds the rest of the condenser. If a condenser goes either directly or through a low-impedance path to ground, this ground connection should be made to the outside foil end of the condenser—the outside foil then acts as a grounded shield and prevents undesirable coupling between the condenser and other circuits. In most well-designed receivers, however, it won't make any difference which end of a paper condenser is grounded. If the condenser is used for coupling (neither end grounded), ig nore the outside foil marking.

ELECTROLYTIC CONDENSERS

Electrolytic condensers often prove puzzling to newcomers in the service business. When replacements are to be made, many questions about capacity, working voltage, and types come up.

Let's consider capacity first. A replacement should not be much below the capacity of the original, but can be much higher. For example, a 10-mfd. *output* filter condenser should not be replaced by one smaller than 8 mfd., but a much larger condenser can be used and will give better filtering. However, do not replace an *input* filter condenser with one of more than twice the capacity of the original, for the peak current through the rectifier tube may increase to the point where the tube will be damaged. This is particularly true of a.c.-d.c. sets.

In replacing electrolytic by-pass condensers, never use a capacity lower than the original; a larger capacity will give better results. In replacing condensers used across the filament strings of three-way receivers, stick to the original capacity if possible.

Here is a good rule to remember about working voltage. *The working voltage of the replacement must be at least as high as the original;* if it is higher there will be less chance that the new condenser will break down. If you are in doubt about the voltage applied to the condenser, check it with a d.c. voltmeter. When the set is first turned on, the voltage may be considerably higher than when the tubes start drawing current. It is this initial high voltage that the condenser must withstand. A working voltage of 150 volts is standard for filter condensers in a.c.-d.c. sets (voltage doublers use 250 volts), while 450 volts is standard for a.c. receivers. C bias by-pass condensers are usually rated at 25 or 50 volts.

Dry electrolytics usually—but not always—can be substituted for wet electrolytics. Remember the fundamental difference between the two. The dielectric of wet electrolytics can be broken down by an overload, but when the overload is reduced the dielectric film will reform. If dry electrolytics are overloaded for any length of time, their dielectric film breaks down *permanently* and the condenser must be discarded. In some sets using wet electrolytics, the initial starting surge breaks down the dielectric film each time the set is turned on. If you want to substitute drys, be sure to check this starting voltage. If it exceeds the working voltage of the condensers, either install wet electrolytics, or try a 50,000-ohm, 5- or 10-watt bleeder resistor across the output filter condenser. The resistor will draw current as soon as the rectifier tube starts passing current and usually will reduce the starting voltage to a safe level. Be sure to measure the voltage again after installing the bleeder, however, to be certain it does not lower operating voltages too much.

The type of can or container used for electrolytic condensers has nothing to do with replacements. For example, a condenser in an aluminum can may be replaced by a tubular paper type electrolytic with similar ratings.

► If there are a number of condensers in a case and only one is bad, you can connect a single-section replacement unit outside the case in the place of the defective section. However, it is best to replace them all, since the others will not last as long as the new one. Not only must the replacement contain the correct number of condensers, but also their leads must be arranged so that they can be properly wired into the circuit. As an example, look at Figs. *17A* and *17B*. Each condenser block contains the same condensers and each has three leads. Yet the blocks could not be interchanged—the block in Fig. *17A* has a *common negative* lead for both condensers, while the block in Fig. *17B* has a *common positive* lead for both condensers. If any of the leads in a block are common to two or more condensers, say so when you order a replacement. Two separate condensers, or two condensers in a block with separate positive and negative leads, could be used to replace the condensers in Figs. *17A* and *B*.

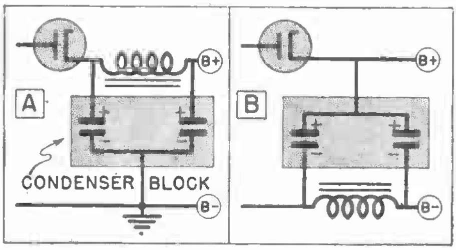


FIG. 17. Two styles of filter condenser blocks. These are NOT interchangeable, so be sure you get the proper replacement.

MICA CONDENSERS

Mica condensers rarely go bad; when one does, it is best to use a replacement of the same capacity. Because different color codes are often used on micas, it is usually easiest to identify the proper size from the wiring diagram. If you have no service information, examine the original. You may find the capacity value is stamped on the condenser, or it may be marked according to the standard color code (see Fig. *18*). Remember, *private* color codes are sometimes used, so if you come out to some unreasonable capacity value, the marking is probably *not* the standard code.

RMA COLOR CODE FOR MICA CONDENSERS

COLOR A is first figure of capacitance.
COLOR B is second figure.
COLOR C is number of zeros after second figure.

COLOR A is first figure of capacitance.
COLOR B is second figure.
COLOR C is third figure.
COLOR D is number of zeros after third figure.
COLOR E is tolerance.
COLOR F is working voltage.

Capacitance in MMFD for condensers smaller than .01 mfd, capacitance in MFD for larger condensers.
Arrow or lettering usually shows right direction for reading dots.

COLOR	FIGURE	TOLERANCE	WORKING VOLTAGE
BLACK	0	—	—
BROWN	1	1%	100 V.
RED	2	2%	200 V.
ORANGE	3	3%	300 V.
YELLOW	4	4%	400 V.
GREEN	5	5%	500 V.
BLUE	6	6%	600 V.
VIOLET	7	7%	700 V.
GRAY	8	8%	800 V.
WHITE	9	9%	900 V.
GOLD	—	5%	1000 V.
SILVER	—	10%	2000 V.
NONE	same as case color	20%	500 V.

FIG. 18. The RMA color code for mica condensers.

GANG TUNING CONDENSERS

In modern receivers the tuning condenser gang seldom becomes so defective it cannot be repaired. Even badly bent plates usually can be straightened with a thin putty knife. However, if they are beyond repair, the shaft is bent, or the bearings are damaged, a new gang—an exact duplicate—should be installed. Unless you order from the set manufacturer, remove the old gang and send it with your order to make certain you get the correct replacement. Be sure to give the make and model number of the receiver.

The plates of older condensers were often set in white metal castings. This metal may warp, throwing the condenser out of line and causing the rotor and stator plates to scrape against each other. Don't try to bend the plates, unless no replacement is available, as the casting will continue to warp and the trouble will reappear in a short time.

Replacing Resistors

Resistors fall into several classifications: fixed, semi-variable, and variable types. They may have carbon, a metallic deposit, or resistance wire as the resistive element. Let's take up each type in turn.

FIXED RESISTORS

You're usually safe in suspecting excess current as the reason for a metallized or carbon fixed resistor's going bad, particularly if the resistor has a burned or charred appearance. (Wire-wound resistors rarely burn out—electrolysis at the junction of the terminal lug and the resistance wire is the usual trouble.) Look carefully for the cause of this excess current before installing a new resistor. A check from the low potential end of the resistor to the chassis with an ohmmeter will show whether a broken-down condenser or

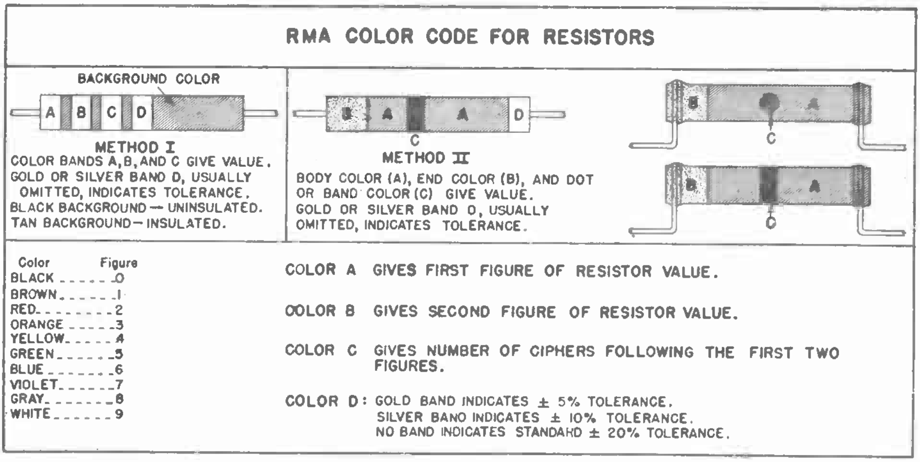


FIG. 19. The RMA color code for resistors.

some other short burned out the resistor. If the resistor is not changed in appearance and no short can be found, the element is probably cracked.

After you've repaired the short (or made sure there is none), determine the proper size for the replacement.

Resistance values are not critical and a variation of 20% is of little importance. You can find the value of the original resistor from the schematic diagram, or from the color code markings (if it follows the standard code). The color code for resistors is shown in Fig. *19*.

The circuit in Fig. *20* shows some typical resistor value ranges. If you can't determine the resistance of the burned-out resistor, install one that is shown by this figure to be appropriate for the circuit involved. If the set works satisfactorily and the voltages seem to be normal, leave the resistor in—otherwise, experiment with different values until you get the results you want.

► Always use a replacement resistor with a wattage rating equal to or higher than that of the original—*never lower*. Otherwise, the replacement will burn out. You can use the physical size of the resistor as a guide if the replacement is the same type (carbon, metallized, or wire-wound) as the original. The replacement should be the same physical size, or larger.

If carbon resistors used as bleeders or voltage dividers are defective, replace them with 10- or 20-watt wire-wound types.

When sections of a candohm unit fail, it is generally best to replace the entire unit with a duplicate or with individual wire-wound units. Don't use the lugs on the candohm as anchor points for individual resistors, because the defective unit may "come alive."

Your stock of resistors should include a kit of carbon or metallized resistors in the ½-, 1-, and 2-watt sizes. You will usually find that values of 200, 300, 1000, 5000, 25,000, 50,000, 100,000, 250,000, and 500,000 ohms are used most. Then, you can add a kit of wire-wound 10- and 20-watt types. The most used sizes of these depend on the kinds of radios you service most, and they can be learned best from experience.

► Most wire-wound voltage dividers have fixed, predetermined values. If a duplicate divider cannot be obtained and the section values cannot be determined from the service data, install a 25,000- to 50,000-ohm, 50-watt semi-variable unit and adjust it to give the proper voltages. Then, measure the sections and use fixed resistors as replacements for them.

► Some of the new molded resistors look like the small mica condensers. These resistors are ordinarily black, marked with three colored dots. Read these dots in the same order as you would those on a three-dot condenser; they then have the same meaning as the body, end, and dot colors respectively, on regular carbon resistors.

There are also condensers shaped like resistors. The condenser values are indicated by bands of color. Two groups of bands may be used, with the bands in each group being the same width, and the groups of bands being different in width. The bands of greater width indicate the significant figures of the capacity, while the bands of smaller size indicate the number of ciphers, the tolerance, and the voltage rating respectively.

VARIABLE RESISTORS

Volume and tone controls are the most important variable resistors. Exact duplicate controls are available and are the simplest to install. Some special dual control units can be replaced only by exact duplicates. However, a kit of universal sizes will permit replacement of most controls; sooner or later you will probably stock such a kit.

The physical size of a volume or tone control will not matter as long as it is not too large for the space provided. However, there are several types of

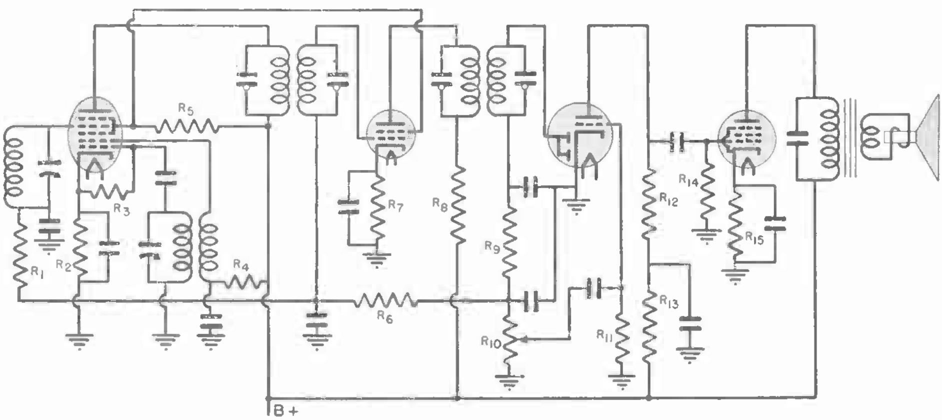


FIG. 20. This circuit shows the locations of most of the resistors used in modern radio receivers. (The diagram is incomplete otherwise.) Here are typical values used:

R_1 —a.v.c. decoupler—50,000 to 250,000ω (100,000 most common)
R_2 —1st det. bias resistor—200 to 300ω
R_3 —osc. grid resistor—50,000ω for a.c., 100,000-200,000ω for battery tubes
R_4 —osc. plate resistor—20,000ω
R_5 —screen dropping res.—50,000ω if no bleeder
R_6 —a.v.c. decoupler—500,000ω to 2 megs. (1 meg. most common)
R_7 —i.f. bias—200-600ω (usually 300ω)
R_8 —i.f. plate decoupler—1,000 to 10,000ω (usually 2000 or 5000ω)
R_9 —i.f. filter—50,000ω
R_{10}—diode load—50,000 to 500,000ω (100,000ω most common)
R_{11}—1st a.f. grid—500,000 if biased; 10 to 20 megs. if convection biased
R_{12}—R-C plate res.—50,000 to 250,000 (100,000 most common)
R_{13}—plate decoupler—5000 to 50,000 (10,000 or 20,000 most common)
R_{14}—R-C grid res.—100,000 to 500,000 (250,000 most common)
R_{15}—power tube bias—150 to 600ω (depends on tube, and whether bias is for single or push-pull tubes)

shafts, and if the wrong one is used the knob may not fit. Most shafts which are not exact duplicates are considerably longer than necessary and must be cut to the right length with a hacksaw.

The original control may have been equipped with an ON-OFF switch. If so, a switch can be attached to the back of a universal control by following the manufacturer's instructions. Consult a control guide book if the original switch is a special type, such as may be found in battery sets; you may have to use a duplicate control.

The electrical size of a volume control depends on the circuit in which it is used. Some representative circuits are shown in Fig. *21*. (Volume control guides show many more.) These guides will also prove helpful if you can't determine resistance values from the schematic diagram or the original control. Actually, the resistance value is seldom critical.

Of the three types of connections commonly used today, the combination antenna-C bias control (Fig. *21A*) may have any value between 10,000 and 25,000 ohms; the a.f. grid control (Fig. *21C*) may be between 250,000 ohms and 2 megohms; and the diode load type (Fig. *21E*) may be from 50,000 to 250,000 ohms.

More important than the resistance value is the control taper—the manner in which the resistance varies with the shaft rotation. You don't have to worry about this, however; just name or sketch the circuit in which the control is used and your supplier can furnish the proper replacement. (Your kit of universal types will have a guide book showing the proper types.)

Some controls have taps for automatic bass compensation circuits. Be sure the replacement has similar taps.

► Tone controls are ordered and replaced the same as volume controls. Again, a guide book will prove helpful.

► Before removing an old control, always draw a connection diagram so you'll have no trouble wiring up the new control. When the old control is removed, measure the distance from the end of the shaft to the threads on the bushing. If necessary, cut the new control shaft to the same length with a hacksaw. Hold the end of the shaft in a vise while cutting it.

When one terminal of a control must be connected to the set chassis, you will sometimes find that the connection was made internally in the original control. An *exact duplicate* replacement will have a similar connection, but a *universal* replacement will not. In this last case, you have to run a wire from the proper terminal lug to the chassis, in addition to making the other connections.

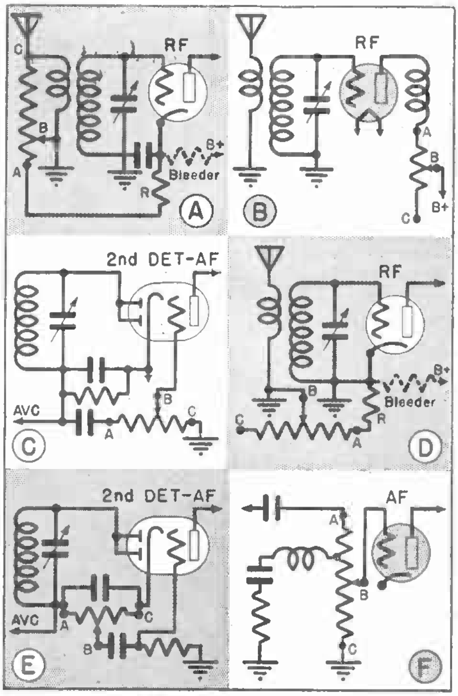


FIG. 21. Typical volume control connections.

Replacing Loudspeakers

Speaker repairs generally are made by the manufacturer or by firms specializing in this service, although occasionally you may find it profitable to replace a cone-voice coil assembly or a field coil yourself. Very often, particularly in small sets, the cheapest course is to buy a new speaker. Let's see just how you should go about ordering new parts, repairs, or new speakers, and how you should install replacements.

Replacement Cones. If you are going to have a cone replaced by the set manufacturer or by a firm specializing in this service, send in the entire speaker. It will come back with the proper cone installed.

If you decide to replace the cone yourself and can get the old cone out of the speaker intact, send it to the set manufacturer or to a firm manufacturing cones and request a duplicate. Include the make and model number of the receiver with your order.

If the old cone is completely torn up or missing, or if you are servicing some private brand or orphan* receiver, you can send the speaker to a cone manufacturer and have an acceptable cone installed. Should you prefer to install the cone yourself, and don't know the name of the set manufacturer, examine the speaker carefully to see whether you can determine the name of the speaker manufacturer and the model designation of the speaker.

If you can't find this information, specify the diameter of the cone, the diameter of the voice coil, and the impedance of the voice coil when you order a replacement from a cone manufacturer. Be sure to state whether the diameter is that of the cone opening or that of the speaker frame rim. You should specify also the depth of the cone housing from the front pole piece to the front edge of the housing. It is advisable to make a drawing showing just what measurements you are giving, to help the manufacturer determine the right size for the cone.

Field Replacements. What we've said about cone replacements applies also to the speaker field. You can return the original speaker to the set manufacturer or send it to a firm specializing in replacements, allowing them to install the proper type for you. If you want to do the work yourself, be certain that you specify the make and model number of the set, as well as any other numbers which may appear on the speaker itself.

If an exact duplicate replacement is unavailable, you must give the resistance of the field and its physical dimensions (length, and inside and outside diameter). Universal replacement speaker fields are available which have two windings; the resistance of these can be adjusted by making series or parallel connections, but the range of the adjustment is limited, so the field selected must be near the right size in the beginning.

You may wonder how you can give the field resistance when the original field is burned out. A service manual or a speaker field replacement guide usually will tell you what the resistance should be. If these sources fail, you can make a reasonable estimate of the resistance from the way the speaker is used, or you can find it by a resistance substitution method.

*A private brand set is manufactured for department stores, chain stores, or small retail outlets. An orphan is one which does not have the manufacturer's name on the set, or one of which the manufacturer is out of business.

► For example, you know that usually the speaker field of an a.c.-d.c. receiver either is connected across the output of the rectifier, as shown by coil L_1 in Fig. *22A*, or is connected to a single diode as in Fig. *22B*. In either case, the field value will be 2500 to 3000 ohms, and any value in this range will prove satisfactory.

Should the speaker be used as a choke in an a.c.-d.c. receiver, in the position indicated for coil L_2 in Fig. *22A*, the resistance is low—usually 300 to 400 ohms.

► In the standard a.c. receiver, the speaker field is usually used as a choke coil, illustrated as coil L_1 in Fig. *23*. If this coil is burned out, a resistance substitution method will let you find its approximate resistance.

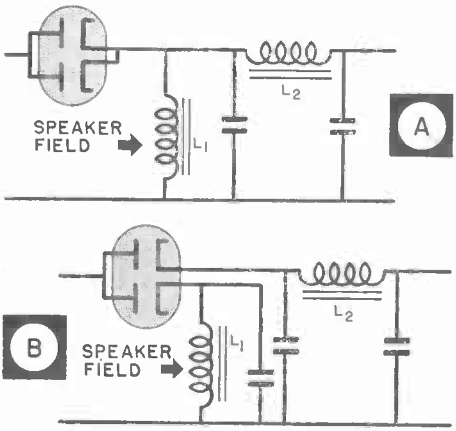


FIG. 22. Two methods of connecting speaker fields which are used in universal a.c.-d.c. sets.

First, check the set to be certain that no short circuits have passed excess current through the field and caused the burnout. Repair any shorts that you find. Next, connect a resistor in place of the field as shown in Fig. *24*. Use a 5000-ohm variable resistor, rated at 20 watts or more, which has one or more sliding taps. First move the slider to the end of the resistor, placing all the

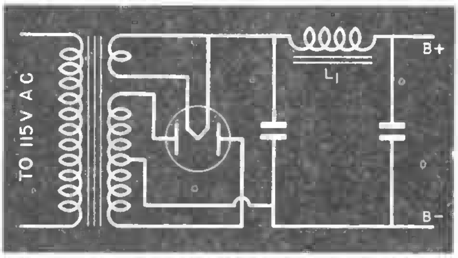


FIG. 23. The speaker field is used here as the choke.

resistance in the circuit. Then turn on the set and measure the voltage between B+ and B—. Compare this voltage with the voltage given in the service diagram or with the normal voltages usually applied to the output tubes. If the measured voltage is too low, decrease the value of the resistor by moving the tap (turn off the set before doing this). Experiment with the tap position until the correct B supply voltage is secured, then disconnect the resistor and measure the resistance of the section finally used with an ohmmeter. This is approximately the resistance of the field.

A speaker in the negative side of the circuit may have a tap for bias connections, as shown in Fig. *25*. If an open is found between the tap and ground, in the bias section, it is frequently possible to replace this section of the field with a resistor, allowing the remainder of the field to act as a choke coil.

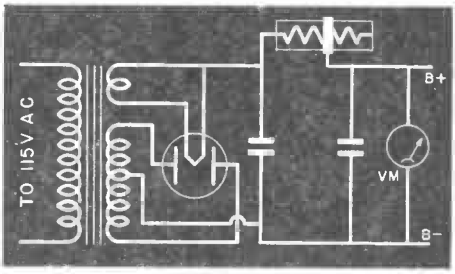


FIG. 24. Finding the resistance of a burned-out field by resistance substitution.

Since the tapped section of the field usually has a resistance of only 300 ohms or so, a 500-ohm, 10-watt resistor with a slider tap can be used. (See Fig. 25.) To adjust the resistor, first put all the resistance in the circuit; then, with the receiver turned on, gradually reduce the resistance until the proper bias voltage appears across it.

If the open is in the main section (L), a replacement is necessary.

ORDERING AND INSTALLING REPLACEMENT SPEAKERS

There is, of course, no particular problem involved in ordering or installing an exact duplicate speaker. Simply order the replacement from the set manufacturer or distributor, giving the model number of the set and the make and model numbers of the speaker.

Some set manufacturers sell new speakers on a "trade-in" basis. When you send in the old speaker to get a new one on this plan, give the model number of the receiver. Any other information the manufacturer needs he can get from the old speaker.

► If you want to use a speaker which is not an exact duplicate, you must be sure the voice coil impedance, the speaker field resistance, and the physical size of new speaker are acceptable. For instance, the new speaker should not have a cone diameter larger than the opening in the baffle of the radio cabinet—if it does, it will be necessary to cut a larger opening in the cabinet, which may not be practical. (Of course if the speaker is smaller, you can always mount it on a board which has an opening of the proper size and fasten this board over the original baffle opening.) And when you order a speaker for a table model cabinet, you must be sure to get one of such size or shape that it will fit into the cabinet with the radio.

As you have learned, the voice coil impedance can be found by measuring the voice coil resistance with an ohmmeter, then multiplying this resistance by 1.5. This is just an approximation, and it is possible for some mismatch to occur. Therefore, if you're not positive that the voice coil impedance of the new speaker is the same as that of the old one, replace the output transformer as well as the speaker. You can usually buy an output transformer with the speaker which will match it to the output tubes used. Specify the make and model number of the speaker and the number and types of output

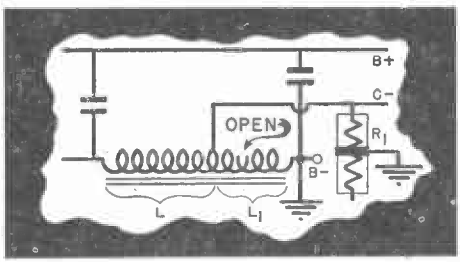


FIG. 25 A tapped speaker field.

tubes when you order the transformer.

You might use a universal output transformer, adjusting it in the manner you learned earlier in this lesson.

Replacing Magnetic Speakers. Since magnetic speakers are far inferior in performance to p.m. dynamics, many servicemen use p.m. replacements for them. Usually, magnetic speakers are found in midgets, where space limitations are important. However, p.m. type speakers are made with diameters as small as 2 inches, and usually take no more space than the equivalent magnetic speaker.

Although a matching transformer is necessary with the p.m. speaker, those used with little speakers are generally small enough to fit into even a midget receiver without trouble. When you order your p.m. speaker, specify that it be equipped with an output transformer which will match it to the power tube used.

Replacing P.M. Speakers. You should always replace a defective p.m. speaker with another p.m., to avoid having to energize a field. You have to consider only the size of the replacement and the voice coil impedance. A new output transformer is necessary if the voice coil impedance differs from the original.

Replacing Electrodynamic Speakers. Should you wish to replace an electrodynamic speaker with a p.m. speaker, you must match the voice coil impedance of the p.m. unit to the set output (using a new transformer if necessary) and also make whatever set adjustments are necessary to compensate for the loss of the field coil.

If the field of the original speaker was in parallel with the voltage source (like L_1 in Figs. *22A* and *22B*), as it is in many a.c.-d.c. receivers, just remove the original field connections. If

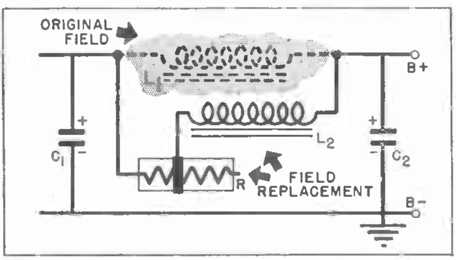


FIG. 26. A choke-resistor substitute for a speaker field.

the field is used as a choke like L_2 in Fig. *22A* or L_1 in Fig. *23*, you will have to provide a choke coil to obtain equivalent filtering. For an a.c.-d.c. set, order an a.c.-d.c. filter choke, which is usually rated at 10 henrys and 50 ma. The resistance of this choke will be

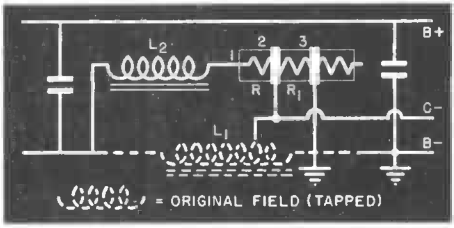


FIG. 27. A substitution for a tapped speaker field.

comparable to the field resistance.

You will have to use both a choke and a resistor in a standard a.c. receiver, since the average choke coil has a resistance of only 300 to 600 ohms, while a speaker field resistance may be anywhere from 1000 to 3000 ohms. The proper connections are shown in Fig. *26*, where the choke L_2 and the resistor R replace the original field (shown as L_1).

The replacement choke coil should have an inductance rating between 10 and 30 henrys and a current rating at least as high as the receiver current. A choke rating of 75 to 100 ma. is usually sufficient.

If the field was tapped and used to supply bias for the power output tubes (Fig. *27*), you can follow the same general method of replacement used in Fig. *26*, except that the resistor must have two slider taps. Connect one of these sliders to the point connected to the tap on the original field, and connect the other slider to the set chassis (see Fig. *27*).

Make the resistance between points *1* and *3* of this figure approximately equal to the original field resistance. Then bring slider *2* toward slider *3* until the voltage drop across section R_1 delivers the proper bias for the output tubes.

Lesson Questions

Be sure to number your Answer Sheet 47RH-2.

Place your Student Number on *every* Answer Sheet.

***Send in your set of answers for this lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. Suppose a power transformer stops smoking and cools off when the tubes are removed, even though the on-off switch is still turned on. Was the overheating due to an overload, or is the transformer defective?

2. Suppose the tester shown in Fig. *1* is being used to check the primary current of a transformer having an internal short. Should the lamp light: 1, *dimly;* 2, *brightly;* 3, or should it show *no light?*

3. Suppose a power transformer is available which has a filament winding rated at 6.3 volts and 4.5 amperes. The set in which you want to use it has tubes rated at 6.3 volts, and they draw a total of 2.7 amperes. Can the transformer be used?

4. An input push-pull transformer has a defective primary, and a check of the secondary shows a resistance of 300 ohms. Is the transformer an input for a class *A output stage*, or for a *class B stage?*

5. Suppose a plate by-pass condenser in an i.f. stage becomes defective. Would you use 50 $\mu\mu$f., .01 mfd., .5 mfd. or 8 mfd. as the replacement capacity?

6. If a 10 mfd., 150-volt electrolytic condenser becomes defective, could a 16-mfd., 250-volt condenser be used as a replacement?

7. When you install a replacement r.f. coil having a variable inductance, is the coil inductance adjusted at 600 kc., or at 1400 kc?

8. Suppose a receiver using the a.f. volume control circuit of Fig. *21C* has a defective control rated at 500,000 ohms. Could you use a 1-megohm audio type control as a satisfactory replacement?

9. If a receiver uses a dual electrolytic filter condenser having a common positive lead, can you replace it with a dual electrolytic condenser having a common negative lead?

10. If you do not know the voice coil impedance of a loudspeaker, how can you approximately determine its value?

Be sure to fill out a Lesson Label and send it along with your answers.

YOUR REPUTATION

Success in business depends on a number of things, but your reputation is probably the most important of these. Your sense of "fair play," and of honest dealing will determine your reputation, whether you operate a store or work as a serviceman. To help you get started properly, here are a few of the business rules you should memorize well:

Keep your promises. Be careful to make only promises which you are reasonably sure you can keep.

Keep accurate records. Only records can show what your profits are; what your costs are; and what your tax bill is. Adequate records are needed to show you how to adjust your charges so that you can be fair to both yourself and your customer.

Be honest in all your dealings. Honesty goes far beyond "dollars and cents"—it includes fairness to your employees; telling the truth in your advertising; guaranteeing your work and your merchandise; and reasonableness in dealing with your suppliers.

Yes, a *good* reputation is certainly to be desired. With it, you are well on the road to success!

SERVICING RECORD CHANGERS

48RH-2

PIONEER HOME STUDY RADIO SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 48

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. Introduction . . . . Pages 1-4

The general characteristics of non-mixing and mixing record changers are described in this section.

☐ 2. A Study of Changer Functions . . . . Pages 4-24

Here you study each of the operations of a record changer in detail.

☐ 3. Servicing Record Changers . . . . .Pages 24-28

This section shows you how to service a defective changer.

☐ 4. Pickups and Their Servicing . . . . .Pages 28-32

A brief description of the 3 types of pickups and instructions for servicing them are contained in this section.

☐ 5. Motors and Their Servicing . . . . Pages 33-35

This section contains servicing instructions for the popular types of phonograph motors.

☐ 6. Microgroove Records . . . . Pages 35-36

The newest developments in records and their players are briefly discussed here.

☐ 7. Answer Lesson Questions and Mail Your Answers to NRI for Grading.

☐ 8. Start Studying the Next Lesson.

NPC6M1150 1951 Edition Printed in U. S. A.

SERVICING RECORD CHANGERS

AUTOMATIC record changers are the logical outgrowth of the return to popularity of phonograph records. Before the advent of radio, the phonograph was very popular. Then, for a time, the radio supplanted the phonograph in the home. Gradually, however, electrical record players that operated through the radio receiver or had built-in amplifiers became increasingly popular. As you know, these record players consist of a motor-driven turntable and a pickup arm. The latter, through either an electromagnetic pickup or a crystal pickup, converts the modulation on a record groove into an electrical signal that can be amplified and reproduced by an audio amplifier and loudspeaker.

You are undoubtedly familiar with the method of operation of such a record player. You place the desired record on the turntable, turn on the power, and lower the pickup arm into position on the outside edge of the record. When the record is finished, you remove the pickup arm, turn off the power, and remove the record, either to turn it over or to replace it with another. You can play any size record that is 12 inches or less in diameter—the standard 10-inch or 12-inch diameter records, or the smaller "specials."

The automatic record changer is designed to make it easier to play records. In all of the automatic record-changer systems, a collection of records is arranged in the order in which they are to be played. These records are stacked in some storage system. When the device is turned on, a record moves to the playing turntable, and the pickup arm is automatically placed on it. At the end of the record, the pickup arm is removed and the next record is put into playing position. This operation is repeated until all have been played. Most changers handle enough standard records to play for more than half an hour before it is necessary to handle the records.

Ordinarily, automatic record players play only one side of a record before going to the next record. As a result of the widespread use of such record changers, most symphonies and other selections requiring more than a single

Photo above, Courtesy Webster-Chicago Corp.

Courtesy Olympic Radio Corp.

A typical record-player-radio combination. A single record is played at a time.

record are arranged in a sequence so that side 1 is on the first record, side 2 is on the second record, side 3 on the third, etc. Then, by turning the records over, you can run the stack in opposite order through the succeeding sides to the end of the performance.

Of the common record-changer types, there are two basic varieties—the non-mixing and the inter-mixing. In the non-mixing types, a control is set so that either 10-inch records or 12-inch standard records may be played, but not the two sizes mixed. In the inter-mixing kind, both 10-inch and 12-inch standard records can be mixed in any order and the machine will automatically play them properly.

There is a third kind of record changer that is designed to play both sides of a record. So few of these have been made, and they are so complex, that we shall not describe them in this Lesson. However, the following information on the two more common basic types will help you in understanding how a two-side player should work. If you should get such a player to service, you can always consult the manufacturer's instructions.

THE NON-MIXING CHANGER

The most popular record changer is the non-mixing type, because it is somewhat less complex in its design and operation and therefore less expensive. Let's run through the operation cycle for a basic non-mixing changer:

First, a group of records, all of the same size (either 10-inch or 12-inch), are selected. Changers have different capacities, but most of them will play from eight to ten 12-inch records or ten to twelve 10-inch ones. Of course, any smaller number can be used at a time. Once the records are selected and have been placed in the order in which they are to be played, they are put into the storage mechanism.

The control switch or lever is now placed in the position corresponding to the record size. On many machines, this act also automatically turns on the changer mechanism.

When the changer starts to operate, the first record is dropped into playing position on the turntable. At the same time, the pickup arm is lifted from its rest beside the turntable and moved over the record, which by now is revolving. A positioning mechanism stops the pickup arm and lowers it so that the needle is on the outside plain edge of the record. Gravity, a spring, or the take-in groove on the record now swings the needle into the first playing groove.

To act in this manner, the changer must have some mechanism capable of separating one record from the rest. It must also contain a mechanism that can lift the pickup arm from its rest, swing it to the proper position, and then lower it onto the record. Once the pickup arm is placed on the record, it must be free to follow the record grooves. Therefore, the mechanism that moves the pickup arm must release it completely while the record is playing, then regain control of it when the record is finished.

The eccentric groove cut as the last groove on a phonograph record is almost always used to make it possible for the pickup arm to be brought under control again. This groove is shaped with respect to the spindle about which the record revolves so that the pickup arm, when it engages the groove, is forced to move rapidly back and forth. A tripping mechanism is then actuated, either because of the back and forth motion or because the pickup moves faster in this groove or because the pickup is brought close to the spindle. Once the trip is actuated, the pickup arm is lifted from the record, then swung to the side out of the way. The next record in the group is now dropped into playing position. Once there, the pickup arm is returned over the edge of this record and dropped into playing position.

When the last record in the group has been dropped and played, some changers automatically move the pickup arm to the side and turn off the mechanism. Others repeat the last record over and over until they are turned off.

Courtesy Bendix Radio

Automatic changers are generally used in console combinations like this.

In most cases, the control lever has a reject position so that you can reject any record in the group you don't want to hear. Pushing the reject lever to the proper position actuates the trip that the pickup arm normally actuates at the center of the record. This automatically causes the mechanism to pick up the arm from whatever position it is in and play the next record.

If you want to play 12-inch records when 10-inch ones have been played before, or vice versa, put the proper records into position and move the controls to the appropriate position. This automatically moves a stop so that the pickup arm will drop in the right position. The remainder of the change cycle is identical with the one we just described.

INTER-MIXING CHANGERS

In an inter-mixing changer, 10-inch and 12-inch records can be mixed up in any order in the storage system. When the mechanism is turned on, and the first record is caused to drop, the dropping mechanism makes use of a system of fingers or feelers to determine the size of the record that dropped. Automatically, as a result of this, the stop for the pickup arm is set to the proper position so that the arm will land on the plain outside edge of the record. The playing cycle is identical with that of the non-mixing kind except for this additional automatic feature of the device's determining the record size and setting the pickup arm to drop in the proper position.

All changers, whether non-mixing or inter-mixing, can be played manually by setting the control lever to the proper position. Doing so takes the record dropping mechanism out of operation, and individual records can be placed on the turntable and played just as on any single record player. This operation is necessary when any of the non-standard record sizes, such as certain children's records, are to be played.

From the foregoing you can see that even the simplest record changer must be rather complex. It must separate one record at a time from the storage system and place this record on the turntable. It must lift the pickup arm, move it into position, and lower it onto the record. At the end of the record, it must remove the pickup arm so that the next record can be dropped. If it is an inter-mixing changer, it must determine the size of the record and from that properly place the pickup arm. (Incidentally, some manufacturers refer to the pickup arm as the "tone arm.") Finally, at the end of the group of records, it must either cut itself off or repeat the last record.

All of these operations are performed by a mechanical system driven by the same motor that operates the turntable. In a mechanical system as complex as this, there are almost endless possibilities for variations. In fact, a great many variations have been designed—far more than we can hope to cover in this one Lesson. We shall describe several of the most common record-changer mechanisms; studying these will make it easier for you to understand any other types you may meet.

A Study of Changer Functions

Rather than try to study record changers as an entirety, we shall break down their operations into separate functions. This study of individual actions is desirable because it will show you how to concentrate on one particular action at a time. This is usually necessary in servicing these devices, because, in most instances, only one particular operation of the changer will be out of order. If you know how that operation should be carried out, it will be much easier for you to see just what adjustments are necessary to correct the difficulty.

RECORD PLAYING

Let's start our study of a changer with one record on the turntable and the pickup arm on this record in a playing position. This is a logical place to start, because none of the changer mechanism is in operation. The motor is revolving the turntable and the record, and the pickup needle is following the record groove. To permit the needle to track properly on the record, the pickup arm is freed from the changer mechanism as much as possible.

The conditions while the record is being played are shown in Fig. 1A. The pickup arm is gradually approaching the center hole of the record because the spirally cut playing groove of the record gradually draws the needle toward the center hole. For several reasons, this spiral groove cannot be continued right up to the middle of the record. The most important reason is that the groove velocity would be entirely too high for the needle to follow the variations. Therefore, the actual recording ends about two inches from the center spindle. The recording is followed by a few more turns of the spiral groove containing no recording, then the last turn of the spiral groove feeds into an eccentric groove.

As shown in Fig. 1A, this eccentric groove is off-center with respect to the center hole—the distance W is less than the distance X. In Figs. 1B, C, D, E, F, and G, we have shown what happens when the pickup needle enters the eccentric groove. Because this groove is off-center, the pickup arm is rapidly brought in toward the center spindle as shown in B, C, and D. Then, as the groove continues its rotation, the pickup arm is moved rapidly away from the center spindle. In other words, in E, F, and G, the direction of movement of the pickup is reversed from the normal direction that it has had throughout the playing of the record. This eccentric groove is endless, so the pickup arm oscillates back and forth in this same manner until it is taken from the record either by hand or by the record changer mechanism. As we said earlier, this motion of the pickup arm in the eccentric groove is used to actuate the trip mechanism that allows the changer mechanism to regain control of the arm.

TRIP MECHANISMS

Because the pickup arm is forced to move close to the center spindle by the eccentric groove, some trip mechanisms are arranged to trip when the pickup arm gets close enough to the center spindle. Others depend upon the fact that the motion of the pickup arm is reversed during a portion of the eccentric groove travel. Still others depend upon the velocity at which the pickup arm moves toward the center spindle. We'll describe all types.

Fig. 2 shows how the motion of the pickup arm is conveyed to the trip assembly. The pickup arm is mounted on a hub that is fastened to a hollow shaft. The weight of the pickup arm is carried on ball bearings above a support post that is a part of the motor shelf (or motor board, so called because the motor is suspended from it.)

Attached to the end of the hollow shaft is a trip lever. This may be an individual lever, or may be part of the arm crank that is used to move the pickup arm back and forth when the automatic mechanism is operating. In any case, as shown in B, a motion of the pickup arm causes a similar motion of the trip lever underneath the motor board.

We cannot have a heavy trip lever, because the pickup arm, while playing the record, must be held back as little as possible so that it can easily follow

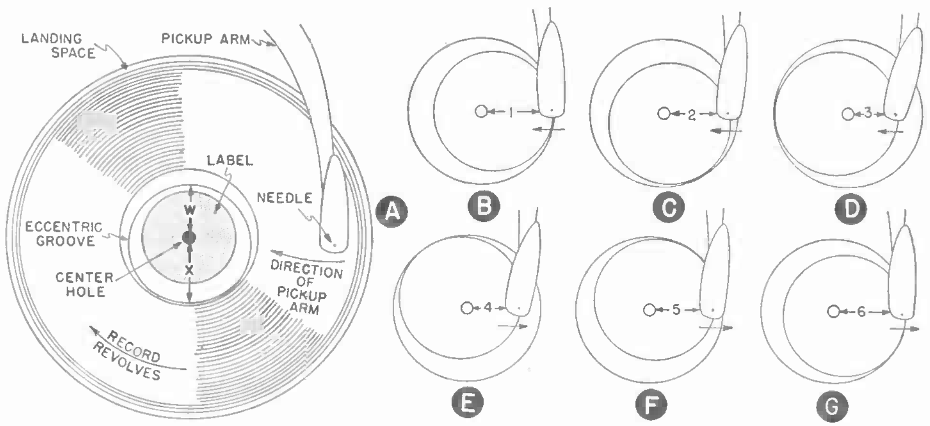


FIG. 1. How the eccentric groove on a record swings the pickup arm in and out at the end of a record.

the spiral groove on the record. Therefore, the trip lever is an exceedingly lightweight arm that is used to actuate another arm or lever, thus starting the record-changing operation.

Incidentally, in a number of our drawings, we shall look down upon the operation as if we could see through

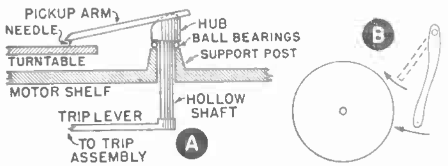


FIG. 2. How the trip lever is attached to the pickup arm.

the motor shelf from the top of the turntable. This helps in seeing just what goes on, but you must remember that the action will be reversed when you are watching the parts from underneath. We are also going to show some drawings of the mechanisms viewed from underneath so that you can become familiar with their appearance in this orientation.

Eccentric Trips. Now that you have a general idea of how the pickup arm can move a trip lever, let's see how the trip lever can be used to start the change action when the pickup needle gets to the eccentric groove. Fig. 3 shows one of the systems that operates when the pickup arm reverses its normal motion. As shown here, the arm shaft connects to a trip lever. At the end of this lever is a trip pawl. The pawl swivels on a bearing, and a spring holds a stop on the end opposite the finger against a cut-out in the trip lever.

While the record is playing, the normal motion of the trip pawl is to the left in this figure. We are looking upon this action from the top. During most of the playing of the record, the trip pawl is not even engaged with the teeth on the ratchet lever. However, as the end of the record is approached, the trip pawl engages the teeth on the ratchet lever. The spring holding the trip pawl is relatively weak, and the direction of the trip lever mechanism is such that the trip pawl tends to slide over these teeth (Fig. 3B). As long as it moves to the left, it will merely slide over the teeth. As the spiral groove brings the pickup arm closer and closer to the center, this pawl moves along tooth after tooth of the ratchet lever.

When the pickup arm enters the eccentric groove, it will move in the opposite direction during a portion of the rotation, as you learned from Fig. 1. When the motion is to the right, the trip pawl cannot escape the teeth. Therefore, the trip pawl is rotated toward a position in line with the trip lever (Fig. 3C). This increases the distance the end of the pawl projects beyond the trip lever. The pawl then forces the toothed end of the ratchet lever away from the trip lever. (The distance E in Fig. 3C is greater than D in Fig. 3B; and since the trip lever can-

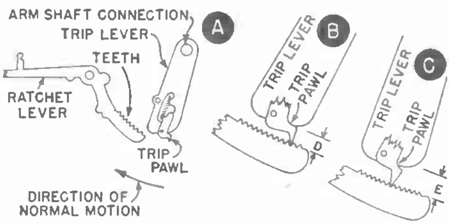


FIG. 3. One trip mechanism.

not shorten, the ratchet arm is forced to move away from it.) The movement of the ratchet lever releases the mechanism, as we shall show a little later.

Another eccentric groove trip is shown in Fig. 4. This time we are showing the view as you would see it from underneath the record changer, so the direction of the trip lever is reversed. In this system, a trigger is held by spring pressure against a trigger ledge on the ratchet arm. If the end of the ratchet arm with the teeth is pushed upward, the trigger can escape from the trigger ledge, allowing it to drop downward and thus move the "bell crank" to engage the changer mechanism. The trip pawl, as it moves to the left (Fig. 4A) engages the teeth on the ratchet arm (Fig. 4B). Then, when the eccentric groove forces the trip lever to move in the opposite direction (Fig. 4C), the trip pawl straightens up and pushes on the ratchet arm. This moves the ratchet arm in the direction shown by the arrow, allowing the trigger to drop downward.

Positional Trip. Incidentally, this same changer also has a positional trip.

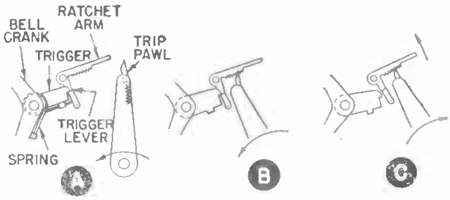


FIG. 4. Another eccentric trip.

That is, it is so arranged that should the eccentric trip fail to operate, the device will automatically trip anyway when the pickup arm reaches a fixed position from the spindle. The mechanism for this is shown in Fig. 5. An adjustable screw called a limit stop is fixed to the trip lever. If the trip lever moves far enough counter clockwise in Fig. 5, this stop will strike the lower end of a pivoted fork called a trip link. If this happens (it can happen only if the trip pawl has not yet moved the ratchet arm), the trip link will pivot clockwise, moving the ratchet arm and releasing the trigger.

Velocity Trip. Fig. 6 shows one of the velocity systems. There are many styles of these, but practically all of them depend upon some friction device that does not trip the mechanism until the pickup arm travels inward at high speed, as it does in the eccentric groove.

In Fig. 6, the pickup arm is coupled through a link to a friction plate. Therefore, the friction plate is pushed clockwise in this figure. This motion is transferred to the trip arm through

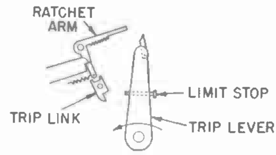


FIG. 5. A positional trip.

a friction pad that is between the friction plate and the trip arm. The amount of friction here is very little, but it is sufficient to move the trip arm clockwise. There is a projection called a striker on the spindle at the center of the turntable. This striker moves clockwise in this illustration. As the trip arm moves during the playing of the record, the end of the trip lever is brought to where the striker can hit it.

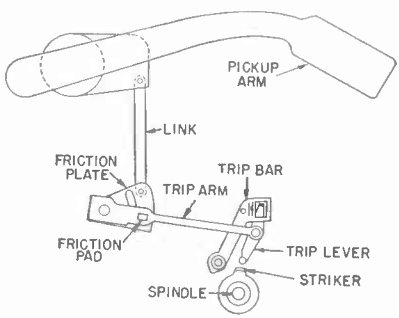


FIG. 6. A velocity trip.

This feed-in of the trip lever is very slow. As a result, just the very tip end of the lever is eventually hit by the striker on one of the revolutions of the spindle. When the striker hits the trip lever such a slight and glancing blow, the trip lever jumps back away from the striker. The amount of friction between the trip arm and friction plate is such that the trip lever can thus escape from the striker during the normal playing of the record.

However, when the eccentric groove is reached, the pickup arm moves in toward the spindle very rapidly. As a result, the friction plate moves the trip arm in rapidly, so the trip lever is moved well over in front of the striker during a single revolution of the spindle. As a result, the striker now hits the side of the trip lever a full blow. The trip lever cannot now escape, because the pressure is no longer applied to its end but is applied to its side. Therefore it pivots at its junction with the trip arm, forcing its other end to the left in the slot in the trip bar. The trip bar is then forced to move to the left and thus engages the mechanism.

To sum up what we have learned: The eccentric groove that is cut on all modern records is used to notify the automatic mechanism that the end of the record is reached. Through a trip mechanism that depends on the waving back and forth produced by the eccentric groove, or on the velocity of travel during the eccentric motion, or on the fact that the pickup arm is brought within a preset distance from the spindle, some tripping mechanism is actuated that allows the automatic mechanism to go into action. In every instance, a trip lever or mechanism attached to the pickup arm (light in weight so that it puts no real restriction on the pickup arm motion) transfers the eccentric motion through other levers to a mechanism that allows the turntable motor to operate the changer mechanism.

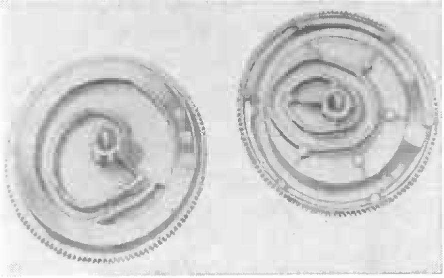
Of course, as you might expect, there are many variations on these basic devices. There are even some types in which a switch is closed by the tripping mechanism, and the actuating system is electrical. However, regardless of the system, all tripping mechanisms have the purpose of initiating the changer action. And they all have their troubles—they fail to trip, or trip too early, depending upon their adjustment, the tensions of their associated springs, etc. We will discuss some of these troubles later in this Lesson.

THE MAIN CAM

It is necessary that all the changer actions be synchronized with each other—the pickup arm must be removed at the proper time, just before the next record drops into position; and, once the record has dropped, the pickup must be brought back. To control these actions simultaneously, changer mechanisms are arranged so that the entire cycle is controlled by a single main cam or by a single drive mechanism that operates all the cams simultaneously.

Fig. 7 shows the top and bottom views of a typical main cam. The top view is shown at the left. Notice that there are a number of grooves, rims, and raised ledges on this wheel, all of which are used to control, individually, some particular portion of the changer operation.

To prevent the main cam wheel from rotating when power is not applied, usually some form of detent is used to latch the wheel in the out-of-cycle position. In the example shown in Fig.



Courtesy Motorola, Inc.

FIG. 7. A typical main cam wheel.

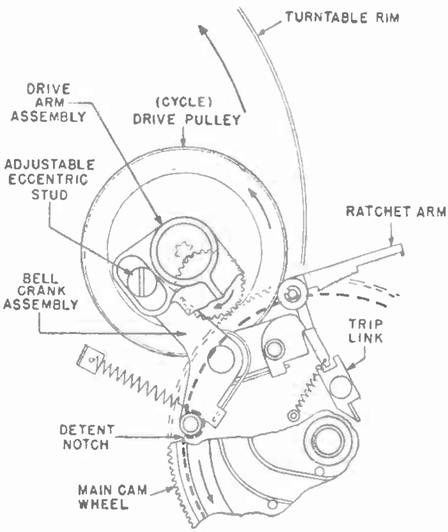


FIG. 8. One way of supplying power to the main cam wheel.

7, notice the detent notch at the left edge in the top view. A stud on the end of a lever fits into this notch until power is applied. This stud is withdrawn when power is applied so that the main cam can rotate and control the mechanism. At the end of the cycle, the stud is traveling on the rim, and falls into this detent notch just as at the end of the cycle to hold the main cam wheel motionless again.

There are almost as many ways of supplying power to the main cam wheel as there are record-changer systems. Fig. 8 shows the method used for the particular cam that we have shown in Fig. 7. First, if you will examine the bell crank assembly, you will find that the lower end has a stud that fits into the detent notch on the main cam wheel. The upper end of the bell crank assembly is fastened to a drive arm assembly. On this drive arm is a drive pulley that operates a small gear. This gear drives an idler gear that is meshed with the gear teeth on the main cam wheel.

When the ratchet arm moves away so that the trigger can fall downward, the bell crank moves in accordance with this motion. As a result, the lower end of the bell crank is moved outward so that the stud moves out of the detent notch; at the same time, the drive pulley and the whole drive arm assembly are forced over by the movement of the upper end of the bell crank so that the drive pulley touches the turntable rim. Since the turntable is being driven by the motor, the drive pulley starts to rotate, driving the main cam wheel through the gear train.

When the changer has run through its entire cycle and the pickup arm is being put back on the record for playing, the main cam wheel rotates to a position where a raised section on the wheel engages the trigger and forces it upward. When the trigger reaches the proper position, the spring on the lower end of the ratchet arm pulls the shelf under the lip of the trigger, resetting the trigger for the start of the next cycle.

The trigger is connected to the bell crank by a very heavy spring. When the trigger is reset, this spring would force the bell crank to pull the drive mechanism out of contact with the turntable rim, except that at that instant the stud on the end of the bell crank is riding on the rim of the main cam wheel, which holds the bell crank so that the drive mechanism still operates. When the detent notch comes around, however, the stud on the bell crank falls into this notch; this allows the upper end of the bell crank to pull the drive pulley away from the turntable rim. The main cam wheel does not turn again until the end of the next record or until a reject button is depressed to release the trigger again.

Another system is shown in Fig. 9. The tripping mechanism is that shown in Fig. 3, but this time the drawing is such that we are looking at the mechanism from the bottom.

When the trip pawl engages the ratchet lever, the left-hand end of the lever in Fig. 9 is forced downward, which raises the right-hand end. This frees the drive cam pawl and also takes a stud on the ratchet lever out of a

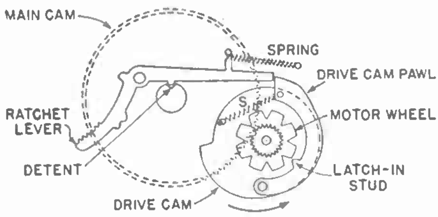


FIG. 9. The ratchet lever holds the drive-cam panel away from the motor wheel until the trip mechanism is actuated.

detent on the main cam, much as in the system we just described.

However, the drive mechanism is a little different here. The motor wheel is actually a form of gear having a number of slots cut in it. This turns all the time. The drive cam is a circular wheel mounted over the motor wheel. On the drive cam is a drive cam pawl, which has a latch-in stud on it that will fit into the slots on the motor wheel when the drive cam pawl is released. Attached to the drive cam is a small gear that has teeth engaged with the main cam.

Therefore, when the ratchet lever releases the drive cam pawl, the spring S pulls the drive cam pawl over so that its latch-in stud engages the motor wheel. When this happens, the motor wheel revolves the drive cam, which in turn revolves the small gear and drives the main cam.

Meanwhile, the ratchet lever is held up from the position in which it engages the drive cam pawl, because a bump on the lever is riding on the rim of the main cam detent. When this bump reaches the notch of the detent, the ratchet lever spring pulls the lever down into the notch. This brings the right-hand end of the ratchet lever down in front of the approaching drive cam pawl. As soon as the drive cam rotates sufficiently for the ratchet lever to engage the pawl, the pawl stud is pulled away from the motor wheel; this stops the driving of the mechanism.

Fig. 10 shows an electrical system for controlling the application of power to the main cam. In this system, there is a main drive wheel, practically the same size as the main cam, that is adjacent to the main cam. On the main cam there is the drive pawl shown in Fig. 10. This pawl cannot engage the teeth on the drive wheel until the armature of the relay R is moved away from the upper end of the drive pawl. When the tripping mechanism closes a switch, power is applied to the relay, which draws away the armature and allows the drive pawl to be pivoted so that it engages the teeth on the main drive wheel. The main cam is then driven by the main drive wheel through the pawl. At the end of the cycle, the armature, which is released by now, is in a position to engage the end of the

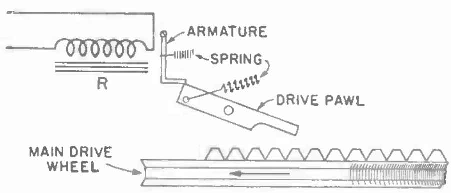


FIG. 10. A basic electrical system.

drive pawl and thus withdraw it from contact with the main drive wheel.

Fig. 11 shows another type rather similar to that shown in Fig. 10 except that the trip mechanism is mechanical. This trip mechanism holds the drive dog up from the drive wheel (Fig. 11A) until the trip is actuated. The trip then moves out of the way, allowing the drive dog to drop down (Fig. 11B). The drive wheel has a series of bosses or raised projections on it; one of these catches the drive dog and thus forces the rotation of the main cam. At the end of the cycle, the drive dog is lifted

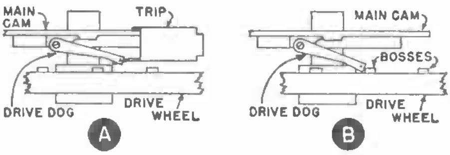


FIG. 11. Another drive-wheel system.

by the resetting of the trip mechanism, and the main cam is disengaged.

Now that we have arranged for the end of the record to signal the start of the automatic operation, and have learned how power can be applied to the automatic mechanism, let's go on and see how each individual action is carried out by the mechanism. Remember, we have to elevate the pickup arm and lower it, move it in and out, and drop the record to the playing surface. Although we shall break these down into individual actions, always remember that many of the processes may be combined so that a single master lever can perform several of these actions simultaneously. However, once you understand basically how each action is carried out, it will be rather easy for you to pick out and study that part of the operation of any record changer you may service.

PICKUP ARM ELEVATION

During each cycle, the pickup arm must be lifted and lowered. The arrangement for elevating the pickup arm is ordinarily separate from all the other functions. Fig. 12 shows two of the more popular systems.

In the system shown in 12A, the main cam has a cut-out space in it into which the end of the lift lever fits while the pickup arm is on the record. The lever is shown in this position. When the end of the record is reached, the main cam rotates. The end of the lift lever then rides up on a raised ledge on the cam. This depresses the left end of the lever, which means that the right end of the lever goes up. This right end presses against a bearing plate and so moves a push rod upward through the center of the hollow shaft. The pickup arm is fastened at bearing A. Therefore, when the push rod moves upward, the needle end of the pickup arm is lifted. Other mechanisms then move the arm out of the way and drop the next record. When the arm is moved back into the playing position, the main cam is completing one revolution, bringing the notch on the cam ledge back into position over the left-hand end of the lift lever. This end of

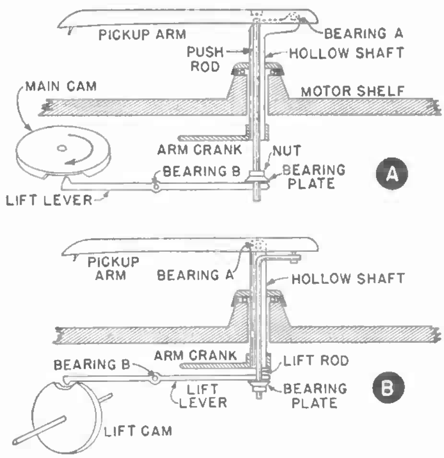


FIG. 12. Two basic elevator mechanisms.

the lever then rises, lowering the push rod and allowing the pickup arm to drop to the record. The main cam is then stopped so that it cannot rotate farther until the end of the record.

In the system shown in Fig. 12A, the push rod is threaded so that the bearing plate can be moved up or down.

This makes it possible to adjust the vertical movement of the push rod and consequently of the pickup arm. If the pickup cannot come down far enough to allow the needle to touch the record, then the bearing plate is too far down on the push rod. On the other hand, if the arm does not bring the needle up far enough to clear a stack of records on the turntable, the bearing plate is too high on the push rod. The latter condition is more common; it is corrected by lowering the bearing plate by screwing it downward on the push rod. In some systems, a nut follows the bearing plate and is used to lock it into position; in others, there are set screws in the hub of the bearing plate that are used to lock it.

The system shown in Fig. 12B is the same except that it is practically the inverse of that shown in A. Here, when the "lift cam" rotates, the left end of the lift lever is forced up, which pulls the lift rod down. Since the lift rod is bent at the top and attached behind bearing A, a downward movement of the lift rod pulls down on the rear end of the pickup arm and raises the needle end.

This mechanism can also be adjusted by moving the bearing plate up or down on the lift rod. Moving the bearing plate upward in this case provides a greater lift.

Fig. 13 shows two other basic systems of this kind. A cord is used in Fig. 13A to provide the lift. The cam in this case has an eccentric slot cut in it. The end of the lift lever moves in this slot. When the slot moves the lever toward the left, it pulls on the cord and so lifts the arm. Then, when the slot permits the lever to move to the right, the cord slackens and allows the pickup arm to drop. This system is usually adjusted at the point where the lift cord attaches to the lift lever. This end of the cord is normally attached to a threaded rod that can be run in or out of a bracket, effectively adjusting the length of the cord.

The system shown in Fig. 13B is the simplest of all. Here, the cam is directly under the push rod. As the cam rotates, the push rod is forced directly upward by the shelf on the cam edge, lifting the pickup arm. Simple systems such as this are found in the less expensive changers. They work as long as the tolerances in parts are carefully controlled, but there is usually little or

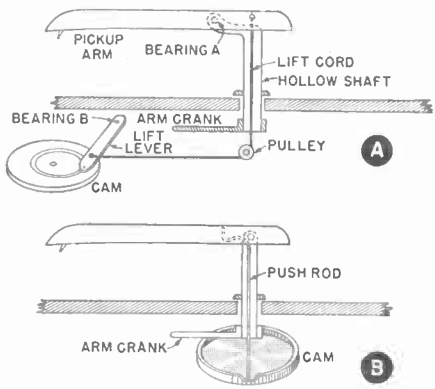


FIG. 13. Two more elevator mechanisms.

no means for adjustment. In the style shown here, the only manner of adjusting is to bend the push rod at the top. Any such bending operation is rather critical, since the rod is liable to break.

PICKUP ARM ROTATION

Now that you know various methods of elevating the pickup arm, let's see how the arm can be carried into the proper playing position and then removed at the end of the record.

In Figs. 12 and 13, you will notice a projection at the bottom of the hollow shaft labeled "arm crank." Moving the arm crank to the right or left will move the pickup arm similarly, because they are connected by the hollow shaft. Therefore, all we need is to arrange for the arm crank to be controlled by the changer mechanism so that the pickup arm is moved in the desired manner.

To see the general way that this control is exerted, study Fig. 14. The arm crank is connected at bearing A to the pickup arm. The other end of the arm crank has a finger that is in an eccentric groove in the main cam. (To get a general idea of what some of these grooves look like, examine Fig. 7.) Let's suppose the eccentric groove has the shape shown in Fig. 14A. When the cam rotates around its bearing, marked C, it causes the finger on the arm crank to move so that it follows the groove. In Fig. 14A, the changer is in cycle and the finger of the arm crank is farthest from bearing C, which is at the center of the turntable. Therefore, the pickup arm is as far as it can be from the center bearing and is off the record completely.

Further rotation of the cam brings the groove to the position shown in Fig. 14B. The shape of the groove is such that the finger on the arm crank is now brought closer to the bearing C, bringing the pickup arm over the edge of the record. The elevator mechanism now allows the pickup arm to drop on the edge of the record just as the eccentric groove moves to the position where the finger enters the wide spacing of the groove. The finger is now released, because the cam ceases to rotate. The pickup needle now follows the record grooves, and except for moving the pickup arm, the trip, and the arm crank, the pickup is entirely divorced from the player mechanism.

As the needle is drawn toward the center of the record by the record groove, the arm crank moves through the free space. This space on our imaginary assembly is wider than the rest of the eccentric groove so that there is no interference with the movement of the arm crank.

At the end of the record, the trip mechanism goes into operation and starts rotation of the cam. The position of the arm crank just before this moment is shown in Fig. 14C. As the cam rotates farther, the finger on the arm crank enters the groove. When the elevator has lifted the arm from the record, continued rotation of the cam toward the position shown in Fig. 14A rapidly moves the pickup arm out of the way so that the next record can be dropped.

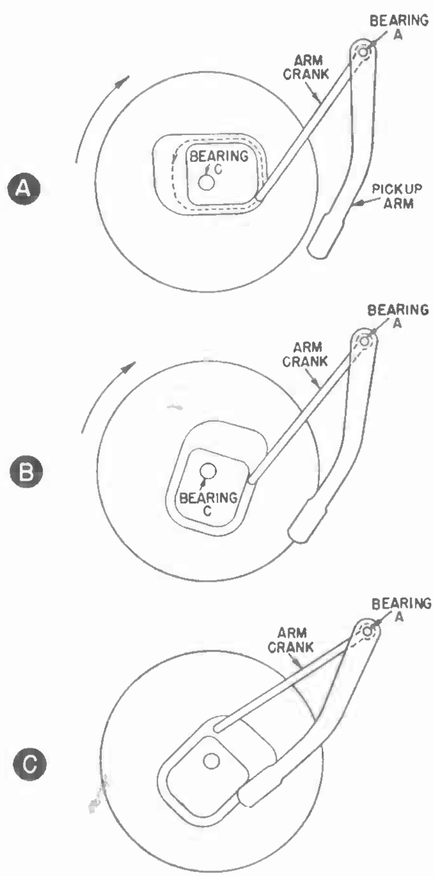


FIG. 14. A basic pickup arm left-to-right motion control.

The system shown in Fig. 14 is basically that used in all changers. However, the actual mechanism is considerably more involved than we have shown, because we must arrange for the pickup arm to be brought to the proper position for either 10-inch or 12-inch records.

If there were only one record size to be played, we could easily adjust the position at which the arm lands (the only critical factor) by adjusting the angle of the arm crank with respect to the pickup arm. However, we do have two record sizes. Let's look at some of the basic systems used to make it possible to shift from one to the other.

10-12 LANDING SHIFT

Fig. 15 shows one way of adjusting the position at which the pickup arm will land. An additional T-shaped crank is used between the arm crank and the groove in the cam. This T crank can be moved to either of two positions by rotating the control cam attached to it.

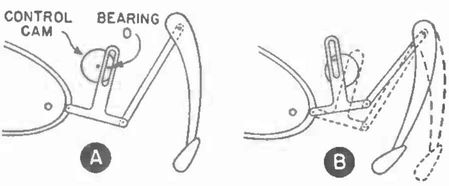


FIG. 15. A T-crank is used here to provide the landing adjustment for either 10- or 12-inch records.

In Fig. 15A, the T crank is in one of its two possible positions. As the cam rotates, the groove moves the finger on the end of the T crank, which transfers this motion directly to the arm crank and thus to the pickup arm. The T crank is able to follow the eccentric groove because a slot on the crank permits it to move in all directions with respect to its bearing D.

To change the landing position from the 12-inch to the 10-inch position, the control cam in Fig. 15A is rotated 180°. This moves bearing D from one side of the control cam to the other, as shown in Fig. 15B. The T crank must now move along this new position. In Fig. 15B, the original positions of the T crank, arm crank, and pickup are shown in dotted lines. As you can see, the pickup arm now has a new position although the finger on the T crank is still in the same place on the eccentric groove. This means that the pickup arm will land in a different place when it is dropped by the changer mechanism. In this particular case, it will land an inch nearer the center of the turn-table, in the proper place for a 10-inch record.

A system of this sort usually has only one adjustment: the fastening between the arm crank and the pickup arm can be adjusted to make the pickup land properly on either a 10-inch or a 12-inch record. The pickup should then also land properly on a record of the other size when the control cam is turned to the other position.

Fig. 16 shows another basic system. Here, the cam has a raised ledge W that is eccentric with respect to the cam bearing C. The arm lever, which pivots about bearing E, is held against the side of this ledge by the spring S. The arm lever is therefore swung in and out by the eccentric ledge as the cam rotates.

Under the conditions shown in Fig. 16, the record is being played and the cam is motionless. This figure is drawn so that we are looking down through the top of the motor mounting board. The pickup (shown dotted here) is connected to the pickup arm crank at the bearing A, as in the systems we have studied up to now. When in the position shown, the arm crank is not restricted at all, so the pickup arm is free to follow the record grooves.

The end of the arm crank has a

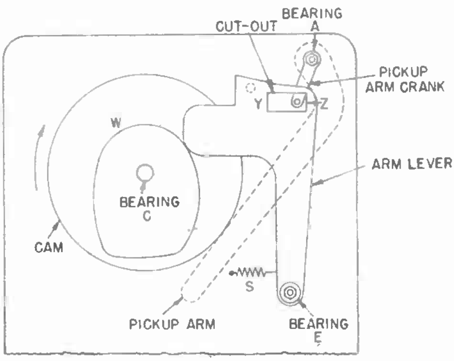


FIG. 16. Compare the operation here with that in Fig. 17.

finger that protrudes through the cut-out in the arm lever. As the pickup nears the end of the record, the mechanism is tripped, so the cam starts to turn. The pickup arm is elevated from the record by operation of the elevating mechanism, then the rotation of the ledge W begins to move the arm lever to the right. Soon end Y of the cut-out bears against the finger of the arm crank, thus forcing the arm crank to move to the right also. In turn, this swivels the pickup arm out of the way in the same direction.

When the next record has dropped, and the arm lever begins to return toward the position shown here, end Z of the cut-out presses against the arm crank finger and thus brings the pickup arm back in toward the edge of the record. At the proper point in the cycle, the elevator mechanism lets the pickup arm down on the record edge.

The operation just described is the one that occurs when a 10-inch record is played. Fig. 17 shows what happens when the mechanism is set to handle 12-inch records. The mechanism used to control the size setting of the changer has either an arm or a pin that can be dropped down in front of a finger on the arm lever. When this pin is up or out of the way, as it is when the size control is set for 10-inch records, the arm lever bears directly on the ledge W at all times. However, if the control is set for 12-inch records, the pin (labeled stop H in Fig. 17) is dropped into place while the arm lever has the pickup arm at its extreme right-hand position. Then, as rotation of the eccentric ledge W brings the arm lever to the left, the lever strikes stop H; it can then travel no farther to the left. This position is the proper one for the 12-inch record size while the pickup arm crank finger is against side Z of the cut-out.

Now let's see what the cycle of operation of this mechanism is when it is set for 12-inch records. During the playing of the record the pickup arm crank finger moves through the

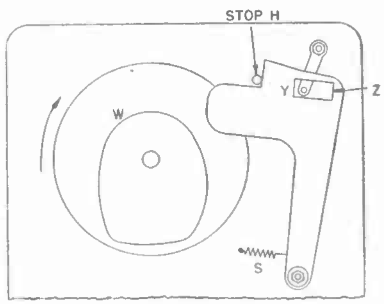


FIG. 17. Compare this 12-inch landing arrangement with the 10-inch one in Fig. 16.

cut-out opening to approach side Y. When the mechanism is tripped, the pickup arm is elevated. However, the arm lever cannot move until ledge W comes over and bears against it. Then, however, it is carried to the right to the same extreme position as before. Then, when the next record drops, the ledge W allows the arm lever to return as far

Courtesy Farnsworth Tele. and Radio Corp.

FIG. 18. A bottom view of a changer using the system described in Figs. 16 and 17.

as stop H. The arm is held here by the stop while the cam continues to rotate, and the pickup arm is allowed to be lowered to the record surface.

At either setting of the mechanism, then, the ledge W always moves the arm lever sufficiently to remove the pickup arm from the turntable vicinity so that the next record can be placed in position. On the return of the pickup arm, the arm lever either rides on ledge W for the 10-inch landing position, or is stopped by stop H for the 12-inch landing position. Once the pickup arm has been lowered to the record, the arm crank is entirely free of the changer mechanism and progresses through the cut-out space.

Fig. 18 shows a picture of a changer that uses this operation. Notice that much of the mechanism we have described is hidden by levers and support plates. Notice, also, that this is a photograph from the bottom, so it is the reverse of our drawing.

There are numerous other systems for bringing the pickup arm in to the record edge and removing it so that the next record can be put into place. In general, all systems use eccentric grooves, eccentric ledges, or eccentric screw mechanisms to make the pickup arm move through the proper motions. Some systems use a double groove on the cam, one groove for 10-inch and one for 12-inch records, and have arrangements whereby the arm crank finger can be switched from one groove to the other. Basically, however, all of them go through the actions we have just demonstrated.

RECORD-DROPPING SYSTEMS

So far, we have learned how the pickup arm is moved in and out and how it is raised and lowered. Next, let's see how records are fed one at a time from the storage system into the playing position. In general (except for a few complex types that play both sides of records), all changers made today drop records from storage above the turntable. The differences between them are in the means of separating the bottom record from the group and of supporting the stack.

There is probably more difference between changers in this particular item than in any other. Basically, there are two methods of separating the bottom record from a stack so that it can be put into playing position. In one system, support shelves originally hold up all the records. As the changer goes into operation, a set of knives is inserted in the record stack between the bottom record and those next above it. Then the supports are withdrawn, allowing the bottom record to drop onto the turntable. The knives then support the group.

Once the bottom record has been dropped into playing position, the support shelves are returned and the knives withdrawn, allowing the record stack to drop down onto the shelves.

The system is now ready for the knives to separate the bottom record of this stack on the next playing sequence.

In the other system, the bottom record is pushed off a supporting ledge, which then catches the remaining records.

Let's now turn to several typical changers and see just how they work. We can divide them into single-post, two-post, and three-post types.

Courtesy Webster-Chicago

FIG. 20. A single-post, bent-spindle record changer.

SINGLE-POST CHANGERS

Figs. 19 and 20 show pictures of two basic single-post record changers. On these changers the records are supported by an offset ledge on the center spindle and by a single side post or platform. In the style shown in Fig. 19, the spindle is straight; the one shown in Fig. 20 has a "bent" spindle.

Courtesy Motorola, Inc.

FIG. 19. A single-post, straight-spindle record changer.

Straight-Spindle Types. Fig. 21 shows more details of a single-post straight-spindle changer. A section of the spindle at the center of the turntable is cut out to form a shelf. At the rear of this shelf is a guide trigger that makes the records move in the direction of the support head as they feed down the spindle. The records are thus supported at their center hole by the shelf on the spindle and at one outside edge by the support head.

Two systems of making the bottom record drop down the spindle onto the turntable are in use. In one, operation of the changer mechanism makes a trigger protrude from the support head when the pickup arm has been moved out of the way. This trigger pushes the bottom record to the left so that its center hole lines up with the spindle and its edge is off the support head. Unsupported, the record spirals down the spindle to the turntable. The trigger withdraws into the support head, and the next record in the stack drops down onto the shelf and onto the lip of the support head at the same time.

When the record that dropped finishes playing, the cycle is repeated and the next record is dropped.

In this particular system, the adjustment for 10- or 12-inch records is made by rotating the support head. By com-

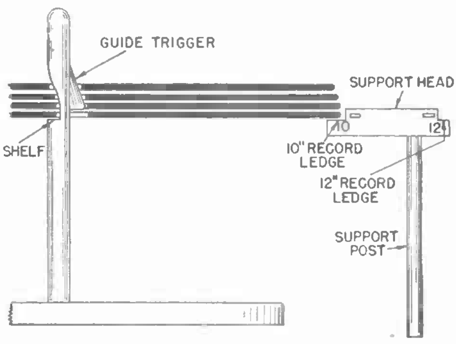
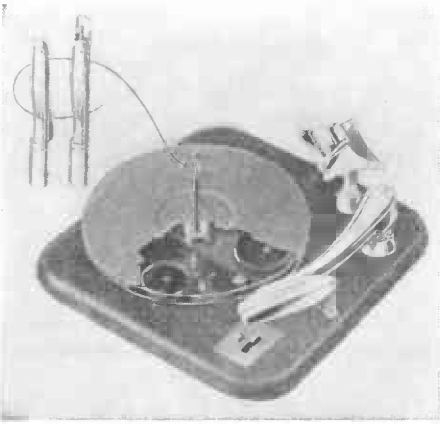


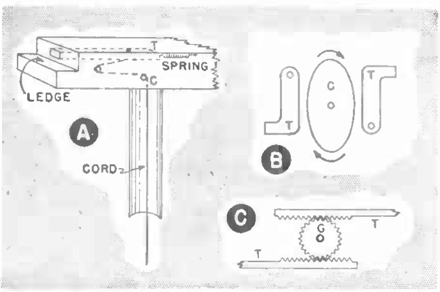
FIG. 21. Details of a straight-spindle changer.



Courtesy Motorola Corp.

This shows how the guide trigger retracts as records are lifted up the spindle to remove them from the changer. The trigger drops into playing position, however, as records feed down the spindle.

paring the distances from the support post to each of the record ledges in Fig. 21, you will see that the ledge marked 10 is spaced farther from the post than the ledge marked 12. Therefore, the 10-inch ledge extends closer to the spindle, and is just the right distance away for 10-inch records. When the support head is rotated 180°,



Three of the many methods of actuating a trigger to push a record off the ledge of a support head. At A, the cable C is pulled by an arm traveling in a groove on the main cam, and this motion forces the trigger T to protrude. At B, the cam C is rotated by a shaft that runs down the support post; this forces the triggers T to protrude because of the eccentric cut of the cam. At C, the gear G is rotated to force the triggers T to protrude, then the direction of gear rotation is reversed to pull them back in. The types at A and B are pulled back in by springs.

the 12-inch ledge is the right distance from the spindle to accommodate 12-inch records.

Some changers of this sort have a link mechanism down the support post column so arranged that rotating the support post head also adjusts the mechanism underneath to make the pickup arm land at the proper place for a 10-inch or 12-inch record. In others, it is necessary to set the support head and then throw a switch to adjust the landing point of the arm.

When the records have all been played, the support post is turned to a neutral position in which the shelves are out of the way. (Incidentally, this

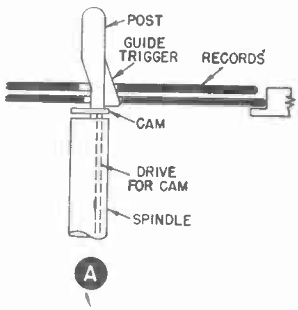
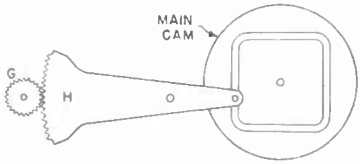


FIG. 22. Details of a cam system of aligning records with the spindle.

is the position to which the support post is turned when the record changer is played manually.) Then, the stack of records is lifted up the spindle. On most models, the guide trigger on the back of the spindle slides into a slot in the spindle and thus out of the way as the records are lifted upwards.

Another style of single-post straight-spindle changer uses an eccentric cam to take the bottom record off the stack. Details of its construction are shown in Fig. 22. The spindle is hollow and has within it a drive shaft to which is fastened the cam. This drive shaft is offset toward the rear of the spindle so that the cam will move in an eccentric fashion with respect to the spindle.

When the cam is in the position shown in Fig. 22A, it is lined up with the bottom portion of the spindle. It then acts as the top of the spindle to form a shelf upon which the records rest. As in the system just described,



The eccentric cam drive in Fig. 22 is attached to the gear G. This is driven here by the drive H, that in turn operates from a groove in the main cam. The drive works in one direction, then runs back to return the cam to its initial position.

the guide trigger directs the records, as they move down the post, onto the shelf furnished by the cam and onto the lip of a support head.

Let's suppose records have been loaded onto the mechanism as shown in Fig. 22A. When the changer first starts to operate, and the pickup arm is out of the way, the cam above the spindle is rotated by its drive shaft to the position shown in Fig. 22B. This brings it directly under the center hole of the bottom record, which then drops over the cam. The cam is not quite as thick as a standard record, so no more than one record can get onto it. The cam then rotates back to the position shown in Fig. 22A, dragging the bottom record with it and off the lip of the support head. When the cam is lined up with the spindle again (Fig. 22A), the record drops down the spindle to the turntable, and the next record is supported by the cam.

The storage mechanism of this type of changer, like that of the one previously described, is adjusted for record size by rotating the support platform.

The Bent-Spindle Changer. Fig. 23 shows a variation on the single-post changer. The spindle is like the others in that it has a shelf and usually a guide trigger. However, it has a bend in it that permits a somewhat different construction and action. The records feed down the spindle and over the trigger so that the shelf on the spindle supports them. The outer edges of the records are supported by a record head, which has a shallow notch into which the bottom record fits. The actuating means for getting the records to feed down the spindle is in the record head itself—the head and its support post move toward the spindle. When the head moves forward, the bottom record is pushed forward also by the back edge of the notch in the head; the rest of the records, however, slide back along the platform in the head just above the notch. When the center hole of the bottom record lines up

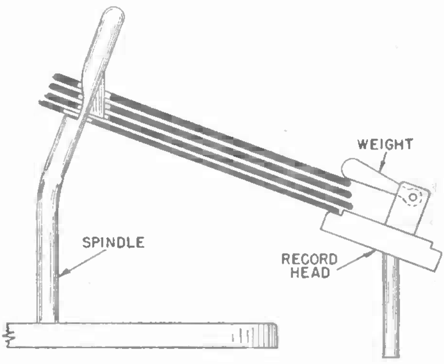


FIG. 23. A bent-spindle type.

with the spindle, the record feeds down the spindle. In going around the bend of the spindle the record is pulled away from the record head so that it falls free onto the turntable.

The next record then drops down on the shelf of the spindle. At the end of the playing cycle, the record head moves back away from the spindle, allowing the bottom record to drop into the notch in the head. It then moves forward again, pushing the next record off the spindle shelf.

In the type shown in Fig. 23, the record head is revolved to play 12-inch records. Sometimes a switch or button must be actuated to cause the pickup arm to drop in the right position with this system.

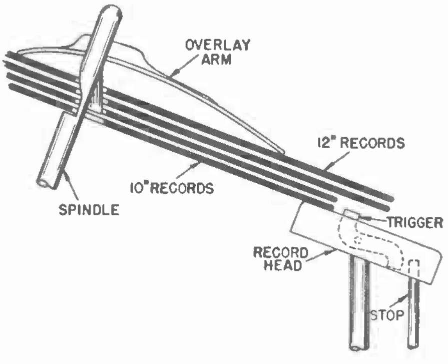


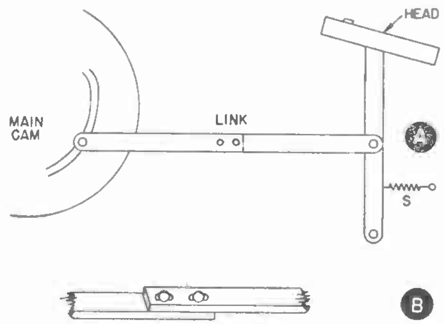
FIG.24. This bent-spindle type is an intermixing changer.

To prevent the records from tilting, there is a hinged weight on the record shelf that is dropped on top of the record stack. (Most single-post changers use such a weight.) This weight holds the records steady while the shelf moves back and forth underneath the stack.

To load this changer, the weight is moved out of position, the stack of records is fed down over the top portion of the spindle, and the weight is then replaced. To remove the records, the weight, which protrudes somewhat, must be rotated out of position, or the entire record shelf must be turned 90° to clear the record stack as it is lifted off the spindle. In many of the bent-spindle types, the spindle can be lifted out of its socket so that the records can be removed without having to feed them up the spindle.

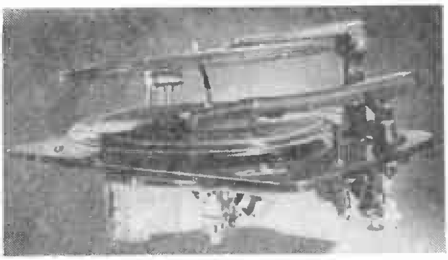
Some of the bent-spindle changers can play records that are mixed in size. Fig. 24 shows one system. The record head contains a trigger. When the records are placed on the storage portion of the spindle, 10-inch records will rest on the front edge of the head, ahead of the trigger, and 12-inch records will extend over the trigger. Let's suppose we have the stack as shown in Fig. 24. When the first record, a 10-inch one, is to be played, the record head moves forward; the trigger, which is a square protrusion on the head, strikes the edge of the record and forces it off the shelf on the spindle.

When this record drops, the next 10-inch record drops down in front of the trigger. It, too, is pushed off by the trigger on the next operation of the changer. The next record, however, is a 12-inch one; therefore, it drops on top of the trigger instead of in front of it. The trigger is pivoted (see Fig. 24),



The link pulls the head forward against the pull of spring S. At B is shown the method of adjusting the length of the link, which adjusts the limit of forward motion of the head. Another lever (not shown) may be attached to the head support post to shift the link into the proper groove on the main cam for either the 10-inch or the 12-inch record sizes.

and the weight of the record on top of it pushes it down flush with the top of the record head. As shown by the dotted lines, this raises the rear end of the trigger so that it is above a stop that up to now has prevented the record head from moving more than a certain dis-



Courtesy Garrard Sales Corp.

FIG. 25. An inter-mixing bent-spindle changer.

tance from the spindle. When the rear end of the trigger is able to clear this stop, the record head is able to move considerably farther from the spindle—so far, in fact, that the trigger is brought out beyond the edge of the 12-inch record. The weight of the rear end of the trigger restores it to its original position once it gets out from under the record, so, when the record head moves forward again, the trigger is behind the edge of the 12-inch record and pushes the record off the spindle shelf.

This mechanism also automatically sets the landing position of the pickup arm for 10-inch or 12-inch records. The motion of the record head sets stops that control the pickup arm crank, with the result that the landing position of the pickup arm depends on whether the record head has moved back for a 10-inch or for a 12-inch record.

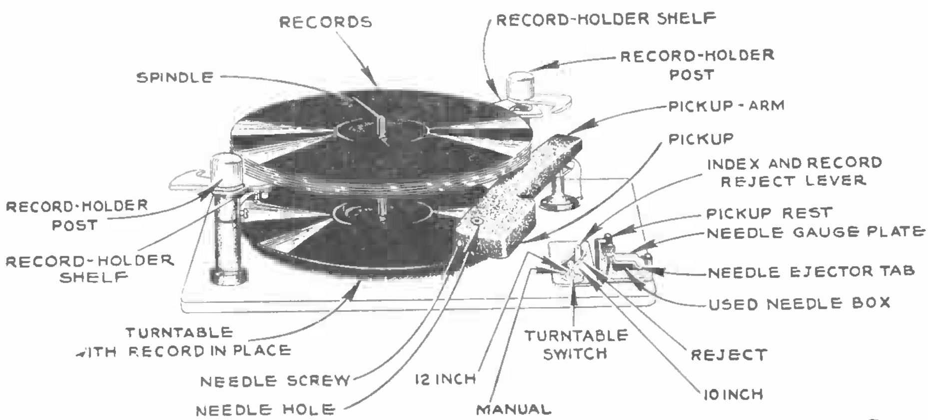
Fig. 25 shows a picture of a unit of this type. Notice the overlay arm that lies over the top of the records and straddles the spindle. This arm is necessary in this system to keep the records level while the record head moves back and forth and also to provide the force to keep the records moving down the spindle. It serves a purpose somewhat similar to the weight in the system shown in Fig. 23. However, because of the wider motion of the record head here, the overlay arm must be accurately positioned.

TWO-POST CHANGERS

Fig. 26 shows one of the two-post record changers. In this style, the center spindle is used only for guiding the record down to the turntable—it has no shelf on it.

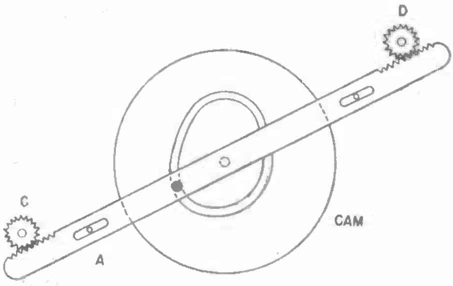
The record is supported at two points by record-holder shelves that are attached to the record-holder posts.

When a record is to be dropped, the pickup is elevated and moved out of the way. Then the record-holder posts begin to rotate. Each of these posts carries a "knife" just above its rec-



Courtesy RCA

FIG. 26. A typical 2-post changer, the RCA U-128.



The support posts may be rotated by means of a belt or gear system from the main cam. Here is a simple gear type; the arm A is moved from side to side by the eccentric groove in the main cam. It rotates gears C and D that are at the base of the support posts. Hence, the posts and accompanying knives are rotated about 180°, then are returned to their resting positions.

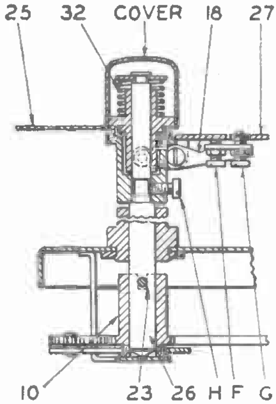
ord-holder shelf. This knife is a sharp-edged shelf that is spaced approximately the thickness of the average record above the record-holder shelf. Therefore, as each knife comes around and contacts the record stacks, the pointed tip of the knife is in just about the right position to go in between the bottom record of the stack and the one next above it. The mechanism rotating the knife is usually either spring loaded or allowed to have considerable play so that the knives can adjust themselves and slip in between the bottom record and the stack.

As the knife penetrates the record stack, continued rotation of the record-holder post will place the knife under all the records except the bottom one, and the record-holder shelf will be rotated completely out of the way. When this happens, the bottom record no longer has anything to support it, and the remainder of the record stack is supported by the knives on the two posts. Therefore, the bottom record drops onto the turntable. Before the pickup arm is placed in the playing position, the record holder posts rotate back to their normal positions. This withdraws the knives and drops the stack of records onto the record holder shelves, thus completing the changing cycle. The thickness of 10-inch records is somewhat different from that of 12-inch records. Although the knife is so loose that it will usually find the proper spacings and go in between the records, it is always possible for the knife to strike the edge of a record and cut into the record rather than separate it from the stack.

On some changers, the spacing is adjustable. Fig. 27 shows the details of one such system. The small screw marked G protrudes through the record-holder shelf. When 10-inch records are on the shelf, they do not extend over the shelf far enough to reach this screw. However, 12-inch records will lie on the screw and depress it.

When 10-inch records are on the shelf, the knife spacing above the shelf is that of the average 10-inch record. When the thicker 12-inch records are on the shelf, screw G is depressed, and a lever arm connected to it raises the knife slightly so that the spacing between the knife and the record-holder shelf increases enough to clear the records.

This form of storage mechanism will usually permit the intermixing of 10-



Courtesy RCA

FIG. 27. How the knife spacing may be adjusted.

and 12-inch records. Some of them require setting for the record size, in addition to setting the index lever to the proper position to control the pickup arm landing position. Others, of which the one we are discussing is an example, determine the record sizes automatically.

The mechanism used to do so in this changer is shown in Fig. 28. The lever 17 stands beside the turntable. Ten-inch records drop from the record support shelves to the turntable without striking lever 17. When this happens, the pickup arm automatically comes in for the 10-inch position.

However, a 12-inch record, because of its greater diameter, strikes lever 17 as it falls. This pushes the lever to the right in this drawing, moving its end out of the way of the pin marked V. This allows the pickup arm crank to move to the proper position for a 12-inch record.

Another form of two-post changer is shown in Fig. 29. In this, the spindle has a crook or hump in it. There are two heads on which the records are supported. When the device is actuated, the spindle is rotated by the main cam through a gear system.

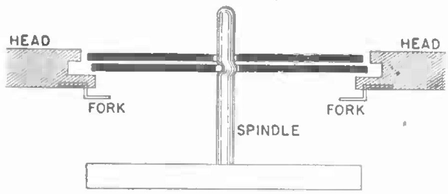
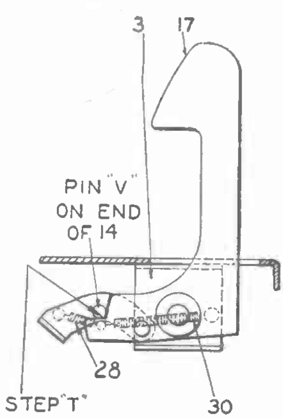


FIG. 29. Another two-post changer.

In its initial position, the hump is at a point halfway between the two support heads. As it rotates, however, the hump approaches the left-hand head, thus forcing the bottom record into the slot in the left-hand head. This pulls the other edge of the record from the support ledge of the right-hand head and allows it to drop on the right-hand fork. (This fork is a movable support bar.) Then, as the spindle continues its rotation, the hump pushes the record to the right, into the slot provided by the fork on the right-hand head. This pulls the record from the supporting shelf on the left-hand head, allowing this edge of the record to drop similarly on the left-hand fork. The spindle comes to a stop in its neutral position, and the bottom record is now supported at both edges by the forks just below the two heads. The next records are down on the support shelves of the heads. Just before the record is to be played, the two forks are withdrawn by a linkage down the support post, allowing the bottom record to drop down the spindle.

Thus, the operating principle of this changer is that rotation of the spindle moves the bottom record from its support posts onto two forks, which are then withdrawn to allow the record to drop onto the turntable.



Courtesy RCA

FIG. 28. The lever 17 controls the mechanism that sets the pickup landing according to the record size.

THREE-POST CHANGERS

The three-post changers are usually of the knife-blade type like the one shown in Fig. 26, except that they have three posts 120° apart instead of two posts 180° apart. The same cycle of operation is used—three knives go in between the bottom record and the remainder of the stack, then the support shelves are withdrawn to allow the bottom record to drop.

It is possible to make either the two or three-post changers intermixing types by causing the record to strike a lever as it drops, or by using a trigger mechanism on the support shelves that is depressed by 12-inch records.

Servicing Record Changers

In the preceding section, we have analyzed the operations of changer mechanisms separately because, in general, you will find that only one thing is wrong when they are out of adjustment. That is, the trip mechanism may fail to operate or operate too

Courtesy Motorola, Inc.

A bottom photograph of a typical record changer. This is the type of photo given in the manufacturer's manuals.

soon, the pickup arm may not be picked up high enough or may not be let down low enough, the records may not be dropped, or more than one may drop, and so forth. Of course, it is always possible for the mechanism to jam completely, stopping all operation. Such jamming can be the result of a failure of some part or the result of mishandling of the changer. Most particularly, jamming can occur when someone moves the pickup arm while it is "in cycle"—that is, while the mechanism is trying to manipulate the pickup arm itself. (Moving the pickup arm while it is in cycle may also throw the changer out of adjustment.) Generally, however, the trouble is in only one portion of the change cycle. Therefore, when you are called on to service a record changer, first determine exactly what it fails to do or does incorrectly. You can then tell what adjustments need to be made to put it back in proper operating condition.

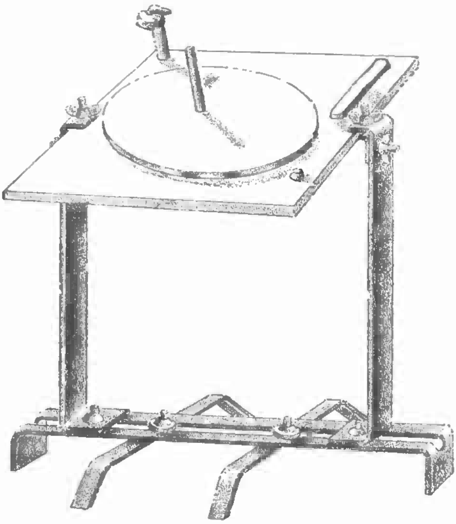
Even though you know just how a changer should perform a certain task, you may still have to spend a considerable period of time watching it go through its cycle again and again before you can see exactly which lever, gear, crank, or arm is incorrectly performing its duty. To save time, you should have all the information you can get on any particular record changer that you have for service. Fortunately, because of the complexity of changers, the manufacturers publish rather complete service manuals. These may be obtained directly from the manufacturers, like any other service information.

In addition, you can obtain much valuable service information in the Service Manuals of Rider and Howard

W. Sams. These Automatic Record Changer Service Manuals cover many different models. They are available from radio supply houses and local wholesalers.

However, if you have to service a changer on which you do not have service information, and you cannot get this information in time to complete the job, all you can do is run the changer through its operation several times and watch it carefully. By locating the apparatus that controls the faulty action, you will usually be led right to the proper adjustment.

Before you can seriously consider the servicing of automatic record changers, you must have some means available for supporting the changer on your workbench so that you can see underneath it as well as above it.



Courtesy General Cement Co.

FIG. 30. A commercial adjustable cradle for holding record changers. This style can be tilted for servicing without the changer's being removed from the cradle.

This support must maintain the changer in a level, normal playing position. This is important. In fact, many service complaints are brought about by the changer's not being level. For example, the pickup arm is adjusted to land in the blank space at the outer edge of a record. Then, if the changer is level, a slight spring pressure or gravity feed will cause the needle to move over toward the spindle sufficiently to engage the first playing groove. If the changer is not level, the needle may not move into the playing groove, or may even jump the other way—completely off the record. Similarly, in cases where the spring tensions are critical, you cannot have the changer up on edge without putting excess tension on some springs or releasing others so that the changer cannot perform satisfactorily.

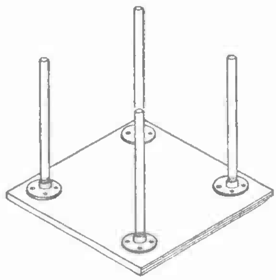


FIG. 31. A home-made jig. The leg spacing must be adjusted for different changers.

There are several support jigs for record changers that may be purchased from the radio supply houses. A typical one is shown in Fig. 30. If you prefer, you can make a jig like the one shown in Fig. 31. Of course, the spacing between the posts will be proper only for certain types of changers, so a home-made gadget of this kind is not quite as flexible as are some of the adjustable commercial jigs. In any case, the jig must fit the changer, must support it securely, and must hold it level. To be useful, the jig must hold the changer above the workbench high enough for you to see and adjust the changer mechanism from underneath. You don't have to put your head under the changer to watch its operation—you can always use a mirror to let you see underneath—but you will usually have to get under it yourself when you make adjustments.

When you are servicing a record changer, it isn't always desirable to have electric power applied. The changer may run through its operation too fast for you to watch everything sufficiently, or there may be some jamming condition that could actually damage parts if power is applied. For this reason, it is frequently necessary to disconnect the motor from the power line and rotate the turntable by hand to drive the changer mechanism slowly through its cycle of operation.

Sometimes you will find that support straps, mounting boards, or other objects obscure the view of the parts you want to watch. In such a case, removing the turntable may let you see the mechanism underneath. However, this won't always prove helpful—in some instances the motor board is solid, and only the spindle comes through the board. If so, removing the turntable does not permit you to see underneath at all.

Now let's describe a few basic troubles and learn their remedies before going on to examples of manufacturers' service data.

NON-STANDARD RECORDS

A great deal of the trouble experienced with record changers is caused by the fact that the records involved are warped or are not standard in some way.

The standard 10- and 12-inch records made by the reputable manufacturers are all held reasonably close in their sizes. They are of the proper thickness and diameter, and in general the edges of the records are smoothly rounded. However, it is always possible for even a standard record to be outside tolerance in some way, and many of the records made by smaller companies are not standard at all. Here are a few of the troubles caused by non-standard records.

No Eccentric. You will find that many of the older recordings either do not have an eccentric groove at the center of the record or have one so shallow that it cannot trip some of the changer mechanisms. This is particularly true of some of the earlier classical recordings. Unfortunately, these classics are frequently the very records that appeal to owners of record changers. They may not realize that the eccentric groove is necessary for the trip, so you may very well get a call to repair a changer because it does not trip, when actually the trouble is this lack of an eccentric groove. Be sure to find out from the customer on such calls whether the mechanism fails to trip only on certain records—he may have noticed this characteristic, which will lead you at once to the trouble.

There are a few records, mostly foreign ones, that have the eccentric groove but carry the recording groove too close to the center spindle. This is perfectly all right as long as the trip mechanism operates from the eccentric groove. However, if used in a changer having a positional trip (in which the trip is actuated as soon as the pickup arm is brought within a preset distance from the spindle), these records may tend to trip too soon. If you find that the changer has a positional trip, check the manufacturer's instructions to learn the distance from the spindle the device should be set. If it trips at the proper distance, the record is at fault.

Thickness Variations. Records that are too thick or too thin can cause trouble in the mechanism designed to feed the records from the storage system to the turntable. For example, in all systems like that shown in Fig. 21, the record must slide under the guide trigger. A thick record may not be able to feed through here. On the other hand, if two very thin records get together, they may both try to feed through. The result could be a jamming on the shelf, or they both may drop at once. In the case of the thick record, of course, jamming results.

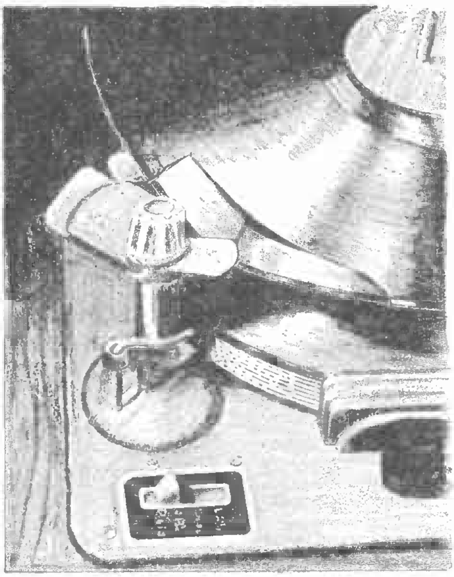


FIG. 32. An off-size record or improperly adjusted separating knives may result in record breakage like this.

In a changer that uses separating knives, records that are too thick or too thin may not be properly separated by the knives. If the record is too thick, the knives may cut into it instead of passing over it. If it is too thin, the knives may cut into the record above the one to be separated. Incidentally, rough or chipped record edges can also cause trouble by catching the knives. Fig. 32 shows an example of what may happen in such a case. Of course, this can also be the result of an improperly adjusted knife.

Improper Diameter. If the record is too large or too small in diameter, it may not feed through the storage mechanism properly, and naturally the pickup arm will not land properly on the record. Of course, a record that is off standard size this way is usually easy to detect because it can be directly compared with others in the stack. It is less easy to detect records that are thick or thin.

JAMMING

When a record changer is jammed, it is not advisable to try to force it to continue its changing cycle. Of course, just what is wrong depends upon whether the jam was caused by a defective part or by someone's trying to force the mechanism. In general, however, it is possible to clear jamming by rotating the turntable backwards. Of course the power must be shut off when you rotate the turntable by hand in this manner.

If the changer has a damaged part, it will jam at the same point in its cycle each time. In such a case you can rotate the turntable in the proper direction, by hand, until the jam occurs. You will then be better able to see just what has gone wrong.

Incidentally, it is possible for jamming to occur because the changer is not level or because it has shifted in its position in the cabinet. It may be that all the levers and gears originally cleared the interior of the cabinet but that a shift in position has permitted some lever to strike the cabinet. You can check the levelness of the changer with a carpenter's level.

GENERAL DEFECTS

Ordinarily, a changer is in need of repair because of the normal wear of some of the parts in it. This wear may be of such nature that an adjustment, provided by the manufacturer, can clear up the difficulty. However, once a bearing becomes so loose that the lengths or positions of levers vary during the changing cycle, it will be necessary to make a major repair or to replace the changer.

Another common source of trouble is fatigue in the springs, of which changers have many. With use, these springs will eventually stretch so that they do not provide the proper tensions. When this happens, it is usually necessary to replace the offending spring; once in a while, however, you may find that the manufacturer has provided an adjustment for the spring by attaching one end of it to a movable terminal.

Incidentally, much of the trouble that is encountered with record changers comes about because of lack of proper oiling. Although oiling instructions usually accompany a changer, few owners remember to follow them—perhaps because the necessary oilings are infrequent and therefore easily forgotten.

The manufacturer's instructions should be consulted when it is discovered that oiling is needed. It is usually safe to oil any metal-to-metal bearing, although often a light grease is indicated instead of regular oil.

There are some spots about a record changer that should *never* be oiled. Certain tripping mechanisms that depend upon friction may or may not require oiling, depending upon the materials used in them. For example, one changer has a cork washer to provide friction. Oil on this washer completely upsets the operation of the trip mechanism.

Similarly, it is desirable to keep oil away from all rubber parts. Many drive mechanisms are friction types, using rubber-tired pulleys. It is important to keep oil away from the rubber, but nevertheless to oil the bearings of such pulleys.

Pickups and Their Servicing

The pickup device itself has nothing to do with the automatic record changer other than the reproduction of the recording as an electrical signal. Nevertheless, when the output from a changer is distorted or sounds tinny or when there is no output at all, the serviceman is certain to get a call.

There are three types of pickups in common use today—the crystal, the magnetic, and a variable reluctance type of magnetic pickup. Let's study their operation briefly.

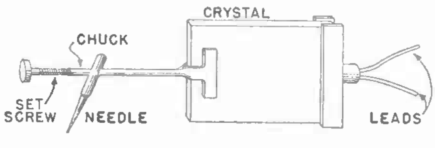
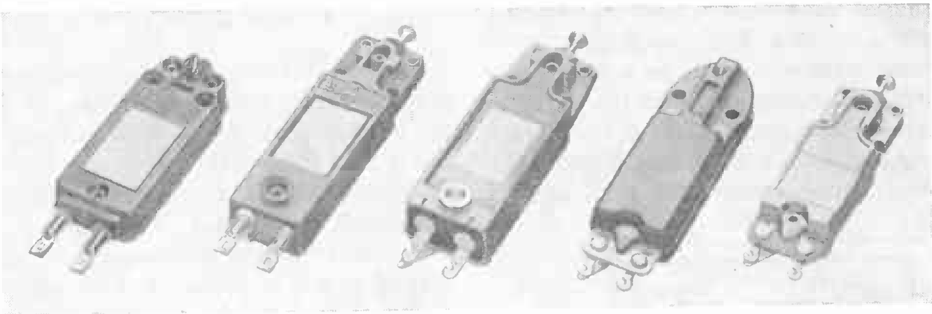


FIG. 33. Details of a crystal cartridge.

As you know, all standard recordings used in the home are the result of modulating a groove so that it has "wiggles" from side to side in it. The record player needle fits in this groove and is forced to follow the variations. To reproduce the recorded sound, we have to have some means of translating this mechanical side-to-side motion of the needle tip into an electric signal.

Crystal Pickups. Probably the most widely used pickup today is one containing a crystal element. These units are inexpensive, easy to replace, and give a high output.

Fig. 33 shows the operating details of a crystal cartridge or pickup. The



Courtesy Astatic Corp.

FIG. 34. Several typical crystal cartridges. They vary in physical size, method of connecting leads, and whether or not permanent needles are used. Some have greater outputs, and others offer better fidelity.

phonograph needle is held in a chuck by a screw. In turn, the chuck is clamped to one end of the crystal element. The opposite end of the crystal is mounted in the case so that it cannot move. Now, as the record grooves force the needle to move from side to side, the chuck is twisted. This twists the end of the crystal, applying a mechanical stress to it that causes it to generate a voltage, which appears on its opposite faces. Foil plates on the crystal surfaces pick up the voltage and feed it through the leads.

The physical appearance of crystal cartridges vary somewhat, as shown by several typical ones in Fig. 34. However, they all operate on basically the same principle—the only differences are in the housings, the methods of connecting the cable to the cartridge unit, and the styles of needle mountings. We shall go into needles a little later.

Magnetic Pickups. Fig. 35 shows the details of the operation of a magnetic pickup. Essentially, this consists of a permanent magnet, a coil, and an armature that can be actuated by the phonograph needle. As shown in this figure, motion of the needle from side to side directs the flux in opposite directions through the armature. Therefore, since the coil is essentially around the armature, the flux variations in the armature cause voltages to be induced in the coil.

Variable Reluctance Pickup. The variable reluctance pickup, a typical example of which is shown in Fig. 36, is a variation of the magnetic type. However, the difference in the amount of needle pressure needed is appreciable. A magnetic head must be heavy

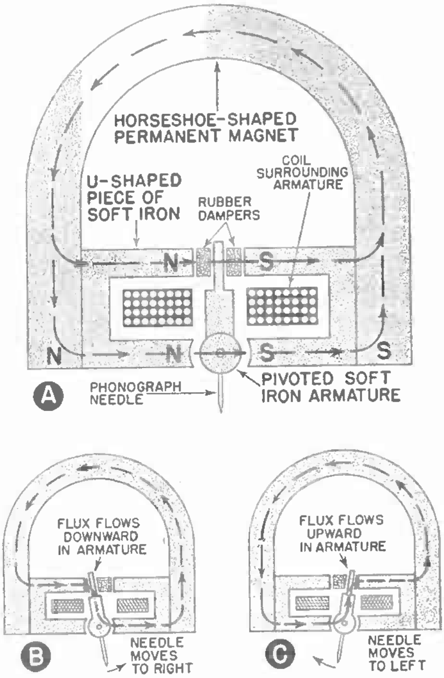


FIG. 35. Details of a magnetic pickup.

so that the head will not vibrate when the armature does; consequently, it presses rather heavily on a record and wears it out quickly. In the variable reluctance pickup, however, the vibrating device is a very tiny, lightweight reed; consequently, the head can be

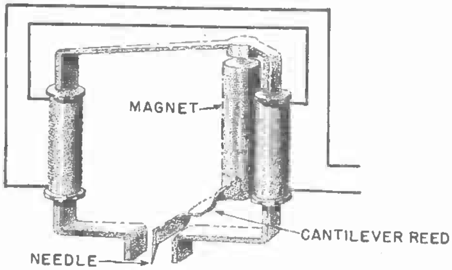


FIG. 36. One type of variable reluctance pickup.

made light enough to cause practically no record wear.

This change in weight comes about because the coil no longer picks up the flux variations directly from the armature. Instead, the armature in the variable reluctance type merely varies the reluctance in a magnetic path, and the coil picks up its energy from the variations in flux in this path.

As Fig. 36 shows, there are two paths for magnetic flux in this pickup. In each path, flux flows from the magnet through half of the pickup coil and through the reed back to the magnet. The position of the vibrating reed in the air space between the two coil cores determines how much flux flows in each half of the coil at any instant. When the reed is near one of the cores, the flux through the half of the coil wound around the other core decreases. The two halves of the coil are wound in opposite directions around their cores, however, so a decrease in flux through one has the same effect as an increase in flux through the other. This doubles the effect of the movement of the reed in producing a signal.

PICKUP DEFECTS

Crystal Pickup. A crystal cartridge is rather easily damaged. If the pickup head is ever dropped, it is quite likely that the crystal will be cracked. Excessive motions of the needle may also crack the crystal. Moisture can also destroy a crystal. So can heat: a crystal should never be allowed to get hotter than 110°. Many pickups are ruined because the head is allowed to remain so long in the path of sunshine streaming in a window that the crystal becomes overheated.

A defect in the crystal practically always shows up as a severe distortion accompanied by weak volume. When you find a changer with such characteristics and have determined that the audio amplifier is not at fault, it is advisable to replace the crystal. Generally, the crystal is held in the pickup arm by two screws or by a simple clamp arrangement. Simply remove the defective unit and install a good one of the same type in its place.

When you replace a crystal, be careful not to overheat the terminals if you must solder a cable to the cartridge. Excessive heat from the soldering iron will destroy the crystal. Therefore, it is best to have the pickup cable terminals well tinned and coated with solder so that you can sweat the cable end to the crystal terminals quickly.

Magnetic Pickup. The armature of a magnetic pickup sometimes strikes the pole pieces, either because the rubber damping blocks have worn out or because the armature has shifted its position. When this happens, the device will chatter, and the output will be severely reduced. Occasionally an armature moves over far enough to stick to one of the pole pieces by magnetic attraction. When this happens, of course there will be practically no output. No output may also be the result of an open coil.

It is impractical to repair the pickup; the only thing to do is to replace the head when you are sure it is at fault.

Incidentally, with any type of pickup, it is well to be cautious about the cable that connects the pickup electrically to the amplifier. The cable almost always consists of a center wire surrounded by insulation, which is surrounded in turn by a braided shield that is grounded to prevent hum pickup. This shield is one of the conductors. Rather often the insulation between the center conductor and the shield wears through, permitting the cable to short. This is particularly likely to occur at the point in the cable where it leaves the end of the pickup arm and goes down underneath the motorboard. The moving of the arm back and forth twists and untwists the cable at this point so that the insulation may be mechanically worn out. It is well to examine and check cables for both opens and short circuits before condemning the pickup.

The position of this cable is such that oil may get on it if anyone is careless in oiling surrounding parts of the changer. This will speedily destroy the rubber insulation, permitting the cable to short-circuit. Naturally, this will reduce or kill the output.

PHONOGRAPH NEEDLES

As you will realize, it is desirable for a needle to be as permanent as possible. If the needle wears excessively, it may not even be able to play a stack of records. This is particularly true of some of the non-metallic needles, such as the thorn or cactus types.

Needles should be made so that they fit the grooves of the record. If the needle point is too small, as shown in Fig. 37A, it can skid from side to side in the groove and thus introduce false frequencies. It may even ride out of the groove in such cases. In addition, a narrow needle may strike the bottom

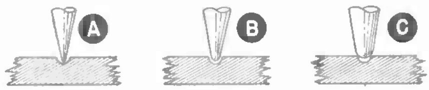


FIG. 37. Effects of needle-point sizes.

of the groove and pick up a great deal of noise from the imperfections there.

On the other hand, if the point is too broad, as shown in Fig. 37C, it cannot fit down into the groove and will tend to escape and permit the pickup head to slide across the record. When the needle fits the groove properly (Fig. 37B), it will follow the modulations in the record grooves without introducing other frequencies and without escaping from the grooves.

The harder the needle point, the more important it is that it have the correct needle shape initially. Unless a hard point is made with extreme care, it may have imperfections that will wear down the walls of the record groove and so destroy the fidelity of the recording.

The standard steel needle is usually only an approximation of the right shape. However, it is made of a material sufficiently soft so that the abrasive contained in a standard record will quickly wear the needle down until it fits the groove reasonably well. This wearing causes shoulders to build up on the needle, however, soon shaping it so that it can damage records. For this reason, a standard steel needle should be replaced each time a record is to be played. Obviously, this makes such needles rather impractical for record changers.

Longer playing steel needles are

made for record players. These needles are tipped with alloys that make the tips very hard. Then the needles are carefully selected so only those having the correct shape are sold. For permanent-point needles, it is well to remember that it is a good idea to buy those made by a reliable manufacturer. Any imperfections will remain for the life of the point and will cause wear of the record grooves. Most such points are shadowgraphed by the manufacturer, which means that an enlarged shadow of the needle point is thrown upon a screen for examination. Any needle with an imperfection is rejected.

In addition to the steel needles, there are available needles tipped with sapphire or diamond. These are the longest playing of all. Of course, these needles are rather expensive; if handled carefully, however, they will last for many thousands of playings.

The standard needle is straight and has a relatively thick shank. The more rigid the shank of the needle, the better it will transmit high audio frequencies —including scratch noises. Many people find the elimination of the scratch more desirable than good fidelity; to do this, some needles are made thin and flexible; others are coated with paint; and, finally, many actually have a bend or knee in them. All of these changes in the basic shape of the needle result in a reduction of the high-frequency response and a corresponding reduction in scratch noise.

Most modern record changers have permanent built-in needles. If anything is wrong with the needle, the entire pickup cartridge must usually be replaced. There are a few exceptions in which it is possible to replace the needle, however.

One exception is shown in Fig. 38. This is a view of a cartridge used on certain RCA changers. The sapphire playing tip is held in a tiny socket by rubber cement (such as Goodrich Plasticon). If this needle needs replacement, it may be grasped firmly with a pair of tweezers, given a few turns to loosen the cement, and then pulled out.

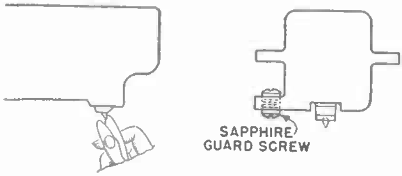


FIG. 38. How to replace the sapphire tip on certain RCA changers.

A new sapphire can be re-inserted, with just a drop of the rubber cement on it to hold it in the socket.

RECORD CARE

Many people do not know how to take proper care of their records. Whenever you find that the record collection of one of your customers is not in good condition, you can do him a service and create some good will for yourself by passing along these hints:

Records will become noisy if they are allowed to collect dust. They must be kept clean. It is best to store records in their original envelopes or albums, and then, if they do collect some dust, to brush them with a record brush.

It is necessary to store records properly to prevent them from warping. As you have learned, a warped record can easily get into trouble with the changer mechanism, because it may be impossible for the mechanism to separate warped records. Records should never be left resting on the support shelf of a record changer for a long time. They should always be stored carefully.

Motors and Their Servicing

The motors used on record players and changers must maintain their speeds accurately. The two basic motor types used in record changers—the synchronous motor and the induction motor using a governor—meet this requirement.

There are several forms of the synchronous motor. Most of them are of the eddy current type, but you will occasionally encounter shaded-pole or capacitor motors. Any of these are relatively constant in speed as long as they are not overloaded.

In general, little goes wrong with the motor itself as long as it is oiled properly. Once in a great while, you may find a changer in which the motor has a burned-out winding, but this is very rare. More commonly, any trouble will be with something related to the motor—the on-off switch may be defective or the motor may be overloaded. On the induction types, the speed governor may cause trouble.

A simplified drawing of a typical speed governor is shown in Fig. 39. This device contains a shaft that is coupled to the motor. Two weights are connected by springs to a collar on the end of the shaft. A wheel is also connected to the weights by springs. Let's see how the device works.

As the shaft rotates, the weights are thrown outward by centrifugal force. The pull exerted on the springs by the outward movement of the weights pulls the wheel to the right, bringing it up against two friction pads made of felt. As soon as the wheel strikes the friction pads, it is slowed down by the friction; since the wheel is connected to the shaft through the springs and collar, the shaft is slowed down also. Thus, the motor is retarded if it attempts to run faster than the speed for which the governor is set. This keeps the motor running at a fairly constant speed as long as nothing happens to make it run too slowly; the governor has no action that will speed up a slow motor. The speed at which the governor will start to slow down the motor can be adjusted by moving the friction pads toward or away from the collar; the farther they are from the collar, the slower the speed at which the governor acts.

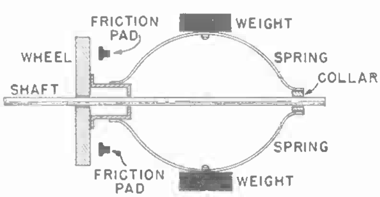


FIG. 39. Details of a typical speed governor.

These governors will not maintain the speed properly if the friction pads wear down or become hard because of a lack of oiling. Watch for this if the speed is uneven.

DRIVE MECHANISMS

The driving force of a phonograph motor is applied to the turntable either at the center spindle or at the rim. Fig. 40 shows one form of spindle drive, in which the motor drives a gear mounted on a shaft secured to the spindle.

When the center spindle is driven this way, considerable power is needed to get the turntable started. Once started, however, the inertia of the rotating mass of the turntable tends to keep it going.

Many changers use a less powerful motor and drive the turntable from its rim. In systems of this kind, as shown in Fig. 41, the motor turns a small

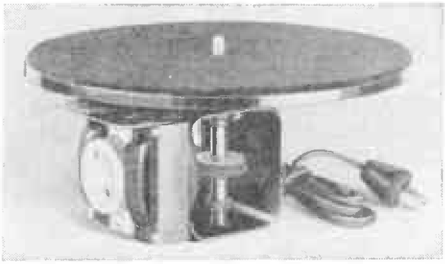


FIG. 40. A drive system that operates through the center spindle. This photo shows a record player; a changer would use a different spindle and would have the changer mechanism. These are omitted here to show the drive more clearly.

drive pulley. This is held against the rubber-tired idler pulley, the edge of which is against the rim of the turntable. Incidentally, it is necessary to use either gearing or an idler pulley system of this kind so that the motor can turn at a fair rate of speed, yet maintain the standard 78 revolutions per minute for the turntable.

There is another advantage to the rim drive system. In a center spindle drive, the motor is more or less directly connected through a gearing system to the turntable. Vibrations produced by the motor can travel to the turntable and be picked up by the pickup. On the other hand, with the rim drive system, the motor can be flexibly mounted in a spring suspension. Springs keep its pulley in contact with the idler pulley. With this arrangement, any variation up or down in the drive pulley does not transfer any motion through the idler pulley to the turntable.

Spring suspension of the motor is important to keep down what is called turntable rumble, a frequent cause of customer complaints. This noise consists of a low-frequency rumbling sound, somewhat similar to hum, that can be heard only when the record is being played. Generally you will find it is caused by the fact that the motor is no longer suspended on springs—someone may have tightened the mounting so much that the springs are no longer effective, or they may be weakened so that the motor can jar the motorboard and, through it, the turntable. Sometimes this condition is made worse by the fact that the entire

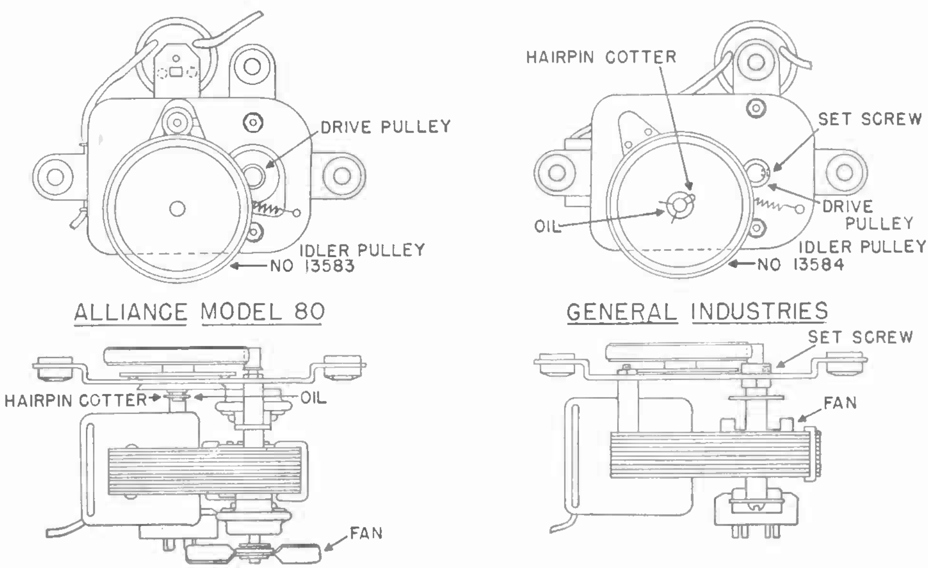
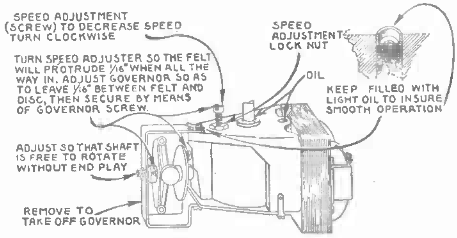


FIG 41. Details of rim-drive systems.

motorboard is not sufficiently spring-mounted, either because someone has screwed down the changer too tightly to the cabinet or because it has shifted in position so that the motorboard is bearing against the cabinet wall. Sometimes flexible couplings are used between the motor drive and the rest of the drive mechanism to cut down some of this transfer of noise.

Improper speed is perhaps the most common complaint involving the motor system and drive mechanism. A synchronous motor never runs too fast, but it may run too slowly if the motor or the changer mechanism needs lubrication. Usually, careful oiling and greasing will clear up a trouble of this kind.

An induction-type motor that has a governor usually also has an adjusting screw by which the speed of the motor can be changed. A typical example is shown in Fig. 42. To get the motor to the right speed, a stroboscopic disc is placed on the turntable. This is a disc having a special pattern on it; when the disc is observed under a light operated from 60-cycle power, the pattern will apparently stand still if the motor is turning at the proper speed but will appear to revolve if the motor is going too fast or too slow. The proper turntable speed is secured, therefore, by



Courtesy RCA

FIG. 42. Certain RCA changers have speed adjustments as shown here.

turning the adjustment screw until the pattern appears to be motionless. These discs are available from radio supply houses and from many record dealers.

Remember that improper line voltages or variations in line voltage may affect the speed of the motor. Of course, if any foreign particles have lodged between the armature and the field pole pieces, or in any of the gearing, the motor may vary in speed or may even jam and not run at all.

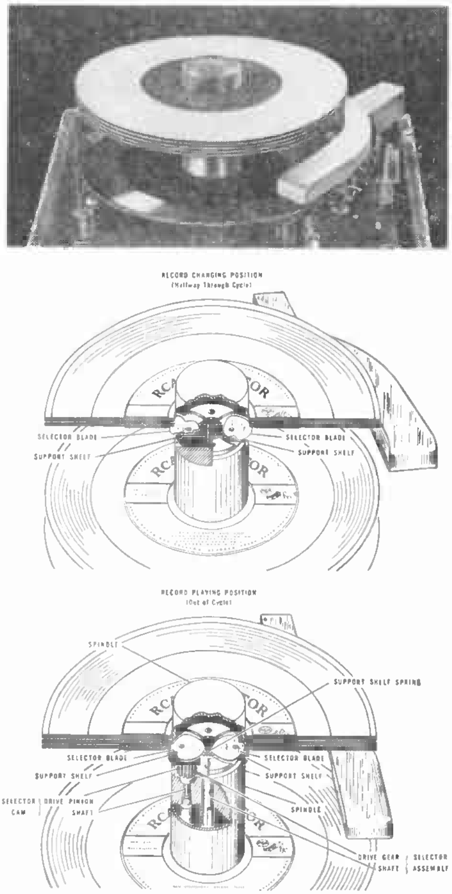
Overheating is another motor trouble. This of course can be the result of insufficient lubrication, but may also be the result of bearings that are too tight, of short-circuited coils in the motor, or of an excessive load on the motor, such as may be produced by improper lubrication of the drive mechanism or by off-center mounting.

Microgroove Records

Recently there have been introduced two different series of records having very fine grooves (generally called microgrooves because of their thinness); these records are intended to rotate at slower speeds than 78 r.p.m.

LP Records. One microgroove type consists of 10-inch and 12-inch records designed to be played at 33⅓ r.p.m. The slower speed and increased number of grooves permit these records to hold much more recorded material; it is possible to get an entire symphony on both sides of one 12-inch record, whereas four to eight standard records would be needed for the same symphony.

The advantages of such a long-playing record are obvious—one no longer has to put up with the unnatu-



Courtesy RCA

Fig. 43. A photo and two sketches of the player designed for 45 r.p.m. microgroove records. The upper sketch shows how the separator knives move in between records while the support shelves are withdrawn simultaneously to allow the bottom record to drop. In the lower sketch, the support shelves now hold the record stack and the knives are withdrawn into the spindle.

ral break in the music that occurs when a record is changed in a conventional changer.

Both single-record players and changers designed only for these LP (long-playing) records have been developed. Of course, the new speed requires a change in gearing or size of idler pulley, and the fine record groove requires a special fine-tipped needle and light-weight tone arm.

Combination changers can handle both the LP and the standard records (as long as they are not intermixed) by having a switch to change the turntable speed, and either using separate tone arms or a switching arrangement that will change the arm weight and needle size. The latter is obtained generally by using a dual needle and a tilting or revolvable crystal so that the proper tip is put into play. However, there is a new 7-inch microgroove record for popular music; this requires an additional switch to set the pick-up arm landing position, plus an extension spindle or platform to provide proper storage support for this small-size record.

45-R.P.M. Type. Another microgroove system uses a record 6⅞ inches in diameter and a turntable speed of 45 r.p.m. These records are radically different in that they are designed to operate on a changer having the "works" in the center post. Hence, the records have a center hole 1½ inches in diameter, and are made thicker in the label area to provide a space for the separating knives.

These records were introduced along with the unique changer shown in Fig. 43, but some of the recent changers will handle not only these records, but also the LP and standard ones by having interchangeable center spindles, three speeds, dual needles, and a new landing position for the tone arm.

Lesson Questions

Be sure to number your Answer Sheet 48RH-2.

Place your Student Number on every Answer Sheet.

Send in your set of answers for this Lesson immediately after you finish them, **as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. What feature is provided on standard records to make it possible for the changer mechanism to regain control after the record has finished playing?

2. What are the three main types of trip mechanisms?

3. What is the function of the main cam in most record changers?

4. In the elevator system shown in Fig. 12A, how would you adjust for the condition wherein the pickup arm is not lifted sufficiently to play a record on top of a stack?

5. What is the function of the guide trigger in the spindle of a single-post changer?

6. What is the function of the knives in a 2-post or 3-post changer?

7. What two things can happen if the pickup arm is moved when a changer is in cycle?

8. What precaution must be taken when replacing a crystal pickup?

9. Why should one be careful to keep oil off the electrical cable that connects the pickup to the amplifier?

10. What two things may cause a governor-controlled motor to run unevenly?

Be sure to fill out a Lesson Label and send it along with your answers.

THINK AND BELIEVE

Here is some very sound advice written by a highly regarded authority, Joseph H. Appel:

"You want a better position than you now have in business, a better and fuller place in life. All right. Think of that better place, and you in it, as already existing. Form the mental image. Keep on thinking of that higher position. Keep the image constantly before you. No, you will not suddenly be transported into the higher job, but you will find that you are preparing yourself to occupy the better position in life. Your body, your energy, your understanding, your heart will all grow up to the job. And when you are ready, after hard work, after perhaps years of preparation, *you will get the job and the higher place in life.*"

Remember, Mr. Appel does not promise miracles. But by developing confidence and assurance—by sincerely *believing* that you will accomplish *what you want* to accomplish, you make great progress on the road to success.

J. E. Smith

THE TELEVISION SIGNAL

49RH-4

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 49

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. **Basic Principles of Television** . . . . **Pages 1– 4**

How television signals are transmitted and received. their limitations, and the basic equipment necessary for their transmission are discussed.

☐ 2. **Image Scanning in Television** . . . . **Pages 4–11**

A description of how a scene is broken down into elemental impressions, and how these impressions and the necessary synchronizing signals are transmitted in a sequence of pictures.

☐ 3. **The Cathode-Ray Tube as an Image Reproducer** . . **Pages 12–16**

In the television receiver the cathode-ray tube reassembles the elemental impressions to reproduce the television signal on the screen.

☐ 4. **Image Detail** . . . . **Pages 17–20**

A description of the factors which are required to give pictures good definition without flicker.

☐ 5. **Interlaced Scanning** . . . . **Pages 21–23**

How 60 pictures per second are used to reduce flicker within the bandwidth requirements of a 30-picture-per-second system.

☐ 6. **Brightness and Contrast Controls** . . . . **Pages 23–26**

These two important controls in television systems are discussed and the principles of operation and adjustment are given.

☐ 7. **Television Signal Standards** . . . . **Pages 26–31**

The technical standards of television signals and synchronizing pulses which affect both transmitter and receiver operation.

☐ 8. **Fundamentals of TV Receiver Operation** . . . . **Pages 32–36**

The passage of sound and sight signals through a typical TV receiver and the basic controls which will be encountered.

☐ 9. **Answer Lesson Questions, and Mail your Answers to NRI for Grading.**

☐ 10. **Start Studying the Next Lesson.**

JD6M151 1951 Edition Printed in U.S.A.

YOU are now beginning your special training in the field of television. This first Lesson will give you an understanding of modern television, showing how it is possible to see on the screen of a picture tube in a receiver a scene that is at that same instant taking place miles away and being viewed by the television camera.

In the NRI Television Lessons you will find presented in a simple, logical, and understandable manner the important principles underlying all phases of modern television systems. After mastering these Lessons you will find it easy to understand the operation of any TV set. Then you will learn how to service TV sets. You will learn the basic techniques employed, and the difference between servicing broadcast receivers and servicing TV receivers. You will also be shown how to make installations and you will instruct the customer in the operation of his receiver.

Photograph above, courtesy RCA.

THE TV CARRIER SIGNAL

The process of scanning that breaks up a televised scene into successive signal elements results in a frequency range for picture signals of from zero to more than 4,000,000 cycles (4 megacycles, abbreviated 4 mc.) per second. Thus the television signal covers more space in the radio spectrum than the entire broadcast band. For this reason only very-high frequency carriers are suitable for transporting through space a signal that has a frequency range of over 4 megacycles. With ordinary modulation practices, such as are used in the broadcast band, this means that the frequency range of each TV station would be over 8 megacycles. However, by partially suppressing one side band, this range is reduced to less than 6 megacycles and each station is allocated a channel 6 megacycles wide.

Consistent television reception at greater-than-line-of-sight distances is now definitely a reality. This was considered impossible for many years by most engineers as well as by the Federal Communications Commission. The general theory was that the signals traveled in a straight line and that once line-of-sight distances had been exceeded, signals dropped off in strength so rapidly that they were not usable. The fact that these signals travel in a straight line is correct, but the point that was generally overlooked was that refractions (bending of the signals) occurred and that it was possible to use these refracted signals to produce satisfactory pictures at distances of two and three times line of sight. These refracted signals are a normal occurrence and are always present at distances up to approximately 100 to 125 miles, depending upon the height of the transmitting and receiving antennas.

When actual practice proved that long-distance television reception was possible, the Federal Communications Commission found it necessary to stop all television station construction permits because stations that were located less than 300 miles apart were interfering with each other. This interference manifested itself in the form of black lines running through the picture, commonly referred to as "venetian blinds," also the audio was garbled. This stoppage of construction permits was to allow time for the FCC to study and rectify the already existing situation. It appears that in the future the ultra-high frequency spectrum in the neighborhood of 500 megacycles will be opened up, and that station permits will be issued so that the number of TV stations may be increased. The higher the carrier frequency, the more the signal acts like light rays and the less chances there are of interference between stations located fairly close together.

Channel Number	Channel Freq. Mc.
2	54–60
3	60–66
4	66–72
5	76–82
6	82–88
7	174–180
8	180–186
9	186–192
10	192–198
11	198–204
12	204–210
13	210–216

FIG. 1. That portion of the spectrum between channels 6 and 7 is assigned to FM and other services, and the frequencies from 54 mc. to 88 mc. and from 174 mc. to 216 mc. are reserved for TV transmission.

The Federal Communications Commission originally allocated thirteen channels to television, extending from 44 megacycles to 216 megacycles. Channel No. 1 was eliminated and at the present time there are twelve TV channels, designated by their original numbers, 2 to 13, with the frequency coverage shown in Fig. 1. Additional assignments of TV channels will be in the ultra-high frequencies.

TV IS AN EXTENSION OF RADIO PRINCIPLES

A television camera is needed to pick up picture signals in a television studio, and a special reproducing device is required at the receiver to reproduce the transmitted picture. Between these two special devices we find a great many familiar radio circuits. At the television transmitter there is a master oscillator that generates the r.f. carrier, together with r.f. power amplifiers, a modulator, linear r.f. power amplifiers, and a transmitting antenna. At the receiving location the television signals are picked up by an antenna, and are amplified and selected in the preselector of the television receiver. The superheterodyne circuit is used in television sets and hence the receiver will have an r.f. amplifier, a mixer first detector, a local oscillator, an i.f. amplifier, a second detector, and a picture-signal amplifier, all of which prepare the received signal for the picture-producing device.

The sound accompaniment for a television program is handled in essentially the same way as in f.m. program broadcasting. However in television the frequency deviation of the sound signal is limited to $\pm$ 25 kc.

In a television receiver you will find tubes, coils, resistors, condensers, transformers, etc., just as in ordinary broadcast receivers. In many instances, as you will learn later, some of the parts do not have the same physical appearance but many are identical.

Television circuits may be exactly the same as radio circuits or there may be entirely new circuits developed to meet special requirements of picture reception.

Sounds, no matter how complex, are inherently a succession of signal intensities. Unfortunately, a scene does not exist in this desired state. Therefore a scene must be converted into a succession of signal intensities by a process of scanning, as the first step in sending images by radio or wire. The television camera provides this scanning, and feeds into the television system a signal corresponding to that fed into a radio system by a microphone. The succession of signal intensities in a television signal is handled by the transmitting and receiving systems in a more or less conventional manner. These varying intensities must be reassembled in proper order and position by an image-reproducing device at the output of the receiver in order to reconstruct the original scene. The image reproducer in a television receiver corresponds to the loudspeaker in a broadcast set.

The scene is taken apart at the transmitter so that it can be sent as a succession of signal intensities and must then be properly reassembled at the receiver. To do this the circuit that controls the scanning at the television camera must also control the scanning process at the receiver. This act of controlling the receiver scanning system so that it is in step with the picture camera is referred to as synchronization, and the signals that do this are known as synchronizing signals. (They are commonly referred to as sync signals.) The sync signals are produced by special oscillator circuits and are sent out on the carrier along with the picture and sound signals in a conventional manner. At the receiver the sync signals are separated from the picture signals by special circuits that are not found in the usual broadcast set. In the final analysis, however, all these special circuits are based upon extensions of well-known radio principles.

Once the requirements of a television system are recognized, the special circuits will seem quite natural rather than something strange and new. By studying the process of scanning first, giving special attention to the sync signals, and the circuits that handle these signals we can make television circuits seem just as logical and understandable as ordinary radio circuits. This Lesson is primarily intended to acquaint you with the important problems in television and later Lessons will go into details on the various circuits and the actions that take place in them.

Image Scanning in Television

Television involves a transmission of intelligence that reaches our brain through our eyes. First, let us consider what the eye sees when it looks at an object. Ordinarily, it looks at reflected light, made up of electromagnetic waves; occasionally, it looks directly at light sources such as electric lamps, a fire, or the sun. The eye sees color because the electromagnetic waves in the visual band have different frequencies, each frequency or group of frequencies giving, through the action of the brain, a color sensation. The human eye serves as a complicated lens (much like the lens in a camera), for it projects these electromagnetic waves on the retina, a surface at the back part of the eye. This retina has millions of nerve endings, each of which is connected to the brain. These nerve endings interpret the strength of each electromagnetic wave that hits them (determined by the brightness of the object) and they also interpret the frequency of the wave (the color of the object). Each nerve ending "sees" only a tiny portion of the entire scene; the brain reconstructs the over-all picture by assembling all the nerve impulses. Thus, the eye breaks up the scene into two elements, each of which is transmitted over a separate nerve channel to the brain.

One scientist calls the human eye nature's own television system. The object viewed acts as the transmitter system sending out electromagnetic waves. The eye, acting as a receiver, picks up the waves and relays them to the brain to give us the sensation of seeing.

A SUGGESTED TV SYSTEM

This action of our visual mechanism suggests the construction of a television system. Why not arrange thousands or millions of tiny electric eyes on a screen to pick up the light waves, and connect these by thousands of wires of radio-frequency transmitters to a receiver containing thousands of tiny glow lamps? Each of these would reproduce the amount of light picked up by its corresponding electric eye, so the combination of all the lamps would reproduce the object viewed by the transmitter. Yes, a television system like this has actually been tried for land-wire television, but only on a small scale. The scheme was found to work after a fashion, but obviously it was far from practical, for entirely too many wires were necessary.

PRACTICAL TV SYSTEMS

The television systems in use today do not attempt to pick up a complete scene and transmit it to a receiver all at once. Instead, television takes advantage of an eye characteristic known as persistence of vision—the ability of the eye to retain an impression of an object for a short time after the object has disappeared from view. This makes it possible to send a portion of a scene at a time; just so the entire scene is transmitted before the eye has had a chance to "forget" the first part of it.

The scene is broken up into elements by scanning, or by viewing a small portion of it at a time. Scanning is an operation very like what you are doing now as you read this page. You don't look at the page and attempt to read every word in one glance. Instead, you read the first line from left to right, swinging back quickly to the left-hand side of the second line, read the second line, go back to the beginning of the third, and repeat the process until you have taken in every word.

That is just about what a television camera does. (This camera is the pick-up device in a television system, corresponding to the microphone in the radio system.) In effect, an "eye" in the camera travels over the top edge of the scene from left to right, swings quickly back to the left-hand side, moves down slightly, travels horizontally over the scene again, and repeats the process until the whole scene has been scanned. As you no doubt know, or have guessed, this "eye" is really a light-sensitive surface that converts the light received from the scene into an electric current. This current, which of course varies as different parts of the scene come into view of the scanning eye, is then transmitted by radio to the receiver. At the receiver, the process is reversed, and the original scene is traced out line by line.

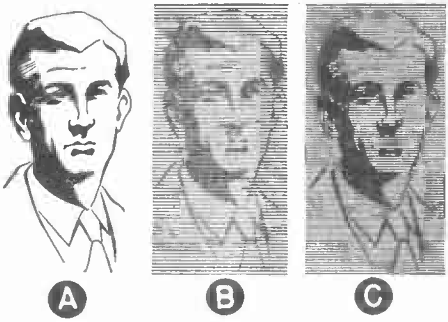


FIG. 2. The drawing at A is reproduced as a series of lines at B and C. Greater detail is obtained by using more lines, as at C.

This is a highly simplified version of how a television system works, but it will serve to show you the basic idea of operation. Right now, the important fact for you to grasp is that a scene is televised "bit by bit," and not as a whole.

Fig. 2 illustrates the general effect produced when a scene is scanned.

Suppose we wish to televise a picture like that shown in Fig. 2A. After it has been scanned by the camera, transmitted to the receiver, and reproduced on the receiver screen, it will appear as shown in Figs. 2B and 2C. That is, it will consist of a series of lines; these lines will vary in brightness along their length, and so make up the picture we see. The more lines we have in a given area, the greater the detail of the final picture. Fig. 2C, which has 120 lines, exhibits more detail than Fig. 2B which has only 60 lines.

Note that as you move the illustrations in Fig. 2 farther and farther away from you, a point is reached for each illustration where the details seem to blend into a complete and nearly perfect reproduction of the original. This brings out an important fact about television: if a reproduced picture is made larger without increasing the number of lines, the picture will have to be viewed from a greater distance to get a satisfactory eye impression. This is particularly noticeable in picture tubes 15 inches or larger. When you are close to the screen, operating the controls of the receiver, you will see the individual lines. If you move back only a few feet it will cause them to blend together and give good definition.

How Scenes are Scanned and Reproduced. Before considering the technical details of breaking up a scene into a number of lines, it will be valuable to get clearer ideas of how a scene is taken apart or scanned, and how a scene is reproduced.

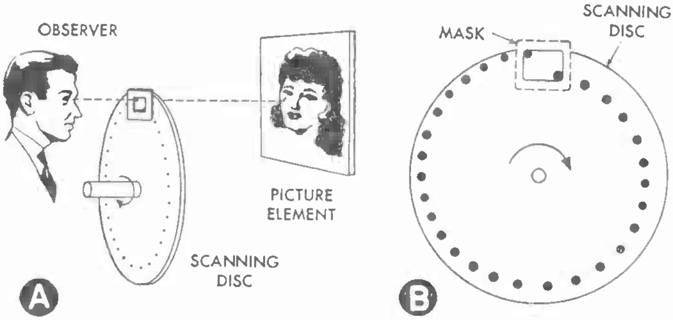


FIG. 3. This diagram shows an elementary mechanical scanning disc system. If the disc is rotated rapidly enough, the observer will be unconscious of its presence, as persistence of vision will allow him to apparently see the entire scene, although he is actually viewing only a tiny spot at a time.

MECHANICAL SCANNING METHODS

Even though mechanical methods of scanning are considered inadequate today, except for some experimental work in color television, we will consider them first since they are easier to understand and will help you to understand the electronic scanning methods.

Punch a hole with a pin in the center of a small business card and hold the card up to one of your eyes so that you can look through the hole. Turn to some object or scene. Notice that you can see only a small part of the scene through the tiny hole. Now move the card horizontally from left to right; you see all the portions of the scene along the line that you are scanning. Move the card back and forth horizontally while shifting it vertically downward a little at the end of each line and your eye will see the entire scene, piece by piece.

The Scanning Disc. In place of this card-scanning device we can use the system shown in Fig. 3A, in which a large number of holes are arranged in a spiral fashion on a rotating disc called the scanning disc. This disc really replaces the business card that we used in our previous example. One complete revolution of the disc gives one complete scanning of the entire picture, because each hole in the disc scans one line. If the disc is revolved fast enough, the visual sensation is the same as though the entire picture were being seen at one time.

The exact arrangement of the holes on the scanning disc is shown more clearly in Fig. 3B. The observer is viewing the scene through the mask, a rectangular opening in a piece of black cardboard. As the disc is rotated, each hole moves across the opening in the mask, the outermost hole in the spiral moving across the top of the opening and each succeeding hole moving across one line down. Finally, when the innermost hole has moved across the bottom of the opening, the outermost hole again scans the top line and the entire scanning process starts over again.

MECHANICAL TV TRANSMITTERS

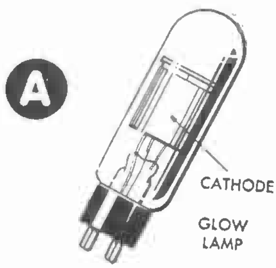
If the observer in Fig. 3A is replaced with a light-sensitive cell, this cell will deliver a varying electric current that is at all times proportional to the amount of light that is reaching the cell, and therefore proportional to the shade of lightness or darkness of the element of the picture that is being scanned at a particular instant. This arrangement gives us a means of converting a picture or scene into a varying electrical current. This current, or picture signal, can be amplified and placed on a radio carrier for transmission through space. At the receiver, a carrier can be demodulated and the picture signal amplified sufficiently to operate a picture reproducer.

Courtesy Don Lee Broadcasting System

The engineer is holding an electronic pickup tube such as is used in television studios. Scanning is accomplished within this tube by electronic means.

MECHANICAL TV RECEIVERS

In the early television receivers, the amplified picture signal was fed to a neon glow tube like that shown in Fig. 4A. This lamp consisted of a wire anode and a rectangular flat metal piece (the same size as the reproduced picture) that served as a cathode. These elements were enclosed in a gas-filled envelope. A red glow of light formed on the plate when sufficient voltage was applied between the electrodes; the intensity of this glow varied with the applied voltage. The amplified picture signal was made to change the applied voltage, thus changing the intensity of the glow.



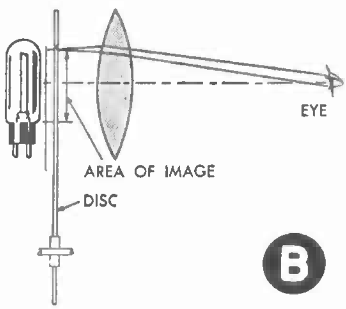


FIG. 4. An early type of mechanical television reproducer. The glow-lamp light depended on the brilliancy of the spot being scanned at the transmitter at that moment. The scanning disc is synchronized (in step) with the transmitter disc so that it arranges the light elements in their proper sequence.

A pin-hole scanning disc was rotated before the glow lamp in such a way that the holes scanned the glowing plate. The transmitter and the receiver were so synchronized that when the scanning disc at the transmitter started to scan the top line of the scene, the receiver scanning disc likewise started to scan the top line. Line-by-line scanning discs were kept in step or in synchronization, so that the intensity of the glow lamp at any instant corresponded to the intensity of the light reflected from that same element on the actual scene. The arrangement of the scanning disc and the glow lamp are shown in Fig. 4B. The lens shown is a magnifying glass that is used to enlarge the image to three or four times the size of the glow lamp plate.

ELECTRONIC TV TRANSMITTERS

Although present-day methods of scanning in picture reconstruction differ greatly from the method just described, the principle of breaking up the picture into a number of elements that are scanned line after line is still used. Fig. 5 illustrates the basic elements of an electronic television camera. The scene is focused on the photoelectric plate by a high-grade camera lens combination. This light-sensitive photoelectric plate consists of millions of tiny light-sensitive spots, each insulated from the others and each scarcely larger than the point of a pin. Under a microscope this plate looks as if it were covered with grains of sand.

When a scene is projected on the photoelectric plate by the lens, the action of light drives out the electrons from each of the tiny light-sensitive units. These electrons pass through the space in the tube to a conducting surface on the inside of the glass envelope, which is at a high positive voltage and therefore attracts the electrons. The action of light thus leaves the photoelectric plate elements more or less positively charged (because they have lost their electrons).

Naturally, the amount of electron loss from any given section of this photoelectric plate depends upon the amount of light reaching that section. Thus, some spots on the plate are more

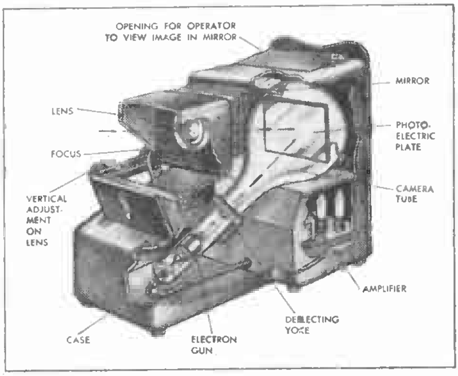


FIG. 5. A cut-away view showing the arrangement of parts inside one type of electronic television camera.

positively charged than others, and we actually have an electronic image of the scene. An electron gun now shoots a fine stream of electrons at the photoelectric plate. Electromagnetic deflection coils (here designated as the "deflecting yoke") shift the electron beam horizontally and vertically, one line at a time, to scan the entire photoelectric plate from top to bottom. When this electron stream strikes a positively charged surface, that surface recovers its electrons and, in so doing, relays the charge to a flat metal supporting electrode that is back of, but insulated from, the photoelectric plate.

In this manner, an electronic impulse is relayed from each spot that is hit by the electron beam. The size of each impulse corresponds to the amount of light striking the spot, so the sum of all the impulses (sent one at a time) constitutes a picture signal.

The supporting electrode collects the picture signal and, after a great deal of amplification, the picture signal is placed on a carrier wave and transmitted through space, just as in the mechanical television system. In addition to this, impulses are sent at the end of each vertical scan or frame of a new picture, to keep the image-reconstructing device in step with the scanning mechanism at the transmitter.

While the picture and synchronizing signals are being sent out, a sound carrier is also being transmitted. This carrier is always separated by 4.5 megacycles from the picture carrier. The sound is transmitted by f.m. modulation in essentially the same way as in f.m. program broadcasting except the frequency deviation is plus or minus 25 kc., which is much less than ordinary f.m. modulation. However, the sound signal of a TV system, if a satisfactory audio amplifier is used, is entirely adequate.

ELECTRONIC TV RECEIVERS

Fig. 6 shows a simplified diagram of a typical electronic picture reconstructor. This employs an electron gun and two sets of electromagnetic deflecting coils. Special oscillators generate the current pulses that flow through these coils; the oscillators are

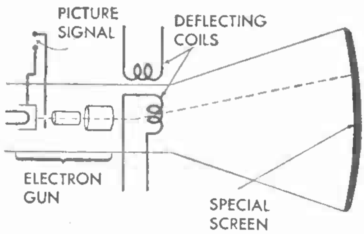


FIG. 6. A simplified diagram of an electronic picture reconstructor tube.

controlled by the synchronizing impulses sent out by the transmitter. A spot of light appears on the fluorescent screen at the end of the tube when it is hit by the electron beam that is produced by the electron gun; the brilliance of the spot increases with the number and speed of the electrons in the beam. The picture-signal voltage controls the speed and number of electrons in the beam by means of a special grid electrode, and the deflecting coils carry the current which results in the scanning of the beam across, and up and down, the screen. The combined action is such that while the beam is sweeping across the screen, its intensity is changing continually in accordance with the picture signal, and the effect of "painting" light on the screen is secured. The current through the deflecting coils is produced by special circuits that are kept in step with the scanning at the transmitter by special signals commonly called vertical and horizontal sync pulses.

During the transmission of a television signal the horizontal sync pulse exists for an instant after each line has been scanned and the vertical sync pulse exists for a longer period after each frame has been scanned. (A frame is one complete scanning of every part of the picture that is being transmitted.) It is not necessary for the video signals to exist while sync pulses are being transmitted and as a matter of fact the video (picture) signals are stopped entirely during the transmission of sync pulses.

There is sufficient difference between the horizontal and vertical sync pulses so that they may be readily separated at the receiver by R-C filters and applied to the proper control circuits. This separation can easily be accomplished, because the vertical sync pulse lasts a much longer time than does the horizontal sync pulse, and by allowing the sync pulse voltages to build up across a condenser it is possible to use capacities of such size that they will definitely discrimi-

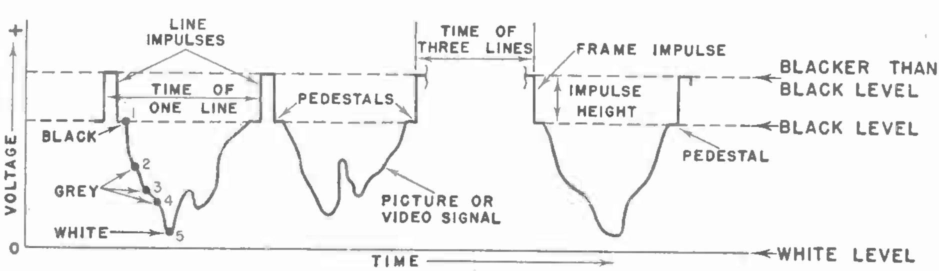


FIG. 7. This diagram shows the three essential components of a television signal—the video signal, the horizontal sync pulse, and the vertical sync pulse. This is a modulated d.c. signal. Since the picture signal voltage swings in a negative direction with increases in line brilliancy, we have what is known as a negative picture phase.

nate in favor of either the horizontal or vertical sync pulse. This, too, will be described in detail later on. The three basic components in a television signal (the picture or video signal, the horizontal sync pulses, and the vertical sync pulses) are transmitted as shown in Fig. 7. The r.f. carrier will be considered later and hence is not shown in this diagram.

First of all, notice that this television signal is a pulsating d.c. signal with all its components above the zero voltage line, which is known as the white level. The video or picture signal is contained between the white level and the black level. The sync pulses are all between the black level and what is commonly known as the blacker-than-black level. In other words, signals that swing above the black level do not cause any lines to become visible on the face of the picture tube.

The vertical sync pulse lasts about three times as long as the time for one line. The black level is 75% of the maximum television signal amplitude.

Notice that points 1, 2, 3, 4, and 5 along the video signal, corresponding to elements along one line of the picture that is being scanned, are for increasing values of brightness, with point 1 corresponding to a black elemental area on the picture, points 2, 3, and 4 for gray areas, and point 5 for a white area. When increases in brilliancy make the picture signal voltage swing in a negative direction in this manner, we say that the picture has a negative picture phase. The sync pulses are kept in the region that is never occupied by the video signal in order to make possible the use of a biased triode or diode tube for sync separation of these pulses from the video signal. You will also notice from Fig. 7 that before and after each sync pulse the television signal voltage remains constant for a short interval of time. These constant voltage components are known as pedestals.

In a.m. broadcasting, the large carrier currents correspond to the loud sounds, and low carrier currents correspond to the weak sounds. Exactly the opposite is true in sight transmission. With a very-high frequency r.f. carrier that is modulated with a television signal as shown in Fig. 7, the white components of the television signal will exist as low carrier currents and the sync pulses will exist as large r.f. carrier currents. This type of modulation is known as negative modulation. It is necessary that the sync pulses represent the highest currents so that they will be less affected by noise pulses. Negative modulation is always used in broadcasting television programs in this country.

The Cathode-Ray Tube as an Image Reproducer

While electromechanical methods of picture scanning and reproduction are feasible, they are far more cumbersome than electrical methods. On the other hand, the electrical methods, employing various types of cathode-ray tubes, are far more satisfactory for high definition home television receivers than any mechanical system. Therefore, electronic systems are used exclusively.

The two main types of cathode-ray picture tubes in use today are the electrostatic and the electromagnetic

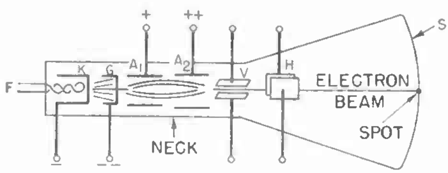


FIG. 8. Essential elements in a cathode-ray tube of the electrostatic deflection type used for image reconstruction in small inexpensive television receivers.

types. In the electrostatic type, focusing and sweeping are done by applying voltages to various electrodes in the tube. In the electromagnetic type, focusing and sweeping are done by means of magnetic fields. Both types will be treated extensively in your Course but in this Lesson we will concentrate on the electrostatic type which is widely used in the less expensive home receivers.

The essential elements of this type of cathode-ray picture tube are shown in Fig. 8. They are: K—the cathode, which emits electrons when heated; F—the filament, which heats the cathode; A_1 and A_2—anodes which accelerate the electrons and focus them into a narrow beam; S—the fluorescent screen, which glows when hit by the electron beam; G—the control electrode which controls the number of electrons entering the electron beam and thus controls the brightness of the spot on the screen. This electrode is called the control grid even though it looks entirely different from the grid in an ordinary vacuum tube; V—the vertical deflecting plates which move the beam up and down on the screen; H—the horizontal deflecting plates, which move the beam horizontally in either direction.

Electrode A_2 is always at a higher positive potential than electrode A_1. As much as 5000 or 6000 volts may be applied to electrode A_2. The voltage applied to electrode A_1 is variable and is controlled by means of a potentiometer. By varying this voltage the beam is focused to a sharp point. The high voltages applied to these two electrodes serve to accelerate the electrons in the beam, giving them greater speed and hence increasing the brightness of the image obtained on the face of the tube.

Control grid G is always negative with respect to cathode K, the value of this negative potential determines the number of electrons that the cathode can force through the control grid into the electron beam. When correct grid and anode voltages are applied to the tube and no voltage difference exists between the two vertical plates and between the two horizontal plates, the beam travels straight out and strikes the center of the screen. The resulting spot will be in the center of the screen as indicated in Fig. 8. Increasing the negative voltage on the control grid reduces the number of electrons in the beam and reduces the brightness of the spot.

The negative bias between the control grid and cathode is adjusted so that the screen is almost dark when no television signal is present. The television signal is applied in series with the negative grid bias in such a way that the spot will be black each time a pedestal is transmitted. This condition is secured when the pedestals (sync pulses) line up with the brilliancy cut-off point on the characteristic curve of the picture tube.

Video signals make the control grid less negative, swinging the grid above the cut-off point, thus varying the brightness of the spot on the screen. The sync pulses make the control grid more negative than the cut-off voltage so that the screen will be dark during the very short intervals of their duration. Thus the retraces as the beam swings back to its starting point do not appear as lines in the picture.

The spot is in the center of the screen only when there are no voltage differences between the vertical deflecting electrodes and between the horizontal deflecting electrodes. Now let us see how these electrodes can be made to move the spot to any desired point on the screen. Referring to Fig. 9, notice that we have an electron beam traveling between two oppositely charged metal plates. Remember that the electrons in this beam have negative charges; this means that the positively charged plate will attract these electrons while the negatively charged plate repels them, thus bending the beam upward and causing it to strike the fluorescent screen at point b rather than at a, the center. The greater the voltage between these two deflecting plates, the more bending of the electron beam there will be.

The electron beam, however, must be moved in a definite manner if it is

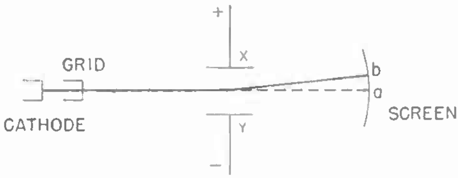


FIG. 9. An electron beam passing between two oppositely charged plates is always bent toward the positive plate.

to produce an image on the television screen. You will remember that the scanning process in a television camera involves analyzing the scene line by line in a manner exactly similar to that in which our eyes read this printed page. First of all, it is necessary to have some means for sweeping the electron beam gradually from left to right in a horizontal line, then quickly back again to the left, with this horizontal line sweeping motion being repeated continuously.

We can secure a horizontal sweeping of the beam by varying either the electromagnetic or the electrostatic field in the tube. As stated before, the magnetic method will be studied later. We will now study the electrostatic sweep which is obtained by applying to the horizontal deflecting plates of an electrostatic type picture tube a voltage having the characteristic shown in Fig. 10. Due to the shape of this curve we call this a saw-tooth voltage. A push-pull amplifier is used to drive these plates, and the signals delivered by the amplifier tubes are 180° out of phase. Thus when one plate is being driven positive, the other is being driven negative.

Observe that at points 1, 2, 3, and 4 in Figs. 10A and 10B there is no voltage difference between the two plates. The voltage on plate x is positive at points 8 and 9 and negative at points 5, 6, and 7.

Conversely, plate y is positive at points 5, 6, and 7 and negative at points 8 and 9 (see Fig. 10C). If the voltage is applied to plates x and y in Fig. 9, plate x will be positive when the voltage is following path 1-8-2 and negative when the voltage is following path 2-6-3 in Fig. 10B.

At the same time (see Fig. 10C) plate y will be negative when the voltage is following path 1-8-2 and positive when the voltage is following path 2-6-3. When plate x acts as the positive plate, then plate y is negative and vice versa.

When the charge is at point 1 the deflecting plates will have equal voltages on them and they will have no effect upon the electron beam and the spot will be in the exact center of the screen. As the charges on plates x and y approach point 8 the electron beam will be attracted gradually and uniformly toward plate x and repelled in the same manner from plate y. As the charges drop to zero again at point 2, the spot will move rapidly back to the center of the screen. From point 2 to point 6 plate x will become increasingly negative, repelling the beam and bending it toward plate y which is becoming increasingly positive. From point 6 to point 9 the beam will move gradually from plate y to plate x, and from point 9 to point 7 the beam will move rapidly back toward plate y again.

We have seen that a saw-tooth voltage of the form shown in Fig. 10A will produce the desired sweep of the electron beam. If this saw-tooth voltage is applied to horizontal deflecting plates H in Fig. 8, it will cause the spot to sweep slowly from left to right across the screen, then return rapidly to the left again. If this voltage is applied to the vertical deflecting plates V in Fig. 8, it will cause the spot to move gradually from top to bottom and return rapidly to the top again.

In the earlier part of your Course you made a preliminary study of the

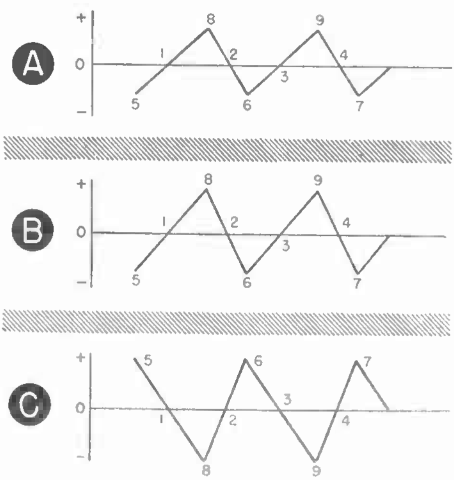


FIG. 10. (A) Wave form of saw-tooth voltage used for electrostatic sweep. (B) Sweep voltage for plate x. (C) Sweep voltage for plate y.

special oscillator circuits used to produce these saw-tooth voltages. Later, however, we will cover them again in greater detail.

None of these circuits are absolutely steady in frequency, and it is therefore necessary to send synchronizing signals along with the television signal for the purpose of controlling and stabilizing the sweep circuits. One saw-tooth oscillator circuit is required for the horizontal sweep and another for the vertical sweep. The horizontal sweep circuit builds up its voltage uniformly from point 5 to point 1 to point 8 in Fig. 10A; at point 8, corresponding to the end of the line, a horizontal sync pulse arrives with the television signal and causes this voltage to drop back to point 6 rapidly. The building up of the voltage starts again, only to be stopped at point 9 by another horizontal sync pulse.

Since the sharp decreases in voltage are accurately controlled by the transmitter through the horizontal sync pulses, we know that the electron beam in the picture tube will be swept horizontally in exact synchronism with the scanning device at the transmitter. The vertical sweep circuit operates at a much lower frequency, and is controlled in the same manner by the vertical sync pulses broadcast by the transmitter.

Now let us follow the movement of the spot on the screen of a picture tube as it is swept back and forth and up and down by the sync-pulse controlled sweep circuits.

When the beam is under the control of the horizontal and vertical sweep voltages, we can consider its starting point to be point 1 in Fig. 11, at the

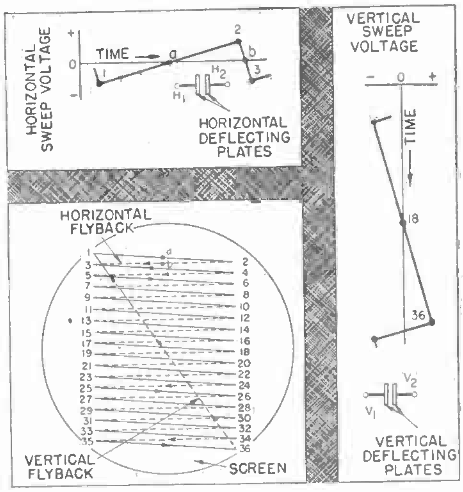


FIG. 11. The path traced on the fluorescent screen of a television cathode-ray tube by an electron beam under the influence of horizontal and vertical saw-tooth sweep voltages is shown in this diagram. The wave forms of the sweep voltages are shown above and at the right of the screen; these voltages are applied between deflecting plates in each case. Thus, when horizontal plate H_2 is highly negative at (1), the spot will be at the extreme left side of the screen at point 1; when this plate is at zero potential (a), the spot will be at a in the center of the screen; when this plate is highly positive (2), the spot will be at the extreme right side of the screen at 2; when the saw-tooth voltage drops suddenly back to the highly negative value (2 to b to 3), the spot flies back from 2 to b to 3 on the screen. Likewise, when vertical plate V_2 is highly negative (1), the spot will be at the top of the screen at point 1; when this plate is at zero potential, the spot will be halfway down the screen at point 18; when this plate is highly positive (36), the spot will be at the bottom of the screen at point 36; when the saw-tooth voltage drops suddenly back to the highly negative value 36 to 1, the spot flies up from 36 to 1 on the screen over a zig-zag path which for simplicity is shown here as a straight line.

upper left-hand corner of the screen. Here the spot has been bent far to the left. From this point the horizontal sweep voltage gradually allows the beam to "unbend" or return to the center of the top line. The beam is then gradually bent in the opposite direction until the spot reaches the right-hand edge of the screen. While this action occurs, the vertical sweep voltage is gradually moving the spot in a downward direction; a distance equal to the spacing between two lines.

At point 2 a horizontal sync pulse arrives from the transmitter, causing the horizontal sweep voltage to move the spot almost instantly back to the left-hand side of the screen along the dotted line path 2-3. This return motion is very rapid and if a trace is made it could not be seen as such, but sometimes, if the receiver is not properly adjusted, it will produce on the screen a faint haze or glow instead of a line.

This process continues for each other line until the spot is swept to point 36 at the end of the last line. At this time the vertical sync pulse arrives from the transmitter and stops the gradual building up of the vertical sweep voltage, causing the spot to move back up to the top of the screen. The vertical sweep voltage drops back to its starting value at a rapid rate, but the change takes more time than is required for a complete horizontal sweep. As a result, the spot actually takes a zig-zag path from side to side as it is being returned to the top of the screen. For simplicity the vertical retrace is shown as a straight-line path, 36-1, in Fig. 11. Actually, if the receiver is misadjusted you will see a number of diagonal lines, across the screen, which is the vertical retrace.

The scanning path just described, going from point 1 down to point 36 and then back to point 1 again constitutes one complete normal scanning of the scene or one frame. The entire process is repeated for each succeeding scanning.

When either the horizontal or the vertical sync pulse is being sent by the transmitter, no television picture signal exists and the appearance of retrace lines would only cause diagonal streaks in the picture, marring reproduction. The sync pulses are applied to the control grid of the picture tube in the receiver in such a way that they drive the grid highly negative, causing almost complete cut-off of the electron beam and thereby preventing retraces from showing.

Image Detail

A consideration of the processes of scanning and reproduction just described should make it clear to you that the video signal exists only while the spot is traveling from left to right along the line. At all other times the television transmitter is sending out pedestals with synchronizing signals. The changes in the intensity of the video signal from one instant to another produce the essential picture detail. The more changes there are per line for an actual given scene that is being scanned, the greater will be the amount of detail in the reproduction.

The more frames there are per second, the better they blend and the less chance there is for the eye to see them individually. If too few are transmitted, flickering results. Increasing the number of frames per second reduces flicker.

Greater detail can be obtained by increasing the number of lines per frame. Both the number of frames per second and the number of lines per frame contribute to high definition, or high-fidelity reproduction. However, there are definite limits to the number of lines and frames that can be handled economically. Let us first examine the factors that determine the high frequencies.

PICTURE ELEMENTS

All television equipment must be designed to handle the maximum frequency of the picture signal current. To calculate the maximum frequency of a signal it is assumed that the picture being scanned consists of a checkerboard pattern of black and white squares, as shown in Fig. 12, with each square being equal in size to one of the sensitized spots on the photoelectric plate of the television camera. Since each of these is the smallest part of the scene the camera can see, they are called picture elements. The signal current is said to go through one cycle each time the electron scanning beam passes over one light and one dark picture element as shown in Fig. 13, because the signal current goes through a maximum and a minimum value each time this happens.

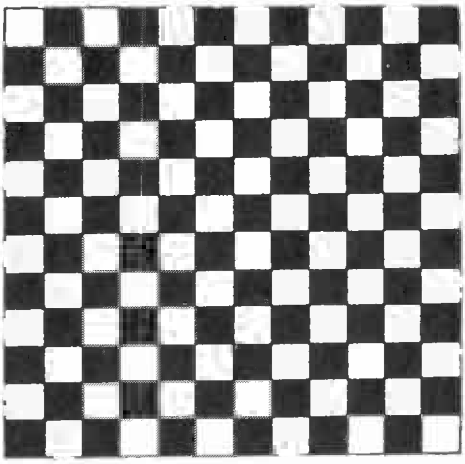


FIG. 12. The photoelectric plate can be visualized as a checkerboard of dark and light squares. Each square stands for a light-sensitive spot or picture element.

To find the maximum frequency of the picture-signal current, all we have to do is compute the number of picture elements that are scanned per second and divide by two, since one cycle consists of two elements.

If each picture element is considered to be as high as it is wide, it is easy to compute the number of elements in one complete picture. For example, in a square picture with N lines there will be N picture elements per line, or N times N picture elements in the complete square picture, which is known technically as one frame. For

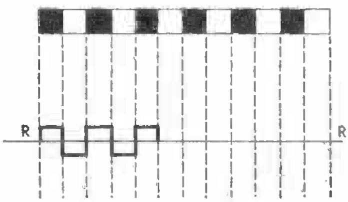


FIG. 13. The signal goes through one cycle each time the beam passes over one dark and one light element.

example, at present the television standards call for a 525-line picture. Hence, in a square picture there would be 525 times 525 or 275,625 picture elements. For ordinary calculations, 276,000 elements will be sufficiently accurate.

Aspect Ratio. The pictures that are commonly involved in television are not square, however. They are wider than they are high as shown in Fig. 14. The width of a picture divided by its height is called the aspect ratio which, in order to conform to motion picture standards, has been standardized at 4/3 or 1.33. This means that the number of elements in each line has been increased by the aspect ratio which we will designate as A. Now the number of picture elements per frame, or picture, will be N times N times A. For the example just considered, the total number of elements will therefore be 276,000 times 4/3, or 368,000.

FRAME FREQUENCY

The number of pictures sent per second is the frame or picture frequency. It is designated as F. By multiplying the number of elements in a frame by the frame frequency, we get the total number of picture elements per second. This total number of elements per second is N times N times A times F. Since it takes two picture elements to make a cycle, we get the maximum number of cycles per second by dividing this formula by two. The standard frame frequency is 30. In our example, then, we get the frequency involved by multiplying 368,000 by 30 and then dividing by 2. The result is 5,520,000 cycles per second.

SYNCHRONIZING PULSES

In practice the picture is scanned only about 85% of the time. The remainder is used for horizontal and vertical sync pulses. This increases our maximum picture frequency because it crowds our elements into 85% or 85/100 of a second. We, therefore, multiply our computed value by 1.17,

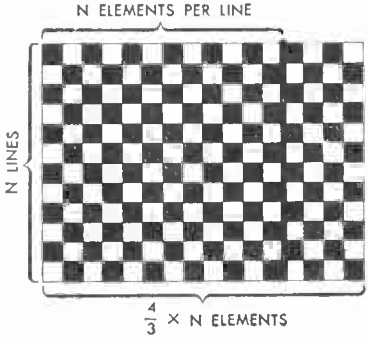


FIG. 14. When the picture is changed to the rectangular form shown here, the elements of a square picture are multiplied by 4/3.

making the maximum theoretical picture frequency 1.17 times 5,520,000, or approximately 6,460,000 cycles.

In our analysis of the theoretical maximum frequency we have assumed that there is always a sharp contrast between adjacent elements of a scene. This is not true in practice. Several adjacent picture elements may reflect the same or nearly the same amount of light. Also, in moving scenes, it is not necessary to transmit slight variations between adjacent elements. This is illustrated roughly in Fig. 15. Actually, the picture would be broken up into much smaller elements, but even here with the relatively large squares you can see that in many instances there is practically no change from one square to another. The average scene thus requires considerably less than the maximum frequency. Practice has shown that apparatus capable of sending about 60% of the maximum theoretical frequency is satisfactory. Since the maximum number of cycles was assumed in our example, we multiply 6,460,000 by .6 and get about 3,900,000 cycles or 3.9 megacycles, as the actual frequency. Any increase in this frequency up to the limit of 4.5 megacycles that is permitted within a television band gives a definite improvement in fidelity.

Monotones Require Very Low Frequencies. The upper part of an outdoor scene, like the sky, as shown in Fig. 16, is usually bright, while the lower part is considerably darker. The picture elements in such a scene vary in light intensity at a high level for the upper half of the picture and at a low level for the remainder. This gives one cycle of change from light to dark for each scanning. Transmitting these changes properly calls for a low frequency corresponding to the vertical scanning frequency (the frame frequency). However, within the background, satisfactory reproduction of the slow changes in intensity requires frequencies down to at least 10 cycles. Therefore, for a 525-line picture with an aspect ratio of 4/3 and a frame frequency of 30, the picture frequency ranges from 10 cycles to about 3.9 megacycles.

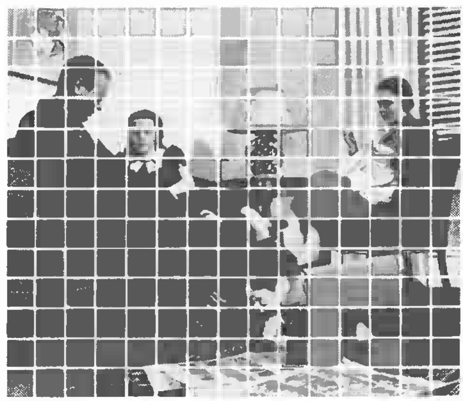


FIG. 15. Not all the neighboring spots on a line vary in shade. This reduces the necessary maximum frequency.

FLICKER

The human eye is sluggish in its response to moving objects, for it continues to see an object even after the object has disappeared. Motion pictures depend upon this persistence-of-vision characteristic of the human eye. In a motion picture projection twenty-four separate still pictures per second are flashed upon the screen in sequence, but the eye sees a continuous action rather than a series of separate pictures. The eye can detect individual views up to a rate of about

10 pictures per second, but above this rate the scenes blend together, accompanied by pulsating light impressions which give the effect of flicker. At about 20 pictures per second the blending of pictures into motion is almost perfect, but flicker is still not entirely absent. Even at 24 pictures per second, the standard in the motion picture industry, flicker can still be noticed. For this reason motion picture projectors have a shutter in front

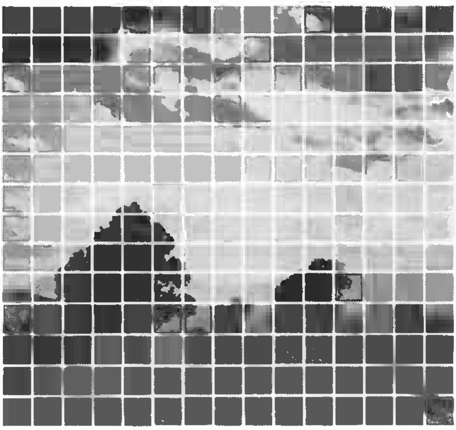


FIG. 16. Changing from a bright sky to a dark foreground once each frame, as in a scene like this, would require a 30-cycle frequency. Others with less variation could require frequencies as low as 10 cycles.

of the lens that breaks up each still picture into two separate views, giving the effect of 48 pictures per second, although only 24 of them are different. As you will see shortly, much the same thing is done in television.

In television the frequency of the available a.c. power has considerable effect upon the choice of a frame frequency (number of pictures transmitted per second). Since the power line frequency in the United States is standardized at 60 cycles, ripple voltages at this frequency or some multiple of it will get into the video signal and the sweep voltages, tending to cause ripple effects, wobbling of the picture, and random movement of bright bands on the image if the number of pictures is increased to 48, or even 72, in order to eliminate flicker. By using a frame frequency equal to some sub-multiple of 60 (such as 30 or 20) or some multiple of 60 (such as 60, 120 or 240), these ripple effects can be removed or at least made stationary so that they will be less objectionable. Frame frequencies of 20 or 30 are still too low to eliminate flicker entirely. On the other hand, a frame frequency of 120 pictures per second would increase the maximum frequency of the video signal to an extremely high value. There is left then, a scanning rate of 60 complete frames per second, which imposes quite a burden upon the transmitting system, insofar as maximum frequency range is concerned. With a 525-line image being scanned 60 complete times each second, the upper frequency limit for high definition becomes about 7.8 megacycles. It is possible to make amplifiers that will handle a range of from 10 cycles to 7.8 megacycles, but the cost of these amplifiers is so high that the production of inexpensive television receivers would become a serious problem.

Interlaced Scanning

To avoid increasing the frequency requirements of TV systems and to eliminate flicker, a simple scanning trick is used that makes the maximum video signal frequency correspond to that of a 30-picture-per-second transmission while still keeping the scanning rate at 60 pictures per second. In this system, known as interlaced scanning, only half of a picture is transmitted during one complete scanning. The other half is transmitted in the next complete scanning. Lines 1, 3, 5, 7 and all other odd lines are covered during one scanning, and lines 2, 4, 6, 8 and the other even numbered lines are covered during the next scanning. Two complete scannings are therefore required to cover every elemental dot area on the scene that is being televised.

At the receiver there must likewise be two complete scannings to give a complete reproduction of the image. With interlaced scanning, the frame or picture frequency is 30 cycles per second, since that is the number of complete pictures transmitted. For each complete picture the scene is scanned twice, so the vertical sweep frequency (field frequency) is 60 times per second. In referring to a field we mean the area covered during one vertical sweep of the scene. In ordinary scanning the field is the entire scene, but in double interlaced scanning the field is only half of the scene. By the frame we mean one complete scanning of every elemental area in a scene. In ordinary scanning this occurs for each vertical sweep, but in interlaced scanning two vertical sweeps are required for a frame.

For double interlaced scanning of a given number of lines per second at a given frame frequency there are two requirements: 1, an odd number of lines per picture; 2, a vertical scanning rate that is twice the frame frequency.

This automatically gives scanning of the odd-numbered lines during one vertical sweep and scanning of the even-numbered lines during the next vertical sweep, with odd and even line scanning alternating automatically.

Just how this may be done is best illustrated by an example, but instead of using a 525-line image that would be too cumbersome, a lower number of lines will be used to illustrate the principles involved.

Suppose we divide our picture into ten lines as shown in Fig. 17A and that we scan this complete scene ten times per second which gives a vertical sweep frequency of 10 per second. This means that one complete scanning of the scene, starting at point 1, proceeding to 2, 3, 4, 5 . . . 17, 18, 19, 20 and then returning to point 1, will take 1/10 of a second. Assuming flyback time to be negligible in these examples, we see that it will take 1/100 of a second to scan one line, moving from point 1 to point 2 and back to the starting point of the next line at point 3.

Now suppose that we scan the scene, which has an even number of lines, 20 times per second by doubling the vertical sweep frequency. We will

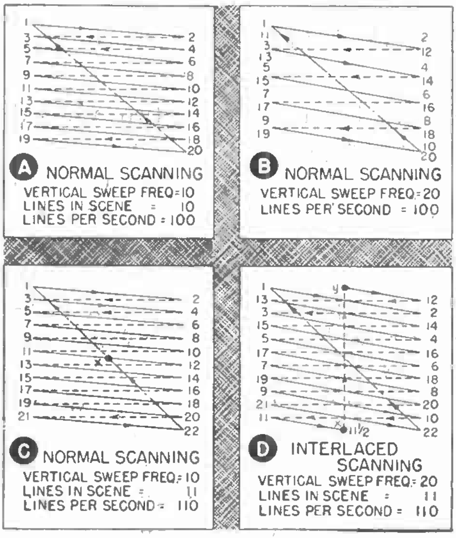


FIG. 17. These diagrams show that interlaced scanning can occur only when there is an odd number of lines in the scene and the vertical sweep frequency is twice the rate for normal scanning. Under these conditions, the same number of lines is transmitted each second with either normal or interlaced scanning.

still be scanning the same total number of lines per second, and it will still take 1/100 of a second to scan one line. But now only five lines will be covered in one complete scanning from top to bottom. Referring to Fig. 17B, the scanning path starts at 1 and goes to points 2, 3, 4, 5, 6, 7, 8, 9, and 10 during one complete scanning of the scene. Vertical fly-back now brings us to point 11 at the upper left-hand corner and we cover exactly the same scanning path for the second scanning of the scene. This shows that a television system using an even number of lines per picture could not secure interlaced scanning by doubling the vertical sweep frequency.

Now let us take an example in which we have an odd number of lines (11) per picture, and we use a vertical sweep frequency of 10 per second as indicated in Fig. 17C. All eleven lines are covered in one complete scanning, and vertical fly-back takes us directly from point 22 back to the starting point at 1.

Next, suppose we double the vertical sweep frequency, giving 20 complete scannings of the picture per second without changing the total number of lines transmitted per second. This doubles the speed at which the scanning spot is moved downward, so that we arrive at point x in Fig. 17D (at the bottom of the picture) in exactly the same time it took to reach point x in the middle of the picture in Fig. 17C.

In Fig. 17D, however, we have scanned only half the lowest line when vertical fly-back moves the spot up to point y for the following scanning. This time we scan along path 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, and 22. From point 22 the spot goes back to point 1 to start the next complete scanning. We are thus securing interlaced scanning of the complete scene.

Interlacing twice, as illustrated in Fig. 17D, is standard practice. To secure this without changing the total number of lines scanned per second, which would change the picture detail, the vertical scanning frequency must be twice the frame frequency and there must be an odd number of lines per frame.

Let us now consider interlaced scanning in terms of the standards in use for television. With 525 lines per frame, a vertical scanning frequency of 60 per second, and double interlaced scanning, the total number of lines scanned per second must correspond to that scanned normally with a frame frequency of 30 per second. Multiplying 525 by 30 gives us 15,750 as the total number of lines scanned per second. This means that the frequency of the horizontal sweep is 15,750 cycles per second and that the vertical scanning sweep has a frequency of 60 cycles per second.

The detail in the image will correspond to that of 30 complete scannings per second of all lines in the 525-line image.

Actually a few lines at the top and bottom of each picture are blanked out by the blanking system associated with the vertical sync pulses for reasons that will be taken up later. The sync pulse itself prevents vertical fly-backs x-y and 22-1 in Fig. 17D from being visible.

Brightness and Contrast Controls

It is necessary that the television signal that is fed between the control grid and the cathode of the picture tube be pulsating d.c. and that it be applied to the tube in such a way that sync pulses will cause darkness, and picture signals will give various degrees of spot brightness. Another requirement for faithful reproduction of a scene is that the pedestals all line up with each other at the input of the picture tube despite any variations in the brightness of a scene. An example of this is shown in Fig. 18 where you will note that the pedestals in Fig. 18A have no more amplitude than those shown in Fig. 18B, although the video signal of Fig. 18A is far brighter than that of Fig. 18B.

Now let us see how signals such as those shown in Fig. 18 affect tube spot brightness when the pedestals are lined up with each other. Remember that the electron beam is focused to a small spot on the screen and that the negative voltage applied to the control grid of the tube determines the brilliance of the spot.

The control that this grid has upon the spot brilliancy is fairly linear with respect to the applied grid voltage, except that complete cut-off or darkening of the spot occurs at a definite high negative bias voltage.

This is clearly illustrated in the curve shown in Fig. 19. Note that as

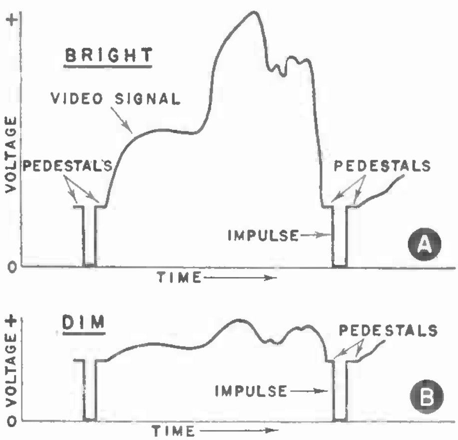


FIG. 18. The television signal which is applied between the grid and the cathode of a cathode-ray tube must have a constant pedestal voltage for scenes with all degrees of brightness, and must have a positive picture phase as shown here, so that the video signal will be positive with respect to the pedestal voltage, and the impulse signals will all be more negative than the pedestal voltage.

the video signal drives the grid of the picture tube in a positive direction the spot brilliancy will increase. Points 2, 3, 4, and 5 are increasingly brilliant and correspond to increasingly positive control grid voltages. This grid-voltage brilliancy-characteristic curve shown in Fig. 19 is quite similar to the grid-voltage—plate-current (Eg-Ip) characteristic curve of the average vacuum tube.

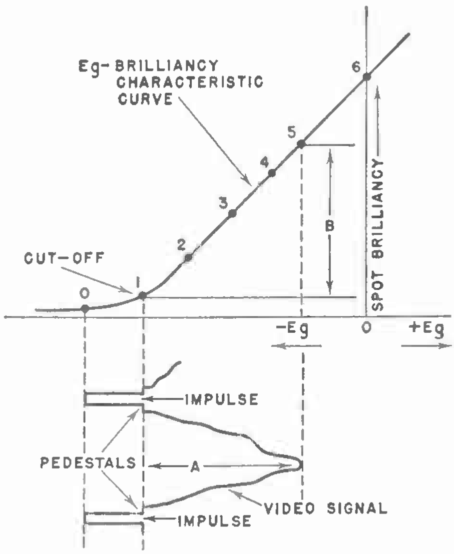


FIG. 19. Typical grid-voltage-brightness characteristic curve for a cathode-ray tube in a television receiver. Point 1 is considered the brilliancy cut-off point for the tube, as it corresponds to a spot brilliance weak enough to be indistinguishable to the human eye.

The negative bias on the grid of the picture tube must be chosen so that the pedestals in the applied television signal will be at the brilliancy cut-off point (point 1 in Fig. 19) on the characteristic curve of the tube.

With the picture tube bias properly adjusted, the video or picture signal will swing the grid more positive than cut-off, giving various degrees of brightness, and the sync pulse signals will drive the grid more negative than cut-off, so that the spot is darkened to the point where it cannot be seen. This is known as the blacker-than-black region of the characteristic curve.

When the video portion of the signal shown in Fig. 19 is acting on the grid-cathode of the picture tube the instantaneous control-grid voltage will vary between points 1 and 5 on the curve, and spot brilliancy will vary over the region indicated as B. The sync pulses associated with this signal will swing the grid beyond visual cut-off at point 1, and hence cannot produce a spot on the screen. As long as the pedestals line up with the cut-off point, the impulses cannot produce a visible spot even with a weak video signal, and a weak video signal, corresponding to a dim line or a dark scene, will cause the brilliancy to vary in the desired manner over the lower portion of the characteristic curve, such as between points 1 and 2.

However, suppose that the television signal in Fig. 19 were applied in such a way that the pedestals lined up with point 2. The video signal would swing the grid voltage positive from point 2 up along the curve to point 6, which is perfectly all right since the various shades of brightness would appear, but the sync pulses would only swing a small amount below cut-off and would not darken the spot completely. As a result vertical retraces would be clearly visible at the beginning and end of each frame as shown in Fig. 20. Such a condition would not give a picture that is satisfactory. Horizontal retraces are not seen as lines because their time duration is too short to result in a trace visible to the eye.

Another undesirable condition occurs when the pedestals are beyond cut-off and line up with point 0 on the characteristic curve in Fig. 19. Under this condition, portions of the video signal will swing into the dark region beyond cut-off, causing dimly lighted portions of the scene to appear black instead of gray as shown in Fig. 21. This condition is just as undesirable as that illustrated in Fig. 20.

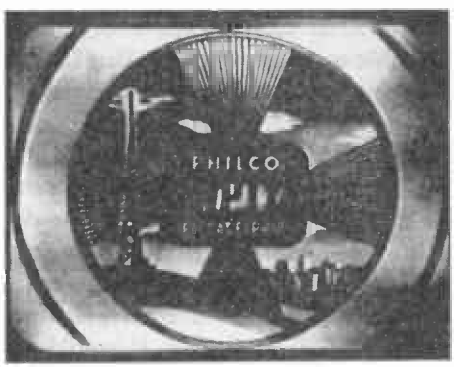
Courtesy Philco Corp.

FIG. 20. A zigzag line rather than a single diagonal line appears because the horizontal sweep moves the beam from left to right several times before the vertical fly-back is completed.

The operating point on the Eg-brilliancy characteristic curve of a picture tube may be shifted in two different ways in order to make the pedestals line up with the black level (cut-off point) of the tube. One method involves adjusting the fixed C bias of the picture tube; the control in a television receiver that changes this bias is called the brilliancy control because its most noticeable effect is a change in the brilliancy of the reproduced image.

It is also possible to shift the pedestals in one direction or the other to make them line up with the cut-off point by changing the amplitude of the picture signal that is applied to the picture tube. The amount of signal that reaches the grid of the picture tube depends upon the amplification of the receiver, and by changing the gain of one or more stages through which the television signal passes we can vary the amount of signal that will reach the picture-tube input. The receiver control that changes the gain is called the contrast control, because its most noticeable effect is a change in the amount of contrast between bright and dark areas of the reproduced image.

If the picture appears as shown in Fig. 21, we can reduce the contrast control to restore the proper relationship between the bright and dark areas. On the other hand, if the receiver amplification is too low, giving us a flat gray picture with insufficient contrast, the amplification may be increased until the desired light and dark relationship is obtained.



Courtesy Philco Corp.

FIG. 21. The grid bias in this case is adjusted so that gray portions of the test pattern appear black, and we say the picture has too much contrast.

One point should be mentioned here that will be gone into in greater detail later. If the contrast is adjusted too high on a strong local station, some of the pedestals may be clipped by overloading the amplifier stages in the receiver and it will then be impossible to obtain proper synchronization of the picture due to the loss of the sync pulses.

Another requirement for a clear image is that the electron beam be focused to a clearly defined spot of the correct size on the screen. Improper adjustment will result in a fuzzy picture in which the lines are not clearly defined. An adjustable control, called the focus control, is provided to correct for errors in focusing due to the natural aging of the picture tube or to changes in part values.

The main adjustable controls for the sight section of a television receiver are the brilliancy control, the contrast control, the focus control, and the tuning control. Additional controls are also used that will be described later, but they are generally not on the front panel as they do not often require adjustment.

The controls on the front panel mentioned above must be adjusted to give an image that has the proper brilliancy and the correct contrast between elements along the line, with no vertical retraces visible. In general, when the brilliancy control is adjusted, the contrast control will also require resetting since there is some interaction between these controls.

Television Signal Standards

In order for a television system to be successful, the receiver must be easy to adjust, the cost of the receiver must be relatively low, and the transmitter must have as much control as possible over the receiver. This last requirement means that the receiver and the transmitter must be interlocked and synchronized. Furthermore, the type of transmission employed must be standardized to a certain extent—otherwise radical changes in the method of transmission might make all existing television receivers obsolete. At the same time, it would not be advisable to set up standards in such a way that it would be impossible to make improvements in the transmitting and receiving circuits. Standards are essential for a successful television system, but these standards must be sufficiently broad to permit future improvements that might make interlock and synchronism more reliable, or increase the definition of the reproduced scene.

Present standards set by the FCC for television transmission are summarized below:

1. *Television Channel Width; Channel Allocations.* The present standards provide for essentially single side-band transmission and reception (partial suppression of one set of side frequencies results in *vestigial side-band transmission*), for with this method of operation, sufficient detail for a satisfactory image along with the

accompanying sound can be transmitted in a definite channel width of 6 megacycles. Twelve 6-mc. wide channels have been allocated by the Federal Communications Commission for television transmitters, as follows: 54 to 60, 60 to 66, 66 to 72, 76 to 82, 82 to 88, and seven other channels from 174 to 216 mc. A number of very-high frequency and microwave channels have been allocated for television relay purposes, such as linking the television studio to the transmitter by radio, linking the remote pick-up point to the transmitter by radio, or linking together television stations in different cities and towns to form a network. There is a possibility that the u.h.f. spectrum, around 500 mc., may be opened up for low-power transmitters to serve small cities and towns. For present-day receivers to pick up such transmissions a converter would be required. If such an addition to present TV channels should be made, such converters will be manufactured for them.

2. *Video and Sound Carrier Spacing.* The audio and video signals that make up a television program cannot be modulated on the same r.f. carrier; each must have its own carrier. By agreement *the sound carrier must be exactly 4.5 megacycles higher in frequency than the picture carrier.* To prevent interference between adjacent television channels or between a television carrier signal and services operating on adjacent carrier frequencies, it has been further agreed that there must be a .25-megacycle wide guard band at the high-frequency end of each television channel. These facts are illustrated by the chart in Fig. 22, that shows a typical distribution of signals in one 6-megacycle wide television channel.

3. *Frequency Relation Between Video and Sound Carrier.* An example will best illustrate the frequency relationship existing in a television channel. Suppose that the 76- to 82-megacycle channel is assigned to a particular television station. To give the required .25-megacycle guard band at the high-frequency end, the audio signal carrier must be placed at 81.75 megacycles. According to the standards, the video carrier must be 4.5 megacycles lower, or at 77.25 megacycles. It is not practical to remove all of the side frequencies below the frequency of the video carrier, so a portion of the channel must be provided for those frequencies that cannot be removed. This portion is indicated by the cross-hatched lines in Fig. 22. With this arrangement of a 6-megacycle channel, the frequency range of television equipment can be improved up to a maximum of about 4.25 megacycles without making existing television equipment obsolete.

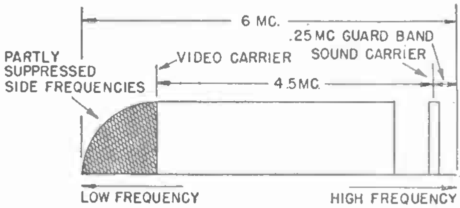


FIG. 22. Distribution of signals in a 6-megacycle-wide television channel.

4. *Type of Modulation; Black Level.* Negative modulation of the picture carrier signal is standard for the United States. As we have already pointed out, negative modulation means that *bright elements of a pic-*

ture are transmitted at low carrier levels, and *dark elements at high carrier levels*. The standards further specify that the black level or pedestal level at the transmitter shall be at a definite carrier level that remains fixed regardless of variations in sync pulse signals or in video signals. The black level at any one point in a television system is the

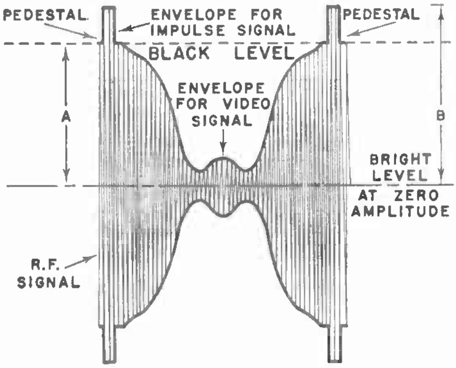


FIG. 23. Modulated r.f. carrier signal, with the amplitudes varying in accordance with a television signal. A is the unmodulated, and B the peak carrier level. This entire figure represents the transmitted side band. The vestigial side band (not shown) is much smaller in amplitude and would be somewhat distorted.

voltage that must exist at that point to give a just barely visible spot on the screen of a properly adjusted receiver.

5. *Sync-Pulse Amplitude*. Both horizontal and vertical sync pulses must be transmitted as carrier values higher than unmodulated carrier level (black level). These pulses extend from 75% (black level) to 100% of the peak carrier amplitude. The video signals may vary in amplitude from the black level down to 15% of the carrier level or lower. The general appearance of a typical modulated video carrier signal as it is fed into the television transmitting antenna is shown in Fig. 23. When there is no modulation, the r.f. carrier will have amplitude A, corresponding to the black level. Any increases in carrier amplitude must be for the synchronizing impulses; and decreases in carrier amplitude must be for the video signals.

6. *Horizontal, Vertical, and Frame Frequencies*. The establishment of standard values for these three frequencies was based upon the need for high-image definition with a minimum of flicker. The vertical scanning frequency (field frequency) is 60 times per second, for this value minimizes any trouble due to 60-cycle power ripple. (In England, where 50-cycle power lines are used, the field frequency has been standardized at 50 vertical scannings per second.) Since double interlaced scanning is used in the United States, two field sweeps are required to analyze all of the details once in a particular scene; these two vertical or field sweeps constitute a frame (one complete transmission of the picture), and consequently the standard for the frame frequency is 30 frames per second. As we have already seen, there are 525 lines per frame; this means that there are 262½ lines per field. With a 525-line picture being sent 30 times each second, the horizontal frequency becomes 525 times 30, or a total of 15,750 lines per second.

7. *Aspect Ratio*. This ratio has been standardized at 4/3, corresponding to existing motion picture standards and giving a width-to-height ratio of 4 to 3.

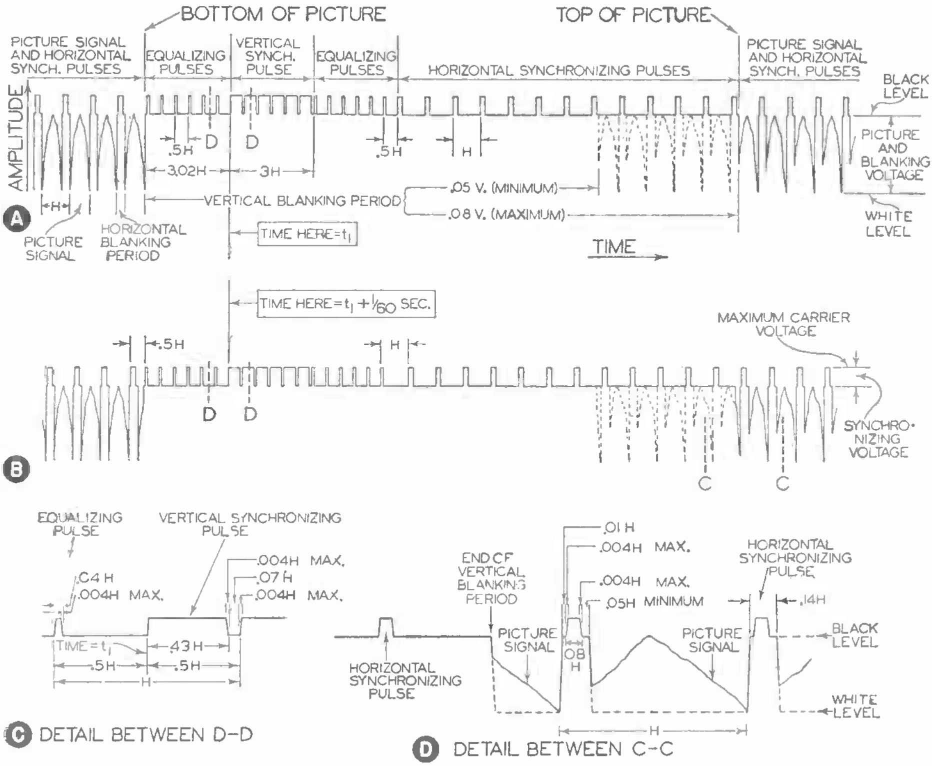


FIG. 24. Specifications for the standard television signal for 525-line pictures transmitted at the rate of 30 frames per second with double interlaced scanning, giving 60 fields per second. In these diagrams H is the time from the start of one line to the start of the next line, and is equal to 1/15,750 second. The time from the start of one field to the start of the next field is 1/60 second.

Diagrams A and B show blanking and synchronizing signals in regions of successive vertical blanking pulses. The black level is about .75 of the synchronizing pulse amplitude.

Horizontal dimensions in these diagrams are not drawn to scale. The receiver vertical retrace will be complete at the end of about .07 V during the vertical blanking period. The length of the vertical blanking period produced by the transmitter may vary between .05 V and .08 V. The leading and trailing edges of both the horizontal and the vertical blanking pulses have slopes (not indicated in A and B), which should be kept as steep as possible.

Diagram C is an enlarged detail view, drawn accurately to scale, of the signal between points D-D in diagrams A and B.

Diagram D is an enlarged detail view, drawn accurately to scale, of the signal between points C-C in diagram B.

8. *Synchronizing and Equalizing Impulses; Blanking.* The ability of a television transmitter to control the reproduced picture at the receiver depends entirely upon the synchronizing impulses. Many years of research have been spent on this problem, and many different forms of impulse signals have been tried. The standard synchronizing impulses shown in Fig. 24 have been found best suited to present and future requirements of television in this country. Pattern A shows, among other things, the sync

pulses recommended for the end of a frame; these will move the spot up to the top of the picture along the retrace path for the beginning of a new frame. Pattern B shows the impulse signal sequence recommended for the end of the first half-frame (the end of the first field); this moves the spot from the bottom to the top of the picture for the beginning of the second interlaced field scanning. A careful study of the diagrams in Fig. 24 will reveal five outstanding characteristics of a television signal:

I. The horizontal sync pulse that is transmitted at the end of each line is not exactly rectangular. The enlarged diagram in Fig. 24D shows the exact shape of this synchronizing signal.

II. The video signal is blanked out for a short interval before and after transmission of the horizontal sync pulse at the end of a line, in order to insure blanking during the horizontal retrace. The total time for this horizontal blanking shall be about 14% of the time from the start of one line to the start of the next line (this is designated as .14H at the right in Fig. 24D, H being the time from the start of one line to the start of the next line). Note that the horizontal pulse occupies about half of this blanking time, and that the front (leading) edge of the pulse is near the start of the horizontal blanking. The two portions of this blanking signal that are on each side of the horizontal sync pulse are known as *pedestals*, and are originally at the black level.

III. The vertical sync pulse exists for an interval of three lines, but this pulse is divided into six small pulses, each acting for half a line. This serrated pulse is shown in Fig. 24A. Each vertical pulse is divided into six small pulses or serrations in order to maintain horizontal sync pulses at all times. These serrations will be explained in detail later.

IV. Six equalizing pulses precede and six follow each vertical pulse period. The purpose of these will also be covered later.

V. The vertical blanking period starts slightly ahead of the first equalizing pulse and extends considerably beyond the last equalizing pulse; this vertical blanking period should take between 5% and 8% of the time for one vertical sweep. Note that horizontal sync pulses are transmitted during the latter portion of the vertical blanking period.

Explanation of Standards. As long as we have 60 vertical sweeps per second, interlaced scanning will continue automatically throughout a transmission. The vertical fly-backs or retraces will be 1/60 of a second apart; they may occur either near the beginning or near the end of the vertical sync pulse interval, but must occur at the same point in each pulse (this point is controlled by the design of the receiver).

Although the leading (left-hand) edge of the vertical sync pulse in Fig. 24A is directly above the leading edge of the vertical sync pulse in Fig. 24B, these actually occur 1/60 of a second apart due to interlacing. For this reason, the horizontal pulses at A and B in Fig. 24 are not in line.

Experience has shown that no matter what happens, the horizontal sync pulses must not stop even for a single line. If the vertical sync pulse were made three lines long without breaking it up, no horizontal pulses would exist for this period. To avoid the situation, the vertical pulse is serrated or separated into six smaller pulses.

To visualize why the vertical sync pulse must be broken up, let us first assume that it is broken up into three pulses as shown in Fig. 25, and see what occurs under this condition. For the moment we will forget about the equalizing pulses. Pattern A in Fig. 24 shows the last horizontal sync pulse (just before the bottom of the picture) as being one whole line ahead of the start of the vertical blanking period, and pattern B shows this last horizontal pulse as only half a line ahead of the vertical blanking period; these are actual conditions for successive field sweeps, so we must consider them in Fig. 25. Horizontal sync pulses must exist for the entire vertical blanking period; this means that there should be horizontal sync pulses at points 2, 3, 4, and 5 in Fig. 25A. At each of these points there is a break or serration in the vertical pulse; since the leading edge of a pulse or serration is sufficient to control the horizontal sweep in the receiver, this will give adequate control of the horizontal sweep.

When we turn to pattern B in Fig. 25, however, we find that horizontal sync pulses should occur at points 2, 3, and 4. There are no steep leading edges at these points to control the line sweep, and consequently three serrations in the vertical impulse are not adequate for pattern B, which occurs for every other scanning of the picture. If the vertical impulse is divided into six parts as shown in Figs. 24A and 24B, we secure the desired steep front at points 2, 3, and 4 in pattern B in Fig. 25.

The vertical synchronizing pulse is chopped into segments by the application of a special signal having a rate twice that of the horizontal synchronizing signal. Because of the difficulty of synchronizing this signal exactly with the vertical pulse, this twice-normal signal exists somewhat before

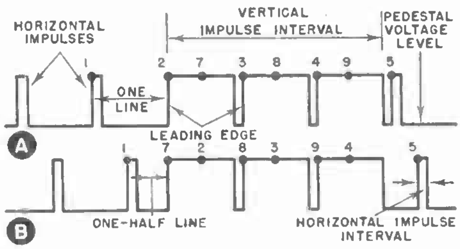


FIG. 25. These diagrams tell why the vertical synchronizing impulse signal must be broken up into six smaller impulses.

and after the vertical pulse as a series of horizontal synchronizing pulses at half-line intervals. Then, it is sure to cut up the vertical pulse properly. In Fig. 24A, these additional pulses are labeled "equalizing pulses." A pulse one-half a line from the proper one is ignored at the receiver; the sweep oscillator responds only to the pulse that occurs at the proper time to maintain the horizontal synchronization.

The value of this information will become apparent when you study sync circuits and methods of observing wave shapes with an oscilloscope. At that time you will find a review of this information helpful.

Fundamentals of TV Receiver Operation

Let us imagine that a TV transmitter that is operating on channel 2 is sending out signals having a frequency distribution as shown in Fig. 22, and let us consider just how this would be received and converted into an image by a typical television receiver having the sections shown in Fig. 26.

The superheterodyne circuit shown in Fig. 26 has the usual r.f. amplifier, mixer-first detector and local oscillator. In television, these sections are generally built together as a unit on a separate chassis. Where serious difficulty is experienced in this unit (called the "front end") the entire unit is removed and another one substituted. The front end is generally returned to the factory for any major repairs.

Referring to Fig. 22 again, you will see that two carriers are picked up by the antenna—the video carrier and the sound carrier. The r.f. amplifier response is sufficiently broad to pass both carriers without appreciable attenuation, and they are fed into the mixer input. In the early television receivers, the r.f. amplifier had an untuned input, double tuning of the band-pass variety being used between the r.f. amplifier and the mixer-first detector. In later models, the input of the r.f. amplifier is tuned, thus giving a much better signal-to-noise ratio and improving the over-all sensitivity of the receiver.

The two carriers are amplified by the r.f. amplifier and injected into the mixer, where they beat with the local oscillator signal and two separate i.f. signals are produced. The i.f. that is to be employed depends upon the design of the receiver. Generally the i.f. will be somewhere between 21 megacycles and 45 megacycles. The tendency is to go toward higher i.f. values to reduce image interference.

In this particular case we will assume that the local oscillator is operating at 81 megacycles. Since our station is assigned to channel 2 (54 to 60 megacycles), the picture carrier will be 55.25 megacycles and the sound carrier 59.75 megacycles. When these carriers beat with the 81-mc. signal of the local oscillator, a sound i.f. of 21.25 mc. and a picture i.f. of 25.75 mc. will be produced.

Sound Channel. In many receivers, separation of the two i.f. carriers is made at the output of the mixer as shown in Fig. 26. The sound i.f. signal then is fed through the sound amplifier, the limiter stage, a sound discriminator (which removes the audio modulation from the f.m. signal), through the first a.f. amplifier, to the power amplifier and to the loudspeaker.

As shown by the dotted lines, the sound i.f. signal may be taken off from the output of the first or the second video i.f. amplifier. In this case these amplifiers must have a wide enough response to pass both the video and the sound i.f. carriers. The object of taking the signal from the output of one of the video i.f.'s rather than from the mixer is to obtain a stronger sound i.f. signal, thus reducing the amount of amplification necessary in the sound i.f. amplifier.

As will be described in another Lesson in detail, the sound is sometimes taken from the output of the video amplifier. In this case the video i.f. amplifier must pass both the sound and the picture carriers. Since they are always separated by 4.5 mega-

Video Channel. At the mixer output we also have the video i.f. carrier that contains the picture signal and the sync pulses. You will note that four video i.f. stages are used in this particular circuit. Some less expensive receivers use three video i.f. amplifiers. In general the i.f. amplifiers are stagger-tuned, each i.f. stage being tuned to a different frequency. This enables us to obtain the necessary band width with a reasonably

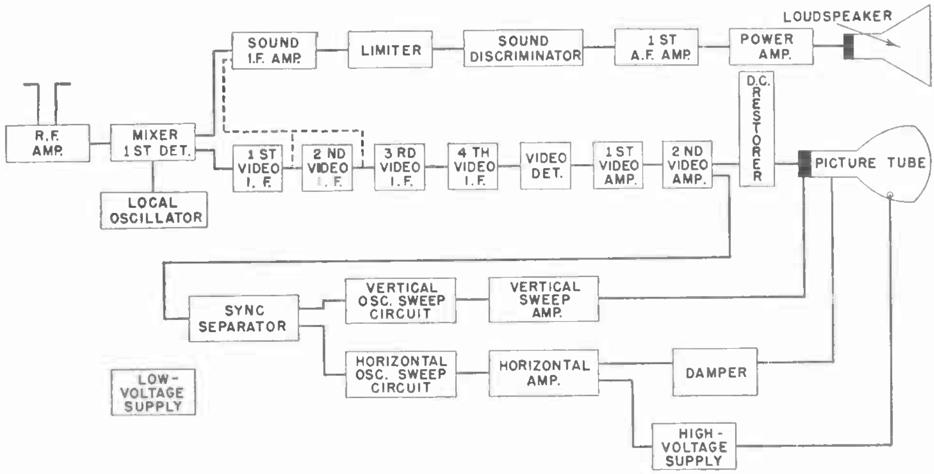


FIG. 26. Block diagram of modern TV Receiver.

cycles, they will beat together in the video detector, producing a 4.5-megacycle signal modulated at an f.m. rate by the audio signal. The video amplifier will amplify this 4.5-megacycle signal and it may be removed from the output of the video amplifier and fed through a sound i.f. amplifier tuned to 4.5 megacycles. This signal is then fed through the sound discriminator, and the rest of the audio section in the usual manner. This is known as the intercarrier sound system and is employed in many of the lower-priced TV receivers.

flat-topped response.* The amplified video i.f. carrier signal with its modulation is fed into the video detector, which is generally a half-wave diode. Here the modulation envelope is stripped from the carrier, giving us a signal similar to that shown in Fig. 18. This signal is then amplified by the first and second video amplifiers which correspond to audio amplifiers in a sound receiver. If direct coupling is used between the amplifiers and

* Some receivers use double-tuned video i.f. transformers that are overcoupled to give the necessary band width.

between them and the picture tube, the d.c. restorer shown in Fig. 26 is not needed.

If the video amplifier passes only the a.c. component of the television signal, a d.c. restoring circuit should be used just ahead of the television picture tube to restore the d.c. component, as you will learn in another Lesson. This d.c. potential must be restored in such a way that the pedestals will all line up with each other again, for they may be thrown considerably out of line by the video amplifier stages. All the components in the television signal, including the video signal itself, the horizontal and vertical sync pulses, and the equalizing pulses and pedestals are applied to the control grid of the picture tube.

Automatic gain control (a.g.c.) is a very desirable additional circuit in any TV set. Like automatic volume control in an ordinary sound receiver, a.g.c. compensates for fading and it also serves to supply the demodulator with an essentially constant signal. Of course, normal fading due to interaction between ground and sky waves is not apparent in a TV system, but it is perfectly possible for an effect like fading to occur due to swaying of the receiving antenna or the transmission line in the wind, or reflection of radio waves from moving objects such as automobiles or airplanes. If there are two or more television stations in a given locality, one may provide a stronger signal than the other at a given receiving point, causing different signal levels at the second video detector. Automatic gain control can compensate for all these effects.

In some receivers the a.v.c. system is actuated by the average carrier levels; in a television system, however, the average carrier level varies with the nature of the video signal being transmitted. The one fixed characteristic of a television signal is the black level; for a given station, this is fixed and corresponds to a definite carrier level. The sync pulses that are transmitted at amplitudes above the black level are likewise fixed, so by feeding the TV signal from some point in the receiver where the pedestals line up with each other (such as the output of the video second detector) and using an ordinary R-C filter that makes the output follow the peaks of the sync pulses, we can secure for the a.g.c. system a d.c. voltage whose value varies with the true carrier level of the TV signal.

Sweep Circuits. So far our study of the block diagram in Fig. 26 has been chiefly a review of an ordinary superheterodyne circuit. The remainder of the TV receiver, constituting the sweep circuits, is the only new thing.

In order to make the electron beam in the picture tube sweep both horizontally and vertically we need two sweep oscillators. These must be so designed that they can be controlled by the horizontal and vertical sync pulses in the TV signal. The sync pulses must be separated from the video signal before they can be applied to the sweep circuits. This separation is accomplished in the stage known as the sync separator.

The TV signal that is fed into the sync separator must be taken off from some point after the video detector.

A sync separator may consist of a diode tube or a negatively biased triode tube that will clip off the video signals, leaving only the sync pulses.

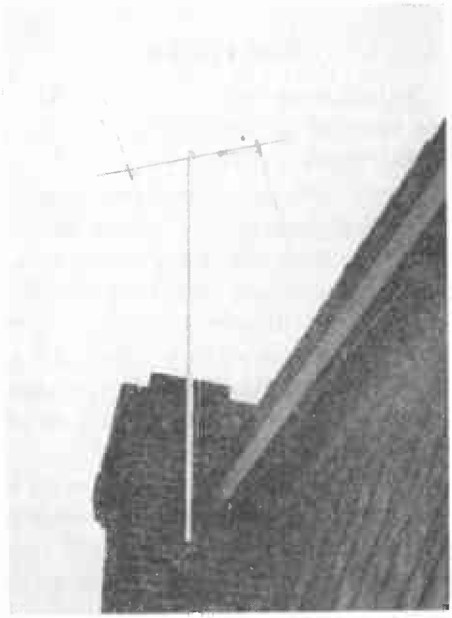
After the pulses have been separated from the video signal there will remain the problem of separating the horizontal sync pulses from the vertical sync pulses. The circuits that accomplish this are built into the inputs of the vertical and horizontal sweep circuits. Generally they consist of ordinary R-C filters; a low-pass filter is used for the vertical sweep input, and a high-pass filter that will accept the 15,750-kc. horizontal pulse is used at the input of the horizontal sweep circuit.

The outputs of the sweeps are fed through amplifiers and into the picture control circuits that will be either deflection plates in the case of the electrostatic picture tube or deflection coils in the case of the electromagnetic type picture tube.

The damper shown in Fig. 26 is used with electromagnetic picture tubes and damps out any tendency toward oscillation in the horizontal deflection coils. Due to the relatively high frequency employed here and the inductance in the coils, oscillation might take place if it were not for this damper circuit. This circuit will be studied in detail in other Lessons. The damper is not required where electrostatic deflection is employed.

Power Supplies. Power supplies are an essential part of a television receiver since the various tubes will require both a.c. and d.c. operating voltages. The low-voltage supply is similar to those used in sound receivers, although due to the large number of tubes in a TV set a pair of rectifiers in parallel may be used instead of a single rectifier. The power transformer will be much larger than that found in a broadcast set.

In many of the inexpensive television receivers the tube filaments are wired in series as in an a.c.-d.c. set. Due to the number of tubes encountered, more than one filament string is generally necessary. Selenium rectifiers are also widely used in voltage-doubler, and in some cases voltage-tripler, circuits. This eliminates the expensive power transformer.



Courtesy Philco Corp.

A typical TV antenna installation.

In addition, high voltage must be supplied for the second anode of the picture tube. This is obtained from a separate supply source. In the electromagnetic type receiver that is illustrated in Fig. 26, the high voltage is obtained from a part of the horizontal amplifier circuit. In other cases the high voltage may be independent of this circuit. The great advantage of having the high voltage tied to the horizontal amplifier circuit is in case the horizontal sweep chain fails, the high voltage will go out so that the picture tube will be protected. All types of high-voltage supplies will be described in greater detail later on.

CONTROLS

Adjustments must be provided in the receiver for controlling the action in the various circuits.

There will be a channel selector that corresponds to the tuning control in a broadcast set, a picture contrast control that corresponds to the volume control, a brilliancy control to vary the bias of the picture tube, and in addition to this there will be the usual audio type volume control and on-off switch in the sound system.

Additional controls will be found in the sweep- and picture-tube circuits. We must have controls that will vary the size of the picture horizontally and vertically, also controls that will make the vertical and horizontal oscillators lock in with the sync pulses. In any TV set you will find some means of centering the picture in the middle of the screen since in the manufacturing of tubes it is almost impossible to line up the electrodes perfectly.

The controls that are associated with the sweep circuits are generally on the back of the receiver since they seldom need to be adjusted. In some sets a few other special controls that need not be considered here will be encountered.

LOOKING FORWARD

In this first introductory Lesson on television we have surveyed the important needs of a television system. In some cases, brief explanations of these needs have been given and in other cases we have simply made statements because the explanations would be lengthy and not essential to clearness in this "bird's-eye view" of the entire television setup. The various methods for producing saw-tooth sweep signals, for providing interlocks, and for separating sync-pulse signals will all be taken up in later Lessons along with the typical circuits for the various other sections described in this Lesson.

Lesson Questions

Be sure to number your Answer Sheet 49RH-4.

Place your Student Number on *every* Answer Sheet.

***Send in your set of answers for this Lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. Why is it that a TV picture signal does not require a channel band width equal to twice the modulating frequency?

2. What converts a scene into a succession of signal intensities?

3. What characteristic of the eye makes it possible to send a picture signal a portion at a time, and yet have the resulting picture appear as a complete scene?

4. What is the purpose of the sync pulses sent out by the transmitter?

5. Are the line sync pulses sent: 1, *at the beginning;* or 2, *at the end* of each line?

6. What is the advantage of using negative modulation of the picture carrier signal?

7. In an electrostatic picture tube, the voltage on which element is varied to focus the beam?

8. What effect on the picture is seen when the gain of a TV receiver is varied?

9. What is the frequency of (A) the vertical scanning, and (B) the horizontal scanning?

10. If both the sound and picture carriers are allowed to reach the second video detector, what will be the resulting beat frequency?

Be sure to fill out a Lesson Label and send it along with your answers.

SELF-EDUCATION

"The best culture is not obtained from teachers when at school or college—but by our own diligent *self-education* when we have become men."

This quotation has been proved true many, many times. Let's take a few outstanding examples. President Ulysses Grant was often called "Useless" by his mother because he showed so little promise as a young man. General Stonewall Jackson was noted for his slowness while a pupil at West Point. Watt—who invented the steam engine—was notoriously dull in school. Sir Walter Scott was outstanding in school *only* for his readiness to pick a fight—and was not known as an author until he was over forty.

To again quote, Gibbon said, "Every person has two educations. One which he receives from others—and one, more important, which he gives to himself."

You are now busy *giving yourself* education in Radio and Television which can and should be the most important education of your entire career.

J. E. Smith

BASIC TV RECEIVER CIRCUITS

50RH-2

PIONEER HOME STUDY RADIO SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 50

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. **Introduction . . . . Pages 1-4**

Here you learn what the input tuner, the r.f. amplifier, the mixer-first detector, and the oscillator of a TV set do.

☐ 2. **Video I.F. Amplifier and Detector . . . . Pages 4-8**

The functions of these important TV stages are discussed in this section.

☐ 3. **Video Amplifier and D.C. Restorer . . . . Pages 9-17**

How the video signal is amplified and how its d.c. level is restored are the subjects of this section.

☐ 4. **Forming the Picture . . . . Pages 18-25**

Here you learn how the video signal is converted into a visible picture.

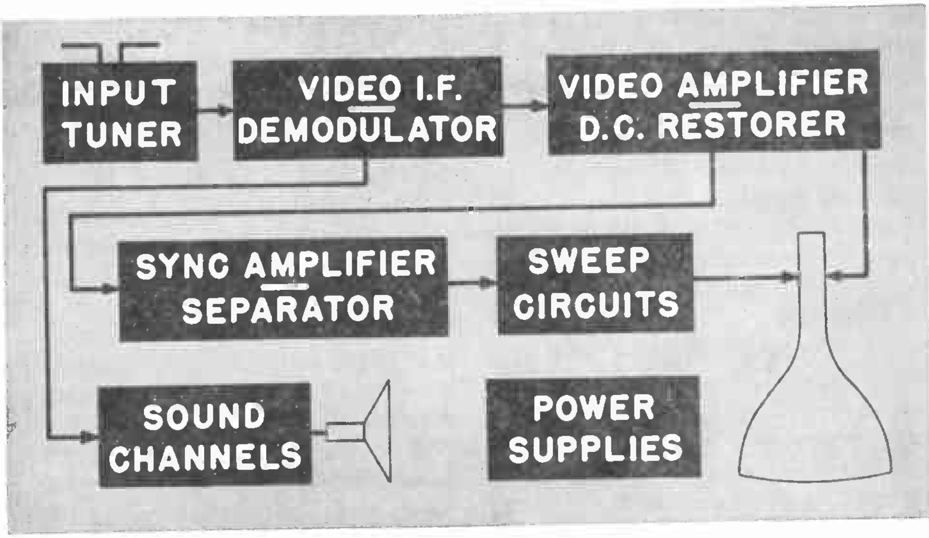
☐ 5. **Sync-Separating and A.G.C. . . . . Pages 26-28**

In this section, you learn how the sync signals are separated from the video signals, and how the contrast level of the picture is kept constant even when the signal strength varies.

☐ 6. **Answer Lesson Questions and Mail Answers to NRI for Grading.**

☐ 7. **Start Studying the Next Lesson.**

BP6M151 1951 Edition Printed in U.S.A.



YOU HAVE previously studied in block form the various sections of a TV set and have learned something about the functions performed by the TV receiver stages and sections. In this Lesson you will get acquainted with typical TV circuits and their operation. You will not have to cover all the variations in the circuits used by different manufacturers because each section of a TV set will be treated in detail elsewhere. Now, you will build the foundation for this future study by covering only the fundamentals of television circuits.

THE INPUT TUNER

This section of a TV receiver is also commonly called the front end or head end of the receiver. It contains the r.f. amplifier and the local oscillator-mixer-first detector. The first section of the front end is the r.f. amplifier. This section increases the amplitudes of both the sound and the video r.f. signals without changing their characteristics in any way, and hence must have a pass band of at least 6 megacycles. In addition to this, the r.f. amplifier must give some rejection of carrier frequencies outside the desired channel that might cause interference.

The amplified video and sound r.f. signals are fed into the mixer-first detector section where they are combined with the unmodulated r.f. signal that is produced by the local oscillator. As a result, two i.f.-modulated carrier signals are produced; one is the sound i.f. carrier and the other is the picture i.f. carrier. Various i.f. values, ranging from 12 to 25 megacycles, have been used, but higher i.f. values in the vicinity of 40 megacycles are becoming more popular, since this gives the r.f. amplifier a better chance to reject signals that could produce image interference.

THE R.F. AMPLIFIER

The r.f. amplifier has three important functions. Since it is between the mixer and the antenna, it *reduces radiation from the local oscillator.* The local oscillator, if the r.f. stage were not used, would radiate energy from the TV antenna that might be picked up in a nearby TV set, and cause considerable interference.

The r.f. amplifier increases the signal strength on the desired TV chan-

nel. This gives a better signal-to-noise ratio in the TV set. The response of the r.f. amplifier should be broad enough so that it does not cut off any of the desired signals. However, equal amplification of the TV signals is generally not obtained, but this may be made up for in other stages of the receiver by increasing the amplification of the signals that are slighted in the r.f. amplifier.

The r.f. amplifier must also give some degree of selectivity and it should reject image signals that create interference with the desired station. The selectivity of a TV r.f. amplifier, however, is not high, and if the interfering signals are exceptionally strong, wave traps in the antenna circuit are often used to reduce the interference.

A typical TV r.f. amplifier circuit is shown in Fig. 1. Notice that the input of the r.f. amplifier is tuned. This results in better image rejection. However, many r.f. amplifiers have an aperiodic (untuned) input from the antenna system.

Also notice the band-pass r.f. coupler between the output of the r.f. amplifier and the mixer grid. This tends to improve the selectivity and to give an essentially uniform response of 6 megacycles.

To give broad-band response and to prevent oscillation, stagger-tuning is often used. Two of the resonant circuits shown in Fig. 1 are tuned to different frequencies. Two circuits alone give a deep valley between the peaks of response, and the third circuit is therefore tuned to a mid-frequency and serves to fill in the valley. The valley may also be filled in by loading the resonant circuits with low shunt resistances such as R_1 and R_5.

Fig. 1 illustrates only one way that these three tuned circuits may be arranged. Tuned circuit L_2-C_2 is tightly coupled to the antenna coil. Resistor R_1, which may be as low as 2000 ohms, is shunted across the tuned circuit to broaden its response. The band-pass coupler consisting of L_3, C_6, C_5, C_7, and L_4 has a broad response and is loaded through coupling condenser C_4 by R_4 and through coupling condenser C_8 by R_5.

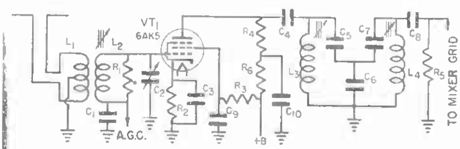


FIG. 1. Typical TV r.f. amplifier circuit. This circuit amplifies the modulated carriers for both sound and picture portions of a TV program.

The tube used in the preselector section is a pentode r.f. amplifier and may be of either the variable-mu or the sharp cut-off type. The gain in this circuit is controlled by the a.g.c. system, although in some cases a variable cathode bias resistor may be used to vary the bias of VT_1 and the tubes in the following stages.

The r.f. tube must have certain characteristics that make it suitable for amplification of very-high frequencies. Its grid-to-plate capacity must be low if feedback is to be kept at a minimum. For the same reason, the capacity between the plate and grid leads to this tube must be as low as possible. In addition to this, the grid-to-cathode and plate-to-cathode interelectrode capacities and the capacities between the leads to these

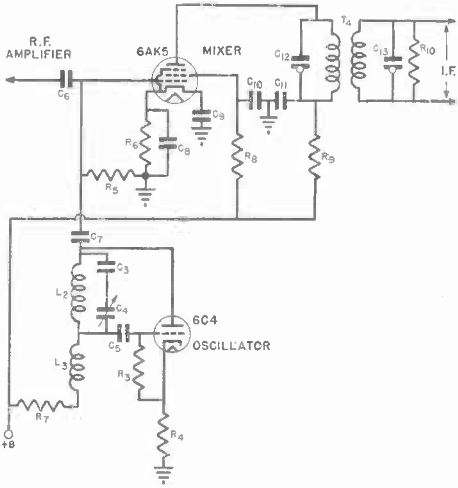


FIG. 2. A separate oscillator is used here to feed the signal into the mixer-first detector.

electrodes must be low enough so that reasonably high gain can be obtained, and so that the r.f. amplifier can be tuned to the highest desired television channel when the inductance of L_2, L_3, and L_4 are set at a minimum value.

MIXER-FIRST DETECTOR AND OSCILLATOR

The process of frequency-conversion involves the mixing of the locally generated oscillator signal with the incoming modulated carrier signal. The process is basically the same as in an ordinary broadcast superheterodyne receiver except that in a television set there are two r.f. carriers that beat with the local oscillator signal to produce two i.f. carrier frequencies.

In broadcast and f.m. receivers a pentagrid converter is generally used as a combination mixer-first-detector-oscillator tube, but this tube is inadequate for the very high frequencies employed in television, and would result in noise and low output due to degeneration and oscillator drift. In a TV set, there is a separate oscillator tube, which may be in the same envelope as the mixer.

Pentodes are commonly used in the mixer circuit, but they require a high-level signal from the r.f. amplifier if noise is to be avoided. If a low-level signal reaches the mixer input from an inefficient r.f. amplifier, or if the receiver is located in a fringe area, it has been found that a triode mixer will give as much output as a pentode and at a considerably lower noise level.

Fig. 2 shows a typical mixer-first detector-oscillator circuit. Here a 6AK5 tube is used as the mixer. This tube is biased by the drop across R_6 caused by the cathode current, and by the drop across R_5 caused by current flow through the mixer grid. This mixer-grid current flows because the oscillator output drives the grid positive. This voltage built up across R_5 charges condenser C_6 and serves to bias the tube so that it will act as a mixer.

The i.f. transformer T_4 is double-tuned and is overcoupled to provide the necessary band width. In this particular circuit both the sound and video i.f. carriers pass through the i.f. transformer and are fed to the input of the first video amplifier tube. Resistor R_{10}, which shunts the secondary of transformer T_4, loads the transformer to give a flat response.

The oscillator is a 6C4 triode tube connected as an ultra audion (modified Colpitts) using the grid-to-cathode and plate-to-cathode interelectrode capacities to maintain oscillation. Resistors R_4 and R_7 isolate the oscillator, permitting it to act as an ultra-audion on any TV channel. Choke L_3 is needed to isolate the oscillator's tuned circuits further, providing a d.c. path for the plate circuit.

The oscillator is tuned above the picture carrier by the amount of the i.f. frequency. Trimmer C_4 in the oscillator tank circuit is connected in series with C_3, so that the range of adjustment will be limited and the adjusting screw will be nearer r.f. ground potential. Even so, a well-insulated alignment tool that is designed for high frequencies is necessary when C_4 is to be adjusted. The oscillator is biased by the feedback voltage on the grid. The tube then rectifies the resulting grid current and the resistor-condenser combination R_3-C_5 is charged up to produce the operating bias. Other tubes are, of course, used as oscillators, but in practically every instance the ultra-audion circuit is used, and the tube interelectrode capacities form a portion of the tuning circuit. You will find that not all tubes will function satisfactorily as oscillators, although they may be perfectly all right in some other circuit. For this reason, servicemen always try several tubes in the oscillator stage when trouble is suspected there and thus avoid many realignment problems.

Video I. F. Amplifier and Detector

Practically all of the selectivity of any superheterodyne is in the i.f. amplifier. A TV set is no exception, and as a matter of fact the TV receiver is even more dependent on its picture i.f. amplifier for rejection of undesired signals than broadcast sets are. This is in part due to the low selectivity of the front end, which is incapable of rejecting adjacent-channel interference. The average video i.f. amplifier alone is not capable of rejecting such interference if it is designed to pass the 4-megacycle band width containing the video intelligence. A less expensive TV set having a narrower pass band in the video i.f., has sufficient selectivity to minimize adjacent-channel interference. In receivers designed to give the ultimate in definition, special traps that reject adjacent-channel interference are used in the video i.f. amplifier.

A high i.f. gives the front end a better chance of rejecting image interference, but traps in the antenna circuit are often needed for complete freedom from interfering signals that are operating at image frequencies or frequencies at or near the i.f.

Separation of the sound and picture i.f. carriers may take place at the mixer output or at the output of the first or second video i.f. amplifier. In the latter case the sound i.f. will be somewhat stronger than at the mixer output, since the picture i.f. stages will be aligned to afford some gain at the sound i.f. frequency.

THE VIDEO I.F. AMPLIFIER

The coupling of the video i.f. amplifier in a TV receiver is considerably different from that of the amplifier in a sound receiver. Some TV sets, such as that shown in Fig. 2, use double-tuned i.f. transformers. Other forms of coupling will be described elsewhere, but the most common type, impedance coupling, is shown in Fig. 3. Although plain chokes are shown, often these form parallel-resonant circuits with the tube interelectrode capacities.

To obtain the necessary wide-band characteristic with adequate gain, four stages of i.f. amplification are used in the typical amplifier shown in Fig. 3.

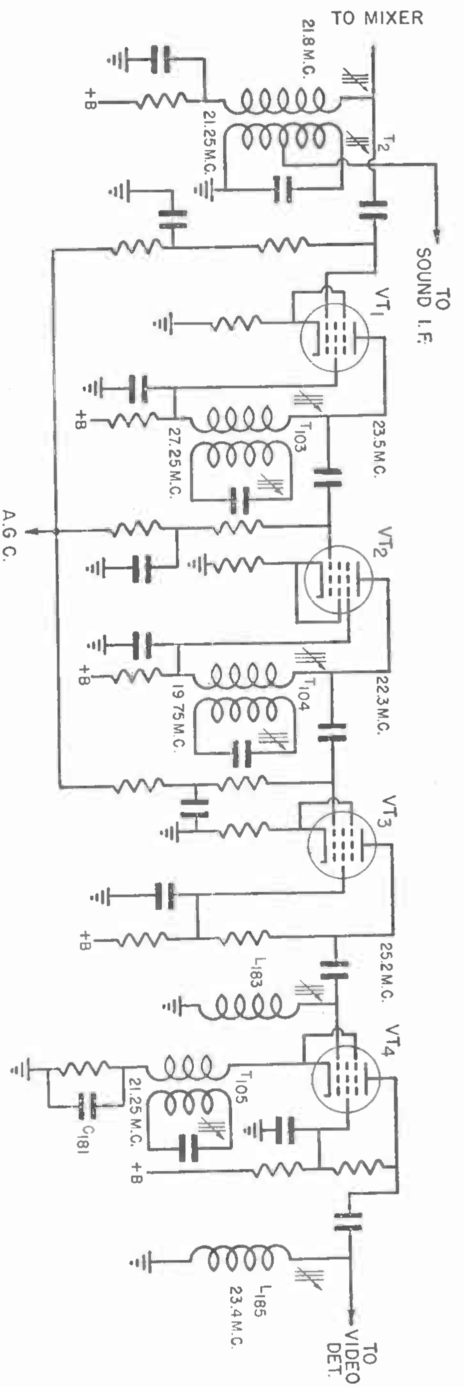


FIG. 3. A typical video i.f. section. In this example, the picture carrier is 25.75 mc. and the sound carrier is 21.25 mc.

The converter plate and the i.f. transformers each utilize only one tuned circuit, each tuned to a different frequency. The effective Q of each coil is determined by the plate resistor or the grid resistor so that the product of the responses of the total number of stages produces the desired over-all response curve. Fig. 4 shows the relative gains and selectivities of each coil and the shape of the curve of the over-all combination. This is indicated by the dotted line.

In order to obtain this band-pass characteristic, the picture i.f. transformers for this particular amplifier are tuned as follows: primary of con-

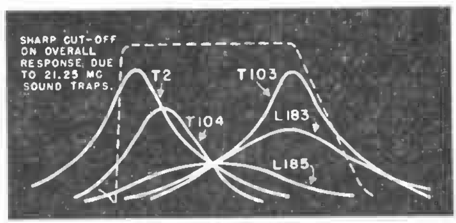


FIG. 4. Stagger-tuned i.f. response.

verter transformer T_2, 21.8 megacycles; primary of first video i.f. transformer T_{103}, 25.3 megacycles; primary of second video i.f. transformer T_{104}, 22.3 megacycles; third video i.f. coil L_{183}, 25.2 megacycles; fourth video i.f. coil L_{185}, 23.4 megacycles.

To align the i.f. system, the transformers are simply peaked to the specified frequencies with a signal generator. The over-all i.f. response can then be observed by use of a sweep generator and oscilloscope. The sweep generator is similar to that used to align f.m. and high-fidelity a.m. receivers, except for the fact that it operates at a much higher frequency and with a much greater sweep width. If the correct response curve cannot be obtained, the difficulty is likely to be in some part of the circuit that affects either the frequency or the Q of one or more of the i.f. transformers.

Fig. 5 shows the relative positions of the picture and sound carriers for

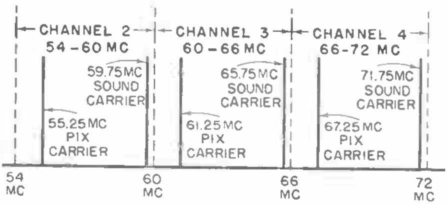


FIG. 5. Television channel frequencies.

channels 2, 3, and 4. If a station on channel 3 is transmitting a picture with video frequencies up to 4 megacycles, the picture carrier will have side-band frequencies up to 65.25 megacycles. The lower side bands, as you know, are suppressed at the transmitter. With the receiver r.f. oscillator operating at a higher frequency than the receiver channel, the i.f. frequency relation of picture-to-sound carrier is reversed as shown in Fig. 6.

Since it is necessary for the picture i.f. to pass frequencies quite close to the sound-carrier frequency, the sound carrier would produce interference in the picture. In order to prevent this interference, traps must be added to the picture i.f. amplifier to attenuate the sound carrier. If the receiver is operating on channel 3, it is possible that there will be interference from the channel 2 sound carrier and the channel 4 picture carrier. The adjacent-channel traps are provided to attenuate these unwanted frequencies. In receivers having a narrower video i.f. response, this interference is not present and such traps are not required—however, the picture definition suffers from the restricted i.f. band width.

The first three traps in Fig. 3 are absorption circuits. The first trap (T_2 secondary) is tuned to the accompanying sound i.f. frequency, the second trap (T_{103} secondary) is tuned to the adjacent-channel sound frequency, and the third trap (T_{104} secondary) is tuned to the adjacent-channel picture-carrier frequency. The fourth trap (T_{105} secondary) is in the cathode circuit of the fourth picture i.f. amplifier and is tuned to the accompanying sound-carrier i.f. frequency. The primary of T_{105} in series with C_{181} forms a series-resonant circuit at the frequency to which L_{185} is tuned (23.4 megacycles). This provides a low-impedance path in the cathode circuit at this frequency and permits the tube to operate with gain. However, at the resonant frequency of the secondary (21.25 megacycles) a high impedance is reflected into the cathode circuit and the resulting degeneration reduces the gain of the tube at this frequency. The effect of these traps on the i.f. response curve are shown in Fig. 6.

In Fig. 3, although the sound is taken directly from the output of the

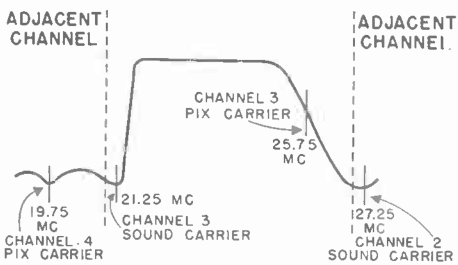


FIG. 6. Over-all picture response.

mixer, it may in some cases be taken from the output of the first or second video i.f. stages. You will note that a.g.c. in this particular case is applied to the control grids of the first, second, and third video i.f. tubes. If a.g.c. were not used, this lead would go to a manual bias control used to vary the i.f. gain.

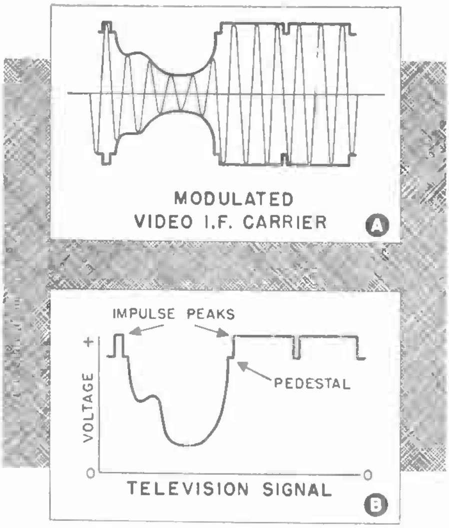


FIG. 7. The demodulated signal at B is obtained from the r.f. form at A.

THE VIDEO DETECTOR

At the output of the last video amplifier the video signal is still in its r.f. form, having both positive and negative peaks as shown in Fig. 7A. This signal must be demodulated so that it will have the form shown in Fig. 7B before it can be applied to the input of the picture tube.

To produce this demodulation, it is necessary to rectify the modulated video i.f. carrier and filter out the i.f. components. A linear detector is required for this purpose. A diode is generally used. A typical video detector circuit is shown in Fig. 8A. The video i.f. amplifier output signal existing across the final resonant circuit, consisting of L_1 and the capacity between the plate of the detector tube and ground, sends electrons through a load made up of the internal resistance of the diode detector tube, peaking coil L_2 and shunt resistor R_3, peaking coil L_3, and diode load resistor R_4, producing across the last two components a pulsating d.c. voltage. The cathode-to-filament capacity of the tube shunts to ground all a.c. components above the video range so that the video detector output voltage contains only the desired a.c. components and the d.c. component of the demodulated television signal. The pedestals for the horizontal and vertical sync pulses will now all line up at the same level.

The direction of the electron flow through diode load resistor R_4 determines whether sync pulses will make output terminal d swing in a positive direction or in a negative direction with respect to the chassis. In the circuit of Fig. 8A, electrons enter R_4 at its grounded end, making that end of the resistor negative with respect to point d. Under this condition, the

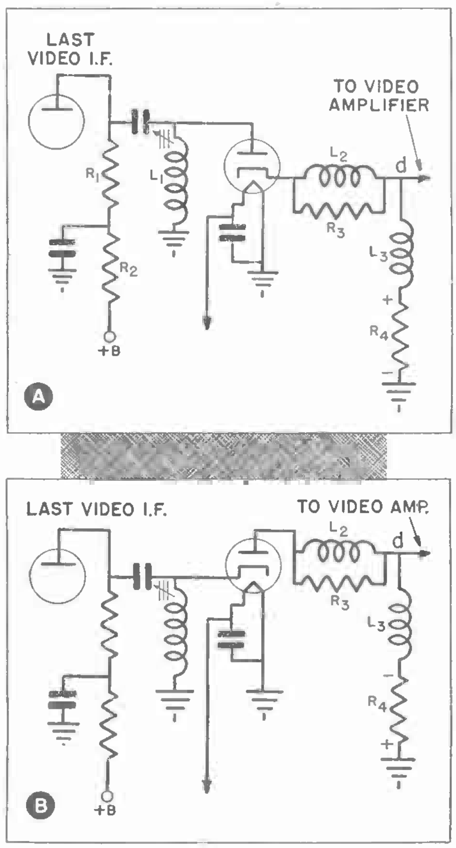


FIG. 8. Video detectors.

video detector output voltage (a modulated d.c. voltage) will vary as shown in Fig. 9A, with the sync pulses making point d swing more positive, and with the bright areas in the original scene making point d swing in a negative direction from the pedestal level.

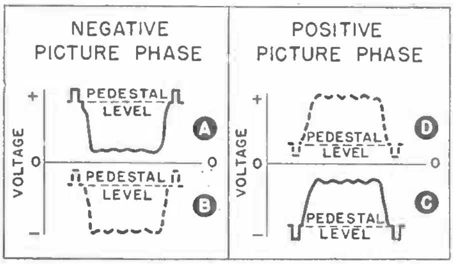


FIG. 9. When a diode video detector is connected as in Fig. 8A, the output signal has a negative picture phase (A and B); with diode connections as in Fig. 8B, the output signal has a positive picture phase (C and D).

Since this corresponds to negative modulation as at the transmitter, the modulated d.c. signal is in this case said to have a negative picture phase.

The phase of the picture signal at the output of a diode video detector can be reversed simply by reversing the connections to the diode detector tube, as is indicated in Fig. 8B. This reversal of connections makes electrons flow from the plate of the detector through the load to ground, making the take-off point from the video amplifier negative with respect to ground. In this case the video output signal is as shown in Fig. 9C. Note that bright lines now drive the signal in a positive direction from the pedestal level, giving the equivalent of positive modulation, while sync pulses drive the signal in a negative direction from the pedestal level. The modulated d.c. output signal of the video detector is in this case said to have a positive picture phase.

The addition of a d.c. bias voltage to a video-frequency TV signal has no effect upon the phase of the signal. For example, if a negative d.c. voltage is added to the signal in Fig. 9A, making the entire TV signal negative with respect to the chassis as shown in Fig. 9B, we still have the required conditions for negative picture phase (bright lines swing the signal in a negative direction from the pedestal level). Likewise, adding a positive bias to the signal in Fig. 9C may make all parts of it positive as shown in Fig. 9D, but we still have the equivalent of positive picture phase.

At this point it should be brought out that it is not necessary to use a tube as the detector. A germanium crystal, as shown in Fig. 10, makes an excellent detector, saves spaces, and eliminates the heater current of one tube. By reversing the connections to the crystal, either a positive or negative picture-phase signal can be obtained at the detector output. In Fig. 10, L_2 and L_3 together with C_2 form a low-pass filter that removes i.f. components and filters out i.f. harmonics. In this case the load consists entirely of resistor R_3, and the video signal across this resistor is applied to the input of the video amplifier.

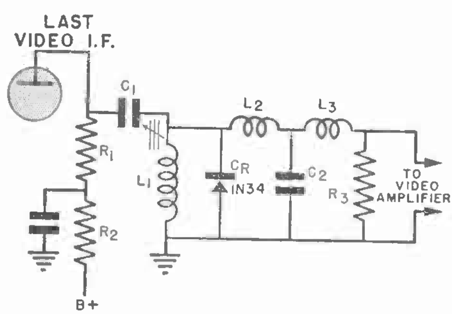


FIG. 10. A crystal video detector.

Video Amplifier and D. C. Restorer

THE VIDEO AMPLIFIER

The video amplifier in a TV receiver corresponds to the audio amplifier in a broadcast set. The video amplifier drives the picture tube, swinging the bias on the picture tube to give the necessary variations in light intensity along each line of the scan.

The signal from the output of the video amplifier may be used to drive the grid, or we may hold the grid of the picture tube at a fixed voltage and drive the cathode. It is more usual to drive the grid of the tube just as in an ordinary stage of amplification, so we will consider this method here. Later the cathode drive will be studied.

If we assume for the moment that the signal level at the output of the video detector is strong enough to excite the picture tube in the receiver, which signal in Fig. 9 would we select? This question can be quickly answered by considering the E_g-B (grid voltage-brilliancy) characteristic of a picture tube as shown in Fig. 11. If we choose a signal with negative picture phase and apply it in such a way that the pedestals line up with point B on the E_g-B characteristic in Fig. 11, spot brilliancy will vary as shown by curve N. As you can see, this type of signal is incorrect, for bright portions of the scene at the transmitter would be reproduced as dark portions and the sync pulses would cause white lines to appear on the screen.

When the applied signal has a positive picture phase, and the pedestals are lined up with point A by adjusting the bias, spot brilliancy will vary as shown by curve P. In this case sync pulses will darken the spot, and increasingly bright video signals will give increasingly bright spots on the receiver screen. Since point A on the E_g-B characteristic is at the brilliancy cut-off point for the tube, the sync pulses will always drive the spot into the blacker than black region, and the video signal will always make the spot more or less brilliant, which is exactly what we want. It follows from this

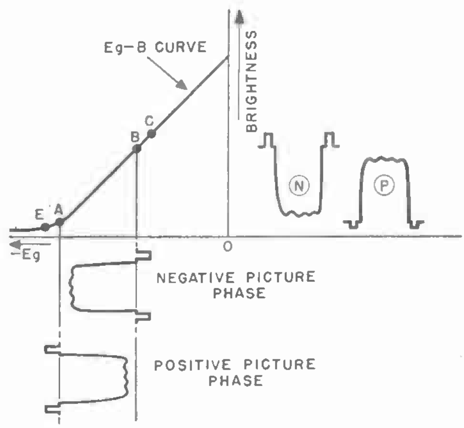


FIG. 11. Grid voltage-brilliancy (E_g-B) characteristic curve for a television picture tube.

that the picture tube in a TV set must have its grid driven with a signal having a positive picture phase, and the bias voltage must be applied in series with the signal to make the pedestals line up with the cut-off point.

In general practice, the output of the video detector is not sufficient to drive the control grid of the picture tube directly. There is seldom more than one volt output from the detector, and some tubes may require as much as 60 or 70 volts. Because of this, amplification of the signal at the output of the video detector is required. This calls for one or more video frequency (v.f.) amplifier stages between the video detector and the picture tube. These video-frequency amplifier stages introduce a number of problems, as you will see.

The video amplifier must respond more or less uniformly to signals over the entire range between 10 cycles and 4 megacycles. Furthermore, if any unequal amplification of the various frequencies takes place ahead of the video amplifier, the video amplifier response must be such that its output will be uniform. In some cases extra amplification at the high frequencies may be required, or perhaps it will be necessary to have slightly more gain in the middle register.

termined by the d.c. plate voltage and the negative C-bias voltage. For the duration of this steady-state condition, point 4 on the load resistor will be negative with respect to point 3, for electrons flow from cathode to plate, enter the resistor at 4, and flow through it to point 3.

Now suppose that we feed into the circuit the TV signal shown in Fig. 9A. This signal has a negative picture phase and makes point 2 have a varying positive potential with respect to point 1. This varying positive potential cancels out part of the fixed negative C bias, making the grid-to-cathode voltage on the tube less negative and therefore making plate current i increase. This increase in i serves to increase the voltage drop across R_L, making point 4 more negative than before with respect to point 3. In other words, when point 2 swings positive with respect to 1, point 4 swings negative with respect to 3, thereby giving a 180-degree phase reversal. This means that if a signal having a negative picture phase (Fig. 9A) is applied to the grid of an amplifier having a resistance load like that in Fig. 12, the output signal will have a positive picture phase, as in Fig. 9C. Likewise, if the signal in Fig. 9C is applied to the grid, the output signal will be like that in Fig. 9A. A stage of video amplification thus reverses the phase of the applied signal.

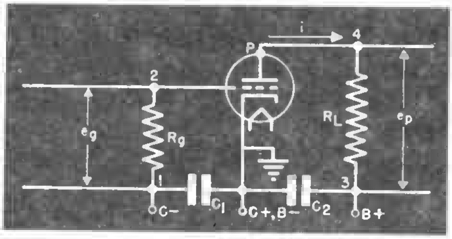


FIG. 12. Simplified video-amplifier stage.

Because of the frequency requirements resistive loads must be used. Transformer loads would be too frequency-discriminatory, and we would not be able to get a flat response.

The fact that an amplifier of any type is used introduces the problem of phase reversal, for each amplifier will reverse the phase of the picture signal. Thus, if a signal of a negative picture phase (Fig. 9A) is fed into a stage, the signal at the output of that stage will have a positive picture phase (Fig. 9C).

We can see exactly how this reversal in phase occurs by studying the action of the simplified video-amplifier stage in Fig. 12. When E_g is zero (as when no TV signal is present), a definite d.c. plate current will flow through load resistor R_L, its value being de-

Suppose we utilize the output signal between point 4 and ground in Fig. 12

instead of that between points 4 and 3. If the signal between points 4 and 3 corresponded to Fig. 9C, the resulting signal between point 4 and ground would be like that in Fig. 9D. If the signal in Fig. 9A existed between points 4 and 3, a connection between point 4 and ground would give exactly the same signal, but at a higher positive bias.

Keeping in mind that the TV signal that is feeding the control grid of the picture tube must have the equivalent of positive modulation, we can make two general conclusions as to the type of video detector circuit required:

1. If two stages of video-frequency amplification are used after the video detector in order to secure the required television signal voltage at the input of the picture tube, the video detector circuit must be of the type shown in Fig. 8B, delivering a signal with a positive picture phase.

2. If either one or three stages of video frequency amplification are used, the video detector circuit must be of the type shown in Fig. 8A, delivering a signal with a negative picture phase.

In high-definition reproduction of television signals it is absolutely essential that the pedestals all line up at the same constant signal level at the input of the picture tube. When this condition is achieved, it is possible to adjust the bias on the picture tube so that the sync pulses always drive the spot into the blacker than black region and the video signals always vary the spot brilliance. In other words, the pedestals must be lined up at the input of the picture tube so that we can make all the sync signals invisible and all the picture signals visible. It is a fundamental fact that the demodulated television signal (including the sync pulses along with the video signal) will retain its alignment of pedestals only as long as it has its d.c. component.

The only way in which we can amplify the d.c. component along with the television signal, thereby retaining the alignment of the pedestals, is by using d.c. amplifier stages in the video amplifier. This is sometimes done, but it is more usual to employ a.c. amplifiers and then to restore the d.c. component at the output of the video amplifier, as will be described later.

With only one stage of video-frequency amplification it is possible to connect the load of this stage directly to the grid-cathode of the picture tube, giving true d.c. amplification without the complications of the expensive power supply that is necessary for two or more direct-coupled stages. With two or more stages in the video amplifier, either true direct coupling or resistance-capacitance coupling can be used. When the latter system is used, the coupling condenser removes the d.c. component from the TV signal, thereby causing the pedestals to get out of line.

It is important to visualize what happens to a demodulated TV signal when it is passed through a condenser. Signal I in Fig. 13A corresponds to a line having maximum and uniform brightness, and signal II corresponds to a solid black horizontal line on the scene that is being televised. These two signals are shown as they would appear across the detector load resistor, so the pedestals all line up at a constant level with respect to the zero voltage line. Each signal is made up of an a.c. component (having equal areas on each side of the average value line for each cycle) and a d.c. component, with the average values of the a.c. components considerably out of line, and with the d.c. components of the black line considerably larger than those for the bright line.

When these TV signals are passed through a condenser, the d.c. components are blocked out, bringing the average value line down to the zero line. As a result, the average values of

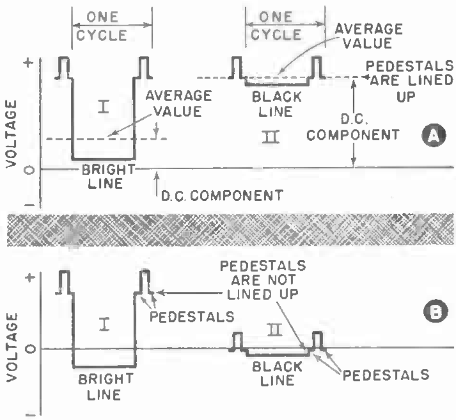


FIG. 13. Passing the demodulated television signal I in A through a condenser removes its d.c. component, giving a.c. signal I in B. Likewise, passing signal II in A through a condenser gives a.c. signal II in B.

the a.c. components line up at zero, as in Fig. 13B, after the signal has passed through the condenser. It is seen from this that the pedestals are no longer lined up.

The addition of a fixed d.c. bias voltage to the a.c. signals shown in Fig. 13B (placing the signal either entirely above or entirely below the zero voltage line) would convert them into pulsating d.c. signals, but would not get the pedestals in line again. We must add a different d.c. bias voltage value for each line if we are to make the pedestals all line up again after a TV signal has passed through a condenser.

With the pedestals in an a.c. TV signal all at different levels, it is impossible to line up all of the pedestals with the cut-off point on the picture-tube characteristic. Remember, however, that we chose two extreme line conditions in Fig. 13. When the average brightness of a line is about the same for all portions of the televised scene, the difference between pedestal levels will not be nearly as great as that shown in Fig. 13. Under this condition it is possible to secure fairly satisfactory image reproduction by adjusting the picture tube bias to correspond to the average brightness level (average pedestal level in the a.c. signal).

For high-fidelity reproduction, a d.c. restorer is essential, but on small low-priced TV receivers it is sometimes omitted. After analyzing a typical video-frequency amplifier stage, we will study the problem of realigning pedestals by properly restoring the d.c. components, as is necessary in cases where a.c. video amplifiers are employed.

Typical Video-Frequency Amplifier Stage. Assuming that we have a TV receiver that requires two video-

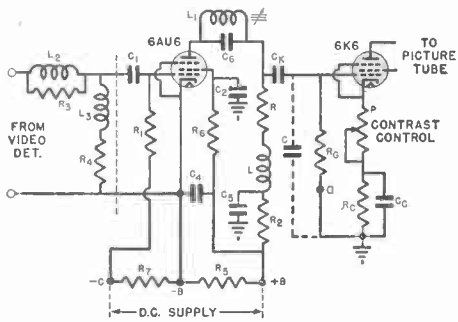


FIG. 14. Typical circuit for the first video-frequency amplifier stage in a TV receiver having two v.f. stages. Parts L_2, R_3, L_3, and R_4 are the same as in the video detector circuit of Fig. 8B.

frequency amplifier stages between the video detector circuit and the picture tube (shown in Fig. 8B), we can consider the type 6AU6 tube circuit, shown in Fig. 14, as being typical of the circuit in the first video-frequency amplifier stage. The television signal from the detector is developed across diode load L_3-R_4. Then the video signal passes through coupling condenser

C_1, which strips off the d.c. component. Only the a.c. component of the television signal is thus applied to the control grid of the type 6AU6 tube. This first video-frequency amplifier tube uses fixed bias that is developed across resistor R_7 in the voltage-divider circuit, and this bias is applied to the control grid through resistor R_1.

The remainder of this video-frequency amplifier circuit is more or less conventional except for the presence of choke L in the plate load of the tube, and tuned circuit L_1-C_6. Choke L serves to boost the high-frequency response while L_1-C_6 is tuned to the 4.5-mc. beat frequency formed by the interaction of the picture and sound carriers. If this beat frequency is allowed to reach the picture tube, fine dots will appear as in a coarse-grained photograph. Thus, L_1-C_6 is called a "grain" trap.

One fundamental consideration in building a video-frequency amplifier stage like that in Fig. 14 is the value of capacity C. This capacity is shown dotted in the diagram, since it is a combination of the output capacity of the first stage, the input capacity of the second stage, and stray-lead capacity coupled together by C_K. The reactance of this capacity to ground becomes low enough at the higher video frequencies being amplified to provide a serious shunting effect. The presence of this capacity can be neutralized to a certain extent, however, by keeping plate-load resistor R low in ohmic value, somewhere around 3000 ohms. Thus, the use of a low plate load in a video amplifier stage gives wide-band response. With such a low plate-load value, a tube with a high transconductance is needed to provide the required amount of amplification.

Even more important than the attenuation of high-frequency components in the video signal is the distortion that is produced by capacity C. Coil L is introduced into the circuit for two reasons:

1. Its inductive reactance partially or totally balances out the capacitive reactance of C, thereby eliminating or at least reducing the amount of distortion.

2. If the value of coil L is properly chosen, L and C can be made to resonate at the higher video frequencies, thereby giving a broad parallel-resonant circuit that boosts or peaks the gain at the higher frequencies, and thus counteracts the shunting effect of capacity C. Coil L is called a peaking coil. In some instances you will find additional peaking coils used between the load resistor in the plate of the tube and also between the coupling condenser C_K and the control grid of the following tube. Sometimes these coils are connected in parallel with the resistors to broaden their response. Usually the coil is wound right on the resistor, which serves as a form for the coil.

You will remember that a video amplifier must handle frequencies as low as 10 cycles. At frequencies below about 60 cycles, a coupling condenser C_K of the size generally used in amplifier circuits will not allow square-top pulses or flat (constant level) video signals to pass without causing a gradual drop in the flat top. Therefore, a large coupling condenser is generally used between two video stages to increase the low-frequency response. To decrease the amount of shunting capacity C, this coupling condenser is not allowed to lie on the chassis.

In addition, some method of increasing the gain at low frequencies is incorporated in the circuit. In Fig. 14, R_2 and C_5 are inserted in the plate-load circuit as shown, to overcome the drop-off in low-frequency response. The value of C_5, which is usually an electrolytic, is chosen so that it acts as a shunt to ground for the high frequencies, but is not a complete shunt to ground at the very low frequencies. This means that at low frequencies the effect of C_5 is negligible, and R_2 then acts as a part of the plate load, increasing its resistance and thereby raising the gain.

The variable C-bias arrangement for the type 6K6 tube in Fig. 14 provides a manual contrast control. Contrast control potentiometer P is connected in series with the minimum fixed bias resistor R_C. Varying the contrast control not only changes the bias on the tube and its over-all gain, but also it introduces a certain amount of degeneration, since the contrast control is not by-passed. As the degeneration is increased by inserting more resistance in the circuit, the stage gain decreases.

There are, of course, many modifications in the video amplifiers and contrast control circuits, but we will study these in detail later.

THE D.C. RESTORER

As you have already seen, passage of the television signal through a condenser such as is used for coupling purposes in the video amplifier, will remove the d.c. component. This will leave the video signal in its a.c. form as shown in Fig. 13B. As a result, when resistive-capacitive coupling is used between the video detector and the grid of the picture tube, a d.c. restorer section must be used following the condenser to restore the d.c. component and realign the pedestals. This section adds to the a.c. television signal a d.c. voltage that varies from instant to instant in exactly the proper manner to make the pedestals line up again.

In many receivers the d.c. component of the television signal is restored in the output stage of a resistance-capacitance-coupled video amplifier. This is done simply by eliminating the fixed C bias in this last stage and allowing the sync pulses that are applied to the grid of this tube to develop their own C bias by means of a rectified grid current flow through a grid resistor of high ohmic value.

A typical video output circuit that reverses the phase of the a.c. signal and at the same time restores the d.c. component in the correct manner to make the pedestals line up is shown in Fig. 15. Although this circuit employs

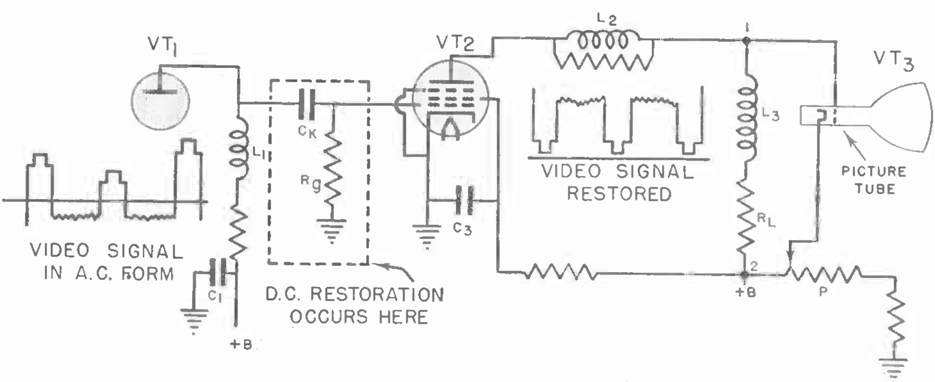


FIG. 15. One method of lining up the pedestals in a TV signal after the d.c. component has been removed by passing the signal through an a.c. amplifier.

a pentode tube, a triode tube could be used. Peaking coils L_2 and L_3 in the plate circuit of tube VT_2 are designed to give gain equalization, and resistor R_L serves its usual function as the plate load.

When an a.c. television signal of the form shown at the left in Fig. 15 (having a negative picture phase) is applied to the circuit, the output signal will be of the form shown at the right, with the pedestals all lined up to give proper restoration of the d.c. component and with the positive picture phase required by the picture tube.

Grid resistor R_g plays an important part in the d.c. restoration process. This resistor has a high ohmic value, generally between 0.5 and 1 megohm, depending upon the type of tube used for VT_2. In order to understand the action of this resistor, we must consider both the E_g-I_p and the E_g-I_g characteristic curves of a tube as shown in Fig. 16. Since there is no fixed C bias for tube VT_2 in Fig. 15, the initial application of a.c. signals I and II to the input of the tube makes the average values of these signals line up with the zero bias line in Fig. 16, and the grid of the tube is therefore driven in both a positive and a negative direction about point A on the E_g-I_g characteristic curve. Since signal I in Fig. 16 corresponds to a bright line and signal II to a black line, we can see that the amount that the grid swings positive is proportional to the brightness of the line being transmitted. These conditions hold true only at the instant of application of the a.c. signal to the grid.

Earlier in your Course you learned that a small amount of grid current flows in the tube even at negative grid-bias values, for some of the electrons that flow from the cathode to the plate under the influence of plate voltage will be trapped by the grid, then flow through the grid resistor to ground. Curve E_g-I_g in Fig. 16 shows how this grid current flow begins at a negative C-bias value corresponding to point B, and increases as the grid is driven less negative and is finally driven positive.

The application of an a.c. television signal (either I or II in Fig. 16) to the

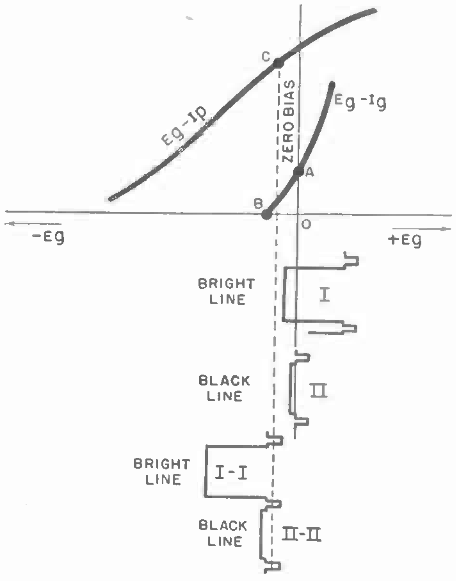


FIG. 16. Characteristic curves for a triode video output tube.

output stage will cause grid current to flow at all instants when the signal is to the right of point B. In Fig. 15, the electrons will travel from the cathode to the grid inside the tube and then through resistor R_g to the cathode again, producing across R_g a voltage drop that drives the grid negative. We thus have a negative voltage on the grid, acting in series with the applied a.c. television signal. The value of this negative voltage depends upon how much the a.c. signal swings positive from the zero bias line, and this in turn depends upon the brightness of the line that is being transmitted. We are thus applying, in series with the television signal, a d.c. voltage whose value is proportional to line brightness. If the ohmic value of R_g is made sufficiently high, the sync pulses alone will produce the grid current that is required for this form of automatic C bias and d.c. restoration action. Use of part or all of the video signal for this purpose would result in undesirable amplitude distortion.

With a negative C bias whose value is proportional to the brightness, each line of the a.c. television signal will be moved in a negative direction along the E_g-I_p characteristic curve in Fig. 16 an amount corresponding to the brightness of the line. Signal I (for a bright line) will be shifted automatically to position I-I, and signal II (corresponding to a black line) will be shifted only a small amount, to position II-II in Fig. 16. The result is an automatic alignment of the pedestals. The alignment is not exactly perfect, but it is near enough for all practical purposes. The operating C bias for the output stage will shift with each change in line brightness, but the tube will always be acting on the linear portion of the E_g-I_p characteristic (as a class A amplifier), producing an output signal which has the required phase and the required alignment of the pedestals.

The time constant of part C_K and R_g in Fig. 15 must be so chosen that it is at least equal to the time period for one line, in order to make the instantaneous grid bias dependent upon the average brightness of a line. Since average brightness ordinarily does not change rapidly from line to line, the time constant can be increased considerably; in fact, a time constant equal to the time for about 10 lines appears to be quite satisfactory.

You will notice from Fig. 15 that the picture-tube grid and cathode are connected across the plate load of the last video tube. As a result, the restored signal across this load is applied between the grid and the cathode.

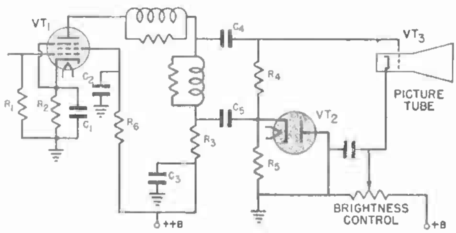


FIG. 17. Here d.c. restoration is secured in the control-grid circuit of the picture tube by means of diode rectifier VT_2. A germanium crystal is sometimes substituted for VT_2, saving space and the filament-current drain of the diode.

In some instances, however, a condenser may be inserted in series with the grid of the picture tube; this, of course, removes the d.c. component. When this is done, another method of restoring the d.c. component is used. This is illustrated in Fig. 17, where the d.c. component is reinserted in the signal at the grid of the picture tube. It will be noted here that the d.c. restorer uses a diode rectifier that could be a tube or a germanium crystal. Both types of rectifiers are widely used in modern television receivers.

Two typical conditions will serve to illustrate how the d.c. restorer in Fig.

17 operates. If the scene being televised is completely black, the amplitude of the voltage representing the picture content will be equivalent to the black level. As a result, if the d.c. component is removed, the picture signal will be at the a.c. axis and the only amplitude variations from this point will be those corresponding to the sync pulses, which will represent rather small amplitudes. If these small pulses are to drive the picture tube beyond cut-off, some means must be provided whereby the bias on the grid is automatically adjusted to cut-off.

We can assume that the initial picture tube bias is determined by the setting of the brightness control, so with no signal, the picture tube is operating at the point of cut-off. Now, if, as described in the previous paragraph, the signal voltage across the video amplifier plate load is small, only a low a.c. voltage is applied in series with the a.c. circuit represented by the plate-circuit decoupling condenser C_3, the plate load resistor R_3, condenser C_5, and the diode rectifier. When the plate is positive with respect to the cathode, the diode rectifier passes current that charges condenser C_5. During periods when the plate is negative with respect to the cathode, the diode rectifier is non-conducting, and the condenser discharges partially through resistor R_5. If the values of R_5 and condenser C_5 are correctly chosen, the charge across the condenser, and therefore the voltage from cathode to ground, will remain substantially constant during the picture interval between successive horizontal sync pulses. The effect of this circuit action is to develop across resistor R_5 a variable bias voltage that opposes the bias due to the brightness control. If part values are properly chosen, this automatic variation in bias will be sufficient to line up the pedestals at the cut-off level, and thus enable the sync pulses to drive the picture tube beyond cut-off.

Another analysis may be made using as an example an all-white scene. Under such a condition, the amplitude of the voltage, corresponding to the picture content, will be maximum. Consequently, after the d.c. component is removed from the signal voltage that is developed across the video detector load resistor, the voltage excursions from the a.c. axis represented by the sync pulses will represent comparatively high amplitudes. Under such conditions, the picture tube bias must be automatically reduced from its correct value for a black scene for blanking pulses to drive the tube to the cut-off point and the sync pulses beyond cut-off. An analysis of the circuit indicates that the larger voltage excursions or peak amplitudes would cause a greater amount of rectification, and therefore a correspondingly greater reduction in picture-tube bias. Thus the d.c. restorer is in reality an automatic bias control that continually adjusts the bias so that the blanking pulses always drive the picture grid to the desired cut-off point and the sync pulses drive it beyond cut-off.

Forming the Picture

THE CATHODE-RAY TUBE

The C-bias voltage for the control grid of the picture tube must have a value that will make the line-up pedestals in the television signal operate at the cut-off point on the grid voltage-brightness (E_g-B) characteristic curve for the picture tube. Let us see how this is accomplished.

When no television signal is being fed to the grid of the video output tube in Fig. 15, there is zero C bias in tube VT_2. As a result, the plate current for tube VT_2 is at its maximum value. This gives a maximum voltage drop between points 1 and 2 on the plate load, with point 1 negative with respect to point 2. If the grid of the picture tube is connected to point 1 and the cathode to point 2, as shown, the negative C bias on the picture tube for no signal will be the entire drop across R_L and L_3; this might correspond to voltage A on the E_g-B characteristic curve in Fig. 18. This voltage places the C bias for the picture

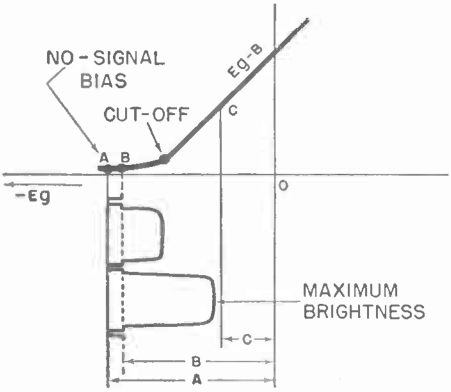


FIG. 18. Grid voltage-brightness characteristic curve for a cathode ray tube, with the television signal shown for the condition where the pedestals are not at the cut-off point.

tube beyond cut-off, and the screen will be dark when no station program is being received.

Application of an a.c. television signal to the grid of the video output stage initiates d.c. restoration action, producing the varying negative C bias required to align the pedestals. As a result, the instantaneous voltage on the grid of the video output tube varies from nearly zero for a sync pulse to a maximum negative value corresponding to a bright line (as shown at I-I in Fig. 16). The pedestals might all line up at voltage B in this case; obviously this is not a desirable condition, for it allows part of the video signal to swing beyond brilliancy cut-off.

To make the pedestals line up at the cut-off voltage, it is necessary to introduce in the grid circuit of the picture tube a positive voltage of the proper value. This can be done as shown in Fig. 15 where the cathode of the picture tube is connected to the movable arm of potentiometer P, a part of the voltage divider connected between B+ and chassis. As the slider of potentiometer P in Fig. 15 is moved toward the right, the negative voltage on the control grid of the picture tube is reduced, and increased brilliancy results. Moving the potentiometer toward the left as shown in Fig. 15 results in increased bias and a darker over-all picture.

Although the brightness control shown in Fig. 15 is entirely satisfactory and is widely used, there is some danger of damaging the picture tube if the video output tube burns out. In this case no plate current would be drawn by the video output tube and point 1 would be of the same potential as point 2. If the slider of potenti-

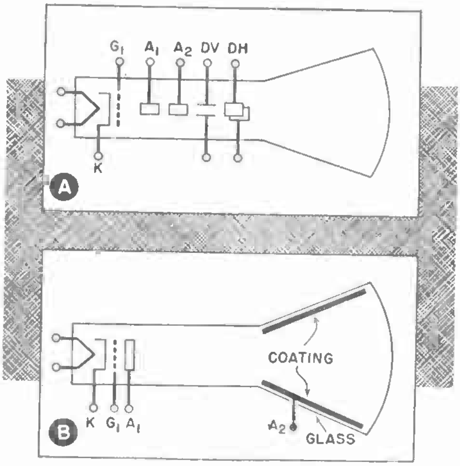


FIG. 19. The electrodes found in electrostatic and electromagnetic picture tubes.

ometer P is turned toward the right, the cathode of the picture tube will be negative with respect to the control grid—in other words, a positive voltage will be applied to the control grid. Usually this will not damage the screen of the picture tube, but the cathode of the tube could be harmed.

If the brightness control shown in Fig. 17 is used, the bias on the picture tube is entirely independent of the last video amplifier, and unless leakage should develop in condenser C_4 or C_5 nothing would occur that would drive the picture tube grid positive. These are obscure complaints, however, that seldom occur and are not a great problem.

PICTURE-TUBE ELECTRODES

The important electrodes in an electrostatic picture tube are shown in schematic form in Fig. 19A. In addition to the heater (filament), the cathode, and the control electrode G_1 (the control grid), there are two anodes marked A_1 and A_2. These anodes are positive with respect to the cathode, and provide acceleration of the electrons. Anode A_2 is higher in potential than anode A_1. The difference in potential between these two anodes serves to produce an electric field that makes the electrons focus to a point on the screen. Finally, there are electrostatic deflecting plates DV and DH that serve to sweep the beam horizontally and vertically across the screen.

In Fig. 19B the electrodes of an electromagnetic picture tube are shown schematically. Again we have the heater, the cathode, the control grid, and anode A_1 which serves as an accelerating anode. Further acceleration is obtained by means of anode A_2 which consists of a coating on the inside of the glass envelope of the tube. In the metal tubes, the entire metal shell serves as the second anode. A very high voltage is applied to the second anode, and a relatively low voltage, about 300 volts, is applied to the first anode. In these tubes, focusing is accomplished by means of a magnetic field produced by direct current through a focusing coil; other coils carry the currents used to provide magnetic fields for the vertical and horizontal sweeps.

SWEEP CIRCUITS

In both the electromagnetic and the electrostatic picture tube, a saw-tooth sweep is used to move the electron beam back and forth and up and down across the face of the tube. In the electrostatic tube, a saw-tooth voltage is applied to the deflecting plates; in the electromagnetic tube, a saw-tooth current is produced in the deflecting coils that surround the neck of the picture tube.

The sweep circuits used for the electromagnetic and electrostatic tubes are quite similar, although there are a few differences. First, we will consider the sweep circuits for the electrostatic tubes.

In the electrostatic tube each pair of deflecting plates must be fed with a saw-tooth voltage of the correct frequency. The voltage applied to a pair of deflecting plates should have the form shown at C in Fig. 20, which is an a.c. voltage having a saw-tooth wave form.

The circuit shown in Fig. 20 will produce a saw-tooth pulsating a.c. voltage if its grid is controlled by pulses of constant amplitude and duration, so this circuit is satisfactory for a television receiver. The circuit uses an ordinary high-vacuum triode tube, with plate voltage applied through resistor R_L. A bias voltage applied through resistor R_g makes the grid sufficiently negative to give plate-current cut-off, there is no plate current, and condenser C becomes charged to the full plate-cathode voltage of the tube.

Each time a positive sync pulse (A) reaches the grid of this tube, the pulse overcomes the negative grid bias and makes the tube conductive for the duration of the pulse. Condenser C then discharges through the tube, which has a definite resistance when conductive. At the end of a sync pulse, plate current flow stops, and condenser C charges up again through R_L. Since the tube when conductive has a considerably lower resistance than R_L, the discharge is far more rapid than the charge. We thus have a gradual build-up in the voltage across C until a pulse arrives, then a sudden drop in voltage during the pulse interval, this process repeating itself for each sync pulse. The voltage across C will be a d.c. voltage having the saw-tooth wave shape shown at B in Fig. 20. When this voltage is applied through condenser C_K, the d.c. component is removed, giving the a.c. saw-tooth wave shape shown at C in Fig. 20.

The saw-tooth generator circuit shown in Fig. 20 cannot be driven directly by the received sync pulses, because the shape of its saw-tooth output wave depends upon both the amplitude and the duration of the pulses fed into it. Under practical receiving conditions, the sync pulses are not constant in amplitude and duration. If they were used to drive a saw-tooth generator, therefore, the shape and frequency of the saw-tooth output would not be constant. Instead, each saw-tooth generator circuit must be driven by an oscillator that will produce pulses of constant amplitude and the correct duration. This will make the saw-tooth generator circuit produce a constant and correct saw-tooth sweep voltage at all times.

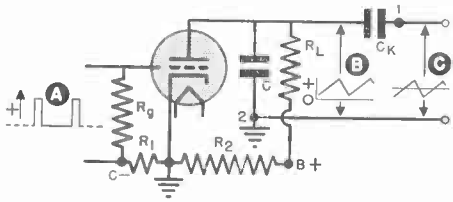


FIG. 20. Saw-tooth sweep circuit.

An oscillator that is controlled by the TV sync pulses but disregards any variation in their amplitude or duration is used as the driving unit for the saw-tooth generator. Furthermore, each oscillator circuit produces positive pulses at a rate slightly lower than the correct frequency for the generator, and is so designed that the frequency of the oscillator will increase to the correct value automatically when fed with the sync pulses that are associated with the TV signal.

An oscillator circuit that meets these requirements is shown in Fig. 21. It is known as a self-blocking oscillator, commonly called a blocking oscillator, and is used for both electromagnetic and electrostatic sweep systems.

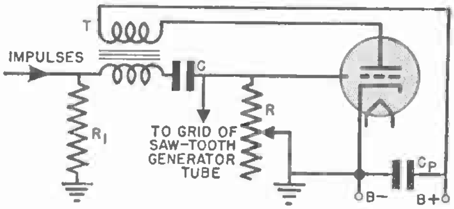


FIG. 21. Self-blocking oscillator circuit which can be controlled by synchronizing impulses.

Transformer T in this circuit provides feedback from the plate circuit to the grid circuit. The transformer connections are such that when the circuit is in operation, the feedback voltage drives the grid positive, just as in a conventional oscillator. The resulting flow of grid current through R produces a voltage drop across R which drives the grid highly negative and at the same time charges condenser C. This charging action lasts for only a brief interval equal to the time required for the negative grid to stop all electron flow in the entire circuit. Condenser C then begins discharging through resistor R at a rate determined by the values of C and R. Both R_1 and the grid winding of transformer T have a low resistance, and consequently the terminal of the winding to which R_1 connects can be considered as connected to ground during this discharge process. When the charge on condenser C has leaked off enough to lower the negative C bias on the grid sufficiently to allow plate current to flow again, feedback then takes place, driving the grid positive, and causing a repetition of the entire cycle.

The frequency of the blocking oscillator circuit in Fig. 21 is controlled by variable resistor R, because it controls the time constant of C and R. The natural frequency of blocking should always be lower than the frequency of the sync pulse that is fed into the circuit, because then the sync pulse will arrive just before the oscillator can unblock by itself and will therefore control the unblocking action. (If the pulse were to arrive after the oscillator had unblocked, it would have no effect on the frequency of operation.) The sync pulse controls the unblocking action because it swings the grid positive almost instantly, starting a new cycle. The same form of sync pulse is produced by this blocking oscillator regardless of the amplitude and duration of the TV signal sync pulses (provided their amplitude is sufficient to swing the grid positive). Sync pulses thus determine the exact frequency of the controlled pulses that are fed to the saw-tooth generator, and these new pulses always have the correct amplitude and duration to control the saw-tooth generator so it will produce the desired sweep voltage.

In actual use, resistor R may be mounted on the front panel so that the customer can make readjustments as necessary, or it may be of a semi-adjustable type mounted on the rear chassis apron. In the latter case, R is adjusted by the technician (at the time of installation) to a compromise setting which gives maximum sensitivity to weak pulses and at the same time insures that the pulses will control the frequency of blocking under all normal receiving conditions.

The grid of the blocking oscillator in Fig. 21, being highly negative with respect to the chassis except for the duration of each pulse, may be connected directly to the grid of the saw-tooth generator circuit in Fig. 20. With this connection, no separate negative bias is needed for the saw-tooth generator grid, and parts R_g and R_1 in Fig. 20 may be omitted. Usually the generator tube and the oscillator

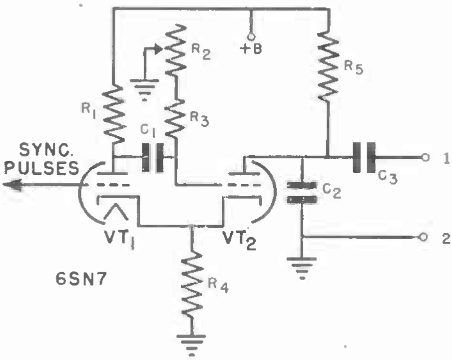


FIG. 22. Saw-tooth generator of the mutivibrator type.

tube are in a single envelope. A double triode such as the 6SN7 is used. One double triode with its blocking oscillator and saw-tooth generator circuit must be provided for the horizontal sweep and another similar system for the vertical sweep, each circuit being adjusted to give the proper sweep frequency.

In some instances, particularly in receivers using electrostatic tubes, the self-blocking oscillator in Fig. 21 and the discharge tube in Fig. 20 may be replaced by a multivibrator like that shown in Fig. 22. This saw-tooth generator uses a type 6SN7 tube as a conventional cathode-coupled multivibrator. The multivibrator can be easily adjusted with the hold control R_2 to oscillate slightly below the correct frequency. The pulses that are applied to the grid of VT_1 will increase the multivibrator frequency automatically to the correct value. Tube VT_2 acts as a discharge tube across condenser C_2 to give a saw-tooth output. The values of C_2 and R_5 are chosen to permit use of the linear portion of the charging curve.

SWEEP AMPLIFIERS

The output of a sweep generator is never sufficient to bend the beam in a picture tube. For this reason, amplification of the sweep generator output is always required.

In the electromagnetic picture tube, the current that passes through the deflection coils is used to produce the magnetic field that bends the beam. A power amplifier between the sweep generator output and deflection coils is required.

In Fig. 23 you will find a typical voltage amplifier for an electrostatic picture tube. Notice that push-pull operation is used because it reduces the total amount of sweep voltage required. The saw-tooth voltage is developed across discharge condenser C_1 in Fig. 23 and is applied through coupling condenser C_2 to the input of tube VT_2. Resistor R_2 controls the

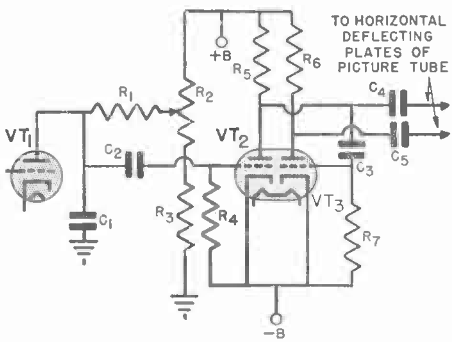


FIG. 23. Push-pull horizontal sweep amplifier for an electrostatic picture tube.

amplitude of the saw-tooth sweep. The signal across grid resistor R_4 is amplified by VT_2 and appears across plate load resistor R_5. This saw-tooth voltage is passed through coupling condenser C_4 directly to one of the horizontal deflection plates of the picture tube. Some of the voltage at the output of tube VT_2 is tapped off through condenser C_3 and develops a saw-tooth voltage of the correct amplitude across grid resistor R_7 of tube VT_3. This tube amplifies the signal, which is 180 degrees out of phase with the signal that is fed to the input of

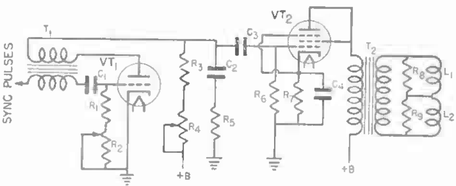


FIG. 24. Single-ended amplifier typical of those used in vertical sweep circuits of electromagnetic picture tubes.

VT_2, and the amplified signal appears across the plate load R_6. Coupling condenser C_5 serves to impress this voltage on the other horizontal deflection plate.

There is practically no difference between the horizontal- and vertical-sweep amplifiers used in electrostatic receivers, with the exception of part value variations. Coupling condensers C_4 and C_5 for the vertical sweep must be far larger in capacity than those for the horizontal sweep, since the vertical sweep operates at 60 cycles, and the horizontal sweep operates at 15,750 cycles.

Fig. 24 is a typical vertical-sweep amplifier circuit used with an electromagnetic picture tube. A conventional blocking oscillator is used, and resistor R_2 is used to vary the sweep-frequency rate. The blocking oscillator also acts as the sweep generator. The amplitude of the generated sweep signal is determined by the setting of resistor R_4. Condenser C_2 and resistor R_5 serve to produce the correct sweep wave shape, which is applied through condenser C_3 to the input of vertical-amplifier tube VT_2. This tube is a pentode but you will note that it is connected as a triode, with the plate and screen tied together. An output transformer that will permit maximum power to be delivered to the vertical deflecting coils marked L_1 and L_2 is used. Resistors R_8 and R_9, in parallel with the vertical deflection coils, are used to damp out any tendency toward self oscillation in this circuit. The currents through L_1 and L_2 have a saw-tooth wave shape, although they are produced by a voltage that differs considerably from a saw-tooth. The reason for this will be explained in greater detail when we study sweep circuits in another Lesson.

There is considerable difference between the horizontal and vertical amplifiers in an electromagnetic picture tube. A horizontal-amplifier circuit is shown in Fig. 25. A high-power tube is used here. The plate generally comes out to the top-cap connection. (You should never make the mistake of touching a top cap of a horizontal output tube since several thousand volts may be present as a result of the high value of inductance in the plate circuit.)

The sweep signal is applied to the input of this tube across resistor R_1 in the usual manner, and the amplified

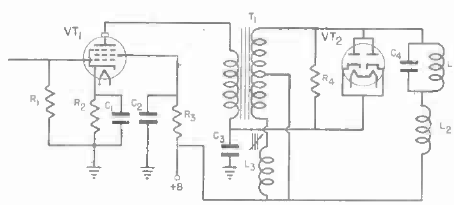


FIG. 25. Horizontal amplifier and deflection coils showing damper tube used to prevent fold-over in the raster.

signal across the primary of T_1 is transferred to the secondary. The current flowing in the secondary circuit and through deflecting coils L_1 and L_2 can be limited by adjustable inductance L_3. This inductance is therefore the horizontal-width control.

The Damping Tube. The linear rise of current through the horizontal deflection coils moves the electron beam from the left to the right side of the picture in approximately 53 microseconds. The current must then return to its starting value at approximately 7 microseconds to produce the

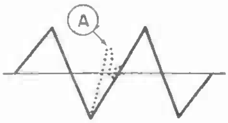


FIG. 26. Current through horizontal deflection coil and oscillation removed by damping tube.

retrace. This sudden collapse of current through an inductance produces an oscillatory condition, shown at A in Fig. 26, that would destroy the linearity of the sweep and must be removed by the damping tube. This tube is VT_2 in Fig. 25. When the plate of the damping tube becomes more positive than its cathode, conduction occurs, heavily loading the circuit, and preventing the undesirable oscillation. As a result of this conduction, a d.c. potential of approximately 100 volts is developed and stored in condenser C_3. This voltage is added to the normal plate voltage of the horizontal amplifier and makes its potential considerably higher than that from the power supply of the receiver alone. Unless this salvaged energy is used, there will be considerable loss in efficiency.

Damping-tube actions will be described in greater detail elsewhere in the Course, but you will be interested to see in Fig. 27 the effect of a burned-out damping tube. Notice how the horizontal-sweep linearity is destroyed so that overlapping or "fold-over" occurs at the left of the test pattern.

SPOT-CENTERING CONTROLS

It is not economically practical to build a gun in a cathode-ray tube that will produce a spot in the exact center of the screen when there are no deflecting voltages applied to the plates of an electrostatic tube, or when there is no current flowing through the deflecting coils of an electromagnetic tube. Some adjustment must be provided that will move the spot to the exact center of the screen and thereby center the reproduced image on the screen.

In Fig. 23, the required sweep voltage exists at the output of condensers C_4 and C_5 and must be applied to a pair of deflecting plates in the picture tube as shown in Fig. 28. Condensers C_4 and C_5 are coupling condensers (like the ones shown in Fig. 23), and resistors R_1 and R_2 complete the return circuit for deflecting plates 1 and 2 and also serve as the signal load for the sweep voltage supplied through condensers C_4 and C_5. Notice that plate No. 1 connects to point b on the voltage divider. Plate No. 2 connects

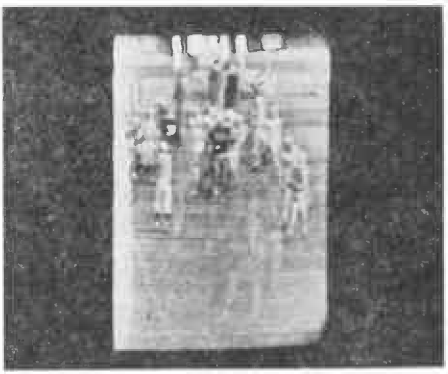


FIG. 27. Fold-over in raster due to defective damper tube in horizontal sweep.

to the slider of potentiometer R_6. Moving the slider toward point a makes plate 2 more positive than plate 1, and the beam is bent toward plate 2 while being repelled by plate 1. Moving the slider toward point c makes plate 2 negative with respect to plate 1, and the beam is repelled from plate 2 and attracted toward plate 1. By properly adjusting R_6 the beam can be exactly centered. A similar system is used for the other pair of deflection plates.

It is also necessary to center the beam in an electromagnetic tube using a sweep system such as that shown in Fig. 24. In this figure, no means is provided for centering the beam; centering is done by moving the focus coil. This will be taken up in detail later. In many sets, an actual adjustment is often used for centering purposes in an electromagnetic picture tube. A typical system is shown in Fig. 29. Here we have a low-resistance tapped potentiometer in the B-supply circuit. Notice that the secondary of the sweep transformer connects directly to point 2 and through deflecting coils L_1 and L_2 to the slider of the potentiometer.

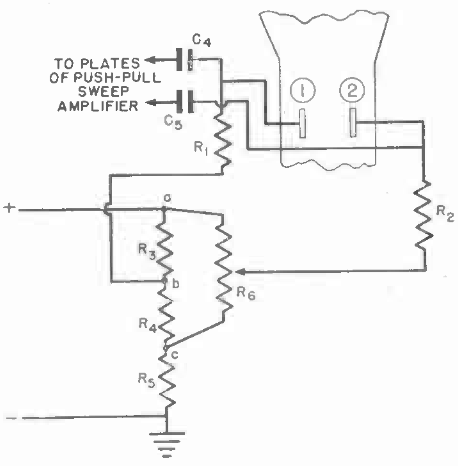


FIG. 28. Electrostatic centering control.

When the slider is placed at point 2, no d.c. flows through the deflecting coils. When the slider is moved toward point 1, electrons will flow from point 2, through the secondary of output transformer T_1 and through L_1

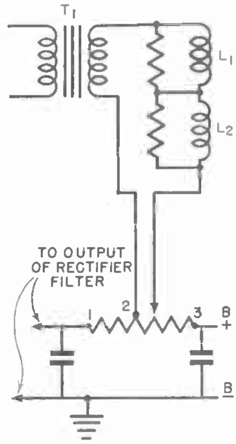


FIG. 29. Electromagnetic centering control.

and L_2 back to the slider. This will bend the beam in a given direction. When the slider is moved toward point 3 it reverses the direction of current flow, and the electrons now travel from the slider, through L_2 and L_1, the secondary of T_1, and back to point 2. This moves the beam in the opposite direction. Proper adjustment of the slider gives exact centering of the beam, and hence centering of the reproduced picture on the screen. The same method can be used for either the horizontal or vertical sweeps in electromagnetic picture tubes.

Sync-Separating and A. G. C.

SYNC-SEPARATING CIRCUIT

Before the synchronizing pulses that accompany the video signal can be made to control the horizontal and vertical sweep circuits, the sync pulses must be separated from the video signal, and the horizontal sync pulses must be separated from the vertical sync pulses.

Either a triode or a pentode tube that is negatively biased to plate current cut-off or a diode tube will separate the sync pulses from the video signal, provided that only the pulses cause plate current to flow. The television signal that is fed into the sync separator circuit can have either a positive or a negative picture phase, but in either case *the pedestals must be lined up*. Alignment of the pedestals makes the use of a negative picture phase more desirable, as you will shortly see.

If the sync separator is to be connected to a point in the video amplifier where pedestals are not lined up (where only the a.c. component of the television signal is present), *the pedestals must be lined up by properly restoring the d.c. component* before the signal can be fed into the sync-separator tube.

The sync separator will have a loading effect upon any stage to which it is connected, even though the separator tube is negatively biased, for the separator circuit has an input capacity that can affect the high-frequency response of the video amplifier. There is one point in a television receiver to which this input capacity can be connected without affecting high-frequency response. Referring to Fig. 30, you will see that one half of a duo diode is used as a video detector. The other half of the tube may be used as the sync separator or clipper. This is section VT_1 of the 6AL5 shown in Fig. 30. Section VT_1 rectifies the video signal applied to it through condenser C_1, the path of electron flow being through R_2, VT_1, and R_1. The input time constant, which is governed by the values of C_1 and R_1, is such that VT_1 holds its bias just above black level and delivers separated sync pulses to sync amplifier VT_3. The pi filter composed

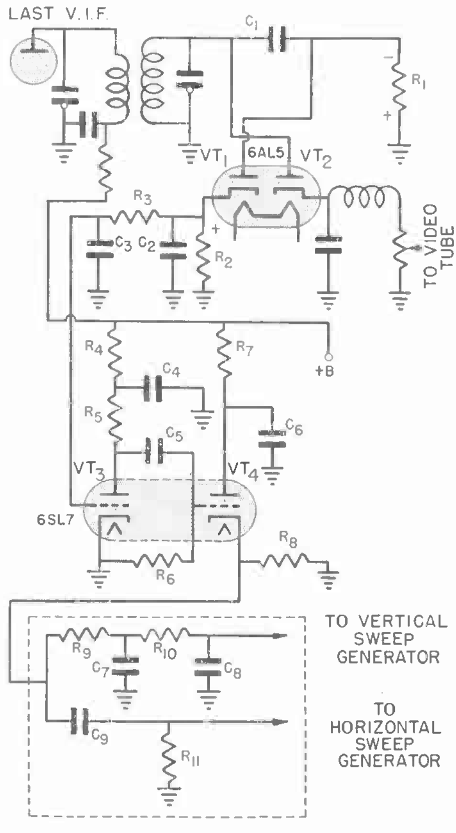


FIG. 30. Here are shown the detector, the sync separator and amplifier, and the sync limiter, which delivers noise-free, constant amplitude pulses to the sweep generator. That portion of the circuit shown in the dotted lines separates the horizontal and vertical pulses.

of resistor R_3 and condensers C_2 and C_3 separates the video i.f. frequency and hash from the sync pulses.

The sync amplifier VT_3, and the sync limiter VT_4, frequently precede saw-tooth generators of the multivibrator type shown in Fig. 22. VT_3 and VT_4 share a type 6SL7 tube and VT_3 amplifies both the horizontal and vertical pulses obtained from VT_1. Section VT_4 acts as a limiting cathode follower which clips off the noise peaks and supplies constant amplitude sync pulses to the saw-tooth generator circuits.

The grid of sync amplifier VT_3 is d.c. coupled to the cathode of VT_1. Resistor R_4 drops the voltage applied to the sync amplifier with R_5 as the plate load resistor. Resistor R_7 and condenser C_6 supply low d.c. voltage to the plate of the cathode follower. When a sync pulse is rectified by VT_1, it causes the cathode end of R_2 to become positive, thus applying a positive voltage pulse to the grid-cathode of VT_3 and increasing its plate current. The voltage drop across R_5 increases, which reduces the plate voltage of VT_3, allowing C_5 to discharge through R_6 and VT_3. Electrons flow from C_5 through R_6 to the chassis, making the grid of VT_4 negative and decreasing its plate current. This reduces the voltage across R_8. When picture signals are being transmitted, no signal reaches the grid of VT_4 and the voltage across R_8 has a constant value. Sync signals cause this voltage to decrease.

When the voltage variations are of short intensity, as they are for the horizontal sync pulses and the horizontal equalizing sync pulses (serrations) in Fig. 31, C_9 charges and discharges through R_{11}, producing the required horizontal timing pulses for the horizontal saw-tooth generator. This is due to the short time constant of C_9 and R_{11} which enables the condenser-charging current to follow faithfully the voltage variations shown in Fig. 31. Thus, horizontal sync pulses are obtained even during the vertical synchronizing periods, as is required.

With no sync signals being received, C_8 in the vertical separator circuit is charged up to the same voltage as appears across R_8. The time constant of this circuit is slow, and C_8 does not have time to discharge on the widely separated horizontal sync pulses. When the vertical sync pulses arrive, C_8 will gradually discharge, being relatively unaffected by the short duration serrations, and the decrease in voltage across C_8 at this time is used to control the vertical saw-tooth generator.

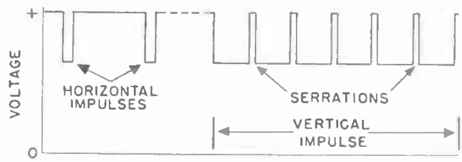


FIG. 31. Wave forms of impulses at the output of the amplitude-separator section.

AUTOMATIC GAIN CONTROL

The final television receiver section to be considered is that which provides the automatic gain control voltage. In this section, again, it is best to use the television signal in its d.c. form with pedestals lined up. The voltage for the a.g.c. circuit should be obtained across a load resistor which is shunted by a large condenser, in order to give a time constant so long that the voltage will follow the sync pulse peaks. Doing this insures that the a.g.c. voltage will depend upon carrier level (or its equivalent, the level of the sync pulse peaks), rather than upon line brightness.

Tube VT_1 in Fig. 30 produces across

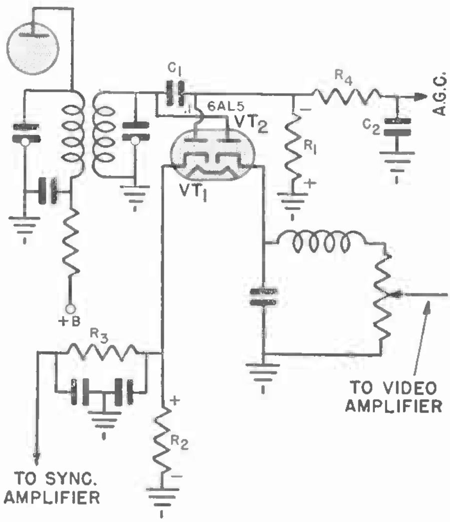


FIG. 32. By filtering the voltage across R_1, and a.g.c. voltage is obtained across C_2.

R_1 a voltage that follows the sync pulse peaks and has the correct polarity for a.g.c. purposes. It is only necessary to add an R-C filter composed of C_2 and R_4, as shown in Fig. 32, to complete the a.g.c. system. The a.g.c. voltage appears across C_2 and will follow at all times the level of the sync peaks. If for any reason the carrier fades, the a.g.c. voltage will be reduced and the receiver gain will increase. An increase in carrier level increases the a.g.c. voltage, which in turn will reduce the receiver sensitivity.

In this manner the 6AL5 tube shown in Fig. 32 serves three purposes; acting as the video detector, the amplitude separator, and the a.g.c. This is a very simple a.g.c. system. Some sets use complicated circuits. These will be described in detail in another Lesson.

REVIEW OF LESSON

In reviewing this Lesson, try to visualize the frequency conversions that occur and the new frequencies developed as the television signal progresses through the receiver. Learn the frequency ranges that are handled by each stage and section, and above all, try to visualize the characteristics of the television signal at each stage or section. Furthermore, keep in mind that in television the terms *picture signal, video signal, image signal,* and *sight signal* are used interchangeably. The terms *sound* and *audio* are likewise used interchangeably.

Lesson Questions

Be sure to number your Answer Sheet 50RH-2.

Place your Student Number on *every* Answer Sheet.

***Send in your set of answers for this Lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. If a signal having a positive picture phase is fed to the grid of a video amplifier, what will be the picture phase of the amplified signal in the plate circuit of the stage?

2. Why does passage of a video TV signal through a condenser cause misalignment of the pedestals?

3. Why cannot the sync pulses in the TV signal be used to drive a sweep saw-tooth generator?

4. Why should the natural frequency of a sweep oscillator be lower than the frequency of the sync pulses?

5. How may the phase of the picture signal at the output of the diode video detector be reversed?

6. Why must the pedestals of a video signal all be lined up at the same constant level at the input of the picture tube?

7. Why are video amplifier stages operated with low plate loads?

8. Why is a large capacitor usually used as the coupling condenser between two video stages?

9. What is the purpose of the resistors connected in parallel with the vertical deflection coils in an electromagnetic sweep circuit?

10. What is the purpose of the sync separator or clipper?

Be sure to fill out a Lesson Label and send it along with your answers.

PAY ATTENTION TO LITTLE THINGS

It is the close observation of *little things* that is the secret of success in business, science, and every pursuit in life. Human knowledge is only an accumulation of small facts.

You may come across some facts and observations in your NRI course that may seem to be unimportant. But keep in mind that all will have their eventual uses and will fit into their proper places.

When Franklin made his discovery of the identity of lightning and electricity, people asked, "Of what use is it?" Franklin replied, "What is the use of a child? It may become a man!"

When Galvani discovered that a frog's legs twitched when put in contact with different metals, his observation did not seem important. But this observation was the "germ" of the telegraph.

Yes—it is well worth-while to *pay attention* to little things. When added up and used properly, great things may result.

J. E. Smith

RADIO ACCOUNTING AND RECORDS

REFERENCE TEXT 50RX

PIONEER HOME STUDY RADIO SCHOOL

NRI

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WASHINGTON, D. C.
ESTABLISHED 1914

KNOW YOUR COSTS

Where does your money come from, and where does it go?—these are two simple questions which have determined the success or failure of many a man starting up a business of his own.

There is a fair charge for each piece of work you do; excessive charges give high profits temporarily but result in failure through lack of business in the future, and too low profits or even losses on a job are just as disastrous. In order to determine the proper charge for each job, you must keep records of your expenses and your income, just as is done in any other successful business. These records need not be complicated—in fact, you will marvel at the simplicity of the system described in this lesson.

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

1951 Edition

A LESSON TEXT OF THE N. R. I. COURSE
WHICH TRAINS YOU TO BECOME A
RADIOTRICIAN & TELETRICIAN
(REGISTERED U. S. PATENT OFFICE) (REGISTERED U. S. PATENT OFFICE)

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RADIO ACCOUNTING AND RECORDS

A Simple System of Records

THERE are certain basic dollars and cents facts that a man must know about his business to operate it successfully. The simplest possible system of records that will give you these facts is the best system for you. Elaborate records have no place in a one-man business. Your records, on the other hand, must be adequate to fit your needs, and give the necessary figures that are required for proper management and planning. Your records must be set up to provide adequate figures for the preparation of State and Federal tax returns statements that may be required by your bank should you desire to borrow, and financial statements as requested by Finance and Credit Companies. If you expect to grow and prosper under present-day competition, you must start at the beginning to use the tools of business. Figures are the tools of business, just as meters, screwdrivers, and soldering irons are the tools of the repair man.

► We recognize that you cannot spend much time on accounting work, so in this lesson we have planned a very simple Accounting System.

When your business grows and a more elaborate system of records becomes necessary it will be to your advantage to employ an accountant to install such a system, and you should hire a bookkeeper - typist - telephone clerk to do the office and clerical work and relieve you of this detail. Your job is to get out after the business, render satisfactory service, and bring in the profits.

► In the beginning, as you build up your volume of service work, you will need to know the exact cost of doing the work. How else can you know what to charge to make a profit? You must know how much profit you make and where the profit is coming from. You must know how much money you take in, where it goes, what is owed to you, and exactly how much you owe.

There are other facts and figures that may be helpful in building up your business. Those just mentioned are the essential ones, however. You will find them all included in the simple system described in this book.

If you follow the rules given in this lesson, you will be well on the road to success. If you do not follow them, you take the chance of becoming a complete failure as a business man, and this will be true no matter how skillful you are as a Radiotrician.

Income and Expenses. The first essential of any system of records is that a *complete and detailed* account be kept of all income and all expenses. Therefore, we will start with a record of cash received and payments made.

CASH

The first rule in our system is extremely simple; for that reason, it is easy to neglect it. This rule is sound accounting practice—and sound business sense as well.

► *Rule No. 1. All cash that comes in to the business and all cash that you receive for your service work must be deposited—without deductions of any kind—in the bank.* If the receipts are large enough to deposit daily, make a deposit every day. If not, then make your deposits twice a week. Establish this practice in the beginning and stick to it.

Maintain this practice by keeping all personal funds and expenses separate and distinct from those of your business. If you mix them, there will be no good way of determining the profit your business is earning, and the whole purpose of these simple records will be defeated. For your personal needs such as clothing, salary, etc., draw a check against your business and payable to yourself, stating clearly on the stub of the check that it is for personal use. The reason for this rule will shortly become apparent.

Petty Cash Fund. You will naturally ask, "If I put all the money in the bank, how will I pay for the many small items that I have to buy for the business, such as replacement parts, stationery, office supplies, etc.? These small expenses come up every day. I have to pay for them with cash."

You will handle this in the manner used by nearly every business, large and small—by the use of a petty cash fund. Write out a check payable to yourself for $5, $10 or $15, depending on your requirements. Put this money in a safe, convenient place. This can be a box or a drawer, or even a special wallet or money pocket. The important thing is to keep it strictly separate from all other funds.

Pay all small bills chargeable to your business from this fund. As you spend the money from this fund, place a receipt or slip of paper in the money box, showing the exact amount of money spent, what it was spent for, and the date.

The total of these receipts and slips plus the balance of cash left in the fund should at all times equal the total amount of the fund you began with. Thus, if your original petty cash fund is $10 and the balance of the cash on hand is $4.18, you should have receipts, slips, and tickets accounting for the expenditure of $5.82.

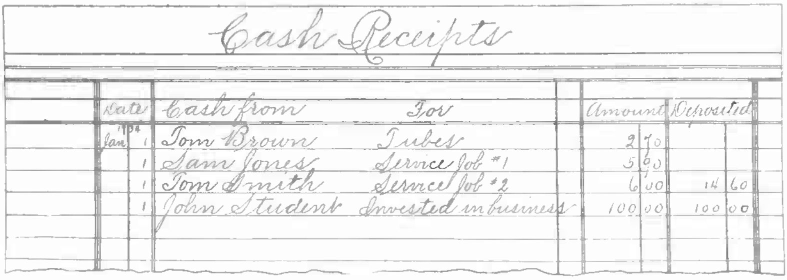
You may be out on a job and find it necessary to buy some small part out of your pocket. Be sure to collect from the petty cash fund when you return. A large part of your expenses will be paid from petty cash, and strict adherence to this rule is even more important to you than to a larger business.

When your petty cash fund gets low, take all the receipts or memos, and add them up. Write out a check payable to yourself for the total of these receipts, cash the check, and place the amount received in your petty cash fund. The cash from the check, added to the amount remaining in the fund, should bring the amount of cash on hand to the original figure. Repeat this procedure as often as necessary. The receipts and memos should be clipped together or put in an envelope, marked plainly with their total and the date, and filed away as shown in the section "A Voucher System."

Cash Receipts Record. For our record of cash received we shall require a standard blank book which can be obtained from practically any stationer. Be sure to get one that is "journal-ruled." Forms *1* and *2* illustrated in this book are made on journal-ruled paper.

Turn to the middle of the book and head one of the pages *Cash Receipts*. This part of the book will be your *Cash Receipts Register*. Head the columns as shown in Form *1, Date, Cash from, For, Amount,* and *Deposited*.

► Now for *Rule No. 2. Enter faithfully in this book all cash received, including the personal cash that you put into the business*. The last column you will note is reserved to show the deposits in the bank. At the end of the month add the column showing the *amount* received. Then add the column showing the amount *deposited*. If you have followed rule No. 1 and if your figures are correct, these two totals will agree.



Cash Receipts

Date		Cash from	For	Amount		Deposited	
Jan	1	Tom Brown	Tubes	2	70		
	1	Sam Jones	Service Job #1	5	90		
	1	Tom Smith	Service Job #2	6	00	14	60
	1	John Student	Invested in business	100	00	100	00

Form 1

A VOUCHER SYSTEM

It is as important to keep a record of all payments made by the business as it is to record all cash received. It is necessary to buy shrewdly and watch expenses carefully. It is equally necessary to know at all times how much you owe, which items are due, the bills that have been paid, and the date that they were paid. A properly kept voucher system will give you this information with a minimum of work.

A voucher in its simplest form is any okayed or approved invoice or bill for goods purchased, or memorandum of services purchased. You do not require a special printed form. If you buy ten tubes from the O.K. Tube Company and they render an invoice, all you have to do is mark it "goods received and okay," date it.

number it, and for your purpose it is a perfectly good voucher. When you take the slips from your petty cash box, put them in an envelope or fasten them together; put a slip with them showing their total amount, the date, number of the slip, and it becomes a voucher. When you draw cash from the bank for your personal expenses, write out a slip with your name on it, the amount, the date, and number it — and this memo serves as your voucher.

► Now we have *Rule No. 3. Never make a payment of any kind unless you have a bill, or a complete memorandum showing the date, the amount, the purpose of the payment, and a voucher number.* Vouchers should be numbered consecutively. (You can start with number 1.)

A simple method is necessary for recording, paying, and filing vouchers. Use the first part of the journal-ruled blank book already mentioned. (See Form *2*.)

Head up the first page of your blank book with the words *"Voucher Register."* Then mark the columns as shown in the figure, *Date, Pay to, For, Voucher No., Amount,* and *Date Paid.*

Let us suppose that your first transaction is to set up a petty cash fund. You make up a memorandum for "Petty Cash," write the amount, the date, and number it in the upper right-hand corner "Vou. No. 1." You might next receive a bill for tubes sold on thirty-day terms, which means that it is to be paid in thirty days. If you think that you will have enough money to take the discount offered for prompt payment, deduct the discount. If, on the due date you find that you cannot make payment, it will be necessary for you to make another entry in the Voucher Register (using the original voucher number) for the amount of the discount originally deducted from the bill. Check this bill carefully against the tubes received, okay it, mark the date, and number it "Vou. No. 2" in the upper right-hand corner.

Now enter both of these vouchers in the voucher register that you have prepared; enter the amount due or to be paid in the first money column and leave the second money column (Date Paid) blank for the present.

All vouchers must be carefully filed. Have one file for unpaid vouchers and one for paid vouchers. Elaborate facilities are not necessary—probably a stout cardboard box will do. A heavy envelope or file pocket may be satisfactory for each file. Place unpaid vouchers in your unpaid voucher file in alphabetical order, and paid vouchers in your paid voucher file in numerical order.

Turning again to your voucher register, you can see how easy it is to tell once a month what the total expenses of your business have been, what you have withdrawn for your personal use, and the grand total of all expenses.

PAYMENTS

As you know, Rule No. 1 is to deposit all money in the bank. This means that it is necessary to pay all bills by check. (The only exceptions are small bills paid out of petty cash fund, but, as this fund is always renewed by check, we accomplish the same result.)

► The success of the voucher system and the control of expenditure of business funds lies in strictly following *Rule No. 4. Always pay by check.*

All bills that are to be paid have been made vouchers with numbers on them and filed in the unpaid voucher file. When the time comes to pay the voucher, remove it from the unpaid voucher file and use the following safe procedure in making up your check. (See Form *3*.)

Before filling out the check, fill out the check stub. Show, in the usual spaces provided, the date of the check, the number of the check, the name of the person or firm to which the check is payable, and the number of the voucher that is being paid.

Now fill in the check completely, being careful of the check number, the date, and especially of the amount to be paid. In the lower left-hand corner of the check put the number of the voucher being paid. If the payment is for more than one voucher, show all voucher numbers. This makes it easy in case of dispute to get out the paid vouchers covered by the check.

Now get out your voucher register and make sure that every voucher being paid is properly entered and that the amount of the check agrees with the total of the vouchers being paid, not only as shown on the vouchers but also as entered in the register.

Then, note in the last money column of the voucher register, opposite the items paid, the date of payment, and the check number. Mark your voucher paid, showing the date of payment and the check number. Then file the voucher in the paid voucher file in proper numerical order.

At the end of the month, your voucher register will very likely show some items with no payment notations beside them. These should be items which are not yet due. Check these open items on your voucher register against your unpaid vouchers, and add them up; you should have the exact total of the amount that you owe.

In a sizeable business, a payment register becomes necessary. To save you work, the system outlined in this book eliminates a payment register and uses the check stubs only. You will simply show on each check stub the amount of each check as drawn and the total amount of the checks already drawn to date during the month. Add the amount of each check to the sum of the checks brought forward. You will thus have at all times the total of the checks drawn during the month and will automatically have this figure ready at the end of the month when you do your checking.

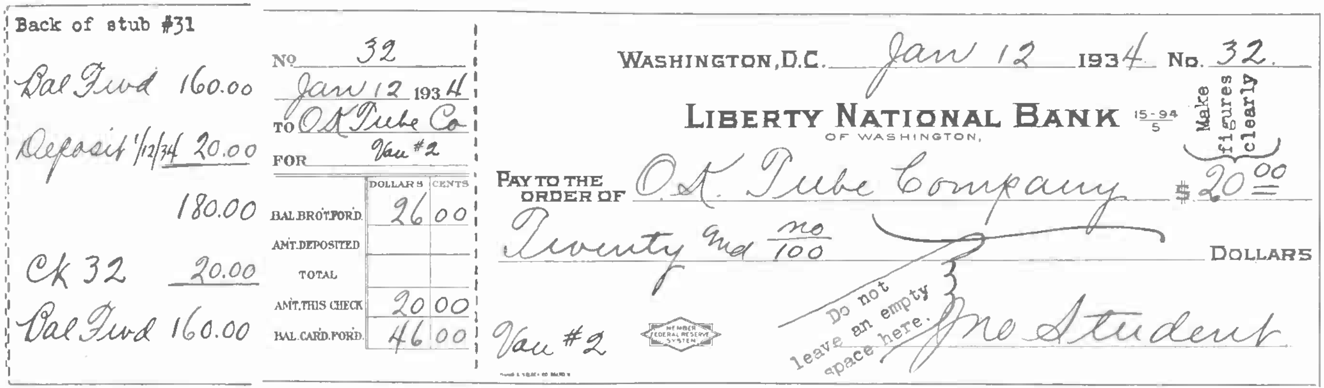
Under this system, the only amounts to be entered on the face of the check stub are the amount brought forward (which is the total of checks drawn already during that month to date), the amount of the check being drawn, and the total to date.

Keep the record of your bank balance on the back of the previous stub

Voucher Register

Date		Pay to	For —	Vou. No.	Amount	Date Paid	
1934 Jan.	1	John Student	Petty Cash	1	15 00	Jan 1	Ck 1
	2	O.K. Tube Co	Tubes	2	20 00	Jan 12	Ck 2
	6	Radio Supply Co.	Parts	3	3 90		

Form 2



Form 3

(in Form *3* this will be the back of Stub No. 31), where you will show the additions for deposits made and deductions for checks drawn. Study Form *3* very carefully.

This departure from the usual method of recording changes in the bank balance on the face of the stub may be confusing, but the purpose is the determination of the total of the checks drawn for the month. This figure would normally be found in a Payment Register mentioned before in this text.

RECONCILING YOUR BANK ACCOUNT

At the end of the month, when your paid checks are returned by the bank, place them in numerical order, check them against the stubs, and mark the stubs to show which checks have been paid. List and add the unpaid checks, adding their total to your own balance shown on the back of the stub at the end of the month; then you should have the balance as shown by the bank for that date.

Here is a simple way to test the accuracy of your record-keeping and, at the same time, make an additional check on your bank account: Add the total of the deposits as shown in your cash receipts register for the month to the amount of cash in the bank as shown by your check book at the beginning of that month. Then subtract the total amount of the checks drawn during the month as shown by your check stubs. If your figures are correct, you will have the same balance as shown on your check book.

► This gives us *Rule No. 5*, a very important rule. *Check or balance your accounts once a month. Make sure your work is accurate.* If any mistakes have been made, find out where and correct them. Thus, your records will be dependable and will tell you the facts you need to know.

Job Costs and Billing

So far, our system has shown you how to account for all cash received and paid, how to handle all payments, and how to use a petty cash fund. Now, avoiding all accounting technicalities, we are going to supply a simple system of billing for your goods and services. This system will include a method of determining the cost and the profit on each service job. At the same time, you will furnish your customer with a bill and a complete statement of the work done.

For this purpose, a combination bill-and-job ticket has been designed. We recommend strongly, since the original copy of this bill remains with the customer or is mailed to him, that you have a good job of printing done, using good bond paper, and neat type set-up. A little care on your part and a few extra pennies will impress your customer with the fact that, if you are so careful and exact in your business methods, your service methods and service work are probably just as exact and careful.

The second copy of your form is somewhat different from the original copy. It should be printed on card stock or paper that is stiff enough so that you can stand it on end in a file box. When making up your bill, you will use a piece of carbon copy paper between the original and the second copy.

It is not necessary to have these forms bound together. A paper clamp or clip board will hold both copies and the carbon paper between them in proper position for writing.

In order to get a clear impression on your file copy of the invoice, you will need a good pencil. We suggest a "copy" or "indelible" pencil, or a No. 3 lead pencil. A stiff point fountain pen (manifold point) would be better, but is not essential. Keep two or three well-sharpened pencils in your kit and at your shop so that you need never fail to render a bill on every job.

Now examine carefully our invoice and job ticket and see how they are used. (See Form *4*.) Your name, address, and telephone number should be attractively and plainly printed. Then we shall number the first job on which we use this form Job No. 1 Now fill in the date.

Notice particularly the little item, "Terms: Cash." If your customer is sound enough financially to have the job charged, cross off the word "cash" and write ten days or thirty days, or the date on which he agrees to pay. Some people entertain the false idea that, when no definite date of payment has been agreed upon, payment can be made at any convenient time, perhaps a year or two. They are wrong, but a few such customers can quickly stop your business from functioning, due to lack of funds. Never leave a bill or mail a bill to a customer without the terms of payment clearly stated.

Now let us assume that you are

receiving a call for service. Enter on the invoice the customer's name and address, the location of the job or where the service call is to be made, and as much detail of the job as you can get, including the time when the job can be done. Knowing in advance when you can do the job enables you to plan your work, and having this much of the invoice and job ticket filled out in advance saves you time when you are on the job.

As you start working on a job, lift up the original and carbon paper and

Form 4

JOHN H. JONES
AUTHORIZED RADIO-TRICIAN
442 CAPITAL STREET
WASHINGTON, D. C.

Phone 3x67 — Job No. 49
Terms: Cash — Date May 10, 1934

BILL FOR SERVICES RENDERED, MATERIAL AND PARTS

Name James T. Brown
Address 3426 Main Street
Location of job 3426 Main Street
Work to be done No reception

Quantity:	Material Used:	Price
1	Tube 27	.70
1	.5 MFD By-pass Cond.	.60
1	Lightning Arrestor	.50
	TOTAL MATERIAL CHARGE	1.80
	SPECIAL CHARGES	
	LABOR CHARGE	2.10
	TOTAL BILL	3.90

DATE PAID May 10, 34
J. H. Jones

THANK YOU

Work O. K.

Signed James T. Brown
Owner or Tenant

Form 4

enter your starting time on the shop copy. As you use parts or material, enter them on the original copy, with the carbon in place, being sure to show the price as the selling price. If you have to buy special parts while on the job, list them on the original, but lift up the original and carbon paper and enter the cost price immediately of these special parts on the shop copy. Incidentally, this may remind you to collect the cost of these parts from your petty cash fund when you get back to the shop.

When you finish the job, be sure to enter on the shop copy the stopping time, figure the amount of time between starting and stopping time and enter this elapsed time in the proper place.

Then enter on the original, with the carbon in place, the amount you wish to charge for your labor. You already have the prices of material used entered at their selling prices. Now add the totals for material and labor, bringing the grand total down to the space, "Total bill."

If the customer pays you, mark the bill paid, date it, sign it, and give the original to him. If the job is to be charged, get the customer to accept the bill by signing at the bottom after the words "Work O.K. Signed." Be sure the carbon is in place so that on your copy you have a complete okayed copy of the original bill.

As soon as you return to your shop, fill in the cost column on your carbon copy. On the job illustrated, the cost price of the parts which sold for $1.80 was $1.07. For your own information you figure the difference and get the profit on materials as $0.73 which you might note near the words, "Total material."

Now figure the cost of your labor just as though you had hired it done, pricing it at a definite hourly rate, which you feel you earn, or which you would have to pay an employee doing the same quality of work that you do and who has your technical qualifications. Where you are the only servicemen, then you should charge exactly what you would earn per hour if you were employed by some other organization.* (This does not include the profit on the labor.)

OVERHEAD

The next item to figure is overhead. An entire book could be written on this subject, but for practical purposes it is enough to understand that overhead is simply the total of all expenses incurred by your business during the month that cannot be charged directly to particular jobs. These indirect expenses must be spread over all the jobs you do. Such items are solder, wire, and all miscellaneous items of supply, including business stationery and gasoline for your car. These must be estimated as closely as you can reasonably do so in advance. Items such as rent, light and heat, and telephone can be estimated closely.

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* When you start a business, you should draw no more than you earn by your labor charges. When the business becomes established you may fix a weekly wage for yourself.

Certain important items such as wear and tear on shop equipment and on your car must be estimated. Suppose that you are using a $48 multimeter which you expect to last two years. The *monthly* cost of this instrument to you is one-twenty-fourth of $48 or $2 a month. We will assume your car to be worth approximately $240 and that you estimate it will be one-half this value or $120 at the end of twelve months. This loss in value or depreciation is $120 for the year or $10 a month.

Form 4

JOHN H. JONES
AUTHORIZED RADIO-TRICIAN
442 CAPITAL STREET
WASHINGTON, D. C.

Phone 3x67 — Job No. 49
Terms: Cash — **SHOP COPY** — Date May 10, 1934

RECORD OF SERVICES RENDERED, MATERIAL AND PARTS SOLD

Name James T. Brown
Address 3426 Main Street
Location of job 3426 Main Street
Work to be done No reception

Quantity:	Material Used:	Cost Price	Selling Price
1	Tube 27	42	70
1	.5 MFD By-pass Cond.	36	60
1	Lighting Arrestor	29	50
	List additional material on a second sheet, bring forward total, and enter here		
	TOTAL MATERIAL	1 07	1 80

LABOR

Serviceman on Job	Start	Stop	Hrs.	Rate	Cost Price	Selling Price
J. H. Jones	4:00	5:00	1	1.00	1 00	
TOTAL LABOR COST AND CHARGED					1 00	2 10
Add 60 % Overhead					60	3 90

DATE PAID May 10, 34	Material Cost	1 07
	Total Cost of Job	2 67
ENTERED ON CHARGE CARD J. H. Jones	Add Estimated Profit	1 23
	Total Billed	3 90 TOTAL BILLED

Work O. K.
Signed James T. Brown
Owner or Tenant

Form 4

List all your indirect expenses for one month, and you may have a result something like the following:

Gasoline for the car	$ 5.50
Wire, solder, etc.	3.50
Telephone	3.50
Light and heat	9.00
Rent	25.00
Tools worn out or lost	1.50
Depreciation of test equipment	2.00
Depreciation of automobile	10.00
Total indirect expenses	$60.00

How shall we distribute this overhead to the actual jobs you will handle? You know about how many hours you expect to devote to service charged the customer will be $2.10, which we get by adding cost of labor $1.00, profit on labor 50¢, and overhead 60¢. The addition of $2.10 to the selling price of material makes the total billed $3.90.

Now, to get the estimated profit, subtract $2.67 from the total amount of the bill which is $3.90 and enter the difference of $1.23 after "Estimated profit." To check your work, add again the total cost of job and the estimated profit and your *total billed* should read $3.90. Remember that all of this detail is entered on your carbon copy only and is confidential information for your use.

Job Card Register

Date		Customer's Name	Job No.	Cost		Selling Price	
1934 Jan.	1	Sam Jones (Cash)	1	2	62	3	90
	1	Tom Smith (Charge)	2	4	20	6	00

FORM 5

work in the coming month. Let us assume that this will be one hundred hours. Divide $60 by 100 and you will find your overhead expense for each hour of labor is 60 cents. Since our sample service job took just one hour, we add in 60 cents for overhead. To this you add the profit derived on labor—in this case 50 cents per hour. The total charge for labor should not be unreasonable, as the customer is bound to complain. The total labor

Frequently, you will make an outright sale of receiver parts, accessories, electric appliances, or a radio receiver. There will be no service cost, labor charges, or overhead charges, on any such direct sales. Use your invoice form by making entries in the material spaces only, bringing the amount down to the *Total billed* space. On your carbon copy, enter the cost of the goods to you and figure your profit. You understand, of course, that this profit is known as gross profit and should be high enough to cover all costs of selling and handling, and still leave you an actual, or net, profit.

In the case of sale of a receiver, you will, in practically every case, be expected to make the installation. You really have to do this to make sure that you will have a satisfied customer. When making an installation, work without charge reduces the margin of profit on a receiver sale, and an accurate record of installation costs should be kept for your own guidance.

The full value of this combination invoice or bill-and-job ticket form will only be brought out as you use it. Retail prices of radio parts, accessories, etc., are fixed within certain limits. Selling service and labor is a very different matter. This is perhaps

NAME John Brown DATE Jan 18 1934
ADDRESS 4350 Oak St. PHONE Walnut 1776
SET MAKER Kennedy YEAR MODEL NO. 32
SET: AC: DC: BATTERY: AUTO: ELIMINATOR A.C. BATTERIES USED ——
TUBES 24-24-24-27-27-45-45-80
(ORDER—BACK ROW FIRST, LEFT TO RIGHT—CONTROL KNOBS AND UPPER CHASSIS FACING YOU)
TYPE OF PICKUP SYSTEM Indoor aerial
DATE INSTALLED Jan 1932

CHARGES FOR SERVICES AND SALES

JOB NO.	DATE 1934		COMPLAINT	NATURE OF REPAIR OR CHANGE	AMT. CHARGE		DATE PAID 1934	AMT. PAID	
6	Jan	18	Dead	New Power Unit	15	60	Feb 1	10	00
187	Mar	28	Weak	New Tubes	4	90	" 15	5	00
							Mar 28	5	50
					20	50		20	50

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FORM 6

you may or may not find it advisable to make an installation charge. If an installation charge is justified, use the entire form the way that has already been explained just as if you were making a service call. Where there is no additional charge, you can show on your carbon copy the starting and stopping time, the cost of the time and overhead, and subtract their total from the gross profit. Installation the simplest way to make sure you receive a reasonable profit on your servicing ability. If you can service a receiver twice as fast as the average technician and he charges $1 an hour, there is no reason why you shouldn't charge $2 per hour. Referring to the cost sheets on past jobs, you have a dependable method for estimating on future work, when you are requested to give a price.

JOB CARD REGISTER

This is a simple record we can keep in a convenient, unused portion of the blank book already purchased. Write in the heading, *"Job Card Register,"* and head the individual columns, *Date, Customer's Name, Job No., Cost,* and *Selling Price.* (See Form *5.*)

Enter each day's job tickets, writing down the date and customer's name. Then show whether the job is a cash job or a charge job. Fill in the job number, your cost, and the selling price in the proper columns.

It is particularly important to show whether the job is cash or charged, since there is no profit until you get the money. If the job is for cash, make the necessary entries in the "Cash Receipts" section of your record book. Should the job be on a credit basis, get out your "Set Record and Accounts Receivable Card" (See Form *6.*) From your Job Card, make the necessary entries in the columns "Job No.," "Date," and in the "Amount Column," this latter being the amount charged the customer. When the customer makes a payment on account, the payment must be entered in the Cash Receipts Register, and the date of the payment and its amount entered on this card. If you wish your record of Customer's Sets to be complete, cash jobs could be entered on this card, writing the word "cash" in the payment column.

You should have a box or file in which to keep your "Set Record and Accounts Receivable Cards" on which there are unpaid balances; these cards should not be removed or put in the general file until the accounts have been paid in full.

Adding the balances due, as shown by the cards in the unpaid file, you will get the amount owed to you from your customers at any time. When an account is paid in full, you withdraw the card from the unpaid file and file it with other record cards in the general file.

Profit or Loss

Once a month, when figuring your accounts and checking your work, you will by all means want to determine the amount of your profit for the month. We will assume that your figures are correct and that you have been careful in figuring your overhead. In this particular case, we will assume that you have actually worked one hundred hours and that for every hour you have worked, you have actually charged the 60-cent overhead so that your total overhead of $60 has been distributed over work done and accounted for.

Now add up the cost column and the selling price column in your job register, subtracting the first total from the second total. The result is your profit for the month.

Add to this figure the total labor allowance you have given yourself on your job tickets, and you will have the total of your earnings for the month. You must bear in mind that the difference between the cost column total and the selling price total represents the profit over and above your labor. If you have paid a helper, his cost to you is already included in your job cost figures so no adjustment is necessary and the method just described enables you to arrive at your profit immediately.

It is desirable to be able to check or prove the correctness of this profit figure. To do this, list all the values owned at the beginning of the month and right beside them list these values as they are at the end of the month. For illustration, assume that the cash on hand at the beginning of the month was $110 and at the end of the month $260. The actual cash value of parts on hand at the beginning of the month was $60, at the end of the month $70. List these as shown in Form 7.

After these two columns, head up two more columns, the first one being marked "Decrease" and the second, "Increase." Subtract your value at the beginning of the month from your value at the end of the month and enter the difference under the word "Increase." (If the value at the end of the month is lower than at the beginning of the month, subtract the other way and enter the result under the heading "Decrease.") When you are through, the difference between the total decrease and the total increase will show whether your net value for the month has increased or decreased, and to what extent.

Now put down the total of all unpaid vouchers at the beginning of the month and the total at the end of the month. If what you owe has increased, deduct the amount of this increase from the amount of the increase in values owned to ascertain your profit. If what you owe has decreased, add the amount of this decrease to the amount of your increase in values owned, to arrive at your profit. If your values OWNED have decreased and your values owed have increased, add to get your loss.

From the increase in values owned, which is $145 in the illustration, subtract the increase in values owed, which is $10, and the profit is found to be $135. Let us assume you have $100 of your own money into the business. In this case your profit would be $100 less, and your final profit for the month is $185.

We would recommend that you set

FORM 7

Owned	Beginning Month	End Month	Decrease	Increase
Cash	$110.00	$260.00		$150.00
Parts on hand	60.00	70.00		10.00
Auto (Depreciated Value)	220.00	210.00	$10.00	
Analyzers, testers, etc.	60.00	55.00	5.00	
	$450.00	$595.00	$15.00	$160.00
Less decrease in value				15.00
Net increase in values owned				$145.00
Owed				
Accounts Payable	$70.00	$80.00		$10.00

Increase in values owned	$145.00
Increase in values owed	10.00
Profit for month	$135.00
Add withdrawals	150.00
Earned	$285.00
Earned	$285.00
Contribution (incl. in cash on hand)	100.00
Actual earning	$185.00

FORM 7

withdrawn for your personal expenses, $150. Add this to your profit of $135 and you find your total earnings for the month have been $285. Let us assume, however, that during the month you have put an additional up theoretical combinations of figures and, with a pencil and paper, figure out these combinations until you thoroughly understand this procedure.

Now this profit should be the same in amount as the profit shown on your job register, added to your personal labor allowance and less your personal withdrawals. If it is not, get out your job tickets for the month, take a sheet of paper, and draw columns. Then, list the cost and selling prices of material, the amounts you have allowed for overhead, the amounts you have allowed for labor, the estimated profits, and the charges for labor. Add your lists, study them, and check carefully. You should find it easy to determine where profits were made and where losses occurred. You should be able to tell readily whether or not you are charging too little or too much for your services. Careful and intelligent use of this system will keep you informed as to where you are heading financially and help you to build a sound, well-managed business.

Bear in mind that this system has been simplified for your convenience and to save you time. It is possibly not the most exact system, and we have omitted records that you would find in a system of "bookkeeping," but it is probably the most practical that could be devised. Just a few minutes each day and a few hours once a month, plus a little study and thought, will enable you to advance from being just a serviceman to being a businessman. As your success increases, you will want to go deeper into the accounting side of your business.

Large Store Accounting

The simple system of record-keeping and accounting described for a small service and merchandising business should give you a good check on your costs and earnings while your business is small, consisting perhaps of a clerk, a serviceman, and yourself. As you diligently apply yourself to building up your business, the time will come when you will have a larger store, employ several servicemen, operate one or more sound trucks, install light-control devices. If you branch out into the sale of refrigerators, electrical appliances, phonograph combinations, you will also hire salesmen and special servicemen.

A successful business can be established only by close study of business records. If you borrow money from the bank, you will have to render standard business reports. In order to prove that the taxes you pay are correct, you will need adequate accounting records. If you want to know whether certain lines are more profitable than others, only records and not opinions can give you the proper information.

The installation of a complete bookkeeping system to give the above facts is a job for a public accountant. Have one install a system for you. Keeping the books is a job for a bookkeeper. Be sure you hire one that is capable. The time to do this is when you *start* to grow and feel that you can afford a bookkeeper. If you get the information you want and use it intelligently, the bookkeeper's salary will be earned many times over.

Because installing and keeping an accounting system is a job for a specialist, it would be impossible to tell you all about it in a few pages. But every radioman who plans to become a radio merchant should know something about his bookkeeping system, what it contains, what it can do for him, and, in general, how it works. What are the essential features of an accounting system for a large store?

ESSENTIALS

The purposes of all accounting and bookkeeping are to arrive at two main objectives. These objectives are represented in two statements known as the "Balance Sheet" and the "Profit and Loss Statement"—the first representing the static position of the business, and the second the "action" of the business. In other words, the Balance Sheet shows you exactly what the business is worth at a stated time, while the Profit and Loss Statement sets out the causes of changes in the worth of the business during a particular period. A Balance Sheet at the beginning of the year may show your worth to be $2,500, while a Balance Sheet at the end of the year shows your worth to be $3,600. As demonstrated previously, you have an increase of $1,100, but from the balance sheets you do not know why, and if you know why you would be better able to increase this earning to $1,500. This cause of increase is shown in the Profit and Loss Statement, and, for purposes of management, it is the most important of all statements.

The preparation of these statements can be most conveniently made if your books are kept on the double entry method. This means that theoretically there are two entries for every transaction. We say theoretically, because in no modern bookkeeping will you find two actual entries. For example, suppose you make three hundred sales in a month on credit; you would not make six hundred entries. You would make three hundred entries on one side of the ledger and perhaps only one on the other side. Now what do we mean by sides of a ledger?

THE LEDGER

You must know what a ledger is. In double entry bookkeeping, the ledger is the book of final entry. All the facts of your business finally find their way into this book in condensed form. A page is headed up with a title that tells you just what kind of information is shown on that particular page. Look at Form *8*, an illustration of a sample ledger page (there are other rulings, but this one is the oldest and serves our purposes better), and you will get an idea of

A Ledger Account

DR. DATE	DETAIL	AMOUNT	DATE	DETAIL	AMOUNT CR.
	Balance Sheet Items				
	Assets:- Subdivided: Cash Accounts Receivable Notes Receivable Radios Parts Automobile Furniture and Fixtures, etc.			Liabilities:- Subdivided: Accounts Payable Notes Payable Finance Company, etc. Net Worth or Capital Subdivided: Investment and Profits (assets less liabilities)	
	Effect of entries on ledger accounts, the results of which affect the Balance Sheet and Profit and Loss Statement				
	TO DEBIT SIDE (1) Increases Assets (3) Decreases Liabilities (5) Adds to costs or expenses (7) Shows a loss (9) Decreases Net Worth (11) Measures Purchases			TO CREDIT SIDE (2) Decreases Assets (4) Increases Liabilities (6) Decreases Costs or Expenses (8) Shows profits (10) Increases net worth (12) Measures income (14) Sets up reserves for contingencies (16) Measures Sales Volume	

FORM 8

what a ledger is and its purposes. Also, consult definitions at the end of the book for a better understanding of the ledger.

In order to develop the idea of the ledger, let us assume now that you have one enormous sheet on which you make all entries. This sheet is divided in half: the left half (or side) is called the *Debit* side, and the right side is called the *Credit* side. Every transaction that occurs in your business will affect an account listed in Forms *9* and *10*. Since the two sides must be kept in balance, put every transaction in one of the classes shown on the debit or credit side of our illustration; then the balancing entry will be classified under one of the headings on the other side.

Now refer to lower section of Form *8* and you should understand the effect of every entry made to the debit and credit sides of this large sheet.

Suppose we sold a radio set that cost $20.00 for $30.00 cash. We would increase the asset (*1*)* cash $30.00 by making a debit entry. We could decrease the asset (*2*) stock in trade, radios, by $20.00 and could show a profit (*8*) of $10.00 by making two credit entries on the credit side. However, in practice we do not make the two credit entries at this time because the two entries would not give the exact information desired for making up your profit and loss statement. Instead, we credit sales (*16*) with $30.00. Remember every sale should have three elements, the element of cost and the element of profit, on the credit side; and the asset element (cash, accounts receivable, or notes receivable) on the debit side. The same theory and practice applies when you pay your rent. You debit an expense account (*5*); and you credit an asset account (*2*). It is not so hard to understand, if you analyze each entry to determine its effect. As you record a debit or a credit on this large sheet, you would key this entry with the key number shown in Forms *9* or *10* which identifies the type and account.

*Refers to items on lower part of Form *8*.

JOURNAL

We will leave the ledger for the moment and introduce you to the journal. In modern accounting, the journal is of relatively little use. Due to labor-saving methods it is used only for extraordinary entries, for adjustments and corrections. We introduce it at this point because it ties in with the development of the ledger. Remember, we suggested that all entries might be made on one ledger sheet. Now let us move the debit column on the ledger sheet over beside the credit column, and you have the same old ruling as shown in Forms *1* and *2*. We have a journal instead of a ledger. The two transactions would appear as follows:

	Dr.	*Cr.*
Cash	30.00	
Sales		30.00
(Sale of one radio set, cost 20.00)		
Rental Expense	25.00	
Cash		25.00
(Rent on store paid for January)		

Now a journal kept in this manner would be of no benefit to us in determining our financial position quickly, so we make up an individual ledger sheet for every kind of asset, liability, or expense necessary to make up our Balance Sheet and Profit and Loss Statement.

In theory, we make every entry in the journal as shown, then we transfer (post) the individual items to the proper sheet in the ledger by making entries on the ledger sheet on the debit or credit sides exactly as they appear in the journal.

CLASSIFICATION OF ACCOUNTS

To get the best results from your accounting, you must determine exactly the information desired, and then you must accumulate the information in an orderly manner. To accomplish this end, you must make a survey of the business and determine what is necessary. The accounts in the ledger should be arranged as nearly as possible in Balance Sheet and Profit-and-Loss order to facilitate the taking off of these statements. To help you in this we give you a chart of accounts, Form *9*, prepared by the Charles R. Hadley Company and printed with their permission. You should note that each item having a number represents a ledger sheet, and note particularly the arrangement of the accounts. This is a very excellent and complete chart of ledger accounts.

Form *10* is a condensed form of a Chart of Ledger Accounts, which we can recommend for a small or medium business.

CASH BOOK

In your ledger, you have an account with cash. You will find that you are making numerous entries to this account, and probably the work involved in doing this posting will become burdensome. There is a simple way to get around this. Use a special book for making cash entries; both incoming and outgoing cash. We still follow the rules that all cash be deposited and that you pay only by check. Use a journal-ruled book like that shown in Form *1*. Open the book and head up the left-hand page, "Cash Receipts," and the page directly opposite, "Payments." You now see what we have done—we have lifted the cash page out of the ledger. All cash received is entered in detail on the left page, together with the deposits. (Of course, the amount received and the deposits should balance.) Also, all checks issued are entered in detail on the right page. Find the difference between the totals of the two sides each month. This difference, added to the balance at the beginning of the month if there is a debit balance, or subtracted from the balance at the beginning of the month if there is a credit balance, will give you the balance in the bank. You may post the totals of the pages at the end of the month to a cash account in the ledger, but this is not necessary. For detailed handling of this work, you should consult your

CHART OF GENERAL LEDGER ACCOUNTS

Pathfinder Bookkeeping System for Radio Dealers

ASSETS

CURRENT

Cash and Bank

1 Petty Cash
5 Bank
11 Cash Sales Clearing Account

Notes and Accounts Receivable

21 Contracts Receivable
22 Contracts Receivable Discounted
23 Notes Receivable
24 Accounts Receivable
39 Reserve for Bad Debts

Inventory

41 New Radios
42 Used Radios
43
44 Parts and Accessories
79 Reserve for Used Radio Revaluation

Other Current Assets

Accounts 80 to 89 may be used as needed to show investments in marketable securities and indebtedness of officers, stockholders, and employees.

FIXED ASSETS

101 Land
102 Buildings
103 Reserve for Depreciation on Bldgs.
104 Machinery, Fixtures and Equipment
105 Reserve for Depreciation on Machinery, Fixtures and Equipment
106 Automobiles
107 Reserve for Depreciation on Autos.
116 Leasehold Improvements
117 Reserve for Amortization of Leasehold Improvements

DEFERRED CHARGES

131 Prepaid Rent
132 Prepaid Insurance
133
134 Other Prepaid Expenses

OTHER ASSETS

151 Finance Company Reserve

LIABILITIES

CURRENT

Notes Payable

201 Notes Payable—Bank
202 Notes Payable—Others

Accounts Payable

211 Accounts Payable
217 Taxes Payable
218 Finance Charges
219 Finance Company Collections
220 Due to Finance Company on Repossessions

OTHER LIABILITIES

241 Mortgages
Accounts 242 to 249 may be used for bonds, debentures, or other fixed obligations

CAPITAL

251 Capital or Investment
(If a partnership, use a separate account for each partner, numbering accounts 251, 252, 253, etc. If a corporation, use a separate account for each class of stock).

261 Drawing Account
(If a partnership, use a separate account for each partner, numbering accounts 261, 262, 263, etc. Not required if firm is incorporated.)

270 Surplus
(Use for corporation only. Not required for partnership or single proprietorship.)

271 Profit and Loss (Current)

REVENUES

SALES

341 New Radios
342 Used Radios
343
344 Parts and Accessories
345 Service Labor

COST OF SALES

441 New Radios
442 Used Radios
443
444 Parts and Accessories
445 Service Labor
479 Used Radio Inventory Adjustment

EXPENSES

Symbols: A Administrative and General Expense; B Selling Expense; D Automobile and Delivery Expense

501	Salaries	A	Officials or Proprietors
		A	Office and Clerical
		B	Salesmen
502	Indirect Labor	A	Janitors and Porters
		B	Non-Productive Shop
		D	Delivery Drivers
503	Commission & Bonuses to Salesmen	B	Salesmen
504	Employees Compensation Insurance	A	Office and Clerical
		B	Salesmen
		B	Shop
		D	Delivery Drivers
505	Rent	A	Rent
		A	Amortization of Leasehold
506	Taxes	A	Land and Buildings
		A	Machinery, Fixtures and Equipment
		B	Merchandise
		D	Taxes and Licenses on Automobiles
		A	Occupation Tax
		A	Corporation Tax
507	Supplies	A	Stationery and Office Supplies
		A	Janitors Supplies
		B	Shop Tools
		B	Shop Supplies
		B	Demonstrating Supplies
		D	Gas, Oil and Grease
		D	Other Automobile Supplies
		A	Miscellaneous Supplies
508	Advertising	B	
509	Gratis Material and Labor	B	
510	Heat, Light, Power and Water	A	
511	Communication	A	Telephone
		A	Telegrams
		A	Postage
512	Insurance	A	Buildings
		A	Machinery, Fixtures and Equipment
		B	Merchandise
		D	Automobiles
513	Freight, Express & Parcel Delivery	D	
514	Repairs	A	Buildings
		A	Machinery, Fixtures and Equipment
		D	Automobiles
515	Depreciation	A	Buildings
		A	Machinery, Fixtures and Equipment
		D	Automobiles
516	Bad Accounts	A	
517	Professional Services	A	Legal
		A	Auditing
518	Traveling and Entertainment	A	General
		B	Selling
528	Unclassified	A	Membership Dues and Subscriptions
		A	Donations
		A	Miscellaneous

MISCELLANEOUS GAINS AND LOSSES

OTHER INCOME

601 Interest Earned
602 Discounts Earned
603 Cash Over
604 Miscellaneous Income

DEDUCTIONS FROM INCOME

611 Interest Paid
612 Cash Short
613 Miscellaneous Losses

COURTESY CHAS. R. HADLEY CO.

FORM 9

FORM 10

CHART OF LEDGER ACCOUNTS

Recommended for a Small or Medium Business

BALANCE SHEET ITEMS

ASSETS:

1. Current Assets.
    - 11 Cash in Bank
    - 12 Petty Cash
    - 13 Accounts Receivable
    - 14 Inventories
        - 141 New Radios
        - 142 Used Radios
        - 143 Tubes
        - 144 Parts & Accessories
        - 145 Misc. for Sale
    - 15 Tools and Shop Supplies
2. Fixed Assets.
    - 21 Furniture & Fixtures
        - 211 Allowance for Depreciation F & F
    - 22 Analyzers, Testers, etc.
        - 221 Allowance for Depreciation 22
    - 23 Automobiles
        - 231 Allowance for Depreciation Autos

LIABILITIES:

31. Notes Payable & Finance Co.
32. Vouchers Payable

CAPITAL:

41. Investment
42. Drawing Account
43. Profit and Loss

PROFIT AND LOSS ITEMS

5. Purchases for Sale
    - 51. New Radios
    - 52. Used Radios
    - 53. Tubes
    - 54. Parts and Accessories
    - 55. Misc. for Sale

8. Operating Expense. (Control)
   Distribution Columns for
    - 81. Salaries
    - 82. Service Labor
    - 83. Tool Expense
    - 84. Shop Supplies
    - 85. Rent
    - 86. Taxes
    - 87. Heat, Light, Telephone
    - 88. Depreciation
    - 89. Sales and Advertising
    - 90. Office Supplies
    - 91. Automobile Expense
    - 92. Miscellaneous Expense

6. Sales
    - 61. New Radios
    - 62. Used Radios
    - 63. Tubes
    - 64. Parts and Accessories
    - 65. Misc. Sales Items

7. Sales of Service
    - 71. Service Labor
    - 72. Overhead
    - 73. Estimated Profit

10. Miscellaneous Income & Losses
    - 101. Commissions Earned
    - 102. Commissions Paid
    - 103. Interest Received
    - 104. Interest Paid
    - 105. Discounts for Cash
    - 109. Bad Debts
    - 110. Misc. Income and Loss

FORM 10

accountant. This much is given you to show the development of many other books used in accounting and that, in many cases, these books are simply ledger accounts removed from the ledger.

You must understand that the detail as to the keeping of records showing who owes you money and how much, and to whom you owe money and how much, would be used in the double entry method, exactly as explained in the section considering a simple accounting system. Double entry is simply an elaboration of the method; you would still have the Cash Receipts Register, the Voucher Register and file, the Accounts Receivable Cards and the Job Card Register which would be the same as the Sales Record.

From what has been said up to this point, we may now summarize the essential features of a double entry bookkeeping system. With the cash book, the voucher register, the job card register or their equivalent we have what are referred to in accounting as the books of original entry. This, of course, does not entirely eliminate the journal which is used (as we have said) merely for the recording of extraordinary entries, such as correcting errors in your accounting and closing the books at the end of an accounting period. From the totals of the columns in the books of original entry, postings are made to specific accounts in the general ledger at the end of the accounting period and these, in turn, serve to give information for the setting up of the Balance Sheet and the Profit and Loss Statement.

► In the first section of this text we have outlined a simple method of accounting for your guidance, believing that if you use this system you will have sufficient knowledge to guide you to success in your undertaking. The section under Large Store Accounting is necessarily sketchy and is written only for the purpose of giving you an over-all knowledge of what to expect in an accounting system. We have given you the bare essentials and the many other books and records that are used are for the purpose of giving more detailed information and they all tie in with some account in the General Ledger.

Definitions

Realizing the difficulties met by the beginner in business in the understanding of accounting terms, we have listed a few of them, each with a brief definition. An understanding of each meaning will aid you in the operation of your business and in discussions with your banker and your accountant.

Account. As we understand it, an account is a detailed statement found in the Ledger. It has a heading which shows the name of the asset, liability, income, or expense to which the items therein pertain. There is a column for charges and a column for credits, and a column for the difference or balance. There is a space for date, and space for such detail or explanation as you wish to enter. Accounts can be generally classified as: Asset Accounts, which record values owned; Liability Accounts, recording values owed; Capital Accounts, which represent investment in the business, plus or less, profits or losses. Income Accounts, for our purposes, show the amount and source of income, while the Expense Accounts show the detail of the costs of doing business, including the cost of goods sold.

Asset. An asset is something of value, owned. *Fixed assets* are those assets used for business purposes and have a determined value. They remain in the business, and are not bought and sold in the regular order of business. *Current assets,* are those that are coming in and going out. They are constantly increasing or decreasing due to regular operation of the business.

Audit. To audit means to verify the accuracy of the books of account. Also, to check a bill for its accuracy as to prices, goods, and calculations is to audit a bill.

Balance. A balance is the excess of the sum of the column on one side of an account over the sum of the column on the other side. If the debit or left-hand column has the larger total, the balance will be a debit balance; if the credit or right-hand column is the larger, it will be a credit balance.

Balance Sheet. A balance sheet is an orderly arrangement of assets, classified as to kinds, balanced against an orderly listing of liabilities plus capital. It shows the relation between different kinds of assets and between assets and liabilities. It shows proprietorship or net worth as represented by the difference in assets and liabilities.

Budget. A budget is a forecast of income, against which an estimated allotment of expenditure is made.

Capital. Your capital is your investment or equity in the business. It is the excess of assets over liabilities; or, if there are no liabilities, the total of the assets invested. As a matter of good business and good bookkeeping, do not contribute funds to the business or take funds out of the business without charging or crediting the Capital Account.

Consignment. A consignment is a shipment of goods to a person, known as the consignee, to be held or sold for the benefit of the shipper, who is the consignor. Ownership and all rights in the goods remain in the consignor.

Depreciation. Depreciation is an estimated decline in the value of assets, due to the wear and tear of use and the ravages of time. It represents the difference between the cost and the scrap value of the asset, this value being divided by the time intervening between the date of purchase and the probable date of scrapping or other disposition. The time may be measured in months or years as suits the necessities of the accounting system. In our illustrated accounting, we take our old car into the business at a value of $160.00 on January 1. On December 1 its trade-in value would be $50.00. The depreciation will be $110.00. We know we will use the car eleven months so the depreciation will be $10.00 a month.

Discount. Discount is a deduction from a listed figure or cost, and it may be a Cash Discount, which is an allowance of usually one or two per cent of the bill for prompt payment, or it may be a Trade Discount, which is a percentage reduction from a fixed or quoted price on a radio set or on standard parts.

Entry. An entry, for our purpose, is the recording of a fact in any of the books in our bookkeeping illustration.

Expense. An expense, briefly, is any expenditure of funds or other assets necessary to the carrying on of the business, excluding of course the substitution of assets for assets, as would occur in the purchase of goods for sale. Rent and labor are expenses. The exchange of cash or our credit for radios is not an expense, but an exchange of one kind of asset for another asset.

Expenses in a servicing business are *Direct Expenses,* that is, those that can be charged directly to a particular job; labor is one example. *Indirect Expenses* are those that must be estimated or allocated to many jobs. See definition of *Overhead.*

Income. Income is that value which comes into the business in exchange for goods and services. *Gross Operating Income* includes total revenue, while *Net Operating Income* is *Gross Operating Revenue* less costs of operations. *Non-Operating Income* is that derived from sources other than operation. Interest on savings deposits would be non-operating revenue.

Insolvency. Insolvency is inability to pay debts, due frequently to inability to convert assets readily into cash. Bankruptcy is an excess of liabilities over assets, which makes it impossible for the person to meet his obligations under any circumstances.

Inventory. An inventory is an itemized list of goods or other assets which shows a number of items, cost or selling price per item, and total value. You may inventory the accounts of your customers or you may inventory your liabilities, or furniture and fixtures.

Liability. A liability is a debt. It may be *current,* such as amounts that are due for rent, merchandise purchased; or it may be *accrued,* such as salaries to employees earned but not paid or due. There can be *fixed* liabilities, such as mortgages.

Obsolescence. Obsolescence is that loss in value not due to wear and use, but due to new inventions of tools or machinery which makes the use of the old unprofitable.

Overhead. Overhead is that cost of production or of doing business that cannot be definitely applied to a particular activity, and must be distributed to various jobs on a more or less arbitrary basis. For instance, in servicing, your tools suffer obsolescence and depreciation; you use solder; and your car uses gas; and the tires wear out. You must pay rent. You advertise. All these items amount to quite a sum of money in a month, but are too indeterminate to be charged directly to each job. To take care of the situation, we arbitrarily add to the cost sheet on each job an amount estimated to cover (totaling amounts added to all job sheets) the total of these expenses for a given period. There are many ways of charging overhead, but the most satisfactory way for you in the service business is to charge it to each job as a fixed percentage of the actual labor cost.* The total overhead charged on jobs for a period may be checked against the actual expenditure for miscellaneous indirect items for the period and the percentage or rate adjusted up or down, to more equitably distribute the costs on future work.

Petty Cash. Petty Cash is a small sum set aside for the payment of small expense items where it is inexpedient to draw a check. In the books of account, the petty cash fund is a fixed amount as long as it is in existence. Checks are drawn at necessary times to replenish the fund, which brings it back to the original amount. The slips or vouchers representing payments are classified and the check is charged to the various accounts affected.

Posting. Posting is the transfer of items from books of original entry to the Ledger.

Profit. Profit is the increase in net worth or capital from the beginning of a period to the end of a period. *Gross profit* is the excess of selling price over the cost of goods sold. *Net Profit* is the Gross Profit less all costs of selling and all other costs of doing business.

Trial Balance. A trial balance is a list of balances of all ledger accounts. The balances listed in columns of debits and credits should total the same.

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* In the merchandising of radio and electric appliances, the selling price is set for you. In this case, it becomes the problem of the merchant to keep his overhead and direct expenses below a value that will assure him a reasonable profit, or give up the unprofitable line.

Turnover. Now we come to turnover. This is one of the vital factors in the operation of your business. Turnover in its simplest meaning is the number of times that you can use a capital asset in a given period or the number of times that assets renew themselves in a given period. For instance, on the first of January you buy for sale a receiver for $100.00; you sell it for $167.00, and you do the same every month of the year. At the end of the year your cost of receivers sold would be $1,200.00. Your investment is $100.00, your rate of turnover is 12, and your gross profit is $804.00. Had you bought and sold only two radios a year, your rate of turnover would have been 2, your investment still $100.00, and your gross profit $134.00. It is obvious that the higher the turnover figure the greater will be your gross profit.

Where the selling price is not set by the producer of the product you sell and your turnover is high, you may figure a small profit on each sale and make just as much gross profit as you would if you had a small turnover figure and had added, to your cost of goods sold, a high profit.

Substitute the amount that you have invested for the hundred dollars and divide this into your cost of sales for a year to get your capital turnover.

What is your turnover in accounts receivable, or how well are your customers paying? Are they taking too much time, or are you extending too much credit? Suppose your sales average $30.00 a day. When you balance your books, you find you have accumulated outstanding accounts of $1,350.00. This shows your accounts receivable to be an average of 45 days' sales. In other words, you are granting 45-day terms of credit, while you think your selling terms are 30 days. You will have to speed up collections to pay your own bills in thirty days.

Voucher. A voucher is any bill, invoice, memorandum or evidence of expenditure of funds or evidence of liability to pay out money. There should be present such proofs of correctness or evidence of payment as to make it of itself sufficient proof to be acceptable by anyone as a proper expenditure.

CUSTOMER COMPLAINTS

Every businessman expects a certain number of complaints in spite of his best efforts to please his customers. Some complaints are justified; it is human to make mistakes. Others are the result of misunderstandings, while a few are not justified at all.

You cannot avoid having some "call-backs," but your handling of these calls will have much to do with your customer good-will and your reputation.

Be just as pleasant and courteous in handling complaints as possible. The customer is doing you a favor by complaining to *you* rather than telling his friends that you cannot fix his set!

Even when the complaint is unjustified, it is frequently better to repair the set at no charge than to try to convince the customer that the new trouble is not related to your original repair.

Follow the practice of most businesses—charge these jobs to your overhead expense. Thus, by adding a small amount to the cost of each job, you can afford to handle these call-backs—you'll be keeping your customer good-will at no loss!

J. E. Smith

HOW THE TV PICTURE TUBE WORKS

51RH-3

NATIONAL RADIO INSTITUTE
WASHINGTON, D. C.
ESTABLISHED 1914

STUDY SCHEDULE NO. 51

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

BP6M151 1951 Edition Printed in U.S.A.

TV PICTURE TUBES

IN THE SOUND section of a TV system, a microphone changes the sound into electrical signals that vary in amplitude. These signals are then changed into frequency variations (FM) and are sent out on the TV sound carrier. In the receiver, the discriminator-type second detector changes the frequency variations into amplitude variations, and after amplification, the loudspeaker changes them back to the original sound that was picked up by the microphone. This portion of a TV system is just like that of a standard radio system.

Let us now compare the operation of the video section of a television system with that of the sound section. In the upper left corner of Fig. 1 is shown an artist whose picture is to be transmitted. The light that is reflected from her face is collected by the lens system and focused on the plate of the television camera tube. This plate is covered with a mosaic composed of an innumerable quantity of minute photoelectric cells. The camera tube also has an electron gun similar to that used in a standard picture tube. The scanning, in this case, is accomplished by deflecting the electron beam electromagnetically by means of the coils around the neck of the tube. These coils are fed with signals that cause the point of impact of the electron beam to move across the mosaic in approximately a horizontal line at a uniform speed, then fly back and scan another line, and so on until the entire mosiac has been scanned by 525 lines in the desired sequence. This complete scanning is repeated at a rate of 30 times per second. As the electron beam sweeps over the mosaic, each element transfers its charge, which varies according to the illumination of that portion of the scene, to an amplifier. The resulting voltage pulses, called video signals, are amplified and combined with special signals for controlling the timing of the camera-tube electron beam during the return time. The resulting composite signal is then used to modulate a high-frequency transmitter.

In the TV receiver, the video program is treated like any other amplitude-modulated signal. It is amplified by the r.f. stage and then fed to the mixer stage where it is mixed with a signal from the local oscillator to produce the i.f. signal frequency. The signal is then amplified by the i.f. stages, and is fed to the second detector where the carrier is stripped from the composite video signal. The video signal is then amplified by the video amplifier which corresponds to the audio amplifier in a sound receiver.

The TV video signal is then ready to be changed back into a scene. As you already know, this is accomplished by use of a picture tube. The application of the video voltage variations to the grid-cathode of the picture tube results in variations of the electron-beam intensity and causes corresponding variations in the brightness of the spot that is formed on the screen of the picture tube. To duplicate the scene that caused the electrical variations on the camera-tube mosaic, these spot-brightness variations must occur at the right place on the screen. This is accomplished by sweeping the electron beam across the face of the picture tube in step (synchronized) with the camera-tube beam. The sync signals that were separated from the video signals, are used to synchronize the horizontal and vertical sweeps of the TV receiver with the horizontal and vertical sweeps of the camera tube.

Now that you have a basic understanding of all the TV stages and sections and their operation, you are ready to study them in greater detail. Let's start in this Lesson with a study of the picture tube, and learn how the electron beam is formed, how it is focused to a pin point on the fluorescent screen, and how it is swept across the screen. Then you will have a full understanding of how the video signal is converted into a scene.

Picture tubes are made in various sizes and types. However, all picture tubes are fundamentally the same, and every tube has the following basic elements:

1. A source of electrons in the form of a cathode.
2. A filament to heat the cathode so that it will emit electrons.

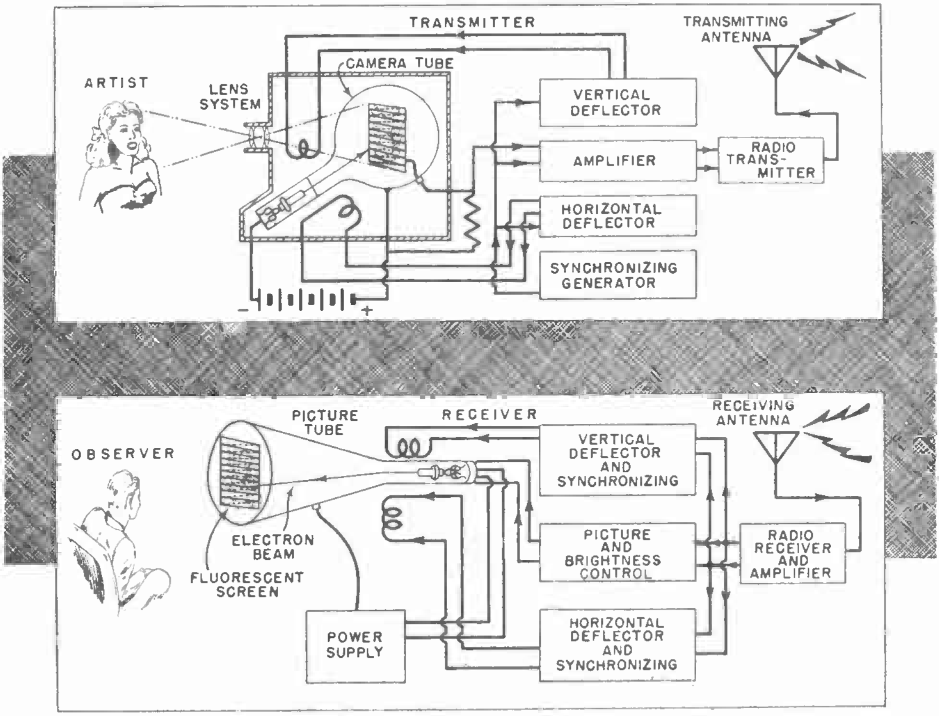


FIG. 1. Block diagram of the video portion of a television system.

3. A control grid to vary the number of electrons passing through it.
4. A means of concentrating the electrons leaving the cathode into a beam.
5. A fluorescent coating on the screen that glows upon the impact of the electron beam.
6. A means of focusing the electron beam into a small spot on the tube screen.
7. A high-voltage anode to accelerate the electrons in the beam.
8. A means of deflecting the electron beam in any desired direction.

ELECTRON GUNS

The electron gun is the complete electrode assembly in picture tubes that produces and focuses a beam of electrons as a pin point on the viewing screen. Let's study its elements in order.

Electron Emitter. In a picture tube, the source of electrons is a cathode that is heated by a filament that is electrically insulated from it. This filament is wound non-inductively so that no stray fields are produced by the alternating current flowing through the filament.

Fig. 2 shows the arrangement of the elements in a typical electron emitter. A cap made of nickel is heated from the inside by the filament. The end of this cap is coated with a special chemical oxide mixture that emits electrons freely when it is heated. Since a thin pencil of electrons is desired, only the end of the nickel cap is coated with the oxide mixture. The electrons leave the cathode more or less at right angles to the surface, and consequently these electrons start traveling over paths essentially parallel to the principal axis of the picture tube. But electrons have negative charges and repel each other, so when they are emitted from the end of the cathode, if left to their own devices they would quickly spread out, and all beaming action would be lost. How this is avoided will be described shortly.

Electron emission should take place in a vacuum for two important reasons. First, the absence of air particles in the vicinity of the cathode makes it easier for electrons to jump away from the cathode. Second, in a vacuum the emitted electrons cannot create very many heavy positive ions that would be attracted to the cathode, bombard it, and destroy the coated emission surface. However, since no vacuum is perfect, some ions are created, and the negative ones join with the electrons in the beam. As you will learn later, a special means is necessary to prevent these negative ions from striking the screen and burning the fluorescent material.

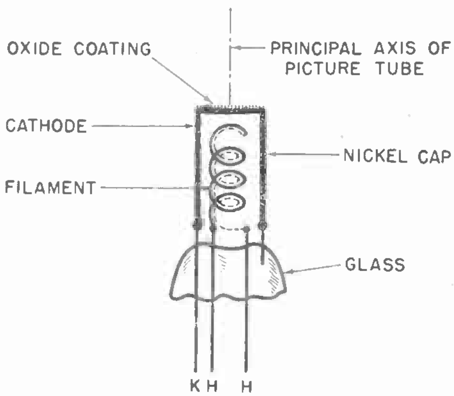


FIG. 2. Arrangement of the elements in the electron emitter of a picture tube.

A mixture of about 40% barium oxide and 60% strontium oxide on the cathode surface has been found to give far better electron emission than either one of the oxides alone. A mixture such as this emits electrons generously at relatively low temperatures, beginning at about 850 degrees Centigrade.

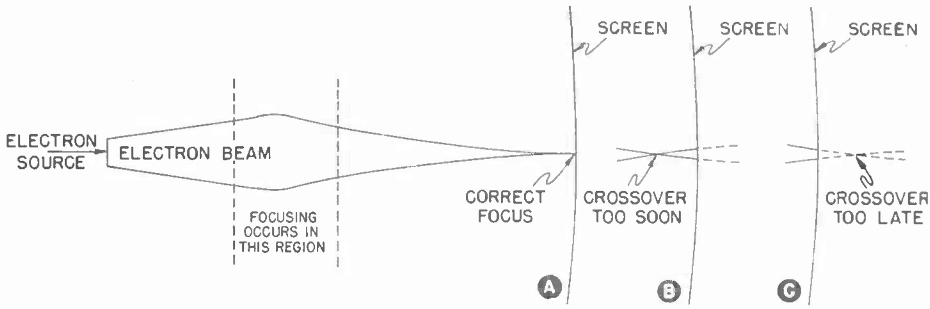


FIG. 3. The electron beam is correctly focused when it crosses over at the point where it strikes the screen.

As a rule, the oxide coating is sprayed on the end of the cathode in the form of a liquid. While the picture tube is being evacuated, an intense heat is applied to the cathode (usually by inducing strong eddy currents in the nickel cap), changing the sprayed-on materials to the desired active oxides.

Other Gun Elements. As stated previously, the electrons leaving the end of the cathode will, due to their repelling action on each other, tend to spread out so that they will not reach the screen as a small compact beam. To avoid this, specially-constructed electrodes are used to accelerate the electrons to a high speed so that they will not have time to spread out. Even so, a spot the size of the coated portion of the cathode would be entirely too large, therefore the beam must be reduced to a very small diameter at the point of impact on the screen. Since the electrons are leaving all parts of the cathode in a more or less straight line, it is possible to make these individual lines cross over one another by varying the electrode voltages or by the use of a magnetic field. Just how this is accomplished will be described later.

Fig. 3A shows that as the electrons cross over, the beam becomes a fine pin point and, if properly focused, this crossover can be made to occur just where the beam strikes the screen. Figs. 3B and 3C show what happens if the beam is improperly focused. If the crossover occurs too soon or too late, the spot will be a large circle on the screen instead of the desired pin point, the details will be lost, and the picture will be blurred.

Not only is it necessary to focus the spot on the screen, but also the number of electrons in the stream must be controlled by the video signal in order to vary the brilliancy of the spot. An element called the "control grid" is used for this purpose. This element is entirely different in appearance from the tube grid with which you are familiar and operates on a somewhat different principle. This difference is based upon the behavior of an electron in an electrostatic field, as we will show.

By making use of the electronic-optic principle of electrostatic focusing, it is possible to bundle these emitted electrons into a small-diameter stream, and make them form a small brilliant spot on the screen that will vary in brightness with the applied video signal. Only the cathode-ray tube designer is interested in the actual shapes of the electrodes, their arrangement, and the voltages applied to each. However, the serviceman who understands the problems of cathode-ray tube design, and knows how the desired effects are accomplished, is in a better position to service, install, and adjust cathode-ray tube equipment.

EQUIPOTENTIAL LINES

The underlying principles of electronic optics are not difficult to understand. An electron is always attracted to a positively charged electrode; it is the path that the electron takes in getting there that requires study. You know that electric lines of force exist between any two differently charged bodies, such as between the emitter (source of electrons) and the anode of a cathode-ray tube; it is along these lines of force that electrons travel. It is easier, however, to predict how electrons will move by referring to what are called equipotential surfaces, for these are simpler to locate in actual practice than electric lines of force, and electrons moving from one equipotential surface to another always behave in a definite manner. The first electronic-optics principle to be studied is the relation between electric lines of force and equipotential surfaces.

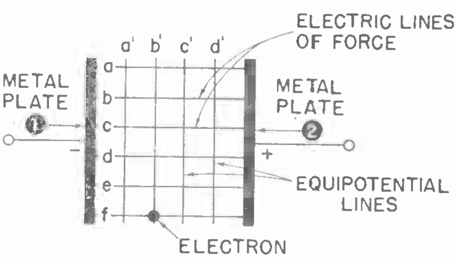


FIG. 4. Cross-sectional view showing electric lines of force and equipotential lines between two charged parallel plates.

Fig. 4 represents a cross-sectional view of two parallel metallic surfaces, with surface 2 positively charged with respect to surface 1 (which can be a cathode). Electrons are urged from 1 to 2 along lines a, b, c, etc., which represent electric lines of force. An electron moving from surface 1 to surface 2 starts from rest (zero speed) at surface 1, gaining speed as it moves. All along the path it gains energy, because the energy of a moving body of constant mass increases with its

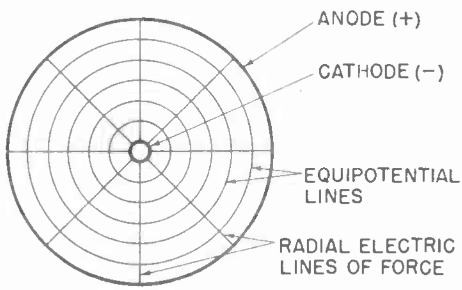


FIG. 5. Cross-sectional view showing electric lines of force and equipotential lines between two charged coaxial cylinders.

speed. Other electrons starting from rest at various points on plate 1 gain speed at the same rate, so that all electrons moving between the plates possess the same energy at any given distance from plate 1. We can indicate this on Fig. 4 by putting in lines a′, b′, c′, and d′, drawn at right angles to the electric lines of force. These lines represent positions of equal potential or energy level, and are called equipotential lines or surfaces. (Equipotential lines on a cross-sectional view actually represent equipotential surfaces, just as the heavy lines 1 and 2 in Fig. 4 represent plates.)

Fig. 5 illustrates the electric lines of force (radial) and equipotential lines (concentric) as you will find them in a simple electronic tube having a cylindrical cathode inside a cylindrical plate. Although the drawing gives only one cross-sectional view of the tube, all other cross sections are alike. Electrons going from the cathode to the anode will travel along the electric lines of force, and will therefore move at right angles to the equipotential lines shown.

A free electron that is traveling along the path of an electric line of force between two bodies in the direction of increasing potential (toward the highest positive body) will gain velocity. A gain in velocity is the same as a gain in potential, for this is the way of assigning a definite velocity to the electron. Since the electron has mass, it is also gaining energy as it travels along the path in the direction of increasing potential (a rock traveling down to earth from a height of twenty feet will have far more energy at the bottom of its fall than would a rock dropped from a height of five feet.) This means that when an electron travels through an electric field in a direction of increasing potential, it will receive energy (or potential, or velocity, as you prefer) from the electric field.

An electron traveling in a direction of decreasing potential (toward the lower potential body) will be retarded, and will lose some of its energy, potential, or velocity. An electron moving along an equipotential line will neither gain nor lose velocity, energy, or potential.

An equipotential line passes through all points having the same potential. Any number of equipotential lines, each corresponding to a different potential, can be drawn between two charged bodies; some will have low potentials and some will have high potentials. When an electron moves from a low equipotential line to a high equipotential line, its velocity is increased. An electron moving from a high to a low equipotential line will lose velocity.

An electron traveling at right angles to equipotential lines is speeded up or retarded, as the case may be, but is not diverted from its straight path of travel. Only when an electron is traveling through an electric field at an angle other than 90° to the equipotential line is its direction, as well as its velocity changed. This change in the direction of travel of an electron merits further study, for it is the fundamental action of electrostatic focusing systems in picture tubes.

Equipotential lines are straight and parallel only when the charged bodies are two large, parallel, metal plates; the lines are then parallel to the flat plates. In all other cases, equipotential lines will be curved. In picture tubes, we deal almost entirely with curved equipotential lines.

Let us consider first the condition shown in Fig. 6A, where electron "e" is traveling at an angle to the principal axis of a picture tube and is passing from a low potential region to a high potential region. The change in potential along the path of the electron is actually quite gradual, there being no definite boundary for a region, but we can simplify our study greatly by assuming that the curved equipotential line shown here represents the boundary between regions of different potential. The results obtained with this assumption will be sufficiently accurate for our purposes.

In the low-potential region in Fig. 6A, electron e has velocity P_1, that may be broken up into two components P_{T1}, tangential to the equipotential line and P_{P1} perpendicular to the equipotential line.

The tangential velocity component P_{T1} remains unchanged as the electron moves from a low- to a high-potential region, for this component represents motion along the equipotential line. The velocity component that is perpendicular to the equipotential line increases as the electron crosses this line, so that the velocity that is perpendicular to the line in the high-potential region is P_{P2}. Combining the two velocity components again after the electron has crossed the equipotential line, we get P_2 as the new electron velocity. This is larger than the original electron velocity P_1 and is bent closer to the principal axis.

The passage of an electron from a low-potential region to a high-potential region, under the conditions in Fig. 6A, results in increased electron velocity and a travel path that is more normally parallel to the principal axis. By repeating this process for three other conditions of electron travel, as indicated in Figs. 6B, 6C, and 6D, we can determine the nature of the bending in each case.

All four diagrams in Fig. 6 are reversible; that is, the indicated electron paths are correct for either direction of electron travel along the path.

If we limit ourselves to equipotential lines that are portions of circles having their centers on the principal axis, we can summarize the results of the diagrams in Fig. 6 as follows:

1. Electrons approaching a concave equipotential line, moving away from the principal axis, and passing from a low- to a high-potential field are bent back toward the principal axis.

2. Electrons approaching a concave equipotential line, moving toward the principal axis, and passing from a low- to a high-potential field are bent away from the principal axis.

3. Electrons approaching a concave equipotential line, moving away from the principal axis and passing from a high- to a low-potential field are bent away from the principal axis.

4. Electrons approaching a concave equipotential line, moving toward the principal axis, and passing from a high- to a low-potential field are bent toward the principal axis.

5. Electrons approaching a convex equipotential line (traveling in a direction opposite to that in Fig. 6)

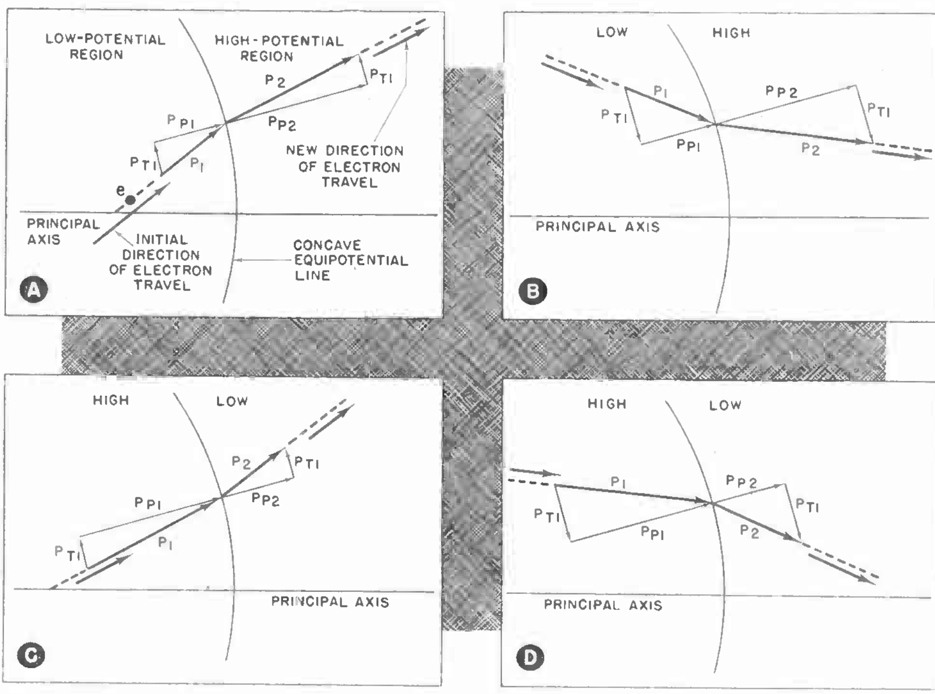


FIG. 6. How the path of an electron is changed as it moves at various angles through regions of differing potentials.

moving toward the principal axis, and passing from a high- to a low-potential field are bent toward the principal axis.

6. Electrons approaching a convex equipotential line, moving away from the principal axis, and passing from a high- to a low-potential field are bent away from the principal axis.

7. Electrons approaching a convex equipotential line, moving toward the principal axis, and passing from a low- to a high-potential field are bent away from the principal axis.

8. Electrons approaching a convex equipotential line, moving away from the principal axis, and passing from a low- to a high-potential field are bent toward the axis.

Although these eight statements take care of all conditions in picture tubes, it is far easier and better to remember the method shown in Fig. 6 for deriving these facts than to memorize the eight statements.

Concentrating the Electron Beam

In a practical picture tube, a beam of electrons that focuses to a small spot on the fluorescent screen is produced by two distinct sections: 1, a hot cathode and an electrode system that converges the emitted electrons to a point quite near the cathode on the principal axis of the tube; 2, one or more electronic lens systems located between the first converging point and the fluorescent screen, to produce equipotential lines that will converge the electron beam to a small spot on the fluorescent screen. This second section will now be considered in its simplest form as a bi-potential electronic lens.

ELECTRONIC LENS

In the electronic lens, the bending is continuous throughout the electric field that forms the lens (since there is an infinite number of equipotential lines at which bending can occur).

Expert mathematicians can calculate the positions of equipotential surfaces by a long, tedious process, but only for simple electrode shapes. The usual, and quite practical procedure involves making a large accurately scaled model of the electrodes, immersing this model in a conductive liquid, and applying voltages to the electrodes. A test probe that is completely insulated except for a tiny metal ball point at its tip is connected to a vacuum-tube voltmeter. This probe is then moved around in the liquid between the electrodes to search out points of equal potential. These points are plotted on a cross-sectional diagram of the electrodes, and connected together by smooth curves to give the equipotential lines for that electrode arrangement.

In Fig. 7A is shown a cross-sectional view of a simple bi-potential lens made up of two metallic cylinders placed end to end on a common principal axis. The smaller cylinder has a lower positive potential than the larger cylinder, and the difference in potential between the cylinders results in equipotential lines distributed as shown in Fig. 7A for any lengthwise cross-section of the cylinders.

Point 0 can be considered as the point source for the electronic lens in Fig. 7A, as electrons are concentrated at this point by the first section of the picture tube gun (by the cathode and its associated focusing system). Since the two metal cylinders produce the same electric field for any cross-section, electrons leaving 0 in all directions at any given angle with the principal axis will be acted upon in a similar manner by this electronic lens.

Notice that electrons traveling to the right from point 0 first encounter convex equipotential lines. These lines gradually straighten out, then become concave inside the larger cylinder. Let us see what happens to electrons as they pass through one convex equipotential line and one concave equipotential line.

An electron traveling from point 0 through the 1100-volt convex equipotential line (shown by itself for clearness in Fig. 7B) is bent toward the principal axis. If this were the only equipotential line acting upon electrons, the beam would be focused to point X on the principal axis. In passing through the 4400-volt concave equipotential line, however, the electron beam is bent away from the principal axis, so that it now focuses at a point farther away along the principal axis, at Y.

Returning to Fig. 7A we see that the convex equipotential lines having potentials from 1020 volts to 2200 volts will progressively bend the electron beam toward the principal axis, and at the same time will increase the velocity of the electrons. The concave equipotential lines from 2200 volts to 4580 volts will gradually straighten out the electron beam until it is almost parallel with the principal axis and is converged to a spot of the desired size at point I on the fluorescent screen. Line 1 in Fig. 7A represents the path to the screen taken by electrons leaving the point source 0 at angle θ_1 with the principal axis. Electrons leaving point 0 along the principal axis will be accelerated but not bent, since these electrons will travel at right angles to all equipotential lines.

ELECTRONIC BAFFLES

There is a practical limit to the angle at which electrons can leave point 0 and still be focused to a point

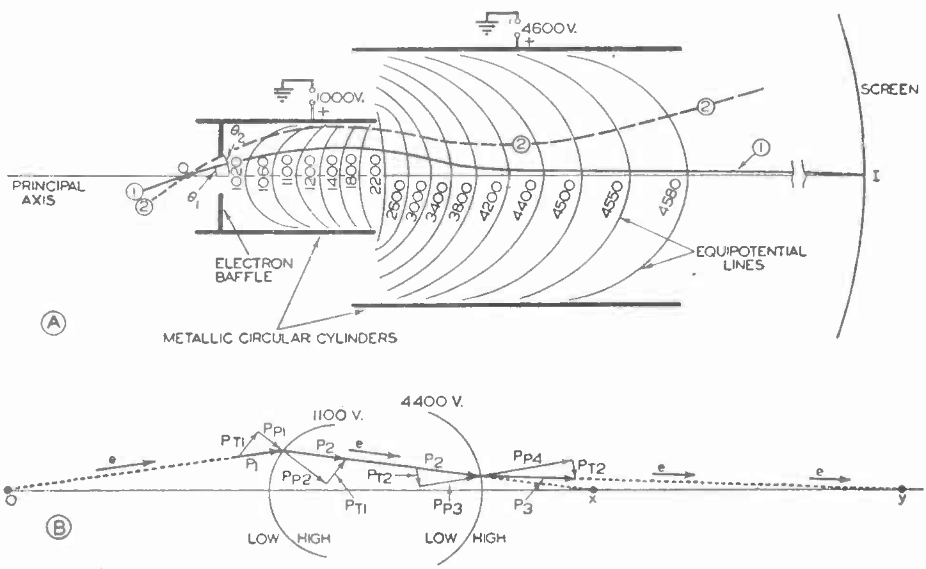


FIG. 7. Electron paths through a bi-potential electronic lens.

on the screen. For example, electrons leaving point 0 at angle θ_2 are acted upon by the electronic lens in such a way that they take path 2, and this would cause undesirable spreading of the beam. To overcome this, one or more electron baffles (each a disc with a hole in its center) is used in a picture tube to block all electrons that do not converge to the desired narrow beam along the principal axis.

THE FIRST LENS

As has been previously pointed out, there are two electrostatic lens systems in a picture tube. The first one is near the cathode, and is used to bring the emitted electrons to a more or less sharp point that can act as a source of electrons for the second lens. The first lens is essentially produced by the control grid, which is a cylinder with one or more baffle plates located in front of the cathode. This first lens is known as the cathode lens or immersion lens (any electrostatic lens in which the object or source of electrons is inside or immersed in the lens is an immersion lens). The grid cylinder is usually given a negative bias with respect to the cathode, and is excited

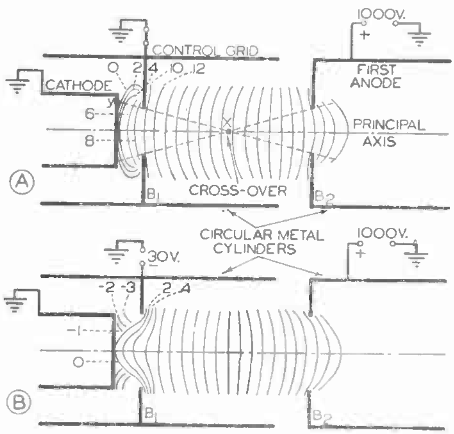


FIG. 8. Equipotential lines within an immersion lens when there is no bias (A) and when there is a 30-volt bias (B) applied to the control grid.

by the TV signal, thus serving as the control electrode.

The cross-sectional diagram in Fig. 8A shows a typical arrangement of the electrodes that are located near the cathode of the picture tube. These electrodes are metal cylinders. The equipotential lines in Fig. 8A are shown for the condition where the control electrode is at zero potential with respect to the cathode, a condition corresponding to maximum brilliancy of the spot on the screen.

Since the first anode is at a high positive potential with respect to the cathode, positive equipotential lines exist right up to the cathode as shown in Fig. 8A.

Along the surface of the cathode, the positive potentials pull electrons away from the heated electron-emitting surface. Those electrons that are traveling along the principal axis are accelerated, but not bent as they move toward the first anode, because they are moving perpendicularly to the equipotential lines.

An electron leaving the cathode at a point away from the principal axis, such as at point Y, will encounter convex equipotential lines of increasing potential; these will force the electron to take the indicated path from Y to the cross-over point X, and at the same time will accelerate the electron.

Any electrons traveling from point Y away from the principal axis will follow an equipotential line without accelerating, until they are redirected toward the principal axis again. They are then attracted by the first anode, and are accelerated along with the other electrons in the beam. Stray electrons may form an electron cloud around the cathode, outside the zero equipotential line. This electron cloud will tend to repel electrons back to the principal axis, and force them to go through the cross-over point X.

Most of the electrons that make up the final beam will be pulled out from the center of the cathode, and will be accelerated rapidly with a minimum change in direction. Electrons emitted at such angles that they could not possibly go through the cross-over point are blocked by electron baffle B_1. The first anode has another electron baffle (B_2) that also blocks electrons that are outside the desired beam.

When the control electrode has a negative bias of 30 volts with respect to the cathode (a condition corresponding to a low-brilliancy spot on the picture-tube screen), the equipotential lines will be arranged as shown in Fig. 8B. The negative charge on the control electrode has the effect of making the positive equipotential lines sharply convex for electrons leaving the cathode; in addition to this, the positive potential increases rather slowly near the control electrode.

We also have negative equipotential lines in the vicinity of the cathode shown in Fig. 8B. Many of the electrons that would normally leave the cathode because of the potential that is given them by the heat of the filament cannot overcome the repelling force of these lines, and consequently are kept at the cathode. The result is that only electrons near the principal axis are pulled away from the cathode by the first anode. We thus see that a negative charge on the control grid reduces the number of electrons that can enter the electron beam.

The control electrode has its greatest effect in the region between the cathode and the electron baffle B_1. The electrostatic field between the electron baffles B_1 and B_2 is essentially constant for a definite first-anode voltage. With proper electrode design, the equipotential lines in this region will be so shaped that there will be convex lines for focusing the electrons to cross-over point X, and concave lines for narrowing the beam again as the electrons spread after leaving point X.

A COMPLETE ELECTRON GUN

The general arrangement of the electron gun elements in a picture tube is shown in Fig. 9. Since we have already considered the action of each component in the system, we will now review the action of the entire system.

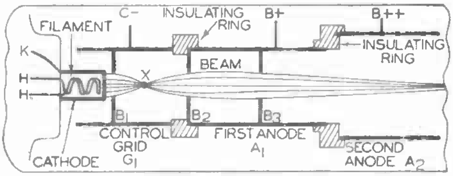


FIG. 9. General arrangement of the elements in the electron gun of a picture tube.

Cathode K serves as the primary source of electrons. The control electrode G_1 produces between baffle B_1 and the cathode an electrostatic field that controls the number of electrons in the beam. The first anode A_1 provides between it and G_1 an electrostatic field that focuses the emitted electrons to cross-over point X. The first and second anodes, A_1 and A_2, together form a bi-potential electronic lens that converges the electron beam back into a narrow straight stream and focuses the stream or beam of electrons to a spot of the desired size on the fluorescent screen. Electron baffles B_1, B_2, and B_3 block any electrons that tend to widen the final electron beam.

The number of electrons in the beam will vary at different points, for the baffles will divert some electrons to the positive supply leads. If milliammeters are inserted in the B+ and B++ leads, the sum of their readings will be approximately equal to the electron currents at cross-over point X. The current in the second anode supply lead is a better indication of screen spot brightness, however. The beam current is very small, varying from approximately 50 to 250 microamperes, depending on the type of tube and the anode voltage employed.

SECONDARY EMISSION

When the electron beam strikes the fluorescent screen it causes secondary electrons to be emitted from the screen. If these secondary electrons are not removed they will accumulate and form an electron cloud in front of the screen that will interfere with the normal operation of the tube, tending to slow down the beam and making it spread.

To prevent this electron cloud from forming, the inside of the glass envelope in practically all picture tubes is coated with a conductive material such as carbon or powdered graphite. This coating is called aquadag, and is similar to the coating found on resistance strips of volume controls. The coating usually extends from the neck of the funnel-shaped part of the glass envelope to within an inch or so of the fluorescent screen. One end of the aquadag coating is connected to the second or accelerating anode through spring clips, and hence has a high positive potential so that it will attract secondary electrons that are emitted from the fluorescent screen during bombardment by the beam. This prevents a large accumulation of secondary electrons in front of the screen. In some picture tubes, no metallic accelerating anode is provided, and the aquadag coating, in addition to collecting secondary electrons from the screen, also acts as the accelerating or high-voltage anode of the tube.

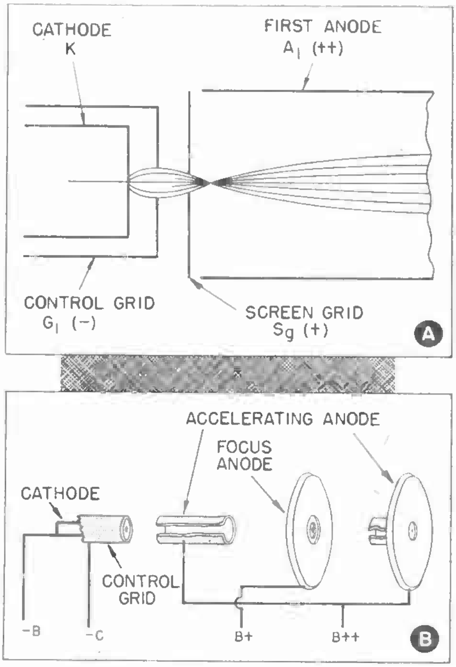


FIG. 10. Methods of reducing interaction between the control grid and the focusing anode.

On many magnetic-deflection tubes the outer portion of the glass envelope also has a conductive coating that is grounded. The glass between the inner and outer conductive coatings acts as a dielectric, and in this way a condenser is formed that has considerable storage capacity. The condenser so formed acts as a portion of the filter system for the second anode high-voltage supply.

In the gun shown in Fig. 9 there is considerable interaction between the control grid and focusing anode No. 1. Variations in control grid voltage will vary the number of electrons striking baffles B_2 and B_3, thus undesirably changing the first anode voltage with respect to the second anode voltage, and defocusing the beam.

In some early tubes, this was avoided by using an element called the "screen grid" between the control grid and the first anode as shown in

Fig. 10A. More recently, however, the second anode has been split; one part, electrically connected to the second anode, now is inserted between the control grid and the focusing anode as shown in Fig. 10B. Not only does splitting the second anode cause rapid acceleration of the electrons, but also interlocking between the adjustment of the control grid voltage and the focusing anode voltage is thus eliminated. The arrangement in Fig. 10B also allows a simpler power supply than that in Fig. 10A.

In the terminology of some picture-tube manufacturers, the control grid is designated as G_1, the first section of the accelerating anode in Fig. 10B is designated as G_2, the focus anode as G_3, and the other section of the accelerating anode as G_4; G_2 and G_4, of course, being tied together.

Focusing the Electron Beam

The technician's primary interest in a picture tube is the effects that variations in electrode voltages have upon the spot size and the spot brilliancy. However, there are two types of picture tubes; one uses electrostatic focusing and deflection, while the other uses electromagnetic means for both these purposes. We shall study both, beginning with the electrostatic type.

ELECTROSTATIC FOCUSING

The schematic circuit diagram for a typical electrostatic picture tube and its operating voltage supply is shown in Fig. 11. The voltages applied to the various electrodes in the picture tube depend upon the size of the tube. For example, in a tube having a face diameter of 7 inches, the highest a.c. supply voltage E_3, applied between the second anode and B–, may be as much as 6000 volts. The first anode may have a potential of 1500 to 2500 volts. The cathode may be positive with respect to ground (the control

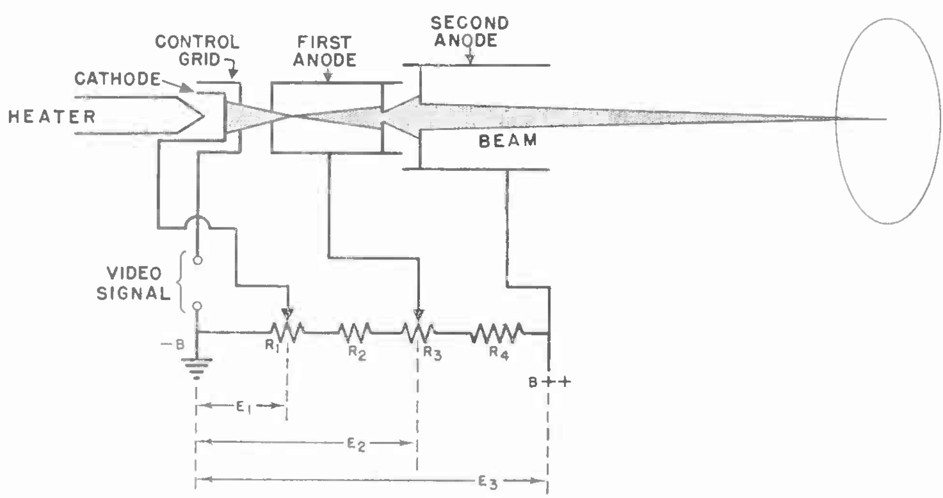


FIG. 11. Schematic diagram of the voltage distribution system used with a typical electrostatic tube.

grid return) by 30 or 40 volts, so that the control electrode is always negative. The exact d.c. voltage between the cathode and the control grid depends upon the setting of R_1 which serves as the brilliancy control. Now let us see how the spot size and the spot brilliancy will vary as the voltages are varied.

Let's assume first that the control grid is highly negative, with the spot brilliancy correspondingly low. Electrons under this condition are flowing into the first anode in a narrow cone with the result that the beam is focused to a small spot. As the control grid is driven in a positive direction by the video signal or by reducing the bias set by R_1, more and more electrons enter the stream, and the spot brilliancy increases. At the same time the electrons in the stream repel each other more than before, and the spot size is therefore increased when the control grid is driven more positive. By careful tube design, the spot diameter can be maintained within reasonable limits for normal variations in the control grid voltage. This variation will not greatly affect line definition if the largest spot diameter is less than the width of a line.

Raising voltages E_1, E_2, and E_3 will increase spot brilliancy. Conversely, reducing these voltages will reduce spot brilliancy. To see how these voltages affect spot size, we may consider each electrode by itself. Increasing the first anode voltage causes electrons to be drawn from a larger area on the cathode, giving more electrons in the beam and a larger cone at the cross-over. The result is a beam with less effective focusing, due to the greater repelling action among electrons in the beam. These factors together cause spot size to be increased when the first anode voltage is increased.

Provisions are always made for varying the first anode voltage in electrostatic picture tubes because this provides a simple way of focusing the electron beam to a spot. Increasing E_2 without increasing E_3 reduces the potential difference between the first and second anodes. The equipotential lines then become flatter (less convex and less concave), with the result that there is less bending as the electrons pass through the second electrostatic lens, and the point of focus (the point at which the beam is focused to a sharp spot of minimum size) is moved farther away from the second anode. Increasing E_2 also gives increased acceleration of electrons. We can therefore say that increasing the voltage E_2 on the first anode will move the focus spot outward, and at the same time give a brighter spot. If the point of focus is originally between the second anode and the fluorescent screen (so that electrons are diverging again as they reach the screen), increasing the first anode voltage will move the point of focus closer to the screen, thereby reducing spot size. When the point of focus is exactly at the screen, the spot size will be a minimum, and all changes in anode voltages will increase the spot size. Decreasing the first anode voltage E_2 will reduce the spot brilliancy, and bring the point of focus closer to the second anode. With those picture tubes that are designed for electrostatic focusing, it is customary to vary the first anode voltage until a sharply-focused image is obtained on the screen.

Normally, the second anode voltage is not readily adjustable, although in certain type high-voltage power supplies an adjustment can be made. A definite voltage, however, is always recommended for this anode, and focusing is accomplished by adjusting the voltage that is applied to the first anode. Any change in the voltage on the second anode will require readjustment of the focus control (R_3 in Fig. 11) to produce the proper equipotential lines between the first and the second anodes so that the beam will focus to a sharp point on the screen.

MAGNETIC FOCUSING

The fact that an electron in motion in a vacuum is the equivalent of a current, and is producing magnetic lines of force makes it possible to employ a magnetic field for focusing a divergent stream of electrons to a point. To understand exactly how this magnetic field can be utilized for electron-beam focusing, we must first consider a few fundamental principles of the behavior of electrons in magnetic fields.

A typical t.c.r. tube employing magnetic focusing is shown in Fig. 12. At the left end of the tube is a conventional electrostatic lens made up of a heated cathode, a negatively biased control grid, and low- and high-voltage anodes that serve as the first lens to focus the emitted electrons to cross-over point X, and to accelerate the electrons. From this point the electrons spread out into a cone, and are focused to a spot of the desired size on the screen by the magnetic field that is produced by the focusing coil that surrounds the neck of the tube. The magnetic lines of force produced by this coil are essentially parallel to the principal axis of the tube, and are distributed uniformly through the neck of the tube.

In Fig. 12, the path taken by an electron leaving point X at the angle θ with the principal axis is shown as a long sweeping curve, first away from the principal axis and then toward it. Actually, however, the electrons are twisted around the principal axis in a spiral manner at the same time that they are moving away from or toward the axis.

In order to prove that electron e, as it leaves cross-over point X, will take the path shown in Fig. 12, we must consider its velocity as having two components. Velocity component e_L provides motion longitudinally along the axis, while velocity component e_R provides motion radially outward from the principal axis. You will shortly see that motion along the axis is not affected by the magnetic field, whereas radial motion through the magnetic field forces electrons to bend back to the principal axis.

Electron e is thus moving longitudinally along the axis toward the screen at the same time that it is moving radially away from and back to the principal axis. If the radial motion back to the axis can be completed by the time the electron has reached the screen, the desired focusing is secured.

Let's suppose that a straight wire is placed in a uniform magnetic field

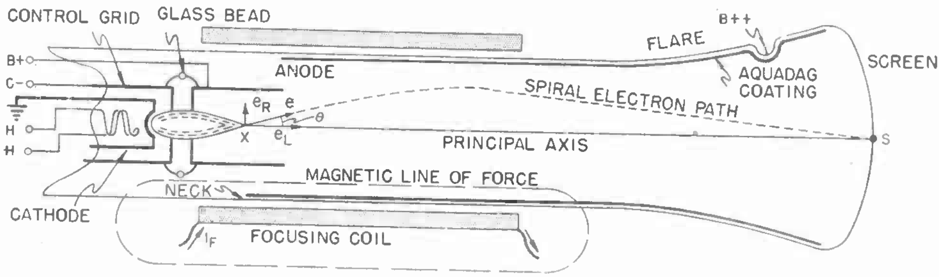


FIG. 12. Elements of a typical electromagnetic picture tube.

that is made up of straight parallel magnetic lines of force, with the wire parallel to these lines of force. When a current is sent through this wire, the current will set up a magnetic field of its own surrounding the wire. These circular magnetic lines of force will be at right angles to the existing straight lines of force at all points, and consequently the interaction between the two fields will be exactly the same at all points around the wire. The result is that the original magnetic field has no effect whatsoever upon the flow of electrons through the wire.

We can replace this wire with a stream of electrons flowing parallel to the magnetic lines of force, because it is electrons in motion that produce magnetic fields; we thus see that when magnetic focusing is employed, electrons traveling along the principal axis are unaffected by the magnetic field.

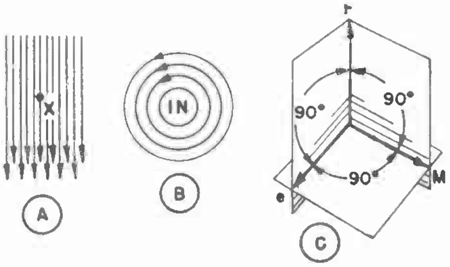


FIG. 13. How the interaction between a fixed magnetic field and the magnetic field of an electron forces the electron path to change direction.

When a wire carrying current is placed at right angles to a magnetic field, we know that there will be interaction of the magnetic fields and a resultant force that tends to move the wire (this is the principle of an electric motor). Electrons traveling at right angles to the focusing magnetic field in a picture tube are acted upon by a resultant force in much the same manner.

Imagine that the magnetic lines of force shown in Fig. 13A are parallel to the plane of this page, and the electrons are moving into the field (into the paper) at point X, along a path or beam that is at right angles to the page. Associated with these moving electrons will be circular magnetic lines of force having the directions shown in Fig. 13B. When these circular magnetic lines of force exist in the magnetic field of Fig. 13A, there will be a crowding of flux at the left of point X, and a thinning out of flux at the right of point X. This unbalance causes electrons to move to the right, thereby rebalancing the field.

The complete picture of this action is shown in the three-dimensional diagram in Fig. 13C. The initial direction of electron movement (e) and the direction of the magnetic flux (F) are at right angles (90°) to each other. As a result of the interaction between the magnetic lines of force, the electrons will be moved to the right (arrow M indicates this motion), at right angles to both the initial electron flow and the original magnetic field. From this fundamental analysis, we can see that an electron traveling perpendicular to a magnetic field is forced to move in a direction at right angles to both its original path and the original magnetic field.

Returning to Fig. 12, we can now see that it is the reaction between the radial electron velocity component e_R and the focusing magnetic field that causes electron e to be redirected back toward the principal axis of the tube. It will be more convenient to look at a cross-sectional diagram through cross-over point X of the picture tube (Fig. 14) while studying this action.

Let's assume that electrons are moving radially away from cross-over point X, which is our electron source.

If there were no magnetic field in the vicinity, these electrons would move radially out to the neck of the tube, as indicated by path e_1. With a focusing magnetic field here, at right angles to the electron path, these electrons are given a side push at right

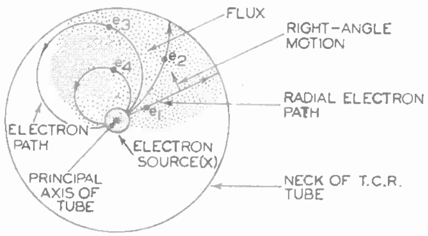


FIG. 14. How the strength of the focusing magnetic field affects electron paths in an electromagnetic tube.

angles to their original path, with the amount of this push depending upon the flux density. For a low flux density, the electrons would therefore take path e_2, and for increasing flux densities they would take paths e_3 and e_4 respectively. In a system of magnetic focusing the magnetic field density is increased simply by increasing the value of direct current through the focusing coil.

Note that paths e_3 and e_4 in Fig. 14 are both complete circles that bring the electrons back to the principal axis. For a given initial electron velocity, increasing the magnetic field density shortens this circular path back to the principal axis. By adjusting the field strength so that it takes electrons just as long to travel this circular path back to the axis as it does for them to travel longitudinally along the axis to the screen, we can make electrons hit the screen right at the principal axis even though they leave the cross-over at an angle. Varying the focusing coil current changes the magnetic field strength; therefore, in a tube employing electromagnetic focusing, the focusing coil current is varied in order to focus the electron beam.

It is not essential that the focusing coil enclose the entire distance from the cross-over point to the screen. A short coil located near the cross-over point will give electrons the essential twist back to the principal axis, so that they will focus to the desired spot size at the screen.

There is a definite relationship between the velocity of the electrons at the cross-over point and the magnetic field strength required for correct focusing. The greater the electron velocity, the greater must be the flux density in order to secure the desired focusing. Any change in the electrode voltages changes the electron velocities, making it necessary to readjust the focusing coil current in order to maintain the desired sharply focused spot on the screen.

In tubes employing magnetic focusing, the control grid is so designed that it essentially controls only the number of electrons in the beam. The first anode, aside from its action in focusing electrons to the cross-over point, determines the velocity of the electrons at the cross-over point. With this arrangement, there is a minimum of defocusing when the electron beam is modulated with a television signal. Further velocity is imparted to the beam by the second anode which is not designed to form an additional lens with the first anode.

Deflecting the Electron Beam

Having passed the focusing structure, which may be either a bi-potential lens or an electromagnetic focusing coil, the electron beam travels to the screen in the form of a beam more or less along the principal axis of the tube. This electron beam must be swept horizontally across the screen 15,750 times per second, and must be swept vertically up and down the screen 60 times each second.

There are two methods for accomplishing this sweeping of the electron beam across the screen: 1, electrostatic deflection, in which the beam passes between charged parallel metal plates that attract or repel the electrons to produce the desired bending of the beam; 2, electromagnetic deflection, in which an electromagnetic deflecting yoke produces a magnetic field that interacts with the magnetic field of the electron beam to produce the desired bending.

ELECTROSTATIC DEFLECTION

When using two parallel charged metal plates to deflect an electron beam, the plates are fed from a push-pull amplifier with a saw-tooth a.c. sweep voltage that makes one plate negative while the other is positive, and vice versa, alternately. Thus the beam will be attracted toward the positive plate and repelled by the negative plate. Since this is a saw-tooth voltage of the a.c. variety, the plates will regularly reverse polarity, and the beam will be swept back and forth across the face of the tube as shown in Fig. 15A, in this case tracing a straight horizontal line. With other plates placed at right angles to those shown in Fig. 15A, as is illustrated at B, a straight vertical line will be traced on the face of the tube. When swept both horizontally and vertically at the same time, the rapidly occurring horizontal lines are gradually moved down the face of the tube by a single vertical sweep, the vertical sweep then returns the beam to the top of the tube, and the process is repeated, thus scanning the entire screen. This pattern of light produced by the scanning is called the raster.

In modern television work the deflecting plates are maintained at approximately the same d.c. potential as the second anode, being connected to it through decoupling resistors. The sweep signals are then fed through coupling condensers to the deflecting plates.

Electrons enter the region between the parallel plates in Fig. 15A with a definite velocity, corresponding to that given by the potential of the second anode. When plate X is positive with respect to plate Y, it will attract the electrons in the beam and conse-

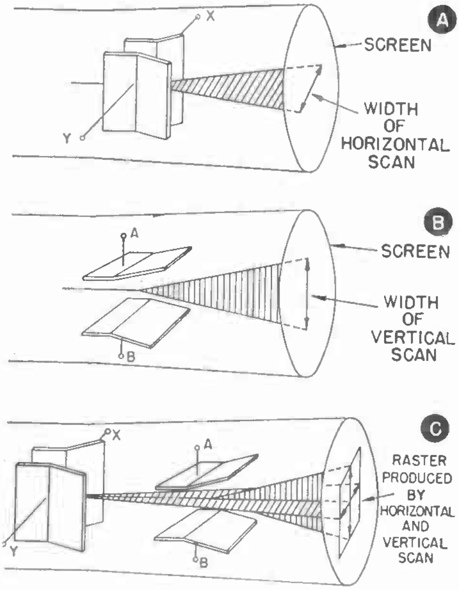


FIG. 15. How the electron beam is swept in an electrostatic tube.

quently pull the beam toward it. On the other hand, when plate Y is positive with respect to plate X, electrons will be repelled from plate X and bent toward plate Y.

The amount of bending will depend upon the voltage difference between the two plates, upon the distance between the plates, and upon the length of time the electrons are between the plates. The greater the voltage difference, the greater will be the bending or deflection. The closer to each other the plates are, the greater will be the deflection. The longer the electrons take to travel between the plates, the greater will be the deflection.

The length of time it takes the electrons to pass through the plates depends upon the electron velocity (the second anode voltage), and upon the length of the plates along the principal axis. The higher the velocity, the less time the electrons are between the plates. Looking at this condition in a slightly different way, we can think of a high-velocity electron beam as being stiff, and hence more difficult to bend. The bending action of an electron beam should be considered in terms of the spot deflection on the screen rather than in terms of the bending angle. Of course, for a given bending angle, the spot movement on the screen will depend upon the distance between the deflecting plates and screen, increasing as this distance is increased.

The deflection sensitivity of an electrostatic deflection system can be expressed either in terms of the deflecting plate voltage that is required to move the spot on the screen a unit distance (the lower the deflection voltage, the greater is the sensitivity), or the distance that one volt will move the spot on the screen (the greater the distance, the greater is the sensitivity). Remember, however, that the second anode voltage that governs the electron velocity must be specified whenever a sensitivity rating is mentioned. This is necessary because increasing the velocity (by increasing the second anode potential) will reduce the deflection sensitivity, and make it necessary to apply higher deflecting voltages to obtain the desired sweep.

Curved Deflection Plates. As has already been pointed out, the deflection sensitivity is dependent upon the lengths of the deflecting plates and upon their separation. For a given electron speed, there is an optimum length and optimum separation, but deflection sensitivity can be increased by keeping the beam close to the plates without actually hitting the plates. Curved plates that flare outward in the manner shown in Fig. 16 meet this requirement. You will find that plates of this type are used extensively in picture tubes because they permit a closer spacing of the gun end of the plates, and still do not intercept the beam when it is bent a maximum amount.

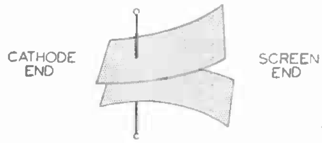


FIG. 16. Flared deflection plates of this sort are often used in electrostatic tubes.

TYPICAL ELECTROSTATIC PICTURE-TUBE CIRCUIT

Let us briefly review what we have learned about electrostatic picture tubes, and see how they are actually connected in practical TV circuits.

A cross-sectional diagram of an electrostatic-type picture tube, including the electron gun and one set of deflecting plates, is shown in Fig. 17.

Electrons, emitted by the cathode, are accelerated by the first and second anodes. The voltage between the grid and the cathode controls the number of electrons that are able to pass the grid, and this in turn controls the intensity of the spot produced on the screen of the tube.

The grid is at a fixed d.c. potential with respect to ground, but the voltage between the cathode and the grid can be varied by means of potentiometer R_1 that functions as the intensity or brilliancy control. The video signal is applied to the control grid through coupling condenser C, and is developed across resistor R. Thus, this signal is effectively in series with the bias voltage.

As you know, the focus of the electron beam is controlled by varying the voltage difference between the first and the second anodes. Thus R_4 serves as the focus control. Resistor R_3 is connected in series with the first anode to limit the anode current to safe values by causing the anode voltage to drop as the current increases.

The high B voltage (accelerating voltage) is applied to the second anode through protective resistor R_5. The deflecting plates must have a d.c. voltage almost as high as that applied to the second anode to avoid defocusing of the beam. Therefore one deflecting plate is connected between R_7 and R_8, and the other deflecting plate is connected to potentiometer R_9. The sweep voltage is applied through condensers C_1 and C_2, with resistors R_{10} and R_{11} acting as coupling resistors.

If the center arm of R_9 is varied until the voltage applied to the upper deflecting plate is equal to the voltage applied to the lower plate (that is, at the same potential as the junction of resistors R_7 and R_8), then the electron beam will have the center position shown at A if the tube is perfect. (The beam is being deflected to either side of this position by the a.c. sweep voltage applied through C_1 and C_2.)

If we move the center arm from this position (position 2 on R_9) so that the

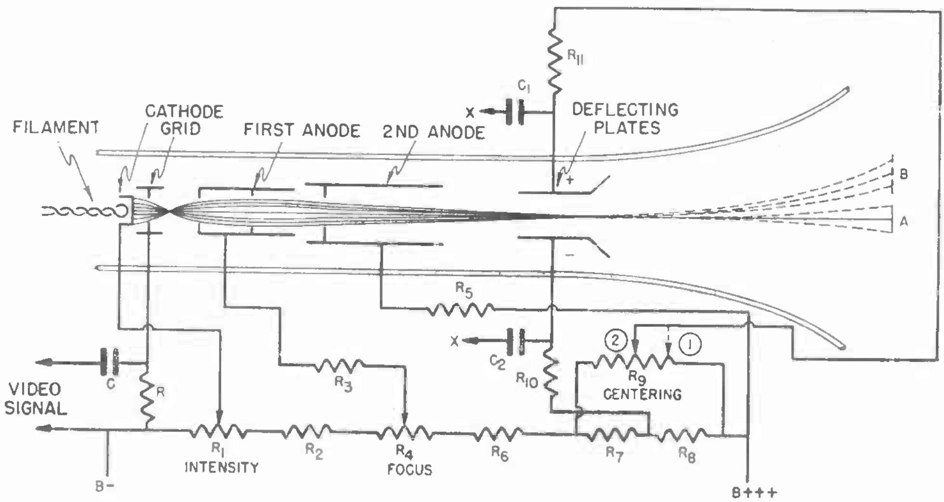


FIG. 17. Cross-sectional view of a typical electrostatic tube, showing voltage division arrangement for one pair of deflection plates.

upper plate is more positive than the lower plate, then the electron beam will be moved upward to position B; that is, as we move the center arm from position 2 to position 1, the beam moves from position A to position B. The beam is still moved to either side of the center position by the saw-tooth sweep-deflecting voltage applied through C_1 and C_2. Similarly, by moving the R_9 slider the other way, the beam is moved nearer the lower deflection plate. Therefore, R_9 acts as a centering control; irregularities in the tube may prevent the beam tracing from being centered on the tube face, so R_9 can be adjusted as required to center the raster.

The other resistors in the voltage divider, consisting of R_2 and R_6, serve simply to divide the voltages in the proper proportion between the various electrodes of the picture tube.

We have not shown the other set of deflecting plates here, so in Fig. 18A, a more complete and more typical voltage divider circuit is shown. The high B voltage is supplied to the upper end of the voltage-divider circuit, and the lower end is connected to ground at the point where B– from the high voltage supply is connected. Voltage is applied to the second anode through resistor R_1 which acts to limit second-anode current to a safe value.

Resistors R_2 and R_3 correspond to R_7 and R_8 in Fig. 17. A lead is taken to one of the vertical deflecting plates through R_9, while another lead is connected to one of the horizontal deflecting plates through R_6.

Potentiometers R_4 and R_7 are connected in parallel with R_2 and R_3; R_4 is connected through R_5 to the other horizontal deflecting plate. By varying the position of the center arm on R_4, we can vary the d.c. potential between the two horizontal deflecting plates. Therefore, R_4 acts as the horizontal centering or positioning control. Resistor R_7 serves a similar function for the vertical plates and is thus the vertical centering control.

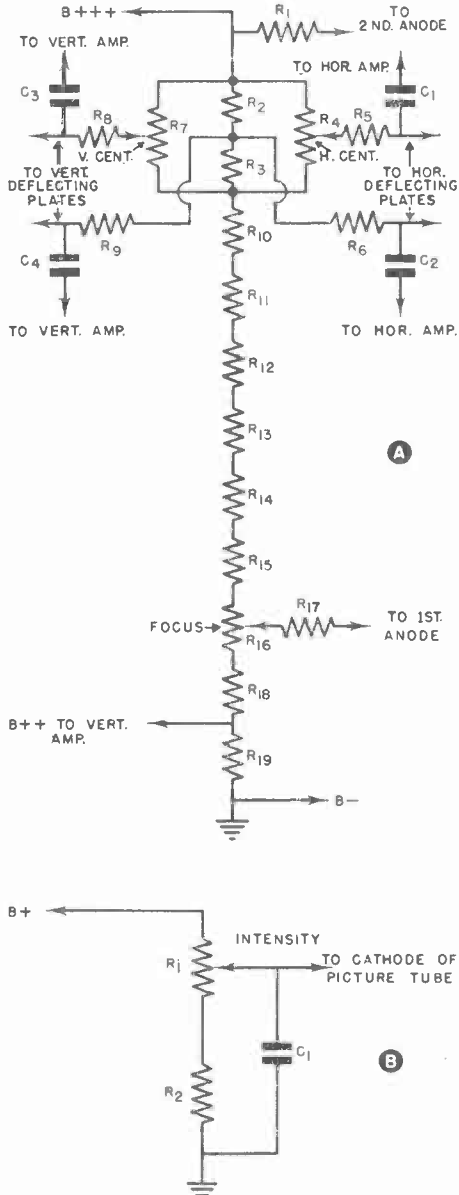


FIG. 18. Typical complete voltage division arrangement used with electrostatic picture tubes.

The sweep voltage for the vertical

plates is applied through condensers C_3 and C_4, while the sweep voltage for the horizontal plates is applied through C_1 and C_2. Since the horizontal-sweep frequency is much higher than the vertical-sweep frequency, smaller condensers may be used at C_1 and C_2 than at C_3 and C_4.

Note that we have six resistors instead of one between the lower end of R_3 and the upper end of focus control R_{16}. These correspond to resistor R_6 in Fig. 17. The heat dissipation in a high-voltage divider circuit is comparatively high so a single standard-size resistor, even of a comparatively high wattage rating, is not satisfactory. Rather, a series of resistors are used, with the total resistance of the individual resistors adding up to the correct value for proper voltage division.

Thus the wattage dissipation is divided among the various resistors, and lower-wattage, and hence physically smaller resistors, may be used. If some of the resistors in this group should change in value, the voltage division would also change, and it may be impossible to focus the electron beam. There is less chance of such a change occurring if the wattage rating of the individual resistors is not exceeded.

In this particular voltage divider, provision is not made for controlling the intensity of the electron beam. Rather, a separate d.c. voltage is applied to the cathode of the picture tube as shown in Fig. 18B. By varying the position of resistor R_1, the potential between the cathode and the grid may be varied with a resultant change in brilliancy. A by-pass condenser, C_1, is connected between the center arm of the intensity control, shown in Fig. 18B, and ground. This serves to keep the cathode at ground potential as far as video signals are concerned.

Instead of using resistors such as R_2 and R_3 for applying a fixed d.c. voltage to one of a pair of deflecting plates, a tap may be provided on the centering control as shown in Fig. 19. This may be a center tap, but in some cases it will be found that the tap is off center. This is because some electrostatic tubes, due to manufacturing tolerances, may not require exactly the same voltage applied to the horizontal deflecting plates as is applied to the vertical deflecting plates for proper centering. Thus, the horizontal centering control may have the tap off center, whereas the vertical centering control may have the tap exactly in the center.

Service Hints. When replacing the centering controls in a TV set, it is important that an exact duplicate replacement be obtained if a tapped control is used. This insures that the tap will be in the right position for the particular pair of deflecting plates to be controlled.

A change in value of resistors R_2 or R_3 may make it impossible to correctly center the raster. More often this is due to leakage in one of the coupling condensers that feeds the deflecting plates. Leakage in one of the condensers will change the d.c. voltage

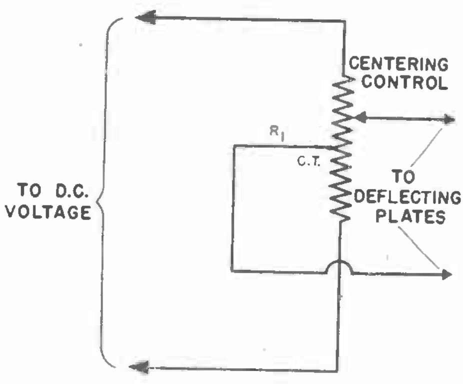


FIG. 19. Tapped centering control often used with electrostatic tubes.

applied to the plate in question, and may even throw the raster entirely off the screen, either in a vertical or in a horizontal direction.

ELECTROMAGNETIC DEFLECTION

You already know that when an electron stream passes through a magnetic field at right angles to the lines of force, the stream is bent at right angles to both the lines of force and the original path. Fig. 20 illustrates how this principle is employed to give electromagnetic deflection in a picture tube. Electrons e, traveling along the principal axis of the tube in a stream, enter a uniform magnetic field having bending action will be uniform at all points in the field, and the electron stream will follow a circular path having a radius R. Once electrons emerge from the field at point 2, they travel in a straight line again. The path shown in Fig. 20 would take the electron stream to the outer edge of the fluorescent screen.

When an electron stream travels through a uniform magnetic field, the velocity of the electrons is not altered by the magnetic field. Increasing the flux density in the magnetic field shortens the length of radius R, thereby increasing the amount of deflection on the screen. Increasing the length of the magnetic field along the path of

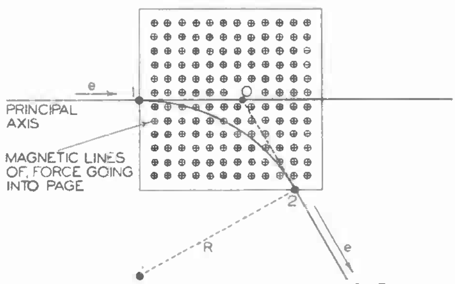


FIG. 20. How electromagnetic deflection works.

lines of force flowing into the paper. By applying the left-hand rule to determine the direction of the magnetic flux created by this electron flow, we find that there is a crowding of flux above the path, and a thinning out or canceling of flux below the path. The electron stream is thus bent downward in the plane of the paper, at right angles to both the original path and the magnetic lines of force. Reversal of the magnetic lines of force will cause the beam to be bent upward. Thus, we can get magnetic deflection as well as magnetic focusing just by using the proper coils for each purpose.

As long as the density of the magnetic field in Fig. 20 is constant, the electron travel does not affect the value of R, but does increase the amount of deflection since the electrons are under the influence of the magnetic field for a longer period of time. The higher the velocity of the electrons in the stream, the greater must be the flux density in the field in order to secure a given amount of deflection, for a stiff (high-velocity) electron beam is not bent as readily as a low-velocity beam.

In a practical tube, a magnetic field for beam deflection is produced by an electromagnet that surrounds the neck of the tube. Once the poles of this electromagnet are identified, we know that the electron beam will be deflected at right angles to the line between the pole faces. Thus, the pair of magnetic poles that serves for vertical deflection of an electron beam will be mounted horizontally, and the poles that give horizontal deflection will be mounted vertically.

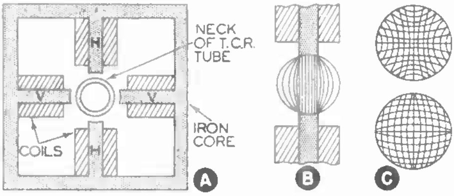


FIG. 21. Design and characteristics of a simple electromagnetic deflecting yoke.

A simple electromagnetic deflecting yoke that provides both vertical and horizontal deflection is shown in Fig. 21A. Note that the vertical deflecting poles V are arranged horizontally, and the horizontal deflecting poles H are arranged vertically. The yoke is constructed from laminated sheet steel, with the coils wound on bobbins, or forms that slip over the poles. Opposite coils are connected so that they have opposite polarity.

Although the simple electromagnetic deflecting yoke in Fig. 21A will give a spot deflection that is essentially proportional to the deflecting circuit current, it will also produce defocusing and pattern distortion. This is because of the fact that the magnetic field between opposite poles is not uniform, but rather has curved lines of force as shown in Fig. 21B. It can be shown by means of a very complex analysis that when electrons travel through a non-uniform magnetic field, the circular beam is flattened out to an egg-shaped spot instead of a round spot on the screen.

When the fields for both horizontal and vertical deflection are non-uniform in density and are curved, pattern distortion of the type shown in Fig. 21C occurs when an image made up of perfectly vertical and horizontal cross lines is being reproduced. We need not consider these defects in detail, since they can be avoided by using deflecting yokes that give uniform, straight-line magnetic fields.

In the improved type of electromagnetic deflecting yoke that is used with modern picture tubes, rectangular coils are wound in such a way that they fit inside one another as shown in Fig. 22. The windings for each coil are connected in series, then bent into the half-cylinder shown in Fig. 22B. Two such systems of coils are placed around the neck of the picture tube, and are connected together in series in such a way as to produce poles of opposite polarity. A pair of coil systems like this produces the desired uniform straight magnetic field. One pair of coils is placed directly over the neck of the tube and made to serve for horizontal deflection, and the other pair is placed over the first pair and made to serve for verti-

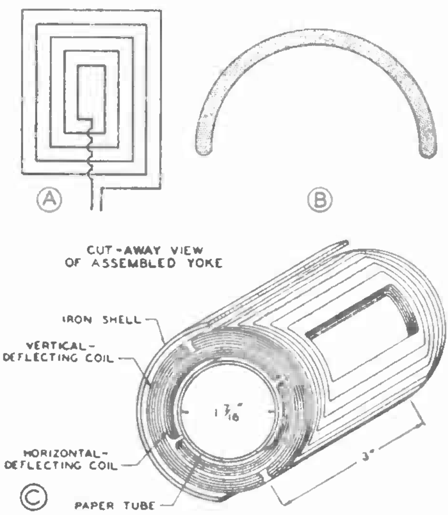


FIG. 22. Construction of a modern deflecting yoke.

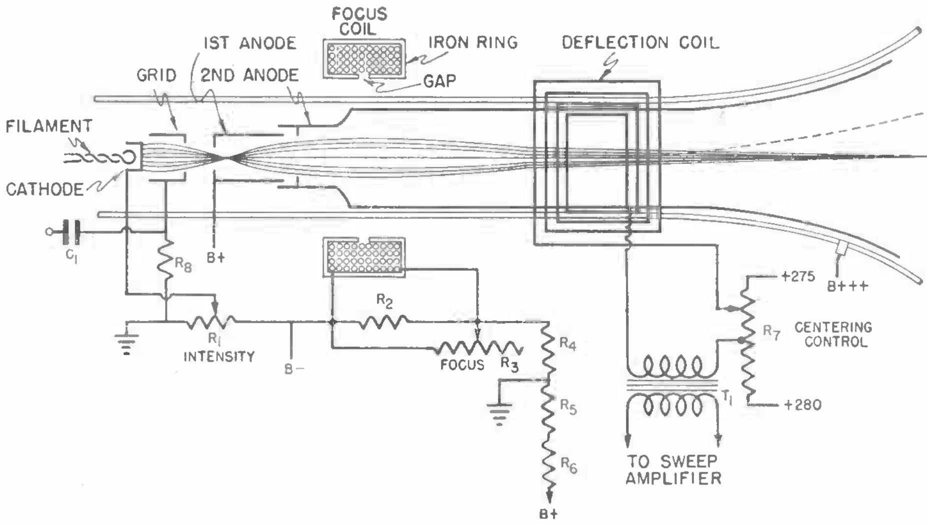


FIG. 23. Cross-sectional view of an electromagnetic tube, showing where the various operating voltages are applied.

cal deflection as shown in Fig. 22C. The entire coil assembly is encased in a soft-iron shell in order to reduce the reluctance of the magnetic circuit, to prevent stray magnetic fields from affecting the deflection circuit, and to prevent the magnetic fields of the coils from affecting the focusing field of the picture tube.

In an electrostatic deflection system, the sweep voltage that is applied to the deflecting plates must have a true saw-tooth characteristic. In an electromagnetic deflecting system, the current through the deflecting coils must have this same saw-tooth characteristic.

ELECTROMAGNETIC TUBE CIRCUIT

Let us now briefly review some of the things that we have learned about electromagnetic-type tubes, and see how they function in actual receivers.

In electromagnetic tubes the intensity of the electron beam is controlled in the same way that it is in electrostatic tubes, that is, the d.c. voltage applied between the control grid and the cathode of the tube is varied by means of a potentiometer such as R_1 shown in Fig. 23. The signal is applied through C_1 so that it appears across R_8.

The current through the focus coil that is placed around the neck of the picture tube is varied in order to change the focusing of the electron beam. As the resistance of R_3 is increased, for example, more current can flow through the focusing coil, and a stronger magnetic field will be produced, changing the focus point of the beam.

A cross-sectional view of the construction of the focus coil is illustrated in Fig. 23. The coil is wound of copper wire and a soft-iron ring is placed around it. A gap is provided in the iron ring, and the magnetic field spreads out from this gap. This provides a concentrated magnetic field that will not extend beyond the section of the tube of the neck in which the focusing action is desired. No matter at what angle the electrons enter the field, the magnetic field provides enough deflection so that they will all be focused at the same point on the screen. The path followed by any one electron will be a cork-screw shape because of the resultant action of the two forces—the force acting to accelerate the beam (high voltage on the second anode), and the force acting to focus the beam.

Positioning the Beam. To position the electron beam, d.c. is passed through the deflection coil in series with the a.c. obtained from the sweep amplifiers. It is quite easy to provide a variable direct current. A variable resistor is placed in the voltage divider of the low-voltage power supply. In Fig. 23, a tapped potentiometer R_7 is used. Thus, as the center arm is moved past the tap, the direction of the d.c. flow through the coil will be reversed, reversing also the movement of the electron beam. Tapped centering controls are not used in all sets, however. In many instances, centering is accomplished by moving the focus coil. Once the correct position of the focus coil has been obtained for proper centering of the picture, the current through the coil may be readjusted to give correct focus. The focusing adjustment will not change the centering of the picture.

Instead of centering the focus coil or allowing d.c. to flow through the deflection coil, centering is sometimes accomplished by means of permanent magnets mounted on the neck of the picture tube between the focus and deflection coils. Such an arrangement is illustrated in Fig. 24. The centering ring and the support assembly are shown here between the focus coil and the deflection yoke. The centering assembly consists of a large ring that can be moved forward or backward along the ring-support assembly. To center the electron beam, move the large ring toward the focus coil. The whole centering assembly is rotated until the beam moves to the proper position. Then the large ring is moved forward until the beam is centered. The present trend is, however, toward centering (without special controls or additional magnets) by adjusting the position of the focusing coil.

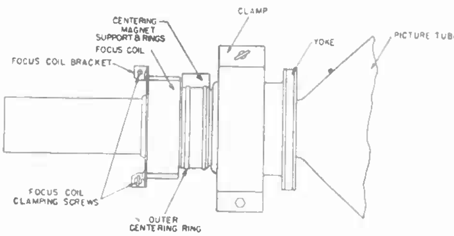
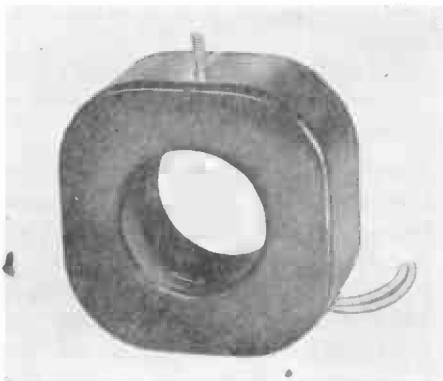


FIG. 24. How a permanent centering magnet is installed.

A typical focus coil is shown in Fig. 25A. This focus coil is an electromagnetic coil, that is, the magnetic field depends directly upon the current flowing through the winding. The bolt extending from the top of the focus coil passes through the mounting assembly, and may be tightly fastened to the assembly with a wing nut after the focus coil has been positioned. This holds the focus coil in place so that it will not be jarred out of position.

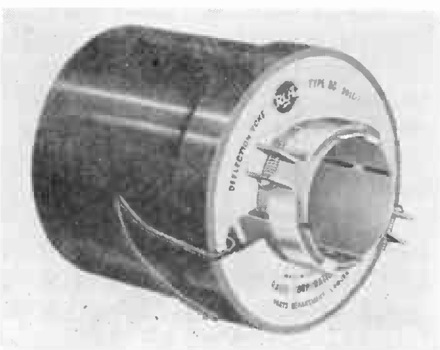
Considerable current through the coil is usually required—100 ma. or more. This current, however, is easily obtained from the low-voltage supply of the receiver. When this is done, a large percentage of the direct current required from the B supply of the receiver can be passed through the focus coil with only a slight voltage drop. It would, of course, be possible to use a permanent magnet for the focus coil, or to use a permanent magnet to furnish most of the field and a small auxiliary electromagnet for fine focusing.

The focusing field must be produced by well-filtered d.c. in order to avoid blurring of the spot; a.c. ripple through the focus coil would produce a changing electromagnetic field, and as a result the beam would go in and out of focus. For a typical 10-inch picture tube about 450 ampere-turns are required for the focusing coil to obtain sharp focusing of the beam. For a projection tube with a very stiff beam, about 1000 ampere-turns are required for focusing.



Courtesy RCA

FIG. 25A. Typical focus coil.



Courtesy RCA

FIG. 25B. Typical deflection yoke.

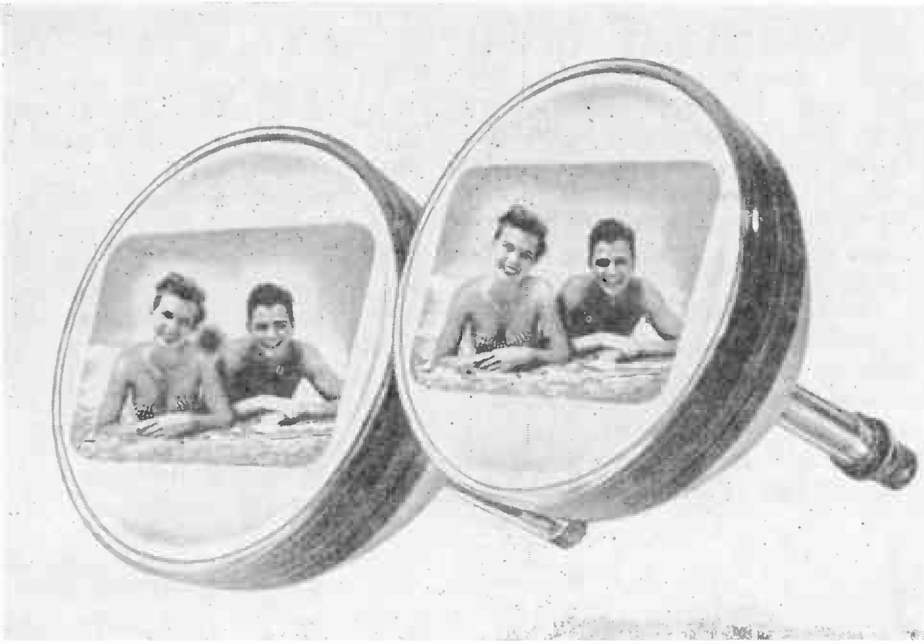
A typical deflection yoke containing the horizontal and vertical deflection coils is shown in Fig. 25B. This also slips over the neck of the tube in front of the focus coil as we illustrated in Fig. 23.

THE ION SPOT

One of the defects of early picture tubes employing electromagnetic deflection was the formation of a dark spot in the center of the screen. This occurred after a few hours of use, and, as shown in the picture at the left in Fig. 26, was very objectionable. Once this dark spot appeared on the screen nothing could be done about it except to replace the tube.

This dark spot is caused by a beam of negative ions that bombards the fluorescent coating at the center of the screen, causing that portion of the screen to disintegrate, and rendering it incapable of producing very much light.

These negative ions in the electron stream have a much greater mass than the electrons, because they are much heavier. The ion spot can be avoided by using electrostatic-deflection tubes because the electrostatic field deflects these heavy ions and the lighter electrons equally well, so there is no concentration of ions at the center of the screen and no ion spot is formed. However, an electromagnetic field has little effect on the heavy ions, deflecting the electrons only. Therefore, when electromagnetic deflection is used, the heavy ions will strike the center of the screen, and in a short time will cause a dark spot to appear in the center of the screen.



Courtesy Sylvania Electric Products, Inc.

FIG. 26. Notice ion spot in center of the face of the tube at left.

ION TRAPS

There are a number of methods for preventing these heavy ions from causing a dark spot on the screen. One method is to use an ion trap. This ion trap actually traps the ions in the electron gun, and prevents them from reaching the screen. There are many variations of this trap used by different tube manufacturers, but all operate on the same principle—that an electrostatic field will deflect both ions and electrons equally well, but an electromagnetic field will deflect only electrons.

One popular ion trap arrangement consists of a special construction of the electron gun and a magnetic ring assembly placed around the neck of the tube. The special construction of the electron gun is shown in Fig. 27A. Note that the adjacent ends of the first and second anodes are cut at an angle rather than straight across as in the conventional manner previously described. Also there is a small aperture at the end of the second anode through which the electrons must pass in order to reach the screen of the picture tube. In general, the first anode will operate at approximately 250 volts while the second anode may have around 8500 volts applied to it. Therefore a strong electrostatic field exists in the air gap between these anodes. Because the gap between the anodes is slanting, the electrostatic field set up in the gap will not follow the normal axis of the tube, but will be slanting like the cut. The ions and the electrons entering this slanting electrostatic field will be deflected away from the principal axis of the tube, and will not get through the small aperture at the end of the second anode, being trapped in the second anode. In order to separate the ions from the electron stream we make use of the fact that a magnetic field will deflect the electrons, but has little or no effect on the heavier ions. By placing a magnetic ring on the outside of the tube neck, approximately over the gap between the two anodes, and magnetizing the ring in such a way that magnetic flux cuts across the neck of the tube, the effect of the slanting electrostatic field on the electrons can be neutralized.

By proper adjustment of the magnetic ring the electrons can be made to return to a straight line along the principal axis of the tube, passing through the opening in the end of the second anode so that they can strike the fluorescent screen. The heavier ions, however, will remain trapped in the second anode, since the magnetic field has practically no effect on their direction of travel, and they are not deflected back to the principal axis of the tube. This action is illustrated in Fig. 27B. Another but smaller magnetic ring usually follows the first one to compensate for the fact that the first magnet does not exactly line up the stream with the mask hole. However, in some picture tubes only one magnetic ring will be used.

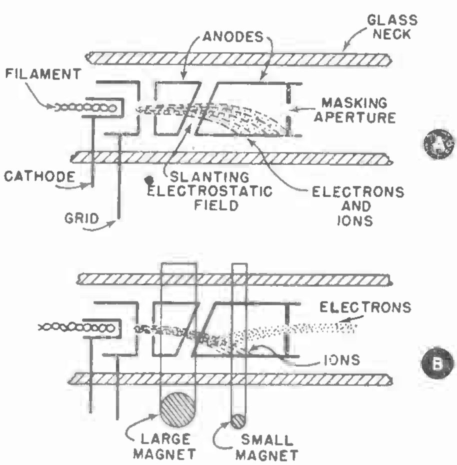


FIG. 27. How a two-magnet ion trap works.

ION-TRAP ADJUSTMENT

The proper adjustment of the ion-trap magnet on the neck of the picture tube is of major importance in installing and servicing a TV set.

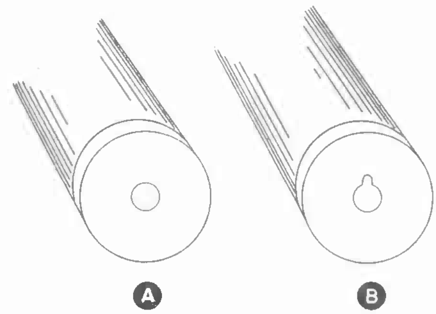


FIG. 28. If the ion trap is not properly adjusted, the aperture at the end of the second anode may be burned.

When the ion trap is completely out of adjustment, the electron beam cannot escape from the second anode, so there is no raster (no screen illumination) at all. If this condition of electron bombardment of the second anode continues for long, a hole may be burned in this element.

When the ion trap is in partial adjustment, there will be a raster, but it will be dim, and may have a "shadow" in one corner or on one side. This occurs because, when the magnet is not in the correct position, the electron beam bombards the edge of the hole in the second anode baffle, instead of going through the aperture. The reduced number of electrons reduces the raster brilliancy. Even worse, the heat thus produced will vaporize the metal of the disc, producing a non-circular hole as shown in Fig. 28B, and releasing gases that have a harmful effect on the operation of the tube. Some of this vaporized material may be deposited on the screen, causing permanently darkened areas.

To avoid damage to the picture

tube, the ion-trap magnet should be adjusted immediately when the tube is installed in the set, and should be checked when the set is moved to a new location as the magnet may have been jarred out of position.

The ion trap is adjusted until the brightest raster is obtained. With the tube operating, and with the brightness control adjusted for low intensity, the magnet should be moved a short distance forward and backward, and at the same time rotated until the combination of these movements produces this condition of brightest raster. By keeping the brilliancy control at a low setting, the beam current is low enough so that the electron beam is not likely to damage the anode aperture before the magnet is adjusted.

Fluorescent Screens and Tube Envelopes

Now that you have seen how the electron beam is produced, focused, and deflected, let's learn more about the screen that produces light when struck by this beam.

FLUORESCENT SCREENS

The special chemical material that is deposited on the inner face of a picture tube (in the position shown in Fig. 29) will produce light when bombarded with a stream of electrons. The explanation usually offered for this phenomenon is that the energy of electron impact disturbs the electrons in the atomic structure of the chemical material, thereby making this material absorb energy. In returning to their normal state, the electrons in this material give off light. Any material that behaves in this manner is known as a phosphor. The production of light by a phosphor while being excited by an electron stream is called fluorescence.

The preparation of phosphor material for picture tubes is a highly specialized branch of chemistry. The most commonly used materials are willemite and zinc sulfide. Willemite is a chemical made up chiefly of zinc, silicon and oxygen, and gives a green to yellow fluorescence when bombarded with electrons. Zinc sulfide phosphors are available under various trade names, and normally give a blue fluorescence. When used with small portions of other materials known as activators, the fluorescent action is increased and the color of the light is changed. By properly combining the different materials, it is now possible to secure an almost white fluorescence.

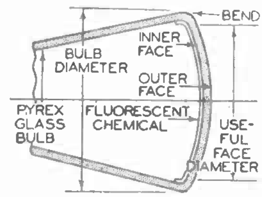


FIG. 29. The fluorescent screen material is deposited on the inner face of a picture tube.

Decay Time. Once a fluorescent material is bombarded by an electron stream, it will continue to glow even after the electron stream has moved away or has stopped. It is possible to make phosphor materials that will glow as long as one minute after excitation, but these materials would hardly be suitable for picture tubes. In television it is desirable to use materials that glow for very short periods after the excitation has been removed, so that an image remains almost until the next one takes its place, but the

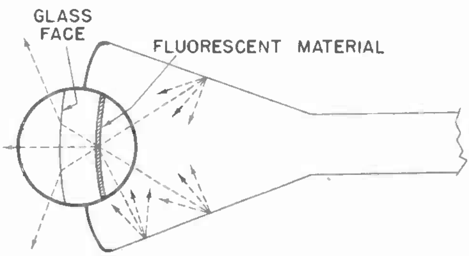


FIG. 30. Light is emitted in all directions from an element of the fluorescent screen of a conventional picture tube.

image should not remain long enough to interfere with a following one.

The glowing of a screen after removal of excitation is referred to as the persistence of the screen, and the time it takes to reduce the glow a certain amount (say to 1/10 of its original brilliance) is known as the decay time. By selecting a decay time that will give a reduction in brilliancy to a negligible value in 3 milliseconds or less, one image will be almost completely dark by the time the following image is produced, and there will be no overlapping of images. The persistence characteristic of a fluorescent screen is highly desirable in that it aids the persistence of vision of the human eye, thereby reducing flicker and helping to maintain screen brilliancy.

DAYLIGHT TUBES

Considerable work has been done to improve the amount of light obtained from picture tubes. A cross-sectional area of an ordinary picture tube is shown in Fig. 30. In this figure the region in the circle is greatly magnified to show one element of the phosphor that is fluorescing. Light is emitted in all directions from the spot, so at least 50% of the light generated in the screen is emitted toward the electron gun in the neck of the tube. Another 20 to 25% is lost by reflection from the glass on the inside of the tube face. Thus only 25 to 30% of the total light generated passes through the glass face in the form of useful light output.

Fig. 31 shows a tube whose screen is covered with a layer of aluminum deposited behind the phosphor crystals. The light that ordinarily would go back toward the electron gun is reflected forward in the direction of viewing. These tubes with an aluminum backing are frequently referred to as Daylight tubes because they can be viewed in full daylight.

The metallic backing on the screen must be thin enough not to slow down the electron beam, and it should be optically flat so that it will reflect the light that is given off by the phosphor, thus increasing the efficiency of the

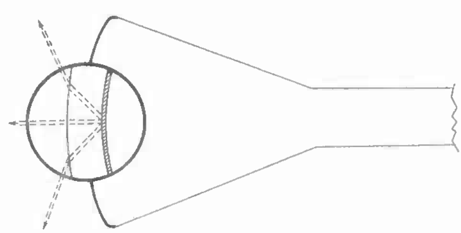


FIG. 31. Most of the light emitted by an element of the fluorescent screen is directed forward if the screen has an aluminum backing.

tube. Also, the metallic backing should provide a conductive surface over which the electrons can move, preventing the screen from assuming a negative charge, so that maximum energy is available from the electrons.

In construction, the aluminum is usually vaporized onto a flat intermediate surface of organic material deposited on the phosphor. The organic coating is then evaporated, leaving the new surface supported on the tips of the phosphor crystals. In addition to producing far more light output, the aluminum backing prevents the formation of an ion spot

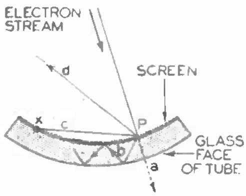


FIG. 32. Light emitted from an element of an unbacked fluorescent screen may take any of these paths.

burn on the screen because the large ions cannot penetrate the aluminum to strike the screen. Hence, a special gun with an ion trap is not required with tubes of this type. These tubes are widely used for direct viewing and practically all projection tubes employ this aluminum backing, since all the light possible is required in projection.

As shown in Fig. 30, some of the light reflected back into a tube without the aluminum backing will strike the side of the bulb, and is then reflected back through the screen. This may cause an area that is normally dark to be illuminated. As a result the contrast will be poor. To have good contrast the black areas must be black and the white areas must be white with the proper shadings in between. Thus the aluminum backing will, to some extent, improve the contrast.

HALATION

As stated previously, only a portion of the light produced by the electrons bombarding the screen is visible from the outside. The point at which the beam strikes the fluorescent material becomes a source of visible light, and the produced light rays spread in all directions. Light rays at a large angle to the direct path shown as A in Fig. 32 are reflected back and forth between the inner and outer surfaces of the tube face as indicated by path B.

Some rays from this point source go directly to some other point on the screen such as along path C to point X, causing excessive brightness (particularly when point X represents a dark spot). This latter effect is increased by the curvature of the glass front plate. When relatively flat faces are employed, this trouble is not apparent and as stated before does not occur when aluminum backing is used.

Sidewise dispersion of the light as shown by line B in Fig. 32 causes more difficulty and results in halation. This is illustrated in Fig. 33. Along any one line the effect of halation will cause shadowy lines to border the desired bright line. For this same reason there will be a halo around the spot if the beam were stationary. Focusing adjustments are always made for the sharpest possible line with minimum halo. A technician must be able to

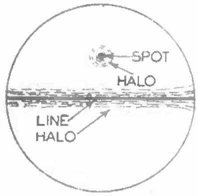
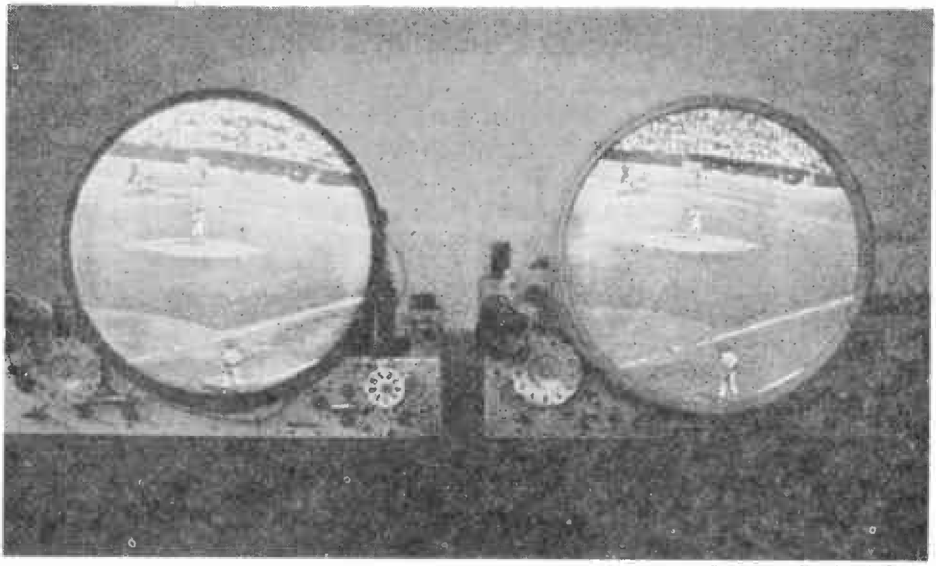


FIG. 33. Effects of halation.

recognize halation as an inherent defect in some picture tubes, and should not waste valuable time in attempting to correct the trouble.

SPECIAL SCREENS AND FILTER GLASS

Halation can be minimized by using an opaque binder with the crystals. The binder confines the light emission



Courtesy Rauland Corp.

FIG. 34. Improvement in contrast produced by the use of a special glass for the picture tube face is illustrated at the right.

of each crystal to the viewing side of the crystal. This action prevents the scattering of light, and as a result increases the contrast of the picture.

The reflection of light from the air surface of the glass face plate back to the screen, to the surface and back to the screen again is minimized in some tubes by the use of special optical filter glass. (One filter face of this type is called Teleglas; the improvement in contrast is shown in Fig. 34.)

Ordinarily, any light falling on the tube face would change the blacks in the picture to a lighter shade, thereby reducing the over-all range of contrast. By using tubes with a filter glass face plate it is possible to have more illumination in the room where programs are being viewed without the attendant reduction in contrast.

At first, thin filters, sometimes of colored material and sometimes of polaroid, were used in front of the tubes in an effort to preserve contrast in an illuminated room. This cut down on external glare, but did not take care of the reflections inside the tube face plate that produce halation. It was found that by making the entire face plate a filter, both external and internal reflections could be reduced to a minimum. Thus, both the halation and the external glare are reduced by using optical filter face plates.

Tubes using filter face plates are known as grey tubes, and sometimes as black tubes since the tube when not illuminated has a face considerably darker than that of the ordinary picture tube.

FACE SHAPES

For viewing purposes, a flat face is desirable for a picture tube, but it is difficult to maintain sharpness of focus on a completely flat screen with a tube having a diameter of more than 10 inches. Referring to Fig. 35, we see that point O is the apparent source of the electron beam after it has been acted upon by the deflecting system. The focusing system in a picture tube is designed to bring the beam to a spot of a definite area at a definite distance from the focusing electrode structure. Thus, with proper adjustments the spot will be focused at point S in the center of the screen in Fig. 35. The spot will also be focused properly anywhere along the arc 2, for all points along this arc are the same distance from the focusing system as is point S.

If the face of the picture tube is made with a curvature corresponding to arc 2, the spot will be in focus on the screen at all times. Hence, a certain amount of curvature will give better over-all focusing than will a flat face.

On the other hand, if a screen has a radius that is too short (too much curvature), as indicated by arc 3 in Fig. 35, the image will be noticeably out of focus near the edges. Hence, such a radically curved face gives poorer picture quality and also is undesirable to watch as the image is curved. In general, therefore, the face plates found in use will either be flat, or will have a slight curvature—just enough to provide better focus and give reasonable safety.

The safety factor is particularly important in the larger picture tubes. A picture tube has an almost perfect vacuum inside, and consequently the normal atmospheric pressure of about 15 pounds per square inch is pressing against the glass envelope at all points, tending to collapse it. A 15-inch diameter picture tube has a face area of about 177 square inches. Multiplying 177 by 15 gives a pressure of about 2655 pounds on the face of the 15-inch tube.

A flat surface bends far more easily than does a curved surface. If a flat screen were used on a tube of this size, a slight jar or blow might be sufficient to cause collapse of the face. Under this condition the glass flys inward (an implosion) and then outward again, with sufficient force, in the case of the larger tubes, to cause serious personal injury. The use of a high-strength glass that is carefully annealed so that there are no strains, and the construction of the glass envelope in such a way that there are curves rather than flat surfaces at all points minimize the danger of collapse.

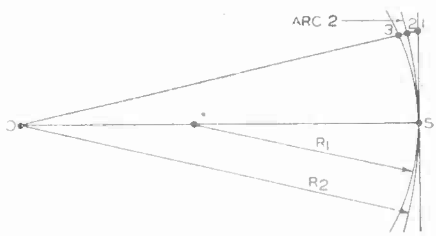
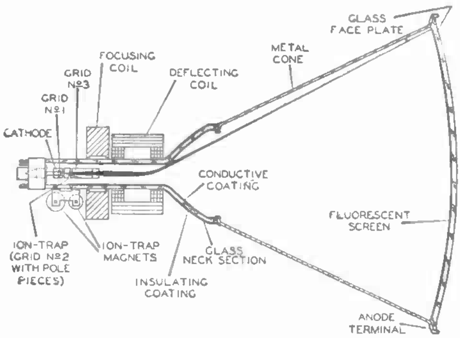


FIG. 35. Effect of screen curvature upon the sharpness of focus.

METAL TUBES

The trend in TV receivers has constantly been toward larger pictures and less expensive receivers. The price of picture tubes, however, has made big-picture receivers expensive, since there is a limit to the saving that can be made in component parts and in receiver assembly procedures.

A 16-inch metal tube has been developed that has made drastic price cuts possible for large-picture receivers. This tube provides a picture size intermediate between the popular ten-inch picture tube and the large-screen projection television systems. This tube is illustrated in Fig. 36. The envelope consists of a metal cone. To the large end of the cone is fused a slightly curved glass face plate; to the smaller end is fused the glass neck section containing the electron gun. The metal cone is made of a chromium-iron alloy chosen because of its



Courtesy RCA

FIG. 36. Cross-sectional view of a 16-inch metal tube.

excellent sealing quality. The shape of the cone was chosen because of its strength and its adaptability to mass production. Unique features of the tube are the large area of glass-to-metal seal between the face plate and the metal cone, and the stress system that permits the use of a relatively thin face plate of uniform curvature.

In order to fit into a wide range of uses, the tube was designed to operate either with a lower-cost power supply, such as is used in present 10-inch receivers, or at much higher voltages.

One of the features of this tube is its light weight. Heretofore, large glass tubes have been extremely heavy, but the 16-inch tube weighs no more than the glass 10-inch tube.

The metal shell serves as the anode, being electrically connected to the anode gun through a conductive coating deposited on the inside of the glass neck section. The metal cone, therefore, is at a high potential and is often covered by a plastic insulating sleeve. The connection is made to the anode at the portion of the metal envelope marked "anode terminal" in Fig. 36. The flared glass section provides electrical insulation between the deflecting coils that operate at ground potential, and the exposed metal cone surface that operates at a high potential. Of course, one should avoid contact with the metal shell while the receiver is operating because the high voltage is dangerous.

Many of the dangers of implosion are removed by the use of the metal tube, since most of the flying glass comes from a fracture of a tube near the face plate. Breakage of the face plate in the metal tube usually will not send glass flying in all directions.

Metal tubes have also been made in other sizes such as the 8-inch tube and the 19-inch tube. All-glass tubes, however, will continue to be manufactured for a long time, and their price will drop as glass manufacturers find more efficient methods of production.

SAFETY RULES

As the old saying goes, "Familiarity breeds contempt," and many TV technicians handle picture tubes without the caution that they deserve. To be on the safe side, respect the picture tube, since under some conditions they may be extremely dangerous. Never drop a tube, even from an elevation of a fraction of an inch. Do not slide a tube over any hard surface, because it may scratch at the bend around the face and so weaken the tube that at some future time a slight jar may cause an implosion. A tube should always be placed in its carton or on a rack when not in use. Never subject a tube to sudden changes in temperature; when a tube has been operating for some time, allow it to cool before taking it outdoors.

In tubes that have an outer conductive coating, remember never to touch this coating and the anode connector simultaneously; if you do you may receive a shock because of the charge between the inner and outer conductors. This shock in itself is not particularly dangerous, but could startle you sufficiently to make you drop the tube with a resulting implosion. To avoid such a shock, the anode connector should be discharged to the outer coating before handling the tube, even though it has been out of use for some time.

Although it is a rare thing for a tube to implode, picture-tube manufacturers always emphasize the following: "Shatter-proof goggles and heavy leather gloves should be worn when handling picture tubes. Persons not protected in this manner should be kept at a distance." Observe these picture-tube safety rules at all times.

Practically all large television receivers have a safety glass window over the viewing face of the picture tube. This window prevents accidental damage to the tube by objects falling on it, and protects the viewers from flying glass if an implosion occurs for any reason. Never remove this protective glass window from the customer's receiver, even though it does slightly reduce the brilliancy of the viewed picture.

From time to time it is necessary to replace defective picture tubes, and this brings up the problem of disposing of the old tube. Use discretion in the breaking up or disposal of picture tubes. Even when put out for the rubbish collector be sure that they are broken to avoid their coming into the possession of children, or for that matter, curious adults. A quick easy method of disposing is to seal the tube in its shipping carton, and then drive a heavy tool such as a wrecking bar through the side or bulb end of the case. Sealed shipping cartons are strong enough to withstand the implosion of the tube.

Lesson Questions

Be sure to number your Answer Sheet 51RH-3.

Place your Student Number on *every* Answer Sheet.

***Send in your set of answers for this Lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. Why is the inside of the glass envelope of a picture tube coated with powdered graphite which is electrically connected to the second anode voltage supply?

2. What is the purpose of varying the first anode voltage in an electrostatic tube?

3. Why is a variable d.c. voltage applied between the horizontal deflection plates and between the vertical deflection plates in an electrostatic tube?

4. Give two reasons why several series resistors rather than a single resistor are used in the divider networks of some high-voltage supplies.

5. In the deflection system used in an electromagnetic tube, will the horizontally mounted magnetic poles produce: 1, horizontal deflection; or 2, vertical deflection?

6. How can you tell when the ion trap on an electromagnetic tube is properly adjusted?

7. Why is an ion trap unnecessary with aluminum-backed tubes?

8. What is accomplished by making the face plate of a picture tube also serve as an optical filter?

9. Would you expect best over-all focus in a picture tube with a flat face, or in one with a reasonable amount of curvature?

10. Why is it dangerous to touch the shell of a metal picture tube while the receiver is in operation?

Be sure to fill out a Lesson Label and send it along with your answers.

EACH DAY COUNTS

Each day of our life offers its own reward for work well done, its own chance for happiness. These rewards may seem small, and these chances may seem petty in comparison with the big things we see ahead. As a result, many of us pass by these daily rewards and daily opportunities, never recognizing that the final goal, the shining prize in the distance, is just a sum of all these little rewards we must win as we go along.

J. E. Smith

TV INPUT TUNERS

52RH-2

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE No. 52

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ **1. Introduction** .... **Pages 1-5**

The duties of an input tuner and the interferences to which it is subjected are discussed in this section.

☐ **2. TV and V.H.F. Requirements** .... **Pages 5-11**

Here you learn how internal noise, interelectrode capacities, and input resistances at v.h.f. affect the design of input tuners.

☐ **3. The R.F. Stage** .... **Pages 11-20**

Details of practical r.f. stages are described in this section.

☐ **4. The Converter Section** .... **Pages 20-24**

Here the circuits and operation of practical TV converter sections are discussed.

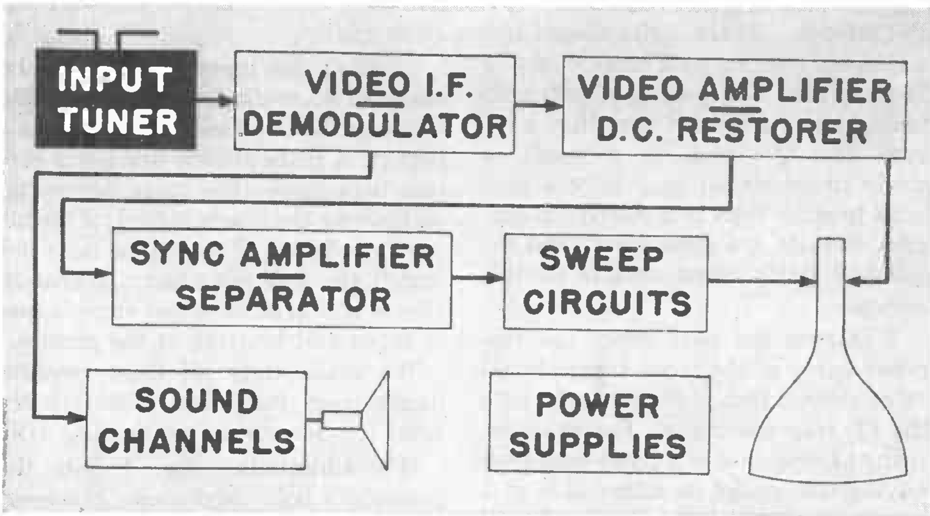
☐ **5. Tuning Systems** .... **Pages 25-36**

The various kinds of continuous and step tuners in use today are described here.

☐ **6. Answer Lesson Questions and Mail your Answers to NRI for Grading.**

☐ **7. Start Studying the Next Lesson.**

JD6M151 1951 Edition Printed in U.S.A.



PRECEDING LESSONS of this television series have introduced you to the basic idea of producing a picture by means of a television system—you have been introduced to the basic circuits, and have made a detailed study of the television picture tube.

In this Lesson, you will continue your detailed study of the sections of a TV receiver with the section called the "input tuner." This section is also known by other names; some manufacturers call it the "r.f. unit," others call it the "front end" or the "head end." Regardless of the name, it corresponds to the preselector-converter section of a sound receiver.

You have studied r.f. amplifiers, band-pass tuners, oscillators, and converters in your Fundamental Lessons, so in this text we shall primarily discuss the special requirements of TV—the basic theory will not be repeated fully here. If you find that you have forgotten some of the fundamentals, review the Lessons in which they were presented. The better you understand how these sections operate, the easier it will be to service them quickly and professionally.

Duties. The input tuner, as a preselector-converter, must initially select the desired signal and, by the heterodyne process, produce from it an i.f. signal. Hence, the input tuner must be tunable to the television channels that are in use. When tuned to any one channel, it should have sufficient selectivity to eliminate at least image interference; some are designed to reduce other interferences as well.

The preselector must pass at least the full 6-megacycle band occupied by each television channel. The pass-band depends on both the resonant frequency and the Q of the tuning circuits, as follows:

$$\text{Pass band} = \frac{\text{Resonant Frequency}}{Q}$$

Hence, at the high carrier frequencies used in television, wide pass-bands are obtainable with a single resonant circuit having a reasonably low Q. For example, a circuit tuned to 60 mc. can pass a band of 6 mc. if its Q is 10 ($60 \div 6$). One tuned to 210 mc. can pass a 6-mc. band if its Q is 35 (210÷6). If the latter circuit had a Q of only 10, its pass band would be 21 mc. wide! The loading of television tuning circuits is such that they have very low Q's, and, as a result, a single tuned circuit may have a pass band broader than is required. Band-pass circuits are sometimes used instead of single tuned circuits for this reason.

Whatever the pass band, the response curve of the input tuner should be so shaped that it fits properly with the i.f. response curve. For example, if the i.f. response is a band-pass type having two peaks on either side of a resonance point, the response curve of the input tuner should have a single peak that occurs in the valley of the i.f. response; the over-all response of the two will then be relatively flat. We'll discuss this later at greater length.

An input tuner cannot have much gain. Its gain depends on the impedance of the resonant circuit used as the load for the input tuner r.f. stage. This impedance depends upon the Q of the circuit, which, as we just said, is kept low. In addition, the converter has very low gain, so the over-all input-tuner gain may be only around 10 to 15.

Finally, the input tuner must be designed to work from some specific transmission line (lead-in from the antenna). A transmission line has a certain impedance (the value depending on the way the line is made); if the input impedance of the tuner does not match the line impedance, reflection effects will exist that can cause a loss of input and blurring of the picture.

We shall study all these requirements more fully, but first let's see what frequencies we are dealing with.

TV Channels. Fig. 1 lists the present v.h.f. television channels. Each of these channels is 6 mc. wide and is designed to contain one complete video and accompanying sound signal. To identify the channels conveniently, they are numbered from two to thirteen. Originally there was a channel No. 1 between 44 and 50 megacycles; this is now assigned to other services, but, since many receivers having channel selectors marked for channel 1 had already been produced by the time this channel was abandoned, the channel numbers have never been changed. Many television sets are still made with the

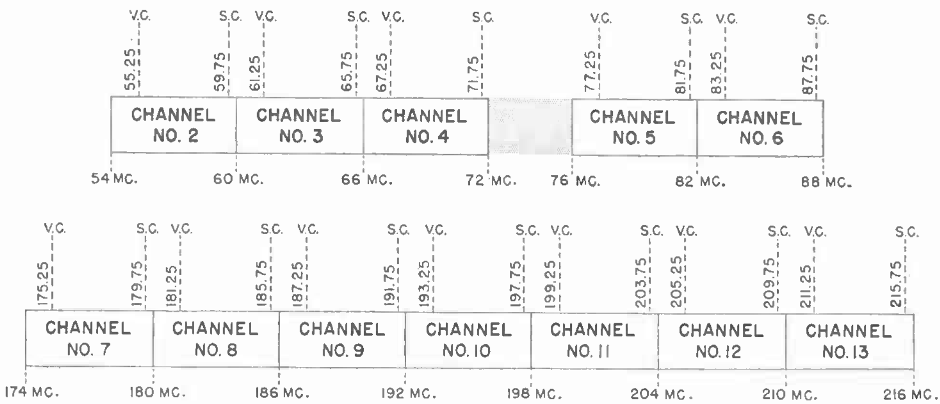


FIG. 1. These are the channels presently assigned to television.

original thirteen-channel selector with a "dead" channel No. 1.

The television channels are not consecutively assigned; there is a small gap of 4 mc. between channels 4 and 5, and a large one of 86 mc. between channels 6 and 7.

Ignoring the small gap, channels 2 to 6 inclusive are called the "low band," and channels 7 to 13 inclusive are called the "high band" or "upper band."

INTERFERENCE PROBLEMS

Interference is more annoying in a television receiver than in a radio, because the eye is far more critical than the ear is. Consequently, television sets are designed to eliminate interference as much as possible. Let's see what can be expected of the input tuner in this respect.

Man-Made Interference. Interference resulting from the operation of electrical apparatus can best be eliminated at the source, as has been shown in another Lesson. About all that can be expected of an input tuner in eliminating such noise is that it should be able to reject noise, whose frequency is as far from that of the desired signal as the image frequency is. Fortunately, many common noise sources produce relatively low-frequency interference that does not affect TV reception seriously. The most troublesome sources are diathermy (medical) instruments and ignition systems.

Harmonics. The TV channels are subject to harmonic interference from other services. F.M. transmitters cause considerable TV interference, for example, because the second harmonic of the f.m. band (88 to 108 mc.) is from 176 to 216 mc. and hence lies in the upper TV band. Of course, the amount of second-harmonic radiation from an f.m. transmitter is kept down at the station, but if the TV set is too close to an f.m. transmitter, it may pick up second-harmonic interference from this station. Fortunately, the second-harmonic radiation dies down rapidly with distance, and it is rather small anyway, so it is unlikely that there will be interference from very many stations in any one locality.

F.M. transmitters are not the only ones producing interference of this kind. For example, second harmonics of the 10-meter amateur band lie within channel 2. In other localities, other services may similarly cause harmonic interference. There is, of course, nothing that the input tuner can do about such interference, since it occurs on the same frequency as the channel being picked up.

Adjacent - Channel Interference. The i.f. amplifier is the section that is supposed to keep down interference from stations on adjacent channels—the input tuner is far too broad to be of much help if the adjacent-channel interfering signal is strong. The present station assignments help in this by skipping adjacent channels in any one locality. Of the twelve channels, no more than seven are given to any one area. Thus, large metropolitan areas such as New York, Chicago, Los Angeles, and Washington-Baltimore are assigned the seven channels 2, 4, 5, 7, 9, 11, and 13. (Note that Washington and Baltimore are in the same area.)

The in-between or alternate channels are assigned to cities between these localities. Thus, channels 3, 6, 10, and 12 are assigned to Philadelphia, which is about half way between New York and the Washington-Baltimore area. In any of these areas, there is little signal pickup from any of the others, and consequently the problem of adjacent-channel interference is reduced. In localities between these major centers, however, it may be possible for a set to pick up signals on adjacent channels. Thus, in a location half-way between New York and Philadelphia, it may be possible to receive some signals from both cities. However, they will be on adjacent channels and not on the same channel, so the amount of interference will depend on the adjacent-channel selectivity of the set.

Some television receivers are primarily designed for use in the large metropolitan areas and are therefore built with somewhat less gain and possibly less adjacent-channel selectivity. Used in their proper localities, such sets are satisfactory. On the other hand, in outlying areas where signal strengths are low, and where it is possible to pick up stations on adjacent channels, sets with more sensitivity and better selectivity are required. These are made by changing the design of the i.f. amplifier.

Images. Image interference should be eliminated by the input tuner, but only the more recent designs do so well. As you know, the image is above the desired signal by twice the i.f. For example, let's suppose we have a TV set with an i.f. pass band from 21.5 mc. to 26 mc. When the set is tuned to channel 2, the local oscillator is at about 81 mc., so any station between 81 + 21.5 (102.5 mc.) and 81 + 26 (107 mc.) will be an image and will be capable of feeding through the i.f. amplifier if it can get through the input tuner. There are f.m. stations in this particular frequency range; if the set is near one of these stations, interference is rather likely.

Since the Q of preselector circuits of TV input tuners is low to give the required pass band, they cannot offer very good image rejection, as they have poor selectivity. For this reason, many modern receivers have wave traps at the input of the tuner that permit one interfering station to be cut out. This will not, of course, eliminate interference from another station on a different channel.

If the i.f. were higher, the front end would be better able to cut out image interference because the image and the desired frequencies would then be separated by a wider band. This is one of the reasons for a move toward intermediate frequencies in the neighborhood of 40 mc. in modern sets. Even with this higher i.f., however, it is still desirable to increase the selectivity of the input tuner; for this reason, the use of band-pass couplers is becoming popular in modern sets.

I.F. Interference. The frequency of the i.f.'s used in TV receivers corresponds to carrier frequencies used by other services. If the TV set is near a strong station using some carrier frequency in the i.f. region, it is quite possible for this signal to get through the preselector (unless it is fairly selective) and thus cause interference. Such interference can be eliminated by using a wave trap at the input of the set. We will describe such traps later in this Lesson.

Cross-Channel Interference. Sometimes TV signals interfere with one another. For example, it is possible for channel 7 to interfere with reception on channel 5, as follows:

When the set is tuned to channel 5, and is using an i.f. for the video carrier of 25.75 mc., the oscillator in the set will be adjusted to 103 mc. If the oscillator signal radiates or is conducted to the r.f. tube grid, it will mix with the incoming signals. Should the channel 7 station be nearby and powerful, its signal may be strong enough to overload the r.f. stage and cause it to act as a first detector on these mixed signals. If this occurs, a beat will be produced between the 103-mc. oscillator signal and the 179.75-mc. sound carrier of the channel 7 station; this beat will have a frequency of 76.75 mc., which lies in channel 5. In other words, when the set is tuned to channel 5, the local oscillator may beat with a carrier from channel 7 and produce a channel 5 frequency. This beat signal will, of course, go through all the tuned circuits with the desired signal.

This interference is gradually being eliminated by advances in design and shielding. However, in some of the earlier television receivers, the manufacturers had to include traps to cut down on the r.f. grid signal from the local oscillator; they also sometimes used attenuators in the transmission line to cut down on the strength of the signal received from the interfering station.

Incidentally, it is possible for a set to radiate a signal from its local oscillator on a frequency that can cause interference in nearby receivers. Any kind of a set (not necessarily a television receiver) can produce the interference if the fundamental or harmonic radiation of its oscillator is in a channel to which a television receiver is tuned.

Now that you have reviewed the duties of a preselector-converter and know something about the interferences found in television, let's discuss some of the special problems of TV input tuners.

TV and V.H.F. Requirements

Since the input tuner now handles frequencies between about 54 mc. and 216 mc. (and will eventually go higher if the 500-mc. band is opened), the design and layout of the circuits are far more critical than for, let us say, broadcast-band frequencies. Because the positioning of the parts and the shielding is so critical, the input tuner is usually manufactured as a complete unit on its own sub-chassis; then, when it is completed and aligned, this sub-chassis is mounted on the main television receiver chassis. This simplifies the problems of layout and shielding.

Because of the nature of the input tuner, some specialty firms make complete tuners just as other firms make condensers, resistors, tubes, and other parts. For this reason, you will find that a particular tuner may be used on several different brands of television receivers. Since only a few firms specialize in making these tuners, and not very many receiver manufacturers make their own, only a few basic types of tuners are now in use. We shall study each of these after we learn more about the problems and requirements of tuners.

INTERNAL NOISE

The television picture is greatly affected by even small amounts of noise, and because the eye is very sensitive to such degrading of the picture, considerable effort is made to get a high signal-to-noise ratio at the output of the set. The ultimate limit on this ratio (in the absence of interference) is the noise level in the input tuner. (Incidentally, the *sound* is f.m. and is not affected by small noise levels; it is the amplitude-modulated *picture* signal that is upset.)

Let's see what the sources of noise in the tuner are.

Thermal Agitation. You are familiar with the fact that heat causes an agitation of the electrons within materials—in fact, if the heat is great enough, electrons will be emitted from the material. That is why electrons are emitted from the cathode of a vacuum tube.

Even at room temperatures, there is an agitation of the electrons in all conductors, so there is an irregular and random electron motion within all parts of a receiver. When signal or supply currents flow through these parts, they are varied or modulated by these irregular motions; as a result, a noise component is added to the signal.

The hotter it gets, the greater this noise becomes. TV sets run warmer than sound receivers because they have many more tubes and transformers, so this thermal agitation is higher in them than in sound receivers.

The amount of this noise depends on the band width and on the resistance of the parts being affected as well as on the temperature.

The random electron motion that causes the noise occupies an infinite frequency band—some electrons move at very slow or audio rates, whereas others move extremely fast. Therefore, since the noise energy is scattered throughout a very wide frequency band, the amount of noise energy that we get will depend upon how much of the frequency band is being handled by the system at that time. The wider the pass band, the greater the amount of noise energy passed, and hence the higher the noise voltage. As an example, assuming room temperature, an amplifier with an input resistance of 1 megohm and a pass band of 10,000 cycles may have a noise voltage of 10 to 15 microvolts —about what is developed in the input circuit of a broadcast band receiver r.f. stage. If we have the same input resistance for a band width of about 6 mc., we will find that the noise level will be up over 200 microvolts. This large increase is produced entirely because we are covering a wider band and therefore are collecting more of the noise energy.

Such a noise level is avoided in TV by limiting the resistances or impedances in the input circuit of the r.f. stage to low values around 300 to 10,000 ohms, which are required anyway to provide the impedance matching and tuned-circuit loading that we need. Such low resistances limit the thermal noise to 10 or 15 microvolts even at TV band widths.

It is particularly important to keep the noise down in the first r.f. stage, because this is the stage in which the signal is weakest. Once the signal has been amplified by the first stage, noise added by succeeding stages (except for the converter) has little effect on the signal-to-noise ratio.

Tube Noise. The tubes also contribute considerably to the total noise. One cause of tube noise is that the electrons traveling to the plate have a random variation or fluctuation. Instead of moving as a steady, regular stream, they tend to travel in bunches; hence, there are variations in the rate at which they arrive at the plate of the tube. The average of this electron flow is the plate current. The fluctuations above this average constitute noise. When amplified, this noise sounds as if the plate were being bombarded with pebbles, or as if a shower of shot were falling upon a metal surface. It is therefore called "shot noise."

The internal tube noise also depends upon the number of elements that are drawing current. There is a random distribution of this fluctuating noise energy between the plate and the screen grid, for example, with the result that the plate current noise is doubly varied—in fact, the noise level in the average pentode is about 3 to 5 times as great as that in a triode producing an equivalent amplification. This has caused many designers to use triode tubes in input tuners.

These internal tube noises arise in the plate circuit. In determining the input signal-to-noise ratio, tube noises are referred to the grid circuit by the relationship:

$$e_g = i_p \div G_m$$

where e_g is the equivalent noise voltage that would cause the noise plate current i_p. This voltage e_g combined with the thermal agitation noise gives the effective noise at the input of the set. Once again, keeping the input impedance low reduces the effects of the noise. Also, notice that tubes with higher G_m (mutual conductance) effectively have less equivalent input noise, another reason for using such tubes in TV.

Converter Noise. As we mentioned, the only *amplifier* noise of importance is that generated in the input tube and its grid circuit, because here the signal is the lowest. However, there is another troublesome noise source in the mixer-detector stage. Here the usual internal tube noise is increased because the oscillator signal varies the detector plate current so that it is near zero part of the time, and at such times the noise component is a greater portion of the total signal. Therefore, any tube used as a mixer-first-detector will have a far greater noise level than the same tube will when it acts as an amplifier. As a matter of fact, both triodes and pentodes have about four times as much noise when used as mixer-detectors as when used as amplifiers. The pentagrid-converter tubes commonly used in sound radio receivers have such high noise levels that they are not used in TV sets.

INTERELECTRODE CAPACITIES

At the v.h.f frequencies handled by the input tuner, the designer has to worry about tube characteristics other than mutual conductance, plate resistance, and amplification factor. A very important consideration is the tube interelectrode capacity.

You will recall from your fundamental studies that capacities exist between the tube elements, as shown in Fig. 2. Considering just the basic capacities themselves, you can see from Fig. 2 that the capacity C_{GK} be-

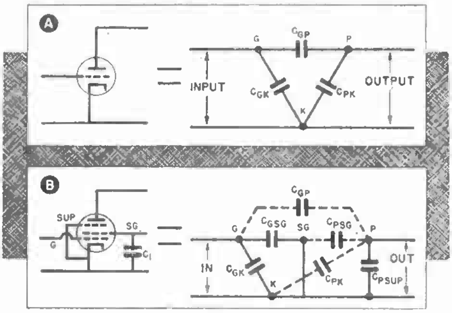


FIG. 2. The inter-electrode capacities of a triode (A) and of a pentode (B).

tween the grid and cathode is across the input and is itself shunted by several combinations of other capacities. For example, in the triode in Fig. 2A, the grid-plate capacity and the plate-cathode capacity in series are also across the input. The output of the stage is similarly shunted, this time primarily by the plate-cathode capacity with the other two in series.

The input capacity of the pentode (Fig. 2B) is primarily the grid-cathode capacity shunted by the capacity C_{GSG} between the grid and screen grid. This comes about because the screen grid is effectively tied to the cathode through a by-pass condenser (C_1) in all practical circuits. Certain other capacities are present in pentodes. These, however, are diminished because of the presence of the suppressor grid and screen grid, which is why they are shown by dotted lines.

At the output of the pentode, the capacity between the plate and suppressor grid, in combination with the plate-screen-grid and such plate-cathode capacity as exists, represents the output capacity.

At broadcast-band frequencies, these capacities are troublesome enough, but in the tuning range used in television, ordinary tube types have far too much capacity. Even miniature tubes, in which the capacity is reduced by making the tube elements physically smaller, by shortening the leads from the elements to the socket, and by removing the base dielectric material, have appreciable interelectrode capacities at television frequencies. Hence, it is customary in most television receivers to use the internal tube capacities as the tuning capacities, dispensing entirely with a tuning condenser. In such cases, variable inductances are used to get the final alignment to the desired frequency. This is the only way that a desirable L-C ratio can be maintained. If we tried to use tuning condensers, there would be so much capacity in the circuit that we would have to use extremely small inductances—and we are already down to values that are represented by straight pieces of wire!

Miller Effect. The input capacity of a triode is actually far larger than just the internal tube capacity, because there is an interaction between the output and input circuits through the grid-plate capacity. The signal voltage developed across the load feeds back through the grid-plate capacity to the input with the result that the grid-plate capacity acts as if it were increased by as much as the amplification factor of the tube. The exact amount of this increase depends on the stage gain and on whether the load is purely resistive or has a reactive component. However, the result is that if the gain of the stage is high, the input capacity is effectively much increased. This apparent increase in the input capacity is known as the "Miller" effect. This effect is not very important in the pentode, because it has only a small grid-plate capacity.

The output capacity is not amplified this way. However, the load is in parallel not only with the output capacity of one tube but also with the input capacity of the next tube, so this shunting capacity can have a considerable effect on the load also.

INPUT RESISTANCE

Another problem at v.h.f. is that a tube often acts as if it had a low resistance between the grid and the cathode. You may recall from an earlier Lesson that the feedback through the grid-to-plate capacity can cause this effect in a triode. However, at TV frequencies, transit time and inductive cathode leads produce far more trouble of this kind, even with pentodes.

Transit Time. You will recall that problems arise because it takes a certain finite time—called "transit time"—for electrons to move from the cathode to the plate of a tube.

As long as the frequency is low enough so that electrons can get through the tube before the grid can change appreciably in voltage, the plate current is unaffected by the transit time through the tube. However, at very high frequencies, the grid voltage changes so rapidly that an electron may be acted on by a considerable part of a grid-voltage cycle before escaping the influence of the grid. Thus, an electron being speeded on its way by a positive grid may not get so far away that the following negative grid swing will not slow it down. Similarly, an electron that is first retarded by a negative grid action may be speeded up by the following positive swing. As a result, electrons tend to bunch up in the tube space, traveling in "clouds" rather than in a fairly steady stream. As a cloud of electrons approaches the grid, the negative charge of the cloud causes electrons to be forced out of the grid; then, as the cloud moves away, electrons flow back toward the grid. A current flow is produced in the grid circuit by this electron movement, just as if there were a low resistance between the grid and cathode elements within the tube.

This effect is quite remarkable in a tube having a long transit time. For example, a pentode tube that is commonly used in sound receivers may have an input resistance of several megohms at broadcast-band frequencies, but at around 100 megacycles it may act as if its input resistance were only 1000 to 2000 ohms. Such a drop in the input resistance would obviously load the input circuit heavily.

The answer is, of course, to reduce the transit time as much as possible.

Obviously, if the spacing between the cathode and the plate is reduced, it will take an electron traveling at a fixed rate a shorter length of time to travel the distance. Making tubes with smaller cathode-plate spacing is therefore one way to reduce transit time. A triode can be made better than a pentode in this respect, because the pentode must have a large enough cathode-plate space to accommodate three grids. Modern miniature pentodes are still usable at the TV frequencies in use today, but if television transmission eventually moves up into the u.h.f. bands around 500 mc., entirely different tube structures will become popular.

Cathode-Lead Inductance. As you know, even a straight piece of wire has some inductance, small though it may be. At TV frequencies, the inductance of a straight piece of wire begins to become important.

In one television receiver, for example, a straight piece of wire provides inductive coupling between two circuits. This piece of wire is in one circuit, and the second resonant circuit is tapped on the wire about two inches from the grounded end. These two inches of wire provide sufficient common inductance to the two circuits to give band-pass coupling!

Because lead lengths are so extremely important in TV sets, the input tuner has to be designed as a complete unit, with all wiring carefully taken into consideration. It isn't practical to replace parts haphazardly in such a tuner, because any disturbance whatever in the lengths of leads or their positioning could easily throw the tuner completely out of alignment on the upper channels. In fact, many input tuner r.f. amplifiers are aligned by bending the inductance wires. (Of course, this is a factory job—not something a serviceman should try!)

The tubes used in input tuners today are almost invariably the miniature types so that the lengths of the leads from the elements to the circuit are as short as possible. However, as shown in Fig. 3A, the cathode lead (between the actual cathode and the common point of connection to the grid and plate circuits at the tube socket) has a certain amount of inductance. The a.c. plate current flowing through this inductance will cause a voltage drop across it. This voltage will reduce the input voltage just as if the grid were drawing more current. Effectively, then, the grid input resistance is again reduced, thus further loading any input device there may be between grid and cathode.

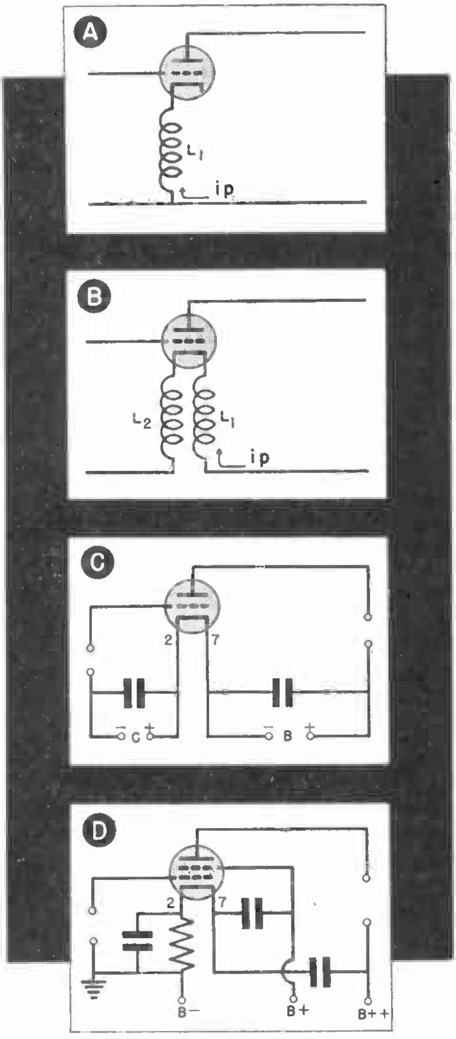


FIG. 3. To eliminate the coupling between the plate and grid circuits caused by the inductive effects of the cathode lead (A), many TV tubes have two cathode leads (B). Sketches (C) and (D) show practical circuits.

To reduce the effects of an inductive cathode lead, many of the tubes specifically designed for use in TV and f.m. receivers have two leads coming from the cathode to the tube pins (see Fig. 3B). Now, if the a.c. plate circuit is attached to one terminal and the grid return to the other, the inductive drop will no longer matter. Although there is an inductance in each lead, the a.c. plate current gets to the cathode through one lead, and the grid is connected to the cathode by the other, so the voltage drop caused by the plate current is not applied to the grid circuit.

Practical circuits are shown in Figs. 3C and 3D. Fig. 3C shows the connection used when a separate source of C bias is employed. Fig. 3D shows how it is possible to get self bias with such a tube. Remember that it is not the d.c. plate current but the a.c. or signal plate current that causes the trouble. Therefore, as shown in Fig. 3D, B— can be connected to the cathode lead to which the grid circuit is connected provided the plate and screen-grid by-pass condensers go to the other cathode lead. When these connections are made, the a.c. signal returned from the plate and screen circuits goes directly to the cathode, and only the d.c. plate current is involved in producing the C bias.

In servicing TV receivers, you will have to watch out for connections like this. Although both pins 2 and 7 of the tube are connected to the cathode, it is very important that the respective grid- and plate-circuit by-pass condensers be connected to the proper pins. Hence, in replacing a by-pass condenser, not only must you position it properly and keep its leads to the same length as those of the one you are replacing, you must also connect it to identically the same points in the set.

Originally, input tuners almost always used a tuned-plate circuit in the r.f. stage rather than a tuned-grid circuit. Although the latter is preferable because it makes it easier to eliminate strong interference, the excessive loading and the high input capacities both tended to prevent the proper use of a tuned-grid circuit. However, since cathode-lead inductance effects and input capacity effects have been overcome by proper tube design, more manufacturers have begun to use tuned-grid circuits.

Now that you understand some of the problems involved in the design of input tuners, let's study some practical r.f. and converter stages.

The R.F. Stage

As you have learned, the r.f. stage of a TV set must be designed so that its impedance matches that of the transmission line, to have as much selectivity as possible, and at the same time to maintain an adequate pass band. In addition, it should have as much gain as possible so that there will be a good signal-to-noise ratio when the input is low. Every bit of gain ahead of the converter is important when weak signals are being received, because any such gain increases the signal strength so that the converter noise is easier to overcome. (Even at best, however, the amount of gain obtainable at the r.f. level is small—the television set depends on the i.f. amplifier for most of its gain, just as sound receivers do.)

Even though the loads used in TV tuners are much lower than those that are generally used with pentodes, a pentode will still give more gain in an r.f. stage at TV frequencies than a triode will. However, as we have pointed out, the triode is far less noisy. Also, transit time effects are somewhat worse in the pentode, making it have lower input resistance than the triode.

Because of the importance of reducing noise in TV tuners, designers would probably prefer the triode to the pentode even though the pentode gives more gain. However, the triode tube, because of grid-to-plate feedback, either requires neutralization or must be used in a grounded-grid circuit.

Neutralization. Fig. 4 gives two examples of neutralized triode amplifiers. In Fig. 4A is a neutralization system for a single tube, in which the condenser C_N feeds back part of the energy from the plate tank to the grid circuit so as to counteract that coming through the internal grid-plate capacity.

In Fig. 4B is shown a circuit for a push-pull triode amplifier. Such push-pull circuits have been used by a number of manufacturers for several reasons, one of which is that the input capacities are in series across the input, an arrangement that effectively cuts the net capacity in half. This arrangement also gives a "balanced"

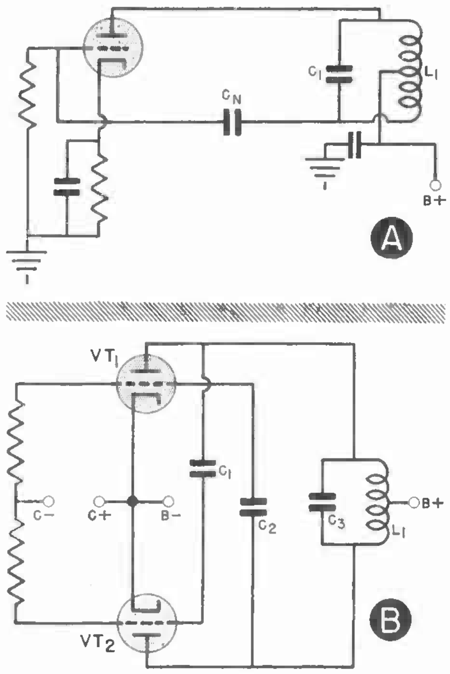


FIG. 4. Two kinds of neutralized triode amplifiers.

input and permits neutralization without the loss of loading that is caused by the tapped coil in Fig. 4A.

In Fig. 4B, the condensers C_1 and C_2 are the neutralizers. C_1 is connected from the plate of VT_1 to the grid of VT_2, and C_2 is connected from the plate of VT_2 to the grid of VT_1. Because of the phases across the resonant circuit C_3-L_1, these two condensers provide the proper neutralization feedback.

Neutralization will work over a very wide number of channels only if the different tuning coils are carefully designed to provide the proper feedback ratio. To avoid such problems, many sets use the grounded-grid amplifier instead.

Grounded-Grid Circuit. As you will recall from your studies of fundamental r.f. stages, the standard (grounded-cathode) stage shown in Fig. 5A has the signal source between the grid and ground. In the grounded-grid circuit in Fig. 5B, the signal is between the cathode and ground, and the grid goes directly to ground. Insofar as the grid action is concerned, either position of the signal source will produce the same result, because it is the voltage between the cathode and the grid that matters. However, the grounded-grid circuit shown in Fig. 5B has the control grid at ground potential, so that it effectively acts as a shield between the signal source and the plate. As a result, the grid-plate capacity no longer provides a feedback path, so neutralization is generally unnecessary. However, the grounded-grid circuit usually gives less gain than does a neutrodyne, because the signal source is in the plate circuit and hence effectively feeds into a low resistance. The signal source is therefore heavily loaded, and if it is a tuned circuit, its Q and gain will be lowered.

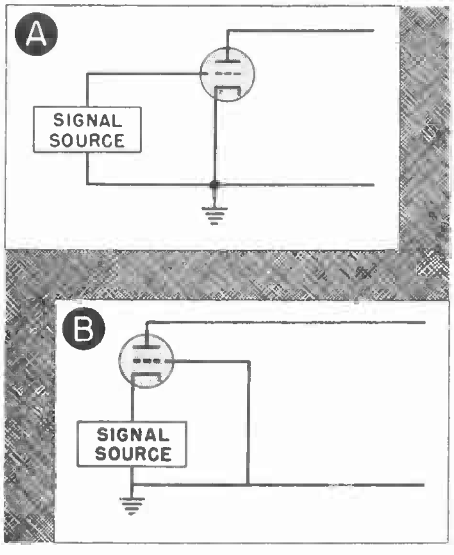


FIG. 5. This illustration shows the basic difference between the common grounded-cathode amplifier (A) and the grounded-grid amplifier (B).

Thus, neither the triode nor the pentode is markedly superior to the other for use in the r.f. stage of a TV set; the pentode gives more gain, but is noisier. As a result, both kinds of tubes are used in modern sets. The pentode is perhaps slightly more popular, but there are a number of triode circuits used, which makes the r.f. circuit of a TV set quite different from that of a sound receiver.

Now, let's study the input and output connections of the r.f. stage.

INPUT CONNECTIONS

The input of the r.f. amplifier is connected to a two-conductor transmission line that is used to feed a signal from the antenna to the receiver. Another Lesson will go fully into the theory of television antennas and transmission lines. Briefly, however, we can say that the television antenna acts as a low-impedance source and that the transmission line has a "surge" impedance that depends upon the size of the conductors and the spacing between them. It is chosen so that its surge impedance will effect some compromise match with the antenna impedance for maximum power transfer.

At the receiver, it is quite important that the surge impedance of the line be matched by the input of the set. If the receiver end of the line is not matched, the energy coming down the line will not all be absorbed, and some will be reflected back up the line. This energy will then be reflected again at the antenna unless there is a perfect match here, with the result that the signal will appear a second time at the receiver end of the transmission line. This second signal will at least cause blurring of the original signal and may produce what is known as a "ghost" (a second image, much weaker than the original image and displaced to the right from it, on the screen of the picture tube). Of course, any such blurring and ghosts are very undesirable. They can be reduced or eliminated merely by matching impedances at the input of the receiver.

Types of Lines. Physically, the transmission lines now used consist of two types, one known as twin-lead and the other as coaxial cable.

The twin-lead type consists of two parallel wires embedded in a plastic insulation. Each wire goes to one leg of a dipole or doublet antenna as shown in Fig. 6A. To reduce interference pickup to a minimum, neither wire is directly grounded; instead, they are connected to ground through equal impedances so as to give a "bal-

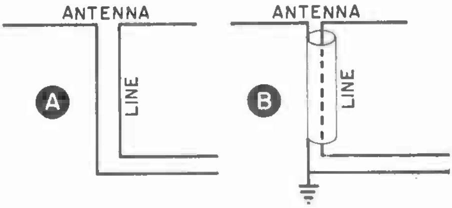


FIG. 6. Schematic representation of (A) twin-lead and (B) coaxial transmission lines.

anced" input at the set. Any currents caused by interference picked up by the conductors in the line will flow in opposite directions through the input device to ground, so they will tend to cancel. The desired signal does not go to ground so it does not cancel. Even with this interference cancellation feature, however, these lines still may feed in considerable interference.

The coaxial line consists of a wire surrounded coaxially by and insulated from a hollow flexible braid or tube of metal. The wire is one conductor and the outer shell the other. Its connections are shown in Fig. 6B. The outer shell of the coaxial line is always grounded; it therefore acts as a shield and virtually eliminates interference pickup. Because one conductor is grounded, the coaxial line produces an unbalanced input.

Although the coaxial line has the advantage of eliminating interference pickup, twin-lead is preferred in many locations where interference is not a problem because it attenuates the signal less. Of course, the impedance of the line is also an important consideration. Either type could be made to have almost any desired impedance, but manufacturers have practically standardized on a twin-lead having an impedance of about 300 ohms and on a coaxial line having an impedance of 72 ohms. Therefore, practically all television receivers are made for one or the other of these two values, or both.

Balanced Inputs. If a balanced transmission line is used, the lines must be kept at equal impedances with respect to ground. The grid circuit of a tube is ordinarily unbalanced in that whatever is connected to the grid has its other end directly connected or by-passed to ground. Fig. 7A shows how a balanced transmission line can be fed through a transformer input to an unbalanced grid circuit. The primary coil L_1 has a center tap that goes to ground, so the impedance between ground and each wire of the line is the same. Any noise voltage that is developed between the line and ground will cause currents that will flow from point 1 to ground and from point 2 to ground (or vice versa). Since these currents will flow in opposite directions through the two halves of L_1, their inductive effects will virtually cancel. The desired signal voltage, since it is applied across the transmission line by the antenna, will cause current flow through the whole

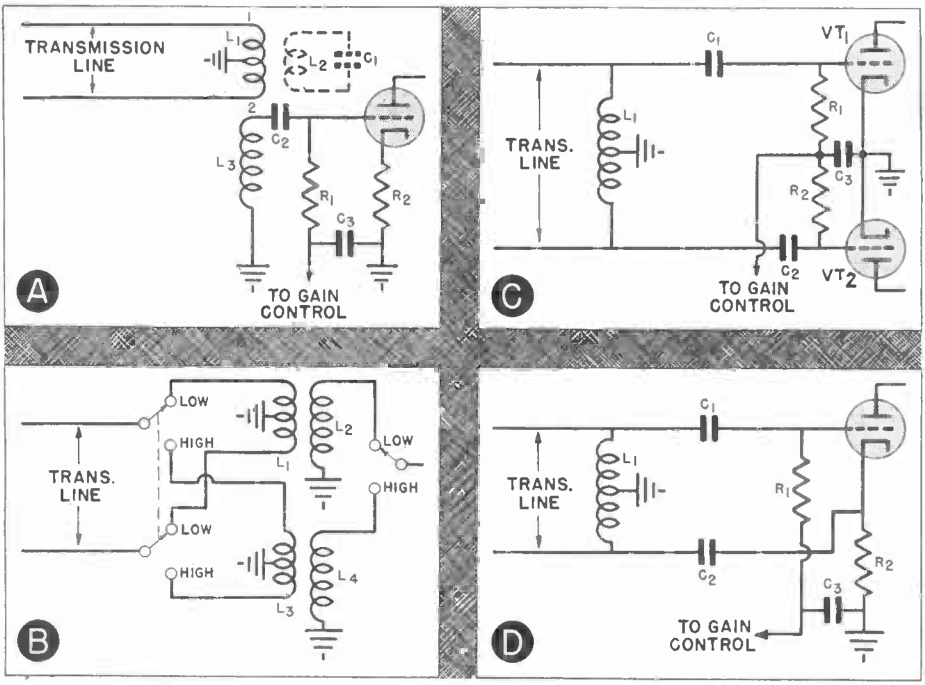


FIG. 7. Methods of coupling a balanced transmission line to various input circuits.

of L_1 (from 1 to 2 or from 2 to 1, but not from either point to ground).

This desired signal current will induce a voltage in L_3. (Sometimes a tank circuit L_2-C_1, shown by dotted lines in Fig. 7A, is placed so that the signal will be inductively transferred from L_1 to L_2 and thence to L_3. In this case, the tank circuit is tuned to the desired frequency by C_1.)

The load the transmission line "sees" is the impedance, as it appears through the transformer, of R_1 shunted by the input impedance of the tube. If the turns ratio and coupling of the transformer L_1-L_3 are properly chosen, any value of R_1 can be matched to the transmission line. Since the transmission line impedance is 300 ohms, the usual practice is to make R_1 this value also, in which case the input impedance of the tube is of little importance. Then, the L_1-L_3 transformer is made to match 300 ohms directly to 300 ohms.

Should L_3 be made resonant, R_1 would be whatever value was necessary for loading the tuned circuit, and the transformer would be designed to provide the necessary match. If L_3 is untuned, it must cover the television band and must be carefully designed to prevent the input capacities from causing resonance at an undesired point.

Coil L_3 is coupled to the grid through blocking condenser C_2 because a gain-control voltage is being fed through R_1. We'll go into this gain control later in this Lesson.

Some manufacturers use different input coils for the low and the high television bands, particularly when a tuned input is employed. In such a case, a switching arrangement like that shown in Fig. 7B is desirable. When the switches are in the position shown, the low-band coils L_1 and L_2 are energized. When the switch is thrown, the high-band coils L_3 and L_4 are connected into the circuit. With this arrangement, the electrical connections will be like those shown in Fig. 7A except for the switching.

Fig. 7C shows the means of feeding from a balanced transmission line into a push-pull r.f. stage. Here, the center-tapped coil L_1 balances the transmission line to ground. Resistors R_1 and R_2 are 150 ohms each; their total impedance (300 ohms) matches that of the transmission line.

Blocking condensers C_1 and C_2 are needed because a gain-control voltage is fed through R_1 and R_2.

Coil L_1 is not really necessary in this circuit, because the resistors could provide the balance to ground for the transmission line. However, if it is properly chosen, the coil can help reduce interference. Since its inductive reactance depends on the frequency, it can be made to be practically a short circuit at frequencies below the low TV band, thus almost eliminating signals of these frequencies, and yet be enough above the resistor values in impedance at TV frequencies so that the line will be matched.

Notice that a push-pull input is already balanced, so a transformer between the line and the grids is not necessary if the resistor values match the impedance of the transmission line.

Fig. 7D shows how it is possible to get a balanced input to a single tube without using a transformer. Practically speaking, this is a combination of a grid-fed and a grounded-grid circuit in that the input signal across the upper half of L_1 is fed to the grid and that across the lower half of L_1 is fed to the cathode. Resistors R_1 and R_2 together match the transmission line,

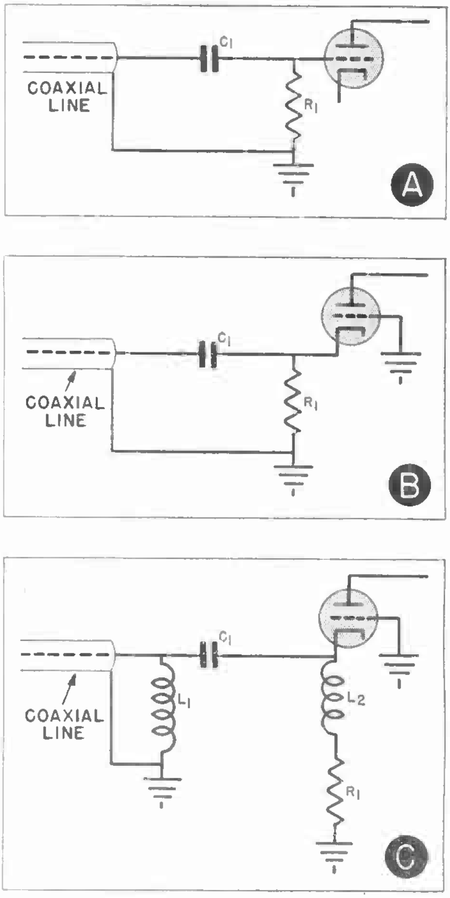


FIG. 8. Ways of coupling an unbalanced transmission line to various input circuits.

and coil L_1 provides the balance to ground, as before.

Although we have shown triode tubes in these figures, pentodes are also used in the same circuit arrangements.

Unbalanced Inputs. When a coaxial line having a grounded shield is to be used, an unbalanced input arrangement is necessary. Since the grid circuit of a tube is naturally an unbalanced input, it can be connected directly to a coaxial line as shown in Fig. 8A. Here, resistor R_1 is chosen to match the line impedance, which is usually 72 ohms.

The grounded-grid circuit shown in Fig. 8B is more commonly used when an unbalanced input circuit is wanted. As you will observe, the signal is now fed into the cathode circuit. A somewhat more elaborate arrangement for a grounded-grid input is shown in Fig. 8C. Here, coil L_1 is again used to act as a low impedance for frequencies below the TV bands and thus to reduce interference. The load for the transmission line is a combination of R_1 and coil L_2. This particular combination of an inductance and resistance may be used to eliminate a possible capacitive unbalance, thus keeping the loading on the transmission line more nearly constant over the desired frequency range.

Of course, the grounded-grid connection is most commonly used with triode tubes. The circuit shown in Fig. 8A is the one that would more probably be used with a pentode. A coil like L_1 in Fig. 8C may be added to this circuit.

Dual Inputs. In receivers that use a transformer input, it is possible to match either the 72-ohm coaxial line or the 300-ohm twin lead. The arrangement is shown in Fig. 9. The coupling between L_1 and L_2 is adjusted so that a resistor (not shown) connected to L_2 appears as a 300-ohm impedance across L_1. Therefore, the impedance of a 300-ohm line will be

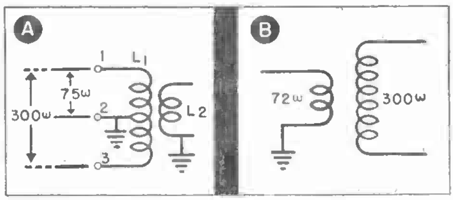


FIG. 9. Some sets (A) have dual inputs to which a balanced or an unbalanced line may be connected. The transformer (B) can be used to connect an unbalanced line to a balanced input.

matched if the line is connected to terminals 1 and 3 of L_1.

When the impedance appearing across the whole coil is 300 ohms, the impedance across half the coil is one-quarter this value, or 75 ohms. This is close enough to 72 ohms for all practical purposes, so the impedance of a 72-ohm line will be matched if the line is connected to terminals 1 and 2 (or 2 and 3) of coil L_1. Basically, therefore, a receiver with a dual input is actually a balanced-input receiver so arranged that an unbalanced line may be matched to it.

The balanced input of a set having an input circuit like those in Figs. 7C and 7D can be preserved by interposing a transformer like that shown in Fig. 9B between the set and the line when a 72-ohm unbalanced line is to be used. This transformer matches 72 ohms to 300 ohms. Such transformers are available because some sets are designed only for balanced inputs, and local noise conditions may be such that a shielded transmission line is necessary. It is also possible to reverse this transformer if a 300-ohm twin lead is to be used on a set designed for a coaxial line. This would happen only if a special antenna were being used.

Wave Traps. Since it is undesirable to amplify interfering signals any more than is necessary, it is common practice to place wave traps in the input coupling to reduce the strength of such interferences. Such wave traps are arranged to act as short circuits to the undesired signal. Fig. 10 shows how such wave traps may be connected to the input. Fig. 10A shows a balanced line connection, in which resistors R_1 and R_2 load the line, and coil L_3 provides the ground connection. There are two wave traps (L_1-C_1 and L_2-C_2) used here, one between each side of the line and ground. Both traps are tuned to the interfering frequency. Since they are high-Q series-resonant circuits, they are practically short circuits at their resonant frequency but offer a fairly high impedance at other frequencies. Therefore, they short out the undesired signal but affect other signals very little.

These traps are sometimes tuned to interfering signals occurring in the i.f.

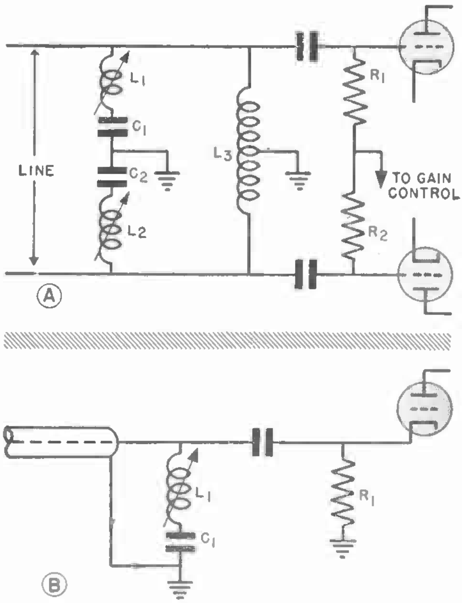


FIG. 10. Two ways in which wave traps can be used.

pass band, or to f.m. stations, or even to the second harmonic of the oscillator if co-channel interference is a problem.

The connection shown in Fig. 10B is for an unbalanced line. It operates in the same manner as the one in Fig. 10A, but only a single trap is used.

GAIN CONTROL

You may have noticed that the schematics given so far of the r.f. stage usually indicate that the grid return goes to a gain-control voltage source. Later, when we take up other stages, we will show that the gain of the r.f. stage is not varied in most TV sets until the input signal is so strong that it threatens to overload the mixer or a later i.f. stage. In other words, the gain of the set is controlled primarily in the i.f. amplifier. If the signal is very strong, however, the r.f. stage gain may have to be reduced to prevent overloading.

Incidentally, many television receivers have a manual control, whereas others use an automatic gain control that is practically identical to automatic volume control (a.v.c.) circuits used in sound receivers.

Also, when you study antennas and transmission lines, you will find that even this method of gain control may

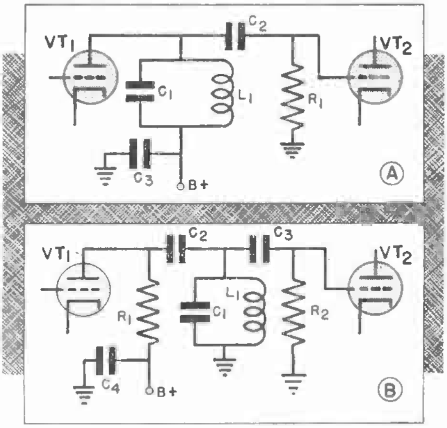


FIG. 11. Two forms of resonant coupling used between the r.f. and converter stages.

prove unsatisfactory in locations very near a powerful television station. In such cases, resistive voltage dividers called attenuators are inserted in the transmission line to decrease the signal from the powerful station to a level that can be comfortably handled by the set.

COUPLING TO MIXER

Because of the difficulties with input resistance, and the requirement of transmission-line matching, many TV sets do not use input tuning. However, whether input tuning is used or not, all TV sets use resonant coupling between the r.f. and converter stages. Some use only a parallel resonant cir-

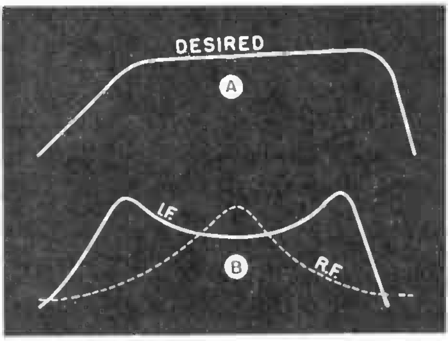


FIG. 12. The desired over-all response (A) of the r.f. and video i.f. sections can be secured by matching the response of the two sections (B).

cuit as the plate load, but many use some form of band-pass coupling.

Fig. 11A shows a basic tuned-plate coupling. We need tuning to give initial selectivity and whatever image rejection the set may have. Once again, however, we must compromise between gain and selectivity. It would be quite desirable to use a high-impedance load for the r.f. tube so as to get sufficient gain, but we could not then get the necessary band width for fidelity. In the circuit shown in Fig. 11A, the resistor R_1 loads the tuned circuit to broaden its response, making the resultant load for VT_1 quite small. If the detector bias is obtained from a grid-leak action, the grid resistor R_1 should have reasonably high resistance. In such cases, the arrangement shown in Fig. 11B may be used. Here, the resistor R_1 loads C_1-L_1, and grid resistor R_2 can then be a higher value.

If the i.f. response is properly designed, this problem is not difficult. We must pass a band of about 6 megacycles, but we need not get flat amplification over this entire band if the video i.f. response is designed to make up deficiencies in the r.f. response. Fig. 12A shows the over-all response desired for the r.f. and video i.f. stages. (This curve is non-symmetrical because trap circuits are used to reject the sound and adjacent-channel signals.) This response can be obtained by a combination of an i.f. response and an r.f. response like those shown in Fig. 12B. Notice that the r.f. response can have a single peak that is compensated for by a dip in the i.f. response.

Before leaving the parallel resonant circuit, let us point out that it is important that you realize the effect of shunting capacities. For example, the diagram of one set has the circuit connections shown in Fig. 13, except that C_O is not on the schematic. Con-

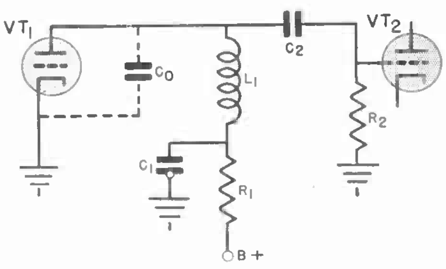


FIG. 13. Although internal tube capacities are not marked on schematic diagrams, they are actually part of the circuit in r.f. sections of TV sets.

denser C_1 is a trimmer condenser and, with coil L_1, apparently constitutes the tuned circuit. This looks like a series-resonant circuit, which would offer *minimum* impedance at resonance. Actually, however, the internal tube capacities of tube VT_1 and the input capacities of VT_2, which are represented by condenser C_O, are in parallel with L_1. (Since schematic diagrams do not show internal tube capacities, you must be careful to remember that this capacity exists when you are analyzing operations at TV frequencies.) As a result, what appears to be a series resonant circuit is

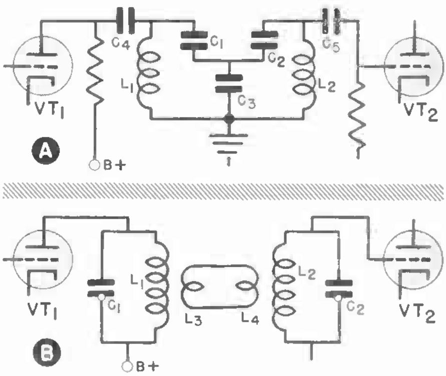


FIG. 14. Basic band-pass circuits.

actually a parallel resonant one, which it must be to provide the proper load for VT_1.

Even with the tubes used in television sets, the capacity of C_O is so high that it is hard to get reasonable sizes for L_1 in the high band. Therefore, condenser C_1 is added in series with L_1 so that it is effectively in series with C_O. Since C_1 is a small capacity, and since the capacity of condensers in series is always less than the smallest, adding it to the circuit effectively reduces the capacity of C_O enough to make the combination provide the proper tuning capacity for a coil L_1 of practical size. Because C_1 is a trimmer condenser, it may be used to compensate for such variations in C_O as may exist in different receivers.

Band-Pass Coupling. Some manufacturers make the r.f. stage have a band-pass response that is flat-topped and about 6 megacycles wide by using two resonant circuits that are tuned to the same frequency and are coupled to give the appropriate response.

Basic band-pass circuits are shown in Fig. 14. In Fig 14A, the two resonant circuits consist of L_1-C_1-C_3 and L_2-C_2-C_3. Condenser C_3 is common to both resonant circuits, and the drop across this condenser provides the coupling between the two circuits. Resistors load each resonant circuit to make the over-all response flatter.

Another form of coupling is shown in Fig. 14B. Here, a link consisting of coils L_3 and L_4 provides the coupling.

It is also possible to couple two resonant circuits through a third one that is tuned to resonance at a mid point, thus providing a three-peaked response characteristic. In general, however, band-pass units follow the standard a.m. practice that you have studied in your fundamental Lessons.

The Converter Section

The converter section of a television receiver, like that of a radio, consists of a mixer-detector and an oscillator, which together produce an i.f. signal from the incoming signal. The pentagrid converter is commonly used in sound receivers for both these functions, but the oscillator is always a separate tube in television sets (although it may be in the same envelope as a mixer-detector), principally because the pentagrid converter is a poor oscillator at TV frequencies and is extremely noisy.

Let's study the requirements of a mixer-detector a little more fully.

MIXER-DETECTOR

One of the most important sources of noise in a radio is the mixer-detector. The internal tube noise in this stage is considerably higher than in the average amplifier, even when both use the same tube. Both pentodes and triodes used as mixer-detectors are about four times as noisy as they are when used as amplifiers. Since, as you have already learned, pentodes are generally noisier than triodes, the latter are more commonly used in mixer-detector circuits. Pentodes are used only where there is sufficient gain in the r.f. amplifier or where the signal is normally so strong that the converter noise can be completely over-ridden.

The gain we can expect from a mixer-detector stage depends upon the load in the plate circuit and upon what is known as the conversion conductance of the tube. The conversion conductance expresses the efficiency of the tube as a detector; it is equivalent to transconductance except that it is always less—only about one-quarter of the actual transconductance in the case of triodes. We must use this special term because, when a tube is acting as a detector, we are interested not in the total change in plate current but in that part of the plate current that represents the desired i.f. signal. All other a.c. components of the plate current, such as signals at the original and oscillator frequencies, and various harmonics of all these, are undesirable and are by-passed. With normal efficiencies of operation, therefore, we find that a tube used as a converter gives only about one-quarter of the gain that it would as an amplifier.

CIRCUIT TYPES

The standard mixer-detector is fed at its grid by both the oscillator signal and the incoming signal from the tuning arrangement at the output of the r.f. stage. The oscillator signal may be connected to the grid circuit through a link coupling to the tuned circuit, or it may be fed in through a coupling condenser.

The converter is usually self-biased by a grid-leak and condenser, because it is desirable to ground the cathode circuit. Except for this and for the use of triode (or pentode) tubes, the mixer-detector in a TV set is much like that in a sound receiver.

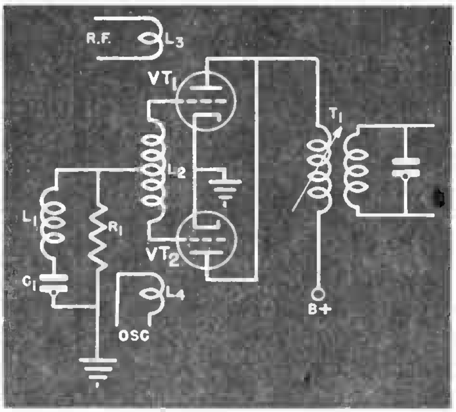


FIG. 15. A push-pull input, parallel output converter stage.

An interesting variation is the type shown in Fig. 15. Here, coil L_2 is one of the preselector circuits; it is tuned by the input capacity of the two tubes VT_1 and VT_2 that together act as the detector. Coil L_3 feeds the incoming r.f. signal into L_2, and L_4 feeds in the signal from the oscillator. The converter bias is obtained from the drop across resistor R_1, which uses C_1 plus stray circuit capacity as its grid condenser. Transformer T_1 is the first i.f. transformer, both windings of which are tuned. The primary of T_1 is a parallel resonant circuit that uses the output capacities of the two tubes as its tuning capacity.

The signals from L_3 and L_4 are applied to both tube grids simultaneously. When the two signals are mixed and detected, the beat products (i.f. signal) at the two plates will be in phase. Therefore, the tube plates are connected in parallel to the primary of T_1. As far as the individual input components (the r.f. input signals and the oscillator signal) are concerned, however, the two grids are being fed in push-pull; therefore, the two plate current components resulting from each input component will be out of phase, and, because the plates are connected in parallel, these plate-current components will cancel. In other words, the output of the stage will contain neither of the original input signals—only their difference frequency, which is the desired i.f., and a few undesired harmonics. This push-pull input, parallel output connection also tends to cancel any incoming interfering signals at the i.f. frequency, because they are fed to the grids in push-pull just as the desired incoming signal is.

I.F. Trap. The combination L_1-C_1 and the halves of L_2 form a series-resonant circuit from each grid to ground. The upper half of L_2 plus L_1-C_1 is the circuit for VT_1, and the lower half of L_2 plus L_1-C_1 is the series circuit for VT_2. These circuits, which are made resonant to the i.f. frequency, serve two important purposes.

One is that they keep the two tube grids at a very low impedance with respect to ground at the i.f. frequency. Therefore, interfering signals at the i.f. frequency cannot drive the grids much.

Another important purpose they serve is to prevent oscillation in the mixer. With *triode* mixers, feedback from the plate to the grid circuit could make the stage oscillate at the i.f. frequency. This could occur because the resonant input circuit consisting of coil L_2 and the input capacities is tuned to the incoming signal, which is higher than the i.f. in frequency. Hence, this circuit is inductive at the i.f. frequency, which means that feedback through the grid-plate capacity will be applied to the grids in the proper phase to cause oscillation at the i.f. frequency. As we said earlier, however, the series resonant circuits keep the impedances between the grid and ground very low at the intermediate frequency; therefore, whatever i.f. feedback exists from plate to grid is unable to develop more than a very small grid signal, so oscillation will not occur.

A similar oscillation problem exists even with a single-ended triode stage, so almost all triode TV converters have such series trapping arrangements to prevent an i.f. voltage from being developed at the grid. These traps are unnecessary in converter stages using pentodes, since such tubes have very little plate-to-grid capacity.

OSCILLATORS

The oscillator is inductively or capacitively coupled to the first detector by the usual methods. In general, as in standard radios, the oscillator signal should be about ten times the strength of the incoming signal so that linear mixing will occur without distortion of the modulation of the input signal.

In most modern TV receivers, the oscillator is above the incoming frequency by the amount of the i.f. frequency. There are a few exceptions, however.

In one of these, the oscillator is above the signals on the low band but is below those on the upper band. This switch is possible only because the set in question uses an "intermodulation" sound system, which we shall study elsewhere. When the "standard" sound system is employed, the oscillator must either be above all incoming channels or below all, so that the proper intermediate frequency will be produced.

Even though the band widths of television i.f. amplifiers are broad, they must have sharp sides to give reasonable adjacent-channel selectivity. Therefore, since the signal fills the whole band width, a considerable portion of the signal would be cut off if the oscillator frequency should drift even slightly. Temperature-compensated parts are commonly used in the oscillator circuit to help minimize this drift. Most generally, a temperature-compensated condenser is added to the tuning circuit. It is possible to make such a condenser either increase or decrease in capacity with changes in temperature. Therefore, the manufacturer determines how the oscillator circuit of a run of sets tends to drift, then installs a compensated condenser that drifts the other way. As a result, the net oscillator drift is minimized (though seldom eliminated completely).

Tuning. There are two basic tuning systems—continuous tuning much like the ordinary manual tuning of sound receivers, and step tuning much like the push-button systems of sound receivers.

In the continuous tuning systems, variations in the oscillator frequency can be compensated for by retuning. This may mean that a compromise position is used that detunes the preselector to keep the oscillator in step, but this won't matter much if the preselector is sufficiently broad.

When step tuning is used, the oscillator is aligned approximately for each channel by the parts inserted by the switching mechanism. Then, to get the oscillator to the exact frequency, it is standard practice to include some means of adjusting the oscillator. Manually, this may be done by what is called the "fine-tuning" control, which is a small variable condenser in the resonant circuit that acts as a trimmer. This may be adjusted from the front of the set when necessary.

Instead of a fine-tuning control, a number of television receivers use automatic frequency control (a.f.c.) to adjust the oscillator. The control voltage, which is obtained from the discriminator in the sound channel, is coupled to the oscillator tuning circuit. Let's review automatic frequency control briefly.

A.F.C. As you learned in your fundamental Lessons, an a.f.c. system consists of a discriminator circuit that determines whether the oscillator circuit is producing the proper i.f. frequency with the incoming signal. If it is not, the discriminator produces a voltage that can be used to control the oscillator frequency through what is called the control tube. This control tube is a tube that is set up to act as a capacity or as an inductance; it is connected across the oscillator resonant circuit and can therefore be used to shift the frequency of the oscillator.

A typical circuit diagram is shown in Fig. 16. Here, VT_1 is the discriminator in the sound system of the television set. Briefly, the signal from the resonant circuit C_1-L_1 is coupled by mutual inductance into the L_2-C_2 resonant circuit, and, through blocking condenser C_5, the same signal is also applied to coil L_3. As a result, two different voltages are applied to each diode plate of VT_1 in such a way that the two diode plate voltages are exactly equal at resonance. When these plate voltages are equal, the diode currents through R_1 and R_2 are also equal. Since these currents flow in opposite directions, and since the resistors R_1 and R_2 through which they flow have the same resistance, the resulting voltage drops across these resistors are equal and opposite.

Tube VT_2, the oscillator, is used in an ultra-audion circuit. Tube VT_3, the control tube, is connected to the oscillator tank in such a way that it always draws a current that is out of phase with its plate voltage—in other words, the tube acts like a reactance.

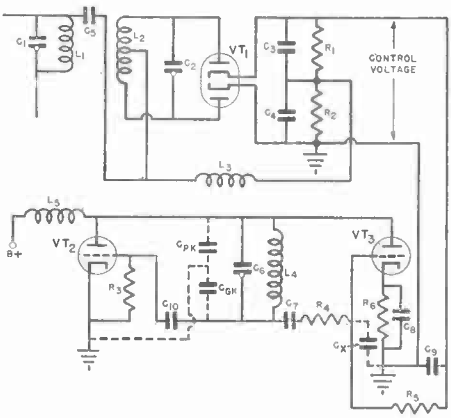


FIG. 16. A typical a.f.c. system.

In the particular circuit shown, it is adjusted so that it acts like a condenser.

If the oscillator frequency drifts, the i.f. signal produced in the sound channel and applied to VT_1 will not be the correct i.f. to which the tank circuits C_1-L_1 and L_2-C_2 are tuned. The voltages will then be different on the two diode plates, with the result that there will be a net control voltage across R_1 and R_2. This voltage will change the bias applied to VT_3, thereby either raising or lowering the plate current so that the tube acts like a bigger or smaller capacity, whichever is needed to retune the oscillator to the correct frequency value.

The action of this circuit was covered in detail in one of your earlier Lessons, to which you should refer if you wish a fuller explanation. At the moment, all you need to remember is that a drift in the oscillator frequency can be automatically corrected by an a.f.c. system.

OSCILLATOR CIRCUITS

As you learned in your fundamental Lessons, television receivers most commonly use the ultra-audion oscillator. This is the variation of the Colpitts oscillator in which the internal tube capacities set the feedback voltages. In addition, the tuned-plate push-push oscillator is used in a few sets, and the Hartley oscillator in a very few.

One of the reasons why the ultra-audion oscillator is so popular in television sets is the fact that the Miller-effect capacities are small in this circuit. At the frequencies involved, the tuning capacities needed are quite small, so the tube and circuit capacities must be kept down.

For example, in the ultra-audion circuit shown in Fig. 17A, the internal tube capacities are across the resonant circuit L_1-C_1 as shown by the dotted lines. Effectively, the C_{PK} and C_{GK} capacities are in series, so the net capacity is less than that of the smaller of this pair. The grid-plate capacity C_{GP} is also across the tank circuit, but only as it exists in the tube; in a tuned-grid or tuned-plate oscillator having an inductive load, this capacity would be multiplied by as much as the gain of the tube because of the Miller effect. Therefore, the total amount of capacity shunting the tuned circuit in Fig. 17A is less than it is in a tuned-grid or tuned-plate oscillator, so, for fixed sizes of the tank circuit parts, it is possible to tune this ultra-audion circuit to higher frequencies than can be reached with either a tuned-grid or a tuned-plate oscillator.

Fig. 17B shows the capacities shunting the tuned circuit in the tuned-plate push-push oscillator. Here the

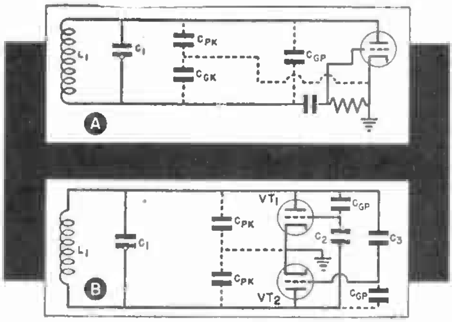


FIG. 17. Internal tube capacities in the ultra-audion circuit (A) and in the tuned-plate push-push oscillator (B).

plate-cathode capacities of the two tubes are effectively in series, an arrangement that reduces their effects considerably. Although the feedback condensers C_2 and C_3 provide paths for the grid-plate capacities to be in shunt with the tuned circuits, these feedback condensers are small enough to prevent the grid-plate capacities from having too much effect.

In all TV oscillators, the internal tube capacity does affect the frequency by being part of the tuning circuit. When it becomes necessary to replace an oscillator tube, it is necessary that one be found that has internal capacities not too far different from those of the original tube, or else the receiver may not tune over the proper range. Hence, it may be necessary to try several tubes to find one that permits the normal tuning range.

Tuning Systems

Now that you have a general understanding of the circuits used, let's study some of the physical details of input tuners.

We have already mentioned that each of these tuners is on its own subchassis, which is mounted on the main chassis after the input tuner has been assembled and aligned. Operating voltages are obtained from the low-voltage supply of the receiver. To prevent leakage of the r.f. and oscillator signals, R-C filters are used in the B+ leads (and, of course, the unit is shielded). The by-pass condensers used must be non-inductive, so it is fortunate that small by-pass values are effective at these frequencies. In the r.f. and i.f. sections, the by-pass condensers are usually ceramic or mica types rather than paper. The ceramic types are preferred because of their small physical size. Incidentally, these condensers closely resemble resistors in size and shape, so don't identify them wrongly when you examine a TV receiver.

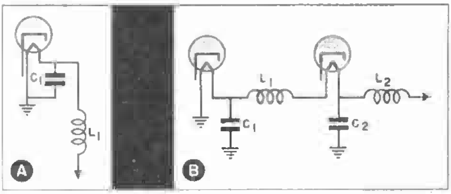


FIG. 18. Filtering systems used with (A) parallel and (B) series filaments.

Appreciable by-passing of the B+ leads is secured just by running these leads next to the chassis, so don't move leads carelessly in TV sets!

The filament leads of input tuners are elaborately by-passed and filtered. Fig. 18A shows the choke and condenser combination used for parallel filaments; Fig. 18B shows a series filament filter. These filters prevent stray r.f. from traveling through the filament leads to other sections of the set.

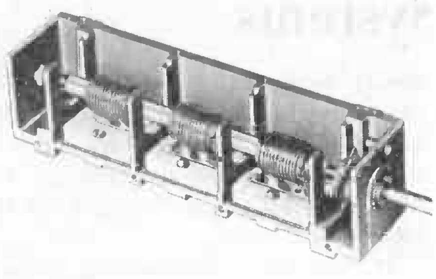
Mechanically, tuning systems may be divided into continuous tuners and step tuners. A continuous tuner uses a variable inductance or a variable condenser and is so arranged that it tunes over a complete band of frequencies that includes all TV channels.

In one form of continuous tuner, the tuning mechanism tunes all the way from about 50 megacycles to the upper end of channel 13. This means that it covers a number of other channels too, including the f.m. band. A set with this kind of tuner can therefore be used as an f.m. radio receiver when it is tuned to this band.

Other "continuous" tuners are actually two-band tuners in that they tune through the low band, and then a switch is thrown (sometimes automatically) to allow them to tune through the high band. In these sets, the intervening bands assigned to f.m. and other services are not tuned in.

A step tuner has some form of switching mechanism that throws in resonant circuits (in both the oscillator and preselector) that are tuned to the respective television channels. Some of these switches are rotary types, some are slide switches, and some are push-button arrangements, but they are all arranged to connect in the necessary resonant circuits, which have been pretuned to the desired channels.

Now let's study the continuous tuner in more detail.



Courtesy P. R. Mallory and Co., Inc.

FIG. 19. This is the Mallory Inductuner (Trademark registered U.S. Patent Office) that is used in several brands of TV sets.

CONTINUOUS TUNER

One of the very popular continuous tuning systems used by a number of set manufacturers contains the Mallory Inductuner that is shown in Fig. 19. This tuning unit consists of three coils wound on ceramic forms that are mounted on a single insulated shaft. A sliding contactor or shoe rides in "trolley" fashion between the coil wire and a plate, and maintains a constant contact between the two. As the tuning mechanism rotates the coil, this shoe moves along the coil, thus shorting out an increasing number of turns. This system of shorting the inductance makes it possible to vary the total inductance from approximately one microhenry to .02 microhenry, which is a change of about 50 to 1. This provides a very wide tuning coverage—the unit covers the entire low and high band as well as the f.m. band in between.

Fig. 20 shows a schematic of an input tuner that uses the system shown in Fig. 19. The black box encloses the three coils that are the variable portion of this tuner.

Tube VT_1 is a grounded-grid r.f. amplifier. The signals are fed into the cathode. Since this is an unbalanced input, a coaxial transmission line will be used.

The load for VT_1 is a band-pass tuner. One section consists of L_3-L_1-C_3-C_4, and the other consists of L_4-L_2-C_5-C_4. Since C_4 is common to both circuits, it provides the coupling between the two sections. Resistor R_3

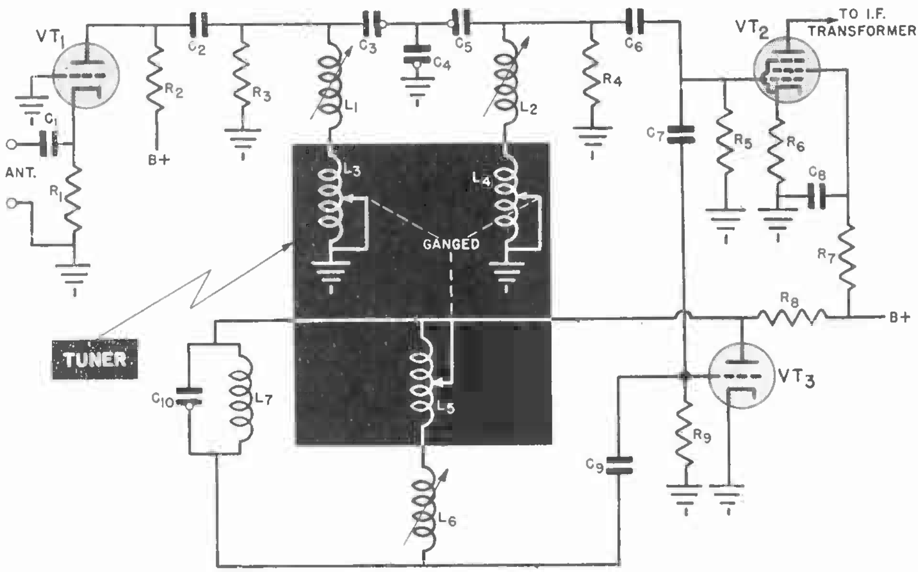


FIG. 20. The schematic of an input tuner in which the Mallory Inductuner is used.

loads one section of this tuner, and R_4 loads the other. Condensers C_2 and C_6 are d.c. blocking condensers.

Tube VT_2 is the mixer-detector. Notice that it is a pentode.

The oscillator tube VT_3 uses the ultra-audion circuit. The tuning inductance consists of L_7 in parallel with a series combination of L_5 and L_6. Condenser C_{10} plus the internal capacities of the tube provide the capacity.

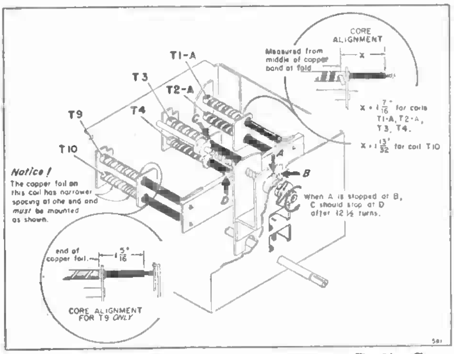
When this circuit is aligned at the factory, the tuning inductances L_3, L_4, and L_5 are set at minimum inductance, and the inductances L_1, L_2, and L_6 are adjusted to bring in channel 13. The oscillator frequency is then higher than that of the incoming signal. It is possible to get an alignment at another television channel by adjusting C_3, C_5, and C_{10}, and then adjusting C_4 to change the coupling between the band-pass sections. Some of these adjustments can be made only by the manufacturer.

Obviously, this continuous tuner provides a very simple front-end construction. The only basic difficulty with it is the fact that a number of spurious responses are obtainable at various points over the tuning range. Once the receiver owner learns to ignore all but the correct response points, which are approximately marked on the tuning dial, this arrangement is quite satisfactory. Having the device tunable through the f.m. range means that the receiver can also be used as a sound receiver for f.m. signals. When this is desired, a switch can be thrown to cut off the picture tube and its associated circuits.

TWO-BAND TUNERS

In the second form of continuous tuning, the band over which the set will tune can be selected by throwing a switch. In this form, all those frequencies between the lower and the upper band are skipped, a fact that makes a somewhat different design possible. Some two-band continuous tuners of this kind use variable inductances, and some use variable condensers. Let's study both briefly.

Variable Inductance. A variable-inductance tuner is shown in Fig. 21. In this unit, the coils are made of flat copper ribbons wound spirally around the coil forms. The tuning arrangement varies the permeability by moving powdered-iron cores in and out of the coil forms. These cores are mechanically ganged so that they move



Courtesy Belmont Radio Corp.

FIG. 21. A variable - inductance 2-band continuous tuner.

in unison as the receiver is tuned. A spiral gear arrangement, driven from the tuning knob, moves the insulated plate on which the cores are mounted toward or away from the coils.

The schematic diagram of a set using a tuning arrangement of this kind is shown in Fig. 22. Starting at the antenna terminals, you will observe that this receiver is designed for a balanced input and has a high-low switch that permits the proper coils for each of the bands covered to be thrown in. The primary of the antenna coil feeds into a tuned secondary, which is somewhat unusual

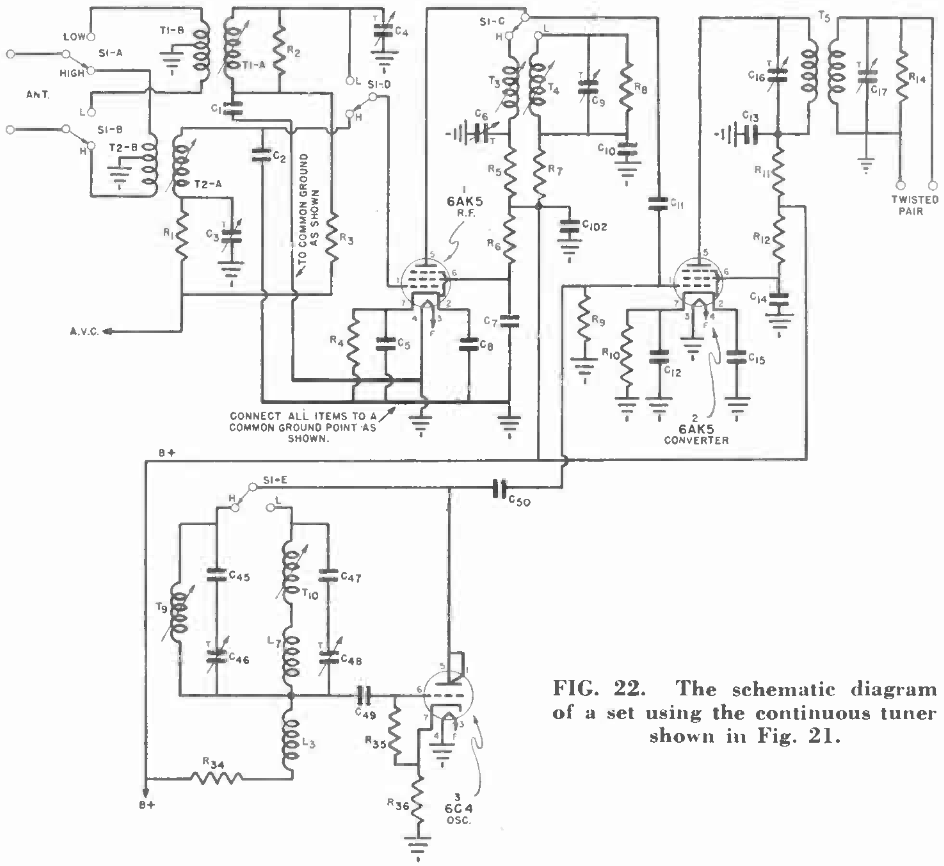


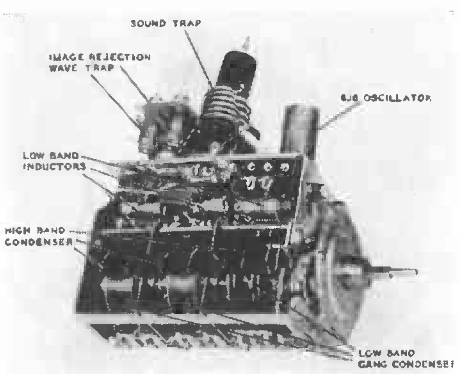
FIG. 22. The schematic diagram of a set using the continuous tuner shown in Fig. 21.

in television. The pentode r.f. tube is coupled to a pentode mixer through a parallel-resonant circuit. With the switch in the high position as shown, the coil T_3 is the plate tuning inductance; it is tuned by the output capacities of the r.f. tube in parallel with the input capacities of the mixer. To reduce the effects of this capacity, and to make it possible to adjust for differences in tubes, the trimmer C_6 is connected in series with T_3.

When the switch S1-C is thrown to the low position, coil T_4 becomes the tuning inductance. This is shunted by additional tuning capacity C_9 and is loaded by R_8.

The oscillator is again our familiar ultra-audion type, with a separate resonant circuit for each band.

Variable Capacity. Fig. 23 shows a tuner that uses variable condensers. This is somewhat similar to the tuning condenser with which you are familiar on sound receivers except for the unique arrangement whereby a large capacity variation is obtained. As shown in Fig. 24, this unit is so constructed that there are two tuning condensers in series for each tuning section of the condenser. Since condensers in series always have a capacity less than that of the smallest, and since both of these are varied simultaneously by the tuning control, the range is greatly extended over that of the usual tuning condenser. Furthermore, the amount of capacity is quite small considering the sizes of the plates that are used.



Courtesy Howard W. Sams and Co., Inc.

FIG. 23. A variable-capacity two-band continuous tuner, made by the General Instrument Corporation.

In the particular unit shown in Fig. 23, a band-change switch is actuated by the tuning control when the control is moved from channel 6 to channel 7 (or vice versa). To mark the proper positions for each channel, this tuner has a notch or detent cut so that the person tuning the unit can feel the "bump" as the correct position is reached.

The particular tuner shown uses a band-pass preselector that has inductive coupling between the sections.

Dust and grime must not be allowed to accumulate on the plates of a variable condenser used in a TV set. Although ordinary sound receivers may work satisfactorily with heavy accumulations of such particles, a television receiver can be considerably upset by their presence. Dust shields are necessary.

The tuners we have described so far were originally developed for individual set manufacturers, but most are now used by other manufacturers as well. Therefore, you can usually expect to find the same tuner used in several different receivers. Even when the same tuner mechanism is used, however, it is possible for the manufacturer to change the electrical circuit. For this reason, it is always advisable to consult the manufacturer's manuals whenever you have to service these units.

STEP TUNERS

There are many different kinds of step tuners that are designed to tune directly to specified television channels. All involve some form of switch —a rotary-selector switch, a sliding-turret switch, or a push-button unit. Basically, regardless of the switching mechanism, there must be an arrangement whereby the inductance, the capacity, or both are changed in each resonant circuit to tune in the proper channel for each switch position.

Incidentally, receivers vary somewhat in regard to the number of channels to which they will tune. Most manufacturers who use a step tuner arrange it so that it will tune to all twelve of the channels in use today. This permits them to ship their sets anywhere, with the expectation that all the local television stations can be picked up. However, a few manufacturers save a little on the cost of their

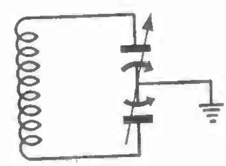


FIG. 24. This special arrangement provides a large capacitive variation in the tuner in Fig. 23.

receivers by making them tune to only seven or eight channels. Since no locality at the present time has more than seven channels assigned to it, the manufacturer need supply only this number of tuning circuits. The distributor or local dealer then adjusts the set to receive the local channels before he delivers it.

Since adjacent channels are never

used in the same locality, most such sets use a "choice" arrangement. For example, one switch position may be adjusted to tune to either channel 12 or channel 13. The local dealer or serviceman merely makes sure that whichever of the two channels is in use locally is the one the set is adjusted for, and so on down the line.

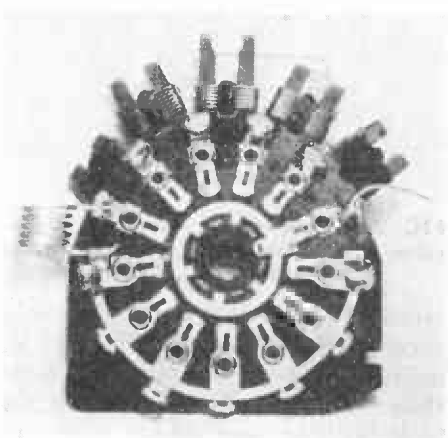
As was mentioned earlier, all step tuners only approximate the proper oscillator frequency. In order to set the oscillator exactly to the correct frequency, either a fine-tuning control or a.f.c. will be used.

Let's now look over some typical step tuners.

ROTARY SWITCHES

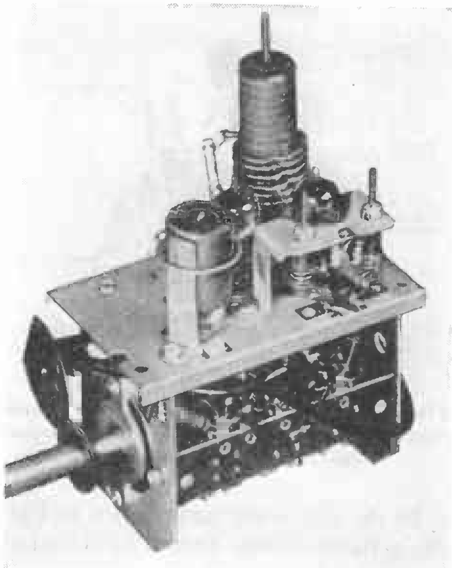
Fig. 25 shows one of the most widely used types of rotary switch selectors. In this unit, tuning to lower-frequency channels adds inductance to the circuit. The inductance coils are arranged right on the switch decks.

The schematic diagram of a tuner that uses this system is shown in Fig. 26. The selector switch blades slide along the contacts numbered from channel 1 to channel 13. (Channel 1 is commonly indicated as a "position" on the selector switches, although it is no longer assigned to television.)



Courtesy Radio Maintenance Magazine

FIG. 25. One of the switch decks used in the r.f. section of an RCA tuner. The inductance for the high band is provided by the semi-circular loop of metal at the bottom of the deck.



Courtesy RCA

The side view of the tuner in which the switch deck in Fig. 25 is used.

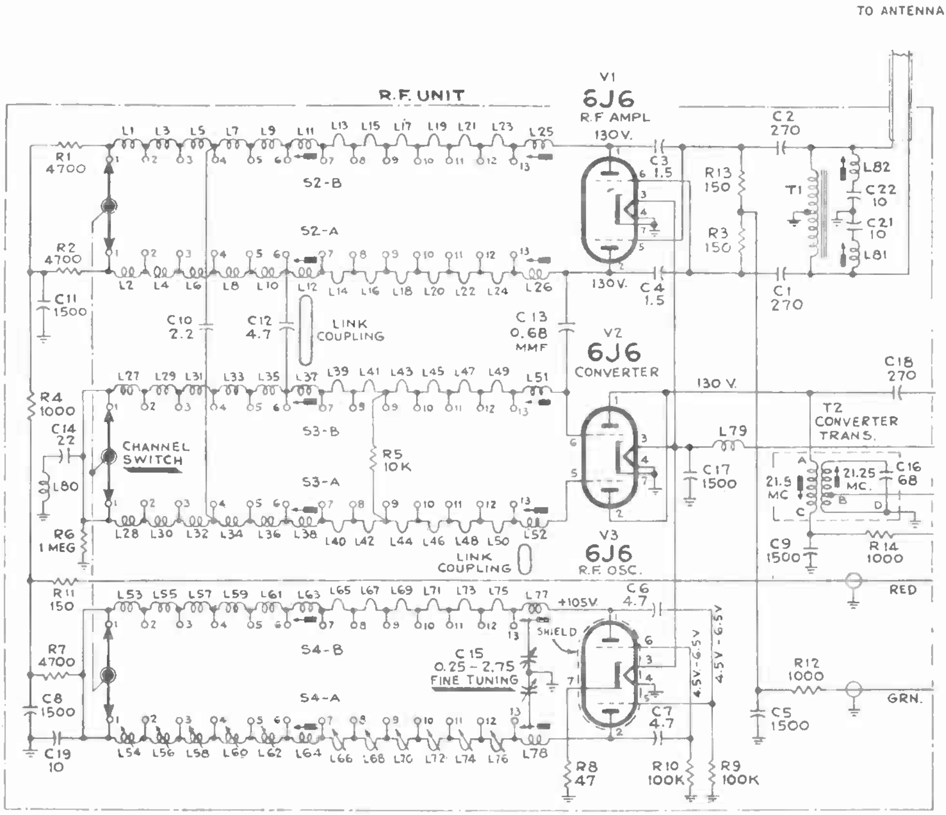
Let's run through the circuit. Starting at the antenna terminals, we first come to balanced wave traps L82-C22 and C21-L81. These wave traps are used to tune to any station that may be interfering. Choke T1 is used to reduce signals having frequencies lower than the lowest television channel. Resistors R3 and R13 load the transmission line and provide signals to the grids of the push-pull r.f. triodes. Since triode tubes are used here, neutralizing condensers C3 and C4 are necessary.

When the selector switch is set for channel 13, the tuned circuit in the plate of the push-pull r.f. stage consists of coils L25 and L26. As the selector is tuned to other channels, additional inductances are added in series with each of these coils. The added "inductances" for the upper channels (L13 to L24) are actually just short pieces of wire soldered between the switch terminals.

As the switch is moved from channel 7 to channel 6, the inductances L11 and L12 provide the rather large frequency change from 174-180 mc. to 82-88 mc. Then the coils L10 to L1 are added for the lower channels. Even here, the inductance needed is quite small, so these coils are wound in a "figure-eight" form so as to have minimum inductance. Effectively, this tuner is just a tuned line except for the inductances L11, L12, L25, and L26.

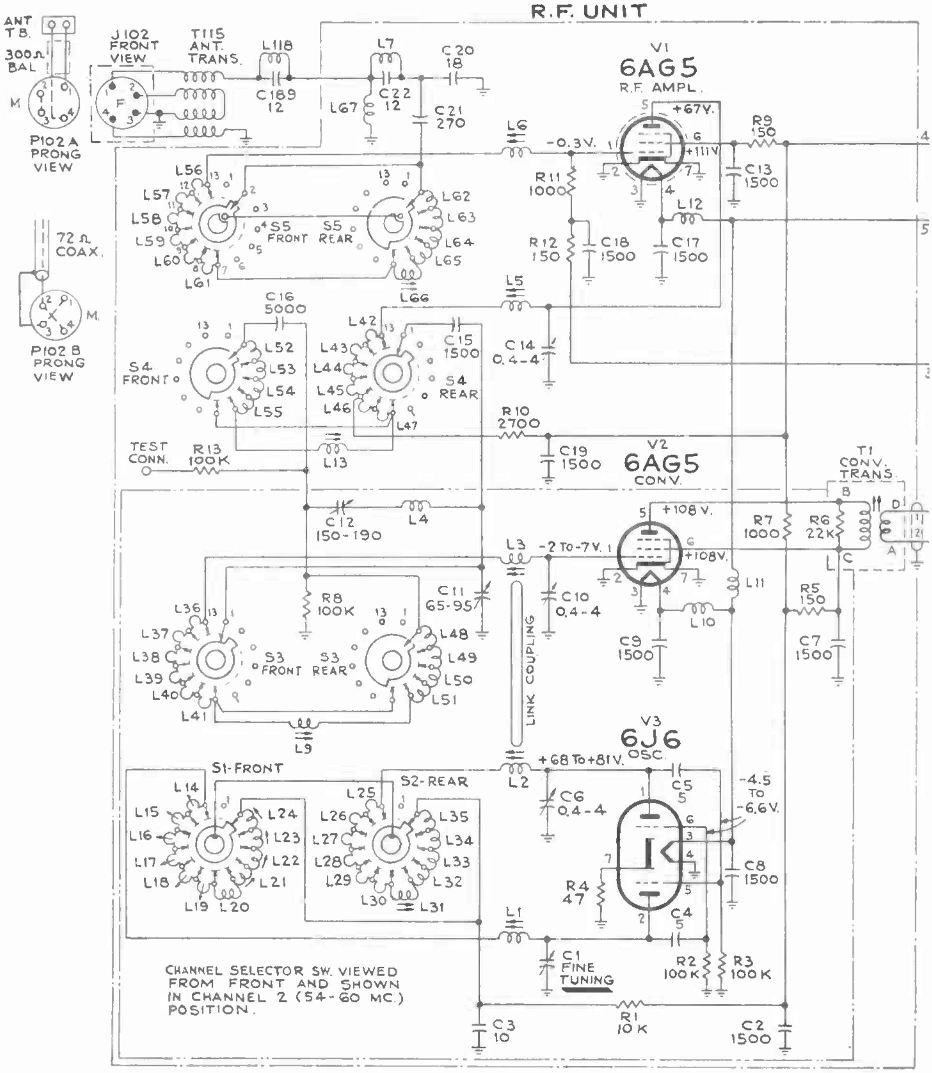
The tube capacities form the capacitive element. The only adjustable parts are coils L25 and L26 for channel 13 and L11 and L12 for channel 6. To make adjustments for any other channel, the manufacturer must shorten, lengthen, or bend the wires forming the inductances.

Coupling to the grid circuit of the converter tube V2 is through coupling condenser C13 for channel 13. For other channels, additional couplings are provided, first through a link coupling and then through two additional coupling condensers for lower channels (where more coupling is necessary).



Courtesy RCA

FIG. 26. The schematic diagram of the tuner in which the switch deck shown in Fig. 25 is used.



Courtesy RCA

FIG. 27. Another kind of circuit in which a rotary selector switch is used.

In addition, since the coils are mounted on switch wafers, there can be additional inductive coupling between the coil units if this is wanted.

In any event, the tuned-plate r.f. circuit is coupled to a tuned-grid converter, which forms a band-pass tuner. The converter input for channel 13 consists of the coils L51 and L52, which in turn are tuned by the input tube capacities. The grid resistor R6 has an i.f. wave trap connected across it, designed so that L80, C14, and the channel tuner coils act as a series-resonant circuit at the i.f. frequencies.

The plates of the converter tubes are connected in parallel. Transformer T2 is both the i.f. transformer and a sound trap used to take the sound signal from the output of the converter. That is, the primary of transformer T2, along with the tube capacities, is a parallel-resonant circuit across which the sound and video i.f. signals are developed. The video signal is fed through coupling condenser C18 to the video r.f. amplifier, and the sound signal is taken from the secondary of transformer T2.

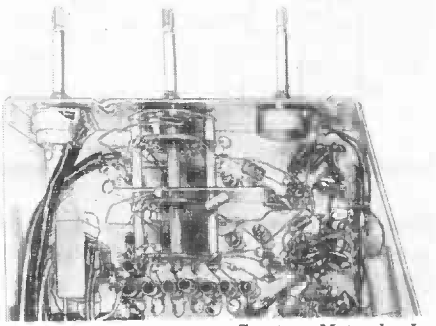
The oscillator is a tuned-plate push-push type. The oscillator signal is fed to the converter through a coupling link.

Many other circuits may be obtained using such a rotary selector switch. One of these is shown in Fig. 27. In this particular circuit, the input feeds in through an antenna matching transformer that permits either balanced or coaxial transmission lines to be used. Then the signal is fed through a series of traps into a tuned-grid circuit in which a pentode is used. The plate circuit of this tube also has a resonant circuit, which is band-pass-coupled to the grid tuning of the converter stage. The converter is also a pentode. The oscillator is a tuned-plate push-push type.

Although the electrical connections are quite different, the same basic switching arrangement is used here that is used in the circuit in Fig. 26. Extra sections are used to short-circuit unused coils, but the general arrangement of the switch and the coils is otherwise the same.

EIGHT-POSITION SWITCH

The same basic switch used in the last two examples can be used in a set that is intended for coverage of only seven or eight bands. An example of such a tuner is shown in Fig. 28, and its schematic is shown in Fig. 29. In this particular receiver, the selector switch is wired to coils that are mounted individually on the set chassis. This is one of the few examples of this kind of wiring used in television.

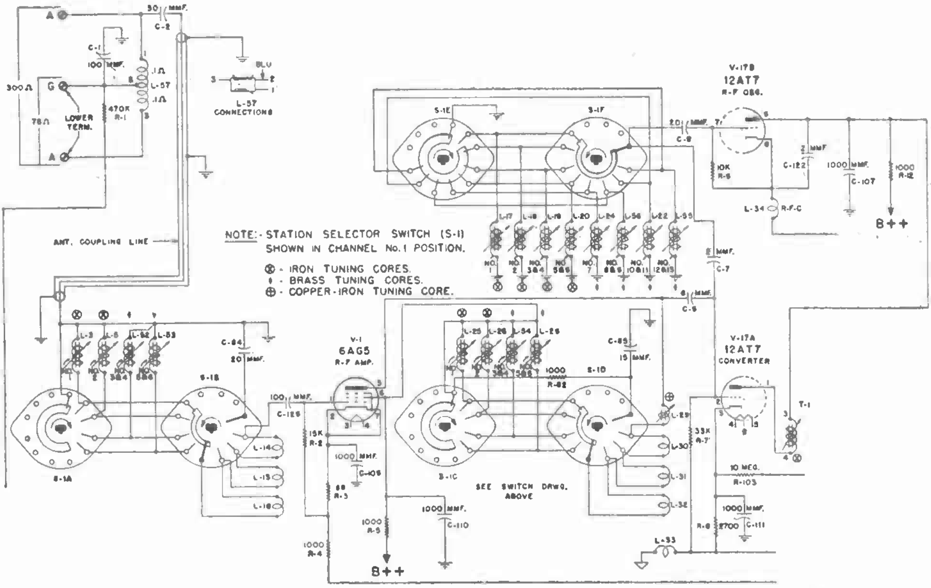


Courtesy Motorola, Inc.

FIG. 28. The set in which this tuner is used can be tuned to only eight channels.

As you can see from the schematic, the input is designed for either the balanced or unbalanced type of transmission line. From the line, the signal is fed through a coaxial loop to a bus-bar wire that acts as the coupling inductance. That is, the bus-bar wire acts as the primary coupling inductance, and the secondary windings are soldered to this wire at carefully calculated spacings along the wire. This circuit uses a tuned-grid pentode r.f. amplifier, which feeds into a parallel-resonant plate circuit that in turn feeds the converter.

The oscillator is an ultra-audion type. The switching arrangement ap-



Courtesy Motorola, Inc.

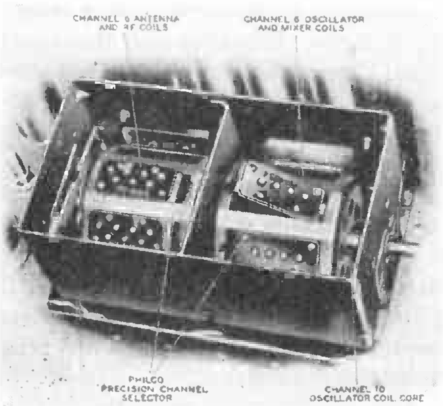
FIG. 29. The schematic diagram of the tuner shown in Fig. 28.

pears somewhat complex because one section of the switch connects the desired coil into the circuit and another section of the switch short-circuits all the coils that are not used, effectively removing them from the circuit.

Notice that the oscillator is somewhat unusual in that a separate coil, rather than a series-coil arrangement, is used for each of the bands.

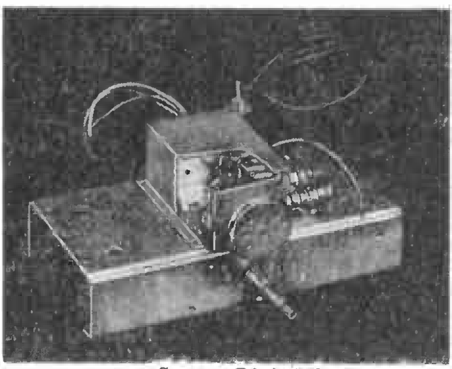
As we mentioned earlier, this particular arrangement is such that the set can be aligned to whatever seven channels are in use in any one locality.

Turret Tuner. Fig. 30 shows an example of an entirely different type of switch selector. In this one, there is a rotary turret on which several plates are mounted. Attached to each plate are the inductances needed to



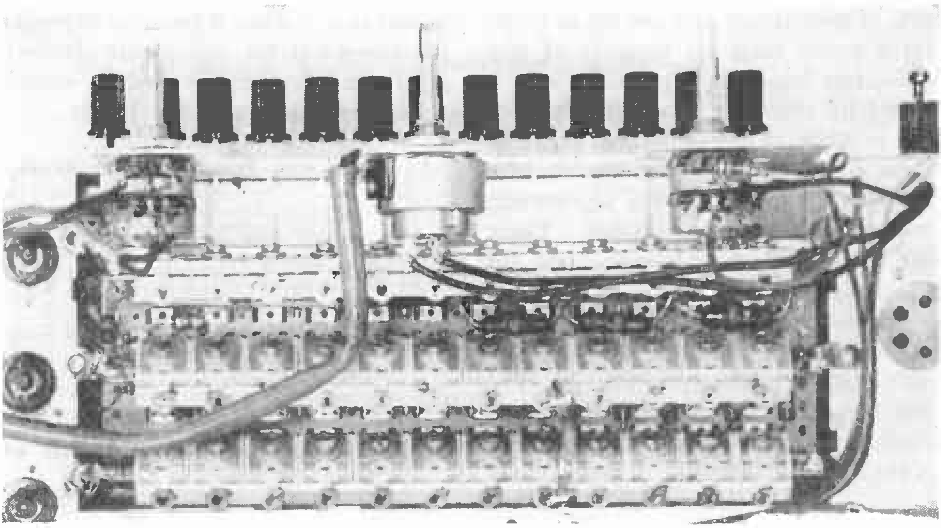
Courtesy Philco

FIG. 30. What a turret tuner looks like.



Courtesy Edwin I. Guthman and Co.

FIG. 31. Another kind of turret tuner. In this, the turret moves horizontally.



Courtesy Hallicrafters

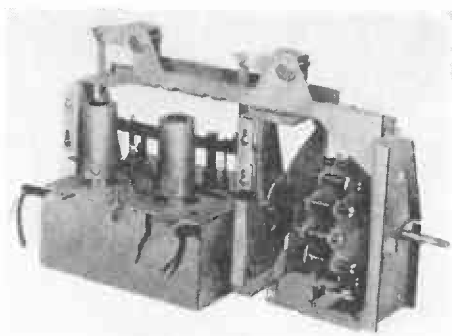
FIG. 32. A push-button tuning arrangement that can be used for all channels.

tune the preselector and oscillator to one channel. These inductances, in each case, are connected to contactor points that project through the bottom of the plate. A particular channel is tuned in by turning the turret until the plate supporting the inductances for that channel is in a position where contacting springs engage the contactor points of the plate. This connects the inductances into the circuits. Most turret tuners of this kind carry only seven or eight plates, so the proper ones must be installed for each locality.

Fig. 31 shows another type of turret unit in which the turret moves horizontally instead of rotating. Basically, this is the same as the unit we just described in that the coils or tuning circuits are movable. Unless the mechanical design prevents doing so, it is possible to use tuners of this kind with any standard circuit.

Push-Button Tuner. It is, of course, possible to use a standard push-button arrangement, as shown in Fig. 32. Here, the desired inductances, along with their associated tuning capacitors, are switched in by an ordinary push-button arrangement much like those in a standard radio. It is possible to use a tuner of this type with any standard circuit; the push-button arrangement merely provides the mechanical means of tuning in the desired stations.

Variable-Core Tuner. Figs. 33 and 34 show a final example of a switch-type tuner. This tuner contains two



Courtesy American Steel Package Co.

FIG. 33. A switch tuner in which variable-core tuning is used.

sets of preselector and one set of oscillator coils; each set consists of two coils, one for each band. The unit is tuned by moving the coil cores in or out in steps. The mechanical arrangement for tuning the unit consists of a rotating drum fitted with adjustment screws that bear on a plate. There are twelve of these screws, one for each channel. When the tuning shaft is rotated, the drum turns, causing a different screw to press against a movable plate C as shown in Fig. 34. The position of C governs the height of an insulated strip G to which the coil cores H are fastened. A screwdriver adjustment makes it possible to preset the screws B for any given channel. A trip mechanism is used to switch coils for the high and low bands.

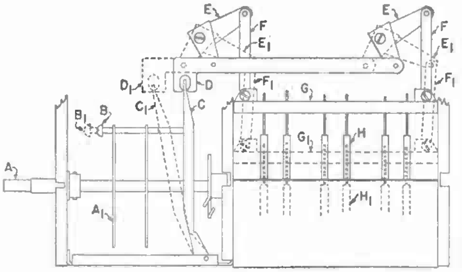


FIG. 34. The operating mechanism of the tuner shown in Fig. 33.

Lesson Questions

Be sure to number your Answer Sheet 52RH-2.

Place your Student Number on every Answer Sheet.

***Send in your set of answers for this Lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. Which of the following sections of a TV set is supposed to minimize adjacent-channel interference: 1, *the input tuner;* or 2, *the i.f. amplifier?*

2. What makes it difficult for the input tuner of a TV set to have good image rejection?

3. For minimum noise, should the resistances or impedances in the input circuit of an r.f. stage be: 1, *low;* or 2, *high?*

4. Why are some tubes (designed for f.m. and TV equipment) equipped with two cathode leads?

5. Name two methods of preventing oscillation when triode tubes are used as r.f. amplifiers.

6. What is the impedance between *one* outside terminal and a grounded center tap on a transformer designed for a balanced 300-ohm transmission line?

7. Where would you expect to find a wave trap designed to eliminate interference from an f.m. station: 1, *at the input of the r.f. stage;* 2, *between the r.f. and converter stages;* 3, *in the i.f. amplifier?*

8. Give two reasons why a series-resonant i.f. trap is used in the grid circuit of a *triode* TV converter.

9. Why is it frequently necessary to try several tubes when replacing the oscillator tube in a TV set.

10. In step-tuner systems, what two methods are used to get the oscillator adjusted exactly to the proper frequency?

Be sure to fill out a Lesson Label and send it along with your answers.

ALL MEN WANT TO SUCCEED

Here's a quotation I ran across the other day that made me think of several fellows I know:

"All men want to succeed. A few men want success so badly that they are willing to work for it."

Isn't it true that almost every fellow you know *wants* success, *wants* more money, *wants* security?

But how many of these men are willing to buckle down and study—work—think—to get the good things they want?

It is very true that only *comparatively few men* are willing to really work for success.

You are one of those few men. You have proved this fact by enrolling for the NRI course—by working to complete many of your Lessons. *You* are taking the first and most important step toward success.

J. E. Smith

INTRODUCTION TO PUBLIC ADDRESS

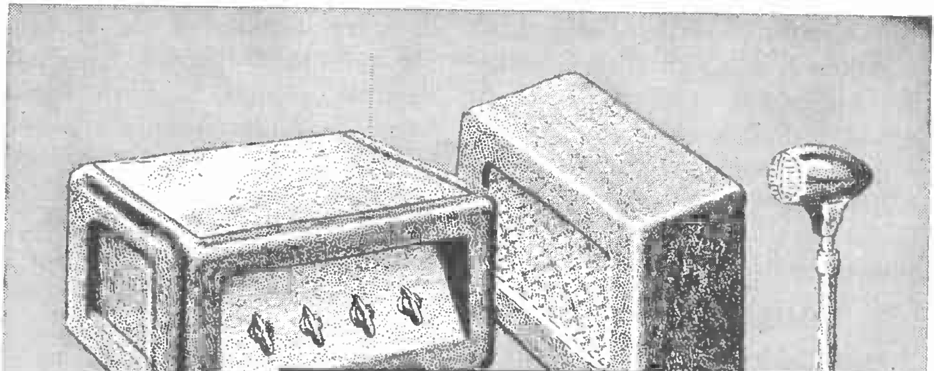
REFERENCE TEXT 52RX

NATIONAL RADIO INSTITUTE
WASHINGTON, D. C.
ESTABLISHED 1914

STUDY SCHEDULE

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

NPC8M351 1951 Edition Printed in U. S. A.



INTRODUCTION TO P. A.

RADIO servicemen constantly have opportunities to take on profitable side lines. Of course, a man who has so much radio service work that he does not have the time to do anything else may be uninterested in any of these extra sources of income. However, radio servicing is a seasonal business—there is much more repair work at certain times of the year than others, and a means of keeping up the income during the dull season is desirable. Also, to the man who is not overloaded with service work, because of competition or the smallness of his community, these side lines represent a means of augmenting the regular service income.

As you might expect, these side lines usually involve electrical apparatus or electronic equipment in one form or another. For example, it is quite common to find that the local radio serviceman also repairs home appliances, such as irons, toasters, and lamps. In an industrial community, he may work on a certain amount of electronic control equipment.

A profitable and logical side line is public address. It is a logical field because it uses loudspeakers and other devices with which you are already familiar. Servicing such equipment is just as profitable as servicing radios is; furthermore you can make additional profits by installing and selling equipment if you wish.

A lack of information about public address equipment prevents many servicemen from taking advantage of this field. Also, in many localities the opportunities appear to be limited. However, in most cases, this lack of opportunity is entirely a result of the fact that no one has taken the time and made the effort needed to create a demand for public address equipment, because there have been too few men trained to recognize the usefulness of the equipment, to recommend the proper installation, and to install it. The wide-awake serviceman can increase his opportunities by seeing to it that more use is made of this equipment.

Whether future opportunities cause you to enter the field only part way—

to the extent of servicing or perhaps occasionally doing installation work—or whether you eventually decide to specialize exclusively in public address, you will find these Lessons helpful. They will present the important details you need to know to succeed in this field.

WHERE IS P.A. USED?

Public address (commonly abbreviated "p.a.") equipment is known to most people only as a system used where large numbers of people are to be addressed. As examples of occasional or seasonal uses, p.a. equipment is being used more and more at circuses and carnivals, political conventions or rallies, and at special events such as county and state fairs, rodeos, etc. There are other places, such as airports, railroad and bus terminals, etc., in which year-round use is made of sound-amplification equipment.

In addition to these applications, in which the sound systems are primarily used for amplifying speeches or giving information, there is an increasing use of p.a. systems in the entertainment field. Sporting events require systems for making announcements. Lecturers and speakers at dinner meetings also use sound systems to amplify their voices. Dance music in ball-rooms is now commonly fed through p.a. systems; in addition, such systems are frequently used for amplifying the music of soloists or even full orchestras at concerts.

Moving from the field of gatherings brought together for specific entertainments or functions, we find that sound systems are beginning to be widely used to provide entertainment in many factories—music is being played for the workers and apparently increases production. Even further from the conventional use of p.a. systems are the installations in hotels and hospitals in which individual speakers in rooms are used to bring entertainment to the hotel guests or to the hospital patients more or less individually.

Similar to these are intercommunicators, which are basically amplifier units designed for communication between just two people or between small groups of people. Typical uses are for interoffice communication between an executive and his secretary or his department heads, for communication from a service desk to a service department in a store, and for communication from lunch counter to cook in a restaurant, to mention just a few.

As this list shows you, there are a great many possible uses for p.a. equipment, and therefore there are a great many p.a. systems already in existence. All of these systems have to be serviced from time to time. Furthermore, many new systems are being installed all the time as new uses for p.a. equipment are developed. There is, therefore, an increasing opportunity for the serviceman in p.a. work.

P.A. REQUIREMENTS

Now that you've seen what some of the uses of p.a. systems are, let's see what requirements the equipment must meet in these applications.

The basic p.a. system is shown in Fig. 1. It consists, as you can see, of an input device (in this case, a microphone), an audio amplifier, and a loudspeaker. All p.a. systems contain these elements. Many systems are more complex than this, having extra input devices (other microphones, record players, and occasionally radio tuners) and multiple loudspeakers, but basically they are all alike.

When such a system is used for addressing a large crowd, the chief requirement made of it is that it must have enough power to make it possible for everyone to hear. If music is to be played over the system, it must have at least a reasonably good fidelity of response in addition to sufficient power. If the music is intended for a critical audience, the fidelity of the system must be excellent. Let's discuss these requirements more fully.

One of the first things that must be considered in planning a p.a. installation is how much power is necessary to cover the audience properly. This problem can be solved only by having some knowledge of the acoustic problems involved in distributing sound. In a small living room, a power of two or three watts is entirely sufficient. However, in a large auditorium or at an outdoor gathering or sporting event, an electrical power of as much as 500 watts or more may be required.

There are many factors involved in the determination of the proper power levels. We'll learn more about these later, but some of these factors are:

1. Noise Level
2. Acoustic Problems
3. Fidelity
4. Loudspeaker Efficiency

Noise Level. Whenever there is any appreciable amount of noise, any other sound tends to be masked. You are undoubtedly familiar with the fact that it is much easier to hear someone talking in a quiet room than in a noisy one. Conversely, a speaker must talk loudly in a noisy room to be heard. This fact means that the noise level at the location must be taken into account when a p.a. installation is planned. In general, it is necessary that the desired sound be amplified so that it is considerably stronger than the noise level. There are limits to this—if the noise level is too high, as it may be in a factory, it may be impossible to get above it without making the amplified sound so loud that it is actually painful.

Acoustic Problems. The loudspeaker cone moves air particles directly before it, and these in turn move other particles at a distance. As this movement fans out, and as the distance between the loudspeaker and the listeners increases, a decreasing amount of sound power reaches individual listeners. Furthermore, much

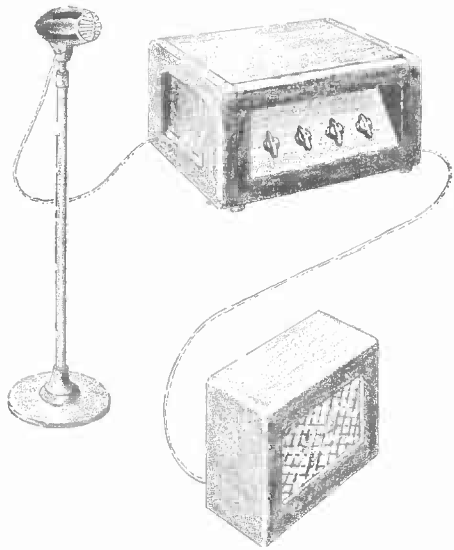


FIG. 1. This is the basic p.a. system—a microphone, an amplifier that builds up the signal from the microphone, and a loudspeaker that converts the electrical signal into sound.

of the sound power is absorbed by the cushions on chairs, by hangings on the walls, carpets on the floors, and by the people and the clothing they wear. Any soft material readily absorbs sound energy. All of these absorptions, plus that of any acoustic treatment that may be placed in a hall, will reduce the sound reaching the rear of the hall appreciably. Outdoors, sound is similarly absorbed by people and dispersed by the wind. All such effects increase the amount of power a p.a. system must produce to give adequate sound coverage.

One acoustic problem that occurs only indoors is caused by sound reaching listeners over two or more paths. For example, if sound reaches a listener directly from the loudspeaker and indirectly by reflection from a wall, the sound traveling over the longer path will arrive later than that over the more direct path. In an extreme case, this can cause an echo effect, with one sound heard separately before the other. If the time difference is too short to amount to an actual echo, the sound arriving over other paths may be sufficiently out of phase to produce a muddled response. This phase difference may be exactly 180°, causing sound cancellation: in fact, it is quite common to find that reflections from the walls, floors and ceilings are such that there are actual dead spots in the hall.

As we shall show later, the reflection problem can be partially solved by acoustic treatment of the room, but it is quite possible that severe reflections will require the use of additional loudspeakers, so distributed that sound energy will be put where and only where it is wanted. Any such multiple speaker installations will usually require more power.

Fidelity Requirements. It is not usually difficult to design a public address system to handle only spoken words. However, when music is also to be handled, the fidelity of the system enters into its design to a great extent. The greater the fidelity requirements, the greater the power requirements. Low frequencies in particular require large amounts of power to be heard at a distance, because the human ear falls off in its response characteristics at low frequencies. Similarly, there is a drop-off in the high-frequency response because of the greater absorption of these frequencies in the acoustic materials of the hall. To make up for these rather large drop-offs, it is necessary to have high powers at the low and high frequencies, and to design the loudspeakers and their baffles to reproduce such frequency ranges properly. Therefore, when high fidelity is required, the power demand is increased tremendously.

Loudspeaker Efficiencies. Once the problems of noise, acoustic conditions, and fidelity have been considered, it is possible to determine about what acoustical power will be needed to cover a certain area or number of people outdoors or to cover a certain room volume or number of people indoors. In fact, in later Lessons, we will give tables that can be used, once the necessary facts about the installation are known, for determining roughly the acoustical power needed.

When the acoustical power is known, you can find the electrical power from the loudspeaker efficiencies. The loudspeaker converts electrical power into sound power. Unfortunately, this conversion occurs with extremely low efficiency, so a considerable amount of electrical power is required to produce a small amount of sound power. At best, the ordinary cone-type loudspeaker of the sort used in home receivers has an efficiency of only about 2%. If this cone loudspeaker is placed in a carefully designed baffle, its efficiency rises to as much as 5%. Even the best speakers, using efficient diaphragm driver units in trumpets, have efficiencies of only about 15%, and this is obtained only at a considerable sacrifice in fidelity. In most cases, however, a surprisingly small amount of sound pressure is needed, so it isn't necessary to go to extremes in electrical power to overcome this great loss in the loudspeaker.

Once we arrive at a reasonable estimate for the electrical power required, this sets at least one of the requirements to be made of our amplifier. Thus, if we find that we need 12 watts for a particular small installation, the amplifier must deliver at least this power output.

GAIN REQUIREMENTS

Turning now to the other end of the system, how much are we getting from the microphone? We shall find in other Lessons that this depends on the kind of microphone, and on the distance between the microphone and the person speaking, as well as on the sound energy delivered by that person. However, even at best, a microphone delivers a power that is only a fraction of a microwatt! Therefore, our amplifier must have sufficient voltage and power amplification to raise the output of the microphone to the power needed to drive the loudspeaker system. This gives a second requirement for the amplifier—it must have sufficient gain in addition to delivering the required output.

Once we have chosen the microphone, amplifier, and loudspeakers, we are faced with the problems of connecting them together. Often very short leads are all that are required, but sometimes we may have to put our loudspeakers several hundred feet away from the amplifier. As you will learn later, special impedance-matching methods must be used in this case.

Another problem rises when a sound system is used for amplifying music. To get fidelity, it is frequently necessary to use combinations of low-frequency and high-frequency loudspeakers. The power distribution problem is complicated by this, because we must not only match impedances properly, but also use frequency-dividing networks so that the speakers will get power at the frequencies they are designed to handle most effectively.

Further, we may not always want to use only a microphone with the sound system. Very frequently phonograph records are played over p.a. systems, for example, and occasionally radio programs are reproduced over them. The amplifier must therefore be capable of operating from a phonograph pickup or from the audio output of a radio receiver unit as well as from a microphone. These devices all have different output levels and are of different impedances. This brings up another problem in impedance matching, this time at the input of the amplifier.

Furthermore, the use of several input devices introduces the problem of switching from one to another. We can just unplug one and plug in the other, or just throw a switch, but, if we do, we will get a very loud click or pop from the loudspeaker. Most p.a. systems have some form of fading control, so arranged that the output of one or the other of the devices can be reduced to the minimum and then the output of the other can be raised gradually, or so arranged that they can be mixed together.

We are introducing you to these various public address problems so that you can better appreciate the material in the next several Lessons. Now that we have a general understanding of some of the problems, we can go on to a more detailed study of the amplifier itself.

The Decibel and Power Ratios

In public address work, we are dealing with extremely large power ratios. The acoustic power at the microphone is exceedingly small, whereas the sound output of the loudspeaker may be so loud that it is actually painful. The power ratio (output power divided by input power) is therefore so large that the figures involved become inconvenient to handle. It is not unusual to have gain figures representing power increases of as much as a billion times. For convenience, it is desirable to express the gains and power ratios involved in p.a. work in some way that will not demand such large numbers. This has led to the adoption of a special unit called the decibel, which we shall discuss in a moment.

Another factor that makes it desirable to use decibel units is the fact that the human ear responds exponentially to sound powers, rather than linearly. This means that if we double the sound power, we don't get twice as much sound as far as the ear is concerned—in fact, we can just barely detect the fact that the loudness of the sound has increased.

In other words, the human ear is so constructed that any complex sound must be doubled in power before it sounds louder. This is true at both low and high sound levels, provided the original sound is loud enough to be heard at all. For example, going from 2 to 4 *microwatts* produces a detectable increase in loudness; the apparent increase produced by going

TABLE 1

db	Power Ratio
1	1.25
2	1.6
3	2.0
4	2.5
5	3.2
6	4.0
7	5.0
8	6.4
9	8.0
10	10.0
15	32.0
20	100.
30	1000.
40	10,000.
50	100,000.
60	1,000,000.
100	10,000,000,000.
110	100,000,000,000.
120	1,000,000,000,000.

TABLE 2	
Power Ratio	db
1.0	0
1.5	1.8
2.0	3.0
2.5	4.0
3.0	4.8
3.5	5.4
4.	6.0
6.	7.0
7.	8.4
8.	9.0
9.	9.5
10.	10.0
15.	11.8
20.	13.0
30.	14.8
40.	16.0
50.	17.0
60.	17.7
100.	20.0
200.	23.0
500.	27.0
1000.	30.0

from 200 to 400 *watts* is no greater.

This peculiar property of the ear is another reason why the use of decibel units in discussing sound power ratios is convenient, because the decibel system expresses these ratios in terms of what the ear can hear. Let's go on now and learn what these important units are.

DECIBEL DEFINITION

The decibel (usually abbreviated db) is logarithmically related to the ratio of two powers by the formula

$$db = 10 \log_{10} \frac{P_1}{P_2}$$

where P_1 and P_2 are the powers. To solve this equation, the two powers are inserted and their ratio determined. Then the logarithm to the base 10 of this power ratio is looked up in a table. Ten times this logarithm is the decibel gain or loss.

In this Lesson, we cannot go very far into the subject of logarithms. Briefly, however, a logarithm of a number is the power to which a base number must be raised to equal the original number. For example, you know that the second power of ten (10^2) equals 100. In the common logarithms that use the base 10, 2 then becomes the logarithm of 100.

It is unnecessary to use the db formula because there are tables available, such as Tables 1 and 2, that give the decibels corresponding to certain power ratios. Furthermore, there are meters that are designed to indicate decibels directly. We'll say more about these shortly.

USES OF DECIBEL UNITS

Although the decibel was originally developed purely from power ratios, careful tests have indicated that one decibel of power increase is just about the smallest change in power that can be detected by the average human ear. This change is detectable only when it consists of a single pure tone and only when the test is carried out under carefully controlled conditions. For complex tones—music, for example—a change of 3 decibels is ordinarily necessary to produce a detectable volume level change. Table 1 shows that a 3-decibel change indicates a power ratio of 2, meaning that the power must be doubled before we can tell that the complex sound is any louder. If we want to make it still louder, the power must be doubled again, and so on.

Since the decibel expresses the relationship between two powers, it is a convenient unit with which to measure power gains or losses. Furthermore, it can be used to express sound power or electrical power in terms of some reference value of power. The reference level commonly used when sound powers are given in decibels is the sound power that is just barely audible to the average ear—in other words, the threshold of hearing of the average person. For convenience, technicians do not usually bother to mention the reference level when they talk about sound powers in db, but you should always remember that a sound level expressed in db is really the level with respect to the threshold of hearing. For example, the noise level in the average home living room has been found to be about 55 db; from what we just said, you know that this is 55 db with respect to the reference level, or about 300,000 times the power of the least audible sound.

Notice how much more convenient it is to say "55 db" instead of "300,000 times the power of the least audible sound." Obviously the decibel measurement is far easier to use in speech or writing. Furthermore, stating the noise level in db lets us get some idea of just how noisy the location is. Since each 3-db increase produces a barely audible increase in loudness, we know that the noise is 55 ÷ 3 or about 18 steps up the scale of comparative loudness.

Electrical powers are also often expressed in decibels in sound work. Here again, some power level must be used as a reference. In the past, considerable confusion arose from the fact that three different reference levels were used by different branches of the communications industry—the telephone company and the radio amplifier manufacturers, particularly, differing in their standards. Of these three older standards, a reference level of 6 milliwatts was the most commonly used; in fact, it still is in sound work. However, in recent years, there has been an attempt in the communications field to secure universal use of a new standard based on a 1-milliwatt reference level. This new unit is used throughout both the broadcast industry and the telephone companies. As a result, it is gradually spreading to sound equipment, and may eventually replace all of the older reference levels. Although the new unit is still a decibel, because the only change has been in the reference level, it is a common practice to indicate the new unit as a "VU" or "dbm" instead of "db" to avoid confusion.

In either case, the reference level is assumed to be the zero db level. Any power that is higher than the reference level is therefore a power increase above the reference level and is considered to be a plus db value. Power levels below the reference level are minus db values.

Table 3 gives some typical db levels based on the 6-milliwatt (.006 watt) and on the 1-milliwatt (.001 watt) reference levels. There is no need for you to try to memorize these values. All you need to do now is to learn how they are used. To that end, let's take a few practical examples of the use of decibels in sound work.

Let's suppose we have a case in which 60 watts of power fed through certain loudspeakers will produce sufficient audio power to cover an audience properly at the desired level. From Table 3, we see that this is an output of about 40 db above the reference level of .006 watt.

A typical microphone may have an output of −60 db, which means that its output is 60 db *below* the reference level of .006 watt. Therefore, we have to raise the microphone output of

–60 db to a plus value of 40 db. This means that the amplifier must have an over-all power gain of 100 db. The output power of the amplifier is therefore about ten billion times that of the microphone!

An important point to remember is that we have to double the output power before we can get a noticeably stronger signal. If one amplifier is rated at 15 watts, and another is rated at 20 watts, their power difference is only slightly more than 1 db. Obviously, therefore, the 20-watt amplifier will not produce any appreciably louder sounds than the 15-watt one. This doesn't mean that the 20-watt amplifier wouldn't be the better choice of these two—we get somewhat less distortion by running an amplifier at less than its rated output, and of course one having the higher power rating would be better able to handle high power peaks without too much distortion. The 20-watt amplifier may therefore be the better of the two, on the basis of freedom from distortion, but it will not be any louder for complex sounds. If we had a 15-watt amplifier, we would have to go to a 30-watt amplifier to get a noticeable increase in loudness level. Similarly, we would have to go from 100 watts to 200 watts to get an appreciable increase in sound at a higher power level.

TABLE 3

Reference Level: 0 db = 1 milliwatt — Watts	db	Reference Level: 0 db = 6 milliwatts — Watts
1000.	+60	6000.
100.	+50	600.
10.	+40	60.
1.	+30	6.
.1	+20	.6
.01	+10	.06
.001	0	.006
.000 1	—10	.000 6
.000 01	—20	.000 06
.000 001	—30	.000 006
.000 000 1	—40	.000 000 6
.000 000 01	—50	.000 000 06
.000 000 001	—60	.000 000 006
.000 000 000 1	—70	.000 000 000 6
.000 000 000 01	—80	.000 000 000 06
.000 000 000 001	—90	.000 000 000 006
.000 000 000 000 1	—100	.000 000 000 000 6

Amplifier Specifications

There are many types and sizes of p.a. amplifiers. In addition to differing in amount of electrical power output and in fidelity of response, they have different power-supply requirements, are capable of operating from different types or numbers of microphones or other inputs, and have different input and output impedance characteristics. All these factors must be considered in the choice of a particular amplifier for a specific job. To assist in making this choice, manufacturers' catalogs give the following information about each amplifier listed, either in the form of a complete description or as tabulated data:

Power Output
Gain
Frequency Response
Hum Level
Input Impedances
Output Impedances
Power Required
Tubes
Physical Specifications

In addition, you may find a few other special features described, such as the kind of tone control.

Naturally, it is important for you to understand the real meaning of each of these specifications. Let's examine the important ones now to see just what they mean.

POWER OUTPUT

The power output is usually stated in watts, although you may sometimes find that the manufacturer also gives the output level in decibels above the 6-milliwatt reference level.

Some manufacturers give both a "normal" and a "peak" output rating. In these cases, the *normal* output level is the output for a certain specified percent of total harmonic distortion. The peak value is the *maximum* amount of power that can be obtained from the amplifier without regard to distortion.

It is common practice to select 5% total harmonic distortion as the acceptable distortion for normal output, because, at this level, the amount of third harmonic distortion is not so high that it is seriously objectionable. To obtain the power rating, therefore, the manufacturer increases the input while analyzing the wave form of the output. When the harmonic distortion reaches the value chosen, such as 5% (or 2% in the case of high-fidelity equipment), the output is measured. This becomes the *normal* power output. Then, the input is increased further until the point of maximum power output is reached. This too is measured. This becomes the *peak* rating.

If you find only one output value listed for an amplifier, you won't always know whether the manufacturer means normal output or peak output. The normal output is considerably less than the peak rating; therefore, if the rating given is close to the value needed for the installation in such a case, you would do well to determine just which is meant before purchasing the equipment.

Amplifiers intended for public address can be grouped into low-power, medium-power, and high-power classes. There is no strict border line between these classes, however. In general, any amplifier under about 10 to 15 watts is a low-power type, those between this value and about 50 watts are medium power, and those above 50 watts are considered to be high power.

As we pointed out while discussing decibels, it takes a doubling of the power output to produce a noticeable increase in volume, so of course amplifier manufacturers do not make many different sizes in any of these groups. Usually a manufacturer makes only 4 or 5 amplifiers in each series—say a low-power amplifier of about 8 to 10 watts, a medium-power one of 15 to 20 watts, another somewhere between 35 and 50 watts, and then perhaps a high-power one. The outputs chosen are selected with the idea of having some amplifier in the line fairly close to any output that may be desired.

Manufacturers usually also make amplifiers for battery or a.c.-d.c. operation. These are not usually merely the standard a.c.-operated amplifiers with modified power supplies, because, for battery operation at least, it is necessary to make amplifiers as economical of power as possible, something that designers of a.c. equipment don't worry much about. We'll discuss this later.

AMPLIFIER GAIN VALUES

Because of the extremely high power ratios involved in public address work, it is standard practice to give the gain of amplifiers in decibels. Because these amplifiers are commonly used with phono pickups in addition to microphones, most amplifiers have input circuits for each. Since the output of a phonograph-record player is much higher than that of a microphone, less gain is needed for the phono channels. Therefore, the gain values are usually given for each input—some such value as 100 db gain for microphone and perhaps 40 to 60 db for phonograph. As you learned from Table 1, a db gain of 100 represents a power ratio of ten billion.

Sometimes, in connection with the gain values, the manufacturer will list specific types of microphones or phonograph players that are suitable for the particular amplifier. If such information is not given, it may be necessary to make a calculation to determine whether a specific input device can be used with a particular amplifier. In such cases, the output power rating must be converted to decibels. Let's suppose the amplifier is rated at 60 watts and has a gain of 100 db for the microphone channel. From Table 3, we find that a 60-watt output represents +40 db, based on a 6-milliwatt reference level. Since the output of our amplifier is +40 db, and the gain is 100 db, the amplifier will deliver its rated output of 60 watts if the input is –60 db. That is, a gain of 100 db will raise a level of –60 db to +40 db (100 minus 60 equals 40).

Microphones have different outputs ranging all the way from –40 db to perhaps –100 db. (This is from the 6-milliwatt reference level.) Naturally, if you have a microphone capable of giving –50 db, it has more than enough output to drive the amplifier we are discussing to full rated output. It will work satisfactorily with the amplifier because we can always

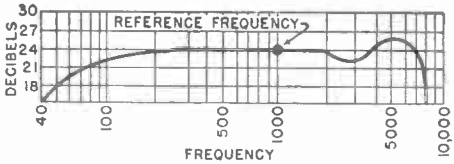


FIG. 2. This frequency-response curve shows the db output of an amplifier at various frequencies.

reduce the gain with the volume control. On the other hand, a microphone with an output of –70 db will not permit this amplifier to give full rated output. If we must use a microphone of this kind, we will have to have a preamplifier with a gain of at least 10 db to raise the microphone signal level from –70 db to –60 db so that the amplifier can be operated at full output.

This discussion shows you why the decibel is used in p.a. work. With its aid, it is rather simple to see just what will work with what. Any power losses or power gains in the systems can be taken into consideration simply.

FREQUENCY RESPONSE

The amplitude or harmonic distortion is given along with the power output rating, or is understood to be at some standard level when normal outputs are given. However, in addition, we can have frequency distortion—the limitation of the frequency range over which the amplifier will operate with a reasonable output. In public address work, the frequency response is rather important. If voice alone is to be handled, there is no need for very low notes, nor is there need for high notes above 5000 cycles. If the system is to have high fidelity, on the other hand, you'll want as wide a frequency response as is obtainable within the price range in which you are interested.

To arrive at the frequency response, the manufacturer determines the input at a reference frequency, usually 1000 cycles, that will produce the rated output. Then, the same input is fed into the amplifier at other frequencies. The amplifier output at each of these various frequencies is then expressed either in decibels or in terms of the number of decibels it is up or down from the output at the reference frequency.

Data on frequency response are frequently given in the form of response curves. In the type shown in Fig. 2, the output is given in terms of the rated output of the particular amplifier. A somewhat more common form is that shown in Fig. 3, in which the response at various frequencies is given in terms of its db variation from the reference frequency output. This curve applies to any amplifier having this response, regardless of its rated db output level.

A frequency response curve is ordinarily carried out only to the points at which the frequencies fall off 3 db from the reference value. Beyond these points, it is understood that the characteristic may have peaks, but in general, will be worse than 3 db off from the reference level. Therefore, whenever the manufacturer says that an amplifier is "flat within 3 db from

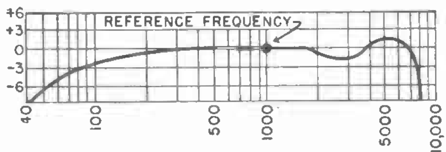


FIG. 3. This frequency-response curve shows how many db up or down the amplifier output is at various frequencies.

40 to 10,000 cycles," he means that the output will vary slightly but will remain within 3 db above or below the output at 1000 cycles between these limits. Notice that the curves shown in Figs. 2 and 3 are flat within 3 db from 80 to about 7500 cycles.

Many manufacturers give information on the effects of the tone controls on the frequency response. They will state that the tone control raises or lowers the output so many db at a given frequency. This will give a general idea of what happens to the response curve as the tone controls are varied.

AMPLIFIER HUM LEVELS

Naturally, the output hum and noise levels from an amplifier must be just as low as possible for best results. In any amplifier of reasonably good design, the noise level is far below that of the hum.

In high-fidelity systems, the hum voltage applied to the loudspeaker must be very small to prevent excessive hum output. The hum level is not quite so important in a low-fidelity system, however, because the low-frequency output is usually attenuated.

The manufacturer commonly gives the hum level as so many db below rated power output. A value around 35 to 50 db down is considered acceptable for general-purpose amplifiers.

When the noise level is given too, it is likewise given in terms of decibels down.

INPUT IMPEDANCES

When an amplifier is given a certain rating, it is assumed that its input and output will be properly impedance-matched so that the maximum power transfer will occur. Therefore, the number and impedance values of the input channels are important amplifier ratings.

The simplest amplifier may have only a phonograph input; very elaborate ones may have provisions for three or four microphones and perhaps two or three phonograph players. Because it may be desired to fade one signal out and fade another in gradually, without affecting the strength of any other signals, all of these input channels are usually fed through separate preamplifier stages, whose outputs are then combined in a mixing circuit arrangement. We'll study these amplifiers in more detail later.

Some microphones, such as the crystal types, are high-impedance devices that should feed into the grid input circuits of tubes. As a practical matter, you know that the grid circuit must have a d.c. path to the cathode. Since a resistor of around 100,000 ohms is commonly used to provide this path, it is standard practice to consider a high impedance input to be approximately 100,000 ohms for microphone services.

Microphones such as the dynamic types have low impedances, which are brought up to standard line impedances by means of matching transformers built into the bodies of the microphones. For low-impedance microphones, therefore, the input of the set has to be a transformer rated at some standard line impedance such as 250 or 500 ohms. Because high-impedance inputs are less costly, basic amplifiers are usually supplied with high-impedance inputs, with low-impedance inputs being available at a slight extra cost. The type of input impedance is usually optional in the more elaborate amplifiers.

Phono channels are today practically all high-impedance types because it is standard practice to use crystal pickups. If magnetic pickups are used, it is expected that a matching transformer will be used to match the pickups to the grid circuit of a tube or to match from a standard transmission line to such a grid circuit.

OUTPUT IMPEDANCE

It is standard practice today for practically all amplifiers to have a tapped arrangement for matching various loudspeaker voice coil impedances. Values of 2, 4, 6, 8, and 16 ohms are usually available. In addition, most amplifiers also have provision for at least a 500-ohm line. Some of the more elaborate types have additional taps for 125 ohms and 250 ohms for use when lines are connected in parallel.

In addition to giving the output impedance values, the manufacturer will usually mention the method used for making connections to the output terminals of the amplifier. In some instances, these terminals are just brought out to terminal strips. In others, the terminals are brought out to sockets into which the loudspeaker lines are plugged, the proper impedance being selected by turning a switch. Such refinements as this latter are not absolutely essential, but they are helpful, particularly for amplifiers that are going to be set up and taken down frequently under conditions under which different types of loudspeakers may be needed. We shall go further into the subject of loudspeaker connections later (in another Lesson).

POWER REQUIREMENTS

Like radio devices, public address amplifiers operate from power supplies. It will do no good to find exactly the right amplifier for your installation if it will not operate from whatever power is available. Therefore, although the power requirement is usually far down on the list, it is one of the first things you should look for.

Of course, 115-volt, 60-cycle a.c. power is commonly available throughout the United States, and most p.a. amplifiers are designed to operate from such a.c. power lines. There is a wide variety of amplifiers available for such operation, so the choice of a particular amplifier depends on other considerations.

However, there are many cases where the proper power lines are not available. In some of the larger cities, for example, there are large districts in which only 110-volt d.c. power is available. In a few localities, the power lines supply only 25-cycle a.c. Special amplifiers are rarely available for such power supplies. The only thing that can be done in most instances is to obtain an inverter unit that will convert the available power to 60-cycle a.c. Such inverter units are available from radio supply houses.

Public address equipment used in a sound truck must operate either from storage batteries or from some form of power supply carried with the amplifier in the truck. In the case of high-power units, it is standard practice to equip the truck with a small a.c. generator driven by a gasoline motor. Because of the efficient circuits incorporated in modern amplifiers, however, it is practical to operate the small units from 6-volt storage batteries. Vibrator-type power supplies are used in such cases. Most such units supply enough 115-volt, 60-cycle power to operate a record player as well as an amplifier.

Naturally, when we are dealing with special units of this kind, it is particularly important that the required power levels be calculated accurately. Large sound systems drain storage batteries quickly and are rather costly. On the other hand, units that are too small are practically worthless. It is therefore necessary to select equipment that is adequate for the job but not more powerful than it needs to be.

TUBES

In practically all cases, manufacturers list the number and types of tubes used in p.a. amplifiers. This information is helpful if you find that some of the tubes listed are not the types that are commonly available in your locality, because then you can stock up on an extra set or so. The tube list will also give you a general idea of the circuits that are used, and from the power output rating, you can get an idea of how hard the tubes are being driven.

PHYSICAL SPECIFICATIONS

It is important that you know the dimensions and weights of public address units, particularly when they are to be permanently installed in a given location. The kind of housing, too, is frequently important. Sometimes you will want the amplifiers mounted in a standard rack. In other cases, you will want them to be enclosed in a metal shield or case, which is common practice for most amplifiers today.

The manufacturer may also describe the color and type of decoration on the housing, and, of course, he will usually show photographs of the general appearance of the amplifier. Naturally, it is always desirable to have a unit that is physically pleasing in appearance whenever it is to be located where it will be used by the public. Therefore, although such considerations are less important than getting the right technical equipment, they must be taken into account.

Now that we have a general idea of the data that can be expected in the manufacturer's literature, let's go on and briefly examine some typical p.a. amplifiers to see how they differ from standard audio amplifier equipment like that found in radio receivers.

Power Supplies, Output Stages, and Drivers

As we have mentioned before, the public address amplifier is essentially like the audio amplifier in a standard radio receiver. As a matter of fact, the low-powered types are, for all practical purposes, identical with such amplifiers. Not only are the circuits similar, but also the same kinds of tubes are used. The only radical difference is that low-powered p.a. units usually require one more voltage amplifier stage so that they will have sufficient gain to operate from the very low output of microphones. Higher-powered units differ more markedly from the audio sections of radio receivers, mostly because different tubes and circuits are needed to permit the handling of the increased power.

In the following discussion, we shall not go deeply into the basic theory of voltage and power amplifiers, because you have already studied this in other Lessons of this Course. (If you are hazy on certain points, review your Lessons on low-frequency amplifiers and on power supplies.) Instead, we shall point out the important differences between radios and p.a. systems. Let's start with power supplies.

POWER SUPPLIES

The smaller p.a. units operate from power supplies that are identical with those in standard radio receivers. The most common power supply uses a standard power transformer, a full-wave rectifier, and a filter, although you will find that a few of the small portable p.a. units use a.c.-d.c. supplies. The small mobile p.a. systems that are designed to operate in trucks use vibrator-type power supplies operating from a storage battery, almost identical with supply units you find in auto-radio receivers except that they are capable of delivering somewhat more power. If we consider devices like hearing aids to be public address-systems in miniature, we will even find batteries are used to furnish power directly.

Therefore, in all low-powered p.a. systems, we can expect to find power supplies that are identical with types we have included before in our study of radio receivers. It is only when we get up in the high-power units that we find much difference.

In high-power applications, it is standard practice to use a power supply with a power transformer, operating from 60-cycle a.c. If the equipment is to be used in mobile services, it is commonly operated from a gasoline - engine - driven motor - generator that develops the necessary 110-volt, 60-cycle a.c. In districts with d.c. power or 25-cycle a.c., a motor-generator would be used to deliver the 110-volt, 60-cycle a.c. Hence, you will usually find that all high-power amplifiers are alike in their power supplies to this extent.

Voltages around 300 to 400 volts are easily obtained from a transformer power supply. Receiver-type rectifier tubes may be used; if the current requirements exceed the rating of a single tube, two tubes can be used with the sections in parallel, as in Figs. 4A or 4B. These two connections both deliver twice the current of a single tube. The only difference is that you will get only half-wave rectification, with consequent hum, if one tube fails in the circuit shown in Fig. 4A. The circuit in Fig. 4B will still give full-wave rectification as long as the remaining tube lasts. Of course, this tube will be heavily overloaded, so it won't last long.

As we shall soon see, some p.a. systems use power output tubes operated in class AB_2 or even in class B. Because of the very wide changes in current requirements between the no-load and full-load conditions, power supplies used with such output tubes must have good regulation. Ordinarily, this means that the transformer and choke coils must have low resistance, and that a very high bleeder current must be drawn. This increases the current requirements.

Since the final stage requires more plate current than any other, its current is frequently taken directly from the rectifier output without passing it through the filter choke. This is permissible because there is no amplification beyond the output stage, so any hum developed is swamped by the desired signal. When the output current does go through the filter, a swinging choke is commonly used as the input choke to help keep the output voltage constant in spite of the high current changes between no-load and full-load conditions.

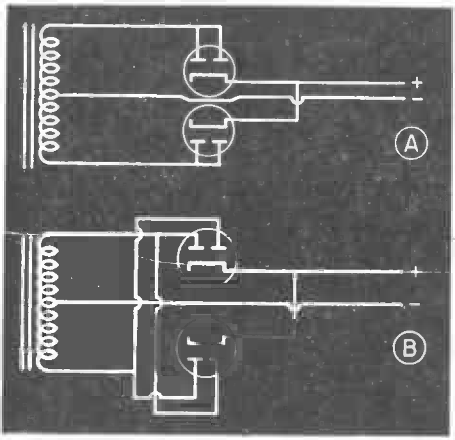


FIG. 4. Two typical full-wave rectifier circuits used in p.a. power supplies.

In some of the p.a. units of the highest powers—those rated well over 100 watts—the power output tubes are actually small transmitting tubes intended to operate on higher voltages than are applied to receiving tubes. The power supplies of such units must, of course, be designed to deliver appropriate voltages—around 800 to 1500 volts. This means that the secondary of the power transformer must have a higher voltage rating than is usual in p.a. equipment. To withstand the higher voltages, special rectifier tubes of the types that are more commonly found in amateur transmitting equipment are sometimes used. In addition, the filter condensers must be designed for these high voltages, which means that they are usually oil-filled paper condensers of the kind used in transmitters. The need for this special, expensive equipment makes high-power amplifiers disproportionately costly. For this and other reasons, high-power p.a. units of this kind are rather rare; when high powers are needed, it is common practice to use several amplifiers connected in parallel instead. The use of several smaller amplifiers is preferable because it is lower in cost, gives a more flexible arrangement (since the system can be expanded at any time by adding more units), and simplifies future servicing.

POWER OUTPUT TUBES

As you might expect, beam power and pentode tubes, which have high power sensitivity and high plate efficiency, are used as the power output tubes in practically all p.a. amplifiers. Obviously, if a triode tube requires 40 volts as the grid signal voltage for full excitation, and a pentode or beam tube is capable of giving the same power output with only 15 volts of grid drive, the latter is more desirable, since much less voltage amplification is necessary ahead of it. These tubes also have an advantage over triodes in that they convert somewhat higher percentages of their plate power into usable power output.

The one advantage of the triode over the beam power and pentode tubes is that it has far less distortion. However, modern inverse feedback circuits make it possible to obtain reasonable fidelity from pentode and beam power tubes. Therefore, the triode power tube has practically disappeared from the p.a. field except for very high-fidelity systems.

In general, the types of tubes used in p.a. amplifiers are exactly like those in radio receivers, except that, because of its high power capabilities, the 6L6 tube is more commonly used in p.a. work than it is in radio receivers. Even the smaller receiver-type tubes are commonly used, sometimes in circuits that get more from them than is required in radio receivers.

Class A Operation. The power output stages of p.a. amplifiers are most commonly operated in class A,

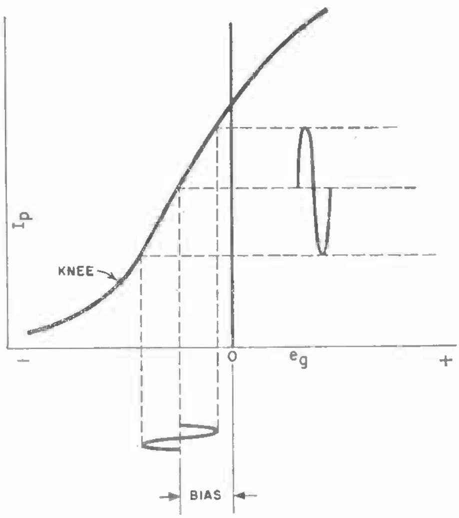


FIG. 5. This shows class A operation of an amplifier. The input signal swings over the straight part of the tube characteristic, and the grid voltage never goes positive.

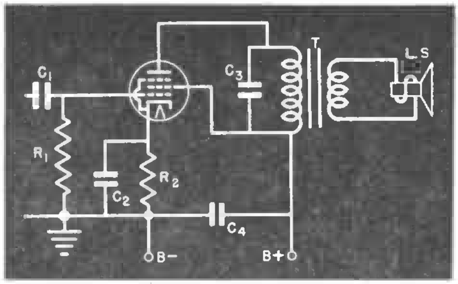


FIG. 6. A single-ended class A stage.

just as are those in radio receivers. In this class of operation, the operating point of the tube is set by the bias on the midpoint of the straight portion of its characteristic (see Fig. 5). The complete cycle of the incoming signal is reproduced in the plate current. As long as the input signal is not so high that it swings as low as the bottom knee of the characteristic or higher than the zero bias point, this class of operation is reasonably free from distortion. This matter of distortion is important because it places the real limit on power output. We can get only so much power output at a given distortion level from any particular tube once its operating condition has been specified. When the acceptable distortion level has been chosen, the drive or grid signal applied to the power output tubes can be increased only until this distortion percentage is found in the output.

In applications in which the tone quality is not very important and low powers are all that is required, the single-ended class A stage like that in Fig. 6 is sometimes used. If higher output levels are required and somewhat better tone quality is desirable, a push-pull circuit like that shown in Fig. 7 is used. Here, because the even harmonics are cancelled in the output transformer, it is possible to get greater power output from each output tube than is possible in the single-ended connection shown in Fig. 6. As a matter of fact, properly increasing the grid drive permits about two and one-half times as much power to be obtained from a pair of tubes in push-pull as can be gotten from a single tube for the same relative amount of distortion.

Both the single-ended and push-pull class A stages are usually self-biased by a resistor in the cathode circuit. However, there are exceptions—the bias can be obtained from the power supply, making it a form of fixed bias. Such a system is rather commonly used with push-pull outputs, because it is desirable to balance plate currents of the push-pull tubes. Therefore, as we shall see later, the grid returns are split and brought back to separate adjustable bias resistors in the power pack; it is then possible to adjust the bias to produce equal plate currents.

The circuits in Figs. 6 and 7 use resistance coupling to the power tube grids. It is possible to use transformers, of course, but an input transformer is bulky and rather costly. Furthermore, unless it is of high quality it will introduce considerable frequency distortion and also pick up stray hum fields.

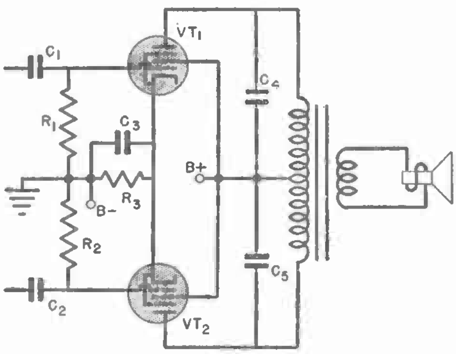


FIG. 7. A push-pull class A stage.

When resistance coupling is used at the input of the push-pull stage, a phase inverter must be used. Any of the types that you studied in your fundamental Lessons may be found in p.a. amplifiers. Several typical schematics of phase inverters are shown in Fig. 8. In each instance, the necessary 180° phase shift is obtained either by an additional tube or, as shown in Fig. 8C, by making use of the fact that the cathode voltage is out of phase with the plate load voltage.

If a transformer input is used for the push-pull stage, of course, a single-ended driver stage can be used.

GETTING MORE POWER

Once we have reached the maximum permissible output with a particular tube in class A operation, the only way of getting more power output is to change the conditions of operation or change the tube. Equipment designers usually prefer to use more efficient classes of operation, since transmitter tubes, the only types capable of giving more power output, are expensive.

Instead of class A, we can use classes AB_1, or AB_2, or even class B provided we use a push-pull circuit. The power output increases remarkably—if two tubes deliver 18 watts in class A push-pull, they may give 25 watts in AB_1, 45 watts in AB_2, and 60 watts in class B.

Fig. 9 shows the difference between these classes of operation. The class

A grid signal is limited so that the operation remains over the straight portion of the characteristic between the lower knee and the zero bias line. The plate current change for class A operation here reaches the peak value represented by 1. Naturally, the greater this amplitude can be made, the greater the amount of signal power output. Therefore, if we move the operating point down near the knee of the curve, we can apply a higher grid signal and produce AB_1 operation. The plate current swing for this class of operation is shown at the

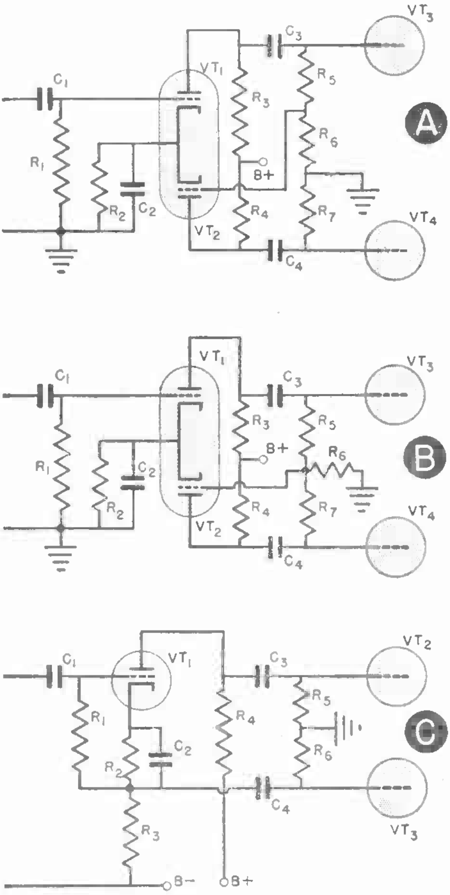


FIG. 8. Typical phase-inverter circuits.

right at 2. Notice that amplitude 2 is higher than 1; this means a greater amount of power output is obtainable. However, the lower half of this plate current cycle is flattened out, meaning that a large increase in even-harmonic distortion has occurred. This distortion would make class AB_1 operation undesirable were it not that push-pull operation fortunately eliminates the even harmonics.

Increasing the grid drive more produces class AB_2 operation, in which the grid actually goes positive for a small portion of the cycle. This operation gives even greater power output, shown by the fact that peak 3 is higher than either 1 or 2.

Finally, when we move the operating point to class B operation, right at the cut-off bias level, only one-half of each cycle of the incoming grid signal is reproduced in the output. The plate current for this class is represented by peak 4, which is much greater than that of any of the preceding classes of operation. When two tubes are operated in class B push-pull, one tube furnishes power for one-half cycle, then it is cut off while the other tube is delivering power.

In class AB_1 operation, in which no grid current is permitted to flow, it is possible to use the same kinds of circuits as in class A operation. In class AB_2 and class B operation, however, the grids of the power output tubes draw current during small portions of the grid cycle. As a result, there is a power dissipation in the grid circuits of the tubes; this power must come from the driver stage. Furthermore, to avoid extreme distortion, the total grid circuit resistance must be kept very small so that there will be but a small voltage drop while grid current is flowing.

For these two reasons, resistance coupling is not used for class AB_2 or class B operation. Instead, the drive signal is applied through a specially designed input transformer that has a secondary winding with very low resistance or through a cathode follower circuit like that shown in Fig. 10. In the latter case, the "load" on the driver tubes VT_1 and VT_2 consists of the coil L_1 and the cathode resistors R_2 and R_4. The low-resistance coil is in the VT_3 and VT_4 grid circuits, so grid losses are avoided. This connection provides a good impedance match between the drivers and the output tubes and thereby reduces distortion. Incidentally, the drivers VT_1 and VT_2 are actually small power tubes (operating in class A) that are driven by a voltage amplifier and a phase inverter.

For these classes of operation, it is desirable to have the grid bias of the power tubes adjustable so that the plate currents can be balanced. The balancing arrangement shown in Fig. 11 is commonly used. Adjusting the two potentiometers R_1 and R_2 makes it possible to get the plate currents equal and thus minimize the distortion that will naturally occur with these classes of operation. Incidentally, since the bias is at the cut-off value for class B operation, it is not practical to use self-bias for the power tubes—the bias must be supplied by a separate source such as the power supply.

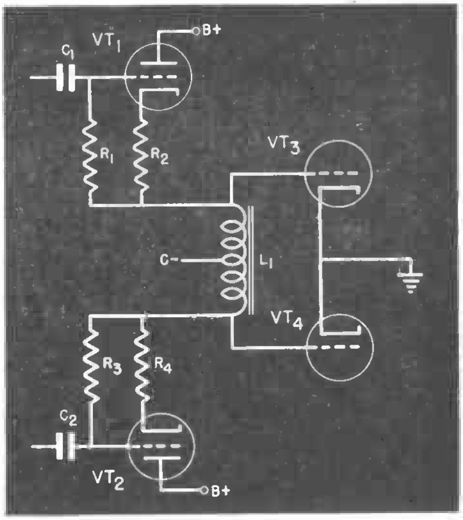


FIG. 10. A cathode-follower circuit used to feed the output stage in amplifiers operated in class AB_2 or B.

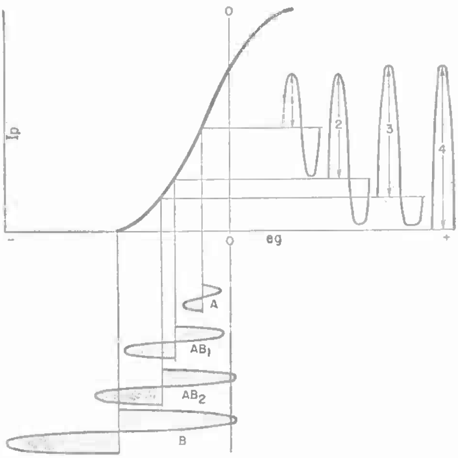


FIG. 9. Four classes of amplifier operation.

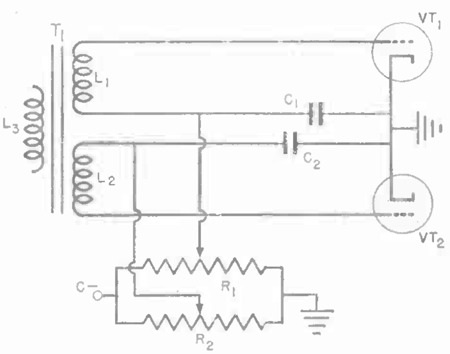


FIG. 11. The plate currents of the two tubes are equalized by adjusting R_1 and R_2.

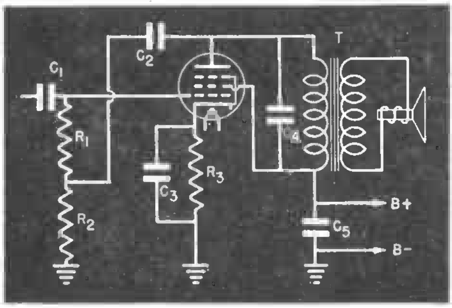


FIG. 12. One method of introducing inverse feedback. The feedback path consists of C_2 and R_2.

A family of tubes that cut off at zero bias was once developed for class B operation. These tubes, of which the 6N7 is an example, require no external bias at all, and the signal swings for a half cycle into the positive grid region. Such tubes are not used in modern amplifiers, but you may find them in some of the older ones.

The problem of supplying an input signal to a class AB_2 or class B stage frequently means that the tubes preceding the power output tubes must be small power tubes themselves. The required grid input, although it may be only a fraction of a watt, is frequently more than the ordinary voltage amplifier tube is capable of supplying.

Inverse Feedback. Any of the forms of inverse feedback that you studied in your fundamental Lessons may be found in public address systems. The feedback may just be across the output stage–from the plate to the grid circuit, for example –or it may be over a loop of several stages. We'll see some typical diagrams later, in addition to the examples given in Figs. 12 and 13. To

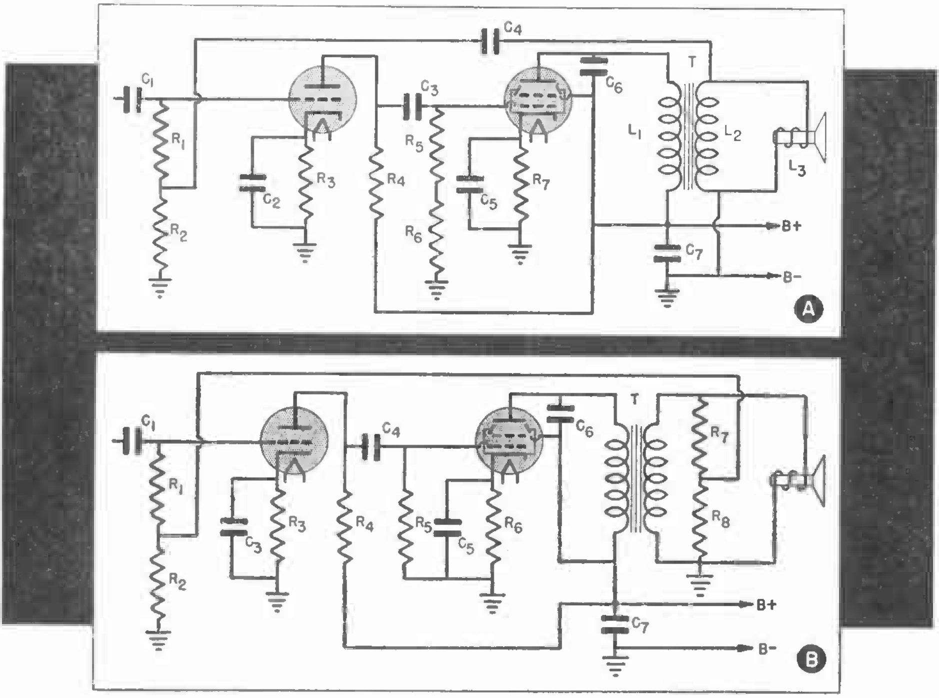


FIG. 13. Multistage feedback circuits. The feedback path in A consists of C_4 and R_2. In B, the fraction of voltage that is fed back is determined by the voltage division across R_7 and R_8. This voltage is fed back directly to R_2.

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refresh your mind—the feedback voltage is out of phase with the incoming signal and is of such nature that it decreases any distortion that is introduced between the point where the feedback occurs and the output. At the same time, the output level is reduced and the plate impedance of the output tube is brought down more nearly to that of the triode. The over-all result of this is that pentode and beam power output tubes can be used with nearly the fidelity obtained from the use of triodes. Although one of the advantages of the pentode and beam power tubes is lost in that the power sensitivity is reduced, it is still better than that of triodes.

LOUDSPEAKER COUPLING

As you know, the ordinary radio receiver commonly has an output transformer designed specifically to match the particular loudspeaker used in the set to the output tube or tubes. In public address work, however, an amplifier may be used with any one of several types of loudspeakers or with a group of loudspeakers, depending on the installation, so the output transformer must have taps to accommodate different voice coil impedances.

Fig. 14 shows a common output transformer tap arrangement. Each impedance value represents the impedance between that tap and the "common" terminal. Some amplifiers may have a few less taps and others may have a few more, but in general this is the basic arrangement.

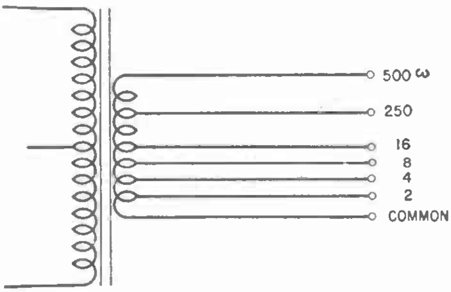


FIG. 14. The taps on a typical output transformer.

Standard loudspeakers have voice-coil impedances of 4 ohms, 8 ohms, or 16 ohms. There are a few others, but these are the most common. If you are using a single loudspeaker of any of these values, all you need to do is to connect it between the proper taps to provide the desired impedance match to the output stage.

If you are using more than one of these standard loudspeakers, the voice coils may be connected either in series or in parallel to equal some impedance value that the transformer can supply. For example, if you connect two 8-ohm loudspeaker voice coils in parallel, their net impedance will be 4 ohms, so you can use the 4-ohm tap. Connecting the same two 8-ohm loudspeakers in series would give 16 ohms net impedance, and the 16-ohm tap could be used; however, it is more common practice to connect the loudspeakers in parallel so that both will not be cut off if one of them should open or become defective.

Naturally, the more loudspeakers used, the more troublesome becomes the problem of impedance matching. We could connect four 8-ohm loudspeakers in parallel to get a net impedance of 2 ohms, which our transformer is capable of matching. However, connecting three such loudspeakers in parallel would give an impedance of 8 ÷ 3 or 2.6 ohms, for which there is no transformer tap. When an in-between value like this is obtained, it is usually best to use the output transformer tap that is next lower in impedance, because doing so minimizes distortion and loss of power. Therefore, we should use the 2-ohm tap. (As a practical matter, although it is desirable to match within 10%, mismatching up to 25% is tolerable and causes very little power loss.)

Elsewhere, we will go further into this problem to show in more detail some of the difficulties met in coupling loudspeakers to amplifiers.

Returning now to our transformer, you will notice that there are two high-impedance terminals, one rated at 250 ohms and the other at 500 ohms. These are needed because the loudspeakers must frequently be at considerable distances from the amplifier. The loudspeaker voice coils have relatively low impedances, so even if you use rather large, low-resistance wires to connect them to the amplifier, there will still be considerable loss in the wire. For example, if we use No. 20 B & S wire to connect a 4-ohm loudspeaker to an amplifier, we cannot have the loudspeaker farther than twenty-five feet from the amplifier if we are to keep the line loss to a value of 15%. If the loudspeaker must be placed farther away from the amplifier, or if the power loss is to be kept less than 15%, we would either have to use much larger wire or, preferably, use a higher-impedance line. Such a line will also be discussed elsewhere, but for now let us say that a line will transmit power with a minimum loss if we connect a fairly high impedance to both of its ends. An impedance of 500 ohms is commonly used. With the higher impedance, we can have a higher terminal voltage and a much smaller current for the same power. Since the loss in the line depends upon the I^2R value, reducing the current for the same power delivery means that the loss is decreased.

Therefore, if we connect one end of a line to the 500-ohm terminals of the output matching transformer, and connect the other end to a transformer that is designed to match 500 ohms to a voice coil, the line becomes relatively loss-free and can be run for considerable distances. For example, the No. 20 wire that we mentioned before, when used as a 500-ohm line, can be run for 1500 feet with a power loss of only 5%. As you recall, such wire has a 15% loss in a 25-foot run when it is used to feed the voice coil directly.

We'll go further into this problem of lines and impedance matching elsewhere. The important thing to know, as far as the amplifier itself is concerned, is that its output transformer has a number of secondary taps with which it is possible to match impedances under most ordinary circumstances.

Amplifiers vary considerably in the physical arrangement of their terminals. Some have them brought out to a terminal strip to which the necessary loudspeaker connections can be made. In others, they are brought out to sockets into which the loudspeaker cables can be plugged.

Voltage Amplifier Considerations

An amplifier must have enough gain to raise the voltage level from that of the output of the microphone to whatever is required to drive the power output stage so that it will deliver the rated power output. By taking the ratio of these two voltage

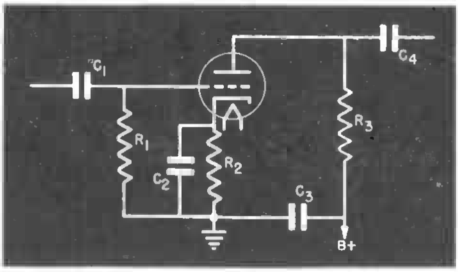


FIG. 15. A typical triode voltage-amplifier stage.

levels, we can determine the gain in decibels needed. From this, we can set up any combination of stages, the product of whose gains equals the necessary gain value. In practically all modern amplifiers, the voltage amplifier stages are resistance coupled and, in general, they duplicate receiver voltage-gain stages in their design. Triodes are commonly used; sometimes pentodes are used also. Figs. 15 and 16 show typical circuits.

The only major differences between p.a. amplifiers lie in the number of stages used and in the special features, such as the input coupling, the methods of mixing signals, and the tone-control network. We shall now take up these special items, leaving complete schematics for later.

INPUT CONNECTIONS

Standard practice is to bring the input terminals of the p.a. amplifier to jacks so that the microphones and other devices may be plugged in easily. From these points, the circuit goes to the grid of the first tube. There are three basic input arrangements, all of which are shown in Fig. 17.

Fig. 17A shows a high-impedance input, intended to operate from any high-impedance device such as a crystal phono pickup or crystal microphone. As you will learn in later Lessons, any signal source whose impedance is above, let us say 40,000 ohms is considered to be high impedance and can be fed directly to a tube grid as shown here.

Many microphones and the magnetic phono pickups are relatively low-impedance devices. For example, some dynamic microphones have as low an impedance as have many electrodynamic loudspeaker voice coils.

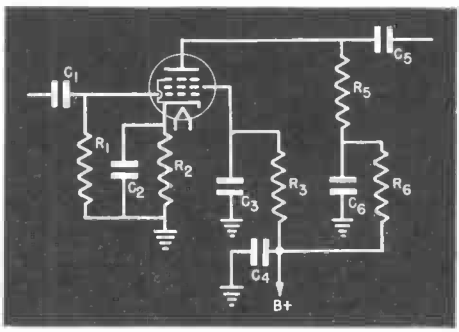


FIG. 16. A voltage-amplifier stage in which a pentode is used.

With devices of this kind, the proper impedance match must be made to the grid of the tube so that there will be sufficient voltage for proper operation. Also, since the microphone may sometimes have to operate at a distance from the amplifier, it is standard practice to use a matching transformer between the microphone or pickup and connecting line, which is almost always rated at 500 ohms. Then, at the amplifier, another transformer is used to match the 500-ohm line to the grid input of the first tube.

There are two basic arrangements for low-impedance inputs, which are shown in Figs. 17B and 17C. To set a fixed value for the grid input impedance, a resistance of some value around 100,000 ohms may be connected as R_2. Then, the transformer matches 500 ohms to the resistor value.

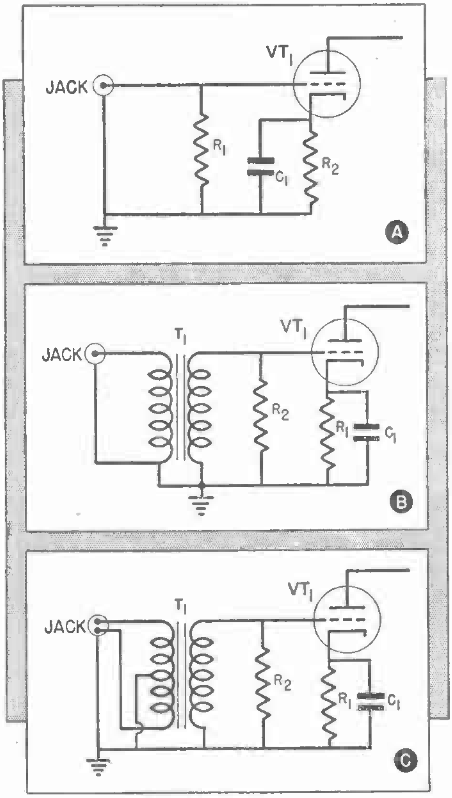


FIG. 17. Three kinds of input circuits. A high-impedance circuit is shown in A, an unbalanced low-impedance circuit in B, and a balanced low-impedance circuit in C.

Fig. 17B shows what is known as the unbalanced line, in which one side of the line is grounded. The microphone cable used here (and in the high-impedance circuit in Fig. 17A) is a coaxial type consisting of an insulated conductor surrounded by a flexible braided shield, which acts as the other side of the line. In Fig. 17C is shown the balanced line. The basic difference here is that there are two separate conductors and that the ground is made to a center tap at a transformer at each end of the line. These two conductors can be and usually are surrounded by shielding braid that serves as a ground return. The advantage of the balanced system is that both lines will pick up an equal amount of noise or hum voltage and will feed these equal voltages in opposite directions through the input transformer of the receiver so that they will cancel. (The signal current sets up a circulating current throughout the entire system, however, so it is not cancelled.) Therefore, in applications where noise and hum are troublesome, the balanced input is used.

MIXING AND FADING

One of the important problems in p.a. work is the necessity of operating from more than a single source. Even the simplest of p.a. systems will have at least one microphone and one phonograph pickup, and will ordinarily have provisions for connecting

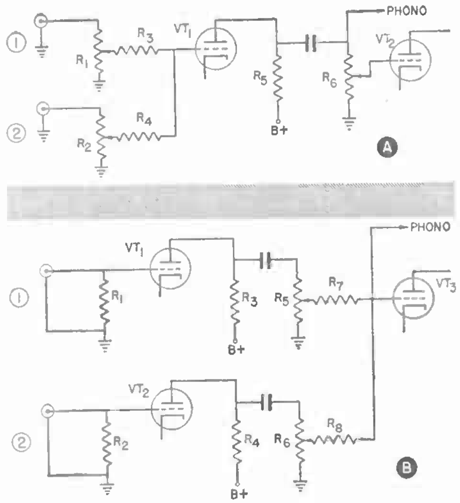


FIG. 18. Two kinds of resistance mixing circuits.

several other devices of these kinds if they are required. In some of the very elaborate systems, there may be anywhere from three to six microphones connected at one time, and there may well be two record players so arranged that it is possible to supply music continuously by fading from one to the other.

We can't just connect several microphones in series or in parallel and feed them all into the grid of a single tube. Besides introducing problems of impedance matching, this would not permit us to have control over each individual input, which is quite necessary. Even when you have a group of microphones picking up the same program, as when you have two or three picking up an orchestra, it is necessary to adjust the level of each microphone individually to get the proper balance between all of the input levels. Then, to have a truly flexible arrangement, it is desirable to be able to turn one microphone off and turn another one on smoothly and simultaneously, without having to unplug a microphone and then plug another one in its place. And, as we mentioned before, the same is true of record players—when continuous music is desired, it is important to be able to fade out one player and run in another one without any appreciable break in the continuity of the program.

Therefore, p.a. systems have a number of input terminals, each with its own separate control to make it possible to adjust the levels individually. You will find that p.a. amplifiers differ widely in the number of such input channels provided, according to the uses for which they are designed. However, regardless of whether there are two microphone or phono input terminals or six, the following basic facts will apply.

Resistance Mixing. Fig. 18 shows two examples of what is known as resistance mixing. In Fig. 18A we have two microphone channels, each feeding into its own individual level control R_1 or R_2. By adjusting these controls individually, we can adjust the output from the corresponding channel to any desired level. Thus, it is possible to cut one off and the other one on, then to fade from the one that is on to the other one. Or, if desired, they may both be fed in at the same time at some predetermined level. From these controls, the signal goes through preamplifier tube VT_1 and then is resistance coupled to amplifier tube VT_2.

Potentiometer R_6 acts as a master volume control in that it controls the total signal level. With this form of control, it is possible to preset the mixer control R_1 and R_2 at some desired level and then use the master control to vary the volume as required. Placing the master volume control after amplifier tube VT_1 is desirable because all controls become noisy with use as poor contacts develop within them. Any noise signal caused by a control at the input of VT_1 will go through the entire amplifier and therefore receive maximum amplification. A similar noise caused by a control located at the input of VT_2 will produce far less noise output from the amplifier, because it will be amplified only by VT_2 and succeeding stages, not by VT_1 as well. In effect, then, placing a control at the input of VT_2 lengthens the life of the control, because it can get much noiser before it has to be replaced.

Going back now to the input: resistors R_3 and R_4 are used to prevent interaction between the two controls as much as possible. If these resistors were not used, and, for example, R_1 were set at zero, the grid of the tube would be grounded; there could then be no input no matter where R_2 was set. With resistors R_3 and R_4 in the circuit, however, the grid cannot be grounded by setting either R_1 or R_2 to zero; as a matter of fact, R_3 and R_4 are so large that adjusting either control throughout its range changes the resistance in the grid circuit very little. As a result, any adjustment of the control in one channel has little effect on the other channel.

The output from a microphone is always much less than that of any standard phonograph-record player. Therefore, there is always an extra triode or pentode preamplifier in the microphone channels. Notice that the phonograph outputs feed directly to the master volume control R_6 in Fig. 18A, whereas VT_1 acts as a preamplifier for all the microphone channels.

Although R_1 and R_2 get less use than the master volume control, they will still get noisy in time, and, because of the extra amplification, this noise will become objectionable very quickly. Furthermore, this particular form of resistance mixing always results in signal loss because R_3 and R_4 act as a voltage divider for any input signal. Since the signal is very weak at the grid of the preamplifier tube, very often the arrangement shown in Fig. 18B is used instead. Here, separate preamplifier tubes are used for each microphone channel, with the result that the very weak microphone signal feeds directly to the grid of its preamplifier tube and is boosted in volume at once. Then, each channel feeds into its volume control—R_5 for channel 1 and R_6 for channel 2. Resistors R_7 and R_8 are used to prevent too much interaction between these controls, just as R_3 and R_4 are in the circuit in Fig. 18A. Since the channel fader controls are now in the position occupied by the master volume control in Fig. 18A, it is common practice to eliminate the master volume control altogether and to use these fader controls as individual volume controls and as the fader-mixer control.

Electronic Mixing. Another input system is shown in Fig. 19A. This system is called "electronic mixing"; it is not the same as the electronic mixing with which you are familiar from your studies of radio, however, because the mixing does not occur in the electron stream of a tube. Separate amplifier tubes are used for each channel, both of which feed into a common-load resistor. This arrange-

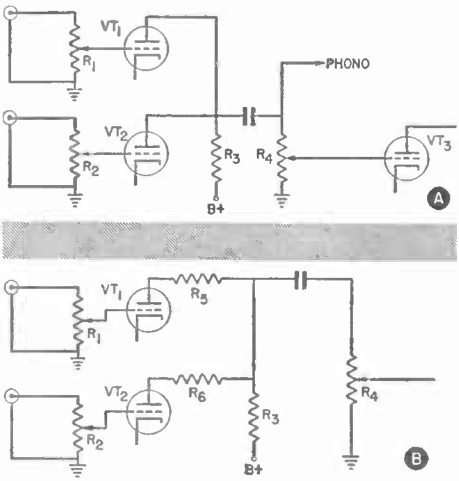


FIG. 19. Two examples of electronic mixing.

ment makes it possible to adjust the input levels to either of the tubes without seriously affecting the other channels. The tubes thus act as decoupling devices that isolate the channels from each other.

Of course, if any channel is overloaded so that the plate resistance of its corresponding preamplifier tube changes, there will be an effect on the other channel, because each tube's plate resistance acts in shunt across load resistor R_3. This effect can be reduced by the arrangement shown in Fig. 19B, in which resistors R_5 and R_6 have been added to stabilize the two plate resistances. There is no appreciable interaction between the two channels when they are coupled this way.

Of course, this arrangement has the disadvantage of requiring that each channel be controlled at its input by a mixer control. As we mentioned, this is bad from the standpoint of noise production. Therefore, a combination consisting of two preamplifier tubes in each channel is sometimes used (see Fig. 20). Here, we still have the so-called electronic mixing in that tubes VT_3 and VT_4 feed into a common load resistor R_7. The controls are now not at the input —tubes VT_1 and VT_2 amplify their corresponding input signals so that the signals will be above any normal noise level produced by the control. A master volume control can be used at the input of VT_5 if desired, but in most cases the fader controls are used as volume controls.

When there are three, four, or more microphone channels, they can be connected in the same manner as two are. Usually all the microphone channels are treated alike.

Phonograph Channels. It is necessary to control the outputs of the phonograph-record players just as it is the outputs of microphones. If the system uses a master volume control like those shown in Figs. 18 and 19, it can be used to set the volume level. However, there is usually a separate control in each phonograph channel so that the average level can be set to correspond somewhat with the outputs from the microphone channels. Such a separate control is also necessary if phonograph music is to be used in the background behind programs

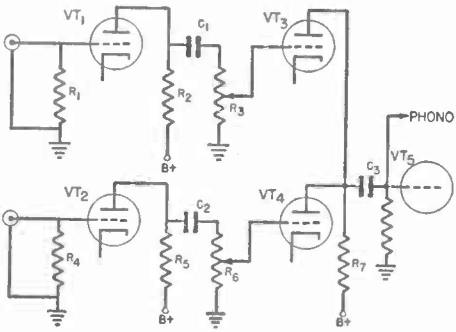


FIG. 20. An improved electronic mixing circuit.

coming through a microphone channel. In such cases, it is necessary to balance the volume levels of the two channels so that they have the desired relative loudness. The master volume control can then be used to regulate the over-all volume.

Ordinarily, when there is more than one phonograph channel, a resistive mixing circuit like the one shown in Fig. 21A is used. As before, resistors R_3 and R_4 are inserted to prevent the controls from having too great an effect on each other.

A special fader control that is sometimes used for two phonograph channels is shown schematically in Fig. 21B. This control has a grounded center tap. As you can see, the output of each channel is applied across half the control. With this arrangement, there is zero output when the slider is set at the center. When the slider is moved toward one end of the control, the output from the channel connected to that half of the control is increased, but the other channel is cut off. If the control arm is moved in the other direction, the output of the other channel is increased and that of the first one is cut off.

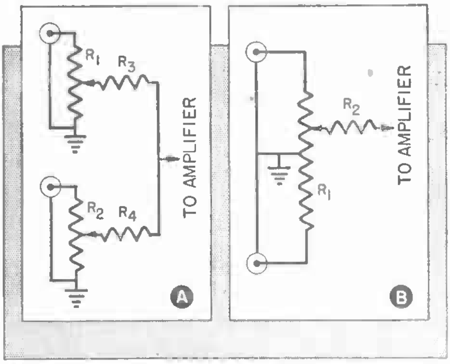


FIG. 21. Two kinds of circuits for phono inputs: a mixing circuit (A) and a fader circuit (B).

This is called a fader control because it is possible to move from maximum volume for one channel down to zero for both and then gradually up to maximum for the other. Such a control has the worthwhile feature that only one hand is necessary to operate it.

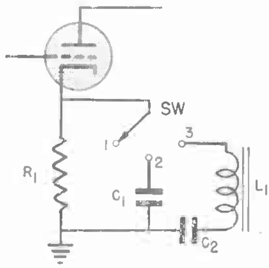
Similar fading can be obtained with the controls shown in Fig. 21A, except that two hands must be used, one on each control. Since the operator may at that time have other duties, such as placing the pickup head properly on the record that is just starting, the one-handed control is desirable. However, it has a disadvantage in that you can *only* fade from one channel to the other, you cannot mix them. The control in Fig. 21A permits both record players to be operated at the same time, if this is ever desired.

Resistors R_3 and R_4 in Fig. 21A serve the same purpose they did in Fig. 18A—they prevent the controls from interacting on each other too much. Similarly, resistor R_2 in Fig. 21B acts as a decoupling resistor to prevent the control from grounding the grid circuit to which it connects.

TONE CONTROLS

Every form of tone control with which you are familiar in radio receivers is used in p.a. equipment. In addition, there are a few types found only in p.a. systems. Most of these involve some type of degeneration. A basic example is shown in Fig. 22. Here, when the switch SW is in position 1, all the a.c. components of the plate current must flow through R_1. Since the bias for the grid of the tube is developed across this resistor, all a.c. components are fed back equally, so we have degeneration that is flat with respect to frequency.

When the switch is thrown to position 2, condenser C_1 is connected across R_1. If condenser C_1 is large enough, its reactance is so small that all audio frequencies are by-passed around R_1, and there is no degeneration at all. However, if this condenser is made rather small, its reactance comes into play. At low frequencies, it becomes a poor shunting path around R_1, so low frequencies are degenerated. On the other hand, since its reactance drops as frequency increases, it becomes a better by-pass at high frequencies, which are therefore not degenerated. Since degeneration reduces the output, this condenser now effectively reduces the bass response, because the bass frequencies are degenerated but the treble frequencies are not.



Courtesy Thordarson

FIG. 22. A basic tone-control circuit.

In position 3, a choke coil is substituted as the shunt across R_1. The large condenser C_2 is in series with the coil to act as a blocking condenser to prevent it from changing the bias by shunting R_1 by a d.c. path. However, the action is now the opposite to that when C_1 is in the circuit. Now, L_1 offers a low-impedance path for low frequencies, so there is no degeneration at these frequencies. It is a high-impedence path for high frequencies, however, so they are degenerated. Hence, the high-frequency response is reduced when the switch is in position 3.

The actual tone control circuits used are frequently more elaborate than this. We'll see some practical examples when we take up typical diagrams of complete amplifiers.

Typical P.A. Diagrams

In the following section, we are going to show two typical p.a. amplifiers. We have chosen these diagrams to illustrate some of the circuit ideas we have discussed. Other complete diagrams will be discussed elsewhere.

LOW-POWER AMPLIFIER

Our first example is shown in Fig. 23. An examination of the power supply shows that it is a standard a.c. type with a transformer, using a full-wave rectifier and a brute-force filter. There is nothing at all remarkable about the power supply.

This particular amplifier has one microphone and one phonograph pick-up connection. The microphone connection is of the high-impedance type, since it is arranged to feed directly into the grid of the 6J7 microphone preamplifier tube. The phono pickup is likewise of the high-impedance type and feeds into the grid of the second tube. The potentiometer R_1 acts as a volume control for the phonograph, and R_6 acts as the control for the microphone channel. No master control is used. Since R_6 is to be used as the volume control for the microphone channel, rather than just a level-setting control, it is in the grid circuit of the second tube that you would expect to find the master volume control. This arrangement permits the control to have a longer life, as you have learned, because any noise developed by the control is not amplified as much as is the signal from the microphone.

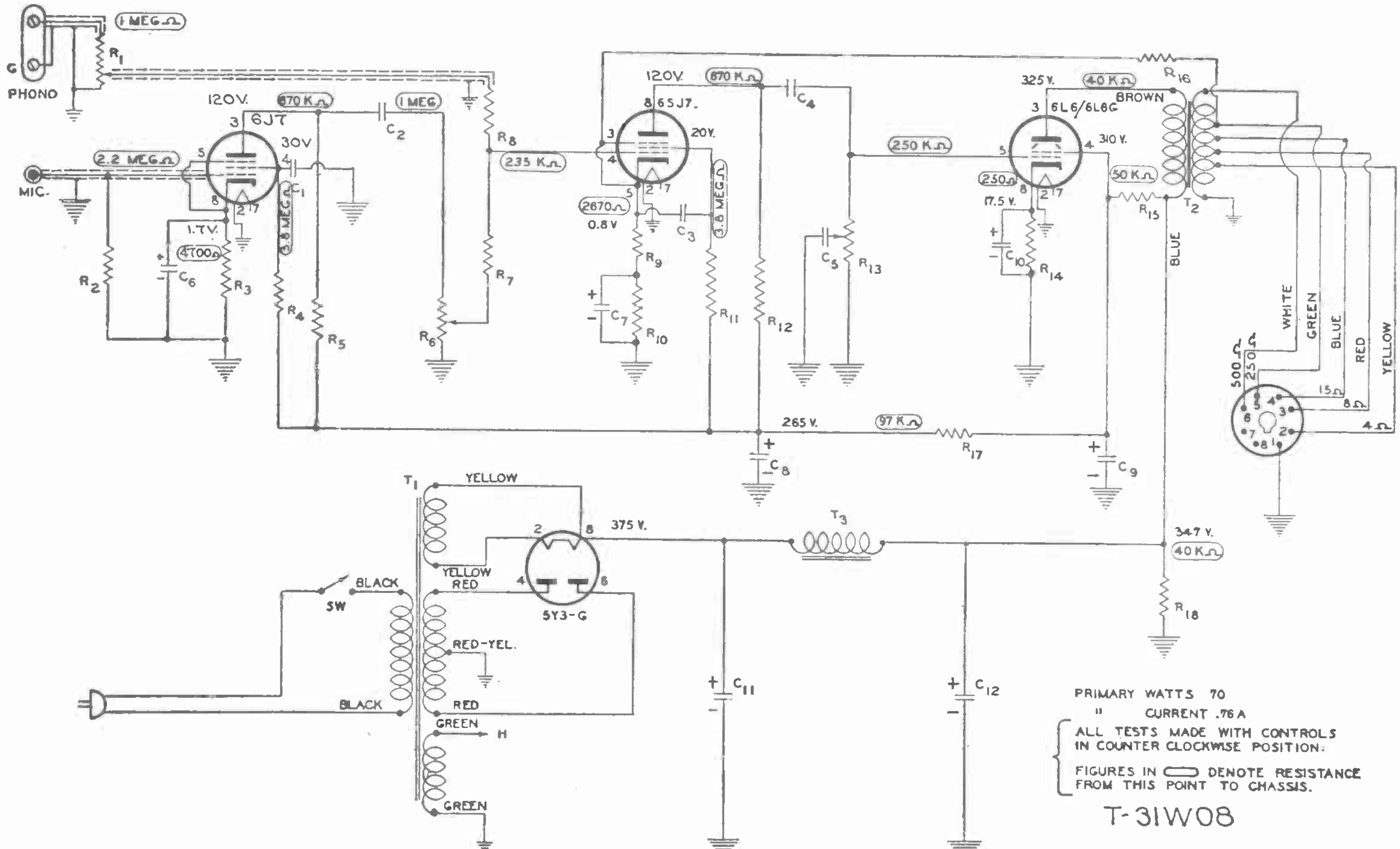
Resistors R_7 and R_8 are decoupling resistors used to prevent too much interaction between the two controls. It is possible to blend the phono pick-up in with the microphone signal if this is desired.

Whatever the signal source may be, the second (6SJ7) tube acts as the major voltage amplifier. Its output drives the grid of a 6L6 beam-power output tube.

The output transformer has a tapped secondary, the various taps of which are connected to a socket into which the loudspeaker line is plugged. Any of 5 output impedances can be selected by plugging the line into the proper terminals. Since this amplifier delivers only 8 watts, it is generally used to drive a single cone-type loudspeaker, although it can be arranged to drive two small loudspeakers at reduced output.

The output impedance of 4, 8, and 15 ohms provide for direct voice-coil connections, and the line impedance values of 250 and 500 ohms allow a transmission line to be used.

Inverse feedback is used to improve fidelity. The feedback path is from the 250-ohm tap on the secondary of the output transformer through R_{16} to the cathode of the 6SJ7 voltage amplifier. The inverse feedback voltage is developed across R_9, which is not by-passed. If the proper output transformer connections are made, this feedback voltage will be out of phase with the applied signal in the cathode circuit; it will therefore reduce the over-all gain but at the same time will reduce even more any distortion developed within the voltage amplifier and output stages.



Courtesy Montgomery Ward

FIG. 23. Schematic diagram of the low-power Thordarson T-31W08 amplifier.

The tone control consists of resistor R_{13} and condenser C_5, which is connected to the slider of R_{13}. As the slider is moved toward the grid end of the control, C_5 becomes more and more of a by-pass, thus reducing the high-frequency response of the amplifier.

MEDIUM-POWER AMPLIFIER

Fig. 24 shows a medium-power amplifier that has several unique features. There are two microphone inputs, each feeding into its own triode preamplifier. R_{11} is a gain control for microphone No. 1 and R_{10} a similar control for microphone No. 2. Notice that these are connected in an unusual manner—they appear to be backward from the way you are used to seeing volume controls. This connection makes it impossible for one gain control to short out the other when it is turned to zero, as you will find by examining the circuit. For example, if the slider on R_{11} is run up to the top, R_{11} is shunted by R_7 and by the plate impedance of the preamplifier tube for the No. 1 microphone. Therefore, it is never a complete short circuit. Resistor R_7 is necessary because the plate impedance of the preamplifier tube is not sufficiently large to make it a satisfactory shunt. R_9 is used similarly in series with the slider on R_{10}.

There are two phonograph terminals, and the phono gain control is of the center-tapped type so that it can act as a fader from one to the other. An additional phono input is connected in parallel with phono input No. 1. However, this is for use with a built-in record player, which may be made a part of the amplifier cabinet. When this is used, phono input No. 1 is normally not used.

The phono gain control feeds into the grid of the 6SJ7 mixer tube, along with the microphone input. This is a resistance form of mixing, since all the signals are combined at the grid of this tube.

The plate of this tube is resistance-coupled to the control grid of the 6V6 driver tube. This driver tube is a beam-power tube but is connected here as a triode. It still furnishes considerable power through transformer T_1 to the grids of the actual power output tubes, which are two 6L6's connected in push-pull.

The tone control network consists of C_6, R_{14}, R_{16}, and C_4, which are connected in series from the plate to the cathode of the 6SJ7 mixer tube. When the slider on the tone control R_{16} is at the upward position (at the terminal connected to R_{14}), then C_6 and R_{14} are in series to ground from the plate of this tube. They act as a high-frequency by-pass. At the same time, all the resistance of R_{16} is in series with C_4, so this condenser is effectively no longer a by-pass across the cathode resistor R_{12}. Therefore, complete degeneration occurs, which tends to flatten the over-all response.

When the slider on R_{16} is moved to the opposite end of the control, the full value of R_{16} is in series with R_{14}, and C_6 is no longer an effective by-pass. At the same time, condenser C_4 is connected across R_{12}. Since C_4 is a fairly small condenser, it is a very poor by-pass at low frequencies, so the low frequencies are still degenerated. It does become an effective by-pass at the high frequencies, however, thus reducing the degeneration at the

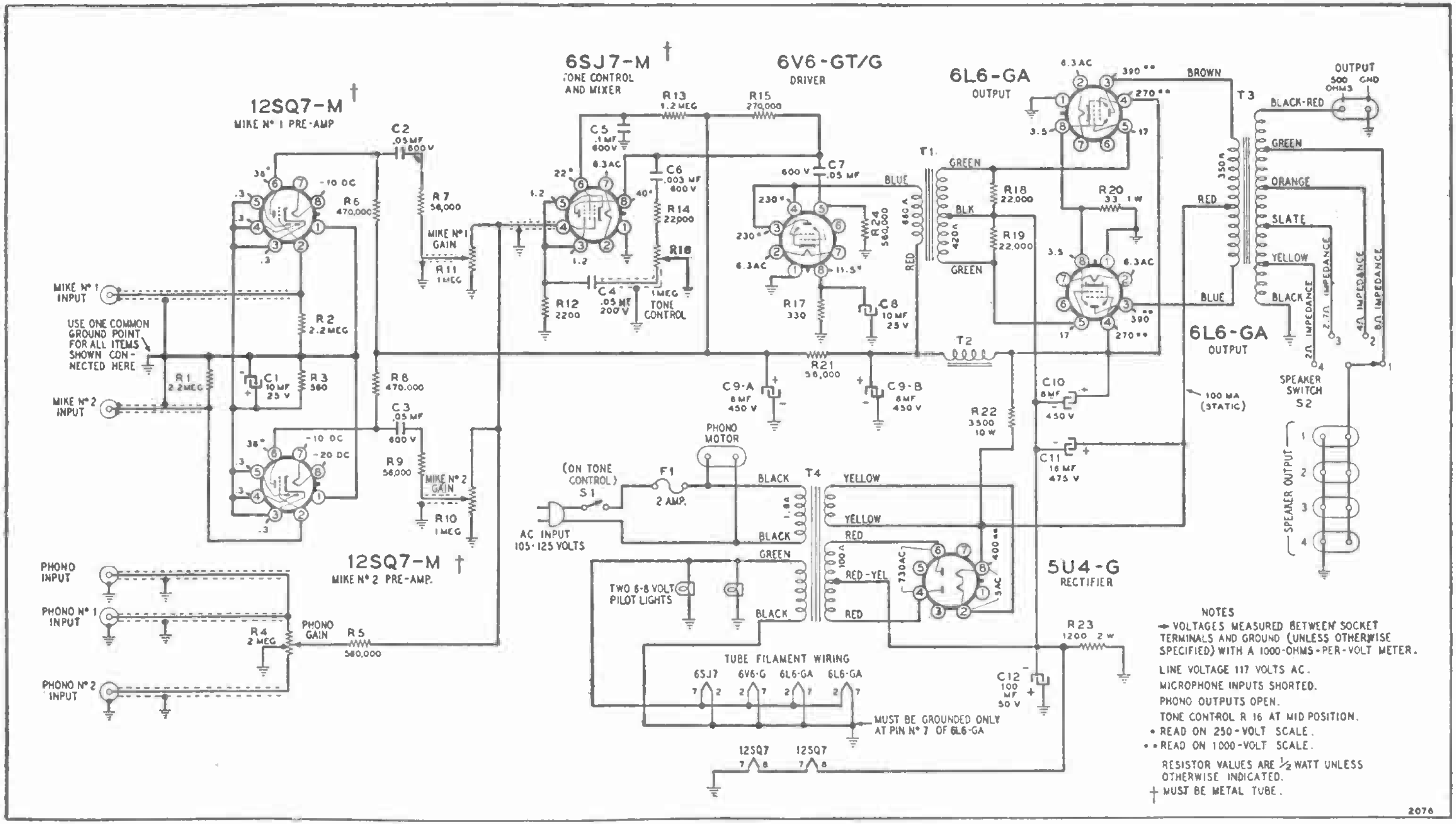


FIG. 24. Schematic diagram of the Airline Model 64BR-7320A, a medium-power portable amplifier.

high frequencies. Therefore, at this end of the control we are favoring the high-frequency response of the amplifier by reducing the effect of C_6 and putting C_4 in the circuit. At the other position, the high frequencies are reduced because C_6 is an effective bypass.

The output transformer has a tapped secondary, the taps of which are connected to a 4-position "speaker switch." Rotation of this switch connects the various taps to 4 paralleled sockets into which the loudspeaker lines are plugged. Thus it is possible to add or remove loudspeakers at will, provided the switch is set to give the proper impedance match. A separate socket is provided for use when a 500-ohm line is to be used.

Examining the power supply, we find that the B power supply is more or less standard. There is a direct connection, with no filtering except for the input filter condenser, to the plates of the output tubes. The supply to the output tube screen grids is filtered by an R-C filter consisting of R_{22} and output filter condenser C_{10}. The plate supply of the 6V6 is filtered by R_{22} and C_{10} and is additionally filtered by choke T_2 and C_9B. Similarly, R_{21} and C_9A provide more filtering for the screen grid and plate of the 6SJ7 tube and the plates of the 12SQ7 tubes.

Because the preamplifier provides high gain, great care must be exercised to reduce hum. In this amplifier, the filaments of the 12SQ7 tubes are fed from a d.c. source; they are connected in series across R_{23}, which is in the B– lead of the power supply. Effectively, therefore, the plate current for all the tubes flows through these two filaments and through R_{23}. This means that the supply is nearly pure d.c., and is much more hum-free than an a.c. supply would be. Incidentally, the drop across this combination of R_{23} and the two tube filaments also acts as grid bias for the 6L6 tube.

YOU HAVE TO WORK

Here is another one of my favorite quotations—this one by Bob Burdette.

"My son, remember you have to work. Whether you handle pick or wheelbarrow or a set of books, digging ditches or editing a newspaper, ringing an auction bell or writing funny things, you must work. Don't be afraid of killing yourself by overworking. Men die sometimes, but it is because they quit at five p.m. and don't go home until two a.m. It's the intervals that kill, my son. The work gives you appetite for your meals; it lends solidity to your slumber; it gives you a perfect appreciation of a holiday. There are men who do not work, but the country is not proud of them. It does not even know their names; it only speaks of them as old So-and-So's boys. Nobody likes them; the great, busy world doesn't know they are here. So find out what you want to be and do. Take off your coat and make dust in the world. The busier you are, the less harm you are apt to get into, the sweeter will be your sleep, the brighter your holidays, and the better satisfied the whole world will be with you."

J. E. Smith

VIDEO I.F. AMPLIFIERS AND VIDEO DEMODULATORS

53RH-3

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE No. 53

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ **1. Introduction** .... **Pages 1-7**

The basic requirements of television i.f. and demodulator circuits and a brief statement of how they are met are given in this section.

☐ **2. Getting the Desired Response** .... **Pages 8-14**

Here you learn how i.f. circuits are arranged to give the response needed in a TV set.

☐ **3. Typical Video I.F. Amplifiers** .... **Pages 15-21**

This section contains descriptions of the basic i.f. circuits and the various ways in which i.f. circuits are coupled.

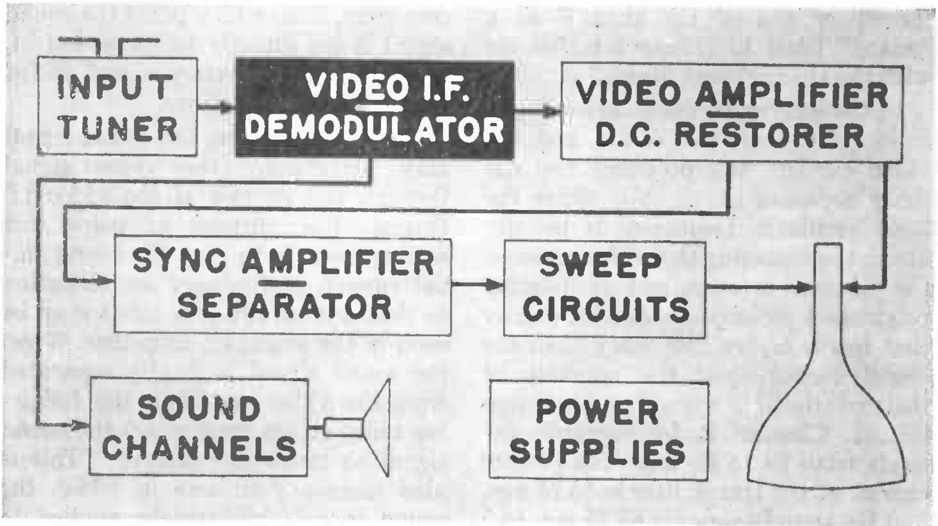
☐ **4. Video Detectors** .... **Pages 22-28**

In this section, you learn how the output of the i.f. amplifier is demodulated to recover the video signal.

☐ **5. Answer Lesson Questions and Mail Your Answers for this Lesson to NRI for Grading.**

☐ **6. Start Studying the Next Lesson.**

JD6M151 1951 Edition Printed in U.S.A.



A PREVIOUS LESSON has shown you how the television input tuner selects the desired signal and, by the heterodyne process, converts it to an i.f. signal. Just as in a sound receiver, the video i.f. signal must now be passed through an i.f. amplifier to a demodulator (detector). We shall study the operation of both these sections of a TV receiver in this Lesson, starting with the video i.f. amplifier.

There are three things the video i.f. amplifier must do:

1. It must amplify the video i.f. signal. Most of the gain of a TV receiver is obtained from the i.f. amplifier, just as it is in sound receivers. Naturally, this amplification must be obtained over the band width that is desired. This presents quite a problem at the TV frequencies.

2. It must provide sufficient adjacent-channel selectivity. As we shall see later, it is not easy to get the response curve as sharp as is desired if we use the tuning methods with which we are familiar, because we have to use such low Q values to get the desired band width. In fact, it is necessary to use traps to get the selectivity needed.

3. It must get rid of the sound signal if the sound is not supposed to go through the video i.f. amplifier.

Sound and Picture Carriers. The problem of the sound signal brings up the important point that we have two separate and distinct signals for each television program. The video signal is an amplitude modulation on one carrier, and the accompanying sound signal is a frequency modulation on an entirely separate carrier. Both signal frequencies for a particular station are located within the "channel" assigned to that station, and, as shown in Fig. 1, the carrier frequencies are 4.5 mc. apart. This figure shows the arrangement of the signals for all TV stations.

As you can see from this illustration, the transmitted picture carrier is 1.25 mc. from the lower edge of the channel, and the sound carrier is 4.5 mc. higher in frequency, leaving about .25 mc. between the sound carrier and the upper end of the channel as a "guard" band to reduce interference with the channel next above.

In the converter, the local oscillator beats with both the sound and the video carriers and produces two entirely separate i.f. signals. Since the local oscillator frequency is usually above the incoming signal frequencies, the normal arrangement of beating produces a picture or video i.f. carrier that has a *higher* frequency than the sound carrier—just the opposite of their relationship when they are transmitted. Channel 2, for example, extends from 54 to 60 mc. The picture carrier at the transmitter is 55.25 mc., and the sound carrier is 59.75 mc. (4.5 mc. higher). Let's say it is picked up by a receiver that has an i.f. range of about 21-26 mc., the oscillator of which is set at, say, 81 mc. for reception of this band. The video i.f. carrier in this receiver is then 25.75 mc. (81−55.25). The sound carrier frequency is 21.5 mc. (81−59.75). Thus, the heterodyning process changes the positions of the frequencies—the one that was higher in the transmitted signal produces the lower i.f. signal.

Since we have two entirely separate and distinct i.f. carriers at the output of the converter, it is possible to treat them as independent signals. That is just what is done in many television receivers. The two i.f. carriers are separated right at the output of the converter, from which point the sound signal is fed directly to the sound i.f. amplifier and the video signal is fed to the video i.f. amplifier.

In other receivers, the sound signal may accompany the video signal through one or two of the video i.f. stages. The purpose of using this arrangement is to give the sound signal enough preliminary amplification so that one or two less tubes may be used in the sound i.f. amplifier. When the sound signal is finally separated from the video amplifier, the following video stages must reject the sound signal as much as possible. (This is also necessary in sets in which the sound is not deliberately applied to the video i.f. amplifier.) Unless the sound i.f. signal is rejected before both signals can get to the video detector, the two carrier frequencies will beat against each other to produce a 4.5-mc. signal. This 4.5-mc. beat signal will produce an undesirable fine overall dot or grain pattern in the picture that will make it impossible to get the maximum of picture detail. Also, cross-modulation products may produce sound "bars" across the picture. To prevent such effects from occurring, receivers that have a separate sound i.f. amplifier that is tuned 4.5 mc. lower than the video i.f. use sound-rejection traps in the video i.f. amplifier beyond the point where the sound signal is taken off.

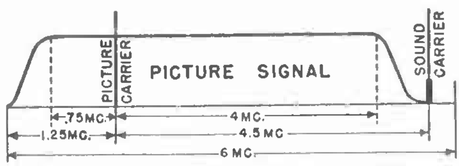


FIG. 1. This illustration shows the relative positions of the picture carrier and the sound carrier within a 6-mc. television channel. The two carriers are in these relative positions in all channels.

Not all sets use this kind of sound i.f. amplifier, however. Several use a system known as intermodulation for producing the sound signal. In this system (which is used chiefly because a few less tubes are needed in it than are needed in other systems), both the sound and the video signals are allowed to pass through the video i.f. amplifier and into the video detector. In the detector, the 4.5-mc. beat mentioned above is produced. This 4.5-mc. signal constitutes an i.f. carrier, frequency modulated by both the amplitude modulation of the picture and the frequency modulation of the sound.

To separate the sound from the picture signal, the modulated 4.5-mc. signal is passed through a limiter, which wipes out the amplitude variations, leaving the carrier frequency modulated by the sound. This signal is then fed into a discriminator, which demodulates it and so furnishes the desired sound signal to the audio amplifier.

Traps are used in the video amplifier to remove the 4.5-mc. beat signal from the picture signal. Traps are also used in the video i.f. to reduce the sound carrier so that it will be easier to separate the sound and picture signals after the video detector.

For now, let's ignore the problems of the sound signal (which we shall study in another Lesson) and consider the video i.f. signal by itself. Basically, the video i.f. signal is an i.f. carrier that is amplitude-modulated by frequencies ranging from about 10 cycles to about 4 mc. In this modulation are both the picture signal and the synchronizing impulses from the transmitter. If the set is to have high definition, the video i.f. must be capable of passing all these frequencies—in other words, it must pass a band of signals about 4 mc. wide. (In sets that use a 7-inch picture tube, extremely high definition is not an absolute requirement, because a watcher is not able to see fine detail in a small picture at normal viewing distances. For this reason, some of these sets have band widths of only about 3 mc.)

As you will recall, amplitude modulation produces side bands on either side of the carrier. If we use a 4-mc. modulation, therefore, we ought to need a band width of 8 mc. Obviously, it is desirable to avoid using such a band width, because it would be very difficult to cover at the i.f. frequencies: we would have to use circuits that were very low in Q—so low, in fact, that we would get very little gain from the i.f. amplifier. Let's see how we are able to avoid using an 8-mc. band.

VESTIGIAL SIDE-BANDS

When a signal is amplitude modulated, the carrier frequency is mixed with the modulating frequency in such a manner that a sum frequency and a difference frequency are produced for each frequency in the modulating signal. Let's suppose, for example, that we have a carrier of 100 mc. and that we are using a 2-mc. modulating signal. Two side frequencies will then exist, one on either side of the carrier: one will be 102 mc. (100 mc. plus 2 mc.), and the other will be 98 mc. (100 mc. minus 2 mc.). Similarly, other modulating frequencies will produce signals on either side of the carrier.

Half of the modulating energy is used to produce each of these side frequencies: that is, one-half of the modulating energy is in the upper side band, and one-half is in the lower. The modulation in each side band is identical with that in the other; if we cut off one of the side bands, therefore, the remaining one will contain all the information that was in the original modulating signal. However, we shall lose half of our power in the process. This loss of power will produce some amplitude distortion; more important, the loss will reduce the signal strength and hence cut down on the reception range.

To avoid this loss of power, it is common to use double side-band modulation in all cases where it can be used. However, if there is a wide band of signals to be passed, as in television, or if the spectrum is very crowded by signals, as in certain commercial services, it is standard practice to eliminate one of the side bands (it doesn't matter which one) and to supply more energy at the transmitter to make up for the loss of signal. At the receiver, the process of demodulation will reconstruct the modulation signal from the remaining side band and the carrier.

In television, however, there are two reasons why we do not completely suppress all of the side band we are trying to get rid of. One is that we should have to use extremely sharp filter circuits in the transmitter. Remember, we must not get rid of the carrier—it is vital that the carrier be transmitted so that we can regain our desired modulation. Therefore, if we were going to remove one side band completely, our filter would have to remove frequencies within about 10 cycles of the carrier frequency but not cut into the carrier or the desired side band.

It is very difficult to make a filter that will cut off as sharply as this. Instead of attempting to do so, we use a filter that cuts off more gradually, thus taking out most but not all of the undesired side band. This is called partial suppression, since some of the undesired side band is left intact.

Phase Shift. At the receiver, there is another reason for not cutting off the frequencies too sharply. When we feed a double side-band signal through a resonant circuit, the carrier or resonant frequency undergoes no phase shift, but frequencies above and below the carrier do: frequencies on one side of resonance are forced to lead the carrier frequency, and those on the other side are forced to lag the carrier. The phase shift undergone by the side-band frequencies increases rapidly with their displacement from the carrier, reaching 90° at frequencies very close to the carrier. The phase shift of the frequencies displaced farther from the carrier remains relatively constant at about 90°.

These phase shifts are unimportant when we have both side bands, because they cancel in the process of detection. When we suppress one side band, however, all the remaining side-band frequencies are on one side of the carrier; as a result, the phase shift they undergo will not be automatically cancelled in the detector.

As you will learn later, the problem of phase shift is particularly important in television, especially at the lower modulation frequencies. Therefore, it is a good idea to let the lower frequencies in the undesired side band stay in the transmitted signal, because their phase shifts will cancel those of the equivalent frequencies in the desired side band when detection occurs. The shift in the higher frequencies will still be present, but that shift is not as troublesome.

For these reasons, the filters at the transmitter are designed to pass all frequencies in the *undesired* side band out to about .75 megacycles from the carrier, then to introduce a gradual suppression so that the undesired band is completely cut off at about 1.25 megacycles from the picture carrier.

This is the relationship shown in Fig. 1, where the lower side band is the one being suppressed.

Effectively, therefore, we have double side-band transmission for frequencies within the range from about 10 cycles out to .75 mc. The amplitude of the lower side band is then systematically reduced until it reaches zero at 1.25 mc., beyond which point we have only the upper side-band frequencies. This system has two advantages: it eliminates the phase shift of the lower frequencies, and it makes it possible to use a relatively simple filter.

Since a part (a "vestige") of one side band and all of the other are transmitted, this system is known as "vestigial" side-band transmission. If we want to pass the signal in the form shown in Fig. 1, we need to pass a band only about 5 mc. wide instead of having to pass the 8-mc. band that would be needed if double side-band transmission were used. However, as we shall show, it's possible to get along with a pass band only about 4 mc. wide.

I.F. RESPONSE

We said earlier that transmitting two side bands gives double the energy that single side-band transmission offers. Since vestigial side-band transmission is actually double side-band

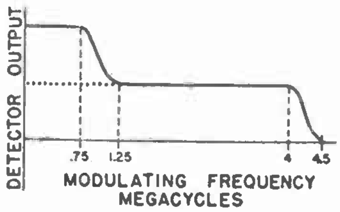


FIG. 2. The heavy line shows what the detector output would be if all the transmitted TV signal were applied to the detector. The output would be high at the low frequencies because part of the lower side band is transmitted.

FIG. 3. A receiver would have to have an i.f. pass band of the width shown here to pass both the desired side band and the vestigial side band.

transmission as far as the low frequencies are concerned, the detector output for low frequencies (up to .75 mc.) will be twice what it is for the higher frequencies, as shown in Fig. 2, if the transmitted signal is not modified before it is applied to the detector. The output for frequencies between .75 mc. and 1.25 mc. will gradually roll off as the one side band is suppressed; at frequencies above 1.25 mc., the detector output will remain constant out to the modulation limits around 4 mc.

This increased detector output at the lower frequencies can be permitted; we can correct for it easily by making the low-frequency response of the following video amplifier fall off so that the over-all response will be flat. However, if we were to pass all the vestigial side band as well as all the desired one, we would need an i.f. pass band like that shown in Fig. 3. In other words, we would need a pass band of about 4.75 to 5 mc. (Remember that the "pass band" lies between the points having 70% of the maximum response, not between the points of zero response.)

Therefore, what is generally done is to arrange the video i.f. response so that the carrier frequency is on the slope of the response, as shown in Fig. 4. (Remember that the heterodyne process inverts the frequencies so that the upper side band in the transmitted signal is lower in frequency than the carrier in the i.f. stages.) If the carrier frequency is at a point where the i.f. response is 50% of the maximum response, and the curve A-B-C has the proper slope, the vestigial side band and the corresponding frequencies in the desired side band will be gradually attenuated. As a result of this attenuation, the low-frequency response will be no greater than the high-frequency response if the curve is properly shaped, even though two side bands furnish the low frequencies. The detector output will therefore be flat.

When this system is used, the increased attenuation of the lower side band means that the frequency at which phase shift will be troublesome will be somewhat lower than it would be if the whole vestigial side band were passed. However, it will still be high enough to make correction of the phase shift a relatively simple matter.

The advantage of this system, aside from the fact that it can be made to give a flat detector output, is that it permits all the frequencies in the upper side band to be passed with an i.f. band width of 4 mc. (between the points at which the output is at least 70% of the maximum).

If the carrier is placed nearer point A on the A-B-C section of the curve in Fig. 4, the low-frequency response will be higher than it would be with the carrier at point B. Some manufacturers secure greater low-frequency response in this way, putting the carrier at a point where the response is 60% or 70% of the maximum instead of at the 50% point.

The "standard" i.f. response shown in Fig. 4 is also subject to other variations. It is quite possible that there may be peaks in the response to compensate for deficiencies in the input tuner or in the video amplifier. Furthermore, in those sections of the video i.f. amplifier that pass the sound carrier as well, the response must be broad enough to permit the sound carrier to go through these stages. In a set in which the intermodulation system is used, the sound carrier is passed through the entire i.f. amplifier; the band width of this amplifier must therefore be greater than 4 mc. in such a set.

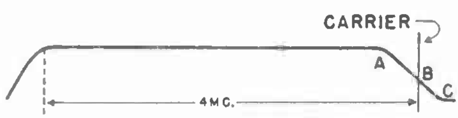


FIG. 4. Arranging the i.f. response so that the picture carrier falls at the point shown makes it possible to have a flat detector output and to pass all the desired side band with an i.f. band width of 4 mc.

VIDEO I.F. VALUES

There are several conflicting factors that engineers have to consider when they select the video i.f. carrier frequency.

The range within which the i.f. frequency may lie is limited at its upper end by the fact that the i.f. must be below the lowest channel that it is desired to tune to. The wide range of modulating frequencies used makes it impractical to have the i.f. too low. As a matter of fact, the wide frequency range makes it impossible to get much gain at a low carrier frequency, because, as you know, the band width of an i.f. stage is approximately equal to the quotient of the resonant frequency divided by the Q in the circuit. If the resonant frequency is low, the Q must also be low to create the band width necessary in a video i.f. amplifier; and a circuit having low Q has low gain also.

There is one other important factor that affects the choice of the i.f. frequency. The i.f. band should not be in a channel that is used extensively in other radio communications fields; if it is, undesired station signals at any of the i.f. frequencies may ride through the input tuner and cause serious interference.

In early television receivers, low i.f. values were used. The video i.f. carrier was about 13 mc. and the sound i.f. carrier about 8.5 mc. These values were used because it was extremely difficult to obtain high gain at higher frequencies at that time. Recently, however, wiring techniques have been refined. In addition, miniature tubes have been brought out that have very high mutual conductances and relatively low interelectrode capacities; these permit us to secure better L/C ratios and hence higher load impedances for the same Q. All these improvements combine to make it possible to obtain reasonable gain at high frequencies.

In the recent past, many manufacturers settled on frequencies somewhere in the range between 21 and 26 mc. for the i.f. pass band. However, image interference difficulties have produced a movement at the present time toward even higher frequencies, because the use of these helps the preselector in its duty of getting rid of image frequencies. (You will recall that the image frequency is twice the i.f. above the desired signal. The higher the i.f., the further removed is the image frequency from the desired one, and hence the easier it is for the preselector to tune it out.)

Some manufacturers are now using i.f. frequencies in the region around 40 mc. In the future, more manufacturers may use i.f. frequencies this high, or input tuners may be redesigned so that the image problem can be solved with the present 21-26 mc. frequency range.

Getting the Desired Response

A little consideration will show you that it is not practical to try to get the "standard" response shown in Fig. 4 with just a parallel resonant circuit. First of all, the band width is so great that even a heavily loaded single-tuned circuit could not give the desired response. Furthermore, we must use more parts than a single circuit contains to get the rather peculiarly shaped edges of the pass band shown in Fig. 4.

Let's learn a little more about the problem and then see what kinds of circuits can be used to give us the response we want.

PARALLEL RESONANT CIRCUIT RESPONSE

By itself, a parallel-resonant circuit like the one shown in Fig. 5A will have a response something like curve 1 in Fig. 5B. The height of the peak in the response of this circuit depends on the Q of the circuit: if the Q is high, the peak will be too. If we load this circuit by connecting resistances in parallel with it, we can reduce the peak and at the same time broaden the pass band, producing a response curve that is much like curve 2. You will recall that the pass band is considered to be between those points at which the output is about 70% of the peak value. Thus, for response curve 1 in Fig. 5B, the pass band has a width approximately equal to the frequency range between points A-A, whereas the band for curve 2 has broadened out to the frequency range between the points B-B.

As we increase the loading of the circuit, the peak becomes lower, and the pass band becomes wider. To produce a band width of 4 mc. with a video i.f. of about 25 mc. (which is what most TV sets have to do), the Q of a single tuned circuit would have to be about 6. Rather heavy loading would be needed to make the circuit have so low a Q.

Although it is possible to load a single circuit to this extent and thus get a broad-band response, the gain would be very low, and the curve would not have as flat a top as we want. If we were to add more stages in cascade to increase the gain, the response would become more peaked again, and the pass band would become narrower. If, for example, curve 1 in Fig. 6 represents the response of a single stage, curve 2 shows the response that two identical stages would have in cascade, and curve 3 shows the response that three stages would have. Obviously, each of these curves is far from having the ideal shape shown in Fig. 4, so there is no combination of parallel resonant circuits all tuned to the same frequency that will give us the response we want.

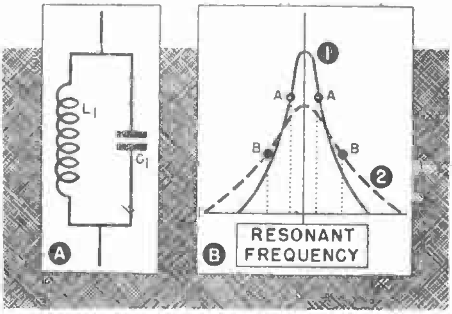


FIG. 5. Curve 1 in part B of this illustration represents the normal response of the parallel resonant circuit in part A. Curve 2 shows the effect produced on the response by connecting resistors in parallel with the circuit.

However, it is possible to get the response needed if we stagger-tune parallel resonant circuits. In fact, that is the most commonly used way of producing the desired i.f. response.

STAGGER TUNING

In a stagger-tuned system, a broad pass band and high gain are secured by connecting several resonant circuits in cascade and tuning each circuit to a different frequency. Fig. 7 shows an example of the response that can be secured in this way. If the various tuned stages in the i.f. amplifier are each tuned to different frequencies as indicated in this figure by the curves a, b, c, d, and e, and each stage has the response characteristic indicated (this can be obtained by using the right coupling and loading), the overall i.f. response characteristic will have the shape shown by the dotted line.

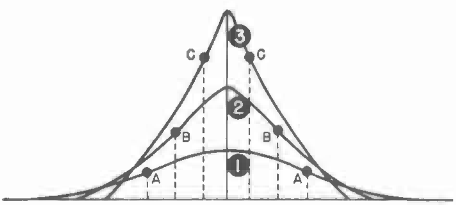


FIG. 6. These curves show the effect of connecting parallel resonant circuits in cascade. Curve 1 shows the response of a single stage, curve 2 shows that of two stages in cascade, and curve 3 shows that of three stages in cascade.

This system is called stagger tuning because the various i.f. stages are not all tuned to the same frequency but to frequencies that are staggered within the pass band desired. Of course, careful engineering is necessary to get the original responses of the several stages to fit together properly, and it is important to choose the proper loading. Some stages have rather high Q values and hence high gain; others (such as the one having the response shown by curve C) have very low Q and low gain but are nevertheless important because they fill in the over-all response to produce the desired flat-topped characteristic.

This is one of the more popular i.f. systems and offers several advantages over other types. First, since each stage is tuned to a different frequency, such an amplifier system is remarkably free from oscillation. This means that very little shielding is required. Second, since the over-all response characteristic depends upon the combined effects of several stages, it is relatively easy to vary the over-all response characteristic to obtain the best possible response by varying the responses of individual stages.

Another important advantage of this kind of i.f. section is that it can be aligned by using an ordinary signal generator and a multimeter. This is possible because it is necessary only to peak the various i.f. stages at their particular frequencies, which are given in the manufacturer's instructions, to get the desired over-all response characteristic.

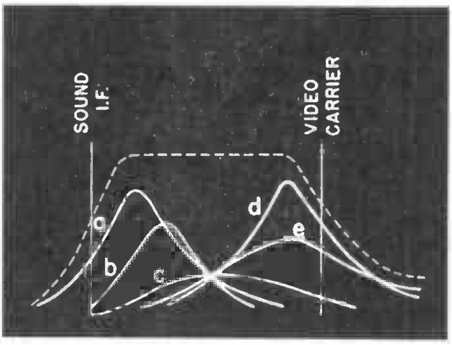


FIG. 7. If the stages in a five-stage i.f. amplifier are stagger-tuned and made to have the responses shown by the solid lines, the overall response of the amplifier will have the form shown by the dashed-line curve.

There are some disadvantages to the stagger-tuning system, but they are far out-weighed by the advantages. One disadvantage is that the over-all i.f. response will change as the gain of the individual stages is changed. As an example, if the gain of one or more of the i.f. stages should be changed by varying the bias on the stage (either by means of a.g.c. voltage or by means of the contrast control), the over-all response characteristic may change. Such a bias change will change the plate resistance and thus the loading; it may also detune the circuit, because the input capacity of a tube changes with its mu. Of course, the change in capacity will be small if pentode tubes are used. The change in loading will be relatively small, also, because the loading in a stage generally depends more on the loading resistors used than on the plate resistance of the tube in the stage. Nevertheless, it is necessary to align these circuits with the recommended bias applied, and some variations in response can be expected when any change occurs in the bias.

A practical example of the basic circuit that is used in a stagger-tuned video i.f. amplifier is shown in Fig. 8. Here we show part of one i.f. amplifier stage. The tuned circuit is made up of coil L_1, and the capacity is represented by C_3 (which is not a condenser but is a capacity that comprises the distributed capacity of the coil, the tube interelectrode capacities, and the capacities between the various components and the chassis). The circuit can be tuned to resonance by adjusting the powdered-iron core of L_1 and so changing the inductance of the coil.

The load for the VT_1 stage consists principally of the grid resistor R_1, which also serves as the d.c. grid return path for the VT_2 stage. The ohmic value of this resistor may be different in each stage, since different amounts of loading may be required for each.

In some receivers, the coil is wound of resistance wire, an arrangement that puts resistance directly in the resonant circuit. Just a few ohms here can be as effective as several thousand in the position occupied by R_1. If this method of loading is used, each coil must be specifically designed for the particular response wanted; therefore, it is not as easy to change the response of this circuit as it is to change that of the circuit in which the grid resistor acts as the load. (In the latter circuit, changing the resistance of the grid resistor will change the response.) However, circuit requirements may make the resistive coil winding desirable. You should not, therefore, assume that there is no loading if R_1 has a high resistance.

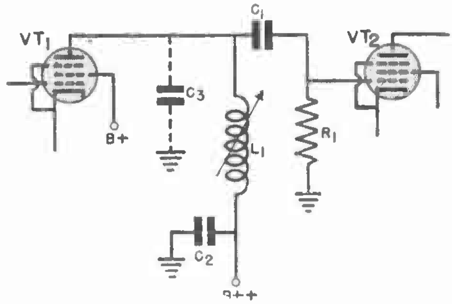


FIG. 8. The basic circuit of one stage of a stagger-tuned video i.f. amplifier. The other stages are similar.

The response of a stagger-tuned i.f. section is much more like that we want, but, as we shall show in a moment, it is necessary to add wave traps to the circuit to produce the exact response needed.

BAND-PASS COUPLING

A basic band-pass coupling circuit used in TV sets is shown in Fig. 9A. It is much like those used in sound i.f.

amplifiers except that the coupling is far tighter. As you have learned, the response of such a circuit depends upon the coupling. Thus, curve 1 of Fig. 9B shows the over-all response that might be obtained with loose

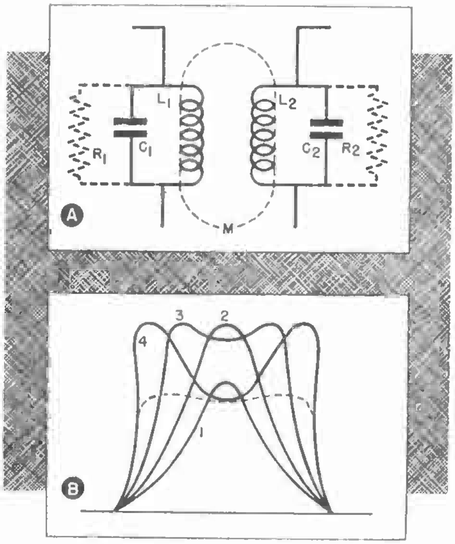


FIG. 9. Part B of this figure shows the effect of varying the coupling in the band-pass circuit shown in Part A. Curve 1 shows the response with loose coupling, curve 4 shows the response with extremely tight coupling, and the others show the response with intermediate couplings. The dashed-line curve shows the response that can be gotten by modifying curve 4 by adding resistance to each tuned circuit.

coupling. Curve 2 shows the effect of somewhat closer coupling—as the coupling is increased, the output will increase (up to a certain maximum) and the over-all response characteristic will tend to broaden.

With close coupling (or "tight" coupling), we may get the over-all response characteristic shown by curve 3. This has a double-peak response, and its over-all band width is much greater.

Finally, at an extreme of coupling, we can get the very wide double-peaked response of curve 4, which has a sharp valley in the center. By loading the resonant circuits (using resistors across both the primary and secondary windings), the peaks are reduced to the values shown by the dotted lines, thus producing an over-all response that is relatively flat.

Such band-pass circuits may be connected in cascade to get greater gain. If they are overcoupled (curve 4), they may be tuned to the same frequency; if the coupling is less extreme, they may be stagger-tuned just as parallel resonant circuits are.

WAVE TRAPS

By themselves, neither the stagger-tuned parallel-resonant circuits nor the overcoupled band-pass circuits will give sufficient adjacent-channel selectivity and reject the accompanying sound signal if such rejection is wanted. The trouble is that the slopes

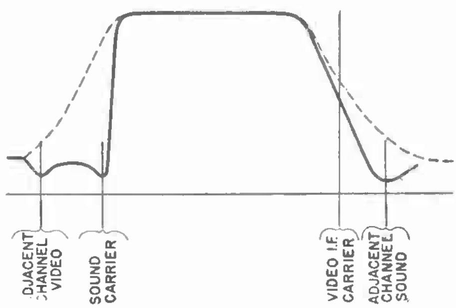


FIG. 10. As you can see, the response of a stagger-tuned system (shown by the dashed lines) is so broad that it accepts part of each adjacent channel.

of the "skirts" of the response are bound to be too gradual when the pass band is so broad. Fig. 10 compares the response of a stagger-tuned system (dotted lines) to the response that a receiver must have (solid lines) if the sound signal is to be led to a sound i.f. amplifier right after the

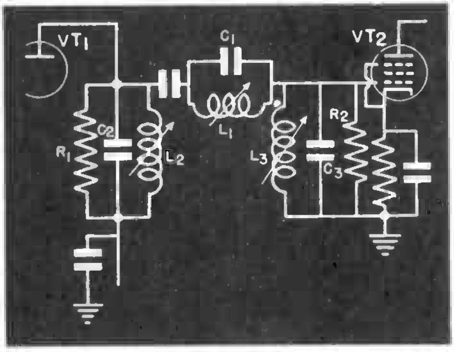


FIG. 11. The parallel resonant circuit L_1-C_1 is called a series trap because it is placed in series with the signal path.

converter, and the adjacent carriers are to be rejected.

The steep skirts needed to produce the latter response can be obtained by using trap circuits—high-Q resonant circuits that are tuned to the undesired frequencies. Any of the traps to be described may be used either as a sound trap or as an adjacent-channel trap. Therefore, we shall first discuss only the electrical characteristics of the trap, remembering that it might be used in any one of several ways: as an adjacent channel trap (either above or below the i.f.), as a sound i.f. trap, or simply as a "shaping" trap, tuned so as to aid in shaping the over-all response curve. We shall cover these applications later.

Series Traps. The series trap is shown in Fig. 11. Basically, it consists of a parallel-resonant circuit, L_1-C_1, that is placed in series between two i.f. tubes and is tuned to the frequency to be rejected. When a signal having the frequency to which the trap is tuned is applied to this circuit, the impedance offered by L_1-C_1 is so high in comparison to the grid-to-ground impedance of VT_2 that the trap absorbs most of the undesired signal voltage. (It acts as a voltage divider with the grid impedance.) As a result, only a negligible voltage at the trap frequency is applied to the grid of the next stage.

Most trap circuits are very sharply tuned, since they are designed to reject either one particular frequency or, at the most, a very narrow band of frequencies. For this reason, L_1-C_1 has a high Q and is not shunted with a resistance.

At all other frequencies, of course, the tuned circuit (L_1-C_1) will offer very low impedance in comparison to the grid circuit and will allow the signals to pass and be applied to the grid of the next stage.

Absorption Traps. Another popular kind of trap circuit is the absorption trap (L_1-C_1) shown in Fig. 12.

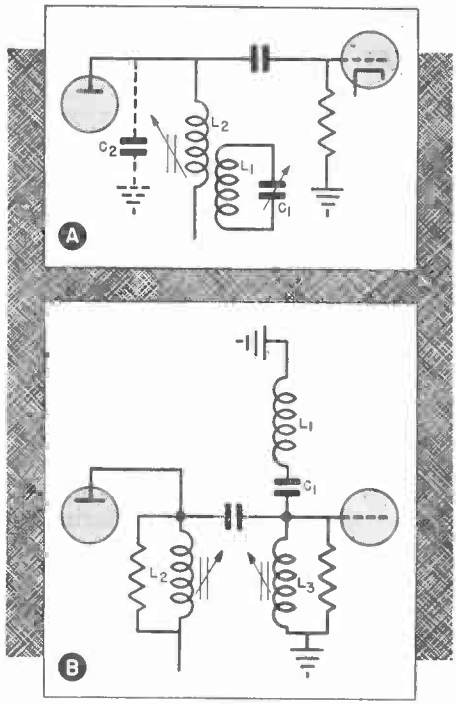


FIG. 12. Two forms of absorption trap. The one in part A of this figure is inductively coupled to the circuit; the one in part B is capacitively coupled to it.

This tuned circuit may be inductively coupled to a tuned circuit in the amplifier, as shown in Fig. 12A, or may be capacitively coupled, as shown in Fig. 12B. In either case, the operation is the same. At the resonant frequency of the trap circuit, it acts as a heavy load on the amplifier, absorbing the signal.

For example, at the resonant frequency of the tank circuit L_1-C_1 in Fig. 12A, a high circulating current develops in the trap. This effectively loads the tuned circuit L_2-C_2, causing it to act as a load having an extremely low Q. As a result, the stage has practically no gain at the undesired frequency. The series trap L_1-C_1 in Fig. 12B is practically a short circuit across the load for the frequency to which it is resonant, so it, too, reduces the stage gain at this frequency.

The trap circuit may be tuned either by a variable inductance, as shown in Fig. 11, or by a variable trimmer condenser, as shown in Fig. 12A.

Cathode Traps. Occasionally a tuned trap circuit is inserted in the cathode circuit of an amplifier stage to provide degeneration at the trap frequency and thus to reduce the gain of the stage, effectively rejecting the signal. This arrangement is illustrated in Fig. 13.

The trap circuit consists of L_1 and C_1. At its resonant frequency, this circuit has a very high impedance; therefore, a very high voltage will be developed across it at this frequency.

The voltage developed across the cathode trap at its resonant frequency is applied to the grid-cathode circuit in such a way that it is 180° out of phase with any applied signal of the same frequency; thus, for this applied signal, degeneration is produced, and little or no gain is obtained from the stage. At other frequencies, the tank is non-resonant and produces little degeneration.

A cathode trap is not always connected to the cathode circuit directly. Sometimes it is coupled to a coil in the cathode circuit, as shown in Fig. 13B; its effect when it is used in this

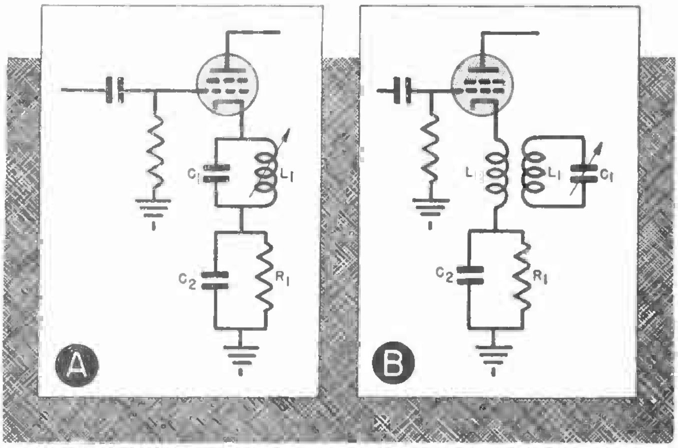


FIG. 13. This shows two ways in which a trap may be used in the cathode circuit of an amplifier stage. In each case, the trap creates degeneration at its resonant frequency and thus effectively rejects a signal of that frequency.

way is the same as that of the trap in Fig. 13A.

TRAP APPLICATIONS

As many as four or five individual traps may be used in a particular i.f. amplifier—perhaps as many as two traps in a single stage. Several traps may be tuned to the same frequency to get better rejection of signals at that frequency.

When you are aligning the i.f. stages in a television receiver, you must adjust the trap circuits as well as the individual tuned circuits. In fact, in certain television sets that have broad-band stages, the trap circuits may be the only circuits you can adjust.

Now that we have discussed the various trap circuits as far as electrical characteristics are concerned, let us see how the trap circuits are used. There are two primary uses to which trap circuits are put: sound i.f. traps and adjacent-channel traps.

Sound Traps. Sound-trap circuits are placed in the i.f. amplifier to reject the sound i.f. signal so as to prevent this signal from beating with the video i.f. in the second detector stage. Therefore, these traps are tuned to the sound i.f. and have high Q values. Also, the sound trap may serve as the source of signal for the sound i.f. section, as we will show.

Adjacent-Channel Traps. If you look back at Fig. 10, you will see that the skirts of the normal response curve (dotted lines) of a channel are broad enough to permit the sound carrier of one adjacent channel and the picture carrier of the other to be passed. By using traps tuned to these frequencies, however, we can cause dips in the response curve at these unwanted carrier frequencies and thus get the final over-all response curve shown by the solid curve in Fig. 10. Notice that the response to the signals produced by the adjacent channel carriers is now so low that they cannot cause interference. A dip or "notch" in the response curve is put in at the proper frequency by each of the traps.

The solid-line curve in Fig. 10 represents the response we want for a receiver in which a separate sound i.f. channel is used. Therefore, there is a notch caused by a sound i.f. trap in this curve. The curve for a set in which the sound carrier is supposed to go through the video i.f. would not have as deep a notch at the sound i.f. frequency. A trap would probably still be used to reduce the response at this frequency, however, to reduce the strength of the 4.5-mc. beat to such a level that the traps in the video stages could remove it.

Now that we have studied the basic i.f. circuits, let's go on to complete amplifiers.

Typical Video I.F. Amplifiers

Since the video i.f. amplifier section of the television receiver contributes most of the gain for the video channel, it is customary to use tubes that give as much gain as can be secured. Tubes with a high transconductance (Gm) are used, because the gain is directly proportional to the Gm of the tube in a pentode amplifier. The miniature tubes used in modern receivers generally have low interelectrode capacities as well.

Since it is customary to vary the gain of the video i.f. amplifier either by a contrast control or by an a.g.c. circuit, tubes with remote cut-off or variable-mu characteristics are needed. Instead, however, tubes that normally have sharp cut-offs are used, because only the sharp cut-off types can be made to have very high mutual conductance. The variable-mu characteristic causes a loss in Gm because not all the grid is usable at any one voltage.

Fortunately, a sharp cut-off pentode tube can be made to act as if it had something of a remote cut-off characteristic if a series resistor is used in its screen-grid circuit. If the proper resistor is used, the d.c. voltage on the screen grid will vary with the bias on the control grid in such a way that, as the bias is increased, the screen current will drop, allowing the screen voltage to rise and partly counteract the bias change. This arrangement makes bias control reasonably effective even on sharp cut-off tubes.

Number of Stages. The number of i.f. stages needed depends on whether the receiver is intended only for areas having high signal levels or is designed for "fringe" areas where weaker signals are the rule. It takes a signal voltage of 40 to 60 volts to operate the average picture tube. The usual video amplifier (the section between the video detector and the picture tube) has a gain somewhere between 20 and 50, so the detector output must be from 1 to 2 volts to make the video amplifier output large enough to operate the picture tube.

The weakest input signal from which the set can produce a picture must be at least slightly above the noise level, which ranges from 50 to 100 microvolts on the average. Hence, a signal about 100 microvolts is the weakest that can be successfully applied to a set; reception is impossible in an area in which the signal level is lower than this, unless the noise level is exceptionally low. In strong signal areas, the signal strength may be 5000 microvolts or more.

Let's assume we are studying a set that is designed to produce a usable picture from a 100-microvolt signal. Let's say the input tuner has an overall (r.f. plus conversion) gain of 10. The tuner output from a 100-microvolt signal will then be 1000 microvolts. The i.f. amplifier must raise this to perhaps 2,000,000 microvolts (2 volts), so the gain needed may be 2,000,000 ÷ 1000, or 2000. Three stages with gains of about 13 each would give more than this if each amplified all frequencies equally well. However, with stagger tuning, not all stages have the same gain at any one frequency in the pass band. One stage may have a gain of 30 to 50 for a particular frequency, but the other stages may have very low gains for that frequency and high ones for others. As a result, it is usually necessary to have four i.f. stages to produce sufficient amplification of all frequencies in a 100-microvolt signal.

If the set is intended for use in an area where the signals are always considerably stronger than 100 microvolts, or if its pass band is restricted enough to permit the gain of each stage to be at least relatively high for all frequencies, only three video i.f. stages may be necessary.

Now let's turn to typical video i.f. amplifiers. You can expect to find either band-pass or stagger tuning used as the basic method of getting a pass band of sufficient width; stagger tuning is used in by far the majority of circuits. A number of traps will be found, arranged to cut out adjacent channel signals sharply and usually to cut down or to eliminate the accompanying sound signal.

The couplings between stages may be transformer, complex, or impedance coupling, or a combination of these. Let's study examples of each in video i.f. circuits.

TRANSFORMER COUPLING

Fig. 14 shows two stages of a video i.f. amplifier that uses transformer coupling. A number of signals are present in the plate circuit of the mixer stage VT_1, including the video and sound i.f.'s. These two signals are selected by tuned circuit L_1-C_1, which is broadly tuned and low in Q. The selected signals are inductively transferred to the secondary circuit L_2-C_3, which, in turn, is loaded by resistor R_2 so that it has a broadly tuned characteristic. The signal is coupled to the grid of the first amplifier through condenser C_4; resistor R_3 serves as the

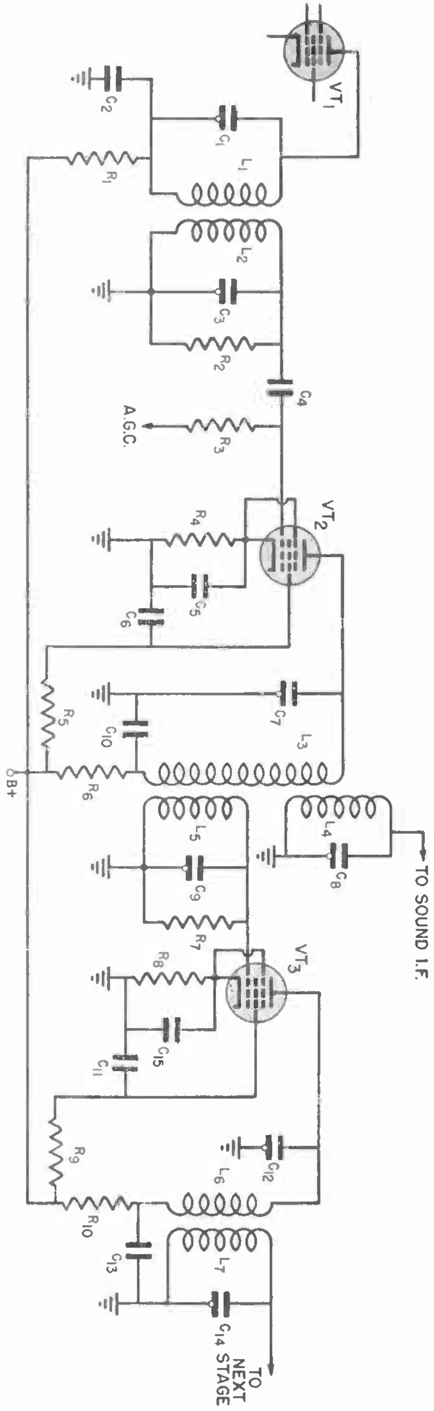


FIG. 14. This is part of the schematic diagram of the video i.f. amplifier of an actual set in which transformer coupling is used between the stages.

grid return resistor for this stage and may be connected to the a.g.c. bias voltage source.

The R_1-C_2 combination serves as the decoupling filter for the B supply of the mixer stage.

Amplifier tube VT_2 may be either a remote-cut-off tube (since we are applying a variable bias through R_3) or a sharp-cut-off tube that exhibits remote-cut-off characteristics because of the presence of the series screen resistor R_5. Condenser C_6 acts as a screen by-pass condenser. The minimum bias for the stage (to which the a.g.c. voltage is added) is provided by R_4, which is by-passed by condenser C_5 so that there will be no degeneration caused by the presence of an i.f. voltage across R_4.

Tuned circuit L_3-C_7 is in the plate circuit of VT_2; it may be tuned to a different frequency from L_1-C_1 to provide stagger tuning, or it may be tuned to the same frequency if this is a band-pass circuit. Since the schematic will look the same for either case, you will have to consult the service manual on such a set to see which arrangement is being used.

The signal present across L_3-C_7 is coupled both to the trap L_4-C_8, which is tuned to the audio i.f., and to L_5-C_9, which is tuned either to some other frequency within the video pass band or to the same frequency as L_3-C_7. Resistor R_7 loads the L_5-C_9 circuit.

Notice that the sound trap L_4-C_8 serves two purposes. First, it reduces the sound carrier signal strength by absorbing energy and loading the primary. Also, since it has a maximum sound signal across it, the circuit acts as a signal source for the sound i.f. amplifier.

Tube VT_3 operates in much the same manner as tube VT_2. The chief difference is that a.g.c. is not applied to this stage. (This is not a universal practice: a.g.c. may be applied to any or all of the stages in a video i.f. amplifier.)

Tuned circuit L_7-C_{14}, inductively coupled to the plate tuned circuit L_6-C_{12}, is used to supply the signal to the next stage.

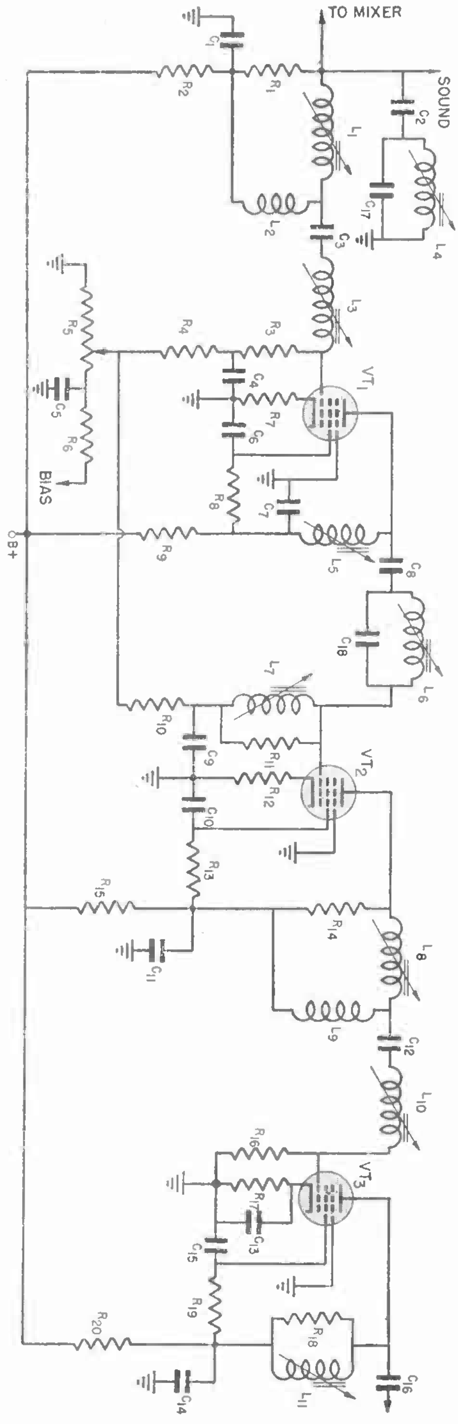
We see that the distinguishing feature of a transformer-coupled video i.f. amplifier is the fact that the different stages are inductively coupled —that is, there is actually a primary and a secondary winding on each i.f. "transformer." We make this distinction because the single-tuned circuits used in the impedance-coupled i.f. amplifier are often called "transformers" even though there are no specific primary and secondary circuits.

COMPLEX COUPLING

Fig. 15 shows an example of "complex" coupling. Here, the sound i.f. signal is developed across resonant circuit L_4-C_{17}, which is tuned to the sound carrier. Hence, this circuit acts both as a sound trap and as a coupling method. Notice that here we tap off the sound signal from the mixer plate circuit rather than from the plate circuit of the first video amplifier as we did in Fig. 14.

A tuned circuit consisting of inductances L_1 and L_2 in series, tuned by the distributed capacities in the circuit (including the plate-cathode capacity in the mixer tube) and loaded by resistor R_1 broadly tunes to the video i.f. or to somewhere within the video i.f. pass band. Condenser C_1, which is practically a short circuit as far as r.f. is concerned, acts in conjunction with R_2 as a decoupling network for the B supply voltage to the mixer stage.

Another tuned circuit is made up of L_2, L_3, and the distributed capacities in the circuit, including the grid-



cathode capacity of VT_1 and distributed wiring capacities. Condenser C_3 acts simply as a blocking condenser to prevent the B voltage from being applied to the grid of VT_1.

Notice that both tuned circuits contain L_2; the "primary" consists of L_1-L_2 plus certain capacities, and the "secondary" consists of L_3-L_2 and other capacities. Hence, this is one form of band-pass coupling. However, whether we have a stagger-tuned or a band-pass response depends on the actual coupling. If the inductance of L_2 is quite large, the circuit is probably overcoupled, which means that it has a band-pass response; otherwise, the coupling is low, and stagger tuning can be expected.

You can see one difference between this circuit and the circuit previously described—in the previous circuit, each stage was tuned by variable condensers. Here, we use variable inductances. The inductances can be made variable simply by providing each with a small powdered-iron core rod that can be screwed in or out of the coil. As the core is moved inward, the inductance increases.

Bias is provided for VT_1 and VT_2 by a combination of methods. First, the cathode resistor R_7 provides a fixed minimum bias for VT_1. R_{12} serves the same function for VT_2. An additional bias is supplied from a "bias" source across the R_6-R_5 network through R_4-R_3 to VT_1 and through R_{10}-L_7 to VT_2. The resistor-condenser combination R_4-C_4 serves simply as a decoupling filter and corresponds to the combination R_{10}-C_9 for VT_2.

The bias voltage is provided either from a fixed source (such as a bleeder

FIG. 15. This figure illustrates the use of complex coupling between the stages of the video i.f. amplifier.

resistor in the low-voltage power supply) or from a combination of a fixed source and a.g.c. The bias voltage appears across resistor R_5. This resistor is a potentiometer, so any portion of the available bias voltage can be applied to the tubes by setting the position of the slider properly. This arrangement allows the bias of these two stages to be adjusted so that the gain can be controlled. Thus, resistor R_5 serves as an i.f. gain control or a contrast control. As the slider is moved toward the right-hand side of the resistor, the bias voltage will increase, and the gain provided by stages VT_1 and VT_2 will decrease.

Notice that R_7 and R_{12} are not by-passed. By not by-passing these resistors, the designer has introduced a certain amount of degeneration. This tends to stabilize the stages and to make the tube characteristics a less critical factor in the operation of the stages. In other words, if one of the tubes goes bad and is replaced by a tube that is of the same type but has slightly different characteristics, retuning will either not be necessary or not be difficult. Also, because of the "leveling-off" effect of the un-by-passed cathode resistor, the tube replacement will cause no great change of gain as far as the particular stage is concerned.

Screen-grid voltage for VT_1 is provided through R_8; condenser C_6 serves as the screen by-pass. Similar functions are performed for VT_2 by R_{13} and C_{10}, and for VT_3 by R_{19} and C_{15}.

These tubes may be remote-cut-off tubes; alternatively, they may be sharp-cut-off tubes with R_8 and R_{13} chosen so that the tubes exhibit remote-cut-off characteristics.

In the plate circuit of VT_1, we have a tuned circuit consisting of variable inductance L_5 plus distributed capacities, including the interelectrode capacities of VT_1. The signal appearing across this circuit is applied through coupling condenser C_8 to a series trap L_6-C_{18} and to a resonant circuit consisting of L_7 and the distributed capacities in the circuit.

The series trap L_6-C_{18} is tuned to the sound i.f. and offers a very high impedance to this frequency; therefore, most of the sound i.f. present across L_5 will be dropped across the trap and not applied to L_7. At frequencies other than the one to which it is resonant, the trap L_6-C_{18} will act simply as either an inductance or a capacity having comparatively low impedance. Thus, the trap will offer little or no opposition as far as the picture i.f. is concerned, so most of the picture i.f. will appear across L_7 and be applied to the grid of the tube. Resistor R_{11} serves as a loading resistor to broaden the response of the L_7 tuned circuit.

The coupling network between VT_2 and VT_3 is quite similar to the coupling network between the plate of the mixer and the grid of VT_1. Therefore, we shall not discuss it in detail.

A variable bias voltage is not applied to VT_3. Because of this fact, the cathode resistor R_{17} is somewhat larger than R_7 or R_{12}. You will recall that R_7 and R_{12} are not by-passed because it is desirable to have a certain amount of degeneration in the VT_1 and VT_2 stages. Because R_{17} has a relatively high resistance, however, too much degeneration would be produced if it were not by-passed. Therefore, the by-pass condenser C_{13} is used in the cathode circuit of VT_3.

A complex coupling network is not used to couple the plate of VT_3 to the detector stage. Instead, the coupling is furnished by a simple tuned circuit made up of L_{11} and the distributed capacities in the stage, including the plate-cathode capacity of VT_3. This resonant circuit is loaded by R_{18}.

IMPEDANCE COUPLING

One of the most popular types of i.f. amplifier circuits is shown in Fig. 16. A four-stage amplifier is shown here, but the same type of circuit may be used as a three-stage amplifier. This circuit is a typical stagger-tuned, impedance-coupled i.f. amplifier. It provides good gain, good band width, and is remarkably free from any tendency to oscillate.

The plate circuit of the mixer stage is tuned by L_1 and the distributed capacities in the circuit.

The signal present across L_1 is coupled through condenser C_2 to the grid of amplifier tube VT_1. Resistor R_2 serves as a grid d.c. return path. A bias voltage is also applied to the grid of VT_1 through R_2 Similarly, a bias voltage is also applied to the control grids of VT_2 and VT_3 through their respective grid resistors—R_7 for VT_2 and R_{12} for VT_3.

A trap circuit consisting of variable inductance L_2 and fixed condenser C_{19} is coupled to coil L_1 in the plate circuit of the mixer. This absorption trap circuit is tuned to the sound i.f., and a tap is provided on it from which the sound i.f. is obtained.

The tuned circuit acting as the plate load of VT_1 consists of inductance coil L_3 and the distributed capacities. These distributed capacities include not only the capacities between the wiring and the chassis but also the plate-cathode capacity of VT_1 and the grid-cathode capacity of VT_2. The signal across L_3 is applied to the grid of VT_2 through blocking condenser C_6.

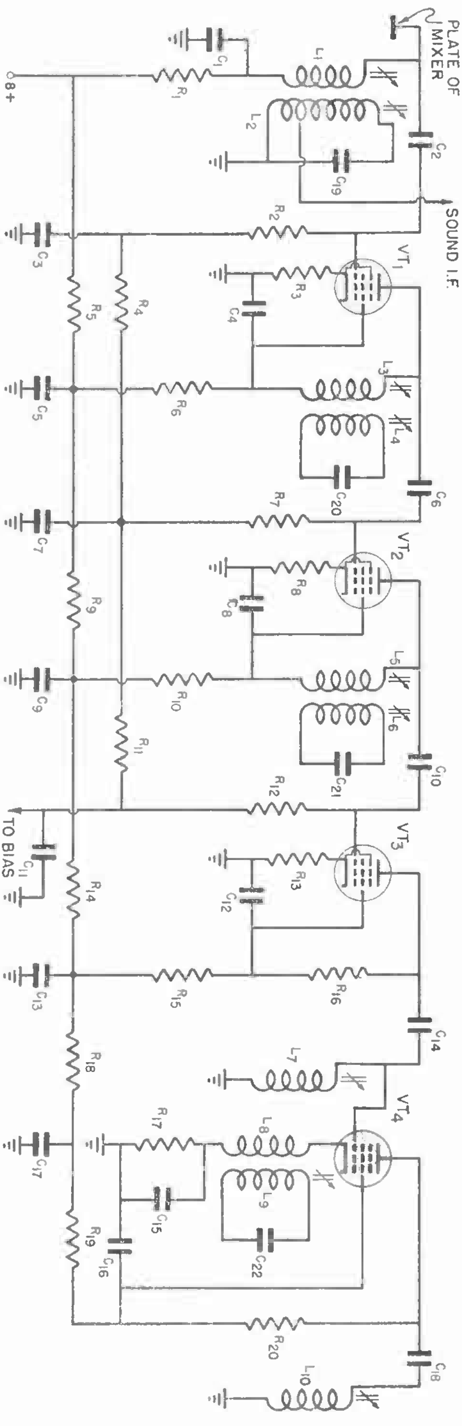


FIG. 16. The schematic diagram of a typical stagger-tuned video i.f. amplifier in which impedance coupling is used between the stages.

Coupled to L_3 is an absorption trap L_4-C_{20}. This may be tuned to an adjacent-channel sound carrier, for example, in which case it will serve to reject signals of this frequency.

Coil L_5 in the plate circuit of VT_2 also has an absorption type trap L_6-C_{21} coupled to it. This trap circuit may be tuned to an adjacent-channel picture carrier.

Notice that the plates and screens of the tubes are operated at approximately the same B voltage in this amplifier circuit. This is fairly common practice when a comparatively low plate voltage is used (around 125 volts).

The plate circuit of tube VT_3 is different from those of the previous stages: a resistive load is used here. The tuned circuit, which consists of coil L_7 tuned by the distributed capacities, is placed in the grid of the next stage.

Because there is a resistor used as the load in the plate circuit, the plate voltage of VT_3 will be somewhat lower than the plate voltages applied to the tubes in the previous stages; as a result, not quite as much gain can be expected from this stage. The tuned circuit will also be rather heavily loaded, since the plate resistor will normally be fairly low in resistance—lower, at least, than the grid resistors that load the previous stages. For this reason, the response curve of this stage will not be as sharply tuned as those of the others discussed, nor will quite as much gain be obtained.

A coil is provided in the cathode circuit of VT_4 to which a tuned absorption trap L_9-C_{22} is coupled. This trap circuit may be tuned to the sound i.f. and thus may serve to provide additional rejection of this signal.

A resistive load is also used in the plate circuit of the last video i.f. amplifier stage. The final tuned circuit consists of coil L_{10} and the various distributed capacities. This last tuned circuit is loaded quite heavily, since it feeds the video detector; therefore, it will have the broadest response of all.

Notice that all the tuning in this amplifier circuit is furnished by variable inductances. This is quite common practice at high frequencies, since it permits higher L/C ratios (the only capacities are the distributed ones, so the minimum possible capacity is present; this permits a higher L value to be used).

In the stages having a variable bias supply, small un-by-passed cathode resistors furnish a small initial bias and provide some degeneration. The only bias on VT_4 is furnished by the cathode resistor R_{17}, which is by-passed. Each plate supply lead is decoupled by R-C filters.

You will notice that none of the i.f. tuned circuits we have discussed has been shown as being shielded. Sometimes the i.f. transformers (or coils) are left completely unshielded in a TV set. This is particularly true of stagger-tuned i.f. amplifiers, because there is little or no danger of oscillation between adjacent stages. When the stages are tuned to different frequencies, there is practically no feedback between stages that has sufficient amplitude and the correct phase (at a specific frequency) to cause oscillation. Thus, shielding is not always necessary.

In other sets, you may find that two or more of the i.f. tuned circuits are shielded but that the others are not shielded. In still other sets, every i.f. coil will be shielded.

Video Detectors

Once the video signal has been built up by the video i.f. amplifier, it must be passed through a detector (demodulator) if we are to regain the modulation. In this case, the modulation consists of the picture components plus synchronizing and blanking pulses. This intelligence is amplitude-modulated upon the picture carrier, so a basic rectifier type of detector will serve to demodulate the signal.

The only requirements made of the video demodulator that the detector of an a.m. radio broadcast set does not have to meet are that the polarity of its output must be considered and that more care must be taken to prevent loss of the high-frequency components of the signal. We shall investigate both of these requirements after we see how the circuit works basically.

THE I.F. SIGNAL

The modulated i.f. carrier that is fed into the video detector is a signal of varying amplitude like that shown in Fig. 17A. The "envelope" of this signal represents the modulation. The partial suppression of one side band has served only to reduce the amplitude of the modulation; this has produced a certain amount of amplitude distortion by compressing the range between white and black signals, but since the eye is a very poor judge of the amount of light and of relative changes in light intensities, even fairly large amounts of amplitude distortion can be tolerated. Therefore, if the previous circuits have not introduced frequency distortion and phase delay, our signal will be entirely satisfactory.

It is standard practice in the United States to use "negative" modulation of the picture carrier: that is, the brighter the image, the less amplitude of the radiated signal. (The British system is exactly the reverse.) The maximum level is reached by the synchronizing pulses; the "black" level is the blanking pedestal height, which is about 75% of the maximum amplitude; and the "white" level is at about 15% of the peak level reached by the synchronizing pulses. This is, of course, the opposite of the method used in a.m. radio broadcasting, in which the loudest sound (corresponding to the greatest light intensity) produces the highest modulation peak; that is why this system is called negative modulation.

As you have learned, this method of modulation is used because it produces the most reliable synchronization. Since the synchronizing pulses are transmitted at the maximum amplitude, synchronization can often be maintained even if there is fairly heavy interference. Further, any noise or other interference that increases the signal amplitude will drive the picture tube dark instead of appearing as a bright flash.

To remove the modulation, it is only necessary to rectify the signal shown in Fig. 17A as shown in Fig. 18A and then to by-pass the high-frequency i.f. pulses to obtain a signal that follows the pattern of the modulation envelope. Thus, a video detector operates in exactly the same manner as the second detector used in an a.m. sound receiver. This is to be expected, of course, since the video signal is simply an amplitude-modulated signal.

PICTURE PHASE

Fig. 18 shows two ways of connecting a diode to an i.f. source L_1-C_1. It is important to choose the proper method of connection, because the polarity of the output depends upon the one we choose, and, as we shall see in a moment, this polarity must be the right one for the particular set in which the detector is used.

In either case, we apply the signal shown in Fig. 17A to the demodulator circuit. The arrangement of the circuit in Fig. 18B is such that current can flow only when point 1 on L_1 is positive with respect to point 2, since the diode plate is then positive. Therefore, the negative alternations of each cycle are rejected, and only the positive swings pass. This gives us the output shown in Fig. 17B. Since the synchronizing pulses reach the maximum in the positive direction, and the brightest portion of the picture is the least positive point in the intelligence signal, the rectified voltage produced across R_1 has a negative picture phase. This means that the signal swings in the negative direction for increases in brightness.

If we invert the diode, as shown in Fig. 18C, conduction can occur only when point 1 is negative. Therefore, this arrangement rejects the positive swings of the signal in Fig. 17A and causes the output voltage developed across R_1 to have the form pictured in Fig. 17C. Now, the brighter the picture, the more positive (or, rather, the less negative) the signal; there-

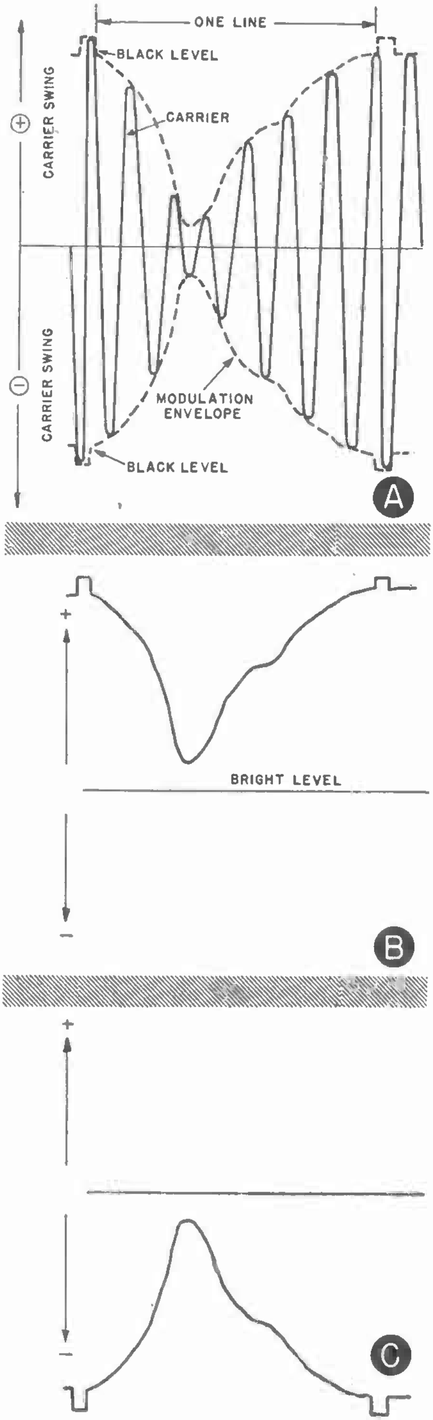


FIG. 17. Part A of this figure represents the modulated i.f. carrier that is fed into the video detector. Part B shows the form of the modulation if the detector is arranged to produce a negative picture phase. Part C shows the form of the modulation if the detector is arranged to produce a positive picture phase.

fore, the R_1 voltage has a positive picture phase.

This phase is important to us because it is necessary to feed the signal to the picture tube in such a way that the number of electrons in the beam will be increased when the scene calls for a brighter element. Hence, a signal that is applied to the grid of the picture tube must have a positive phase so that the grid will go more positive for increases in brightness.

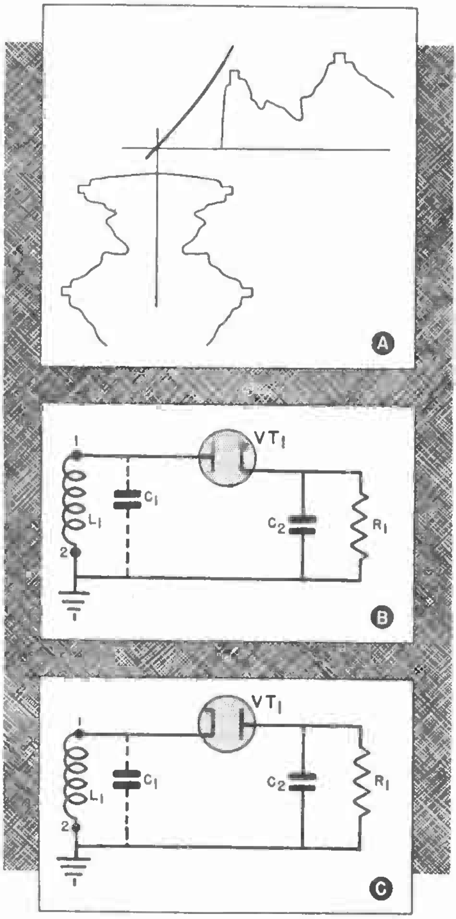


FIG. 18. The detector circuit shown in part B of this figure will produce an output having a negative picture phase. Inverting the diode as shown in Part C will give the output a positive picture phase.

Swings in the negative direction will then reduce the number of electrons in the beam and produce darker spots.

The television signal at the video detector is not sufficiently strong for direct application to the picture tube. This means that there must be a "low-frequency" amplifier (called the video amplifier) between the detector and the picture tube to raise the one- or two-volt output of the detector to the 40- to 60-volt signal that is needed to operate the picture tube. Each video amplifier stage reverses the picture phase 180°, so if we feed in a signal of positive phase to a one-stage amplifier, we will get out a negative one, and vice versa.

Now, if we are going to feed the signal to the grid of the picture tube, and if only one stage of video amplification is needed, the second detector must be connected to give a negative picture phase. The one stage of amplification will then cause a 180° reversal in the signal, and we will have a positive picture phase when the signal is applied to the grid of the cathode ray tube.

If two stages of video amplification are used, on the other hand, the video detector must be connected to give a positive picture phase. In fact, we can make the general statement that if one or three video stages are used, the output of the video detector must be connected to give a negative picture phase; if two video stages are used, the video detector must be connected to give a positive picture phase.

This statement is true if the picture signal is eventually applied to the grid of the picture tube. In some television receivers, however, the video signal is applied to the cathode rather than to the grid of the picture tube. If this is done, the video signal must have a negative picture phase when it is applied to the picture tube. It is easy to see the reason for this if you remember that driving the grid of the tube more positive (less negative) is equivalent to driving the cathode of the tube more negative (less positive) with respect to ground. In other words, it is the voltage *between* the grid and cathode that is important. If the cathode is made more positive without there being any change in the voltage applied to the grid, the voltage difference between the grid and cathode is increased, with the result that the grid is more negative with respect to the cathode. This effect is exactly the same as the one that would be produced by making the grid more negative without changing the voltage on the cathode.

Therefore, our rule about the detector polarity and number of stages must be reversed when the output of the video amplifier is applied to the cathode of the picture tube. Hence, once the manufacturer has decided whether to feed the grid of the cathode of the picture tube, and has decided on the number of video stages, the video detector must then be designed to deliver the required picture phase. In one set this may be a positive phase; in another it will be negative.

FREQUENCY DISTORTION

Like any other a.m. detector, it is necessary for the video detector stage to reject the r.f. components—that is, the high-frequency pulses contained in the rectified modulated i.f. signal must be filtered out of the load circuit in some manner. At the same time, however, all components of the modulation envelope must be reproduced with the correct amplitude, regardless of frequency. Frequency distortion can occur if the amplitude of either the higher or the lower-frequency video signals is seriously attenuated. Generally, we do not have to worry about the lower-frequency components in the video detector, because these will normally be reproduced properly.

To reproduce all the high-frequency components, however, it is necessary to avoid excessive by-passing. The basic r.f. filter in a detector circuit is a capacity across the load, such as C_2 in Figs. 18B and 18C. In a TV set, the distributed capacities in the wiring and the tube interelectrode capacities may well be large enough to supply all the filtering desired; in fact, they can be large enough to by-pass and thus attenuate some of the higher-frequency components of the desired signal. Hence, it is necessary to keep this capacity as small as possible or to reduce its effects.

If we make the load resistance very small, the effect of the shunting capacity will be reduced, because the impedance of the parallel combination depends more on the low resistance than on the capacitive reactance. In addition, high-frequency compensation may be used in the form of "peaking" coils in the load arrangement. Let's see how these are used by making a brief study of a few typical circuits. Much more detail on this compensation will be given in another Lesson in which you will study the video amplifier.

SERIES PEAKING

A typical video detector circuit arranged to deliver a negative picture phase is shown in Fig. 19. The modulated i.f. signal is applied to the plate of the video detector VT_1 from i.f. transformer L_1. Tube VT_1 will conduct only on positive peaks, so the signal appearing across diode load resistor R_2 will have negative picture phase. (That is, if a modulated i.f. carrier signal like that shown in Fig. 17A is applied, the lower half will be stripped away, and the signal reproduced across R_2 will have the form shown in Fig. 17B.) An odd number of video frequency amplifier stages will follow this detector if the signal is to be applied to the grid of the picture tube.

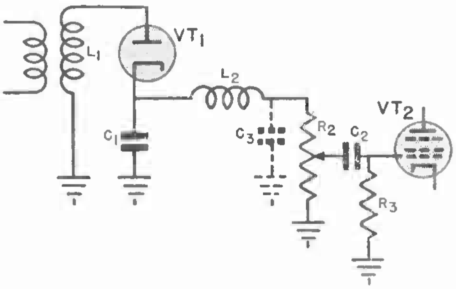


FIG. 19. A typical video detector circuit. Its output has a negative picture phase.

Condenser C_1 represents part of the distributed capacity, and includes such items as the cathode-filament capacity of VT_1. To increase its size and get proper filtering of the i.f. pulses, a small by-pass condenser may be used here in addition.

The rest of the distributed capacity (in particular, the input capacity of video stage VT_2) is represented by C_3.

Coil L_2 serves three purposes. It separates the capacities C_1 and C_3, reducing their shunting effect across the load R_2. If its size has been properly chosen, it forms a low-pass filter that further removes the i.f. pulses. Finally, it can also act as a series resonant circuit with C_3 and can thus be used to boost the higher video frequencies. That is, if we consider that L_2 and C_3 form a series resonant circuit at a frequency somewhat higher than the highest video signal, we know that there will be a boost in signals around this frequency because of resonance step-up. Diode load resistor R_2 acts to load this resonant circuit and thus to broaden its peaking action. When the coil is used in this manner, it is called a "series peaking coil."

COMBINATION PEAKING

Fig. 20 shows another typical circuit, arranged this time to produce a positive picture phase.

Coil L_1 may be the last tuned circuit in the i.f. amplifier of the television receiver. The modulated i.f. carrier signal will appear across this coil and will be applied to the cathode of VT_1.

Tube VT_1 will conduct only when the cathode is made negative with respect to the plate. Thus, the tube is connected to give a positive picture phase. (In this case, if a modulated carrier like that shown in Fig. 17A is applied to the detector, the upper half

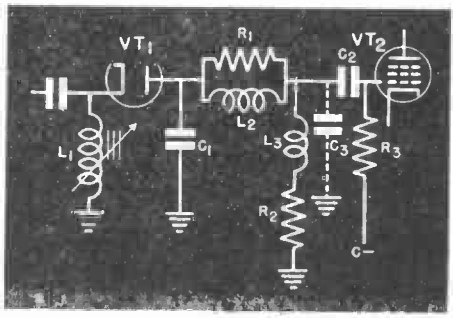


FIG. 20. This video detector circuit produces a positive picture phase. Coil L_2 acts as a series peaking coil, and coil L_3 acts as a shunt peaking coil.

will be stripped away, and the envelope from the lower half of the signal will appear across the load as a signal having the form shown in Fig. 17C.)

Condenser C_1 charges on the peaks of the rectified i.f. pulses and discharges in the valleys between the pulses, thus smoothing out the rectified i.f. signal and producing the video signal. Acting in this manner, it bypasses the high-frequency i.f. pulses. Since the i.f. frequencies are quite high, this condenser has a fairly small value—usually something on the order of 10 mmf. It acts in conjunction with other distributed capacities in the circuit.

Coil L_2 is a series peaking coil that serves to split the distributed capacities, to filter the i.f., and to increase the strength of the higher video frequencies by resonance step-up. Resistor R_1 loads coil L_2 and acts to prevent transient oscillation. This latter function is needed because coil L_2 may resonate with various capacities in the circuit at some particular frequency and tend to set up a damped oscillation at this frequency when a pulse is received. If we load the circuit with R_1, however, such transient oscillation can be avoided.

Coil L_3 is chosen to resonate with the distributed capacities in the circuit (including not only wiring capacities but also the grid-cathode capacity of tube VT_2) near the highest-frequency video signal to be transmitted. Hence, it forms a parallel-resonant circuit that is part of the load across which the signal is developed. Maximum voltage will appear across this resonant circuit at its resonant frequency, so it tends to boost the signal at the higher frequencies and thus to make up for any loss of high frequencies due to distributed capacities in other parts of the circuit. It is a resonant circuit with a low Q, however, because of the loading effect of R_2, so a sharp peak is not produced—instead, the circuit boosts a rather wide range of frequencies near the upper limit to be transmitted.

Because of this action, coil L_3 is called a peaking coil. Since it is connected in parallel with the distributed capacities in the circuit, it is called a shunt peaking coil.

Since this detector circuit is connected to produce a demodulated signal having a positive phase, it must be followed by an even number of video amplifiers to obtain the proper positive picture phase for driving the grid of the picture tube, or by an odd number if the signal is eventually applied to the cathode of the picture tube.

DETECTOR VARIATIONS

An unusual video detector circuit is shown in Fig. 21. Diode VT_1 in this circuit has a low ohmic resistance when it is conducting current; when it is not conducting, it acts simply as a low capicity. When the video i.f. voltage makes point 1 positive with respect to point 2, diode VT_1 will conduct and will have a much lower resistance than R_1. The signal voltage will then be divided in such a way that practically all of it will be dropped across R_1 and practically

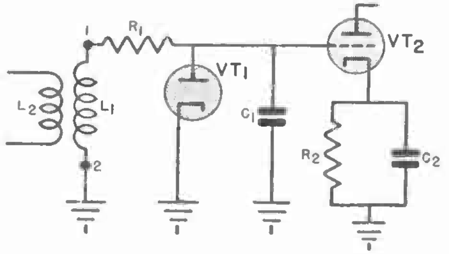


FIG. 21. Another form of video detector.

none across VT_1; as a result, only a negligibly low i.f. signal voltage will be applied to the grid of the first video-frequency amplifier tube.

However, when point 1 is negative with respect to point 2, diode VT_1 will be an open circuit, and the complete negative half-cycle of the video i.f. signal across L_1 will be applied

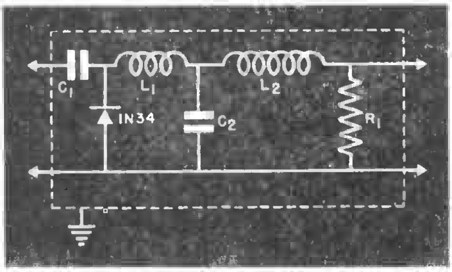


FIG. 22. A video detector circuit in which a germanium crystal is used instead of a diode.

through R_1 between the grid and cathode of VT_2. Thus, only the negative alternations will act upon the grid of the video amplifier tube; this means that we shall obtain a positive picture phase from the video detector.

When the negative alternation of the i.f. signal is applied to the grid of the video amplifier tube, the combined capacity between this tube and ground (the capacity of C_1 in parallel with the plate-cathode capacity of diode VT_1 and the grid-cathode capacity of the first video amplifier tube) is charged and discharged through R_1. This action makes the net voltage on the grid of the video tube follow the desired modulation envelope, and at the same time removes i.f. components more or less completely. Resistor R_1 also serves to limit the current through diode VT_1 to a safe value during the half-cycles on which VT_1 conducts.

Crystal Detector. Still another video detector circuit is shown in Fig. 22. Here, the diode detector tube has been replaced by a germanium crystal (type 1N34). A germanium crystal will allow current to pass better in one direction than in the opposite direction. Because of this action, it can be used as a rectifier and thus as a second detector. It occupies less space than a vacuum tube and does not require heater current.

When a germanium diode is used as a detector, it is customary to build the entire second detector circuit (including the peaking and filtering coils L_1 and L_2 as well as condensers C_1 and C_2 and the diode load resistor R_1) inside a shielded can. Therefore, if you encounter a television set that appears to have no video demodulator, careful investigation may well prove that the entire second-detector stage has been built into a small shield can from which only the output and input leads project beneath the chassis.

In the circuit shown in Fig. 22, condenser C_1 acts as a blocking condenser to prevent the application of d.c. to the 1N34 crystal. Resistor R_1 is the diode load resistor, and the detected video signal appears across its terminals.

Lesson Questions

Be sure to number your Answer Sheet 53RH-3.

Place your Student Number on every Answer Sheet.

***Send in your set of answers for this Lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. Are the sound and the picture signals from a TV station on the same carrier or are they on separate carriers?

2. When a TV set does not use an intermodulation sound system, why is it desirable to eliminate the sound carrier in the video i.f. amplifier before the carrier can reach the video detector?

3. If the i.f. carrier is located on the slope of the i.f. response at a point higher than that giving 50% carrier response, will the over-all low-frequency response be: *higher than; lower than; the same as;* that for other frequencies in the pass band?

4. Name the two basic ways of getting the broad-band i.f. response needed in a video i.f. amplifier.

5. What happens to the response when resistors are used to load both the primary and the secondary of an overcoupled band-pass video i.f. transformer?

6. How are the steep slopes on the response curves of the video i.f. section obtained?

7. In addition to reducing the response (to the sound carrier) of a video i.f. section, what other use frequently is made of the sound trap?

8. How is a remote-cutoff characteristic obtained when sharp cutoff pentode tubes are used in the video i.f. amplifier?

9. If the signal is to be applied to the grid of the picture tube, and there are two video stages, what must be the phase of the signal at the output of the video detector—positive or negative?

10. Why is it necessary to use a low capacity as the r.f. by-pass across the diode load in the video detector?

Be sure to fill out a Lesson Label and send it along with your answers.

GET ALONG WITH PEOPLE

In a recent study covering the activities of several hundred successful men, this question was asked:

"What single ability is most essential to success?"

The almost unanimous answer was:

THE ABILITY TO GET ALONG WITH PEOPLE.

You will agree with this, I am sure.

The successful technician—engineer — business-man—must *get along with* other people, if he is to gain the greatest success, and earn the greatest profit from his technical abilities.

Keep this in mind in your everyday life. *Practice getting along with* people. We can all improve on our abilities in this "art"—and will profit by doing so.

J. E. Smith

VIDEO AMPLIFIERS AND D.C. RESTORERS

54RH-3

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE No. 54

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. **Introduction** . . . . **Pages 1-6**
The video amplifier is compared to the audio amplifier in a sound receiver, then signal characteristics are discussed.

☐ 2. **Video Signal Distortions** . . . . **Pages 7-10**
This section covers amplitude distortion, frequency distortion, phase distortion, and time delay.

☐ 3. **Fundamental A.C. Video Stages** . . . . **Pages 11-20**
Low-frequency response, high-frequency response, series compensation, and shunt compensation are covered here.

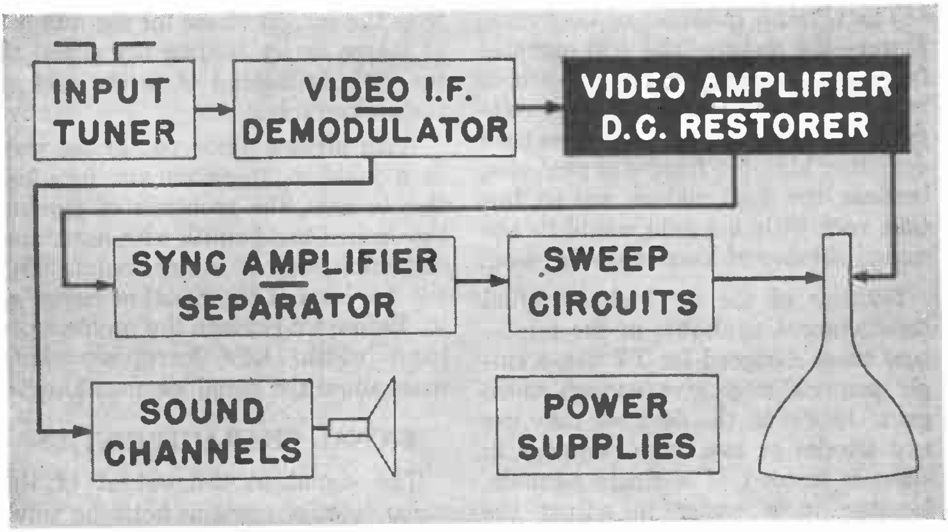
☐ 4. **Fundamental D.C. Amplifier** . . . . **Pages 21-30**
You study the power supply, a typical circuit, and signal operation of a two-stage d.c. amplifier, then learn about brilliancy control and contrast control.

☐ 5. **D.C. Restorers** . . . . **Pages 30-36**
This discusses the basic d.c. restorer, then describes a practical diode restorer, restoration in the last video stage, and in the picture-tube circuit.

☐ 6. **Answer Lesson Questions and Mail your Answers to NRI for Grading.**

☐ 7. **Start Studying the Next Lesson.**

JD6M151 1951 Edition Printed in U.S.A.



NOW that you have followed the video signals through the r.f. section (the input tuner and i.f. amplifier) and have studied the video detector, you are ready to make a detailed study of the video amplifier. This video amplifier can be compared directly to the audio amplifier of a sound receiver; it is the "low-frequency" section of a television set—the section that takes the signal from the detector and delivers it to the picture tube. It is necessary because the signal output of the detector is insufficient to operate the picture tube.

The early history of the development of video amplifiers is much like that of audio amplifiers. Originally, the gain obtainable in the r.f. section was low, so a number of video stages had to be used, even though fidelity was sacrificed thereby. Then, as developments in tubes and circuits permitted more amplification at high frequencies, the number of video stages was decreased, thus permitting wider frequency response. Today, many TV sets have only one video stage, although most use two, and a very few use three.

Basically, the video amplifier stage is either a resistance-coupled or a direct-coupled stage. The transformer coupling commonly used in audio amplifiers is completely impossible in video amplifiers because the very wide frequency range present in video signals simply cannot be passed through audio transformers. Hence, the maximum gain can be no more than the mu of the tubes; actually it will be far less than this because the load values must be kept small.

To get a general idea of the gain needed, we can assume that the output of the video detector will be somewhere around 2 volts in a set installed within a few miles of a television station. The amount of signal required to drive the picture tube may be anywhere between 40 and 100 volts, depending on the tube type. This means that the video gain necessary will be between 20 and 50.

There is no question of delivering power—the picture-tube grid operates from a voltage, so all the video stages in a TV set are essentially just voltage-amplifying stages. The tubes used are either high-mu triodes or pentodes, because the load values are so low that very little net gain would be obtained if tubes of lower mu were used.

Because of the far higher mutual conductances available in the miniature tubes designed for TV use, a single pentode may give enough video gain. However, the designer may use two triodes or even two pentodes in cascade instead of a single pentode, because it is easier to adjust the two load circuits to give the required band width than it is to adjust the single load circuit of a single stage.

Picture Phase. When the signal is fed to the grid of the picture tube, it must have a positive picture phase—that is, the signal voltage must go increasingly positive as the scene increases in brightness. Each video stage reverses the phase 180°, so when an odd number of video stages (one or three) is used, and the signal is fed to the picture-tube grid, the detector must deliver a negative picture phase. On the other hand, when an even number of stages (two) is used, and the signal goes to the picture-tube grid, the detector output must have a positive picture phase. At one time this had to be taken into consideration; today, however, the detector output can be of either phase because it has been found possible to secure a positive picture by feeding a signal of negative picture phase to the cathode of the picture tube. Therefore, today, regardless of the number of stages used in the video amplifier, the picture phase is adjusted properly either by setting the detector to deliver the correct phase for the number of stages or by feeding the signal to the cathode instead of to the grid of the picture tube.

With picture phase out of the way as a problem, there remain, in addition to gain, the problems of passing the desired band width with minimum distortion and of either maintaining the d.c. level of the signal or restoring it. Before we get into the problems of band width, let's learn something more about the signal we must handle.

SIGNAL CHARACTERISTICS

The signal at the output of the video detector contains both the video and synchronizing signals. The complete video signal, including the sync pulses, is fed to the picture tube. It is not desirable to separate the synchronizing signals from the picture signal in the video amplifier, because the sync pulses help to blank out the tube during sweep retraces, as we will show elsewhere.

At some point between the detector and the picture tube, a copy of the entire signal is taken off to be fed through the stages engaged in controlling the sweep circuits. The exact point depends on the sync level and phase, as another Lesson will show.

Frequencies. The video amplifier must pass signals ranging from about 10 cycles to as much as 4.25 megacycles in high-definition systems. The upper limit is subject to some variation; when small picture tubes are used, it is impossible to see fine details at normal viewing distances, and furthermore, such sets are frequently inexpensive types. In such cases, the upper frequency limit may be cut to be only about 3 mc. Receivers with medium definition may cut off around 3.5 to 3.75 mc.

A good low-frequency response is necessary so that the system will reproduce slow changes in brilliancy or gradual changes in shading from light to dark. On the other hand, a good high-frequency response is quite necessary so that the set will be able to reproduce satisfactorily the sudden and sharp changes that occur when the scanning spot moves from a light to a dark object in a scene.

D.C. Component. In addition to having an extremely wide frequency range, the video signal differs in one other important respect from the sound signal with which you are familiar. The video signal has a d.c. component; it is actually a pulsating d.c. signal rather than a true a.c. one. The effect of the d.c. component is shown in Fig. 1. In A, B, and C of this figure we have the same a.c. signal, except that in each instance the level about which it varies is different. In A we have the signal for a dark scene, in B that for a gray scene, and in C that for a brightly lighted scene. All three a.c. signals may represent two scanning lines crossing the same object: for example, they may be scans of a scene that shows a house in darkness, in moonlight, and in sunlight.

For simplicity, let's wipe out the variations in the a.c., thereby getting the signals shown in Figs. 1D, 1E, and 1F. (These could well represent scenes having a solid over-all dark, gray, or white tone respectively.)

Examining these three signals, you will see that the only basic difference between them is in the amplitude of the video portion, which is shaded in this figure. Thus, as we move from the dark scene to the gray scene, the amplitude represented by the shaded area increases. It increases more as we move from the gray to the white scene. However, this increase is all on one side of the black-level line. That is, the synchronizing pulses are not changed in amplitude at all; we have merely changed the amount of video signal by adding a d.c. to our a.c. signal.

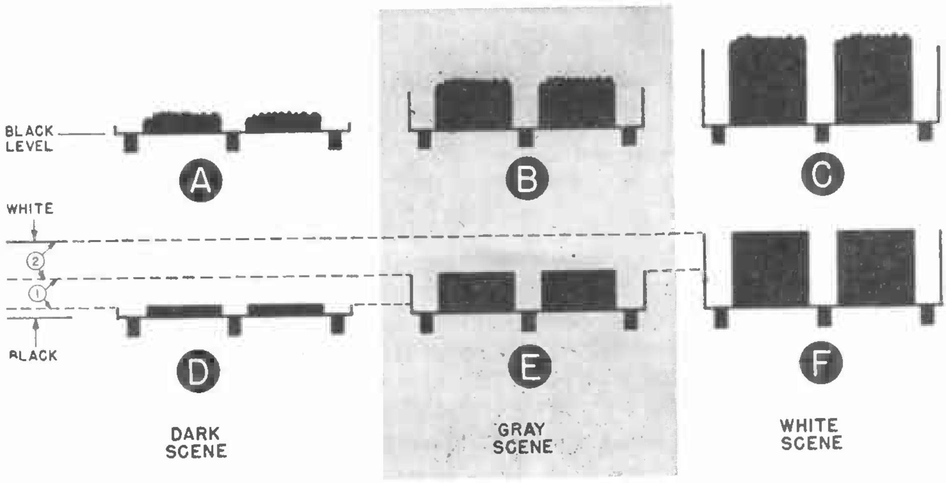


FIG. 1. How the d.c. component affects the video signal.

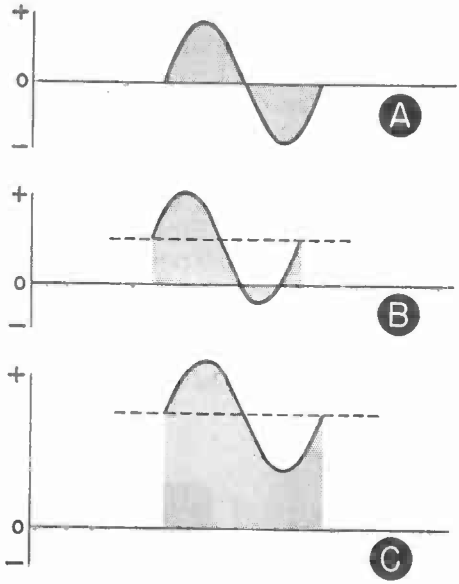


FIG. 2. What happens when a d.c. component is added to an a.c. sine-wave signal.

If we add a d.c. to an a.c. sine-wave signal, as shown in Fig. 2, the effect produced is the same as that shown in Fig. 1. That is, the addition of the d.c. moves the a.c. signal with respect to the zero reference line.

If we pass the combined a.c. and d.c. signal of Fig. 2C through an a.c. amplifier, the d.c. component will be wiped out, and we will have only the a.c. component of Fig. 2A. There is no way for us to regain the d.c. component here, because the signal, after a.c. amplification, contains no component that indicates what its previous d.c. level was.

In a TV signal, however, the presence of the pedestal and sync pulse does let us regain the d.c. component after it has been wiped out by a.c. amplification. Let's see why it is important to regain this d.c. level and learn how it may be done.

Figs. 3A, B, and C show the pulsating d.c. forms of the TV signals we had in Fig. 1. In Figs. 3D, E, and F are their respective a.c. equivalents. Notice that the pedestals of the a.c. signals do not line up, although they do in the d.c. signals. This change has occurred because the areas of an a.c. signal on either side of the zero line are always equal (or, in other words, the average of an a.c. signal is always zero). The pedestals of signals having large d.c. components must therefore shift considerably below the reference line when the signals are converted to a.c.

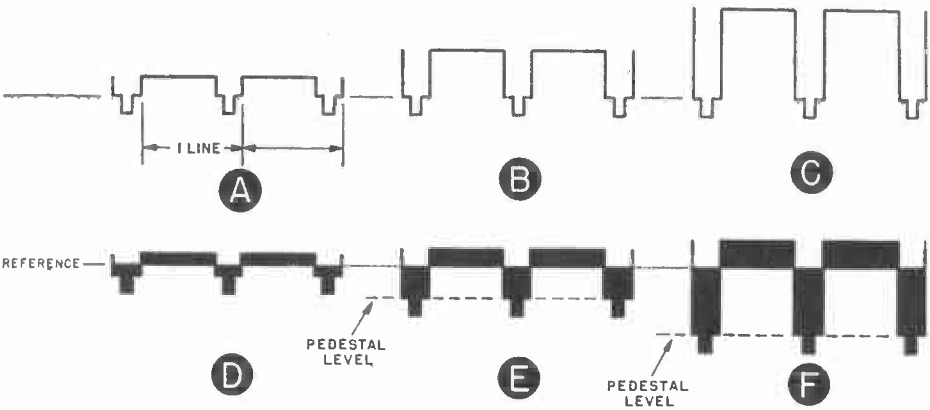


FIG. 3. Pulsating d.c. signals (top) and their a.c. equivalents (bottom).

It is possible to apply these a.c. signals to the grid of the picture tube without first lining up their pedestals. If this is done, however, improper operation will be produced, as you can see from Fig. 4. Here, a dark scene (Fig. 4A) has been lined up so that its pedestal coincides with the operating point X on the tube curve. Video signals now swing to the right to give increases in brilliancy, and sync pulses go to the left into the blacker-than-black region to cut off the tube during retraces. A bright scene, however, as shown in Fig. 4B, would give but little increase in over-all illumination, because the effect of any swing in the direction to the left of the operating point would be lost. On the other hand, if we arrange the circuits so that the pedestal of a bright scene (Fig. 4C) lines up with the operating point of the tube, even the sync pulses of a dark scene (Fig. 4D) will be well to the right of the operating point; the retraces of the dark scene will therefore be visible in the picture, and the scene would be very much brighter than it should be.

All this wouldn't matter if all scenes had the same background brilliancy. Since they don't, however, the pedestals of the signals applied to the picture tube must be lined up, as shown in Fig. 5, so that changes in background illumination will be reproduced accurately and so that the retrace lines will not be visible. In other words, the signals applied to the picture tube must contain a d.c. component that will permit alignment of the pedestals.

Since the signal is produced in the proper form (with the d.c. component so that the pedestals are aligned) at the video detector, we must somehow get this signal to the picture tube unchanged.

One way of avoiding a.c. amplification is to use a d.c. amplifier (one that does not have coupling condensers). A single-stage d.c. amplifier is relatively simple—the grid of the tube is fed directly from the video detector load, and its plate circuit is directly

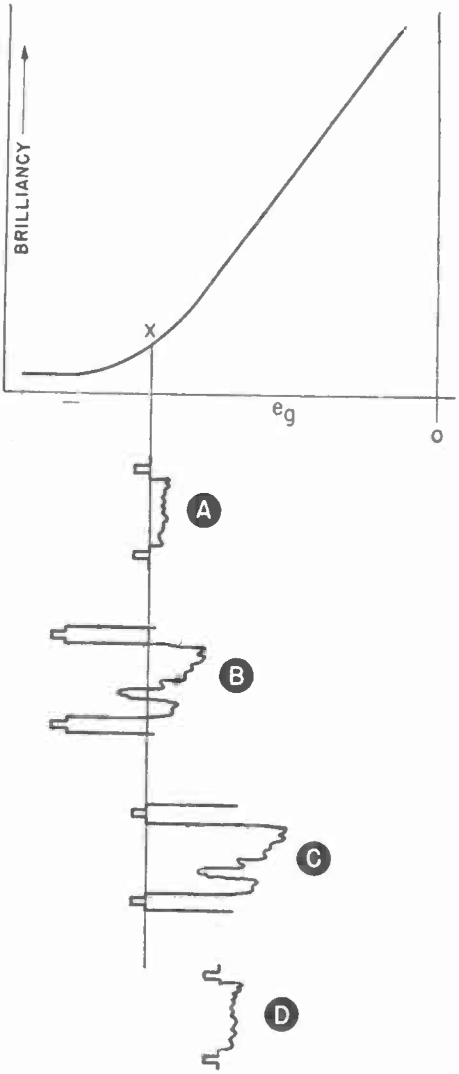


FIG. 4. This illustration shows what happens if the pedestals of the a.c. signals are not lined up before they are applied to the grid of the picture tube.

coupled to the grid circuit of the picture tube.

When we get into more stages, however, a number of major problems arise. A high-voltage power supply is required; if it is not furnished, the tubes must operate at reduced voltages, because the total supply voltage needed is the sum of the maximum voltages required for each stage. In the early days of television, this was a real stumbling block because of the tube types available. However, the tubes now used operate at relatively low voltages and do not draw excessive plate currents, so two-stage direct-coupled amplifiers are practical. They are used to a considerable extent, as we shall see later in this Lesson.

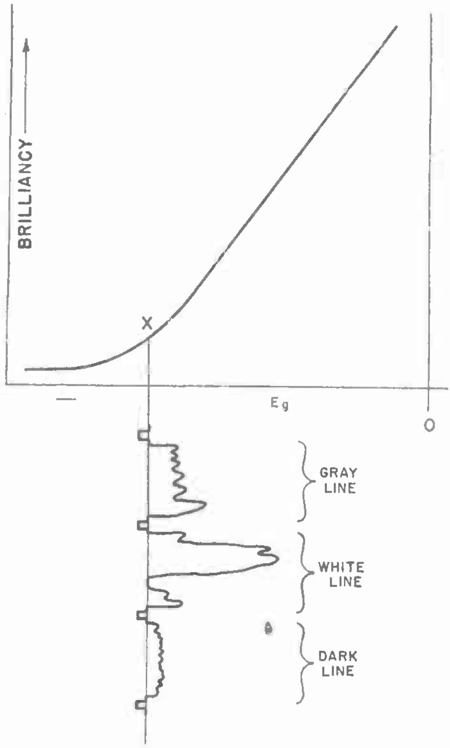


FIG. 5. How the pedestals of a.c. signals should be lined up to produce the proper variation in the relative brightness of the scene reproduced on a picture tube.

With the d.c. amplifier, special precautions must be taken to prevent low-frequency oscillation (corresponding to motorboating in a sound receiver). Also, there is a high cathode-to-heater voltage in the final stage of the d.c. amplifier, which may lead to tube leakage difficulties.

These problems, particularly the one of instability, make a.c. amplifiers quite desirable. Fortunately, we can use a.c. amplifiers even though they do wipe out the d.c. component of the signal, because it is possible to restore the d.c. component, using a circuit known as the d.c. restorer, so that the signal fed to the picture tube grid or cathode will have the pedestals lined up again properly. When this arrangement is used, the video amplifier does not require such extremely high voltages and is in general much more stable. For these reasons, a.c. amplification with d.c. restoration is more common than d.c. amplification. We'll study both types, but first let's go into the distortions that are troublesome in video amplifiers.

Video Signal Distortions

Video signals can be considerably upset by improper phase relationships as well as by frequency and amplitude distortion. Let's review these distortions and learn of the new requirements.

FREQUENCY DISTORTION

As you will recall, frequency distortion occurs whenever an amplifier does not amplify equally all the frequencies in the desired pass band. An amplifier that is defective in this respect may amplify some frequencies more than is desired and some less, or may not pass some frequencies at all.

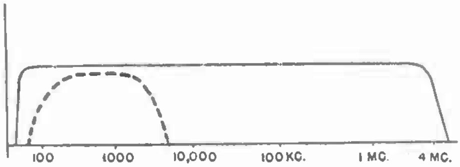


FIG. 6. The solid line shows the frequency response that the video section of a TV set should have; the dotted line shows the response of the average audio amplifier.

Fig. 6 shows the frequency response that the video section of a TV set should have. (Compare this with the frequency response of the average audio amplifier, shown by the dotted line.) It is not absolutely necessary that the response of the video amplifier alone be as flat as this. If there is a loss of high frequencies in the video i.f., for example, it can be compensated for by having a peaked response at these frequencies in the video amplifier. Similarly, any peaking in the r.f. or i.f. sections can be compensated for by a reduced response in the video amplifier at the appropriate frequencies. Thus, the response of the video amplifier can be adjusted to make up for deficiencies in the responses of preceding sections, thereby creating an approximately flat over-all characteristic for the entire set.

AMPLITUDE DISTORTION

When the wave shape of the output of a radio circuit or device is not exactly proportional to the wave shape of the incoming signal, we have what is known as amplitude distortion. This distortion results in the production of harmonics that were not present in the original signal. Such changes in the shape of the signal are commonly produced by operating an amplifier too near one of the bends of its characteristic; they may also be produced by overloading. Overloading is commonly avoided in television through the use of a gain control in the i.f. amplifier or in one of the video stages. Set designers are always careful to choose operating voltages and loads such that amplitude distortion is not appreciable when a set is operating as it should.

While we are on the subject of amplitude distortion, we might mention intermodulation distortion as well. Intermodulation distortion occurs when two signals are mixed and their beat (sum and difference) frequencies are produced. These sum and difference frequencies are not harmonics, but they are produced by operation over a bent characteristic just as amplitude distortion is. Therefore, intermodulation distortion is low whenever the amplitude distortion is low, and vice versa.

PHASE DISTORTION

Phase distortion exists in all amplifiers—sound as well as video. It is of no particular importance in sound amplifiers, but it is extremely important in video circuits.

Phase shifts occur because there is some reactive component in the circuit. Even in a direct-coupled amplifier, the tube capacities shunting the load introduce a certain amount of phase shift. This comes about because the impedance of the load circuit changes as the frequency of the signal changes. Therefore, in most cases, the amount of phase shift changes as the frequency of the input signal changes.

A phase shift causes the wave form of the signal to be changed because the relative positions of the various components in the signal are changed. For example, in Fig. 7, we are applying to the amplifier an input signal consisting of two components, 1 and 2, with the second having twice the frequency of the first. If there were no phase shift, the components in the output would be in the same phase as are the input components.

If, on the other hand, one frequency gets more of a shift than another, the resultant output wave form will be quite different from the input. In Fig. 7, the output signals show that the higher frequency has been shifted 90° in phase with respect to the lower one.

The resultant of the two input signals is shown in Fig. 8A; the 90° phase shift produces the resultant output shown in Fig. 8B. By comparing the two resultant waves, you will see that the over-all wave form of the output is quite different from that of the input, which means that distortion has been introduced.

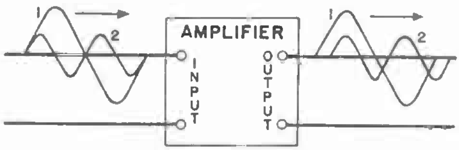


FIG. 7. The phase relationship of the components of a complex wave can be altered by a video amplifier. This causes "phase distortion."

One effect of this distortion is shown by the change it causes in the displacement from the zero line of points on the resultant wave. As you can see, point X in Fig. 8A is at a considerably greater distance from the zero line than is point X in Fig. 8B, although the two occur at the same time in the cycle. Since its displacement from the reference line determines the shade (relative grayness) of a point in a signal, phase distortion is thus capable of changing the shade of various parts of a picture.

At first glance, it might appear that we could avoid difficulty if we could arrange for the same phase delay at all frequencies. However, another factor is involved here—the fact that a phase delay results in a delay in time. Any time delay in the application of a signal to the picture tube will, of course, cause the part of the scene represented by that signal to appear in the wrong place. Hence, a phase shift may not only change the shade of parts of the picture, but may also produce an actual physical distortion by causing some portions of the image to be out of place. The image blurring caused by time delay is even less desirable than changes in shade are, so television circuits are arranged to produce a constant *time* delay rather than a constant phase shift. If all components of the signal are *time* delayed the same amount, the entire picture is shifted slightly to the right or left, which doesn't matter. We get into trouble only when some elements of the picture are shifted more than others.

TIME DELAY

To get an idea of how the phase shift and time delay are related, refer to Fig. 9. In Fig. 9A, we have assumed that we have a 100 cycle-per-second sine-wave signal. If this signal is shifted 90° (one-quarter cycle), as shown by the dotted-line wave, there will be a certain definite delay between the time that the original signal performs some action (such as going through zero) and the time that the phase-shifted signal performs the same action. After it has passed through zero, for example, the original signal will go through a quarter of a cycle before the phase-shifted signal goes through zero. The time delay suffered by the shifted signal is therefore equal to the time duration of a quarter-cycle. Since the time for one cycle of a 100-cycle signal is 1/100 of a second, the time delay caused by a phase shift of one-quarter cycle is 1/400 of a second.

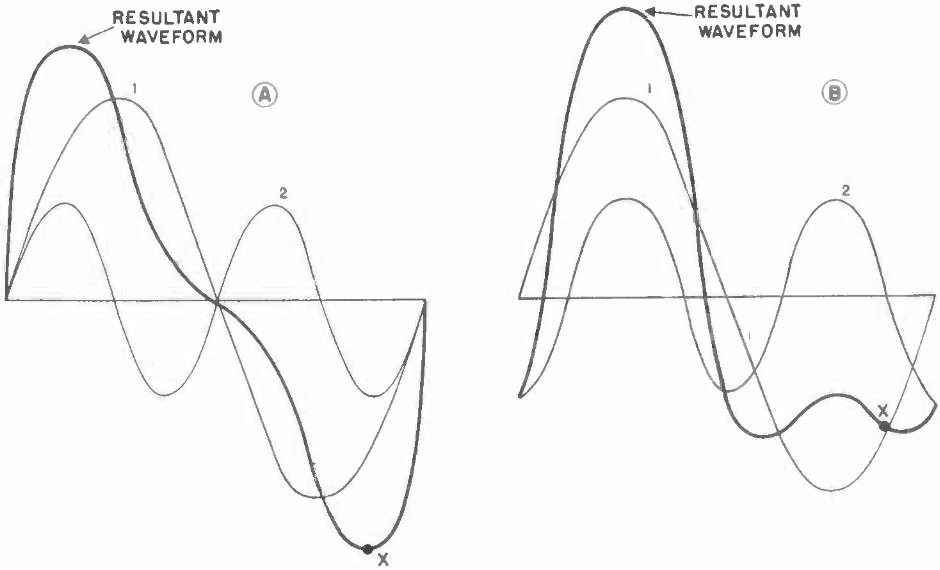


FIG. 8. If two input signals are applied simultaneously to an amplifier, and one is shifted more in phase than the other is, the resultant waveform of the output (B) will be quite different from the resultant waveform of the input (A).

Now let's see what happens with a 200-cycle signal. As shown in Fig. 9B, the time for one cycle is 1/200 of a second, so the time delay for a phase shift of one quarter cycle would be

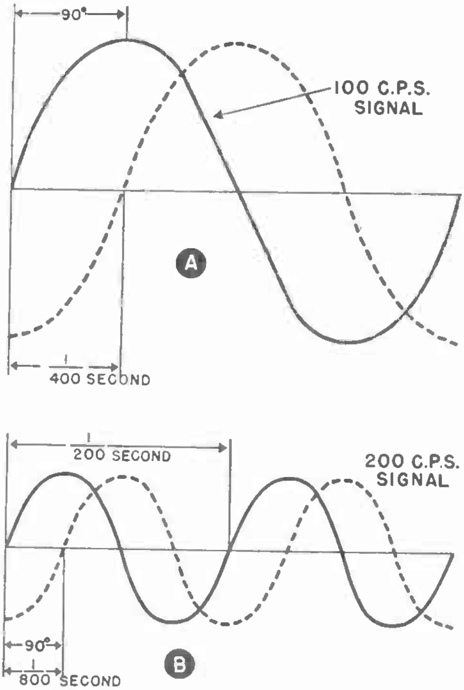


FIG. 9. How phase shift and time delay are related.

1/800 of a second. Thus we see that the *time delay* for a phase shift of 90° at 200 cycles is one-half as long as the time delay caused by the same amount of phase shift at 100 cycles. Therefore, if phase-shifted signals of various frequencies are to undergo a *constant time* delay, the amount of phase shift must increase as the frequency increases. In other words, the phase shift must vary linearly with frequency.

As an example, if an amplifier has a phase shift of 6° at 500 cycles, it must have a 60° phase shift at 5000 cycles and only a .6° phase shift at 50 cycles if it is not to produce time-delay distortion of the amplifier signal. The formula that shows the relation between time delay (t) and phase shift (θ) is:

$$t = \frac{\theta}{360\,f}$$

where t is in seconds, f is in cycles per second, and θ is in degrees.

We will give a somewhat better idea of the effects of time delay later, when we consider the effects of such delay at low and at high frequencies. (Incidentally, this really should be called a time shift rather than a time delay, because it is possible for there to be speeding up or advance in time of some components, however, since it is customary to refer to it as "time delay," we shall use that form too.) Let's now turn to a.c. amplifiers to learn of their characteristics, then go on to d.c. amplifiers.

Fundamental A.C. Video Stages

Let's start our study of a.c. video stages by reviewing the resistance-capacitance-coupled amplifier shown in Fig. 10, which is much like the audio amplifier with which you are familiar. Briefly, you will recall that the gain of the VT_1 stage depends on

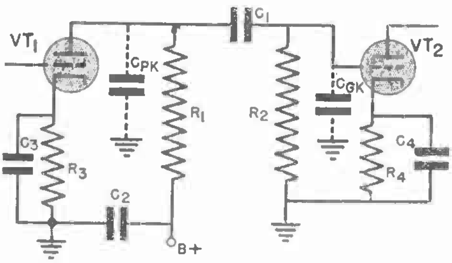


FIG. 10. A fundamental resistance-coupled amplifier.

the amplification factor of the tube and on the load used with that tube. At middle frequencies in the pass band, the load is the parallel combination of resistors R_1 and R_2. If R_2 is fairly high in value compared to R_1, the load is approximately the value of R_1 alone.

If such a stage contained no reactive components, its frequency response would be flat from zero to infinity. This is shown by the horizontal line in Fig. 11. As a matter of fact, however, the frequency response of an amplifier of this kind rolls off in both the low- and the high-frequency regions, as indicated by the dotted lines in Fig. 11. The fall-off in the response at the low-frequency end, in the region marked X, is chiefly caused by the coupling condenser C_1 in Fig. 10, which acts as a voltage divider with R_2. As the frequency decreases, the reactance of C_1 increases, and less signal appears across R_2 for application to the next tube.

The low-frequency response is further reduced by the cathode by-pass condensers C_3 and C_4 in Fig. 10, because their reactances rise so much at low frequencies that they are not effective by-pass condensers, with the result that degeneration occurs.

At the high frequencies, the response falls off because the load is shunted by the output capacity of VT_1 (marked C_{PK} in Fig. 10), by the input capacity of VT_2 (marked C_{GK} in Fig. 10), and by such distributed capacities as exist from the plate and grid wires and from C_1 to chassis. The reactances of these capacities fall as the frequency increases, so they shunt the load at high frequencies. This reduction in the net load causes the high-frequency roll-off marked Y in Fig. 11.

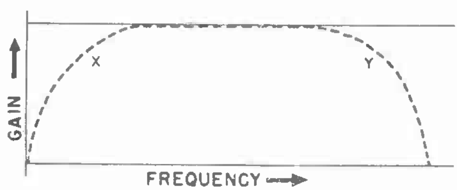
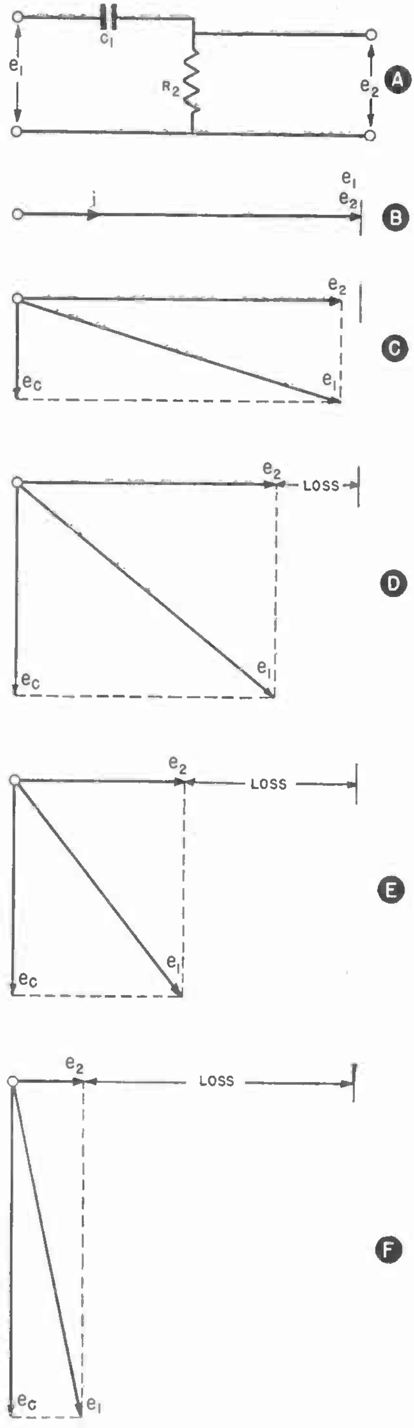


FIG. 11. The frequency response of a simple R-C amplifier rolls off at both the low and the high frequencies.

Thus, we have two different problems—we have to extend the low-frequency roll-off so that the gain will be reasonably high at the lowest frequency we want, which is around 10 cycles in the case of the video amplifier, and we must also keep up the high-frequency response out to about 4 megacycles. Let's investigate both these problems.



LOW-FREQUENCY RESPONSE

As we just mentioned, the primary reason for the roll-off in the low-frequency response is that the coupling condenser and the following grid resistor form a capacity voltage divider. The action is brought out more clearly in Fig. 12. When we apply the voltage e_1 (from the load for VT_1) to the combination shown in Fig. 12A, a current will flow through C_1 and R_2; the current through R_2 produces the voltage drop e_2, which is the grid voltage for the following stage.

When the frequency is so high that the capacitive reactance of C_1 is negligible with respect to the value of R_2, e_1 and e_2 are equal, as shown in Fig. 12B.

As the frequency decreases, however, the reactance of C_1 increases. As it becomes larger, the current flow through the series circuit of C_1 and R_2 causes an increasing voltage drop e_C across the condenser. The same current flows through both C_1 and R_2, but the voltage drop across R_2 is in phase with the current, whereas that across C_1 is 90° out of phase with the current and lags behind it. Hence, as shown in C, D, E, and F of Fig. 12, when the drop e_C increases, the voltages e_1 and e_2 are pulled out of phase, and e_2 decreases. Eventually, at very low frequencies, the reactance of C_1 becomes so high that practically all the voltage e_1 is dropped across the condenser, and there is virtually none left as e_2. Therefore, this voltage divider reduces the output at low frequencies. In addition, as you can see from Fig. 12, the phase difference between e_2 and e_1 increases as the fre-

FIG. 12. These vector diagrams show why a roll-off occurs in the low-frequency response of an R-C amplifier.

quency decreases, eventually reaching approximately 90° at the low-frequency extreme of the frequency range.

The amount of this phase shift is very important. If it is as much as 45° or 1/8 of a cycle at 10 cycles, the time delay will be 1/80 of a second or .0125 second. This is 12,500 microseconds, which is almost equal to the time it takes to scan an entire field! Obviously, the phase shift must be kept very small if the amplifier is to handle very low frequencies.

Another way of looking at this action is to consider it as a time-constant problem. Let's suppose we have a scene like that shown in Fig. 13A. At the condenser becomes charged, however, the current flow into it decreases, so the voltage across R gradually drops, producing a sloping top on what should be a square wave. When the voltage suddenly changes to the black level, the signal produced by the current flow through R goes to the black level at first, but the charging of the condenser produces a sloping bottom on what should be a square wave. When this signal is applied to the picture tube, the highest swing at the bright level will produce a white background, but since the voltage does not maintain this level but gradually fades off into the gray region, the picture will gradually get gray as the

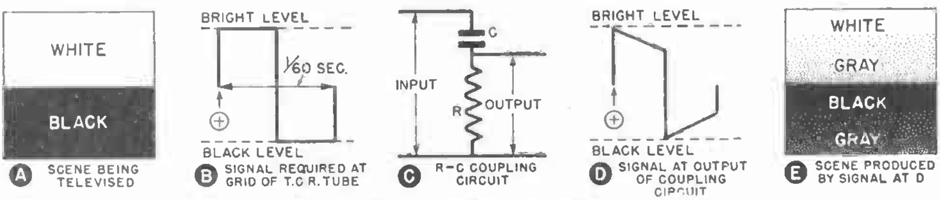


FIG. 13. These diagrams shown how an R-C coupling circuit produces background distortion. A long time constant for the coupling circuit minimizes the distortion.

the top of the picture, the signal voltage should rise to the white level. It should remain there until the middle of the picture is reached, when it should instantly shift to the black level, remaining there until the end of the picture. Hence, the signal applied to the grid of the picture should be like that shown in Fig. 13B.

If this signal is fed through an R-C coupling circuit like that in Fig. 13C, the signal at the output of this circuit will be like that shown in Fig. 13D if the time constant of the circuit is too short. At the instant the voltage changes from zero to the bright level, maximum current flows through R. As center of the screen is approached. At the center, the signal will suddenly produce a black picture, but this will become gray towards the bottom of the picture.

It would appear that we could prevent this graying of the whites and blacks by increasing the time constant of the coupling network—that is, by using large values of C and R so that it would take longer for the condenser to charge. This would keep the output more nearly constant by reducing the amount of slope in the top of the wave.

By increasing the values of either R_2 or C_1 in Fig. 10, we can keep the output more nearly constant and also reduce the phase distortion that occurs in such a coupling. However, there are practical limits to the values that may be used. If the resistor R_2 has too high a resistance, gas in VT_2 may cause difficulties; this resistor is in the grid circuit of VT_2, and a high resistance develops an unwanted positive "bias" when even small amounts of gas current flow through it. Increasing the value of condenser C_1 may also cause trouble, because this increases the capacity between the condenser and ground and therefore reduces the high-frequency response, as we shall show later. Furthermore, high-capacity condensers are likely to have relatively high leakage, which may upset the C bias in the following stage. Finally, and perhaps most important, making the time constant of the coupling circuit too long will make it impossible for the following stage to recover from transient voltages quickly, with the result that sharp changes in voltage may cause motorboating.

Because the use of a long time constant has so many drawbacks, designers use other methods to compensate for low- and high-frequency roll-off.

Low - Frequency Compensation. Fig. 14 shows the low-frequency compensating arrangement that is normally used in video amplifiers. This consists essentially of the by-pass condenser C_2 and the resistor R_5. At first glance, this looks like an ordinary decoupling network, and in fact it acts like one at the medium and high frequencies. By-pass condenser C_2 offers negligible impedance at high frequencies, so it prevents signals from getting either into or out of the VT_1 stage through the B+ lead.

The value of C_2 is chosen, however, so that it is somewhat smaller than it would be in a sound receiver, with the result that it becomes part of the load at medium-low frequencies. In other words, at these frequencies, the load for VT_1 is made up of R_1 and C_2, since this condenser completes the a.c. plate circuit back to the cathode. The voltage developed across both R_1 and C_2 is applied to C_1-R_2. Effectively, therefore, we have a circuit in which the load increases in impedance as the frequency decreases. As a result, the voltage applied to C_1-R_2 increases as the frequency decreases, which makes up for the increased voltage drop across C_1.

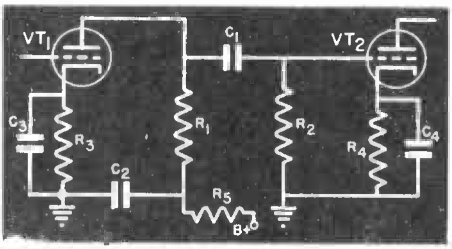


FIG. 14. A circuit that is often used for low-frequency compensation.

Fortunately, this also compensates for the phase shift that we described earlier. The capacitive reactance of C_2 causes a phase shift in the source voltage for the C_1-R_2 divider of such a nature that the voltage at the grid of VT_2 is kept in nearly the proper phase.

The resistor R_5 is needed to make C_2 become part of the load. The value of R_5 should be as high as possible; if it is made too high, however, there will be too great a drop in the B supply voltage. Therefore, in most practical circuits of this kind, R_5 has a resistance about 20 times as great as the reactance of C_2 at the lowest frequency the circuit is designed to pass.

If the C_1-R_2 phase shift were the only shift of importance, it could be removed by making the time constant of R_1 and C_2 equal to that of C_1 and R_2 (the time constant $R \times C$). However, you won't always find these two products equal in practical circuits, because there may be other phase shifts that must be compensated for. For example, the cathode by-pass condenser C_3 is supposed to prevent degeneration at all frequencies. However, at very low frequencies, the reactance of even a very high capacity will be appreciable in comparison to the low resistance it by-passes. Hence, there will be a certain amount of degeneration in the VT_1 stage in Fig. 14 at low frequencies, reducing the gain of the stage at those frequencies. Some of this effect can be compensated for by the C_2-R_5 combination, because the increase in the load will counteract the drop in gain.

Although we have shown triodes, pentodes are quite commonly used in video amplifiers because of their greater gain. The screen-grid circuit of a pentode introduces a low-frequency drop, because the screen-grid by-pass condenser is not large enough to be a completely effective by-pass at these low frequencies. This drop must also be compensated for by the C_2-R_5 combination.

The values used for C_2 and R_5 therefore have a considerable effect on the low-frequency response of the video amplifier. In replacing these parts, it is important to use exact duplicates to avoid upsetting the compensation.

More low-frequency compensation can be obtained, if desired, by allowing more of the vestigial side band to pass through the r.f.-i.f. sections. This will cause the output of the video detector to be higher in the low-frequency region.

HIGH-FREQUENCY RESPONSE

At the higher frequencies, ranging from about 15,000 cycles to 4 megacycles, compensation is absolutely necessary if we are to obtain a reasonable response. As a matter of fact, most engineers consider it more important to get the high-frequency response ironed out than to compensate the low-frequency response. Although it is true that the background brilliancy may be disturbed if the low-frequency response is poor, the *detail* in the picture is determined by the high-frequency response.

The low-frequency response is dependent on three items (the coupling condenser, the cathode by-pass condenser, and the screen-grid by-pass condenser), but the response at the high frequencies is dependent primarily only on the capacity that is in shunt with the load. In other words, the parts that cause the low-frequency roll-off play no part in causing the high-frequency roll-off, because the condensers involved have such low reactances at high frequencies that they act as short circuits and introduce no drop.

Therefore, at high frequencies, the typical circuits shown in Figs. 10 and 14 can be resolved into the equivalent circuit shown in Fig. 15. Here, the load resistance R_1, the grid resistance R_2, and the shunting capacities are all in parallel and make up the net load. The capacity we have marked as C_{PK} represents not only the plate-cathode capacity of VT_1 but also the stray capacities to the chassis of the load resistor and of the tube socket. The capacity C_{GK} represents not only the

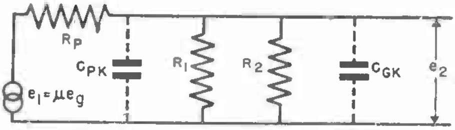


FIG. 15. The equivalent circuit of an R-C amplifier at high video frequencies.

input capacity of the following tube but also the stray capacities to the chassis of the grid resistor and of the coupling condenser.

If we combine the parallel resistors and the parallel capacities, we get the equivalent circuit shown in Fig. 16. You can see that, as the reactance of the capacity decreases, the net impedance of the parallel combination of C and R will drop. This means that more and more of the source voltage e_1 will be dropped in the plate resist-

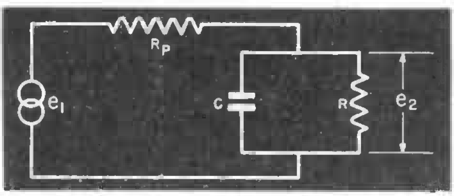


FIG. 16. The circuit in Fig. 15 can be simplified to this form.

ance R_P of tube VT_1. Hence, the output voltage e_2 will be reduced with increases in frequency.

This variation in the load impedance with frequency also causes phase-shift difficulties. The total plate current must equal the vector sum of the currents through the resistive and capacitive portions of the load; therefore, as the capacitive current increases because of the reduction in reactance, the total current becomes increasingly out of phase with the output voltage e_2. This is the same as saying that the output voltage is becoming increasingly out of phase with the input voltage, because the input voltage and the total current are in phase. Hence, the variation in the load introduces a phase shift.

Since this difficulty is caused by shunting capacities, the most direct remedy is to reduce these capacities as much as possible. Miniature tubes and sockets are used to reduce the

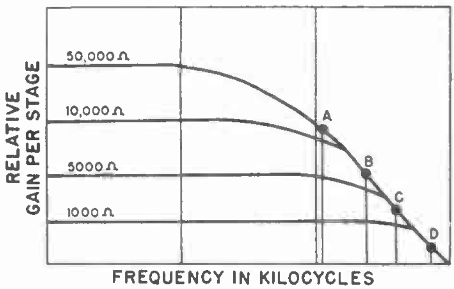


FIG. 17. These curves show that a reduction in the plate-load resistance of an R-C coupled stage improves frequency response at a sacrifice in gain.

tube capacities, and the parts are mounted well away from the chassis to reduce the capacity of the resistors and of the coupling condenser to the chassis. Even when these capacities have been reduced as much as is practical, they are still too high for the very wide frequency range we need.

As Fig. 17 shows, it is possible to reduce the effects of these shunting capacities further by reducing the plate load resistance. In drawing this figure, we assume that the shunting capacities had the same value in each case. (The actual point at which the curves begin to slope will, of course, depend on what the capacity is. The larger the capacity, the lower the frequency at which the roll-off will occur. In general, however, the curves will have the same shape regardless of capacity.)

You will recall from your studies of wide-band amplifiers that the pass band is considered to extend out to the point where the relative gain is about 70% of the maximum gain. If we follow this principle in examining the curves in Fig. 17, we find that the pass band extends to point A when the load is 50,000 ohms. When the load is reduced to 10,000 ohms, the response extends to point B; reducing it to 5000 ohms extends the response to C; and reducing it to 1000 ohms extends the response to point D. In other words, reducing the load gives an increasingly wider pass band, because the response is extended toward the high-frequency end of the band.

As you can see, however, this extension of the pass band is accompanied by a reduction in gain at all the other frequencies. There is, therefore, a definite limit to how far we can reduce the load impedance. Even though we use tubes of high mutual conductance, the load resistance must be kept at a reasonable value so that normal gain can be obtained. The high-frequency response must therefore be extended in other ways. There are two basic methods of doing this; let's study them now.

SHUNT COMPENSATION

One of the basic ways of extending the high-frequency response is shown in Fig. 18. An inductance coil L_1 is added in series with the plate load resistor. This coil increases the high-frequency response because it forms a parallel-resonant circuit with the shunting capacity. This is called "shunt compensation" because the inductance is in shunt (in parallel) with the capacity (represented as C). The coil is selected so that the circuit is made resonant at a frequency at or above the highest picture frequency to be passed. The resulting over-all response of the stage is then the combination of the resonance curve and the normal response curve.

If the capacity remains fixed, the resonant peak can be moved to the right or left by choosing different values for the coil L_1, as shown in Fig. 19. The actual height of the peak

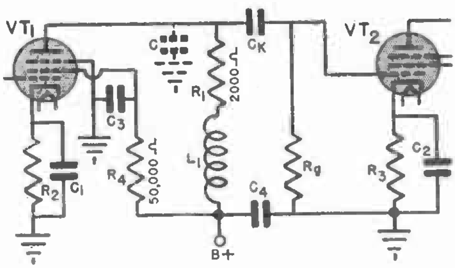


FIG. 18. Coil L_1 in this R-C coupled amplifier provides shunt compensation to offset attenuation of high picture frequencies by C.

depends on the Q; if we increase the Q by increasing the inductance without changing the load resistance, we will get a higher peak at a lower frequency. The choice of the coil therefore depends on the frequency range desired and on whether the compensation should raise the high-frequency response above normal.

Since the effect of such a coil is to give a peak in the response, it is known as a "peaking" coil.

The introduction of the coil to cause resonance at the higher-frequency end of the pass band tends to reduce the phase shift. Unfortunately, the values of inductance and load resistance that give the best phase characteristics are not the ones that give the best peak output, so a compromise is necessary.

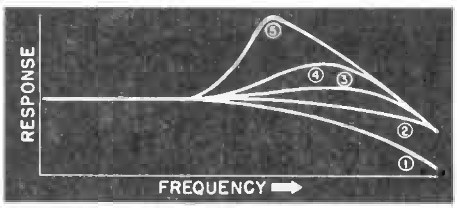


FIG. 19. These curves show how the high-frequency response of the amplifier shown in Fig. 18 depends upon the Q of coil L_1. Curve 1 shows the effect of a low-Q coil. Curve 5 the effect of a high-Q coil; the other curves show the effect of intermediate values of Q.

SERIES COMPENSATION

Another system of compensating for the roll-off in the high-frequency response is to install an inductance in the position occupied by L_1 in Fig. 20. This system is known as "series compensation," because the coil is in series with the signal path.

The effect of this inductance is to split the shunting capacity in half. That is, the output capacity of VT_1, represented as C_A, and the input capacity of VT_2 (C_B) are separated by coil L_1. (Insofar as R_1 is concerned, therefore, it is now shunted only by C_A.) These two shunting capacities and L_1 now form a low-pass filter of such a nature that all frequencies are passed that are below the frequency at which L_1 and C_B become series resonant; above this point, however, the frequency response is cut off sharply.

Since R_1 is now shunted by a much smaller condenser than the one that shunted it before L_1 was installed, the frequency response is extended considerably. As a matter of fact, the characteristics of the filter are such that it is superior to shunt compensation with respect to frequency response, minimum phase shift, and output.

The exact response obtainable with series peaking depends on where coil L_1 is located. As shown in Fig. 21, there are three possible positions for coil L_1. In Fig. 21A, it is located between the load resistor and the coupling condenser, a position that makes the capacity C_B include that between the coupling condenser and ground.

In Fig. 21B, the coil is on the other

side of C_1; now the C_1-to-chassis capacity is part of C_A.

In Fig. 21C, the coil is located between the plate of tube VT_1 and the entire coupling network. Now the capacity C_A is just that of the tube VT_1, whereas C_B includes all other shunting capacities.

In each of these cases, the position of the coil determines how much capacity C_A has and how much C_B has. Since the relative capacities of these two have a pronounced effect on the action of the filter, it is possible to change the resonant point by changing the position of the coil in the circuit.

You will notice that a resistor R_3 is in parallel with the series peaking coil in each case in Fig. 21. In a shunt compensating circuit, the load resistor controls the Q, but the Q for a series peaking coil is not similarly controlled. Therefore, a resistance is added in parallel with the inductance to adjust the Q properly. As a matter of fact, the coil is made with a resistor as an integral part of the assembly: the coil itself is wound right around

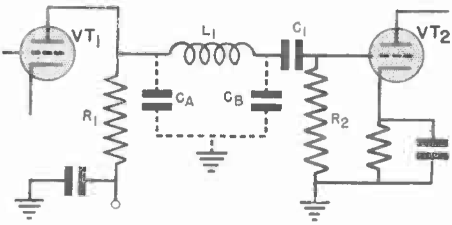


FIG. 20. A series-compensation circuit.

the resistor so that the two form a single unit. This adjustment of the Q affects the response to frequencies near the resonant cut-off frequency.

Since a combination of series and shunt peaking gives better response than either alone, it is very common to find both used together in a circuit like that shown in Fig. 22. Here, shunt peaking coil L_2 is shunted by R_4 to give a lower Q than is provided by R_1. (This is necessary in this par-

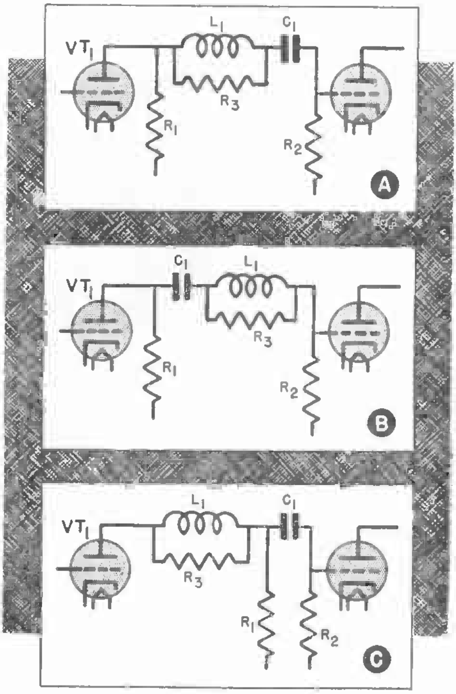


FIG. 21. Three possible positions for the peaking coil in a series compensation circuit.

ticular circuit because the value of R_1 is fixed by other requirements at a resistance that is too small to give the Q desired.) The combination C_2-R_5 gives low-frequency compensation in this stage also.

One stage usually cannot give all the compensation needed, so, to even out the response, it is fairly common to use more than one stage of amplification and to equalize them differently. Thus, you may find two triode stages used to get this equalization, even though the net amplification is no more than could be obtained from a single pentode stage.

Summing up for a.c. amplifiers—one to three stages of resistance-capacitance coupled amplifiers are used in modern sets. Several forms of low- and high-frequency compensation are used with these amplifiers to extend the frequency range and remove frequency and phase distortion as much as possible.

The use of coupling condensers provides an advantage in that it makes each stage independent of all others in its operating potentials. Bias voltages can be fixed in each stage independently. However, coupling condensers affect the low-frequency response and remove the d.c. component of the video signal. Since, as we showed in Figs. 4 and 5, it is necessary to have this d.c. component of the video signal, we must either use d.c. amplification or restore the d.c. component if we are to get the pedestals lined up again so that the circuit will respond properly to any changes that may occur in the background illumination.

Let's first see how the d.c. amplifier differs from the a.c. form, before we study the restorers.

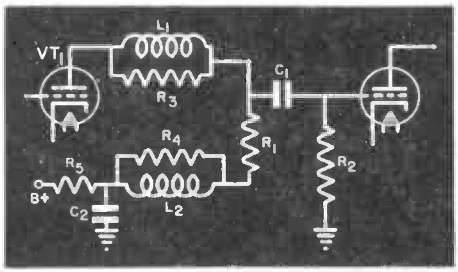


FIG. 22. A combined shunt-peaking and series-peaking coupling circuit. Coil L_1 is the series-peaking coil; coil L_2 is the shunt-peaking coil.

Fundamental D.C. Amplifier

Basically, a d.c. amplifier is one that does not contain blocking condensers or transformers. (The "d.c." in this name can mean either "direct-current" or "direct-coupled"; both names are applied to this amplifier.) This makes it possible to pass along the d.c. component of the signal as well as the a.c. component.

The d.c. component acts throughout a d.c. amplifier as a variable bias that accompanies the signal and arranges the operating points of the amplifier so that the pedestals in the signals will be lined up regardless of the average brightness or darkness of the particular scenes.

Fig. 23 shows a basic circuit of this kind. Here, tube VT_1 is the video detector, which is fed from the i.f. coil L_1. Its load resistor R_1 has the shunt peaking coil L_2 in series with it to increase the high-frequency response. Notice that the control grid of VT_2 is directly connected to this load; no coupling condenser is used. Hence, the d.c. level of the signal is passed right on to tube VT_2. That is, the d.c. drop across R_1 acts as a variable bias that follows the signal brightness level. This bias is applied to VT_2 and causes its operating point to shift as the brightness changes.

You will observe that the plate circuit of tube VT_2 contains the series-peaking coil L_3 shunted by R_6, and that its load resistor R_7 has L_4 as a shunt-peaking coil in series with it. R_8 and C_5 provide a low-frequency compensation as in other circuits we have studied.

The control grid of the picture tube is connected directly to the plate end of the load for VT_2; again, there is no intervening coupling condenser. The picture tube cathode is connected to the chassis by condenser C_6, so the a.c. signal across the L_4-R_7-C_5 load is applied between the grid and cathode of the picture tube. There is also a path from the grid to the cathode (through L_4, R_7, and R_8) across which is developed a d.c. that varies as the

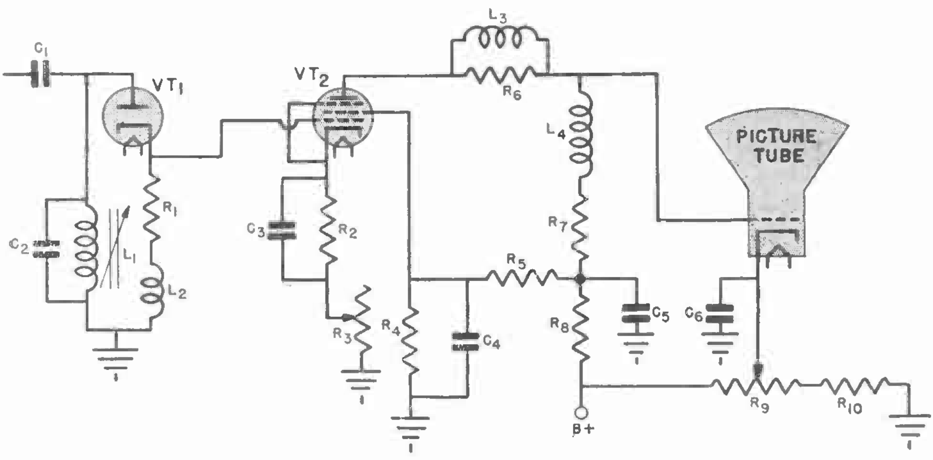


FIG. 23. A basic d.c. amplifier.

brightness changes. Therefore, both the d.c. and a.c. components of the signal are applied to the picture tube, with the result that the pedestals stay lined up.

The absence of coupling condensers removes one of the factors that can cause a low-frequency roll-off, but we still have the cathode circuit of VT_2 to worry about, plus the fact that the over-all design may be such that the low-frequency response is limited. Therefore, although low-frequency compensation is not as necessary in the direct-coupled amplifier as it is in an a.c. amplifier, a certain amount of this compensation may be needed.

not be sufficient high-frequency compensation. For these two reasons, it is sometimes necessary to use a two-stage direct-coupled amplifier.

At once we run into a supply voltage problem. Since the stages are directly coupled, the plate supply of the first stage affects the bias of the second, and the plate supply of the second must be higher than that of the first to get normal operation. Let's run through this problem before studying a typical two-stage amplifier.

Power Supply. Fig. 24 shows an elementary two-stage direct-coupled amplifier. Let's assume that the voltages marked on the diagram are those

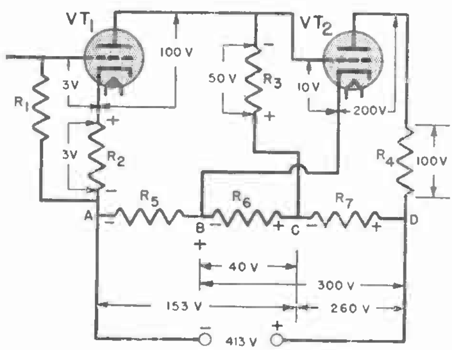


FIG. 24. The power-supply arrangement used for a basic two-stage d.c. amplifier.

TWO-STAGE AMPLIFIER

The single-stage direct-coupled amplifier in Fig. 23 has several factors to recommend it. We do not need voltages as high as are needed in multi-stage d.c. amplifiers, and the likelihood of motorboating is not great in a single stage. Further, there is no need for d.c. restoration, since the d.c. component of the signal is kept throughout.

The only things wrong with the circuit are the facts that there might not be enough gain and that there might

we require for operation. That is, tube VT_1 requires a 3-volt bias for 100 volts on the plate. The normal VT_1 plate current through load resistor R_3 causes a 50-volt drop. Therefore, the total supply for this tube is 50 + 100 + 3 or 153 volts. This is obtained from the voltage divider between terminals A and C.

For tube VT_2, we need a 10-volt bias and 200 volts on the plate, and the plate current causes a 100-volt drop in the load R_4. First, we have to get the 10-volt bias. We have a 50-

volt drop in R_3, which has the right polarity but is 40 volts too much. Therefore, the cathode of VT_2 must be returned to point B on the voltage divider so that it will be 40 volts *negative* with respect to point C. Then, the 40 volts developed across R_6 will be opposed by the 50 volts across R_3 with the result that the difference of 10 volts will appear as the bias for tube VT_2.

Next, we require a total of 300 volts between the cathode and B+ for this tube (200 volts for the plate plus 100 volts that is dropped across R_4). Hence, 300 volts must be developed between point B and point D of the voltage divider. Since there is a 40-volt drop between B and C, a voltage of 260 volts is needed across R_7. The total voltage must therefore be 260 plus 153 or 413 volts. Notice that this direct coupling of two stages makes it necessary to have a high B voltage available even though the plate voltages needed are quite ordinary.

Typical Circuit. A typical two-stage d.c. amplifier circuit is shown in Fig. 25. We can break down the supply circuits of this amplifier into the basic elements shown in Fig. 26. The total supply here is 215 plus 120 or 335 volts. We can analyze this circuit in much the same way as the circuit of Fig. 24 by noticing that the voltages are all measured with respect to ground.

The cathode of VT_2 is tied through R_5 and R_1 to a point that is at —120 volts with respect to ground. There is a 3-volt drop across R_5, which becomes the bias for the grid of VT_2, since the grid returns to this point through R_3.

The plate current of tube VT_2 flows through R_{10} and R_9 to the +215-volt terminal of the power supply. In addition, R_{11} acts as a bleeder to cause additional current to flow through R_9. The total drop across R_9 is therefore more than 215 volts; it is actually 225 volts, which makes the junction of R_9 and R_{11} be at a potential of —10 volts with respect to ground. There is an additional 9 volts across R_{10}, so the plate of VT_2 is —19 volts and its cathode is —117 volts with respect to ground. The plate voltage is the difference between the two, or 98 volts. Although both the plate and the cathode are negative with respect to ground, the cathode is more negative than the plate, which means that the plate is positive with respect to the cathode, as is required.

The bias needed for tube VT_3 is about 4 volts. The grid of this tube is at a potential of —10 volts with respect to ground, because it is connected to the junction of R_9 and R_{11}. To produce the proper bias, the cathode of VT_3 is tied to a terminal that is —6 volts with respect to ground.

The plate voltage needed for VT_3 is about 134 volts, and there is a drop of 81 volts in its load resistor. The total supply needed for VT_3 is therefore 6 + 134 + 81 or 221 volts. The total B supply is 120 + 215 or 335 volts.

As you can see, high power-supply voltages are required for multi-stage direct-coupled amplifiers — so high that practically all circuits use only one or two stages. Occasionally three stages are used, but any more than this would be impractical because of the excessively high voltages that would be needed.

Signal Operation. Returning now to Fig. 25, we can analyze the circuit in regard to its operation on the signal. Tube VT_1, the video detector,

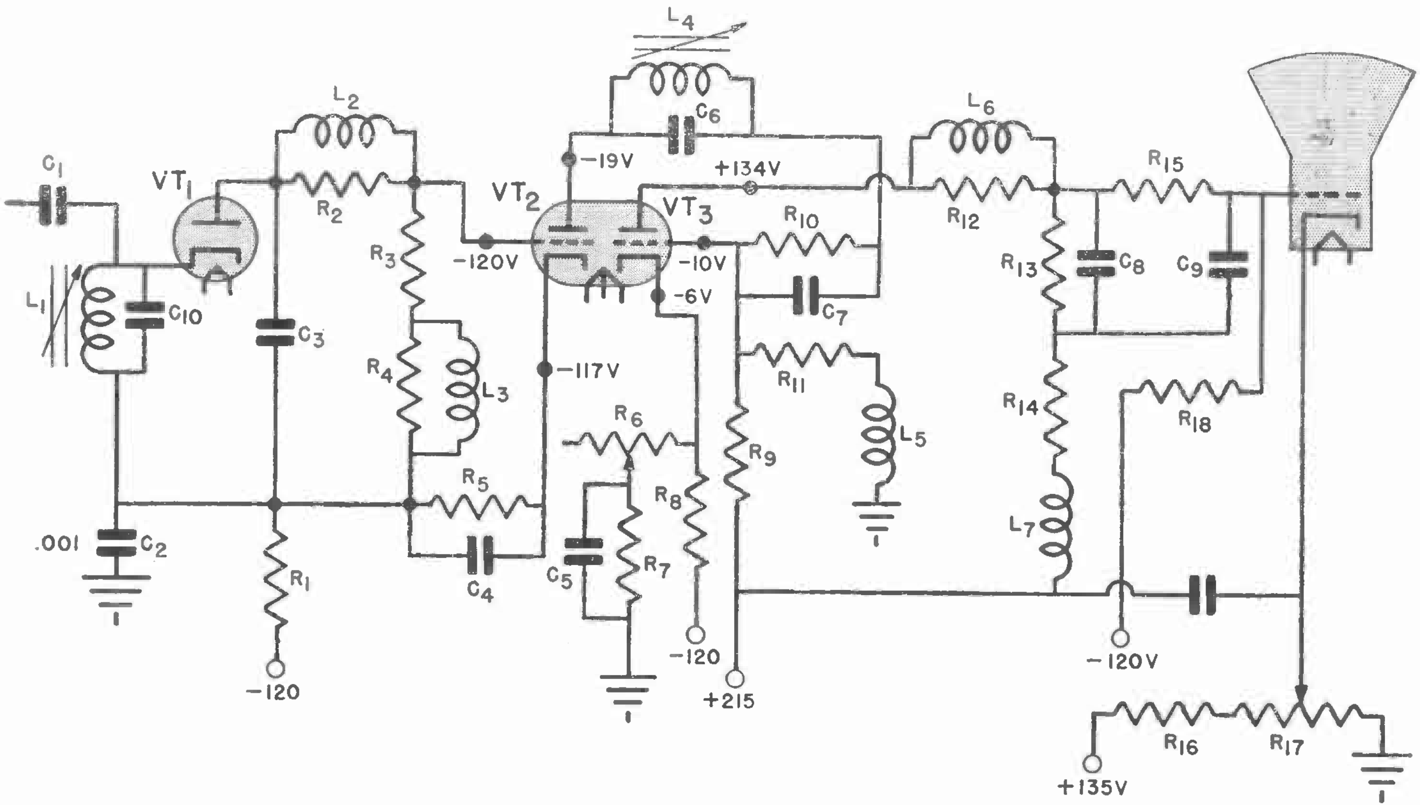


FIG. 25. The schematic diagram of a typical two-stage d.c. amplifier.

feeds into load R_3, shunt compensating coil L_3, and series compensating coil L_2. The signal from this stage is fed directly to the grid of VT_2.

In the plate circuit of VT_2 are a coil L_4 and condenser C_6 that together form a 4.5-megacycle trap. This trap, which is called a "grain" trap, eliminates whatever beat there may be between the sound and video carrier signals; such a beat, if not removed, would cause a fine-grained dot pattern on the picture.

The plate of VT_2 is directly coupled through R_{10} to the grid of VT_3, and the plate of VT_3 is in turn directly connected through its load and a filtering circuit to the grid of the picture tube. Effectively, R_{15}, C_8, and C_9 form a low-pass filter that tends to eliminate components that are higher in frequency than the desired signal.

Although triode tubes are shown in this circuit, pentodes might equally well have been used. Also, separate tubes might have been used instead of the dual triode shown here. Such minor changes could be introduced without making any basic modification of the circuit.

From what we have said, you can see that the direct-coupled amplifier works much like an a.c. amplifier. Its advantages are that the d.c. component of the signal is not removed and that the elimination of coupling condensers helps to maintain a good low-frequency response.

Its disadvantages are that a high operating voltage is needed and that the very good low-frequency response makes motorboating likely to occur. Motorboating may result from the fact that any slow supply-voltage

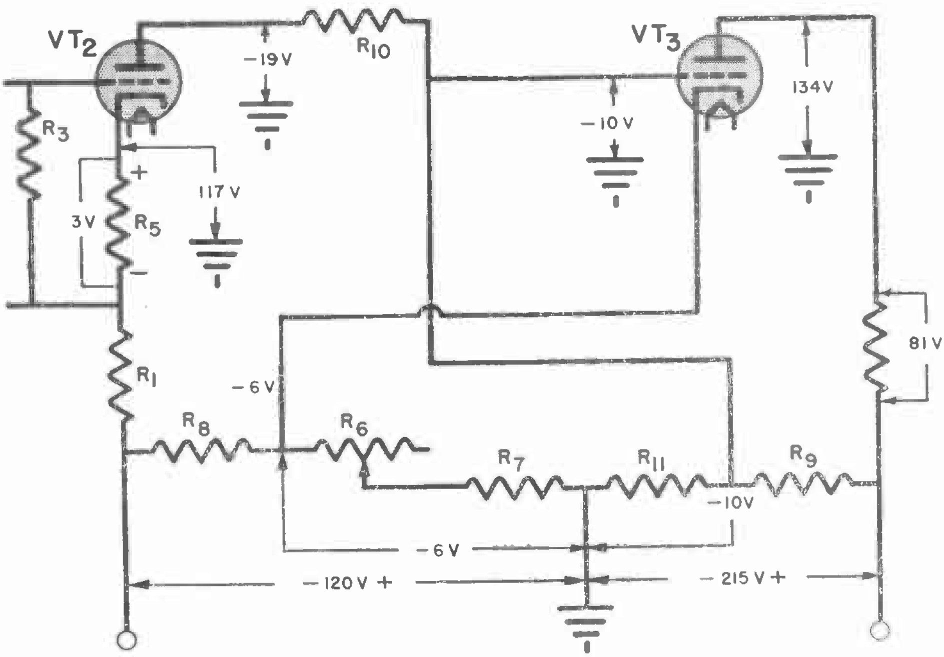


FIG. 26. The power-supply circuits of the amplifier shown in Fig. 25 can be drawn in this form to make it easier to understand the requirements the supply must meet.

change in the first tube will affect the bias on the second, causing a plate current change in the second tube that will aid the change in the first tube. For example, suppose the plate current of the first tube drops. This will reduce the bias on the second tube; its plate current will consequently increase, causing a greater drop in the power supply. This drop will reduce the plate voltage on the first tube decreasing its plate current further and thus continuing the action of decreasing the bias and increasing the current in the second tube. An opposite series of actions will occur if the plate current of the first tube increases. Once this action starts, the circuit is likely to go into oscillation or to motorboat, because the plate current of the second tube can be driven between saturation and zero alternately.

To prevent this from happening, the power supply must be carefully designed to have good regulation. This means it must have low internal resistance and use high-capacity condensers, which makes it more expensive to build.

The a.c. amplifier does not have these two disadvantages, and d.c. restoration will give back the d.c. level. Before we go on to d.c. restorers, however, let's learn more about brilliancy and contrast controls.

BRILLIANCY CONTROL

The picture tube must have an initial bias that will set its operation at the proper point on the brilliancy-grid voltage curve. The operating point is set at the point of greatest curvature, as at point X in Fig. 27A. This point then represents the "black" level at which the pedestals line up; the video signal swings the grid toward zero to give increases in brilliancy, and the sync signals make it more negative so that the screen is blanked completely during the sweep retraces.

Let us momentarily assume that we can couple the signal to the picture

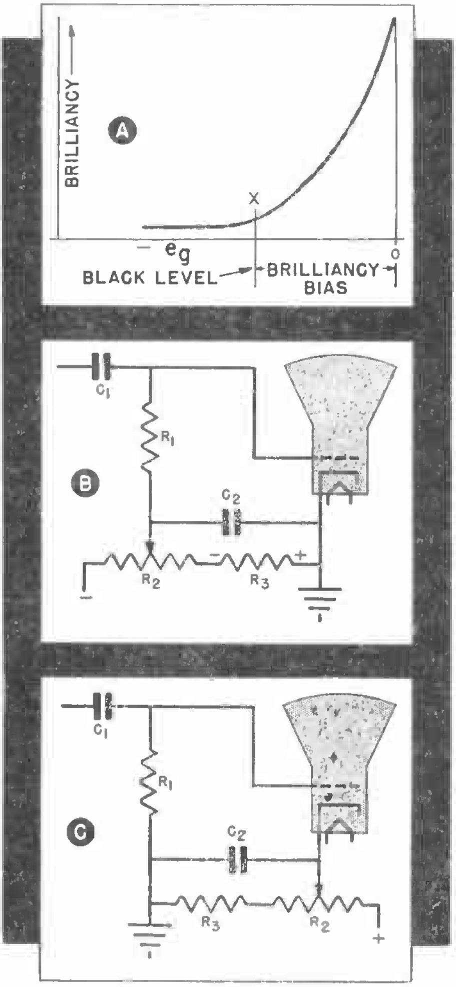


FIG. 27. Basic methods used in a.c. amplifiers for setting the operating point of the picture tube at the desired point on the tube characteristic (A) are shown in (B) and (C).

tube through a coupling condenser C_1, as shown in Figs. 27B and 27C. The initial brilliancy bias must then be obtained from the power supply. The variable bias control resistor R_2 in both these figures can be used to adjust the bias to cause operation at the proper point on the curve. The fixed resistor R_3 is added to prevent the setting from ever being reduced to zero; this is necessary because the tube might be ruined by the excessive current flow if the bias became zero for very long.

Since any change in the setting of the variable bias control changes the average brilliancy of the scene by moving the "black" level, it is known as the brilliancy control. If the brilliancy control is set so that the bias is not sufficiently negative, the overall picture will be light; the retrace lines can be seen if the control is far enough from the proper setting. If the control is set so that the operating point is too far in the negative direction, the darker portions of the scene will be telescoped together, with the result that some portions that should be gray will be black. On some sets, the brilliancy control is a screw-driver adjustment; on most, however, it is operated by a front-panel knob so that the set owner may adjust the brightness of the picture to a level that suits him.

Of course, a d.c. restorer (which we will study later) would be needed in circuits like those in Figs. 27B and C. However, these are the basic methods used in a.c. amplifiers for getting the initial bias for the picture tube.

The absence of a coupling condenser in a d.c. amplifier means that the drop in the load of the last video stage will

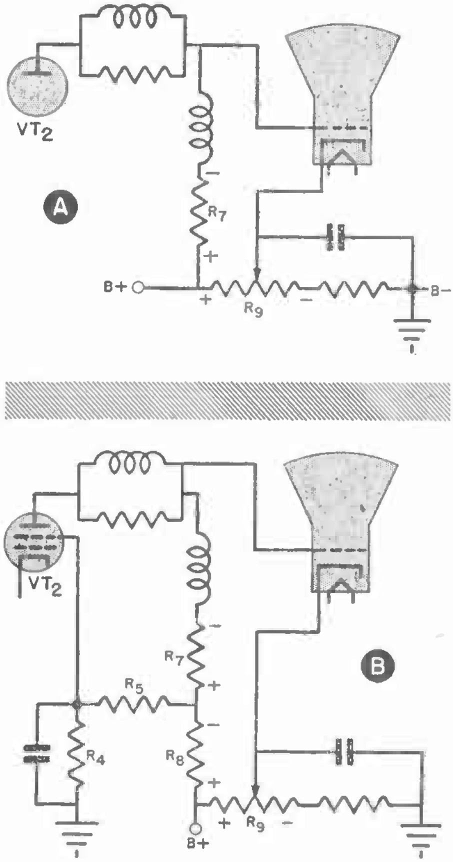


FIG. 28. Two methods of obtaining the initial bias on the picture tube when a d.c. amplifier is used.

affect the bias of the picture tube. Thus, in the direct-coupled system, the inital bias (the bias when no signal is being received) is obtained from the d.c. voltage drop across R_7, as shown in Fig. 28A. The drop across this resistor is determined by the plate current of VT_2; with usual current and load values, this drop is normally more than is wanted.

In the circuits in Figs. 23 and 28, therefore, there is a control in the cathode circuit of the picture tube that makes it possible to apply a bucking voltage that will reduce the bias. When the slider on R_9 is all the way to the left in Fig. 28A, the bias is that across R_7 alone. However, when the slider is moved toward the right, a voltage of opposite polarity is added between the cathode and grid of the picture tube, thus reducing the bias. Resistor R_9 thus acts as the brilliancy control.

The arrangement shown in Fig. 28A has one serious defect. If tube VT_2 ever became defective so that its plate current was cut off, there would be no

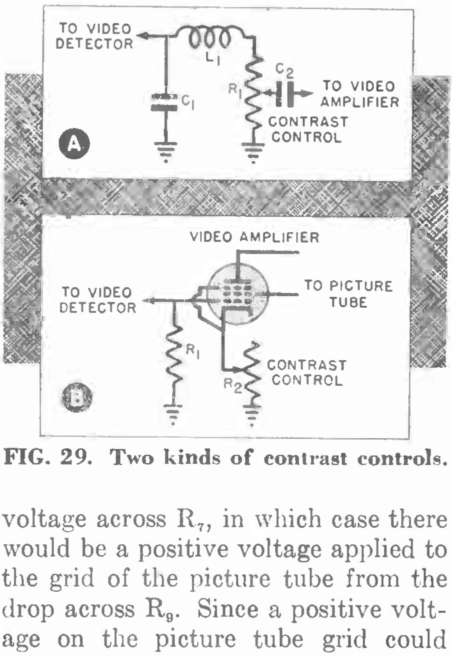


FIG. 29. Two kinds of contrast controls.

voltage across R_7, in which case there would be a positive voltage applied to the grid of the picture tube from the drop across R_9. Since a positive voltage on the picture tube grid could ruin the picture tube, the circuit is sometimes modified as shown in Fig. 28B to prevent such an occurrence. In this latter circuit, a bleeder resistor R_4 draws an additional current through resistors R_8 and R_5. The drop across R_8 is dependent on both the plate current of VT_2 and the size of the bleeder resistor R_4. When the set is operating normally, this drop increases the bias on the picture tube, an effect that is compensated for by adjusting R_9 so that it provides a greater bucking voltage. If the tube VT_2 becomes defective, there will still be a drop across R_8 because of the bleeder current. The values of the various resistors can be so chosen that this drop will keep the grid of the picture tube at a safe voltage.

A basically similar arrangement was shown earlier in Fig. 25. Here, the voltage fixing the initial operating point of the picture tube is determined by the d.c. drop in R_{14} and R_{13} caused by the plate current of VT_3 and also by the voltage division along the path R_{18}, R_{15}, R_{13}, R_{14}, L_7 from the —120-volt to the +215-volt terminal of the power supply. If tube VT_3 should fail for any reason, the drop across R_{13} and R_{14} caused by the flow of its plate current through them would disappear, but the voltage resulting from current flow through the other path would keep the tube safely biased.

In normal operation of the circuit in Fig. 25, the picture tube grid is slightly positive with respect to ground, but its cathode is considerably more positive. As a matter of fact, under normal operating conditions, the grid-to-ground potential is about +14 volts and the cathode-to-ground potential is about +42 volts. The difference represents a bias of approximately —30 volts on the grid. The brilliancy control R_{17} permits adjustment of the cathode potential, so this bias level can be varied.

Service Hint. When d.c. coupling is used, any defect that reduces the plate current of the output video amplifier, or that increases the plate current of the first video stage, will cause a bright screen. Conversely, either an increased plate current in the output video stage or a decreased plate current in the first video stage will reduce the screen brilliancy.

Notice that this applies ONLY to d.c.-coupled video stages. If a.c. coupling is used, the coupling condensers block the d.c. path, so each stage is independent as long as there is no leakage in the coupling condensers. Hence, in a set using a.c. video coupling, changes in video amplifier plate current cannot normally affect the initial brilliancy setting of the picture tube.

CONTRAST CONTROL

The contrast control is basically the "volume" control for the picture signal. When the set does not have a.g.c., the contrast control is always arranged so that the gain of the i.f. and r.f. stages can be varied with it. When a.g.c. is used to control these stages and prevent overloading, the contrast control is in either the a.g.c. circuit or the video amplifier.

In any case, the contrast control is used to increase gain on weak signals and to reduce gain on signals strong enough to overload the set. When used in the video amplifier, it may be either a control used to vary the signal itself (see Fig. 29A) or one used to adjust the gain by varying the operating bias (Fig. 29B). The latter control is favored because it introduces fewer difficulties with the shunting capacities across the control and its terminals.

The contrast control gets its name from its effect on the signal. When the gain of the receiver is increased, the signal is "stretched" so that the contrast range from white to dark is increased. The contrast control is therefore used to adjust the peak voltage value S of the signal, as shown in Figs. 30B and 30C. Thus, with the signal shown in Fig. 30B, we have a certain range from light to dark. If the gain of the set is increased, the value S is increased (Fig. 30C). As you can see, we have the same basic signal form, but its amplitude has increased. If the black level remains the same, the peak value will show up as a whiter signal.

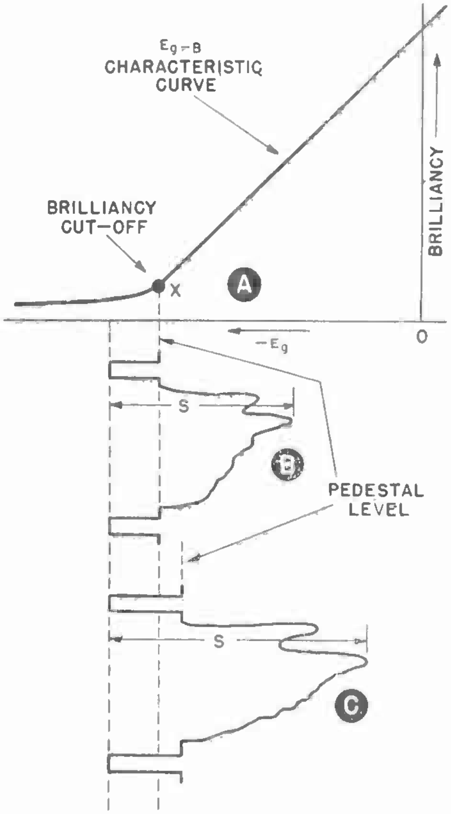


FIG. 30. What the contrast control does to the video signal (B) is shown in (C).

Notice, however, that the stretching of the signal has also increased the amplitude of the sync pulse, with the result that the pedestal level has moved. In other words, the pedestal level in Fig. 30C no longer lines up with the operating point and with the pedestal level in Fig. 30B. Therefore, if it is necessary to increase the contrast control setting, it will also be necessary to vary the brilliancy control to bring the pedestal levels back into line with the brilliancy cut-off X on the curve. If this is not done, dim retrace lines may be visible in the picture.

In general, this "interlock" between the brilliancy and contrast controls occurs regardless of where the contrast control may be.

However, when the contrast control is in a direct-coupled video amplifier like that in Fig. 23, adjustment of the control automatically tends to reset the brilliancy properly. In this circuit, adjustment of resistor R_3 varies the contrast by changing the bias on tube VT_2 and hence changing the gain of this stage. At the same time, this adjustment changes the plate current through R_7 and thus changes the bias applied to the picture tube, thereby resetting the brilliancy level. The circuit arrangement is such that increasing the contrast also tends to move the brilliancy cut-off point in a more negative direction, which automatically tends to line up the pedestals. This is a desirable feature if the parts values used in the circuit can be selected so that the compensation is exact.

D.C. Restorers

To review briefly, Fig. 31 shows the difference between the a.c. and d.c. types of video signals. You will recall that in the a.c. versions shown in D, E, and F of this figure, the areas on either side of the reference line are equal (because the average of an a.c. signal is always zero). As a result, the pedestals and sync pulses of the a.c. signals do not line up if they are associated with lines of different brightness: those representing the brightest lines go farthest below the zero reference line. The displacement of the peak of each sync pulse from the zero line is proportional to the

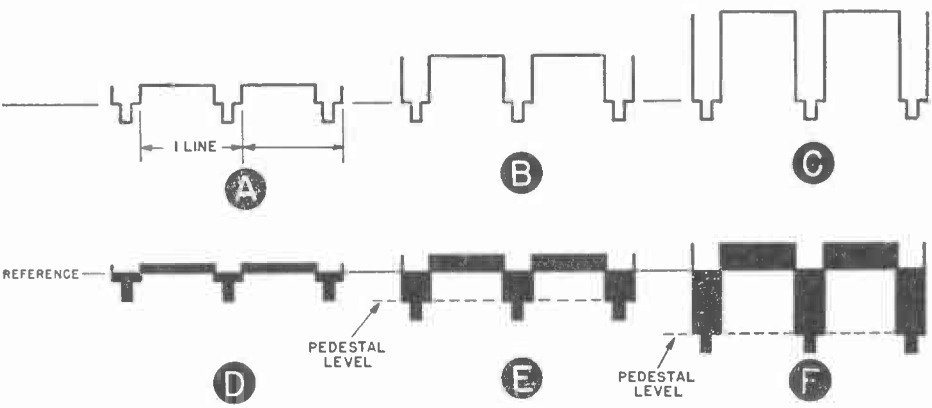


FIG. 31. This is the same illustration that was shown earlier in Fig. 3; it is repeated here for your convenience.

brightness of the scanning line with which that pulse is associated.

This last fact makes d.c. restoration possible. Fundamentally, we can secure d.c. restoration by applying the a.c. signal to a rectifier circuit that can develop a d.c. voltage that is proportional to the peak values reached by the sync pulses. This d.c. voltage can then be added directly to the a.c. signal to produce the original pulsating d.c. signal form, examples of which are shown in A, B, and C of Fig. 31.

BASIC D.C. RESTORER

An elementary d.c. restoration circuit is shown in Fig. 32. The a.c. signal voltage is applied to the input terminals of this circuit from the last video amplifier. This a.c. signal passes through coupling condenser C_1 and develops across resistor R_1 a duplicate of itself for application to the grid of the picture tube.

The diode rectifier tube D is connected so that it will conduct only when terminal A is negative with respect to terminal B. Therefore, when the a.c. signal is applied, that portion of the a.c. signal that makes terminal A positive with respect to terminal B is merely applied across R_1 to the picture tube. On the negative alternations, however, when the sync pulses make terminal A negative with respect to terminal B, diode D conducts heavily and puts a charge on condenser C_1 that is proportional to the peak value of the negative swing of the a.c. signal.

On the following positive swing condenser C_1 discharges as well as it can through R_1; however, the time constant of C_1 and R_1 is chosen so that it would take several lines and hence several sync pulses of time before C_1 could discharge completely. Usually, the time constant of C_1 and R_1 is made approximately equal to the time required to scan about ten to twenty lines, because this has been found sufficient for the normal changes in brilliancy that occur in the average scene. The time constant cannot be much longer than this, because then it would tend to hold over from one brightness level to the next. If it were made too short, changes in brightness level along a scanning line would begin to affect the background brightness.

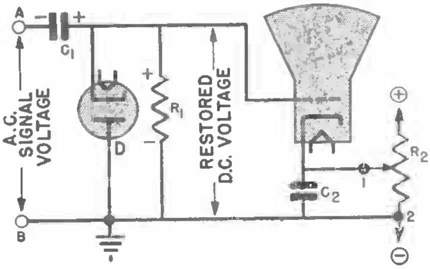


FIG. 32. Simple d.c. restoring circuit in which D is a diode tube. In some television receivers, a germanium crystal rectifier of small area may be used in place of the tube.

When the time constant is correct, conduction of the diode puts a charge on C_1 that is proportional to the average scene brightness. A d.c. voltage resulting from this charge is across R_1 when the diode is cut off; it therefore varies the operating point of the picture tube, thus moving the a.c. signal so that the pedestals line up with the cut-off point of the tube. The brighter the line, the greater the d.c. voltage developed across C_1, and hence the greater the sum of the d.c. and a.c. voltages. That is, the d.c. voltage added to the a.c. signal of a bright scene is much higher than is the d.c. added to the signal of a gray or a black scene. This means that brighter scenes will drive the grid of the picture tube harder in the positive direction, as they should.

PRACTICAL DIODE RESTORER

In an actual receiver, the diode d.c. restorer would not be connected across the entire grid resistor of the picture tube as shown in Fig. 32, because the diode capacity would then be shunting the amplifier plate load. This would seriously reduce the high-frequency response of the system.

A basic circuit that is typical of those actually found in TV receivers is shown in Fig. 33. Here, VT_1 is the tube in the output video stage. The plate load for this tube consists of the series-peaking coil L_1, the shunt-peaking coil L_2, and the load resistor R_4. Low-frequency compensation is not added in this stage; it probably is used in preceding stages, however.

The a.c. signal that is developed across the load resistor and shunt-peaking coil is applied to the grid of the picture tube through coupling condenser C_2. The a.c. grid circuit for the picture tube consists of the resistances R_6, R_7, and R_8 and the by-pass condenser C_4.

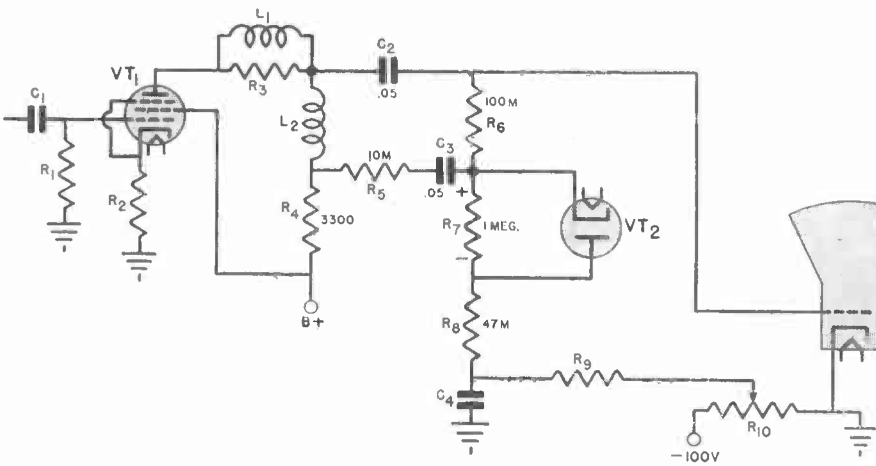


FIG. 33. Schematic of a typical practical d.c. restorer.

The internal capacity of the diode restorer VT_2 acts as a by-pass across R_7, but the high-frequency components of the signal coming through C_2

are developed across R_6 and R_8, which are sufficiently high in resistance to act as a normal grid resistance.

However, VT_2 must charge a condenser if it is to operate properly as a restorer, and it is isolated from C_2 by R_6. Therefore, the signal is fed to it through condenser C_3. The C_3-to-diode path is isolated from the plate load resistor R_4 by the resistance R_5. However, since most of the high frequencies appear across L_2, there is little other than the middle and low frequencies across R_4; therefore, the by-passing action of the diode on R_4 is small, and R_5 need not be high in resistance.

The d.c. restoration action is much like that in the circuit in Fig. 32. The negative swings of the pedestal and sync pulses are applied to the diode through C_3 (and also through the path C_2-R_6, but this path is not considered to be very effective). When the diode conducts, it charges C_3 (through a path consisting of R_8, R_9, R_{10}, the B supply, R_4, and R_5). When the diode ceases to conduct, R_7 is added to the other resistors in the d.c. path between the terminals of C_3. Since the resistance of R_7 is high in comparison to that of the other resistors in the path, most of the voltage across C_3 is developed across R_7. The time constant of C_3-R_7 is such that C_3 is held at a charge that corresponds to the average brightness of ten to twenty lines. Hence, the d.c. voltage across R_7 corresponds to the average brightness of the scene, and, since it is applied to the grid of the picture tube, it acts to line up the pedestals.

R_9 and C_4 isolate the grid circuit of the picture tube from the brightness control, which is a part of the power pack. The a.c. signal path is through C_4 to the cathode, and R_9 acts as a blocking resistance.

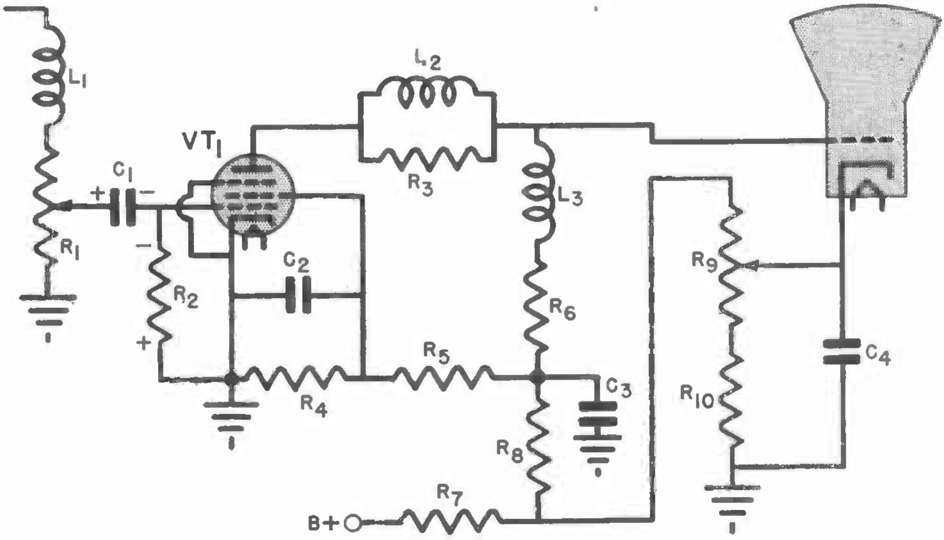


FIG. 34. How d.c. restoration can be produced in the last video stage.

RESTORATION IN LAST VIDEO STAGE

It is possible to make the last video stage do its own restoring as long as it is directly coupled to the picture tube. Fig. 34 shows a typical example of a circuit of this kind. Here, the signal is fed to the grid of VT_1 through the coupling condenser C_1. This is an a.c. coupling, since any d.c. that may be in the signal from the preceding stage will be wiped out by C_1.

The plate load for VT_1 is the series-peaking coil L_2, the shunt-peaking coil L_3, and the load resistor R_6. Resistor R_8 and condenser C_3 provide low-frequency compensation. The signal developed across L_3, R_6, and C_3 is applied directly to the grid of the picture tube.

Restoration. The restoration in this stage occurs in the grid circuit of VT_1. This tube has no initial operating bias; it gets the bias for operation by grid rectification. The action, which is much like that of a grid-leak detector, occurs as follows:

To begin with, you know that the signal applied to the grid of the picture tube must have a positive picture phase—that is, it must swing in the positive direction for increases in brilliancy. Therefore, the signal applied to the grid of VT_1 must have a negative picture phase, because VT_1 inverts the entire signal 180°. (This is not the same kind of phase shift that we studied earlier, because here the action occurs on the entire signal. All frequencies are held in their same relative positions with respect to each other—the entire signal is "flipped over" as a unit.)

Since the signal applied to the grid VT_1 has a negative picture phase, the sync signals drive the grid in the positive direction, and the picture components drive it in the negative direction.

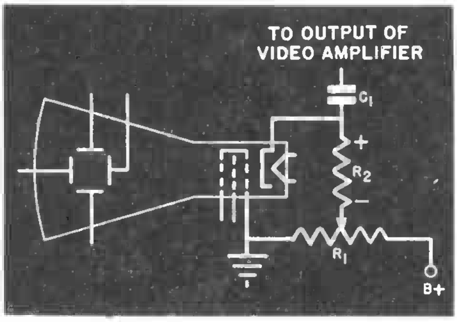


FIG. 35. How d.c. restoration can be produced in the picture-tube circuit.

Since VT_1 has no initial grid bias, the sync signals drive the grid positive, and the grid draws current through R_2. This current flow sets up a bias voltage across R_2 that is proportional to the amount the grid is swung positive by the sync signal peaks. This puts a charge on condenser C_1 that creates a d.c. voltage across it having the polarity indicated in Fig. 34. This d.c. voltage acts as a varying bias on VT_1 during the negative part of the signal, moving the operating point of the tube in accordance with the brightness level of the picture to make the pedestals line up.

Basically, the only difference between the grid circuit of the VT_1 stage in Fig. 34 and any similar grid circuit in an a.c. amplifier is the fact that there is no (or little) initial bias in this circuit, which means that the grid of VT_1 can go positive on the signal swings. The time constant of C_1 and R_2 must equal the time of several lines, but this is needed anyway to give reasonable low-frequency response.

Since the pedestals are aligned in the grid circuit, they remain aligned in the plate circuit. The plate of VT_1 is directly coupled to the picture tube grid, so the restored signal is applied to the picture tube much as it is in a d.c. amplifier. In fact, the output coupling is practically identical with that of the d.c. circuits we have studied.

D.C. RESTORATION IN PICTURE-TUBE CIRCUIT

It is also possible to obtain a d.c. restoration action in the picture tube circuit itself when the signal is fed to the cathode. (We cannot obtain restoration by grid rectification in the grid circuit of the picture tube, because we cannot allow the grid to go positive.) The circuit in Fig. 35 is used for this purpose.

In this circuit, the initial operating point is set by the bias developed across R_2. This bias is determined by the beam current of the picture tube, which flows to the cathode through R_2. Resistor R_1 is a vernier brightness control that is used to provide an additional bias to set the final operating point.

It is possible to feed the video signal to the cathode of the picture tube this way as long as it has a negative picture phase. Then the cathode will be swung more negative by brighter elements of the picture; since this is the same as making the grid more positive, we will have normal a.c. signal action.

In addition, d.c. restoration occurs because of a shift in the bias developed across R_2. When the pedestal and sync pulses drive the cathode positive (which is the same as making the grid more negative), the beam current through the picture tube is cut down. This reduces the bias that is produced across R_2. An increase in brightness therefore causes a reduction in the beam current and in the bias applied to the grid of the tube. This allows the grid to go less negative (by making the cathode less positive with respect to the grid) and thus produces a brighter picture.

The coupling condenser C_1 prevents the bias from following changes in the signal too rapidly. The time constant of C_1 and R_2 is such that the bias is determined by the average brilliancy of several scanning lines, as it is in other d.c. restoration circuits.

One manufacturer calls this particular arrangement "automatic brightness control," and another refers to it as "stabilized brightness control." Although it is true that this and all other d.c. restoration methods are effectively variable brightness controls, we usually consider the brightness level to be set by the initial adjustment of the operating point of the picture tube.

CONCLUSION

In the last several Lessons, you have followed the video signal through the r.f.-i.f. section, the video detector, and the video amplifier. This completes the journey of the video signal—it is now applied to the grid of the picture tube and serves to vary the brightness of the spot produced on the face of the tube. However, having a varying spot is not enough; we must move this spot to the proper position to reproduce each element in the scene. Therefore, in addition to varying the content of the electron beam, we must sweep it horizontally and vertically across the face of the tube. Furthermore, it must be kept in step with the transmitter so that each line will start at the proper time.

In the next Lessons, we shall study the circuits that produce sweep voltages and those that synchronize the sweeps with the transmitted signal. These are sections of a TV set that have no counterparts in a sound receiver.

As you will learn, the sweep circuits basically consist of an oscillator, followed by a special wave-shaping circuit or network that is employed to give a voltage of a particular shape. In turn, this voltage is fed through an output or amplifying stage to the deflection plates or deflection coils of the picture tube. One sweep chain operates to sweep the electron beam in the picture tube from left to right in a horizontal direction to form the lines, while another entirely separate sweep chain produces the deflection signal for moving the beam from top to bottom of the picture-tube face.

In the sync-control circuits, the control signal is stripped from the video signal, and then the vertical and horizontal control pulses are separated from each other. These signals are then used to control the frequencies of the oscillators in the sweep circuits so that each line and each frame starts exactly in step with the scanning at the transmitter.

After you have studied sweep circuits and synchronizing control circuits, you will study receiver power supplies, the sound channels, and special systems used in receivers. This will complete your basic theory of television, after which you will go into the study of television antennas, and the installation, adjustment, and servicing of television receivers.

Lesson Questions

Be sure to number your Answer Sheet 54RH-3.

Place your Student Number on every Answer Sheet.

***Send in your set of answers for this Lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. Is the final video amplifier a power or voltage amplifier?

2. If the signal available at the output of the video amplifier has a negative picture phase, how must it be fed to the picture tube?

3. Why is good low-frequency response necessary in a video amplifier?

4. What causes the high-frequency response of a video amplifier to fall off?

5. Is the detail in the picture determined by the high-frequency response or by the low-frequency response?

6. What is done in the video section to eliminate the beat between the sound and video carrier signals?

7. Why does an increase in contrast control setting make it necessary to vary the brilliancy control?

8. Why is it not practical to connect a diode as a d.c. restorer directly across the entire picture tube grid resistor?

9. Which of the following statements is correct: the time constant in the d.c. restoration circuit is such that the condenser is held at a charge that corresponds to the average brightness of: *one line; several lines; several frames?*

10. If a two-stage video amplifier is a.c.-coupled throughout, and the first tube burns out, will the picture tube bias be affected?

Be sure to fill out a Lesson Label and send it along with your answers.

TAKE TIME

Here is a quotation from the *Santa Fe Magazine* which appealed to me as containing much good, common sense. I hope you too will enjoy it—perhaps profit by it:

"Take time to live. That is what time is for. Killing time is suicide.

"Take time to work. It is the price of success.

"Take time to think. It is the source of power.

"Take time to play. It is the fountain of wisdom.

"Take time to be friendly. It is the road to happiness.

"Take time to dream. It is hitching your wagon to a star.

"Take time to look around. It is too short a day to be selfish.

"Take time to laugh. It is the music of the soul.

"Take time to play with children. It is the joy of joys.

"Take time to be courteous. It is the mark of a gentleman."

J. E. Smith

ACOUSTICS IN PUBLIC ADDRESS WORK

REFERENCE TEXT 54RX

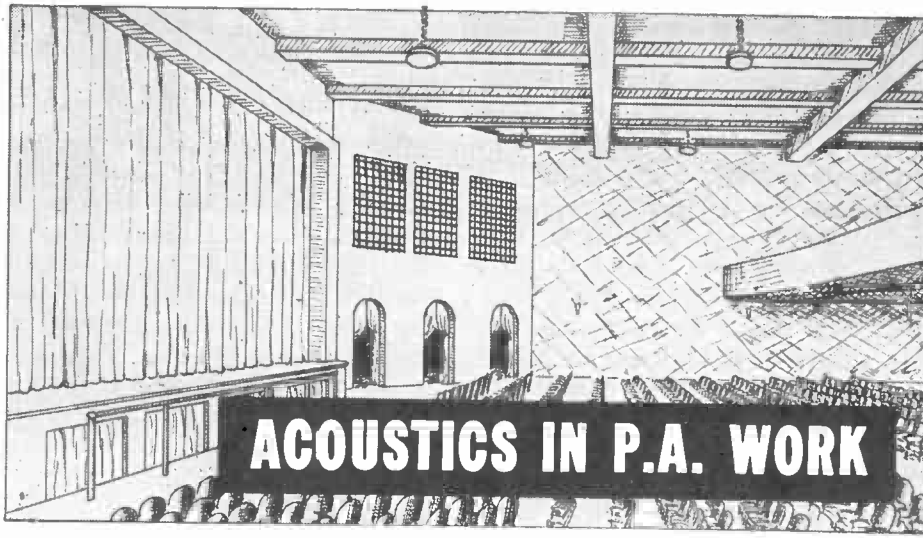
NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE

NPC5M551 1951 Edition Printed in U.S.A.



ACOUSTICS IN P.A. WORK

BEFORE it is possible to choose an amplifier for a particular location, it is necessary to have at least a general knowledge of some of the acoustic problems involved in public address work. Acoustics—the study of sound and its effects upon hearing—is considered to be a science, but is more of an art as it is practiced in p.a. work. That is, although it is possible to make carefully controlled scientific measurements of the conditions in a particular installation, such a scientific survey would be costly and would be of little use unless it were made under the exact conditions that exist when the equipment is in use. Therefore, in practice, acoustic problems in p.a. work are solved by using good judgment and past experience to a large extent. As we shall show later, certain tabulated information on acoustics is available that is helpful in planning an installation, but each job usually brings up its own special problems. Let's see what some of them are.

Sound reflection and absorption cause trouble in indoor installations. Sound waves bouncing from wall to wall cause different effects, depending on the lengths of the paths traveled. Sounds coming from two directions to a particular spot may arrive 180° out of phase, with the result that the sound energy cancels, producing what is known as a dead spot. They may also arrive 360° out of phase, producing sound reinforcement. (There are several noted "whispering galleries" in which a whisper uttered in one spot can be heard at another spot perhaps 50 feet away, but nowhere else. This effect is the result of sound reinforcement.) Most commonly, the sounds are only partly out of phase; the result of this is usually that the sound is muddled and made hard to understand.

If the reflection path is long enough, there will be a complete echo—that is, the sound will arrive so much later over the longer path that it can be heard twice. This, too, is troublesome.

Another effect associated with reflections is reverberation. This occurs when there are many sound-reflecting surfaces in a room, as a result of which a sound is reflected many times and therefore takes a relatively long time to die out. The reverberation period of a room is measured by how long it takes a sound to drop 60 db from its original loudness. If this time is excessive, any continuous series of sounds produced in the room will seem extremely jumbled to a listener.

Another factor that varies from installation to installation is the surrounding noise level. This level plays an important part in determining the amount of power needed, because the p.a. system must have enough output to keep the average sound level well above the noise.

Absorption also creates problems. The system that sounds all right in an empty auditorium may not give enough power when the audience is present, because sound is absorbed by the clothing worn by the audience.

Outdoors, sound energy is rapidly dispersed even on a still day, because there are no containing walls to keep it in. If there is much wind, the sound dispersal is even more rapid. Noise is a problem outdoors also, of course.

All such factors must be considered before an installation is completed. As far as possible, they should be considered before the installation is even started; however, it is usually impossible to do much about reflections until the equipment is at least temporarily installed. (Reverberation, a special case of reflections, can be cured before installation of the equipment.) You can see, then, that far more is involved in making a p.a. installation than just setting up an amplifier, a few loudspeakers, and a microphone or two. The job must be carefully planned so that the installation will be adequate for its intended use but not so unnecessarily powerful that it is more expensive than it should be. Remember that the cost of an amplifier goes up directly with the power rating, because naturally more expensive power and output transformers must be used, as well as parts that have high wattage ratings.

PLANNING A P.A. SYSTEM

The purpose for which a p.a. system is to be used must be considered first of all when you are planning its installation. If the system is to be used only for paging or announcing, it should be designed to handle only the limited frequency range of the human voice: in this case, the system can be fairly inexpensive. If the system is to handle music, however, at least a fair degree of fidelity over a much wider frequency range will be necessary. This means that the microphones, amplifiers, and loudspeakers will have to be capable of delivering the required frequency range, and in general, that more power output will be required, as we shall show later.

Next, it is necessary to consider the location. It is possible to determine arbitrarily the amount of sound power that will be necessary to fill a certain cubic volume, so if we know the length, breadth, and height of a room, we can determine roughly what sound or acoustic power will be needed to fill it adequately with sound. To this basic amount, we must add enough power to overcome the average noise level plus enough more power to overcome the effects of absorption and dispersal. Then, once we have determined the acoustic power that will be needed, we can work backwards to find how much electrical power will be necessary. Certain specific kinds of loudspeakers and baffles may have to be used to meet the fidelity requirements, as we shall show later in this Lesson. Knowing the efficiency of these loudspeakers, we can determine how much electrical power output our amplifier has to have to produce the acoustical power needed. This sets the amplifier size.

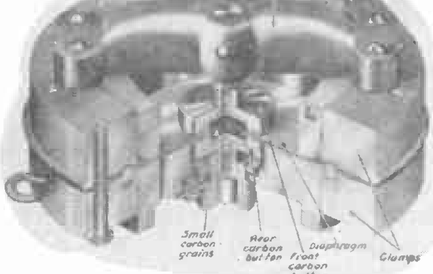
Now that we have certain kinds of loudspeakers and an amplifier chosen, we must turn to the input. The number of microphones required depends on the conditions that are to be met. If the system is to be used for a large orchestra or to amplify the voices of actors who may be at different points on a large stage, a number of microphones may be needed. Very often, on the other hand, only a single one will be necessary. The types of microphones to use will depend on the fidelity wanted, on how rugged they must be, and on how necessary it is that they pick up only the desired sounds and ignore others.

Before we get into the acoustical problems of p.a. installations and learn exactly what must be done to solve them, we need to know more about the characteristics of loudspeakers and microphones. Let's take time out to study these two devices now.

Microphones and Their Characteristics

A public address amplifier may operate from a phonograph pickup, from a radio tuner that feeds a radio program to it, or from a microphone. The phonograph pickup and the radio tuner are covered elsewhere, so we shall consider only the microphone here. Incidentally, the microphone is the only one of these that brings up the problem of acoustic feedback, which we are going to study.

Any microphone is simply a device that will transform sound energy into electrical energy. Basically, all microphones contain some form of diaphragm—a movable cone, a plate, a ribbon, or the face of a crystal. When sound waves strike this diaphragm, the variations in air pressure cause it to move; its motion is used to set up an electrical current that varies correspondingly.



Courtesy Western Electric

FIG. 1. The construction of a double-button carbon microphone.

Let's examine the various types of microphones to learn something of their physical construction.

CARBON MICROPHONES

Essentially, the carbon microphone consists of a diaphragm that is in contact with either one or two "buttons" consisting of small packages of loose carbon granules or grains. Fig. 1 shows a cut-away view of a double-button type—one that has a button on each side of the diaphragm. A single-button type, of course, has only one button.

The diaphragm is a very thin metal plate, the edges of which are clamped in a ring assembly. The plate is so flexible that it vibrates when sound waves strike it. When it moves in on the package of carbon grains, they are pressed tightly together; when the diaphragm moves away from a button, the carbon particles separate or loosen up. When the carbon grains are pressed together, they make better electrical contact and the resistance through the button decreases. Conversely, the resistance through the button increases when they are allowed to be looser. In other words, the resistance of the buttons varies as sound waves strike the diaphragm;

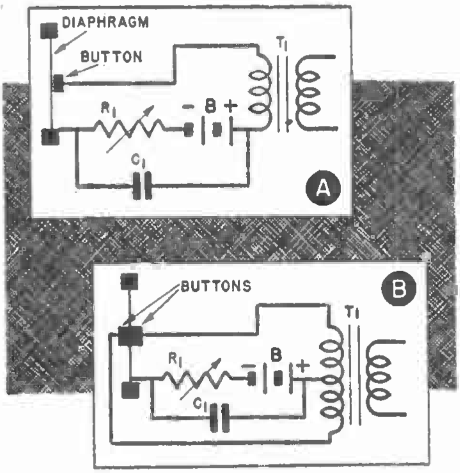


FIG. 2. How carbon microphones are connected to produce an output signal. The single-button type is shown in A, the double-button in B.

This varying resistance can be made to vary the current in a circuit by connecting the buttons in series with a battery.

The electrical connections for both single and double-button types are shown in Figs. 2A and 2B, respectively. In each circuit, the resistance R_1 is used to adjust the current to the desired initial value. Then the microphone causes the current to increase and decrease above and below this starting value in step with the sound waves. This varying current flowing through the primary of transformer T_1 induces a voltage in the transformer secondary; this voltage becomes the signal output of the microphone and can be fed to the grid of the first amplifier stage, either directly or through a transmission line. The transformer is necessary to match the low impedance of the microphone (200 to 500 ohms) properly to the transmission line or the grid of the first amplifier tube.

The double-button type is capable of giving better frequency response than the single-button. Both carbon microphones are relatively noisy compared to other types, however. Tiny sparks are formed as the carbon grains press together or loosen up, with the result that there is always an appreciable noise output. Although the carbon microphone gives a greater output than any other type, this noise trouble, and the need to use a rather large battery with it, have led to its almost complete disappearance from public address work. Today the only carbon microphones you're likely to find are certain hand-held microphones of the telephone type.

CONDENSER MICROPHONES

The condenser microphone, shown schematically in Fig. 3, is essentially a condenser whose two plates consist of a flexible diaphragm and a fixed plate. In Fig. 3, the diaphragm D is held in the clamp rings R, much as is

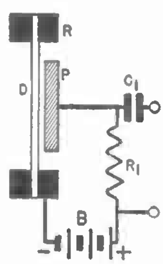
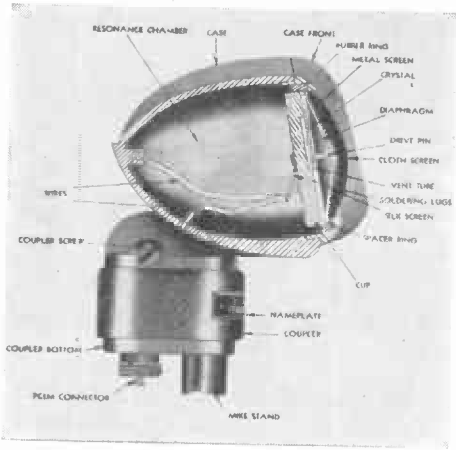


FIG. 3. How a condenser microphone is connected to produce an output signal.

the diaphragm of a carbon microphone. The plate P is very close to the diaphragm. The battery B furnishes a high voltage that charges the condenser formed by D and P. As the diaphragm is vibrated by sound waves, it alternately approaches and moves away from the plate P. This increases and decreases the capacity. For a fixed voltage, the amount of charge that can be held by a condenser depends on its capacity, so this variation in capacity obviously changes the amount of charge stored in the microphone. Hence, a varying



Courtesy The Turner Co.

FIG. 4. Cut-away view of a crystal microphone.

current flows through R_1 as the charge increases and decreases. The varying voltage drop across R_1 is the signal output of the microphone; this is fed out through the coupling condenser C_1.

Since the capacity of the condenser microphone is very small, the current change caused by movements of the diaphragm is measured in microamperes. As a result, R_1 must be very high in resistance for there to be an appreciable signal voltage. This means that the microphone must feed into a very high impedance for there to be an efficient signal transfer; as you know, any such high-impedance connection would be subject to hum and noise pickup if there were any considerable length of line between the microphone and the amplifier. Because of this fact, and because of the low output of the microphone, it is necessary to have a preamplifier right at the microphone; customarily, as a matter of fact, it is built into the microphone housing. Therefore, the housing must be rather large. Furthermore, the charging voltage for the microphone must be fairly high and must be pure d.c. if hum is to be avoided. Therefore, either batteries or an exceedingly well-filtered power supply is required.

Since a preamplifier is always a part of the microphone unit, it is customary to rate the output of a condenser microphone in terms of the preamplifier output. The condenser microphone therefore delivers a comparatively large output. However, its bulky nature and critical power-supply requirements make this a relatively unpopular type for p.a. use.

CRYSTAL MICROPHONES

Fig. 4 shows a cut-away view of a typical crystal microphone, and Fig. 5 shows its operational details. Once again we have a diaphragm that is clamped in a retaining ring. This diaphragm is coupled mechanically through a drive pin to a pair of Rochelle salt crystals. These crystals

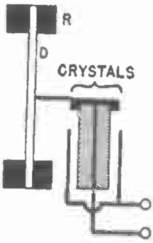


FIG. 5. How a crystal microphone is connected to produce an output signal.

are very similar to the ones used in phonograph pickups. Two crystals are used, connected back to back. One terminal of the microphone unit is a tinfoil plate in contact with the two crystals where they join. On the outside of each crystal there is another plate; these plates are connected to form the other terminal.

Rochelle salt crystals exhibit what is known as the "piezo-electric" effect, meaning that a voltage will appear on the opposite faces of the crystal if the crystal is mechanically stressed in any way (or, conversely, that the crystal will be temporarily deformed if a voltage is applied to its opposite faces). In this unit, one edge of the crystal assembly is clamped tightly in the case and the other edge or corner of the assembly is secured to the diaphragm. As the diaphragm moves back and forth, the crystals are bent or twisted, which causes them to generate a voltage.

Fig. 6 shows another form in which a crystal microphone may be manufactured. In this unit, known as a "sound cell," groups of crystals are cemented into frames. The diaphragm and driving pin are dispensed with and the crystal units are acted upon directly by the sound waves.

Because the surface that is worked on by the sound waves is less in this microphone, the output is smaller than it is in one using a diaphragm. However, the sound cell microphone is less affected by shock and vibration than is the diaphragm type, so it is popular in uses where it may be subjected to rough handling.

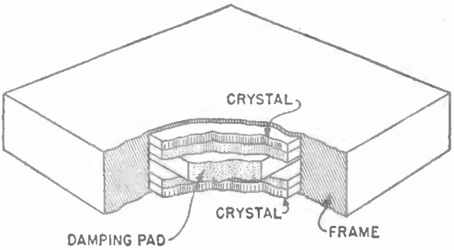


FIG. 6. Cut-away view of a sound-cell microphone.

The crystal microphone is relatively rugged, and is less expensive than some of the other types. These factors make it one of the most popular of the microphones used in p.a. work.

It does have certain disadvantages, however, chief of which is that the crystals can be destroyed by very rough handling or by high temperatures. A crystal microphone cannot be used, therefore, in any location where conditions of high heat may exist. It is not a good microphone for use in a sound truck or for outdoor locations where the sun may get to work on it.

In the cut-away view in Fig. 4, there is a space in the microphone case marked "resonance chamber." We'll explain the purpose of this shortly.


Courtesy Shure Bros.
This shows what a typical crystal microphone looks like.

DYNAMIC MICROPHONES

The dynamic microphone is almost the same as a p.m. dynamic loudspeaker, except that the cone is replaced by a diaphragm. Figs. 7 and 8 show the details of a typical one. A voice coil is placed in an air gap so that it is in a very strong magnetic field. When the diaphragm is actuated by sound waves, the voice coil (which is secured to the diaphragm) is forced to move in and out through the magnetic field; as a result, a voltage is induced in the coil. This is passed on through a transformer mounted in the case to the output terminals.

As a matter of fact, a small p.m. dynamic speaker makes a relatively acceptable microphone—this idea is commonly used in intercommunication systems where the dynamic loudspeaker acts as a microphone when the appropriate switch is set in the "talk" position, but then is switched to be an actual loudspeaker at the output of the amplifier when the switch is allowed to return to its normal "listen" position. You'll learn more about this elsewhere.

The dynamic microphone is one of the most popular types used in p.a. work. It costs somewhat more than the average crystal microphone but is very rugged. It can be used where temperature and humidity conditions make the crystal type unsuitable.

Although the dynamic microphone is not commonly a high-fidelity microphone, it can be made to have a good frequency response, as we shall see.

AIR-RESISTANCE LOADING

In all of the microphones discussed so far except the sound cell, a diaphragm is used to convert motions of air particles into mechanical motion that may be used to generate the desired electric current. All such diaphragms contain sufficient material to have a certain amount of mass, and they are mounted so that the natural springiness of the material will tend to restore it to its original shape when sound pressure is removed. Since it has mass and springiness, which are the mechanical equivalents of inductance and capacity respectively, the diaphragm has a resonant frequency at which it will vibrate most readily. This resonant point is quite likely to occur in the audio spectrum, with the result that the microphone will exhit a very undesirable peak in its response.

To a great extent, this peak can be ironed out by enclosing the back of the microphone so as to form an air chamber. A cut-away view of this arrangement in one form of dynamic microphone is shown in Fig. 9. A small tube, or vent, connects the air chamber to the outside air. You can understand the function of this vent readily if you have ever used a pump of the sort used to inflate footballs. Such a pump has a small, removable, hollow needle at one end through which the air being pumped out must pass. It is appreciably harder to pump air through this needle than it is to operate the pump with the needle

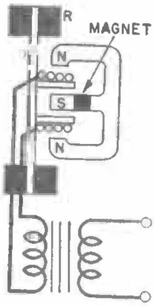
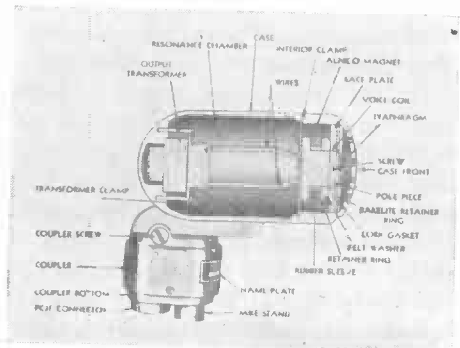


FIG. 8. How a dynamic microphone is connected to produce an output signal.



Courtesy The Turner Co.

FIG. 7. Cut-away view of a dynamic microphone

removed. The reason is that the small opening offers considerable resistance to the movement of air through it.

By the same token, the small vent in the air chamber of the microphone in Fig. 9 does not pass air readily. Thus, when the diaphragm in this microphone moves inward, part of the energy of its motion is absorbed in forcing air out through the vent. If we again consider the diaphragm to be a resonant device, we can say that the air chamber and vent add resistance to the circuit. You know that adding resistance to an electrical resonant circuit reduces its output at the resonant frequency; similarly, the addition of this acoustical resistance to our mechanical-acoustical circuit reduces the tendency of the diaphragm to vibrate at its resonant frequency. As a matter of fact, it is possible to eliminate resonant effects almost completely by designing the air chamber and vent properly.

The cut-away views in Figs. 4 and 7 show the air chambers. Although Fig. 9 shows a dynamic microphone, the same general principle can be made to apply to others with diaphragms. Such microphones are called "pressure" microphones, because the voltages they generate are directly proportional to the pressures of the sound waves striking them.

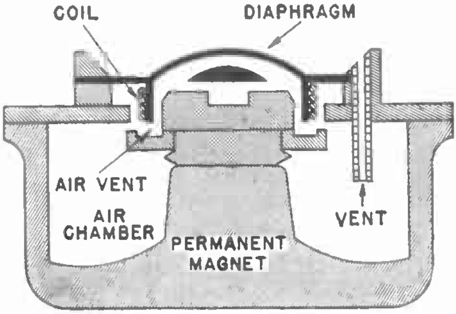


FIG. 9. Cut-away view showing the resonance chamber and vent in a dynamic microphone.

Courtesy RCA

FIG. 10. A typical velocity microphone.

RIBBON MICROPHONES

The ribbon microphone, shown in Figs. 10 and 11, is rather different from the types we have discussed so far, because it has no circular diaphragm. Instead, a very thin ribbon of an aluminum alloy is suspended between the poles of a powerful magnet. The ribbon is clamped at its ends, where connecting wires attach it directly to a matching transformer. The ribbon completes the primary circuit of this transformer and therefore acts as a 1-turn coil. When it moves in the magnetic field, a voltage is induced in it.

To permit movement of the ribbon, it is crimped or "accordion pleated." This ribbon has no springiness whatever, and very little mass—it is so light that it practically floats in air. When sound waves strike it, the ribbon moves back and forth in step with the air particles. The microphone is enclosed only by a perforated shield (which was removed before the picture in Fig. 11 was made) that offers no resistance to the free movement of air in and out.

Since the ribbon moves in step with

the moving air particles just as if it were an additional air particle, it is said to respond to the velocity of the air particles rather than directly to the actual pressure of the wave. For this reason, you'll find that the ribbon microphone having both the front and back of the ribbon exposed to sound waves is called a "velocity" microphone.

Pressure Type. It is possible to make the ribbon microphone respond to sound pressure like other microphones, however, by enclosing the back of the ribbon in an air chamber. Fig. 12 shows the most common way of doing this. A pipe is used to enclose the rear surfaces of the ribbon completely. This pipe then leads down into a box at the bottom of the microphone where there is an air chamber. Enclosed on one side in this manner, the ribbon acts like a diaphragm, so the microphone becomes a pressure-actuated device.

The ribbon microphone is rarely used in p.a. work, because of its extreme delicacy. A single gust of wind, or a sharp puff of air from a person speaking directly into one, will un-

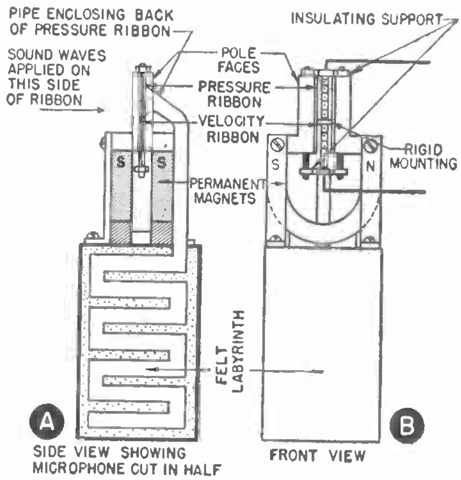
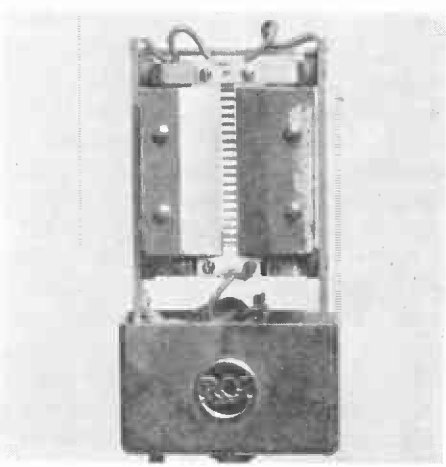


FIG. 12. Front view (A) and side view (B) of the internal appearance of a pressure-operated ribbon microphone.

crimp and straighten out the ribbon so that it sags completely out of position. This calls for a replacement of the ribbon, which can be done only at the factory. When these microphones are moved, they must be carried in a normal operating position—that is, with the ribbon in a vertical plane. Carrying the microphone in a horizontal position makes the ribbon sag or stretch. Jarring or rough handling may cause the ribbon to move far beyond its normal limits, with the result that it may be stretched out of shape or even stick to the magnet. In addition, rough handling may cause the magnet to move. The spacing in this microphone is very small to begin with, so even a slight change in the position of the magnet will restrict the air gap so much that the ribbon cannot move properly in it.

Despite all these difficulties, the velocity microphone is used in some high-quality installations, particularly when music is being picked up, because it offers higher fidelity than does any other kind of microphone commonly used. Should you encounter such a microphone, remember the



Courtesy RCA

FIG. 11. Internal appearance of a velocity microphone.

above characteristics. Shield it always from wind, and instruct persons speaking into it to stay well away from it and speak "across" the face of the microphone rather than directly into it. Always see to it that a velocity microphone is kept away from alternating current fields such as may be produced by power transformers and by power lines. If anything is the matter with such a microphone, don't open it; it must go back to the factory for repair. Under factory conditions, in air-conditioned, dust-free rooms, it is possible to repair one. However, even taking the screen off to examine such a microphone in an ordinary service shop is quite likely to permit metal particles to get into the air gap and prevent it from working.

For that matter, it is not desirable to try to repair any kind of microphone. If you suspect the microphone of causing trouble, it is far better to try another in its place. If the substitute works properly, then something is the matter with the original microphone and it should be sent back to the factory for repair.

You have now learned basically how all the important types of microphones work, except for the cardioid types, which are combination microphones that we shall discuss a little later. Now let's compare the characteristics of the various microphones to see what makes one type better than the others for different uses.

FREQUENCY RESPONSE

Practically any kind of microphone will prove satisfactory for voice pickup. However, there is quite a difference in the responses of microphones to music. Furthermore, we can't say that just because a particular microphone happens to be a crystal type or a dynamic type that it necessarily must have a certain specific fidelity, because it is quite possible to get a better response by careful design of the unit. For example, many of the more common dynamic microphones are reasonably flat over a frequency range of only 100 to 5000 cycles, but high-fidelity types are available that have flat responses from 25 cycles to 12,000 cycles. Other dynamics have responses in between these two extremes.

The same can be said for the crystal microphone, whose response may range from perhaps 100 to 7000 cycles to as much as 30 to 10,000 cycles. Velocity types are practically all high fidelity, with responses from 40 to somewhere between 10,000 and 15,000 cycles, depending on design.

The obsolete carbon types were all low-fidelity units, which is one reason for their disappearance from the p.a. field. The condenser microphone actually offers the widest frequency response of all, but, because of the disadvantages we discussed earlier, it is not used in p.a. Therefore, in general, if the conditions of use would permit either the crystal or dynamic microphone to be used, it is necessary to be sure that the one chosen has a frequency response that is suitable for the fidelity wanted. Naturally, the prices of microphones go up as their fidelity becomes better, because a high-fidelity microphone must be carefully made and uses costly materials. At the same time, high-fidelity microphones are usually more delicate than are low-fidelity units. Hence, it is common practice to choose a microphone that meets the fidelity requirements of the installation but does not exceed them much.

Microphones are like loudspeakers in that their response over a frequency range is not uniform but instead has many peaks and dips. In general, the dynamic microphone is particularly subject to such variations and the velocity type is least subject to them. However, a well-made, high-quality microphone will have a smoother response than an inexpensive type.

PICKUP PATTERNS

Microphones do not respond equally to sounds coming from different directions. Some types exhibit definite directional characteristics.

All of the diaphragm types that we have studied are usually made with an enclosure at the rear of the diaphragm. Effectively, therefore, the diaphragm faces only one way in these units. As you might expect, they are much more sensitive to those sounds coming straight toward the front of the diaphragm than they are to sounds coming from other directions. However, these types are classed

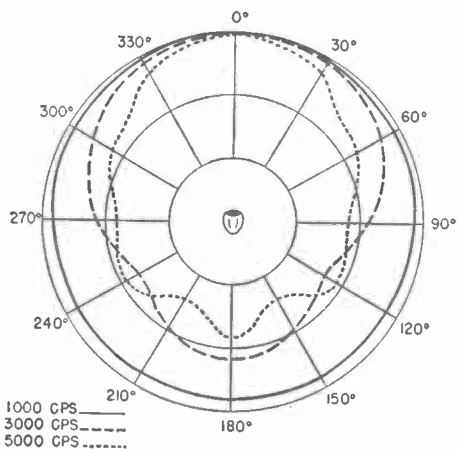


FIG. 13. This graph shows how a nondirectional microphone picks up sound coming from various directions. The response at three different frequencies is shown. The front of the microphone faces the 0° line.

as non-directional microphones because at low frequencies (below 1000 cycles) they do tend to respond to sound waves from all directions. This comes about because at these frequencies the microphone itself is rather small in comparison to a wave length, with the result that the diaphragm is operated upon by the pressure of a sound wave regardless of the direction of the wave. At higher frequencies, however, these microphones become at least semi-directional in that they respond better to sound coming from the front (see Fig. 13).

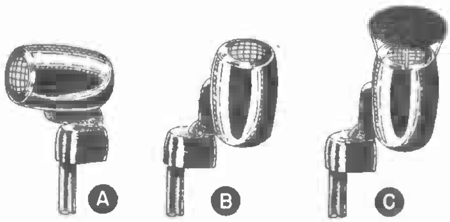


FIG. 14. A microphone that is relatively non-directional in its normal position (A) becomes even more so if it is turned to face upward (B). The response can be further improved by putting a shield above the microphone (C).

If such a microphone is to exhibit good frequency response, then, it must be made to face the source of the sound so that its response will be approximately equal to all frequencies in its normal response range. Hence, the microphone and its stand must be placed so that the microphone faces the source of the sound that is to be picked up.

If sounds from several different directions are wanted, the microphone can be made much more non-directional by pointing it upward. For example, in Fig. 14A, the microphone faces the left, so sounds coming from this direction will be picked up best. The sound pickup will be poorest from the right in this drawing. However, if the microphone is swiveled on its stand so that it faces directly upward (Fig. 14B), it will receive sound best from directly overhead, but will pick up equally from all horizontal directions.

An improvement over this latter arrangement is shown in Fig. 14C. Here a metal shield is placed a short distance from the opening of the microphone. This prevents sound coming from directly overhead from being picked up much and improves the pickup from the sides.

The ribbon microphones that have their rear sides enclosed in a baffle, which makes them pressure-actuated,

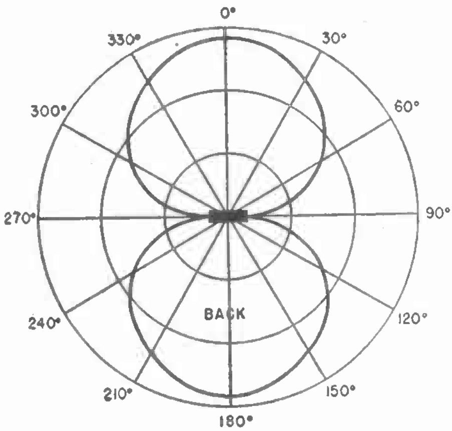


FIG. 15. The response curves of a bidirectional velocity microphone.

operate just like other pressure microphones as far as directionality of pickup goes. Of course, as you learned earlier, these microphones should not be turned upward because of the possibility that the ribbon will be damaged. Velocity ribbon microphones, which are open on two sides, are most sensitive from directly in front or directly in back, and least sensitive at the sides, as shown in Fig. 15. Sound is blocked off from the sides by the mass of the magnetic structure and by the wind shield that encloses the microphone. Therefore, response is greatest along the 0° and 180° lines in Fig. 15, and decreases gradually to a minimum at 90° and at 270°.

This bidirectional response can frequently be made use of when you have two different sound sources to pick up simultaneously. Suppose, for example, you want to pick up the music of an orchestra that is playing in a pit in front of a stage. The orchestra will be in two groups, with the conductor in the middle. You can get the desired pickup by placing the microphone in front of the conductor and orienting it so that the two halves of the orchestra are in line with the lines of maximum response of the microphone. This orientation will not only permit the orchestra to be picked up well but will also minimize pickup from the audience, which will be on either the 90° or 270° line of the microphone.

Incidentally, the problem of picking up unwanted sounds such as audience noise, is a severe one in p.a. installations. In fact, very often the possibility of noise pickup determines both the kind of microphone that should be used and the place where it should be located. We shall have more to say about this later in this Lesson.

Cardioid Responses. Several microphones have been developed that

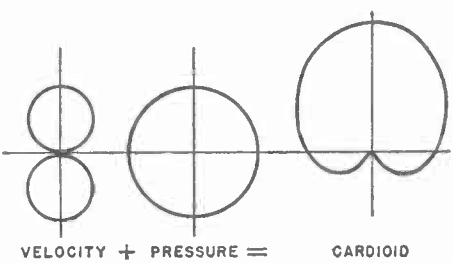


FIG. 16. The cardioid response is produced by combining the responses of a velocity and a pressure unit.

are combinations of pressure-operated and velocity-operated units. These have pickup patterns like that shown in Fig. 16. This pattern is said to have a "cardioid" shape, because it resembles somewhat the shape of a heart.

A microphone having this response

picks up best from in front, less well from the sides, and very little from the rear. It is therefore very useful in applications where there is a single source of unwanted noise: the microphone can be turned so that its rear is toward the noise source, and pickup of the noise will be minimized.

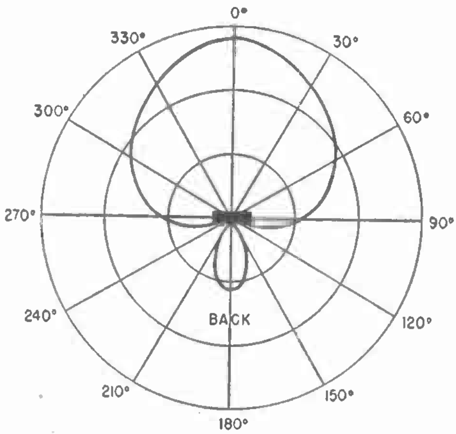


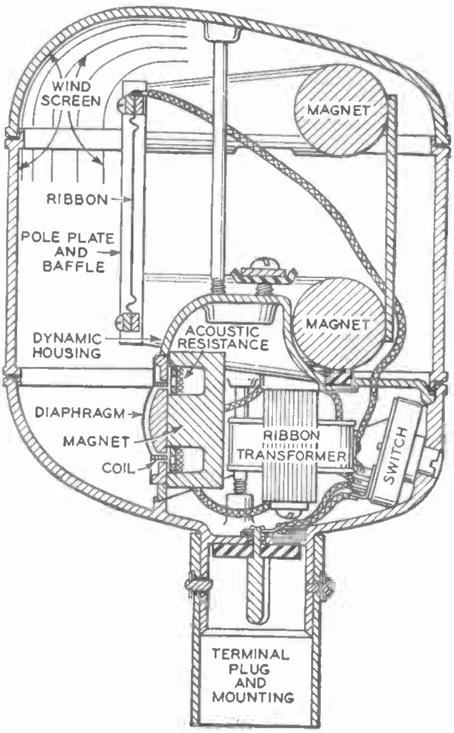
FIG. 17. The response curve of one type of cardioid microphone. Notice the difference between this curve and the true cardioid shown in Fig. 16.

It is also possible to make a microphone having the modified pickup pattern shown in Fig. 17. As you can see, this pattern has two minimums. The microphone will pick up to some extent from the rear but nowhere near as much as from the front. At angles of about 130 and 230 degrees, it has minimum response. A microphone having these characteristics is particularly useful where there are two noise sources.

The cardioid microphone usually contains a ribbon velocity element in combination with something that will act as a pressure device. The kind shown in Fig. 18 has a ribbon element on top and a dynamic unit underneath it. A switch arrangement makes it possible to use the ribbon alone for a bi-directional response, the magnetic unit alone for a non-directional response, or the two in combination for a cardioid response. The amount of response from the two units can be varied to produce the response shown in Fig. 17, also.

Other combinations are also available, such as a ribbon and crystal unit. A third variety uses only a ribbon that has an air chamber behind half the ribbon and none behind the rest of the ribbon. With this unit, the half with the air chamber acts as a pressure-actuated type and the other half, of course, as the velocity unit.

Still another kind of microphone, known as the Super-Cardioid, has the directional effects of the 2-unit cardioid but contains only a single pressure-actuated unit (either crystal or dynamic). The cardioid effect is



Courtesy Western Electric

FIG. 18. Cross-sectional view of a microphone that can be used as a nondirectional, bidirectional, or cardioid microphone by turning the switch (lower right) to the proper position.

achieved by incorporating a special acoustic chamber in the microphone housing.

The cardioid reception pattern is obtained from a combination of pressure and velocity units because of the difference in the manner in which the two units respond to sound waves. When the waves come from the front of the microphone, both units are energized simultaneously. Their signal voltages are therefore in phase; and, when they are added in a suitable network, they produce an increased output. When the sound waves come from the back of the microphone, however, the action is not the same. The velocity unit is energized as soon as the waves reach the microphone, but the pressure unit is not energized until the waves reach the front of the microphone a short time later. The output signals of the two units are now out of phase; therefore, they cancel when they are combined, producing a minimum response to waves coming from the rear of the microphone.

Incidentally, the bi-directional response of the velocity microphone does not vary much with frequency: practically the same pattern is obtained for all frequencies to which the microphone responds. Some of this same effect is carried over to the cardioid, although here the pressure-actuated device can cause the pattern to vary somewhat with frequency.

Although it is never a true cardioid, the response of a non-directional microphone can be sharpened so that the response is mostly from the front by the use of an acoustic shield around the face of the microphone. Such a shield plate cuts down on the energy received from any direction except the front. Certain microphones come equipped with such shields; they are usually removable so that non-directional response can be obtained when it is desired.

MICROPHONE OUTPUTS

Microphones differ considerably in their output levels, even though all are low and require the use of high-gain amplifiers. The carbon microphone has the greatest output for a fixed sound level; the condenser microphone and its built-in amplifier have nearly as much; the crystal microphone has the next greatest output; and the dynamic microphone output ranges from about the level of the crystal microphone down to that of the velocity, which has the least power output.

Naturally, if you are to drive an amplifier to full output, the microphone you use with it must supply at least the minimum input power for which the amplifier was designed. As a practical matter, it is best to use the kind of microphone recommended by the manufacturer of the amplifier, if he makes any recommendation. If the amplifier manufacturer does not recommend a specific microphone, you must choose one that has a suitable output. If low-impedance dynamic and velocity microphones can be used with a particular amplifier, any other kind can also be used with it, because all other kinds have higher outputs.

Microphone sensitivity ratings are often confusing, because at least six different reference levels are in use. Most manufacturers rate their microphones in terms of the electrical output across a properly matched load at a reference frequency, with respect to a particular reference sound pressure. A few rate microphones unloaded, however; doing so gives an output that is 6 db more than it will actually be when the microphone is properly matched. (The unloaded voltage is higher because, when the microphone is properly loaded by an impedance equal to its own impedance, half the source voltage is dropped across the microphone impedance.)

Microphones are usually rated in terms of decibels down from either a reference voltage or a reference power, with the reference sound pressure given in dynes per square centimeter. (Sometimes the pressure is stated in bars; a bar is equal to one dyne per square centimeter.)

The reference voltage is usually 1 volt, but the reference power may either be 1 milliwatt or 6 milliwatts. Table 1 gives the six most commonly used reference levels. As a typical example, you may find the rating of a microphone given as "—50 db below 1 volt/1 dyne/cm² into a load of 1 megohm." When the complete rating is given this way, you know at least what reference level was used. On the other hand, if the listing is just "—50 db," as it frequently is in supply-house catalogs, you won't know what reference level was used; and you may be badly misled if you compare the output level of this particular microphone with that of another that was rated on the basis of a different reference.

TABLE I

1 volt/1 dyne/cm²
1 volt/10 dynes/cm²
1 volt/100 dynes/cm²
.001 watt/1 dyne/cm²
.001 watt/10 dynes/cm²
.006 watt/10 dynes/cm²

For example, three different pressure reference levels are given in Table 1, each 10 times the pressure of the one preceding. A 10-times difference in pressure on a microphone increases its output by 20 db. Therefore, the same microphone could be rated at —70 db below 1 volt/1 dyne/cm², or —50 db below 1 volt/10 dynes/cm², or —30 db below 1 volt/100 dynes/cm².

Similarly, a power rating in terms of 1 milliwatt is 8 db higher than it would be if the microphone were rated on the basis of a 6-milliwatt reference level. In other words, a microphone rated at —50 db for the 1-milliwatt level would have to be rated at —58 db if the 6-milliwatt level were used as the reference.

All this means that we have to be careful to choose a microphone whose db output level is high enough to give full rated output from the amplifier used. Then, when we compare microphones made by different manufacturers, we must be careful always to make sure that their ratings are in terms of the same reference; otherwise, we may get the wrong idea of their relative outputs. If you cannot tell what rating standard was used from the information given, write both the manufacturer of the microphone and the manufacturer of the amplifier. One or the other will be able to tell you whether the particular microphone and amplifier you are interested in will work properly together.

Of course, once you have had experience with particular brands of microphones, you won't have to worry about the reference standards used. because you will know what their ratings are.

MICROPHONE IMPEDANCES

In general, microphones are classed as either low impedance or high impedance. The ribbon microphone has a very low impedance, and it nearly always has a built-in transformer that is designed to match the microphone either to a 500-ohm audio line or directly to the grid of an amplifier tube. Dynamic microphones have impedances ranging from around 8 ohms up to about 50 ohms. Sometimes built-in transformers won't be provided with those around 50 ohms, but the ones commonly used in p.a. work all have transformers designed to match them to 500 ohms or to a high-impedance input.

The only other common type—the crystal microphone—is usually a high-impedance microphone.

Amplifier inputs are generally designed either for high-impedance microphones or for 500-ohm transmission lines. One designed for a high-impedance microphone can be used with either a crystal microphone or a magnetic or velocity microphone that has an appropriate matching transformer.

When high-impedance inputs are used, the cable from the microphone to the amplifier cannot be very long. One reason is that there will be considerable frequency attenuation, as we shall learn elsewhere. Another reason is that if any point in the circuit is at a high impedance with respect to ground, very small stray hum and noise fields will introduce fairly large disturbing voltages. And, of course, the longer the section of the circuit above ground, the more likely there is to be trouble. It is therefore necessary to keep the microphone cable as short as possible—lengths are usually held to 10 to 25 feet at the most.

If the amplifier has a 500-ohm input, on the other hand, it is possible to use a 500-ohm transmission line, which permits cable lengths to be as much as 1000 feet. When a 500-ohm line is used, it is of course necessary that the microphone have a transformer designed to match it to the line and that the line be matched to the grid of the input tube of the amplifier by another transformer.

As a general rule, therefore, we can say that if the microphone is to be used within 10 to 25 feet of the amplifier, we can use a high-impedance microphone that is connected directly to the amplifier. This may be either a crystal microphone or a dynamic or velocity microphone containing a transformer that matches its impedance to that of the amplifier input circuit. A dynamic or velocity microphone that is matched to 500 ohms by its built-in transformer can also be used if it is connected to the 500-ohm input of the amplifier or if it is connected to another transformer that will match 500 ohms to the high-impedance input of the amplifier.

On the other hand, if the microphone is to be used at a greater distance from the amplifier, we must either use a low-impedance type matched to a 500-ohm line, which in turn is matched to the amplifier, or we must feed from a high-impedance microphone into a preamplifier that is a separate unit from the main amplifier. Then, this preamplifier can be connected to the main amplifier at a distance by proper matching through a 500-ohm line, as we will show later.

Loudspeakers and Their Enclosures

You have studied loudspeakers elsewhere in your Course, so we shall not have to spend time here to describe their operation. Instead, we shall discuss their use in p.a. work.

A few magnetic loudspeakers are used in p.a. installations, but dynamics are by far the most common. Permanent-magnet dynamics are almost always the kind chosen, because they do not require a field supply. Since the loudspeakers must frequently be mounted at a great distance from the amplifier, it would be impractical to furnish a field supply from the amplifier, because the extra pair of leads in the cable would greatly increase the cost and complicate the installation. Therefore, if an electrodynamic loudspeaker were to be used in such cases, it would have to have its own built-in field supply, which would have to be connected to a source of power. This would greatly increase the expense and would probably cause a higher hum level.

Therefore, the electrodynamic loudspeaker is commonly used only in small portable p.a. systems in which the loudspeaker is built into the amplifier assembly or is connected to it by a rather short cable.

The voice coil impedances of the loudspeakers used in p.a. work are similar to those of the loudspeakers used in home radio receivers: 4 ohms, 8 ohms, and 16 ohms are the most common.

Two basic loudspeaker types are used in p.a. installations. One is the familiar kind in which the voice coil drives a paper cone; in the other, the voice coil drives a metal diaphragm.

The paper-cone type is usually found in the lower-powered indoor installations and in high-fidelity installations in which large amounts of low-frequency power must be handled. In the latter case, cone-type loudspeakers are used because of the nature of the baffle enclosures that must be used to give the desired fidelity.

The cone-type loudspeaker has two major disadvantages. One is that it is remarkably inefficient. Even when it is placed in a proper baffle enclosure, it is usually considered to be no more than 2% efficient. This means that only 2% of the audio power fed to the loudspeaker is actually converted into sound power. Fortunately, the human ear responds remarkably well to very small amounts of sound power, or cone loudspeakers would be completely impractical.

Another disadvantage of the cone loudspeaker is the fact that the paper cone will deteriorate with age, particularly if it is subjected to conditions of high humidity. Naturally, such a paper cone could not be used

Courtesy University Loudspeakers, Inc.

This is a typical driver unit used with horn loudspeakers.

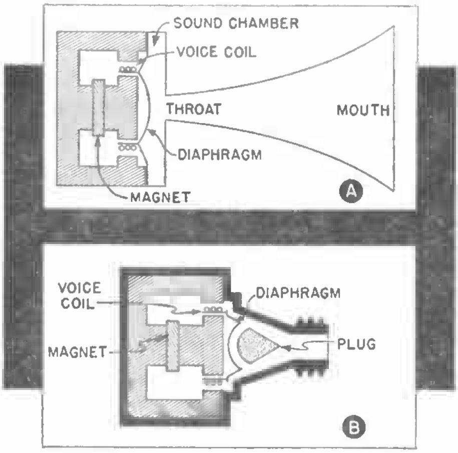


FIG. 19. An early form of horn loudspeaker equipped with a driver unit is shown in A. In the modern form, shown in B, reflections within the sound chamber are eliminated by adding a plug in the throat and by shaping the diaphragm to match the end of the plug.

outdoors without ample protection against weather.

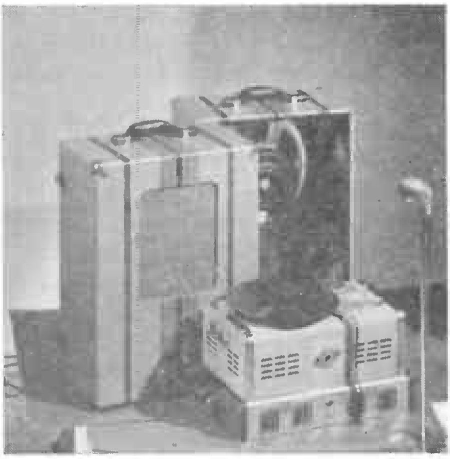
These disadvantages of cone loudspeakers have led to the development of high-powered driver-type units that have metal diaphragms instead of paper cones. Such driver units are invariably used with horn enclosures, which we shall describe shortly. When the diaphragm is properly coupled to the air by a horn enclosure, it is possible to get an efficiency of 15% to perhaps 30% from a driver unit.

The basic structure of a driver unit is shown in Fig. 19A. For the horn size to be practical, the throat of the horn must be relatively small, considerably smaller than the diaphragm. Therefore, the diaphragm in this figure drives the throat through a sound chamber. Effectively this gives a very good coupling to the air, with the result that large amounts of air are moved at the throat. However, there is some difficulty with the frequency response, because, particularly at high frequencies, there are reflections within the sound chamber.

Fig. 19B shows one way this problem can be solved. As you can see, the diaphragm has a ball-shaped indent in it, and there is a plug in the center of the sound chamber whose rear edge is shaped like the indent in the diaphragm. The motion of the diaphragm forces air to flow around the plug and thence through the throat into the horn. This arrangement makes it practically impossible for any sound waves to be reflected from the walls of the sound chamber back to the diaphragm; instead, any reflected waves are channeled toward the throat by the sloping sides of the plug and the chamber. Many variations of this plug system have been worked out, but they all work on similar principles.

LOUDSPEAKER BAFFLES

A cone loudspeaker unit must be enclosed in some form of baffle to produce a reasonable coupling to the air. The shape and size of this baffle in a radio receiver depend on the fidelity and the efficiency desired. The same factors enter into p.a. work, and in addition, we have to worry about the possibility that sound from the



Courtesy Allied Radio Corp.

FIG. 20. These are box baffles of the sort commonly used in portable p.a. systems.

loudspeaker may travel through the air to the microphone. If sufficient energy can get from the loudspeaker back to the microphone, the system can become a self-sustaining oscillator, because this fed-back sound can replace the original sound and continue to repeat itself over and over through the microphone-amplifier-loudspeaker-air-microphone path. For this reason, loudspeaker baffles for p.a. work commonly have closed backs; this makes it possible to operate the loudspeaker near the microphone location without fear that the sound coming from the back surface of the loudspeaker cone will reach the microphone directly. An open baffle can be used only when the loudspeakers are located in such positions that feedback is unlikely.

Let's see what various common baffles are like.

CONE-LOUDSPEAKER BAFFLES

The simplest enclosure for a cone loudspeaker is the box baffle shown in Fig. 20. Two such box baffles are commonly used in portable p.a. systems, the two being so constructed that they can be secured together to form a closed box in which there is room for the amplifier when it is desired to carry the whole system from one place to another.

Courtesy RCA

FIG. 21. A typical wall baffle.

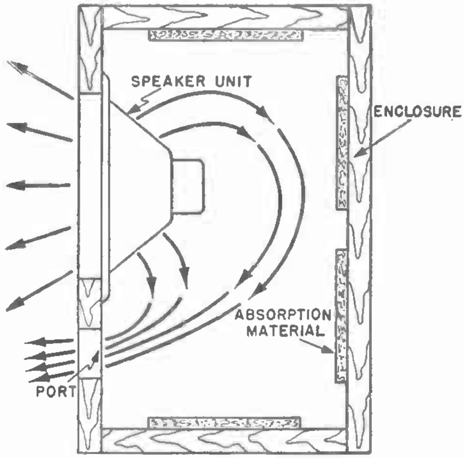


FIG. 22. Cross-sectional view of a bass reflex baffle. The arrows show the directions of the sound waves from the front and the back surfaces of the loudspeaker cones.

A baffle of this sort is not sufficient to give high fidelity, but it is adequate for voice or popular music. Since the back of this baffle is completely open, it must be carefully located with respect to the microphone to prevent feedback from the loudspeaker to the microphone.

Another simple baffle is shown in Fig. 21. This is a box that is intended to be hung on a wall. If enclosures of this sort are properly scattered around, well away from the microphone, it is possible to keep the feedback down to a satisfactory level. This baffle is actually enclosed at the back when it is mounted firmly against the wall, but since it is mounted so that it faces into the room, it can feed sound into the microphone unless the latter is carefully placed.

The larger cabinet baffles that are used where better tone quality is desired are generally completely enclosed at the rear. In most instances, such units are of the bass reflex type, an example of which is shown in Fig. 22.

Any of the baffles described so far gives a relatively broad sound distribution somewhat like that obtained from a radio receiver. There are occasions, however, when it is desired to project sound in a more compact "bundle" to a distance, or when it is

FIG. 23. A cone loudspeaker mounted in a projector housing.

necessary to prevent sound from going in certain directions to eliminate feedback. With cone loudspeakers, projectors (sometimes called trumpets) are used for such occasions. An indoor type is shown in Fig. 23. Basically, this is a directional enclosure,

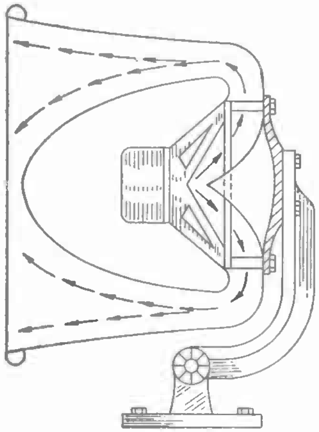


FIG. 24. A cross-sectional view of a cone loudspeaker mounted in a weatherproof projector. Such an assembly can be used outdoors.

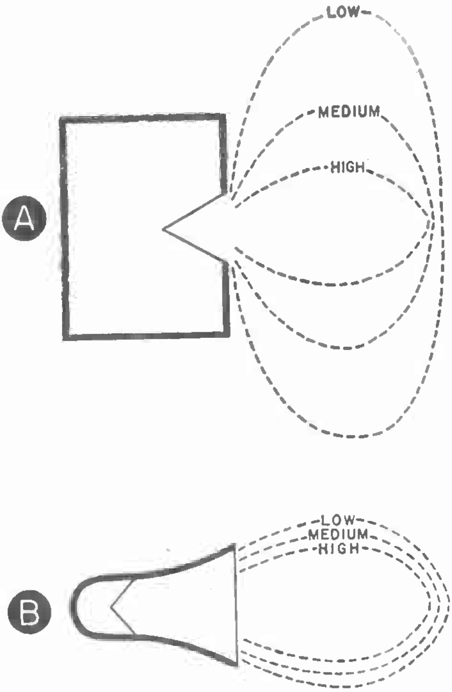


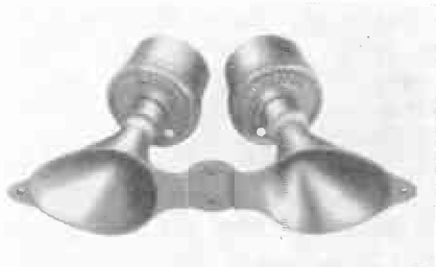
FIG. 25. This shows how a cone loudspeaker mounted in a box baffle (A) and one mounted in a projector horn (B) differ in their sound distribution characteristics.

very similar to a horn in its directive effects.

Outdoors, a variation of the projector is the only kind that is practicable with cone loudspeakers. Cones must be protected from the weather outdoors, so a weather-proof projector like the one shown in Fig. 24 is used. This is so designed that rain and spray will not seriously affect the cone even if they enter the mouth of the projector directly.

Sound Distribution. Incidentally, the sound output from loudspeakers is rather peculiarly distributed. Fig. 25A shows the result of using a cone in any standard wall or cabinet baffle. As you can see, low frequencies are distributed rather uniformly from the front of the baffle over a wide area. Medium and high frequencies become more and more directional, however;

the sound distribution at the highest frequencies is practically a narrow beam straight in front of the cone. This unequal sound distribution presents quite a problem if we are interested in high-fidelity sound distribution. It is obvious that only the

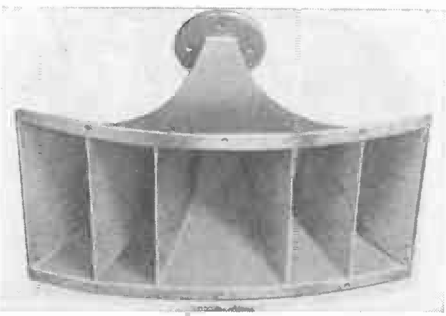


Courtesy University Loudspeakers, Inc.

FIG. 26. A double loudspeaker designed to give wide-angle distribution of high-frequency sounds.

people who are directly in front of the cone will get all the frequencies with equal intensity.

The projector distribution shown in Fig. 25B is much more nearly uniform. However, here we run into the fact that the projector isn't a very good baffle, because its low-frequency response is poor for reasonable pro-



Courtesy Jensen Mfg. Co.

FIG. 27. A cellular high-frequency horn.

jector sizes. In other words, a projector gives more uniform sound distribution with frequency than a box baffle does, but the box baffle gives better fidelity.

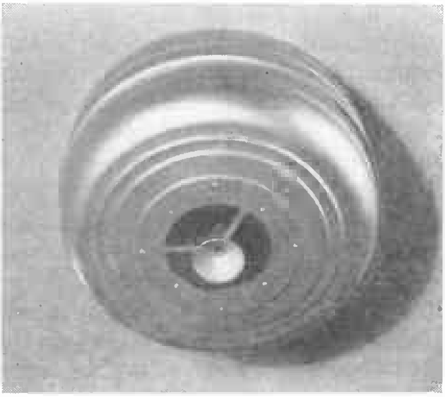
To improve sound distribution, high-fidelity installations frequently use dual loudspeakers. In such installations, a large cone loudspeaker is used to give low-frequency coverage; the high frequencies are handled by a small loudspeaker unit (usually a driver type) that is designed to give an angle of coverage that approximates the medium-frequency coverage of the large cone. Fig. 26 shows one type of high-frequency loudspeaker, which consists of a pair of driver units arranged with dual horns at such an angle that a rather wide coverage is obtained. Fig. 27 shows a "cellular" construction in which the

Courtesy Jensen Mfg. Co.

FIG. 28. A typical coaxial loudspeaker.

horn is broken into segments that disperse the sound to give a wide angle of coverage. This horn is driven by a single driver unit.

A form of dual loudspeaker that is commonly used in high-fidelity installations is shown in Fig. 28. This unit, called a coaxial loudspeaker, is used chiefly because it has a wide frequency range. In the immediate vicinity of such a loudspeaker, the fidelity is quite good, but it does not offer particularly wide-angle high-frequency coverage. Where a large area is to be covered with such loud-



Courtesy Langevin

FIG. 29. A loudspeaker in a housing designed for ceiling mounting. The small horn at the bottom helps diffuse the sound.

speakers, therefore, it is necessary to use a number of them to be sure of having reasonable sound distribution at all frequencies.

Fig. 29 shows an enclosure intended to be mounted in the ceiling and to distribute sound in all directions. This enclosure is very useful when the loudspeaker is to be mounted near the center of a room. However, it is probably the least desirable loudspeaker to have in the same room with the microphone, because some of the loudspeaker's energy is directed right at the microphone.

HORN ENCLOSURES

Some form of horn or trumpet enclosure is invariably used with driver units. Both the fidelity and the coverage angle are largely determined by the kind of enclosure chosen. A long, narrow horn with a small mouth tends to project sound directly in front of the mouth of the horn without allowing it to spread very much. On the other hand, if the horn flares outward rapidly, sound is distributed over a much wider angle.

From a fidelity standpoint, the rate of increase of the cross-sectional area of the horn is particularly important. In general, the horn must be rather long to have good low-frequency response. Since it should increase regularly in cross-sectional area as it increases in length, we must start with a very small throat if we are to have a reasonable mouth size in any practical horn length.

Horns that carry speech only need to handle only a limited frequency range; therefore, they can be, and commonly are, rather short. However, if music is to be carried through the horn, it must be long—so long, in fact, that the space required by the horn is quite a problem. One solution to this problem is to fold the horn up on itself as shown in Fig. 30. Even folded in this manner, the horn is rather large; a horn of this sort is generally used only in large auditoriums or theaters.

A more commonly used arrangement for getting a relatively long horn length in a small space is shown in Figs. 31 and 32. This device is known as the re-entrant or reflex horn. The name comes from the fact that the sound travels down an inside horn,

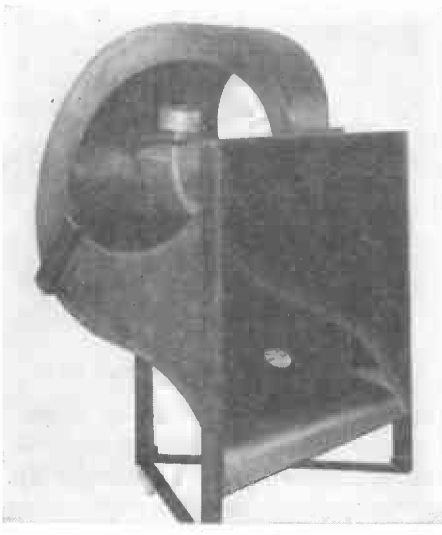


FIG. 30. A folded horn of the sort used in theaters and large auditoriums.

Courtesy University Loudspeakers, Inc.

FIG. 31. A typical reflex trumpet, much used for outdoor installations.

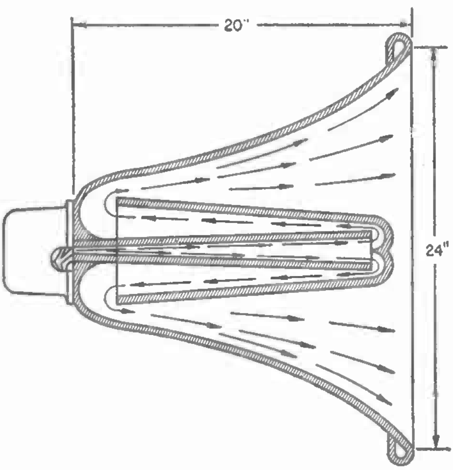


FIG. 32. Cross-sectional view of a reflex trumpet.

then is forced back toward the rear before it finally comes out of the mouth of the horn, as shown in Fig. 32. Because of this internal folding, it is possible to make the over-all dimensions of the horn rather short and yet have a fairly long air column. Furthermore, such a horn is weather-

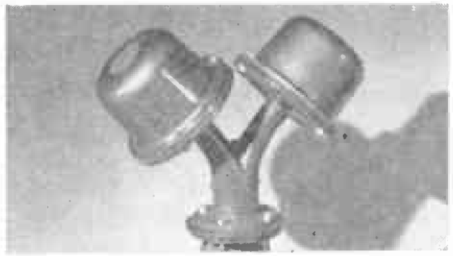


FIG. 33. A coupling of this sort makes it possible to use 2 driver units with one horn.

Courtesy University Loudspeakers, Inc.

This is an extremely powerful loudspeaker in which 12 driver units are used. It can handle powers up to 300 watts and can be heard for several miles.

proof, making it ideal for outdoor use.

Most drivers designed for use with horn units are rated at 25 watts but will work efficiently on 8 to 10 watts. If greater power is needed, extra loudspeakers may be used, or more than one driver may be used with a single horn. Fig. 33 shows a two-unit type; as many as twelve drivers are used on super-powered horns.

Now that you have a general idea of what the pickup patterns of microphones and the sound distribution patterns of loudspeakers are like, let's take up the practical problems of determining how much power is necessary for an installation.

Practical Acoustics

The amount of power needed for any particular installation depends on a number of factors. First of all, the hearing characteristics of the human ear must be considered. There must be a certain amount of power before the human ear registers any sound at all, the exact amount depending on the frequency of the source. At this threshold level, the ear is not at all a high-fidelity device; therefore, considerably more than this minimum power is needed to permit an audience to hear comfortably and with reasonably good fidelity.

As we have pointed out before, the noise level at the location of the installation must also be taken into account in determining the amount of power needed; the greater the noise, the greater the power that will be necessary. Indoors, we also have the problem of sound reflection from the walls and ceilings. Sound reflection is seldom a problem in an outdoor installation, but sound dispersal is. Let's make a complete study of each of these factors in turn to see how they affect the amount of power needed.

HEARING CURVES

The ear is very peculiar in the manner in which it responds to sound levels at different frequencies. It is most sensitive to sounds at about 2000 cycles. In other words, a very low-power sound at this frequency will be audible. At low or high frequencies, however, far more power is necessary to make a sound audible.

Fig. 34 contains a series of curves that indicate the average hearing ability of the human ear. Sounds having the intensities shown by curve A can just barely be heard, and sounds having lower intensities cannot be heard at all: curve A is therefore called the "threshold of hearing." Notice that this curve is very non-linear, illustrating what we just said about the ear being most sensitive at the minimum-loudness level to sounds around 2000 cycles and least sensitive to low-frequency and high-frequency sounds.

This variation in sensitivity with frequency becomes less marked at higher loudness levels. The dashed curves above curve A show the response of the ear at various loudness levels 10 db apart. (The threshold of hearing is used as the zero db reference.) As you can see, the response becomes much flatter as the loudness increases.

If a sound is made loud enough, the ear will feel pain instead of hearing

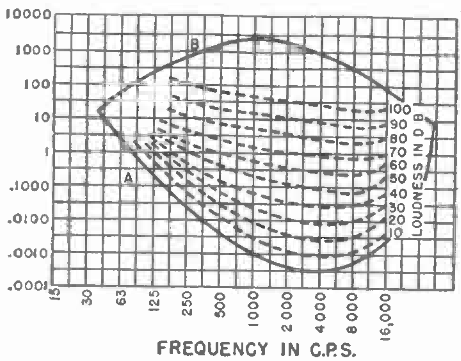


FIG. 34. The frequency-response curves of the human ear for sounds of various levels. Curve A shows the threshold of hearing, curve B the threshold of pain.

the sound. The loudness level at which pain is felt (which is called the "threshold of pain") is represented roughly by curve B in Fig. 34. Notice that this curve intersects the threshold of hearing at very low and very high frequencies but is widely separated from it at the middle frequencies. At frequencies around 1000 to 2000 cycles, the change is roughly about 120 to 130 decibels from the threshold of hearing to the threshold of pain.

You can see from these facts that the average person is able to hear only the middle frequency range if the sound level is very low; the low and high frequencies are completely inaudible. As the sound level is increased, higher and lower frequencies can be heard.

Obviously, the sound output of a p.a. system should be at least great enough to permit all the frequencies we are interested in to be heard comfortably. This means that the power required for a particular installation depends on what the system is intended to carry. If it is to be used for instrumental music, a wider frequency range must be handled than is needed if only voice frequencies are to be carried; consequently, more power is needed for the former kind of installation.

For convenience in comparing sound levels, it is standard practice to choose a reference frequency in the range where the hearing is most acute. The level necessary to produce an audible sound at this reference frequency is then considered to be the threshold of hearing, and other sounds and noises are said to be a certain number of decibels above this threshold level.

EFFECT OF NOISE

The ability to hear any sound is considerably affected by the noise level. Theoretically, even the weakest of the sounds in which we are interested should be at a level above the surrounding noise level if it is to be heard easily. Therefore, we need to know the noise level before we can choose the p.a. system.

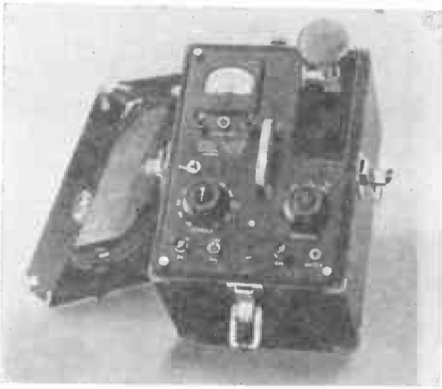
Fig. 35 shows the sound levels of various common noises, and the noise levels that are found in typical places

Type of Sound Source	*DB Level*
Threshold of painful sound	**130**
Hammer blows on steel	**120**
Riveting machine	**100**
Factory (very noisy)	**90**
Machine Shop (average)	**90**
Heavy street traffic	**85**
Printing Press	**80**
Ball Rooms	**80**
Restaurant (noisy)	**80**
Factory (average)	**75**
R.R. waiting room	**75**
Auditorium (average)	**75**
Office (busy)	**65**
Department store (average)	**65**
Auditorium (quiet)	**65**
Ordinary conversation	**60**
Quiet residential street	**60**
Restaurant (average)	**60**
Store (quiet)	**60**
Office (quiet)	**60**
Hotel lobby	**55**
Hospitals	**55**
Average quiet residence	**35**
Quiet garden	**25**
Average whisper	**20**
Rustle of leaves in gentle breeze	**10**
Threshold of hearing	**0**

FIG. 35. These are the levels in db above the threshold of hearing of various common sounds and noises. The figures have been compiled from several sources.

where p.a. systems may be used. Notice that the noise level in the average quiet home is about 35 db above the threshold; since the average conversation level is higher than this, we, of course, need no amplification to overcome the noise in a home. As a matter of fact, p.a. amplifiers are not needed to overcome noise until the noise level is above that of the desired sound. Acoustics standards state that the *average* sound level for *speech* should be maintained at least 10 db above the surrounding noise level. This is not practical, of course, when the noise level is up near the threshold of pain, because the sound level might then be over the threshold for some frequencies. It is therefore frequently impossible to keep the sound level above the surrounding noise level to any great degree in installations in very noisy factories.

For ordinary music, it is desirable to have the *average* sound level 15 db higher than for voice, or a total of 25 db above the noise. High-fidelity reproduction of symphonic music requires another 10 db above ordinary music, or an *average* level 35 db above the noise level. Of course, there will be peaks that exist above the average levels; however, proper design on an average power basis permits the peak power capabilities of the amplifier to handle these.



Courtesy General Radio Co.

A sound-level meter of this sort is very useful for determining the noise level at the site of an installation.

One of the problems always facing the sound engineer, therefore, is the determination of the noise level at the location where a p.a. system is to be installed. This determination must, of course, be made under the conditions that will be present at the time the p.a. system is to be used. An empty auditorium is far quieter than one filled with people. This is particularly true at a sporting arena, where an enthusiastic crowd of spectators can make the noise level very high.

To determine the noise level, one must guess at it (a very difficult thing to do accurately), measure it with a noise level meter, or depend upon practical tables or charts like Fig. 35. Loudspeaker manufacturers give average levels in charts designed around their particular loudspeakers. We'll say more about this later.

SOUND REFLECTIONS

As we have already said, sound reflections from the walls, floors, and ceilings of a room are a major problem in indoor p.a. installations. These reflections provide additional paths over which sound waves travel from the source to the listener. Fig. 36 gives a simple example.

Such reflections occur because whenever sound waves strike a surface, some of the energy is absorbed and lost, some is transmitted through the material, and the remainder is reflected much as light rays are reflected by a mirror. How much reflection there is depends on the material; hard, smooth materials like plaster reflect far more than do soft materials like drapes. These reflections "save" energy by preventing it from escaping from the room. However, the re-

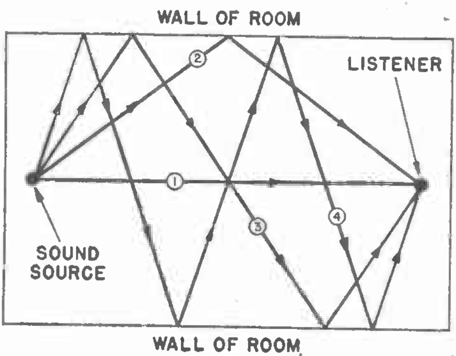


FIG. 36. The direct sound wave between the source and the listener travels over path 1, which is the shortest path between these two points. Waves traveling over paths 2, 3, or 4 must go a greater distance to reach the listener, and consequently arrive somewhat later than those taking path 1.

turn of this sound energy is not instantaneous; it takes more time for sound to travel over a longer path, so sound waves that reflect from wall to wall do not arrive at a given point in step with sound waves coming over a more direct path. Such reflected waves may cause the sound at any particular spot to be louder, softer, or unintelligible. Let's study this last effect first.

REVERBERATION

When the surfaces of a room are hard and smooth, reflections occur and recur, with the result that it takes time for sounds to die out. Consequently, syllables or words traveling over direct paths are interfered with by earlier sounds traveling over the reflection paths. This prolongation of sounds, which is called reverberation, is the most common acoustic problem in auditoriums.

Unless a room is made absolutely dead by special acoustic treatment (by making the surfaces absorb energy instead of reflecting it), there will always be a certain amount of this reverberation. The actual amount depends on the size and shape of the room and on the characteristics of the materials used in the room. We don't want a room to have no reverberation—such a room sounds "dead," and music or speech is flat in it. A certain amount of reverberation makes a room "alive"; music, in particular, has more brilliance and richness of tone in such a room.

To determine what treatment may be necessary to make a room more nearly ideal in this respect, engineers assume that the *period* of reverberation is the time it takes for a sound to decrease in energy by 60 decibels. To measure this period, a short, sharp sound is made, and timing devices are used to determine when it has decreased by this amount. If the time taken is reasonable for the size of the room, no treatment is necessary.

In general, the larger the room, the longer the reverberation period that can be permitted. There is no exact agreement on the amount of time that is permissible, however, because this depends upon whether it is speech or music that is to be reproduced and upon what the installer thinks is an ideal "liveness" for the room. Usually periods of under two seconds are necessary. "Ideal" periods for music in rooms of various sizes are shown

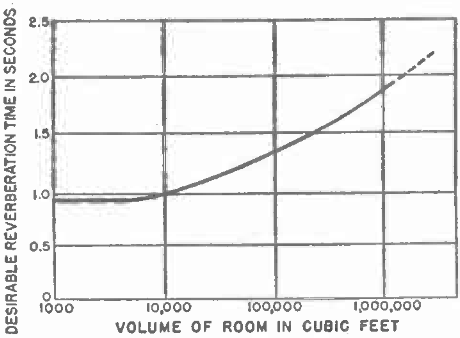


FIG. 37. This graph shows the desirable reverberation time for rooms of various sizes in which music is to be played.

in Fig. 37. For speech, the ideal is from half to two-thirds the values given in this figure.

As an example of how excessive reverberation affects the ability to understand speech, a reverberation period of 5 seconds in a 5000-cubic foot auditorium reduces the number of recognizable syllables to only about 60% of the total. At least 75% recognition is necessary for intelligibility with very careful listening, and about 90% is needed for high-quality reproduction. In a room of 5000 cubic feet, a reverberation period of about .6 second is required for 90% intelligibility.

ACOUSTIC TREATMENT

Since the reverberation time is related to the volume of the room in cubic feet and to the absorbing ability of the surfaces of the room, there is a formula that can be used for calculating the approximate reverberation period of a room. It is:

$$t = \frac{.05V}{a}$$

where "V" is the volume of the room in cubic feet, "t" is the period in seconds, and "a" is the number of absorption units of the materials used. We shall discuss absorption units in a moment.

This formula makes it possible to calculate the approximate period for a room. If the period is wrong, we can determine how much the absorption has to be changed to make the reverberation proper by restating the formula as:

$$a = \frac{.05V}{t}$$

which gives us the number of absorption units needed for a room of volume V to have the desired reverberation period t.

In general, acoustic treatment of a room is best left to an acoustical engineer. In a large auditorium, proper acoustic treatment involves a considerable expense, so it is far better to have the room treated by someone familiar with the materials that can be used for the purpose. If you have such a problem, therefore, you should call in an engineer or a representative of a company manufacturing sound-absorbing material. However, so you will understand what must be done, let's see how such an expert would go about planning the acoustic treatment of a room.

Courtesy The Celotex Corp.

A small broadcast studio that has been acoustically treated with Acousti-Celotex tile on the ceiling and carpeting on the floor. The walls have been irregularly shaped to improve sound diffusion. Acoustical treatments in rooms served by p.a. systems are similar, though seldom so extensive.

The number of absorption units in a room is computed by multiplying the area in square feet of each surface by a factor (called the absorption coefficient) that indicates the absorbing power of each square foot of the material. The total number of absorption units in the room is the sum of these, plus the units furnished by the audience and by the furniture.

As a general rule, any hard, smooth surface has very little absorption, so materials such as plaster walls will reflect sound and keep the reverberation period high. The same can be said for hard floor materials and for wooden seats.

On the other hand, soft, coarse materials absorb sound, so the period of reverberation can be reduced by the use of drapes or other cloth hangings, upholstering or pillows on the seats, rugs on the floor, etc. Even better sound absorption can be obtained through the use of special acoustic materials, which are commonly made of cane fibers. These materials either have a rough surface or have a surface with many small holes in it that break up the sound reflection and absorb much of the energy of the sound wave. Covering plaster ceilings and walls with such materials cuts down greatly on the reverberation and also reduces the noise (since it, too, is absorbed).

Materials	Coefficients
Floor Coverings:	
Carpet	.20
Cork flooring	.08
Linoleum	.03
Rug, Axminster	.20
Wood flooring	.03
Hangings:	
Fabrics:	
Light	.11
Medium	.13
Heavy	.50
Hard Wall:	
Brick, painted	.017
Cement	.025
Plaster on lath	.03
Openings:	
Window	.5—1
Balcony	.5—1
Audience and Chairs:	
People	3—4.3
Chairs, wooden	.17
Chairs, upholstered	1.6
Acoustic Materials:	
Acousti-Celotex C-2	.67
Acousti-Celotex C-4	.99
Acoustone F	.87
Fiberglas Tile (1″)	.97
Permacoustic (1″)	.71

FIG. 38. The absorption coefficients of various materials. The figures given for audience and chairs are in terms of absorption units per person or per chair; the other figures are for absorption units per square foot. These units were determined at 512 cycles. The absorption at other frequencies differs somewhat, usually, though not always, increasing at higher frequencies.

Wood floor:
(100 x 20 = 2000) x .03 = 60

Plaster walls:
(240 x 10 = 2400) x .03 = 72

Plaster ceiling:
(100 x 20 = 2000) x .03 = 60

Wood Chairs: 50 x .17 = 8.5

200.5

Volume = 100 x 20 x 10 = 20,000 cu. ft.

$$t = \frac{.05 \times 20{,}000}{200} = 5 \text{ sec.}$$

FIG. 39. The computations needed to determine the reverberation period of the room described in the text before it is acoustically treated.

The presence of an audience may change the characteristics of a room considerably. Clothing is very efficient as an absorption material.

Fig. 38 gives a general idea of the absorption coefficients of several typical materials. (The figures given for people, wooden chairs, and for upholstered chairs are absorption units per person or per chair, not absorption coefficients.)

To take a practical example, let's suppose we have a small hall 100 feet by 20 feet by 10 feet high, which has a volume of 100 × 20 × 10 = 20,000 cubic feet. Let's suppose it has a wood floor and plaster walls and ceilings. Let's also suppose there are about fifty wooden chairs in the hall.

Fig. 39 shows the details of calculating the absorption units present in the basic hall, using the average coefficients given in Fig. 38. There are 2000 square feet of floor space, and wood flooring has an absorption coefficient of .03, so the floor has a total of 60 units. A plaster wall around the room has a total area of 2400 square feet; its absorption coefficient is also .03, making its absorption 72 units. The ceiling has a total of 60 units and the chairs a total of 8.5 units. The sum of all these is 200.5, which we can round off to be 200 units.

The volume of the room is 20,000 cubic feet, so the time, as shown by the calculations, is five seconds. This is too long; Fig. 37 shows that it should be about 1.1 seconds for a room of this size if music is to be played in it.

An audience of fifty people present in the chairs will change matters, because the audience has an absorption of about four units per person or a total absorption of 200 units, which cuts the time in half, or to 2.5 seconds. Therefore, this hall will have much better characteristics with an audience than it has when empty. Even so, it still has too long a period. Using the formula for determining the absorption units needed, we find that to produce a 1.1-second period, we need:

$$a = \frac{.05 \times 20{,}000}{1.1} = 910 \text{ units}$$

(approximately) instead of the 200 to 400 we have.

Covering the floor with carpet, hanging medium-weight drapes on the walls, and using upholstered chairs produces the effects shown by the calculations in Fig. 40—the reverberation period is changed considerably. Our time of 1.17 seconds is now much better for a room of this size. With an audience adding 200 more units, the time is reduced to about one second, so this treatment is just about right.

Of course, a treatment that involves hanging drapes completely around the room, installing a carpet over the whole floor, and changing from wooden chairs to upholstered chairs cannot be described as a simple one. It may be less costly and more satisfactory in the long run to leave the floor and chairs alone and to have an acoustic material applied to the wall or ceiling. If we were to cover the entire wall with Acousti-Celotex type C-4, the number of absorption units for this treatment alone would be 2376 (2400 $\times$ .99). This would be too much and would make the room rather dead, because the reverberation period would then be only about .4 second. To come out around 700 units, so that with an audience (200 units) the period will be about one second, we need only about 600 feet of this acoustic material on the wall. Therefore, it is possible to hang several panels of this material at various points along the wall and thus deaden the room just as much as it would be deadened if

Carpet: (100 x 20 = 2000) x .2 =	**400**
Med. drapes on walls: 2400 x .13 =	**312**
Plaster ceiling: 2000 x .03 =	**60**
Upholstered chairs: 50 x 1.6 =	**80**
	852

$$t = \frac{.05 \times 20{,}000}{852} = 1.17 \text{ sec.}$$

FIG. 40. How acoustical treatment affects the reverberation period of the room.

we were to hang drapes over all the walls and put a carpet on the floor.

As you can see, there are a number of different things that can be done to change the reverberation period of a room. Initial costs, ease of application, and upkeep costs must all be considered in selecting a method of treatment. This is particularly true when a large auditorium is to be treated, because the cost of such a project may be very high.

An auditorium intended to seat several thousand people is a difficult problem to treat acoustically because of the fact that the audience may vary in size from just a few people to a capacity crowd. There will obviously be a tremendous difference in the absorption of the auditorium under the two extreme conditions; if the treatment is such that the reverberation period is correct when the auditorium is filled to capacity, the reverberation will be excessive when the audience is small. Usually the treatment for such an auditorium is calculated on the assumption that it is to be only moderately full. Then, as the audience varies around this average, the period is made slightly higher or lower, but never varies as much as it would if we assumed either zero or a capacity audience.

FOCAL POINTS AND DEAD SPOTS

Another factor that must be considered in planning a p.a. installation is the possibility that the shape and size of the room will cause unequal sound distribution over the floor area. An example of just such a room is shown in Fig. 41. The dome-shaped ceiling of this auditorium provides sound paths that tend to concentrate the sound from the origin to a spot in the balcony. At this particular spot, the sound will be excessive.

On the other hand, it is equally possible for the shape of the room to cause dead spots—points at which

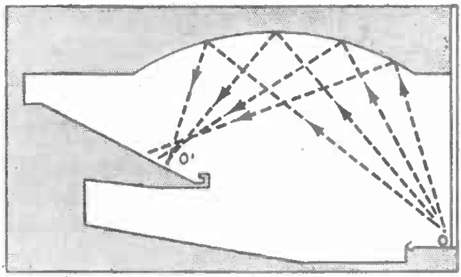


FIG. 41. Sounds reflecting from various points on the curved ceiling of this auditorium are brought to a focus at a single small area in the balcony, making the volume level there considerably higher than it is elsewhere.

there is sound cancellation because the sounds arrive out of phase over two different paths. Such spotty responses are not likely in small rooms but are quite common in large auditoriums. In such cases, it is either necessary to treat the room acoustically to break up these reflection points or to place the loudspeakers so that the sound is more evenly distributed. The latter method is usually preferable, since it is less difficult and expensive than is changing the contour of a room.

Determining Acoustical Powers Needed

From the foregoing section, you can see that there are a number of factors involved in determining how much acoustical power will be necessary to obtain the desired performance from a p.a. system in a given location. Engineering methods can be used to calculate the exact power necessary, but the practical sound man seldom bothers to make such elaborate computations. Instead, he uses some table or graph that gives a general idea of the power that should prove suitable under average conditions.

Most such published tables, which, incidentally, may be found in the literature of the loudspeaker manufacturers, assume that the reverberation period of the room is normal for its size and for the conditions that will be met. If you find upon examination that the room is not normal in this respect, a correction must be made to make the room suitable for a permanent sound installation.

If the reverberation in the room is reasonable or is made so, we can find the power necessary if we know the volume of the room in cubic feet and the noise level that can be expected.

Unless you are going to go to the expense of purchasing or renting a noise level meter to check the exact level, you will have to depend on the averages that have been found for installations that are similar.

Tables, such as Figs. 42 and 43, give acoustic powers needed for particular noise levels and room volumes. To use them, you will have to estimate or determine the noise; the tables then give the approximate acoustic power needed for a room having the area of the one in which you are interested. Notice that the *minimum* powers for the reproduction of speech or music are given—more power may be needed if the room is dead or if it is necessary to overcome dead spots or reflections in the room.

Once you have determined how much power is needed, you will have to divide the number of acoustic watts by the speaker efficiency to get the electrical wattage the amplifier must supply. For example, if the acoustic power is .5 watt, and you are using ordinary cone loudspeakers, which are about 2% efficient, the amplifier must have an output of 25 watts of electrical power ($\frac{.5}{.02} = 25$). Generally, it is best to choose an amplifier rated somewhat above this minimum, to allow for losses in the transmission lines, and for possible increases in the noise level.

The tables in Figs. 42 and 43 are incomplete, since they cover only a

Noise Level (db) Above Threshold of Hearing	*Area (sq. ft.)* 500-2000 *Assumed Room Height (ft.)* 10-15	*Area (sq. ft.)* 2000-5000 *Assumed Room Height (ft.)* 15-20	*Area (sq. ft.)* 5000-10,000 *Assumed Room Height (ft.)* 20-25	*Area (sq. ft.)* 10,000-30,000 *Assumed Room Height (ft.)* 25-35	*Area (sq. ft.)* 30,000-70,000 *Assumed Room Height (ft.)* 35-50
70	0.001-0.004	0.004-0.010	0.010-0.019	0.019-0.056	0.056-0.126
80	0.012-0.044	0.044-0.100	0.100-0.199	0.199-0.562	0.562-1.26
90	0.126-0.447	0.447-1.0	1.0-1.99	1.99-5.62	5.62-12.6
100	1.26-4.47	4.47-10.0	10.0-19.9	19.9-56.2	

Courtesy John F. Rider

FIG. 42. Minimum acoustic power in watts required to override noise for reproduction of speech only in indoor coverage areas indicated. Areas are in square feet.

Noise Level (db) Above Threshold of Hearing	Area (sq. ft.) 500-2000 Assumed Room Height (ft.) 10-15	Area (sq. ft.) 2000-5000 Assumed Room Height (ft.) 15-20	Area (sq. ft.) 5000-10,000 Assumed Room Height (ft.) 20-25	Area (sq. ft.) 10,000-30,000 Assumed Room Height (ft.) 25-35	Area (sq. ft.) 30,000-70,000 Assumed Room Height (ft.) 35-50
70	0.039-0.141	0.141-0.316	0.316-0.631	0.631-1.78	1.78-3.98
80	0.398-1.41	1.41-3.16	3.16-6.31	6.31-17.8	17.8-39.8
90	3.98-14.1	14.1-31.6	31.6-63.1		

Courtesy John F. Rider

FIG. 43. Minimum acoustic power required to override noise for normal p.a. requirements for speech and music reproduction in indoor coverage areas indicated. Areas are in square feet.

few noise levels. However, the trend of powers is obvious, so you can fill in for lower or higher noise levels by the simple process of dividing or multiplying by a factor of 10 for each 10 db decrease or increase in noise.

In attempting to estimate the amount of noise, you can use tables like that shown in Fig. 35 or charts that you obtain from loudspeaker manufacturers. Such loudspeaker charts give usual noise levels and the power needed for various room volumes when using certain particular loudspeakers. These charts apply only to the loudspeakers made by that manufacturer—you should obtain the one for the brand in which you are interested, because differences in efficiencies and coverage angles exist that make them wrong for other brands.

Let's sum up what we have learned about calculating how much power is needed for an indoor installation. First, you must determine whether the room has the proper reverberation period or needs acoustic treatment. Then, from a table or chart, you must find how much acoustic power is needed for a room of the size of the one with which you are concerned, taking into consideration the average noise level of the room and whether music and speech, or speech alone, is to be carried by the p.a. system. Naturally, even more acoustic power is needed for the high-fidelity reproduction of music than is necessary for ordinary dance music or for speech.

To convert acoustic power into electrical power, you must know the efficiencies of the loudspeakers you intend to use. As we said earlier, cone loudspeakers are commonly considered to be 2% efficient in baffles and 5% efficient in projectors. By dividing the acoustic power level (in watts) by the speaker efficiency (expressed as a decimal), you will find the electrical power needed.

SOUND OUTDOORS

We have no reverberation problems outdoors but do have the problem of rapid attenuation of the sound. Since there are no walls to reflect energy back to the audience, sound power goes down 6 db for each doubling of the distance from the loudspeakers to the listener.

Horn loudspeakers are generally used in these installations. The horns may have either narrow or wide coverage angles, depending on the installation. Both types have their advantages and disadvantages. Horns with wide coverage angles cover a larger area, but since the sound is spread out over this area, it is weaker at any distance from the horn than it would be for a horn with a narrower coverage angle. On the other hand, if we use narrow-angle horns and must cover a wide area, we have to use more of the horns to cover this area properly.

Noise Level (db)	10-30 ft.	30-75 ft.	75-150 ft.	150-300 ft.	300-500 ft.	500-1000 ft.
70	0.002-0.017	0.017-0.112	0.112-0.501	0.501-1.78	1.78-5.01	5.01-20.0
80	0.020-0.178	0.178-1.12	1.12-5.01	5.01-17.8	17.8-50.1	
90	0.200-1.78	1.78-11.2	11.2-50.1			
100	2.0-17.8	17.8-11.2				

Courtesy John F. Rider

FIG. 44. Minimum acoustic power required to override noise for reproduction of speech outdoors for coverage of indicated distance in feet. A coverage angle of 30° is assumed. More power is required if larger angles of coverage are used.

Fig. 44 shows a table for determining the sound power necessary outdoors. Notice that the table is for a certain specified coverage angle of the horn.

A comparison of Fig. 44 with Figs. 42 and 43 shows that the acoustic power needed outdoors is far higher than it is for indoor installations. However, since horns have a 15% efficiency, the actual electrical power increase needed is not as great as you might at first imagine. For example, if the indoor acoustic power needed is 1 watt, and 2% efficient loudspeakers are used, 50 electrical watts are necessary. With a 15% efficient loudspeaker, 1 acoustic watt is obtained from only about 6 electrical watts, however. Fifty watts delivered to 15% efficient loudspeakers will deliver as much as 7.5 acoustical watts, which is a respectable amount of sound power.

PLACING LOUDSPEAKERS

Either indoors or outdoors, once we decide on the electrical power that will be needed, we must then determine both from the power level and from the surrounding conditions the number of loudspeakers that will be needed. Cone loudspeakers are available in various power-handling capacities from as low as 1 watt to perhaps 40 watts. If the necessary amplifier power level is higher than one loudspeaker can handle, then obviously more than one must be used. Most driver units are rated at about 25 watts, but they operate satisfactorily from powers as low as 6 to 8 watts. However, if the output from the amplifier is greater than 25 watts, again more than one loudspeaker is needed.

Extra loudspeakers may be needed to give the proper coverage for the area. There are locations at which it is best to use a number of loudspeakers and divide the sound for better dispersion. In some instances, such as when sound is distributed to hotel or hospital rooms, this is a necessity—a small loudspeaker must be placed in each room, which of course means that there will be quite a number of loudspeakers.

Even when the major sound distribution comes from one or two large loudspeakers located near the source of sound, a few supplementary loudspeakers may be necessary to take care of spots that would otherwise be dead.

Incidentally, when the loudspeaker is in the room in which the performance is occurring, it is considered good practice to get the loudspeakers somewhere near the source of sound, so that the sound will apparently be coming from its source. This, of course, introduces the problem of feedback to the microphone through the air, which means that the loudspeakers must be so enclosed or so positioned that the feedback will not be excessive.

Of course, this does not mean that all the loudspeakers must be grouped in one place. Even if the main ones are so grouped, there may have to be supplementary loudspeakers to feed sound into dead spots, under balconies, etc.

When you are feeding sound into rooms other than the one in which the performance is occurring, you do not have to worry about feedback to the microphone. It is possible to use a single cluster of loudspeakers in such a room, but because sound may be excessively loud near the loudspeakers and too weak farther away, it is more common in this kind of installation to scatter the loudspeakers about. The only problem here is to make sure that the coverage is approximately uniform over the entire room.

We will go into greater detail on loudspeaker placement when we take up typical installations elsewhere. For now, let's cover a few general rules that will prove helpful in any installation.

Loudspeaker Phasing. When more than one loudspeaker is used in a cluster, it is important that the voice coils be connected so that the sounds from these loudspeakers are in phase. If the loudspeakers are outwardly identical, you can usually assume that the connections from the voice coil to the terminals on the loudspeaker are the same on each, and you can connect similar terminals together when the loudspeakers are in parallel, as shown in Fig. 45A. Fig. 45B shows the proper way to connect loudspeaker voice coils in series.

It is always possible, however, that the manufacturer has reversed one of the windings; if so, neither of these connections will be right for these particular loudspeakers. When the loudspeakers are out of phase, the sound from them tends to cancel. Therefore, the correct in-phase connection will be the one that gives the louder response for the same fixed input. If there is any doubt about this, you can make the simple test of listening to the loudspeakers while you reverse the connections to one of them.

You don't have to worry about the phase of loudspeaker connections when the loudspeakers are very widely separated, particularly when they are outdoors.

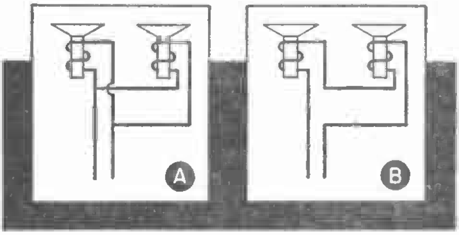


FIG. 45. Proper method of connecting loudspeaker voice coils in parallel (A) and in series (B).

Coverage Angles. Loudspeakers in box baffles have fairly wide coverage angles at low frequencies, but the angle of coverage for the middle and high frequencies is more restricted. For this reason, loudspeaker placement may become rather critical. If it is desired to have the sound apparently come from the source on a stage, the loudspeakers should preferably be mounted above the stage and should be tilted downward to point toward the audience. If there are two loudspeakers, better results can be obtained by placing them to the right and left of the center of the stage, turning them so as to give the greatest coverage.

If a room is to be covered by a series of separated loudspeakers instead of by a centralized group, you can either locate them along the longer wall or use ceiling loudspeakers that have 360° coverage. Incidentally, when loudspeakers are located along a wall, they should never be more than about 40 feet apart; if they are more widely separated than this, there will tend to be an echo effect as sound comes to listeners from different loudspeakers.

In general, outdoors, it is preferable to have the loudspeakers in a single cluster if possible. Of course, it may not be possible to use a single cluster. In football stadiums, for example, it may be necessary to string the loudspeakers around so that each covers a portion of the audience.

MICROPHONE PLACEMENT

The proper placement of microphones is often a problem. Of course, if voice is being picked up, it is common practice to have the microphone directly in front of the person speaking. Stage presentations, however, often require not only that the sound be picked up over a wide area but also that the microphone be concealed. Generally, in such cases, from two to four microphones are located in the footlight region of the stage, or several microphones are suspended from above the stage so as to cover as much of the area as possible.

When instrumental music is to be picked up, it is often necessary to locate the microphone or microphones very carefully with respect to the various instruments being used. Several typical examples are shown in Fig. 46. In cases of this kind, the only practical way to find the right microphone positions is to be present at a rehearsal and try various positions until the proper ones are found.

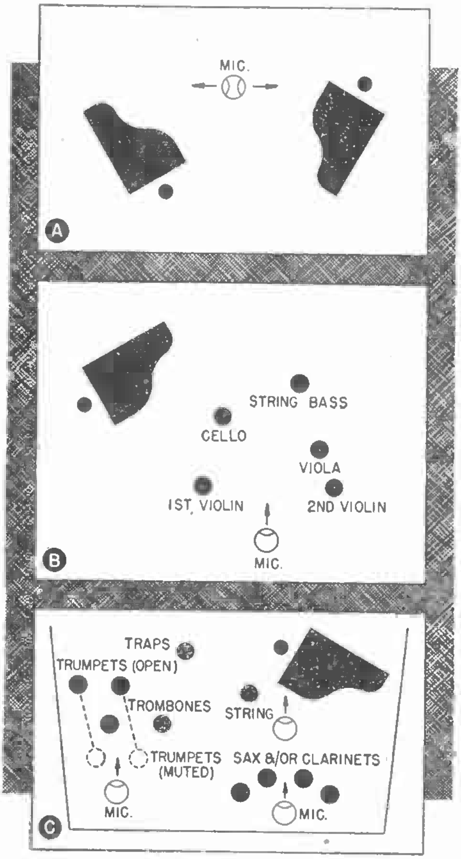


FIG. 46. Practical microphone placements for picking up (A) a 2-piano team, (B) a small salon orchestra, and (C) a dance orchestra.

THE MAN WHO COUNTS

The man who counts is the man who is decent and who makes himself felt as a force for decency, for cleanliness, for civic righteousness. First, he must be honest. In the next place, he must have courage; the timid man counts but little in the rough business of trying to do well the world's work. In addition, he must have common sense. If he does not have it, no matter what other qualities he may have, he will find himself at the mercy of those who, without possessing his desire to do right, know only too well how to make the wrong effective.—Theodore Roosevelt.

* * *

This statement of Theodore Roosevelt's has always appealed to me as being a very sound piece of practical advice. Read it carefully. It can be of real value to you.

TV SWEEP CIRCUITS

55RH-3

NATIONAL RADIO INSTITUTE
WASHINGTON, D. C.
ESTABLISHED 1914

STUDY SCHEDULE NO. 55

For each study step, read the assigned pages first at your usual speed, then reread slowly one or two times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☑ **1. Introduction . . . . Pages 1–7**

Here you learn what characteristics the scanning signal in a TV receiver must possess.

☑ **2. Generating a Saw-Tooth Voltage . . . . Pages 7–9**

In this section, you learn how a wave-shaping circuit is made to produce a saw-tooth wave.

☑ **3. Basic Sweep Oscillators . . . . Pages 9–18**

This section contains descriptions of the blocking oscillator, multivibrator, and sine-wave oscillators that may be used to drive a shaping circuit.

☑ **4. Electrostatic Sweep Circuits . . . . Pages 18–24**

The ways in which saw-tooth sweep voltages are produced in sets using electrostatic deflection are described in this section.

☐ **5. Basic Electromagnetic Sweep Circuits . . . . Pages 24–29**

Here you learn how saw-tooth vertical sweep currents are produced in sets in which electromagnetic deflection is used.

☐ **6. Horizontal Electromagnetic Sweep Circuits . . . . Pages 30–36**

The more complex circuits needed to produce saw-tooth horizontal sweep currents are described in this section.

☐ **7. Answer Lesson Questions and Mail Your Answers to NRI for Grading.**

☐ **8. Start Studying the Next Lesson.**

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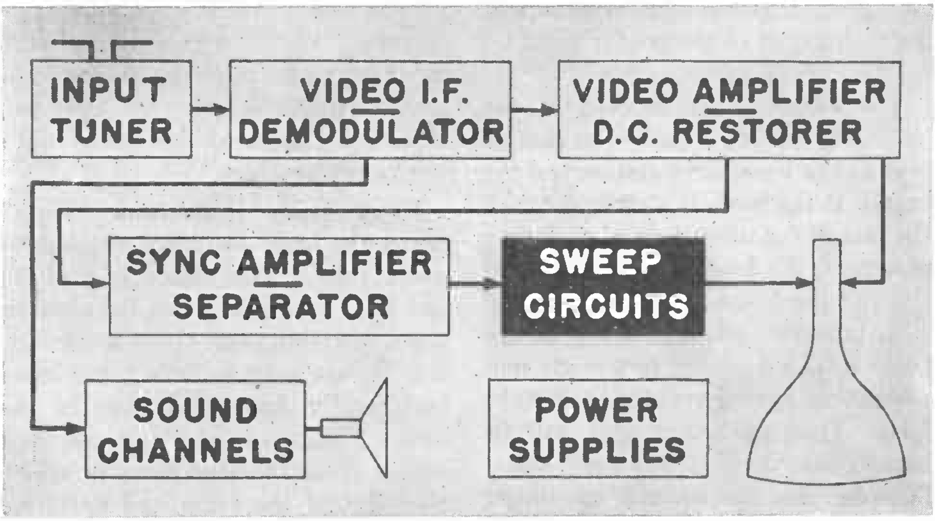


APPLYING a video signal between the grid and the cathode of the picture tube varies the number of electrons in the beam through the picture tube and thus varies the brightness of the spot struck by the beam on the face of the picture tube. As a result, the brightness of the spot at any instant corresponds to the light level at some point on the mosaic of the camera tube from which the video signal originates. To reconstruct the original scene, we must move (or sweep) the picture-tube beam across the face of the tube line by line in synchronism with the scanning of the camera tube so that the spot of varying brilliance will always be at the right point in the picture. Only in this way can we reconstruct the scene from its elements into a complete picture.

The human eye is capable of seeing an entire scene at one time because each tiny portion of the scene is carried over a separate nerve path to the brain. There are thousands of nerve channels from the eye to the brain, so it is possible for the brain to reconstruct an entire scene from the individual elements delivered to it over each nerve path. In television, it is impossible to transmit an entire scene as a single unit this way, because there would have to be a separate channel for each element of the picture. Instead, a televised scene is broken up into its individual elements, which are sent consecutively.

When the transmitter has sent a signal corresponding to all the elements along one line, it starts to send one that corresponds to those of the next line. Therefore, we must have some means of moving the electron beam within the picture tube across the face of the tube as each line signal is received and some way to move it down the face so it will be in position for the next line. In this way, we can reassemble the signals from the various scene elements in their proper order to give us a picture.

To get a picture, therefore, we must have a spot whose brightness corresponds to the brightness of an element in the original scene, and we must also have a sweep system that will move this spot to the proper point on the face of the tube.

The range of adjustment of the brilliancy control is limited so that as long as the beam is in motion and the energy in the beam is distributed over the face of the tube, there is no danger of burning the fluorescent screen material. If the beam is allowed to stand still, however, all the energy of the beam will be delivered to a single spot rather than spread over the entire tube face. That particular spot will be burned so that it can no longer fluoresce and hence will no longer produce light. *Therefore, we must have a sweep system that will keep the electron beam in motion whether we have a signal or not.* Then, when a signal is tuned in, the sweep system must fall under the control of the sync pulses that accompany the video signal, so that the lines can be made to start at the proper time. Before going on to learn more about sweep systems, let's see how the beam is moved inside the picture tube.

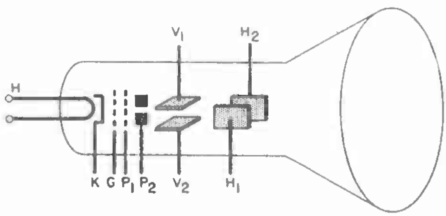


FIG. 1. Basic design of an electrostatic tube.

DEFLECTION METHODS

As you learned in your study of the picture tube, there are two basic methods of deflecting the electron beam. In one, sweep *voltages* are applied to deflecting plates within the picture tube; in the other, sweep *currents* are applied to deflection coils that are around the neck of the tube. Let's briefly review these.

Electrostatic Deflection. Fig. 1 shows the basic design of an electrostatic tube. The plates labeled V_1 and V_2 are used to deflect the electron beam vertically, and those labeled H_1 and H_2 are used to deflect the beam horizontally across the face of the tube. *These sets of plates get their names from the directions in which they deflect the beam and not from their physical positions.* (Notice that the horizontal deflection plates are vertically mounted and the vertical deflection plates are horizontally mounted.)

Since the electron beam consists of negative particles, it will be attracted toward any positive element within the tube. Therefore, let's assume that we are facing the front of the tube and have the conditions illustrated in Fig. 2. Let's first just apply a voltage between the horizontal deflecting plates H_1 and H_2 that makes the plate H_1 positive, as shown in Fig. 2A. The electron beam (indicated by a dot) will move toward this plate, the distance it is moved depending on the voltage applied between the plates.

(Of course, the distance the beam is moved also depends on its stiffness, which is determined by the accelerating voltage applied to the second anode.)

If we reverse the polarity (Fig. 2B), the electron beam will move toward plate H_2. Therefore, if we alternately make first one and then the other plate positive, the electron beam will be

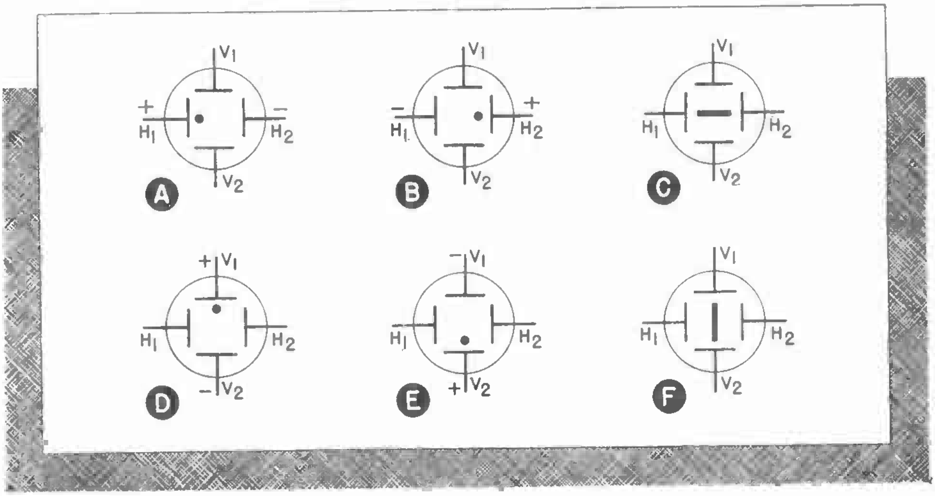


FIG. 2. How the electron beam is swept across the face of an electrostatic tube.

swept back and forth as shown in Fig. 2C, thus producing a line.

Similarly, the electron beam can be deflected up and down by voltages applied to the vertical deflecting plates V_1 and V_2, as shown in Figs. 2D, E, and F. When the proper voltages are applied to both sets of plates, the electron beam will be swept over the entire tube face, as shown in Fig. 3.

Electromagnetic Deflection. The other system of deflection makes use of a magnetic field set up by two sets of coils (called deflecting coils) that are at right angles to each other. The moving stream of electrons within the picture tube constitutes a current flow, and therefore it has a magnetic field associated with it. As these electrons flow through the magnetic field set up by the coil systems, the interaction between the field of the electron beam and that of the coils will cause the electron beam to move. For any particular accelerating voltage, the distance of movement will depend on the strength of the magnetic field of the deflecting coils, which is proportional to the current through them.

The vertical deflecting coils are mounted horizontally, and the horizontal or line deflecting coils are mounted vertically. The two sets of coils are arranged as shown in Fig. 4A when you look from the face of the tube toward the cathode. These coils are actually wound flat (Fig. 4B)

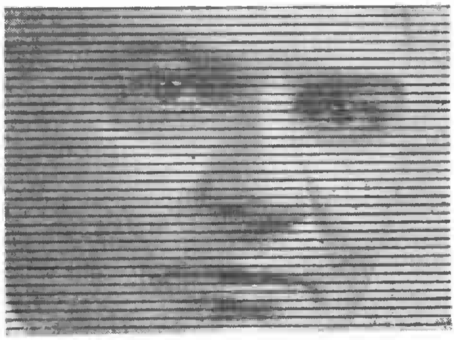


FIG. 3. This enlargement of a section of a TV picture shows that it is made up of a series of lines of varying brightness separated by fine black spaces. (Look at it from 10 feet away and you will see that the lines blend together.)

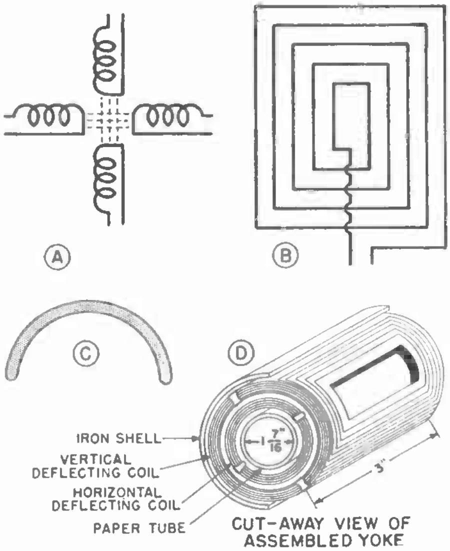


FIG. 4. How an electromagnetic deflecting yoke is made.

and then curved as shown in Fig 4C. Then the two sets are interleaved (Fig. 4D) into a single yoke assembly that slips around the neck of the picture tube.

With this brief explanation of the actual mechanics of getting the electron beam to move, we can now return to a study of the shape of the sweep signal that is needed and can learn more of its characteristics. Keep in mind that the deflection in an electrostatic deflection system is proportional to *voltage,* whereas the deflection in an electromagnetic deflection system is proportional to *current.* This important difference has much to do with the design of the sweep circuits, as we shall show later in this Lesson.

THE SCANNING SIGNAL

If we were interested only in protecting the fluorescent coating of the tube by causing the electron beam to be swept over the entire face, we should not have to worry much about the shape of the scanning signal. Since we are going to reproduce a picture, however, it is very important that the scanning signal have exactly the same characteristics as the signal that is used to sweep the face of the pickup tube at the transmitter. The control pulses that come from the transmitter determine only the frequency or rate at which the scanning occurs, not the wave shape. Fortunately, however, as we will show shortly, it is relatively easy to get the right scanning wave shape in the receiver.

At both the receiver and the transmitter, the scanning signal must move the electron beam linearly with respect to time. If the scanning signal is non-linear, so that the beam deflection is slow part of the time and fast the rest of the time, more electrons will hit the spots over which the beam travels slowly and less will hit those over which the beam travels quickly. The brightness of a spot on the tube face depends on the number of electrons hitting it; therefore, non-linearity in the scanning signal will produce brightness variations in the raster (the pattern formed when no picture is being received). If we use a sine-wave signal for scanning, for example, the beam will move slowest at the left and right of the screen and fastest in the middle, with the result that the raster will be dim in the middle and excessively bright at the sides.

To get an even distribution of the brilliancy, the scanning signal must change so that the distance moved by the beam is exactly proportional to time, as shown in Fig. 5A; the "curve" followed by the signal must be a straight line. This means that the rate of movement of the beam across the screen should be absolutely uniform; if it moves a certain distance in a certain time, it should move twice as far in twice the time.

Once we have moved the electron beam from left to right across the face of the tube, we must then get it back to the left to start the next line. The ideal action would be to make the electron beam snap back to the left instantly, because then the full scanning time could be used to transmit a signal. In this case, the movement of the beam would be as represented in Fig. 5B. The electron beam would move steadily from the left (L) through the center (C) to the right (R) as the scanning signal changed from W to X. At point X, the end of one line would be reached. Instantly, the electron beam would move from the right to the left as the scanning signal snapped from X to Y. The beam would then be back in the

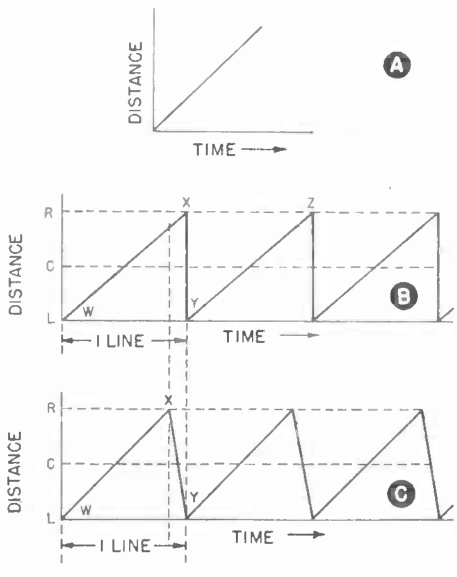


FIG. 5. Evolution of a saw-tooth scanning signal.

same relative position at the left of the tube face as it was at W. The next line would then be scanned from Y to Z, and so on.

Unfortunately, such a very abrupt change in the position of the electron beam from right to left would call for extremely high-frequency components in the scanning signal, which would not be easy to handle. In practice, therefore, a certain amount of time is allowed for the beam to move back to the left-hand side of the screen; a scanning signal having the shape shown in Fig. 5C is used. (This is called a "sawtooth" wave, because its shape is somewhat like that of a tooth on a handsaw.) Notice that the "retrace" signal from X to Y (that is, the signal that moves the beam from right to left on the picture tube face) now has an appreciable slant. Although the retrace (X to Y) is faster than the scan (W to X), it nevertheless takes an appreciable length of time to make the retrace. It is standard practice to arrange for the retrace from X to Y to occur in about 8% to 10% of the total time required to reproduce one line. This means the scanning from left to right (W to X) must now occur somewhat faster than it did in Fig. 5B to complete each line in the same line period. This is indicated by the fact that X in Fig. 5C occurs sooner than in Fig. 5B.

To prevent the retrace (X to Y) from being seen as a streaky line from right to left, the screen of the picture tube is blanked out by the blanking pedestal and the sync pulses that accompany the signal. To be sure that the retrace will occur during this blanking, the retrace is started slightly after the blanking has begun and is finished well before the blanking period ends. This means that the blanking period, which uses up 14% of the time allotted to the reproduction of one line, cuts a slight amount off each line at both ends.

Of course, we don't want the lines to occur right on top of each other—they must be spaced down the tube face so that each line will be below the one preceding. Therefore, a vertical scanning signal is applied to the beam simultaneously with the line, or horizontal, scanning signal. As a result, the beam is moved slowly downward as it moves across the screen during the transmission of a single line, producing a slight slant in each line. Then, when one line is finished and the retrace (or "flyback," as it is sometimes called) snaps the beam back to the beginning of the second line, the second line will occur underneath the first.

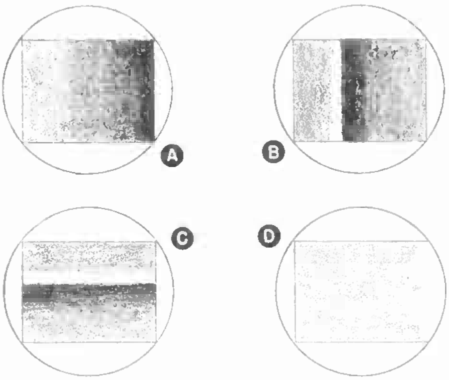


FIG. 6. Defects caused by scanning signal variations.

The vertical scanning signal has exactly the same shape as the horizontal or line scanning signal. The only basic difference between them is that the vertical scanning occurs at a much lower frequency. Under present standards, there are 525 lines for each complete frame of the television signal, and there are thirty frames per second. Because of the use of interlaced scanning, this is broken so that there are 262.5 lines per field, and 60 fields per second. Therefore, the frequency of the line scanning signal is 15,750 cycles per second (262.5 × 60), and the field frequency is 60 cycles per second.

Let's sum up what we have learned. To produce the desired scanning, we must use two scanning signals, one that will move the electron beam at a constant velocity along each line, and one that will move it downward to produce succeeding lines. The lines must be linear with respect to time, and both the scanning and retrace must be identical from line to line. Finally, we must control either the number of lines or the frequency (which effectively controls the length of each line). This control is produced with the aid of the synchronizing pulses sent out with the video signal.

Fig. 6 shows the effects of several possible variations in the scanning signals. In Fig. 6A, for example, we have a nonlinear horizontal scanning signal. Since it moves the beam slower at the left and faster at the right, the picture appears brighter at the left side. In Fig. 6B, the horizontal scanning signal moves the beam at the normal rate first, slows it down near the center of the picture, then moves it much faster than normal, and finally makes it travel at the normal rate again; this produces a bright vertical area followed by a dark vertical area in the center of the picture. Fig. 6C shows the effect of one kind of non-linearity in the vertical scan. Here the vertical signal is such that the beam moves at the normal rate first; then it moves slowly, producing closely spaced lines; then it moves rapidly, widening out the spacing; and finally it moves at the normal rate again. Fig. 6D shows what happens if each horizontal scanning signal is not the same length; as you see, a ragged edge is produced at the right. These are not, of course, the only troubles that might occur.

In this introduction, we have shown that the scanning signals or sweep signals must have a certain basic shape. Although these signals exactly duplicate the sweeps used at the transmitter, they are formed in the television receiver: the synchronizing pulses that accompany the signal from the transmitter serve only to signal the end of a line and thus start the retrace for the next line. As a matter of fact, the sweep circuits must operate all the time (whether a signal is tuned in or not) to protect the picture tube. Therefore, a television receiver must contain circuits that will generate the proper sweep signals at approximately the right frequencies by themselves. In addition, these circuits must be arranged so that they can be locked in with the synchronizing pulses when a signal is received. In this Lesson we shall cover only the production of the sweep signals—their synchronization will be covered in another text.

Generating a Saw-Tooth Voltage

The oscillators you have studied in other Lessons all generate either a sine wave or some form of square-wave signal. To get from such oscillators the saw-tooth sweep signal we need, therefore, we must use a wave-shaping circuit. Fortunately, it is simple to get the desired saw-tooth by taking advantage of the manner in which a condenser charges through a resistance. Let's see how.

SAW-TOOTH GENERATORS

To see how it is possible to get a saw-tooth wave, let's start with the circuit shown in Fig. 7A. Suppose we first close switch SW_1 (leaving SW_2 open). At the instant SW_1 is closed, current will start flowing through the circuit. However, the battery voltage will not appear instantly across the condenser. It takes the condenser a certain length of time to charge; this time is determined by the values of

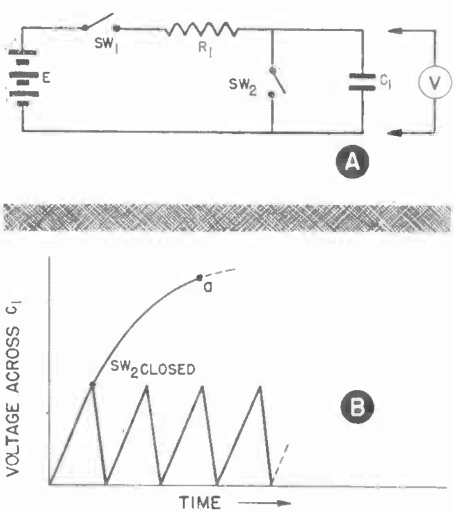


FIG. 7. A basic saw-tooth generator.

resistance and capacity in the circuit. (As you know, the product of the resistance and the capacity is called the time constant of the circuit; it is equal to the time it takes the condenser to charge to 63% of the maximum voltage it can reach in that circuit.)

The left-hand curve in Fig. 7B shows how the voltage across the condenser varies with time. At the instant that SW_1 is closed, the voltage across condenser C_1 builds up almost linearly with time. However, as C_1 becomes charged, the rate of charging gradually tapers off.

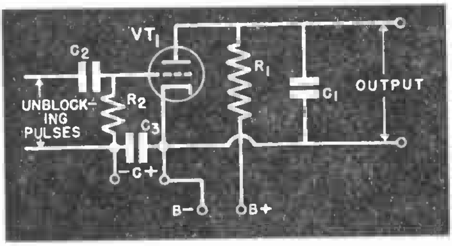


FIG. 8. Discharge circuit having a saw-tooth output.

We aren't at all interested in the full-charge condition, nor in any of the portion of the curve above the point (a) where it bends. However, the fact that the first portion of this curve is reasonably linear makes it possible for us to get our saw-tooth voltage.

All we need to do is open SW_1 and close switch SW_2 after C_1 reaches an appreciable charge. C_1 will then be discharged through the short-circuit path provided by SW_2. If we then open SW_2 and close SW_1 again just when C_1 is completely discharged, it will charge again. If we repeat the action over and over, we will get the series of curves shown at the right in Fig. 7B. Therefore, if we operate over the linear portion of the charging curve of the condenser and use the right value of resistance for R_1, we can get a saw-tooth voltage.

Of course, it isn't practical to use mechanical switches this way. Instead, we use electronic switching.

DISCHARGE CIRCUIT

In another Lesson, you learned that a special gas-filled tube was used as a sweep generator with cathode-ray tube test equipment. Such tubes are unsatisfactory for television, however, because the tube characteristics change with age and are affected by temperature.

Therefore, in television, the "switch" we need to discharge the condenser is provided by a vacuum tube that is biased so that plate current is cut off and the tube cannot conduct until a sufficiently large pulse is applied to the grid. Fig. 8 shows the basic circuit.

In the absence of an applied signal, the C bias prevents the tube from conducting, so C_1 charges through R_1. When an unblocking pulse is applied to the grid, the grid is driven sufficiently positive for the tube to conduct; C_1 then discharges through it. As soon as the unblocking pulse is removed, the tube cuts off, and C_1 begins to charge again. The rate of discharge and hence the retrace time depend on how far positive the grid is driven; an unblocking pulse of sufficient amplitude will cause the tube to conduct heavily so that C_1 will be rapidly discharged.

In this circuit, the discharge time

can be made short, and the operation is relatively independent of the tube characteristics and of temperature variations. However, it does have a very important disadvantage: this circuit is not free-running. In other words, the circuit will not produce a sweep voltage at all until unblocking pulses are fed to it. Therefore, we cannot use the circuit shown in Fig. 8 by itself, because we would have no sweep until the proper signal voltage was applied to the grid of the tube.

Another difficulty with this circuit is that it is greatly dependent upon the amplitude and duration of the unblocking pulse fed to it. This means that we cannot operate it directly from the sync pulses that accompany the signals, because these pulses may vary in either amplitude or duration. For instance, the sync pulse may be small if the signal is weak: a small pulse would not make the tube conduct heavily, which means that C_1 would not discharge completely before the pulse ended. On the other hand, the sync pulse might be increased either in height or in width by, let us say, noise pulses: a wide pulse would make the tube conduct for a longer period of time than is desired, thus delaying the start of the next line.

Both these difficulties are overcome in television sets by using this circuit in conjunction with an oscillator that feeds it regulated unblocking pulses. This makes the sweep generator free running because the oscillator works whether there is a signal tuned in or not, and the pulse amplitudes are independent of the incoming signal. In such use, the circuit shown in Fig. 8 is known as a *wave shaper*, or as a *discharge* circuit. Some manufacturers call it the saw-tooth generator, but most reserve the name saw-tooth generator for the combination of oscillator and discharge circuit.

Basically, therefore, the sweep generator in the average television receiver consists of an oscillator that operates all the time plus a discharge circuit that produces a saw-tooth wave from whatever the output of the oscillator may happen to be. The sync signal is used to control the frequency of the oscillator and thus to control the output of the shaping circuit.

Now, let's study the oscillators used in these sweep generators.

Basic Sweep Oscillators

The standard oscillator with which you are familiar produces sine-wave oscillations. Other basic types are usually set up to produce square-wave outputs. Neither of these wave shapes is ideal for operating a discharge circuit, because we want pulses having shapes somewhat like the sync pulses. In addition, we want these pulses all to be of the same amplitude and the same width so that the discharge circuit will always operate in the same manner, line after line and frame after frame.

Blocking oscillators and multivibrator oscillators, which have the ability to produce pulses of the right kind, are most commonly used in television sweep generators. It is also possible to use a sine-wave oscillator in a sweep generator circuit, as we shall show after we have described these basic pulse-producing oscillators.

BLOCKING OSCILLATORS

In television, one of the most frequently used oscillators for producing

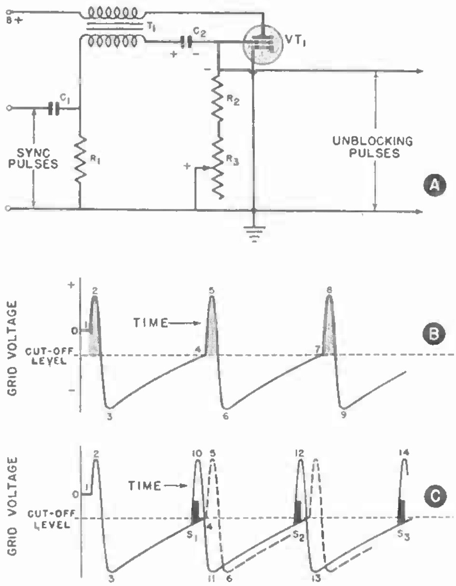


FIG. 9. Schematic diagram of a blocking oscillator.

the discharge of unblocking pulses is the blocking oscillator shown in Fig. 9A.

The circuit associated with VT_1 here looks at first glance like an ordinary oscillator, and as matter of fact it is basically a standard sine-wave oscillator except for the unusual values chosen for the grid condenser C_2 and the grid resistor R_2-R_3. These parts values are so high that the oscillator blocks and is forced to operate intermittently. Notice that the voltage across the grid resistor furnishes the unblocking pulses that constitute the output of the circuit.

The oscillator operation may be explained briefly as follows, using Fig. 9B to represent the changes in the grid voltage:

Initially, plate current flowing through transformer T_1 induces a voltage in the grid that drives the grid highly positive. In other words, the circuit starts to oscillate vigorously. At the same time, this positive-swinging grid voltage makes the grid draw a high current; as a result, electrons flow through R_2 and R_3 and develop a voltage across them having the polarity shown in Fig. 9A. This current flow also charges C_2 to a voltage that is far beyond the cut-off bias for the oscillator tube VT_1.

The grid-voltage curve in Fig. 9B shows what happens. Initially, the positive pulse (point 1 to point 2) appears on the grid. When the grid swings in a negative direction to point 3, it is far beyond the cut-off level. As soon as the grid voltage falls below the cut-off level, the plate current is cut off completely, and no further current can flow until the grid voltage once again gets above the cut-off level. However, when the plate current is cut off, no further voltage is applied to the grid, so the grid current ceases. As a result, condenser C_2 can discharge through the resistors R_1, R_2, and R_3, and through the secondary of transformer T_1. The resistances of R_1 and of the transformer secondary are small, so the time it takes condenser C_2 to discharge depends mostly on its capacity and on the values of resistors R_2 and R_3. Therefore, the rate of change from point 3 to point

4 in Fig. 9B is determined by the time constant of C_2-R_2-R_3.

As soon as C_2 has discharged sufficiently for the grid voltage to be above the cut-off level, plate current will again start. The feedback to the grid circuit will then instantly build up another positive pulse from 4 to 5, and the action will repeat itself. The high grid current will produce a bias that will once again block the circuit for a time represented by the distance from point 6 to point 7 in Fig. 9B.

Here, therefore, we have a circuit that will produce a pulse and will then cut off. The spacing between the pulses is determined by the time constant of the grid leak and grid condenser. The pulse width and height are basically determined by the initial frequency of oscillation and by the supply voltages. The shape and size of this pulse will therefore remain relatively fixed once the frequency and the voltages have been set.

The frequency at which this oscillator would oscillate if more normal grid-leak and grid-condenser values were used is relatively immaterial except for its effect in fixing the shape of the pulse. Generally, it is chosen (by choice of transformer inductance and distributed capacity) to be some frequency about 10 or more times as high as the spacing wanted between pulses, thus making the pulses narrow.

Since the spacing between the pulses and hence the sweep time is determined by the time constant of C_2-R_2-R_3, the variable resistor R_3 acts as an adjustable frequency control. This is usually known as a "hold" control, because proper adjustment of this resistor to a value that produces nearly the right frequency will cause the oscillator to lock in with the sync pulses.

How lock-in is produced is shown in Fig. 9C. The frequency of oscillation determined by the R-C time constant is made slightly longer than is desired. Then, when a sync pulse comes along at S_1 (between points 3 and 4 on the grid voltage curve), it will instantly force the grid to a point above cut-off. Plate current will start to flow at once, so the positive pulse produced by the circuit will occur at the same time as the leading edge of the sync pulse. Instead of the grid voltage changing from 3 to 4 to 5, in other words, it changes from 3 to S_1 to 10. The grid voltage pulse is produced exactly as before; it is again controlled by the C_2-R_2-R_3 time constant until the next sync pulse S_2 arrives, when once again the circuit is kicked off in synchronism with the pulse.

Notice that all that the sync pulse has to do to produce lock-in is to drive the grid of VT_1 slightly above the cut-off level. Once this has been done, the oscillator will take off by itself. The height and width of the sync pulse are unimportant as long as it is high enough to drive the grid of VT_1 above cut-off.

The hold control, R_3, must be set so that the frequency of the circuit will be lower than the desired frequency. The sync pulses will then take over and force the blocking oscillator to lock in with each succeeding sync pulse. If the sync pulse amplitude is reasonably high, R_3 can be varied over a fairly wide range without causing a loss of sync. The frequency set by R_3 cannot be made too low, however,

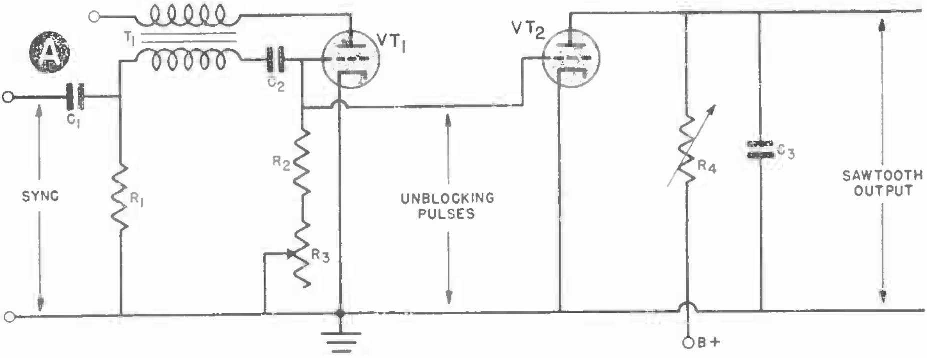
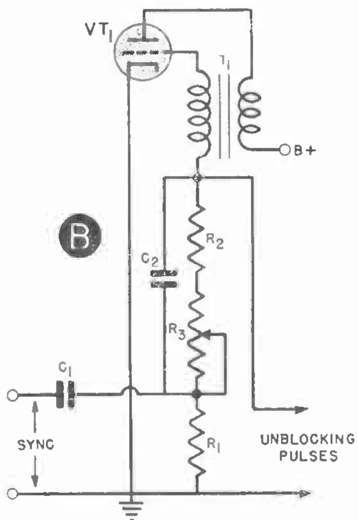


FIG. 10. Part A of this illustration shows a complete blocking oscillator-discharge tube circuit. Part B shows another form in which the same blocking oscillator may be drawn on a circuit diagram.



because then it would take a very high sync pulse to drag the frequency to the proper value. It cannot be made too high, either, because then the unblocking pulses would occur before the sync pulses, and the sync pulses would no longer be effective.

Now that we can produce controllable unblocking pulses, we can feed them into a discharge circuit as shown in Fig. 10A. The blocking oscillator in this circuit duplicates that in Fig. 9A. VT_2 is the discharge tube. No grid bias is necessary for VT_2, because the bias voltage developed across R_2 and R_3 (which is applied to this tube directly) will block it. While VT_2 is cut off by this voltage, C_3 will charge through resistor R_4 to produce the sweep portion of the saw-tooth wave. Then, when the voltage on the grid of VT_1 swings suddenly positive, VT_2 will conduct and discharge C_3. This gives the retrace portion of the saw-tooth wave. Since the amplitude of the pulses received from the blocking oscillator is fixed, this circuit produces saw-tooth pulses that are alike; and the blocking oscillator-discharge combination circuit will be self-operating and will supply the necessary sweep even if no sync pulses are tuned in.

Variable resistor R_4 controls the height of the saw-tooth pulse; varying its resistance changes the charging time of C_3-R_4 and thus determines the voltage to which the condenser will charge before the discharge tube operates. Thus, this control can be used to vary the length of a line or the height of the picture, depending on whether the circuit generates the horizontal or the vertical sweep.

The circuit in Fig. 10B shows another variation of the blocking oscillator. The operation is the same; the only difference is in the positions of the components, which bear the same labels as their equivalents in Fig. 10A. This circuit is shown to give you an idea of some of the variations you may expect in schematic diagrams.

Combination Generator. Many receivers use a combination of a separate discharge tube and a separate blocking oscillator like that shown in Fig. 10A because doing so permits the shape of the saw-tooth wave and of the control pulses to be individually adjusted. However, since the plate current of VT_1 flows in pulses that are exactly like the grid-voltage pulses, it is possible to use a single stage, as shown in Fig. 11, to produce both the pulses and the saw-tooth waves reasonably well. In this circuit, the saw-tooth-producing condenser C_3 and its associated charging resistance R_4-R_5 have been moved to the plate circuit of the blocking oscillator tube VT_1. When this tube is allowed to conduct, it will discharge condenser C_3 at the same time; when it is not conducting, C_3 will charge through R_5 and R_4 just as it would in a separate discharge circuit.

Combining functions in a single stage this way does not allow quite the fineness of adjustment of the wave shape that the use of separate circuits permits, and it requires a somewhat more critical adjustment of part values. However, it is an arrangement that is used in many receivers.

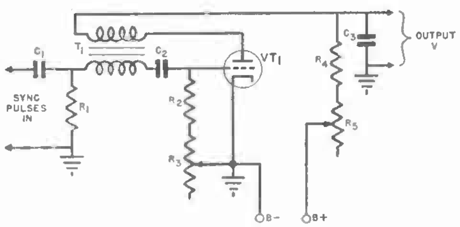


FIG. 11. A one-tube saw-tooth generator.

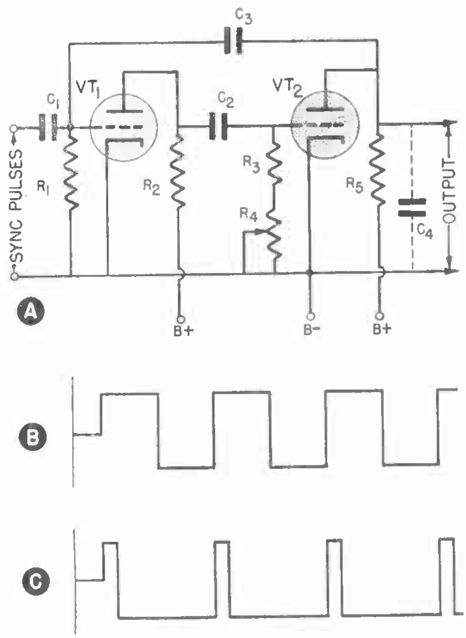


FIG. 12. A basic multivibrator circuit.

MULTIVIBRATOR OSCILLATORS

Another quite commonly used means of generating the control pulse is the multivibrator oscillator. As shown in Fig. 12, this is basically just a two-stage amplifier in which the output of the second stage is fed back to the input of the first stage. The arrangement is such that the signal fed back from VT_2 to VT_1 through C_3 is in the proper phase to produce oscillation.

If tuned circuits were used somewhere in this arrangement, this would be a sine-wave oscillator. However, because R-C elements are used instead of tuned circuits, the multivibrator basically produces the square wave signal shown in Fig. 12B. Let's first see how it produces this signal, then learn how it is possible to get the desired series of pulses shown in Fig. 12C.

The basic operation of this circuit is that the tubes conduct alternately, with conduction of one causing cut-off of the other. The increases and decreases in the plate current of each tube occur very quickly, with the result that these currents are pulses having very steep sides.

When the circuit is turned on, one of the tubes will draw slightly more current than the other and thus initiate the action. To understand the operation, let's assume that both C_2 and C_3 have an initial charge and that the plate current of VT_1 is decreasing.

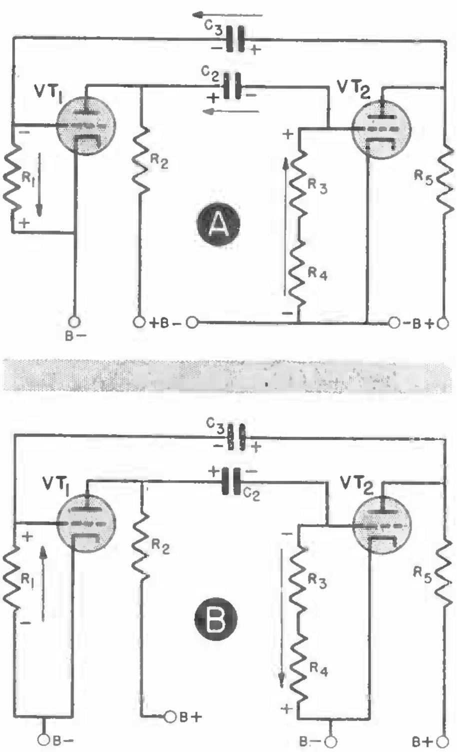


FIG. 13. How a multivibrator works.

The conditions then will be like those shown in Fig. 13A.

Condenser C_2 is connected across the B supply through resistors R_3, R_4, and R_2. The voltage applied to C_2 when VT_1 is conducting is equal to the difference between the B voltage and the voltage drop across R_2 caused by plate current flow through it. When the plate current of VT_1 decreases (this is what we have assumed is happening), the drop across R_2 will decrease. C_2 will therefore start to charge, causing an electron flow through the grid resistors for VT_2 in the direction shown that will make the grid of VT_2 positive. With a positive grid, there will be an appreciable grid current flow; in other words, the internal resistance between the cathode and grid of VT_2 will become a low resistance through which C_2 can and will charge rapidly.

At the same time, this positive grid potential will make VT_2 pass a high plate current, so the drop across resistor R_5 will increase greatly. As you can see, condenser C_3 is connected across the B supply through R_1 and R_5. Since the voltage drop across R_5 caused by plate current flow is opposed to the B voltage as far as C_3 is concerned, this increase in the drop across R_5 will cause a decrease in the net voltage applied to C_3. Therefore, C_3 will start to discharge, causing an electron flow through R_1 in the direction shown. This will drive the grid of VT_1 negative, thus making the tube cut off.

Since R_1 is a high resistance, C_3 will discharge slowly. When it eventually reaches a voltage equal to the difference between the B voltage and the drop across R_5, its discharge current will cease to flow, and the voltage across R_1 will disappear. VT_1 will then be able to conduct again, so it will draw current through R_2.

The conditions in the circuit when VT_1 conducts again are shown in Fig. 13B. Since there is now a voltage drop across R_2 caused by the plate current flow, the voltage across condenser C_2 is reduced. Therefore, it will discharge through R_3 and R_4 in the direction indicated, thereby making the grid of VT_2 negative. Since this will cut off the plate current of VT_2, the drop across R_5 will disappear. The voltage applied to C_3 will therefore increase; consequently, C_3 will begin to charge, causing an electron flow through R_1 in the direction indicated. This will make the grid of VT_1 positive, thereby creating a low-resistance grid-cathode path in VT_1 through which C_3 can charge rapidly.

At the same time, C_2 will discharge relatively slowly through the high resistance R_3-R_4. It will eventually become stabilized, whereupon its discharge current will cease. The grid of VT_2 will then change from a negative potential back to zero, and VT_2 will again begin to conduct. The circuit conditions will then become those shown in Fig. 13A, and the cycle of events will start again.

You can see from Fig. 12A that the output pulses of this circuit are produced by the flow of the VT_2 plate current through R_5. If both tubes conduct for equal periods of time, the output will consist of the square-wave pulses shown in Fig. 12B. To get the pulses we want (Fig. 12C), we must make VT_2 conduct for a much shorter period than VT_1 does. We can do so by making the time constant of C_3 and R_1 far shorter than that of C_2-R_3-R_4. Check back through the preceding description of the action of the circuit, and you will see that adjusting the time constants this way will permit VT_2 to conduct for only relatively brief periods. The voltage across R_5 will then consist of the unblocking pulses we need to operate a discharge circuit.

A separate discharge circuit may be used with this oscillator, or the circuit can be made to act as its own saw-tooth producer. We can produce the latter circuit by adding a condenser C_4 across the output as shown by the dotted lines in Fig. 12A. This condenser will charge through R_5, the value of which can be adjusted to give the required charging time, and it will be discharged when tube VT_2 conducts: this charge-discharge action will give us the saw-tooth output we want.

Sync pulses may be fed in across R_1 as shown in Fig. 12A. If they occur at the proper time, they will drive the grid of VT_1 negative just before it would normally go in this direction, thus initiating the charging action of C_2 and hence causing plate current to flow through VT_2.

Cathode-Coupled Multivibrator. A simpler and somewhat more common variation of the multivibrator is shown in Fig. 14. This is known as a cathode-coupled multivibrator because the feedback voltages are produced across the bias resistor R_4, which is in the cathode circuits of both VT_1 and VT_2.

The action is basically like that just described except for the way in which VT_1 is prevented from conducting. Briefly, the action is as follows:

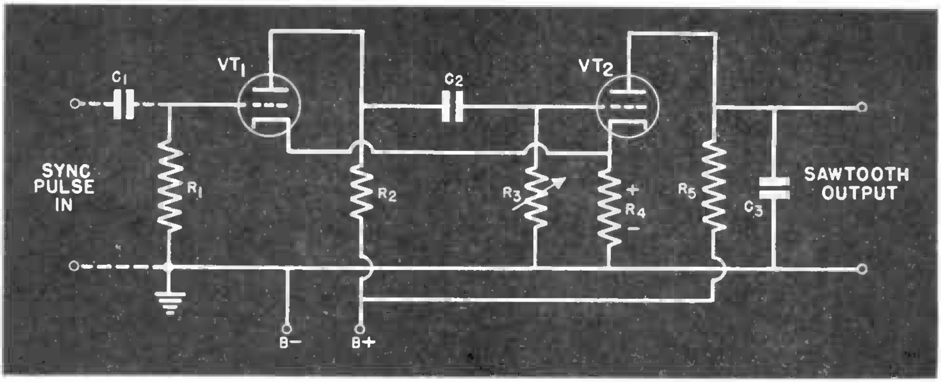


FIG. 14. A cathode-coupled multivibrator.

Condenser C_2 charges from the B supply when the circuit is turned on, producing an electron flow upward through R_3 that makes the grid of VT_2 positive and makes the grid-cathode path of this tube conductive. Condenser C_2 thus charges rapidly through a low-resistance path consisting of R_4, the internal grid-cathode tube resistance of VT_2, and R_2.

While C_2 is charging, VT_2 passes a high plate current. The grid and plate currents of VT_2 passing through R_4 create a high bias voltage drop across this resistor having the polarity shown in Fig. 14. Since the grid of VT_1 is tied to the negative end of R_4, this bias cuts off the plate current of VT_1. (VT_2 conducts because the voltage drop across R_3, produced by the charging action of C_2, is greater than the voltage developed across R_4.)

When C_2 approaches a full charge, the current flow through R_3 becomes less; the bias voltage across R_4 then becomes greater than the voltage drop across R_3, so VT_2 is cut off. Current flow through R_4 then ceases; the bias voltage across R_4 vanishes, and VT_1 is able to conduct. Conduction of VT_1 causes a drop across R_2, reducing the voltage across C_2, which then begins to discharge. Its discharge current produces a voltage drop across R_3 that keeps VT_2 cut off.

When the discharge of C_2 ceases, the drop across R_3 disappears, and VT_2 is again able to conduct. As soon as it does, a bias is built up across R_4 that begins to cut off VT_1. When this happens, condenser C_2 starts to charge, and the cycle repeats.

Since VT_2 cannot conduct while C_2 is discharging, we can control the interval between the plate current pulses of VT_2 by varying R_3, the high resistance through which C_2 discharges. R_3 thus acts as a hold control for the circuit.

The output of the circuit consists of the voltage pulses developed across R_5 by the plate current pulses of VT_2. Once again, we can either feed these voltage pulses to a discharge tube circuit or use a condenser C_3 in conjunction with R_5 to generate a saw-tooth output.

SINE-WAVE GENERATORS

Sine-wave oscillators are used in some television sweep circuits. Because of the extra effort needed to convert a sine wave into the right wave form, such oscillators are used only if another advantage, such as better synchronization, can be obtained through their use.

Fig. 15 shows a somewhat idealized sine-wave oscillator. Here, VT_1 is used in a Hartley oscillator circuit, with the screen grid acting as the plate. The signal produced across the L-C circuit is a sine wave (Fig. 15B). However, the bias and strength of oscillation are adjusted so that the tube reaches plate-current saturation early in each cycle; as a result, the plate current of the tube is squared off into the form shown in Fig. 15C.

This nearly square-wave pulse is fed into C_3 and R_4. Since these have a very short time constant, C_3 charges or discharges very rapidly, producing a brief pulse across R_4, every time the applied voltage charges. As a result, the square-wave voltage from VT_1 is converted into a series of sharp pulses as shown in Fig. 15D. These pulses can be used to operate the discharge tube VT_2.

Such sine-wave oscillators are allowed to operate at exactly the frequency desired for the sweep. So elaborate an oscillator chain is practically never used for frame scanning; only the horizontal or line sweep must be controlled so accurately that such an arrangement is desirable.

When a sine-wave oscillator is used, a sine-wave signal is coupled from L into a frequency-discriminating network where it is mixed with the sync pulses. An automatic frequency control (a.f.c.) arrangement is then used to set the sine-wave oscillator exactly on frequency, as you will learn when we study control circuits. This arrangement permits very accurate control of the fundamental frequency.

SUMMARY

We have learned that a saw-tooth voltage is produced by charging a condenser fairly slowly through a resistor and discharging it rapidly through a tube. Pulses obtained from one of three basic oscillators are used to con-

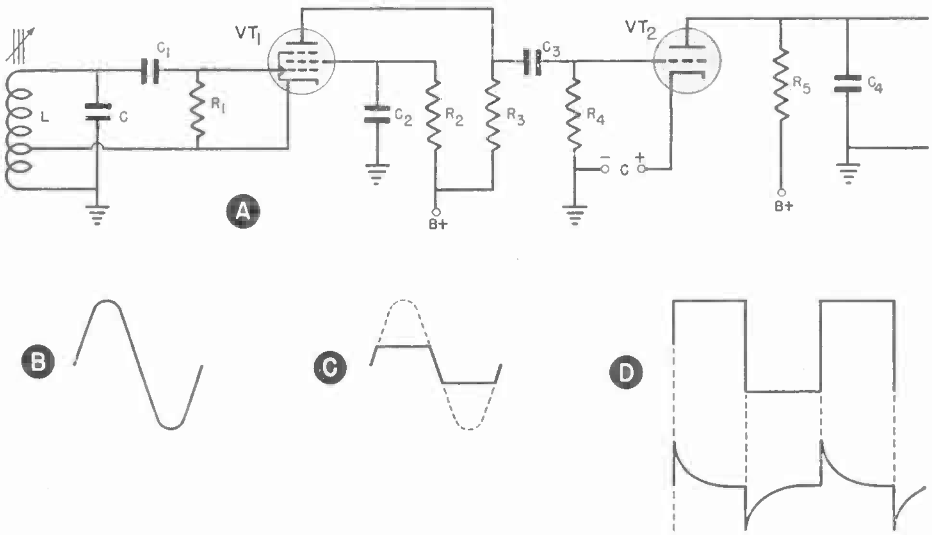


FIG. 15. A sine-wave sweep oscillator.

trol the discharge. This arrangement makes it possible for the circuit to produce the sweep voltage even when no control pulses are fed in from an external signal. Each of the three oscillators is arranged so that it will lock in with the signal when one is received and will therefore operate in synchronism with the lines or frames of the incoming signal.

The saw-tooth voltage that we have produced so far has nearly the right shape for use in all electrostatic systems and in certain electromagnetic circuits. (In other electromagnetic deflection systems as you will learn farther on in this Lesson, additional shaping of the wave is necessary.) Let's see how such a voltage is used to produce electrostatic deflection.

Electrostatic Sweep Circuits

The saw-tooth voltage that we described in the previous section is of the proper shape for an electrostatic deflection system, but it has two things wrong with it. First, it is not of sufficient amplitude, which means that it requires amplification. (Incidentally, the amplitude of a saw-tooth voltage is always measured from peak to peak—that is, from its least amplitude to its greatest amplitude.) Second, each discharge circuit we have pictured so far has one end of the wave-forming condenser going to ground, so one of the deflection plates to which the saw-tooth voltage is fed would have to be grounded also—an undesirable arrangement. Let's briefly study both of these problems.

Deflection Voltage. The voltage needed to deflect the electron beam in an electrostatic tube depends on the velocity attained by the beam, which is determined by the voltage applied to the second anode. In fact, there is a direct relationship between the second anode voltage and the deflection voltage needed: in a typical tube, the horizontal deflection voltage needed is about 30 volts for each inch of deflection, per kilovolt of second anode voltage.

To produce the 5½-inch line commonly secured on a 7-inch tube, assuming the tube has this 30-volts-per-inch rating, we need 165 volts per thousand volts on the second anode. This means that the horizontal deflection voltage must be 3 × 165 or 495 volts if the second anode is run at 3000 volts—and 990 volts if the second anode is run at 6000 volts!

We want high second-anode voltages to improve the picture brightness, and we want large picture tubes so we can have a big picture. We are limited in both respects, however, by the deflection voltages that it is possible to get. As a matter of fact, the deflection-voltage problem has limited electrostatic tubes to a maximum size of 10 inches. All picture tubes above 10 inches in diameter (and most of the 10-inch ones) use electromagnetic deflection.

Since the sweep voltages needed are much higher than the discharge circuit can furnish, there must be voltage amplifiers between the discharge circuit and the picture tube deflection plates. We'll study deflection amplifiers in a moment.

Balanced Deflection. There are several reasons why it is desirable to feed a pair of deflection plates with equal and opposite voltages with respect to ground rather than to have one plate grounded.

One reason stems from the fact that the second anode must be connected to the deflection plates so that the deflecting voltage will add to and subtract from the second anode voltage, rather than be entirely independent of it. This arrangement is necessary to minimize the electric field that forms between the second anode and the deflection plates and causes defocusing. If one of the plates were grounded, therefore, the second anode would have to be grounded also, which would mean that the cathode would have to be highly negative with respect to ground. The tube would operate all right this way, but the filament of the tube could not be operated from the same filament supply as other tubes, because it would not be safe to have a great difference in potential between the cathode and the filament of the picture tube. A separate filament winding would therefore be necessary, which is undesirable. Hence, the usual practice is to ground the cathode so there is a minimum difference between the cathode and filament potentials; this means the second anode cannot be grounded, and because of the common connection, the deflection plates cannot be directly grounded either.

More important, not grounding either deflection plate makes it possible for us to supply them from a push-pull stage in a balanced arrangement. The advantage of the push-pull drive is that one plate goes positive at the same time that the other goes negative, so the effective voltage between the plates at any time is twice as large as the voltage output of either tube alone. Remember, the deflection is proportional to the difference in voltage between the deflecting plates; for a given input signal to the driver stage, therefore, the push-pull circuit gives us twice as much deflection as a single-ended driver stage would.

Fig. 16A shows the basic connections for a balanced deflection system. The vertical sweep is applied to plates P_1 and P_2 through coupling condensers C_1 and C_2. The a.c. sweep voltage is developed across resistors R_1 and R_2.

Similarly, the horizontal sweep is applied to plates P_3 and P_4 through

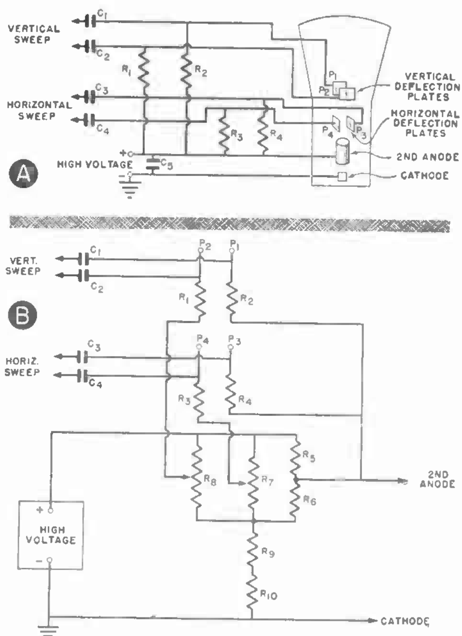


FIG. 16. The elements of an electrostatic deflection system.

condensers C_3 and C_4 and appears across R_3 and R_4.

The return circuits for both sets of deflecting plates are tied to the high voltage, which is applied directly to the second anode. Insofar as the sweep signal is concerned, the path is completed to ground through C_5. Since the impedance from each of the deflecting plates to ground is the same, this is a balanced system.

The actual connections are somewhat more elaborate than those shown here; Fig. 16B is more realistic. In this case, plate P_1 (through R_2) and plate P_3 (through R_4) are tied to the

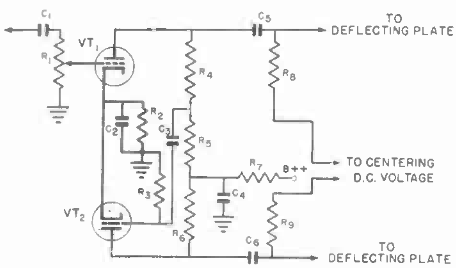


FIG. 17. A basic vertical deflection amplifier.

second anode, which goes to a junction of resistors R_5 and R_6 across a section of the voltage divider on the high-voltage supply. Shunting these two resistors are two variable resistors, R_7 and R_8, to which the other deflection plates are connected.

These variable resistors serve as centering controls; adjustment of either applies a d.c. voltage between the plates with which it is associated and thus moves the picture horizontally or vertically. In this circuit, adjustment of R_7 will move the picture horizontally, and adjustment of R_8 will move it vertically.

Electrostatic deflection systems vary in their complexity. In general, however, all of them have these features:

1. There is a d.c. path from the deflection plates to the second anode so that the deflection voltage will add to and subtract from the second anode voltage.

2. There is some means of varying the d.c. voltage applied to the plates to center the image.

3. The sweep voltages are applied to the deflecting plates through coupling condensers (such as C_1, C_2, C_3 and C_4 in Fig. 16), which must have voltage ratings high enough so that they can withstand the voltage applied to the second anode. These coupling condensers are special oil-filled paper types having voltage ratings of as much as 10,000 volts.

DEFLECTION AMPLIFIERS

The high sweep-voltage requirement means that we must have an amplifier following the discharge circuit. Therefore, in all practical television receivers, the sweep circuit is actually a chain of stages that include a sweep oscillator, a discharge circuit, and an amplifier. The amplifier stage of the sweep chain in the electrostatic system uses a push-pull arrangement to get a balanced output. Since it is necessary to use a great many tubes in a television receiver, every effort is made to reduce the number of tubes needed in the sweep chains; as a result, there are some rather unusual designs in use. Let's study some of these.

Vertical Deflection Amplifier. Fig. 17 shows a basic amplifier of the kind used in the vertical or frame sweep chain. Tubes VT_1 and VT_2 are in push-pull. In a sound receiver, this stage would be preceded by a separate tube used for phase inversion, but here tube VT_1 acts as a combination amplifier and phase inverter. Its load is the combination of resistors R_4 and R_5, which act as a voltage divider and are arranged so that the signal voltage drop across R_5 applied through C_3 to the grid of VT_2 will feed just enough signal to the grid of VT_2 to cause its output across R_6 to be equal to that across R_4-R_5. Of course, VT_2 inverts the phase of this signal 180°, so we get normal push-pull operation—at the moment the plate of one tube is at its maximum positive point, the signal output of the other is reaching a maximum negative value.

This one amplifying stage is all that is needed. We have a reasonably high input from the discharge circuit—perhaps as much as 100 volts is available. It is customary, however, to take only about 20 volts from the discharge stage and then to use high-gain triodes or pentodes in the amplifier to give a stage gain of at least 20.

Of course, the amount of gain in an amplifier stage depends on the load—the higher the load resistance, the more nearly the gain equals the amplification factor of the tube. If, for example, we feed a voltage of 20 volts into VT_1 by adjusting the input control R_1 properly, and the stage has a gain of 20, the voltage across the load will be 400 volts. The exact amount we want depends on the needs of the picture tube, of course; we can get what we want by adjusting R_1 to provide the proper input. Hence, this control will set the picture height or width, depending on whether this is a vertical or a horizontal sweep chain. Since the picture width is greater than the picture height by a ratio of 4 to 3, more voltage is needed for the horizontal sweep than for the vertical sweep.

However, the output voltage can reach such levels only if the B supply voltage is high enough to provide the plate voltage needed to deliver the high signal we want and also to make up for the loss in the high-resistance load. The B++ voltage applied through R_7 may be as high as 500 to 1000 volts; such voltages are usually obtained from the high-voltage supply that operates the picture tube.

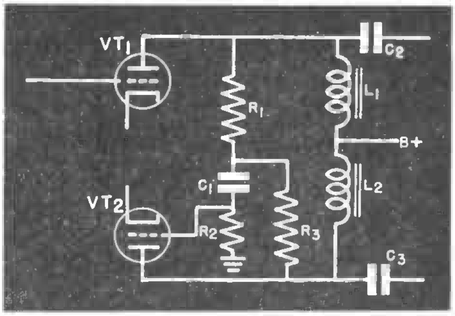


FIG. 18. Diagram of a horizontal deflection amplifier.

The amplified sweep voltage that exists across R_4-R_5 and R_6 is applied to the deflecting plates. These voltages are balanced with respect to ground; the ground circuit for the a.c. sweep signal is from the common point of the load resistor through C_4 to ground. The filter circuit (C_4 and R_7) keeps the sweep voltage out of the B supply.

Condensers C_5 and C_6 are coupling condensers used to feed the sweep signal to the deflecting plates. Because of the high voltages that come from the anode supply to the deflecting plates, these condensers must have high voltage ratings.

Horizontal Deflection Amplifier. The circuit shown in Fig. 17 can also be used for the horizontal sweep, but the one in Fig. 18 is more commonly used for this purpose because it is better able to deliver the high voltages needed for horizontal deflections. In this circuit, inductances L_1 and L_2 serve as the loads. These choke coils are made to have very high reactances at the sweep frequencies, so the tubes are offered a full load and therefore deliver maximum signal output. The only d.c. voltage loss occurs in the relatively low resistances of these coils, so not much of the B supply voltage is wasted.

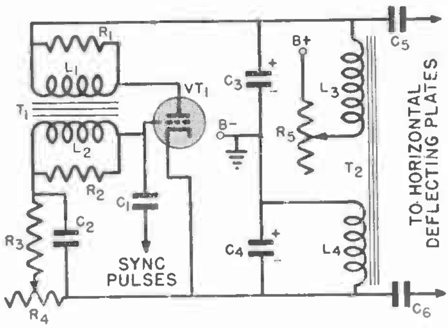


FIG. 19. Single-tube sweep circuit.

The network of R_1, blocking condenser C_1, and R_2 acts as a voltage divider to supply the signal necessary to operate tube VT_2. Resistor R_3, connected from the plate of VT_2 back to this network, provides degeneration by feeding back a voltage to the grid of VT_2 that is out of phase with the incoming voltage. This degeneration not only flattens the response of VT_2 but also makes the gain of the stage more independent of minor changes in the characteristics of the tube. This is one form of balanced phase inversion.

Single-Tube Sweep. The amplifiers in Figs 17 and 18 are usually preceded by a sweep oscillator (either a multivibrator or blocking type and by a discharge circuit that may be a part of the oscillator. In the unique circuit shown in Fig. 19, however, a single tube acts as a combination blocking oscillator-discharge-push-pull amplifier!

In the blocking oscillator section of this circuit, transformer T_1 provides the feedback path from plate to grid, and condenser C_2 along with resistors R_3 and R_4 provide the blocking action in the grid circuit. R_1 and R_2 are damping resistors that smooth out the oscillatory pulse produced by the blocking oscillator.

The sync pulses necessary to control the oscillator are fed in through C_1.

Instead of being produced by the usual R-C charge circuit, the saw-tooth wave is formed by a resonant circuit that, by resonance step-up, gives the needed amplification. Let's start our study of the action of this circuit during a time when VT_1 is cut off or not conducting. At such times, condenser C_3 is charged through R_5 and L_3 because it is across the B supply, as shown in Fig. 20A. (Notice that B+ is connected to R_5.) The charging current for C_3 that flows through L_3 induces a voltage in L_4, with the result that condenser C_4 is charged at the same time and to the same voltage as C_3. The polarity of the condenser voltages is such that the voltage applied between the deflection plates through the coupling condensers C_5 and C_6 is the sum of the two condenser voltages.

Returning now to the blocking oscillator action, when the charge stored in the grid condenser C_2 (Fig. 19) leaks off enough so that VT_1 suddenly starts to conduct, it effectively ties the upper end of C_3 to the lower end of C_4 through the combination L_1-R_1 and through the tube resistance (see Fig. 20B). Since the positive terminal of one condenser is thus tied to the negative terminal of the other through this low-resistance path, the condensers discharge rapidly; this gives the retrace portion of the cycle. Then, when the tube cuts off again, condenser C_3 again starts to recharge and

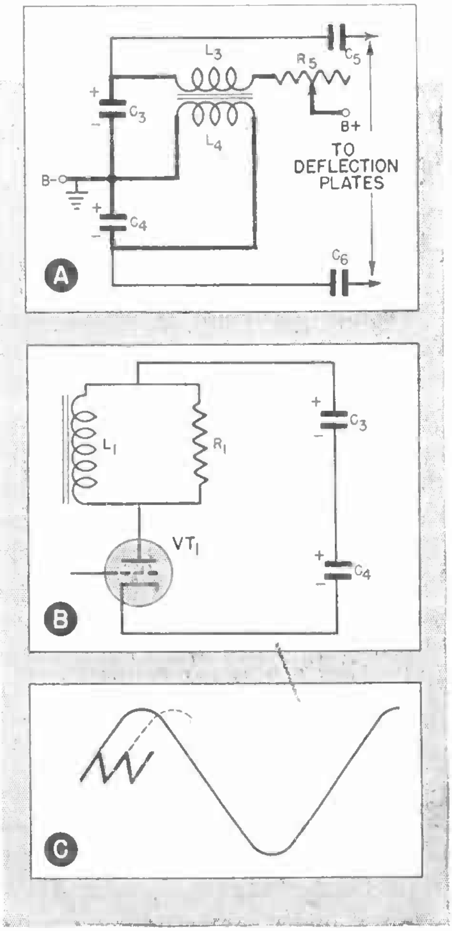


FIG. 20. How the single-tube sweep works.

the scanning voltages build up again.

In this circuit, resonance step-up is used to make the output voltage several times that of the B supply so that sweep voltages of 800 to 1200 volts can be obtained with a B supply of 250 volts.

The tube and blocking oscillator parts effectively disappear on the charging cycle, so the circuit is then like that in Fig. 20A. The parts C_3, L_3, and R_5 form a series-resonant circuit across the B supply. This is a high-Q circuit, capable of producing a sine-wave voltage across C_3 of five or ten times the supply voltage if it were allowed to reach its peak. However, the parts values of the circuit are chosen so that resonance is at a frequency far lower than the horizontal sweep frequency: long before the voltage across C_3 can reach its peak sine-wave value, therefore, the discharge action is initiated. As a result, only the relatively straight portion of the sine-wave voltage across C_3 is used (Fig. 20C). Even so, the peak reached can be two or three times the supply voltage. This peak voltage is applied across each condenser (remember, C_4 is charged to the same voltage as C_3 because of the interaction between L_3 and L_4). This circuit is normally used for horizontal deflection because of its ability to deliver such a high voltage from a normal plate supply.

If the blocking oscillator should fail to discharge C_3 and C_4, they could charge to the high peak value determined by the Q of the resonant circuit. For this reason, the condensers used in this circuit must have high voltage ratings to prevent breakdown if the blocking oscillator should fail to function.

Resistor R_5 is the horizontal size control; its setting determines the amount of the B supply voltage applied to the circuit and hence controls the amplitude of the sweep voltage. Resistor R_4 (Fig. 19) is the hold control.

From the foregoing, the number of tubes used in an electrostatic deflection system may be as few as one (in a circuit like that in Fig. 19) or as many as five (two tubes in a multivibrator, one in a discharge circuit, and two in a push-pull amplifier. Of course, these can be multi-purpose tubes, with at least two in the same envelope). The practice of using a separate discharge tube is gradually dying out; most commonly, deflection circuits now consist of a single-tube blocking oscillator or a dual-tube multivibrator with a built-in discharge circuit driving a dual-tube amplifier.

In any case, the output will be a saw-tooth voltage of rather high peak value. The frequency of the output will depend upon whether it is for horizontal or vertical deflection; this frequency will be controlled by the sync pulses.

Basic Electromagnetic Sweep Circuits

In an electromagnetic deflection system, one pair of coils is used for horizontal deflection and another pair for vertical deflection. These coils, which are wound around the neck of the tube, establish a strong electromagnetic field within the picture tube.

This deflection electromagnetic field does not have any relationship to the focusing and accelerating fields, so it is unnecessary to tie the coils to the second anode. This is a major difference between the electrostatic and electromagnetic systems that simplifies the latter considerably, because it allows the deflection coils to be operated more nearly at ground potential and makes for simpler connections to them. It also permits the use of single-ended output stages, which proves quite helpful in the design of these circuits.

Another important basic difference between electromagnetic and electrostatic deflection is the fact that the deflecting field in the former is proportional to the number of turns in the coils and to the *current* through them—not to the applied voltage. Therefore, we don't need particularly high voltages across the deflection coils, but we do need high currents. The driving tubes in an electromagnetic system must therefore be power tubes instead of the voltage amplifiers used in electrostatic systems.

As a matter of fact, the power demands in an electromagnetic system are rather considerable, particularly in the horizontal sweep circuit. Here, a rather husky power tube is always used, and sometimes two are used in parallel.

TRAPEZOIDAL WAVES

Since the deflection field in an electromagnetic system is proportional to the current through the coils, we need a saw-tooth current to produce the proper deflecting action. Because a coil resists sudden changes in voltage, such a saw-tooth current cannot be produced by applying a saw-tooth voltage to the coil. Let's see what shape the applied voltage must have to make the coil current a saw-tooth current.

Let's suppose we have a perfect coil (no resistance) as shown in Fig. 21A and want the saw-tooth current shown in Fig. 21B to flow through it.

If we apply a d.c. voltage (Fig. 21C) to a coil, the current through the coil will build up as shown in Fig. 21D. The rate at which this current rises depends on the inductance, on the voltage, and on how long the voltage is applied. In a perfect coil, this current could reach infinity if the voltage were applied long enough.

If we apply the voltage for just a short period of time, then cut it off for an equal period of time (Fig. 21E), we will get the triangular current flow shown in Fig. 21F. We can change this into a saw-tooth current by finding some way of making the right-hand edge of the wave more nearly vertical.

A voltage having the form shown in Fig. 21G will do the trick. The high, short negative pulse will make the coil current drop suddenly, producing the saw-tooth current in Fig. 21H.

The voltage shown in Fig. 21G is very similar to the output from a blocking oscillator or multivibrator. Therefore, if the output of one of these devices could cause enough current to flow, and if the coil had negligible resistance, we could get a saw-tooth coil current without using a discharge circuit.

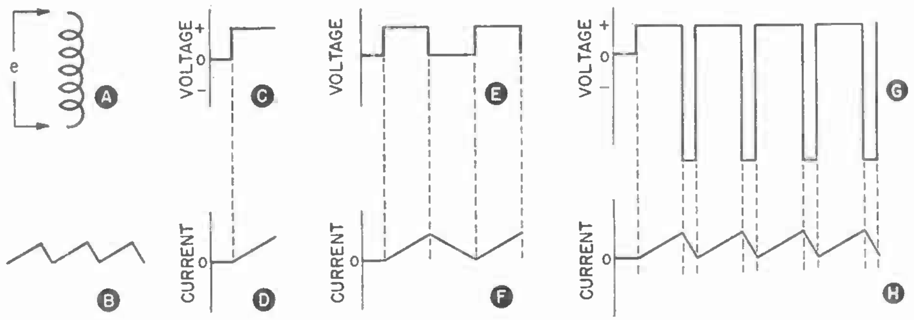


FIG. 21. How a saw-tooth current can be made to flow in a perfect coil.

However, the coils with which we are dealing have appreciable resistance (which, as we shall show later, is needed to damp out oscillations). A practical coil is therefore like the combination shown in Fig. 22A.

A voltage having a rather unusual wave shape must be applied to get a saw-tooth current to flow through this combination. A voltage having the form shown by curve 1 of Fig. 22B must be used to create a saw-tooth current in an inductance, and one having the shape shown by curve 2 must be used to create such a current in a resistance; therefore, the two voltages must be combined, producing the

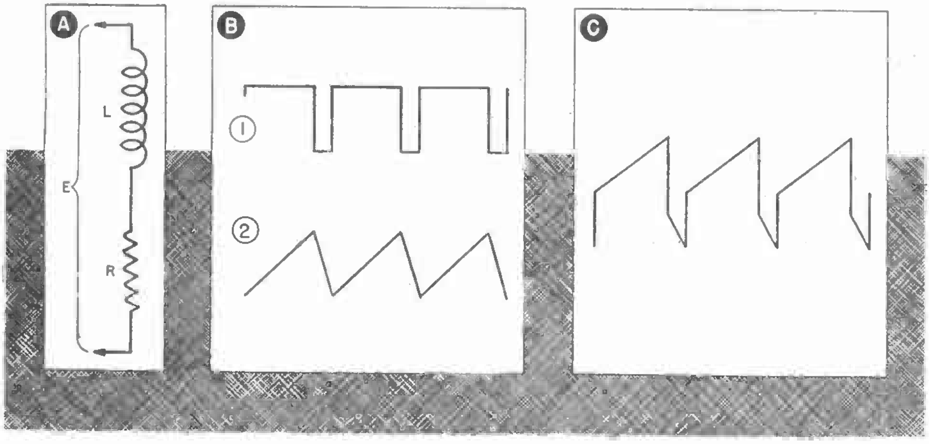


FIG. 22. A trapezoidal voltage wave must be applied to a practical coil to produce a saw-tooth current.

"trapezoidal" wave shown in Fig. 22C, to create a saw-tooth current through a combination of inductance and resistance.

The proportion of pulse voltage to saw-tooth voltage needed in the trapezoidal wave depends on the relative proportions of inductance and resistance in the coil. Therefore, the circuits used to shape this trapezoidal wave must be designed to suit the particular deflection coils to be used with them and may be widely different in parts values in different receivers.

The trapezoidal wave shape wanted can be obtained by making a simple modification in the discharge circuit that we studied earlier. A typical arrangement is shown in Fig. 23. This is a standard discharge circuit except that resistor R_3 has been added in series with C_2. The effect of this addition is to produce the trapezoidal output voltage e_0 shown in Fig 23B. Let's see why.

When the circuit is turned on, condenser C_2 starts to charge through R_2 and R_3 in series. The condenser current flowing through R_3 causes a voltage drop that is in series with the saw-tooth condenser voltage and is maximum when the circuit is first turned on. This voltage drop gives us our initial vertical rise in e_0 from point 1 to point 2 in Fig. 23B, after which the condenser charges in a normal manner from 2 to 3. Of course, as the condenser charges, its current continues to flow through R_3, maintaining the drop across the resistor.

When VT_1 suddenly conducts to discharge C_2, the discharge current flows in the opposite direction through R_3, reversing the polarity of the drop

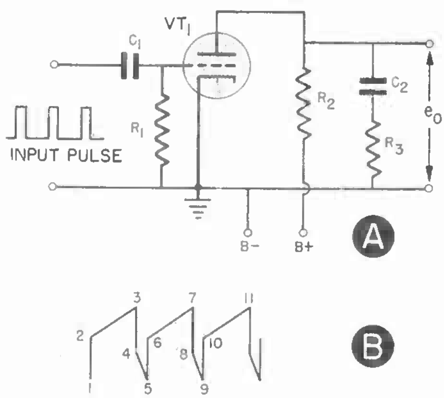


FIG. 23. Trapezoidal discharge circuit.

across it. Since a maximum current flows at the start of the discharge cycle, the output voltage drops suddenly down from its highest peak value (3) to value 4. Condenser C_2 then discharges rapidly through the relatively low resistance R_3, and the tube to form the portion 4-5, which is the retrace part of the saw-tooth cycle. The cycle then starts over again when VT_1 is cut off.

The slopes of the saw-tooth portions of the wave depend on the values of R_2 and C_2, and the heights of the vertical rises and drops depend on the value of R_3. (Because of the special shape of the output, the resistor R_3 is known as a "peaking" resistor.) If the proper values are chosen for these parts, it is possible to produce the exact wave shape required for the particular deflection coils that are to be used.

Although we have shown a separate discharge tube in Fig. 23, the action might equally well be produced by modifying a built-in discharge circuit.

Now that we have the required trapezoidal wave, we need a power amplifier to get the current we need. Since the vertical or frame sweep is simpler in design than the horizontal sweep, let's study it first.

MAGNETIC SWEEP CIRCUITS FOR VERTICAL DEFLECTION

The wave produced in Fig. 23 has the right form, but it must be amplified to furnish the fairly high current needed to deflect the electron beam. A power amplifier much like the output stage of a sound receiver is used to produce this amplification. A typical circuit is shown in Fig. 24.

The vertical deflection coils, L_3 and L_4, are not high inductances because there is practically no iron in their core—only that provided by a bundle of iron wire that is wound around the deflection yoke assembly. Common inductance values for these coils are around 50 millihenrys. At 60 cycles, this inductance has a reactance of only about 20 ohms—in fact, the resistance of one of the coils may easily be 3 or 4 times its reactance.

Notice that the screen grid and the plate of the pentode power tube VT_1 are tied together. This lowers the plate resistance of the tube enough to permit it to be matched to the low-impedance coils by a transformer having a reasonable turns ratio.

Let's run through the operation of the circuit in Fig. 24 briefly:

Condenser C_1 and resistor R_1 are the basic wave-shaping parts, and

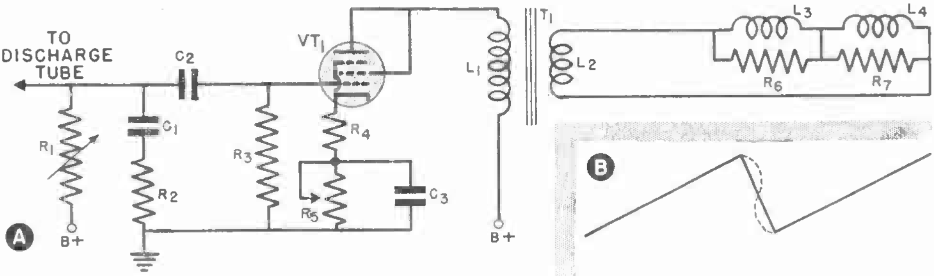


FIG. 24. A typical vertical deflection sweep amplifier.

peaking resistor R_2 produces the trapezoidal wave shape from what would otherwise be a saw-tooth wave. This circuit is operated by a discharge tube (which may be a part of the sweep oscillator).

The signal is applied to the grid of the power output tube through coupling condenser C_2 and appears across R_3. Resistor R_5 is a linearity control; adjusting it changes the bias on VT_1 and thus makes it possible to find the most linear part of the characteristic of the tube. Since varying the bias will change the gain of this stage and therefore change the

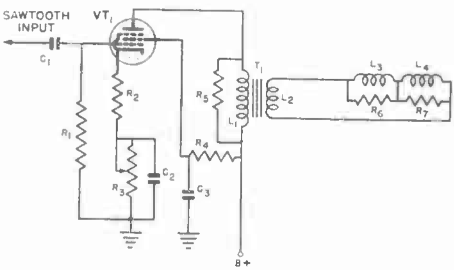


FIG. 25. Pentode vertical sweep amplifier.

height of the picture, the height control R_1 must be readjusted whenever R_5 is adjusted until the best compromise between a perfectly linear sweep and the desired picture height is secured.

During the sweep portion of the cycle, the current through the deflection coils L_3 and L_4 steadily increases in a linear manner, just as it should. When the end of the sweep period is reached, however, and the voltage suddenly changes to produce the retrace portion of the cycle, we do not get the normal retrace shape, because the deflection coils have a tendency to self-oscillate under the shock of the sudden voltage change. (There is considerable distributed capacity in the circuit and in the deflection coils; this capacity forms a resonant circuit with the inductance of the deflection coils and the transformer secondary.)

Instead of going to great trouble to avoid this oscillation, it is permitted to exist during the retrace, so the retrace may be half a sine wave in shape rather than linear with respect to time. As shown in Fig. 24B, the retrace may follow the dotted line instead of the straight line from the end of one scanning sweep to the beginning of the next.

This doesn't matter, because we must have linearity only during the actual sweep. It is perfectly all right for there to be distortions in the shape of the retrace as long as the distortions repeat themselves exactly (so that each line will be of the same length) and are completely wiped out before the beginning of the next sweep.

To meet these requirements, the coils are made with inductance and capacity values such that a half cycle of the oscillation will be completed within the desired retrace time. The oscillation is then forced to die out before the next sweep by the resistive loading in the circuit. There are three forms of loading here: 1, the resistance within the coils provides a low Q; 2, the coils are shunted by resistors R_6 and R_7, which further load them and control oscillations; and 3, the low plate resistance of the tube appears across the coils through transformer T_1 and also tends to load them.

Thus, although we use the proper trapezoidal voltage, the current is not exactly a saw-tooth; however, it is linear during the sweep, and the retrace variations are controlled so that they do no harm.

The circuit in Fig. 24 is the basis for most electromagnetic vertical sweeps. There is one important exception, however, which we shall now describe.

PENTODE VERTICAL OUTPUT

In a few instances, a true pentode connection has been used for the output in the vertical sweep chain of an electromagnetic set. The basic circuit is shown in Fig. 25. The most important difference between this circuit and that in Fig. 24 is the fact that here the screen grid is brought back to a separate voltage supply so that a true pentode action is obtained.

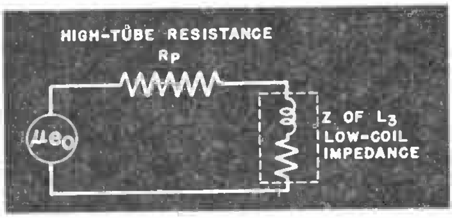


FIG. 26. Equivalent circuit of the pentode vertical sweep amplifier.

This connection leads to several basic differences in operation. To begin with, we now have the extremely high plate resistance of the pentode tube in series with the relatively small load reflected into the primary circuit by transformer T_1. This makes the effective inductance in the plate circuit of VT_1 so small that the circuit is basically resistive, as shown in Fig. 26. Since the circuit appears to be resistive, it is possible to produce a saw-tooth current in the plate circuit by feeding the grid of VT_1 with a saw-tooth voltage, just as we would in an electrostatic system.

Since the plate resistance of the tube no longer acts to damp oscillations, the resistor R_5 (see Fig. 25) is connected across the primary of T_1 to serve this purpose. To stabilize the circuit further, the screen-grid voltage is supplied through resistor R_4. Condenser C_3 is a by-pass for the screen.

Horizontal Electromagnetic Sweep Circuits

Although the horizontal deflection system may seem at first glance to be quite similar to the vertical deflection system in electromagnetic units, there is quite a difference in the actual design of the circuits used.

Since the picture is wider than it is high, the horizontal lines are longer than the height of the picture. The horizontal deflection field must therefore be stronger than the vertical one. However, the horizontal deflection coil cannot be as large as the vertical deflection coil, because the inductance and distributed capacity in the normal coil and output transformer would cause the retrace oscillation to be at too low a frequency. We want a half cycle of the oscillation to be over within the retrace time, which is about 6 micro-seconds; since the line rate is 15,750 lines per second, this oscillatory cycle must be about 71 kc. (The field rate is only 60 cycles, so the half-cycle oscillation need not be completed for about 800 microseconds; hence, the frequency of the vertical retrace oscillation need be only about 600 cycles.)

As a further handicap, a large inductance will have a reactance (at 15,750 cycles) that will be high compared to the resistance. This makes damping more difficult.

We cannot use too small a horizontal deflection coil, because then an excessively high current would be required to produce the magnetic field needed, which would mean that the driving tube would have to deliver extremely high amounts of power. As it is, a small transmitting tube is commonly used for the horizontal deflection output, and in some receivers a pair of these tubes are used in parallel.

Since it is practically impossible to prevent oscillation completely, designers have compromised on reasonably small coils that can produce a frequency high enough for a half cycle to be over in the retrace time, but not so small that the current requirement is unreasonable. Values around 8 millihenrys are used.

This oscillation must be damped out during the retrace time (about 6 microseconds). To provide this high-speed action, the circuit is arranged so that there is no damping except the internal resistance of the deflection coils during the first surge of the oscillation. Then, when a half cycle has been completed, a "damping" or "reaction scanning" tube closes a low-resistance path across the horizontal deflection coils, killing the oscillation very rapidly. Let's see how this damping circuit works.

HORIZONTAL DAMPING

A basic horizontal deflection output is shown in Fig. 27A. The power output tube VT_1 is connected to the primary of transformer T_1. The secondary coil L_2 is connected to the horizontal deflecting coils L_3 and L_4. A diode damping tube VT_2 and a loading resistor R_1 are connected across the deflecting coils.

Let's start our study with the action shown in Fig. 27B. Let's assume that the scanning current is progressing from M to N. At the time it reaches N, the output tube (VT_1) current is suddenly cut off because its grid is driven sharply negative by the trapezoidal voltage applied to it. This produces a sudden and sharp voltage change across the deflection coils L_3 and L_4, with the result that oscillation develops. With no damping other than the coil resistance, the oscillatory cycle would go through the points N-O-P-Q-R. We want only the half cycle from N to O of this oscillation (which gives us the retrace that we want), so we have to find some way to get rid of the energy that would continue the oscillation beyond O.

When the current through the coils reaches its negative peak O, it reverses in its direction. Since the voltage across an inductance is 90° ahead of the current, the voltage across the deflection coil goes through zero at this instant and starts to make the plate of the damping tube VT_2 positive with respect to its cathode. Hence, when the current has reached point O, tube VT_2 begins to conduct, permitting current to flow through R_1. The value of resistor R_1 is chosen so that the circuit is critically damped; the oscillations therefore cease at once, and the current flow through the coil

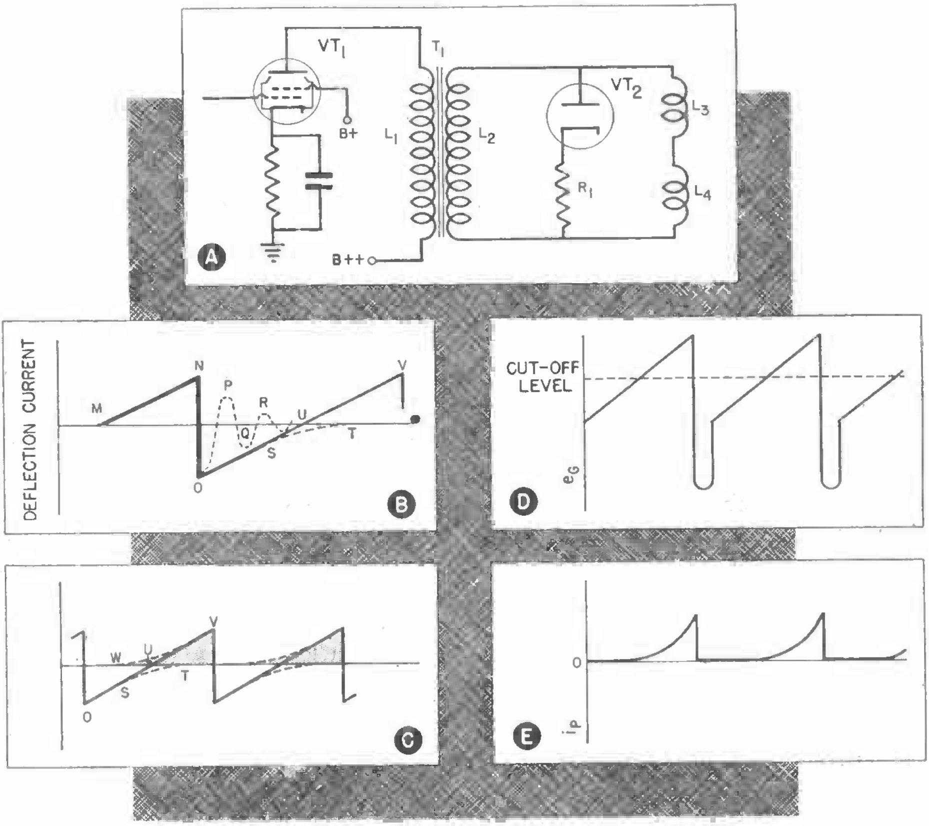


FIG. 27. How the horizontal sweep current for an electromagnetic sweep circuit is produced.

decreases toward zero along the line O-S-T.

To produce the proper deflection, the current through the deflecting coils must have the form shown by the line O-S-U-V. The energy stored in the coils that is released by the damping action supplies the first part of this current (from O to S). Beyond this point, however, the stored-energy current dies off along the line S-T, rather than moving from S to U.

Here the output tube begins to come into play, as shown in Fig. 27C. Just at the time the stored-energy current begins to die out, the tube begins to deliver current along the line W-V. These two currents added together produce the desired deflecting current O-S-U-V.

On succeeding cycles, the action is repeated. Tube VT_1 supplies power through transformer T_1 during the shaded portion of each cycle shown in Fig. 27C. When the tube is cut off suddenly (point V), an oscillatory action is started that produces the retrace and stores energy in the resonant circuit that is dissipated gradually to give the start of the next trace.

The grid voltage applied to output tube VT_1 is shown in Fig. 27D. This tube can pass current only when the grid voltage is above the cut-off value shown by the dotted line. (The rest of the input wave merely keeps the tube from conducting; the trapezoidal wave shape is needed so that the plate current can be cut off sharply.) Therefore, the plate current for this tube has the form shown in Fig. 27E. The curvature in this plate current is caused by the fact that we are operating over the knee of the characteristic curve of the tube. This plate current must be shaped very accurately so that the current flow produced in the secondary circuit will join smoothly with that flowing in the damping tube circuit to give the required deflection current. Therefore, we need some means of adjusting the characteristics of the output tube to make it deliver a plate current having the proper peak value and the proper shape. We'll show how this is done in a moment.

A TYPICAL DIODE DAMPER

Now that we have studied separately the various actions that occur in the output section of a horizontal electromagnetic sweep circuit, let's see how the whole section works. A typical practical circuit is shown in Fig. 28.

The oscillator and discharge circuits are not shown here. For our discussion, let's just say that they furnish a trapezoidal wave of accurate frequency to the grid of the power output tube VT_1.

This tube is usually a small transmitting tube, the plate connection of which is brought out to a top cap. A high-powered tube is needed to handle the current, and the unusual plate top-cap connection is needed because the inductive kick-back through the transformer from the oscillatory action of the deflection coils produces a momentary peak plate voltage of 5000 to 10,000 volts, which the ordinary tube socket and base cannot withstand. Putting the plate connection on top of the tube makes the envelope act as an insulator. Since such high peak voltages exist on the plate of the tube, you should never touch the plate circuit while the set is in operation.

Many receivers use this high peak pulse to supply the high voltage necessary for operating the picture tube. In such cases, the output transformer has the additional windings L_2 and L_3 (Fig. 28), which are connected to a rectifier-filter system that furnishes a d.c. output to the picture tube of from 7000 to 15,000 volts, depending on circuit design. We'll study such high-voltage supplies elsewhere in the Course.

The plate supply path for VT_1 is somewhat involved. Moving from the plate of the tube, it goes through L_1, through coil L_6, and then either through resistor R_4 or through the damping tube VT_2. From here, there is a parallel path through the deflection coils L_8 or through the secondary of the transformer L_4 to the B+ terminal (+280 volts). Since the cathode of the power tube is returned to a point that is at −100 volts with respect to ground, the total plate voltage applied to the tube is 380 volts (280 + 100).

The deflection circuit is somewhat more involved than the one we described earlier. The deflection coils are lumped together here as L_8. An additional condenser C_6 is connected across a part of the winding to supply additional capacity to get resonance at the proper point. Resistor R_5 is a centering control; it can be adjusted to change the d.c. current through the L_4-L_8 path and thus to center the picture on the face of the tube.

Coil L_7 is known as the width control. By varying the inductance of this coil, we can control the amount of signal applied to the deflection coils, thus controlling the width of the picture.

Adjusting this control to vary the width of the picture may make the lines non-linear. This lack of linearity can be corrected by changing the input voltage fed to VT_1 and by adjusting L_6, which is in the plate supply of this tube.

The control that varies the input voltage on the VT_1 grid is known as

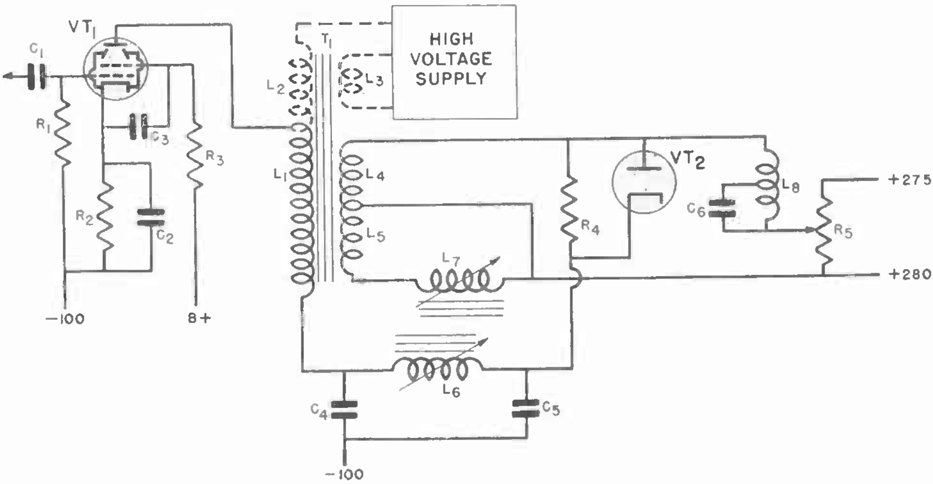


FIG. 28. The output section of a typical horizontal electromagnetic sweep circuit in which a diode damper is used.

the "drive" control because it changes the peak value reached by the grid voltage and hence controls the peak of the plate current.

Coil L_6 is used to adjust the plate voltage applied to VT_1 and hence affects the shape of the plate current pulse. For this reason, it is known as the "linearity" control. Let's run through the operation to see how L_6 works.

The plate supply circuit of VT_1 must be completed all the time, so resistor R_4 is included to complete the path from L_6 back through the deflection network to B+. Since R_4 is a fairly high resistance, it does not act as a load on the resonant circuit, which includes the deflection coils L_8, the condenser C_6, the inductive effects of the transformer secondary, and the width control L_7.

At the end of the oscillatory cycle, when damping is desired, tube VT_2 begins to conduct. The current that is passed by this tube is used to charge condenser C_5. As you can see from Fig. 28, the full B supply voltage (380 volts) is always applied across this condenser. When VT_2 is passing current, the voltage across C_5 rises to about 430 volts; when tube VT_1 starts drawing current, and VT_2 cuts off, C_5 discharges back to the 380-volt B-supply level. Effectively, therefore, there is a pulsating or a.c. voltage having the sweep frequency across this condenser. (This voltage is supplied by the energy stored in L_8 that is released when VT_2 conducts.) As you can see, this a.c. voltage is applied to the plate of VT_1.

Connected to C_5 is a phase-shifting network consisting of condenser C_4 and inductance L_6. By adjusting the inductance of L_6, we can shift the phase of the a.c. voltage across C_5 with respect to the time that it is applied to the plate of VT_1; this lets us control to some extent the shape of the plate current pulse.

All of the controls associated with this circuit are interlocking to a certain extent; in other words, adjusting one usually makes it necessary to adjust one or more of the others also. Adjusting the width control L_7 changes the width but also causes the right side of the picture to stretch slightly by effectively speeding up the scanning in this portion of the scanning cycle. Adjusting the drive control that varies the input to the tube VT_1 also increases the width somewhat but crowds the right side of the picture and stretches the left side. Thus, these two controls tend to off-set each other to some extent. Adjusting the linearity control L_6 does not appreciably effect the width but does correct to a small extent for other irregularities. Rotation of the control in one direction causes the second quarter of the picture to stretch and the first quarter to crowd, and vice versa. In other words, adjusting this control mostly affects the first half of the scanning sweep.

TRIODE DAMPING

The diode damping tube circuit that we have just described is used by a great many manufacturers. Some others use a triode tube connected as shown in Fig. 29. Here, tube VT_2 is a dual-triode power tube arranged with the sections in parallel. The parallel connection of the two triode sections gives them a very low plate resistance that loads the deflection coils during the damping portion of

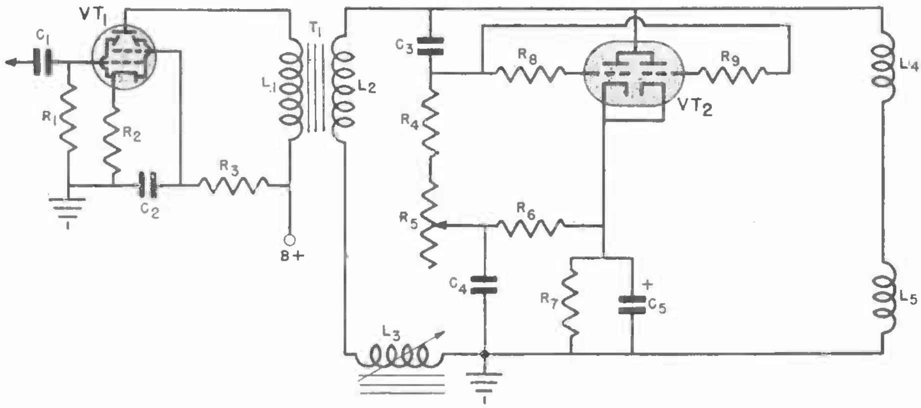


FIG. 29. How a triode damper is used in the output section of a horizontal electromagnetic sweep circuit.

the cycle. Since the tube is a power output tube, it is able to conduct a high current during the damping portion of the cycle.

In Fig. 29, the output tube VT_1 operates the deflection coils L_4 and L_5 through transformer T_1. Coil L_3 is a width control.

The same oscillatory action occurs during the retrace in this circuit as in the one previously described. When the oscillatory cycle reaches the point at which the current through the deflection coils is at its maximum negative value, the voltage across the coils reverses polarity, making VT_2 start to conduct. This coil voltage also passes through C_3 and appears across R_4, R_5, and R_6 as a positive voltage on the grids of VT_2. This makes the plate resistance so low that VT_2 acts practically as a short circuit. During the initial portion of the cycle, therefore, the tube passes a very high current into the damping resistor R_7.

The network C_3-R_4-R_5-R_6 is arranged to have a very short time constant with respect to the oscillatory cycle. Condenser C_3 charges rapidly, with the result that the voltage across the grid resistance network falls quickly from its highly positive value back towards zero bias. As a result, the plate resistance of VT_2 increases rapidly but smoothly as the retrace cycle progresses.

This arrangement tends to smooth out the sweep cycle. Furthermore, since the rate of change of the plate resistance of VT_2 depends on the R-C time constant of the grid circuit, it is possible to vary the damping by changing the setting of resistor R_5 in the grid network. Since the damping action controls the amount of current in the deflection coils during the first part of the sweep cycle, R_5 is a linearity control for the first part of the sweep.

As you can see, there are no controls in the plate supply of tube VT_1. However, there is a drive control (not shown) at the input of tube VT_1.

Notice that the cathode resistor of VT_1 is not by-passed. This introduces degeneration, which improves the linearity of the sweep.

Although it is not shown here, there is an extra primary winding on T_1 from which the high voltage needed for the picture tube is secured. The circuit is like the one in Fig. 28 in this respect.

VARIATIONS

Most receivers in which electromagnetic deflection is used get the high voltage for the picture tube by the method just mentioned (that is, by using the high voltage peak that occurs across the primary of the output transformer). An added advantage of this system is that it protects the picture tube, because the high-voltage supply to the tube is automatically cut off if anything happens to the sweep circuit. However, a few receivers (particularly early ones) have been made that use other methods of getting the high-voltage supply.

In general, you will find that the deflection coils for the horizontal deflection system will have low inductance and that an output transformer will be used. However, there is even an exception to this—one manufacturer has made a circuit using horizontal deflection coils of high inductance, thus eliminating the need for an output transformer. This circuit is carefully designed to have very low distributed capacity so that it is still possible to get a fairly high frequency and thus obtain the retrace action in the same manner as in other receivers.

You can always expect to find variations of this sort where design engineers are trying to eliminate some particularly costly part or are trying to get around some patent restriction. In general, however, no matter how the circuit is changed, it must perform the functions we have described if it is to have the proper sweep characteristics.

In the next Lesson, we shall show how the sweep chain can be controlled either directly by the synchronizing pulses that come in with the television signal or indirectly by a "lock" arrangement that in turn operates from these sync pulses. Just remember that the sweep circuits we have described all have the important characteristic of providing a continuous sweep so that the raster will be produced whether a signal is tuned in or not. This protects the picture tube. Then, when the signal is tuned in, the hold controls can be adjusted to make the sweep circuits lock in frequency with the sync pulses and thus scan in synchronism with the transmitted image.

Lesson Questions

Be sure to number your Answer Sheet 55RH-3.

Place your Student Number on every Answer Sheet.

Send in your set of answers for this Lesson immediately after you finish them, **as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. Why is it necessary to have a sweep system that will keep the electron beam of the picture tube in motion whether we have a signal or not?

2. In which type of sweep is the deflection *voltage-operated?*

3. If one bright vertical or horizontal band is observed in a raster when no signal is being received, is the trouble caused by: (a) *poor screen;* (b) *insufficient high voltage;* (c) *a.c. hum;* or (d) *non-linear sweep?*

4. Is the frequency of a blocking oscillator adjusted to be *higher* or *lower* than the desired frequency?

5. If the second-anode voltage applied to an electrostatic picture tube is increased, will the amount of sweep voltage needed: (1) *increase;* (2) *decrease;* or (3) *remain the same?*

6. What voltage wave form must be applied to the input of the sweep amplifier to create a saw-tooth current through electromagnetic deflection coils?

7. Why does the use of a pentode as the vertical sweep amplifier make it possible to apply a saw-tooth voltage to the grid of the tube and yet produce a saw-tooth current through the vertical deflection coil?

8. When electrostatic scanning is used, why is it necessary to have more horizontal sweep voltage than vertical sweep voltage?

9. Is a damper tube needed in the vertical sweep circuit?

10. Why does the C-bias adjustment in a vertical sweep amplifier (Fig. 25) act as a linearity control?

Be sure to fill out a Lesson Label and send it along with your answers.

ASK WHY

The ability to observe *intelligently*— to learn—to gain information—depends greatly upon your willingness to ask WHY.

Don't simply take things for granted. Get in the habit of asking other people WHY. And most important of all, *ask yourself* WHY—then find out the answers!

Be a *student* for the rest of your life—be a person who seeks knowledge—be a person who *wants to know*—be a man who *asks* WHY!

Thomas Edison became rich and famous because he was curious about the *reasons* for this and the *reasons* for that. He asked himself and others WHY. Alexander Graham Bell was able to invent the telephone, because he asked WHY. Marconi discovered much about Radio because he had the habit of asking WHY.

And so I advise you—a man who wants to know more and more about Radio and TV—to develop the lifetime habit of asking WHY. This will contribute much to your eventual success.

J.E. Smith

TELEVISION SYNCHRONIZING CIRCUITS

56RH-3

PIONEER HOME STUDY RADIO SCHOOL

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STUDY SCHEDULE No. 56

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

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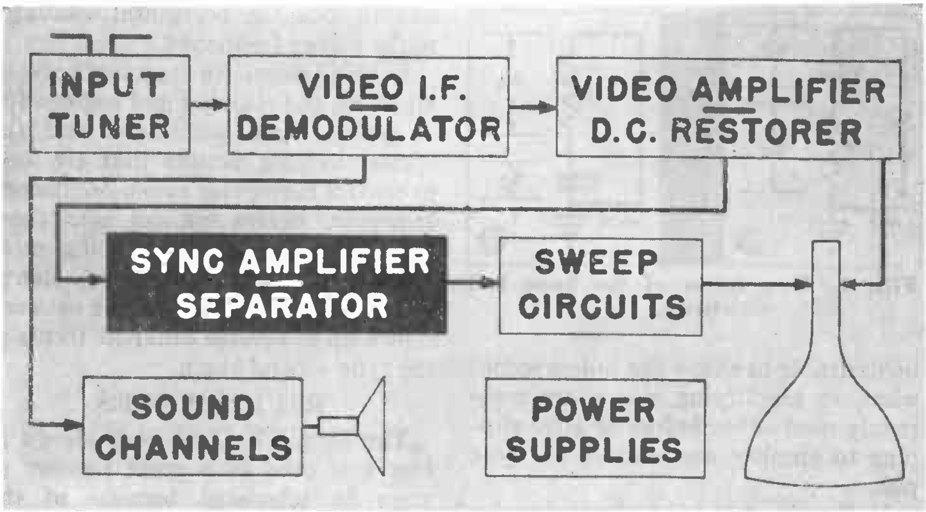

TELEVISION PICTURES can be produced properly only if we are able both to modulate the electron beam in the picture tube and to sweep the beam vertically and horizontally with sweep systems that can be locked with (controlled from) the transmitter. In previous Lessons, you have followed the picture signal to the grid of the picture tube and have learned how the sweep circuits operate. Now we are ready to see how it is possible to control the sweep circuits with the synchronizing pulses that are a part of the television signal as it comes from the transmitter.

As you have learned, the oscillators of television sweep circuits are made free running so that voltages will be produced to protect the face of the picture tube when no signal is tuned in. The frequency at which each runs free is approximately the correct one for the sweep circuit in which it is used. These oscillators are arranged so that they can be made to fall in step with the synchronizing signal, thus making the sweep generators follow the transmitter scanning and reconstruct the picture properly, element by element and line by line.

The signal at the output of the video detector contains the picture information that is used to determine the brightness of the spot. It also contains blanking pedestals, on each of which are the synchronizing pulses —one set of pulses for horizontal or line synchronization and another set for vertical or frame synchronization. Therefore, we must separate these pulses from the picture signal and then separate the line pulses from the vertical pulses. Once we have done so, we can obtain synchronization by applying the pulses to the sweep circuits.

As we shall show in this text, it is possible to separate the synchronizing pulses from the picture signal in a separator stage. Filter circuits may then be used to separate the two kinds of pulses from each other. Since there is more than one separation involved here, it is common practice to call the first operation "clipping," since effectively we "clip" the sync pulses from the rest of the signal. The operation of separating the two kinds of pulses is usually called "segregation."

The synchronizing pulse amplitudes may not be as high as is desired, the polarity may be wrong, and it may

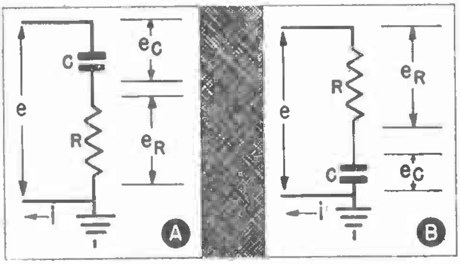

FIG. 1. Two forms of the basic R-C circuit.

be desirable to shape the pulses somewhat, so amplifying stages are commonly used either before or after clipping to amplify and correct the sync pulses.

In the simplest kind of synchronizing systems—known as "trigger" systems — the vertical and horizontal pulses are fed directly to the sweep oscillators after they have been segregated. These simplified trigger systems work satisfactorily as long as there is not a great amount of noise interference and not too much variation in amplitude between pulses coming from stations of different strength. Even in the face of considerable interference and signal variation, the vertical or field sweep can usually be made to lock satisfactorily with a trigger system, because the low-frequency vertical oscillator is relatively stable, and the kind of pulse that is used for controlling the vertical oscillators is of such shape that minor interferences are not too troublesome.

The horizontal sweep is much more susceptible to variations in the controlling pulse, because loss of synchronization for even one line produces a "tearing" across the picture. Therefore, in many receivers you will find that the horizontal sweep oscillator is fed control pulses through a locking or automatic frequency control arrangement of such a nature that the *average* sync pulse spacing over several lines is used in a comparison system to lock the horizontal oscillator to the proper frequency.

In this Lesson, we are going to learn all about the clipping and segregating of pulses, sync amplifiers, and the special locking circuits that are used to control horizontal sweep oscillators. However, before we get into these subjects, let's learn something more about the operation of an R-C charging circuit. This rather simple network shows up in several different forms in the sync control chain.

R-C RESPONSES

The simple R-C network shown in Fig. 1 is used in a great number of ways in television because of the amazing variety of responses this circuit has to waves of different shapes. We have shown two circuits in this figure. As far as a.c. is concerned, their actions are the same. In most cases, the circuit in Fig. 1A (in which the lower end of the resistor is grounded) is used; sometimes, however, it is necessary to ground the condenser, in which case the circuit in Fig. 1B is used. You may, therefore, find either arrangement in television circuits. Just remember that the response of each is the same.

When the input voltage e applied to the circuit in Fig. 1A is a *sine wave*, the only effects produced on the voltage are that it is divided and is shifted in phase. That is, as the frequency decreases, more voltage appears across the condenser and less across the resistance, and the resistance drop gets more out of phase with respect to the source voltage. However, the wave shape is still that of a sine wave. It is important for you to remember this fact—the response of this network to a *sine-wave* voltage is that a sine-wave voltage appears across each of the parts. The relative amplitudes of these voltages depend on the ratio of the reactance to the resistance. When we apply a voltage that is not a sine wave, however, the response of this circuit becomes very different.

Square-Wave Response. Let us briefly review the response of a circuit of this sort to the kind of wave shapes used in the sweep chain. You will recall that if a d.c. voltage is applied suddenly by turning on a switch, the condenser will charge up at a rate determined by the time constant of the R-C parts. Therefore, when a d.c. voltage is applied suddenly as in Fig. 2A, there will be at first a rush of current to charge the condenser. This current flow is limited by the series resistor R. Initially, the condenser will have no voltage across it, but the charge will build up until eventually the condenser voltage equals the voltage of the source. Thus, the condenser voltage curve is somewhat like curve 1 in Fig. 2B.

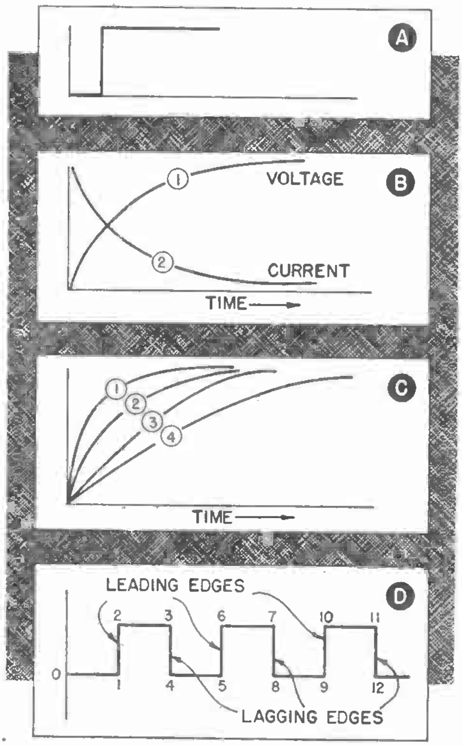

FIG. 2. Response of an R-C circuit.

The current through the circuit (curve 2) goes down as the condenser voltage goes up. The voltage drop across the resistor is in phase with the current flow through the circuit, so that curve 2 can also represent the voltage across the resistor. Thus, the resistor voltage is maximum and the condenser voltage is minimum when the circuit is first turned on; the condenser voltage then goes up, whereas the resistor voltage goes down.

Since the rate at which the condenser charges depends on both the size of resistor R and the size of the condenser, the charging curve changes in shape if different part values are used. For example, if either the condenser or the resistor (or both) is made larger, it will take longer for the condenser to charge, so the charging curve will be flatter. Fig. 2C shows curves for the condenser charging action in circuits having different time constants. Curve 1 is the curve for the circuit having the shortest time constant, curve 4 that for the circuit having the longest time constant. From these curves, you can see that the voltage across the condenser at a particular time depends on the time constant of the circuit: shortly after the switch is closed, the voltage can be high if the circuit has a short time constant but fairly low if the time constant is long. After a while, of course, the condenser in either kind of circuit will charge to approximately the source voltage.

If the applied voltage is turned off and the circuit is short-circuited, it will discharge along a curve much like the charging curve except that it will be inverted. If we apply power and turn it on and off regularly, or apply a square-wave a.c. signal, we will get a charging action that begins at the start of each pulse and a discharging action that starts at the end of each pulse. Thus, if we have the pulses 1-4, 5-8, and 9-12 shown in Fig. 2D, the condenser will start to charge when the "leading" edge of each pulse (the change 1-2, 5-6, or 9-10) occurs, and will start to discharge in step with the "lagging" edges (3-4, 7-8, or 11-12).

Fig. 3 shows the action for different time constants. Notice how the voltages across the condenser and resistor depend on the time constant of the circuit.

If the time constant is long, the condenser can charge but slowly. Hence, the resistance voltage rises to a maximum in step with the leading edge of the square wave, then drops off gradually. At the lagging edge, the current flow reverses its direction, and since the condenser voltage adds to the supply voltage on each alternation, the resistor voltage changes sharply to the opposite polarity. Therefore, when the time constant is long, the voltage across the condenser and that across the resistor have the shapes shown in Fig. 3B. During the time the pulse is applied, the voltage across the resistor will remain at a high value because there is current flow through it all the time until the condenser is fully charged. Since the condenser is charging very slowly, there is practically a constant voltage across the resistor during the charging time.

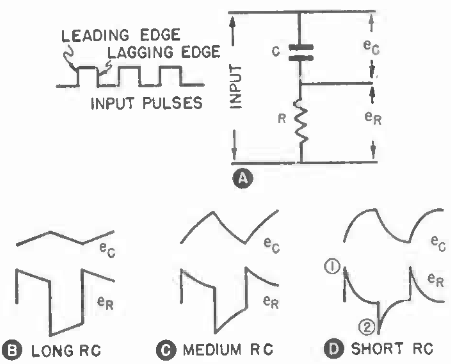

FIG. 3. Variations in output voltages produced by changing the time constant of an R-C network.

If the circuit has a medium time constant, the condenser charges more rapidly, and the voltage across the resistor drops more rapidly. The curves for such a circuit are shown in Fig. 3C.

If the time constant is very short, the voltage curves are like those shown in Fig. 3D. Notice particularly the resistor voltage. Effectively, what we get is a very high, sharp pulse (point 1) in step with the leading edge of the applied square-wave voltage, and another similar pulse (point 2) at the time of the lagging edge of the square-wave voltage.

This ability to produce a very sharp pulse in synchronism with the leading and lagging edges of the applied pulse is quite important, as we shall show later.

Incidentally, the low-frequency components of the signal appear across the condenser because the condenser reactance becomes higher at these frequencies. Therefore, the resistor voltage represents the high-frequency elements in the applied signal. If this network is arranged so that the desired output is taken from across the resistor, it is known as a "differentiating" network, whereas if the output is taken from across the condenser, it is called an "integrating" network. These terms will be met again later in this text.

Special Wave Shapes. There are occasions in the circuits we are going to study in which more than one of these R-C networks may be used in cascade. In particular, you may find two or more integrating circuits used after one another to get a wave of some particular shape.

For example, Fig. 4A shows a kind of pulse that is applied to an inte-

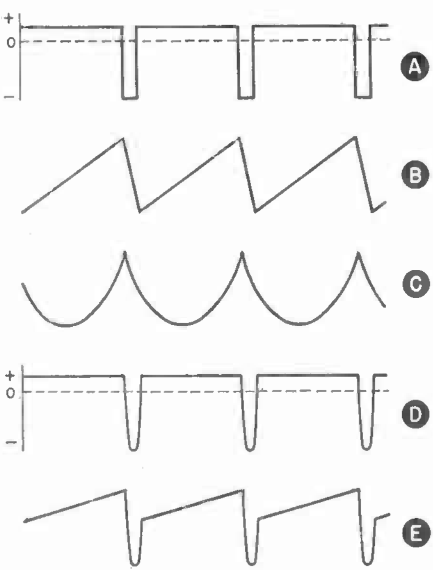

FIG. 4. Responses of integrating circuits to various wave forms.

grating circuit in one part of a TV set. The very high swings in the negative direction are sufficient to force the discharge of the circuit; as a result, the voltage across the condenser has the saw-tooth form shown in Fig. 4B. Then, this saw-tooth voltage can be fed into another integrating circuit from which we will get the parabolic curves shown in Fig. 4C.

It is important when we consider the operation of a circuit like this to realize that the pulses shown in Fig. 4A are actually squared pulses. For example, the wave form in Fig. 4D looks very much like that in Fig. 4A until you realize that the pulses in D are really halves of sine waves. Since a sine wave comes through an integrating circuit unchanged, the result of feeding pulses like those in D to an R-C circuit is much as is shown in Fig. 4E. Here, integration occurs during the flat portions of the wave, but the "dip" in the wave E looks exactly like the sine-wave portion of the original signal in D.

Naturally, the exact wave shape produced by an R-C circuit will depend upon whether it has a short, medium, or long time constant, and hence there are very many different possible shapes that are obtainable.

STANDARD TV SIGNAL

The various signals that are sent out by the transmitter in the region of the vertical blanking during the scan of one frame (two fields) are shown in Fig. 5. Among these is the picture signal for each line, at the end of which there is a blanking pedestal.

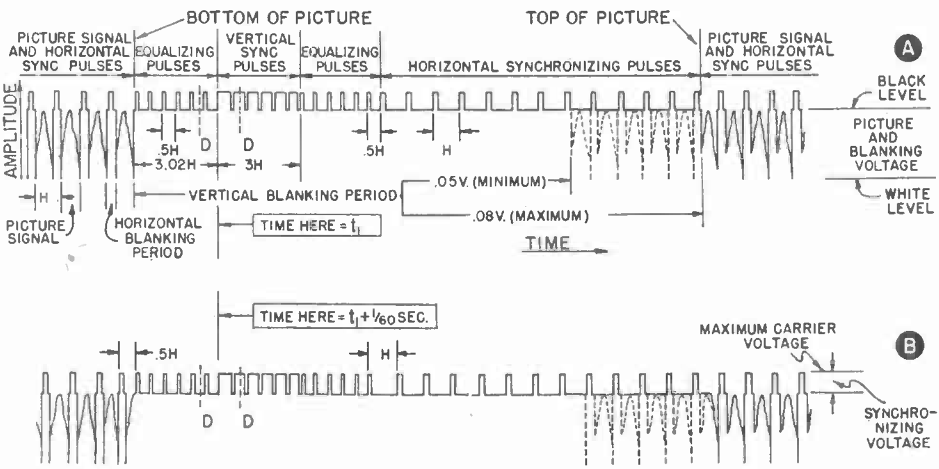

FIG. 5. The voltage forms that make up a complete television signal.

This blanking pedestal represents a voltage that is capable of cutting off the electron beam when it is applied to the picture tube; therefore, the pedestal represents a "black" signal. On this pedestal is the line (horizontal) sync pulse.

The vertical blanking period starts when the bottom of the picture is reached. It exists for the time that it takes to scan about nineteen or twenty lines. At a time approximately three lines from the beginning of the vertical blanking period, the vertical sync pulse begins. It lasts for a time duration of three lines. It is followed by horizontal synchronizing pulses during the vertical blanking period in which the vertical retrace carries the beam back up to the top of the picture. At the top of the picture, several lines are blanked out; during this time, the circuit settles down and prepares for the actual visible portion of the picture.

You can see from Fig. 5 that the horizontal and the vertical sync pulses are on blanking pedestals; therefore, they extend above even the signal levels that represent a black picture, and, as a result, cannot produce a visible picture on the face of the picture tube. A further examination of the sync pulses will show that the sections of the vertical pulse are quite broad compared to the horizontal sync pulses.

Pulses of a third kind—the equalizing pulses — also exist in the transmitted signal. These are even narrower than the horizontal sync pulses and occur at half-line intervals rather than at one-line intervals. These equalizing pulses, as we shall show elsewhere, are needed so that we can maintain horizontal sync during the vertical sync pulse; they break up the otherwise solid vertical sync pulse into segments, and exist for a time before and after the vertical sync pulse. Therefore, we have three different kinds of pulses, all of the same amplitude but of quite different widths, in the transmitted signal. All these pulses are capable of being separated from the signal by an amplitude clipper, because each of them is above the level of the highest signal voltage. Let's go on to see how this is done.

Sync Clippers

The job of separating all the sync pulses from the picture information is made easier by the fact that the former are all above and the latter are all below the level of the blanking pedestals. If we feed a signal like that shown in Fig. 6A into a properly designed clipping circuit, it can cut off the picture information from the sync pulses, producing an output like that shown in Fig. 6B. All pulses above the pedestal level can be removed in

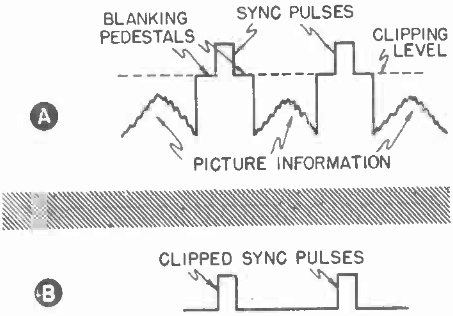

FIG. 6. How sync pulses are clipped.

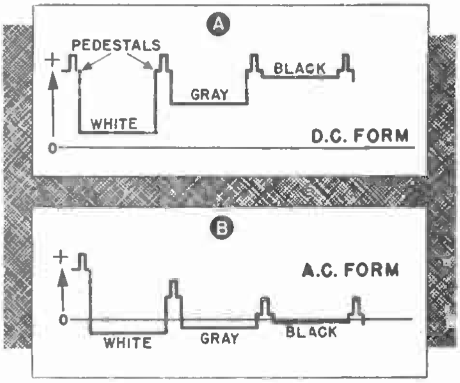

FIG. 7. The d.c. and a.c. forms of a TV signal.

this way—it does not matter to the clipper circuit whether they are horizontal sync, vertical sync, or equalizing pulses.

It is possible to use diode, triode, or pentode tubes in clipper circuits. Before we study the many different kinds of clippers, let us learn a little more about what the requirements for clipping are.

D.C. Level. The first requirement is that the pedestals must be lined up before a television signal can be clipped. That is, we must have the signal in its d.c. form. You will recall that all the pedestals are at the same level, as shown in Fig. 7A, when the signal is in its d.c. form. When it is in the a.c. form, on the other hand, the pedestals are not at the same level. As a simple example, let us suppose that we are using a clipper stage that has an operating curve like that shown in Fig. 8. When the signal is in the d.c. form shown in Fig. 8A, and the pedestals are lined up with the cut-off bias value, the plate current will contain only the sync pulses (Fig. 8B). On the other hand, if we apply the signal in its a.c. form (Fig. 8C), the output will have the form shown in Fig. 8D. In this case, if we set the bias so that the pedestals for a gray line match up with the cut-off value, we will get the pulses from this line. However, the black line pulses will be rejected completely, and part of the video signal will pass along with the white line sync pulses.

From the foregoing, you can see that we can get clipping quite easily by lining up the pedestals with the cut-off point of a tube as long as we have a d.c. signal form. Therefore, as a requirement for clipping, either the clipper must be d.c. coupled to some point in the video amplifier where the signal exists in a d.c. form, or we must introduce restoration to get it back to this form at the input of the clipper.

BASIC DIODE CLIPPER

Fig. 9 shows a basic diode clipper circuit. As you will recall, it is possible for a television picture to have either a negative or a positive picture phase at the output of the video detector or in the video amplifier.

Let us suppose first that we have the negative picture phase shown in

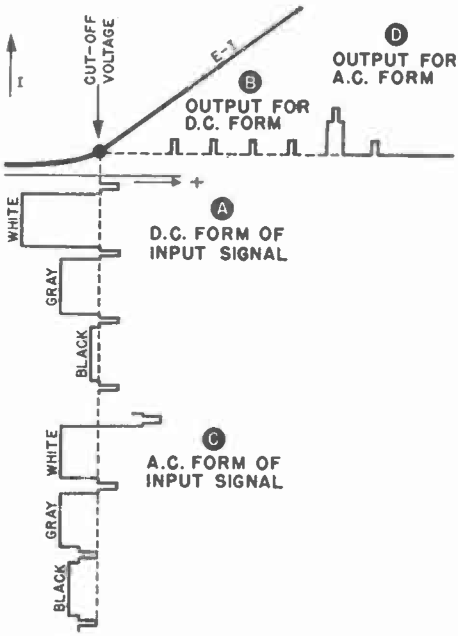

FIG. 8. Why a d.c. signal form must be used for clipping.

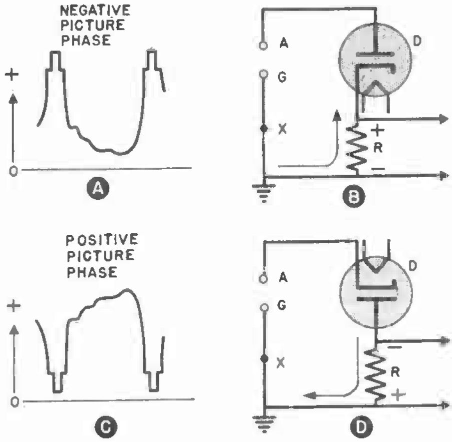

FIG. 9. Basic diode clipper circuits.

Fig. 9A. (The whiter the scene, the more negative the voltage in this case.) If we apply this to the diode circuit shown in Fig. 9B, we will get an exact replica of the signal across the load resistor R. In this case, clipping has not occurred. However, if we introduce a bias at point X of such a polarity that point G is made negative with respect to ground, the picture signal must overcome this bias before any current can flow through the diode tube. Hence, if we arrange this bias so that only the sync pulses can make the diode plate positive and cause current flow, we can secure the form of clipping that was shown in Fig. 8. Of course, we must start with a signal in which the pedestals are lined up.

If the signal has a positive picture phase (Fig. 9C), we must invert the diode as shown in Fig. 9D. With this arrangement, terminal G will always be negative with respect to A when a signal is applied, so no current will flow. However, the pulses are in such a direction that the terminal G will become less negative during the sync pulses. Therefore, we must introduce a bias voltage at point X of such a polarity that point G will be made negative with respect to ground. If this bias voltage is properly adjusted, the sync pulses will drive the plate of the diode sufficiently positive with respect to the cathode for current to flow, but the rest of the signal will overcome the bias and cut off current flow.

With these diode circuits, the output pulses will have the polarities indicated across the load resistor R in either B or D in Fig. 9. In both instances, we need to apply a bias voltage to the diode so that it will conduct only on the sync pulses. Of course, this bias voltage need not come from a separate source—it is possible to obtain it as a result of signal rectification in the diode itself. A more typical diode circuit arrangement in which self-bias is used is shown in Fig. 10.

With the arrangement shown here, the tube VT_1 acts as a clipper and is independent of the video detector and video amplifier. It gets its signal from the i.f. transformer L_1, which is tuned by condenser C_1. This signal is applied to the video detector and also to the clipper VT_1. On the positive pulses of the signal, rectification takes place in the clipper tube, and con-

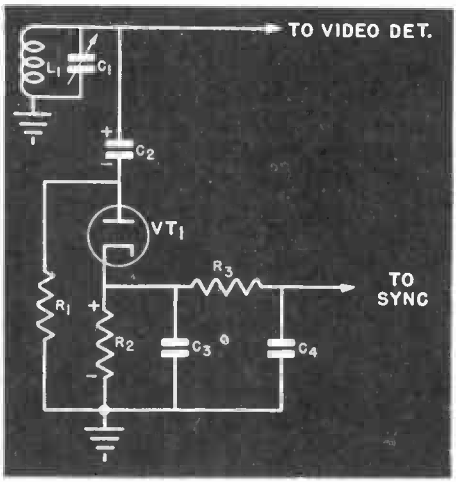

FIG. 10. Practical self-biased diode clipper.

denser C_2 becomes charged with the polarity shown. It cannot discharge rapidly through the high resistance R_1, so its voltage becomes an average bias value that follows the signal levels. Hence, we have effectively a form of d.c. restoration that lines up the pulses. At the same time, this bias voltage is of such value that only the sync pulses can overcome it and cause current flow through resistor R_2.

Here, condensers C_3 and C_4 and resistor R_3 act as a low-pass filter to remove any r.f. that appears across R_2; thus, the output of the clipper contains only the sync pulses. These pulses may be fed to either a sync amplifier or a segregation network. If the polarity of the pulses is wrong for the sweep oscillator, either an amplifier must be used to invert the polarity, or tube VT_1 must be inverted so as to obtain pulses having the opposite polarity.

Since the clipper tube VT_1 can act as its own d.c. restorer, we are now free to connect it to any point we wish in the video amplifier, whether the pedestals are lined up at that point or not. This allows us to take advantage of the extra gain of the video stages. It is becoming common practice to take the sync pulses from the output of the video amplifier. However, it is possible to take these pulses from another stage if polarity is a problem.

It is even possible to d.c. couple, as shown in Fig. 11, to some point where the video signal exists. Here, the signal exists across R_1, which may be a grid resistor or even a load resistor in the video circuit. Tube VT_1 is arranged in a network such that the bias developed by R_2 and C_1 will either act as a bias to provide clipping (if the signal across R_1 is in the d.c. form) or act as a restorer if the signal across R_1 is in the a.c. form. The sync pulses are produced across the resistor R_3.

Although the diode clipper is perfectly satisfactory as a means of separating the picture signal from the synchronizing pulses, it does not amplify; also, it tends to load the source, thus affecting the frequency response of the video amplifier. Clipper circuits in which triodes and pentodes are used have been developed that do not have these disadvantages. Let us see how they work.

TRIODE CLIPPER

A simple triode clipper is shown in Fig. 12B. When the signal shown in Fig. 12A is applied to this circuit, grid current will flow, charging condenser

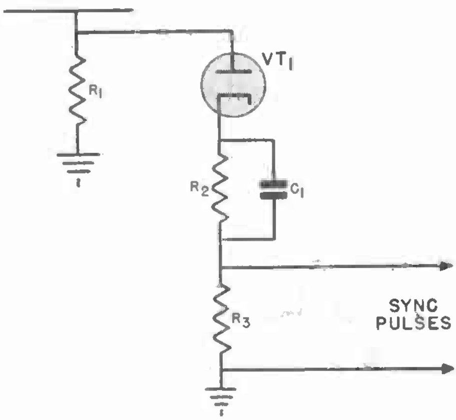

FIG. 11. D.C. coupling to a diode clipper.

C_1. If the proper values are used for C_1 and R_1, this charge will reach such a point that all of the signal below the clipping level will be beyond cutoff, and only the sync pulses will drive the tube into the conducting region. The amplification of the tube will cause the output pulses developed across R_2 to be larger than the original sync pulses. Since it is quite desirable to have large pulses, circuits of this sort are frequently used in TV sets.

Of course, such a tube inverts the phase of the pulses 180°. If the input pulses are going in the positive direction as shown in Fig. 12A, they will be going in the negative direction across R_2. Pulses of this polarity can be used to operate a multivibrator oscillator but not a blocking oscillator; if the latter is used in the sweep circuits, therefore, it will be necessary to invert the phase of the sync pulses.

Such phase inversion may be obtained by following this clipper stage with an amplifier or by inverting the phase of the signal at the input to the clipper. If the latter method is used, some changes must be made in the circuit. That is, if a signal of the kind shown in Fig. 12C is applied, the circuit must be modified as shown in Fig. 12D, and the tube must be made to operate at the plate current saturation point at the upper knee of its characteristic curve. When this operation is used, signal swings will drive the grid more positive, but no more plate current can flow. On the other hand, the sync pulses will decrease the

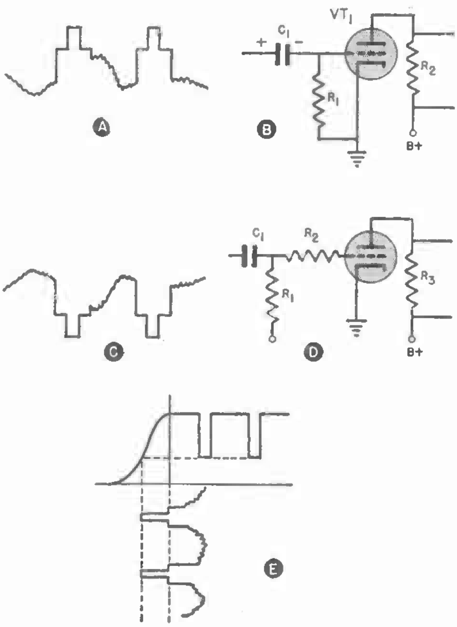

FIG. 12. Two triode clipper circuit arrangements.

grid voltage and thus reduce the plate current.

The operation of this circuit over the upper knee of the charactertistic curve is shown in Fig. 12E. The bias applied through resistor R_1 from a separate source must hold the tube grid near zero bias or even slightly positive to produce this operation. In

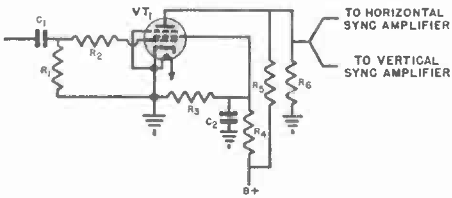

FIG. 13. Typical pentode clipper circuit.

addition, the plate voltage in this stage is made low so that saturation occurs near zero bias.

Resistor R_2 is added to the circuit shown in Fig. 12D so that if the tube should draw an abnormally high grid current, as it may when a strong noise pulse comes through, the circuit will not be blocked and rendered inoperative.

The output pulse is of course opposite in polarity to the plate current change—a drop in the plate current causes a rise in the plate voltage, with the result that the sync pulses are positive at the output of this circuit.

PENTODE CLIPPER

The pentode tube lends itself very well to use as a clipper. A typical circuit arrangement is shown in Fig. 13. The initial bias that produces tube cut-off is obtained by grid rectification —condenser C_1 charges when the grid goes positive and then must discharge through the relatively high resistance R_1. Therefore, the basic clipping action of this circuit is much like that of those we have already described.

However, we can get another action from the pentode circuit by reducing the plate and screen grid voltages to very low values. The voltage division produced by resistors R_5 and R_6 in the circuit in Fig. 13 is such that the plate voltage is quite low—it may be only about 5 to 10 volts. The screen grid voltage, which is determined by the voltage division between R_3 and R_4, is also low.

With both these voltages very low, the circuit will saturate quite easily, producing the action shown in Fig. 14. Once the initial clipping bias has been set up, the picture signal (which swings below the cut-off point) will cause no plate current. The sync pulses will cause plate current, but, because of the upper saturation bend of the characteristic, there is a limit to the amount of plate current they can cause. If the sync pulses are higher than the saturation level, they will be cut off as shown here. Therefore, the circuit can take sync pulses of different amplitudes and produce pulses of constant amplitude from them. Hence, noise pulses and increases in the signal strength that might change the amplitude of the sync pulses will all be wiped out by this circuit. This feature makes the pentode clipper rather popular. With other clippers that do not have this limiting feature, you will generally find that one or more of the associated amplifiers (we are going to study these) will be arranged to provide a limiting action like the one that is obtained in the pentode stage.

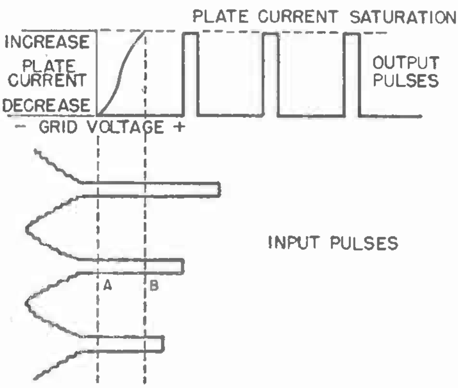

FIG. 14. Limiting action of a pentode clipper.

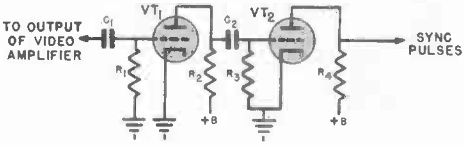

FIG. 15. A double clipper circuit.

Resistor R_2 is added in the circuit of the pentode clipper in Fig. 13 so that strong noise pulses will not cause excessive grid currents and thus develop a blocking bias.

DOUBLE CLIPPER

The same clipping plus amplitude limiting that is obtainable with a pentode can be obtained with two triodes used in the circuit shown in Fig. 15. These two triodes can be in the same envelope in the form of a dual triode.

Initially, the basic clipping occurs in the grid circuit of VT_1, where the grid current flow charges condenser C_1.

The pulses existing across R_2 are therefore separated by VT_1 from the video signal, but the pulses may be of unequal amplitudes. However, VT_1 has inverted the phase, so that the pulses are now swinging in the negative direction. When these pulses are applied to tube VT_2, the pulses above a certain amplitude will be beyond cut-off, so amplitude limiting (or second clipping) occurs. VT_2 inverts the phase again, so that the output pulses across R_4 now swing in the positive direction.

Notice that the grid circuit of VT_2 does not provide a bias to follow the pulses. Such a bias is unnecessary because the pulses swing negative. This is fortunate, because it makes it

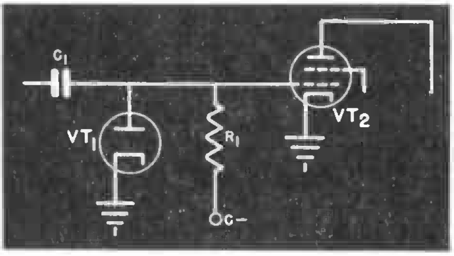

FIG. 16. Sync-clamper circuit.

possible to use a low resistance as grid resistor R_3; it is necessary to use a low resistance here to provide wide band response so that the sync pulses can get through without distortion.

Sync Clamper. Although it is possible to produce d.c. restoration in the clipper circuit quite simply by grid rectification, it is sometimes undesirable to do so, particularly when we want the clipper to act reasonably well as an amplifier. In such cases, often a fixed bias is applied to the clipper; a separate diode rectifier is then used for d.c. restoration. A typical circuit is shown in Fig. 16. The diode rectifier VT_1 acts in conjunction with C_1 and R_1 as a d.c. restorer just like those used in the video amplifier. The restored signal across R_1 is fed to the clipper tube VT_2. This tube is so biased that the pedestals line up at the cut-off point, and plate current will flow only on the swings of the sync pulses into the less negative grid region.

Although tube VT_1 acts exactly like any other d.c. restorer, it is given the name of "clamper" to distinguish between it and the true d.c. restorer that operates on the picture signal.

Sync Amplifiers and Segregating Circuits

As we have pointed out, it is possible to obtain the desired signal for the clipper (the picture signal plus the sync pulses) anywhere in the video amplifier, from the second detector to the grid of the picture tube. Whether or not the signal is in its d.c. form at the point from which it is taken is not particularly important; as we have shown, it is always possible to produce d.c. restoration in the clipper circuit if necessary. Of more importance are the phase of the signal and the level of the sync pulses.

The picture phase on which the clipper is designed to operate restricts the number of points from which the signal can be taken. Obviously, if the clipper requires positive pulses, we must take the signal from some point in the video amplifier where the pulses are swinging in the positive direction, and conversely for a clipper that requires negative pulses.

The strength of the sync pulses (and consequently the definiteness of the control action) depends upon the point in the video amplifier from which the signal is taken, increasing as the point is moved farther along. Therefore, there is a growing tendency to get the signal for the clipper from near the output of the video amplifier. In most modern receivers, in fact, you will find that the sync pulses are obtained either from the plate circuit of the output video stage or from its grid circuit, depending upon the point at which the signal phase is proper for the clipper circuit.

Many manufacturers do not feel that even the signal from the video amplifier is strong enough for best clipping. For this reason, they very frequently include an amplifying stage ahead of the clipper. This amplifier may be either a triode or a pentode tube. When such an additional amplifying stage is used, the fact that it inverts the picture phase 180° must be taken into consideration so that the clipper itself will be fed with signals having the proper phase.

It is also common practice to include amplifiers following the clipper. There may even be amplifiers following the point at which the synchronizing signals are segregated—an amplifier for the vertical pulses being entirely separate from one that is used for the horizontal sync pulses.

As a matter of fact, the double clipper shown in Fig. 15 acts as a double amplifier. It is possible to set the bias so that the second tube will serve only as an amplifier rather than as a second clipper (amplitude limiter). Usually, however, the circuit is arranged so that the amplifier gives the second clipping and thus removes noise pulses that might drive the sync pulses to amplitudes that would be higher than normal.

Fig. 17 shows a typical chain consisting of an amplifier, a clipper, and a second amplifier. In this circuit, tube VT_1 is biased for normal operation as an amplifier. In this example, instead of using self-bias, the grid bias is obtained from a voltage divider arrangement that operates from taps on the power supply. This voltage divider is adjusted so that the proper operating bias is obtained. Manufacturers use arrangements like this rather than furnish additional taps on the voltage divider in the power supply.

The sync pulses obtained from the video output in this instance are in the negative direction. Tube VT_1 amplifies both the pulses and the signal components. However, the arrangement is such that if any sync pulses are driven very far negative by noise pulses, they will be beyond the tube cut-off point. This tube therefore provides an initial clipping of the amplitude of the pulses.

Since VT_1 inverts the phase of the pulses, it feeds positive pulses into tube VT_2. The operating voltages applied to this tube are such that the picture signal is cut off at the pedestal level because all the picture signal is below the cut-off level set for the tube. D.C. restoration occurs in the grid circuit of this tube to align the pedestal levels.

At the output of VT_2, the pulses are again negative. If positive pulses are needed—for application to the grid of

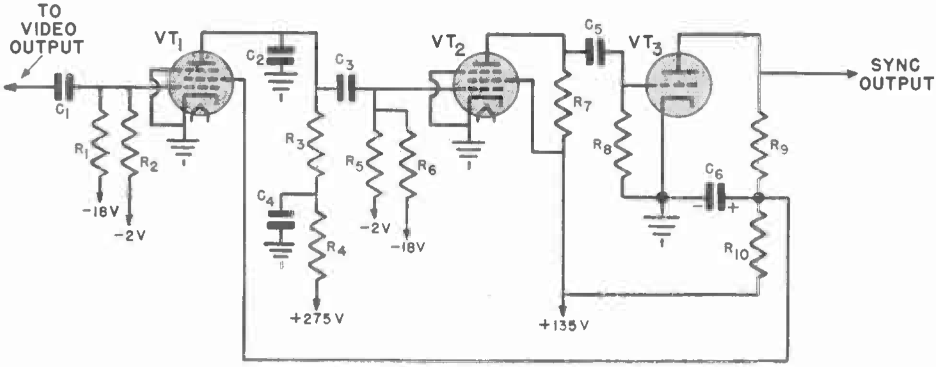

FIG. 17. Typical sync amplifier-clipper chain.

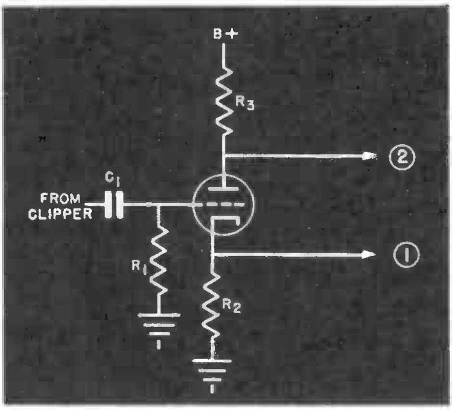

FIG. 18. Circuit furnishing positive and negative pulses.

a blocking oscillator, for example—an additional amplifying tube VT_3 is used to increase the strength of the pulses again and to invert their phase to give an output of the proper polarity. At the same time, any pulses that swing too far negative will be clipped again by VT_3; at its output, therefore, the pulses are restricted and are practically all of the same amplitude. This removes any increases in the pulse levels caused by noise or other interferences.

Although we have spoken of the "proper" polarity for the pulses, it may be that we want pulses of both polarities after clipping, since one of the sweep chains may use a multivibrator and the other a blocking oscillator. Fig. 18 shows a circuit that will furnish pulses of both polarities at the same time. The amplified pulses across R_2 in the cathode circuit of the tube have the same phase as the signal that comes from the clipper, whereas the phase of the voltage in the plate circuit, across R_3, is inverted 180°. Thus, if the pulses from the clipper have a positive phase, the output from terminal 1 will also be positive, but that from terminal 2 will be negative.

To sum up, the chain of stages used to extract the sync pulses from the transmitted signal may consist only of a clipper, but it is more usual practice in the receivers of today to have at least one amplifying stage in addition to the clipper and possibly to have as many as three or four amplifiers—one ahead and one after the clipper, plus an additional one either in the horizontal or in the vertical chain, or in both. One or more of these amplifiers may serve as an amplitude limiter (second clipper) as well as perform as a normal amplifier. In addition, you may find a clamper tube used to give d.c. restoration.

SYNC SEGREGATION

The final product at the output of the clipper or at the output of a following amplifying stage consists of three kinds of pulses. We have the line pulses that occur at the end of each line. Then, we have the vertical pulse, which exists for a space occupied by three lines, but which is cut up at half-line intervals so that the horizontal or line synchronization may be maintained during it.

For a space of three lines before the vertical pulse and for another three-line space after the vertical pulse, there exists a series of equalizing pulses. These pulses occur at twice the horizontal or line pulse rate—at half-line intervals, in other words. These equalizing pulses serve to cut up the vertical pulse and to provide line synchronization at the end of each field. You will recall that one field ends in the middle of a line, but the next one ends exactly at the end of a line. Therefore, there is a half-line difference in the two fields, a condition that is necessary for interlaced scanning. Since the equalizing pulses are at half-line intervals, alternate equalizing pulses are used just like

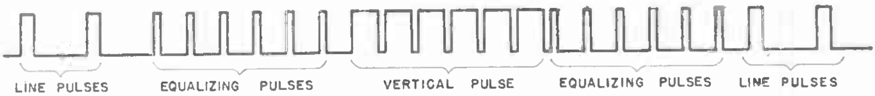

FIG. 19. The line, equalizing, and vertical sync pulses in a TV signal.

the line pulses to control the horizontal sweep chain. One set of equalizing pulses is at the end of one field and the other set at the end of the next, but the action is the same.

The various pulses are shown in Fig. 19. This figure shows the relative widths of the pulses; as you can see, they are different in their widths as well as in their frequencies.

Once the sync signal containing these three kinds of pulses has been separated from the video signal, we must separate the line and equalizing pulses from the vertical pulse so that the horizontal pulses can be applied to the horizontal sweep chain and the vertical pulses can be applied to the vertical sweep chain. To separate these two types of pulses, we use R-C networks.

Horizontal Separation. We can obtain a control pulse that will be timed exactly by the leading edge of the horizontal pulses by using a differentiating network like that in Fig. 20 having a short time constant. Fig. 21 shows what happens when the group of pulses in Fig. 19 is fed to such a network.

In Fig. 21A, we have repeated the group of pulses that we had in Fig. 19. When the pulses are fed into the differentiating network, the output across R_1 will be like that shown in Fig. 21B. Every time there is a sharp change in the voltage caused by either the leading or lagging edge of a pulse, a corresponding sharp pulse will be developed across R_1. As Fig. 21B shows, these pulses will be caused by the edges of each pulse in the output of the clipper, whether the original pulse is a horizontal (line) pulse, an equalizing pulse, or the serrations in the vertical pulse.

Notice that the leading edges produce pulses having a polarity that is opposite to that of the pulses produced by lagging edges. Only the pulses produced by the leading edges (the pulses numbered from 1 to 22 in Fig. 21B) are properly spaced to be usable for horizontal synchronization, because they are spaced so that they are either one-half line or one line apart. The space from pulse 1 to pulse 2 in Fig. 21B, for example, is equal to one line. The same is true of the spacing between pulse 2 and pulse 3. The pulses from 3 to 21 are a half-line apart, because they occur in step either with the equalizing pulses (those from 3 to 8 or from 15 to 21) or with the half-line intervals in the vertical sync pulse (those from 9 to 14).

On the other hand, the pulses produced by the lagging edges in Fig. 21B cannot be used, because they are upset at the beginning and end of the vertical pulse. They are spaced properly from pulse 23 to pulse 24, but the space from pulse 24 to pulse 25 is not equal to either one line or a half line. Then, the space from pulse 26 to pulse 27 is less than a half line.

Of course, since the pulses produced by the leading and lagging edges are

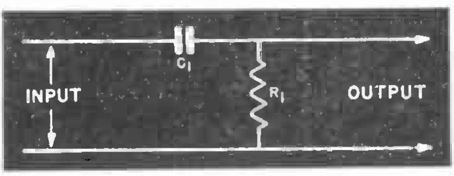

FIG. 20. Typical differentiating network.

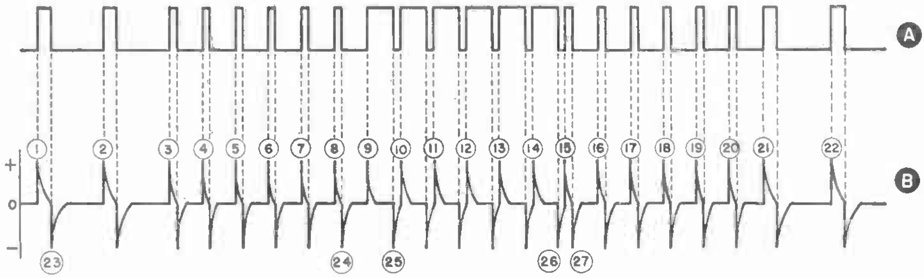

FIG. 21. The pulses in B are produced by feeding those in A into a differentiating network.

opposite in polarity, it is simple to arrange for only those produced by the leading edges to be used. For example, let's assume that the pulses 1 through 22 are all in the positive direction, which makes the other pulses extend in the negative direction. If we apply these pulses to the input of a blocking oscillator, only those moving in the positive direction will be able to set off the circuit. Suppose, for example, that the pulse chain shown in Fig. 22 is applied to the grid of a blocking oscillator. Since the pulses S_1, S_2, and S_3 swing in the positive direction, they will force the grid voltage above the cut-off level, so that the blocking oscillator will produce its pulses in step with these synchronizing pulses. Pulses of the opposite polarity (S_6-S_7-S_8-S_9-S_{10}) will be ignored by the circuit.

We mentioned that there are pulses at half-line intervals during the equalizing and vertical pulse intervals. However, as Fig. 22 shows, half-line pulses S_4 and S_5, although of the right polarity, are not of sufficient amplitude to drive the blocking oscillator grid voltage above the cut-off level. Hence, these pulses are simply ignored —only those occurring at the right time (that is, near the time when the oscillator would operate by itself) can control the horizontal blocking oscillator.

At the end of every alternate field, however, these half-line pulses take over control of the horizontal oscillator. This occurs because alternate fields end in the middle of a line. During one vertical sweep, therefore, the pulses S_4 and S_5 occur at the wrong times to exert control; during the next field, however, they occur at the right times and trigger the horizontal oscillator.

If the horizontal system uses a multivibrator, we need pulses with a negative polarity if the signal is to be applied to the grid of the first tube. As you saw a moment ago, the negative pulses (Fig. 21B) produced by the trailing edges cannot be used because they are not properly spaced. Hence, either we must invert the clipper so as to produce pulses of the opposite polarity, or we must feed the pulses shown in Fig. 21B through an amplifier stage to invert the phase 180° and therefore make the positive pulses become negative ones. In this case, we don't want the pulses that go in

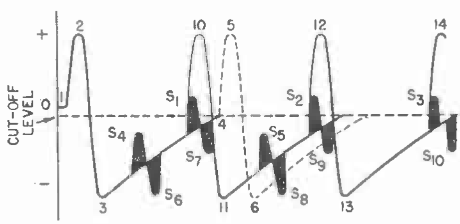

FIG. 22. How alternate positive half-line pulses can control a blocking oscillator.

the wrong direction, so this amplifying stage can act as a clipper, as shown in Fig. 23, to remove the pulses that swing in the wrong direction. If we overdrive this amplifier and use a low plate voltage, the pulses will be reshaped and limited in amplitude and thus be better for use as control pulses. Since the use of such a circuit makes it necessary to have one more

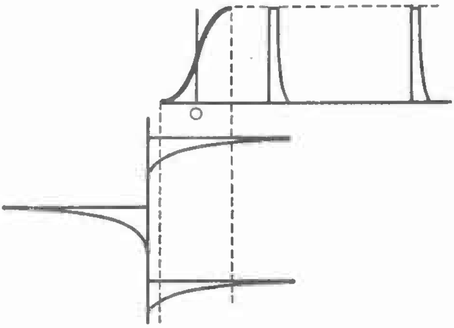

FIG. 23. Using a horizontal sync amplifier as a clipper.

tube, it is more common to arrange the clipper to give pulses of the proper polarity.

Vertical Separation. Now that we have satisfactorily arranged for getting the horizontal pulses, we need to get the vertical control pulse. We can do so by using an integrating circuit like the one shown in Fig. 24. If the time constant is made long enough, the horizontal pulses will be ignored (they produce little charge), but a control pulse is produced during each

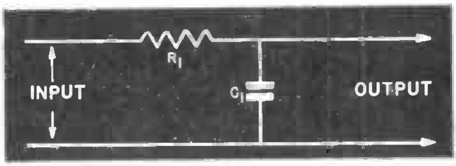

FIG. 24. Typical integrating network.

vertical pulse interval.

When the pulses shown in Fig. 25A are fed into this circuit, its output will be like that shown in Fig. 25B. Because of the long time constant, the condenser is charged only slightly during each horizontal line pulse, and somewhat less during each of the narrower equalizing pulses. The voltages produced by these chargings are ignored by the circuit to which the signal is fed, because they are too small in amplitude to affect the circuit.

During the vertical pulse interval, however, there is time for the charge across C_1 to build up to a much higher level. (Since the vertical pulse shown in Fig. 25A is much wider than the horizontal pulses, the vertical pulse is applied to condenser C_1 for a much longer period of time, so the condenser is charged much more by the vertical pulse than it is by the horizontal pulse.) Naturally, C_1 discharges a little during the gaps in this pulse, but since these gaps are of relatively short duration, the long time constant keeps the discharge slight. Therefore, the voltage across C_1 builds up as shown in Fig. 25B from the value at 1 to the peak value at 2 during the vertical sync pulse interval. When the verti-

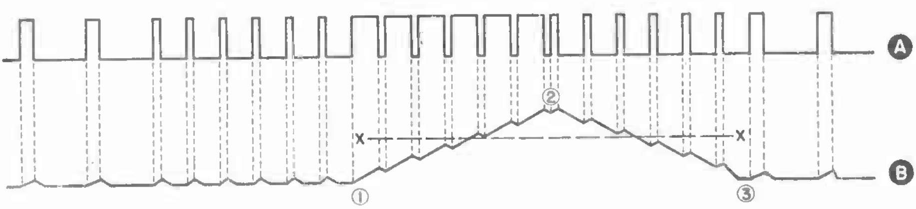

FIG. 25. The long pulse in B is produced by feeding those in A into an integrating network.

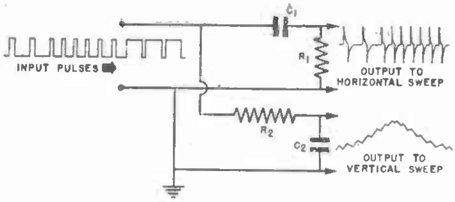

FIG. 26. Sync-segregation circuit.

cal sync pulse stops, the condenser discharges from the value at 2 back to its original value at 3.

From this, by the use of an integrating R-C circuit, we can arrange a gradual charging action on the pulses, and by having a sufficiently long time constant, the horizontal pulses can be ignored (they produce little charge) but the desired vertical control pulse is produced.

All we need to do now is to arrange to feed this pulse into a blocking oscillator or a multivibrator and to see to it that this pulse is high enough to initiate the oscillator action. Thus, we can arrange matters so that whenever the voltage across C_1 gets above the value represented by the line X-X, the oscillator will operate and start the retrace.

Generally, both the horizontal differentiating network and the vertical integrating network are connected in parallel, as shown in Fig. 26, to the output of the clipper or of an amplifying stage. Then, when the pulses are fed in, the respective outputs are led off to either the horizontal or the vertical sweep chains.

In some receivers, you will find that a chain of integrating networks, as shown in Fig. 27, will be used to separate the vertical pulse from the other pulses. This double integrating network (or a triple one) serves to smooth out the "teeth" in the pulse that a single integrating network produces. Curve 1 in Fig. 27B represents the output of a single integrating network, and curve 2 approximates that of the second network. Although the peak value produced by double integration is lower than the one a single network gives, the curve is smoother and therefore produces more precise synchronization. When a single integrating circuit is used, there is a chance that the synchronization may be uneven, because one of the teeth in the curve may happen to fall at a time when the vertical synchronization should occur.

You will notice that there is a difference between the times when the vertical and horizontal circuits "fire." In the case of the horizontal circuits, the synchronizing pulse that is fed to the sweep oscillator occurs exactly in step with the leading edge of the line (horizontal) pulses. On the other hand, the vertical oscillator is not fired until some time late in the vertical pulse interval, the exact time depending upon the R-C time constant. The precise point in the vertical pulse at which the vertical oscillator is set off is not particularly important as long as it is always at the same point in each succeeding frame. If this is accomplished, vertical synchronization will be obtained.

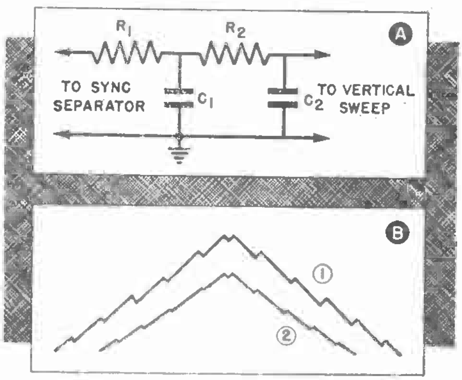

FIG. 27. Effect of double integrating network.

Sync Locking Circuits

In the preceding sections of this Lesson, we have shown how it is possible to separate the sync pulses from the picture signal and to segregate them into vertical and horizontal control pulses. These pulses may be used to trigger the oscillators in the vertical

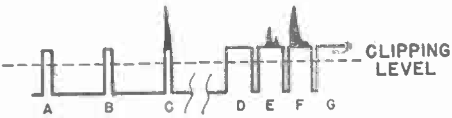

FIG. 28. Clipping removes amplitude changes.

and horizontal sweep circuits. This method of triggering the sweep circuits is entirely satisfactory for the vertical synchronization; it is also satisfactory for horizontal synchronization provided there is not any great amount of interference being picked up along with the signal.

Even if there is interference, the synchronization is not greatly affected as long as only the amplitudes of the pulses are changed by the interference. The use of double-clipping or clipper-amplifier combinations that square off the pulses in both directions will prevent any amplitude changes in the pulses from being passed on. Thus, if we feed the pulses shown in Fig. 28 through such an arrangement, the pulses will be cut off along the dotted line marked "clipping level." Should any interference or noise signal come along as is shown on pulses C, E, and F, it will automatically be clipped off. As a matter of fact, even the normal pulses A, B, D, and G will thus be reduced somewhat in height.

However, noise and interference pulses can also change the pulse widths. This doesn't matter much as far as the vertical pulse is concerned, because it is already so wide that it would take a very long burst of interference to increase its width much, and if the interference is that steady, the picture probably will not be very good anyway. Therefore, the vertical sync system will ordinarily hold, even on an interference that changes pulse widths.

This is not true of the horizontal sweep, however. Should any interference broaden the pulse in such a way as to change the time of the leading edge of the pulse, the horizontal sync will be thrown out for that line.

Fig. 29 shows what may happen. The normal pulse A is clipped in amplitude and is otherwise not affected.

The noise interference on pulse B has changed its amplitude, but the change does not matter because it will be removed by the clipper action. It has also widened the pulse so as to move the trailing edge: the pulse should end along the line 4, but it has been widened so that it extends out to position 5. This broadening of the

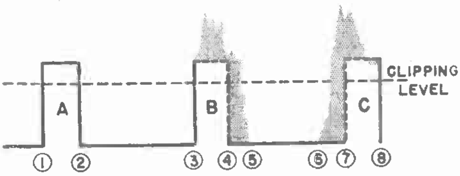

FIG. 29. Clipping does not remove width changes.

pulse is also unimportant, because the trailing edge is not used for synchronization.

However, the interference on pulse C has affected the leading edge. The pulse should start at 7, but actually starts at point 6. Therefore, the spacing from leading edge 3 to leading edge 6 is not correct for a line, so the circuit is kicked off too soon. This puts one line out of position and results in a tear across the picture. If several lines are affected this way, the picture will be torn up to a considerable degree; if they happen to be consecutive lines, it may well be that the horizontal oscillator will get out of synchronization altogether, making it necessary to readjust the hold control to bring the set back into sync.

Therefore, if there is any appreciable local interference or noise, it may well be that the horizontal oscillator cannot be properly operated from the simple trigger system we have described so far. Remember, this system will work where there is freedom from such interference, so it is still quite widely used. However, a more complicated system is necessary if the set is to work properly in areas where the interference level is fairly high.

There are, in common use, three basic locking circuits designed to solve this interference problem. They all operate on the principle that it is possible for the horizontal oscillator to operate by itself and stay in sync for at least a few lines before it drifts off synchronization. Each system is then designed so that the *average* of the pulses for several lines is used instead of individual pulses so that abnormal pulses are ignored.

Each of these locking arrangements makes use of some form of comparator circuit in which the output of the oscillator is compared with the sync pulses. The difference (if any) between the two is used as a control voltage that ultimately causes the frequency of the horizontal oscillator to shift to the proper value. First, however, this control voltage is applied to filter circuits that tend to cause it to follow the average of the difference between the sync and oscillator pulses. Therefore, if the difference between them is only momentary (caused by a disturbance that lasts for only a line or two), there will be practically no average difference between them, and the oscillator frequency will therefore not be affected.

HORIZONTAL A.F.C.

One of the most popular means of controlling the horizontal oscillator is through the use of a standard automatic frequency control (a.f.c.) network like that shown in Fig. 30.

Here, tube VT_3 is the horizontal sweep oscillator. This is a sine-wave oscillator in a relatively stable Hartley circuit. The tank circuit consists of coil L_1 plus the distributed and other shunting capacities. This oscillator is designed to operate at exactly the line frequency of 15,750 cycles.

Shunted across the sweep oscillator tuned circuit is a reactance tube VT_4. You will recall that in a.f.c. systems, the reactance tube is made to draw a plate current that either leads or lags its plate voltage by 90°. Thus, the tube can be made to act either as a capacity or as an inductance, whichever is needed. The amount of reactance simulated by the tube depends on the amount of its plate current. Therefore, the frequency produced by the sweep oscillator depends on how much current the reactance tube is drawing at any particular moment. This current can be controlled by varying the bias on VT_4; in fact, this is the method of control used in the a.f.c. system.

To get this control voltage, a standard discriminator circuit using diodes VT_1 and VT_2 is employed. The differentiated horizontal sync pulses are fed from the sync amplifier through C_1 and developed across R_3; they are thus applied through the the coil L_2 to both diodes simultaneously. Coil L_2 is coupled to the oscillator inductance L_1. A resonant circuit, tuned to the sweep oscillator frequency, is formed by C_2 and variable inductance L_2.

The voltages at the two ends of coil L_2 are 180° out of phase—as one end of coil L_2 is going positive, the opposite end is going negative. Also, as you will recall from your study of discriminators, these voltages are mutually 90° out of phase with the voltage that is applied through the coil center tap to both the diodes.

In this arrangement, the sync pulses across R_3 are applied to the diodes in series with the sine-wave voltage across L_2. Thus, we have the voltages shown in Fig. 31 on the plates of the diodes. When the sweep oscillator is operating at the proper frequency, the phases are such that the pulses occur just as the sine waves go through zero. Therefore, the voltage E_1 applied to one diode is exactly equal to the voltage E_2 applied to the other (since both these voltages at this instant represent only the pulse voltages, which are always equal). Hence, the diodes will pass equal currents through their load resistors (R_1 for VT_1 and R_2 for VT_2); and since these are equal resistors, the voltage drops across them will therefore be equal. Since the current flow is in opposite directions through the two resistors, their drops will exactly cancel.

The bias applied to tube VT_4 comes through these resistors to the grid of this tube. Therefore, when the phase relationship is that shown in Fig. 31A, the only bias on tube VT_4 is made up of the fixed bias coming from the power supply plus the small additional bias drop across R_8 in its cathode circuit.

Let us suppose now that the frequency of the sweep oscillator changes slightly so that it is lower than the correct frequency. The incoming sync pulses continue to occur at exactly the same time, but the sine-wave voltage now lags behind. As a result, the pulses no longer occur just as the sine-wave voltages go through zero (Fig. 31B); and the voltages E_1 and E_2 therefore consist of the algebraic sum

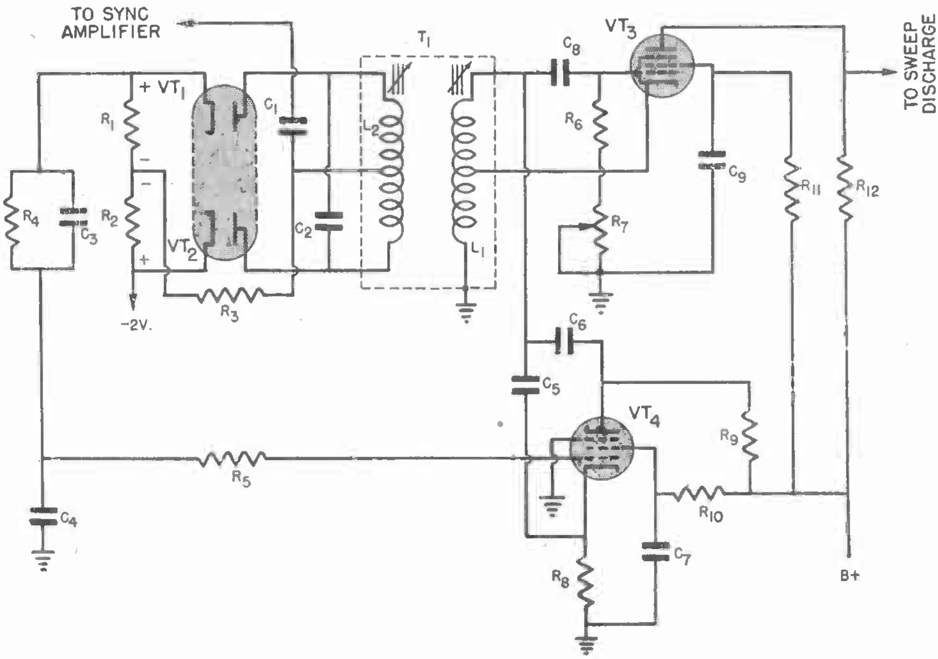

FIG. 30. Horizontal oscillator controlled by an a.f.c. network.

of a sine-wave voltage and a pulse voltage. In this case, E_1 consists of the pulse voltage plus the sine-wave voltage, and E_2 consists of the pulse voltage minus the sine-wave voltage (since this latter sine-wave voltage is going through the negative part of its cycle at this instant). Voltage E_1 is therefore larger than voltage E_2.

Since the voltages applied to the two diodes are no longer equal, the currents through their respective load resistors are also no longer equal. If E_1 is applied to diode VT_1, the drop across R_1 will be greater than that across R_2, with the result that there will be a net voltage across the series combination of R_1 and R_2 having the polarity of the drop across R_1. Therefore, a positive voltage will be added to the bias of VT_4, causing this tube to draw more plate current. This circuit is arranged so that tube VT_4 acts as an inductance (the plate current lags behind the a.c. plate voltage). The addition of a positive voltage to its bias will make it act as a smaller inductance in parallel with L_1, thereby raising the frequency of the sweep oscillator and causing the sine-wave signal to speed up so that the pulse will return to its proper position shown in Fig. 31A.

Conversely, if the local oscillator operates at a higher frequency than it should, E_1 will be a lower voltage than E_2, as shown in Fig. 31C. As a result, the net additional bias applied to VT_4, which will be the difference between the two drops across R_1 and R_2, will have the polarity of the voltage across R_2. This added bias will increase the negative bias on VT_4, thereby reducing its plate current, making it act like a higher inductance, and therefore shifting the oscillator to a lower frequency.

Thus, if the frequency of the horizontal oscillator becomes higher or lower than that of the incoming sync pulses, the action of the circuit is to bring the oscillator back to the correct frequency. This is accomplished automatically.

The circuit is insensitive to pulse amplitude changes because the same pulse is applied to both diodes, and should its amplitude change, both voltages would change to the same degree. If the pulse width should be changed by noise, however, the pulses may effectively occur either sooner or later than they should, causing a shift in the frequency of the sweep oscillator. That is, such a change could occur if the control action were instantaneous. However, the control is not exerted instantaneously; instead, the

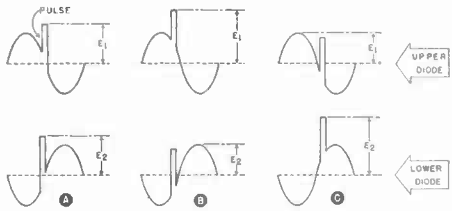

FIG. 31. Possible phase relationships in discriminator output.

output voltage of the discriminator circuit is fed to the R_4-C_4 network (Fig. 30), and the voltage built up across C_4 by this control voltage is what is applied to VT_4 as a control bias. Since the R_4-C_4 network has a fairly long time constant, a voltage difference must exist across R_1-R_2 for several lines before the voltage across C_4 will change appreciably; and, of course, tube VT_4 does not learn of the change until the voltage across C_4 has reached its new level. Therefore, if only one or two pulses get out of line, normal pulses will come along to restore conditions to what they should be before the bias on tube VT_4 can change appreciably. The effect is that one or two bad pulses may change the bias very slightly, but not enough to make any real difference in the operation of the circuit.

Should the sweep oscillator drift off frequency, however, it will get out of step with a number of the pulses, with the result that there will be time for the voltages across C_4 to change and hence for the reactance tube to pull the sweep oscillator back into frequency. Effectively, therefore, we have a circuit that uses the average of the sync pulses to control the output of the sweep oscillator. Because of the time constant network through which the control voltage is applied to the reactance tube, the circuit will tend to ignore irregularities in just a few of the pulses.

SAW-TOOTH A.F.C.

The a.f.c. system we have just described operates with a sine-wave oscillator. To get the sweep signal, this sine wave must be "treated" specially —it is squared and differentiated before application to the discharge-shaping network. To avoid this, many manufacturers desire to operate from either a blocking oscillator or a multivibrator circuit rather than a sine-wave type. Therefore, a somewhat different form of a.f.c. system has been developed for use with these oscillators. Since both these oscillators can be controlled by varying the bias voltages applied to them, it is unnecessary to use a variable-inductance or variable-capacity tube; instead, the simpler system shown in Fig. 32 is usable.

Here, the sync signals are fed through the transformer T_1 and are applied to the two diodes VT_1 and VT_2 in such a way that the voltages applied to the tubes are equal and of opposite polarities. (Some manufacturers use triode tubes instead of diodes as VT_1 and VT_2; in such a case, the grid is tied to the plate to make a diode of the tube.) The circuit is arranged so that the plate of VT_1 is made positive at the same moment as the cathode of VT_2 is made negative, so both tubes conduct strongly when the sync pulses are applied. As a result, the condensers C_1 and C_2 are charged. They then place a bias on the system such that the plates of both VT_1 and VT_2 are negative with

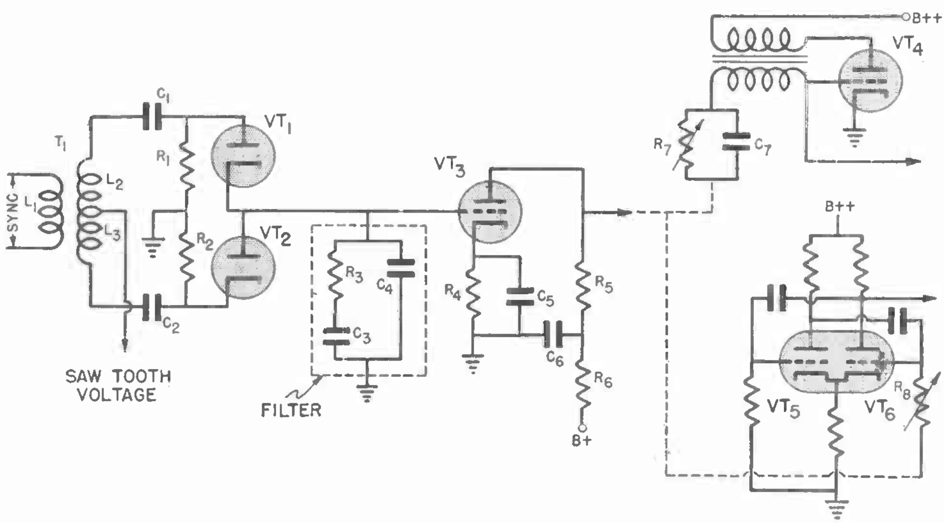

FIG. 32. A saw-tooth a.f.c. sync-locking network.

respect to their cathodes except when the pulses are applied.

A small saw-tooth voltage is applied to the center tap of the secondary of T_1. This saw-tooth voltage can be obtained from anywhere in the sweep circuit beyond the wave-shaping circuit; it is customary to use a portion of the sweep output voltage for this purpose.

The bias produced by the charges on C_1 and C_2 is just enough to prevent tubes VT_1 and VT_2 from conducting when only the saw-tooth voltage is applied to them. Thus, this voltage has no effect on the circuit except when the sync pulses are applied.

In fact, the saw-tooth voltage has no effect at all when the sweep system is operating properly, because the circuit is arranged so that the sync pulses occur just as the retrace of the saw-tooth crosses the zero axis—at the points marked X in Fig. 33. Hence, the saw-tooth voltage has no effect on the diodes even when they are conducting as long as the sweep oscillator is operating at the proper frequency.

Because of the symmetry of the circuit, the mid-point between the plate of VT_2 and the cathode of VT_1 will be at ground potential as long as the two tubes conduct equally. Therefore, no voltage will be applied to the filter R_3-C_3-C_4.

However, if the saw-tooth gets out of step with the sync pulses, the tubes will no longer conduct just as the retrace of the saw-tooth voltage goes through zero but will instead conduct when the retrace is above or below zero. If, for example, a sync pulse occurs when the retrace has not yet reached zero, the saw-tooth voltage and the sync pulse voltage will add together for VT_1, increasing the plate voltage on this tube and making it conduct more than usual. On the other hand, the saw-tooth voltage will subtract from the pulse voltage applied to VT_2, causing the plate current of this tube to decrease. As a result, the voltage at the mid-point between the plate of VT_2 and the cathode of VT_1 will rise above ground potential, thus causing a positive voltage (with respect to ground) to appear across the filter. This voltage will increase the bias on VT_3 in the positive direction,

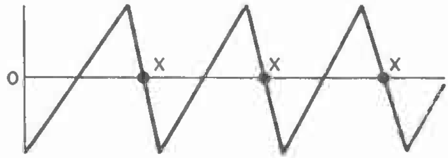

FIG. 33. The sync pulses occur at points X when the horizontal oscillator is in sync.

causing this tube to draw more plate current and hence produce a higher voltage drop across resistor R_5.

On the other hand, if a sync pulse occurs after the saw-tooth retrace has gone below zero, the voltage applied to VT_1 will be decreased and that applied to VT_2 will be increased. As a result, the voltage at the midpoint between the plate of VT_2 and the cathode of VT_1 will drop below ground potential, and a negative potential (with respect to ground) will be produced across the filter. This voltage, applied to the grid of VT_3, will cause a reduction in its plate current and so decrease the voltage across R_5.

The voltage across R_5 can be applied either to a blocking oscillator or to a multivibrator. The VT_4 circuit shown here is a typical blocking oscillator; that in which VT_5-VT_6 are used is a multivibrator. In either instance, the voltage across R_5 is applied in the proper grid circuit as a bias. When this voltage is fixed by the normal operation, the oscillators will both operate at the frequencies determined by the time constants of their grid circuits. On the other hand, when this average bias is changed, the oscillators will be forced to fire sooner or fire later, depending on whether the voltage is more positive or more negative. Thus, the oscillators can be speeded up or slowed down and maintained in step with the sync pulses.

Once again, an important action occurs in the filter. Condenser C_4 and the series combination R_3-C_3 tend to delay the application of the signal change to the amplifier VT_3. Irregular sync pulses and noise pulses cannot build up sufficient voltage across C_4 to cause any great change in the bias that is eventually applied to the sweep oscillators, so this system is also relatively unaffected by noise.

SIMPLIFIED SAW-TOOTH A.F.C.

Fig. 34 shows an even simpler a.f.c. system that may be used to control a blocking oscillator.

Here, tube VT_1 is a sync amplifier tube after the clipper. In the plate circuit of this tube, the signal path divides: part of the signal is fed directly from the plate to an integrating network from which the vertical control pulse is secured, and the rest is fed to the horizontal pulse circuit shown in Fig. 34. Notice that no differentiating network is used in this circuit to separate the horizontal pulses from the vertical pulses. Instead, the transformer primary circuit

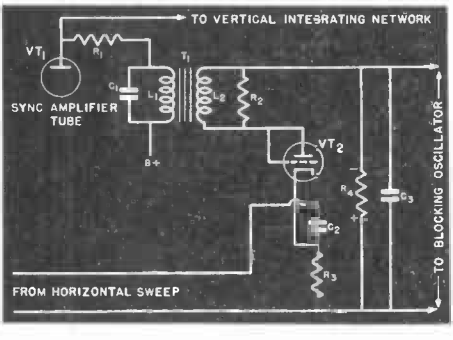

FIG. 34. Simplified saw-tooth a.f.c. system.

L_1-C_1 is tuned to resonate at the frequency of the horizontal sync pulses. It will therefore be forced into oscillation by the horizontal sync pulses and will produce a sine wave in step with each pulse.

This sine-wave voltage that is manufactured from the sync pulses (Fig. 35A) is applied through the transformer to the diode tube VT_2.

In addition, the saw-tooth output of the sweep circuit (Fig. 35E) is applied to the differentiating network C_2-R_3; the resulting pulses that are produced across R_3 are in the cathode circuit of VT_2.

Therefore, both the sine-wave sig-

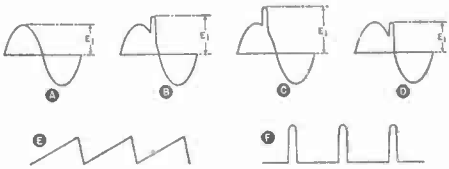

FIG. 35. Possible phase relationships in circuit shown in Fig. 34.

nal shown in Fig. 35A and the differentiated pulses shown in 35F are applied to this tube. The two will combine to produce the signal shown in Fig. 35B. If we choose the proper value for resistor R_4, which is in the grid circuit of the blocking oscillator, the average voltage produced across this resistance will be such that the circuit will stabilize around the desired operating point.

However, if the frequency of the sweep oscillator drifts in one direction, the pulses will move up on the sine wave as shown in Fig. 35C, thus increasing the voltage across R_4. This will increase the bias across R_4 in the negative direction, thereby slowing down the speed of the blocking oscillator so that the pulses can move down on the sine wave to the proper position.

On the other hand, should the blocking oscillator shift in the other direction, the pulse will move down too far on the sine wave as shown in Fig. 35D; this will reduce the drop across R_4 and allow the blocking oscillator to speed up.

The circuit is protected from noise pulses in two ways. Changes in amplitude of the sync pulses caused by noise have no effect, because the amplitude of the sine wave that is used in the control circuit is determined by the Q of the tuned circuit and not by the amplitude of the pulse fed into it. The effect of a variation in pulse width caused by noise is eliminated by C_3 in Fig. 34. Should the pulse width vary, the position of the sine wave would shift with respect to the position of the pulse obtained from the output of the sweep circuit. This would cause a sudden change in the voltage across R_4. However, condenser C_3 must be charged by the average voltage across R_4 before any change can be produced in the voltage applied to the grid of the blocking oscillator; any sudden change in the voltage across R_4 will be ignored, because the condenser cannot charge fast enough to follow very sudden changes. Therefore, only the average change in the voltage across R_4 will be passed on to the grid circuit of the sweep oscillator.

PULSE WIDTH SYSTEM

The next locking circuit we are going to describe is rather different from all the others in that it sets up a system in which the width of a pulse is used to control the blocking oscillator or multivibrator circuit.

The basic circuit for a typical arrangement of this kind is shown in Fig. 36. Here, tube VT_2 is the blocking oscillator. The transformer T_1 is an auto-transformer rather than the two-winding type, but otherwise the circuit is that of a conventional blocking oscillator. The grid condenser is C_9; the resistors R_9 and R_7 make up the grid resistance that determines the "hold" range of the circuit.

Condenser C_{10} and resistor R_{11} make up the charge-discharge circuit that is operated by this blocking oscillator. At the output, across C_{10}, there is the usual saw-tooth voltage, which is applied to the rest of the sweep chain through coupling condenser C_{11}. In addition, a portion of this saw-tooth voltage is taken off and brought back

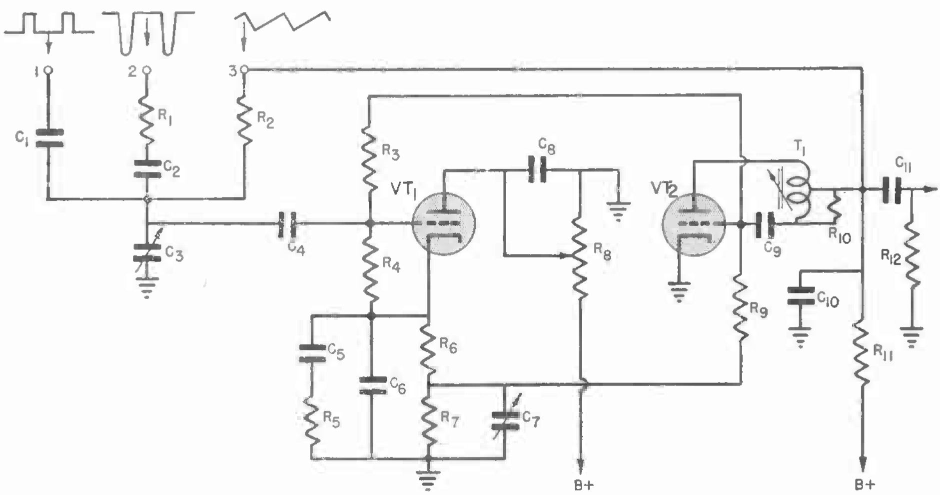

FIG. 36. Pulse-width horizontal sync-locking system.

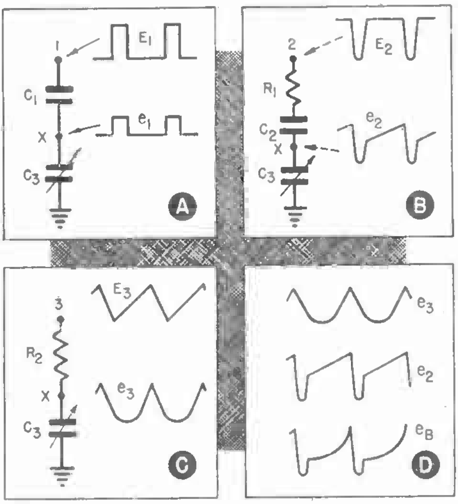

FIG. 37. Effects of shaping networks in Fig. 36.

to point 3, from where an integrated product of it is applied to the grid of the control tube VT_1. Three different pulses are applied through R-C networks to the grid of VT_1—in addition to the saw-tooth, sharp pulses are applied to point 2. It is important to note that these pulses which are obtained from across the yoke of the electromagnetic sweep system, are not square—they represent halves of sine waves. However, they are of high amplitude, because they are produced by the inductive kick that occurs when the deflection coil goes into oscillation during the sweep retrace.

Finally, the horizontal sync pulses from the clipper circuit are applied to point 1.

The networks through which these three different signals are applied to VT_1 have the effect of changing the shapes of the signals. Let's see what each does.

As shown in Fig. 37A, the network C_1-C_3 sets up a voltage divider for the sync pulses, so that sync pulses of rather small amplitude are developed across C_3 for application to the grid of VT_1. Thus, the voltage at point X as a result of the sync pulses is represented by the voltage e_1 in Fig. 37A.

The sine-wave pulses that are applied from the output circuit through path 2 are applied to what amounts to an integrating network made up of R_1, blocking condenser C_2, and the condenser C_3. The integration of these pulses produces the trapezoidal wave e_2 in Fig. 37B.

Finally, the saw-tooth wave applied through path 3 is integrated by R_2-C_3, with the result that the parabolic wave e_3 is produced.

These three signals combine into one before they are applied to VT_1, since all are developed across C_3. Fig. 37D shows the result of combining only e_2 and e_3. As you can see, the resultant signal e_B has a shape similar to the trapezoidal wave, but because of the parabolic wave, it comes up to a very sharp peak and then falls off very abruptly.

The phases of the various signals are arranged so that the midpoint of the sync pulse will be at the peak of the resultant signal e_B if the horizontal oscillator is operating at the proper frequency. Thus, the three signals will combine to form the signal shown in Fig. 38B when the sweep circuit is operating properly. Because of the extremely steep drop-off in e_B, approximately half the sync pulse (shown by broken lines) is cut off when the signals are combined.

The lines marked "cut off" in Fig. 38 show the grid voltage level below which tube VT_1 is cut off. As you can see, only the sync pulse portion of the combined signal is above cut-off; under normal conditions, which are shown by Fig. 38B, the part of the sync pulse that is above cut-off is only half as wide as the original sync pulse.

If the horizontal oscillator drops out of sync, the sync pulse may occur

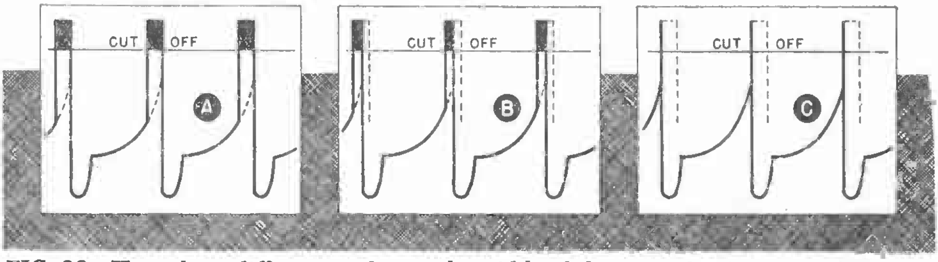

FIG. 38. How phase differences change the width of the control pulse in a pulse-width system.

before or after the right position with respect to the peak of signal e_B. Fig. 38A shows what happens when the pulse occurs early; as you can see, the width of the sync pulse above cut-off is increased. If the pulse occurs late, as Fig. 38C shows, the pulse width above cut-off is decreased.

The amount of time that tube VT_1 can conduct depends on how wide this pulse happens to be. The wider it is, the longer the tube conducts, and the more condenser C_7 in the cathode circuit is charged. The average voltage across this condenser is applied in the grid circuit of the blocking oscillator, so the blocking oscillator frequency is controlled as in the other arrangements we have studied earlier. If the blocking oscillator speeds up, the peak in e_B will occur before the sync pulse, so a narrower pulse will be fed to VT_1. This means that the drop across R_7 will become less, which is the same as making the grid of the blocking oscillator more negative (less positive); therefore, the oscillator will slow down. If it runs slow, on the other hand, the pulse width will increase, so the drop across R_7 will also increase. In effect, therefore, a positive bias will be applied to the grid of the blocking oscillator, which will then speed up.

As in the other control circuits we have studied, a filter system is used to make the system follow the pulse averages. The charging of C_7 and the filtering provided by C_6 and the C_5-R_5 network serve to prevent any sudden change.

The hold control of this circuit consists of the variable resistor R_8 in the plate circuit of the control tube VT_1. Varying R_8 changes the normal plate current of VT_1 through R_7 and thus sets the operating point of VT_2.

The range over which the hold control operates is determined by the setting of adjustable condenser C_3. Varying C_3 will set the amount by which the grid of VT_1 can be driven into the conducting region and will hence also change the range of the hold control. Some sets also use a variable condenser as C_7, an arrangement that offers an extra control over the range of the hold control. When more than one control of this kind is used, one of them (usually the variable resistor in the plate supply) is brought out to the front panel of the receiver to furnish a fine control for the range, and the others are used to give a coarse setting of the range.

Lesson Questions

Be sure to number your Answer Sheet 56RH-3.

Place your Student Number on every Answer Sheet.

***Send in your set of answers for this Lesson, immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. What is the difference between "clipping" and "segregating" the sync signals?

2. If a square-wave signal is fed into an R-C circuit having a short time constant, will the signal pulses across the resistor be: *square; saw-tooth; sharply peaked; parabolic?*

3. Why must the signal be in its d.c. form before it can be clipped?

4. To get a strong signal for clipping, is the signal usually taken from: 1, *the video detector;* 2, *the first video amplifier;* 3, *the output video stage?*

5. What advantage does a pentode clipper have over single-triode types?

6. If the clipper output is to be used to control the grid of a blocking oscillator with no intervening amplifier stage to be used, what phase must the output pulses have?

7. Why must the RC circuit used for segregating the vertical pulse have a long time constant?

8. Which edge of a horizontal sync pulse is used to produce synchronization?

9. In a simple trigger sync system that uses amplitude limiting in the sync amplifiers, which of the following will upset horizontal synchronization: 1, *noise increasing the amplitude of the sync pulse;* 2, *noise moving the lagging edge of a sync pulse;* 3, *noise moving the leading edge of a sync pulse?*

10. Why are horizontal sync locking circuits designed to operate on the average of the sync pulses?

Be sure to fill out a Lesson Label and send it along with your answers.

TO BE INDEPENDENT, PRACTICE ECONOMY

To become truly independent, the practice of *simple economy* is necessary. And *economy* requires neither superior courage nor great virtue. It requires only ordinary energy and consistent attention. Essentially, *economy* is the spirit of orderliness applied to the administration of your own *personal affairs*. It means management, regularity, prudence, and the avoidance of waste.

Economy also requires the power to resist present gratification of your wants, in order to secure future benefits. And even wild animals practice this *economy* when they store food for the winter!

Yes—the practice of *economy* is necessary unless and until you figure out some fool-proof way to make money faster than you can spend it! I'll admit that a few men have been able to do this—but until you can discover this golden secret, your best road to independence will be the day in and day out practice of *reasonable economy*.

J. E. Smith

P.A. TRANSMISSION SYSTEMS

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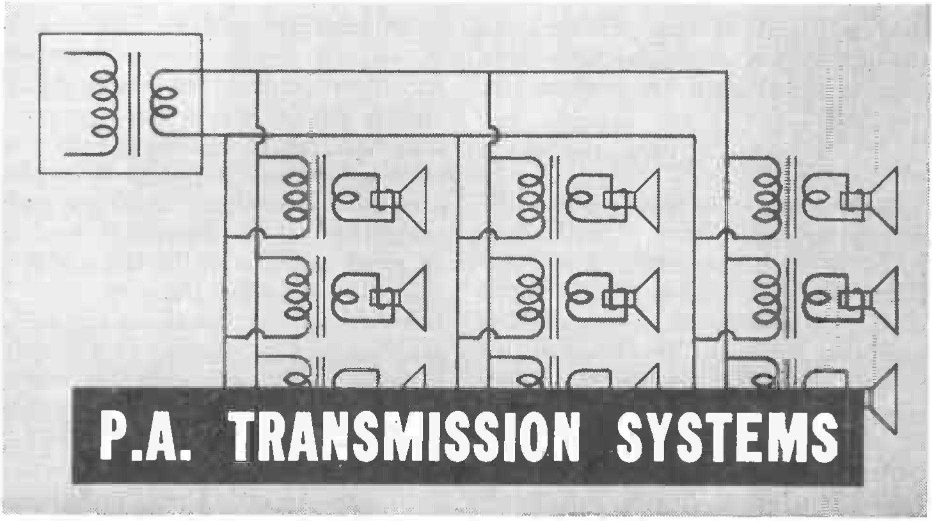


P.A. TRANSMISSION SYSTEMS

AMPLIFIERS, loudspeakers, microphones, and other components of public address systems may be purchased from their respective manufacturers, from local radio wholesalers, or from the mail-order supply houses that handle radio parts. It is possible to obtain a complete system as a "package" consisting of an amplifier together with suitable loudspeakers and a microphone. The portable units that are intended for temporary installations are almost always sold this way. These even come with pre-cut cables to connect the various components together.

There is no connection problem with such package units—all you need do is plug the cables into the proper outlets and place the components where you want them. If such a package unit is used in a permanent installation, you can conceal the cables and place the amplifier in an out-of-the-way location if you wish. In temporary installation work, you will probably mount the various components of the system in convenient places without making any great effort to conceal anything.

With such package units, there will be no problems of impedance matching nor of excessive line losses (provided you use the lines supplied). You can assume that the components of a particular assembly were chosen to operate properly together.

Of course, all sound installations aren't this simple. For most permanent and some temporary installations, you will have to assemble a sound system rather than use one that is offered as a unit.

One of the major problems you will meet in doing so is making the proper connections between the various components. You will have to match impedances to get maximum power transfer and normal frequency response, and you will also have to make sure that excessive power and frequency losses will not occur in the transmission lines used to connect the various components. This last is often a problem when a line must be run several hundred feet from an amplifier to a loudspeaker.

This Lesson is devoted to showing you how to connect the components of p.a. systems properly. We shall study all parts of this problem. As the first step in our studies, let's learn what kinds of lines are used in p.a. work.

AUDIO CABLES

Any set of conductors used to carry energy between pieces of equipment is called a transmission line. At power-line frequencies, parallel wires strung on insulators several inches apart can be used. However, such a line is not desirable for audio-frequency use, both because of difficulty in installation and because such an "open" line will pick up excessive amounts of hum, noise, and interference.

Such stray pickup is reduced by twisting the wires together so that they are separated only by their insulation. Close spacing and the twisting causes the stray pickup of one wire to be mostly cancelled by that of the other. Hence, such twisted wire—ordinary electric lamp cord, for example—is commonly used as an audio line where the power levels are high enough to make the losses unimportant and where the wire would not be subject to deterioration caused by weather or to wearing caused by excessive motion. Such lamp cord is readily obtainable: it is found everywhere that electrical supplies are handled, even in five-and-ten cent stores.

Radio supply houses carry a better wire for this purpose. A typical example is shown in Fig. 1A. This is a twisted pair of wires that is enclosed in a cotton loom that affords additional protection to the wire. It is possible to get wire like this with the loom specially treated to make it weather-proof. Such wire can be used outdoors.

Either of these two types is satisfactory for connecting loudspeakers to an amplifier, and one or the other is used for this purpose in most installations. These wires may be strung around the room in a temporary installation; in a permanent installation, they are frequently put in the walls, preferably in conduit. Outdoors, such cables are often enclosed in conduit or pipes and buried in the ground; this helps to protect the wire.

Incidentally, in installing any cable of this kind permanently, you will have to meet local electrical codes. Despite the fact that relatively low voltages and moderate power are be-

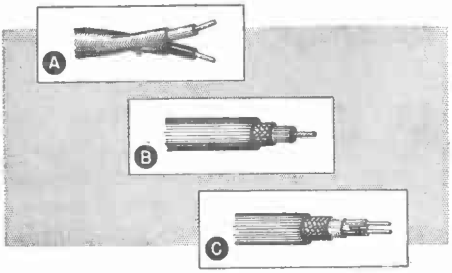


FIG. 1. The three most common kinds of audio lines: A, twisted-pair line; B, unbalanced coaxial line; C, balanced coaxial line.

ing handled, there is always a possibility that someone will make a mistake later on and get the wires crossed up with other electric wires. To prevent this from happening, some electrical codes may require special conduits or special marking of the wires. It may be best to have a registered electrician string the cable for you so that the electrical code requirements will be met; in fact, this is required in many communities.

Ordinary twisted-pair lines cannot be used as high-impedance microphone lines because they are too likely to pick up hum and noise. For this reason, some form of coaxial line is always used for a high-impedance cable. Such a line consists of a conductor surrounded by insulation that in turn is surrounded (coaxially) by a shield that acts as a second conductor. A typical example is shown in Fig. 1B. Because it is necessary that the cable be flexible so that the microphone can be moved about, the outer conductor consists of a number of fine wires braided together rather than a piece of copper tubing. Although the braid shield is not quite as effective a shield as solid tubing would be, it is satisfactory for all normal p.a. uses as long as it is not used near very strong fields.

For balanced microphone lines, two wires are enclosed in a coaxial shield as shown in Fig. 1C. The shield here acts as a third conductor, carrying the ground lead from the microphone transformer to the amplifier.

Shielded wire that has the shield on the outside can be obtained, but for better appearance and for ease in handling, microphone cable commonly has a rubber covering or cotton braid insulation over the shield as shown in the examples in Fig. 1.

Now that you know what kinds of lines are used for microphone and loudspeaker cables, let's learn what important characteristics of these lines must be considered in making an installation.

High- and Low-Impedance Lines

Regardless of the type of transmission line, it will have the following characteristics:

1. Resistance. No conductor is perfect; all have some resistance.
2. Capacity. Whenever two conductors are separated by an insulator, there is a capacity between them.
3. Leakage. Leakage is a measure of the quality of the insulation. Very good insulation has very little leakage; therefore, the current *between* the wires is very small. If the insulation is poor, however, it is possible for there to be an appreciable current between the wires.
4. Inductance. A wire also has a certain amount of inductance. This inductance is relatively small, however, so it is not appreciable at audio frequencies.

Inductance and leakage, then, can be ignored in considering an audio line if we assume that wire of good quality will be used. However, the resistance and the capacity of the line are very important.

The resistance of a transmission line depends on the length of the wire and on the wire size, increasing if the wire is made longer or if its diameter is reduced. (A wire table later in this Lesson will show you exactly how the resistance varies with each of these factors.)

The capacity between wires varies with the wire size, the length, and the spacing between them. The capacity increases if the wires are brought closer together or if the diameter or length is increased.

The resistance of transmission lines is what determines how much power loss there will be, and the capacity determines the frequency discrimination. The amount of this frequency discrimination and the amount of power loss depend upon the conditions under which the line is to be used. However, since both the resistance and the capacity of a line increase when it is made longer, it is obvious that a line should be kept as short as is practical.

LINE IMPEDANCES

When we speak of "low" impedance or "high" impedance audio lines for p.a. work, we are not referring to the resistance or capacity that is possessed by the line. If the line length is appreciable (a quarter-wavelength or more) with respect to the wavelength of the signal being handled, then the line does have a characteristic impedance of its own that is called its "surge" impedance. Telephone lines have such an impedance, and the impedance must be matched at each end of these lines for proper signal transfer. However, p.a. lines are at most only a few thousand feet in length, which is short compared to the wavelengths of audio signals. Hence, when we call a line a "low" or "high" impedance, or call it a "500-ohm" line, we are referring solely to the impedances of the terminating devices—the source and load that the line connects, and not to the actual line impedance.

As we shall show, what may be a low-impedance termination for one service may be high for another, so we qualify the impedance term by referring either to "microphone" lines or to "transmission" lines. The latter term is applied to lines carrying power, such as those that connect amplifiers to loudspeakers.

HIGH-IMPEDANCE LINES FOR MICROPHONES

Microphone lines are considered to be high impedance if they are connected between devices having impedance values above 10,000 ohms. Crystal microphones, for example, may well have impedances of 20,000 ohms or more. A crystal microphone having such an impedance can be connected directly to a tube grid circuit through a connecting line.

The crystal microphone is the only kind that has a high impedance of itself, but a dynamic or other low-impedance microphone is often made to have a high-impedance output by connecting it to a suitable matching transformer, which is frequently built into the case of the microphone. A short line can be used to connect such a microphone to the grid circuit of the preamplifier tube.

When a transmission line is used between two points of high impedance, the power loss in line resistance is negligible. If the terminal impedances are, say, around 10,000 ohms, a line having a resistance of 10 ohms or so will not be able to affect the current distribution appreciably. However, although power loss is no problem with these lines, frequency response and pickup of interference are.

Interference. Stray noise and hum fields are troublesome whenever the impedance to ground is high, because even a small field can develop an appreciable voltage across a high impedance. The impedance between the control grid of a tube and ground is usually 50,000 ohms or more, so the grid is particularly likely to pick up interference. Furthermore, the signal level at the grid of the first preamplifier tube is always low, so even a relatively low hum or noise voltage can be appreciable with respect to the desired signal. This difficulty can be minimized by keeping the impedance to ground low, by keeping physically small the amount of the circuit that is at a high impedance, or by shielding all portions of the circuits that are at a high impedance to ground. This latter method is used to minimize pickup in high-impedance microphone cables, which are always shielded coaxial lines. This shielding is always carried right inside the amplifier all the way to the grid of the tube, and sometimes even encloses the input resistor.

Even though it is shielded, however, a high-impedance line always has a certain amount of pickup per unit of its length. It is therefore desirable to keep the line just as short as possible to minimize this kind of interference.

Frequency Response. The shunting capacity of a microphone line always has an effect on the frequency response. The exact nature of the effect depends on the characteristics of the microphone impedance.

The average single-wire coaxial microphone cable has a capacity of 25 to as much as 75 mmfd. per foot. (It is possible to get lower capacities by increasing the spacing between the center wire and the braided shielding through the use of fillers made of threads or ropes. This increases both the bulk and the cost of the cable greatly, however; as a result, such low-capacity cable is found only in certain high-fidelity installations.) If we were to use a 20-foot cable that had a medium capacity value of 50 mmfd. per foot, the total capacity would be 20 × 50, or 1000 mmfd. (.001 mfd.), which is very appreciable.

Fig. 2 shows how a high-impedance microphone should be connected to the grid of a tube. The grid circuit is completed by resistor R_1, which is chosen to match the impedance Z_S of the microphone. Since the grid of a tube is a voltage-operated device, we might expect R_1 to be several times the microphone impedance so that most of the voltage generated by the microphone would be dropped across R_1. However, it is desirable to load the microphone to minimize peaks in its response. For this reason, it is common practice to make the load into which the microphone works equal to the microphone impedance, even though this arrangement means that only half the microphone voltage is applied to the amplifier grid.

The capacity of the microphone cable, represented as C_C in Fig. 2, is in parallel with R_1. Its reactance, of course, varies with frequency. At low frequencies, the reactance is so high that the capacity is a negligible shunt. It becomes an appreciable factor at higher frequencies, however, and has an effect on the frequency response.

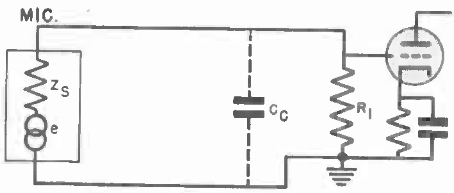


FIG. 2. How to connect a high-impedance microphone to the grid of the input tube of an amplifier.

As an example, let's assume that Z_S and R_1 are 100,000 ohms each, and that we are using a 20-ft. cable having a total capacity of 1000 mmfd. The reactance of the capacity equals the resistance of R_1 at about 1600 cycles. At this frequency, the net impedance of C_C and R_1 in parallel is half that of R_1 alone, so the voltage across R_1 drops to two-thirds its original value. At a frequency twice this, 3200 cycles, the condenser reactance has dropped to 50,000 ohms, so the net impedance is one-third its former value; the voltage across R_1 is now one-half what it was at the low frequencies, where the condenser reactance was too high to matter. Obviously, therefore, the shunting capacity has considerable effect on the frequency response when the microphone impedance is essentially resistive.

If we reduce the values of R_1 and Z_S to, say, 50,000 ohms each, the effects we have just described will occur at a higher frequency: the voltage is reduced to two-thirds at 3200 cycles and to one-half at 6400 cycles. Obviously, therefore, for a fixed cable capacity, the lower we can make the source and load impedances, the less shunting of high frequencies there will be.

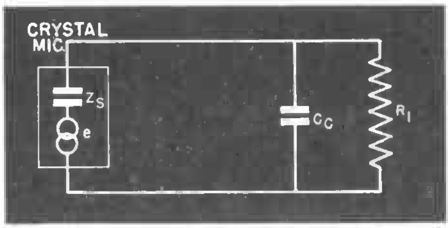


FIG. 3. If the line is properly chosen, the capacity of a crystal microphone and that of the line can be made to balance, producing a relatively flat frequency response.

Of course, we can't change the microphone impedance at will, so our choice of microphone fixes R_1. We must choose a microphone having a reasonably low impedance if high fidelity is wanted.

The effect of the capacity of the cable is made worse if the microphone has an inductive component in its impedance, as dynamic types that use matching transformers to give a high impedance often have. The inductance tends to make the microphone impedance rise with frequency, which produces an even greater voltage division with the line capacity.

Crystal Microphone Cable. Fortunately, the most common high-impedance microphone—the crystal type —has an impedance that is essentially capacitive, as shown in Fig. 3. This comes about because the crystal acts as a dielectric between the two terminal plates of the crystal element. Since it is capacitive, the impedance of the microphone goes down as the frequency increases. If the microphone cable is properly chosen, the internal impedance of the microphone can be made to act with the line capacity as a voltage divider of such a nature that the output is practically constant over the range that the microphone is intended to cover. That is, the impedance Z_S goes down with frequency at the same rate as the reactance of C_C does, so the output remains approximately the same even though the impedances decrease with frequency. Notice that this effect occurs only if the microphone cable has the proper characteristics. Therefore, you should neither shorten nor lengthen the cable that is supplied with a crystal microphone; if you do, the output will not vary uniformly with frequency.

In this case, the value of R_1 really sets the low-frequency response rather than the high-frequency response. As the frequency decreases, the impedance Z_S increases. When it gets well above the value of R_1, an increasing amount of the signal is dropped in the internal impedance of the microphone. In this particular case, increasing the value of R_1 extends the low-frequency response—exactly the opposite of what happens in the circuit shown in Fig. 2. However, the necessity of keeping down hum and noise pickup places a definite limit on the value of R_1.

You can see that a line operated with its terminals at a high impedance must be specially chosen. Its length is critical when it is used with a crystal microphone, and it must be as short as possible when it is used with any other form of high-impedance microphone if reasonable frequency response is wanted. In general, therefore, high-impedance microphone cables are around 10 to 15 feet long; even the longest are no more than 25 feet in length. High-impedance microphones must therefore be placed close to the amplifier.

LOW-IMPEDANCE LINES FOR MICROPHONES

Whenever it is desired to locate a microphone at a distance greater than the allowable length of high-impedance microphone lines, it is necessary to use a line of lower impedance. As a matter of fact, low-impedance lines are generally used even for short distances when low-impedance microphones are used.

Terminating a line with lower impedance cuts down on the noise and hum pickup because the lower impedance to ground decreases the amount of voltage that can be induced by a fixed field. Another advantage of the low impedance is that, as we indicated in the discussion of high-impedance lines, a reduction in the terminating impedance decreases the effect of the capacity of the line on the frequency response. For example, you learned that the 20-foot cable began to be noticeably effective at 1600 cycles when the terminating impedance value was 100,000 ohms. This changes to 3200 cycles when the impedance value is made 50,000 ohms. If we can get the terminating impedances down to 10,000 ohms, we can go out to 16,000 cycles before the capacity of a 20-foot cable will have much effect on the frequency response.

Reducing the terminating impedances also permits the use of longer lines. If we increase the line length to 200 feet instead of 20 feet, the total capacity now becomes .01 mfd. To get out to 16,000 cycles, the terminating line impedance must now be 1000 ohms or less. Because it is sometimes desirable to run microphone lines for 200 feet or more, the industry has standardized the so-called low-impedance microphone terminations at 500 ohms, although a few manufacturers use 200 ohms.

The connections for such a line are shown in Fig. 4. If the microphone is a high-impedance type, transformer T_1 steps down its impedance to 500 ohms. If the microphone is low impedance, transformer T_1 steps up its impedance to 500 ohms. At the amplifier, transformer T_2 matches 500 ohms to the value of R_1, which is usually between 50,000 and 250,000 ohms. (This resistor is used because the transformer would be working into an "open" circuit of no definite impedance value if the resistor were not present. The use of the resistor gives a definite load for the transformer and therefore permits the turns ratio of the transformer to be fixed.) Transformer T_2 is usually located as close as pos-

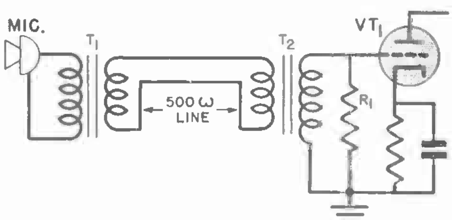


FIG. 4. How a low-impedance line is connected to a microphone and an amplifier.

sible to the tube VT_1 so that the lead from the transformer to the tube grid can be as short as possible.

As we have mentioned, the line is called a 500-ohm line purely because it is used between transformer terminations that have this impedance value. The actual line resistance remains that determined by the length and size of the wire, and the capacity is still determined by the size of wire, the spacing between wires, and the length of the line. Exactly the same kind of cable can be used as a high-impedance line in one case, and as a low-impedance line in another; it just depends on the terminating impedances.

A low-impedance line does not have to be a coaxial cable. The impedance is so low that hum and noise pickup is not usually a problem. However, if conditions are such that a.c. power lines must be near the microphone cable, it may be best to use a coaxial cable for a 500-ohm line.

As we said earlier, 200 ohms can be used as a terminating value if desired. It makes little difference whether a 500-ohm or 200-ohm line is used in most cases; the choice depends mostly on the transformers available for matching.

PREAMPLIFIER LINES

If a microphone must be located a long distance from the amplifier, the very weak microphone signal may be seriously attenuated by losses in the line and the transformers, and may be interfered with by even small amounts of hum and noise interference. In such cases, a preamplifier is used at the microphone location, then the amplified signal is sent down a line to the regular amplifier.

The preamplifier is essentially just a one- or two-stage amplifier, much like the first stage of the regular p.a. amplifier. The signal from the microphone is fed to this amplifier through either a high-impedance or a low-impedance line, depending upon the type of microphone; generally a very short microphone line is used. The output of the preamplifier is fed through a matching transformer or through a cathode-coupling connection to a 500-ohm line that runs from the preamplifier to the main amplifier. At the main amplifier, a transformer matches the line to the grid resistor of the input tube.

LOW-IMPEDANCE LINES FOR LOUDSPEAKERS

At the other end of our p.a. system, we are faced with the problem of connecting the loudspeaker to the amplifier. Here, we are working *from* plate circuits, rather than *into* grid circuits. Also, we are dealing with low-impedance loudspeaker voice coils. In fact, the impedances with which we deal are so low that a loudspeaker line is not considered to be low-impedance unless it is below 50 ohms. In most instances, such lines terminate in values approximating voice coil impedances, ranging from 2 ohms to 16 ohms.

Obviously, since the signal power levels are high, we needn't worry

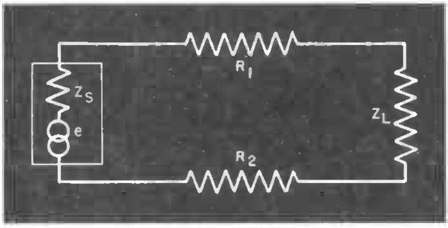


FIG. 5. The resistance of the wire in a low-impedance loudspeaker line acts as a voltage divider with the load impedance.

about hum and noise pickup on a low-impedance loudspeaker line. A twisted-pair line appropriately protected from weather and from mechanical damage is therefore entirely satisfactory. Also, since the terminating impedances on such a low-impedance line (under 50 ohms) are quite low, the capacity across the line will not prove troublesome. The resistance of the line itself is important, however.

The line resistance is distributed in both sides of the line, one half in each, as indicated by R_1 and R_2 in Fig. 5. (Although we ordinarily think of copper wire as having practically no resistance, actually long lengths of wire have appreciable resistance.) These resistances act as voltage dividers with the voice-coil impedance Z_L; if they are relatively high in comparison with Z_L, there will be a considerable amount of power lost in the line.

B & S GAUGE	D. C. RESISTANCE IN OHM
10	0.0020
12	0.0032
14	0.0051
16	0.0080
18	0.0128
19	0.0161
20	0.0204
21	0.0256
22	0.0330
23	0.0407
24	0.0513
26	0.0816

FIG. 6. This table shows the resistance per loop foot of various gauges of wire.

For convenience in use for p.a. installations, tables like Fig. 6 give the resistance "per loop foot for various sizes of wire." A loop foot actually represents two feet of wire, since it is the amount of wire needed to connect an amplifier to a loudspeaker when the two are a foot apart. You can find the total resistance of a loudspeaker cable with the aid of such a table just by multiplying the resistance per loop foot by the number of feet of cable used between the amplifier and loudspeaker locations.

As an example, let's suppose you are using No. 18 wire, which is a common lamp cord size. Its resistance (Fig. 6) is .0128 ohm per loop foot. A 100-foot run of this wire would therefore have a resistance of 1.28 ohms. If we tried to run a wire of this size and length from an output transformer to a 4-ohm loudspeaker voice coil, we would find that we would have appreciable line loss because the line resistance would be high with respect to the load impedance.

In general, engineers consider a line loss of 15% in the 400-to-1000-cycle range to be reasonable. Tables like that in Fig. 7 give the maximum length of line of any one size that can be used for various low-impedance values, assuming a maximum loss of 15%. In our example, the 100-foot run of No. 18 wire is too long for a 4-ohm load; if we were using this load value, we would have to restrict ourselves to 50 feet of No. 18 wire to keep the line loss at 15% or less.

Of course, using a larger size wire reduces the resistance and permits a longer run for the same load impedance, as you will observe from Fig. 7. However, large wire sizes cost considerably more money. Furthermore, if the load consists of a group of loudspeakers, its net impedance will be so low that the permissible length of the line will be severely limited. Hence, you ordinarily will not find low-impedance loudspeaker lines that are longer than about 200 feet and seldom one that is over 50 feet.

WIRE SIZE (B&S)	LOAD IMPEDANCE 4 OHMS	8 OHMS	16 OHMS
14	125′	250′	450′
16	75′	150′	300′
18	50′	100′	200′
20	25′	50′	100′

FIG. 7. Maximum loop lengths that can be used with various load impedances to keep line loss no more than 15% for audio frequencies below 1000 cycles.

WIRE SIZE (B&S)	LOAD IMPEDANCE 100 OHMS	250 OHMS	500 OHMS
14	1000′	2500′	5000′
16	750′	1500′	3000′
18	400′	1000′	2000′
20	250′	750′	1500′

FIG. 8. Maximum loop lengths for high-impedance loudspeaker lines if 5% power loss at the middle frequencies is allowed.

HIGH-IMPEDANCE LINES FOR LOUDSPEAKERS

The problem of power loss on the transmission line can easily be solved by operating the line at a high impedance. This we can do by using transformers at each end of the line, one to match the source to the line and the other to match the line to the load. For power transfer to loudspeakers, terminating line impedance values ranging between 100 and 600 ohms are called high impedances. Notice that these correspond to what we call low impedances for microphone lines.

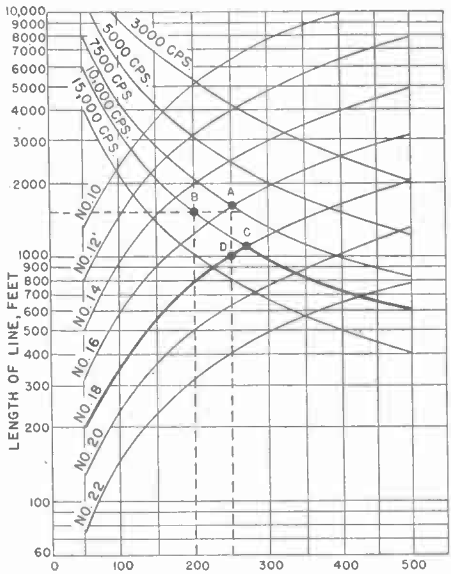
The line loss is negligible when the termination is 500 ohms. Effectively, of course, going to a higher-impedance termination means that, for the same power, we have a higher voltage and lower current. The reduced current causes less drop to occur in the resistance of the line.

Fig. 8 gives line lengths that provide 5% power loss at the middle frequencies. Compare these with Fig. 7. Incidentally, 5% losses are used for these lines rather than the 15% value used for low-impedance lines because the impedance-matching transformers have some loss. The total loss including line and transformer loss will be kept to about 15% if the line loss is kept down to 5%.

Obviously, we can run much longer lines if we terminate them in high impedances. Also, we can use much smaller wire, thus saving something on the cost of the line; this saving is often worth while if a long line is used. Although, of course, we must use transformers at each end of such a line, such transformers may be desirable anyway to give the proper impedance matching and power transfer, as we shall show later.

Although going to a high-impedance line does solve the loss problem, it reintroduces the problem of the shunting capacity. The average capacity of a twisted-pair electric cord is about 50 mmfd. per foot, so the line length must be kept down if the high-frequency response is not to be seriously reduced.

Line Lengths. Fig. 9 shows a chart prepared by one loudspeaker manufacturer that permits you to determine the length of line that can be used for a particular frequency response and a fixed impedance, or permits you to determine the impedance that is neces-



Courtesy Jensen Mfg. Co.

FIG. 9. Transmission line design chart prepared by Jensen Radio Mfg. Co. It is based on a 5% power loss in line and a 3-db loss at upper limiting frequency due to a line capacity of 50 mmfd. per foot across a typical moving-coil loudspeaker load.

sary at the end of the line when a certain length must be used.

As an example, let's suppose that the line is to be 1500 feet long. Also, let's suppose that the response is to go out to 7500 cycles before the power drops to half its normal value (3-db loss). Following the dotted line (at 1500 feet) from the left scale over to the 7500-cycle line, we find that we strike it near point A. Reading downward along the dotted line to the bottom, we find that the line impedance must be 250 ohms for this length and frequency response. The wire size necessary for minimum line loss and for the expected capacity value is the next larger above the point of intersection with the frequency line; in this case, it is No. 16 wire.

If we have a fixed impedance, we can determine the line length for a particular frequency response. For example, let's say that 200 ohms is our impedance value. Reading upward until we strike, let us say, the 10,000-cycle curve at point B, we find that we can again use a 1500-foot line. Notice that changing the impedance from 250 ohms to 200 ohms allows us to go from a 7500-cycle to a 10,000-cycle response for the same line length. If we go the other way—toward a higher line impedance — the fidelity will fall off if we must have a 1500-foot line length. For example, at 500 ohms, the response is something under 5000 cycles for a 1500-foot line.

This same chart can be used to determine the maximum line length for a particular size of wire and a particular frequency response. For example, let's suppose we want to use No. 18 wire. If the frequency response is to be within 3 db to 10,000 cycles, follow the No. 18 wire-size line to where it crosses the 10,000-cycle line. This is at point C. Reading now to the line length scale, you will find that we can use a line length of about 1050 feet, and reading downwards you will find that the impedance should be about 270 ohms. If we used the more practical impedance value of 250 ohms, which crosses the No. 18 wire size at D, we could use a line of 1000 feet of No. 18 wire and have a frequency response that would be somewhat less than 3 db down at 10,000 cycles.

Of course, the response will always be improved if any length less than these maximums is used. For example, returning again to our 250-ohm impedance value, point A shows a length of about 1500 feet and a frequency response out to 7500 cycles. Point D at 1000 feet and the same impedance gives a frequency response flat out beyond 10,000 cycles. If the length is only 800 feet, the frequency response goes out to 15,000 cycles.

To sum up: we see that if we terminate power transmission lines with high impedances, the line losses will in general be negligible, but the frequency response may suffer. On the other hand, the frequency response is good if we use lower impedances as line terminations, but we run into line loss difficulties. Therefore, it is the usual practice to choose some compromise impedance value that gives the desired frequency response without excessive line loss at the line length that is necessary.

Now that you have learned something of the basic characteristics of the transmission lines used, let's turn to the problem of impedance matching.

Impedance Matching

From your earlier Lessons, you will recall that it is necessary to match impedances whenever maximum power transfer is desired.

In public address work, the microphone does not, strictly speaking, require such impedance matching. Since the microphone eventually feeds into the grid of a tube, which is a voltage-operated device, we would ordinarily want the load impedance to be many times higher than the microphone impedance for maximum voltage transfer. If the microphone is operated this way, however, there will be peaks and humps in its frequency response. It is best to load the microphone to smooth out these irregularities. As a compromise between the two opposing possibilities, it is common practice to terminate the microphone line with a resistor having a resistance equal to the impedance of the microphone. Hence, if the microphone is a high-impedance type, the load into which it operates will have the same impedance as itself. If it is a low-impedance type, impedance-matching transformers will be used to match the microphone to the line and the line to the grid resistor, or a single transformer will be used to match the microphone to the grid resistor. (In the latter two cases, the grid resistor is fixed by practical transformer design and by the need to avoid hum pickup at some value between 50,000 ohms and 250,000 ohms.)

At the other end of the system, we are interested in making an efficient transfer of power from the plate circuit of the power output stage to the loudspeakers. As you have learned elsewhere, we will get the maximum power transfer whenever the load impedance equals the source impedance. However, it so happens that because of the characteristic of vacuum tubes, the maximum *undistorted* power output is not obtained at exactly the same point as the maximum total power output. As a matter of fact, for triode tubes, the load should be twice the plate impedance for maximum undistorted power output. Fortunately, the power output secured with a load of this sort is only slightly less than that obtained when the impedances are properly matched.

In the case of pentode and beam power tubes, the impedance that gives maximum undistorted power is about 1/7 to 1/9 the plate impedance of the tube. Although these tubes give considerably less power output when they are operated with such loads than they would give if their loads were equal to their impedances, the distortion is so severe if they are operated in the latter manner that the power sacrifice is considered worth while. The load values chosen still give a reasonably high output.

It is safe to assume that the manufacturer of an amplifier gives load impedance values in terms of the maximum undistorted power output. In other words, when you must match a particular grouping of loudspeakers to an amplifier, the value specified by the amplifier manufacturer is the value you should match for maximum undistorted power output.

Let's learn something about how to match impedances.

OUTPUT TRANSFORMERS

Two kinds of output transformers are in common use in amplifiers. Each, of course, has a primary that is properly designed for the output tubes of the amplifier in which it is used. One kind is designed to match the amplifier output stage to a particular loudspeaker or group of loudspeakers, and therefore has a fixed secondary impedance. If for some reason the loudspeakers chosen by the manufacturer are not to be used, others having the same voice-coil impedances may be substituted.

The second kind of output transformer is essentially a universal type in that its secondary has a number of taps that can be used to match to any common loudspeaker or group of loudspeakers. It is not unusual to find secondaries that are designed to match impedance values of 4, 8, 15 (or 16), and perhaps 30 ohms, and in addition have a 500-ohm and perhaps a 250-ohm tap for matching transmission lines.

Another type of output transformer that is occasionally used is primarily designed to match the amplifier to a line. A transformer of this type usually has taps at about 67, 125, 250, and 500 ohms.

Although the output transformer on the average p.a. amplifier does contain a number of taps, it is quite possible that the exact tap needed will not be available. For highest possible fidelity, the source and load impedances should be matched within 10%, but mismatches of up to 25% may be permissible in practice, depending upon the fidelity demanded. If a wide mismatch must occur, it is always better to connect the loudspeaker to the impedance tap next lower than the load impedance to minimize loss of power and distortion. Thus, if the combined loudspeaker load figures out to be, say, 6 ohms, you should use a 4-ohm tap rather than an 8-ohm tap.

Line Transformers. In addition to output transformers, there are line-to-loudspeaker matching transformers. These are designed to match the loudspeaker voice coil to whatever value is needed to terminate the line properly.

Incidentally, when we speak of the impedances of a transformer, we refer to the values the transformer is designed to match—not to the actual reactances of the transformer windings. The reactance of the primary winding (when there is no secondary load) should be about ten times the source impedance if good low-frequency response is to be obtained. Then, its turns ratio should be chosen so that the secondary load will appear as the desired "reflected" value in the primary. For example, if a transformer is supposed to cause a 4-ohm secondary load to appear as a 3600-ohm reflected impedance across the primary, its turns ratio should be 30.* The actual impedance of the primary winding depends on the plate resistance of the tube to which it is to be connected. If it is to be used with a triode tube having a plate resistance of about 2000 ohms, the primary winding should have a reactance of 20,000 ohms (or more) at, say, 400 cycles.

A 30-to-1 transformer will also cause an 8-ohm secondary load to reflect as 7200 ohms; a 2-ohm load as 1800 ohms; a 16-ohm load as 14,400 ohms; and so forth. In other words, a transformer having a 30-to-1 turns ratio will always produce a reflected primary impedance that is 900 times as great as the impedance that is connected to the secondary. This does not mean that the same transformer can be used for any application in which an impedance ratio of 900 to 1 is wanted, because there is also the requirement that the primary reactance must be at least 10 times as large as

* The turns ratio equals the square root of the impedance ratio. Hence:

$$N = \sqrt{\frac{Z_1}{Z_n}} = \sqrt{\frac{3600}{4}} = \sqrt{900} = 30$$

the source impedance to give good low-frequency response. Hence a transformer designed for "3600 ohms to 4 ohms" is different from one designed for 14,400 ohms to 16 ohms, although both have the same 30-to-1 ratio.

For this reason, transformers aren't listed by turns ratios; they are described by the impedances between which they are to work. Thus, one rated at "500 ohms to 8 ohms" is designed to match a source (or a line matched to such a source) of 500 ohms to a load of 8 ohms. However, it can be used to match 250 ohms to 4 ohms, because the source is lower in impedance than the value for which the primary was designed. It can also be used to match 1000 ohms to 16 ohms with some loss in low-frequency response. In other words, the secondary impedance can be varied over a range from one-half to twice the value for which the transformer was designed without causing too great a loss in power (under .5 db) and without affecting the frequency response too seriously in any but high-fidelity systems.

IMPEDANCE-MATCHING PADS

A resistor network can be used instead of transformers to make an impedance match. A disadvantage of using the resistor network is that it always introduces a loss; however, there are occasions when such a loss is permissible or even desirable.

We can, of course, connect the load and source directly together as shown in Fig. 10A. As long as the difference in their impedances is not too great, there won't be a large power loss. For example, in the case shown in Fig. 10A, the load impedance is one-half the source impedance. From the curve in Fig. 10B, we find that when the generator impedance (R_G) equals twice the load value (R_L) as in this case, we have a loss of only about .5 db. This isn't much power loss. As the difference between the source and load impedances becomes greater, however, the power loss also increases. For example, if we have a 1000-ohm source and a 250-ohm load, R_G equals $4R_L$, and, as the chart shows, we have a 2-db power loss, which represents a loss of about a third of the power.

With the impedance relationship shown in Fig. 10A, we are not losing much power, but the requirements may be such that the frequency response is very poor under this condition. If the poor response is caused by the fact that the source is not properly loaded, we can improve matters by adding a series resistor, as shown in Fig. 11A, having a value such that its resistance plus that of the load equals the source impedance. In this particular example, half the available power is lost in the series resistor, so

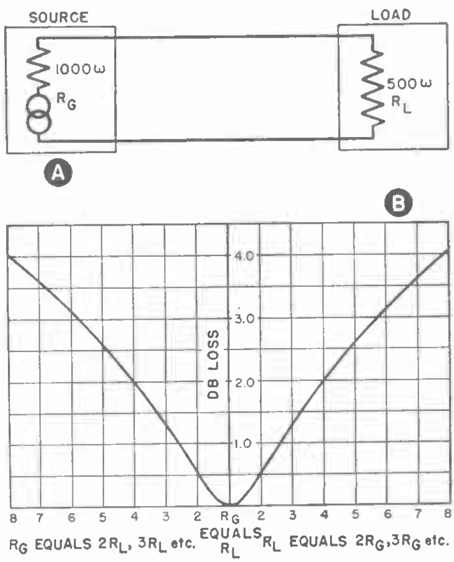


FIG. 10. The chart in part B of this figure shows how much power is lost for various relationships between the load impedance RL and the source impedance RG in a circuit like that in part A.

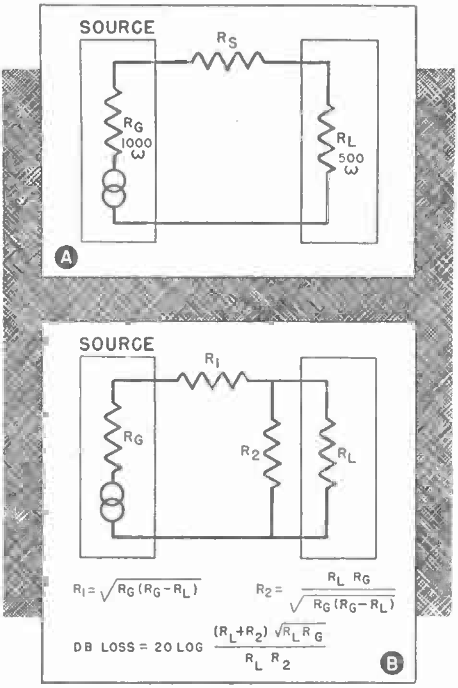


FIG. 11. Use of a series resistor (part A) and of an L pad (part B) to match a source and a load.

we have a 3-db power loss—much more than in the direct connection shown in Fig. 10A. If the ratio of source to load impedance were greater, the series resistor would have to be larger, and more power would be lost.

A bad feature of the arrangement shown in Fig. 11A is that the load R_L does not see its own impedance when looking back toward the source; in fact, the series resistor has made matters worse in this respect. (When we say that a source or a load "sees" an impedance when it "looks" in one direction or another, we are using an engineering expression that is often very convenient. The impedance "seen" is the effective impedance in the specified direction. For example, the source in Fig. 11A sees an impedance consisting of R_S and R_L in series when it looks toward the load; the load, on the other hand, sees an impedance consisting of R_S and R_G in series when it looks toward the source.)

If the load is entirely resistive, this won't matter at all. However, if the load is a reactive one such as a loudspeaker voice coil or a long transmission line, it is quite possible for the load characteristics to be such that this mismatch affects the circuit response. For example, if a loudspeaker voice coil does not see its own impedance, it will have much higher peaks and valleys in its over-all frequency response.

If it is necessary that both the source and the load see their respective impedance values (that is, if they must both be matched), an L-type pad like that shown in Fig. 11B may be used. The formulas given in Fig. 11B are correct if the source has a higher impedance than the load. If the load impedance is higher than that of the source, R_1 should be placed between R_2 and the load rather than as shown, and the terms R_G and R_L in both formulas should be interchanged throughout. (That is, where R_G appears, use R_L, and vice versa.) If we calculate R_1 and R_2, using the formulas given in Fig. 11B and the source and load impedances given in Fig. 11A, we find that they both come out to be about 706 ohms. In this case, R_G sees R_2 and R_L in parallel, with R_1 in series with the parallel group. The resistance of R_2 (706 ohms) in parallel with the 500-ohm load is about 294 ohms; this resistance in series with R_1 (706 ohms) makes a total resistance of 1000 ohms.

The load sees R_2 in parallel with a series combination of R_G and R_1 in series. The combined resistance of these three is 500 ohms, so the load is matched. However, there is now about an 8-db power loss.

Such a power loss always occurs when pads are used to match impedances. The amount of the loss depends upon the ratio of the source to the load impedance, but there is always at least some loss, and sometimes a very large one. Obviously, therefore, this form of impedance matching can be used only if the loss is permissable. If we cannot permit such a loss, we have to use transformers for impedance matching.

Microphone Connections

The input terminals on a p.a. amplifier provide for a certain number of microphones. The connections are usually all low-impedance or all high-impedance types, but occasionally a combination of these is provided. Obviously, if you use the kinds of microphones for which the amplifier input is designed, there is no problem. However, it may well be that an amplifier with exactly the input terminals wanted is not available, or you may be forced to use microphones with amplifiers that have the wrong kind of inputs. Let's see how to do so.

High to Low. First, let's suppose you have a high-impedance microphone that must be used with an amplifier having only low-impedance input terminals. There are two solutions to this problem.

One solution is to modify the amplifier. The fact that an amplifier has a low-impedance input means that it contains a built-in transformer that is designed to match a 500-ohm line to the grid of the first tube. It is possible to remove the transformer and bring the grid lead directly to the microphone jack. If high-impedance microphones are always to be used, such a modification may be worth while. However, if you believe there may be any need in the future for using a low-impedance microphone or for using a line to connect the microphone to the amplifier, such a change should not be made. It should not be made, either, if the additional length of wire connected to the grid of the first tube produces a marked increase in the hum level; unfortunately, you cannot find out whether this will happen without first making the modification.

If changing the amplifier seems inadvisable, the only solution is to use a transformer outside the amplifier that will match the high-impedance microphone to the 500-ohm input. In such cases, it is usually best to obtain a transformer that is designed for this particular microphone from the manufacturer of the microphone. The case of such a microphone often contains space for mounting a transformer right next to the microphone. If it is possible to install the transformer at this position without taking the microphone apart, this is the best place to put the transformer. However, if it is necessary to disassemble the microphone, it is better to send it back to the factory to have this work done, or to place the transformer at the end of the cable, right at the input of the amplifier. The latter method may or may not be desirable, depending on whether the transformer picks up too much hum and noise; again, only a trial will show.

Low to High. The opposite problem occurs when the microphone is a low-impedance (500-ohm) type and the only jacks provided on the amplifier are at high impedance. In this case, the only solution is to use a transformer at the amplifier input that is designed to match 500 ohms to the grid of the first tube. Although such a transformer might possibly be mounted outside the amplifier, the chances are that the high-impedance lead from the amplifier connecting jack to the transformer would be so long that it would pick up excessive amounts of hum and noise. The most satisfactory solution is to mount the transformer as close as possible to the grid of the preamplifier tube. This is rarely a difficult problem, because the manufacturer usually provides space for the mounting of such transformers inside the amplifier on the assumption that he may be requested to supply the amplifier with low-impedance inputs. You can probably obtain the necessary transformer for making the conversion as well as mounting instructions from the amplifier manufacturer.

Multiple Connections. You will sometimes find it desirable or necessary to operate more microphones than the input jacks on the amplifier provide for. Although only one or two microphones are needed for most installations, high-fidelity music pickup or pickup from a stage often requires the use of a number of microphones. Since the average p.a. amplifier has only two microphone inputs and even the most elaborate types have only three or four, it is quite possible for you to need more microphone input terminals than the amplifier offers.

There are two common answers to this problem. If the microphones are to be located at some distance from the amplifier, the use of a preamplifier may well be justified. This will permit a considerable increase in the number of microphones that can be used, since a preamplier commonly has four inputs, all of which feed through the preamplifier into only one input on the main amplifier.

Of course, if the microphones are to be used in a location near the main amplifier, the expense of a preamplifier may be unwarranted. In such cases, you can use commercially available resistor mixer boxes. Fig. 12 shows the schematic of one such box,

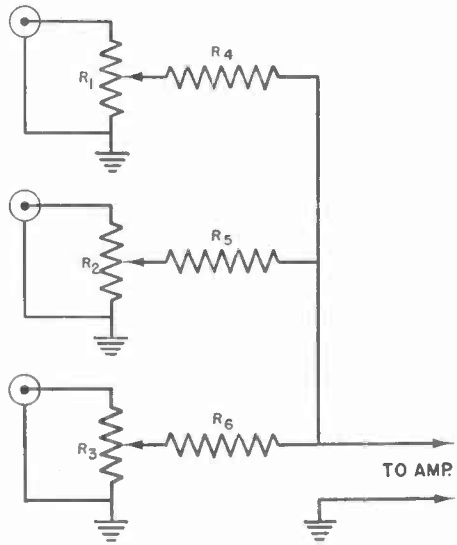


FIG. 12. The schematic of a resistor mixer box used to mix the outputs of 3 microphones.

designed for three microphones, each of which feeds into its own mixer-control potentiometer (R_1, R_2, or R_3). These potentiometers are decoupled from each other by the resistors R_4, R_5, and R_6. The output of the box goes to one microphone input on the amplifier. Thus, like a preamplifier, a box of this sort permits the outputs of several different microphones to be fed into a single input jack on the amplifier.

The mixer boxes available are commonly designed for high-impedance microphone connections. If low-impedance lines are involved, transformers will be necessary for each line, so a preamplifier will probably not be much more costly.

Practical Loudspeaker Connections

At the other end of the amplifier, we are faced with the problem of connecting one or more loudspeakers to the amplifier. In the average job, usually at most only three or four loudspeakers must be connected together. More elaborate installations may require the use of a great many more, however, particularly when several rooms are to be covered. An extreme example of this is a hotel or hospital installation in which separate loudspeakers are wanted in a number of small rooms; as many as 100 or more may have to be connected in such an installation.

You have already learned how to determine the power ratings and the number of the loudspeakers to be used in an installation. Now we are going to discuss the problems involved in connecting these loudspeakers to the amplifier. Before we do, however, we must learn something more about the voice-coil impedances of loudspeakers.

Although voice-coil impedances are always given as some definite number of ohms, this fact does not mean that the impedance is the same at all frequencies. As a matter of fact, the impedance of a voice coil varies widely over the audio-frequency spectrum, reaching high peaks at some frequencies and falling to low values at others. The voice-coil impedance rating of a loudspeaker is therefore either a nominal value that is representative of the over-all characteristics, or is the impedance at some particular reference frequency, such as 400 cycles or 1000 cycles. There is no general agreement among manufacturers on how voice-coil impedance should be rated.

The variations in the impedance of a voice coil are minimized when the coil is properly matched to an amplifier. For this reason, you can compute the load on an amplifier with reasonable accuracy by using the impedance value given by the manufacturer of the loudspeaker.

Very often you will find that you can choose any of several different voice-coil impedances for a given loudspeaker that is usually equipped with an 8-ohm voice coil may instead be obtained on request equipped with a 4-ohm or a 16-ohm coil. It is particularly helpful to be able to make such a choice when you have to connect together a group of loudspeakers and must arrive at some reasonable combined impedance that can be matched by available transformers.

The same 4, 8, and 16-ohm values are almost standard today for driver units, although some that have a higher impedance (about 45 ohms) are also offered. High-impedance voice coils are useful when several loudspeakers are to be connected in parallel, because the total net impedance of the parallel combination will be very low unless the voice-coil impedances are fairly high to begin with.

Now let's study several practical examples of the problems you will meet in connecting loudspeakers to amplifiers and learn how they can be solved.

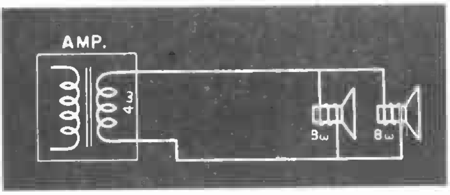


FIG. 13. Matching impedances of parallel voice coils.

LOW-IMPEDANCE CONNECTIONS

If the distance from the amplifier to the loudspeakers is small, it is possible, as you have learned, to run lines at the voice-coil impedance. In such a case, if we have more than one loudspeaker, we can connect the voice coils either in series or in parallel. If we connect them in parallel, and all have the same impedance, the net impedance will be equal to the impedance of any one divided by the number of loudspeakers. For example, the net impedance of the two 8-ohm voice coils in parallel in Fig. 13 is 4 ohms. We can use a low-impedance line to connect these two voice coils to the 4-ohm tap on the amplifier output transformer. In figuring the line loss, we must use the net impedance; in Fig. 13 it is 4 ohms, so the maximum line length is figured on this basis. If we used two 16-ohm loudspeakers, the net impedance would be 8 ohms; this would make it possible to use a longer line for the same wire size.

If two or more loudspeakers are connected in series, and all have the same impedance, the load will be the sum of the voice coil impedances. Fig. 14 shows an example.

It is also possible to connect the loudspeakers in series-parallel, as shown in Fig. 15. The impedance of this combination is the same as that of an individual voice coil as long as all the voice coils are the same and are connected as shown.

As long as the loudspeakers in each of these cases have the same voice-coil impedances, the power will divide equally between them. Thus, if two loudspeakers are connected either in series or in parallel and their voice-coil impedances are equal, each will receive half the power. If there are three loudspeakers, each gets one-third of the power; if there are four, each gets one-quarter of the power; and so on. Therefore, to make sure none of the loudspeakers in such a combination will be overloaded, all we need do is make sure that each has a power rating that is greater than its fractional portion of the amplifier output rating. If the amplifier is rated at 50 watts, for example, and we have two loudspeakers, each will get 25 watts of power and must be rated to handle it.

Unequal Impedances. If the loudspeaker voice-coil impedances are unequal, the power distribution will also be unequal. For example, when two unequal loudspeakers are connected in parallel, the resulting impedance is

$$Z_T = \frac{Z_1 Z_2}{Z_1 + Z_2}$$

As an example, if we have an 8-ohm speaker voice coil in parallel with a 16-ohm speaker, the result will be

$$\frac{8 \times 16}{8 + 16} = \frac{128}{24} = 5.33 \text{ ohms}$$

A tap rated at 5.33 ohms will probably not be found on the output trans-

FIG. 14. Matching impedances of series-connected voice coils.

former of an amplifier; 4 ohms is about the closest we can expect. Connecting this group to the 4-ohm tap will result in a certain loss of power. There will also be an unequal power distribution; the loudspeaker having the lower impedance will receive the greater amount of power when they are in parallel. In this case, with an 8-ohm and a 16-ohm loudspeaker, the 8-ohm loudspeaker will get twice the power of the 16-ohm loudspeaker. (The same voltage is across both, and the power in each is $P = E^2 \div Z$; hence, the lower the impedance, the higher the power.) You should keep this fact in mind if you are connecting loudspeakers of unequal impedance in parallel, because otherwise you may accidentally overload one of the loudspeakers. If a 50-watt amplifier were connected to the 8-ohm and 16-ohm combination we just described, 33⅓ watts would be applied to the 8-ohm loudspeaker and 16⅔ watts to the 16-ohm one. The 33⅓ watts would be a considerable overload if both loudspeakers were rated at only 25 watts, which is the maximum rating for all but the most powerful loudspeakers.

If these two loudspeakers were connected in series, the net impedance would be the sum of the two impedance values, or 8 + 16 = 24 ohms. In a series connection, the loudspeaker with the higher impedance will get the more power: in our example, the 16-ohm loudspeaker would get twice the power applied to the 8-ohm loudspeaker.

You can see that it is desirable to have voice coils of equal impedances when low-impedance lines are used, unless you want to apply more power to some loudspeakers than to others. When a high-impedance line is used, the loudspeakers are matched to the line with transformers; in this case, it is not necessary to use loudspeakers having equal voice-coil impedances to secure equal power distribution, nor does the use of equal impedances mean that the power will necessarily be equally divided. Let's take up high-impedance lines now.

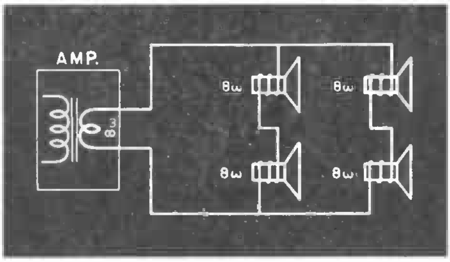


FIG. 15. Matching impedances of voice coils connected in series-parallel.

HIGH-IMPEDANCE LINES FOR LOUDSPEAKERS

One example of the use of high-impedance lines to match loudspeakers to an amplifier is shown in Fig. 16. Here there are two loudspeakers at a location remote from the amplifier. Since they are grouped together, however, it is practical to connect the loudspeakers together as a low-frequency grouping, then use a transformer to match this group to the 500-ohm line. The line is then terminated at the proper 500-ohm value at the amplifier. Operating this way, as

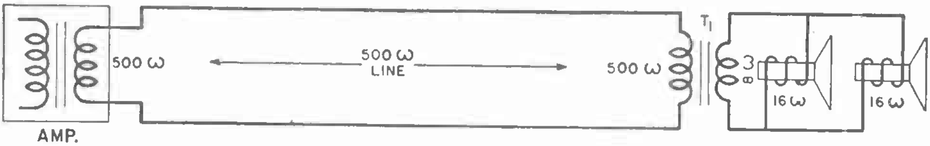


FIG. 16. Use of high-impedance line with grouped loudspeakers.

you have learned, provides far less line loss and permits the loudspeakers to be placed much farther from the amplifier. Because of shunting capacities, however, the permissible length of the 500-ohm line depends on the frequency range wanted. If the line has to be so long that a 500-ohm terminating impedance will not permit the desired frequency response to be secured, lower impedances must be used. Hence, in the example shown in Fig. 16, it might be necessary to use 250 ohms instead of 500 ohms at each end of the line. Transformer T_1 would then have to be designed to match the impedance of the loudspeaker group to a 250-ohm line. If the amplifier transformer did not have a 250-ohm tap, it would be best to replace it with one that did. Such a replacement would, of course, have to be designed to handle the power output of the amplifier.

Obviously, the arrangement shown in Fig. 16 can be used for practically any number of loudspeakers, provided that the loudspeakers can be connected in the proper series or parallel arrangement to give a terminating impedance that can be matched by transformer T_1. If four or more loudspeakers are to be connected in parallel, it is desirable to use 16-ohm rather than 8- or 4-ohm loudspeakers, because the net impedance will be higher and therefore more likely to be a value that can be matched by transformer T_1.

The statements made before about power distribution hold here; in fact, you can consider transformer T_1 to be the same as the amplifier output transformer. Therefore, if we use loudspeakers of equal voice-coil impedance, they will divide the power equally. If their impedances are unequal, they will divide the power according to their respective impedances and to whether they are connected in series or in parallel.

It doesn't always happen that the loudspeakers are grouped closely enough together to make it practical to run a low-impedance connection between the voice coils. In such cases, the loudspeakers must be located wherever they are wanted, and then a high-impedance line must be run to each location. Each location must, of course, have its own matching transformer.

Fig. 17 shows an example. Here, each loudspeaker has a transformer that is chosen to match the voice-coil impedance to the line in such a way

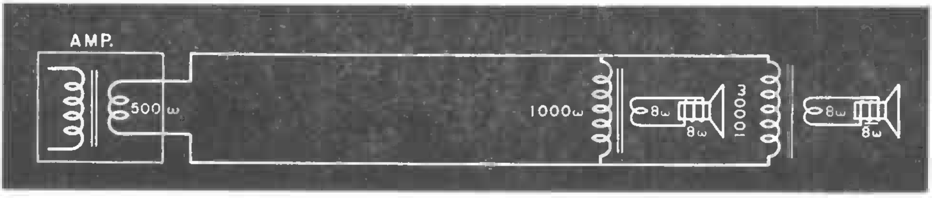


FIG. 17. Use of high-impedance line with separated loudspeakers.

that the net impedance of all the voice coils will equal the proper terminating impedance—500 ohms in this case. Since we have two loudspeakers, the transformers are chosen so that their reflected primary impedances are 1000 ohms; the net impedance of the two in parallel then equals 500 ohms. If we had four loudspeakers, each primary would have to have a 2000-ohm reflected impedance so that the net impedance of all of them would be 500 ohms.

In cases like this, where each loudspeaker is to get the same power, you can find the primary impedance each must have by multiplying the terminating line impedance by the number of loudspeakers wanted. Thus, if there are to be 6 loudspeakers and the terminating impedance is to be 500 ohms, 6 × 500 or 3000 ohms is the primary impedance that each matching transformer must have. Each transformer must then be able to match this impedance to that of the voice coil that is to be connected to its secondary. If each transformer meets this requirement, the power will be evenly distributed among the loudspeakers no matter what their voice-coil impedances may be, since the transformers effectively make them all equal as far as the amplifier is concerned.

UNEQUAL POWER

In many installations, we don't want equal power at each loudspeaker. One example is an installation in which high-powered loudspeakers are used in an auditorium and one or more smaller loudspeakers are used in side rooms to handle an overflow crowd. Obviously, an equal distribution of power would overload the smaller loudspeakers or under-drive the large ones, or perhaps do both.

To see how to create an uneven power distribution, let's suppose we have a circuit like that shown in Fig. 18, in which LS_1 and LS_2 are each rated at 25 watts, LS_3 is rated at 10 watts, and the amplifier has an output impedance of 500 ohms. Our problem is to find the primary impedance values for each transformer that will provide the proper power distribution.

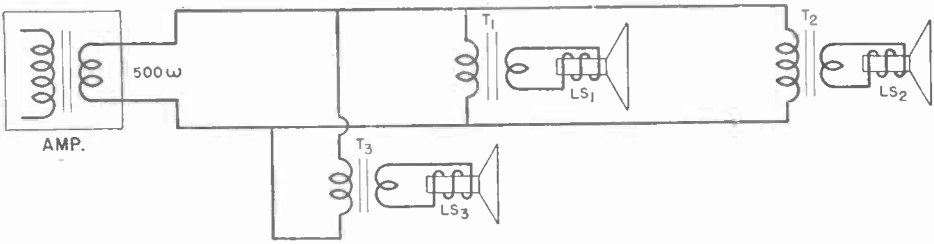


FIG. 18. Unequal powers can be supplied to the various loudspeakers by choosing the prope impedances for the transformer primaries.

To find these primary impedances, we must take these steps:

1. Find the total power.
2. Find the ratio between the total power and that needed for each individual loudspeaker.
3. Multiply the line or amplifier impedance by the power ratio to get the primary impedance each transformer must have.

The total power needed (Step 1) for our example is the sum of the powers of the individual loudspeakers. This is 25 + 25 + 10 or 60 watts.

The ratio of the power (Step 2) of each of the 25-watt units to the total power is 60 ÷ 25 or 2.4. The power ratio for the 10-watt speaker is 60 ÷ 10 or 6.

The line impedance is 500 ohms. Therefore (Step 3), we must multiply 500 by 2.4 to find the impedance that the primaries of T_1 and T_2 must have: this turns out to be 1200 ohms. Multiplying 500 by 6 gives us 3000 ohms as the impedance of the primary for T_3.

We can prove that we have found the correct ratios by computing the net impedance of these three primary impedances in parallel. The net impedance of the two 1200-ohm primaries in parallel is 600 ohms; this 600-ohm value in parallel with the 3000 ohms of T_3 makes a net impedance of 500 ohms for the whole combination. Since this is equal to the amplifier output impedance, the loudspeakers are correctly matched to the line.

Effectively, therefore, if we use transformers that will have reflected primary impedances equal to those we have calculated, the power will automatically be divided so that each speaker will receive the proper amount. Again, it doesn't matter whether the voice coils all have the same impedance or different impedances as long as the transformers match them properly to the calculated primary impedances.

Another way that we can get the same result, and incidentally prove that this power distribution will occur properly, is to calculate the source voltage needed and then to find the impedance of the transformer primary from the source voltage and the required power. In our example, we have a 500-ohm source and require a total of 60 watts. The source voltage can be found from the formula:

$$E^2 = P_S Z_S$$

where P_S is the total power of the source and Z_S is the impedance of the source. Multiplying 500 by 60 we get 30,000 as the square of the voltage. By taking the square root of this value, we find that our source voltage is approximately 172 volts.

The impedance of each primary is given by

$$Z = \frac{E^2}{P_L}$$

where P_L is the power needed for that particular load. As an example, loudspeaker LS_1 requires 25 watts, and the square of the voltage is 30,000. Dividing 30,000 by 25 gives us 1200 ohms as the primary impedance, just as we calculated before.

As another and somewhat more difficult example, let's compute the primary impedance needed for the transformers in the circuit shown in Fig. 19. This is a small hotel installation in which two 25-watt loudspeakers are used in a ballroom, four 5-watt loudspeakers are used in a dining room, and fifteen 2-watt loudspeakers are used in individual rooms. The loudspeaker groups therefore take respectively:

$$2 \times 25 = 50 \text{ watts}$$
$$4 \times 5 = 20 \text{ watts}$$
$$15 \times 2 = 30 \text{ watts}$$

making a total power of 100 watts. The power ratio for the 25-watt loudspeakers is 4 (100 ÷ 25). For the 5-watt loudspeakers it is 20 (100 ÷ 5) and for the 2-watt loudspeakers it is 50 (100 ÷ 2).

With an amplifier termination of 500 ohms, the primary impedance for the 25-watt loudspeakers should be 2000 ohms (500 × 4); for the 5-watt loudspeakers it should be 10,000 ohms (500 × 20); and for the 2-watt loudspeakers it should be 25,000 ohms (500 × 50).

If we were to attempt to locate the

parts for this installation, we would find it difficult or impossible to obtain transformers for the 2-watt loudspeakers. Power-handling transformers rarely have turns ratios that would cause a loudspeaker voice coil to appear as a primary impedance of more than 10,000 to 15,000 ohms at the most. Therefore, it would be wiser for us to use some lower value of source impedance so that we can get this turns ratio for the 2-watt loudspeakers down to something reasonable.

If we use a source impedance of 125 ohms, the 25-watt loudspeakers will require primary impedance values of 500 ohms (125×4), the 5-watt loudspeakers will require 2500 ohms (125×20), and the 2-watt loudspeakers will require 6250 ohms (125×50). Transformers having the necessary turns ratios to produce these impedances can be obtained easily.

Incidentally, while we are on the subject of transformers and the values that are available, there is one fact you should keep in mind when you are looking for transformers: a transformer rated to match two specific impedances can often be used for other impedances that are in the same proportion. For instance, a transformer listed to match 4000 ohms to let's say

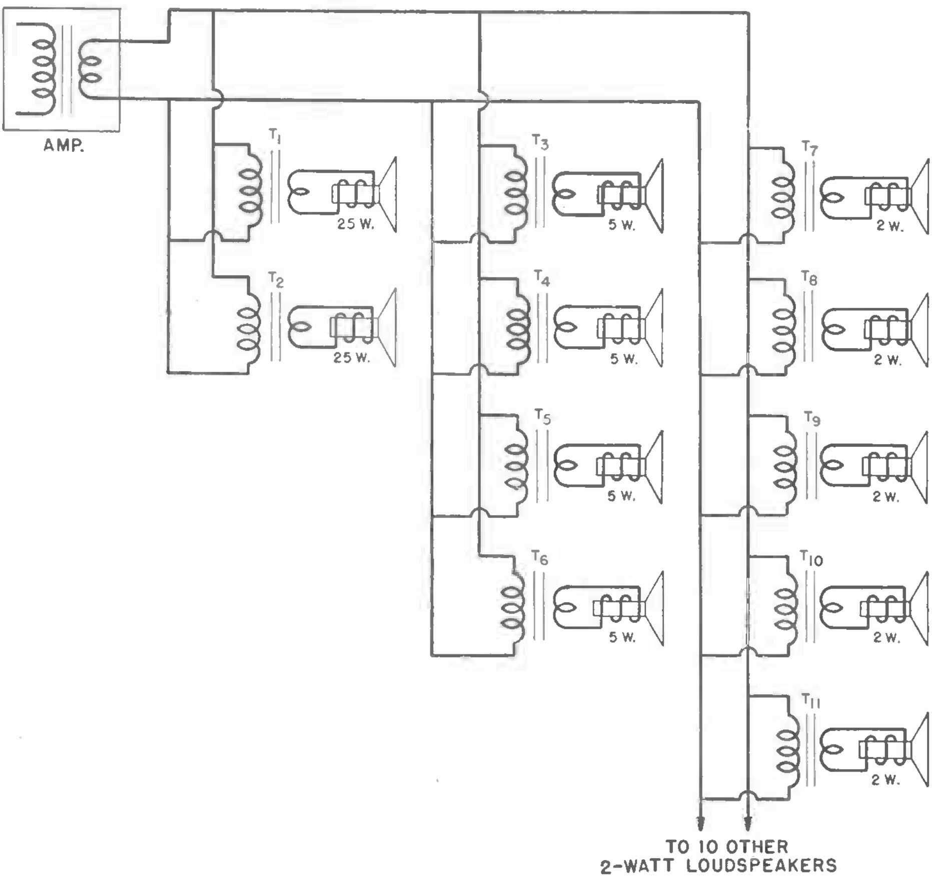


FIG. 19. A small hotel installation in which unequal powers must be applied to the loudspeakers.

an 8-ohm loudspeaker can also be used to match 2000 ohms to a 4-ohm loudspeaker, and can be used to match 8000 ohms to a 16-ohm loudspeaker with only a slight loss in fidelity. Line-to-loudspeaker transformers can be used this way because the source impedance is always less than the actual primary reactance of the transformer, so there is little frequency distortion. Notice that this is different from what you learned earlier in this Lesson about microphone-to-line transformers.

Loudspeaker Switching; Equalizers

In any installation involving a large number of loudspeakers, such as a hotel installation where loudspeakers are in separate rooms, it will always be necessary to make it possible for loudspeakers to be cut in and out at will to suit the desires of the listeners. As we have just shown, however, the loudspeakers are all matched to the line. If we attempt to cut any of them in or out simply by throwing a switch, we will upset the impedance matching and the power distribution. If even one loudspeaker is cut off, the power applied to the others will increase to some extent; if many small or one or two large ones are cut off, the power increase may be so great that small loudspeakers left in the circuit will be ruined. Even if the remaining loudspeakers are not damaged, the frequent changes in volume level as loudspeakers are cut in and out will be highly undesirable. To prevent such effects, it is common practice to arrange the circuit so that a resistor is substituted for the loudspeaker when the latter is out of the circuit. This keeps the total impedance of the circuit constant at all times and therefore prevents any variation in the power applied to the individual loudspeakers.

One such arrangement is shown in Fig. 20A. Resistor R_1 equals the voice-coil impedance. When switch S is in the position shown, resistor R_1 is connected to the line in place of the loudspeaker; when S is thrown to the other position, the loudspeaker is energized and the resistor is cut out. Effectively, therefore, there is a constant-impedance load on the line regardless of the position of switch S.

When transformers are used to match the individual loudspeakers, the arrangement shown in Fig. 20B may be used. Here the value of R_1 corresponds to the reflected primary impedance of transformer T_1. Again the line is not upset whether the loudspeaker is switched in or out.

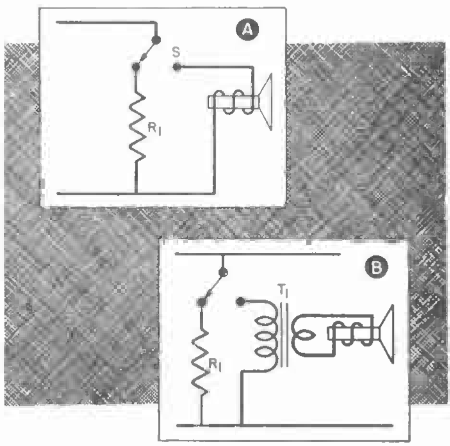


FIG. 20. Two ways of keeping the impedance of a line constant whether loudspeakers are switched in or out.

It is often necessary to make some

provision for adjusting the volume level of individual loudspeakers as well as for cutting them in or out. A hotel room or hospital installation is a practical example of one in which a volume control for each loudspeaker is needed.

Again, it is necessary to be able to

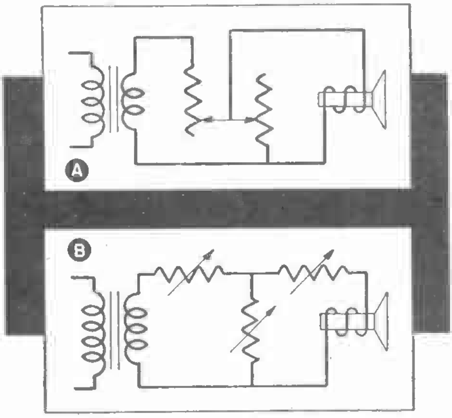


FIG. 21. Typical L pad (part A) and T pad (part B).

control the volume without upsetting the impedance match. Therefore, instead of using an ordinary volume control (which could not handle the power anyway), some kind of special attenuator is used for controlling volume at the loudspeaker. This attenuator is commonly either an L or T pad, so designed that it offers constant impedance at least to the source, and preferably to both the source and loudspeaker loads. Fig. 21 shows typical examples of the L and T connections. The resistor values are so tapered that the proper impedances are maintained. Sometimes these pads are continuously variable, sometimes they are switching units that use fixed resistors to produce a certain amount of attenuation at each position.

In either case, these attenuators are designed to operate between definite impedance values. In the case of the kind shown in Fig. 21, they must be designed to operate at the voice coil impedance.

CROSS-OVER NETWORKS

In high-fidelity systems, dual loudspeakers are used to give a good over-all frequency response. One is a low-frequency or woofer type and the other a high-frequency or tweeter unit. A much better over-all frequency response can be obtained by the proper use of such combination speakers. The woofer speaker can be designed to handle the low frequencies exceptionally well, and the tweeter will give an extended high-frequency range.

However, it is necessary to prevent high frequencies from being fed to the woofer and to prevent low frequencies from going to the tweeter. Fig. 22 shows a typical cross-over network that is used to direct the various frequencies to the proper loudspeakers. It consists of a high-pass filter, C_1-L_1, and a low-pass filter, C_2-L_2. In the high-pass filter, condenser C_1 is small in capacity and therefore offers a high

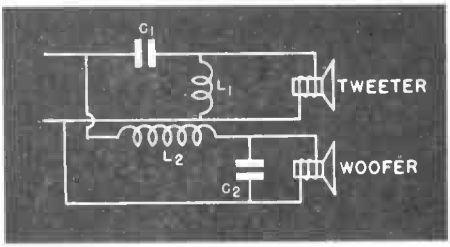


FIG. 22. Typical cross-over network used to separate the frequencies fed to the loudspeakers in a tweeter-woofer combination.

impedance to low frequencies. L_1 at the same time offers low impedance at low frequencies, with the result that practically all low frequencies are dropped across C_1 and are not applied to the tweeter. As the frequency goes up, however, C_1 drops in reactance and L_1 increases, so an increasing amount of power is applied to the tweeter.

The opposite action occurs with the

low-pass filter L_2-C_2 that is connected to the woofer. Here, only the low frequencies get through.

The exact design of the high- and low-pass filters that make up this network depends upon the "cross-over" frequency. The cross-over is the frequency at which the woofer response should begin to die out as the tweeter response begins to increase. The frequency at which cross-over occurs depends on the loudspeaker design. Some loudspeakers are designed for cross-overs around 200 to 400 cycles, others may have cross-overs in the range between 1000 and 3000 cycles. Therefore, the cross-over network used must be designed for the particular loudspeaker combination that is being used. This means that you must select loudspeakers that are designed to work together—you can't just combine a small loudspeaker and a large one and hope to make them work well together. The design of the loudspeaker must be carefully worked out if a smooth over-all response is to be obtained.

If the low-pass and high-pass filters are properly designed, the net impedance at the input terminals of the two loudspeakers will remain practically constant—effectively, as the impedance of one drops, that of the other will rise to compensate for it.

EQUALIZATION

Ordinarily, the over-all response of a complete p.a. system will be reasonably close to the expected design values. However, it is possible that peaks or valleys will appear in the response of a system when it is assembled. This may well occur if all of the components—the microphone, the amplifier, and the loudspeakers—happen to have peaks or dips in their response that occur at about the same frequencies.

The amplifier will usually have a tone control that will compensate for most of this kind of difficulty. However, there may be installations—particularly those in which transmission lines are used—in which it is not desirable to depend entirely on the tone control. For example, let's suppose that a line somewhat longer than usual is required and that the high-frequency response has suffered accordingly. It may well be that the tone control of the amplifier is unable to make up this deficiency or is able to do so only by being turned to maximum treble gain, in which latter case there will be no reserve left for boosting the high frequencies in programs that need it. In either case, some other method of correcting the high-frequency attenuation should be used. If there is enough gain in the amplifier to permit us to throw away half the voltage, the equalizer shown in Fig. 23 can be used. Here, condenser C_1 has a capacity that is approximately equal to the total capacity introduced by the

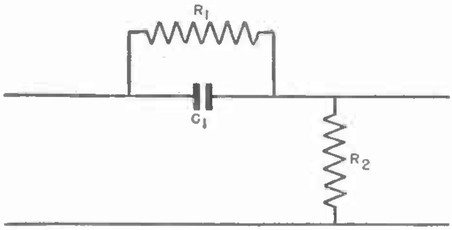


FIG. 23. Simple equalizer circuit used to correct high-frequency attenuation.

line. Resistors R_1 and R_2 have equal resistances. Under these conditions, the over-all gain is reduced one-half, but the frequency response is extended considerably. The over-all response is also flatter. Incidentally, when impedance matching is important, the sum of R_1 and R_2 should equal the desired terminating impedance for this line.

Obviously, equalizers like this one can be used only where there is sufficient reserve gain to make up for the loss introduced by the equalizer.

Equalizers are also used for somewhat different purposes with phonograph pickups. A pickup may have a fairly high response in the region between 5000 and 7000 cycles, with the result that the normal record noises may prove annoying to some listeners. They may be willing to sacrifice fidelity to get rid of such noise. In such cases, scratch filters like those shown in Fig. 24 may be used. That in Fig. 24A is for use with a crystal pickup and that in Fig. 24B is for use with the magnetic pickup. Typical values of the circuit components are shown in each instance.

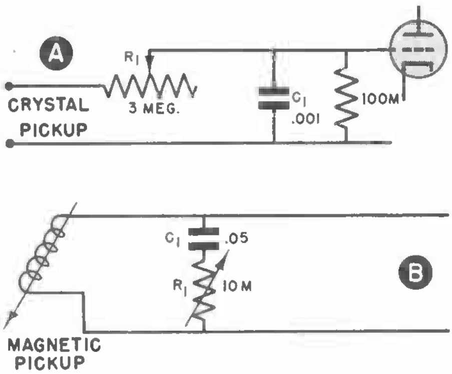


FIG. 24. Scratch filters for a crystal pickup (at A) and for a magnetic pickup (at B).

EXCUSES

Rudyard Kipling once said:

> "We have forty million *reasons* for failure—but not a single *excuse*."

Before you argue or disagree with that statement, think just a minute about a few world-famous men who had *reasons* to fail:

Steinmetz, the great electrical genius, was severely crippled and practically blind. But he did not use his ailments as *excuses.*

Thomas Edison was deaf. But he certainly did not use his deafness as an *excuse* for failure.

When the going is tough, think about Kipling's statement—and think about the marvelous accomplishments of men who had *reasons* for failure, but who refused to use these reasons as *excuses.* Other men have overcome difficulties and handicaps—have succeeded in spite of troubles and difficulties. So can you!

J. E. Smith

TV RECEIVER POWER SUPPLIES, SOUND CHANNELS, AND A.G.C.

57RH-3

PIONEER HOME STUDY RADIO SCHOOL

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STUDY SCHEDULE NO. 57

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. **Introduction** . . . . **Pages 1-11**

The four major kinds of high-voltage power supplies, basic high-voltage distribution systems, and methods of producing extra-high voltages are described in this section.

☐ 2. **Low-Voltage Power Supplies** . . . . **Pages 11-18**

Here you study the power supplies that are used to furnish plate and filament power in TV sets.

☐ 3. **The Sound Channel** . . . . **Pages 18-27**

The characteristics and operation of the sound channel in sets using the standard and the intercarrier sound systems are described in this section.

☐ 4. **Automatic Gain Control** . . . . **Pages 28-36**

You study the circuits used to produce automatic control of video gain in this section.

☐ 5. **Answer Lesson Questions, and Mail your Answers to NRI for Grading.**

☐ 6. **Start Studying the Next Lesson.**

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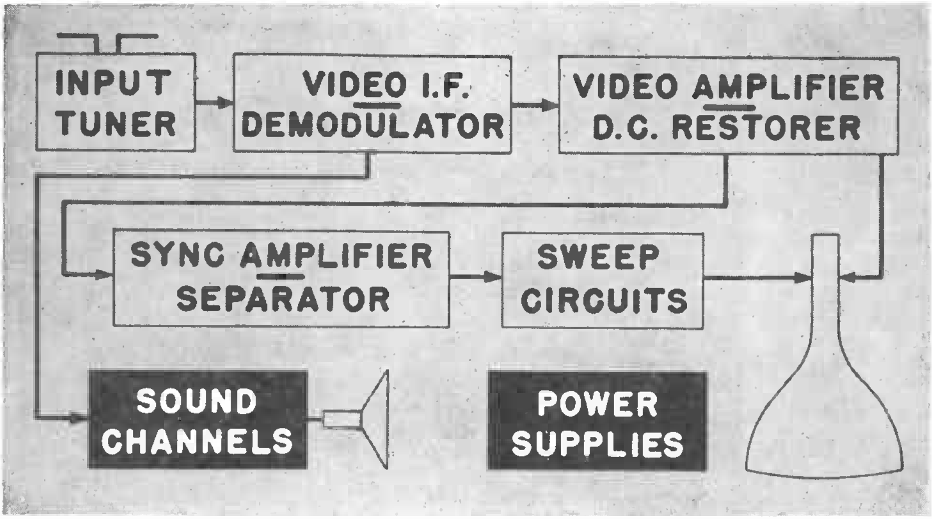

TELEVISION RECEIVERS differ from sound receivers rather markedly in their power supplies. First, a TV receiver always has two supplies: 1, a high-voltage, low-current supply; and 2, a "low-voltage" B supply that is required to furnish voltages in the range from 100 volts to 400 volts at a rather high current level.

The "low-voltage" supply more or less corresponds to the B supply of sound receivers, but because of the large number of stages in the video chain from the antenna to the picture tube, plus the sync and sweep stages, plus the stages in the sound section (which you are going to study in this Lesson), the current and voltage demands made on it are unusually large. Later in this Lesson, we are going to study the B supply in detail.

First, however, let's learn how the high-voltage supply operates.

TYPES OF HIGH-VOLTAGE SUPPLIES

The electrons in the beam in the picture tube must be accelerated by a high voltage if they are to strike the screen with enough velocity to make the fluorescent material glow. The small direct-view picture tubes (7 inches or smaller) will operate reasonably well with voltages under 5000 volts between the second anode and the cathode, but the larger direct-view tubes all require considerably higher voltages—as much as 15,000 volts for a 16-inch tube. The tube in a projection system is commonly operated at 25,000 to 30,000 volts. A TV set must therefore have a power supply capable of furnishing a voltage somewhere between 3000 and 30,000 volts, depending on its type. This supply must be reliable and as safe as possible.

Since it is impractical to get such a high voltage from the same power supply that is used for all the other tubes in the receiver, a TV set always has a separate high-voltage power supply. There are four types of these power supplies now in use, and we shall describe them in turn. They are:

1. A 60-cycle power supply that uses a conventional power transformer and rectifier-filter system almost identical with the low-voltage types with which you are already familiar.

2. A rectified r.f. power supply that uses an r.f. oscillator operating on

some frequency between 50 kc. and 300 kc., followed by a rectifier-filter arrangement.

3. A pulse supply that uses a blocking oscillator, an amplifier tube, and a rectifier-filter.

4. A kick-back supply (also known as a fly-back supply) that operates from the high voltage kick-back from the horizontal scanning yoke of an electromagnetic system.

60-CYCLE SUPPLY

As you know, it is possible to get any voltage we want from a 110-volt a.c. power line by the use of the proper power transformer. To get a high voltage, all we need is a secondary with a sufficient number of turns to give the proper step-up ratio between the secondary and primary. Of course, the secondary windings must be insulated to withstand the high voltage, making such a transformer costly and bulky.

The number of secondary turns needed depends, as Fig. 1 shows, on whether full-wave or half-wave rectification is used. A full-wave rectifier (Fig. 1A) delivers a voltage equal to half the voltage across the secondary, because only half the secondary is used at a time. The same secondary winding in a half-wave rectifier circuit delivers twice as much voltage, because the voltage across the entire winding is used. Of course, the full-wave output is easier to filter, and a higher current may be drawn from it for a given regulation; but these characteristics are not important in a TV high voltage supply, from which very little current is drawn.

At such high voltages, there must be a maximum spacing between the filament and the plate leads to prevent breakdown. For this reason, the plate lead is brought out through a top cap on the tube.

The filter is a standard condenser-input type except that a resistor is used instead of a choke coil. It is practical to use a resistor because the current demand is so low that there is little d.c. drop across it; and it is desirable to do so because it eliminates the insulation problem we would have with a coil and greatly increases the safety factor of the supply.

This safety factor is important. Electricity kills because of *current* flow through certain portions of the human body. The body possesses a fair amount of resistance, so ordinarily a reasonably high voltage is necessary before a lethal current can be made to flow through the body. However, people vary a lot in this respect—people with weak hearts may well be killed by currents that would

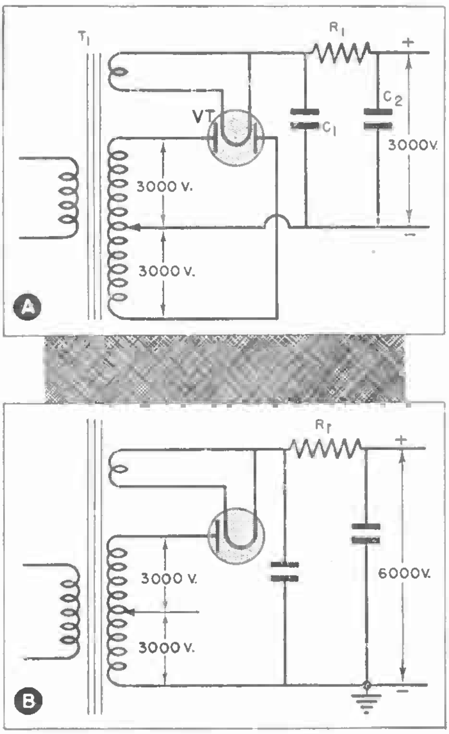

FIG. 1. For the same number of turns on the secondary of the power transformer, a half-wave supply (B) gives twice the output voltage of a full-wave supply (A).

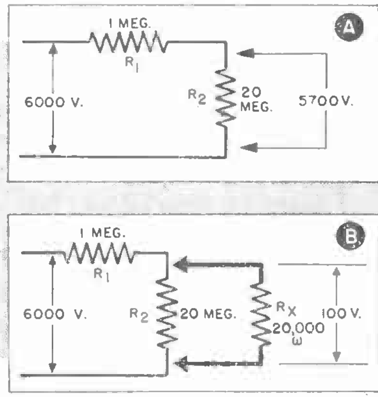

FIG. 2. The use of the series resistor, R_1, gives the power supply very poor regulation, thus making it safer to work with.

not have much effect on others, and of course the body resistance changes drastically with the state of the health, the dryness of the skin, and other such factors. It is possible to get a severe and even dangerous shock from the voltages present in an ordinary radio set; obviously, the danger from the high voltages of a TV set is even greater.

This danger can be reduced very considerably by using a high resistance instead of a choke coil in the power-supply filter section. If any attempt is made to draw much current from a circuit of this kind, the output voltage will be drastically reduced because of the large drop across the series resistor of the power supply.

This effect is illustrated in Fig. 2. In Fig. 2A is shown a simplified circuit in which a 6000-volt power supply having an internal or filter resistance, R_1, of 1 megohm is delivering power to a load of 20 megohms. Under these conditions, there will be a voltage of 5700 volts across the load.

Now, suppose a person having a body resistance of about 20,000 ohms happens to get across the load. This will reduce the load resistance to about 20,000 ohms, thus causing a change in the voltage division in the circuit. As Fig. 2B shows, the load voltage will drop to about 100 volts, and all the rest of the voltage will be dropped across R_1, the filter resistor.

Therefore, the power supply is made safer if a high-resistance R-C filter is used with it. For extra protection, additional resistors may also be added in series with the plate lead going to the rectifier tube, and the power transformer secondary may be wound with very fine wire so that it will have considerable resistance.

These precautions all help, but they still do not make this kind of power supply completely safe. Even though the current drain on such a supply is very small, it may be necessary to use condensers having capacities of as much as .1 mfd. in the filter circuit to remove all traces of hum ripple. A condenser of this size charged to 5000 or 6000 volts contains enough stored energy to kill. Therefore, NEVER touch a power supply of this type under any circumstances while it is operating. In fact, the supply is not safe even when it is turned off unless the filter condensers have been completely discharged. All sets using power supplies of this kind have safety interlocks so arranged that the power is automatically cut off if the shield around the high-voltage supply is opened. Some even use relays to short-circuit the filter condensers. It is never safe to assume that these safety devices are operating, however. If you work on such a power supply, short the filter condensers individually with a test lead having high-voltage insulation.

Because it is so dangerous, the 60-cycle power supply was used only reluctantly by set manufacturers. Just as soon as the types we are now going to describe proved practical, the 60-cycle power supply fell into disuse.

You are likely to find it now only in some of the older sets that may come in for service.

R.F. POWER SUPPLIES

The amount of current needed from the high-voltage supply for the picture tube is exceedingly small—a matter of a few microamperes. This low drain has made it possible to develop several other methods of obtaining the high voltage.

One of the simplest of these power-supply systems is shown in Fig. 3. The circuit contains a tuned-plate oscillator in which tube VT_1 is used. The tank circuit for this tube is C_4-L_3, and the feedback tickler coil is L_1.

Arranged on the same coil form is a closely coupled winding L_2. This coil is tuned to resonate with the frequency of the oscillator by its distributed capacity (C_5) and is designed to have a high Q. By resonance step-up, the voltage across this winding can be made to be a number of times higher than that across the oscillator tank (which is practically equal to the B supply voltage of the oscillator).

The high voltage produced across coil L_2 is rectified by VT_2 and is applied to the filter C_6-R_3-C_7. (The output capacity C_7 may be the capacity between the inner and outer coatings on an electromagnetic picture tube. If an electrostatic tube is used, it will be an actual condenser.)

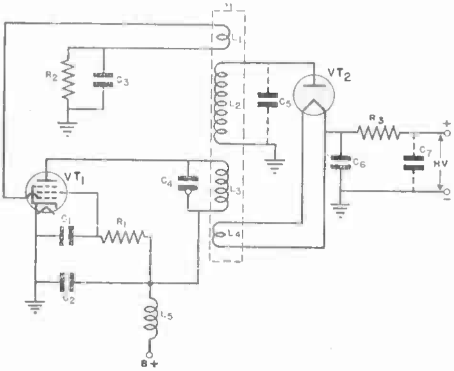

FIG. 3. A simple form of r.f. power supply.

Notice that there are a number of important innovations in this circuit. To begin with, this is an r.f. oscillator that operates somewhere in the frequency range between 50 and 300 kc., so r.f. design practices can be followed in its construction. The coil assembly T_1 is a fairly small air-core type rather than a bulky iron-core transformer. Insulation is no great problem, as the spacing between windings gives most of it. Coil L_2 does not need to have a vast number of turns, because the high voltage across it is produced by resonance step-up, not by transformer action.

The oscillator tube is an ordinary receiver-type low-power output tube, because the high-voltage supply requires a power of only about .5 to 1 watt.

The high-voltage output is dependent upon the tuning of the secondary coil L_2—as a matter of fact, the output voltage is adjusted by varying the tuning condenser in the tank circuit to make its frequency match the resonant frequency of L_2-C_5. If this circuit drifts off resonance, the output will drop appreciably. For this reason, this circuit is commonly modified as shown in Fig. 4 so that there is a feedback path from the high-voltage circuit to the oscillator. A coil of wire or a sheet of tinfoil wrapped around the rectifier tube VT_2 is used to couple the oscillator grid to the high-voltage output through the capacity between this coupler and the electron stream in the rectifier. The feedback connections could be made to the end of the high-voltage winding, but using the tube this way is preferable because it gives coupling and high-voltage insulation at the same time. This coupling makes the high-voltage secondary L_2 become the frequency-controlling winding be-

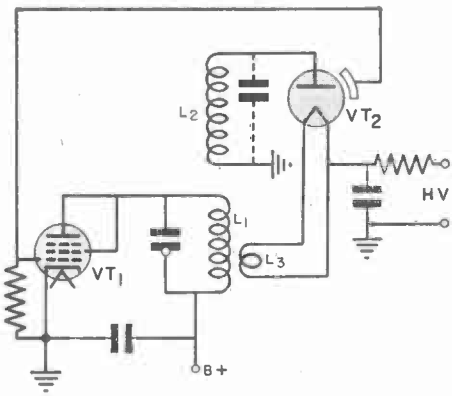

FIG. 4. This method of coupling reduces the possibility of drift in this r.f. power supply.

cause of its high Q, so changing the tuning of the primary has little effect on the output. In other words, the circuits are locked to the resonant frequency of the high-voltage winding, with the result that there is much less danger that frequency drift will reduce the output.

A rectifier tube that has a very low filament-power drain is needed for this circuit. If the rectifier tube filament were supplied from the power transformer as other tubes are, its supply winding would have to have high-voltage insulation, which would make it necessary to use an expensive transformer of special design. Instead, a tube is used that has a filament rating of 1.5 volts and 200 ma. and hence draws only about .3 watt. This low power requirement makes it possible for the tube to get its filament power from the r.f. oscillator as shown in Figs. 3 and 4. The filament winding consists of a one- or two-turn winding on the coil form that is coupled to the primary just tightly enough so that the proper power is removed for lighting the tube filament.

Since there is no way to measure the heating power of the rectifier tube filament directly, you must usually make a visual test to determine whether the tube is operating properly. Examine a tube while its filament is lighted from a 1.5-volt dry-cell battery to get a good idea of the normal filament brilliancy of the rectifier tube used in this circuit. If the filament is not lighted to its normal brilliancy when the tube is in the power supply, the r.f. oscillator is not producing the right output, and it must be retuned.

Since this is an r.f. power supply, the frequency of the ripple is much higher than that of the ripple in a 60-cycle supply and therefore can be filtered out with much smaller capacities. You will recall that the efficiency of a filter depends on the ratio of the choke (or resistor) impedance to the capacitive reactance. The higher the frequency, the less the reactance of a condenser, so a small condenser can be used to filter out high-frequency ripple; in fact, the filter condensers needed here may be as small as .0005 mfd. Such low-capacity condensers are incapable of storing enough charge to be very dangerous. The use of a high series resistance and low-capacity condensers makes this power supply far safer than the 60-cycle types. Of course, this kind of power supply can still give you a nasty shock, but a person in reasonably good health is not in extreme danger from its output voltage.

The r.f. voltage supply we have just described has two basic faults. One is that it can produce interference. In an ordinary radio, a frequency of 150 kc. or so would be ignored. In a television set, however, this signal will produce a visible interference with the picture if it gets into the video system. (Remember that the video amplifier is capable of passing frequencies from 10 cycles out to 4 megacycles, so the r.f. oscillator frequency is well within this range.) Careful shielding and filtering of the supply leads are necessary to keep this interference at a minimum. (In addition, the shielding serves as a safety device by preventing accidental contact with the high-voltage circuits, which could cause shocks or r.f. burns, but this is merely incidental to its primary job of eliminating interference.)

Another fault is that the high-voltage supply is independent of the sweep circuits. Should the sweep system fail and the high-voltage supply remain on, the electron beam would be concentrated in a single spot on the face of the picture tube. This concentrated beam would burn the fluorescent screen away and thus ruin the tube. (This disadvantage is also possessed by the 60-cycle supply.)

Both these objections are avoided in the two types of power supplies we are now going to describe.

PULSE SUPPLY

The pulse supply shown in Fig. 5 contains a blocking oscillator, an amplifier, and a rectifier. The blocking oscillator produces pulses, just as a similar type does in sweep circuits. These pulses are amplified, then stepped up by transformer T_1. Since the blocking - oscillator half - wave pulses have a frequency around 150 kc., T_1 is an r.f. transformer.

For reasons that we shall give in a moment, we want this circuit to operate in synchronism with the horizontal sweep. To produce this action, resistors R_2 and R_3 are connected across the B supply. Their resistances are such that the drop across R_2, which is in the cathode circuit of VT_1, is a bias sufficient to keep the tube blocked. The oscillator therefore cannot operate until a control pulse is received and is applied across R_2 in such a way that the polarity of the control pulse opposes that of the d.c. drop across this resistor.

This trigger pulse for firing the blocking oscillator is obtained from the output of the horizontal sweep amplifier and occurs only during the retrace portion of the horizontal sweep. Thus, the oscillator VT_1 is unblocked only during the horizontal retrace. As soon as it is unblocked, it generates a pulse. This pulse is completed before the horizontal retrace ends; then the oscillator is blocked again by the action of R_2 and R_3 until the next sweep retrace.

The pulses produced by the oscillator are amplified by VT_2, rectified by VT_3, and stored in the input filter condenser. Because very little current is needed, it is possible for a low-capacity

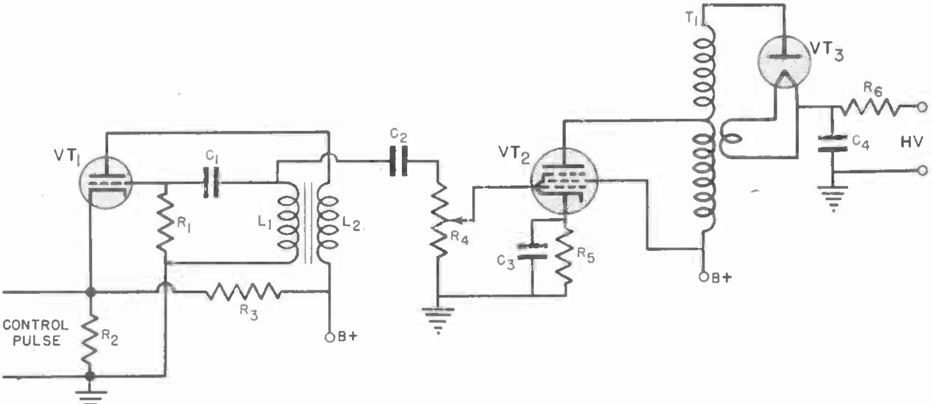

FIG. 5. Schematic diagram of a pulse high-voltage supply.

condenser to hold this charge reasonably well during the long time interval from pulse to pulse.

Since this power supply cannot operate at all unless a trigger pulse comes from the horizontal sweep, the high voltage will be removed from the picture tube at once if anything happens to block the operation of the sweep. Furthermore, the oscillator is allowed to operate only during the time of the sweep retrace. Since the face of the picture tube is kept blank during that interval by the pedestal and the sync pulse, any interference that might be produced by the oscillator will be invisible. Therefore, this circuit eliminates both the objections we found to the r.f. supply.

Another respect in which this pulse supply is better than the r.f. supply is that its output is not dependent upon resonance and therefore is not subject to variations caused by frequency drifts. The step-up transformer T_1 depends upon its turns ratio, not on resonance, for the voltage step-up. The output is controlled by the variable resistor R_4, the setting of which determines the amount of signal fed to the grid of the pulse amplifier.

Of course, more parts are used in this supply than in an r.f. type, but its advantages have made it popular in spite of its greater cost.

THE FLY-BACK SUPPLY

You will recall that when the horizontal sweep amplifier tube of an electromagnetic sweep system cuts off, the energy stored in the horizontal deflection yoke produces a half-sine-wave oscillatory surge of very high amplitude. This current flows through the secondary of the horizontal sweep output transformer and induces a high voltage in the primary. As a result, a peak plate voltage of 5000 or 6000 volts is applied to the horizontal output tube in the usual circuit arrangement of this type. By adding a few more turns to the primary winding, as shown in Fig. 6, we can easily arrange for a voltage of from 9000 to 12,000 volts to be developed across the full primary winding. Therefore, in an electromagnetic system, we can get the high voltage directly from the horizontal sweep circuit simply by adding a few more turns to the primary of the horizontal output transformer and adding a small secondary to supply the filament voltage for the high-voltage rectifier. Obviously, this is by far the most economical power supply arrangement, since it entails mostly only a redesign of the horizontal output transformer. The only new parts needed are a rectifier tube and a filter.

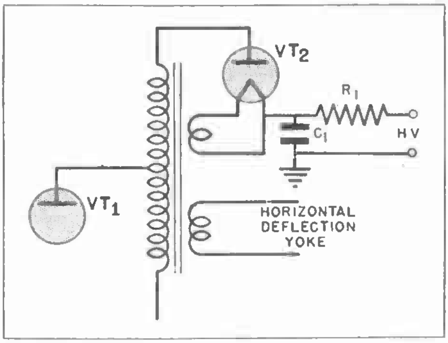

FIG. 6. Schematic diagram of a fly-back high-voltage supply. This supply can be used only in sets using electromagnetic deflection.

Besides being a very inexpensive power supply, it has the advantage of operating only during the retrace time, when the screen is dark. If anything happens to the horizontal sweep oscillator circuit that makes the sweep fail to operate, the high-voltage pulse will not be generated either.

The only basic difficulty with this power supply is the fact that the amount of voltage produced depends on the amplitude of the horizontal sweep, which of course must be adjusted to get the proper picture width.

In most sets, this problem is solved by using a dual amplitude control—one a size control in series with the deflection yoke, and the other a control that varies the input or drive to the horizontal sweep amplifier. It is usually possible to find settings of these controls that will let you get the proper high voltage and the desired picture size.

This system is usable, of course, only in a set that has a horizontal deflection yoke—it cannot be used with electrostatic tubes. It differs in this respect from the other systems discussed, all of which can be used with either kind of picture tube.

HIGH-VOLTAGE DISTRIBUTION

When an electrostatic picture tube is used, a voltage divider is usually connected across the high-voltage supply to furnish the necessary voltages for all the elements within the picture tube. This is almost invariably done when a 60-cycle high-voltage supply is used, because this supply can furnish all the required currents very easily.

A typical basic voltage divider of this kind is shown in Fig. 7A. It is of course nothing but a series of resistances, arranged to give the proper voltage division, and also arranged to act as a bleeder across the power supply. When the supply is turned off, this bleeder permits the filter condensers to discharge.

A modification of this circuit is shown in Fig. 7B. As you know, the horizontal sweep output tube used with an electrostatic tube requires a rather high plate voltage (but very little current). If the power supply can furnish the needed current, the plate supply for this sweep amplifier can be obtained from the voltage divider.

Of course, all the elements of elec-

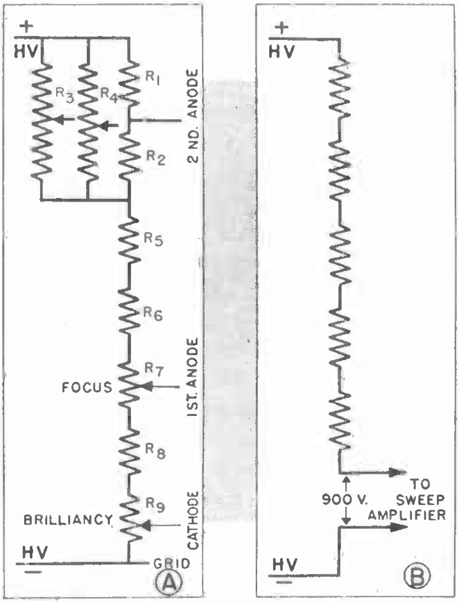

FIG. 7. Typical voltage-divider circuits used with electrostatic picture tubes.

tromagnetic picture tubes could be similarly supplied. Here, however, it is much more common to supply the first anode and the bias voltages of the picture tube from somewhere in the low-voltage supply (normal B supply) and to reserve the high-voltage supply purely for use between the second anode and the cathode as an accelerating voltage. This reduces the load on the high-voltage supply and also insures that the picture tube will go off if the low-voltage supply fails. A voltage divider is seldom used with such a supply. For safety, however, there may still be a bleeder that will discharge the filter condensers soon after the supply is turned off.

EXTRA-HIGH VOLTAGES

The power supplies we have discussed up to now are the kinds that are commonly used to produce voltages under 10,000 volts. Much higher accelerating voltages are necessary for the larger direct-view tubes and for projection tubes, however. Most of the larger direct-view tubes require from 12,000 to 18,000 volts for proper operation, and most of the projection tubes used in home receivers need from 25,000 to 30,000 volts. (Voltages as high as 80,000 volts are used in some of the very large theater-size projection units.)

Such high voltages are secured in home receivers by using a pulse or fly-back supply in combination with a voltage-doubling or voltage-tripling circuit. This arrangement makes it unnecessary to use a transformer and a rectifier capable of handling extremely high voltages, both of which would be expensive.

The most popular form of voltage-multiplying circuit is shown in Fig. 8. Transformer T_1 is the output transformer for either the fly-back or pulse circuit and supplies pulses for the high-voltage supply. The resistance R_1 is the low-voltage bleeder; it is so low in resistance that it serves only to complete the circuit from C_1 to T_1 insofar as the high-voltage supply is concerned. Here is how the circuit works:

On the first pulse, rectifier VT_2 charges condenser C_1 to the full output voltage rating of T_1 through the path shown in Fig. 9A. When the pulse cuts off, there is a relatively long period (during the horizontal trace time) in which there is no voltage pulse. As Fig. 9B shows, C_1 is always connected across C_2 through paths consisting of R_2 on one side and R_1-T_1 on the other. During the time that VT_2 is off, C_1 discharges somewhat, charging C_2 with the polarity shown. (After several cycles of operation, the voltage across C_2 becomes practically equal to that across C_1.)

Now, on the next forward pulse, when the upper end of transformer T_1 is positive, VT_2 again conducts to recharge C_1. At the same time, voltage is applied to VT_3 through the path

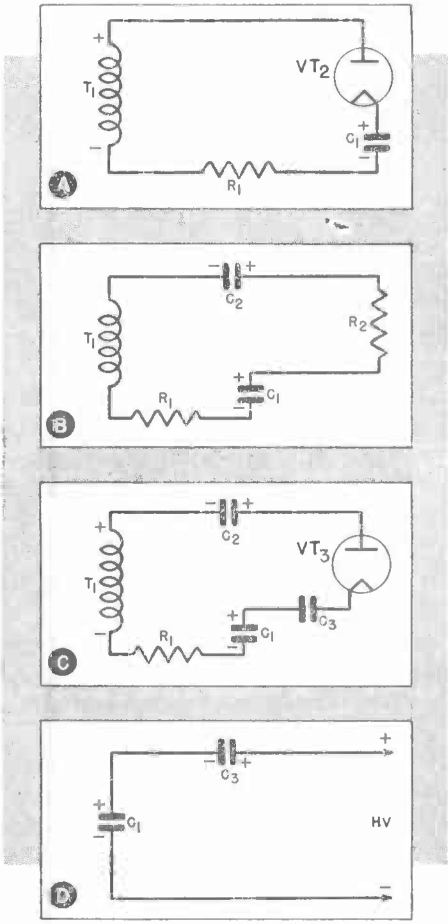

FIG. 9. This series of drawings shows how the voltage doubler shown in Fig. 8 works.

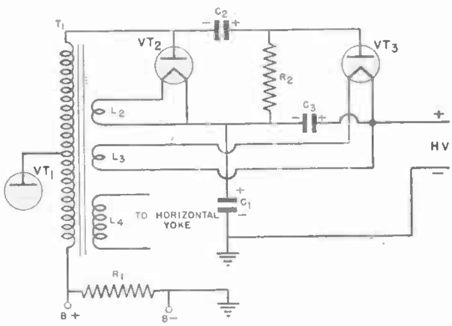

FIG. 8. A voltage-doubler circuit commonly used in home projection sets.

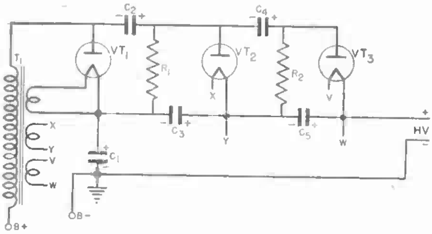

FIG. 10. A voltage-tripler circuit.

shown in Fig. 9C. The voltage applied is the sum of the pulse voltage across T_1 plus the voltage across C_2 and minus the voltage across C_1. Since the voltages across C_1 and C_2 are equal and opposite, the voltage developed across T_1 is what is applied to VT_3. This tube then conducts, allowing the full T_1 voltage to be applied to C_3. As a result, C_3 is charged to the same voltage as C_1 is.

As Fig. 9D shows, the high-voltage output is the voltage across C_1 and C_3 in series. Hence, each condenser supplies half the voltage: if the output is, let us say, 20,000 volts, the voltage across C_1 is 10,000 volts, and the voltage across C_3 is likewise 10,000 volts. Hence, neither of these condensers has to have an extremely high voltage rating, which means they can be relatively inexpensive. That is an important feature of this circuit: in some other voltage-doubling circuits, at least one condenser has to be able to withstand a higher voltage.

This feature is even more important if the voltage must go up to 30,000 volts or more. A voltage tripler, using the same basic circuit (Fig. 10), is used to produce such voltages. In the circuit in Fig. 10, conduction of VT_1 initially charges C_1. Then, while VT_1 is off, C_1 charges C_2. On the next pulse of the input voltage, VT_2 conducts, charging C_3; on the next, C_3 charges C_4; and on the next, VT_3 conducts, charging C_5. All five condensers in the circuit then have the same voltage across them. The high-voltage output is the sum of the voltages across C_1, C_3, and C_5.

Notice that filament-type rectifier tubes are used in the circuits in Figs. 8 and 10, thereby eliminating the cathode-to-heater leakage problem that would exist if rectifiers having separate cathodes were used. Separate filament windings, insulated from each other by high-voltage insulation, must be used to supply these filaments.

In the circuits in Figs. 8 and 10, the high-voltage supply usually feeds into a filter resistor and from it directly to the second anode of the picture tube. If the tube is glass, as you know, the output filter condenser is formed by the coatings inside and outside the

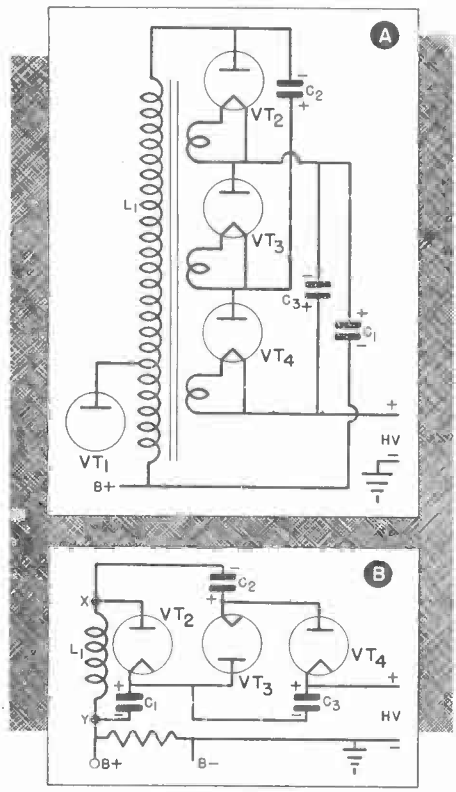

FIG. 11. The action of the voltage-tripler circuit (part A) is shown in part B.

funnel of the picture tube, which are separated by the glass of the funnel. The inner coating is connected to the second anode within the tube, and the outer coating is grounded.

Another form of voltage tripler is shown in Fig. 11. This circuit uses fewer parts than the one in Fig. 10, but two of the condensers must have twice the voltage rating needed in the other circuit. This supply, which is used in a popular projection set, is unusual in that it is driven by a sine-wave voltage instead of by pulses. Although the amplifier VT_1 is driven by a pulse from a blocking oscillator, it excites L_1, which acts as a resonant tank circuit and, by fly-wheel action, produces a sine-wave voltage that is applied to the tripler circuit.

The voltage-multiplying action is shown in Fig. 11B. When the polarity of the oscillatory tank voltage makes the upper end (X) of L_1 positive, current will flow through the rectifier tube VT_2 and thus charge condenser C_1 to a voltage equal to that across the coil (about 8500 volts).

When the polarity of the oscillatory voltage reverses so that Y is positive with respect to X, the voltage across L_1 plus that across C_1 is applied to VT_3, causing VT_3 to pass current. When VT_3 conducts, C_2 is charged; since the applied voltage is equal to the sum of the voltage across C_1 and L_1, C_2 is charged to about 17,000 volts and must be rated accordingly.

On the next reversal of the oscillatory cycle, when X is positive with respect to Y, the conducting path is from the source L_1 through condenser C_1, condenser C_3, tube VT_4, and condenser C_2 back to the source. If you trace this path, you will see that the polarities are such that the voltages across L_1 and C_1 buck each other; as a result, C_3 is charged by the voltage across C_2, meaning that it is charged to twice the source voltage.

The output high voltage is the sum of the voltages across C_3 and C_1; in other words, it is twice the source voltage plus the source voltage, or three times the source voltage. As we pointed out earlier, this tripler uses fewer parts than the one in Fig. 10, but both C_2 and C_3 in Fig. 11 must have at least twice the voltage rating needed for any of the condensers in the other circuit.

Low-Voltage Power Supplies

The high-voltage power supply that we have described is intended primarily to furnish the accelerating voltage for the picture tube. In a set using an electromagnetic picture tube, all other stages, including the low-voltage elements of the picture tube, require normal B voltages from a separate supply. In a set in which an electrostatic tube is used, the high-voltage supply may also supply the lower operating voltages for the picture tube and perhaps the plate voltage for the output sweep amplifier. However, all other stages require normal B supply voltages.

Just as in standard radio receivers, there are two basic forms of B supplies—one that uses a power transformer and one that does not. Let's see how the B supply of a TV set is different from the basic types with which you are familiar.

TRANSFORMER SUPPLIES

Fig. 12 shows a basic full-wave rectifier-filter-divider arrangement like

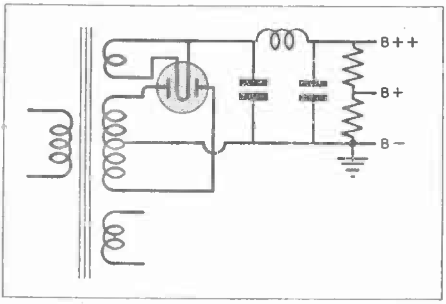

FIG. 12. Basic full-wave rectifier circuit.

that used in a standard radio receiver, and Fig. 13 shows a typical transformer power supply of a TV receiver. Let's analyze the latter supply to see how it differs from the former.

One major difference is that two rectifier tubes in parallel are used in the TV supply. This is necessary because a TV set has three or four times as many tubes as the average radio has and therefore uses much more current.

Notice that one plate of each tube is connected in parallel with the corresponding plate of the other tube. It would also be possible to connect the two plates of each tube in parallel, thereby making each tube a high-power half-wave rectifier, and then use the two tubes in a full-wave circuit. If this were done, however, and one tube should fail, we would get half-wave rectification and consequently hum and a considerably reduced output. With the arrangement shown in Fig. 13, failure of one tube will overload the other one but will not cause hum, because we will still get full-wave rectification. Therefore, the circuit will continue operating until the second tube fails.

The filter arrangement is standard except that condensers are used in parallel to furnish the very high capacity needed to filter when the current demand is high. Thus, C_1 and C_2 form an 80-mfd. input capacity, and C_3 and C_4 give an output capacity of 120 mfd.

The voltage divider is made up of resistors R_1 to R_7 inclusive, plus the focus coil. Different amounts of B supply voltage are available from the taps that are above ground potential; the taps below ground potential furnish bias voltages.

A large number of electrolytic by-pass condensers are used to provide additional filtering. Notice that nearly every tap is heavily by-passed. The bias taps are not by-passed in the power supply, but additional by-passing is used in the receiving circuits to which the bias voltages are fed. This extra by-passing helps to reduce hum

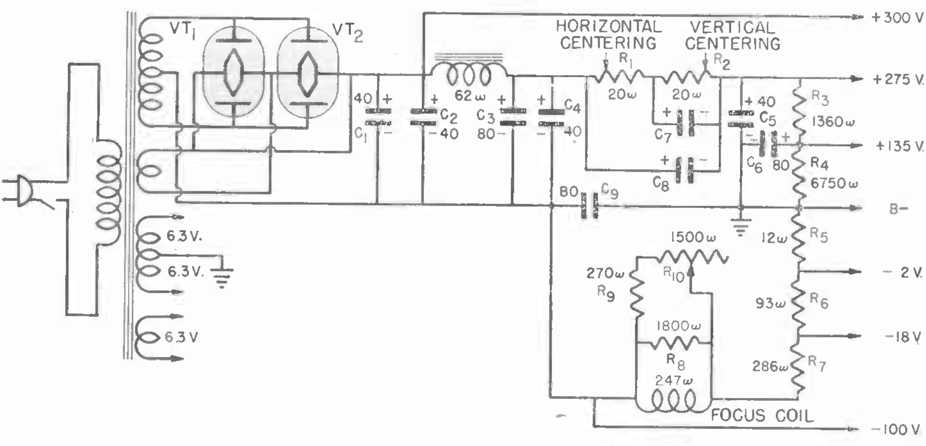

FIG. 13. Typical TV low-voltage supply using a power transformer.

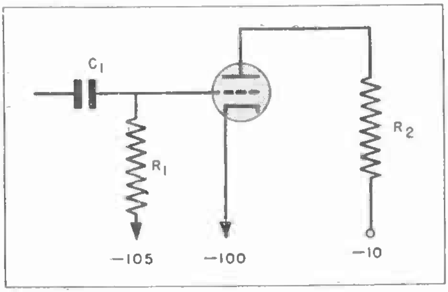

FIG. 14. Although all the elements of this tube are connected to negative voltage sources, there is a normal relationship between the cathode, grid, and plate voltages.

and interaction between stages.

The voltage divider resistors are designed to draw a rather high current so as to stabilize the output voltages at the various terminals. Since the focus coil must have a high current flowing through it for it to be effective, it is placed in the circuit at a point where all of the bleeder current plus the B supply current for all of the tubes (except for the amount that returns through the −100-volt lead) will flow through it. In this set, the focus is adjusted by varying the resistance in parallel with the focus coil and thus changing the current through it. This adjustment is not provided in some sets; in these, the focus is changed by moving the coil on the neck of the picture tube.

Most tube circuits get their B-supply voltage from the +275- or +135-volt tap, and the cathode returns are made through ground to the terminal at the junction of R_4 and R_5. Fixed biases are usually taken from the −2- and −18-volt taps.

The −100-volt tap permits a higher voltage to be applied to certain circuits, such as the sweep output circuit. For example, if the plate of a tube is connected to the +275-volt tap and its cathode to the −100-volt tap, the total voltage between these two elements is 275 + 100 or 375 volts.

Remember that the voltage applied between any two elements of a stage is equal to the voltage difference between the elements. For example, it is not at all uncommon to have an arrangement like that shown in Fig. 14 in which all of the tube elements apparently go to negative voltage terminals. However, this just means that each voltage is negative with respect to ground. The plate of the tube is at −10 volts, whereas the cathode is at −100, so the plate is 90 volts positive with respect to the cathode. Since the grid is at −105 volts, it is negative with respect to the cathode by 5 volts. It is not uncommon to find an arrangement of this sort in TV circuits, particularly when a d.c.-coupled video amplifier is used.

From what we have said, you can see that a television B-voltage supply in which a transformer is used is not very much different from those used in radio sets. Even the filament supply is relatively ordinary. The circuit shown in Fig. 13 is a little unusual in that the major filament winding produces a voltage of 12.6 volts. This winding has a center tap, however, so each half furnishes 6.3 volts, which is what most of the tubes in the set use. This design is used in some sets because there is some economy in making one continuous winding with a tap on it instead of making two separate insulated windings, although the latter construction is also common. In some sets, also, a 12.6-volt supply is needed for one or two tubes: this can be gotten by connecting the tube across the full winding.

TRANSFORMERLESS SUPPLIES

A power transformer of the kind just described, which can handle powers up to 500 watts, is large, heavy, and expensive. Bulk, weight, and manufacturing costs are reduced in many TV sets, particularly the smaller ones, by using transformerless supplies similar to those used in a.c.-d.c. radios. In such TV sets, the high B-supply current requirements are met by using rectifier tubes in parallel and by using selenium rectifiers.

These selenium rectifiers consist of "washers" coated with selenium, which has the property of conducting far better in one direction than in the other. They are satisfactory, if not perfect, rectifiers, and they are small

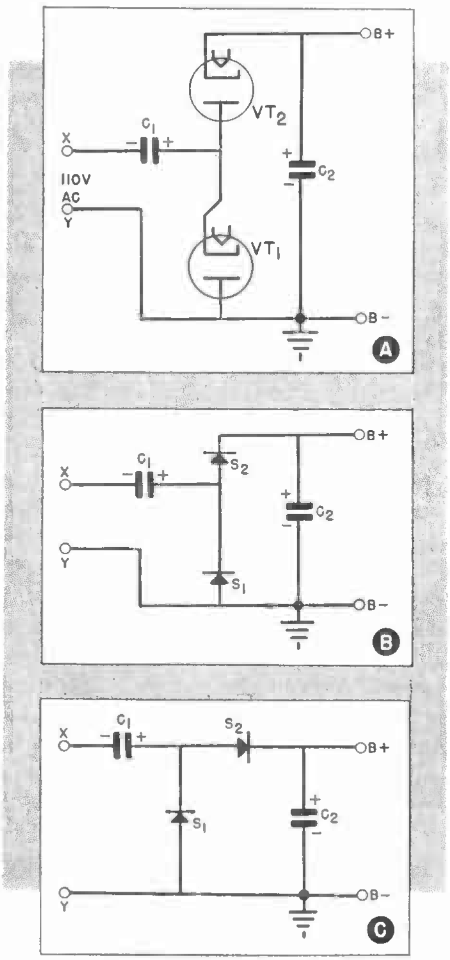

FIG. 15. Typical transformerless TV low-voltage supplies using voltage-doubler circuits.

and easy to mount in any position on or underneath the chassis.

A TV receiver requires B voltages that are at least twice the usual power-line voltage, so voltage doubling is always used in transformerless TV supplies. In fact, voltage triplers and even quadruplers are used.

Fig. 15A shows the usual voltage doubler, which operates like the one described earlier. When the source voltage makes terminal Y positive with respect to X, VT_1 conducts, charging C_1 to the source voltage with the polarity shown. When the polarity of the source reverses, the line voltage plus the voltage across C_1 are applied to VT_2, causing it to conduct and thus charging C_2 to about twice the line voltage. Since both C_1 and C_2 have relatively high capacities (120 to 150 mfd.), they are able to retain considerable charge and consequently remain fairly constant in voltage even when a certain amount of power is drawn from them.

The selenium rectifier circuit shown in Fig. 15B is exactly like the tube circuit in Fig. 15A in its operation. (The "arrow" of the selenium symbol corresponds to the tube plate; the "plate," to the tube cathode.) This latter circuit has been redrawn in Fig. 15C to show how it is usually represented in the schematic diagram of a set.

Incidentally, the ground symbol in these circuits represent the set chassis, not an actual ground. As in any a.c.-d.c. power supply, a condenser must be used between the chassis and any external ground as a protection in case the wrong side of the power line is connected to terminal Y.

Fig. 16 shows a somewhat more elaborate transformerless power supply in which two rectifier tubes and a selenium rectifier are used. With this arrangement, it is possible to get four different B voltages. One is the same

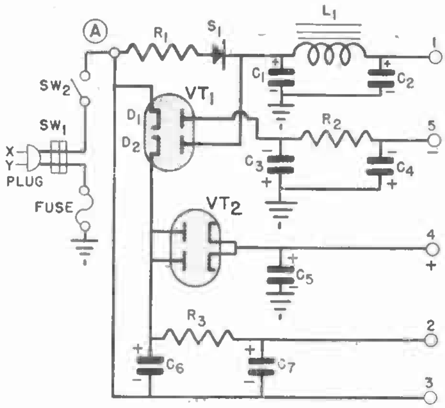

FIG. 16. A transformerless power supply that can furnish four different B voltages.

as the power-line voltage; the others are respectively twice, three times, and four times the line voltage. Each of these voltages can be fed independently to the circuits requiring it.

The selenium rectifier S_1 is used to provide half-wave rectification in the circuit from the power plug through R_1, S_1, and C_1 to ground, and thus back to the power line. The d.c. voltage developed across C_1 (which is approximately equal to the line voltage) is filtered by L_1 and C_2 to produce an output voltage across C_2 that is about equal to the line voltage.

There is also a connection from the junction of rectifier S_1 and condenser C_1 to the plate of diode D_2 of the rectifier tube VT_1. The cathode of this rectifier tube goes to an input filter condenser C_6, the other terminal of which is connected to one side of the power line. This is a voltage-doubler circuit: when the polarity of the power line voltage is such that terminal Y is positive with respect to X, the line voltage will add to the voltage across C_1 and charge condenser C_6 through diode D_2 to approximately twice the power-line voltage. The doubled output voltage across condenser C_6 is then filtered by the combination R_3-C_7 and appears between terminals 2 and 3.

On the next half-cycle, when X is positive with respect to Y, the power-line voltage will add to the voltage across C_6 to charge C_5 through VT_2 to three times the power-line voltage. This tripled voltage appears between terminal 4 and ground.

Finally, diode D_1 of VT_1 acts as a half-wave rectifier to permit condenser C_3 to charge directly from the power line. The voltage across C_3 is filtered by R_2-C_4 and appears between terminal 5 and ground. The connections are such that terminal 5 is negative with respect to ground. Therefore, the voltage between terminals 5 and 4 is equal to four times the line voltage. This quadrupled voltage is used for the sweep output amplifier in the electrostatic set using this supply.

Fig. 17 is a final example of an elaborate power-supply system. The trans-

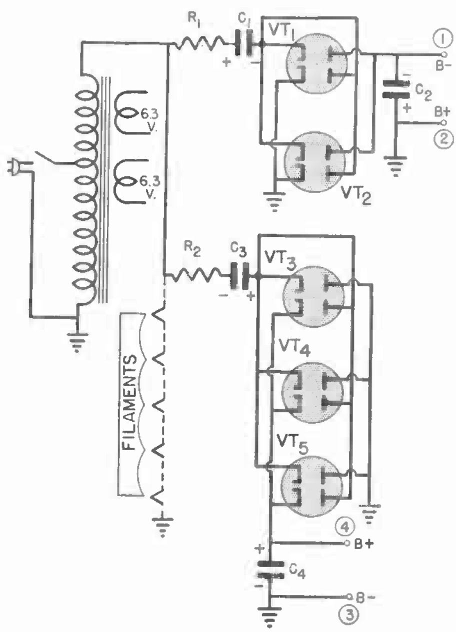

FIG. 17. A compromise power supply that uses an auto-transformer, principally to supply tube filament voltages.

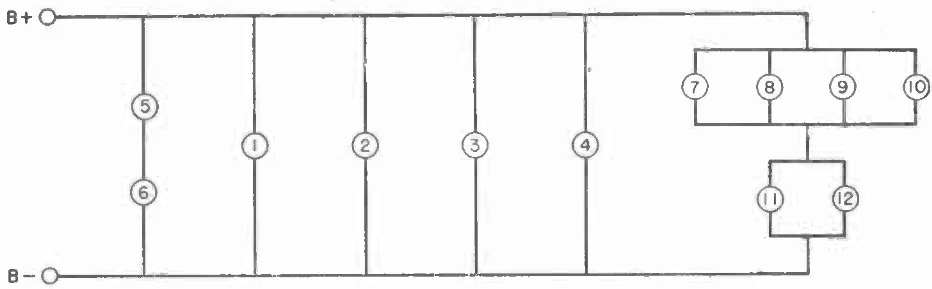

FIG. 18. Typical voltage distribution system used with a transformerless supply.

former used in this circuit is an auto-transformer, the output of which is only slightly higher than the power-line voltage. It is used primarily to supply filament voltages for the tubes in the set.

The upper two rectifiers act as a voltage doubler. One section of one tube is in parallel with a corresponding section of the other tube so that twice the current can be handled. On one half-cycle, condenser C_1 is charged; on the next, the voltage across C_1 adds to the line voltage and charges C_2 to twice the line voltage. Notice that the output voltage of this section of the power supply is negative with respect to ground.

The lower three tubes also make up a voltage doubler, this time with three sections—one of each tube—in parallel so that very high currents can be handled. This section supplies the normal B voltage to the receiver. Since its output is positive with respect to ground, a voltage equal to four times the line voltage is available between terminals 1 and 4 o. the supply.

B-Supply Distribution. Since the current available from any voltage-multiplier circuit is rather limited, it is common practice not to use a bleeder with transformerless supplies but to arrange the tube circuits insofar as possible to use the full output of the B supply. If some stages are to operate at lower voltages, the stages may be connected so as to divide the voltage between them, as shown in Fig. 18. Here, the stages numbered 1, 2, 3, and 4 are connected directly across the full B supply. Stages 5 and 6, however, are in series across the supply. This arrangement is permissible if the two stages are to operate from half the total supply and draw identical currents.

In the remainder of the circuits, the stages 7, 8, 9, and 10 are in parallel, and their currents flow through the stages 11 and 12. In this case, the plate current sum of the first four must equal that of the latter to give the proper voltage division.

Fig. 19 shows how two tubes may be connected in series across the power supply. In this case, the d.c. path, starting from B−, goes to the cathode of VT_1, then through this tube and its load resistor R_2 to the cathode bias resistor R_4 of VT_2. From here, the path is through tube VT_2 and its load resistor R_5 back to B+.

Fig. 20 shows a typical example of

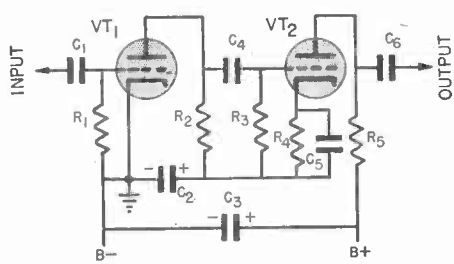

FIG. 19. How two tubes may be connected in series across the B supply.

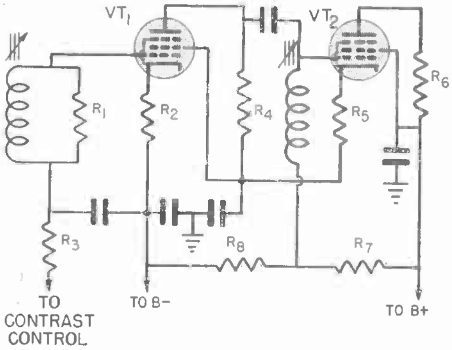

FIG. 20. An example of the use of the circuit shown in Fig. 19 in a practical receiver.

this kind of connection in the i.f. section of a TV receiver. Once again the two tube plate circuits are in series across the B supply. (Trace from B− through R_2, VT_1 R_4, R_5, VT_2, and R_6 to B+.) Notice that the contrast control is connected to the grid of VT_1. If you change the bias on this tube by changing the setting of the contrast control, the plate current through VT_1 will change. The plate current of VT_2 will then also have to change, since the two are in series, and the same current must flow through all the elements in a series circuit. Therefore, adjusting this control changes the current and hence the gain of two stages simultaneously.

FILAMENT DISTRIBUTION SYSTEMS

When a power transformer is used, the tube filaments are usually operated from filament windings, just as they are in standard radio receivers. When a transformerless type of B supply is used, on the other hand, the tube filaments are usually in some series-parallel arrangement so that they may be operated from the power line directly, as they are in a.c.-d.c. radios.

The power supply shown in Fig. 17 uses a compromise arrangement in which the filaments of all the tubes except the rectifiers are supplied from the 6.3-volt windings on the transformer. The five rectifier tubes, which have 25-volt filaments, are connected in series across the "high-voltage" winding of this transformer—which, in this case, is practically the same as connecting the five filaments in series across the power line.

Notice that the manufacturer has obviously made a compromise. He could have used rectifiers having higher current ratings had he wanted to use tubes with 5-volt filaments. Doing, so, however, would have made it necessary for him to have added another filament winding to the transformer; furthermore, he would have had to use a much larger transformer to take care of the extra power needed.

In those receivers that have no power transformer at all, the tubes are of course chosen to have the proper filament voltage and current ratings so that a reasonable filament string can be set up. Of course, it is impossible to connect so many tubes in a single string, particularly since the picture tube, which has a fairly high filament-current rating, must be in the string. Therefore, you will ordinarily find that the filaments are in some series-parallel arrangement such as is shown in Fig. 21. Here, five tubes in series with R_1 form one string, and and eight tubes plus R_2 form another. These two series strings both pass current through tubes VT_1 and VT_2. Tube VT_1 has a current rating twice that of any tube in the series strings so

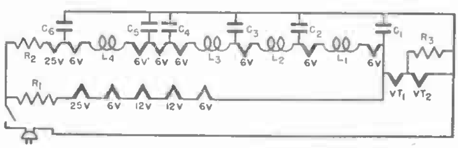

FIG. 21. Some series-parallel arrangement of this sort is always used in transformerless sets to supply the proper filament voltages.

that it can carry both currents. Tube VT_2 does not have as high a rating, so it is shunted by resistor R_3, which carries the extra current.

The resistors R_1 and R_2 have the proper resistances to reduce the supply voltage to the amount required by each series string. They also usually have a ballast action so that they will protect the tubes when the set is first turned on. This is necessary because the tube filaments have low resistance when cold, so a high current can flow through them until they warm up. If this were allowed to happen, the lives of the tubes would be shortened. To prevent it, the series resistors used are usually either ballast tubes or special "Globar" resistors so made that their resistances decrease as they get warm. The cold resistances of these resistors are high enough to limit the starting current to a safe value; then, as the tubes warm up, the resistances of the ballast resistors decrease enough to permit the filaments to get the proper currents. If these burn out, it is important to replace them with exact duplicates.

The by-pass condensers and r.f. choke coils shown in Fig. 21 act as filters on the r.f. and i.f. tube filaments to prevent stray coupling between stages along the filament leads.

The Sound Channel

In general, the sound channel of a TV receiver resembles very closely the i.f., detector, and audio portions of an f.m. sound receiver. There are some differences between them, however, which we shall now discuss.

First, let's make sure you understand the difference between the so-called "standard" or "conventional" and the "intercarrier" or "intermodulation" sound systems.

STANDARD RECEIVERS

Fig. 22A shows in block-diagram form the arrangement of stages in the standard TV receiver. In this set, the mixer-first-detector (or converter) produces two i.f. frequencies—a video i.f. carrier that is amplitude-modulated by the video signal and sync pluses, and an audio i.f. carrier that is frequency-modulated by the sound signal. The transmitter radiates two separate carriers with these modulations, and the local oscillator beats with both to produce the two new i.f. carriers. The sound i.f. carrier is 4.5 mc. *below* the video i.f. carrier when the oscillator is above the frequency of the incoming signal, as it is in most receivers. If, for example, the video i.f. carrier is 25.75 mc., the sound carrier will be 21.25 mc. In most modern TV receivers the video carrier is somewhere between 25 and 46 mc., and the sound carrier is therefore somewhere between 21 mc. and 42 mc.

Since the sound and video carriers

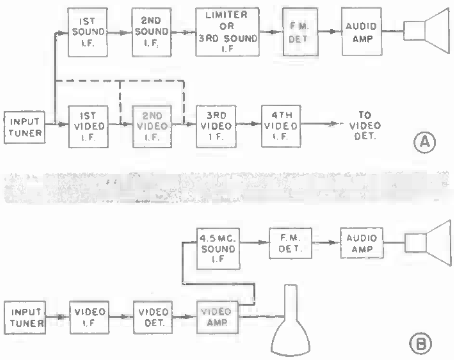

FIG. 22. Block diagram of a standard TV receiver (A) and of an intercarrier set (B).

are two entirely separate signals, the two can be separated by tuned circuits. In some sets, the sound take-off point is right at the output of the converter. However, if greater gain is desired, the sound may be taken out after the first or second video i.f. amplifier, in which case these stages must have a sufficiently broad response to handle both carriers.

After the sound i.f. is removed from the video i.f. path, it is applied to a regular i.f. amplifier having a pass-band of about 300 kc. Usually, there are two sound i.f. amplifier stages, followed by one or two limiter stages, the latter of which feeds into a discriminator. In some sets, a ratio detector is used instead of a discriminator, in which case the limiter stages may be converted into regular sound i.f. amplifiers or may be missing altogether. In general, however, there will be at least three stages in the sound i.f. portion of the set, including the limiter (if one is used).

From the discriminator, the sound signal passes through a normal two-stage audio amplifier before being applied to the loudspeaker. The power output stage may be push-pull in the larger sets.

INTERCARRIER SYSTEM

At first glance, the only difference between the intercarrier system shown in Fig. 22B and the "standard" shown in Fig. 22A appears to be that the sound take-off is at the output of the video amplifier in the former. Actually, in the intercarrier system, there is rarely more than one stage in the sound i.f. portion, which is why the circuit is popular with the manufacturers of smaller receivers.

In the intercarrier system, the two carriers pass through the video i.f. amplifier together. When both are applied to the video detector, a beat of 4.5 mc. occurs between the two carriers. This difference frequency is frequency-modulated by the sound signal and somewhat amplitude-modulated by portions of the video signal. This new 4.5-mc. carrier then passes through one or more stages of the video amplifier. At some point, it is trapped out of the video path and applied to the 4.5-mc. sound i.f. section. The sound i.f. is tuned to 4.5 mc. regardless of the video and sound i.f. carrier frequencies. This 4.5-mc. signal with its complex modulation is amplified by the sound i.f. and then fed to either a discriminator or a ratio detector. Here any amplitude modulation is wiped out, with the result that only the frequency modulation produces an audio signal. (Of course, if any stage in the chain handling the 4.5-mc. signal is overloaded by this or any other signal, cross-modulation products will be set up with the result that some of the video modulation may cause a hum from the loudspeaker.)

The audio amplifier used with the intercarrier system is just like that found in the standard system.

To sum up, the major differences between the standard receiver and the intercarrier type are:

1. In the standard receiver, the sound take-off point is in the video i.f. amplifier, either immediately following the converter or after the first or second video i.f. amplifier stage. In the intercarrier system, the sound take-off is in the video amplifier.

2. In the standard receiver, the sound i.f. amplifier is tuned to a frequency 4.5 mc. below that of the video i.f. amplifier. There are usually two amplifying stages followed by a limiter or two in the sound i.f. section. In the intercarrier system, the sound i.f. amplifier is tuned to 4.5 mc. and rarely has more than one stage.

3. Since the video section of a set

using the intercarrier system handles the sound signal also, it must have a greater band width than is necessary in a standard set.

Whether the standard or the intercarrier system is used, the sound signal must be kept out of the picture as much as possible. In the standard set, the video i.f. stages following the point of sound take-off always have one or two sound i.f. traps. These traps, which are tuned to the sound i.f. frequency, are intended to attenuate the sound signal so that very little of it will reach the video detector. If even a small portion does reach the video detector, the 4.5-mc. beat that is a characteristic of the intercarrier system will be produced, and in addition, because of slope detection in the video detector, the sound modulation will be converted into an amplitude signal. Both these signals can appear in the picture. The 4.5-mc. beat will produce a very fine-grained dot pattern, and the audio signal will produce bars across the picture. Some sets have a 4.5-mc. trap in the video amplifier to remove the 4.5-mc. "grain" pattern.

In spite of the sound i.f. traps, the sound signal may reach the detector if the set is not properly tuned to the station or the circuits are out of alignment. This is why sound bars show up when the fine tuning control is improperly set.

In the intercarrier system, 4.5-mc. grain traps are usually found at or following the point of the sound i.f. take-off. Some of the small (7") sets using the intercarrier system do not use grain traps, since the fine-grained pattern produced by the 4.5-mc. beat is not too apparent at the normal viewing distance for a 7" tube.

PRODUCING THE INTERCARRIER BEAT

The f.m. detector is supposed to remove all amplitude variations from the i.f. beat signal produced in the intercarrier system. To make it easier for the detector to do so, the amplitude modulation in the beat signal is kept as small as possible. This is done by taking advantage of two facts:

1. When two signals are allowed to beat together, and one signal is very much weaker than the other, the amplitude of the beat signal is approximately equal to the amplitude of the weaker signal and practically independent of the amplitude of the strong signal.

2. If either of two beating signals is frequently-modulated, the complete frequency modulation appears in the beat signal.

These characteristics of beat signals are made use of in the intercarrier system by reducing the strength of the sound i.f. carrier so that it is far weaker than the video i.f. carrier when the two signals are applied to the video demodulator. As a result, the 4.5-mc. beat has the full f.m. or sound modulation but very little amplitude modulation from the picture signal.

The sound i.f. carrier can be reduced to the desired strength (about 5% or 10% of the video i.f. carrier strength) in an intercarrier set by using video i.f. stages having the response shown in Fig. 23A. Notice that this response has a small flat plateau around the sound i.f. carrier frequency; as a result, there is little possibility of slope detection of this carrier and consequently little chance of cross modulation. The shape and amplitude of the response at this frequency are determined by the alignment of the i.f. amplifier and by the judicious use of traps. These traps are not tuned directly to the sound carrier; instead, they are tuned near and to either side of it to produce the desired response.

Because of the difficulty of securing the response shown in Fig. 23A, the

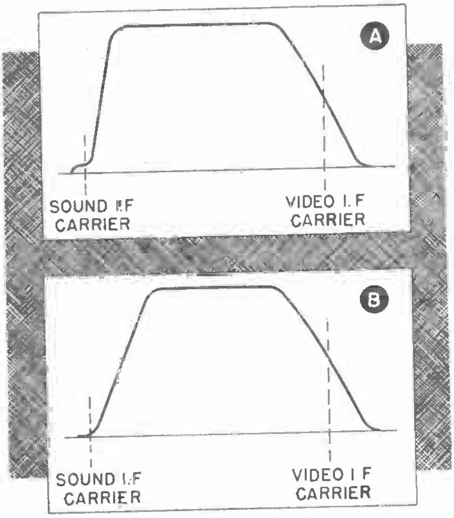

FIG. 23. The ideal video i.f. response of an intercarrier set is shown in part A. The response shown in part B is more commonly used in practice.

one pictured in Fig. 23B is more commonly used in intercarrier sets. There is no plateau at the sound-carrier frequency in this latter; instead, the response is merely made low at this frequency. Cross modulation can therefore occur in a set in which this arrangement is used.

Since the sound i.f. carrier is held at a fairly low value in passing through the i.f. section in the intercarrier system, most of the amplification it is to get must be received in some later section. Usually the video amplifier is used to furnish the desired gain so that it will not be necessary to add a stage to the 4.5-mc. amplifier.

There are a few disadvantages to the intercarrier system that have limited its acceptance. One is that during bright portions of a picture, the video carrier is low, with the result that more of the picture signal gets mixed with the audio signal. During such bright portions or during any overmodulation of the picture signal, therefore, the sound signal may have hum in it. It will be basically a 60-cycle hum, since 60 cycles is the frame repetition rate of the picture signal, and the effect causing the hum occurs in each frame.

Another disadvantage is that if the picture carrier disappears at any time because of difficulty with the picture at the transmitter, the sound will automatically disappear too.

Furthermore, the picture contrast control will also control the sound level. This is not desirable, but there is no easy way to avoid it unless the set has a.g.c., in which case the contrast control can perhaps be placed in a video stage beyond the point of sound take-off.

An advantage of the intercarrier system is that it is far less subject to difficulty because of oscillator drift than the standard system is. In the conventional system, any considerable drift in the oscillator frequency may shift the sound i.f. outside the pass band of the sound i.f. section, distorting the sound or wiping it out altogether. If this occurs, it will be necessary to retune the oscillator, which is done either by adjusting the fine tuning control or by realigning the receiver.

In the intercarrier system, the 4.5-mc. sound i.f. is not produced by the local oscillator. The only thing that an oscillator shift can do is change the relative levels of the sound and video i.f. carriers to such an extent that the sound signal may have an undesired amount of video signal in it; or, if the shift is very large, the sound beat signal may become somewhat weakened. In general, however, the oscillator can drift far more in an intercarrier system than it can in the conventional system before the sound signal is upset to any great extent.

Now that you have a general understanding of the two systems, let's look at the circuits in a little more detail.

TYPICAL CONVENTIONAL SOUND I.F. SYSTEM

In the conventional system, as we have said, the sound i.f. is extracted from the video signal path either immediately following the converter stage or after the first or the second video i.f. stage. It is taken off by inserting a trap circuit tuned to the sound i.f. in the video signal path and using the signal developed across this trap at the source for the first sound i.f. stage.

Sound Take-off. Fig. 24 shows several different sound take-offs. In the arrangement shown in Fig. 24A, the sound trap L_2-C_2 is tuned to the sound i.f. carrier frequency. This trap is coupled to the coil L_1, which is the plate load for the mixer stage and resonates with distributed circuit capacities. The resonant circuit L_2-C_2 absorbs a considerable portion of the sound carrier energy that is in the plate circuit of the mixer and therefore reduces the amount of the sound signal that is applied to the video i.f. stages.

To have the greatest effect, this trap circuit should have a high Q, so it must be loaded as little as possible by the grid circuit of the first sound i.f. amplifier, to which it is connected. This loading is minimized by taking the input for the sound i.f. stage from a tap on the coil.

The arrangement shown in Fig. 24B is somewhat similar. Here, the trap L_5-C_5 is coupled to the primary circuit L_3-C_3 and once again absorbs the sound signal. The video signal is passed on through L_4-C_4.

In the arrangement shown in Fig.

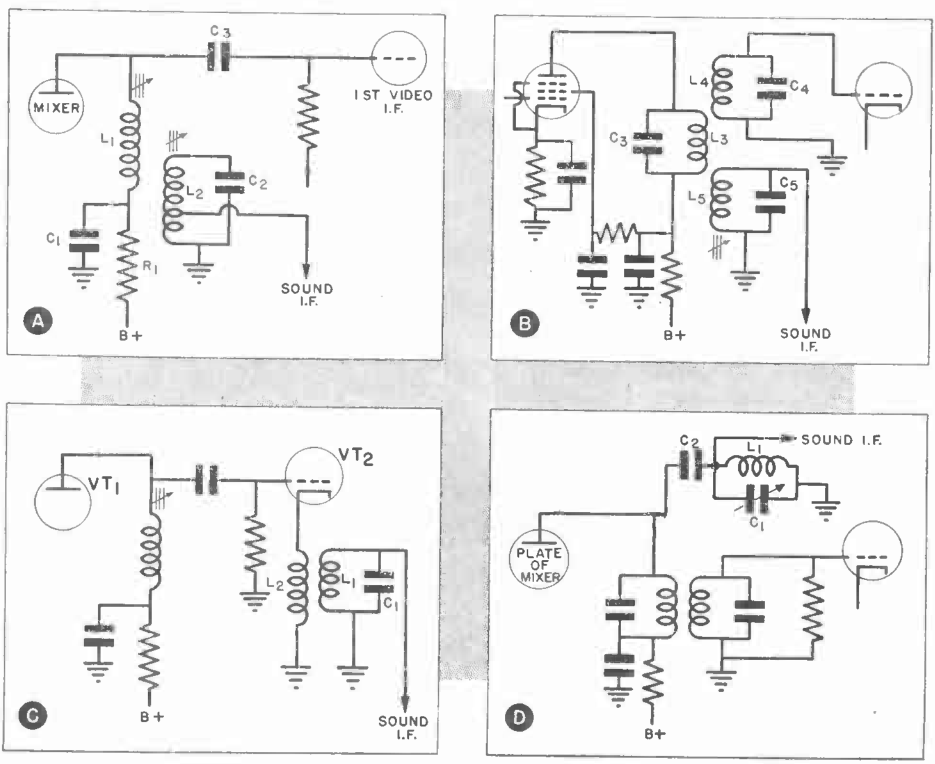

FIG. 24. Various sound take-off systems used in conventional TV sets.

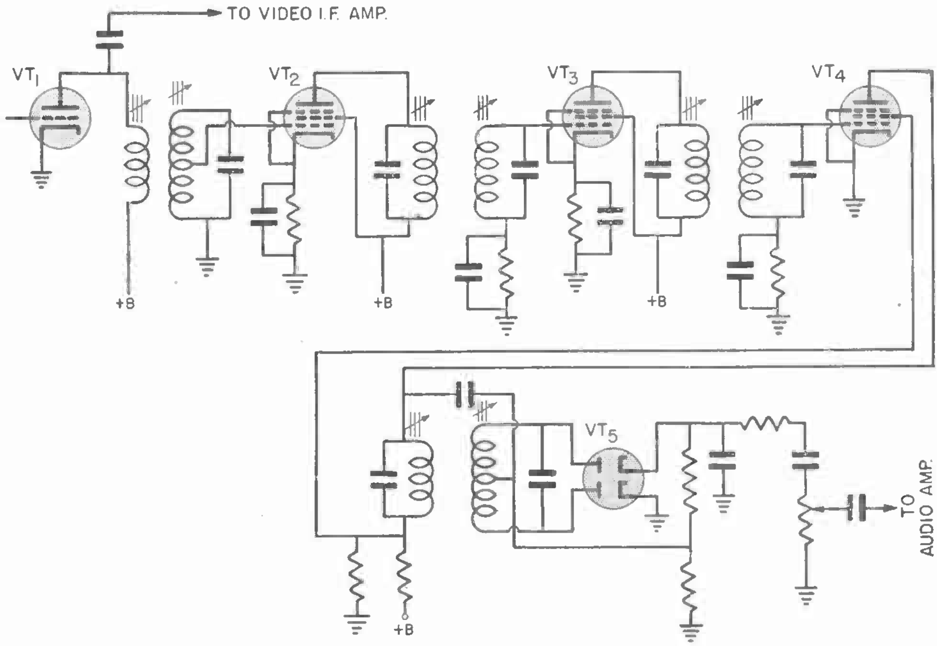

FIG. 25. Typical 3-stage sound i.f. system used in conventional sets.

24C, the sound trap L_1-C_1 is coupled to coil L_2, which is in the cathode circuit of VT_2. The resonant circuit extracts the sound i.f. signal. Further, the reflected effect of this circuit makes L_2 a fairly high resistance for 4.5-mc. signals. There is therefore an appreciable drop across L_2 at the beat-signal frequency. Since L_2 is in the cathode circuit of VT_2, this drop produces degeneration; as a result, only a minimum of the 4.5-mc. audio signal is passed on to the following video stages.

The arrangement shown in Fig. 24D is somewhat similar to that in B, except that the trap L_1-C_1 is capacitively coupled through C_2 to the plate tank coil instead of being inductively coupled to it.

Notice that two desirable effects are produced in each of these circuits when the sound take-off trap is properly resonated: 1, a maximum sound signal is fed to the sound i.f. stages; and 2, a minimum sound signal is passed on to the succeeding video i.f. stages.

If the sound take-off point is at the output of the mixer or after the first video i.f. stage, three or four sound i.f. stages are always used. If the take-off point is beyond the second video i.f. stage, however, one less sound i.f. stage may be used.

Sound I.F. A typical conventional 3-stage sound i.f. system is shown in Fig. 25. Here, tubes VT_2 and VT_3 are the sound i.f. amplifiers, feeding through band-pass tuned circuits that are 200 kc. to 300 kc. wide. (If the signal for this sound i.f. section is taken from the second video i.f. stage, one of these amplifiers will probably not be used.) Tube VT_4 is a limiter stage of the sort used in most f.m. receivers that use a discriminator as the video detector. Tube VT_5 is the discriminator. Both the limiter and the discriminator will be described briefly later in this text.

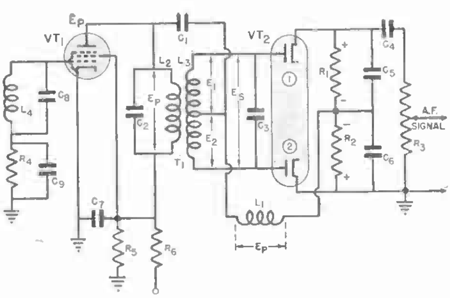

FIG. 26. Schematic diagram of a typical f.m. limiter-discriminator section.

A ratio detector is used in some receivers instead of the limiter-discriminator combination. We shall describe this detector in a moment.

Limiter. Let's review the action of a limiter and a discriminator very briefly, using the typical circuit shown in Fig. 26. (This will be a quick review of a rather complicated subject: if you do not understand it all, read the earlier sections of your Course in which this circuit is described in detail.) Here, the VT_1 stage is much like any other i.f. amplifier stage except that the bleeder resistor R_5 and the series resistor R_6 make the screen grid and plate voltage on this stage very low—only about 48 volts. These low operating voltages make the upper knee of the characteristic response of this stage very low and sharp.

The grid circuit contains the grid leak and condenser combination R_4-C_9. Condenser C_9 tends to keep charged to the average voltage of the peaks of the input signal, thus maintaining a steady bias on the tube that will keep its output constant even if the input signal undergoes sudden momentary changes in amplitude. This condenser therefore minimizes the effect of noise when the signal is weak.

When the signal is strong, the low voltages applied to the screen and plate effectively wipe out amplitude changes in the input signal. Because these voltages are so low, the output of the stage will not go above a certain limit no matter how strong the input signal becomes. Thus, if the strength of the f.m. signal is great enough to drive the stage to its full output, any increases in signal strength caused by noise accompanying the f.m. signal will not affect the output. In other words, the noise will be wiped out by the limiter stage. (In an intercarrier system, this limiting action will also tend to wipe out any portions of the video signal that may accompany the sound carrier.)

Discriminator. The transformer T_1 transfers the signal from the limiter VT_1 to the discriminator circuit, in which tube VT_2 is used. The primary circuit L_2-C_2 is tuned to the incoming signal. This signal is transferred to the tuned secondary circuit L_3-C_3 and is also fed through C_1 so that it appears across L_1.

The voltage induced in L_3 produces the voltages E_1 and E_2 across the two sections of this coil. These voltages are always equal in magnitude and 180° out of phase with each other.

The voltage applied to diode 1 of VT_2 consists of E_1 plus the signal E_p that exists across L_1. (The path from L_1 to the cathode of this diode is through the by-pass condenser C_5, which is virtually a short at the frequencies involved.) Similarly, the voltage applied to diode 2 of VT_2 consists of E_2 plus E_p, the path being completed through by-pass condenser C_6. At resonance and with no modulation, therefore, equal voltages are applied to the diodes; as a result, equal and opposite currents flow through the resistors R_1 and R_2. The voltage between the two cathodes of VT_2 is zero under such conditions.

Off resonance (that is, at frequencies other than the resting or no-modulation frequency), however, the voltages applied to the two diodes are not equal. When the applied signal swings below the setting frequency, the voltage applied to diode 1 of VT_2 becomes greater than that applied to diode 2; consequently, a greater current flows through R_1 than flows through R_2. As a result, the voltage drops across the two resistors become unequal, and a net voltage appears across them that has the same polarity as the drop across R_1. Conversely, when the applied signal swings above the resting frequency, a net voltage appears across R_1 and R_2 that has the polarity of the drop across R_2.

Thus, swings of the applied signal above and below the resting frequency produce an a.c. voltage across R_1-R_2. This voltage feeds through C_4 to appear as the output voltage across R_3. At each instant, the value of this output voltage is proportional to the deviation of the incoming signal frequency from the resting frequency. Thus, it is an audio signal voltage that corresponds to the one used to modulate the f.m. transmitter.

THE RATIO DETECTOR

Some manufacturers prefer to eliminate the limiter circuit and instead use detector circuits that are themselves insensitive to amplitude variations. The only circuit of this kind that is found commonly in television sound systems is the ratio detector. Fig. 27 shows a typical example.

At first glance, this circuit is very similar to that of the discriminator, you have just studied. However, there are two important differences—one of the diode tubes is reversed, and a charge storage condenser C_4 has been added to the circuit.

At the resting frequency, the voltage E_p adds to E_1 and to E_2 to make both diodes conduct equally, just as in the discriminator. Because of the way

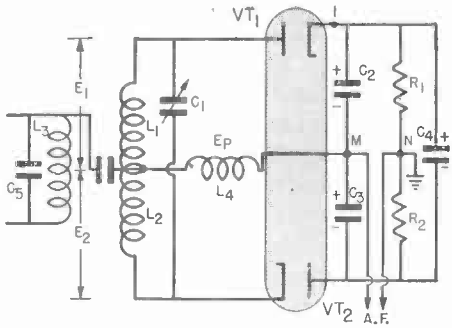

FIG. 27. A typical f.m. ratio detector.

they are connected, both diodes conduct at the same time, charging the equal condensers C_2 and C_3 to the polarities shown. At the same time, condenser C_4 is charged to a voltage that is equal to the *sum* of the voltages across C_2 and C_3.

The size of condenser C_4 is such that the voltage across it cannot change very fast. As a result, the voltage at the midpoint N of the voltage divider R_1-R_2 will remain relatively constant at a voltage equal to half that across C_4.

To take an example, let's assume that the voltage across C_4 is 10 volts, and that only the resting frequency is being applied. In this case, the voltages across C_2 and C_3 will each be 5 volts, so point M will be 5 volts negative with respect to point 1, which we will take as a reference point. Since point N will also be 5 volts negative with respect to point 1, there will be no net voltage difference between points M and N, as shown in Fig. 28A.

Now let's suppose that the incoming signal varies in frequency. When it shifts in one direction, one diode will conduct more than the other, so that the instantaneous voltages across condensers C_2 and C_3 will no longer be equal. However, their sum will remain that of the charge across C_4—namely, 10 volts—because the voltage across C_4 cannot change readily. Let's assume that diode VT_1 momentarily conducts more current so that the voltage across C_2 goes up to 8 volts, and the voltage across C_1 drops to 2. There will now be a voltage difference of 3 volts between points M and N, as shown in Fig. 28B, because the voltage between point 1 and point M has changed, while that between point 1 and point N has not.

When the incoming frequency swings in the other direction, the opposite action will occur—the voltage across C_3 will become greater and that across C_2 will become less. As a result, the voltage relationship shown in Fig. 28C will be produced.

The voltage difference between points M and N will therefore be an a.c. signal whose amplitude depends on the amount the incoming signal deviates from the resting frequency and whose frequency depends on the rate at which the deviation occurs. In other words, it will be a reconstruction of the audio signal that was originally used to modulate the f.m. carrier.

This circuit will not respond to amplitude variations in the input signal, because such changes will merely make both diodes conduct either more or less without making them conduct unevenly. As we have seen, the diodes must conduct different amounts of current to make any voltage difference appear between points M and N, and this difference in their conduction can be produced only by a change in the frequency of the applied signal. Therefore, any amplitude variations caused by noise or a video signal accompanying the f.m. signal will not appear in the output of the circuit.

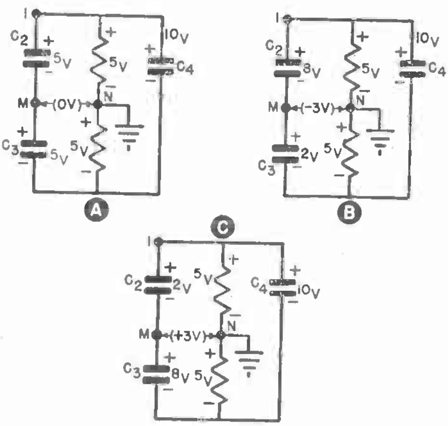

FIG. 28. This series of diagrams shows how a ratio detector works.

INTERCARRIER SOUND I.F. SYSTEM

When the intercarrier system is used for the sound, the 4.5-mc. beat can be taken right from the output of the video detector, but since it is necessary to increase the strength of the signal, the usual practice is to take this signal from the output of the video amplifier. Trap circuits are commonly used as sound take-offs.

Various forms of trap take-offs are shown in Fig. 29. In the simplest (Fig. 29A), a parallel resonant circuit L_2-C_2 tuned to the 4.5-mc. carrier is placed in the grid circuit of the sound channel amplifier VT_2 and is fed through coupling condenser C_1 from the plate of the video amplifier VT_1.

A disadvantage of this arrangement is that it does not reduce the amount of the 4.5-mc. carrier in the video signal. The circuit shown in Fig. 29B is more satisfactory in this respect. Here, the coupling condenser C_1 resonates with coil L_2 to form a series resonant circuit at 4.5 mc. At resonance, this circuit offers a minimum load for the video amplifier VT_1, so the output of VT_1 at the 4.5-mc. carrier frequency is minimized. On the other hand, since this is a series resonant circuit, whatever 4.5-mc. signal does appear across it will produce a maximum voltage across L_2 for application to the sound amplifier.

The arrangement shown in Fig. 29C also minimizes the amount of the beat

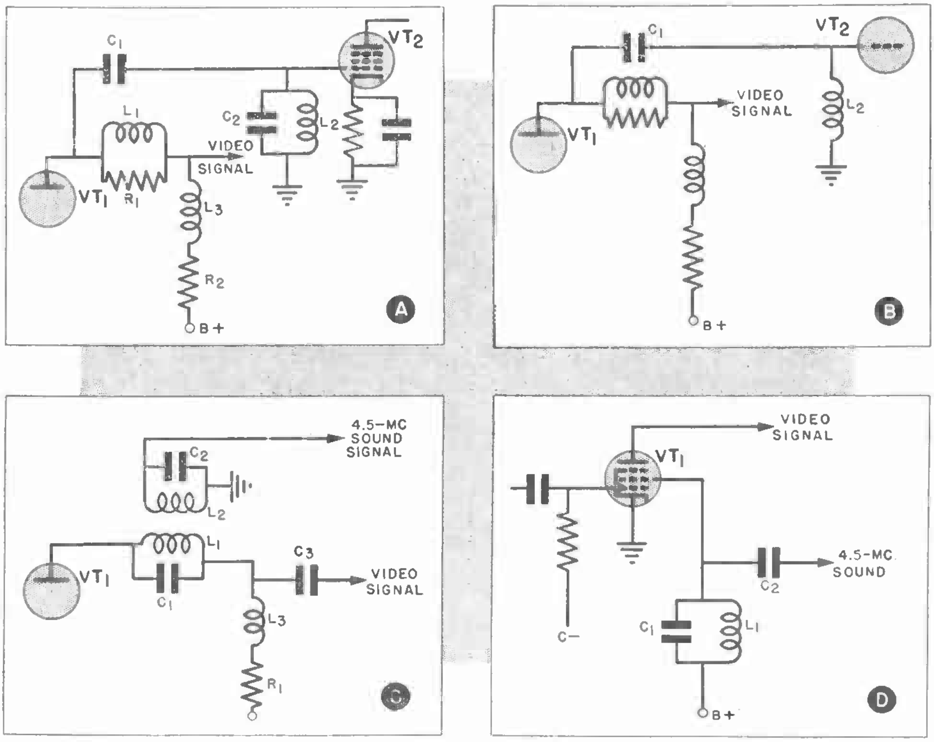

FIG. 29. Various kinds of sound take-off circuits used in intercarrier sets.

signal in the picture signal. Here, a parallel resonant circuit tuned to 4.5 mc. is connected in series with the load circuit of VT_1. Most of the 4.5-mc. beat signal in the output of VT_1 is developed across this circuit, so very little is passed on through C_3 with the video signal. The sound carrier is fed to the sound amplifier from the resonant circuit L_2-C_2, which is tuned to 4.5 mc. and inductively coupled to L_1-C_1.

In the arrangement shown in Fig. 29D, the take-off circuit is in the screen-grid circuit of one of the video amplifier stages. It is possible to take the sound from here because any signal in the plate circuit also exists in the screen circuit. (Ordinarily, of course, we get rid of the signals in the latter circuit by by-passing the screen grid.) With this arrangement, there is a minimum of interaction between the sound and video circuits.

When the take-off systems shown in Figs. 29A and 29D are used, grain traps that are tuned to 4.5 mc. are needed in the stages following the sound take-off points to reduce the effects on the picture of this 4.5-mc. beat signal.

As we mentioned earlier, the 4.5-mc. sound amplifier in the intercarrier system usually consists of only a single stage (tuned to 4.5 mc. but otherwise like a conventional sound i.f. stage). It is usually followed by a ratio detector; if not, the single stage is adjusted to act as a limiter, and a discriminator is used.

In all TV sets, the sound detector is followed by a standard audio system. This is usually a high-gain audio voltage amplifier followed by a single-ended or push-pull pentode power amplifier that feeds the loudspeaker. These stages are identical with those found in the better sound receivers.

Automatic Gain Control

All TV receivers require a gain control, just as a sound receiver needs a volume control, because the signals from different stations are likely to be of different strengths at the receiving location. Within the range of normal signal levels, adjusting the gain of a TV set affects the contrast (range of grays from white to black), so the TV gain control is known as the "contrast" or "picture" control.

Since most of the video gain is obtained in the video i.f. amplifier, these stages are the logical ones in which to control the gain. The simplest contrast control is an adjustable bias on two or three of the video i.f. stages. This can be either a self-bias or a bleeder bias arrangement, as shown in Figs. 30A and 30B. It may not be possible to use this system to control very strong signals, however, because if the bias on the i.f. stages is increased too much, the stages may be operated so near cut-off that distortion will be introduced. Therefore, it is desirable to control the gain of the r.f. stage also on very strong signals. The gain of the r.f. stage should not be reduced on normal signals, however, because the r.f. gain is needed to overcome converter noise.

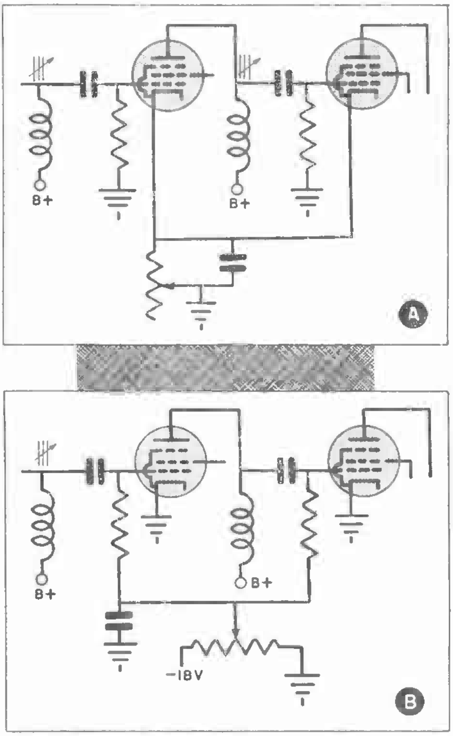

FIG. 30. Two ways of adjusting the bias on video i.f. stages to control the video gain.

In general, it is desirable to have an arrangement that permits the bias to increase first on the i.f. stages, then, as the overload level is approached, to increase on the r.f. stage. Manufacturers differ in the ways they arrange controls to achieve this—some use dual controls, others use voltage dividing and bleeding arrangements. Fig. 31 shows one example.

The i.f. bias network is shown in Fig. 31A. Basically, this consists of a bleeder R_1, R_2, and R_3 arranged across a C-bias section of the bleeder resistor in the power supply. The bias applied to the i.f. grids is adjusted by the setting of R_2—as the slider is moved to the right in this figure, the bias becomes more negative.

The voltage divider R_4-R_5 is arranged so that the i.f. grid bias can never be as much as the total voltage across R_2, for reasons that we shall explain shortly.

The complete biasing arrangement that also supplies bias to the r.f. grid circuit is shown in Fig 31B. When the slider on R_2 is at the left, so that there is little bias applied to the grids of the i.f. tubes, the diode VT_1 conducts heavily because a positive voltage is applied to it from the B+ source

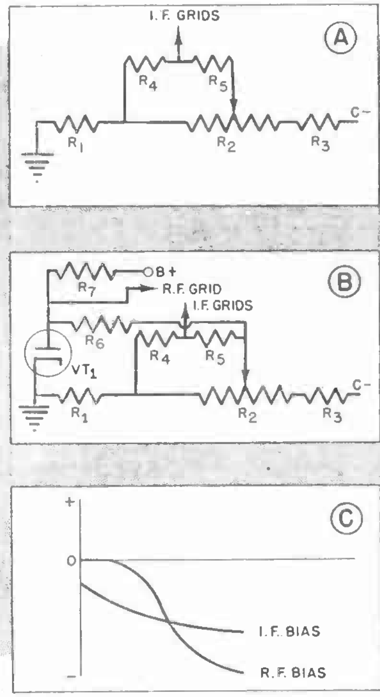

FIG. 31. These drawings show the workings of a contrast control that affects the bias on both the r.f. and video i.f. stages.

through R_7. Since R_7 is a high resistance compared to the diode resistance, there is very little voltage drop across the diode, so the grid of the r.f. tube (which is connected to the plate of VT_1) is effectively at ground potential and has practically no bias.

As the setting of R_2 is changed, however, the negative voltage across R_2 is applied to the diode. Eventually, this voltage will cancel that applied from the B supply; the diode will then cease to conduct. When this happens, the grid of the r.f. tube will be tied through R_6 directly to the slider in R_2, and the full voltage at that setting of R_2 will be applied to this grid. As the slider is moved more to the right, as it must be if the strength of the incoming signal is high, the bias on the grid of the r.f. tube will become greater than the bias applied to the i.f. tubes; in fact, it will approach the cut-off bias for the r.f. tube rather rapidly.

The manner in which the two bias voltages vary is shown in the curves in Fig. 31C. As you can see, the i.f. bias increases gradually and steadily with the rotation of the contrast control. The r.f. bias is zero for a time, then increases rapidly with further rotation of the control. Thus, it is possible to arrange the circuit so that overloading can be prevented, yet at the same time to keep the r.f. gain at maximum until it is necessary that it be reduced.

Although this contrast control arrangement permits the gain to be adjusted manually, there are a number of good reasons why an automatic, self-adjusting control would be better. For one thing, it is annoying to have to readjust the contrast control every time a new station is tuned in. More important, many receiver owners find it difficult to set the control properly. This means that the receiver must be designed so that the video and sync circuits following the i.f. stages will be capable of operating from signals that may not be of the optimum strength, which calls for design compromises. Also, although we do not have the fading with TV signals that is common in distant a.m. reception, we can have a variation in signal due to swinging antenna and transmission lines. Finally, the TV signal may at times undergo violent fluctuation because airplanes or moving automobiles happen to pass through the signal transmission path.

For all these reasons, it is desirable to put into the TV set an automatic gain control (a.g.c.) system, comparable to the a.v.c. system of an ordinary radio, that will arrange the gain of the set so that the signal fed to the video detector will be relatively constant under all normal conditions. When such a system is used, resetting the contrast control is an infrequent and simple operation.

Let's see how practical a.g.c. systems work in TV receivers.

BASIC A.G.C.

An a.g.c. system must operate from some component of the signal that is proportional to the strength of the carrier, since it is the carrier strength at any moment that determines what the gain of the set should be at that moment. The only part of a TV signal that meets this specification is the height of the sync pulses. These extend upward from the no-signal or black level pedestal by a fixed percentage of the carrier strength. (This percentage may be different for different transmitters, but is always the same for one transmitter.) If the carrier strength changes, the amplitudes of the peaks of these sync pulses from the black level and from the zero level will change proportionately.

There are two ways in which we can get a signal voltage from the sync pulses that we can use for a.g.c. One way is to strip the sync pulses from the video signal and use the pulses themselves, depending on the fact that their amplitude is proportional to that of the carrier. The other way is to use the peak value of the sync pulses above the zero level, since the height of these peaks is also proportional to the carrier amplitude.

Of course, the sync pulses exist during only a small fraction of the whole TV signal. If the pulses are to furnish a control voltage, therefore, we must find some way to make their effect last from at least one pulse to the next. This is most easily done by using the pulses to charge a condenser in an R-C network.

A simple a.g.c. circuit that uses the peaks of the sync pulses is shown in Fig. 32A. This consists of a diode rectifier with a time constant filter C_1-R_2.

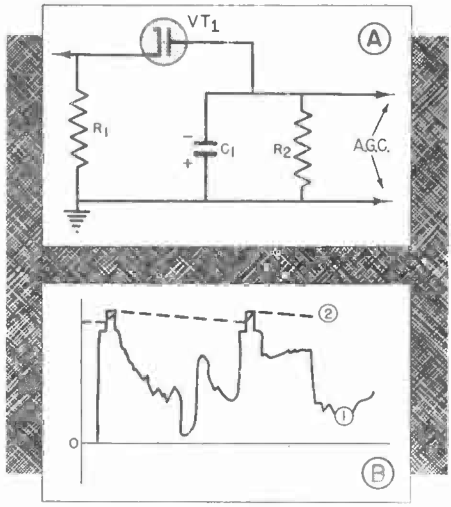

FIG. 32. A simple a.g.c. system.

When a TV signal like that shown by curve 1 in Fig. 32B is applied to R_1, VT_1 conducts whenever the signal exceeds the charge stored in C_1. Since the diode then has low resistance, C_1 charges rapidly up to the peak voltage of the sync pulses during the time that VT_1 conducts.

When the signal swings below the peak level, C_1 must then discharge through R_2. This discharge is slow, since R_2 has a high resistance—so slow that C_1 discharges very little during the period of one line. At the end of this line, another sync pulse recharges C_1 at once to the full peak voltage. Therefore, the voltage across C_1 follows curve 2 in Fig. 32B, and, as you can see, remains nearly at the peak value at all times.

We can use the voltage across C_1 as an a.g.c. voltage by applying it to the video i.f. stages as a bias. When we do so, the bias on these stages will be proportional to the strength of the carrier; it will increase on strong signals and decrease on weak ones, thereby varying the gain so that the signal applied to the video detector will be very nearly constant.

Selecting the proper time constant for the R_2-C_1 circuit in Fig. 32A is somewhat of a problem. There are reasons for making it short and others for making it long. If we make it short (that is, use a value of R_2 that will permit C_1 to discharge fairly rapidly), the circuit will be able to follow more rapid fluctuations in the signal and will offer more freedom from noise interference than it will if we make the time constant long. On the other hand, a short time constant may make the set lose vertical sync. Let's see why these effects can occur.

First, let's suppose a sharp noise pulse that is higher than the peak of the sync pulse is received. The gain of the set will automatically and suddenly be reduced by the a.g.c. circuit. If the time constant is long, C_1 will hold its high charge for several lines, during which time the gain of the set will be reduced. Therefore, the use of an a.g.c. circuit having a long time contant means that there will be "holes" (large blacked-out areas) in the picture when noise is present, whereas the picture on a set with a manual contrast control would show nothing more than nearly un-noticeable short black streaks under the same conditions.

Suppose, on the other hand, that we make the time constant quite short. Condenser C_1 will then discharge considerably in between the horizontal sync pulses, so the average a.g.c. voltage (the voltage across C_1) will be relatively low. When a vertical sync pulse (which is much broader than a horizontal pulse) is received, however, C_1 will be charged for a much longer time than it is during the horizontal pulses; consequently, the average voltage across C_1 will increase during the vertical pulse. This means that the gain of the set will be reduced during the vertical pulse, an effect that may make the set lose vertical sync.

Since synchronization is extremely important, a simple a.g.c. system like this is usually made slow-acting (that is, given a long time constant). Such a system will compensate for signal changes like those produced by switching stations, but cannot take care of rapid fluctuations, and of course is extremely poor when noise is present. Therefore, it is not used much; instead, more elaborate systems that are not bothered excessively by noise and do not interfere with the vertical sync are preferred. Before we discuss these circuits, let's see where the a.g.c. system normally gets its signal and what is done with the control voltage produced.

Obviously, the a.g.c. rectifier can be connected to the output of the video detector. However, it is undesirable to load the video detector circuit or to shunt it by the capacities of the tube used in the a.g.c. circuit, so a connection farther along in the video amplifier is often preferred. An important point is that we must obtain the signal from a point where it has its normal d.c. level so that the pedestals will be lined up (since otherwise the peaks of the sync signals will not be proportional to the carrier strength). If we use an a.c. coupling, a d.c. restoration circuit must be incorporated in the a.g.c. circuit or used ahead of the a.g.c. rectifier.

The d.c. voltage that is obtained as a result of the a.g.c. action is usually applied as a bias to the i.f. amplifier stages, appropriate R-C decoupling networks being used to prevent coupling between the stages. The signal may also be applied to the r.f. stage ahead of the converter, in which case some arrangement is generally used so that the bias applied to the r.f. stage will be unaffected on weak signals but will increase rapidly on strong signals.

There is usually some control in the

a.g.c. network to set the threshold beyond which it operates. This may be the contrast control for the set or may be a separate non-operating control mounted at the rear of the set.

In the latter case, a contrast control is used in the video amplifier at some point beyond the take-off point for the a.g.c. voltage. This is generally a control that can be used to vary the bias on one video stage by a limited amount. When this arrangement is used, the a.g.c. system is adjusted to deliver normal signal to this stage; the contrast control can then be used by the set owner to adjust the picture to the contrast he wants. It should not be necessary to use the control to prevent overloading or to compensate for changes in signal strength.

NOISE LIMITER A.G.C.

One way of getting the proper a.g.c. action and a certain amount of freedom from noise at the same time is to use a limiter circuit in the a.g.c. When a system of this sort is properly arranged, the a.g.c. circuit responds to normal signal levels, but any very sharp and sudden increase is clipped by the limiter so the a.g.c. voltage does not rise unduly. The limiter is therefore much like the amplitude limiter that is used with an f.m. signal.

A typical limiter a.g.c. system is shown in Fig. 33. This circuit has three special features. First, an initial bias set up by the contrast control gives an operating point about which the a.g.c. system performs. Second, it is arranged so that the a.g.c. bias voltage will be divided between the r.f. stage and the i.f. stages on strong signals. Finally, it is relatively insensitive to the changes produced when noise pulses are received. Let's study each of these actions.

The initial bias (the bias when no signal is tuned in) is set by R_6, the contrast control, which is part of the voltage divider R_5, R_6, and R_7 that is connected between ground and a negative voltage source. The grid of VT_2 is tied through R_4, R_3, and R_2 to the negative terminal of this supply, so the cathode of VT_2 is made positive with respect to the grid by an amount determined by the setting of the contrast control. At the same time, the cathode of VT_2 is negative with respect to ground. Since the plate of this tube is tied to ground through R_8 and R_9, it is positive with respect to the cathode; as a result, there is a plate current flow through R_8 and R_9 that produces

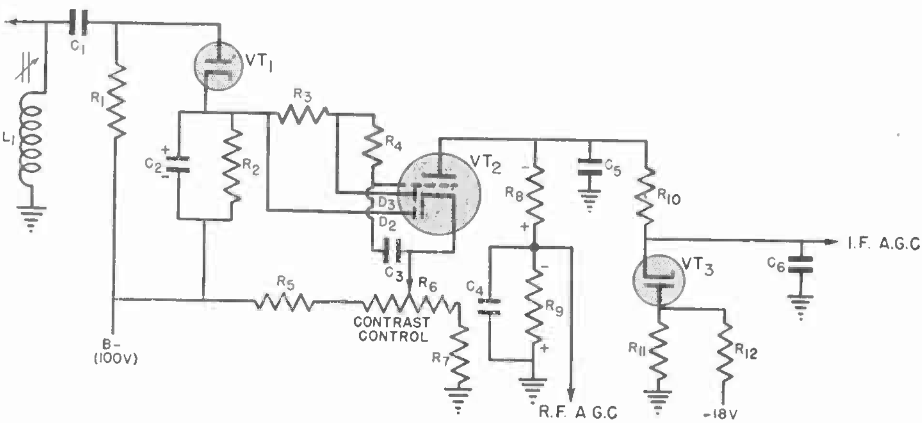

FIG. 33. Typical noise-limiter a.g.c. system.

voltage drops across these resistors having the polarities shown. The relatively small voltage across R_9 is applied as a bias to the r.f. tube; the entire drop across R_9 and the larger resistance R_8 is applied through the filter C_5-R_{10} to the i.f. stages as a bias. (Of course, the amount of the bias that is applied to the i.f. stages will be affected if VT_3 conducts; but, as we shall see in a moment, this tube conducts only when the signal is strong.)

The initial setting can be changed, if desired, by adjusting the contrast control. Doing so varies the bias on the grid of VT_2, thereby changing its plate current and therefore either increasing or decreasing the drop across R_8 and R_9, as desired.

Now, let us suppose a signal of normal strength is tuned in. This signal appears across the video i.f. transformer L_1 and is applied through C_1 to the a.g.c. diode VT_1. The basic a.g.c. action occurs in this diode circuit: VT_1 conducts on the peaks of the sync signal; and C_2 charges to the peak voltage each time VT_1 conducts, losing only a small amount of its charge through R_2 in between the sync pulses, so the voltage across C_2 follows the peaks of the sync pulses. As you can see from the diagram, the plate of VT_3 is usually slightly negative with respect to its cathode because it is connected to a point on the voltage divider R_{11}-R_{12} that is below ground. When the signal is very strong, however, the voltage across R_8 and R_9 will exceed the negative voltage applied to the plate of VT_3, so this tube will conduct. When this happens, the voltage that is across R_8 and R_9 will divide between R_{10} and the resistance of VT_3 and R_{11} in series, and only the part across R_{11} and VT_3 will be applied to the i.f. stages as a bias. The current passed by VT_3 will remain constant even if the applied signal becomes stronger, so the voltage drop across VT_3 and R_{11} (in other words, the i.f. bias) will remain constant. The r.f. bias will increase if the signal becomes stronger, however, since this bias is the result of the flow of the plate current of VT_2 through R_9. Thus, the i.f. bias increases in proportion to the strength of the applied signal until a certain critical signal strength is reached; if the signal then becomes stronger, the i.f. bias remains constant and the r.f. bias increases. As you learned earlier, this is the most desirable action for a contrast control.

Now let's see how the noise eliminating section of this circuit works. This section makes use of the diodes D_2 and D_3, which form part of VT_2.

As long as the strength of the received signal is normal, the voltage developed by the a.g.c. diode VT_1 across C_2 never equals the bias voltage developed across R_5 and that portion of R_6 that is in the biasing circuit. As a result, the diode plates D_2 and D_3 are always at least slightly negative with respect to the cathode, so they do not conduct.

If a sharp, high noise pulse comes along, however, the voltage across C_2 may exceed this bias voltage momentarily. When this happens, the two diodes are driven positive, and both conduct heavily. In effect, each diode acts as a short circuit across C_2 and thus drains off the additional charge that the noise pulse tries to place on this condenser. As a result, noise pulses are unable to produce more than a momentary change in the voltage applied to the grid of VT_2.

Furthermore, the integrating circuit consisting of R_4 and C_3 also helps to limit noise effects. As you can see by examining the circuit, the voltage across C_3 is the bias that is applied to the grid of VT_2. The R-C circuit consisting of R_4 and C_3 has a fairly long time constant: therefore, any sudden

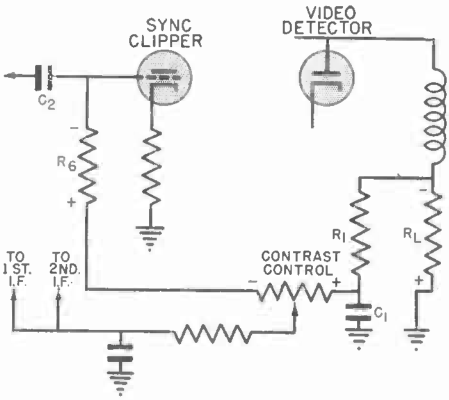

FIG. 34. A relatively noise-free a.g.c. system that operates from the sync pulses themselves.

and momentary change in the voltage across C_2 will be unable to affect the voltage across C_3. Only an average change in signal level over a period of several lines will change the voltage across C_3 enough to change the bias applied to the grid of VT_2.

KEYED A.G.C.

Another way to get relative freedom from noise is to arrange for the a.g.c. network to operate only from the sync pulses and to wipe out all the rest of the signal. This can be done by using a clipping arrangement very similar to the sync separation networks with which you are familiar. A few receivers use a.g.c. networks that operate from the output of the clipper circuit.

A variation of this idea is shown in Fig. 34. In this circuit, there are two separate sources of a.g.c. voltage.

On fairly weak signals, the voltage across the video detector load R_L provides the a.g.c. bias voltage. The filter R_1-C_1 averages this voltage over a number of lines (or even fields) so that the a.g.c. voltage is proportional to the average signal strength.

However, the voltage developed across the video detector load is not high enough to give adequate control on strong signals. Therefore, the other end of the contrast control is tied to the grid circuit of the sync clipper. As you will recall, the signal applied to the clipper must be in its d.c. form (that is, with its pedestals lined up). The signal is converted to this form by grid rectification. The grid-current flow charges condenser C_2, and the average voltage across this condenser sends a current through R_6 and the contrast control to develop voltage drops across them having the polarities shown. Since the charge on C_2 is exactly proportional to the peak levels of the sync pulses, the voltage drop across the contrast control is always proportional to the strength of the signal. The addition of this voltage drop to the one developed across the video detector load gives enough bias voltage to control the gain on strong signals.

Simpler variations of this circuit may dispense with the connection to the video detector load and use only the bias produced by the clipper tube for a.g.c.

Another method uses a keyed network arranged so that the a.g.c. system is tied to the horizontal sweep output and can operate only during the fly-back period of the horizontal sweep signal. Thus, the a.g.c. network is effectively turned on only for very short intervals of time during the horizontal sync pulse. This makes the circuit ignore all noise pulses that occur in between the horizontal sync pulses.

Since this a.g.c. system does not operate for any increased length of time during the vertical sync pulse, it can be made fast acting without affecting the ability of the set to remain in vertical sync. A fast-acting a.g.c. system is desirable, as you know, because it can follow rapid changes in signal level and can also recover quickly from any noise pulses that may affect it.

57RH-3—2nd form

Fig. 35 shows one form of keyed a.g.c. In this figure, tube VT_1 is the video amplifier output tube. The circuits preceding this tube must be arranged so that the signal in its plate circuit, as it exists across its load L_2-R_2, is in its d.c. form and has a positive picture phase.

Ignoring the signal for a moment, let's see how this a.g.c. circuit gets a starting voltage and how it is keyed.

As you can see, the cathode of VT_2 is connected through L_3 to a positive voltage of 150 volts, but its plate is connected to a positive voltage of 300 volts, so its plate is positive with respect to its cathode. No current flows through it initially, however, because its grid is heavily biased by the drop across R_2 that is caused by the plate current of VT_1.

The a.g.c. amplifier tube VT_4 is able to conduct if its grid is properly biased because its cathode is connected to a potential of –100 volts and its plate is grounded. (We shall see in a moment what determines the bias applied to its grid.) The drop across R_7 in the plate circuit of this tube is used as the a.g.c. bias voltage.

The operation of this network starts as soon as the horizontal sweep circuit operates. Transformer T_1, which has the winding L_3, is the output transformer of the horizontal sweep circuit. During the fly-back period of the horizontal sweep (that is, when the horizontal sync pulse occurs), L_3 develops a voltage that drives the cathode of VT_2 highly negative. This produces such a voltage difference between the plate and cathode of VT_2 that it is able to conduct rather heavily in spite of the high bias applied to its grid by the drop across R_2. This plate current produces a voltage pulse across R_3 that is fed through C_1 to R_4. The polarity of this pulse is such that it is able to make VT_3, the a.g.c. rectifier, conduct momentarily. When it conducts, a voltage having the polarity shown is produced across R_5. This voltage charges C_2, which retains its charge well enough during the period between pulses to keep a bias on VT_4 that maintains its plate current at a low level, so that there is only a small drop across R_7. In other words, the voltage obtained from the horizontal sweep circuit during the fly-back time sets the initial low a.g.c. threshold bias level.

Now let's suppose a signal is tuned in. Since the signal has a positive picture phase in the plate circuit of VT_1, the horizontal sync pulses across R_2 must go negative. Thus, the bias applied to the grid of VT_2 increases during a horizontal sync pulse. At

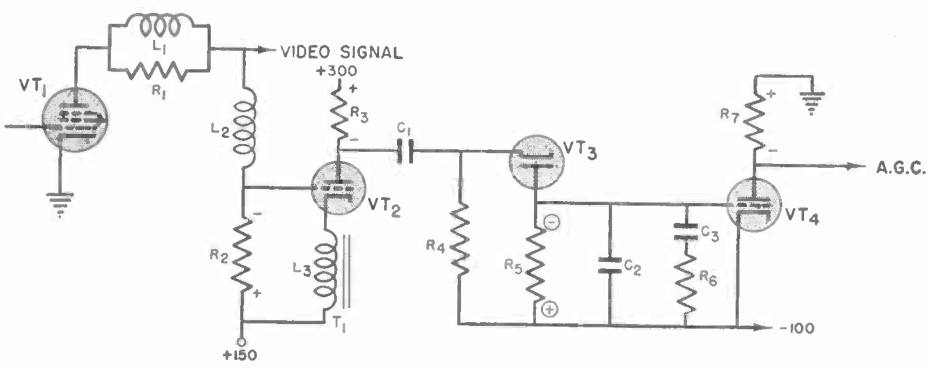

FIG. 35. A keyed a.g.c. system that is fast-acting and affected very little by noise.

exactly the same time, however, the voltage developed across L_3 drives the cathode of VT_2 negative. There are, therefore, two conflicting influences on the plate current of VT_2: the bias applied to the grid tends to decrease the plate current, the voltage applied to the cathode tends to increase it.

Whether the plate current can change or not therefore depends on the *difference* between these two voltages. If the signal level is very low, the bias developed across R_2 will be small; then the high negative voltage applied to the cathode of VT_2 will produce a large pulse across R_3, a large drop across R_5, and hence a small drop across R_7 as the a.g.c. voltage.

As the signal becomes stronger, however, the bias developed across R_2 will reduce the size of the pulse across R_3, thus causing less drop across R_5 and so permitting more plate current to flow through VT_4 to increase the drop across R_7. Thus, the amount of a.g.c. voltage varies in accordance with the strength of the signal.

Since tube VT_2 conducts appreciably only during the horizontal sync pulses, any noise pulse that occurs in between these sync pulses is ignored. If a noise pulse happens to occur at the same time as the sync pulse, the following action takes place:

The noise pulse develops an even higher bias voltage across R_2 than do the sync pulses. As a result, the pulse produced across R_3 is so small that it is less than the voltage across C_2; consequently, VT_3 does not conduct, and no charge is produced in the bias applied to VT_4. Thus, this circuit tends to ignore noise under any circumstances.

Naturally, you are going to find many different kinds of a.g.c. networks in TV receivers. In general, however, each will adjust the gain of the set so that the signal applied to the video detector will be reasonably constant. Each will probably have either a limiter or a keying arrangement to make the circuit insensitive to noise.

There may or may not be an arrangement that will permit the a.g.c. bias to be distributed between the r.f. and i.f. stages. If there is, it will operate so that the bias applied to the r.f. stage will not increase on weak signals but will increase rapidly on strong signals to prevent overloading.

On any set in which a.g.c. is used, the contrast control does not need constant adjustment, but only occasional re-setting for unusual picture conditions. When the set is switched from station to station, or when noise or rapid fading occurs, a good a.g.c. system should maintain the output almost constant.

Lesson Questions

Be sure to number your Answer Sheet 57RH-3.

Place your Student Number on every Answer Sheet.

***Send in your set of answers for this Lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. Why is it necessary to shield an r.f. high-voltage supply?

2. Why cannot a high-voltage supply that is locked with the sweep produce visible interference in the set in which it is used?

3. Why are voltage-multiplying circuits used in preference to conventional supplies to produce voltages over 10,000 volts in home receivers?

4. Why are ballast tubes or Globar resistors used instead of fixed resistors in the filament strings of a.c.-d.c. TV sets?

5. In what *section* is the sound take-off point in (1) a standard TV set and (2) an intercarrier TV set?

6. What two effects will be produced on the picture of a standard TV set if all the sound signal is not trapped out before it reaches the video detector?

7. What two desirable effects result when the sound take-off circuit is properly resonated in a standard set?

8. Why is the 4.5-mc. beat signal usually taken from the output of the video amplifier instead of from the output of the video detector in an intercarrier set?

9. Why is it desirable to have the contrast control affect the gain of the r.f. stage as well as that of the video i.f. stages?

10. What undesirable effect is produced if the time constant of an a.g.c. system is (1) too short; or (2) too long?

Be sure to fill out a Lesson Label and send it along with your answers.

GOOD RESOLUTIONS

When you make a good resolution, put it into effect *at once.* To postpone it is deadly. Anything that can be done next month or next year can be done NOW—or at least a start can be made toward it.

Millions of people dream about doing fine, worthwhile things. But only a *few hundred* people ever get around to actually doing these things.

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J. E. Smith

SPECIAL TV RECEIVER SYSTEMS

58RH-3

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 58

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

JD6M1051 1951 Edition Printed in U.S.A.

SPECIAL TV SYSTEMS

LESSONS up to now have covered all the sections of typical home television receivers that use direct-view picture tubes. Now we are ready to study ways in which the basic television circuits are sometimes modified to fit special viewing conditions or to meet commercial requirements. We shall also learn something about extra equipment often used with TV sets.

Since this Lesson covers a number of unrelated subjects, let's take a moment to learn what they are. First, we shall discuss sets in which provisions are made for controlling from a remote point. This isn't a new idea; remote control for radio receivers has been offered for years as a luxury item. There are people willing to pay extra for the ability to control a television set from a point other than right at the picture tube, so some manufacturers offer suitable equipment.

Another type of remote control consists of television duplicators—systems in which the program is picked up at one central point and is then fed to a number of reproducing units. Duplicators are of considerable importance in wired-in commercial systems like those used in schools, hospitals, and hotels. These, too, are described in this Lesson.

A larger picture is something that a great many set owners want. Because of lack of funds, many people buy sets having one of the smaller picture tubes; after a while, however, they often become dissatisfied with the small picture and obtain magnifying lenses to enlarge the image. Some people, too, want bigger pictures than even large direct-view sets can give; to satisfy this demand, a considerable number of projection television sets have been put on the market. Both lenses and projection systems will be discussed later in this Lesson.

A basic problem for the television viewer is the fact that light reflections from the surface of the picture tube or the protective cover glass will tend to degrade the image and reduce the contrast range appreciably. To eliminate such reflections, people purchase filters for installation in front of the cover glass. We shall discuss filters later on.

Finally, there are a number of laboratory efforts being made today to develop color television, and it is important for the practising technician to know just what these are and what they may foretell for future television possibilities. The basic principles of all modern systems are described in this Lesson.

All of these items operate with or from the basic receivers that you have studied up to now. Most of them are features that are built into the set by the manufacturer: lenses and filters are the only things dealt with in this Lesson that you, as a serviceman, may add to an existing set. However, it is of course important for you to know how all these items work.

Remote Control

There are two general forms of remote control: 1, a "convenience" type that makes it possible to tune in stations and adjust the contrast and the volume from a remote point; and 2, a "duplicator" system, in which more than one picture unit is controlled from a single point. Let's consider both these systems in order.

REMOTE CONTROL

Fig. 1 shows an example of remote control. The unit shown at the end of the sofa can be used to change stations or to adjust the contrast or the volume control settings. Such a system is at least a convenience; if the person operating the set is bedridden or otherwise disabled, it becomes practically a necessity.

There are numerous commercial or industrial applications that require somewhat similar remote control units. In a bar, for example, it may be desirable to mount the viewing unit high on a wall so that it can be viewed from the entire room. It is impractical to tune a set in this position. If the set is remotely controlled,

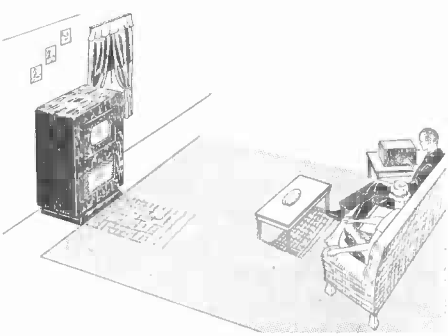


FIG. 1. The remote tuner beside the sofa permits adjustment of the picture unit which is located across the room.

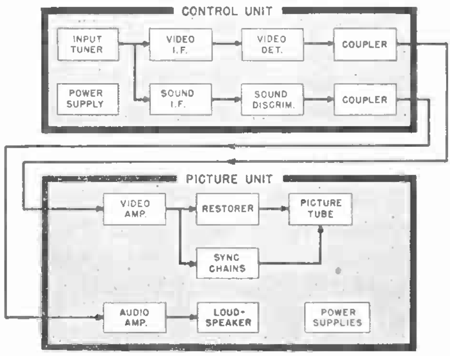
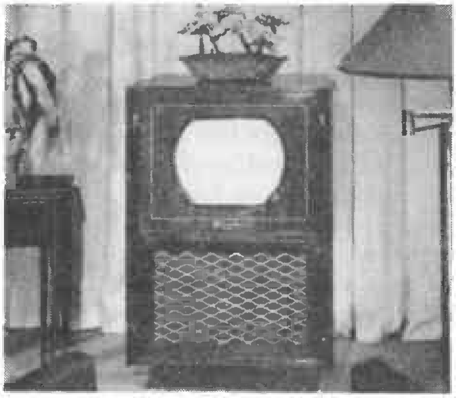


FIG. 2. Block diagram of stages in the control unit and the picture unit.

however, the control unit can be mounted where the bartender can operate it.

Many other similar practical applications can be thought of, all involving a control unit that can perform the normal functions of tuning and adjusting the set and that can be mounted conveniently at some point remote from the picture unit itself.

It would be possible to use some form of motorized control, but practically all the control units made now are actually the tuning portion of a television set. In other words, as



Courtesy Industrial Television, Inc.
A picture unit or duplicator.

shown in Fig. 2, the television set is split into two sections. The control unit contains the input tuner and parts of the video and sound channels. The video path in the control unit consists of the video i.f., the video detector, and a coupler stage that feeds the video signal through a coaxial cable to the separate picture unit. The sound path is similiarly divided: in the control unit we have the sound i.f., the discriminator, and a coupler unit that feeds a sound signal over its own cable to the audio amplifier and loudspeaker, which are in the picture unit.

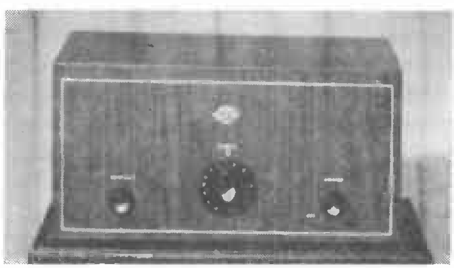
In the picture unit, the video signal goes through a video amplifier and a d.c. restorer to the picture tube. In addition, both the horizontal and vertical sync chains are contained in the picture unit. Suitable power supplies are in each unit, and of course the high-voltage supply is in the picture unit where it will be used with the picture tube.

Basically, therefore, in units of this kind, the television receiver with which we are familiar is split into two units, each of which has its own power supply. A relay is arranged so that when the control unit is turned on or off, the picture unit will also be turned on or off. The tuning, contrast, and sound volume controls (which are associated with the input tuner, the video i.f. amplifier, and the discriminator respectively) are part of the control unit.

At the picture unit will be found the brilliancy control, picture positioning controls, linearity controls, etc., which are usually associated with the sync and sweep chains. Since these controls require only occasional adjustment, they may well all be at the back of the picture unit. The picture unit may use any size of picture tube, but in most applications the installation will be at some distance from the viewers, so the larger sizes (15 inches or more) are most common.

Except for being in two sections, the only thing unusual about these remote control units is the coupler stage that is necessary to feed the video signal into the coaxial cable that connects the two units. A coaxial cable is necessary to prevent interference pick-up. It must have very low impedance so that it can handle the wide range of frequencies. (The video frequencies range from around 10 cycles out to 4 mc.) If the surge impedance of the cable is not low, shunting capacities will limit the frequency range.

If we tried to feed from the video detector directly into such a low impedance, there would be a severe loss of signal, because the line would make a very poor load. Hence, the coupler stage acts as an impedance matcher between the relatively high impedance



Courtesy Industrial Television, Inc.
A control unit for a remote-control system.

of the detector load (several thousand ohms) and the 50-to-90-ohm coaxial cable.

Video Coupler. Schematic diagrams of the control-unit coupling stage and of the input to the picture unit are shown in Figs. 3A and 3B.

The stage shown in Fig. 3A is a cathode follower. The arrangement is such that the signal from the video detector that appears across the detector load R_1 is coupled to the grid of tube VT_1 through the normal condenser - resistor coupling. However, this tube does not have a plate load resistance in the usual sense; resistor R_3 is a voltage adjuster, and condenser C_2 grounds the plate insofar as the signal is concerned.

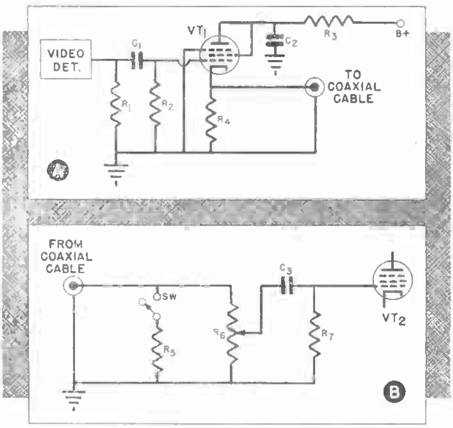


FIG. 3. The coupler stage at A feeds into the picture unit input as at B.

The "load" for the tube is in the cathode circuit, and consists of the terminating resistance of the coaxial cable (about 75 ohms in this case) in parallel with R_4 (about 500 ohms), making a total load of slightly under 75 ohms. Such an extremely low load does not require high-frequency compensation; in addition, the frequency response is improved by the degeneration that occurs because the load is in the cathode circuit.

Since the entire load signal is in the cathode circuit and is applied to the grid circuit, there is 100% degeneration. As a result, the tube acts as though its μ were less than 1, so there is a loss in signal level—the output is less than the input in such a cathode-coupled stage. However, the plate resistance of the tube used in the coupler stage equals $Y_p \div (\mu + 1)$, so it is far less than it would be in a more usual circuit. Also, notice that in Fig. 3A the tube is connected as a triode (screen grid and plate tied together) to give an even lower plate resistance; both these conditions produce an effective match between the tube resistance and the load. Hence, this cathode-coupled circuit makes a very good coupling network for this application; the signal loss is far less than would be caused by the mismatched coupling that would exist without it, and the frequency response is far superior to that of other couplings.

The coupling used at the picture unit is shown in Fig. 3B. The switch SW is provided so that a loading resistor R_5 can be connected as the terminating resistance for the coaxial cable. To prevent reflections, the coaxial cable must be matched at this end by an impedance exactly equal to the surge impedance of the cable.

If a 75-ohm coaxial cable is used, for example, resistor R_5 must have a resistance of 75 ohms. If there is only one picture unit involved, the switch will be closed so that this load resistor is connected directly across the cable.

In parallel with this may be a supplementary contrast control, such as resistor R_6. Alternatively, some means of varying the cathode bias of VT_2 or of a following video stage may be used to furnish a supplementary contrast control. It is desirable to have this supplementary control to set the limits

Courtesy Olympic Radio and Television Co.
A typical duplicator.

over which the one at the control unit will operate; in fact, it is almost necessary to have one if more than one picture unit is used, as we shall see in a moment.

The coupling from R_6 in Fig. 3B is through a standard R-C coupling network to the grid of VT_2, which is the first of the video amplifiers.

The sound coupler is much the same as the one we have just described—it is a cathode follower arranged to feed the sound cable. However, the far more restricted frequency range permits the use of a less expensive and easier matched higher-impedance line (300 ohms) instead of a coaxial cable.

TELEVISION DUPLICATORS

Hotels, schools, and hospitals may want units in different rooms, or there may be cases where more than one picture unit is wanted even in a home. In such cases, the basic remote control arrangement we have just described can be used for operating more than one picture unit. As shown in Fig. 4, all that is necessary is to run a coaxial line from picture unit to picture unit. The switch SW is provided in the circuit shown in Fig. 3B to make such multiple connections possible. Since the line must be loaded only at the end, the load resistor R_L in Fig. 4 is added at the unit C at the end of the coaxial line, but it is disconnected for the units A and B. This arrangement lets the line be terminated in its own impedance; then the relatively high-impedance inputs of the picture units can be attached at other points along the line without upsetting the impedance matching of the line. If the resistor in each of these units were allowed to be across the line, on the other hand, the line would no longer be matched, because the combined resistance of the resistors in parallel would be far lower than is needed. Therefore, when several duplicators are connected to a single line, the last one must give the proper impedance match.

When more than one unit is connected to a line this way, it is very important that each unit have its own contrast control so that, for an initial setting of the contrast control on the control unit, the others can be properly adjusted to give the desired response. Usually only the control-unit contrast control would be used from then on, although the picture-unit

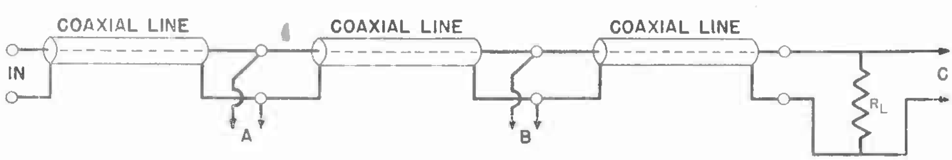


FIG. 4. How to connect a number of picture units to a coaxial line.

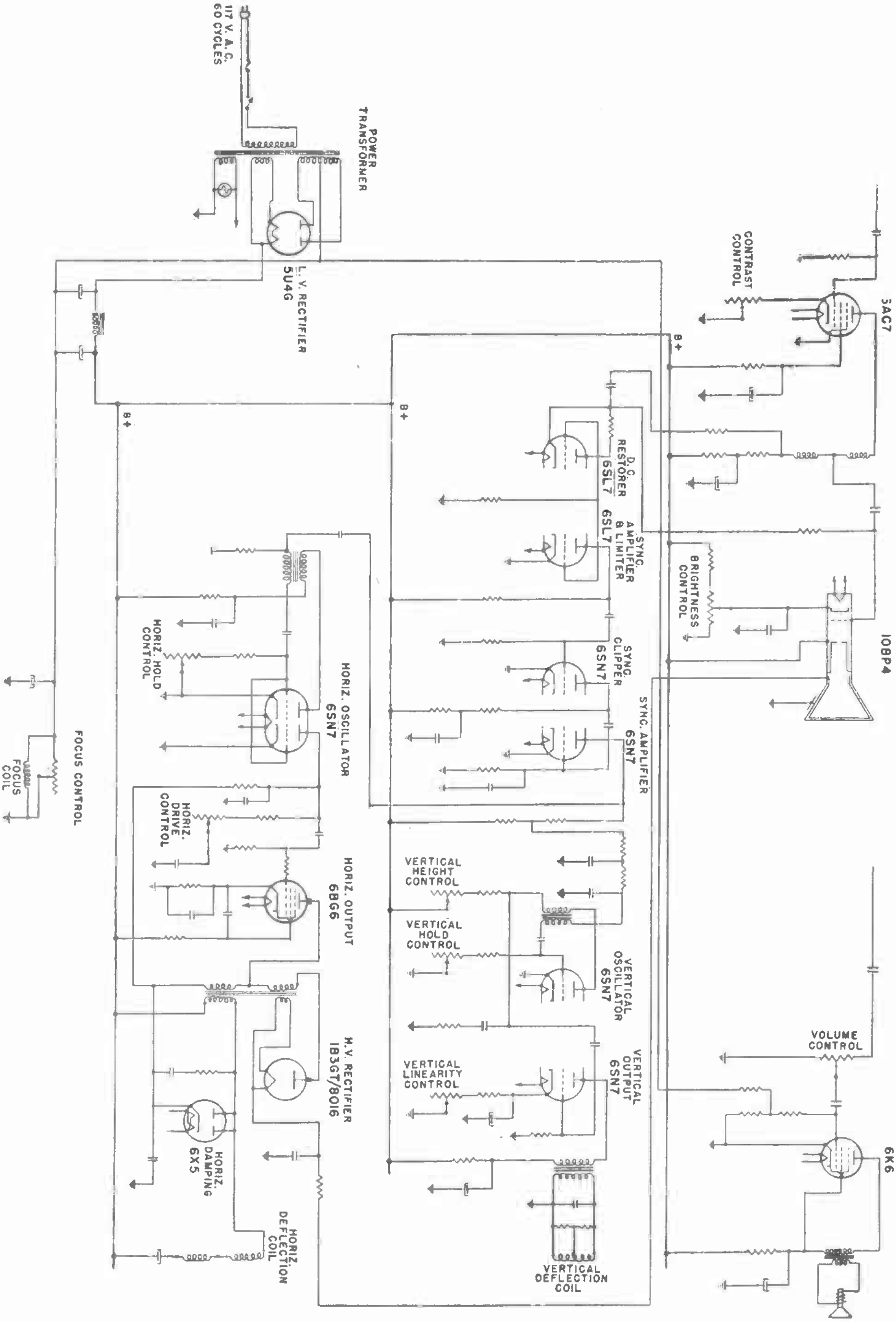


FIG. 5. Schematic of the Olympic Model RTU-3 duplicator.

contrast controls can be used if doing so proves desirable.

Connecting to Receivers. It is also possible to add duplicators to standard receivers, where more than one picture is desired. Fig. 5 shows a schematic diagram of a typical unit of this kind. This unit is designed to be attached to a standard TV set, which of course is a complete unit by itself.

The only modification necessary in the TV set to attach such a duplicator is to arrange for the picture to be picked up from the video output tube of the set. Cathode coupling is again necessary for impedance matching. In most receivers, the cathode of the video output tube is returned to the chassis either directly or through a bias resistor. To install a duplicator, the connection between the cathode of the output tube and the chassis must be opened, and the coaxial cable must then be connected to this point. The circuit is completed at the duplicator by a special plug-in arrangement that contains a matching resistor for the coaxial cable.

If more than one duplicator is to be used, the matching plug is removed and additional lengths of the coaxial cable are added from one unit to the next. The last one on the chain must have the resistor plug still in it, however, to match the coaxial cable and to complete the return circuit from cathode to ground for the output tube of the set. This particular arrangement does not upset the output tube characteristics to any great extent as long as sufficient resistance is in the circuit to give normal biasing. If not, it may be necessary to change the bias resistor; complete details on such changes are furnished by the duplicator manufacturers.

In the circuit shown in Fig. 5, the 6AC7 tube in the duplicator drives the picture tube. Remember that the signal is being picked from the cathode of the output tube of the set; therefore, an additional stage is necessary to get a video signal having the proper phase, and of course we need the gain to make up for the loss entailed in coupling to the cathode of the output tube of the set.

A d.c. restorer is used in this particular circuit. The restored signal is also applied to the sync amplifier and limiter stage. The sync signal then goes through a clipper and amplifier before being separated to drive standard vertical and horizontal sweep chains.

The audio signal is obtained from the primary of the output transformer on the receiver and is fed over a separate cable to drive the 6K6 power tube on the duplicator.

Whatever system of duplication is used, the sizes of the pictures at the main receiving point and at the duplicating points depend entirely upon the requirements. There is no reason at all why the main receiver cannot be a large-screen type and the duplitors even as small as 7 or 10 inches. The opposite is also feasible—it is possible to operate a duplicator with a large screen from a 7-inch tube set. You will notice that the duplicator contains its own sweep circuits and power supply, so it is independent of the receiver for everything except two signals, the combination video-sync signal and the sound signal. Duplicators of different sizes may be connected to the same coaxial line, if desired.

Getting Larger Pictures

Direct-view picture tubes are available today in sizes ranging from 7 inches to 20 inches in diameter. As you would expect, the larger the picture tube, the greater the cost of a set: not only does the tube price increase, but also larger sizes require larger and more expensive cabinets, a higher voltage from the high-voltage supply, and usually a more powerful sweep output. (The use of two output tubes in parallel is common in the horizontal sweep for large tubes.)

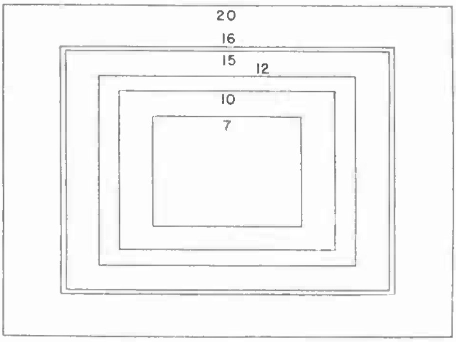


FIG. 6. This shows the relative areas on picture tube faces ranging from 7 to 20 inches in useful face diameter.

Fig. 6 gives a relative comparison between the picture sizes that can be had on the popular tube diameters of 7, 10, 12, 15, 16, and 20 inches. It is obvious that the larger tubes give far more image area. However, since cost prevents many from getting these larger sizes, the manufacturers are attempting to make use of more of the picture tube screen area, and many people enlarge the images with lenses.

The television picture that is transmitted has an aspect ratio (ratio of width to height) of 4 to 3; this means that if the picture is four units wide, it will be three units tall. If the entire picture is to be reproduced on the face area of a direct-view tube, it must be included within the useful tube face area as shown in Fig. 7A. To get the image out near the edges of the usable screen area, the corners of this kind of mask are somewhat rounded, so the area in the original scene shown black in Fig. 7A is lost. The gray area represents the part of the picture tube face that is not used.

This type of mask was the only one used until recently. Then, a trend started in which somewhat larger picture areas were obtained from the same tube face by sacrificing slightly more of the corners of the image, as shown in Fig. 7B. Here, the width has been increased so that the width of the picture exactly equals the usable diameter of the tube face, and the height has been increased correspondingly to maintain the aspect ratio. This gives a picture having the area shown white, and the only thing lost is the area in the corners of the original picture that is shown here in black. Sacrificing these areas, in which very little of the interesting portion of the television image is ever

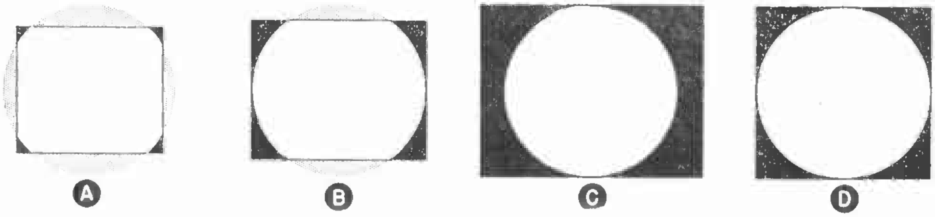
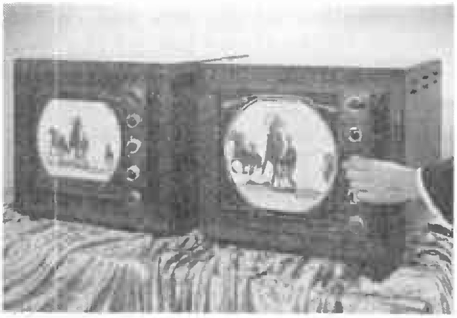


FIG. 7. Comparison of areas obtained with different picture masks.

present, makes it possible to increase the picture size somewhat for the same tube size. For example, with the mask shown in Fig. 7A, a 10-inch picture tube may have a useful area of about 52 square inches. An area of as much as 61 square inches can be obtained with the mask shown in Fig. 7B.

It is possible to carry this idea still further and to make use of the full screen area of the tube, providing we are willing either to sacrifice a considerable portion of the picture or to accept a distorted picture. Thus, if we expand both the height and width as shown in Fig. 7D so that the picture fills the entire screen area of the tube, we will have a square picture



Courtesy Westinghouse Elec. Corp.

FIG. 8. A zoom system enlarges the center of the picture as shown here.

that no longer has the aspect ratio of 4:3. Not very much of the picture is lost—just that in the corner areas that are blackened here—but the picture is distorted because the image produced is higher than is normal for its width. In other words, we are now getting a square picture from the rectangular picture that is actually transmitted.

If we maintain the proper aspect ratio, but enlarge the picture so that the height is equal to the useful screen diameter as shown in Fig. 7C, then we will get just the center portion of the picture. It will be undistorted, but all of the area that is shown in black here will be lost. It so happens that the chief object of interest on the television screen is often a single individual standing near the center of the picture area, in which case loss of the sides of the picture is unimportant. However, if the action spreads out, such as when a chorus line is dancing, for example, or if any other horizontal actions occurs, a great deal of the interesting part of the picture is lost.

For these reasons, the mask styles shown in Figs. 7A and 7B are the most popular. The useful areas are determined by the cut-out opening in the cabinet of the set; the size and drive controls on the set are adjusted until the picture image just fills this mask area.

ZOOM CONTROLS

Since the picture arrangement of Fig. 7C produces an enlarged center portion of a picture, and since this is satisfactory for certain subjects for intermittent viewing, some receivers are equipped with systems for changing instantly from one mask size to another. On such sets, the only physical mask is a circular one—the same size as the useful area of the particular tube screen. The receivers produce a smaller picture that does not fill this mask, like those shown in Fig. 7A or 7B, until the enlarging switch is thrown, at which time the picture size jumps to that of Fig. 7C. Fig. 8 shows a typical example. The "zoomed" or "opera-glass" enlarged picture produces an appreciably larger image of the scenes on which it can be used, but of course does not give an enlargement of the entire picture area unless the system is arranged to switch to the distorted style of image shown in Fig. 7D.

To switch the picture from one size to another, there are two sets of controls for the vertical and horizontal size controls, two sets for the linearity or shaping controls, and two brightness controls. Usually, a 5-pole, double-throw switch is used to change from one set of controls to the other. Fig. 9 shows two sections of such a switch. When it is thrown to the "normal" position, voltage is applied to the set of controls that is adjusted to give the normally masked image with the proper aspect ratio and with very little loss of the total picture area. When the switch is thrown to the other or "zoom" position, the other set of controls is switched in; the settings of these are such that the verti-

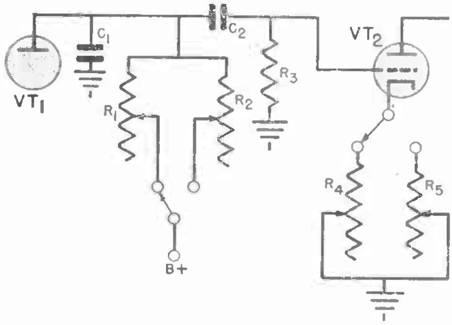


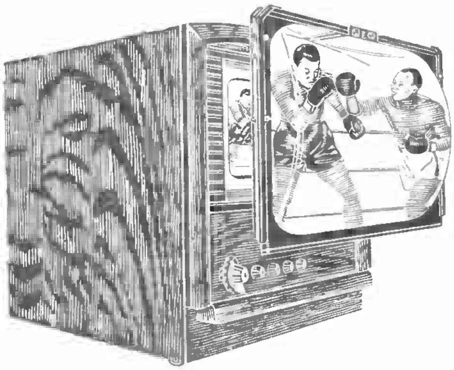
FIG. 9. Schematic showing dual controls for zoom purposes.

cal size, vertical linearity, horizontal drive, horizontal linearity, and the brightness are increased so much that the image makes full use of the entire screen area of the tube.

MAGNIFIERS

A way of getting a larger picture without making any change in the set is to use a magnifying lens in front of the tube. This blows up the whole picture to a larger size. Fig. 10 illustrates a typical installation.

As shown in Fig. 11, when an object is properly placed behind a double-convex magnifier lens, the light rays from the object are bent. To an observer, however, they appear to be coming in a straight line from a considerably larger image. In other words, the observer in Fig. 11 sees



Courtesy Celomat Corp.

FIG. 10. A typical lens magnifier.

an enlarged image of the object, rather than the object itself. The amount of magnification depends on the curvature of the lens and on the position of the object behind the lens.

Since the face of the picture tube represents a fairly large, flat area, it is not practical to use a double-convex magnifying lens like that shown in Fig. 12A to magnify it: because of the curvature of the lens, its center will be closer to the tube face than its ends will be, and distortion will therefore be produced. Instead, we use a lens that has one plane or flat surface as shown in Fig. 12B. Of course, if we take a double convex lens and cut it in half to get this shape, the distance behind the lens that an object must be placed to be brought to focus is greatly increased, because there is only one curved surface instead of two to give the enlargement. Therefore, it is necessary to use a relatively thick

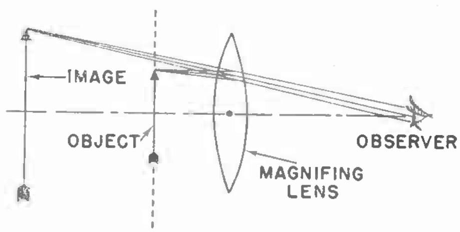


FIG. 11. How a magnifying lens produces a larger image.

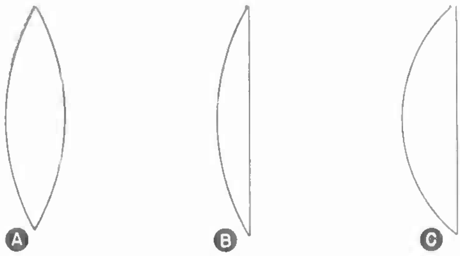


FIG. 12. Magnifying lens shapes.

plano-convex lens, as shown in Fig. 12C, to make it possible to keep the lens close to the face of the picture tube.

The lens used has to be larger than the picture tube face. Obviously, it would be very expensive to cut a glass lens of this size and grind and polish it to the proper shape. To reduce the cost, lenses are instead molded out of plastics, usually Lucite or Plexiglas.

Some of the earlier plastic lenses were solid plastic. However, it was discovered that it was far cheaper, and just as satisfactory, to mold a plastic "bubble" that could be filled with an oily liquid. Two styles of lenses of this kind are shown in Figs. 13A and 13B. In each case, the lens consists of a flat plate to which the molded curved portion is cemented. In the style shown in Fig. 13A, a small filler plug (1) is left open and the liquid is poured into the space between the flat plate and the curved face. Then the plug (which is in a portion of the lens that is not used to view the picture) is inserted. Ordinarily it is not possible to fill the lens absolutely full of liquid, so a small air bubble may be observable when the lens is in the position shown in Fig. 13A. However, when the lens is placed upright in its normal position in front of the picture tube, this air bubble moves out of the way (to the top of the lens).

In the lens style shown in Fig. 13B, the curved portion is filled with the liquid before it is cemented to the flat plate, or else a small filler opening is left at the joint (2).

Fig. 14 shows three ways of supporting the lens in the proper viewing position. In the sketch shown in Fig.

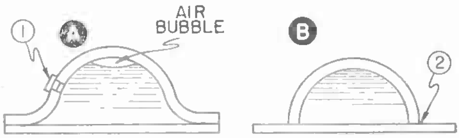


FIG. 13. Liquid-filled lens.

14A, the lens is held in front of the tube by a cord or strap that goes over the set cabinet and hooks at the rear. The lens is spaced out from the picture tube by small plastic bumpers behind the lens.

In the style shown in Fig. 14B, the lens is screwed right to the front of the cabinet. A third mount, shown in Fig. 14C, consists of a frame or bracket that slides underneath the set cabinet. The weight of the set then holds down the rear of the bracket so that the lens is supported in the proper position-

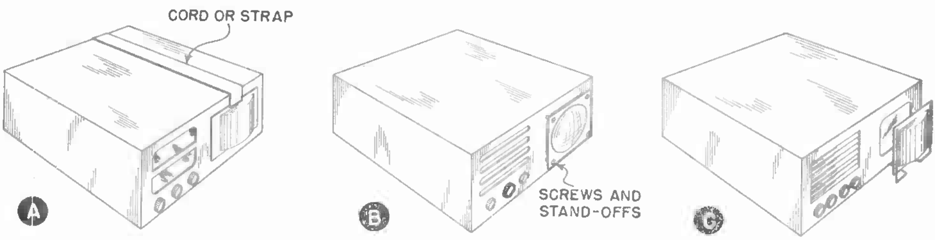


FIG. 14. Typical lens supports.

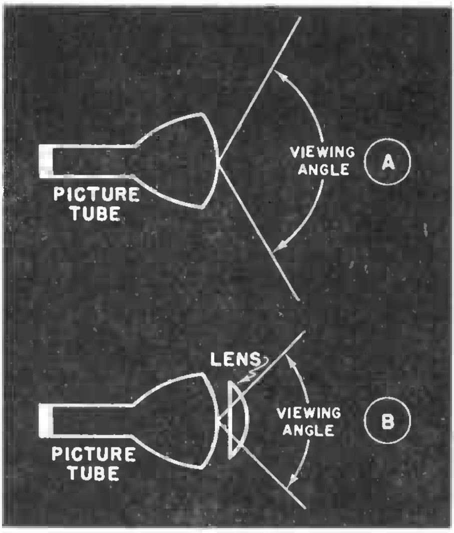


FIG. 15. A lens reduces the viewing angle.

tion. Most systems of this kind are arranged so that the lens can be slid up and down on the bracket to bring it into the proper position for the particular cabinet in question.

Associated with every lens is a distance called the focal length, which is the distance from the lens at which it brings parallel light rays to a focus. If the distance between the picture tube and the lens is less than the focal length, the lens will present a magnified image of the tube face to the viewer; and the farther apart the lens and the tube are, the larger this image will be. If the separation between the two becomes equal to the focal length, however, the magnification will become infinitely large, and the light rays coming through the lens will become parallel, thus making it impossible to see the image. At still greater separations, the image formed by the lens will be inverted and small. The lens must therefore always be separated from the picture tube by a distance that is less than the focal length.

As we said, increasing the separation between the lens and the tube increases the size of the image. However moving the lens away from the picture tube also greatly restricts the viewing angle. When no lens is used, it is possible for people to be at a rather sharp angle with respect to the face of the picture and still be able to see the picture, as shown in Fig. 15A. As soon as a lens is used, however, the people at the extremes of the sides cannot see all of the image. In other words, as Fig. 15B shows, the viewing angle is decreased by the addition of a lens.

This effect of decreasing the viewing angle is made worse as the lens is moved away from the tube to increase the magnification, as shown in Fig. 16. If the picture is enlarged very much, therefore, it may be impossible for more than one or two people to see it.

Some lenses give somewhat more magnification than others for a given viewing angle, depending on their size

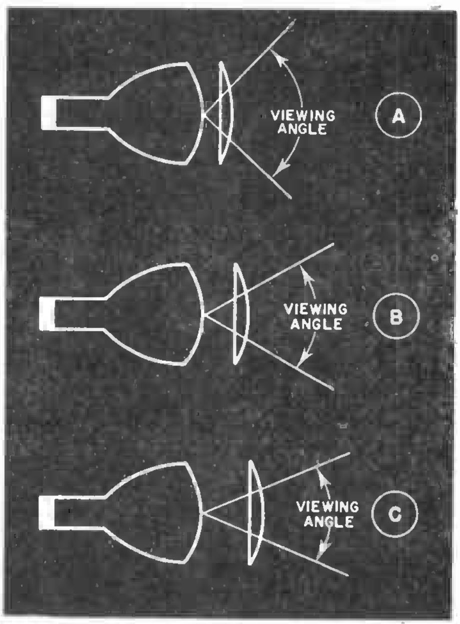


FIG. 16. As the lens is moved to increase the size of the image, the viewing angle is further decreased.

and shape. For this reason, you should check on the viewing angle and magnification of any lens to see if they are acceptable before buying it.

In an attempt to solve the viewing angle problem, some lenses are made as shown in Fig. 17. A rubber sheet or jacket that is secured to the lens makes a water-tight seal between the lens and the tube, and the space between the picture tube and lens is filled with the same kind of liquid that is in the lens. The result of directly coupling the lens to the tube in this manner is that the image seemingly appears to be on the face of the lens. As a result, this lens system gives a very wide viewing angle—practically the same as that obtainable without a lens at all.

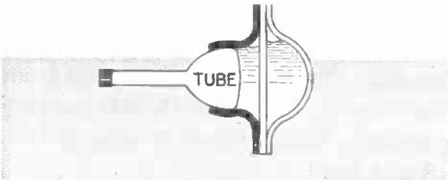


FIG. 17. A coupled liquid-filled lens.

A disadvantage of such a lens system is that it is much more difficult to install. It may be necessary to modify the cabinet to make it accept the lens if the masking opening on the cabinet will not permit the lens coupling to go in and be fastened around the tube. Such a modification of the cabinet may or may not be practical, depending on the conditions in each case. Further, the addition of the lens makes it rather difficult to replace the tube and to service the set, because the tube-lens assembly must be removed as a unit if the liquid is to remain within the sheath between the lens and the tube.

An entirely different method of making a lens is shown in Fig. 18. This lens, known as the "Fresnel" type, consists of a number of circular engravings on a flat sheet of plastic. As shown in the enlargement in Fig. 18B, each succeeding cut on the face of this plastic is at a different angle, so that the sum of their surfaces is equivalent to the surface of a lens having the thickness shown by the dashed line. Effectively, therefore, a thin sheet of plastic can be made to act just like a very thick plano-convex lens by shaping it this way.

If the plastic has a sufficient number of these cuts or ridges in it, and they are accurately cut, this system proves satisfactory. Because of its simplicity, and the small amount of material in it, such a lens is somewhat less expensive than some of the other types.

It is important that the lens be mounted accurately with respect to the face of the picture tube—otherwise a very distorted image will be produced. In addition to its cost, the care needed to mount it, and the restriction in viewing angle that it causes, a lens has the disadvantage that it absorbs a considerable amount of the light traveling through it and

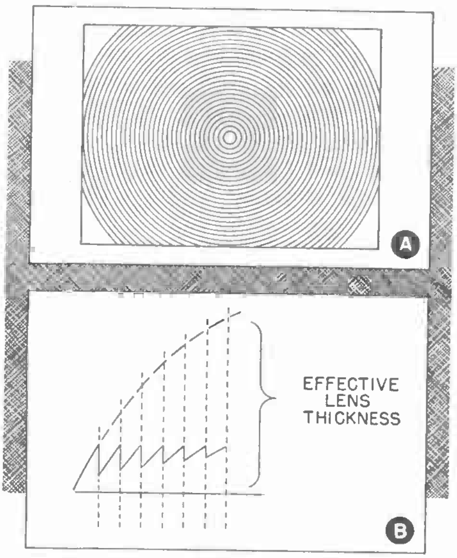


FIG. 18. A Fresnel lens.

therefore reduces the brightness of the image somewhat. Finally, the sharp curvature of the lens introduces problems because of glare due to reflections from light in the room. (We'll study glare in more detail later in this Lesson.) For these reasons, a lens is by no means a perfect solution to the problem of getting a larger picture. Nevertheless, a fairly large number of lenses are in use, particularly with 7-inch and 10-inch picture tubes. They are not very frequently used with the larger direct-view tubes because they cost so much in these sizes.

The direct-view tubes that are in use today are about as large as we can expect to go and still have them reasonable in cost, size, and weight. If larger images are desired, it is necessary to turn to projection systems. As a matter of fact, many home receivers use projection units that give images not much larger than some of the direct-view tubes (about 12 x 16 inches). Other units build on up from this size to the large theatre projection units that produce images around 18 x 24 feet!

Projection Systems

The most obvious projection system consists of using a projection lens (like those used in movie or slide projectors) in front of the picture tube to throw an enlarged picture on a screen as shown in Fig. 19. The size of the image on the screen depends on the lens used, its position with respect to the picture tube, and the distance from the lens to the screen.

The brilliancy of the picture on the ordinary picture tube is far too low for a projection system of this sort. There is a considerable loss of light in the directions A and B in Fig. 19, and, in addition, there is more loss in the transmission through the lens system itself. Finally, when even a rather brilliant small picture is spread over a much larger area in the projected picture, there is a drastic reduction in the amount of light per unit of area. Hence, even though a small direct-view tube may give a picture of sufficient brilliancy to be easily seen in a brightly lighted room, this same image projected on a screen and thus enlarged several times would be difficult to see even in the dark.

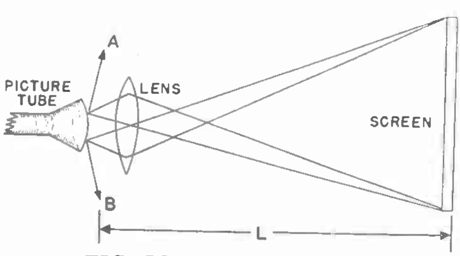


FIG. 19. Lens projection.

The practical solution to the last problem has been the development of special projection-type picture tubes. To begin with, it is desirable to have a tube of small diameter so that the original picture will be small; this simplifies the lens design and allows the use of a less expensive lens system. Then, a picture of very high brilliancy is produced on the face of the tube. This is done chiefly by using very high accelerating voltages (they range from 25,000 to 30,000 volts for home projection units and are as much as 80,000 volts in theatre systems), which produce an extremely bright spot. The brightness of the picture is further increased by using a tube having an aluminum backing behind the fluorescent screen to reflect forward through the face the light that would ordinarily be directed toward the back of the tube and lost. In this respect, a projection tube is like the "daylight" tubes used in many direct-view sets.

The basic "standard" receiver is used in such projection sets. The only modifications consist of using the projection tube, a higher voltage supply for the tube, and usually an increased sweep output.

Courtesy Bausch and Lomb Optical Co.
A TV projection lens.

Because the initial picture is very bright, a lens system can be used to project it on a viewing screen. Even so, in the larger screen sizes, the image is not as bright as that of a direct-view tube, but many people are willing to accept it anyway because of its large size.

Although the system is practical for theatre and club use where a very large image is desired, the system using an optical projection lens shown in Fig. 19 is not much used in home set-ups. One reason is that most of these systems require a fair amount of space; another is that the room in which the set is used must be kept rather dark, much as it must be for home movies. For these reasons, a somewhat different projection system is more commonly used in home installations.

This latter projection system, which was borrowed from the astronomers, makes use of a spherical mirror instead of a projection lens. The particular arrangement of elements in this system is such that more efficient light gathering is obtained, with the result that the image is somewhat brighter than that obtained by the use of a comparable projection lens. Furthermore, this system is more desirable for homes because it is far less costly and much more compact than the lens system.

MIRROR PROJECTION

Fig. 20 shows the basic details of the projection system that is used today in most home receivers and also in many of the large commercial systems. Briefly, the projection tube faces a spherical mirror, and the image from the mirror is brought to focus on a screen at the proper distance away. As long as the projection tube is placed within the focal distance of the spherical mirror, the image at the remote point will be an enlarged one. Whereas the efficiency of a lens system is only about 5% to 10%, mirrors such as this have efficiencies much nearer 30%, so that a considerably brighter image can be obtained.

The spherical mirror by itself will not bring the image to a proper focus. It is necessary either to grind the mirror to a special shape, which would make it extremely costly, or to use a corrector lens. The corrector lens itself has a rather peculiar shape and would be costly if it were ground from glass. However, these corrector lenses are today molded from plastic mate-

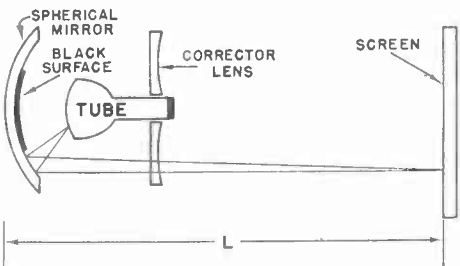


FIG. 20. Spherical mirror projection.

rial so that they are relatively inexpensive.

Fig. 21 shows why the corrector lens is needed. Let's assume that the point O in this figure is a particular spot that is illuminated on the face of the projection tube. Notice that light originating at this point will be reflected to different points along the axis line O-A if the spherical mirror alone is used (follow the dotted lines).

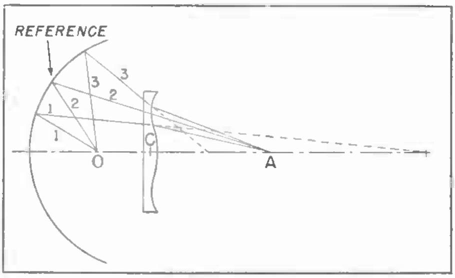


FIG. 21. How the corrector lens works.

Thus, light that follows path 1 strikes the axis at a point far removed from the place where light would fall if it traveled along path 3. Let's say that we want all the light rays to strike the axis at the same point A as the ray following path 2 does. We can produce this effect by using a corrector lens having the shape shown, which will bend the rays traveling along paths 1 and 3 so that they come together with that from path 2 at point A. In fact, if we use a corrector lens of the proper shape, we can bring all the light rays from the spherical mirror to a focus at the desired point.

The exact shape needed for the corrector lens depends on where it is placed in the light path. This lens does not enlarge the image or otherwise change it—all it does is bend the various rays of light so that they all come to the same focal point. The magnification that is obtainable in the system depends entirely on the size of the spherical mirror and its position with respect to the projection tube and the screen.

The combination of the spherical mirror and corrector lens to produce an enlarged image was first developed by an astronomer named Schmidt for use in telescopes. For this reason, you will sometimes find that a projection television system of this sort is called a Schmidt lens system.

If the image is to be projected on a screen at some distance from the receiver, the system shown in Fig. 20 is used much as it is shown here. The tube is mounted with the spherical mirror and corrector lens in an optical "barrel" that is made light-tight in all directions except through the corrector lens to prevent light from external sources from getting in. The system is focused by moving the tube away from or closer to the spherical mirror, and the entire barrel, including the spherical mirror, can be moved with respect to the screen to determine the size of the image.

Notice that there is a black surface directly in front of the picture tube on the spherical mirror. This section is designed so as not to reflect light at all. This is necessary so that light coming from the tube will not be reflected directly back on the face of the tube; if this were to happen, the contrast of the image would be reduced. The rest of the spherical mirror surface reflects the light from the picture tube through the corrector lens rather than back at the tube.

Care of Mirrors. The spherical mirror used in this optical system is unusual in that the reflecting surface is on the face of the mirror rather than on its back. The ordinary home mirror has the silvered surface on the back of the mirror, so that the glass acts as a protection for it. If a back-silvered mirror were used in a system such as this, however, the light rays from the projection tube would have to go through the glass, strike the reflective coating, and then come back through the glass, with the results that they would be bent at the points of entering and leaving the glass, and that light would be lost in traveling through the glass. Therefore, the silvering is placed on the top surface of the mirror, where it faces the tube itself. It is very important that you never touch the mirror surface either with your hands or tools, because the oil and acids normally present on the skin will attack the mirror. This will result in discoloration and corrosion of the surface with consequent loss of reflecting ability. If it is necessary to handle such a mirror, be sure to touch it only on its rear surface or on the extreme edges where it is not coated for reflection.

To prevent dust from collecting on the mirror, the optical barrel is usually made dust-tight. Should there ever be any need for cleaning such a mirror, a small, soft, camel's-hair brush can be used to pick up the dust. It is important to avoid the use of water and other cleaning compounds on these mirrors. Should you by accident touch a mirror, refer to the instructions accompanying the set, because sometimes the manufacturer will recommend a particular cleaner that can be used safely. If you find no such recommendation, however, contact the distributor for instructions rather than damage the mirror by attempting to clean it.

The corrector lens is made of soft plastic material and is very easily scratched; even rubbing it with a cloth may mar it. Again cleaning fluid should be avoided, since the chemicals in some of them may eat away plastic. Use a camel's-hair brush for dusting; for cleaning, again consult the manufacturer's instructions.

There are two basic screen arrangements that may be used. In one, the screen is just like a movie screen, and the image is viewed from the side on which it is projected. In others, the screen is a translucent material on which the image is projected from the rear. Many of these screens are ground glass, although other materials (to be described later) are sometimes used.

THE RCA SYSTEM

Many television receivers use a projection system to give a large image on a screen that is a part of the cabinet. The light path of the system shown in Fig. 20 must be bent for it to be used this way in a cabinet of reasonable depth. In the RCA line of projection receivers, and in all others that are adapted from this line, the system is basically that shown in Fig. 22. Here, a flat plane mirror is mounted at a 45° angle behind a view-

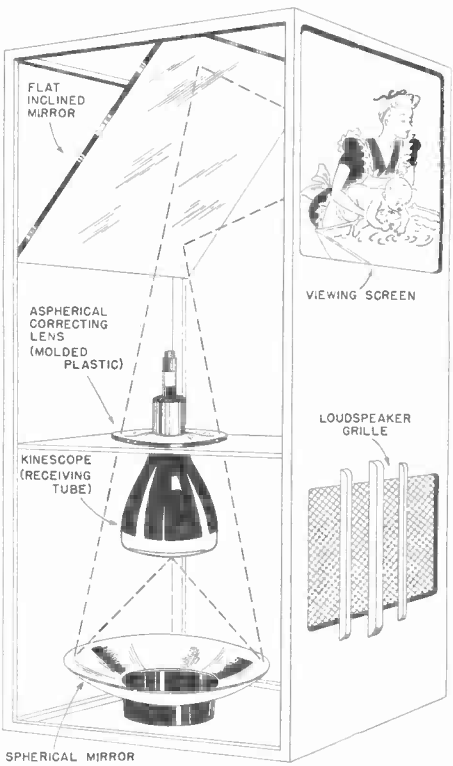


FIG. 22. The RCA projection system.

ing screen, and the image is reflected from this mirror to the screen. Mounting the tube in this way and then bending the optical path with the flat mirror makes it possible to use a cabinet of ordinary depth and not an unusual height to get the enlarged image. The viewing screen commonly

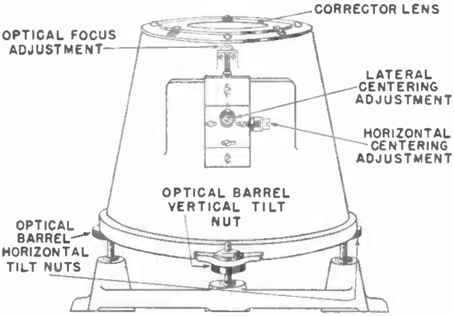


FIG. 23. The RCA optical barrel.

used on cabinets of this kind depends on the design of the cabinet. Common sizes are 16 x 20 inches or 18 x 24 inches—either of them larger than the picture obtainable even on a 20-inch direct-view tube.

A drawing of a typical optical barrel is shown in Fig. 23. The adjustments on the side of the barrel focus and center the image by raising or lowering the tube or by moving it from side to side. The corrector lens acts as the top of the barrel and keeps dust out of it. To keep dust off the top face of the corrector lens, the space between the lens and the plane mirror is usually enclosed in a cloth jacket.

The connecting leads going to the base of the picture tube and to the deflection coils come out through a cable. Although these leads pass through the light path, they do not block any of the image because light from every point on the spherical mirror is used at any one moment to illuminate a point on the screen corresponding to the point illuminated on the face of the picture tube. Therefore, no shadow is cast by these leads. They do reduce the total amount of light reaching the screen, but the loss is very slight.

The cabinet can be kept reasonably low by arranging it as shown in Fig. 24. The screen of this set is secured in a vertical track so that it can be hidden inside the cabinet when the set is not in use but can be brought up to viewing position by raising the lid. In a system of this kind, the lid must come up to exactly the right angle, because the flat mirror is on the lid. Therefore, stops are used in the cabinet to fix the position in which the lid remains when it is lifted.

As we mentioned, the screen itself must be translucent because the image is projected on it from behind and is viewed through it. Ground glass has often been used, but some receivers have a screen that consists of several layers of plastic. The center layer is a diffusing layer. The back sheet of the combination screen is cut to be a

Courtesy RCA

FIG. 24. A typical projection set.

Fresnel lens like the one described earlier. This lens concentrates the light so that it goes directly through the screen. The front layer of the combination has vertical ribs cut in it so that the image can be seen from a somewhat wider viewing angle. This combination screen and lens transfers several times more light than an ordinary ground-glass screen does and also offers a somewhat wider viewing angle. Even so, however, the image on such a screen is bright and clear only within a restricted angle; if one gets too far to the side, the image will practically disappear.

Incidentally, it is not easy to adjust the contrast and brilliancy properly when you are right next to a screen of this kind, so some projection sets have remote control equipment that permits the contrast and brilliancy to be adjusted from the normal viewing position. Such a control does not provide tuning; it is still necessary to operate the tuning control at the set itself.

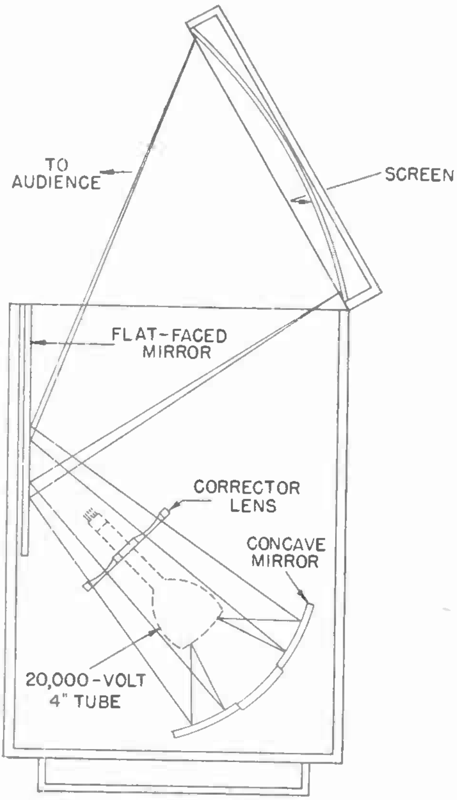


FIG. 25. The Philco system.

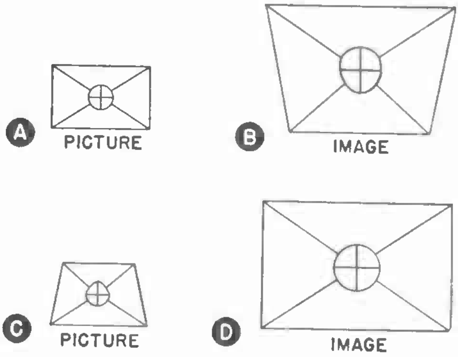


FIG. 26. Keystoning and its correction.

THE PHILCO SYSTEM

Instead of using a translucent screen and projecting the image on the rear of it, the Philco system is arranged so that the image appears on the front of the viewing screen. The shape and reflecting qualities of the viewing screen are such that this system gives somewhat greater light transfer than does rear projection. However, a rather special arrangement is necessary within the set to avoid distortion of the image.

The basic light path is shown in Fig. 25. A projection tube is used in a Schmidt lens system very similar to that of the RCA receivers. The image is reflected from a spherical mirror through a corrector lens to a flat mirror, which then reflects the image onto the front of the viewing screen. In this case the viewing screen is mounted on the lid of the cabinet and is raised to an angle of about 67½° for normal viewing from the front of the cabinet.

The basic difficulty with this system is the fact that the optical barrel is not at an angle of 45° with respect to the plane mirror and that the light path is not at right angles to the viewing screen. As a result, a rectangular picture (Fig. 26A) on the face of the picture tube will produce an image on the viewing screen having the shape shown in Fig. 26B, in which the top of the image is wider than the bottom. (This is called a "keystone" image because its shape is the same as that of the keystone of a stone arch.)

This difficulty can be avoided by distorting the picture on the face of the picture tube so that it has the trapezoidal shape shown in Fig. 26C. Then

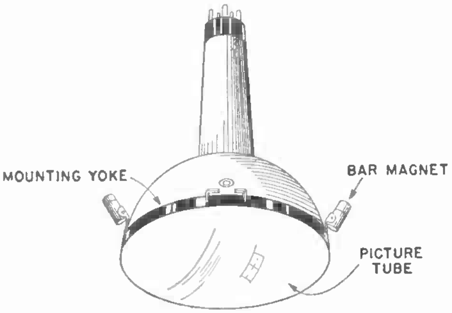


FIG. 27. Keystoning magnets in place.

the distortion in the picture will exactly cancel the distortion introduced by the optical system, and the resulting image will appear in the correct proportions (Fig. 26D).

The required distortion of the initial picture is easily obtained by using a magnetic field to bend the electron beams. Two bar magnets are placed on opposite sides of the tube face as shown in Fig. 27. The magnets are held by a yoke that surrounds the edge of the tube. The positions of these bar magnets can be adjusted to produce a picture on the tube that will be distorted in just the right way to cancel the distortion in the optical system. Because these magnets give the initial picture a keystone shape, they are known as keystoning magnets.

Since the image is formed on the front of the viewing screen, the screen is designed to reflect light rather than to transmit it. It is curved slightly to decrease the vertical viewing angle. This arrangement increases the brightness of the image, because light that would otherwise be directed up or down is concentrated by the curved screen into the forward direction. The screen has vertical ridges in it that are intended to increase the width of the viewing angle somewhat and to decrease glare caused by light that strikes the screen from the side.

This viewing screen is mounted on the inside of the lid of the cabinet, so that the lid must be raised to make the picture visible. There is a special stop arrangement on the lid that allows it to be brought up to the proper position for viewing but no farther.

THE PROTELGRAM SYSTEM

As Fig. 23 showed, the optical barrel in the Schmidt lens system described so far is somewhat bulky. For this reason, a fairly large cabinet is needed to house such a system.

The Protelgram system developed by the North American Philips Company, however, has an optical barrel small enough to be housed in a table-

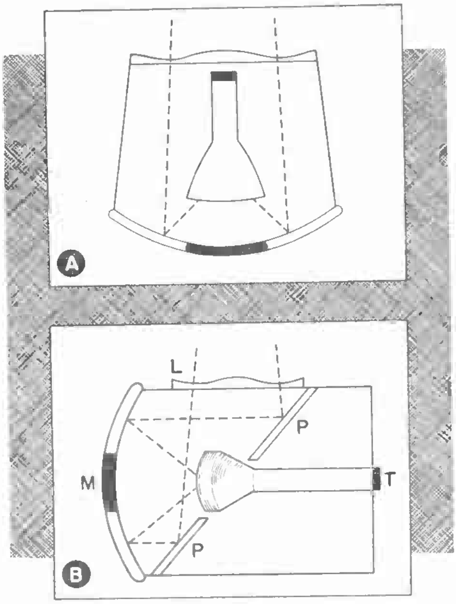
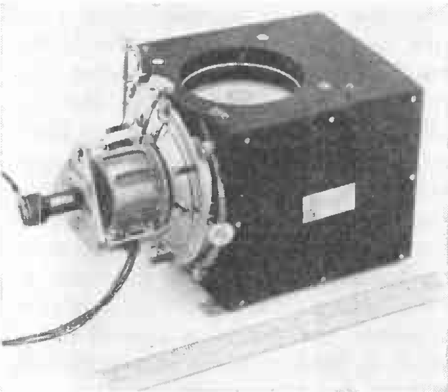


FIG. 28. The Protelgram box compared to a standard barrel.

model receiver. This reduction in size is produced by using a "folded" Schmidt lens system and a 2½-inch projection tube. The basic difference between this and the system used by RCA and Philco is shown in Fig. 28.

As you can see, the tube is inserted in the box in front of the curved mirror M in much the same manner as in the other systems. However, the light path from this mirror M is to a plane mirror P mounted at a 45° angle, which reflects the light up through the correcting lens L and thus out of the box. The projection tube T is inserted through a hole in the

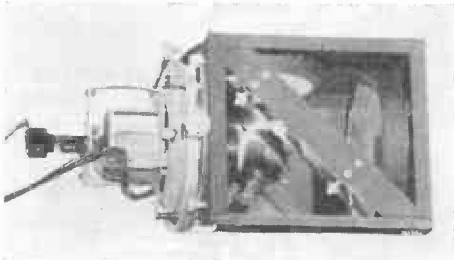


Courtesy North American Philips Co.
FIG. 29. An external view of a Protelgram unit.

center of the plane mirror P. All of the tube except its face is taken completely out of the light path—the focusing coils, wiring, socket, etc., are not in the way at all. This eliminates some of the light losses experienced in the other systems.

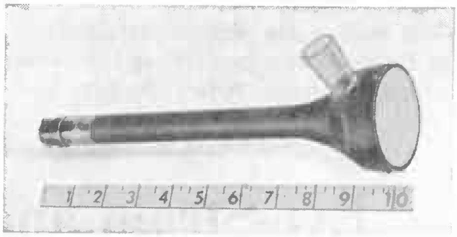
The use of a small picture tube, which makes it possible for the spherical mirror to be small also, and the use of the plane mirror to bend the light path, result in a compact optical unit. A general idea of this optical unit's appearance can be obtained from Figs. 29 and 30. In Fig. 29, the tube and the deflection coils are shown projecting out of the box. In the opened view of Fig. 30, you can see the spherical mirror, the inclined plane mirror, and the corrector lens at the top of the box. Notice how just the tube face protrudes through the plane mirror.

Fig. 31 shows the tube itself. As you can see, it is very small in size.



Courtesy North American Philips Co.
FIG. 30. A cut-away view of Protelgram box.

The glass cup on the bell of the tube near the face is used to insulate the high-voltage connection from the outside of the tube, which is completely covered by a grounded conductive coating. When the high-voltage connection is made inside this glass cup, the leakage path from this connection to the outside conductive coating is the total path up the inside wall of the cup and down the outside. Hence, this cup acts as an insulator.



Courtesy North American Philips Co.
FIG. 31. A projection tube.

As shown at the left in Fig. 32, the Protelgram optical unit can be installed in a console cabinet if desired. Because of its small size, it is also possible to lay the unit on its side, as shown at the right in this figure, and use an additional mirror to get a very compact unit that will fit into a table cabinet. Either of these arrangements in cabinets of the size indicated in Fig. 32 will give a picture of 12 x 16 inches. In addition, this unit can be used for projection onto a screen on the wall, in which case it can be made to give a picture as large as 3 x 4 feet.

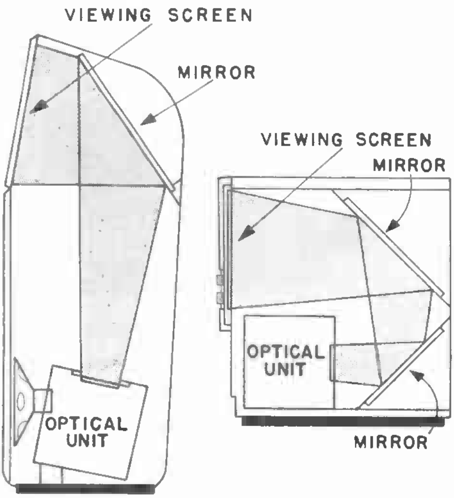


FIG. 32. Two ways of mounting a Protelgram unit.

SUMMARY

From the foregoing details, you can see that projection sets are basically much like direct-view sets. The same receiver chassis can be used in either—the only basic differences are that the former use a projection tube and a higher-voltage power supply and sometimes need a greater sweep voltage. Also, it may be desirable to use a somewhat higher signal on the grid of some projection tubes, in which case the contrast control setting may be at a higher level or an additional amplifying stage may be used in the video amplifier. In general, a projection receiver is otherwise identical with a comparable direct-view set.

You will, therefore, find the usual TV controls on a projection receiver. In addition, there will be the controls that are necessary for proper focusing and picture centering of the projection unit. These controls are physical, rather than electrical; that is, they move the actual position of the tube with respect to the mirror (or to the lens in a lens system). A later text will give more details about the adjustment of these controls. Since there are several variations on the basic systems we have described, it is wise to consult the manufacturer's information for exact details before attempting to adjust one. For example, in some systems the manufacturer recommends the use of a special lamp, which is used in place of the picture tube, to get the optical system lined up. Once the optical system has been brought to a proper focus, the lamp is removed and the picture tube is installed in its place. In other systems, the optical system is lined up with the picture tube already installed.

Eye-Strain and Glare Filters

An important factor affecting the quality of a television picture is its contrast range. By "contrast," in this case, we mean the brightness range between the lightest and the darkest part of the picture. Illumination experts consider that a good picture, whether film, painting, television, or engraving, should appear to the eye to have a contrast range of approximately 30 to 1. This means that the highlights or brightest portions of such pictures, when viewed with normal surrounding illumination, should be about 30 times as bright as the darkest shade obtainable.

With paintings or photographs, this is not too difficult a range to obtain, because dyes, paints, and printing inks used for black are extremely light-absorbent. The black level, therefore, is very low, so a highlight 30 times as bright can readily be secured by using good paper or white pigments.

In the television and motion pictures, however, the "black" is actually just the absence of light, so we can have no true black. The darkest shade we can get is determined by the amount of the surrounding light that is reflected from the screen surface. Therefore, if we start out with a "black" that is actually well up in the gray region, the highlight brightness must be very high if we are to get our desired contrast range. In the case of motion pictures, it is not practical to get such extremely bright levels; for this reason, motion pictures must be viewed in the dark so that the dark elements of the scene will be more nearly black, making it possible for a reasonable light level to represent the lighter portions of the scene.

There are two reasons that make it undesirable to view a television picture in complete darkness—first, it is often inconvenient to try to make a room dark enough, and secondly, viewing such an image in the dark tends to produce eye strain. This strain results from the fact that the eye becomes tired in attempting to accommodate for both the bright picture and the surrounding blackness.

For these reasons, it is desirable to view a television image in a room that is at least reasonably well lit. As a matter of fact, it is the opinion of lighting experts that the amount of light on the surrounding walls should be approximately equal to the highlight brightness in the pictures that are to be seen. This means that the room should be almost normally illuminated for most television picture viewing.

As soon as we introduce such light levels, however, we are back to our original problem of a "gray" black and may even encounter cases of a "mirror" reflection or of glare. Let's see what can be done to avoid these difficulties.

SCREEN ILLUMINATION

As a practical example of the effects of the ambient (surrounding) illumination, let us first assume that we can have a television picture having the optimum range of contrast of 30 to 1. This means that if the brightest point in the scene has a brightness of 30 foot-lamberts (a foot-lambert is a unit of brightness used by lighting engineers), the darkest portion of the scene must have a brightness of only about 1 foot-lambert.

Now, let us suppose that we light up the surrounding room to a brightness of 20 foot-lamberts, which is the level that may be found in a fairly brightly lighted living room. The viewing screen is necessarily also lighted to the same level. The viewing screen is not a perfect reflector, but it may easily reflect half the light falling on it, so now the lowest level of brightness of the screen is 1 plus 10, or is 11 foot-lamberts. Since the minimum blackness we can get is equal to the lowest light level that the screen can reach, our "black" level is now 11 foot-lamberts.

This same 10 foot-lamberts is added to the highlight brightness also, making the highlight brightness now 30 plus 10, or 40 foot-lamberts. However, notice what has happened to our contrast range. It is now 40 to 11 (instead of 30 to 1) or only about 3.6 to 1. Effectively, we now have a washed-out grayish-white image.

To get back the proper 30-to-1 contrast range, the contrast and brightness controls on the receiver would have to be turned up to make the highlight brightness 30 times 11 or 330 foot-lamberts. This would be far too bright a picture for any degree of comfort; in fact, it is a higher light level than the average receiver can produce.

Obviously, therefore, there are only two things that can be done if we are going to get anywhere near the optimum contrast range. One is to greatly reduce the surrounding light, with its attendant problems of being inconvenient and perhaps causing eye strain; the other is to reduce the amount of light that is reflected from the viewing screen. The latter idea brings up the use of light filters. Let's take our example and see just what a filter will do.

In Fig. 33A, we have the screen that is transmitting a highlight brightness of 30 foot-lamberts and a "black" brightness of 1 foot-lambert. Let's assume that the screen has a 50% reflectivity—that is, that it reflects 50% of the light falling on it. If the light from the room falling on this screen is 20 foot-lamberts, the screen will reflect a total of 10 foot-lamberts. Our maximum possible contrast range is now in the ratio of 40 to 11, or about 3.6 to 1.

Now, let's place a light filter in front of this television screen (Fig. 33B). This filter is a light gray sheet of cellophane or similar material of such a nature that it will pass only part of the light that is trying to go through it. Let's first assume that it passes half the light. In this case, the 30-foot-lambert highlight brightness of the picture is reduced to 15 foot-lamberts, and the "black" brightness will be reduced to 0.5 foot-lambert. However, notice what happens to the surrounding (ambient) light. This light must go through the filter to fall on the screen and then must come back through the filter a second time to come out. Therefore, if we have a surrounding light of 20, it is reduced to a value of about 10 before it strikes the viewing screen. Since the screen reflects half the light falling on it, this 10 will return to the filter as 5 foot-lamberts and will be reduced in half again (to 2.5) in passing through the filter a second time. Therefore, our minimum light level has been reduced to 2.5 + .5 or to 3 foot-lamberts. With no change in the original picture brightness, we now have a ratio of 17.5 (15 + 2.5) to 3, which is 5.8 to 1 instead of our original 3.6 to 1.

Of course, we started with an original picture highlight brightness of 30 foot-lamberts. If this represents the highlight brightness that we desire, and if the set has sufficient range, we now can increase the original picture highlight brightness to let us say 60 foot-lamberts, increasing the black brightness to 2 foot-lamberts at the same time. This will be reduced in half by the filter so that the highlight brightness on the viewing side of the filter will be only 30, but we will now

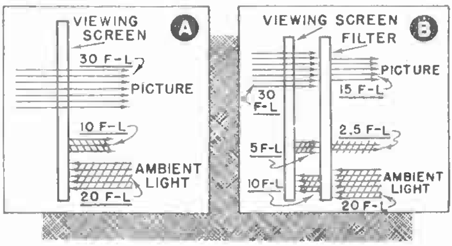


FIG. 33. How a light filter reduces reflection.

have a range of (30 + 2.5) to (1 + 2.5) which is 32.5 to 3.5, or 9.3 to 1. Notice that we obtain this increased range with no increase in the actual brightness of the final picture.

Of course, we could have increased our illumination to 60 in the first case (without the filter) and thus could have nearly doubled the contrast range, but this would have been at the expense of producing an excessively bright scene.

Fig. 34 shows what happens if the filter cuts out even more of the light —if it only transmits, let us say, 20% of the light. We now need 150 foot-lamberts from the screen to give us a highlight brightness of 30, but our

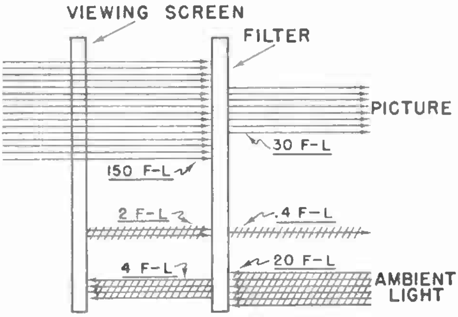


FIG. 34. A filter with 20% transmission.

20 foot-lamberts of ambient light goes through the filter to appear as only 4 on the screen. This is reflected as 2 and comes through the filter the second time as only .4 foot-lambert. This gives a contrast range of 30.4 to 1.4 or 21.6 to 1, which closely approaches the desired 30 to 1.

You can see, then, that it is possible to get an increased contrast ratio in a room that is normally lighted by using a filter in front of the face of the viewing screen, whether this viewing screen be a direct-view picture tube or the screen on a projection system. It is necessary to run the picture at a higher initial brightness level to achieve this, however, and if the set is not capable of producing a sufficiently bright picture, the filter is not as effective. For this reason, filters are less commonly used on projection sets than on direct-view types.

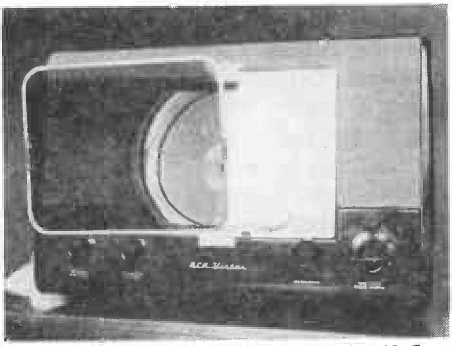
It is important to realize that this filter improves the contrast only by reducing the effect of ambient light. It can do nothing whatever about limited contrast ranges in the pictures themselves. Many television pictures have low contrast ranges, and these may be further compressed by improper adjustment of the contrast and brightness controls on the receiver. Therefore, it is well to be cautious about statements that a filter will increase the contrast in the picture, because this may not necessarily be so at all. The filter merely makes it *possible* for a full contrast range to be visible when there would be such a range in the picture on the tube if it were not for the ambient light.

Notice that the filter will work satisfactorily only when it is in front of the picture screen so that the room light falling on the screen will be doubly cut down. Holding such a filter directly in front of one's face will do nothing except cut down the highlight brightness of the picture. For this reason, goggles or spectacles made like sun glasses will not work in the manner we have described. Of course, if the picture brightness is run up to a very high level so as to get the highlight brightness as far from the minimum level as possible, then such goggles will cut down the terrific brightness that would be harmful to the eyes, but this is not as effective as the use of the filter on the viewing screen itself.

Filters designed for improving the contrast by reducing the reflections from the viewing screen are usually neutral gray filters having light transmission abilities ranging between 20% and perhaps 35%. Some of these filters, however, are tinted blue. These filters are considered desirable by some because the image produced by many picture tubes has a yellowish or brownish cast instead of being a pure black and white picture. This may come about because the fluorescent screen materials do not produce a good white, or because the tube has aged and the screen has become slightly burned, or because the high voltage is somewhat below normal. The use of a blue filter will tend to wipe out this color cast and to make the picture appear more truly black and white.

Since people may object to the effects of filters on the color or appearance of the picture, it is always well to be cautious in recommending the use of filters except on a trial basis.

A Polaroid filter recently put on the market uses the phenomenon of polarization of light to eliminate reflections from the picture tube. As you know, ordinary light consists of electromagnetic waves (like radio waves, but much higher in frequency)



Courtesy Polaroid Corp.

This view shows how a Polaroid filter cuts down glare. A set is facing a window reflecting a strong light, and the filter is shown covering half of the tube face.

that vibrate in all directions at right angles to the direction of propagation. Certain natural crystals have the property of passing practically all the light that vibrates in one plane, and of absorbing light that vibrates in other planes, with a maximum absorption of vibrations that are 90° from the plane that is passed. Such crystals are called "polarizers," because the light they pass is polarized (that is, it vibrates in only one plane).

Polaroid is a material that is made by embedding vast numbers of tiny polarizing crystals in a sheet of plastic. It acts as an efficient polarizer: about 50% of a beam of unpolarized light that strikes a sheet of Polaroid will pass through it, emerging as a polarized beam. The rest of the beam will be absorbed. Its action on polarized light depends upon the angle between the plane of polarization of the light and the polarizing plane of the Polaroid. If this angle is 0° (that is, if the light is polarized in the plane that the Polaroid passes), the light will be passed almost completely; if it is 90°, the light will be almost completely absorbed; and if it is somewhere between 0° and 90°, part of the light will be passed, the rest will be absorbed.

In this new filter, a sheet of Polaroid is bonded to another material that has the effect of producing a 45° rotation of the plane of polarization of any light that passes through it. The filter should be placed on a TV set so that the Polaroid side is farther from the tube. When this is done, it will be impossible for ambient light to be reflected from the face of the tube. Let's see why.

The light from an ordinary source, such as an electric light bulb, is unpolarized. When such light strikes the filter, half of it passes through the Polaroid, emerging as polarized light. The plane of polarization of this light is then rotated 45° by the other material in the filter. Next, the light is reflected from the face of the tube back toward the filter. This time, it strikes the rotating material first, so its plane of polarization is rotated 45° more, making a total of 90°, before it reaches the Polaroid again. Since its plane is now 90° from the plane that the Polaroid passes, the light is almost completely absorbed. Thus, no light is able to pass through the filter, be reflected from the tube, and pass out through the filter again.

Half the light from the tube face, however, which is initially unpolarized, is able to pass out through the filter. Thus, the filter acts as a 50% filter as far as the light from the tube is concerned and as virtually a 100% filter for ambient light.

ROOM ILLUMINATION

You can see from what we have said that it is desirable to have normal room illumination, but it is not desirable to have too much light. If the light level is too high, it is practically impossible to get the highlight brightness of the picture high enough to overcome the surrounding level. It is all but impossible to see the picture if direct sunlight is allowed to fall on the screen, for example.

As a further point, it is of course undesirable to have the set placed next to a bright source of light. If you can see a strong light at the same time you are attempting to watch the screen, your eyes will become tired from trying to accommodate intermittently between the strong light and the less brilliant screen, just as they would for the opposite condition of a bright screen and dark surroundings. That is why it is undesirable to place the television set next to a window through which sunlight may come.

In general, therefore, it is desirable to light the room to a normal level, preferably by the use of indirect or shaded lights during evening hours, and, in the daytime, to cut down somewhat on the amount of sunlight present by drawing the blinds at least part way. Strong light should not be allowed to shine directly on the screen nor to be right beside it.

To make it easier to watch a TV picture, the lights in the room must be properly arranged with respect to the set. Glare can be caused by excessive illumination at the wrong angles to the viewing screen. As a matter of fact, the screen is so mirror-like that it is even possible to get reflections and to see the light source in the screen if the former is placed in the wrong position. In general, therefore, it is not desirable to have lights directly behind the viewer so that the light, viewer, and viewing screens are on the same line, and not to have the lights beside the set. The light from all sources in the room should be practically at right angles with respect to the line formed by the television set and the viewer. Under these conditions, with the normal relatively flat-faced viewing screen, the light source may produce some glare but not at least a mirror reflection.

If a magnifier lens is used in front of the set, the problem is quite severe, because the curved surface of the magnifier is practically certain at some point to be of the right shape to produce a mirror reflection.

Color Television

Ever since the beginning of the idea of a television system, many engineers have been working on television in color. Because it is so desirable from the standpoint of natural rendition of a scene, color television is almost certainly the system that will eventually be put into use providing a practical system that is not too expensive can be developed. Involved in this cost problem is not only the initial cost of the receiving equipment, but also the extra costs at the transmitting end, both in original material and in operation.

Of course, a color system, to be practical, must be as reliable in maintaining synchronization as is the modern black-and-white process. As yet, there has been no standardization on color systems because no one system has yet been adopted. In the following, we shall describe four or five basic color systems that are at least in the laboratory developmental stage, so that you will have a general understanding of the problem and can see the direction of thinking of the engineers that are working on this problem. We shall primarily discuss receiving equipment. You can assume that in all cases, the transmitter must use corresponding units to pick up the image.

We cannot say that any one of these particular systems will ever be the one that is finally developed—but from the emphasis on color development in the laboratories today, and from the great public demand for color television, it seems quite possible that the next few years will see a practical system placed on the market. It is even possible that more than one system may come into use if the standards for picture transmission can be set to permit this.

Before we go on to learn about these basic systems, however, let's briefly review a few facts about light.

LIGHT FILTERS

What we know of as white light is actually a combination of all colors in such proportions as to give the effect of white to the eye. However, we need not have *all* colors to produce white, because of the way in which the "primary" light colors blue, red, and green will add together. As Fig. 35 shows, the proper admixture of these three will produce white. Also, it is possible to get white light by combining the complementary colors. Thus, blue and red combined will give magenta, and magenta with green will give white. Similarly, blue and green will give peacock blue, which when added to red will give white. Finally, red and green light combined will give yellow, which when added to blue will give white. Since the three primary light colors can be combined to give all the colors plus white, we can reproduce a full color image if we can have a system that will break down the original image into these three primary

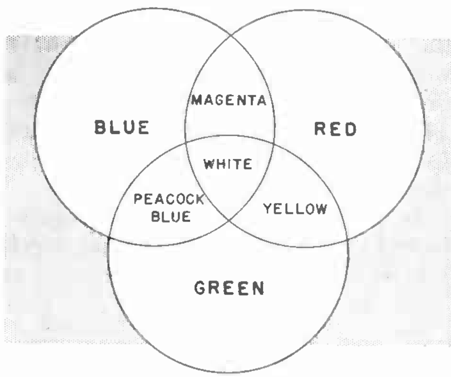


FIG. 35. The effect of mixing various colored lights.

colors at the transmitter and recombine them correctly at the receiver.

The process of adding colored lights together must not be confused with that of mixing paints or dyes, which is a subtractive process rather than an additive process. For example, when yellow and blue *lights* are mixed, the added colors give white as a result. On the other hand, if you mix yellow and blue *paint,* you will get green paint as a result. The difference lies in the fact that the color you see when you look at paint is the color of light that the paint reflects or transmits; all other colors that may be in the light that strikes the paint are absorbed by it.

Suppose, for example, that a yellow paint is illuminated by white light. The paint will absorb or remove from the white light the blue, purple, and red components; it will reflect primarily yellow, plus some green and orange. It will therefore appear yellow to your eyes, which see only the light reflected from it. Similarly, blue paint will absorb and remove from white light the yellow, orange, and red, reflecting primarily blue and some green and purple. If we mix these two paints together, green is the only color not absorbed by either paint, and it is therefore the only color reflected to your eyes.

Basically, therefore, from a lighting standpoint, color television can be obtained simply by taking pictures of the red, green, and blue components of the image to be transmitted, and then, at the receiving end, reproducing each of these three color images and superimposing them upon each other on the viewing screen to form the composite full color scene. Two major problems are involved: first, the separation of the scene into primary colors; and secondly, the recombination of the different images at the receiver. It is necessary that these images be combined at a rapid enough rate to prevent flicker, and the overlapping of the images must be carefully controlled so as to produce the illusion of a solid colored scene. Fundamentally, therefore, instead of dealing with one scene at a time, we are actually trying to handle three.

IMAGE TRANSMISSION

There are two basic methods of sending the colored images as a transmitted signal. First, the respective color images may be sent one after another in sequence, or secondly, they can all be sent simultaneously by using each to modulate a different carrier.

Sequential Scanning. In the sequential system, a line may be scanned for the red values in it, for example, then scanned a second time for the green values, and finally for the blue, after which the process is repeated for the next line. In such a case, the red image is sent as a line; the next line corresponds to the green image; and the next line corresponds to the blue image (see Fig. 36A). When all three images corresponding to a single line of the original scene have been obtained, the next line of the scene is scanned in the same sequence.

If the separate *frames* can be combined at a rate fast enough, it is possible to make this sequential scanning that of a complete frame or picture, instead of lines. Thus, the entire picture could be scanned first to get a red image, scanned again to get a green image, and scanned yet again to get a blue image. Then all three of these images for the complete frame could be recombined. If this is done, it is necessary to transmit at a much higher frame rate, because the color images must all be recombined at a fast enough rate to avoid flicker. This means that about 20 frames per second for each color is about the slowest

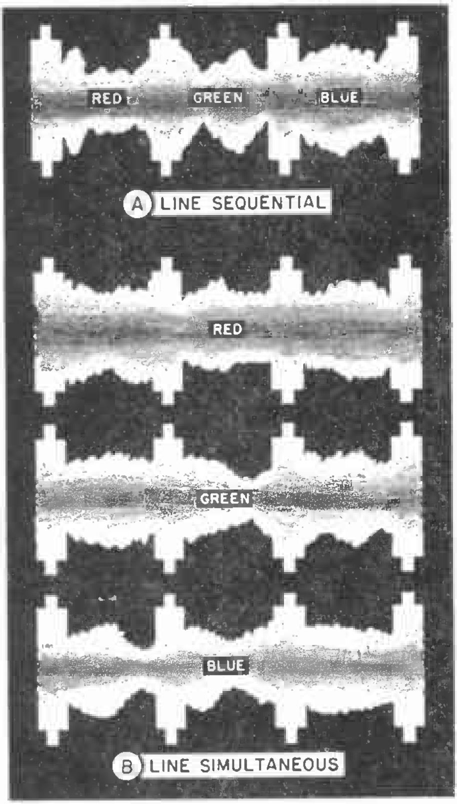


FIG. 36. Scanning methods.

we can expect, and we would probably have to go to 24 or more. Since there are three colors, the number of frames per second would have to be at least three times the lowest number that was found acceptable.

On the other hand, if each line is scanned three times before the next line is scanned, the same number of frames may be used; but now we have three times as many lines. Therefore, no matter how it is done, a sequential scanning system would differ from present-day standards either in the number of frames or in the number of lines, or perhaps even in both. Hence, either a frequency channel wider than the present 6-mc. one must be used, or the image detail must be degraded by reducing the line resolution (a reduction in the detail because of the loss of high frequencies). Whether a poorer color image should be accepted or a channel about 9-mc. wide should be used has not yet been settled.

Simultaneous Scanning. The simultaneous scanning system is one in which we have three different signals produced by three different pickup tubes, each of which scans the scene all the time. One tube picks up the red image, another the green, and the third the blue. The three signals are then modulated on three separate carriers, or on sub-carriers that are combined into one. Since we have three entirely separate images from beginning to end, it is possible to use the black-and-white standards for lines and frames. However, we must use nearly three times as wide a channel to transmit the whole image if today's standards are maintained. Thus, if a 6-mc. channel is necessary today for black and white, a simultaneous system using the same standards for each of the three colors would require an 18-mc. channel. Of course, it isn't quite as bad as this—one or more of the colors could perhaps be sent in a narrower channel, and there is only one sound channel for the entire picture, so a range of from 14 to 16 mc. would handle such an image. In fact, it would be possible to handle the image in a 16 mc. channel by using multiplexing or other tricks of modulation.

The wide frequency spectrum needed is one of the stumbling blocks that has prevented the introduction of this kind of color system. The Federal Communications Commission has insisted that any color system it is to approve for commercial use must be less wasteful of the frequency spectrum.

Another important question not yet settled is whether a color system should exist as an entirely separate service, or whether it should be able to produce an acceptable image on a black-and-white receiver as well. In the case of the simultaneous systems, any one of the three images can be used as a black-and-white image. For example, the green image of a simultaneous system, if it were transmitted according to present day standards, would produce a satisfactory black-and-white picture representing the complete scene. The receiver in this case would just ignore the other two color images, which would be suppressed by its tuned circuits. The sequential systems, however, can be received only on a set designed for the color image. The ability to operate both kinds of receivers has always been one of the strong points in favor of simultaneous transmission; in fact, it may eventually outweigh the objection that a wide frequency band is necessary for such a system.

Incidentally, you may wonder how a color image could be reproduced as black and white. It is very important to notice in the following discussion that in all cases we are merely using a filter in front of the camera to filter out lights of all but the desired color, so that only light of this color is registered by the camera tube. However, the camera tube is the same type as that used today, so the image of any color that is transmitted consists of a voltage variation that corresponds to the varying brightness level of the elements of the scene as far as light of that color is concerned. At the receiver, if there is no corresponding color filter, the pickup tube will be actuated to reproduce a black-and-white picture corresponding to the voltage variations in the transmitted signal. Of course, the contrast of this black-and-white picture produced by a color signal may not be the same as it would be if white light from the scene were picked up by the camera; however, the black-and-white picture produced by, say, the green signal should be acceptable, if not perfect.

Each of the systems to be described holds promise of being workable. The eventual choice will depend upon cost considerations and other factors that we shall mention.

MECHANICAL SYSTEMS

A mechanical means of getting a color image has been known and experimented with for a long time. In fact, the use of a mechanical disc or drum goes back to black-and-white systems that were in use before the development of the electronic picture tube.

A simple form of this system is shown in Fig. 37. The reproduced television image appears on the face of a standard cathode-ray tube as an ordinary black-and-white image. However, the light from this tube must pass through a color filter before being projected on the viewing screen. A color filter is made up of a disc of separate filters for red, green, and blue light. The disc may have six, nine, twelve, or more segments if desired, but the number of segments must be a multiple of three if a three-color system is used.

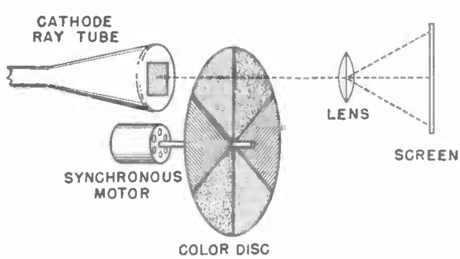


FIG. 37. A mechanical color scanner.

The disc is rotated by a synchronous motor so that the color segment in front of the picture tube at any time is the proper one for the color that is to be reproduced at that time.

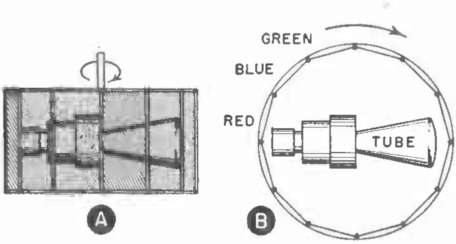


FIG. 38. Another possible mechanical color scanner.

This system must be used with the sequential method of transmitting the color information; to keep the speed of rotation of the filter disc at some reasonable figure, it is necessary to use frame rather than line sequences.

In operation, the color disc is rotated continuously. Its size and speed of rotation are such, however, that one color segment remains in front of the image for one entire frame so that a complete color frame is produced. Then, when the next frame starts, the next color of the disc is interposed between the picture-tube image and the screen. Finally, when the third frame is reproduced, the third color of the disc is interposed. Thus, three separate color images are reproduced in sequence on the same screen area. The rate at which they are produced is so fast that the eye blends them all together as a single image.

One of the disadvantages of this kind of system is that light is lost in passing through the filters. This can be made up for by the use of projection-type tubes. A more important difficulty is that of keeping the synchronous motor exactly in step with the one that is used at the transmitter. Naturally, the color discs at the receiver and the transmitter must be exactly in step at all times—otherwise a color that is transmitted as blue might appear as red or green at the receiver, and so on.

A final disadvantage is the fact that this is a mechanical system—it uses devices that become worn out with use and therefore require maintenance and repair.

The problem of getting the synchronous motor to rotate at the correct speed and to put the right color disc in front of the image at the proper time is not insurmountable. A special synchronizing signal can be sent along with the television image and be applied to the motor circuit through a regulating network that will keep the motor running at the proper speed.

This is basically quite a simple system. If the objections to the use of a mechanical system can be overcome, it may eventually become successful.

Color Drum. A somewhat modified form of the system is shown in Fig. 38. Here, a large drum is used instead of a segmented color disc. A short picture tube is mounted within the drum, and the color filters are mounted so that each will pass in front of the tube in turn as the entire drum rotates. This construction permits a great many filters to be used, which makes it possible to reduce the speed of rotation of the drum.

THREE-TUBE ELECTRONIC SYSTEM

A completely electronic system for reproducing television in color has long been the goal of television engineers. The most basic arrangement of this kind is shown in Fig. 39.

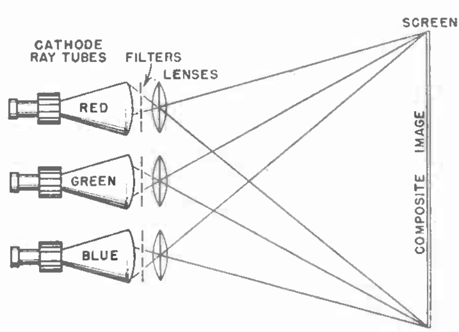


FIG. 39. A three-tube color system.

Basically, this system uses three separate receivers, each feeding a signal representing the light value of a particular color to its black-and-white picture tube. Light from each image then passes through a filter of the right color, after which it is focused by a lens on a viewing screen. The three tubes are arranged so that the three images overlap each other properly to produce a composite image that has the correct color at every point.

Obviously, a device that requires the use of three separate receivers would be very expensive. However, a single receiver can be used if it is specially designed to have r.f. and i.f. systems of the proper wide band width and to incorporate electrical filters to separate the signals of the three images from each other. Three picture tubes are still needed, however.

In this electronic system, we use the same filters used in the mechanical system, but they are now fixed—they do not need to rotate, because the tubes are either operated from entirely separate signals or operated in sequence so that the proper tube behind the proper filter is illuminated at a particular instant.

Although this basic electronic system does work, its cost is too high. Several modified forms of the system have been developed, however, in which a single tube is used. These are considerably less expensive.

SINGLE PICTURE-TUBE ELECTRONIC COLOR SYSTEMS

The system shown in Fig. 40A is one that uses a single picture tube to produce color electronically. In this particular system, the color image is broken up into separate small pictures that all appear on the tube face during a single vertical scan. In other words, when the electron beam completes one vertical scan of the picture tube face, three separate small, black-and-white pictures will have been formed, one corresponding to the red image, another to the green, and the third to the blue. Light from each image passes through an appropriate color filter; then, by means of a prismatic optical system, the three single-color images are combined into a single natural-color image that is projected onto a screen.

To produce these different pictures an optical system at the pick-up camera splits the light from the scene into three parts, each of which is fil-

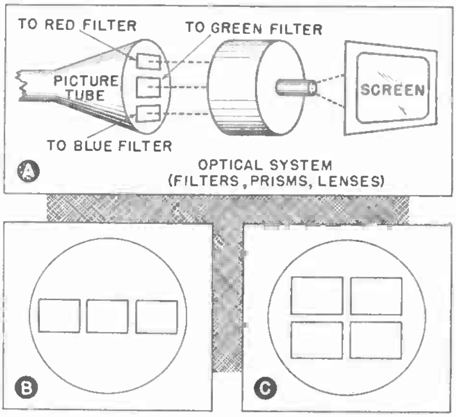


FIG. 40. A single-tube color system.

tered to produce a single-colored beam. Each beam is brought to a focus on a particular area of the mosaic of the picture tube. Thus, three separate images, one in each of the primary colors, are produced on the mosaic. When the mosaic is scanned by the electron beam of the pick-up tube, all three images are converted into electrical signals for transmission.

The optical system at the pick-up camera can be made to arrange the three images one above the other or side by side on the mosaic of the pick-up tube; they will appear in the same orientation on the face of the picture tube (see Figs. 40A and 40B). It is also possible to use an optical system that will produce the image arrangement shown in Fig. 40C. Either three or four images can be produced: if only three are formed, one will be on one line and two on the other.

The chief advantage of the arrangement shown in Fig. 40C is that it permits the individual images to be larger than does either the horizontal or the vertical arrangement. Further, it makes it possible to use a fourth color—yellow, say—if it is found that use of a fourth color will improve the appearance of the final image.

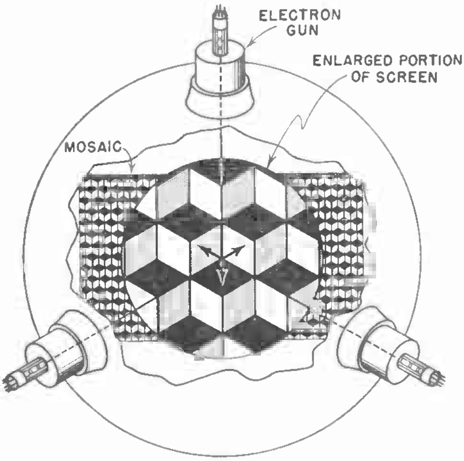


FIG. 41. The tri-Chromoscope.

A good feature of this color system is that it uses only one picture tube to produce a full-color image electronically. On the other hand, very little of the face of the picture tube is actually used, and a fairly expensive optical system must be used to recombine the images. However, this arrangement does offer one possible approach to the problem of getting color television without the use of mechanical moving parts.

COLOR SCREENS

A basic attack on the problem of getting color pictures is an exploration into materials that can be made to fluoresce directly in different colors. The original cathode-ray tubes used screens that produced green images, and it was soon discovered that other fluorescent materials could be made to produce yellow or blue images directly. As a matter of fact, our present-day white image is the result of a combination of several of these fluorescent materials so that the blue and yellow lights balance to produce white.

Therefore, since it is possible with materials known today to get a green and a blue, attempts are being made to find a material that will fluoresce red. Unfortunately, even the green and blue images produced have mostly been pastel rather than brilliant colors, but it is quite possible that a chemist will some day come up with fluorescent materials that will give brilliant primary colors. When such materials have been found, some method must be devised to make the electron beams of the picture tube strike the proper screen at the right time. There are two basic arrangements that have been suggested for this.

The Tri-Chromoscope. One of these systems, shown in Fig. 41, uses a single screen and three separate electron guns. Each of the guns is modulated separately by the signal corresponding to one of the colors, and each scans the screen or mosaic on the face of the tube from a different angle. Magnetic deflection yokes on all three guns are driven in series from one single deflection generator so that the three beams can be held in synchronism.

The mosaic screen surface is made in a series of three-sided pyramids. The surfaces of the pyramids are arranged so that the beam from any one gun strikes only one side of each pyramid. All of the sides facing in one direction are coated with the same color phosphor; but, of course, there is a different phosphor on each of the three sides of any one pyramid.

Thus, each pyramid on the mosaic screen of the picture tube consists of three separate areas of different materials of such a nature that each will glow with a different color. To prevent secondary electrons from one phosphor from exciting adjacent phosphors of different colors, a metallic backing is applied over the phosphors.

In manufacturing the tube, the pyramidal shapes are molded into the back surface of the glass face of the tube. The different color phosphors are then settled into place one at a time. When one phosphor is to be settled, the tube is oriented so that all the pyramid faces on which that phosphor is to be deposited are horizontal. A solution containing the phosphor is then poured into the tube, the phosphor is allowed to settle out of solution, and the remaining liquid is poured out. The phosphor adheres only to the horizontal faces. The tube is then rotated 120°, and the next color phosphor is applied in the same manner.

In this system, the colors are reproduced directly on the screen surface of the picture tube. It is therefore a direct color system and involves no expense for filters or lenses of any sort. However, the tube used is relatively expensive, since three complete gun structures are necessary, and the special mosaic must be carefully made.

The Chromoscope. Another approach to the same basic idea is that shown in Fig. 42. This tube is much more like the standard tubes with which we are familiar in that it has only one electron gun. Instead of having just one screen, however, the tube has four. Three of them are coated with phosphors that will produce the primary colors. The fourth screen—the one nearest the gun—is purely a guard screen and may be just a metal backing on the others.

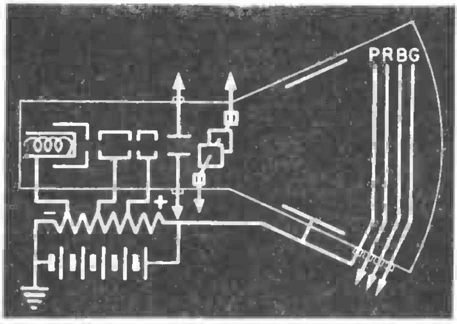


FIG. 42. The Chromoscope.

The color screens are made on a mesh material similar to screen wire, the openings in the meshes being large enough to pass light. Each screen is coated by a very thin coating of fluorescent material. A different material is used for each screen, of course, so that the proper color will come from each.

When this tube is in operation, a high positive potential is applied to the various screens in sequence. At any instant, the high potential is applied to one screen and the others are kept at low potentials. The electron beam strikes all three simultaneously through the openings in each succeeding screen. However, electrons are slowed down by low potentials and speeded up by high potentials. Therefore, electrons will have sufficient velocity to excite (cause light from) the screen that has the high positive voltage on it, but will be slowed down and produce but little light from the other screens. Therefore, the proper colors can be produced by arranging for the proper screen to be connected to the high-voltage supply at the right time.

A tube of this kind uses the same gun structure as the present-day types and differs from them only in the screen. Therefore, the cost of this tube should not be much greater than present ones, providing the fluorescent materials are not overly expensive and no great difficulty is encountered in depositing them on the screens and in subsequently assembling the screens.

The difficulty in designing a set to use this tube will be mostly in obtaining a voltage switching system and a suitable control pulse to actuate it. This arrangement is most readily adapted to a frame sequential system.

We have been able to do little more than describe in brief form the possible color television systems, because none of them has yet been made commercially available. However, as soon as one or more of the systems can be produced economically (with respect to both the transmitter and the receiver), and as soon as it is decided whether to permit color systems to require separate receivers or to insist that they be capable of producing a picture on a black-and-white receiver, we can expect a spurt of further development in these fields.

Lesson Questions

Be sure to number your Answer Sheet 58RH-3.

Place your Student Number on *every* Answer Sheet.

***Send in your set of answers for this Lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. In a remote control system, why is it necessary to use a coupler stage to feed the signal from the video detector to the coaxial line connecting the control unit to the picture unit?
2. When a number of duplicators are connected to the same video-frequency coaxial line, which one uses the line-matching resistance?
3. If the full screen area of a picture tube is to be used to reproduce an image, what compromise must be made?
4. What two effects are produced when a magnifying lens is moved farther away from the face of a picture tube, assuming that the separation between the lens and the tube is kept less than the focal length of the lens?
5. What is the purpose of the corrector lens in a Schmidt lens system?
6. Why is the center of the spherical mirror in a Schmidt system made non-reflective (black)?
7. Why is the reflective coating placed on the face of a spherical mirror instead of on the back as in an ordinary home mirror?
8. Why should cleaning fluids be avoided when cleaning a plastic correcting lens in a projection system?
9. If a light filter in front of a picture tube reduces the light passing through it by half, why does it reduce the ambient light reflection to one quarter?
10. If the present 6-mc. black and white channel is to be used for color, and either the number of frames or the number of lines are increased, what must be sacrificed?

Be sure to fill out a Lesson Label and send it along with your answers.

COMPETITION

When a competitor opens a shop in your neighborhood, your first reactions are probably the same as those of most people—you feel that he is "cutting in" on your trade and that, by fair or foul means, he may run you out of business. However, there is another view to take of this problem.

First, forget your fears! A mind frozen by mistrust and hate is incapable of reasoning; it will lead you to the very downfall you fear. Face the facts: someone else is in the same business, so you must make your services so much *better* than his that you get your share of the work.

Welcome the competition as a spur—something to force you to your best efforts—something to make you become more careful, more efficient, more alert. You will find that honest competition adds enjoyment to your work.

And, another thing, force your competitor to rise to *your* level to survive—don't stoop to his. Do your best work and you'll find that your fears were not justified—there is plenty of business for the man who can deliver the goods!

J. E. Smith

HOW TV ANTENNAS WORK

59RH-3

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE No. 59

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ **1. Introduction . . . . Pages 1-2**

You learn here what basic requirements a television antenna must meet.

☐ **2. Behavior of TV Signals . . . . Pages 2-7**

This section contains a discussion of the transmission and reflection characteristics of v.h.f. waves. You learn, among other things, why reflections may cause ghosts and why TV waves are horizontally polarized.

☐ **3. Types of TV Antennas . . . . Pages 8-29**

In this section, you learn the characteristics of all types of antennas commonly used for the reception of TV signals.

☐ **4. Transmission Lines . . . . Pages 29-36**

Here you learn what the three common types of transmission lines are, how they operate as carriers of r.f. current, why it is important to match their impedances to the receiver and antenna impedances, and how such matches can be made.

☐ **5. Answer Lesson Questions and Mail Your Answers to NRI for Grading.**

☐ **6. Start studying the next Lesson.**

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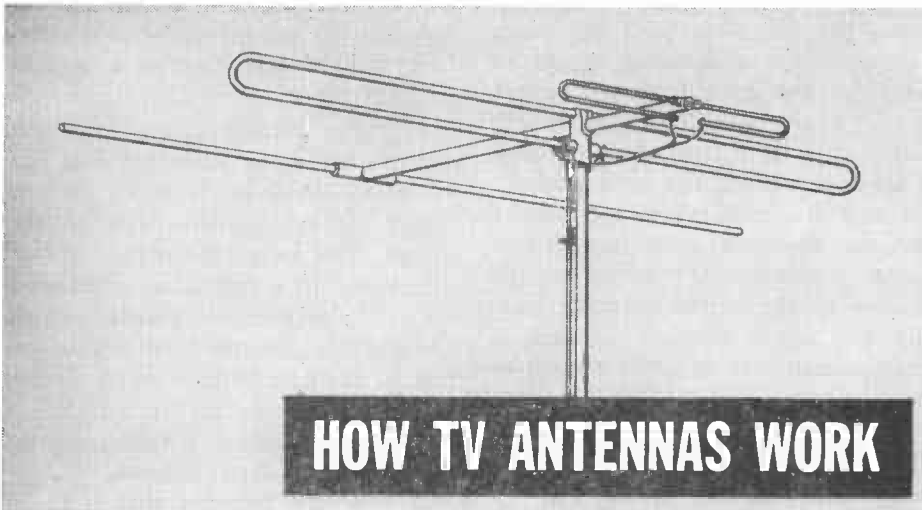


HOW TV ANTENNAS WORK

ANTENNAS are once again important to the radio man. Just as every AM broadcast radio receiver once required a good antenna to bring in a signal, so now do television receivers require good antennas—sometimes even very elaborate ones.

By radio AM broadcasting standards, the signal strength in the service area of a television transmitter is extremely high. However, the transmitted signal covers such an extremely wide frequency range—almost 6 megacycles — that a television receiver must tune very broadly to accept it. Consequently, it cannot have as much amplification as a regular broadcast-band receiver does. This means that a relatively strong signal must be fed into the receiver from the antenna for the set to work properly; as a result, it is usually necessary to have an antenna that will be as efficient as possible in picking up signals.

As a matter of fact, in a great many cases, the success or failure of a television receiver installation depends largely on the type of antenna equipment that is used and on the location at which the antenna is installed. In a relatively few locations that are close to television transmitters, there is usually enough signal strength so that a simple antenna will work satisfactorily. In general, however, it is best to be very careful to choose the right antenna and install it properly if the customer is to get a satisfactory picture. No matter how expensive or well built a television receiver is, it will not work well unless the antenna gives it a satisfactory signal.

Let's see what requirements a television antenna must meet.

BASIC REQUIREMENTS

As you know, two frequency bands are now assigned to television. The low-frequency band extends from 54 to 88 megacycles, and the high-frequency band extends from 174 to 216 megacycles; the frequencies between the two bands are assigned to f.m. stations and to other services. (A third band in the u.h.f. region between 480 and 920 mc. may soon be opened to television.) The large metropolitan areas usually have at least two stations in each band. Locations that are less thickly populated may have only one or two stations, both of which may or may not be in the same band.

Naturally, the owner of a television set wants to pick up every station he can reasonably expect to get. If he lives where stations transmit in both bands, he will want to receive both bands, or at least those portions of them containing the local stations. An antenna installation for such a location, therefore, must have a frequency response that is broad enough to cover all the desired channels. Usually the signal strength in such a metropolitan area is great enough so that the antenna gain is not the major consideration; however, the gain should be as uniform as possible over all the frequencies covered.

On the other hand, there are many locations at which it is barely possible to receive just one station. Wide frequency response is not as desirable in an antenna for such locations as is high gain.

Sometimes it is desirable to pick up the frequencies between the two bands, sometimes not. If a television set is designed for f.m. reception also, of course its antenna should pick up the f.m. frequencies. If the set is not designed for f.m., however, it is desirable to have the antenna reject the frequencies in the f.m. band to prevent the possibility that image reception will cause interference between f.m. signals and television signals in the receiver.

In many locations, the television antenna must be directional in its reception—that is, it must receive better in one direction than in the others. The usual reason for wanting directivity in a television antenna is that it helps prevent "ghosts," which are multiple pictures produced on the face of the picture tube when an antenna picks up signals from a station over different paths. We shall discuss ghosts in more detail later on.

A television antenna that is to be mounted outside must be proof against corrosion and must be mechanically strong enough to stand winds and storms. It should also be so constructed that it is relatively easy to mount and to orient in the desired position.

Before we can say much about television antennas, it would be well for us to go further into the subject of the behavior of television signals. This will make it easier to understand the operation of the antenna as it receives the signals.

Behavior of TV Signals

As you know, radio waves transmitted at broadcast frequencies either travel along the ground or bounce back and forth between the ground and the Kennelly-Heaviside layer. The former are called "ground waves," the latter, "sky waves." The very-high-frequency signals used in television, however, behave differently. They act more like light beams, the resemblance becoming more pronounced as the frequency is increased. By this, we mean that they are transmitted in relatively straight lines outward from the transmitting antenna: they do not bend around hills or other obstructions as do the AM broadcasting waves, nor are they reflected from the Kennelly-Heaviside layer as sky waves are. Therefore, television signals are often considered to be "line of sight"—which would mean, if it were strictly true, that you could not receive television signals at any point unless you could see the transmitting antenna from the location of the receiving antenna. (As we shall show a little later, this is not quite true.)

As a result of this characteristic of television signals, the distance over which a television signal can be received is severely limited. The distance at which dependable reception can be obtained depends, of course, upon the height of the transmitting and receiving antennas; however, television broadcasts from the tower of the highest building in the world, the Empire State Building in the city of New York, can usually be picked up reliably only within a radius of about 60 miles.

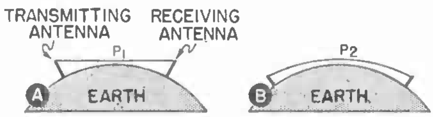


FIG. 1. The slight refraction of TV signals in air permits reception to be had over distances that are longer than the line-of-sight path.

An illustration of a true line-of-sight signal is shown in Fig. 1A. As you can see, the signals from the transmitter travel in a straight line, P_1; those that pass the receiving antenna continue on out into space and never return to earth. Notice that if either the transmitting or the receiving antenna were slightly less elevated, the curve of the earth would interrupt the optical line of sight between them and thus prevent reception of the signals at the receiving antenna.

As it happens, however, there is a certain amount of refraction (bending) of v.h.f. radio signals in the air. As a result of this bending, television signals can travel slightly farther than they could if they were strictly line of sight. This is illustrated in Fig. 1B, where P_2 is the curved path actually taken by the signals. Comparing the length of P_2 with that of P_1, you can readily see that the curved path permits signals to be received over a greater distance. The actual increase in receiving distance is not proportionally as great as is shown here, because the curve of the earth has been greatly exaggerated in these drawings. However, the increase in receiving distance caused by the refraction of v.h.f. signals is appreciable.

The chart in Fig. 2 provides a convenient way to determine the line-of-sight distance between the two antennas. Assuming normal transmission strength and an average good TV receiver, reception within this area should be highly acceptable. Actually, reasonably reliable reception can be had beyond these figures for reasons we have just explained.

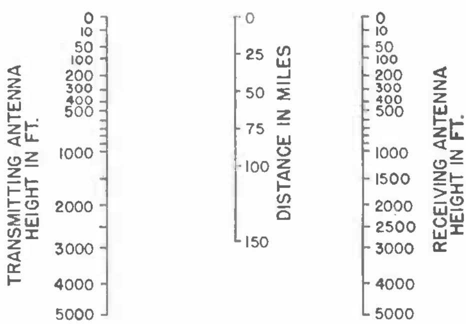


FIG. 2. Chart for determining the maximum line-of-sight distance between two antennas.

To use this chart, mark off the height of the transmitting antenna in feet on the left-hand scale and the height of the receiving antenna in feet on the right-hand scale. Lay a ruler or other straight edge across the two marked points. The point where the ruler intercepts the center scale shows the distance in miles over which line-of-sight reception is possible.

If the area on which the transmitting antenna is erected is at the same height above sea level as the area on which the receiving antenna is erected, you should use the height above ground of the two antennas in computing the line-of-sight distance. Suppose, for example, that the transmitting tower is 400 feet tall, that the receiving antenna is 50 feet above the ground, and that the ground level at both locations is the same with respect to sea level. If you lay out these two distances on the chart and lay a ruler between them, you will find that the line-of-sight distance between them is 38 miles.

If there is a difference in the average height above sea level between the two areas at which the antennas are erected, this difference should be added to the height of the antenna at the higher location. Suppose, for example, that the transmitting antenna is 400 feet high and is on a hill that is 225 feet higher than the level of the area on which the receiving antenna is erected. The transmitting antenna should now be considered to have an effective height of 625 feet. Laying out this height on the left-hand scale and 50 feet on the right-hand scale, you'll find that the line-of-sight distance is now increased to 45 miles.

Conversely, if the receiving antenna is on a hill, its effective height should be increased by the relative height of the hill in computing the corrected line-of-sight distance. There is one limitation that must be placed on this increase in effective height, however. The height of the hill or other elevation can be added to the antenna height only if the area around the other antenna (the one that is not on a hill) is free of obstructions in the line-of-sight direction for a certain distance.

For example, suppose the transmitting antenna is on a hill. For there to be an increase in its effective height, the area around the *receiving* antenna must be clear in the line-of-sight direction. To find out how far it must be clear, lay the ruler from 0 on the transmitting antenna scale to 50 (the height of the receiving antenna) on the receiving antenna scale. The center scale then shows a distance of 10 miles, which is the distance from the receiving antenna in the line-of-sight direction (that is, along a line between the two antennas) in which there must be no obstructions.

If the receiving antenna is on a hill and the transmitting antenna is not, you can find the distance from the transmitting antenna that will have to be clear by laying a ruler between 400 (the height of the transmitting antenna) on the transmitting-antenna scale and zero on the receiving-antenna scale. This will give a distance of 28 miles.

If there are any obstacles between the two antennas, they will usually prevent reception if their width along the line-of-sight path is greater than one-half wavelength of the transmitted wave. If the width of the obstacle is less than a half wavelength, it will not interfere with the reception; the waves will bend around the obstacle and continue as though nothing were in the way.

REFLECTIONS

The waves used to transmit television signals can be reflected from a conductive material. If they strike a building, for example, they will be reflected from the metallic structure of the building just as a light beam would be reflected from a mirror, with the angle of reflection being the same as the angle of incidence. (Some prefer to consider that the metallic structure of the building in such a case acts as an antenna that absorbs the waves and reradiates them. Whichever explanation you prefer, the effect is the same; the radio waves take on a new direction after striking the building.)

This re-direction of television signals by conductors (or by natural objects containing conductive materials, such as hills) is sometimes helpful and sometimes extremely annoying for the man attempting to erect a receiving antenna. It is helpful in those cases in which it permits television reception at points where it would be impossible to receive signals without its aid. Suppose, for example, that there is a large building between the transmitter and the location at which you're attempting to install a television antenna. If you cannot get the receiving antenna above the obstructing building, direct reception of television signals will be impossible. It may well be, however, that signals will be reflected from some other building and reach the receiving antenna along an indirect path. As a matter of fact, this is a very common occurrence in installations made in large cities.

An example of another location at which a reflected signal is very helpful is shown in Fig. 3. Here the receiving antenna is located in a deep valley. As far as the direct signal from the transmitter is concerned, the antenna receives nothing. However, the water tower on the hill at the left of this figure is in the line of the direct signal, and since it is metallic, it reflects the signal (or picks it up and reradiates it, if you prefer) down into the valley to the receiving antenna.

In such cases, reflected signals are certainly helpful. Suppose, however, that the location at which you are installing a receiving antenna is such that you get a perfectly good signal directly from the transmitter but that you also get one or more reflected signals from the same station that traveled over different paths to reach the receiving antenna. Such a state of affairs is illustrated in Fig. 4. As you can see by examining this figure, the direct wave from the transmitter to the receiver travels through a considerably shorter distance than do any of the waves reflected from the various buildings to the receiver.

Radio waves, even though they travel at the speed of light (186,000 miles per second), require a measurable length of time to get from one point to another. Therefore, the reflected waves will arrive at the re-

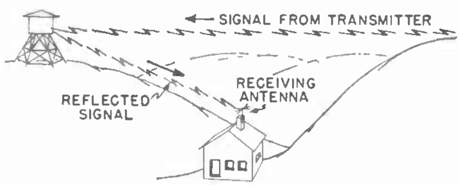


FIG. 3. How a reflected signal may give reception at a location not reached by the direct signal.

ceiving antenna a short time later than the direct wave, the time difference depending on the relative lengths of the paths. A radio wave traveling at the speed of light moves at the rate of 985 feet per microsecond (a microsecond is a millionth of a second), so a wave that travels over a path that is approximately a thousand feet longer than the direct path would arrive at the receiving antenna a microsecond later than does the direct wave.

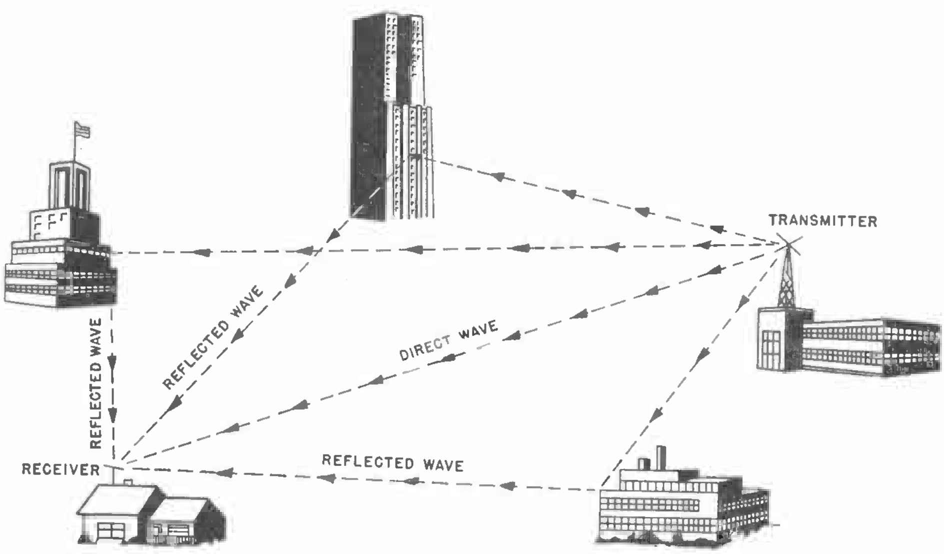
This sounds like a very small interval of time, but its effect on a television receiver is quite appreciable.

The scanning beam of a 10-inch picture tube travels across the face of the tube at the rate of .133 inch per microsecond. Therefore, a reflected wave that reaches the receiving antenna one microsecond later than the direct wave produces a picture on the tube face that is .133 inch (or a little more than 1/8 inch) to the right of the picture produced by the direct wave. If you were looking at the tube, you would see the basic picture—that is, the one produced by the direct wave—on which would be superimposed another image of the same picture that was shifted about 1/8 inch to the right. The effect would be quite noticeable and rather distressing.

A multiple image of this sort is called a ghost. It is possible for there to be several ghosts if there are several reflecting paths—in fact, there can be one for each path. It is not necessary for the time difference between the direct and the reflected signal to be as great as a microsecond to produce a noticeable ghost: if the reflected wave arrives .19 microsecond later than the direct wave, the effect will be quite apparent. A time difference of .19 microsecond means that the reflected wave has traveled .19 times 985 (the number of feet per microsecond that a wave travels) or 187 feet farther than the direct wave. As a matter of fact, a path difference of as little as 70 feet will produce a blurring of the right-hand edge of the picture, although no distinct ghost will be produced.

Ghosts are always injurious to the quality of the received picture. The injury may be only slight if the strength of the reflected signal is low. If the reflected signal is as strong as the direct signal, however, the picture quality may be rather poor. If many ghosts are received, the effect may be to produce gray outlines of the picture rather than distinctly separate images.

The only way that ghosts caused by multiple reception can be eliminated is to orient the antenna so that it picks up only one signal. This usually means that the antenna must be rather directive—that is, it must



Courtesy AVCO Mfg. Corp.

FIG. 4. How reflected signals can cause multi-path reception, which may produce ghosts.

receive much better in one direction than in others. We shall learn more about this later on.

We pointed out earlier that differences in path length between direct and reflected waves cause differences in the time of arrival of signals at the antenna, with the result that ghosts are produced. Any other effect that causes a time delay between the application of two signals to the receiver will also produce ghosts. For example, ghosting is sometimes also caused by reflections within the transmission line that connects the antenna to the receiver. Suppose that a 100-foot transmission line connects the antenna to the receiver. Suppose, too, that all of the signal sent down the transmission line to the receiver does not enter the receiver, but that part of it is instead reflected back up the transmission line to the antenna and then reflected down the line again to the receiver. (We shall describe the cause of such reflections later.) If this happens, the part of the signal that went up and down the line will have traveled 200 feet more than did the signal that went straight down the line to the receiver. As we said before, a path difference of this length can cause an appreciable effect on the picture on the t.c.r. tube.

POLARIZATION OF TV SIGNALS

As you know, a radio wave consists of an electric field and a magnetic field that are at right angles to one another. In radio and television work, we usually consider only the electric field when we are discussing the direction of the wave. Furthermore, we generally deal with a "plane-polarized" form of this field—that is, one that lies all in one plane, which may be at any angle to the earth's surface.

You know from earlier Lessons that a voltage is induced in an antenna when it is in an electric field. If the antenna is in the same plane as the field, the voltage induced in it is a maximum; if it is at some angle with respect to the plane of the field, less voltage is induced in the antenna. Therefore, we get the maximum efficiency from an antenna if we orient it so that it is in the same plane as the electric field of the radio wave.

Television signals are transmitted so that the electric lines of force of the wave are horizontal with respect to the earth's surface. For this reason, television signals are said to be "horizontally polarized." There are several reasons for using horizontal polarization, chief of which is that most noise signals are vertically polarized. Therefore, a horizontal antenna will pick up television signals most efficiently, and, at the same time, will pick up noise signals poorly. For this reason, television antennas are almost always mounted horizontally.

Now, let's learn something about the basic antennas that are used to receive television signals.

Types of TV Antennas

Before we start to discuss actual television antennas, we should review the subject of radiation patterns, which you studied earlier in your Course. The radiation pattern of an antenna is an important part of the description of the antenna, so it is worth while to take a moment to refresh your memory on the subject.

Briefly, the radiation pattern of an antenna is a graph that shows how well the antenna receives from each direction in any given plane. Since television signals are horizontally polarized, the radiation patterns we are going to show in this Lesson will be the patterns for the horizontal plane. In other words, each pattern we give will show how well the antenna for which it is drawn picks up horizontally polarized television signals coming from any direction.

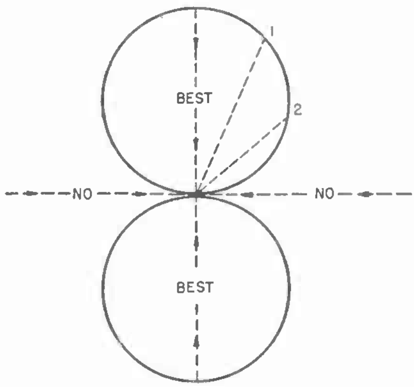


FIG. 5. The common figure-8 radiation pattern.

A very common radiation pattern, usually called a figure-8 pattern because of its shape, is shown in Fig. 5. For the sake of clarity, we have not shown the antenna that possesses this pattern; usually, however, it is drawn in to show the orientation of the pattern with respect to the antenna.

To understand the meaning of this plot, imagine that you draw a straight line from point A in any direction. The length of this line between point A and the point where the line hits either circle is a measure of the receiving ability of the antenna for television signals coming along that line. As you can see, it is possible to draw a straight line from A in such a way that it does not strike either circle. This means that the antenna will not pick up signals from that direction at all. Lines drawn in other directions from A will be of varying length when they intersect the edge of the circle. In each case, the length of the line will show how well the antenna picks up from that direction; the longer a given line is, the better the antenna pickup will be for a signal coming along the direction of the line. For example, a signal coming from the direction of point 1 will be picked up better than will be one coming from the direction of point 2.

Although the parts of the radiation pattern in this example are circles, it is perfectly possible—in fact, much more common—for them to have other and less regular shapes. Whatever its shape, each part of a radiation pattern is called a "lobe."

Now let's discuss each of the major kinds of television receiving antennas, starting with the dipole.

DIPOLE

The dipole antenna consists of two cylindrical metal rods mounted so that they are in line with one another but not in contact (Fig. 6A). As you learned earlier in your Course, an antenna of this sort acts as if it consisted of many small elements of inductance and capacity connected as shown in Fig. 6B.

An exact mathematical analysis of the behavior of a dipole is both difficult and complicated. Fortunately, it is not necessary to make such an analysis for our purposes. As a practical matter, we can consider a dipole (or any receiving antenna, for that matter) to be a generator having an impedance Z_A, as shown in Fig. 6C. Of course, the energy furnished by this "generator" is actually induced in it by the television signal, so it has the characteristics of the received signal.

The impedance Z_A of the antenna depends upon the length of the antenna with respect to the wavelength (λ) of the signal being received. If the antenna is exactly half a wavelength ($\lambda/2$) long, its impedance is approximately 73 ohms; if it is a wavelength (λ) long, its impedance is approximately 2000 ohms; and if it is 3/2 wavelengths ($3\lambda/2$) long, its

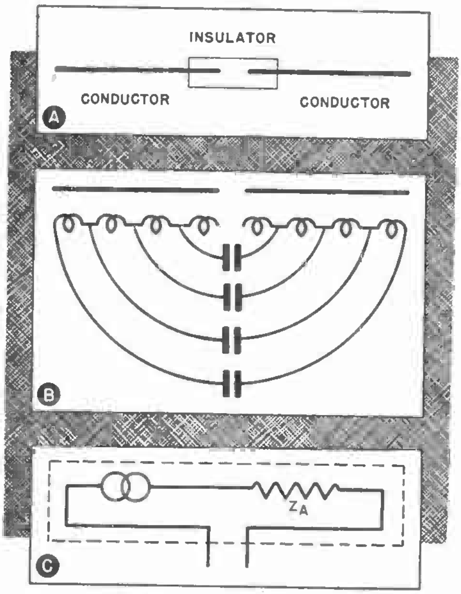


FIG. 6. A dipole antenna and its electrical equivalents.

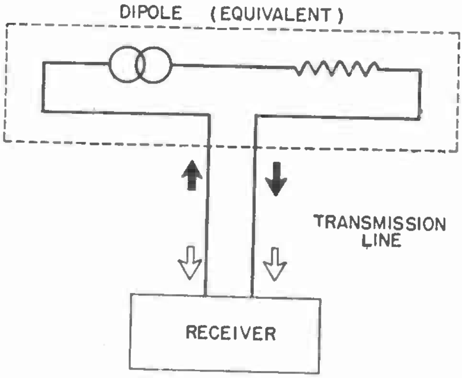


FIG. 7. A two-conductor transmission line passes signal currents (black arrows) from the dipole to the receiver but tends to cancel signals picked up by the line itself (white arrows).

impedance is approximately 90 ohms. In each of these cases, the impedance is a pure resistance. If the wavelength of the received signal is such that the antenna is between $\lambda/2$ and λ long, its impedance is a combination of inductance and resistance having a value between 73 and 2000 ohms; if it is between λ and $3\lambda/2$ long, its impedance is a combination of capacity and resistance having a value between 2000 and 90 ohms. (Incidentally, the easiest way to determine the length in inches of one half wave in free space at the desired frequency is to divide 5900 by the frequency in megacycles.)

A dipole antenna is connected to a receiver through a 2-conductor transmission line, as shown in Fig. 7. As the black arrows in this figure show, the flow of signal current through the two conductors of this line is in opposite directions at any instant.

Because the two conductors are closely spaced, however, any currents that flow in them because of direct pickup of a television signal by the line itself are in the same direction in each at any instant, as shown by the white arrows. These latter currents flow through the antenna transformer of the receiver in opposite directions and cancel. Therefore, they produce no effect at the input of the set. Thus, the television signal delivered to the set is picked up only by the dipole; the length of the transmission line theoretically does not affect the signal pickup. There are practical reasons for keeping the transmission line as short as possible, however. We shall discuss these later in this Lesson.

Radiation Patterns. The radiation pattern of a dipole that is $\lambda/2$ long with respect to the received signal is shown in Fig. 8A. As you can see, this is the figure-8 pattern we discussed earlier. We have drawn in the dipole to show its orientation with respect to the pattern.

This figure shows that there is no pickup off the ends of the dipole and maximum pickup at right angles to it. The fact that both halves of the pattern are the same size shows that the antenna picks up equally well from the front and the back.

Engineers measure the pickup of any antenna by comparing it to that of a simple dipole of this sort. Therefore, the maximum pickup of this antenna, which is indicated by the lines drawn from the center of the dipole to the farthest part of the pattern, is assigned the value 1.

The "dimple" in the radiation pattern shown by the dotted lines in Fig. 8A shows what happens if the wavelength of the received signal is somewhat shorter than that for which the dipole was cut. Notice that reception at right angles to the dipole becomes worse.

If the wavelength of the received signal is twice that for which the dipole was cut (that is, if the dipole is λ long for the received signal), the antenna has the radiation pattern shown in Fig. 8B. This pattern has four elongated lobes, which are at the angles shown with respect to the dipole. There is no pickup off the ends or directly front or back from the dipole as far as signals of this wavelength are concerned.

The two small dotted lobes at right angles to the dipole in this figure show how the radiation pattern begins to change for signals of still shorter wavelength. As the wavelength of the received signal becomes shorter, with the dipole remaining the same physical length, new lobes begin to appear at right angles to the dipole. When the wavelength of the received signal becomes so short that the dipole is $3\lambda/2$ long, the radiation pattern has the shape shown in Fig. 8C. Notice that the reception at right angles to the dipole is as good as it is for a half-

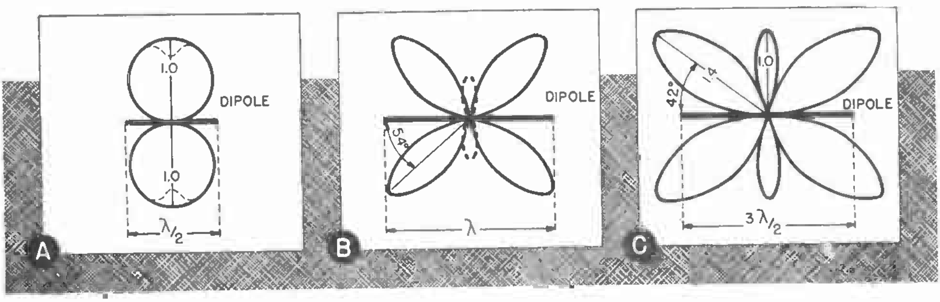


FIG. 8. In these illustrations of the radiation patterns of a dipole as a half-wave, full-wave, and three-half-wave antenna, the dipole remains the same physical length, but the frequency of the signal it is receiving changes.

wave dipole and that the reception at angles of 42° from the dipole is even better: the center line of each of these side lobes has a value of 1.4, meaning that pickup in these directions is 1.4 times as great as the maximum pickup of a half-wave dipole in its most favored directions. In other words, the pickup in the directions of the side lobes is about 2 db greater than the pickup at right angles to a half-wave dipole.

Remember, each dipole shown in Fig. 8 is the same length in terms of inches. Its length in terms of wavelengths increases only because the wavelength of the received signal decreases.

If the wavelength of the received signal becomes even shorter, more lobes will appear in the radiation pattern; each time the dipole becomes $\lambda/2$ longer, one more lobe will be produced on each side of the antenna.

If a dipole is used to pick up signals for which it is less than $\lambda/2$ long, its radiation pattern is a figure 8, just as it is for $\lambda/2$ operation. However, the lobes of the pattern are somewhat smaller than are those of $\lambda/2$ pattern, which means that the amount of pickup is less but that the directions of best pickup are the same.

Because of the distribution of the frequencies assigned to television stations, we are chiefly interested in the operation of dipoles when they are shorter than $\lambda/2$, exactly $\lambda/2$, or $3\lambda/2$ long. A dipole cut to be $\lambda/2$ long for channel 2 (54-60 mc.) will be only about $3\lambda/4$ long for channel 6 (82-88 mc.) and approximately $3\lambda/2$ long for channel 7 (174-180 mc.). It will be λ long somewhere in the region between the two television bands, which is assigned to other services. In fact, a dipole that is cut to be $\lambda/2$ long for any low-band channel will be more than λ long for any high-band channel.

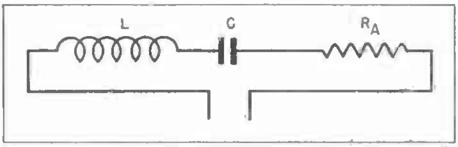


FIG. 9. A dipole can be considered to be a resonant circuit.

This relationship between the wavelengths of the lower and upper bands is the reason why it is often possible to use a single antenna to get reception on both bands even with transmitters in different locations. If we use a dipole cut for the low band and find it possible to orient it so that its center lobe is toward the low-band stations and its side lobes are toward the high-band stations, signals from both can be received efficiently. In the city of Washington, D. C., for example, there are many locations where it is possible to receive all four local stations (which operate on channels 4, 5, 7, and 9) with a single dipole.

Now that you are familiar with the basic television antenna, the simple dipole, we can proceed to study more complex kinds. Before we do, however, let us mention one thing more. We said earlier that a dipole could be considered to be a generator having an internal impedance Z_A. It is also possible, and sometimes much more convenient, to consider it to be a series resonant circuit with an inductance L, a capacity C, and a resistance R_A, as shown in Fig. 9. The values of L and C are such that the circuit is resonant at the frequency for which the antenna is $\lambda/2$ long. In the rest of this Lesson, we shall consider an antenna to be either a resonant circuit or a generator, whichever is the better as a means of making it easier for you to understand the action of a particular antenna.

FOLDED DIPOLE

A common form of television antenna known as the folded dipole is shown in Fig. 10. It consists of a single rod or tube that is bent into the shape shown. In use, the antenna is mounted in a vertical plane with its long sides parallel to the earth and with the unbroken long side on top. The transmission line is connected to the two ends of the antenna as shown.

Such an antenna has the same radiation pattern as does a simple dipole that is half as long as the perimeter of the folded dipole. For example, a dipole cut for channel 2 (54 to 50 mc.) will be about 8.2 feet long. A folded dipole made by bending a rod 16.4 feet long will have the same radiation pattern at the channel 2 frequencies; in fact, as far as the radiation pattern is concerned, we can consider the two to be the same thing at all frequencies. In other words, the two will resonate to the same frequency and have identical radiation patterns.

We can, therefore, find out all we want to know about the radiation pattern of any folded dipole by studying the pattern of a simple dipole that is resonant to the same frequency, meaning one that is half as long as the perimeter of the folded dipole. Or, if we wish to make a folded dipole that will have the same radiation pattern as a particular simple dipole, we can do so by making it out of a rod that is twice as long as the simple dipole.

You may wonder why we should bother to use a folded dipole, since we can always find a simple dipole that will be its equal as far as radiation pattern is concerned. There are two reasons: first, the folded dipole has a higher impedance than a simple dipole has at resonance; and second, the folded dipole has a somewhat broader frequency response than its equivalent simple dipole has.

The impedance of a folded dipole depends upon the spacing between its two long sides. The usual kind is made with a spacing of about $\lambda/64$, which gives it an impedance of approximately 300 ohms—4 times as great as that of a simple dipole—at resonance. As it happens, 300 ohms is the impedance of one very commonly used kind of transmission line; therefore, a folded dipole can be perfectly impedance-matched to such a line for the frequency to which the dipole is resonant.

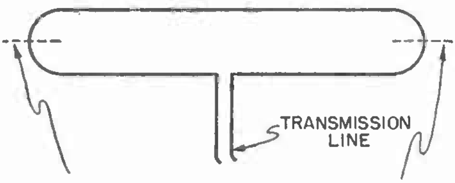


FIG. 10. A folded dipole antenna.

We shall discuss the importance of impedance matching at length a little farther along in this Lesson, but right now we might point out that a proper impedance match between the antenna and the line permits a maximum transfer of power from the antenna to the line. (You are already familiar with the fact that a maximum transfer of power from a source to a load occurs when the two have the same impedance; in this case, we can consider the antenna to be a source and the transmission line to be a load.) This means that a folded dipole will deliver a stronger signal to a receiver than a simple dipole will, even though the amount of signal each picks up is the same, if a 300-ohm transmission line is used with each. (There is also a kind of transmission line that has a 72-ohm impedance and therefore matches a simple dipole perfectly; however, as you will learn later in this Lesson, there are often reasons for preferring a 300-ohm line even when the antenna is a simple dipole.)

We mentioned earlier that the impedance of a simple dipole depends upon the frequency of the incoming signal, since it is this frequency that determines whether the antenna will be $\lambda/2$, λ, $3\lambda/2$, or some other length. At frequencies above resonance the impedance of a dipole increases rather rapidly. The impedance of a folded dipole also depends upon the frequency of the incoming signal; over a fairly wide range of frequencies above resonance, however, its impedance does not change as much as that of a simple dipole does. In other words, the impedance of a folded dipole is more nearly constant than that of a simple dipole over a range of frequencies above resonance.

To see what the practical effect of this fact is, suppose that we have a simple dipole and a folded dipole, each of which is perfectly matched to its own transmission line. With respect to the amount of signal power delivered to a receiver, these two antennas will be the same at their resonant frequency. At frequencies above resonance, the impedances of each will change; consequently, neither will be perfectly matched to its transmission line, and the amount of power each will deliver to a receiver will therefore decrease. Since the relative impedance change of the dipole will be greater than that of the folded dipole, however, the mismatch between the dipole and its line will be greater. For this reason, the power that the dipole will deliver to a receiver will decrease faster at off-resonance frequencies. Over a range of frequencies above resonance, therefore, a folded dipole will furnish more power to a receiver than a simple dipole will.

For this reason, engineers say that a folded dipole has a wider frequency response than a dipole has. This does not mean that the folded dipole picks up over a wider range than a simple dipole does—their pickup is the same at all frequencies, since they have the same radiation patterns. What it does mean is that a folded dipole and its transmission line will deliver more power to a receiver than a dipole and its transmission line will over a range of above-resonance frequencies.

This effect does not hold at all frequencies, because the impedance of a folded dipole rises very sharply at frequencies near twice its resonant frequency — that is, at frequencies where it is approximately equal to a λ antenna. As we saw earlier, however, λ antennas are not particularly important in television, because the frequency for which a lowband antenna is λ long occurs in the band between the two television bands.

At 3 times its resonant frequency (that is, at a frequency for which it is the equivalent of a $3\lambda/2$ antenna), a folded dipole has an impedance of about 400 ohms. It has a somewhat wider response than a simple dipole at frequencies greater than this, though the effect is not as marked as it is at frequencies close to resonance.

F.M. RECEPTION

Many television sets are designed to be f.m. receivers also. The antenna used with such a set must be able to pick up signals in the f.m. band (88-108 mc.) as well as those in the television bands. From what we said earlier, a dipole cut to be $\lambda/2$ long for channel 2 is between $3\lambda/4$ and λ long for signals in the f.m. band. This means that its impedance is high, and, consequently, there is a considerable mismatch between the antenna and the transmission line at these frequencies.

Fortunately, however, an f.m. set can be made to be much more sensitive than a television receiver is. In spite of this mismatch and consequent loss of power, therefore, the f.m. section of an f.m.-television set can generally be operated even by an antenna that is cut for channel 2. For this reason, it is usually possible to use the same antenna for both television and f.m. reception.

DIPOLES WITH PARASITIC ELEMENTS

A parasitic element is a metal rod or wire that is mounted near an antenna for the purpose of changing the

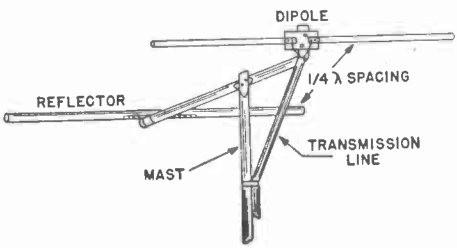


FIG. 11. A plain dipole with reflector.

antenna's radiation pattern. Such an element is not connected to the transmission line, which is the reason why it is called parasitic. It produces an effect on the radiation pattern of the antenna because it picks up the signal and re-radiates it, changing its phase in the process. This re-radiated signal is then picked up by the antenna. The antenna therefore has two signals induced in it, one the original signal and the other the signal re-radiated from the parasitic element; these two may add to produce a stronger combined signal or partially cancel to

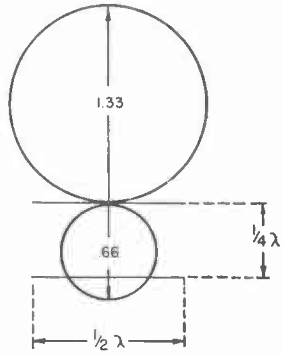


FIG. 12. The radiation pattern for a dipole and reflector of the dimensions shown.

produce a weaker one, depending on the phase relationship between them. As a result, the radiation pattern of a dipole (or a folded dipole; remember, the two have the same radiation patterns) that has a parasitic element mounted near it is different from that of a dipole alone.

The effect of a parasitic element on the radiation pattern of a dipole depends upon the length of the element (in terms of wavelength), its spacing from the dipole (also in terms of wavelength), and the frequency of the incoming signal. It is possible to get almost any desired pattern by choosing the proper element or combination of elements.

One common use of a parasitic element is shown in Fig. 11. Here an element called a "reflector" is placed parallel to the dipole in the horizontal plane. The reflector is about 5% longer than the dipole. The spacing between the dipole and the reflector is usually $\lambda/4$ at the frequency for which the dipole is resonant, though sometimes spacings as close as .15 λ are used.

The radiation pattern at the resonant frequency for a dipole and reflector spaced λ/4 apart is shown in Fig. 12. As you can see, the addition of the reflector increases the pickup of the dipole considerably on one side and decreases it considerably on the other, the decrease being on the reflector side of the combination. If the spacing between them were less than λ/4, the forward lobe would be even longer and somewhat narrower, and the backward lobe (the lobe on the reflector side of the antenna) would be smaller.

Fig. 13 shows the radiation pattern for the combination when it is operating at 3 times the resonant frequency (that is, when the dipole is a 3λ/2 antenna). Notice that the spacing between the antenna and the reflector is now 3 λ/4. This is explained by the fact that the spacing between them is fixed at λ/4 when the antenna is erected; since the wavelength is only ⅓ the original wavelength when the antenna is operating at 3 times the resonant frequency, the spacing, which is fixed in terms of inches, becomes 3 times as great in terms of wavelength.

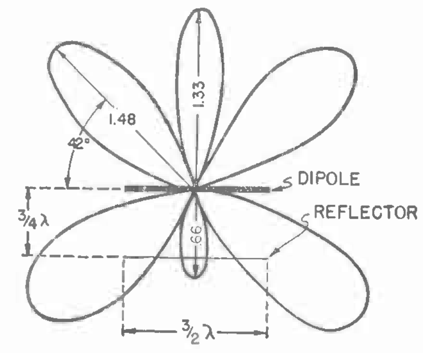


FIG. 13. The radiation pattern of a dipole and reflector operating as a three-half-wave antenna.

As you can see, the center forward lobe is considerably larger and the center backward lobe is considerably smaller than they are in the radiation pattern of a dipole alone. The side lobes, however, are very nearly the same size as they are in the dipole pattern.

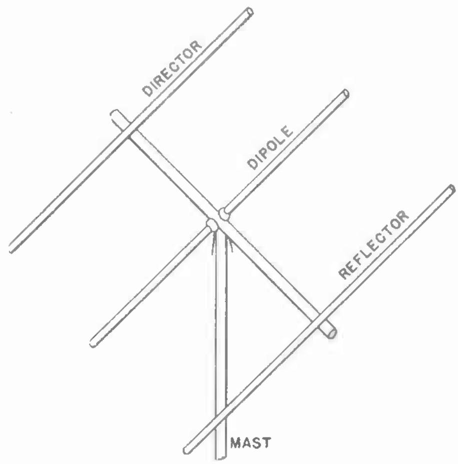


FIG. 14. A dipole with director and reflector.

Since the combination of a dipole and a reflector picks up much better in one direction than in another, particularly at the resonant frequency, it is said to be a "directional" antenna. The combination can be made even more directional by adding another parasitic element on the opposite side of the dipole from the reflector and parallel to both of them (see Fig. 14). This element, which is called a "director," is about 4% shorter than the dipole and is spaced λ/4 or less from it. The radiation pattern for a director-dipole-reflector combination at the resonant frequency is shown in Fig. 15. Notice that the addition of the director lengthens and narrows the forward lobe and shortens the backward lobe.

The impedance of a dipole is decreased to about 60 ohms by the addition of parasitic elements spaced $\lambda/4$ from it. Its impedance can be brought back to about 72 ohms by reducing the spacing to something less than $\lambda/4$.

The increased forward pickup caused by adding parasitic elements to a dipole makes the combination very useful in areas that are some distance from a television station. However, such antennas are also very frequently used in areas where the signal strength is high; here, their decreased backward pickup is the characteristic that makes them desirable. In a location where there are strong reflected signals that cause ghosts in the picture, a properly oriented parasitic array may be able to pick out the desired signal and ignore the reflected one, thus eliminating the ghosts. We shall go into this matter at greater length in another Lesson.

Unfortunately, the increased directivity and antenna gain produced by the use of parasitic elements are accompanied by a decreased broadness in response. This is generally true of any directional antenna array, although some are worse than others in this respect. Some directional antennas have frequency responses so narrow that they will not pick up equally all the frequencies in a 6-mc. television signal. This fact, of course, rules such antennas out for television use, no matter what their other characteristics may be.

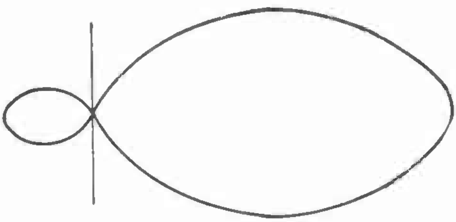


FIG. 15. Radiation pattern of a dipole with reflector and director.

MULTIPLE-CHANNEL RECEPTION

The antennas you have studied so far are the basic ones used in areas where the signal strength is high. There are several other kinds, which we shall discuss in a moment, but the great majority of installations use a dipole or a folded dipole, with or without parasitic elements.

Naturally, the demand for television sets is greatest where television offers the greatest variety of entertainment; therefore, most receivers are located in areas where there are two or more stations. For such receivers, it is necessary to erect an antenna that will pick up all the available stations and preferably pick them up equally well.

How complex such an antenna must be depends on the location. Many things must be taken into account, such as the signal strength in the area where the set is, the relative directions of the stations from the set, whether or not reflected signals are present at the location, the sensitivity of the set, how much electrical noise there is at the point where the installation is to be made: all these play a part in determining what antenna will be satisfactory. We shall study all these factors and several others in this and succeeding Lessons.

Generally speaking, the practice among servicemen making initial installations of sets is to use the simplest and least expensive antenna that will give reasonably good results. As a result, most set installers attempt first to use a dipole or a dipole with a reflector to pick up all the available stations. Very often it turns out that even a simple dipole will give adequate reception on both the low and high bands if the signal strength at the location is high.

We shall go into the question of selecting the proper antenna at some length in a later Lesson, so we shall not devote much time to it here. However, we shall give one example of conditions under which a dipole can be used to receive several stations.

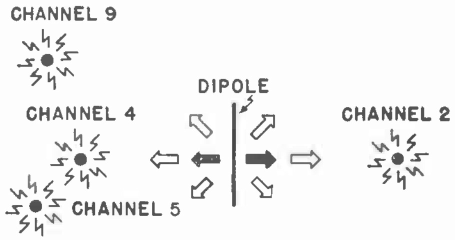


FIG. 16. How a dipole can be used to receive several stations.

This example is pictured in Fig. 16. Notice that there are four stations shown: one on channel 2, one on 4, one on 5, and one on 9. The black arrows show the directions of the major lobes of the antenna radiation pattern for $\lambda/2$ operation, and the white arrows show the major lobes for $3\ \lambda/2$ operation.

If the dipole shown in this example is cut to be a $\lambda/2$ antenna for the channel 4 frequency, it will be about a $3\ \lambda/2$ antenna for channel 9. Therefore, in the location shown, it will have a major lobe pointing toward the channel 4 station and another pointing toward the channel 9 station. There will also be a major lobe pointing toward the channel 2 station: remember, an antenna operating at a frequency less than that for which it is a $\lambda/2$ antenna has a radiation pattern that has the same shape as its $\lambda/2$ pattern, although the lobes are smaller. Finally, since the antenna is $\lambda/2$ long for channel 4, it is reasonably close to being a $\lambda/2$ antenna for channel 5; the channel 5 station will therefore be picked up also, though perhaps not quite as strongly as the others.

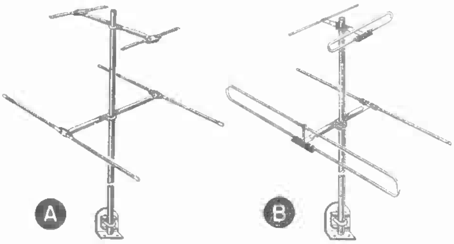
Notice that a reflector could not be used with this antenna because one station is on the opposite side of the antenna from the others. The effect of a reflector, as you saw earlier, is to reduce the pickup on its side of the antenna very strongly. If we used a reflector on the channel 2 side of the antenna in this example, therefore, the channel 2 station would not be picked up if it were at some distance from the receiver. If all the stations were on the same side of the antenna, however, the use of a reflector might well result in improved pickup of all of them.

A simple dipole could be used in this example, but a folded dipole would probably be a better choice. The reason is that the channel 5 station is being picked up mostly because it is fairly near the frequency for which the antenna is cut. Since a folded dipole has a somewhat wider frequency response than a simple dipole has, the former would probably give better reception of the channel 5 station. Then, too, we would get a better impedance match to a 300-ohm line if we were to use a folded dipole, with the result that the signal applied to the receiver would be better for all stations.

Of course, stations are not always located so conveniently with respect to the major lobes of the radiation pattern of a dipole antenna. If both low-band and high-band stations are to be picked up, a dipole will not be very satisfactory unless it can be oriented so that it will pick up the low-band stations as a $\lambda/2$ antenna and pick up the high-band stations as a $3\ \lambda/2$ antenna. It often turns out that such an orientation is impossible, particularly if a station on channel 11, 12, or 13 is to be picked up—

stations up at this end of the high band are harder to pick up than are those operating at lower frequencies.

One way to solve this problem is to use two antennas, one that will be a $\lambda/2$ antenna for the low band and one that will be a $\lambda/2$ antenna for the high band. Fig. 17 shows two common forms of such antennas in which a single mast is used to support both. The one shown in Fig. 17A consists of two simple dipoles and reflectors; the one in Fig. 17B is exactly the same except that the antenna elements are folded dipoles.

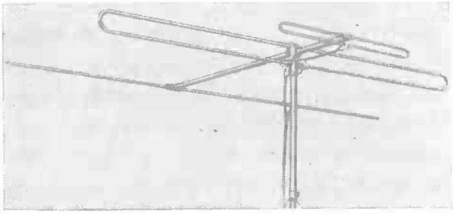


Courtesy JFD Mfg. Co., Inc.

FIG. 17. Examples of two-band antennas.

In most installations, these antennas are connected to the same transmission line. A few sets have an input designed to accept two transmission lines; when an antenna combination of this sort is used with one of these sets, separate transmission lines are run from the antennas to the set. A switch within the set automatically connects the proper line and antenna to the input circuit when the channel selector switch is turned.

When both antennas are connected to the same line, interaction between them is prevented by connecting them with a piece of transmission line that is $\lambda/4$ long at the frequency to which the low-band antenna is resonant; you will learn later in this Lesson what the effect of such a line is. In some locations, this method of isolating the two antennas is not effective:



Courtesy American Phenolic Corp.

FIG. 18. Another form of two-band antenna.

signals picked up by one of the elements are re-radiated and picked up by the other, with the result that ghosts are formed in the picture. Sometimes re-orientation of one of the elements or relocation of the whole antenna will prevent this from happening. If not, some other form of antenna must be used.

Because of its wider frequency response, the folded-dipole form of this antenna combination shown in Fig. 17B is usually preferred to the simple-dipole kind shown in Fig. 17A. Both kinds are very common, however.

One feature of both these antennas is that the high-band and low-band sections can be oriented in different directions if it is desirable to do so.

Antennas like these are almost invariably equipped with reflectors, which, of course, makes them unidirectional in their pickup. If it is

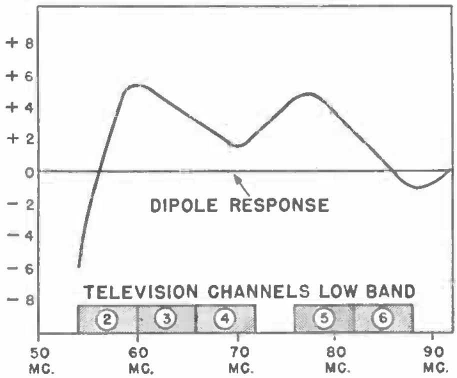


FIG. 19. How the response of the antenna shown in Fig. 18 compares with that of a dipole over the low band.

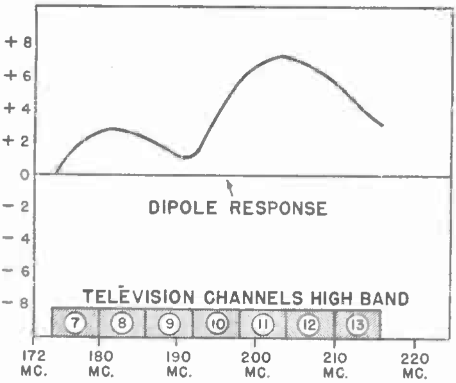


FIG. 20. How the response of the antenna shown in Fig. 18 compares with that of a dipole over the high band.

necessary to use bidirectional antennas at some location, the reflectors can be removed without much difficulty. Their response will be affected somewhat if this is done, because the impedances of the antennas will change, but the effect on the performance of the antennas caused by this change will not be great.

A somewhat different version of the antenna shown in Fig. 17B is illustrated in Fig. 18. This is a widely used antenna. Here the high- and low-band antennas as well as the low-band reflector are in the same horizontal plane; the low-band folded dipole is the reflector for the high-band antenna.

Fig. 19 shows how the pickup of this antenna compares with that of a standard dipole on the low band from 54 to 88 mc. For each channel, the pickup of a folded $\lambda/2$ dipole tuned to that channel is taken as the standard. The curve shows how many db up or down the pickup of the antenna is for each channel, using this standard value as 0 db. Thus, the pickup of the antenna is greater than that of the standard dipole at all frequencies for which the curve is above the 0 db line.

As you can see from Fig. 19, the antenna has a greater pickup than a standard dipole over most of the low band, but its pickup is less than that of the standard dipole at the extreme ends of the band.

Fig. 20 shows how the pickup of this antenna compares with that of a standard dipole over the high band. As you can see, the pickup of the antenna is better than that of the standard dipole at all points in this band and is considerably better around channel 11.

The radiation patterns for this antenna at low-band frequencies and high-band frequencies are shown in Fig. 21. Since the backward lobes are quite small, this antenna is very much one-directional; in fact, it cannot be used unless all the stations it is to pick up lie in the same general di-

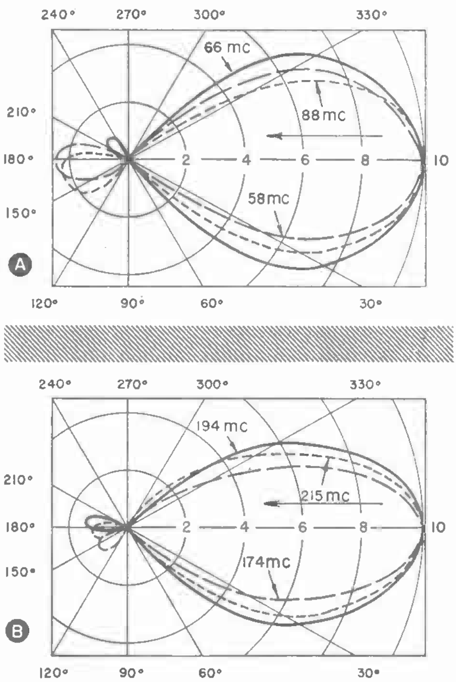


FIG. 21. The radiation patterns of the antenna shown in Fig. 18 for the low and high bands.

rection from the receiver. Of course, it is always possible to use two or more of these antennas, orienting each for one station or group of stations, or to use an antenna rotator to point the antenna at the particular station wanted at the moment. (An antenna rotator is a small, slow-speed, reversible motor that is coupled to the antenna mast in such a way that rotation of the motor will turn the antenna. The direction and amount of rotation of the motor are controlled by a switch or some other control device at the receiver location. Thus, the person operating the set can easily orient the antenna to improve the reception. Antenna rotators will be described more fully in a later Lesson.)

Rather than use combined antennas of the kind we have described, you can erect completely separate antennas for the high band and the low band, mounting them some distance apart to prevent interaction between them and running separate lines to the set. Unless the set is equipped to switch automatically from one line to the other, however, it will be necessary to bring the lines to a low-capacity switch that can be used to connect the desired line to the set.

Most commercially manufactured high-low antennas are cut so that each antenna resonates near the middle of the band for which it is used. Each will then provide reasonably good coverage over its band. If there is only one station in each band in your vicinity, you can get better reception by using antennas cut specifically for those stations. Some manufacturers offer "custom-made" antennas of this sort. If the signal strength in the area is high, however, antennas that resonate near the middle of each band will usually be perfectly satisfactory.

As a matter of fact, almost any form of dipole antenna is reasonably satisfactory in a location where the signal strength is high. An elaborate antenna is needed in such a location only if reflected signals that cause ghosts in the picture are present. Such ghosts can often be eliminated, as you learned earlier, by using a directional antenna that does not pick up the reflected signals.

Antennas for areas where the signal strength is low are another matter. In such areas, it is necessary to use antennas that are as efficient as they can be made. We shall describe such antennas in a few moments. Before we do, however, let us discuss a few unusual kinds that have been developed to give broad-band response.

BROAD-BAND ANTENNAS

It has been found that an effective way to broaden the frequency response of a dipole antenna is to increase the diameter of the poles. (This is the reason why a folded dipole has a broader response than a dipole; effectively, its poles are thicker.) Fig. 22

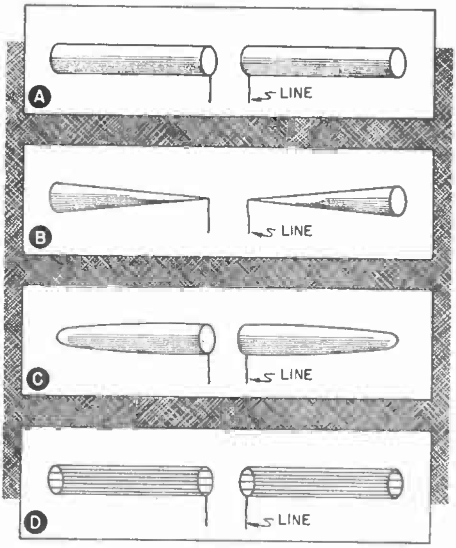


FIG. 22. Forms of broad-band antennas.

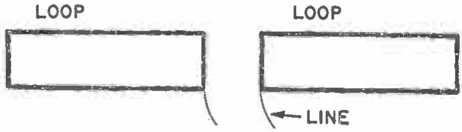


FIG. 23. Another kind of broad-band antenna.

shows several designs of thick-pole antennas that have rather wide frequency response. The one shown in Fig. 22A is like an ordinary dipole except that the diameter of the poles is many times greater. The one shown in Fig. 22B has conical poles, and that shown in Fig. 22C has spheroidal ones. These three are shown as though they were made of sheet metal; however, approximately the same response can be secured by replacing their solid surfaces with taut wires run lengthwise. The example in Fig. 22D shows how the antenna in Fig. 22A would look if such a replacement were made.

These antennas, although they work well, are seldom used and are not commercially available. The reason is that they are not suitable for outdoor mounting, because they can easily be damaged by a strong wind or by the formation of ice upon them. The kind shown in Fig. 22D would not be subject to damage of this sort as much as the others would be, but it would have the disadvantage of whistling as the wind went through it. In addition, and perhaps more important, it would be difficult to make one of these that would be mechanically strong.

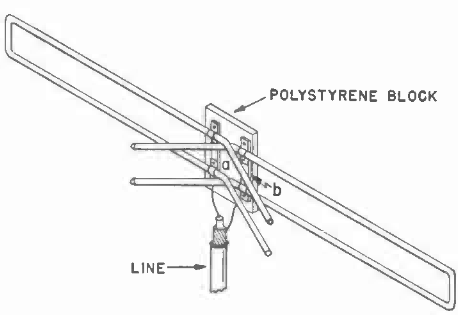


FIG. 24. The bat-wing antenna, a variant of the one shown in Fig. 23.

Another way in which a dipole can be made to have a wider frequency response is shown in Fig. 23. Here, as you can see, the rods of a simple dipole have been replaced by rectangular loops. This produces much the same effect as increasing the diameter of the rods does.

A commercial variation of this antenna, known as the "bat wing," is shown in Fig. 24. In this form, each half of the antenna consists of a rectangular loop that is bent about one-quarter of the distance from its open end and is bridged across by a metal strap near the bend. The two long closed sections thus formed make up an antenna like the one shown in Fig. 23, which has a frequency response that covers the entire low-frequency television band plus the f.m. band. The two short open-ended sections make up a wide-band dipole antenna that provides reception over the entire high-frequency band. Since the transmission line is connected to the bridging straps, the low-band and high-band antennas are effectively connected in parallel to the line. The impedance of the combination is approximately 72 ohms over a wide frequency range.

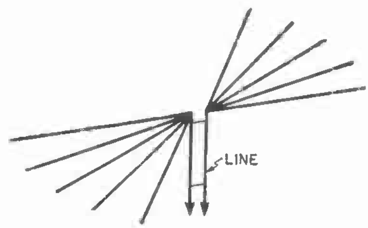


FIG. 25. The di-fan antenna, which has a broad-band response. All the antenna elements shown are in the same horizontal plane.

Another form of wide-band antenna is shown in Fig. 25. This consists of two V-shaped sections, each made up of five rods of equal length. It is mounted so that all the rods are in a horizontal plane. This antenna has an impedance of about 300 ohms over a wide frequency range, and offers good reception over the two television bands and the f.m. band.

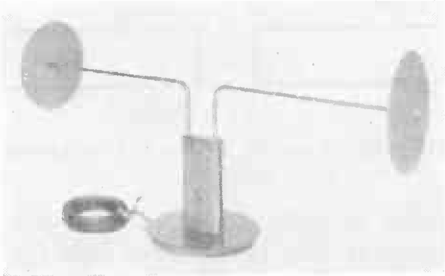
INDOOR AND WINDOW ANTENNAS

Many television installations are made in apartment houses where outside antennas are not permitted. In such cases, indoor or window antennas must be used.

An indoor antenna is not usually as satisfactory as an outdoor one. For one thing, the incoming signal is attenuated by having to pass through the structural materials of the building to reach the antenna. This attenuation may be severe if the building has a steel framework; in fact, it may be impossible to get enough of a signal for satisfactory operation if the building has much steel in its walls.

Courtesy Technical Appliance Corp.

FIG. 26. A widely used form of indoor antenna.



Courtesy RCA

FIG. 27. Another form of indoor antenna.

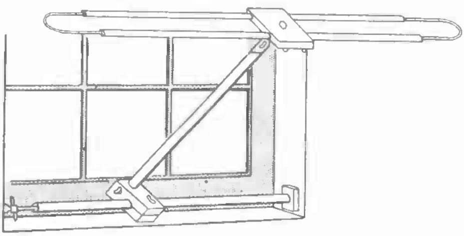
Another handicap under which the indoor antenna labors is that its length is restricted by the fact that it is used inside a home. The usual low-band antenna is too big to keep in the average living room, which is where an indoor antenna is generally placed. Therefore, antennas that are shorter than $\lambda/2$ for the lower channels must be used. The radiation patterns of such antennas, you will recall, have shorter lobes than $\lambda/2$ antennas, meaning that they do not pick up as well.

Finally, there is usually no possibility of using any kind of directive array for an indoor antenna, because such arrays require far too much space. Therefore, it may be difficult or impossible to eliminate reflections in an indoor installation.

In spite of these handicaps, an indoor antenna will often give good results in an area where the signal strength is high. An antenna like that shown in Fig. 26 has proved to be satisfactory in many installations. This antenna consists of two telescoped metal rods secured to a base through a pivot. These rods are electrically insulated from each other and are connected to the two leads of a transmission line. The angle between the two rods can be changed at will, and the length of the rods can be easily changed by pulling out the telescopic sections. The whole antenna can be rotated simply by picking it up and turning it.

The effective length of this antenna depends on the distance between the tips of the two rods. Thus, lengthening the rods or increasing the angle between them makes the antenna resonant to a lower frequency, and shortening the rods or decreasing the angle between them makes it resonant to a higher frequency. Usually it is necessary to adjust either the length or the angle when the set is tuned from one station to another.

Another kind of indoor antenna is shown in Fig. 27. This antenna, as you can see, is a dipole having a large metal disk mounted at the end of each rod. The effect of these disks is to increase the capacity of the antenna. As a result, such an antenna can be considerably shorter physically than a simple dipole that resonates to the same frequency. In addition, its response is somewhat broader than that of a simple dipole.



Courtesy Insuline Corp. of America

FIG. 28. A form of adjustable indoor antenna.

A window antenna often gives better results than an indoor antenna, particularly when it can be placed in a window that is on the same side of the building as is the transmitter. A typical window antenna is shown in Fig. 28. As you can see, it is a folded dipole that is mounted on a very short mast. At the other end of the mast is a cross bar that can be secured to the window frame, usually by extending the end of the bar to wedge it across the frame.

Such an antenna has a response like that of any other folded dipole. The ends of the one shown in Fig. 28 can be extended to make the antenna resonate to a lower frequency if desired; this is usually done, if at all, only when the antenna is first installed, since it is inconvenient to change the length thereafter.

As we said, it is usually better to install a window antenna on the side of the building that faces the transmitter. However, it is often possible to pick up an adequate signal on the other side of the building also if other buildings or objects reflect the signal toward that side of the building.

Many other forms of indoor and window antennas have been developed. Generally speaking, there is little to recommend one kind over another. The only way to tell whether a particular kind will be satisfactory in a particular location is to try it there.

We have discussed the basic antennas used in locations where the signal strength is fairly high. Now, let's see what kinds of antennas can be used in locations that are on the fringe of the reception area.

STACKED ARRAYS

In areas where the signal strength is low or the surrounding electrical noise is high, the signal-to-noise ratio of the voltage applied to the input of a television set is important. This ratio, as you learned earlier in your studies of radio, shows how strong the signal voltage is in comparison to the noise voltage. Any noise voltage of the proper frequency that is applied to the input of a set will be amplified just as the signal voltage is. Consequently, there will be considerable noise in the output of a set if the signal-to-noise ratio of the voltage applied to the input is low.

The noise-reducing feature of the f.m. audio system may keep such noise from being annoyingly audible. It is always visible, however, because it creates lines or snow in the picture; in fact, the picture may be largely obscured if the noise level is high. Therefore, it is always desirable to have a high signal-to-noise ratio in the voltage that is applied to the input of the set.

The only way to get a high signal-to-noise ratio at the input is to have the antenna pick up considerably more signal than noise. If the antenna is at some suburban or country location where the signal strength and the noise level are both low, the antenna

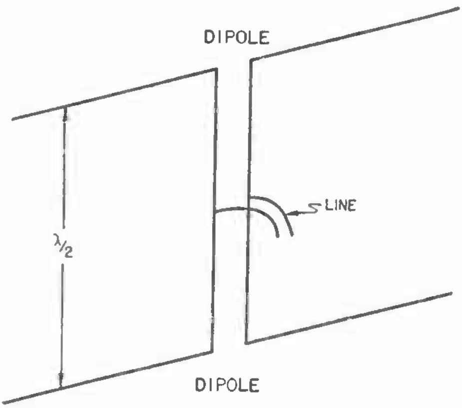
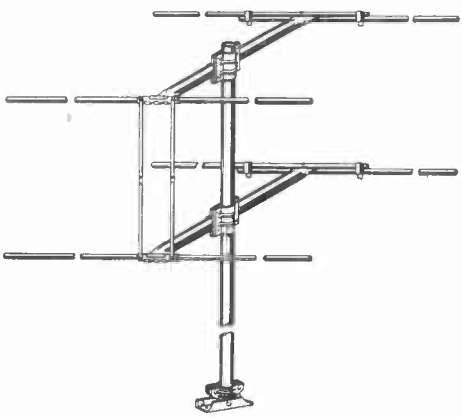


FIG. 29. A simple two-dipole stacked array.

must have a great deal of gain so that it will pick up a good signal. In this case, it does not usually matter whether the antenna is also able to reject noise. If, on the other hand, it is in some city location where both the signal and the noise level are high, the antenna must be able to reject noise; if it is able to do so, its gain is a matter of secondary importance.

Stacked arrays have become popular for both kinds of installations because they provide good gain and good noise rejection at the same time. A simple stacked array is shown in Fig. 29. This consists of two identical dipoles stacked one above the other and spaced $\lambda/2$ apart for the frequency to



Courtesy Technical Appliance Corp.

FIG. 30. A "lazy H" stacked array.

which they are resonant. The two are connected in parallel by lines connected to their inner ends as shown. The transmission line is connected to the midpoint of the lines that connect the two antennas. Since they are in parallel, their net impedance is always half that of one alone; at resonance, it is 36 ohms.

The increased signal pickup of such an antenna is explained by the fact that there are two of them. Their spacing is what makes them able to reject noise. Any noise coming from above or below induces a voltage in each antenna. Since the two are spaced $\lambda/2$ or 180 electrical degrees apart vertically, the noise voltages induced in them are 180° out of phase; therefore, such voltages cancel when they arrive at the point where both are applied to the transmission line.

The noise rejection and the pickup of this stacked array can both be improved by adding a reflector to each element, as shown in Fig. 30. (This array is often called a "lazy H," because it looks like two letter H's lying on their sides.) The pickup is increased thereby just as it is when a reflector is added to a single dipole. The noise rejection is increased because signals coming from the backward or reflector side of the array are reduced, and any noise they contain is reduced likewise. The reflectors have little effect on noise coming from below or above the array, however.

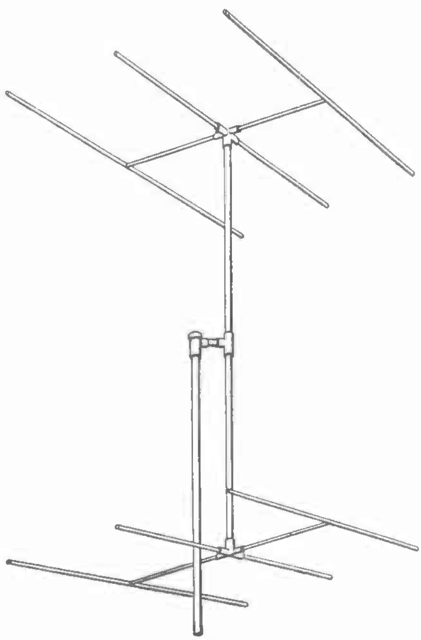


FIG. 31. A stacked array of dipoles, directors, and reflectors.

The impedance of this array at resonance is 30 ohms.

The signal pickup can be still further increased by adding a director to each element as shown in Fig. 31. The director has much the same effect as it does when it is used with a single dipole. Adding it to the array has little effect on the noise pickup, except that it narrows the horizontal angle from which the antenna picks up. This may result in a reduction in noise pickup if the antenna can be oriented so that the desired signal is received but the noise is not. If the source of noise lies in the same general direction as the desired station, however, orientation of the antenna will not help in reducing the noise pickup.

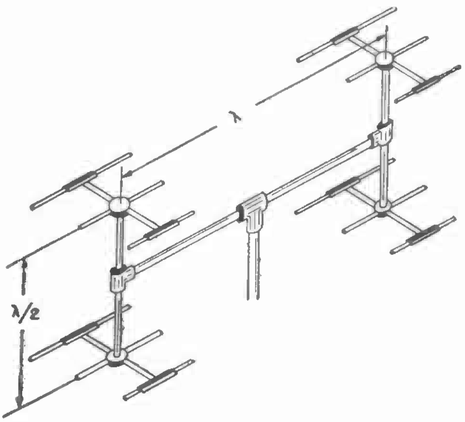
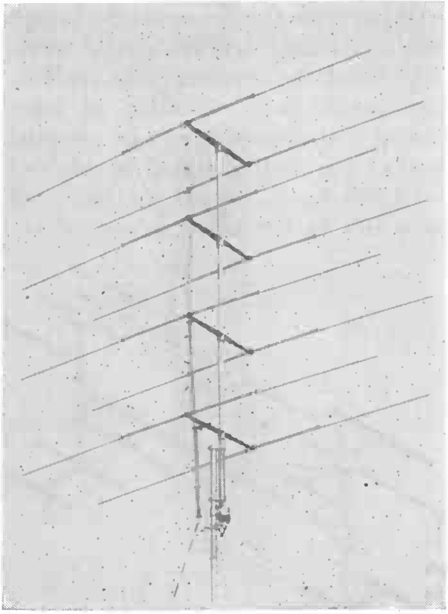


FIG. 32. A combination of stacked arrays.

If further increases in pickup are needed to make reception satisfactory, more elaborate antenna arrangements can be used. One of these is shown in Fig. 32. Here we have two stacked arrays like those in Fig. 31 that are mounted side by side a distance λ apart. This array has a gain of 11 db over a simple dipole and a horizontal pickup angle of only 28°. Since a gain of 6 db represents a doubling of the voltage, you can see that this particular array will deliver almost 4 times the voltage to the transmission line that a simple λ/2 dipole would. All four dipoles used in this array are connected in parallel; the impedance of the array is therefore ¼ the impedance of the individual dipoles.

It is also possible to stack more antenna arrays vertically. One of the



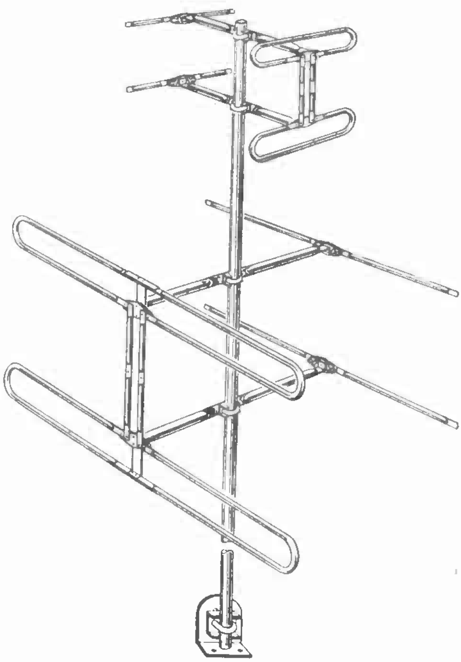
Courtesy LaPointe Plascomold Corp.
FIG. 33. A four-bay stacked array.

most complex of these arrangements that is now in use is shown in Fig. 33. This antenna, which is known as a 4-bay stacked array, consists of four dipoles and reflectors stacked vertically. A feature of this antenna is that the dipoles are connected to parallel rods (called Q sections) as well as to the transmission line. The impedances of the dipoles can be adjusted by sliding shorting bars along these sections; this makes it possible to match the impedance of the array to that of the transmission line.

Antenna Height. When an antenna is installed at a location that is a considerable distance from a transmitter, it must be gotten as high in the air as possible. We have mentioned this fact before, but it is important enough to bear repeating. The receiving antenna must be high enough to be on a line of sight from the transmitting antenna, or at any rate only slightly below a line-of-sight path (as you learned earlier in this Lesson, there is a small amount of bending of v.h.f. signals in the atmosphere). Remember, an antenna cannot manufacture a signal; no matter how efficient it is, it must be placed in a portion of space through which a signal passes if it is to pick up the signal.

Therefore, the use of a high-gain antenna is not the only procedure that must be followed to get reception in fringe areas. Some means must also be found to mount the antenna high in the air.

Band Widths. In general, we can say that the band width an antenna can pick up becomes more restricted as the antenna becomes more complex. Thus, it is possible to make simple stacked arrays like those in Figs. 29 and 30 pick up over the whole low or high band, particularly if folded dipoles are used instead of the simple



Courtesy JFD Mfg. Co., Inc.
FIG. 34. Low-band and high-band stacked arrays mounted on the same mast.

dipoles shown, whereas the complex array shown in Fig. 32 can be used for only one station. If you want to pick up more than one station in a location where it is necessary to use an array of the latter kind, you must use a separate one for each station.

If both low- and high-band stations are to be picked up in a location where it is possible to use antennas of the kind shown in Figs. 29 and 30, you can use a stacked low-band and a stacked high-band array on the same mast, as shown in Fig. 34. The kind of all-band antenna shown earlier in Fig. 18 can also be stacked with consequent improvement in pickup and in signal-to-noise ratio.

inductance of the rod, there is an impedance between the two leads of the transmission line.

The spacings of the reflector and the directors from the dipole are very critical, as is also the spacing between the ends of the transmission line leads. The reflector and director spacings are determined by the manufacturer of the antenna on an experimental basis. The transmission line spacing is found when the antenna is erected, by moving the ends of the leads together or apart until the best picture is secured on the set to which the antenna is connected. The connections between the line and the dipole are usually made with movable clips to make this adjustment easier.

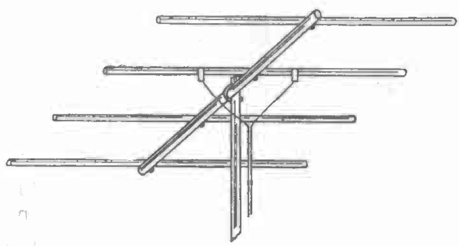


FIG. 35. A Yagi antenna.

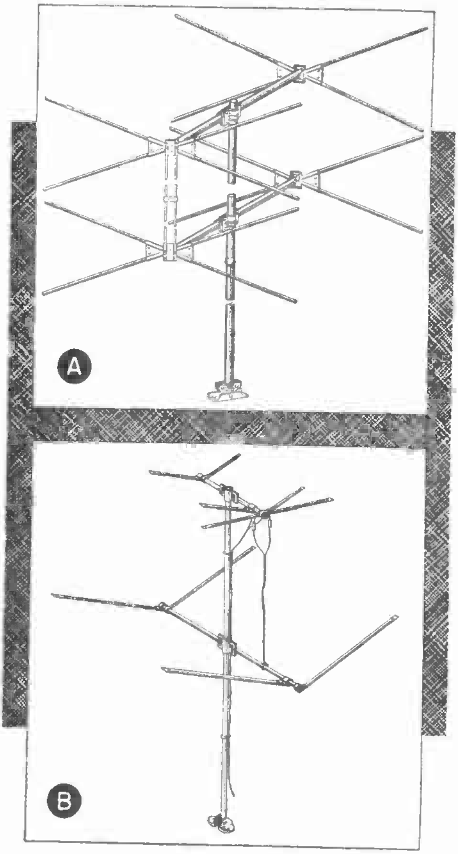
YAGI ANTENNA

The Yagi antenna (named after its Japanese inventor) shown in Fig. 35 is useful in fringe reception areas because of its extremely high gain. This antenna consists of a dipole, a reflector, and either 2 or 3 directors. The dipole in this antenna differs from others we have described in that it is made of one rod, rather than a pair of rods. The two leads of the transmission line are connected to this rod at points equidistant from the center of the rod. At first glance, it would appear that the transmission line is shorted when it is connected to a rod in this manner; actually, however, because of the distributed capacity and

This antenna has a forward gain of 11 db and a very narrow horizontal pickup angle. As you would expect, it also has a very limited band width; as a matter of fact, it can be used for only one station. When you order such an antenna, therefore, you must specify the station it is to be used for, since the spacings between the elements and the lengths of the elements differ for every channel.

NON-HORIZONTAL ANTENNAS

In suburban and country locations where the noise is low and increased signal pickup is the main thing wanted from an antenna, the antennas shown in Figs. 36A and B can sometimes be used. The theory behind these anten-



Top illustration Courtesy Technical Appliance Corp., bottom illustration Courtesy Premax Products

FIG. 36. Antennas designed to pick up both horizontally and vertically polarized signals.

nas is that the television signals, although originally transmitted with horizontal polarization, will be partially vertically polarized by the time they have travelled a long distance, because of reflections and other effects. In other words, the television signal at remote locations will have both a horizontal and a vertical component. A horizontal antenna will pick up a vertically polarized wave only slightly, and, conversely, a vertical antenna will pick up a horizontally polarized wave only slightly; however, antennas like those shown in Fig. 36 will pick up signals of either polarization. Therefore, they will give greater pick-up than a purely horizontal antenna will when the signal contains both horizontal and vertical components.

However, such antennas will also pick up noise (which is usually vertically polarized) better than a horizontal antenna will. They are therefore not suitable for use in noisy locations.

RHOMBIC ANTENNA

If there is enough space available at the location of the set, a rhombic antenna (an example of which is shown in Fig. 37) can be used to get extremely high gain over a wide band. This antenna is made of two long wires strung in a diamond shape parallel to the ground. One end of each wire is connected to a non-inductive resistor; the transmission line is connected to the other end of each.

This antenna is unidirectional, receiving best from the end to which the terminating resistance is connected. The single lobe of its radiation pattern, which is extremely narrow, is lined up with the long axis of the diamond. Because of the narrowness of the pattern, this antenna must be very carefully oriented.

The efficiency of the rhombic increases as the leg length (measured in wavelengths) increases. The legs should be at least 2 λ long for the lowest-frequency station to be received, and preferably more.

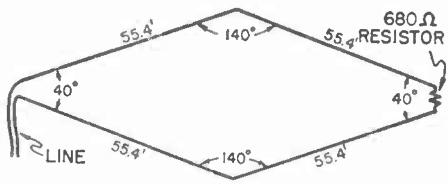


FIG. 37. A rhombic or diamond antenna has a very sharp radiation pattern. It should be oriented so that the resistor end of the antenna will point directly at the desired station.

The chief elements to be considered in the design of a rhombic are the leg lengths and the angles between the legs. If these are properly selected, a rhombic antenna can be made to cover the entire television spectrum at high gain. The design shown in Fig. 37 offers this wide coverage with voltage gains of up to 20 db over a half-wave dipole for the high band.

A rhombic should be strung as high as possible, since its performance improves as its height is increased.

As you can see from the figure, the rhombic requires a great deal of space. An area about 105 feet long and 40 feet wide is needed to erect the antenna shown.

The impedance of a properly designed rhombic antenna is always the same as that of its terminating resistor. In the design shown in Fig. 37, this is 680 ohms. This can be matched reasonably well by a 600-ohm line, which can readily be matched to a 300-ohm receiver through a matching transformer.

Although 600-ohm line is not commercially available, you can make it yourself of two pieces of No. 12 wire spaced 6″ apart (center to center) by insulators. A 2-to-1 matching transformer can be bought or can be made by winding a primary of 29 turns over a ½-inch plastic core form and winding a secondary of 17.5 turns over the center of the primary. Both the primary and secondary windings should be close wound.

Transmission Lines

The lead-in used to connect an antenna to a television set is called a transmission line. Three types of these lines—coaxial, twin-lead, and shielded twin-lead lines—are in use. We shall first learn the physical characteristics of these lines, then study their electrical operation as carriers of r.f. current.

Like any conductors, transmission lines have distributed inductance and capacity. A line therefore has impedance when it is carrying r.f. current. In television, we are concerned with the "characteristic" or "surge" impedance of a line, which is the input impedance of an infinitely long section of that particular line. This characteristic impedance is determined by the physical construction of the line and by the electrical properties of the material used in it.

Other important properties of a transmission line are its attenuation, which is usually stated in db per 100 feet for signals of various frequencies, and its ability to reject interference. We shall discuss each of these factors in the following descriptions of the three main types of television transmission lines.

Coaxial Line. The coaxial line, shown in Fig. 38, consists of a wire surrounded coaxially by a tube of flexible metal braid that is spaced evenly from the wire by insulating material. The center wire and the outer braid (which is covered with waterproof insulation) are the two conductors of this line.

FIG. 38. A typical coaxial transmission line.

The diameter of the wire, the distance between the wire and the braid, and the dielectric constant of the insulating material determine the impedance of a coaxial line. The kind commonly used in television installations has an impedance of 72 ohms. Its attenuation is 2.2 db at 40 mc., 3.75 db at 100 mc., and 5.6 db at 200 mc. per 100-ft. length.

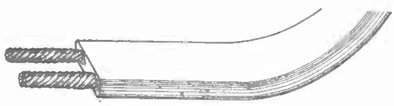


FIG. 39. An unshielded twin-lead transmission line.

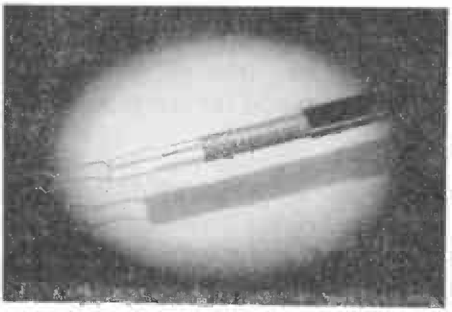
When coaxial line is used, the metal braid is grounded at the receiver. It therefore acts as a shield around the central wire, reducing interference pickup very considerably. Because of this ground connection, the line should be used only with a set having an unbalanced input.

Twin-Lead Line. The twin-lead line, shown in Fig. 39, consists of two flexible wires molded into a flat ribbon of plastic insulating material. The impedance of the line depends upon the diameters of the wires, the spacing between them, and the dielectric constant of the insulation. The kind most commonly used in television installations has an impedance of 300 ohms, although 150-ohm and 72-ohm twin-lead line can also be obtained.

The 300-ohm type has an attenuation of 1.1 db at 40 mc., 2.1 db at 100 mc., and 3.6 db at 200 mc. per 100-foot length. As you can see, its attenuation is far less than that of coaxial cable, a factor that can be very important in an installation made where the signal strength is low. It does not have as much ability to reject noise pickup as coaxial line has, however.

Shielded Twin-Lead Line. If it were made in the conventional manner, a 300-ohm shielded twin-lead line would have to be extremely large in diameter, because the shield would have to be spaced far away from the conductors to reduce the capacity between them. However, a new type of shielded twin-lead line, shown in Fig. 40, is reasonably small and yet has an impedance of 300 ohms.

The two conductors used in this line are crimped into a series of sawtooth sections. In manufacture, a tube of polyethylene (a plastic insulator) is extruded around each of these conductors. Each conductor touches the tube in which it is encased only at the points of the sawtooth; otherwise, the conductor is surrounded only by air. The effect of this construction is to reduce the capacity between the two conductors and the capacity between the conductors and the shield, because air has a lower dielectric constant than has any other insulator. The line can therefore have a 300-ohm impedance and yet be reasonably small in cross-sectional diameter.



Courtesy Federal Tel. and Radio Corp.

FIG. 40. A shielded 300-ohm twin-lead transmission line.

The two conductors in their polyethylene tubes are enclosed in a shield of flexible braid, which is in turn enclosed in a thermoplastic insulating jacket. This shield is grounded when the line is installed and therefore permits the line to have as good interference rejection as coaxial line.

The attenuation of this line is 2.4 db at 50 mc., 3.4 db at 100 mc., and 4.6 db at 200 mc, per 100-foot length —slightly less than that of 72-ohm coaxial cable.

Now that we have learned what practical transmission lines are like, let's learn how they operate when r.f. flows through them.

LINE REFLECTIONS

We mentioned earlier that the three important characteristics of a transmission line are its ability to reject interference, its attenuation, and its surge impedance. What effect the first two of these have on our choice of a transmission line can be stated simply. Generally speaking, we want there to be as little attenuation in the transmission line as possible. All other factors being equal, therefore, unshielded twin-lead line is the best one to choose for an installation. If interference is a problem, however, a shielded line must be used in spite of its greater attenuation.

Now, let us see why the impedance of a line is important.

The job of a transmission line is to deliver a signal to a load. It can do so efficiently only if the load is resistive and has an ohmic value equal to the surge impedance of the line. If the load has reactance, or if its resistance is not equal to the impedance of the line, a phenomenon known as "reflection" occurs: part of the signal that comes along the line to the load is returned, or reflected, back to the line.

To see what effect such a reflection has in a practical case, let's suppose we have a 72-ohm line connected to the input of a set that has a 300-ohm input impedance. (As you learned in an earlier Lesson, sets have input impedances of 72 ohms, 300 ohms, or both.) Suppose, too, that the line is connected to a folded dipole that has an impedance of 300 ohms.

A signal picked up by the antenna is fed into the line and travels down it to the set. Because the line and the set have different impedances (that is, their impedances are not matched), only part of the signal is fed into the set; the rest is reflected back into the line. This reflected signal travels back up the line to the antenna. Because of the mismatch between the antenna and line impedances, part of this reflected signal is reflected again; it travels back down the line and again appears at the input of the set.

If the line is 50 feet long, the part of the signal that has been reflected twice has traveled 100 feet farther than did the part of the signal that was fed into the set at the time of the first reflection. (For convenience in reference, let's call the former the reflected signal and the latter the original signal.) Because of this difference in path length, the reflected signal will be slightly out of phase with the original signal; since both are applied to the input of the set, this phase difference will cause blurring of the picture. In other words, line reflections caused by mismatches of impedance at the ends of the line produce exactly the same effect as that produced by multipath reception. Severe ghosting can be produced by such mismatching, because it is perfectly possible for a strong signal to be reflected up and down the line several times, thus causing several out-of-phase signals to be applied to the input of the set.

Such reflections cannot occur if the impedance of the transmission line matches the input impedance of the set, because then all the signal that comes down the line will be absorbed by the set. If there is a proper impedance match at this end of the line, it does not matter whether there is a match between the antenna and the line as far as reflections are concerned. Therefore, one important thing to remember about a transmission line is that *its impedance must match the input impedance of the set with which it is used.*

Fortunately, this is not a difficult requirement to meet. As you learned earlier in your Course, all modern sets have input impedances of 72 ohms, 300 ohms, or both. Since both 72-ohm and 300-ohm lines are available, it is always possible to secure an impedance match between the line and the set.

Of course, it may happen that a set having a 300-ohm input impedance is to be installed in a location where an antenna having a 72-ohm line is already installed. In such a case, a matching transformer or a resistor network can be used to match the set and the line (or a new line can be installed). We shall discuss such problems in a later Lesson on antenna installations.

ANTENNA MATCHING

Whether or not the antenna impedance is matched to that of the line is not important as far as reflections are concerned, as we just pointed out. However, the lack of an impedance match will have an effect on the transfer of the signal from the antenna to the line.

We mentioned earlier that the antenna can be considered to be a generator and the transmission line its load. You know from previous studies that the greatest transfer of power between a generator and its load occurs when the two are matched in impedance. Therefore, an impedance mismatch between the antenna and the line will give less than a maximum transfer of signal power from the antenna to the line.

As far as the antenna is concerned, a line that is properly matched in impedance at the receiver end will be an infinite line — that is, its actual impedance will be equal to its surge impedance at all frequencies. Therefore, we could be sure of getting a maximum transfer of signal at all frequencies if we could match the impedance of the antenna to that of a properly terminated line at all frequencies.

Unfortunately, this cannot be done. As you learned earlier in this Lesson, the impedance of an antenna depends upon the frequency of the received signal. An antenna can be made to have a fixed impedance for one frequency but not for all. Even a wideband antenna will vary rather considerably in impedance over the television bands.

Fortunately, this fact seldom causes any problems in the metropolitan areas where most installations are made. There the signal strength is almost invariably high enough so that part of the pick-up signal can be wasted without affecting reception. In such areas, usually the only impedance match of importance is that between the line and the set; as long as this match is made, it does not matter much whether the line and the antenna are matched. If they are not, part of the signal will be wasted, but there will still be enough to operate the set satisfactorily in most cases.

As a matter of fact, the antenna and the transmission line are often deliberately mismatched in areas of high signal strength where there are several stations. The purpose of doing so is to make reception fairly uniform over a wide band. If a 300-ohm line is used with a 72-ohm dipole, for example, there will be a 4-to-1 mismatch at the frequency for which the dipole is cut. This will cause a loss of signal for that station; since the signal strength is high, however, this loss is not serious. At higher frequencies, where the dipole does not pick up as well, its impedance will increase. The impedance match between the antenna and the line will therefore improve, and the consequent improvement in signal transfer from the antenna to the line will partially compensate for the reduced response of the antenna.

This effect can be produced, by the way, only if the impedance of the antenna at resonance is lower than that of the line. The reverse of this condition (having the line lower than the antenna in impedance) will not produce any helpful effect, because the impedance of an antenna always rises at off-resonance frequencies; therefore, the mismatch between the line and the antenna will get worse as the frequency increases.

In fringe areas, where every bit of signal is needed, the match between the antenna and the line becomes very important. In this respect, it is fortunate that it is usually necessary to use a separate antenna for each station in such areas, because each antenna and line can then be matched individually for a particular frequency. As we just pointed out, this is the only way in which a perfect match can be secured.

Fringe area reception generally calls for the use of stacked arrays, which, as you learned earlier, have relatively low impedances. If the particular array to be used does not have the same impedance as does the input of the set, obviously no line can match them both. In such a case, the easiest solution is to select a line that will match either the set or the antenna and then to create a match between the line and the other component of the system.

The more common practice is to select a line that will match the set (since it is always possible to make this match) and then find some way to make the line match the antenna also.

Matching Section. An impedance match between an antenna and a line can be secured by connecting the one to the other through a $\lambda/4$ section of line having a characteristic impedance intermediate between the two impedances that are to be matched. Such a connecting line is called a matching section. The characteristic impedance it must have can be calculated from the formula:

$$Z_{MS} = \sqrt{Z_A \times Z_{TL}}$$

where Z_{MS} is the impedance of the matching section, Z_A is the impedance of the antenna, and Z_{TL} is the impedance of the transmission line. Applying this formula to the problem of matching, say, a 72-ohm antenna and a 300-ohm line, we find that the matching section must have an impedance of $\sqrt{72 \times 300}$, which is approximately 147 ohms. Therefore, a $\lambda/4$ length of 150-ohm line (which is a commercially available item) will serve as a matching section in this case. Of course, it will be a matching section for only one frequency, since it will not be $\lambda/4$ long at any other frequency.

Another method of matching an antenna and a line is to use what is known as a "matching stub." To understand the action of this device, we must learn something about the electrical characteristics of $\lambda/4$ and $\lambda/2$ lines.

QUARTER-WAVE AND HALF-WAVE LINES

To determine the characteristics of a piece of transmission line, we could connect it to a source of r.f. energy and measure the r.m.s. values of the r.f. voltages and currents found at various points along the line. We could then determine the impedance at each point along the line; if we plotted this impedance against the length of line, we could get a picture of how the line works. Fig. 41 shows the results we would get if we did this for four special cases that are of particular interest.

Fig. 41A shows how the impedance varies along a $\lambda/4$ line that is open at both ends. We shall speak of the left-hand end of each of these plots as being the source end, because this is the end to which the source of r.f. energy would have to be coupled to get these plots. Notice that the impedance is zero at the source end and high at the other end (which we shall call the load end). In other words, a $\lambda/4$ section of open line will appear to be a short circuit to a source connected to one end of the line.

When a $\lambda/4$ line is shorted at its load end (Fig. 41B), exactly the opposite result is produced: the impedance is high at the source end and zero at the shorted end. Thus, a $\lambda/4$ line shorted at the load end appears to be an open circuit at the source end.

A similar plot for an open $\lambda/2$ line (Fig. 41C) shows that its impedance is high at both ends and low in the middle. Finally, a plot for a $\lambda/2$ line that is shorted at one end (Fig. 41D) shows that its impedance is low at both ends and high in the middle.

An easy way to keep these facts in mind is to remember that a $\lambda/4$ line inverts its load whereas a $\lambda/2$ line repeats its load. If the load end of a $\lambda/4$ line is open, its source end appears shorted, and vice versa. The source end of a $\lambda/2$ line, on the other hand, always has the same impedance as the load end has.

All these facts about the performance of $\lambda/4$ and $\lambda/2$ lines will prove useful to you in your later studies of television. We have already seen one use that is made of the properties of

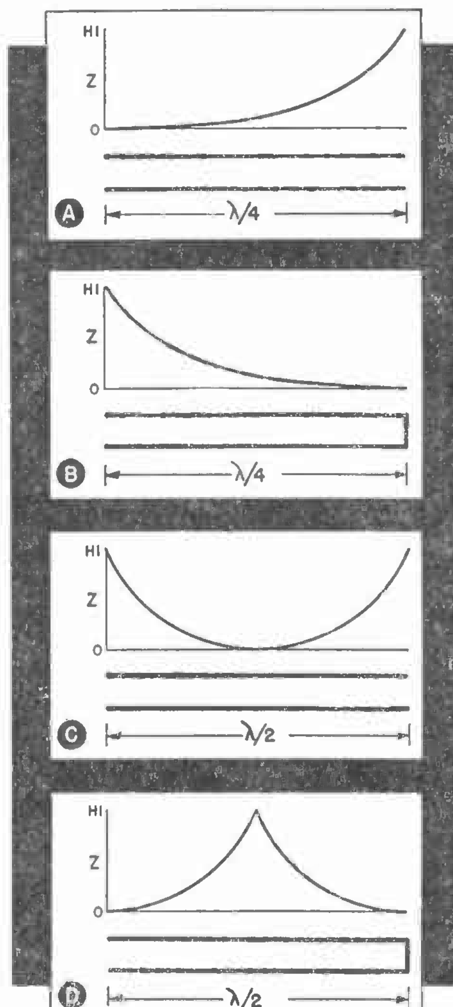


FIG. 41. The characteristics of quarter-wave and half-wave lines.

a $\lambda/4$ line: we learned earlier that a high-band and a low-band antenna are electrically isolated by connecting them with a length of transmission line that is $\lambda/4$ long at the frequency for which the low-band antenna is cut. This isolates the two antennas at low frequencies because the high-band antenna acts practically as a short for these frequencies. Since a shorted $\lambda/4$ line has a high impedance at its other end, the high-band antenna appears as a high impedance across the low-band antenna, and therefore has very little effect on it. At high frequencies, the $\lambda/4$ isolating section is simply an extension of the transmission line as far as its effect on the high-band antenna is concerned. Since the low-band antenna has high impedance at these frequencies, it can be considered to be simply a high-impedance load across the line.

At the moment, we are particularly concerned with the operation of a shorted $\lambda/4$ line when it is used to match an antenna to a transmission line. When it is used for this purpose, a shorted $\lambda/4$ line is called a "matching stub" (the name coming from the fact that only a short stub of a line is used).

To take a practical example, let's say we want to use a matching stub to match a 300-ohm line to a 30-ohm antenna. (The antenna shown earlier in Fig. 30 has an impedance of 30 ohms.) Fig. 42 shows the connections that will permit this match to be made. As you can see, the transmission line is connected to the open end of the matching stub and the antenna is connected to the stub a distance d from its shorted end. Let's see why these connections produce the match we want.

As we just pointed out, the impedance of a matching stub is very high at its open end. When we connect the 300-ohm line to this end of the stub, we are effectively connecting the low impedance of the line and the high impedance of the stub in parallel; consequently, the impedance at the point of connection becomes 300 ohms (since the impedance of a parallel combination of a high and a low impedance is, for all practical purposes, that of the low impedance). Therefore, the impedance of the matching stub now varies from zero at its shorted end to 300 ohms at the point of connection to the line. Somewhere between these two ends of the stub is a point where its impedance is exactly 30 ohms; it is to this point that the 30-ohm antenna is connected. The impedance of the antenna is therefore perfectly matched.

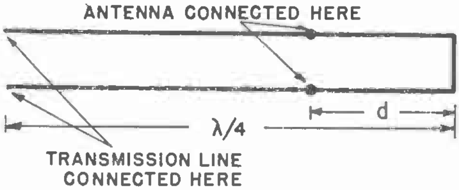


FIG. 42. How a matching stub works.

A matching stub can be used in this manner to match any antenna to any line. If the impedance of the line is lower than that of the antenna, the open end of the matching stub must be connected to the antenna; the impedance of the stub will then vary from zero to the same impedance as the antenna, and the line can be matched to the combination by connecting it to the stub at the proper point.

What the proper point is depends on the ratio of the impedances of the antenna and the line. Table I shows the points of connection for various impedance ratios. In this table, Z_1 is the higher impedance and Z_2 the lower impedance. For instance, if we have a 300-ohm line and a 30-ohm

TABLE I

Stub Connections for Various Impedance Ratios

Z_2/Z_1	d*	Z_2/Z_1	d*
0.05	14	0.55	53
0.10	20	0.60	56
0.15	25	0.65	59
0.20	30	0.70	63
0.25	34	0.75	67
0.30	37	0.80	70
0.35	41	0.85	75
0.40	44	0.90	80
0.45	47	0.95	90
0.50	50	1.00	100

* % of length from shorted end

antenna, Z_1 is 300 ohms and Z_2 is 30 ohms. The ratio Z_2/Z_1 is therefore 30/300 or 0.10. From the table, you can see that for this ratio of impedances, the antenna should be connected to the matching stub at a distance from the shorted end equal to 20% of the length of the stub. If the ratio of impedances were, say, 0.45, the point of connection should be 47% of the length of the stub, and so on. In all cases, these distances are from the shorted end of the stub.

Obviously, it is mechanically more difficult to tap in on a matching stub than it is to use a matching section between the transmission line and the antenna. However, the matching stub has the advantage of being usable no matter what the impedances of the antenna and the line may be, whereas the matching section can be used only if the square root of the product of the impedances of the two is equal to the impedance of some available line. For example, if a section of line were to be used to match a 30-ohm antenna and a 72-ohm line, it would have to have an impedance of $\sqrt{30 \times 72}$, or approximately 46.5 ohms — and no commercially available line has this impedance.

Remember, neither of these matching methods will provide a match at more than one frequency, because a matching section or a matching stub will be $\lambda/4$ long at only one frequency.

Looking Ahead. You have now studied the theory of operation of TV antennas and transmission lines. In a future Lesson, you will learn how to select the antenna and the transmission line for a particular installation and how to make the installation.

Lesson Questions

Be sure to number your Answer Sheet 59RH-3.

Place your Student Number on every Answer Sheet.

Send in your set of answers for this Lesson immediately after you finish them, **as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. Why is it possible to receive TV carrier signals somewhat beyond the line-of-sight distance even though they are not reflected from the Kennelly-Heaviside layer?

2. If the heights above sea level of a transmitting antenna and a receiving antenna are 800 feet and 50 feet respectively, what is the maximum line-of-sight distance between the two?

3. If a reflected signal travels several hundred feet farther than a direct signal and both reach the same antenna, what will be the effect on the picture?

4. What is the impedance of a plain dipole of (a) $\lambda/2$, (b) λ, and (c) $3\lambda/2$ length?

5. A dipole cut to be $\lambda/2$ for channel 2 receives that channel best from a direction perpendicular to its length. At what angle from the dipole will it receive best on channel 7, for which it is $3\,\lambda/2$ long?

6. Is it more important to match the impedance of the transmission line to that of the receiver or that of the antenna, and why?

7. What length of transmission line should be used to connect a high-band to a low-band antenna to prevent interaction between them?

8. How does the active (or driven) element in a Yagi antenna differ from that of an array consisting of an ordinary dipole with reflectors and directors?

9. What should be the impedance of the transmission line connected to a folded dipole if maximum power transfer is wanted?

10. Suppose a shorted $\lambda/4$ matching stub is to be used to match a 300-ohm line and a 50-ohm antenna. Should the open end of the stub be connected to the line or to the antenna?

Be sure to fill out a Lesson Label and send it along with your answers.

SHOULD YOU DEPEND ON LUCK?

Accident—chance—luck—have very little bearing upon the production of any great result or true success in life. Of course, there have been many discoveries and accomplishments which may *seem* to be the result of "luck."

For instance: Newton "discovered" the law of gravity by watching an apple fall from a tree. Galileo "invented" the telescope after hearing of a toy constructed by a spectacle-maker. Brown "invented" the suspension bridge after watching a spider throw its web.

But these discoveries and inventions were made by men *trained* to take advantage of what they observed. Thousands of *untrained* men had seen the same things and paid no attention.

The new discoveries in Radio—Television—Electronics will be made by men *trained to take advantage of what they observe.*

J. E. Smith

HOW TO SELECT AND ERECT TV ANTENNAS

60RH-3

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WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE No. 60

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

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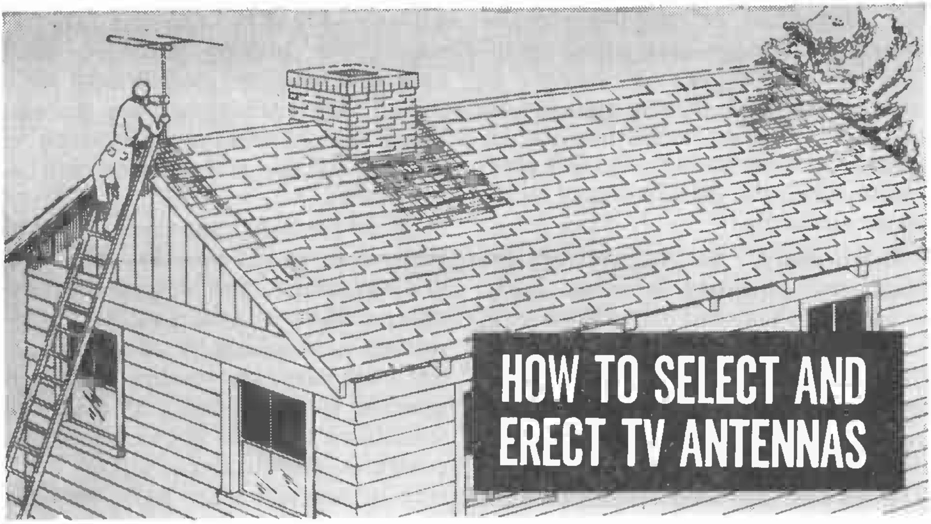


HOW TO SELECT AND ERECT TV ANTENNAS

ANTENNA installation is one of the important activities of a television serviceman. The serviceman may not make the actual installation of an antenna, because this is a mechanical job that can be performed by someone who is not a skilled electrical technician, but he always selects the kind of antenna to be used and more or less supervises the operation of putting it up. He is also called upon to solve the problems that arise when a "standard" installation does not prove satisfactory.

As a television serviceman, therefore, you must know how to select and erect antennas that will bring in television signals of sufficient strength to operate a television set properly. You have already studied the theory of antennas in an earlier Lesson; in this one, we shall describe the practical aspects of choosing an antenna for primary area and fringe area installations and teach you the general procedure used to put the antenna up at a place where it will pick up sufficient signal.

Naturally, every installation is different in some respect from every other. For this reason, we shall give you general information instead of attempting to describe each step of an installation in detail. We shall discuss all types of antenna installations, so this Lesson will give you a good start toward the mastery of all antenna problems.

Before we discuss specific kinds of antenna installations, let's take up a few matters that apply to any installation.

PRELIMINARY SURVEY

Advanced planning will make an antenna installation easier and more apt to be successful the first time. Unless you have had experience with the reception in the general area where the installation is to be made, a preliminary survey of the location should be a part of your advanced planning. Such a survey may be very easy: if you find that nearby houses are equipped with simple TV antennas, you can justifiably assume that such an antenna is all that will be needed for your customer's house. On the other hand, it may be a major project in a fringe area where reception is usually poor or spotty: in such a location, you may find it necessary to make elaborate tests to determine whether enough signal is present to make the installation of a TV set worth while.

Incidentally, the matter of the neighbors' antennas is often fairly important. You will find that a customer will often demand an antenna that is at least as complicated in its appearance as are those of his neighbors, even though it is not actually necessary for the reception of signals. You may be able to overcome such an attitude by pointing out that the customer's set is so excellent that it does not require an elaborate antenna, but very often you will find it simpler just to go ahead and put in the more complex one.

We mention this fact because there is an economic factor to be considered in antenna installations. In most metropolitan areas where the cost of the installation is included in the service contract that the customer buys at the time he gets his set, about $20 is allowed to cover a normal antenna installation, including the cost of the antenna itself. Obviously, then, it is desirable to keep the cost of the antenna as low as possible, since the cost of labor in putting up the antenna is by no means inconsiderable, and the $20 fee must cover both of them. This limited allotment of funds for erection of the antenna is another reason why a preliminary survey that makes the work faster is a very good idea.

Of course, if the location is such that the erection of the antenna is unusually difficult, an extra charge must be made. This is usually necessary in fringe areas, where an installation and antenna erection charge of $100 or $200 is not unusual. The necessity for making such an extra charge is another good reason for a preliminary survey, because the customer should always be warned in advance if the extra charge will be necessary.

If an outside antenna is to be erected on rented property, the owner's permission must be secured in advance. Most service contract forms contain a provision to the effect that the customer must secure such permission; however, you may make installations that are not under service contracts, so you should always make sure before you start work that the necessary permission is secured. It is a wise precaution to make sure that the permission is in writing.

ANTENNA TYPES

You studied the radiation patterns and other characteristics of several kinds of antennas in an earlier Lesson. As we shall point out later in this Lesson, often these antennas are much alike; therefore, although there are a great number of antenna types available, many of them are just about the same as far as their effectiveness in any particular location is concerned. The tendency of antenna installers or those in charge of antenna installations is to settle on a few favorite kinds of antennas that they use for almost every kind of installation. If you follow this system, you will become so familiar with the abilities of the particular antennas you select that you will be able to estimate very accurately which one will be satisfactory in a particular location.

One of the things you should consider when you are comparing one antenna with another is the ease with which it can be assembled. Antennas differ considerably in this respect; some are much easier to put up than others. Naturally, the ease of assembly of an antenna affects the amount of time that must be spent to install it and consequently affects the cost of the job. It may be, therefore, that an antenna that costs a little more than others but is much easier to put together may be less expensive than the others when the labor cost is added to the cost of the antenna itself.

Of course, being easier to put together is no advantage if the antenna is not solid and strong when assembly has been completed. Strength of the antenna should not be sacrificed, because an outdoor antenna must be able to withstand high winds, ice formations, and the effects of weather. An antenna is rather difficult to service once it has been installed, so you should make sure that it is going to require as little servicing as possible when you put it up.

Now, let's learn how to make installations in primary areas where the signal strength is high.

Primary-Area Antennas

Lack of signal strength is usually no problem in the primary area of a television station. Instead, the chief problems are usually to eliminate ghosts and, if there is more than one station in the vicinity, to pick up all of them.

Let us discuss the problem of eliminating ghosts first.

GHOSTS

As you know, one cause of ghosts is the arrival of signals at the receiving antenna over two or more paths that are different in length. An example of such reception is shown in Fig. 1. Here, the dipole picks up a direct signal from the transmitter over path A and picks up a reflected signal over path B. If the difference between the lengths of these two paths is greater than 70 feet, a ghost will be produced in the image on the picture tube of the set.

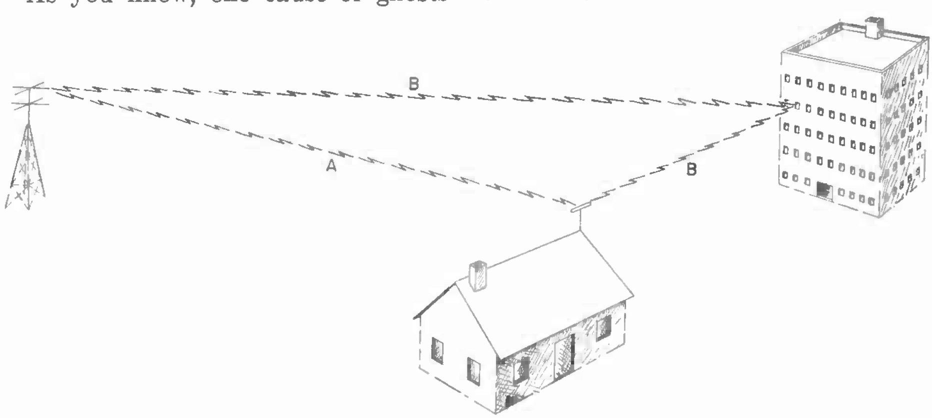


FIG. 1. Ghosts are produced when a TV signal reaches an antenna over two paths that differ considerably in length.

Ghosts may also occur if the impedance of the transmission line does not match that of the receiver and of the antenna. If both ends of the transmission are mismatched, signals will be reflected up and down the line, effectively increasing the path length of the reflected signals as compared with the path length of the direct signal (which, in this case, is the signal that is absorbed by the receiver from the line the first time the signal comes down the line). Again, a path difference of about 70 feet is enough to cause ghosts; in other words, it is possible for ghosts to be visible if the mismatched transmission line is longer than 35 feet (since then the reflected signal will travel a total of 70 feet from the receiver to the antenna and back to the receiver again).

Ghosts caused by the pickup of reflected signals are usually more troublesome inside a large city than they are in the suburbs, because, within the city, the presence of large buildings from which the signals can be reflected may cause the signal to come to the antenna from several different directions. Furthermore, the reflected signals may be quite strong within the city because of the high signal strength that is maintained for such areas. In the suburbs, on the other hand, it is rare for ghost signals to arrive from more than one direction, and they are not usually nearly as strong as the direct signal.

Let's see how ghosts caused by reflections and by improper impedance matching can be eliminated.

ELIMINATING REFLECTIONS

Ghosts caused by the pickup of reflected signals can frequently be eliminated by using a reflector. As you know, the use of a reflector sharpens the directivity of the antenna in the forward direction and makes its pickup very small in back. If the antenna can be oriented so that the desired station is picked up from the forward direction of the antenna and the undesired reflected signals approach the antenna from the reflector side, the antenna will pick up only the direct signal, and ghosts will therefore be eliminated. If necessary, a director can be added to the forward side of the dipole to increase the directivity even more. This may not be possible if several channels are to be picked up, however, because the use of both the reflector and a director reduces the band width of the antenna very seriously.

Although the exact acceptance angles of antennas are often given in theoretical discussions, the only use made of such information in practice is to take it as a guide to whether an antenna is highly directional, broadly directional, or relatively non-directional. No serviceman plots such angles before making an installation in an area where the signal strength is high. Instead, he puts up an antenna and, if ghosts are present, orients the antenna to see if he can eliminate them. Most servicemen put up a plain or folded dipole first if it seems likely that there will be little trouble with reflections. In a congested area, however, where there are many buildings capable of causing reflections, it is highly probable that a reflector will be needed to eliminate ghosts. In such areas, therefore, most servicemen will install a dipole and a reflector from the start, particularly if such antennas are used in near-by locations.

In areas in which there are several stations, the problem of eliminating ghosts caused by reflections is complicated by the fact that orienting the antenna to a position that eliminates ghosts on one station may cut out another station altogether. In such a case, it may be necessary to use two antennas or an antenna rotator. We

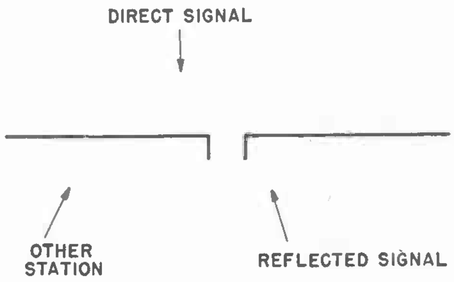


FIG. 2. Here ghosts can be eliminated by not picking up the direct signal.

shall discuss this problem a little farther on in this Lesson.

If it is not possible to orient the antenna so that you can pick up the direct signal but not the reflected one, it may be possible to turn it so that you can pick up the reflected signal and ignore the direct one. An example of a situation of this sort is shown in Fig. 2. Here, we cannot orient the antenna to eliminate the reflected signal without also eliminating the direct signal, because the antenna picks up equally well from the front and the back. Further, we cannot put a reflector on the side of the antenna from which the reflected signal comes, because doing so would also eliminate the signal from the other station. However, we can put a reflector on the side of the antenna from which the direct signal comes, eliminating the direct signal and picking up both the reflected signal and the signal from the other station. A reflected signal is, of course, weaker than a direct one, because part of the signal is absorbed each time it is reflected. In a high-strength area, however, the reflected signal will probably be strong enough to operate the receiver well.

Ghosts can also be caused temporarily by a passing airplane that reflects a signal to the antenna. Such ghosts are often annoying, particularly when the antenna is so near an airport that planes pass by frequently, but there is very little that can be done about them.

It is also possible for ghosts to be transmitted by a station itself. If there is a mismatch between the coaxial network line and the input of the transmitter, for example, there may be reflections up and down the coaxial line that will cause a ghost signal to be applied to the input of the transmitter. There is nothing whatever that can be done at the receiver to eliminate ghosts of this sort, of course. You can usually tell whether a ghost is being transmitted by a station by watching several programs from that station. If the ghost is not present on each program, and particularly if it is present on network programs but not on local ones, the ghost signal is being transmitted by the station.

IMPEDANCE MATCHING

Ghosts caused by mismatches between the antenna, the line, and the set can be corrected by matching the line to the set. On a new installation, it is always possible to use a transmission line that will match the impedance of the set, because there are only two input impedances (72 ohms and 300 ohms) used in modern sets, and both 72-ohm and 300-ohm lines are available. Therefore, if the input impedance of the receiver is fixed at all frequencies, it is possible to eliminate such reflections completely by using the line that will match the impedance of receiver input. Some receivers, however, have tuned inputs that may vary in impedance from station to station. There is no practical way of varying the impedance of the line similarly, so ghosts caused by impedance mismatches cannot be eliminated altogether when such a receiver is used. However, using a line that matches the nominal input impedance of this receiver will usually reduce the ghosts very considerably.

If a customer who already has a television set buys a new one, the chances are that he will already have an outdoor antenna installed. If the line used with this antenna is not of the right impedance to match the new set, you will have to replace the line, or, if that is too difficult, use a transformer to match the line to this set. A matching transformer that will match 72 ohms to 300 ohms is commercially available; a schematic diagram of one is shown in Fig. 3. This

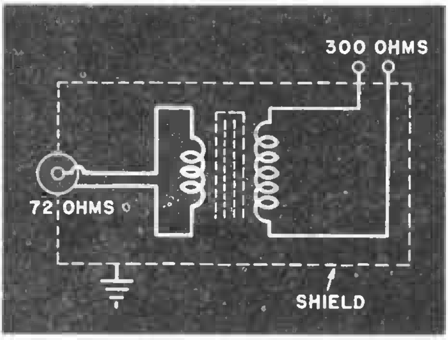


FIG. 3. Schematic diagram of a transformer that matches 72 ohms to 300 ohms.

transformer will produce matches in either direction—in other words, it can be used to match a 300-ohm line to a 72-ohm receiver or vice versa.

Generally speaking, it is not necessary to match the line to the antenna in an area where the signal strength is high. A mismatch between the line and the antenna causes only loss of signal as long as the line and the receiver are matched. As a matter of fact, the antenna and line are often deliberately mismatched to produce broad-band reception. As you learned in an earlier Lesson, this is possible

Courtesy Workshop Associates

This is the matching transformer that is shown schematically in Fig. 3.

only if the line has a higher impedance than does the antenna; then the increase in impedance of the antenna at off-resonance frequencies will make it approach the impedance of the line at those frequencies and therefore make the over-all response of the system better.

Now, let us learn more about the problems involved in securing multichannel reception.

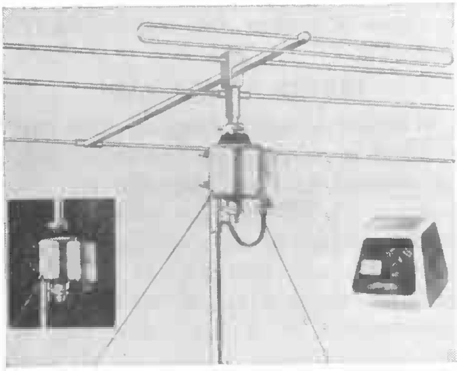
MULTI-CHANNEL RECEPTION

Every TV antenna now used is directive to some extent; in other words, it will receive better in some directions than in others. As we just saw, it is often highly desirable for the antenna not to receive in some directions, since this permits ghosts to be reduced or eliminated. However, it is often not desirable to have the antenna very directive when several stations must be picked up, because it may then be impossible to get all stations with a single antenna.

There are two possible approaches to the problem of getting reception from several stations. One is to use a fixed antenna or a combination of fixed antennas that will, when properly oriented, pick up all stations.

The other way is to use a highly directive broad-band antenna that can be rotated mechanically to pick up the desired stations.

An arrangement of the latter sort is shown in Fig. 4. The antenna, which was described in an earlier Lesson, consists of a high-band folded dipole, a low-band folded dipole, and a low-band reflector mounted one behind the other in a horizontal plane. The high-band dipole acts as a director for the low-band dipole, and the low-band dipole acts as a reflector for the high-band dipole. The radiation pattern of this antenna is very directional for all television frequencies, having a single large lobe projecting forward at right angles to the dipoles and practically no backward pickup. Its pickup is greater than that of an ordinary dipole for all channels except channel 2, for which the average pickup is about the same as that of a dipole. It is, therefore, very suitable for multi-channel use. Because of its single-lobed radiation pattern, however, it cannot be used unless all the stations are in the same general direction from the receiver or unless a rotator is used with it. Incidentally, the transmission line of the antenna is not shown in Fig. 4; the line shown is the control cable for the antenna rotating motor.



Courtesy Alliance Mfg. Co.

FIG. 4. The "Tenna-Rotor" antenna rotator.

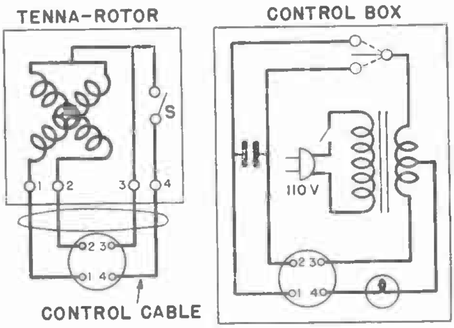


FIG. 5. Diagrams of the electrical components of the Tenna-Rotor and its control box. The 4-lead control cable runs from the motor to the control box. To trace connections, notice that each wire in the cable plugs into the control-box socket bearing the same number.

The "Tenna-Rotor" shown in Fig. 4 is a slow-speed reversible motor that is mounted on top of the antenna mast. It has a hollow shaft into which the mounting post of the antenna can be inserted. Two clamps will hold the antenna mounting post in position. The motor is enclosed in a weatherproof housing.

The direction of rotation is controlled by turning a switch on a control box that is placed near the set. This box contains the transformer and a two-position switch; the schematic diagram of its internal connections is shown in Fig. 5. The transformer converts 110-volt a.c. to 24-

volt a.c., the power supply from which the rotating motor is to run. This low voltage is used because the electrical code permits it to be carried about through an exposed cable. If 110-volt a.c. were used for the control circuits, the electrical cable from the control box to the rotator would have to be installed in rigid conduit, which is both difficult and expensive to use.

Notice the switch S in the schematic diagram of the Tenna-Rotor shown in Fig. 5. This is a limit switch that closes when the motor turns as far as it can in either direction. As you can see from the circuit, closing this switch completes a circuit from the transformer through a small lamp in the control box; the lamp then lights, thus indicating to the operator of the device that the motor will turn no farther in the direction in which it has been moving. Although the motor cannot turn continuously in one direction, it can make a total rotation of 360 degrees from one end of its travel to the other.

The 4-conductor cable, which is visible in Fig. 4, connects the rotator to the control box. This cable is plugged into a receptacle in the box. The rotator will turn at a speed of about 1 r.p.m. when the control switch is thrown to the right or left and will stop instantly when the switch is brought to its center position. This speed of rotation is great enough to make the picture quality change quickly as the antenna rotates but not so great that the point at which the picture is best will be passed before the operator can return the switch to its center position and stop rotation.

Although other kinds of antennas can be rotated by this device, the one shown in Fig. 4 is particularly well suited for this use because it is mechanically strong and not very heavy. It would be more difficult to rotate a stacked array or another form of large antenna, although it can be done.

A disadvantage of most antenna rotators developed up to the present, aside from the fact that they are rather expensive, is that many of them break down after a few months' service. This is purely a mechanical difficulty that will probably be overcome in the future by improvements in design.

Sometimes using a rotatable antenna is the only way that good reception can be gotten from all stations. Often, however, it is possible to use a fixed antenna or a combination of fixed antennas to pick up all stations reasonably well. The use of a fixed antenna is desirable in one respect, because it eliminates the cost of a rotator. Let's learn more about the use of these antennas for multi-channel reception.

FIXED ANTENNAS

Whether or not a fixed antenna can be used in a specific location to pick up several stations depends on the position of the location with respect to the stations and on whether or not reflections are present. It is often possible to use a single antenna or a combination of a high-band and a low-band antenna to pick up all stations. Sometimes, however, it is necessary to use several antennas.

In many locations, a dipole (plain or folded) or a dipole and a reflector will give good reception over several channels. The radiation patterns for a dipole in both the high and the low bands are shown in Fig. 6. The solid lines show the radiation pattern of the antenna for high-band frequencies, the dotted lines show it for low-band frequencies. The addition of a reflector would reduce the backward pickup of low-band frequencies considerably, but it would not affect the pickup of high-band frequencies in this direction very much. It would also increase the forward pickup at low-band frequencies.

As you can see from this radiation pattern, this antenna will pick up from most directions reasonably well. It will not pick up off its ends, however, unless the station is very close by; therefore, if two low-band stations that are at right angles to one another with respect to the antenna location are to be picked up, usually a single dipole cannot be used. It can be used to pick up two high-band stations that are at right angles to its location, however, since there is approximately a right angle between two of the major lobes in the high-frequency pattern.

If all stations are on the same side of the dipole, a reflector can be added to secure greater forward pickup and reduce pickup from the backward direction.

What we have said previously about dipoles applies to both plain and folded dipoles, since the two have identical radiation patterns. They differ in their impedances, however; the plain dipole has an impedance of 72 ohms, and the folded dipole an impedance of 300 ohms. Therefore, if the receiver has a 72-ohm input, it is logical to use a plain dipole and a coaxial line, thus getting an impedance match throughout the antenna system. If the receiver has a 300-ohm input, a folded dipole and a 300-ohm line would give a match throughout. Some prefer to use a plain dipole and a 300-ohm line with 300-ohm receiver, because this gives broad-band reception.

High-band stations are somewhat difficult to pick up with an antenna that is cut for the low band, particularly those stations that are at the upper end of the high band. Therefore, when both low-band and high-band stations are to be received, it is often necessary to add an antenna cut for the high band to one that is cut for low-band use, isolating the two by connecting them with a quarter-wave length of transmission line. The two antennas can then be oriented separately to pick up the stations for which they are cut; and neither will have much effect on the other.

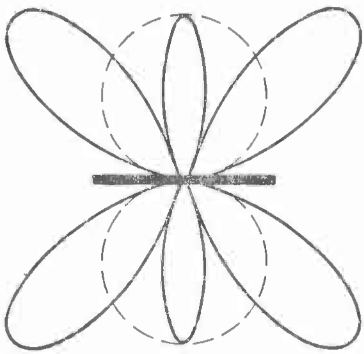


FIG. 6. Radiation patterns in the low band (dashed lines) and the high band (solid lines) for a dipole cut to be $\lambda/2$ long in the low band.

The dipole or folded dipole is the basic antenna that is used in most primary area installations, but there are other kinds having more complex radiation patterns that sometimes prove to be better for multi-channel use. One of these is the bat-wing antenna shown in Fig. 7. The radiation pattern of this antenna is shown in Fig. 8. As you can see, this antenna has multiple lobes at the high frequencies and the familiar figure-8 pattern of the dipole at low frequencies. In some locations, this pattern may prove to be ideal for picking up the various stations in the area.

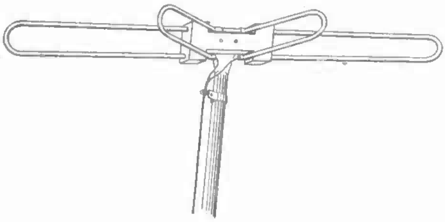


FIG. 7. The bat-wing antenna.

Another antenna having a multi-lobe pattern is the duo-dipole antenna shown in Fig. 9. This antenna consists of a thin dipole cut to be $\lambda/2$ at 70 mc. that is mounted by inductive loops close to a thick dipole that is cut to be $\lambda/2$ at 180 mc. The inductive loops provide both electrical connections and mechanical support for the low-band dipole.

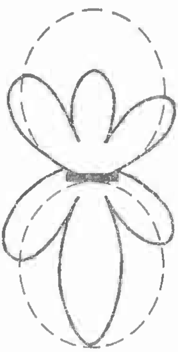


FIG. 8. Radiation patterns for the bat-wing antenna in the low band (dashed lines) and in the high band (solid lines).

The radiation pattern of this antenna is shown in Fig. 10. As you can see, it has multiple lobes much like those of the bat-wing antenna for the high band and roughly a figure-8 pattern for the low band. Because of the similarity in their radiation patterns, there is not much to choose between the bat-wing and the duo-dipole antenna; either may be well suited to a specific location.

These are by no means the only kinds of television antennas that can be used in areas of high signal strength. As a matter of fact, new kinds of antennas are constantly being introduced. Whether other kinds will be more useful to you than those

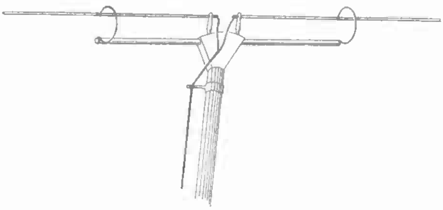


FIG. 9. The duo-dipole antenna. The thick dipole is the antenna for the high band, the thin one that for the low band.

we have already described depends principally on the location: if an antenna has a peculiar radiation pattern, it may solve an installation problem that no other antenna will take care of. Usually, however, you can use a dipole or a combination of dipoles, with or without reflectors, to get a good signal in almost any location in a high-strength area.

As a matter of fact, it is often not necessary to have a roof-mounted antenna in a location where the signal strength is high. It may be possible

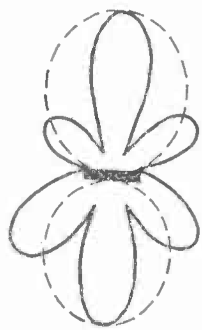


FIG. 10. Radiation patterns for the duo-dipole antenna in the low band (dashed lines) and in the high band (solid lines).

to use an indoor or a window antenna to operate a set satisfactorily. This is fortunate, since many apartment house owners will not permit erection of a roof-top antenna.

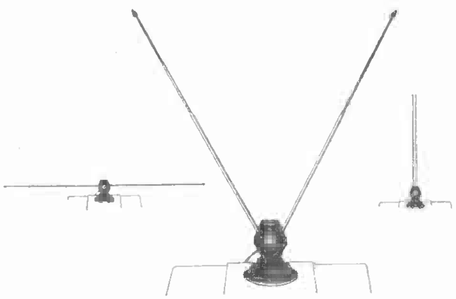
We are going to describe the installation of antennas in the last section of this Lesson. However, since the installation of an indoor or window antenna is a fairly simple job, we shall discuss such installations here and reserve the section on installation for the more difficult problem of installing an outdoor antenna.

INSTALLATION OF INDOOR ANTENNAS

There are many types of indoor antennas on the market, all of them of about equal ability to pick up a signal.

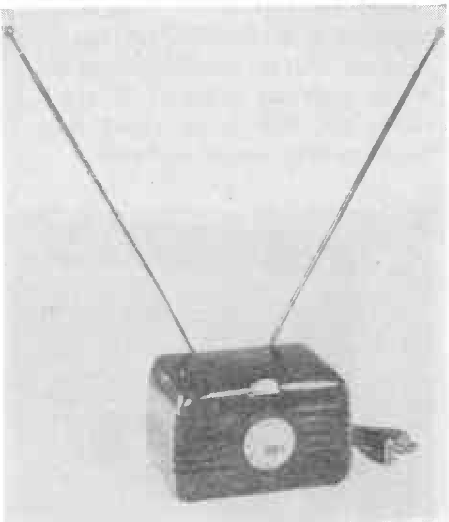
One popular form is shown in Fig. 11. The poles of this antenna telescope and can be extended or closed up readily. As the figure shows, the angle between them can be changed as much as desired. The whole antenna can be picked up and rotated.

Installation of this antenna is very simple. It comes equipped with an 8-foot length of 300-ohm line; to install it, just connect the line to the antenna terminals on the receiver.



Courtesy Insuline Corp. of America

FIG. 11. A common form of indoor antenna that can be adjusted in length, angle, and position.



Courtesy Jerrold Electronics Corp.

FIG. 12. An indoor antenna that is combined with a booster.

Another form of antenna is shown in Fig. 12. This is like the one in Fig. 11 except that the antenna is connected directly to a booster, to the output terminals of which the set is connected. We shall discuss boosters in another Lesson at some length; for now, let's just say that a booster is a one- or two-stage r.f. amplifier connected between the antenna and the input of the set. A booster is usually tunable; the one shown here can be tuned to each of the low-band channels, to the FM band, and to channel 7. A single setting tunes it to channels 8 and 9 and another setting tunes it to channels 10, 11, 12, and 13.

Sometimes, because of its gain, an antenna-booster combination of this sort will permit the use of an indoor antenna in locations where a plain indoor antenna will not furnish an acceptable signal.

An indoor antenna should be placed close to the receiver; very often, it is placed on top of it. Matching the impedance of the line to that of the receiver is of no particular importance when such an antenna is used, because the line is so short that reflections will cause no trouble.

Courtesy Radio Merchandise Sales

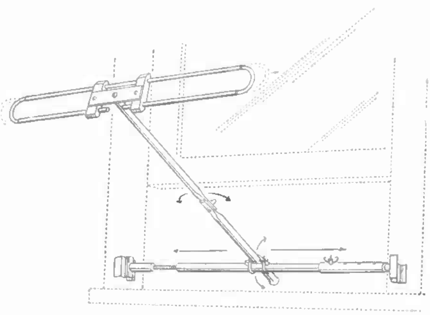
A typical booster. This device may be used with any kind of antenna.

In most locations, it is necessary to adjust an indoor antenna for each station. The lengths of the arms or the angle between them may have to be adjusted, or the antenna as a whole may have to be rotated to get the best signal. This calls for the performing of a certain amount of work by the person operating the set, but, since most programs last for half an hour or an hour, most people are willing to spend a moment in making the adjustments to get a satisfactory signal.

Indoor antennas of this sort will work reasonably well on the upper floors of an apartment building. However, they will often fail to give satisfactory performance on the ground floor or even on the second floor; and in basement installations, they are usually worthless. If it is impossible to obtain good reception with an indoor antenna, the more efficient window antenna may give a satisfactory signal.

A typical window antenna is shown in Fig. 13. Usually an apartment owner who will not permit the use of an outdoor antenna will allow one of this sort to be used, because often his refusal to allow an outside antenna to be erected is caused by the fact that he does not want holes drilled in the side of the building or the window casement to mount the antenna and bring the transmission line into the room. It is not usually necessary to drill any holes to erect a window antenna, and it is usually possible to use a flat ribbon of twin lead line and work it through the window opening without cutting any holes.

To install an antenna of this sort, extend the adjustable cross arm until it is firmly secured between the two sides of the window opening. The short antenna mast can then be placed at any desired angle with respect to the wall of the building. There is no particular advantage to keeping the antenna away from the wall unless the antenna has to be rotated; if rotation is not necessary, bring the antenna up close to the wall to make it as inconspicuous as possible.

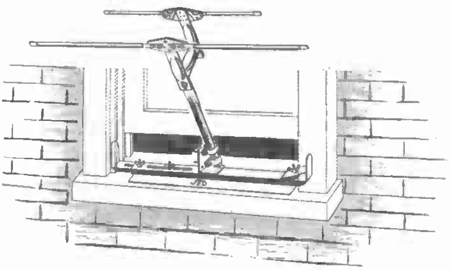


Courtesy Insuline Corp. of America

FIG. 13. An adjustable window antenna.

Such an antenna may not be usable if the windows are of the casement type, which open outward. Even if the windows are of this kind, however, you may find it possible to mount the cross arm below or above the windows in the window opening, in which case you may be able to make the installation satisfactorily.

If the window is the sort that can be raised or lowered, you can usually slip unshielded twin-lead line through the space between the top and bottom sashes. To do this, open one sash, slide the transmission line through



Courtesy J. F. D. Mfg. Co., Inc.
Another kind of adjustable window antenna.

the space between the two, and close the sash again. If the two sashes happen to make a tight fit, there may not be room to do this without cutting or injuring the transmission line in the process. If so, you may be able to bring the line through above the top sash, under the lower one, or at some place where the two sashes do not fit tightly.

Both the length and the orientation of this antenna can be adjusted; and usually both must be to get good reception. Finding the right adjustment of these two is a matter for experiment. It is usually best to start with the antenna extended to about its maximum length. Then rotate it to see if some position can be found that will give acceptable reception on all stations (of course, the antenna must be connected to the set and the set must be in operation when this is done). If it proves impossible to get a good picture from all stations, try shortening the antenna and then changing the position. It may be necessary to repeat this process several times to find the best setting and length.

If you find that one position and length are best for one or two stations, but that another position and another length are needed to bring in some other station or stations, and you cannot find a compromise position that will permit all the stations to be received, it may be practical to install two window antennas, adjusting one for one group of stations and the other for the other group. You may find it possible to connect both antennas to the receiver in parallel. If doing so produces a poor picture, use a low-capacity switch to connect the particular antenna you want to the receiver. The schematic diagram of the switching arrangement of this sort is shown in Fig. 14. An ordinary 2-position knife-blade switch can be used.

Although it is usually best to mount a window antenna in a window that faces the transmitter or transmitters, it is often possible to get just as good a signal on the other side of the house

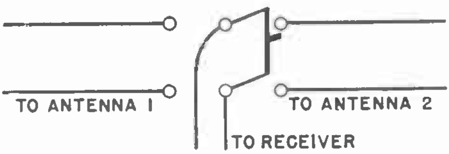


FIG. 14. Arrangement that permits a receiver to be switched from one antenna to another.

if there are near-by objects or buildings that can reflect the signal to this side. Very often it is possible to get reasonably good reception even in unlikely locations with a window antenna. Of course, there are some locations in which a window antenna will not prove satisfactory.

TEMPORARY ANTENNAS

Very often it is impossible to put up the permanent antenna at the same time that a set is delivered to the customer. In such a case, it is almost always necessary to furnish some kind of an antenna so that the customer can get reception temporarily until his permanent antenna can be installed.

Probably the best way to provide a temporary installation is to lend the customer an indoor antenna. One of the kind shown in Fig. 11 is convenient to carry and easy to install.

A temporary antenna can also be made from a piece of 300-ohm transmission line. Use a length approximately 64 inches long, strip the ends

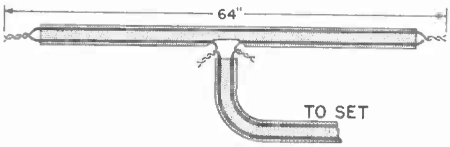


FIG. 15. A temporary antenna that can be made easily. Use 300-ohm unshielded twin-lead line.

of the lines, and solder the leads together. Next, break one of the leads in the center of the strip and connect the two ends thus formed to the ends of another piece of 300-ohm line (see Fig. 15). Connect the other end of this line to the receiver.

A home-made antenna of this kind will usually give satisfactory reception on at least some of the local stations. You can lay it on the floor, perhaps under a rug, or hang it on the wall, say along the top of a window ledge where it may be hung on a curtain rod.

An antenna of this sort will probably pick up considerable noise and may produce rather severe ghosts on some stations. It is not worth while to go to much trouble to attempt to correct these conditions, since a permanent antenna installation will be made very soon, and the customer will probably be content to get at least some reception in the meantime.

TRANSMISSION LINES

Under most conditions, shielded line is preferable for city installations. The reason is that there is apt to be a great deal of man-made noise in almost any city location: if the house where the antenna is to be installed is near the street, for example, the ignition noise of passing cars may cause a considerable amount of interference in the picture. The use of shielded line will pretty much eliminate this source of interference and most others caused by line pickup. In addition, shielded line is much more resistant to the effects of weather than is unshielded line.

Both coaxial line and shielded twin-lead line have higher attenuations than does ordinary twin lead. This is a matter of little concern in most primary-area installations, however, since the signal strength in such an area is high enough so that line losses are unimportant.

However, most servicemen use unshielded twin-lead line whenever possible, because it is less expensive than coaxial line and very much less expensive than shielded 300-ohm line. As we pointed out earlier, costs are often extremely important in an installation.

Fringe-Area Antennas

When you make an installation in a fringe area, your chief problem will probably be to get enough signal to operate the set. For this reason, you must use a high-gain antenna. You will almost invariably find it necessary to mount this antenna high in the air; an indoor or window antenna is seldom, if ever, usable in a fringe area. Because high-gain antennas usually have very narrow band widths, it is not uncommon to have to use a separate antenna for each station that is to be picked up.

One of the main difficulties with fringe-area installations is that reception is apt to be very spotty in locations that are at a considerable distance from the transmitter. It may be possible to get relatively good reception at one point and impossible to get anything at another point only a few hundred yards away. Even though there are television sets already installed and working somewhere near the place where you are considering making an installation, you cannot be sure on that account that a satisfactory installation can be made where you want to make it. For this reason, it is always a good idea to use a test antenna to learn what the reception possibilities are at the place you want to make the installation before you go ahead with the installation.

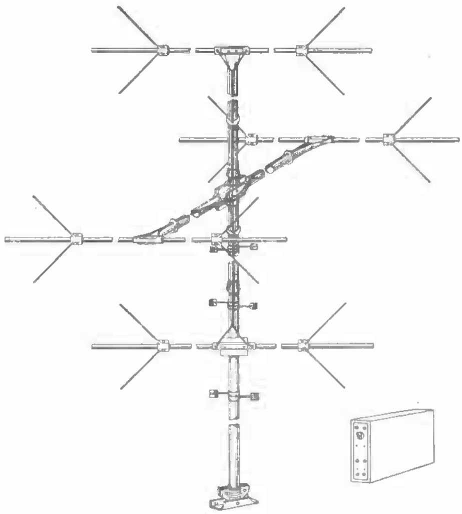
It is no easy matter to determine the signal strength at a particular location, particularly because, if a test antenna is used, you must get it as high in the air as the permanent antenna will be before you can tell what the reception will be like. Several methods have been suggested for putting up a test antenna without installing a permanent mast first. In at least one town, public interest in television was so great that it proved possible to persuade the local fire department to use a ladder truck to put the test antenna high in the air, thus making it possible to plot the signal strength at various locations in the town. Helium-filled balloons have also been used to get a test antenna up; in fact, the Dewey and Almy Chemical Company of Cambridge, Mass., offers such a balloon for permanent antenna installations in fringe areas.

A less spectacular way to find out something about signal strength in a particular location is to raise a test antenna on a light mast. A simple way of doing this is to lay the mast on the ground and fasten the antenna to its top, then to raise the mast by hand and have several men hold it up while you are making your test. The bottom end of the mast can be slipped into a small hole in the ground to help steady it for this period of time.

The local topography often determines whether or not reception can be secured in a particular location. A near-by hill may cut off signals from locations near its base and may not interfere with reception at points farther away from it. A location in a valley may get little or no signal even if it is fairly close to the transmitter. On the other hand, it may be possible to receive well in a location on top of a hill over extremely long distances.

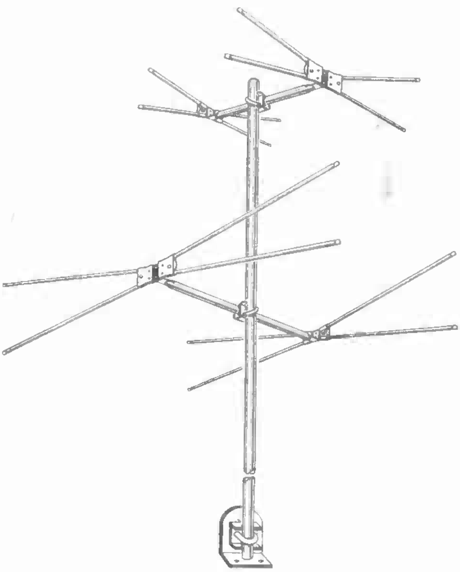
At locations extremely distant from transmitters, it is sometimes possible to get intermittent reception. Stations in Washington, D. C., have been picked up in Texas, for example. Such reception is apparently caused by what are known as "tropospheric ducts," which are sometimes formed when weather conditions create a mass of warm air above the earth that is at a higher temperature than the air below it. Such ducts have the ability to refract or bend television signals so that they can be received over distances considerably greater than the line of sight. The existence of these ducts is only temporary, however, so you should not be fooled by one of them into believing that reliable reception is possible in a place where it is actually not.

Naturally, a test antenna is of no use unless it is connected to a meter or to a television set so that it can show you what results are being secured. Generally speaking, it is better to use a TV set—usually a portable one for convenience—because doing so will let you see how good a picture is being received. A meter may show a relatively high signal level when actually it is picking up considerably more noise than signal. Of course, the very best test would be to use a receiver exactly like the one that is to be installed; this is often not practical, however, particularly since the customer's purchase of any receiver will usually be contingent upon your being able to guarantee him good reception. You can usually be sure that a large set will give good reception if a portable will.



Courtesy Technical Appliance Corp.

The direction from which this antenna picks up can be reversed simply by throwing a switch (shown in its housing at the lower right) that can be mounted beside the set. This feature and the high gain of the antenna make it particularly suitable for use in areas located between two transmitters or groups of transmitters —between New York and Philadelphia, for example.



Courtesy J. F. D. Mfg. Co., Inc.

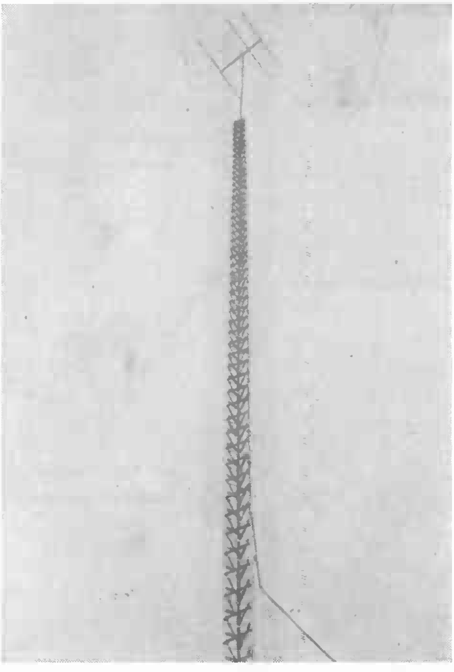
An all-band antenna that can be used successfully in areas where the signal is fairly weak.

About the only general rule that applies to the proper location for an antenna in the fringe area is to get it as high as possible. Doing so will give whatever antenna you use a better chance to intercept a usable signal. In most fringe-area installations, you will have to use some kind of tower or very high mast to support the antenna. Let's discuss these for a moment.

TOWERS AND MASTS

Several kinds of towers that will permit an antenna to be raised high above the ground are now commercially available. The one shown in Fig. 16 is supplied in six-foot sections; as many as 20 of these can be bolted together, making a tower 120 feet tall. A tower this tall must be held up by guy wires. For heights up to 24 feet, however, the tower is self supporting. This particular tower is supplied with a mounting plate that can be used to mount it on the ground or on the roof of a house and with a stand-off support than can be used to secure it to the side of the house.

Another kind of tower is shown in Fig. 17. This tower is only ten feet tall; a pipe extension can be used with it to raise the antenna twenty feet above the base of the tower. Since the tower is intended to be mounted on the peak of a roof, it can give the antenna a total height above ground of thirty or forty feet.



Courtesy Alprodco, Inc.

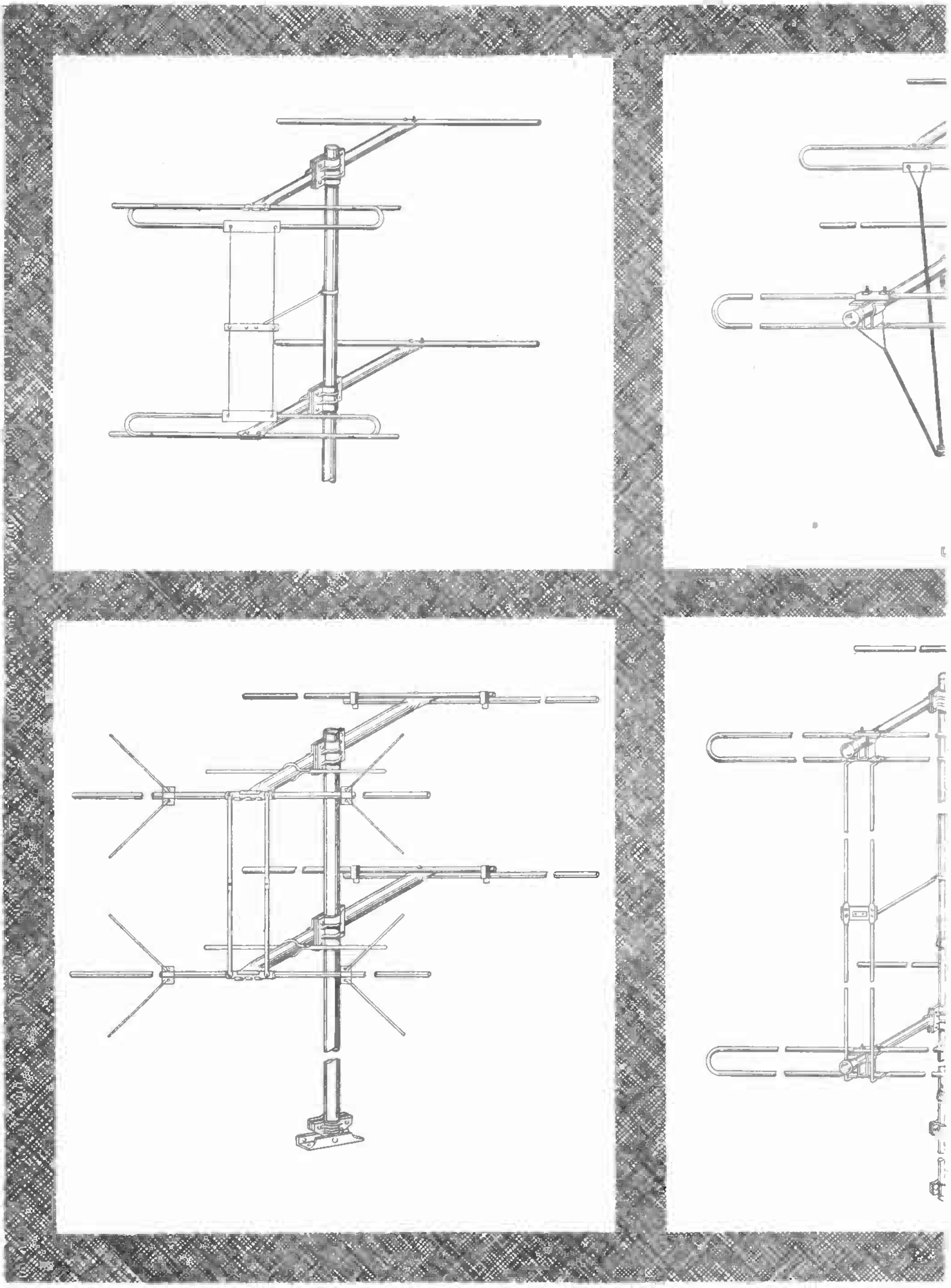
FIG. 16. A light-weight aluminum tower that can be made as much as 120 feet high.

Courtesy Wincharger Corp.

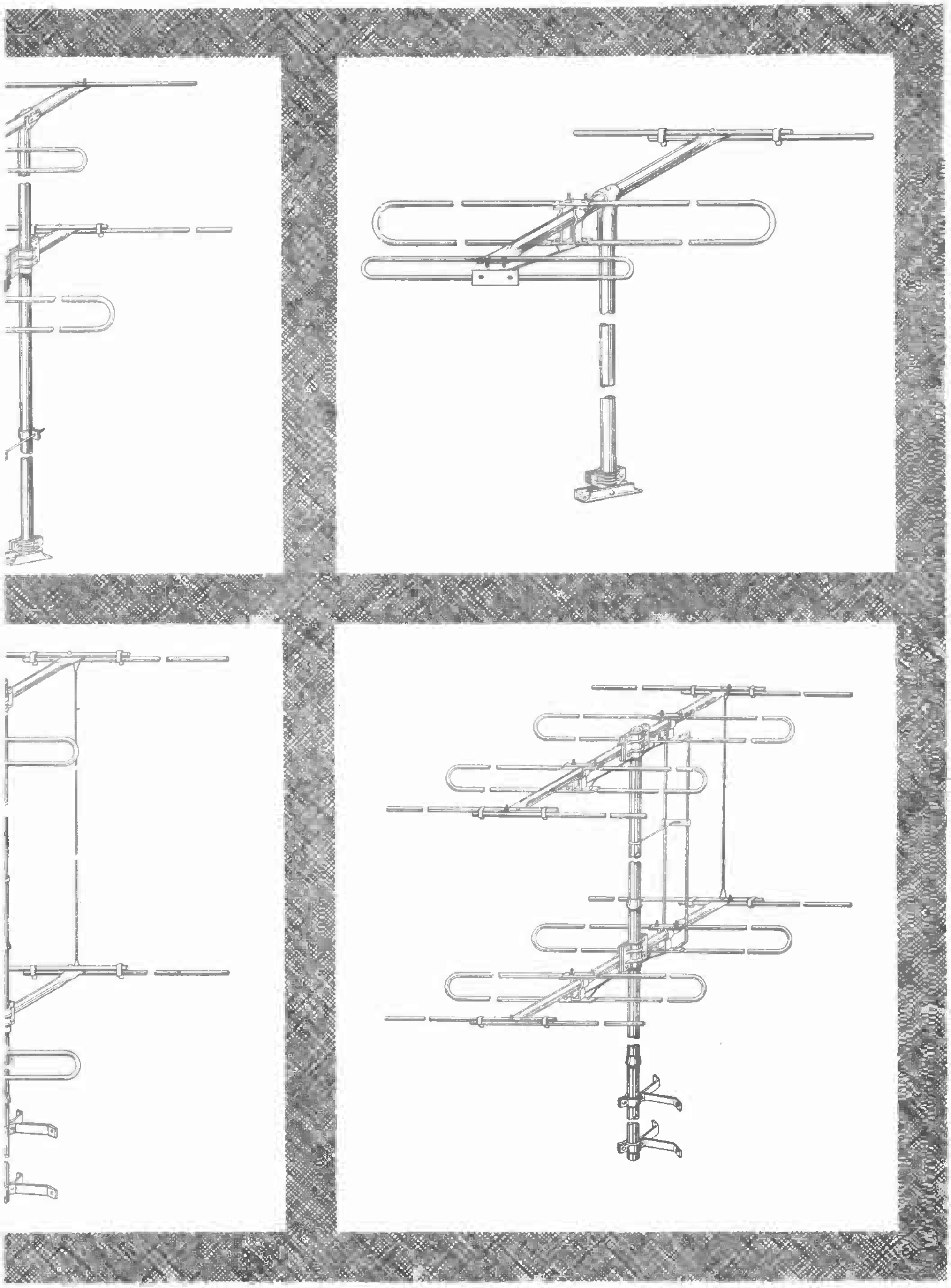
FIG. 17. A self-supporting tower that can be made 20 feet high by using a pipe extension.

If you prefer not to use commercial products of this sort, you may be able to build an adequate tower out of metal or wood. We cannot undertake to give instructions for doing so, but articles on the subject appear in the technical magazines from time to time.

Although it is not likely that you will erect a tower that is tall enough to need a warning light on the top for the protection of passing airplanes, it would be a good idea for you to check the CAA regulations for the location at which you are going to erect the tower. If it is near an air field, a warning light may be necessary.



These pictures show only a few of the antennas offered by one manufacturer. As you c
probably settle on just a few types tha



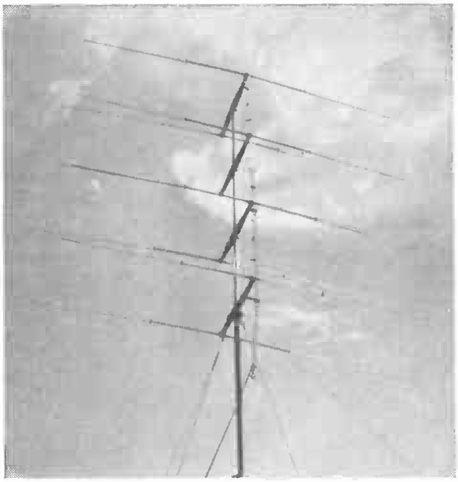
Courtesy Technical Appliance Corp.

ın see, there are a great many kinds of antennas from which you can choose; but you will
t will take care of all your installations.

A mast capable of supporting an antenna 30 or 40 feet from the ground can be made of sections of 2″ pipe fitted together. Such a mast cannot usually be made self supporting—that is, it must be kept in position by guy wires. We shall describe the erection of such a mast later in this Lesson.

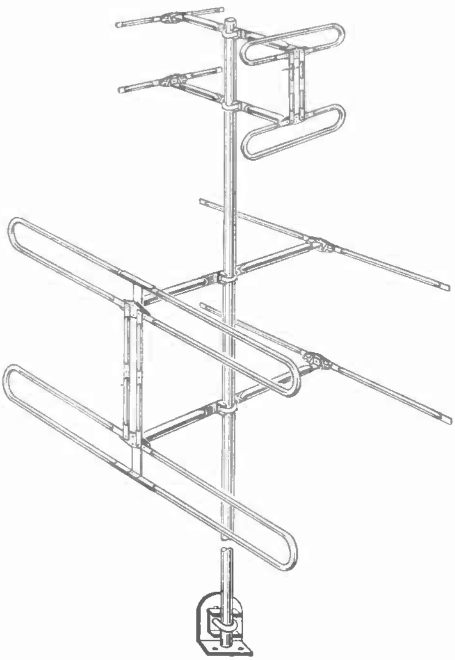
ANTENNAS

As a general rule, the complexity of the antenna you need for a fringe-area installation depends upon the signal strength in that area. If the signal strength is very low, a complicated array may be necessary; such an array is usually of a very narrow band width (in fact, many are generally usable for only one station), so you may have to use several such antennas if there are several stations within range. If the signal strength is not extremely low, you may be able to use a single antenna to get all stations. You should, of course, use the simplest antenna that will give you acceptable reception, particularly since complicated antennas are rather expensive. A stacked array of the sort shown in Fig. 18 will often provide reception in a fringe area. Notice that this antenna has both a stacked low-band and a stacked high-band array; it can, therefore, be used to pick up more than one station. If greater gain is necessary, a multi-element array like that shown in Fig. 19 may be used.



Courtesy La Pointe-Plascomold Co.

FIG. 19. A multi-bay antenna that has been used to secure reception from extreme distances.



Courtesy J. F. D. Mfg. Co., Inc.

FIG. 18. A fringe-area antenna that can be used to receive stations in both bands at fairly long distances.

Since there are so many kinds of antennas now on the market, with new ones appearing almost every day, we shall not attempt to tell you which specific one is best for certain conditions. Instead, you should keep in touch with the latest developments by reading the technical magazines in which new antennas are usually described. When you are considering the selection of an antenna for fringe area installation, make sure you choose one that has enough gain and, if possible, has a radiation pattern with major lobes that can be oriented toward the desired stations. You should not use a more complex array than is needed, both because the installation will be unnecessarily expensive and because the band width of the antenna usually becomes less as its complexity increases, with the result that the use of an over-complex array may prevent you from picking up a station that you could get with one that was less complicated.

The impedance match between the antenna and the transmission line is very important in the fringe area, as you know. Often the loss of signal caused by a mismatch between the antenna and the line cannot be tolerated. Unfortunately, however, the use of stacked arrays reduces the impedance of the antenna very considerably: the various elements in the stack are connected in parallel, so the net impedance of a two-bay antenna, for example, is half that of the individual antennas. Thus, an array consisting of two stacked folded dipoles has a net impedance of only 150 ohms. There will therefore be a two-to-one mismatch between this array and a 300-ohm line, which will cause a fairly considerable loss of signal strength.

If the signal level at that location is so low that such a loss cannot be tolerated, it will be necessary to use some method of matching the antenna to the line.

One way out of this is to use a 150-ohm line and create a match at the set between the line and the set; the advantage of doing this is that it is not necessary to use a matching device at the antenna, where the connections to the device would be subject to the effects of the weather. There is no shielded 150-ohm line available, however; therefore, if it is necessary to use a shielded line because of interference problems at the location, you will have to use a 300-ohm shielded line with a matching section or matching stub at the antenna.

Of course, the match between the antenna and the line is often not critical, even in fringe areas. If the antenna has enough gain, you can afford to waste some signal. If several stations are to be picked up by the same antenna, and the impedance of the antenna does not match that of the line, you will have to forget all about an impedance match; the only practical methods of matching the antenna to the line involve the use of a matching section or a matching stub, neither of which can be used for more than one channel.

The best available antenna for extremely long-range reception is the rhombic. We discussed this antenna in an earlier Lesson, where we pointed out that it is not usable in many locations because of the large amount of space required for it. If there is enough room, however, and the antenna can be gotten high enough, a rhombic will provide reception in a location where no other antenna will.

If several stations that lie in different directions with respect to the receiving location are to be picked up, an antenna rotator will be very helpful. The antenna shown earlier with a rotator in Fig. 4 has fairly high gain, so it may be usable in a fringe area. The rotator shown in this figure is intended to support a maximum weight of only about 20 pounds; therefore, if a heavier or more elaborate antenna is to be used, it will be necessary to use an auxiliary thrust bearing to support the weight of the antenna. Such thrust bearings are available from the manufacturer of the rotator.

There are also heavy-duty antenna rotators available that are designed for use with amateur receiving and transmitting equipment. These are rather expensive, but they are husky enough to move almost any antenna and are relatively trouble-free.

If there is very much electrical noise in a location in the fringe area, it will be almost impossible to get worth-while television reception there unless the antenna used has high noise rejection. The ability to reject noise is one feature of the stacked array that makes it particularly suitable for use in fringe areas. If a great deal of noise is present, the signal-to-noise ratio will be low, with the result that too much noise will be fed to the set, thus producing snow and lines in the picture.

An annoying interference effect is sometimes produced in a fringe area that is about an equal distance from two stations on the same channel. Unless a uni-directional antenna is used, both stations may be picked up simultaneously. Even if they are transmitting the same program, there will usually be enough frequency difference between the two carriers to produce interference. This interference has been described as a "venetian blind effect," because it produces a series of bars across the face of the picture that resemble a venetian blind.

Methods are being developed for synchronizing such transmitters so this interference will not be produced. There is nothing that can be done at the receiver to prevent it, unless a directional antenna is used that will cut out one or the other of the stations.

Installing Antennas

When it comes to installing television antennas, mechanical ability is more important than electrical knowledge. In fact, usually the most difficult part of any antenna installation is the mechanical job of erecting the antenna mast, and bringing the transmission line down into the house. For this reason, dealers and service organizations very frequently have installation crews made up of skilled mechanics who do not or need not have much technical knowledge of television. These men need to know only enough about electrical work to make the proper connections to an antenna and bring the transmission line down to the receiver.

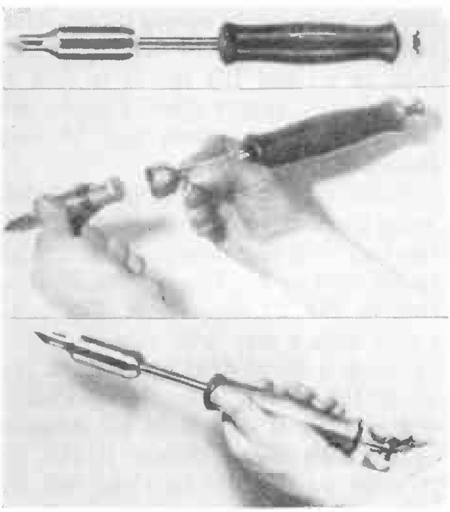
Even though you, as a serviceman, may not make a regular practice of installing antennas, you will probably be called on to do so occasionally or to supervise the work of an installation crew. At any rate, you should know how to put an antenna up. We shall show you how in the following section of this Lesson.

The mechanical problem of mounting an antenna outdoors makes it necessary to use tools that are not usually in a serviceman's kit. Let's see first what these tools are.

TOOLS NEEDED

Since the antenna mast is often secured to the side of a brick building, you will need equipment that will permit you to drill holes in brick or masonry. This should include a slow-speed electric drill that will handle a ½″ masonry drill, a Rawl tool, some Rawl plugs, a supply of ¼-20 machine-screw anchors, a tool for expanding the anchors, a ½″ star drill, and a ball peen hammer. The electric drill should have at least a 100-foot power cord, or a 100-foot extension cord should be used with it.

You will also need various hand tools, such as pliers, wrenches, screwdrivers, and a hack-saw. Further, you will need a brace and bit for drilling through wood and a high-speed electric drill that will handle a ¼" drill for drilling through metal. Finally, you will need a supply of clamps, stand-off insulators, heavily galvanized guy wire, porcelain insulators for use with the guy wire, and galvanized or brass ¼" mounting bolts, as well as any special material needed to secure the antenna.



Courtesy Kemode Mfg. Co.

FIG. 20. An outdoor soldering iron that is heated by firing a cartridge contained in the head of the iron. Top, the complete iron; center, inserting cartridge; bottom, firing cartridge.

Although you do not need to use a soldering iron very often, you will find an occasional use for one when you are making an outdoor installation. A new kind of soldering iron shown in Fig. 20 has been developed for outdoor use. This iron contains a cartridge that can be "fired" by pulling out and releasing a rod that projects through the handle. When this rod strikes the end of the cartridge, chemicals contained within the cartridge are ignited. These chemicals will burn for several minutes, bringing the tip of the iron to soldering temperature in a few seconds and keeping it there for six to eight minutes, furnishing as much heat in this time as a 250-watt iron will. The cartridge is replaceable. An iron of this sort can be a great convenience, particularly when you are working outdoors and no source of electric power is available.

DRILLING MASONRY

Very often in making an installation it is necessary to secure the antenna mast to the side of a brick building. This is done by fastening some form of clamp to the bricks by screws. Since you may be unfamiliar with the technique used to secure screws to masonry, we shall take a moment to explain it.

A screw cannot easily be driven directly into a brick. Instead, the usual practice is to drill a hole in the brick, insert an expandable metal or fiber plug in the hole, and force the plug outward until it is securely fastened in the hole. Screws are then driven into this plug (which is often already threaded to accept a machine screw).

Holes can be drilled in brick either with an electric drill or by hand

Hand drilling, which is done by hammering in a tool known as a star drill, is slower and more laborious than using an electric drill, but it is capable of giving a good job; if electric power is not available, it is usually the only way that the hole can be made.

Fig. 21 shows the various steps involved in the process of securing a screw to brick. First, you should drill a pilot hole with a Rawl drill. The Rawl drill is a sharp-pointed tool that is hammered into the brick; one of the smaller sizes can be driven in rather easily. A typical Rawl drill and drill holder are shown at the left in the top illustration in Fig. 21. Beside them is shown a star drill.

To make a hole with a Rawl drill, hammer it into the brick, using firm but not excessively strong blows. After each blow, rotate the tool a quarter turn or so and lift it. It is best to wear heavy gloves when you do this to protect your hands and to keep them clean.

Next, drill a ½″ hole in the brick, using the small hole as a guide. Make the hole just the depth of the anchor to be used in it. The second illustration in Fig. 21 shows this hole being made with a star drill (the operation of using a Rawl drill would look just about the same). Like the Rawl tool, a star drill is driven in by hammer blows; you should rotate it and lift it after each blow to clear out the chipped masonry and to make a smoother hole.

If electric power is available, an electric drill equipped with a ½″ bit

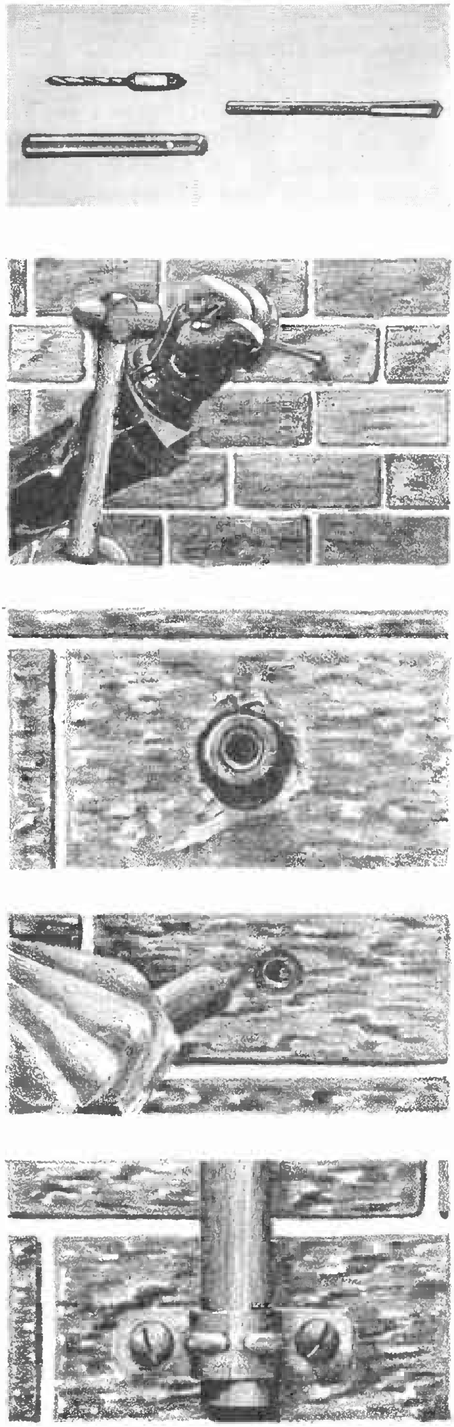


FIG. 21. How to drive a screw into brick. Use a Rawl drill and holder (top left) to drill a pilot hole, then a star drill (top right) to drill a hole for a screw anchor. Imbed the anchor in the hole with an expansion tool. The screw can then be turned into the threaded insert in the anchor.

will let you drill the hole faster than you can with a star drill. Be sure not to drive an electric drill so hard that the bit becomes overheated, because the bit may be ruined if you do.

When the hole is finished, insert a lead screw anchor in it. The next illustration in Fig. 21 shows the appearance of one of these anchors when it is first inserted in the hole.

Next, use an expansion tool to seat the anchor firmly against the sides of the hole. This tool has a small projection on one end that fits into the center hole of the anchor. Hammering the other end of the tool forces the plug to expand tightly against the sides of the hole. The next illustration in Fig. 21 shows what the fitting looks like after it has been imbedded in the hole.

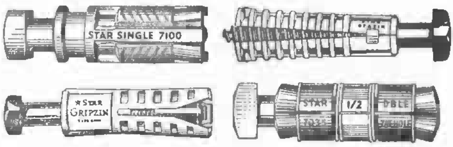
In most forms of these screw anchors, there is a brass insert in the middle of the anchor that is threaded to accept a $\frac{1}{4}$-20 machine screw. Therefore, such a screw can be used to secure a clamp or whatever form of mounting is to be used to the anchor, as shown in the bottom illustration in Fig. 21. If the anchor has been properly installed, the screw will be so secure that it will remain in place when it is subjected to an outward pull almost as great as its tensile strength.

Other kinds of anchors are also used. Most of these are metal devices that will expand when machine screws, lag screws, or special nails are driven into them. Rawl plugs are often used to hold small screws in masonry, such as the small supports used to secure transmission lines to the side of the house. These Rawl plugs are made of twisted jute fibers. When one is installed in a hole and a screw is run into it, the jute fibers are compressed against the sides of the hole and hold the screw securely. These plugs come in various sizes, for each of which there is a Rawl drill and a matching screw. When you are using one of these plugs, drill a hole whose total depth is a little longer than that of the screw that is to be run into it, minus the thickness of the material that is to be fastened.

When you are drilling a hole in a brick wall, be sure not to drill into the mortar between the bricks. A screw anchor will not hold permanently in mortar.

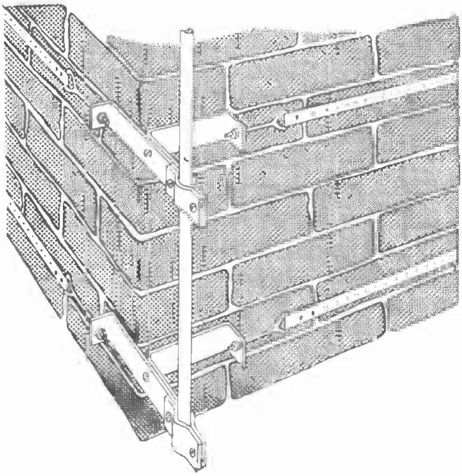
CHOOSING THE ANTENNA LOCATION

The best place to mount the antenna mast depends very largely on the construction of the house. One of the commonest ways of mounting an antenna mast is to secure it to the chimney with chimney straps like those shown in Fig. 22. However, many insurance policies will not pay for damage caused by the wind to a chimney if the chimney is used to support anything (including an antenna). Always check the customer's insurance policy or warn him of this possibility before deciding on the chimney as a place to mount the antenna.



Courtesy Star Expansion Bolt Co.

Four kinds of anchors that can be used to secure screws or lag bolts to brick or concrete. Each is inserted in a hole in the masonry, then expanded (either by using a special tool or by driving in the screw or bolt) until it is seated firmly against the sides of the hole.

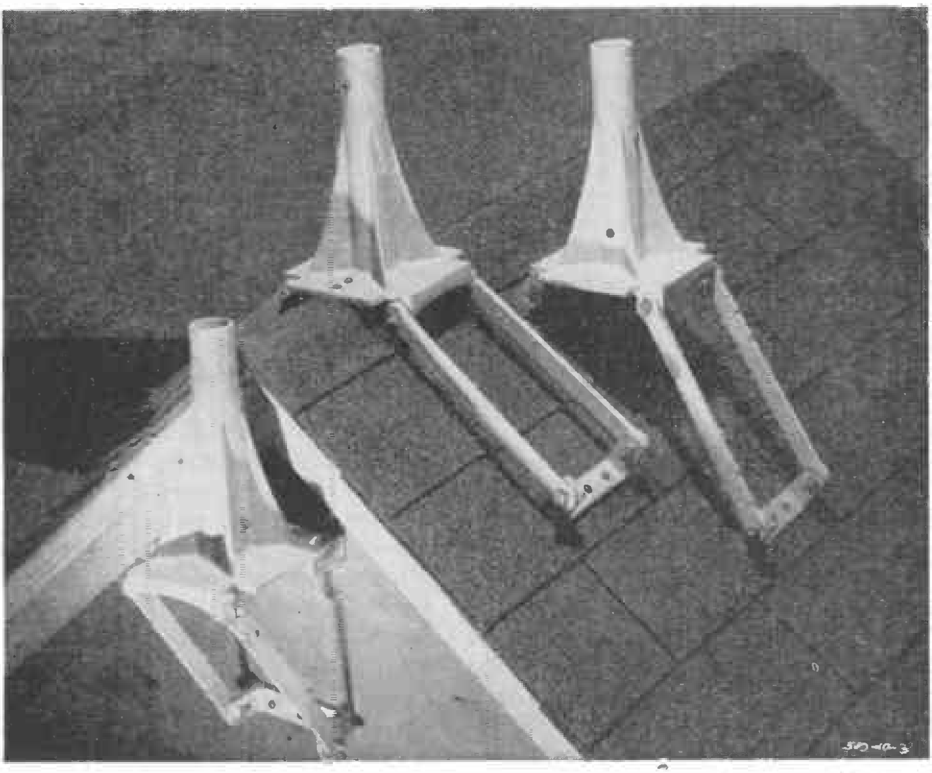


Courtesy Phoenix Electronics, Inc.

FIG. 22. A mount that makes it easy to fasten an antenna mast to a chimney.

Several kinds of smaller straps are also offered that permit a mast to be secured to a vent pipe. There is usually no objection as far as insurance policies are concerned to a mounting of this sort. There are also mounting devices on the market that permit the antenna to be mounted inside the vent pipe. These mounts are not legal in very many places, however, because there are local ordinances in almost all communities that prohibit blocking of vent pipes in any manner.

Always investigate to find out if there are any local ordinances in your community that affect the position, the mounting, or the height of an antenna. Make yourself familiar with

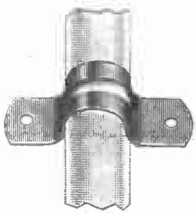


Courtesy Shure-Antenna-Mount, Inc.

FIG. 23. This versatile mount can be used to secure an antenna mast to almost any part of a roof or gable.

such ordinances before you start making installations; otherwise, you may subject yourself or your customers to fines by following some practice that is prohibited.

Antenna masts are often fastened to the roof or side of the building near the roof. An antenna mount of the kind shown in Fig. 23 can be used to mount a mast on the peak of a roof, on the side of a roof, or on the side of a building. The simple clamp shown in Fig. 24 can also be used to secure masts to the side of a building.



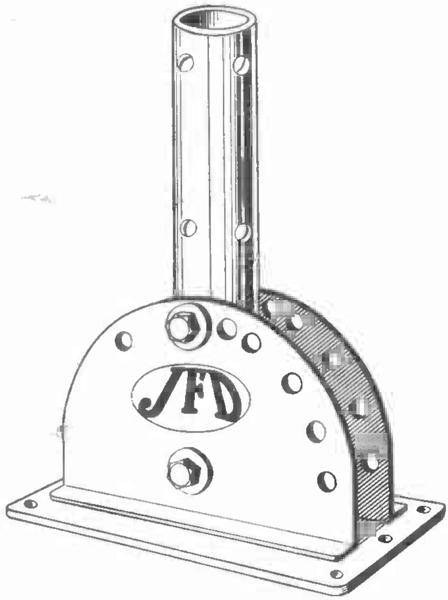
Courtesy Insuline Corp. of America

FIG. 24. Simple pipe clamps of this sort can be used to fasten a mast to the side of a building

When you are mounting an antenna mast on a roof, you should be very careful not to create leaks in the roof by running the mounting screws into it. A good way to prevent leaks is to use a thin lead washer between the head of the mounting screw and the outer surface of the mount. To make such a washer, take a small piece of lead 1/16" thick and punch a small hole in it with a nail. You can then run the screw through the piece of lead and secure a good seal that will prevent water from leaking down the shaft of the screw into the house. As an extra precaution, it is a good idea to put a dab of roofing cement under the mounting plate on the roof at the point where the mounting screw will penetrate.

It is possible to drill holes in a slate roof, but you are always taking a chance of cracking one or more of the slates if you do so. We advise you to avoid roof mounting when the roof is slate. Instead, secure the mounting bracket or clamps to the side of the building.

An antenna mounting plate is ordinarily not secured to a flat roof. Instead, the mounting plate is secured to a heavy block of wood that acts as a base, and the antenna is held in position with three or four guy wires fastened at convenient anchor points. If the roof has a parapet, the antenna can be secured to the parapet with clamps like those used to secure it to a brick wall. The special mount shown in Fig. 25 has been developed for use with parapets, which are very commonly found on top of apartment buildings.



Courtesy J. F. D. Mfg. Co., Inc.

This base plate can be used to mount an antenna mast in almost any position.

Very often, particularly in areas where the signal strength is high, you can get good results by mounting the antenna in the attic. A roof in which little metal is used, such as a slate or wood roof, does not attenuate signals much. Installations of this sort are sometimes permitted in apartment houses where roof-top installations are not. If space is available, it is wise to try the attic before attempting a difficult roof mounting job, unless you are sure that the antenna must be higher than an attic mounting will permit it to be, or unless the roof top

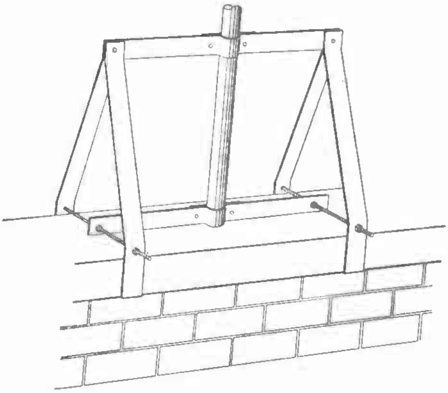


FIG. 25. A parapet mount, often useful in apartment-house installations.

is apt to be covered with snow for a considerable period. A heavy snow on the roof will attenuate considerably the signals passing through the roof.

Whenever you do mount the antenna outdoors, you must make sure that the mast will be strongly and firmly held. Remember that there will be considerable force exerted on the antenna when a strong wind is blowing and that it may become very heavy if snow or ice collects on it. Therefore, the mast must be held very securely.

As a protection against lightning, the antenna mast should be grounded. If its mount insulates it from ground, connect it to ground with a number 8 armored wire or a number 6 bare wire. (These are the wire sizes required by the Fire Underwriters.) Run the grounding wire straight down to a metal stake that is firmly embedded in the ground. If the mast is clamped to a vent pipe, it will be unnecessary to use a ground wire, since the vent pipe will already be well grounded. Just make sure that there is a good electrical connection between the mast and the pipe. Sometimes the ground wire is brought over from the mast to a vent pipe when the mast is mounted somewhere near-by; however, this system does not give as good protection against lightning as does the wire run directly to the ground,

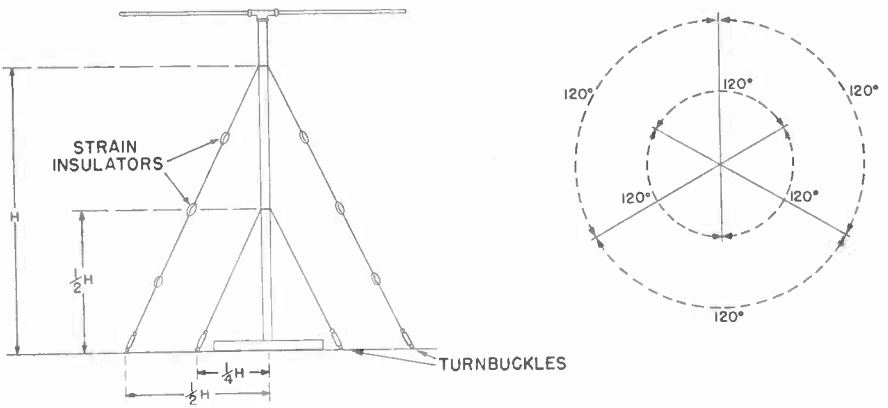


FIG. 26. This drawing shows the dimensions and locations of the guys needed to keep a tall mast in place.

because lightning may escape from a conductor that makes a bend.

If the mast is rigidly supported at its base or supported at two or more points along its length, you will not usually need guys if its unsupported length is less than 15 or 20 feet.

If the base of the mast is not supported but is merely kept from moving by the mount, or if the mast is

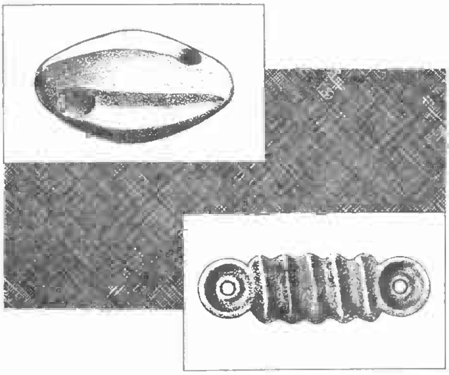


FIG. 27. The kind of strain insulator shown at the top should be used with mast guy wires. The kind at the bottom is not suitable for this use.

very small in diameter or more than 15 or 20 feet tall, guy wires should be used to keep it rigid. The sketch in Fig. 26 shows how these guys should be attached. At least three guy wires should be used at each guying point.

These guys should be made of number 6 or number 8 stranded galvanized steel wire unless the manufacturer of the antenna recommends some other size. The guys should not be continuous; to prevent them from affecting the radiation pattern of the antenna, they should be broken up at intervals that are greater or less than the length of the antenna. Strain insulators of the kind shown at the top of Fig. 27 should be used to break them up. This insulator is made so that the two sections of the guy wire that pass through it are interlocked (although separated by the insulator); thus, if the insulator should break, the guy wire will not come apart. The kind shown at the bottom of Fig. 27 should not be used, because the guy wires will part if it breaks.

There should be a turnbuckle in each guy wire so that it can be tightened after the mast is erected. A guy should not be brought to its final tightness with the turnbuckle the first time it is adjusted; instead, each guy should be tightened in turn until all are moderately tight and tightened in turn again until each is at its final tautness.

TALL MASTS

The erection of a tall mast is much more complicated than the erection of the usual 10- or 20-foot antenna mast. The antenna and transmission line must of course be mounted on the mast before it is erected, which makes the assembly rather heavy. A crew of men is therefore needed to raise the mast with the antenna in place.

Before attempting to raise such a mast, you must have a mount prepared that will hold the base of the mast once it is up. One of the simpler ways of raising the mast after this mount has been prepared is to have one man at the mount to guide the base of the mast into it, another close to the base of the mast who will help in getting the mast started up and then help the first man to guide the mast into its mount, and at least one man on each guy to pull the mast up and to keep it from toppling over after it is erect. Since the mast should be guyed every 10 or 15 feet, and since there should be at least three guy wires at every guying point, some six or nine men will be needed to pull up a 40-foot mast.

Anchors should be provided before the mast is erected so that the guys can be quickly secured once the mast is up. Of course, turnbuckles should be installed in each guy so that it can be tightened.

The mast, of course, should be of strong enough material to be able to hold itself up without bowing. Two-inch pipe is probably strong enough for a 40-foot mast; if the mast is to be much taller than this, either a very heavy pipe or some form of lattice work construction of light pipe or wood should be used.

There are two schools of thought on the subject of how high the top guys of the mast should be. If the mast is to remain rigid, it should be guyed very near the top. Some engineers, however, feel that the top guys should be about 10 feet below the top of the mast. If this latter construction is used, the mast top will sway in a high wind, but it will not break, whereas the rigid mast may be knocked over when the wind becomes very strong. If the place where the antenna is erected is swept by high winds, the construction that permits the mast to sway slightly is probably better.

Courtesy Alprodco, Inc.

A mast is often secured to the side of a house, as shown here, to simplify the problem of supporting it.

MOUNTING THE ANTENNA

Usually the antenna must be mounted on the mast before the mast is put in place. At what point in the procedure this should be done depends upon what kind of installation is being made. If it is a simple roof mounting, often the easiest thing to do is to carry the unassembled antenna up to the roof, assemble it there, mount it on the mast, secure the transmission line to it, and then erect the mast. Of course, this may be something of a job if the roof furnishes only a precarious perch.

Some antennas are designed so that they can be folded until it is time to erect them. Such an antenna can be mounted on the mast on the ground, then the whole assembly can be brought conveniently up to the roof, and the antenna can be snapped out to its final position just before the mast is erected. An antenna of this sort, if it is designed so that it cannot fold up again after the installation is completed, can be a very great time saver.

If the antenna is to be mounted on clamps secured to the side of the building, mounting the antenna on the mast becomes something of a problem. It may be possible to mount the antenna on the mast on top of the roof, then carry the whole assembly over to the side of the house where it is to be mounted. At other times, it may be necessary to mount the antenna on the mast on the ground and then carry the assembly up a ladder. Either procedure may be rather dangerous, so the installing crew should exercise great care in making such an installation.

As we mentioned earlier, the antenna must be mounted on a tall mast before the latter is erected. If a tower is used, it may be possible to climb it afterward and mount the antenna on the peak of the tower, but it is usually a dangerous and difficult task to do so.

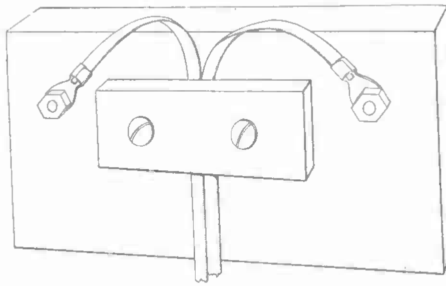


FIG. 28. A typical strain relief clamp. Some such clamp should always be used near the point at which the transmission line is connected to the antenna to prevent the weight of the line from damaging the connections.

ANTENNA ROTATOR

When an antenna rotator is to be used, it must first be clamped on the top of the mast; the antenna must then be installed in the movable section of the rotator. This will, of course, have to be done before the mast is erected. The only extra problems the rotator creates are that it adds weight to the top of the mast and that it must have a power lead brought to it. A suitable power and control line is generally supplied with the device.

RUNNING TRANSMISSION LINES

A transmission line must be secured to the antenna mast or mounting somewhere close to the point at which the line is electrically connected to the antenna. A line should never be allowed to hang free from the antenna, because it will eventually break loose. Often some form of clamp is provided on the antenna or on the mast to remove all strain from the connections themselves. One such strain relief clamp is shown in Fig. 28.

Ordinary twin-lead line is very easily secured to the antenna. All you need to do is to split the insulation in the middle and strip it from the leads with a knife. The leads can then either be wrapped around the terminals of the antenna and bolted or be fitted with lugs that can be slipped over the antenna terminals. The latter method is usually preferred.

Shielded lines are somewhat more difficult to connect to the antenna because of the presence of the braid. One of the best ways of separating the braid from the inner conductor of a coaxial line is shown in Fig. 29. To prepare a coaxial cable this way, first strip off about 6 inches of the rubber outer covering (Fig. 29A). Next, push the braid apart with an ice pick or some other pointed tool at a point about an inch from the end of the outer insulation (Fig. 29B). Next, bring the inner conductor out through the hole thus formed in the braid (Fig. 29C). Stretch the braid by pulling on its end until it closes tightly around the inner conductor. Finally, solder lugs to the end of the braid and to the end of the inner conductor (Fig. 29D).

Shielded 300-ohm twin lead requires even more elaborate treatment so that water will not run down inside it. The steps to follow to prepare the end of one of these lines for connection to an antenna are shown in Fig. 30. First,

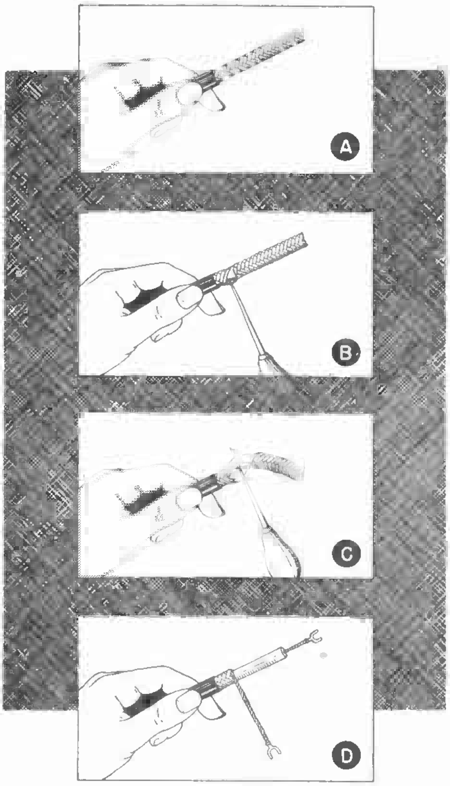


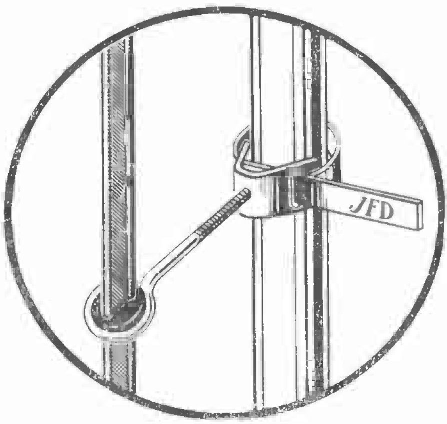
FIG. 29. Steps in fitting terminals to the conductors of a coaxial cable.

remove 3 inches of the outer jacket from the end of the line (Fig. 30A). Next, remove a 2-inch length of the copper braid (Fig. 30B). Pull the remaining inch of braid back over the outer jacket (Fig. 30C). Solder a pigtail of No. 18 wire to the braid, using a length that will leave at least 4 inches of the pigtail free. Strip an inch of the polyethylene insulator from the leads (Fig. 30D). Next, close the end of the cable with Scotch electrical tape (Fig. 30E) to keep water out of the jacket (this is often called "serving" the line). If you prefer, you can apply a coat of some waterproof plastic, such as polystyrene dope, over the exposed ends. Slip solder lugs over the tubing and solder the leads to the lugs, using a minimum amount of heat so that the polyethylene will not be injured. Follow this procedure for both ends of the lead-in.

A shielded line, either coaxial line or shielded 300-ohm twin lead, can be secured directly to the antenna mast. Unshielded twin lead, however, should be spaced out from the mast to prevent its characteristics from being affected by the near presence of the metal of the mast. Masts supplied with antennas often have rubber spacers for this purpose.

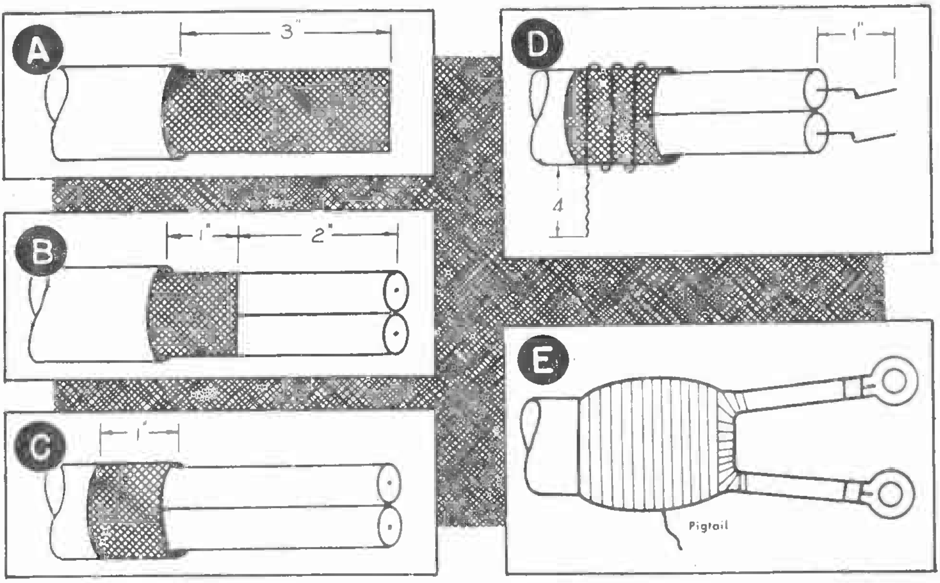
The transmission lines should be led as directly as possible from the antenna to the receiver. Unshielded twin-lead line should be twisted once every foot, to reduce pickup of local interference; shielded line can be run straight.

Whenever possible, it is advisable to bring the line in through the basement and through the floor in back of the set. This will make it unnecessary to run long lengths of line through the house. To make an installation of this sort, the line may be brought down the side of the house



Courtesy J. F. D. Mfg. Co., Inc.

This stand-off insulator is used to space twin-lead line away from an antenna mast.



Courtesy Federal Tel. and Radio Corp.

FIG. 30. Steps in preparing the end of a shielded twin-lead line for connection to an antenna.

to a basement window. You can then drill the casement of the window and bring the line in through it. Just before the line is brought into the house, a lightning arrester should be inserted in it. You can then bring the line over from the window to the point where the hole is drilled in the floor at the rear of the set.

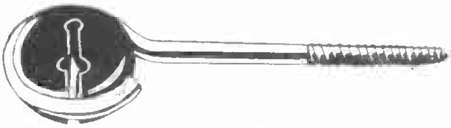
The owner may prefer the transmission line to be brought directly into the room in which the set is located without going through the basement, or the installation may be made in a house that has no basement. If so, bring the line through a hole drilled in the casement of the window, mounting the lightning arrester inside the window. Lead the line to the set from the window along the baseboard. If it is a shielded line, secure it to the baseboard with staples; if it is unshielded twin lead, you can drive fiber-headed tacks through the center of the insulating ribbon to secure it. Twist unshielded line once each foot to reduce pickup of local interference.

Whenever you drill a hole through the casement of a window to bring a transmission line through, be sure to slant the line downward from the inside of the house. This will prevent rain from coming in along the line.

It may be possible to bring unshielded twin lead in between the two halves of the window in the manner described earlier for a window antenna installation. This will make it unnecessary for you to drill a hole through the casement.

A shielded line can be secured to the side of the house without fear that its characteristics will be changed thereby. Unshielded twin-lead line, however, should be fastened to the house with stand-off insulators. The type shown in Fig. 31 is well suited to this use. If the house has masonry walls, you must drill holes and insert plugs in them for the screws in these insulators. Insulators of this sort should be installed before the transmission line is brought down, and they should be placed so they will be directly along the path that the line is to follow.

The location of the transmission line with respect to its surroundings is often important. In addition to being



Courtesy Phoenix Electronics, Inc.
FIG. 31. Stand-off insulator for twin-lead line.

run as directly as possible from the antenna to the set, the line should also be removed as much as possible from sources of interference. For example, a transmission line brought down the back of a house away from the street is much less likely to pick up ignition interference than is one that is brought down the street side of the house. It is also wise to make sure that the transmission line is not in some location where it can be damaged easily—in particular, it should be kept out of reach of children.

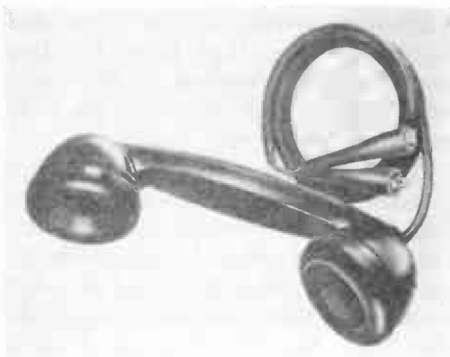
ORIENTING THE ANTENNA

When an antenna has been installed and connected to a set, it must be oriented to produce the best possible reception from each of the stations in the vicinity. If the antenna is equipped with a rotator, of course, finding the right orientation is no problem; the customer will turn the antenna to bring in the best picture each time he tunes in a different station. If the antenna is to remain in one place, however, it must usually be carefully oriented before the installation is completed so that the reception on all stations will be equally good.

Orientation of the antenna is generally a two-man job. There must be one man on the roof to turn the antenna, and there must be another at the receiver to watch the effect of turning it. These two men must have some way of communicating with one another so that the man turning the antenna can learn what happens when he turns it. A telephone like that shown in Fig. 32 is frequently used for this purpose.

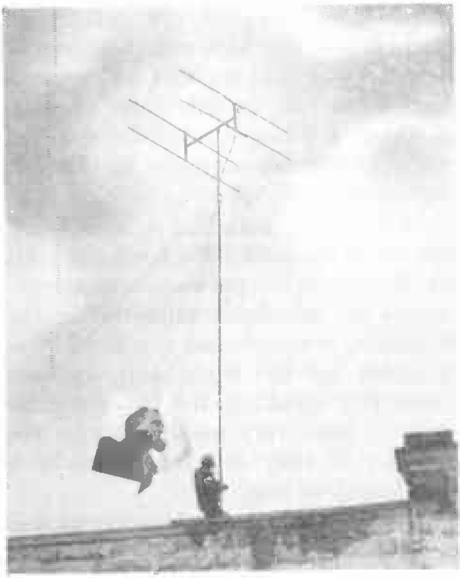
This particular telephone is sound operated. A sound-operated telephone is equipped with a high-output magnetic microphone that is capable of operating a telephone receiver over a considerable distance without amplification. The chief advantage of such phones is that they require no external power source. Conventional battery-operated telephones are, of course, perfectly usable.

Some installation crews clip their sound-powered telephones across the ends of the transmission line, thus



Courtesy Wheeler Insulated Wire Co., Inc.
FIG. 32. A sound-powered telephone handset.

saving themselves the trouble of having an extra inter-connecting line between the antenna position and the set position. However, it is often inconvenient to do this, since the end



Courtesy Wheeler Insulated Wire Co., Inc.

Sound-powered phone in use during orientation of an antenna.

of the transmission line at the antenna may be many feet in the air; further, connecting the telephone across the line may affect the characteristics of the line and thus impair the quality of the picture, thereby making it difficult to judge how good the picture is. For this reason, we recommend that you have a separate connecting line between the two telephones.

There are many possible systems you can use to find the right orientation for the antenna. The one we are going to describe, however, is easy to follow and has proved to be very satisfactory.

Let's assume that you are the man turning the antenna. First, orient the antenna so that it receives best from the north (that is, if it is a dipole, point its rods east and west), and have your assistant at the receiver tune in the lowest-frequency station that can be received. Then have your assistant describe the quality of the picture to you as you rotate the antenna. For example, as the antenna is rotated, your assistant may make a report something like this: "Faint picture. Getting better—better—good picture—getting worse—no picture."

You must keep a record of picture quality versus antenna position as you rotate the antenna. A convenient way to do so is to use a chart like the one shown in Fig. 33. Mark a heavy line on the chart to represent the direction the antenna is turned when the reception is reported to be good, and make a broken line to show those directions in which the picture is reported to be poor or non-existent. If the picture is reported to have ghosts in it, draw a wiggly line to show the directions in which the ghosts appear.

After you have made a complete rotation of the antenna in this manner, you will have a chart that shows how well the antenna receives that particular station in each of its possible positions. Next, repeat the process with the station next higher in frequency tuned in. Draw another line outside the first one to show how well the second station is received.

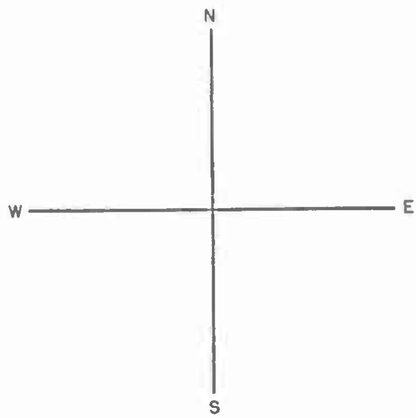


FIG. 33. Use a simple chart of this sort to help you determine the best orientation.

If there are more than two stations, repeat the process again for each.

The completed chart for a location in which four stations are present might look something like the one shown in Fig. 34. This indicates that a clear, ghost-free signal can be gotten from three stations in the position marked A, but that the fourth station cannot be picked up there or in any other position in which the other three stations are picked up well. When this happens, it is usually necessary to add another antenna—a high-band one in this case, since it is channel 9 that cannot be received well. This antenna should be oriented separately.

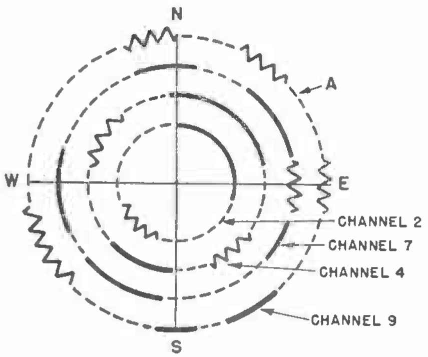


FIG. 34. How the filled-out orientation chart might appear after you have made reception tests at a location.

If you are installing a high-band, low-band antenna right from the start on the basis of previous experience, orient the low-band antenna for the low-band stations and the high-band antenna for the high-band stations. Generally speaking, the two antennas will not have very much effect on one another if they are separated by a $\lambda/4$ length of line.

If you install a single antenna and find it necessary to use a high-band antenna in addition, you can get a high-band attachment that you can clamp on the antenna mast. This will be far more convenient than it would be to install a separate antenna or to replace the antenna with a high-band, low-band combination.

Lesson Questions

Be sure to number your Answer Sheet 60RH-3.

Place your Student Number on *every* Answer Sheet.

***Send in your set of answers for this Lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. What are usually the two chief problems in primary-area antenna installations?

2. Under what two conditions can a highly directive antenna be used to receive signals from *several* stations?

3. Why are antenna rotator motors usually operated from 24-volt a.c.?

4. What is the effect on reception of using a 300-ohm line with a plain dipole in an area where the signal strength is high?

5. In investigating the signal strength in a fringe area, why is it better to connect a TV set to your test antenna than to use a meter to measure the antenna pickup?

6. If a house has a slate or tile roof, where should you secure the antenna mount if an outdoor antenna is needed?

7. Why should guy wires used with antenna masts be broken up by insulators instead of being continuous?

8. Why is it important to "serve" the end of a shielded 300-ohm line at the antenna end?

9. Why should you twist unshielded 300-ohm line once every foot?

10. In a city installation, why is it better to lead the transmission line down the part of the house that is farthest from the street?

Be sure to fill out a Lesson Label and send it along with your answers.

MAKE DECISIONS

It is a very fine thing to have an "open mind." But it is a fine thing ONLY if you have the ability to make a *decision* after considering all sides of a question.

Failure to make a decision after reasonable consideration of all facts will quickly mark a man as being unfit for any position of responsibility.

So practice making clearcut, well thought-out decisions.

Not all your decisions will be correct. No one is perfect. But if you get the habit of making decisions, experience will develop your judgment to a point where more and more of your decisions will be right.

J. E. Smith

INSTALLATION AND ADJUSTMENT OF TV RECEIVERS

61RH-2

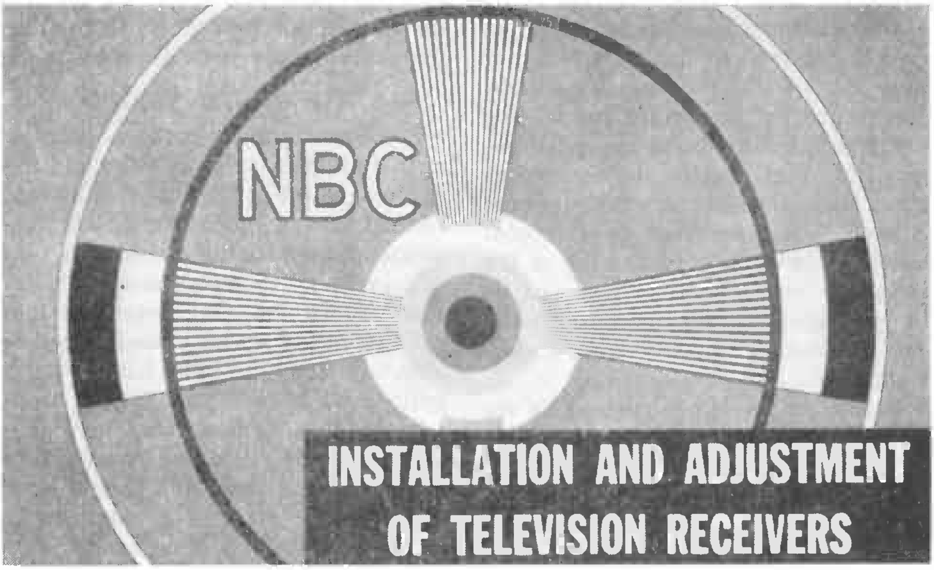
PIONEER HOME STUDY RADIO SCHOOL
NRI

NATIONAL RADIO INSTITUTE
WASHINGTON, D. C.
ESTABLISHED 1914

STUDY SCHEDULE No. 61

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

JD6M1051 1951 Edition Printed in U.S.A.



INSTALLATION AND ADJUSTMENT OF TELEVISION RECEIVERS

WHEN a television receiver is first put into operation, there are a number of servicing procedures that may have to be carried out, ranging from a purely mechanical procedure of installing a picture tube, through an adjustment procedure, to actual servicing for some breakdown. Then, after a period of operation, some of these steps will have to be carried out again —for example, the picture tube will eventually wear out and have to be replaced, or some adjustment or repair will have to be made.

Since certain breakdowns produce symptoms that are similar to those produced by misadjusted controls, it is necessary for the serviceman to be able to distinguish between them, and the easiest way to do this is to carry out an adjustment procedure first. If this does not correct the symptom, then a service procedure is indicated. In this Lesson, we are going to cover the adjustment procedure; actual servicing for breakdowns will be covered elsewhere.

* Photo above, courtesy NBC

In order to give a complete coverage of TV set adjustment, we are here assuming that we have a set to be installed and that it needs the "works." However, in actual practice, very few of the steps given in this text may be required on any one set at one time. That is, one set may need one adjustment, and another set may require an entirely different one. Hence, you need to know them all so that you can carry out those that are called for in each instance.

Even the procedure of installing a picture tube may not be required on some new sets, because it is becoming standard practice with some manufacturers to ship the sets with the tubes installed. However, many sets are shipped without picture tubes, and it is necessary to install one before the set is delivered to the customer. And, of course, you must remember that eventually this tube must be replaced, so the same installation procedure will be needed.

Although in this Lesson we are going to give the complete installation procedure from the unpacking of the set to the final touch-up in the home of the customer, naturally we must give the general or basic steps rather than the specific details. We cannot give the exact procedure for all the many sets that are being made. Therefore, this text is not intended to replace the manufacturer's instructions; it should be considered as a supplement to give you a basic idea of the necessary steps, so that you can go to the manufacturer's instructions and get the details quickly and understandably.

Before we go any further, let's see what the various steps in an installation are. To make an installation, you would usually:

1. Unpack the set and the picture tube, and install the tube if it is not already in place.

2. Check the set in the shop. Make whatever adjustments are needed to get proper reception.

3. Deliver the set to the customer's home and place it in the desired location.

4. Connect the set to the temporary or permanent antenna.

5. Re-check the set and correct any adjustments that have slipped during delivery.

6. If a temporary antenna is installed, place it where it will give the best results.

7. When the permanent antenna is up, orient it to give the best possible reception.

8. Install a wave trap, boosters, a light filter, magnifiers, or other supplementary items that are needed or desired by the customer.

9. Show the customer how to operate the set.

10. Call back a few days later to make sure the set is operating properly.

We shall describe all these steps in this Lesson, except for steps 6, 7, and 8, which are treated in other Lessons. However, before we get into the installation procedure, there are a few general matters we should discuss.

WHERE TO WORK

Some servicemen make a practice of installing the picture tube and adjusting the set in the customer's home instead of the shop. We do not recommend your doing so with a new set; in fact, we recommend strongly that you do not. One important reason is that the set may need considerable adjustment. If you have to work quite a while to adjust the set properly, the customer, who will undoubtedly be watching your every move, will probably get a poor opinion of either the set or your ability. In addition, customers almost invariably ask many questions; they may prove annoying when you are trying to devote all your attention to the problem of getting the set to work properly.

In servicing a set, however, it is best to do the work in the customer's home if possible. There are several reasons for this: the sets are usually heavy and awkward to carry; there is always a chance of damaging the picture tube if you move the set; and the customer usually dislikes to be without his set any longer than is necessary.

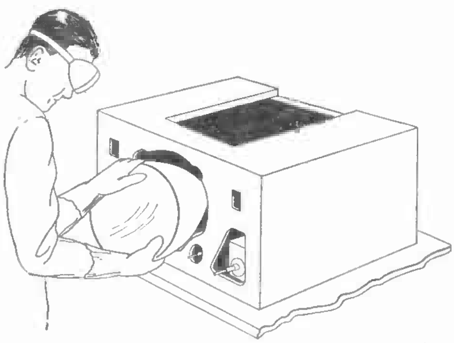
SAFETY PRECAUTIONS

When you are working with or around a picture tube, there are several important safety precautions that you should observe.

A picture tube is very highly evacuated. Consequently, there is a net air pressure of approximately 14 pounds per square inch on the outside of the tube. Because of the large surface area of the tube, the total force on it is very large, and there is danger of an "implosion" (explosion inward) if the tube is cracked or broken. It is possible to be badly cut by flying glass if this happens.

Therefore, you should always wear goggles, heavy gloves, and either a leather apron or a heavy shop coat when you handle the tube. Never hold the tube against your body unless it is absolutely necessary to do so (as it sometimes is if the tube is a very large one). Always be careful to hold it by the funnel (the wide tapering portion between the screen and the neck). Hold the slender neck only if it is necessary to do so to get the tube into position. Even then, support as much of the weight of the tube as possible with your other hand, which should be on the bottom edge of the tube face.

Be very careful at all times not to allow the tube to bump against any hard object nor permit it to be scratched, especially at the rim of the face. If the tube sticks when you attempt to slide it into a support during installation, do not force it; instead, find out what is blocking its entry.



This is the right way to hold a picture tube when you are installing it through the front of the cabinet.

You should also take precautions against electrical shock from picture tubes. The funnel of a metal tube, for example, is usually 10,000 to 15,000 volts positive with respect to the chassis when the set in which it is used is operating; therefore, you should be extremely careful not to touch it when the set is on. Metal tubes are now being enclosed in removable Vinylite boots as a safety measure, but you should not consider that this makes them harmless.

It is possible to get a shock from an electromagnetic glass tube when the set is not operating—or even when it is not in the set at all. Such tubes have conductive coatings on both the inside and the outside surface of the glass funnel; these form a condenser having a fairly high capacity. The inside coating is connected to the second anode, and the outside one is grounded. Since leakage between the two coatings is very low, there may be a considerable charge on this condenser even several days after voltage has been applied to the tube. You can get enough of a shock from a charged tube to startle you, and perhaps make you drop the tube, if you touch both the high-voltage terminal and the conductive coating at the same time. Even an apparently unused tube in its original carton may retain a charge that it received during its final test at the factory. Therefore, you should make a practice of shorting between the high-voltage terminal and the outer coating of the glass tube with a high-voltage test lead before you touch the tube with your hands. (Note: By "high-voltage test lead," we mean a lead having high-voltage insulation—NOT a high-voltage test *probe,* which has a high resistance built into it.) Short the tube this way several times to make sure the condenser is fully discharged.

Remember that insulation that is perfectly safe for ordinary voltages may break down when it is subjected to the high voltages used in television sets. Don't, therefore, assume that you cannot get a shock from a wire just because it is insulated.

UNPACKING A SET

As we said earlier, sets may be shipped with all tubes but the picture tube in place, but very frequently the picture tube is already installed also. The control knobs are usually packed in a small bag that is secured inside the cabinet. Sometimes there is protective packing around some of the tubes, particularly the power tubes. This should be removed before you start to install the picture tube (or to adjust the set, if the picture tube is already installed).

Additional braces are often fastened to large consoles to prevent the cabinet from being broken during shipment. These braces should be left in place until the set is delivered into the customer's home, because they will protect it during delivery. Of course, you should be very careful when you remove outside wrapping and protective packing that you do not damage the set, the chassis, or the tubes in any way.

If the picture tube is shipped in a separate carton instead of being installed in the set, remove it carefully from the carton after making sure that it does not carry a charge. Remember, a glass tube may retain a charge from its final test at the factory; the shock you might get from it would not be dangerous, but it might well be enough to startle you and make you drop the tube.

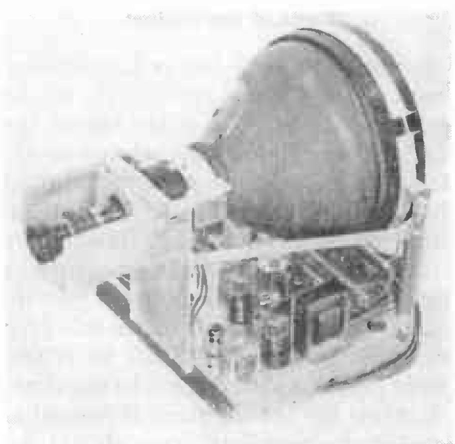
There is no possibility of getting a shock from a metal tube that is not in a set. However, it is important not to handle such tubes by the glass section of the tube funnel, because finger marks on this section of the tube may create leakage paths that will interfere with reception and may create a shock hazard. Such tubes should therefore be handled only by their metal rims. If the glass part of the funnel is accidently touched, you should wipe it clean with a soft cloth that has been moistened with carbon tetrachloride.

Installation of Direct-View Tubes

There are two types of sets in use today—one in which the image is formed on the face of the tube for direct viewing, and a second that uses a projection system. The latter will be described later in this text.

Whenever you have to install a direct-view tube, whether as a part of the initial set-up or as a service procedure, you will find that the tube has two supports: 1, at the front end of the funnel where it joins the face; and 2, either at the base of the funnel or a little farther back on the neck. Most of the weight of the tube is on the front support.

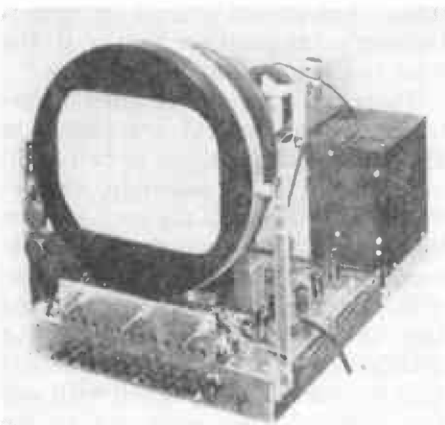
A basic difference is in whether the front support is attached to the chassis or is built into the front of the



Courtesy The Hallicrafters Co.

One common method of mounting a picture tube on a chassis.

cabinet. The most common way of supporting the front end of the tube is to have it rest in a cradle secured to the chassis with a metal strap or a band of webbing running over the top of the tube to keep it from shifting.



Courtesy The Hallicrafters Co.

Notice that this mount permits the position of the front end of the tube to be adjusted.

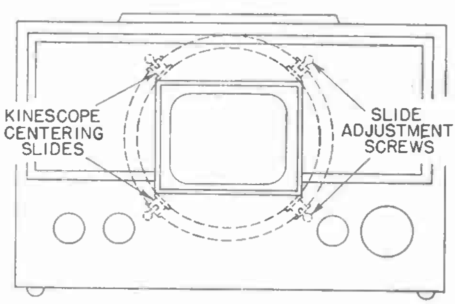
Another method of supporting the front end is to have it rest on brackets that are secured to the inside front of the cabinet. The position of these brackets is usually adjustable so that the tube can be properly oriented with respect to the mask in the front of the cabinet. This difference calls for a change in the method of installation, as we shall show.

Generally, the rear support is mounted on brackets that are supported on the chassis. On an electrostatic tube, the rear support is a strap around the neck of the tube or a mounting plate that holds the socket. However, the neck of an electromagnetic picture tube is supported by a deflection yoke and a focus coil into which the neck is slipped. The deflection yoke is usually secured inside a fiber sleeve that bears a cushion in its front end. This sleeve is usually held in a clamp that is secured by thumbscrews or nuts. If you loosen these nuts, you can move the sleeve back and forth. In addition, the deflection yoke can be moved back and forth or rotated within the sleeve by loosening a thumbscrew or nut. The mounting screws that hold the focus coil to its bracket can be loosened if it is necessary to adjust the position of the coil.

There is another variation—in some sets, both the front and rear supports of the tube are secured to the cabinet and are completely separate from the chassis. This arrangement is used in some 7-inch table-model sets and also in some large sets using a console cabinet.

In at least one set using a 20-inch tube, the tube is secured in a special cradle that permits it to be lowered within the cabinet when the set is not in use.

We shall give instructions for installing the tube in each of the first two mounts mentioned above, which are by far the most common kinds. We shall also describe the installation of



The front of the picture tube is fastened to the cabinet in this manner in some sets.

7-inch cabinet-mounted tubes. If you work on a larger set in which the tube is mounted in the cabinet, either consult the manufacturer's instructions or inspect the set carefully to learn how to install the tube.

Incidentally, if you should ever service a custom TV installation, you may find some special form of tube mounting—in some of these, the tube is even mounted in the wall.

These differences in mounting methods call for changes in the installation procedure, and of course, there are other differences that occur because of the basic differences between electrostatic and electromagnetic tubes. For example, one of the differences is that most electromagnetic tubes use ion traps, but not all do, and no electrostatic tubes use them.

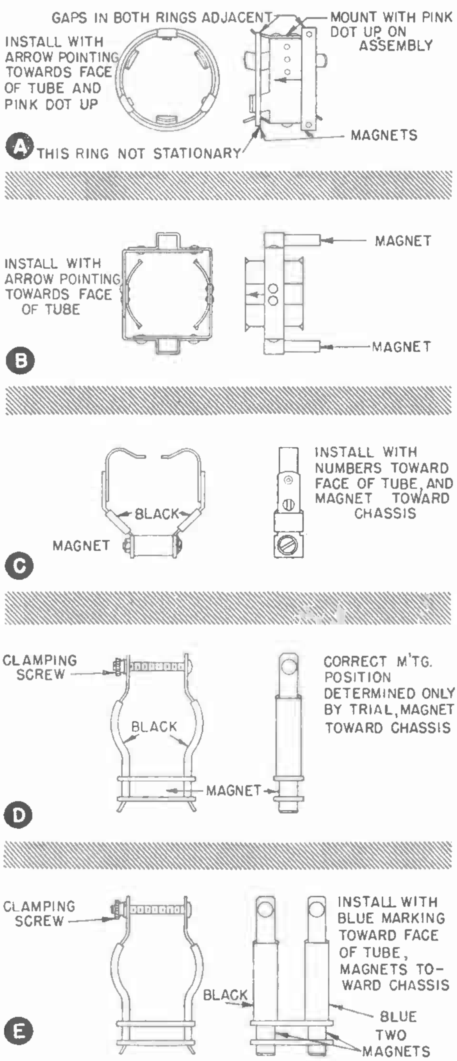


FIG. 1. Five kinds of ion traps. The one in A is the most common.

Ion traps are not used on electromagnetic tubes that have an aluminum backing behind the screen (such as the GE Daylight tubes) nor are they used on the 15 or 20-inch glass tubes. You should consult the manufacturer's information to see if the tube you are installing needs one.

There are a number of different ion traps in use; several are shown in Fig. 1. In each type, one or two small magnets are in an assembly. (Sometimes electromagnets are used.) When there are two magnets, the ion trap is supposed to go on the neck of the tube with the weaker magnet nearer the face of the tube. Fig. 1 gives the details for some types, but you should read the instructions packed with any you install. When removing an ion trap in making a replacement, be sure to notice how it was placed on the tube.

In the following, ignore instructions for installing an ion trap if none is to be used.

Now, let's discuss the installation of picture tubes in sets. We'll start with the installation of electromagnetic (EM) tubes, then take up the installation of electrostatic (ES) tubes. So that you will find everything in one place when you refer to this Lesson in the future, we shall discuss each installation separately and completely—there will, therefore, be a certain amount of repetition in the instructions. Remember — these instructions will apply both to the installation of a tube in a new set and to the installation of a replacement tube in a set that has been in use before.

CHASSIS-MOUNTED EM TUBE

When an electromagnetic picture tube has both its front and its rear support mounted on the chassis of the

TV set, the chassis must first be removed from the cabinet before a tube can be installed. Usually this is done by taking out the back of the cabinet, but at least one type of set has been made in which the whole top is hinged and is moved aside to remove the chassis. Since the usual TV set is rather

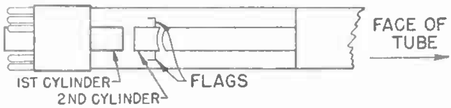


FIG. 2. These flags in the electron gun of a picture tube can be used as guides to correct initial position for the ion trap.

heavy, be sure you have a good grip on it before you try to lift it out of the cabinet.

Before starting to install the tube, loosen the screws holding the deflection yoke sleeve to its support bracket. Remove and discard any shipping bolts. Slide the sleeve toward the rear of the chassis. Loosen the yoke in the sleeve, slide it as far back as it will go, and tighten it again.

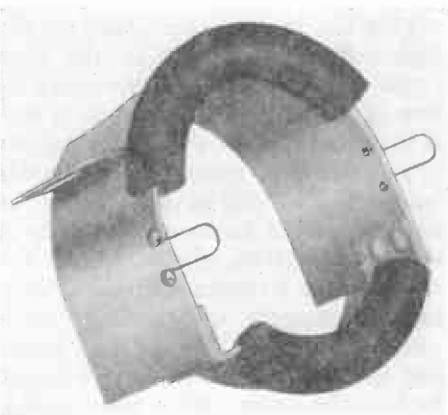
Next, align the focus coil (which is behind the deflection yoke) so that the hole in the middle of the coil is in line with the hole in the middle of the deflection yoke. Loosen the focus coil securing screws if it is necessary to shift the coil position, then tighten them after the coil is properly placed.

If a rubber mask is to fit over the face of the tube, install it. Holding the tube by the face and the funnel (NEVER by the neck), slide its neck through the yoke of the focus coil until the base of the tube is approximately two inches beyond the end of the focus coil. The high-voltage terminal of the tube is a metal well sunk in the funnel; orient the tube so that this terminal is in the upper half of the tube.

If an ion trap like the one in Fig. 1A is to be used, slip it over the neck of the tube with the smaller magnet towards the front of the chassis. The arrow on the trap should then be pointing toward the front of the chassis. (If the trap is different from that in Fig. 1A, consult the manufacturer's instructions.) Be careful not to let the tube hang by its neck at any time while you are installing the ion trap.

Most tubes have two small metal "flags" on the second cylinder from the base in the electron gun structure, as shown in Fig. 2. If the tube you are installing requires an ion trap, you can use these flags as a guide in initially positioning the trap. First, orient the tube so that the flags appear as shown in Fig. 2 when you look down on the tube. Then place the ion trap so that the rear magnet is over these flags.

After the ion trap is in place, plug the picture tube into its socket. Move



Courtesy RCA

The front section of a deflection yoke mount.

the tube toward the back until its face is in the proper position with respect to the front and support.

If the strap that goes over the top of the tube face is elastic or is tightened by a spring, slip it over the tube and adjust it so that it holds the tube properly. If it is the kind that is tightened by a clamp, install the felt or rubber cushions that are provided, then put the strap in place and tighten the clamp.

When the front end of the tube is securely mounted, slide the deflection yoke sleeve as far forward as it will go and tighten its securing clamp. When this has been done, the rubber cushion at the front of the sleeve should be in contact with the funnel of the tube. If the tube is a glass one, the two small wire loops at the front of the cushion should also be in contact with the conductive coating on the tube funnel. These loops ground the outer coating of the tube, so it is very important for them to make good contact. (These loops are NOT used with metal tubes.) When the cushion is in firm contact with the tube funnel, loosen the securing screw or nut holding the deflection yoke, slip the yoke as far forward as it will go, and fasten it again.

Plug the high-voltage lead into the high-voltage receptacle in the tube funnel. This completes the installation of the picture tube; the next step is to adjust the set. (The adjustments to be made are described later in this Lesson.) You will have to install the various control knobs on the shafts of the front controls of the receiver before making adjustments; then, when the adjustments are partially completed, you must remove the knobs and install the chassis in the cabinet, replace the knobs, and make the final adjustments.

COMBINATION MOUNTINGS FOR EM TUBES

In a set in which an electromagnetic picture tube is supported at its front end by brackets on the cabinet (but at the rear by a bracket on the chassis), the picture tube is installed from the front of the cabinet with the chassis in place. To do so, it is necessary to remove the decorative front panel to which the protective glass or plastic plate and the viewing mask for the tube are secured. Usually either the top of the cabinet or a section of the top of the cabinet must be removed also. You can expect to find some variations in the manner of securing the parts of the cabinet.

When the front panel of the cabinet has been removed, you will find a hole in the front of the cabinet that is large enough for the tube to pass through.

Before installing the picture tube, loosen the clamp holding the sleeve of the deflection yoke. Move the sleeve back toward the rear of the chassis. Loosen the deflection yoke securing screw and slide the yoke as far back in the sleeve as it will go. Tighten the yoke.

Next, see that the hole in the deflection yoke and the hole in the focus coil are in line. If they are not, adjust the position of the focus coil.

Loosen the adjustable brackets used to support the tube face. These are mounted on the inside surface of the front panel of the set. Slide the two bottom brackets to about the middle of the range over which they can be adjusted, and tighten their securing screws.

The high-voltage connection to a metal tube is made through one of these supporting brackets. Find out which bracket the high-voltage lead is connected to and make sure that the connection is secure.

If a metal tube is used, slip the Vinylite boot over the metal part of the funnel. Sometimes a clamp is provided to hold the large end of the boot to the metal rim of the tube; if one is used on the set you are working on, install it.

Holding the picture tube by its funnel, (or, if it is a metal tube, by its metal rim), slide the neck of the tube into the deflection yoke and focus coil.

If it is a glass tube, orient it so that the high-voltage receptacle (a metal well sunk into the funnel) is in the upper part of the tube.

When the base of the tube is about two inches past the focus coil, install the ion trap if one is to be used. If an ion trap like the one in Fig. 1A is to be used, it should be installed so that the smaller magnet is toward the face of the tube and the red dot is uppermost. If some other kind of ion trap is to be used, follow the instructions given for its use by the manufacturer. Remember—do not permit the picture tube to hang supported only by its neck while the ion trap is being installed.

If you will look at the neck of the tube, you will see that there are two small metal flags on the second cylinder from the base of the electron gun structure (see Fig. 2). The tube should be oriented so that these flags appear as shown in Fig. 2. The ion trap should then be placed so that the rear magnet is over these flags.

Continue pushing in the picture tube until its face is slightly inside the rear surface of the front panel of the cabinet. Adjust the brackets that support the tube until the face of the tube is centered in the opening.

Wipe the surface of the picture tube and the safety glass or plastic panel that will cover it with some window-cleaning compound. The manufacturer's instructions may specify a particular kind of compound for this job. For example, RCA recommends the use of "Windex."

Put the decorative front panel back on the cabinet, being careful not to get finger marks on the surfaces that you just cleaned.

Slip the picture tube as far forward as it will go. Slide the deflection yoke forward until the cushion is firmly in contact with the tube funnel. If a glass tube is used, there will be two small loops of spring wire beside the cushion; these loops, which ground the outer coating of the tube, must make firm contact with the tube. These loops are NOT used with metal tubes.

Tighten the bracket that encloses the deflection yoke sleeve. Slide the deflection yoke as far forward within its sleeve as it can be moved and fasten it securely. Plug the high-voltage lead into the high-voltage receptacle on the funnel if a glass tube has been installed.

After installation of the control knobs on the front panel of the set, the set is ready to be adjusted, as will be described later in this Lesson.

CHASSIS-MOUNTED ES TUBE

The only basic difference between the mountings for electrostatic and electromagnetic tubes is in the neck support. The deflection yoke and focus coil are not used on electrostatic tubes; instead, there is a clamp support for the neck. However, the installation of a tube on chassis-mounted supports proceeds as follows:

First, remove the chassis from the cabinet. Install the control knobs on their shafts. If a rubber mask is to be installed on the front of the tube, install it now.

Loosen the rear support clamp of the tube (if one is used) and slip the neck of the tube through it. Slide the tube into approximately the right position, then plug it into its socket.

If a clamp is used over the face end of the tube, install it but do not tighten it. It will almost certainly be necessary for you to re-orient the tube to square it with the mask after you have found out where the picture will appear on the tube.

Next, make any adjustments on the set that are necessary. These adjustments will be described later in this Lesson. When you have found the proper orientation of the picture tube with respect to the mask, tighten the clamps holding the tube.

If the mask for the tube is part of the cabinet, it will be necessary to install the chassis in the cabinet part way through the adjustment procedure. Before doing so, wipe the face of the tube and the inside surface of the protective cover glass or plastic plate on the cabinet to remove finger prints and dust. Remove the control knobs, install the chassis in its cabinet, replace the knobs, and finish the adjustment procedure.

In some of these sets, a rubber mask that is mounted on the tube face extends through the opening in the cabinet when the chassis is installed. This might be considered to be a combination of chassis and cabinet mounting. When you are working on such a set, make sure that the mask goes through the cabinet opening as it should.

CABINET-MOUNTED ES TUBE

When an electrostatic tube is supported by the cabinet, it is usual to have both the back and the front supports built in, rather than having one on the chassis and one on the cabinet. In some of the sets in which the tube is mounted in the cabinet, it is installed from the rear; in others, it is installed from the front. In the latter case, the first step is to remove the decorative panel and open the support that will hold the neck of the picture tube.

Install the picture tube in its supports, either from the front or from the rear, whichever is necessary. If the tube is mounted from the rear, wipe off its face and the inner surface of the glass or plastic shield before installing it. Tighten the tube supports enough to keep the tube from slipping but no more than that, since it will have to be moved to orient it properly when you find out where the picture appears on its face.

Connect the socket to the tube. Install the control knobs, connect the set to an antenna and to the power line, and make the necessary adjustments. These adjustments will be described later in this Lesson.

After the correct position of the tube has been found, tighten the front and rear tube supports firmly. If the front panel is removed when you install the tube, wipe the face of the tube and the inner face of the glass or plastic shield, then re-install the front panel that was removed.

These descriptions of the installation of electromagnetic and electrostatic tubes have necessarily been somewhat general. As we said earlier, you should read the instructions issued by the manufacturer of a particular set you're working on before you install a replacement picture tube. If these instructions are not available, however, the instructions we have given you will help you to install a tube properly as long as you keep an eye out for any peculiarities in mechanical arrangements that the set you're working on may have.

Now, let's learn what controls are used on TV sets and how they should be adjusted.

TV Controls and Tuning

A television set has a number of controls on the front panel and within or on back of the set itself. The adjustment of each of these controls affects the performance of the set in some respect. You must therefore know where each of these controls is and what it does before you can adjust the set properly.

Table 1 lists the various controls that may be found in a TV set and tells briefly what each does. (Notice that several names are given for many of the controls. In each case, one of these names is applied to that particular control by one manufacturer or another.) All sets do not have all these controls, but practically all sets have at least the first eleven of them. Some of these are "operating" controls, meaning that they are located on the front panel of the set and are, or can be, adjusted by the set owner to get or to improve the picture. The others are non-operating controls that are located inside the set, behind a panel in the front of the set, or in back of the chassis; these seldom require adjustment except for an occasional touch-up. Certain of the non-operating controls, notably the focus control and the ion trap, consist in some sets of a coil or other part whose position can be mechanically adjusted to produce the desired effect on the operation of the receiver. (The focus control is an operating control in a few sets; in these, of course, it is an electrical control, not a mechanical one.)

In addition, some of the controls listed consist of two or three controls in some sets. An example of this is the horizontal linearity control, of which some sets have three, each exerting varying degrees of control.

Before we describe the adjustment of sets, we shall describe the functions of the most commonly used controls.

The station selector is the main tuning device of the set. You are already familiar with this control and with the fine tuning control that is associated with it in many sets, so we shall not discuss them further. The volume control is like that used in radio sets; this, too, needs no further discussion.

The contrast control might be described as a volume control for the video signal. It can be used to vary the signal in the video amplifier or in the video i.f. amplifier, depending on the circuit arrangement of the set.

The other controls of a television set can be classified into four groups: 1, controls that affect the characteristics of the beam; 2, controls that affect the synchronization of the sweep voltages and currents; 3, controls that affect the dimensions and position of the picture; 4, controls that affect the shapes of the sweep voltages. We shall discuss each of these groups of controls in the order given.

Controls Affecting Characteristics of Beam. The ion trap, the focus control, and the brightness control affect the content, size, and energy of the electron beam. The function of the ion trap (used only with certain electromagnetic tubes) is to bend the electron beam so that the beam can pass through an aperture in the second anode of the tube. The magnetic field of an ion trap is usually supplied by permanent magnets, but some electromagnetic forms of ion traps have been used.

Table 1

CONTROL	USE
1. Station Selector, Channel Selector, TV Tuning	Selects desired TV station.
2. Volume, Volume Control, Sound Volume	Adjusts sound volume.
3. Brightness, Brilliance, Background	Adjusts average light intensity.
4. Contrast, Picture, Picture Control	Adjusts video signal amplitude.
5. Width, Horizontal Size, Horizontal Amplitude, Picture Width Control	Adjusts picture size in horizontal direction.
6. Height, Vertical Size, Vertical Amplitude, Picture Height Control	Adjusts picture size in vertical direction.
7. Horizontal Hold, Horizontal Speed, Framing	Adjusts free-running frequency of horizontal oscillator.
8. Vertical Hold, Vertical Speed	Adjusts free-running frequency of vertical oscillator.
9. Horizontal Centering, Horizontal Position Control	Adjusts picture position in horizontal direction.
10. Vertical Centering, Vertical Position Control	Adjusts picture position in vertical direction.
11. Focus, Focusing Control	Adjusts C.R. tube spot definition.
12. Fine Tuning, Sharp Tuning, Vernier	Tunes local oscillator accurately.
13. Vertical Linearity	Adjusts shape of vertical scanning wave.
14. Horizontal Linearity	Adjusts shape of horizontal scanning wave.
15. Horizontal Oscillator Frequency Adjustment, Horizontal Lock	Adjusts frequency of sine-wave oscillator (a.f.c. control).
16. Tone, Tone Control	Varies audio frequency response.
17. Horizontal Drive, Horizontal Peaking	Adjusts amplitude of peak portion of horizontal scanning wave.
18. Horizontal Oscillator Phase Adjustment	Adjusts phase of horizontal oscillator to pulse rate (a.f.c. discriminator).
19. Picture Cut-off or C.R.T. Bias Adjustment	Adjusts "black" level of picture tube (grid 2 voltage).
20. Ion Trap Adjustment, Beam Bender	Adjusts current through the ion trap magnet coils.
21. Service Control, Screen Voltage Horizontal Output Tube	Adjusts output of horizontal amplifier (auxiliary width control).
22. Coarse Focus	Sets range of main focus control.
23. Phase Detector Balance	Adjusts balance of a.f.c. discriminator.
24. Excitation, Anode Voltage Control of Projection Tube	Adjusts operating point for projection picture tube.
25. High-Low Bandswitch	Selects input system for high or low channel group.

The beam of an electromagnetic tube is focused by varying either the position of the focus coil or the current through it; an electrostatic tube is focused by adjusting the voltage on the first anode of the electron gun. Most commonly, the focus control is a non-operating control, but in some sets it is brought out to the front panel. Of course, the latter is possible only when an electrical control is used; when the focus coil is moved physically, the adjusting screws form a non-operating adjustment.

The brightness control affects the amount of bias applied to the first grid in the electron gun of the tube in both electromagnetic and electrostatic tubes. It therefore controls the number of electrons in the electron beam; since the over-all light level produced by a bombardment of the screen by electrons depends on the number of electrons that strike it, we can say that the setting of the brightness control determines how much light is produced at the face of the picture tube. This is frequently an operating control.

Controls Affecting Synchronization. The horizontal and vertical hold controls are examples of two of these kinds of controls. These two are used in all sets. In addition, sets that have a.f.c. horizontal oscillator control systems have controls that permit the frequency of the horizontal sweep sine-wave oscillator to be adjusted and permit the horizontal discriminator to be balanced. With other locked systems, locking range controls and sometimes oscillator frequency controls are generally provided.

The horizontal hold control affects the frequency of the horizontal sweep oscillator. It is usually an operating control.

The vertical hold control affects the frequency of the vertical sweep oscillator. It, too, is usually an operating control.

Controls that affect the locking system or the horizontal a.f.c. are invariably non-operating controls.

Controls Affecting Dimensions and Position. These controls consist of a width control that affects the horizontal width of the picture, a height control that affects its vertical height, a horizontal centering control that permits the picture to be moved horizontally, and a vertical centering control that permits the picture to be moved vertically.

The setting of the width control determines how much sweep current is allowed to flow in the horizontal deflecting coil of the picture tube (or how much voltage is applied to the horizontal deflection plates in an electrostatic tube). This is a non-operating control in all cases.

The adjustment of the vertical height control determines the amount of sweep current allowed to flow through the vertical deflecting coil of the tube (or the amount of voltage applied to the vertical deflecting plates in an electrostatic tube). This, too, is always a non-operating control.

The horizontal centering control may be either an electrical or a mechanical one. If it is mechanical, it consists of some method of adjusting the position of the focus control, usually with one or more adjusting screws. An electrical control determines the amount and direction of d.c. current flow through the horizontal deflecting coil (or the d.c. voltage applied to the horizontal deflecting plates in an electrostatic tube). This is usually a non-operating control.

The vertical centering control may also be either mechanical (the position of the focus coil) or electrical. The electrical type controls the amount of d.c. current allowed to flow through the vertical deflecting coil (or the d.c. voltage applied to the vertical deflecting plates in an electrostatic tube). The vertical centering control is usually a non-operating control.

Controls Affecting Sweep Voltage Shapes. These controls usually consist of horizontal linearity and drive controls and a vertical linearity control. Either of the linearity controls may have one or more additional controls associated with it that provide varying degrees of control. Linearity controls are seldom used in sets having electrostatic tubes.

There may be as many as three horizontal linearity controls in a receiver, each of which affects the shape of part of the horizontal sweep current. These are always non-operating controls.

Adjustment of the horizontal drive control determines the point in the horizontal sweep current cycle at which the horizontal output tube conducts. Therefore, it affects the shape of the horizontal sweep signal. It, too, is always a non-operating control.

The vertical linearity control, of which there may be two in a receiver, controls the shape of the vertical sweep current. It, too, is a non-operating control.

POSITION OF CONTROLS

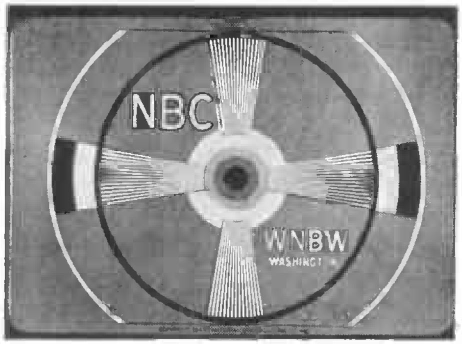
There is no general rule we can give you about where the various controls of a TV set are, except that the station selector, the volume control, and the fine tuning control (if the set has one) are invariably on the front of the set; usually the contrast and brightness controls are there also, and the horizontal and vertical hold controls are frequently there. Occasionally the focus control is also on the front panel. The other controls are usually on the back of the chassis or on top of it. In some sets, some of the non-operating controls are brought out to the front but are concealed by a panel that is secured by screws. In some sets, also, a few of the non-operating controls are on the side of the chassis. Occasionally a control is located beneath the chassis.

In almost every case, the name of the control is engraved near it on the chassis or a paper tag shows what its name is. When the tag is lost, or an unusual name is given a control, you should refer to the manufacturer's instructions, if available. If not available, you can determine its use by the process of trying it, as long as you are careful to note its original position. Do not assume that you have found all the controls on a set with which you are unfamiliar until you have checked these instructions, because there may be one or two that you do not suspect the existence of.

INDICATION OF PROPER ADJUSTMENT

It is possible to tell whether a few of the adjustments we will describe are properly made just by looking at the raster (the line pattern produced on the face of the tube when no signal is tuned in). Some others can be judged when you have a picture tuned in, but you cannot tell whether some of the controls are properly set without having a test pattern to guide you.

Test patterns are stationary pictures transmitted by a television station to assist servicemen to bring sets into proper adjustment, and they can be used to make almost all the adjustments. One of the most popular of these is shown in Fig. 3. (Some are different in appearance but the following facts apply.) If a set is perfectly adjusted, the test pattern's vertical and horizontal lines will be straight, with no moire pattern across



Courtesy NBC and WNBW

FIG. 3. The standard NBC test pattern.

them, the vertical "wedges" of lines will be equal in size to each other, the horizontal wedges will likewise be equal to each other, the circles will have no irregularities and will be perfectly circular, and the shades of gray in the center circles will range from white to black.

The test pattern also shows the width of the frequency band passed by the set (and hence indicates how well it is aligned) by the degree of separation between the lines of the vertical wedges. We shall leave alignment for a later Lesson, but we shall discuss the adjustments of controls in this one.

OPERATING A SET

Before we discuss the adjustments that may have to be made on a set to bring it into operating condition, let us take a moment to describe the process of tuning a set and producing a picture of the desired quality on its face. If you are familiar with the operation of a TV set, you need not bother with this section; it is intended for the man who has never operated one.

First, turn the set on. The on-off switch is usually on the volume (or the tone) control as on a sound receiver. Turn on this control, and adjust both the sound volume control and the contrast (or "picture") control to about their middle settings. Next, turn the station selector to the desired channel. If the set uses a push-button or step tuner, push the proper button or turn the switch to the right number; if it uses a continuous tuner, rotate the tuning knob until the indicator points to the desired channel.

If the station is on the air, you will now get an indication of a picture, at least, and you should turn up the sound volume control until sound is heard.

If the set has a fine tuning control, adjust it for maximum undistorted *sound* volume, paying no attention to the picture. If the set is receiving a strong signal, it will probably be possible to find three volume peaks at any setting of the station selector. However, two of these will be distorted; the one in the middle is the correct one.

If the set uses continuous tuning, it will probably have a double-shadow tuning eye. After adjusting the tuning mechanism to approximately the right place, make small adjustments of the tuning knob until both shadows are of the same size and are lined up with one another.

Sets that do not have fine tuning controls have a.f.c. circuits that are supposed to take care of bringing the set into exact tune when it is turned to the station. With these, selecting the desired channel is all the tuning that has to be done.

Once the station is tuned in according to the sound, adjust the contrast control to get a "normal" picture — not too black nor too white. Now, the picture must be made stationary (if it is not already so) by adjusting the vertical and horizontal hold controls. This is seldom necessary if the set was in use earlier and was turned off without anyone's touching the hold controls.

Once a steady picture has been produced, the contrast and brightness may have to be re-adjusted to get the best picture. It is the usual practice when a set has both these controls to adjust for normal contrast with the brightness as high as it can be made without making the retrace lines visible. However, people differ in their ideas of "good" pictures just as they differ in their setting of tone controls; it is permissible to turn the brightness control higher or lower, if desired.

If the contrast control is set too high, the picture will be excessively "contrasty" — too light in places, too dark in others — and the vertical lines will usually be bent. If the control is set much too high, the picture will be severely distorted or destroyed altogether. If it is set too low, the picture will be gray, flat, and lacking in detail; if it is set much too low, no picture will be visible. A test pattern is good to experiment with; when the contrast control is properly adjusted, the center circles should shade from white to black in such a way that each circle is distinct from its neighbors.

Often, once the brightness control has been set, it is unnecessary to change the setting if the set is then tuned to another station. For this reason, some sets are made without an operating control for the brightness level. In such sets, the contrast control should be adjusted to give the best picture.

After the set has been in operation for a few minutes, it may be necessary to re-tune the fine tuning control if the set is equipped with one.

If the set is re-tuned to another station, probably the fine tuning control (if the set has one) and the contrast control will have to be re-adjusted.

Adjustment of Direct-View Sets

Now that you know how to adjust the main operating controls, let's study the adjustment of the others, particularly those considered "non-operating." We shall assume that a picture tube is installed, and that you can now connect the set to an antenna and power outlet.

To make it easier for you to see the face of the tube while you are working in back of it, place a mirror in front of the tube. Stainless steel mirrors on tripod stands are sold by parts distributors; you will find one of these very convenient for this use.

First let's run through the adjustment of sets using electromagnetic (EM) picture tubes, then study electrostatic types. In the following descriptions, the sentences in boldface type describe the adjustment step, and the succeeding paragraphs show how the adjustment is made.

EM SET ADJUSTMENT

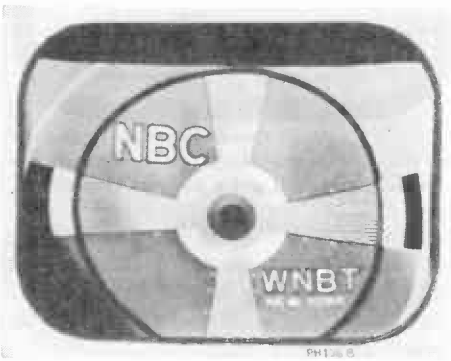
With the tube installed, connect the set to the antenna and power, and turn on the set. Turn the brightness control to its maximum setting and turn the contrast control to its minimum setting.

Position the ion trap. If the set has an ion trap, it must be adjusted *at once* to produce a visible raster on the face of the tube. If this is not done promptly after the set is turned on, the second anode of the picture tube (which is struck by the electron beam until the ion trap is properly adjusted) may be seriously damaged or ruined. To make this initial adjustment of the ion trap, rotate it or slide it back and forth a short distance until at least a fairly bright raster is produced on the face of the tube.

Remember — it is important to get the ion trap into an initial rough adjustment very quickly to prevent damage to the tube. Once a fairly bright raster has been secured, there is no longer any danger to the picture tube, so you will not have to rush the rest of the ion trap adjustment.

The position of the ion trap must be adjusted to produce the brightest raster that can be secured. If it proves difficult to locate the exact position at which the brightest raster is secured, reduce the brightness somewhat by turning down the brightness control, then re-adjust the ion trap.

Next, adjust the focus to make the visible lines in the raster as sharp



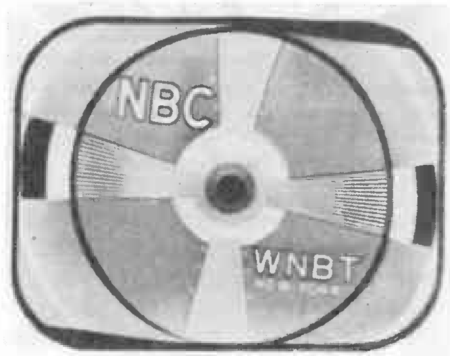
Courtesy RCA

The shadow at the bottom left of this picture is produced by an incorrect adjustment of the ion trap.

as possible. Re-adjust the ion trap for maximum brightness of the raster at which the focus can be maintained.

Inspect all corners of the raster carefully to make sure that none are shadowed. If shadows are present, re-adjust the ion trap to remove them. If shadows persist, the focus coil may be incorrectly positioned; hence you may have to adjust it (as described later), then return to make a final ion trap adjustment.

Square the raster with the mask. If the raster is not square with the picture tube mask, rotate the deflection yoke to make it so. This can be done accurately, of course, only if

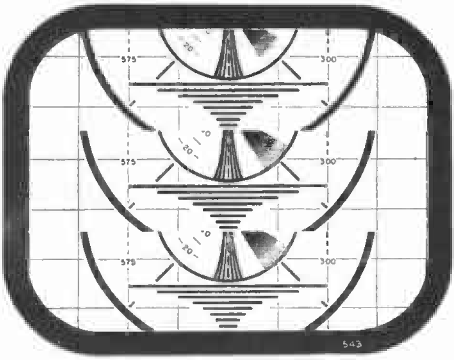


Courtesy RCA

A tilted picture of this kind in a set using electromagnetic deflection means that the deflection yoke is rotated from its correct position.

the mask is up against the tube. If you are making adjustments on a chassis that is not in the cabinet, and the mask is part of the cabinet, you can get the orientation of the raster at least almost perfect by making sure that the top and bottom of the raster are horizontal and the sides are vertical. However, in this latter case, remember that it may be necessary to rotate the deflection yoke slightly after the set has been put back in the cabinet.

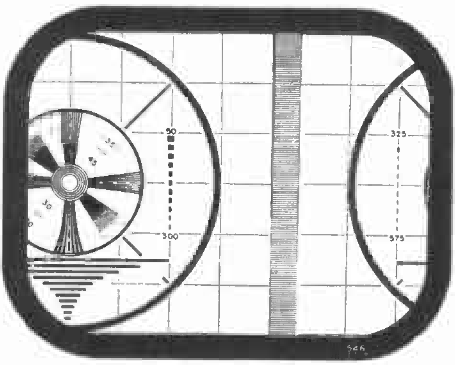
Get a steady picture. Turn the station selector to some station on the air, preferably one that is transmitting a test pattern. Tune in the station in the usual way and turn up the contrast control (which was previously turned all the way down) until the picture becomes visible, then adjust for near normal contrast. If



Courtesy Belmont Radio Corp.

Misadjustment of the vertical hold produces a picture like this that runs up or down at a rate that depends upon how severe the misadjustment is,

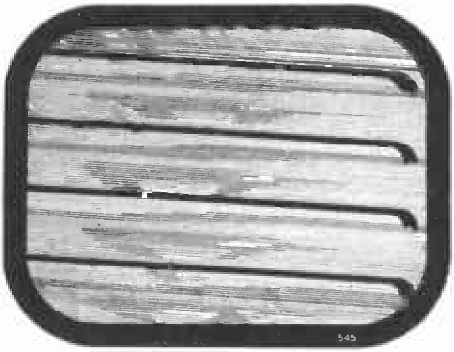
the set is operating properly, and the contrast control is not at a setting far too high or too low, you should be able to sync the picture with the horizontal and vertical hold controls. If the picture runs vertically, turn the vertical hold control until it is stationary. Similarly, if it runs horizontally, bring it to rest with the horizontal hold control. In some sets, misadjustment of the horizontal hold control will not produce a moving picture but will instead produce one that is very highly distorted.



Courtesy Belmont Radio Corp.

If the horizontal hold is slightly out of adjustment in a set that uses the simpler kind of horizontal control, you will get a picture like this that moves slowly to the left or right.

If a steady picture cannot be produced by adjustment of the horizontal hold control, any one of several possible difficulties may exist. If the set uses one of the simple triggered systems of horizontal synchronization, the set will not lock in if the signal is too weak or if too much noise is picked up. If the set uses some locking system of synchronization, there will be an auxiliary synchronizing control that may require adjustment. This auxiliary control may be a control of the horizontal oscillator or a control in the locking circuit. Some sets have both. You will have to consult the manufacturer's instructions to see which auxiliary controls

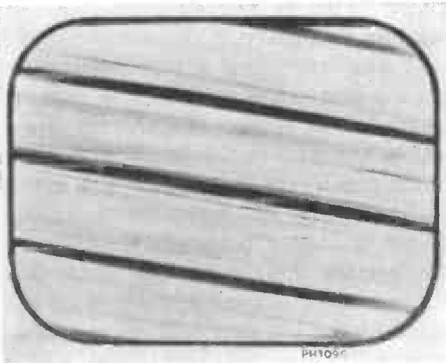


Courtesy Belmont Radio Corp.

If the horizontal hold is badly misadjusted, you will get a picture like this.

are used on the set you are working on. If you cannot get a steady picture by adjusting these controls, the set has some defect that must be found and remedied.

Check the angular range of the horizontal hold. Once you have managed to get a steady picture on the tube, check the range through which the horizontal hold control can be turned without throwing the picture out of sync. In some sets, this range is only about one half of the total possible rotation of the horizontal hold control. In other sets, the range is somewhat greater than this,

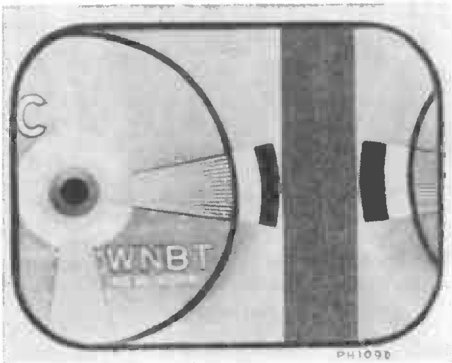


Courtesy RCA

You will get a picture like this if the frequency adjustment of the horizontal sync discriminator transformer is misadjusted.

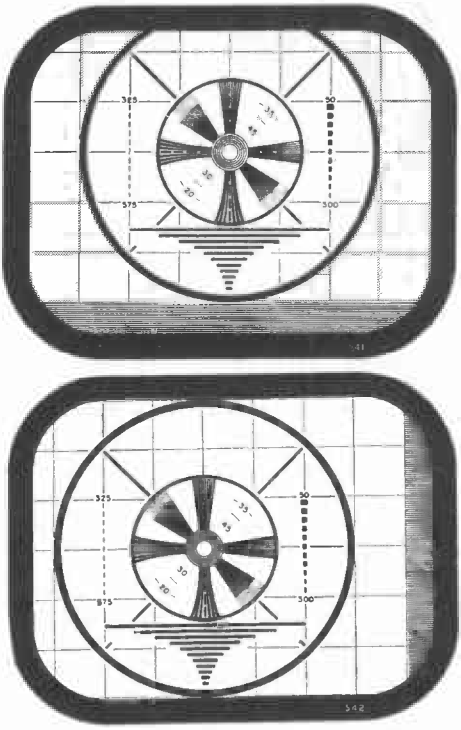
and in still others, it is impossible to throw a properly adjusted set out of horizontal sync with the horizontal hold control. Find out from the manufacturer's instructions what the angular range is for the particular set you are working on, then check the control to see that it works as it should. If it does not, you will have to follow the instructions given by the manufacturer for adjusting the hold circuit. These instructions differ for different sets, depending upon the kind of horizontal sync system used.

Center the picture on the tube. Some sets have electrical centering controls, others use only mechanical ones; the latter is becoming increasingly popular. Mechanical centering controls almost invariably consist of some means of tilting the focus coil on the neck of the tube, usually by adjusting two or more screws. This procedure, incidentally, is often somewhat difficult to follow if the focus coil fits tightly on the neck of the tube, as it does in some sets. In fact, it may sometimes prove impossible to center the picture exactly when a mechanical centering control is used. If so, it will probably be necessary to make the picture extra large so that it will fill the mask properly; we shall mention this again a little farther on.



Courtesy RCA

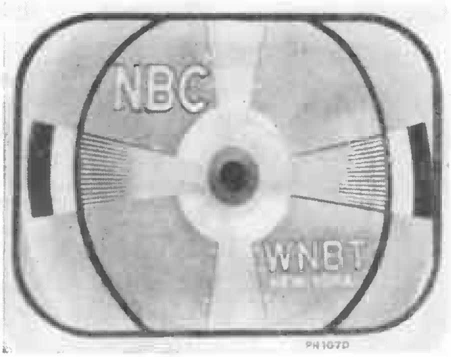
Misadjustment of the phase adjustment of the horizontal sync discriminator transformer produces a steady picture of this sort.



Courtesy Belmont Radio Corp.

Pictures that are off center vertically (top) or horizontally (bottom) look like this.

Install the set in the cabinet. If the set had to be taken from the cabinet to install the picture tube, then we suggest that you put it back in the cabinet now, because the next adjustment steps are concerned with making the picture fill the mask. If a rubber mask is used over the picture tube, it will be unnecessary to install the set in the cabinet at this time. As a matter of fact, when you have had considerable experience in adjusting sets, you will probably not bother to put the set back in its cabinet just yet but will instead be able to judge the size of the picture adequately without having it in its mask. If you do install the set in the chassis at this time, first be sure to wipe off the face of the tube and the inner face of the protective glass or plastic plate on the cabinet. You must, of course, remove the knobs from the set before installing it in the cabinet and replace them afterward.



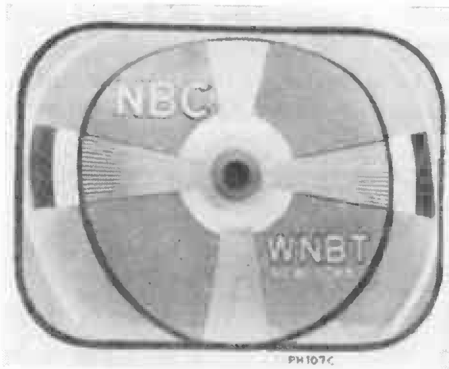
Courtesy RCA

This shows what happens when the vertical height control is misadjusted, making the picture too high for its width.

Make the picture fill the mask vertically. Adjust the vertical height control to make the picture fill the mask. If you have been unable to get the picture exactly centered because the mechanical centering system used did not permit it, you may have to drive the picture beyond the mask at the top or bottom to make it fill the mask. This is not desirable, but it may be necessary.

If you are using a test pattern as your picture, the picture size is considered to be correct if the main circle is just tangent to the top and bottom of the mask (see the test pattern given earlier in Fig. 3). Some people prefer to get a bigger picture by adjusting the vertical height control until this circle is well beyond the edges of the mask at the top and bottom and likewise adjusting the horizontal width of the picture to make the width greater than it should be. Doing so causes some loss of picture at the edges, but it does produce a bigger picture in the center, which is usually the part one is most interested in seeing. For shop adjustment, it is probably best to make the picture just fill the mask; you can then make the picture somewhat larger at the customer's home if he wants you to.

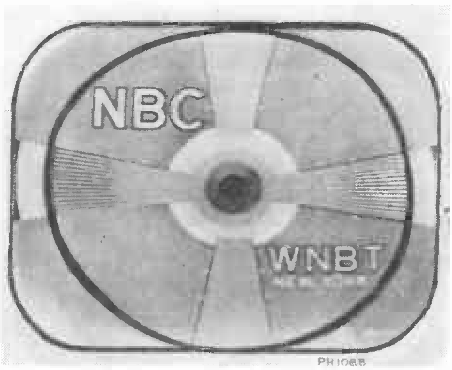
Adjust the vertical linearity of the picture. The vertical linearity control is used to make this adjustment. It is necessary to have a test pattern on the screen to make this adjustment well; it is difficult to make a precise adjustment of linearity on a station signature card or other stationary picture, and it is practical-



Courtesy RCA

Misadjustment of the vertical linearity control may produce this kind of a picture.

ly impossible to do so if a program is being received. The picture is linear vertically if all the lines in the two vertical wedges are straight and the vertical wedges are equal in length. (If the wedges are of equal length, but the lines are bent, and adjustment of the vertical linearity control will not straighten them, probably either



Courtesy RCA

A picture distortion of this sort may be produced if the width control is misadjusted.

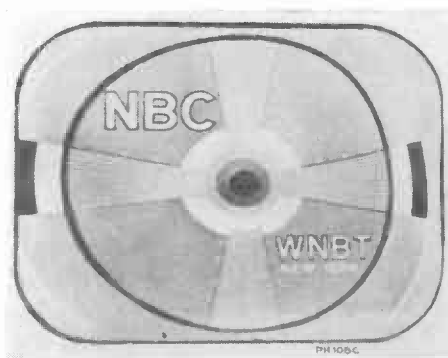
the horizontal linearity is wrongly adjusted or some amplifier in the set is overloaded.) It may be necessary to make several adjustments of the vertical height and the vertical linearity control to remove the vertical distortion in the picture, since the adjustments of these controls interlock to some extent. Also, it may be desirable to repeat some of these adjustments after the horizontal linearity has been corrected.

Adjust the width of the picture. The width control, the horizontal drive control, and the horizontal linearity control or controls must be adjusted to produce a picture that is undistorted and fills the mask horizontally. These controls interact, so you will probably have to make several adjustments of them to get the picture right. In general, you will have to adjust only the width. However, if the horizontal sweep is considerably out of adjustment, you should first adjust the horizontal drive control to get a picture of the maximum width having good linearity, that is, having the lines in the horizontal wedges straight or very nearly so and having equal wedge lengths. Next, adjust the horizontal linearity control to get the best linearity; and finally, adjust the width control to make the picture fill the mask horizontally. If the vertical size has been adjusted, the major circle in the test pattern should now be round.

If the horizontal drive control is misadjusted, the right side wedge in the picture appears to be shorter than the left one on a test pattern, and the outer circle is not round.

If the horizontal linearity control is misadjusted, the picture appears to be cramped in the middle; that is, what should be gray circles in the center of the test pattern become ovals with their long axes vertical, and the right wedge in the picture is somewhat shorter than the left one.

If the width control is misadjusted,



Courtesy RCA

Misadjustment of the horizontal drive control may produce this effect.

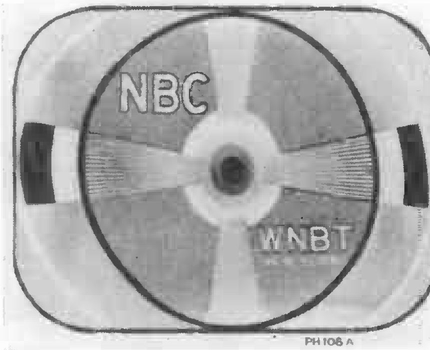
the right wedge of the picture is somewhat longer than the left one, and the center circles of the test pattern are ovals having their long axes horizontal.

If it was impossible to get the picture centered horizontally on the tube face, you may have to overdrive the picture somewhat horizontally to make it fill the mask. Again, this is undesirable but may be necessary.

If the vertical control was adjusted to give a picture larger than normal, the horizontal controls must likewise be adjusted to give a bigger picture. You can tell when the proper aspect ratio is obtained by seeing that the circles of the test pattern are truly circular even though they may go beyond the edges of the mask somewhat.

Some sets have masks having circular rather than straight sides and having horizontal top and bottom edges. The test pattern reproduction looks like that in Fig. 3, except that a slight amount of overdriving of the height may be necessary.

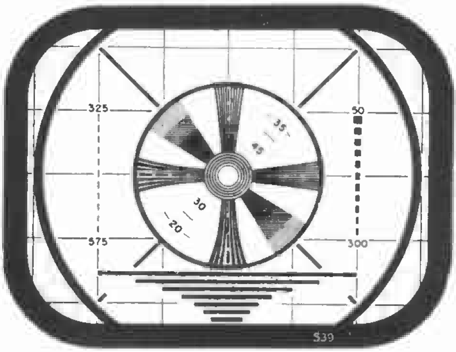
Some sets have circular masks that are approximately the same size as the full face of the picture tube. There are two possible ways of adjusting the size of the picture to make it fill



Courtesy RCA

If the horizontal linearity control is misadjusted, the effect shown here may be produced.

such a mask. One way is just to drive the picture both vertically and horizontally until it has the proper 4-to-3 aspect ratio and fills the whole mask. In this case, the tube will effectively be reproducing the center portion of a large picture, the corners and part of the sides of which will be completely lost. The other method of filling the circular mask is to distort the picture somewhat by making it just fill the mask vertically and horizontally. This will effectively make the height and width of the picture the same. The picture will therefore be distorted, because when it is trans-



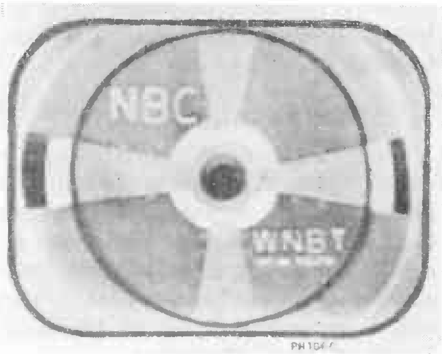
Courtesy Belmont Radio Corp.

This picture is larger than normal both vertically and horizontally. Many people prefer such a picture, particularly on small picture tubes.

mitted it is three units high and four units wide; however, less of the picture will be wasted. When a set is adjusted in this way, the sections of the test pattern that should be circular will instead be ovals having their long axes vertical. Follow the manufacturer's instructions in adjusting the picture size in such a set.

Focus the picture. Adjust the focus coil control to make the picture as sharp as possible. Focusing is most easily done if the set is tuned to a station that is transmitting a test pattern, but it is possible to focus on a regular picture also if the focus control is electrical. To focus on a regular picture, find some part of the picture that is stationary and adjust the focus control rapidly back and forth through the position of best focus. This will make it fairly easy for you to find the point at which the focus is best. If the focus control will not permit you to take the picture through the focus point, but if it instead allows you to bring the picture only into reasonably good focus before you reach the end of the control, you cannot be sure that you have the best possible focus. The focus control should permit you to bring the picture into good focus somewhere near the middle of the range of the control. If it does not, there is probably some defect in the set — perhaps some tube is losing emission. Any such defect should be found and corrected.

If the set is focused by adjusting the position of the focus coil, it is practically impossible to focus on a picture; you will have to use a test pattern or perhaps a station signature card. The reason is, of course, that adjustment of the focus coil is a fairly slow procedure, and it is very difficult to get the proper focus on a scene that changes (as it will in a regular picture if you have to take very long to make the adjustment). If it is necessary to change the position of the focus coil, it may also be necessary to readjust the ion trap to eliminate shadows in the picture. Changing the position of the coil may also affect the centering of the picture. Keep these possibilities in mind if you find it necessary to move the focus coil.



Courtesy RCA

Misadjustment of the focus coil or focus control will produce a blurred picture.

Check the set on all stations. The set should now be in adjustment for all the stations that can be received. Check this by tuning to each in turn. You may find that the best adjustment for one station's test pattern may not give as good linearity as the test pattern of another station. Usually this is caused by irregularities in the transmission from the station, so it is desirable to use the test pattern from the station considered the best operated in your locality; you can then ignore small differences found on other signals. Of course, improper alignment of the set may cause trouble this way, too, so you may have to follow the alignment procedures described in another Lesson.

SET ADJUSTMENTS — ES TUBE

Again, the sentences in bold-face type will indicate the steps in the procedure, and the succeeding paragraphs will show how the steps are carried out.

Produce a picture on the face of the tube. Connect the set to an antenna and a source of power, and turn it on. Tune in a station that is transmitting a test pattern (or a picture, if no test pattern can be found). Turn the contrast all the way down, and turn up the brightness until a raster is just visible on the face of the picture tube. Then turn up the contrast until the picture is visible.

Sync the picture. If the picture is running either vertically or horizontally, use the appropriate hold control to stop its motion. Sets using electrostatic tubes very rarely have any sync locking controls other than the hold controls. If the picture cannot be brought into synchronization by manipulating the hold controls, usually there is some defect in the set that must be found and repaired. If a locking control is used on the horizontal sweep, however, it may have to be adjusted if the horizontal hold control doesn't lock.

Center the picture. Adjust the vertical centering and horizontal centering controls until the picture is in the center of the mask of the set. If the picture is not square with the mask of the tube, rotate the picture tube to make it so. Once the tube is properly oriented with respect to the mask, tighten the clamps that hold it in place.

Make the picture the proper height. Adjust the vertical height control until the test pattern fills the mask vertically. Since the most popular electrostatic tube is the 7-inch tube, which is a relatively small one, the customer may prefer an oversized picture; however, in shop adjustment, you should produce a picture of normal height (that is, one in which the major circle of the test pattern just touches the top and bottom edges of the mask as shown in Fig. 3). You can always increase the size of the picture in the customer's home if he wants you to.

Make the picture the proper width. Adjust the horizontal width control until the picture fills the mask horizontally as shown in Fig. 3. The circles on the test pattern should now be perfectly circular. If you have overdriven the picture vertically, you will also have to overdrive it horizontally to produce the proper aspect ratio (which you will have when the circles are true circles).

Sets using electrostatic tubes rarely have horizontal or vertical linearity controls. Therefore, if the picture is not satisfactorily linear (that is, if lines in the test pattern are not straight and the wedges are unequal in size), there is no adjustment that can be made to improve this condition. The set must have some defect that must be found and corrected if the non-linearity is serious.

Focus the set. Adjust the focus until the picture is as sharp as it is possible to get it. Rotate the focus control until the picture goes through its point of best focus, then turn the control in the opposite direction until the picture goes through the point of best focus again. Repeat this process several times fairly rapidly, decreasing the amount of rotation of the control each time until you are able to stop the control at the exact point of best focus.

Check performance on other stations. The set should now be in adjustment for all stations. See that it is by tuning it to each of the other stations in your vicinity in turn. If it will not pick them all up as well as your experience in that location indicates it should, the alignment of the set is probably defective. You will learn how to align sets in a later Lesson.

SPECIAL ADJUSTMENTS

One "adjustment" you may be called upon to make is actually an alignment or replacement problem that comes up because some sets are capable of tuning in only 7 or 8 channels on a "choice" basis; that is, they will tune to either 12 or 13, either 10 or 11, etc. Manufacturers customarily adjust their sets to receive the stations that are available in the locations in which the set will be shipped. However, it is always possible that someone will move into your territory who has a set that is adjusted for different stations.

How to adjust such sets depends upon the type of set. In some, it is necessary only to change the setting of the r.f. oscillator. You will receive instructions for doing so in a later book on set alignment. Other sets use turret tuners into which new coils must be plugged if a different station is to be picked up. To adjust a set of this sort, you must secure new coils for the desired channel and install them in place of the coils used in the undesired channel. If you find it necessary to do this, follow the instructions given by the manufacturer.

How to adjust a.g.c. controls. In sets using a.g.c., the contrast control is frequently used in that circuit and acts as the only control. In others, however, the contrast control may be in the video section, and a separate "a.g.c." control may be used to set this circuit below the point of overloading. Generally, the adjustment consists of tuning in a strong signal, adjusting the contrast control to maximum, and then adjusting the a.g.c. control to where overloading in the form of a severely distorted picture just begins to appear. Now, turning down the contrast control should give normal contrast, and if the a.g.c. system is operating properly, there should be no overloading on any signal.

Projection Sets

It may take longer to adjust projection television sets completely than it does to adjust direct-view sets, chiefly because not only must the adjustments of the sort described earlier be made, but also the optical system must be properly lined up. For this reason, careful and detailed explanations of how to adjust a projection set are always given by the manufacturer in his manual. To give you some idea of what such adjustments are like, we shall describe the procedures used in the more common sets.

Projection television sets, as you have learned, use either a Schmidt lens system or an ordinary projection lens to produce a large picture from a small picture tube. In a set in which a projection lens is used, the tube is simply mounted behind the lens, and the image on the face of the tube is projected through the lens onto a wall or screen. So far, sets of this sort are manufactured only for custom installations, although modification kits are available that make it possible to convert ordinary receivers for such use.

Most of the projection sets that are sold for home use employ the Schmidt lens system in one form or another. There are three chief variations of this system in use at the present time. One is the RCA system

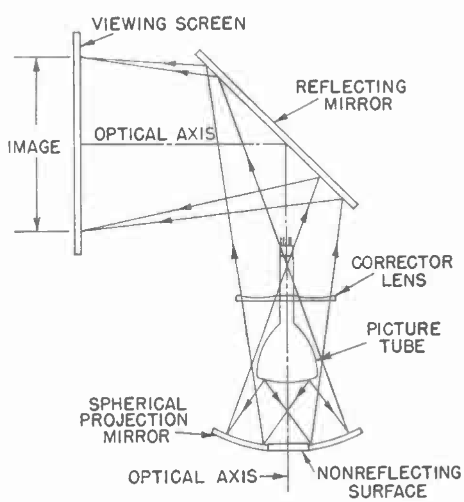


FIG. 4. The basic optical system used in RCA projection sets.

shown schematically in Fig. 4. The spherical mirror, the 5″ kinescope, and the corrector lens used in this system are all secured in a tapered mount called an optical barrel. This is mounted in the bottom of the set, which is always of the console type; the mirror and the viewing screen are mounted on the top of the set.

The system used by Philco is shown schematically in Fig. 5. A 4″ picture tube is used. One major difference between this and other systems is that the final picture is reflected from the front surface of the viewing screen. This eliminates some of the loss of light caused in other systems by projecting the picture through a screen. Another difference is the keystoning that is caused by the fact that the image is not projected onto the mirror

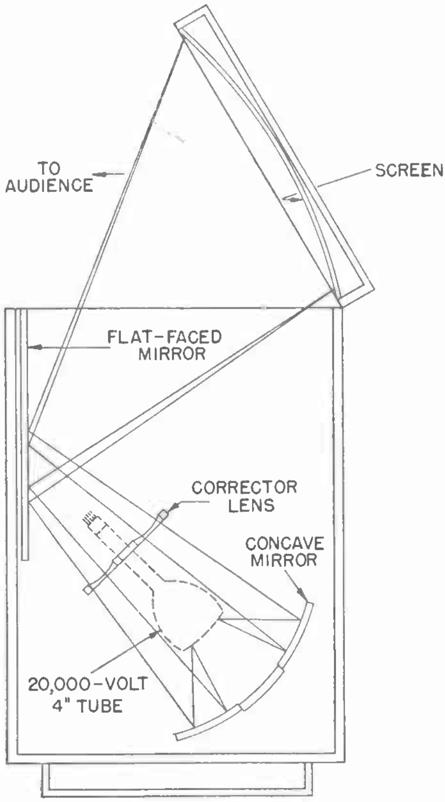
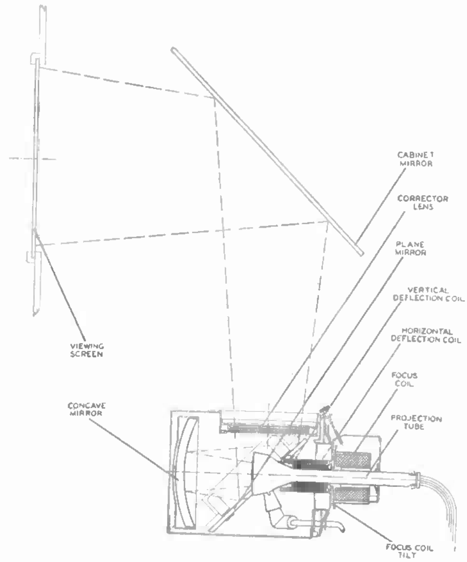


FIG. 5. The Philco projection system.



Courtesy North American Philips Co., Inc.

FIG. 6. The folded Schmidt optical system used in Protelgram projection units.

in the front of the cabinet at 45 degrees. As you learned earlier, this causes a distortion of the picture that must be corrected by distorting the original picture in the opposite manner.

The third method now in use is the Protelgram system of the North American Philips Co. (see Fig. 6). This is known as a folded Schmidt system because the optical path is bent twice between the spherical mirror and the viewing screen. This folding and the use of a very short 2½″ picture tube make the system so compact that it can be used even in table model receivers.

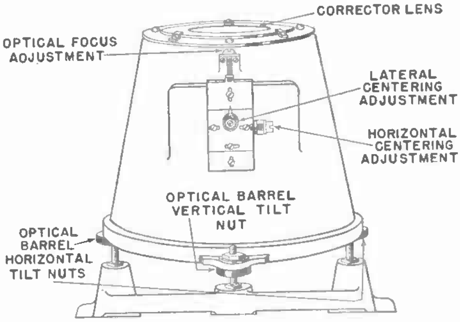
Generally speaking, the only adjustment the serviceman makes in the optical path of one of these sets is an adjustment of the position of the picture tube itself. This is done to bring the tube into the proper location with respect to the rest of the optical system so that the projected picture will be in focus. In the Philco and Protelgram systems, such adjustments must be made whenever the picture tube is replaced. In the RCA system, it may not be necessary to refocus the set after replacing the picture tube, because the tube goes in a holder that positions it, and this holder need not be disturbed when replacing the tube. In any of these systems, of course, it will be necessary to shift the position of the tube if the system becomes out of focus.

We shall now describe briefly how the picture tube is installed in each of these kinds of sets, and how its position is changed to improve the focus of the set. This information is intended to show you what is done, but not specifically how to do it. The actual installation information furnished by the set manufacturer consists of instructions to turn specific screws or other adjustments. Naturally, such information is of little value to you unless you have that exact model to service and can see exactly which adjusting device is referred to and what the effect of turning it is. Hence, we shall give only the general information that will assist you in understanding the details you will find in the set service manual.

RCA SYSTEM

The RCA system shown in Fig. 4 can be adjusted with the picture tube in place, by using a test pattern. However, RCA provides a special test lamp that makes it simpler to align the optical system before installing the picture tube. This special lamp, which works from a 110-volt power line, is placed in the picture tube holder in place of the picture tube. The lamp has a test pattern on its face that is projected through the optical system to appear on the screen, so adjustment is possible whether a signal is available or not. If the optical system is not perfectly aligned, the test pattern will be distorted. Since the test lamp is in exactly the place that the picture tube will occupy when it is installed, the system can be brought to the proper focus by making adjustments that produce an undistorted test pattern on the screen. The manufacturer's instructions show various distortions of the test pattern and tell what adjustments must be made to correct them.

To focus this set, you must first untie a canvas dust cover that encloses the space between the optical barrel and the plane mirror. Move the cover out of the way. Then, remove the corrector lens on the top of the optical barrel. Next, install the special test lamp face down in the picture-tube holder inside the barrel. Center the lamp in the holder by turning the adjusting screws in the holder. When the lamp has been installed, replace the corrector lens. It is important to put this lens back in the proper position; there is an arrow on most, and this arrow should point in the direction given by the manufacturer. Plug in the lamp cord, and rotate the lamp



Courtesy RCA

The optical barrel used in RCA projection sets.

so that the image on the screen is in the proper aspect. Next, cover the hole in the center of the lens (between the lens and the neck of the lamp) with a piece of black paper to prevent light from going through it. Replace the dust cover.

With the test lamp lit, examine carefully the pattern that is found on the screen of the set. If the pattern indicates that the lamp is not properly centered or that the system is out of focus, you can make the necessary adjustments by turning adjusting screws on the optical barrel. The picture-tube holder (and the lamp) can be raised or lowered by a "focus" screw; this changes the distance from the lamp face to the spherical mirror, and corrects the focus. When the focus is proper, good resolution should be had over the entire image. However, unless the holder has the lamp in the center of the optical path, resolution will be poor.

Other adjusting screws will move the holder from right to left, or forward and back, so it is possible to get the holder (and lamp) centered. As a check of the need for this, the focus control is moved from the proper point until a double image is seen on the screen. The lines in the two images should be parallel with each other. If the vertical lines are not parallel, the lateral (left to right) adjustment is made. If the horizontal lines are not parallel, the horizontal (front to back) adjustment is made.

If, upon refocusing, you see that the image comes into focus at some points sooner than at others, the entire optical barrel may have to be adjusted. There are "tilt" screws for this; they are adjusted until the entire picture comes into focus at the same time. The manufacturer's instructions give complete details on these adjustments.

Once the test pattern indicates the set is properly focused, remove the corrector lens and the test lamp. Install the picture tube face down in the holder in the barrel. Bring the corrector lens down over the tube with the hole in the center of the lens fitting over the neck of the tube, and secure the lens to its mounting. Install the deflection yoke, plug the socket onto the tube, and replace the dust cover.

If a picture tube must be replaced, but the optical system appears to be in good adjustment, remove the dust cover, unplug the socket from the tube, remove the deflection yoke, and remove the corrector lens. Remove the old tube and install the new one. Re-install the corrector lens, slip the deflection yoke into place, plug the socket onto the tube, and replace the dust cover. However, unless you are sure that the set was in good focus before the old tube burned out, you should check the focus with the test lamp before installing the new tube.

There are various precautions that you should observe when you are dealing with this or any other projection set. One of the most important is that you must be very careful to avoid shocks, because the tubes operate at voltages around 30,000 volts. You must also be careful not to touch the mirrors used in these systems, because they are usually silvered on their front faces and are therefore very susceptible to damage from the moisture on your fingers. If you do happen to touch one accidentally, some detergent can probably be used to clean it if you are careful. Generally, the manufacturer will specify a particular kind of detergent to be used for such cleaning. RCA, for example, recommends Dreft and water for cleaning the mirrors or the screen on their sets.

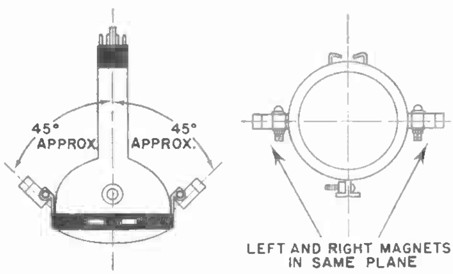
PHILCO SYSTEM

In the Philco projection television system, the picture tube is moved nearer to or farther from the spherical mirror for focusing and also can be moved from side to side to align it properly in the optical path, much as in the RCA system. However, the optical barrel is mounted at an angle, which causes the image to "keystone." This requires the use of special keystoning magnets to pre-distort the image so it will come out right, and causes the correct position of the tube to be at a slight angle with respect to the center of the spherical mirror. No test lamp is used to line up the optical system: instead, it is lined up with the set operating and with the high voltage (which in this set is about 20,000 volts) applied to the picture tube. Therefore, you should be careful about where you put your hand when you are adjusting the position of the tube.

To replace a projection tube in this system, you must first remove the spherical mirror from the bottom of the optical barrel. This is done by unlatching a strap that goes across the bottom of the mirror. Be very careful not to touch the surface of the mirror in removing it.

Next, unplug the high-voltage terminal from the tube.

There are two keystoning magnets held by a strap around the face of the tube. These magnets pick up a static charge during operation of the

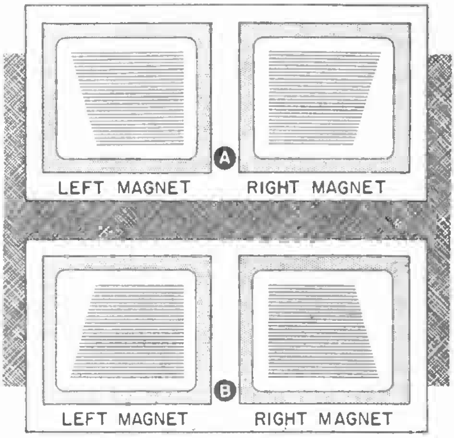


How the keystoning magnets are secured to the picture tube in a Philco projection set.

set, so you must discharge them to the chassis or the optical barrel by touching them with a grounding strap or high-voltage test lead before touching them with your hand.

The base of the tube is held by a clamp, which is at the far end of the optical barrel from the spherical mirror. Loosen this clamp and withdraw the tube.

Remove the keystoning magnets and their securing strap from the defective tube and replace them on the new tube. Orient them so that they are equally spaced with respect to the high-voltage receptacle on the tube



Part A shows the effect of under-keystoning and part B the effect of over-keystoning in a Philco projection set.

and are tilted at approximately 45° from the center line of the tube.

Slip the tube up through the deflection yoke so that its base enters the tube clamp, then tighten the clamp. Plug the high-voltage lead into the picture tube.

Focusing. Before you can adjust the optical system of a receiver using this projection system, you must produce a clear, sharp picture on the face of the picture tube, preferably with a test pattern tuned in. To do this, you must adjust the background, auxiliary background, focus, auxiliary focus, and contrast controls of the set. These are adjusted with the spherical mirror removed from the optical barrel; you must hold a small mirror under the optical barrel so that you can see the face of the tube while you are making the adjustments. The manufacturer gives detailed and specific instructions for making them.

After the picture on the face of the picture tube has been properly focused, replace the spherical mirror on the bottom of the optical barrel. You can then observe the effect of adjustments of the optical system by watching the picture produced on the screen of the set.

First, you must get the top and bottom of the picture parallel to one another. To do this, reach in through the top of the cabinet (which permits you to reach the top of the optical barrel), slightly loosen the clamp holding the picture tube, and rotate the picture tube within the deflection yoke. This changes the position of the keystoning magnets with respect to the electron beam of the tube and thus lets you make the top and bottom of the picture parallel.

If the top and bottom of the picture are not aligned with the viewing screen of the set after you have made them parallel, you must turn the tube *and* the deflection yoke within the optical barrel to make them so. To make this adjustment, reach in through the top of the cabinet, loosen the thumb nuts that hold the deflection yoke, and rotate the yoke and the tube together until the picture and the screen are lined up properly. Tighten the thumb nuts again when the adjustment has been completed.

If the sides of the picture are not parallel to each other and to the sides of the screen, the keystoning magnets are not at the proper angle with respect to the center line of the picture tube. To remedy this condition, you must remove the spherical mirror and adjust the angle of one or both magnets. Be sure to ground each magnet to the optical barrel with a grounding strap before you touch it with your hand. You must replace the spherical mirror to observe the effect of changing the position of the magnet and then remove it again to readjust the magnet position if necessary.

When you have the picture properly lined up with the screen (that is, with the sides parallel to one another and to the sides of the screen and with the top and bottom parallel to one another and to the top and bottom of the screen), you can proceed with the focusing of the set. First, use a protractor to set the angle of the lid holding the viewing screen at exactly 67.5 degrees above the horizontal. An adjusting screw at the back of the cabinet permits you to change the angle of the screen if it is not correct.

As the first step in the focus procedure, you must move the picture tube toward or away from the spherical mirror to produce a good focus at the bottom of the picture. There is a focus lever at the top of the optical barrel that you can use to make this adjustment.

When the bottom of the picture is in good focus, tilt the viewing screen forward slowly to see if the focus at the top of the picture is improved by your doing so. If it is, turn an adjusting nut at the top of the optical barrel that tilts the picture tube so that its lower edge is brought nearer the spherical mirror. Readjust the focus control lever to bring the bottom of the picture into good focus again, and again tilt the viewing screen forward slowly to see if the focus at the top of the picture improves. Repeat the adjustment as many times as necessary until tilting the screen forward no longer improves the focus at the top of the picture.

If the top of the picture is not properly focused, but tilting the screen forward makes it worse, turn the adjusting screw in the opposite direction (moving the bottom of the picture tube away from the spherical mirror). Again, repeat the adjustment as many times as needed until tilting the screen forward does not improve the focus at the top of the picture.

When the top and bottom of the picture are brought into proper focus, check the focus of the sides of the picture by tilting the screen forward slowly again. If both sides go out of focus together, the position of the tube is properly adjusted. If one side is affected more than the other, loosen locking nuts at the top of the optical barrel and slide the assembly of the tube and the deflection yoke horizontally away from the side of the picture that improved in focus. Tilt the screen forward again to check the effect of this adjustment. Repeat this last adjustment, if necessary, until tilting the screen forward makes both sides of the picture go out of focus together.

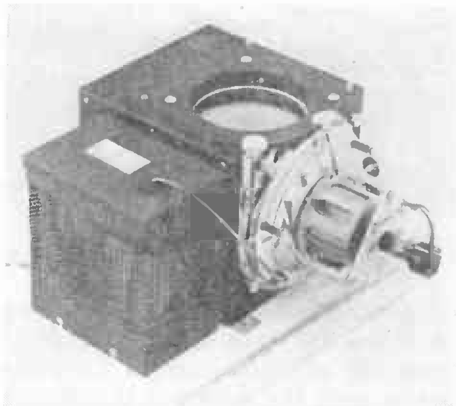
It may be necessary to go through this adjustment procedure several times to get all parts of the picture properly focused.

PROTELGRAM SYSTEM

North American Philips, the company that makes the Protelgram system, furnishes a complete optical unit and the associated high-voltage supply to various manufacturers. You can therefore expect to find this system in use in many different brands of sets.

Removal and replacement of the projection tube in this system is relatively simple, especially since it is possible to slip the whole projection unit out of the cabinet to work on it. To remove the tube, first loosen the locking nuts that secure the mounting bracket of the tube to the box in which the mirrors and the corrector lens are mounted. Next, turn the bracket counterclockwise enough to line up three slots in the bracket with these nuts. Then, withdraw the whole mounting bracket and the tube from the box, being careful not to strike the mirror through which the face of the tube projects. Unplug the high-voltage lead from the tube and loosen the clamp that holds the tube in the bracket. Slide the tube forward out of the bracket and remove the small shade that is held around the tube by a rubber band.

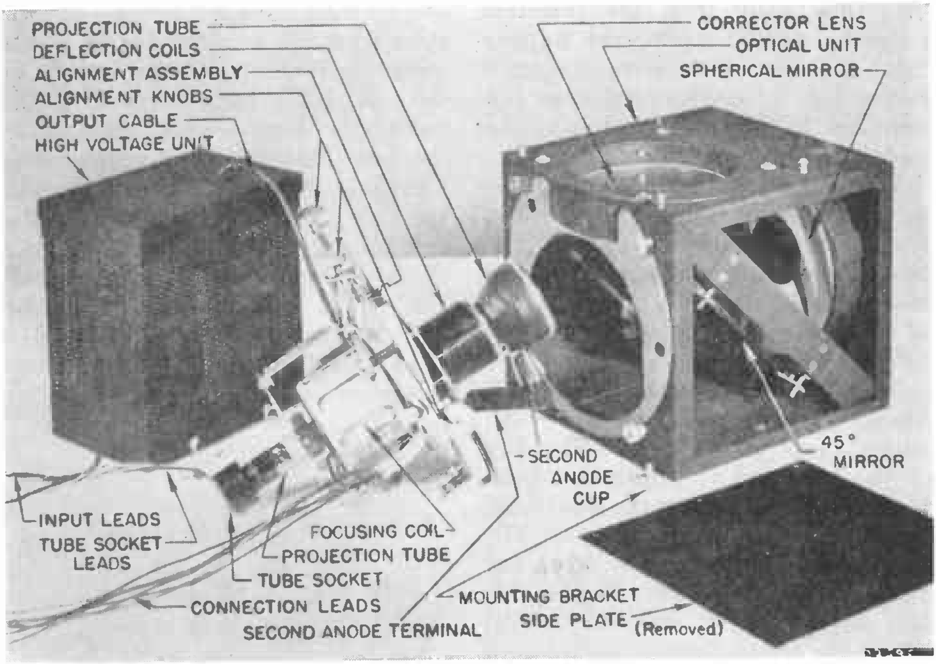
To install the new tube, reverse this procedure.



Courtesy North American Philips Co., Inc.
Outside view of the Protelgram optical and high-voltage units.

Focusing. As in the other sets we have discussed, a Protelgram optical unit is focused by moving the tube. The general procedure for focusing the unit is first to adjust electrical controls of the receiver to get the best possible focus on the face of the picture tube, preferably with the set tuned to a station that is transmitting a test pattern. Next, loosen five locking nuts on the back of the bracket that holds the picture tube.

There are three long adjusting screws on the back of the tube mounting bracket. One of these, which is at the left as you look at the tube from the base end, is the main me-



Courtesy North American Philips Co., Inc.

The components of a Protelgram optical unit.

chanical focusing adjustment; turning it moves the tube forward or away from the spherical mirror. Turn this screw until the center of the picture on the screen is focused.

If the picture is not properly aligned with the screen, align it by adjusting the Allen set screws that support the complete optical unit.

If the sides of the picture are not properly focused, turn the adjusting screw at the center of the top of the mounting bracket. Doing so moves the face of the tube up and down with respect to the spherical mirror. If this adjustment must be made, you will probably have to readjust the main mechanical focus screw.

If the top and bottom of the picture are not in equally good focus, turn the adjusting screw at the right of the tube mounting bracket. Doing so moves the face of the tube from side to side with respect to the spherical mirror. Again, an adjustment of this screw will probably make it necessary for you to adjust the main focusing screw again.

Making the Installation

Once the set has been thoroughly checked and carefully adjusted in the shop, you are ready to install it in the customer's home. This procedure includes connecting the set to its permanent antenna and orienting the antenna to produce the best possible performance. Since this subject has already been discussed in an earlier Lesson, however, we shall not repeat the discussion here.

The first step in making an installation is, of course, to take the set from the shop to the customer's home. If the shop is a moderately large one, it will usually have delivery men to do this, with the installation crew dropping around after the set has been delivered to connect it up. In small shops, the installation crew may also make deliveries.

Special precautions should be taken in transporting a receiver from the shop to the customer's home. As far as possible, it should be kept level at all times to prevent any of its parts from shifting position. To prevent its finish from being damaged, the set should be handled like a piece of fine furniture. It should be protected by quilted pads while it is in the delivery truck, and it should be held by bands or ropes to keep it from shifting around or perhaps falling over while the truck is moving.

Locating the Receiver. The location of the set inside the home is, of course, up to the customer. If he chooses a very poor location, however, you should point out the disadvantages of the location in a tactful manner and suggest a better one. Remember, if the customer gets eye strain from watching a set that is in a poor location, he will be apt to blame the set rather than its position.

In general, a set should not be located so that a bright light (such as from a window or from lamps) is behind it or near it, as at A in Fig. 7; the eye will automatically adjust itself to the brightness level of this light rather than to the brightness level of the picture, with the result that the picture will seem dark. Neither should the set be located so the direct rays of a light fall upon the face of the picture tube, as at B in Fig. 7; if they do, the apparent contrast and brilliance of the picture will be reduced, and there may be reflections and glare from the tube face and from the protective glass in front of the tube. Preferably, the set should be located so that the direct rays of any light entering the room will be

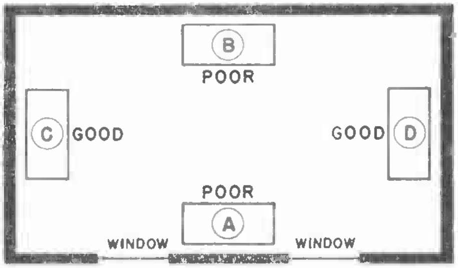


FIG. 7. Two good and two poor positions for a television set. Position A is poor because the bright light from the windows will distract the eye; position B is poor because light from the windows will be reflected from the cover glass and the picture tube.

at right angles to the line of vision of the person watching the set. Hence, from a lighting viewpoint, positions C and D in Fig. 7 are good.

To make viewing easy on the eye over extended periods of time, the room in which the set is located should be well lit from some indirect source of light. Ideally, the surfaces near the set should be almost as brightly lighted as the middle or darker grays of the scene on the picture tube. A complete absence of other light in the room is very hard on the eyes. You should point

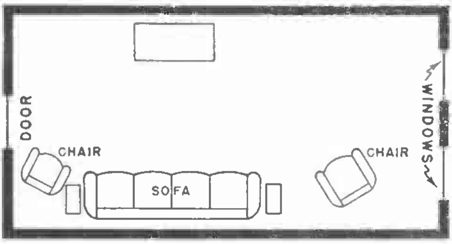


FIG. 8. A good room arrangement for watching television. All light sources are approximately at right angles to the line between the viewers and the set.

these facts out to the customer if he does not already know them.

The set should also be placed so that none of its viewers will have to watch the picture at too great an angle. A typical good location both from a lighting and a seating viewpoint is shown in Fig. 8. People sitting on the sofa or the chairs have a good view of the face of the set. If the set is a projection type, which has a rather limited viewing angle, the chairs may be a little too far to the side in this arrangement. If so, they can be brought nearer the set and pulled closer together without interfering with the view of the people on the sofa.

During the day, light from the windows will illuminate the room without lighting the face of the picture tube too much, particularly if venetian blinds are installed on the windows. At night, light from the adjacent room may be allowed to come through the door, or indirect light sources may be fastened on the wall in which the door is set. This arrangement is therefore good both from the standpoint of furnishing light at right angles to the line of vision and from that of placing all watchers at some reasonable angle with respect to the picture tube.

Always keep in mind the fact that many components in a set may prove unstable or may deteriorate rapidly if they are exposed to excessive heat. Since the set becomes quite warm in normal use, it should be located so that it can have enough ventilation. It should not be placed close to radiators or other sources of external heat, nor should any ventilation holes in the receiver cabinet be blocked by doilies or scarves. It should be located several inches out from the wall to allow heat to escape through the back.

If a table model set has ventilation holes in the bottom, as many do, it is best to mount it on the open-top tables offered by the manufacturer. In addition to permitting proper ventilation, such a table is strong enough to support the set. If the customer wishes to use his own table instead of the one offered by the manufacturer of his set, be sure that the table will be strong enough and that it will not block any ventilation holes in the set.

The proper height for a table model set depends somewhat on the furniture in the room. With ordinary living room furniture, the center of the tube face should be about forty inches from the floor. This is the height the tube will be if the table made by the manufacturer of the set is used. If the furniture is very low, however, the set should be somewhat lower than this so that it can be watched comfortably.

One other factor that should be considered in locating a set is the distance from the set to the chair or sofa from which it will be watched. The optimum viewing distance for each size of picture is equal to 6 to 8 times the height of the picture. A table of the best viewing distances for pictures of different sizes is given in Fig. 9. The viewing distance may be greater or less than the optimum distance, of course, but it is desirable to locate the set so that most of the seats will be somewhere near the right distance for the picture size.

Perhaps you feel that it is not really the business of the installer of the set to determine where it should be placed. Remember, however, that a television set is not like a radio receiver; it cannot be moved about a room readily, because its location is more or less fixed by the placement of the transmission line. Therefore, if it turns out that the customer is not satisfied with the location of his set, he will either call you back to change it or attempt to do the job himself—and in the latter case, he may injure the set or the transmission line. A poor location for the set may therefore result in your getting a call-back that could have been avoided if you had placed the set in a better location in the first place. If the customer has a service contract with you or your firm, he will expect you to change the location of the set free of charge. Therefore, you will be better off to see that the set is in a good location from the start.

SIZE OF PICTURE TUBE	OPTIMUM VIEWING DISTANCE
3"	13½"
7"	33"
10"	48"
12"	57"
16"	96"

FIG. 9. Optimum viewing distances for picture tubes of various sizes.

COMPLETING THE INSTALLATION

When the set has been placed in its desired location, it should be connected to its antenna, and the antenna should be oriented to get the best possible reception. You learned how to do this in an earlier Lesson. Once the right position for the antenna has been found, all that remains to be done is to clear up any interference that is present, to make any minor adjustments needed in the set, and to instruct the customer in the use of the controls. Clearing up interference may turn out to be a big job. However, we shall not discuss it here; you will learn how to do it in a later Lesson.

As a final test of performance, check the reception on each station. The set should be thoroughly warmed up before you make this check.

There is always a possibility that some part may shift position slightly in the set while it is being carried from the shop to the customer's home. The ion trap may slip a bit, for example, if it is one of the kind that is held on the neck of the tube by a spring clamp. As a matter of fact, if the set uses this kind of ion trap, it is a good idea for you to check its position as a matter of routine. Twist it slightly and slide it back and forth a short distance to see if the picture brightness is improved by your doing so.

Customer Instruction. When the installation has been completed, you must show the customer exactly how to operate the set. If the manufacturer supplies a customer manual, see that he gets a copy. If the customer has never owned a television set before, have him tune in each station to make sure that he knows how to adjust all the controls. Don't just show him how the controls should be adjusted—show him the effect of a misadjustment of a control, such as the fine tuning or contrast control, and then show him how to correct it. In other words, take time to make sure that the customer will be able to operate the set to his own satisfaction; you will be saving yourself a call-back or two by doing so.

As a matter of plain common sense, don't compare the performance of your customer's set unfavorably with that of other models. Even if the set is not the best one, don't mention that fact. Tell him what he can expect in the way of reception without saying that he could get better reception with a better set. Remember, he is convinced the set is a good one, or he would not have bought it.

Some customers will want to know exactly how the set works. You should do your best to tell him what he wants to know in language that he understands. If he appears to have a good technical background, you may be able to be fairly detailed in your explanation. If, on the other hand, he has no knowledge of electricity, you'll only be wasting time if you attempt to describe the operation of the set from the technical viewpoint. No matter how simple you make your explanation, however, be careful not to give him any misinformation. He may quote your explanation to his friends when they drop in to see the set; if you have misled him, and someone points this fact out to him, he will bear you a certain amount of ill will.

If you install a set during the day when there is not much on in the way of programs, it will be a very good idea for you to make an appointment to drop back some evening to see how the set sounds. Doing so will let you check up on the way the customer is operating the set as well as on the performance of the set itself.

Lesson Questions

Be sure to number your Answer Sheet 61RH-2.

Place your Student Number on every Answer Sheet.

Send in your set of answers for this Lesson immediately after you finish them, **as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. Why is it important that metal picture tubes be handled only by their metal rims?

2. What is the purpose of the two flags on the gun structure of many electromagnetic picture tubes?

3. Why is it necessary to see that the two small wire loops at the front of the cushion that supports the neck of an electromagnetic glass tube make good contact with the conductive coating on the funnel of the tube?

4. What adjustment should be made if the retrace lines are visible in a picture that is otherwise good?

5. What is the effect on the picture of setting the contrast control too high?

6. Why is it necessary to adjust the ion trap at once when the set is first turned on?

7. How can you square the picture with the picture-tube mask for: (a) an electromagnetic tube; (b) an electrostatic tube?

8. If one corner of the picture or raster on an electromagnetic picture tube is heavily shadowed, what control or controls need adjustment?

9. Why is it unwise to place a receiver with its back very close to the wall?

10. What rough rule is used to find the approximate optimum viewing distance for any size of direct-view picture tube?

Be sure to fill out a Lesson Label and send it along with your answers.

TEN SUGGESTIONS

I. Accept and welcome fair criticism.

II. Don't be a chronic grouch or petty complainer.

III. Develop a "we" and "our" attitude toward your company. Realize that what hurts company business hurts you also.

IV. Hard work brings success just as fast today as ever. Remember this—if you never do more than you're paid to do, you'll never get paid for more than you do.

V. Prepare yourself to handle the work of men above you. A good understudy is valuable.

VI. Always be ready to do new tasks.

VII. Develop confidence in your abilities, but avoid over-confidence.

VIII. Keep your head when the routine of work is varied or when an emergency arises.

IX. Don't bury your nose in the details of your job. Assign routine duties to your assistants, so you will have time for more important things.

X. Devote a few minutes each day to clear thinking about your job, your future and your company's future.

J. E. Smith

MAINTENANCE OF P. A. SYSTEMS

REFERENCE TEXT 62RX

PIONEER HOME STUDY RADIO SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE

NPC4M252 1952 Edition Printed in U.S.A.

MAINTENANCE OF P.A. SYSTEMS

PREVIOUS Lessons have shown you how sound systems are planned and installed. Now we are going to discuss keeping sound systems in good condition.

This Lesson is divided into three sections. First, we shall discuss the renovation of existing equipment to improve its performance; next, we shall study preventive maintenance procedures that should be followed to keep a system from developing complete breakdowns; and finally, we shall learn how to service defective systems.

The need for renovation usually arises when new demands are made of the system. For example, it may be desired to play music over a p.a. system that was originally intended to carry only voice. In almost every such case, you will have to improve the frequency response of the system before it will be able to reproduce music with good fidelity.

Natural aging may make equipment deteriorate to such an extent that it no longer gives satisfactory service even though it is not actually defective. Many consider the restoration of such systems to be a renovation, although it may also be classed as servicing if the final results are not better than the original response.

Preventive maintenance involves making frequent tests and inspections of a system as a matter of routine with the object of anticipating possible part failures and thereby preventing them from happening. The procedures followed in preventive maintenance often seem to be unimportant actions, since they consist mostly of inspecting components, shaking wires, removing dust, and so forth. Their value is proved, however, by the fact that a system stays in operating condition longer when these procedures are carefully followed.

Photo above Courtesy Jensen Mfg. Co.

Repairing defects in a p.a. system is much like repairing the audio system of a radio. As you will learn, however, there are certain defects that are more apt to occur in p.a. systems than in radios, mostly because a p.a. system is worked more nearly at its maximum level, so slight changes in tube characteristics or in operating potentials show up readily in reduced and distorted output. Also there are more connections between the amplifier and the input and output devices, and each joint is a possible source of trouble.

We shall consider both true p.a. systems and office intercoms in this Lesson. Although the office intercom is really just one form of public address system, the fact that it is low powered and is intended to carry only voice makes the general procedure of maintaining it somewhat different from that usually followed for a p.a. system.

Now, let's discuss the renovation of inadequate p.a. systems.

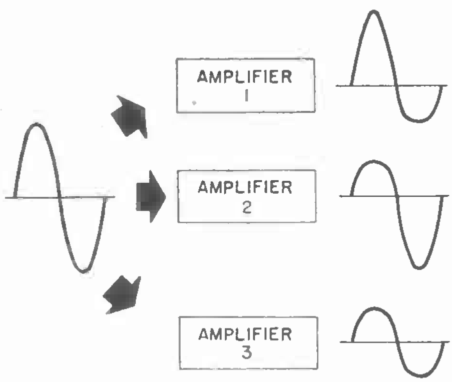
Renovating P. A. Systems

A p.a. system may distort, hum, be noisy, oscillate, or have insufficient volume without being defective in the sense that some part or parts have failed. Any one of these conditions may be bad enough (because of lower original design requirements) to require correction, particularly if greater demands are placed on the system than were originally made. Let's see why these conditions may arise, and what can be done about them.

DISTORTION

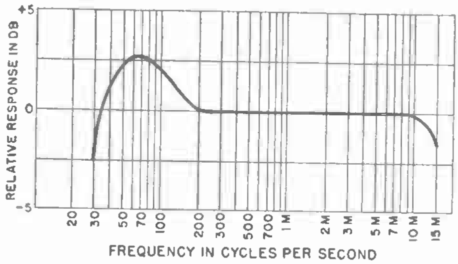
The output of a p.a. system is distorted when it differs from the original input in any way except in a uniform change in volume. There are four kinds of distortion—amplitude, frequency, intermodulation, and phase. Phase distortion is not important in practical sound work, but any one of the other three may be present to an objectionable extent. We have discussed these kinds of distortion in earlier Lessons, but, to refresh your memory, we shall describe briefly what each consists of.

Amplitude distortion is present if the shape of the output signal differs



Amplitude distortion is present when the output signal of an amplifier does not have the same shape as the input signal. Here, for example, a sine wave is applied to three different amplifiers. Amplifier 1 clips the negative half of the input signal, amplifier 2 clips the positive half, and amplifier 3 clips both halves. In each case, the output of the amplifier is distorted.

from that of the input signal. In other words, if we feed a sine wave into a p.a. system and do not get a sine wave out, the system exhibits amplitude distortion. Amplitude distortion usually results in a flattening out of one or both half-cycles of the sine wave. This means, as you have learned, that higher frequencies have been added to the original signal. If only one half-cycle is distorted, even harmonics have been added; if both are distorted, odd harmonics have been added.



This is the frequency-response curve of a typical amplifier of fairly good characteristics.

Frequency distortion is present when some frequencies are amplified more or less than the other frequencies in the input signal. An amplifier that is deficient in high-frequency or low-frequency response, or which has a peak in its response, exhibits frequency distortion.

Intermodulation distortion might also be called audio-frequency superheterodyning. It occurs when two audio frequencies are fed into a non-linear device. The result is the same as that achieved when a radio signal and an oscillator signal are fed into the first detector of a superheterodyne; that is, beat frequencies are produced that are equal to the sum and difference of the two audio frequencies. It is similar to amplitude distortion in that extra frequencies are added; these added frequencies are not harmonics of the original frequencies, however. For example, if an audio frequency of 300 cycles and another of 700 cycles are applied to some non-linear device—such as a saturated transformer—beat frequencies of 400 cycles and 1000 cycles will be produced, as well as frequencies resulting from the interaction of these beat frequencies with one another and with the original frequencies. These beat frequencies are not usually of great amplitude, but there are enough of them, when intermodulation distortion is pronounced, to cause fuzziness in the sound output. Intermodulation distortion is seldom measured for any amplifier, since there is no very easy way to measure it; in general, you can assume that a system having low amplitude distortion will also have low intermodulation distortion, although this is not true in every case.

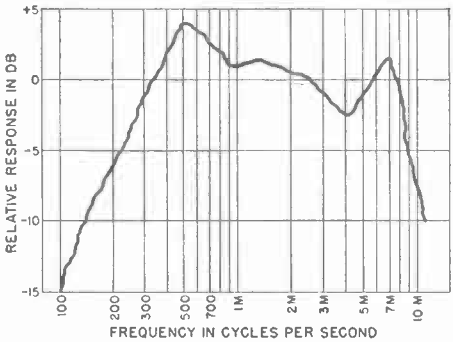
A p.a. system exhibiting any one or any combination of these distortions may be satisfactory for some limited use, such as reproducing spoken words only. However, such a system will almost invariably need renovating if it is to be used for music, since in that case the distortion will be far more noticeable.

Amplitude Distortion. Amplitude distortion may originate in the pick-up device, the amplifier, or in the loudspeaker, but its most usual source is in the amplifier. In fact, any amplifier has a certain amount of amplitude distortion. Therefore, the problem is not to eliminate amplitude distortion altogether, but to reduce it so much that it is unobjectionable. A commercial amplifier of reasonably good quality usually has relatively low amplitude distortion if it is operated conservatively—that is, if its rated output is 20% or 30% more than the power actually drawn from it.

If you are renovating a system that exhibits excessive amplitude distortion, check first to make sure that the amplifier is not being asked to supply more output than it is designed to furnish. If it is, the only remedy is to install an amplifier that is easily capable of handling the load placed upon it.

In fact, whenever new demands make the amplifier of a sound system inadequate, about the only thing you can do is replace it with a better amplifier. We are assuming, of course, that the old amplifier is in good condition but is simply incapable of furnishing all the power needed.

Amplitude distortion may also be caused by a speaker cone that has become relatively inflexible. An old cone, or one that has been exposed to dry heat for some time, may have this defect. The only cure is replacement of the cone or of the speaker.



The frequency-response curve of a typical loudspeaker. Notice how much less flat it is than that of the amplifier shown earlier.

Frequency Distortion. Frequency distortion may be caused by the pick-up device, by an audio line, by an amplifier, or by the loudspeaker. Each of these devices passes some frequencies better than others, even when it is in perfect condition, so the sound system may have marked frequency distortion without having any defective part.

You must always keep in mind the fact that the amplifier frequency response does not necessarily determine the fidelity of the sound system. Even if an amplifier has a perfectly flat frequency response throughout the audio range, the sound system in which it is used may have severe frequency distortion if any of the other elements in the system has peaks or valleys in its response. Therefore, to secure high fidelity in a sound system, you must match the components so that the overall frequency characteristic has the desired shape. Usually it is best to design the system so that it is flat in response within reasonable limits for the desired range, but in some special cases it may be preferable to accentuate the lows or highs.

When you are attempting to improve a system that already exists, you do not usually have the freedom that the original designer had. The customer will generally expect you to make as few changes as possible to give the system the performance he desires. This means that, when a system exhibits frequency distortion, your efforts will be directed toward raising the valleys or lowering the peaks in the response as economically as possible. Very often this will mean that you will change a component of the system rather than attempt to improve its response, because the time cost of your work in making such an improvement would be more than a new component having the desired characteristic would cost.

Curves are very often used in discussions of the fidelity of sound systems. Such a curve usually shows how much db variation there is in the output of a sound system at different frequencies. To the p.a. man, however, these curves have only theoretical interest. As a practical matter, it is impossible to plot such a response curve for a complete installation. It is possible to do so under laboratory conditions, using very elaborate equipment, but it is never done in practice.

These curves do have some valuable information to give you, however. For example, if a frequency response curve furnished by the manufacturer shows that the microphone to be used has a deficient low-frequency response, you know at once that the low-frequency response of the amplifier will probably need to be boosted to give a reasonably flat output. Similarly, if the manufacturer's information on the loudspeaker to be used indicates that it is deficient in response at one end or the other of the frequency range, you know approximately what change you should make in the amplifier output to correct for this condition.

However, curves that apply to general types of microphones or loudspeakers do not necessarily apply to specific microphones or loudspeakers that you may have. These curves are usually plotted for average values, and the equipment you have may not follow the average exactly. For that matter, even if the manufacturer used the particular microphone or loudspeaker you are concerned with in gathering the data for these curves, you have no guarantee that the characteristics of the device have not changed appreciably since the curve was drawn.

Therefore, the only practical use of such curves is to give the man who is designing the system some idea of how well the various components will match. If it appears from the manufacturer's information that the equipment to be used will give a reasonably flat frequency response in combination, the chances are that only small adjustments will be needed to get the desired frequency response after the installation is made.

Fortunately, it is not necessary to make measurements of frequency response when you are renovating a sound system. The object of the system, is, after all, to produce an amplified sound that will be agreeable, or at least acceptable, to the ear. Therefore, you can check the performance of the system adequately simply by listening to it. If it sounds good, it is good—regardless of whether or not a measurement of the frequency response would show it to be perfectly flat. As a matter of fact, a system that has a certain amount of frequency distortion may sound better than does one that is theoretically perfect.

There is one major difficulty you will meet, however, in testing a system by listening to it. This difficulty arises from the fact that people differ in their hearing ability and preferences. Many prefer accentuation of the low frequencies in music, for example. Consequently, you may find that a customer doesn't like the reproduction a sound system gives even though you consider it excellent.

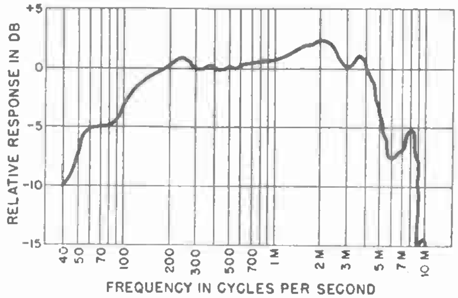
As a matter of fact, it is just about impossible to set up a sound system having a fidelity that everyone will consider satisfactory. Of course, extremely high fidelity is seldom required of a sound system unless it is to be used to amplify fine music for critical listeners. Installations of this sort are relatively rare, and usually highly trained sound engineers make them. We can, therefore, forget the problems of extremely high fidelity and instead consider only the sufficiently large problems of producing acceptable frequency response.

The process of compensating for lack of uniformity in the frequency response of a sound system is called "equalization." Usually equalization involves increasing the low-frequency and high-frequency response of the amplifier to compensate for poor response in the microphone and loudspeaker at the ends of the audio range. Sometimes this can be done satisfactorily by adjusting the tone controls of the amplifier. This is possible, however, only if the system is well designed in the first place so that the components of it are reasonably well matched. If there are serious deficiencies in response in the microphone or the loudspeaker, or if the audio line connecting the various components discriminates excessively between frequencies, more elaborate correction is usually necessary.

A microphone may have weak low-frequency or high-frequency response or may have a peak at some frequency because of mechanical resonance. When this last defect is present, sound waves of the frequency at which the microphone is resonant will cause abnormally large mechanical motions within the microphone, producing an output with a relatively sharp, high peak. This defect is characteristic of low-priced microphones; the better grades contain damping arrangements that largely eliminate mechanical resonance. The only cure for a microphone that does exhibit excessive peaking from this cause is to replace it with a better one. In some cases it is worth while to try a similar microphone in place of the one that is causing trouble, since there may be a considerable difference in their responses.

If a high-impedance microphone is used with a long microphone cable, there will be a very noticeable decrease in the high frequencies by the time the signal reaches the amplifier, because of the shunting effect of the distributed capacity of the microphone cable. For this reason, you should always use a low-impedance microphone and a low-impedance line when the microphone must be over 20 or 25 feet from the amplifier.

Weak low-frequency or high-frequency response, if it is not excessive, can usually be equalized by adjusting the tone controls of the amplifier. If not, you can insert an equalizer network in the line between the microphone and the amplifier. Such equalizers are made by several companies. Almost invariably, however, these are "losser" networks—that is, they compensate for a loss in high frequencies by reducing the low frequencies proportionately; or vice versa, with the result that the signal applied to the amplifier has the right proportion of highs and lows but is considerably weaker than the original output of the microphone. Such losser equalizers can be used only when the gain of the amplifier is great enough to overcome the attenuation they cause. Obviously, if the amplifier is working at its peak output, it cannot have sufficient reserve power to make up for the extra loss.



The frequency-response curve of a typical microphone. Like the loudspeaker, this microphone is far less flat in its response than is the amplifier. Remember that the overall frequency response of a p.a. system depends upon the responses of the individual components, not simply on the response of the amplifier alone. As a matter of fact, as you can see by examining the examples of amplifier, loudspeaker, and microphone responses given in this Lesson, the loudspeaker and the microphone vary so widely that it is they, rather than the amplifier, that determine the overall response.

If the amplifier does not have enough gain to permit you to use an equalizer, probably the best way out is to use a better microphone—unless you intend to install a new amplifier anyway, in which case you may be able to get one having sufficient gain to make the use of an equalizer possible.

Frequency distortion may also occur in the output system of the amplifier. Any one or more of these causes for frequency distortion may exist:

1. The loudspeaker may not be linear in its reproduction.

2. The baffle system used with the loudspeaker may cause a loss of the low frequencies.

3. The line-coupling transformer may cause losses at the high and low ends of the audio range and may possibly cause resonant peaks in the middle.

4. There may be loss of high frequencies in the line from the amplifier to the loudspeaker because of the distributed capacity of the line.

Frequency distortion caused by non-linearity of the loudspeakers can be minimized by using loudspeakers of good quality and efficient design instead of inexpensive and inefficient units. If fidelity is particularly important, separate loudspeakers may be used for the high frequencies and for the low frequencies. As you know, a combination of two speakers used in this manner is called a tweeter-woofer combination. Modern coaxial loudspeakers, in which the high-frequency tweeter is mounted within the cone opening of the low-frequency woofer, will give very extended coverage; the best will reproduce frequencies from as low as 30 cycles up to about 15,000 cycles with a minimum of frequency distortion.

Of course, it is useless to use an extended-range loudspeaker system when the total range of the amplifying system is restricted. For example, if the amplifier system is capable of handling a range of 70 to 8000 cycles, a loudspeaker system that will reproduce from about 60 to about 10,000 cycles will give the system the utmost fidelity of which it is capable. There would be no point in using a loudspeaker system that had a more extended coverage than this.

When a tweeter-woofer combination is installed in this system, it is necessary to use a cross-over network with it to separate the highs from the lows and feed each to its proper loudspeaker. Most high-fidelity loudspeaker systems have such cross-over networks built into them; if not, the manufacturer almost always offers a suitable network separately.

It is practical to install better loudspeakers if the original ones are cone loudspeakers. If the original loudspeakers are exponential horns equipped with driver units, replacing them with cone-type loudspeakers is possible only if the consequent loss in sound power output is not objectionable.

There is usually a distinct loss in the frequencies below 250 cycles when horn loudspeakers are used. This makes them unsuitable for reproducing music when good fidelity is wanted. Folded auditorium horns will provide a greater frequency range but are not used very often, because they are large and expensive. Cone loudspeakers enclosed in suitable baffles offer a wider frequency range than any other kind of reproducer furnishes, and are therefore preferred for faithful reproduction of music. They have several faults, however, mainly that they are limited in their power-handling capabilities and have low conversion efficiency. The fact that a cone loudspeaker has low conversion

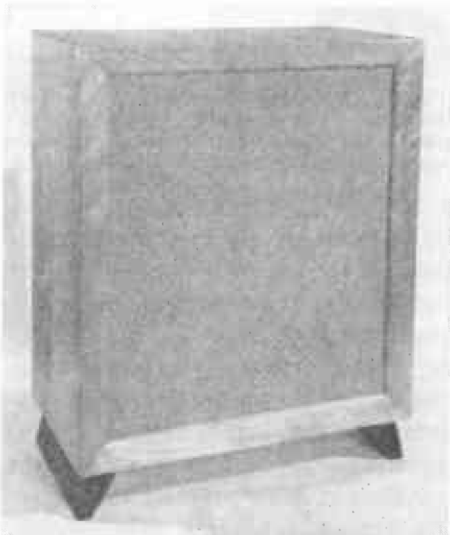
Courtesy Jensen Mfg. Co.

FIG. 1. This is a typical bass reflex loudspeaker baffle. These come in three sizes to accommodate 8", 12", or 15" loudspeakers. The finished appearance of this baffle makes it suitable for installation almost anywhere without need for concealing it.

efficiency means that it must be fed considerably more power than must be applied to a horn loudspeaker to produce the same sound output. Since a single cone loudspeaker cannot handle much power, a great many of them must be used to get a high-level output.

There are various kinds of box baffles available for use with cone loudspeakers. Of these, the bass reflex baffle is the one most commonly used. A picture of one of these baffles is shown in Fig. 1. It consists of a wooden or fiber box that is closed on all sides except the front, in which there are two holes. A loudspeaker is mounted in one of these holes; the other is a port from which emerges the sound waves caused by the movement of the back surface of the speaker cone. The baffle is designed so that the sound coming out of this port reinforces the bass.

Several manufacturers supply dual loudspeakers with matching cabinet baffles for use when high-fidelity sound output is desired. These are, of course, considerably more expensive than an ordinary wall loudspeaker. If it is necessary to use reflex trumpets because high efficiency of sound conversion is needed, it may be possible to get better low-frequency response by installing larger trumpets, which have longer air columns and



Courtesy RCA

This is another type of bass reflex baffle. Two loudspeaker units are used in it, one for high frequencies and one for low. The frequency range.the assembly can reproduce in from 75 to 12,000 cycles, and its power-handling capacity is 20 watts. The unit can be stood on the floor, or the feet can be removed to permit wall mounting.

correspondingly lower cut-off-frequencies. It is possible to get a reflex trumpet that has an air column of 6½ feet and a low-frequency cut-off of 85 cycles. A trumpet having a cut-off frequency this low is adequate for all but the most demanding installations.

An important cause of frequency distortion in the output section of a sound system is the coupling transformer used in the loudspeaker circuit. Unless it is of very good quality, this transformer may introduce losses at the high and low end of the audio band and may cause excessive peaking in the middle of the band. If an undesirable amount of frequency distortion is caused by the matching transformer, you must replace the transformer with a better one unless the adjustment of a tone control somewhere in the system makes it possible to remedy the distortion.

The output audio line going to the loudspeakers may also cause frequency distortion, just as the line from the microphone to the amplifier does. If the amplifier has sufficient reserve power, some form of losser equalization can be used that will attenuate the low and middle frequencies as much as the high frequencies are attenuated by the line, giving, as a result, a final output that is nearly flat. Such a method is particularly useful if the amplifier uses negative feedback in the output stage, and it is therefore not particularly critical with respect to changes in the output circuit impedance.

When a parallel arrangement of loudspeakers is used, it is sometimes necessary to equalize the response of one but not of the others. This may occur, for example, if one loudspeaker is some distance from the others and therefore has a long audio line running to it (Fig. 2). The equalizer used will have very little effect on the amplifier load in such a case; its presence merely means that the impedance of one of the parallel branches is increased somewhat, and this, of course,

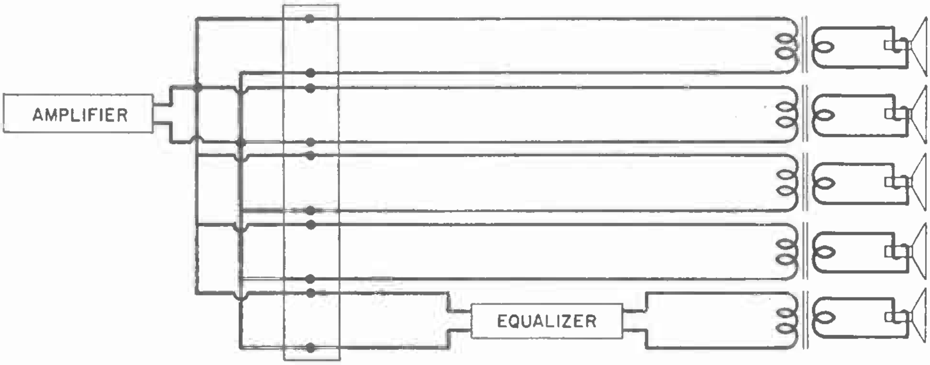


FIG. 2. An example of a loudspeaker system in which one line is equalized but the others are not. This is sometimes necessary, as the text points out, when one line is considerably longer than the others. They are all drawn the same length here because it is not customary to indicate actual line lengths on a schematic diagram of this sort; however, the presence of the equalizer in one line indicates that it is different from the others.

affects the net impedance of the parallel combination only slightly.

If equalization must be introduced in one of the lines of the parallel arrangement, however, it may be that attenuation will have to be introduced in the other lines to keep the outputs of all the loudspeakers at the same relative level. This may become necessary because of the power loss in the equalizer used in the line to the loudspeaker. The necessary attenuation can be secured by installing T pads in the lines of the other loudspeakers. These pads can be purchased commercially if you specify the db loss needed and the source and load impedances.

It is also possible that you may want to run the equalized speaker at a lower level than the others under some conditions. If the equalizer in the line does not reduce the output sufficiently, it may be necessary to use a T pad in the line also.

HUM AND NOISE

Any high-power amplifier has a certain amount of hum. Since this hum is low in frequency (120 cycles if the amplifier uses full-wave rectification), it may not be audible if the amplifier is used with loudspeakers that have poor low-frequency response. Installing loudspeakers with better fidelity characteristics during renovation of such a system may actually make the system sound worse by making the hum more audible. (Also, changing speakers may result in more acoustic feedback, thus causing a howl.) Whenever you improve the low-frequency response of a system, therefore, be on the lookout for an increase in hum. If it becomes objectionably noticeable, it may be necessary to improve the filter system of the amplifier, replace the power pack, or even install a new amplifier with a lower hum level.

Hum may also be produced during renovation if some unshielded part of the system is brought near a source of hum, such as an a.c. power line carrying heavy currents. Check over the installation to make sure this has not happened if the hum level is higher after a circuit change.

Noise in a system usually occurs only because there is some defect in the system. It is possible, however, that a change in microphones or in the conditions at the point where the microphones are may cause more noise to be picked up and reproduced than formerly. This may happen, for example, if you replace a sharply unidirectional microphone in a noisy location with one that has a more widespread pickup pattern. Choosing a microphone with a more nearly unidirectional pattern, or selecting some relatively noise-free location for the microphone, will clear up the difficulty.

OSCILLATION

Oscillation may be caused in a p.a. system either by a defect in the amplifier or by acoustic feedback from a loudspeaker to a microphone. When you have had a little experience, you will usually be able to tell easily which kind of oscillation is occurring. Acoustical howling caused by sounds from the loudspeaker feeding back to a microphone is usually in the middle register—around 2000 or 3000 cycles.

Oscillation caused by a defect in the amplifier is usually either very low or very high in frequency. If you can reduce the microphone input to the amplifier to zero and still hear the oscillation, and the loudspeaker is not so near the amplifier that it is likely to be causing actual physical movement of a tube within the amplifier, you can be reasonably certain that the defect is in the amplifier circuits. This is covered elsewhere under repair of defects. However, acoustic feedback and the resulting howling may be such that renovation of the system is desirable.

Courtesy RCA

This is another type of bass reflex baffle. Two loudspeaker units are used in it, one for high frequencies and one for low. The frequency range the assembly can reproduce is from 75 to 12,000 cycles, and its power-handling capacity is 20 watts. The unit can be stood on the floor, or the feet can be removed to permit wall mounting. This is a dual loudspeaker having an unusually wide frequency response—50 to 13,000 cycles. It is used chiefly in locations where extremely high fidelity is wanted.

There is almost always a certain amount of acoustical feedback in any p.a. system. Oscillation occurs when so much sound energy is fed back to the microphone that the production of sound by the p.a. system becomes self-sustaining. Suppose, for example, that a person speaks into a microphone over a public address system. A certain part of the amplified reproduction of the voice will be reflected back to the microphone. If the reflection is so strong that the volume level at the microphone of this reflected sound is as great as the volume level of the original sound, the amplifier will produce an output equal to the original output, and the process will be repeated over and over again. The result is that the p.a. system will produce a steady tone or howl, probably with a frequency between 2000 and 3000 cycles, because the overall amplification and feedback tend to "peak" in this range. As you can see, this is similar to the production of oscillation in an electrical circuit except that here the feedback is caused by the reflection of sound waves from the output to the input.

You can readily see that both the amplification of the system and the amount of acoustical feedback determine whether such howling will occur. If the amplification is high, even a small acoustical feedback can cause oscillation; or, if the amount of feedback is large, oscillation can occur at relatively low amplifications.

To control this kind of oscillation, therefore, either the amount of feedback or the amplification of the system must be reduced. It is easier, but less desirable, to reduce the amplification—easier because doing so merely involves turning down the volume control, undesirable because doing so puts an upper limit on the output of the system. In renovating a system, you should reduce the feedback to such an extent that oscillations will not occur even when the system is operating at full volume. We shall discuss means of reducing feedback in a moment.

Howling can sometimes also be stopped by adjusting the tone control of the amplifier. It is quite possible that a p.a. system will have peaks at one or more points in the frequency range—that is, some frequencies will be amplified more than others. It is also possible that some frequencies will be fed back to the input more than others; high frequencies are more directional than low frequencies, for example, and may therefore be concentrated toward a wall from which they are reflected very readily, with the result that the sound reflected to the microphone contains more high frequencies than low frequencies. As we said, oscillations may occur if either the feedback or the amplification is too high. If the amplifier response is greater for some frequencies than for others, or if the feedback is greater for some frequencies than for others, those frequencies may cause howling even though all other frequencies do not. If the frequencies causing oscillation can be reduced by adjustment of the tone control, it will not be necessary to reduce the volume of the whole system to prevent oscillation. Like the reduction of volume, this method of preventing oscillation is less desirable than is reducing the feedback, since it reduces the flexibility of the system. Hence, a correction of the frequency response may be the renovation step required.

Reducing Feedback. Assuming that the system does not have any loudspeaker pointing directly at the microphone, the ways to reduce acoustical feedback other than using different microphones or speakers are:

1. Move the speakers to a different location.
2. Move the microphones so that they pick up less feedback.
3. Reduce reflections in the room.

Most usually the latter is done by installing sound-absorbing material on the walls, floor, or ceiling. You learned in an earlier Lesson how acoustical material was used to reduce reflection in the room. Although we dealt with the matter there from the standpoint of the initial installation of p.a. systems, the principles apply just as well to a system that is already in existence.

Finally, the use of speakers having better back baffling and the use of modern microphones having controllable pickup patterns may both help to reduce the feedback.

INTERCOM SYSTEMS

Fidelity, hum, and noise are not usually matters of concern in an intercom system as long as speech can be understood easily over it. In fact, about the only difficulties in an intercom network that require system correction rather than servicing are lack of volume and inflexibility of arrangement.

Both these difficulties occur only in systems that have been poorly designed from the start, or that have been modified after the initial installation in the hope of extending their usefulness.

The usual reason for a complaint of low volume in an intercom system is that a remote station having no built-in amplifier is placed too far from the master. In this case, signals from the remote station may be so attenuated that they are at or below the noise level by the time they reach the master, and therefore cannot be amplified sufficiently to be intelligible above the noise level. Signals from the master will still be audible at the remote location, however, unless the line is extremely long.

The only cure is to install a master or a remote having a built-in amplifier in place of the original remote station.

In a wireless intercom system, a station may no longer receive or transmit signals when it is plugged into a different power outlet. If this happens, you can be reasonably sure that the new power output is not connected to the same branch as the other outlets used for the rest of the system. It is always possible that two outlets in the same room are not both on the same power branch, particularly in a large office building that has several main power lines. This complaint can be remedied rather simply by plugging the intercom into an outlet that is connected to the other outlets used for the system.

A part of a wireless system may transmit or receive poorly, or even fail to do so altogether, if it gets out of alignment. We will discuss the realignment of wireless intercoms later, in the section devoted to servicing.

If the system no longer provides the number of intercom stations that are desired, the renovation consists of adding the required units and using master units having the required number of switch positions.

Now, let's study the preventive maintenance procedures.

Preventive Maintenance

Preventive maintenance is a procedure carried on for the purpose of preventing trouble by anticipating it. In p.a. work, it consists of regular, frequent inspection and testing of the equipment and the installation. Such work is generally done under a service contract, under the terms of which a serviceman agrees for an annual fee to make periodic inspections and to service whatever defects he finds. This fee may or may not include the cost of replacement parts – usually not, since the fee would have to be prohibitively high to take into account such possibilities as the failure of a large and expensive loudspeaker.

Preventive maintenance, if it is properly carried out, is extremely good insurance against breakdowns. To carry it out properly, however, you will have to develop an ability to notice little defects in performance or operation that are advance indications of future part failures. Much of this ability will come with experience. It is easy enough for any one to tell whether a resistor is hot, for example, but you must have had considerable experience in maintenance work before you can decide whether it is so hot that it will burn out quickly or is just operating at a high but safe temperature that it can maintain for a long time without damage.

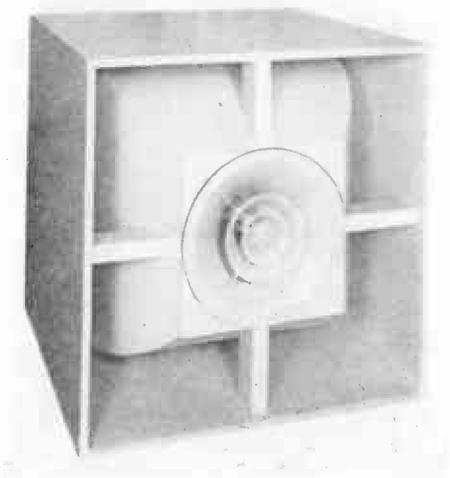
MAINTENANCE PROCEDURE

The most important step in preventive maintenance is to set up a good maintenance procedure. The procedure will depend to some extent in its details upon the specific installation, but the main features of it should be about the same for all installations. We shall, therefore, discuss the basic principles you should follow in any preventive maintenance work.

There are three things you should do on each of your periodic visits to an installation you are maintaining: You should listen to it, inspect it carefully, and make various instrument tests on it. Let's see what you can find out from each of these actions.

Listening Tests. Naturally, the first thing you should do when you make a service call is to ask the user of the equipment if there is any complaint. If he feels that the system has been performing poorly in any way, keep his remarks in mind as you go through your maintenance procedure. Whether or not he has any complaints, you should be on the alert to spot any possible causes of trouble.

Next, turn on the equipment and listen to it carefully. Listen to each of the loudspeakers to make sure that none of them is excessively noisy and that the hum level is not abnormal. If you find no such defects, run the volume and tone controls quickly up and down several times to see if doing so causes an excessive amount of noise. A noisy control should be replaced, since it will usually get worse very soon.



Courtesy RCA

This loudspeaker-baffle combination is designed for installations in which both high power and high fidelity are required. The unit has a frequency range of 50 to 11,000 cycles and is capable of handling powers up to 40 watts. As you can see, two coaxial loudspeaker units are used. These are powered by diaphragm-driven units.

Having tested the system for background noise and hum, your next step should be to try it out in operation. Have an assistant speak into each microphone and operate each record player while you listen carefully to the output of each loudspeaker. After you have had some experience, you can detect increases in distortion or loss in output that indicate the possibility of major defects in the future.

Inspection. While you are making your listening tests, you should also inspect the installation carefully.

Courtesy University Loudspeakers, Inc.

This is the University type MM-1 loudspeaker, a splash-proof marine unit that is unusually small. It has a continuous operating capacity of 8 watts. Its sealed construction makes it suitable for use in either wet or dusty locations.

Look over each loudspeaker while you are listening to it and make certain that it is firmly secured and that the cables going to it are in good condition. If a plug connection is made to the loudspeaker, make sure the plug is firmly seated. See that the shields in the loudspeaker cables make a good connection to ground.

Inspect the shielding on all other cables also. Make sure that the connections at both ends of each cable are firmly made. See that the knobs of all controls fit tightly on their shafts and that pointer knobs do not rub on their dial plates.

To make the instrument tests described a little later, you will have to open up the amplifier to some extent. When you do so, inspect all visible parts of it carefully.

See that the tubes are firmly seated in their sockets, that all shields are in place, that all soldered connections are good, and that all components appear to be in good condition. Dust out the amplifier case. Make sure all grid-cap connections are tight. In brief, use your eyes intelligently and carefully to spot any possible cause of trouble.

Instrument Tests. The most important single test on the system for you to make with instruments is a check of the tubes. This should be done each time the system is inspected. You should discard any tube that appears to be questionable. Tubes are one of the most common causes of trouble in an amplifier, so it will pay you to make a careful check.

You should also make certain voltage measurements as a matter of routine. On each service call, you should measure the output of the power supply and compare it with the reading secured on the last call. If there is a significant difference in the readings, you should discover the cause. Every now and then, also, you should make readings of the plate voltages of all tubes. How frequently you should make these voltage readings depends on the amount of use the p.a. system gets. If it is in fairly constant use, plate voltage readings should be made every three months or less; if it is used relatively infrequently, six-month or even one-year intervals may be frequent enough. Plate voltage readings will be helpful, of course, only if you have other readings with which to compare them. Therefore, you should record all such readings and compare them with those taken previously to see if you can observe any marked change that indicates the possibility of future trouble.

While you have the amplifier opened up, you should, as we said earlier, make a visual inspection of all parts that you can see.

SERVICE PROCEDURES

The discussion we have just given of preventive maintenance procedures makes no mention of the possibility of your finding defects. Naturally, when you find a condition that indicates the possibility of a defect, you must check back through the circuit or part involved to see what might be causing the condition. If you find the hum level has increased, for example, the most probable causes are that cathode-to-heater leakage has developed in a tube or that the filter condensers are losing capacity. Cathode-to-heater leakage should show up when you test the tubes, but may not if the leakage is slight or your tube tester is not well designed for the test. You can check the filter condensers by disconnecting them and testing them with a condenser tester, if you have one, or, if not, by temporarily connecting a filter condenser you know to be good in place of the one you suspect. These, of course, are servicing techniques, which we shall discuss in the next section of this Lesson.

Courtesy RCA

This illustrates one way of suspending a microphone so that it can be raised or lowered easily. Suspensions of this sort are frequently used in boxing and wrestling areas to hold a microphone over the ring. When you inspect an installation of this sort, make sure that the microphone is supported only by the ropes and not by the microphone cable.

As a matter of fact, preventive maintenance becomes servicing as soon as you find any indication of an actual or possible future defect in the system. Now, let's see what techniques are particularly useful for servicing p.a. systems.

Servicing P. A. Systems

A public address amplifier is essentially the same thing as the audio amplifier of a radio, except that it usually has much higher power, and the servicing techniques used for the one are not much different from those used for the other. In our discussion of p.a. servicing, therefore, we shall make use of the knowledge you've already gained about the servicing of radios.

The most common defects of p.a. systems are oscillation or motorboating, hum, noise, low volume, no output, distortion, and intermittent operation. (These are not necessarily arranged in this list in order of relative frequency of occurrence.) Naturally, to service a p.a. system exhibiting any of these defects, you should isolate the defective stage, circuit, and part with the aid of the servicing techniques you have already learned. To assist you to do so, we shall now discuss each of the defects a p.a. system may be expected to exhibit and point out the most common causes for each.

Before we go any farther, we want to give you a word of caution. *Never disconnect a loudspeaker from an amplifier while it is in operation.* If there is only one loudspeaker in the system, disconnecting it while the amplifier is operating may ruin the output tubes because the removal of the load will cause a very high peak voltage to appear across them. If several loudspeakers are used, disconnecting one may cause the others to be overloaded and damaged. By the same token, you should never turn on an amplifier without making certain that the output stage is properly loaded.

In addition, don't try to operate a system with the speaker driver unit out of the horn or baffle. The lack of proper loading on the cone or diaphragms permits overdriving, which results in a ruined cone or diaphragm.

OSCILLATION AND MOTORBOATING

Oscillation in a p.a. system can be caused either by acoustical feedback of sound from the loudspeaker to the microphone or by a defect within the amplifier. We discussed acoustical feedback in the first part of this Lesson, since it is not really a service defect.

Correcting oscillation caused by a defect within the amplifier is done with the aid of the same methods you'd use to correct a similar defect in an ordinary radio. Oscillation in an audio amplifier usually takes the form of motorboating (oscillation at a very low frequency). Its most usual cause is a defect in a filter or by-pass condenser that causes an increase in gain or permits greater feedback. A condenser that is open or has lost capacity or has an increased power factor may cause oscillation. Any defect that changes bias, screen, or plate voltages so as to increase the gain of the stage may also cause oscillation, but is not as apt to do so as is a condenser defect.

HUM

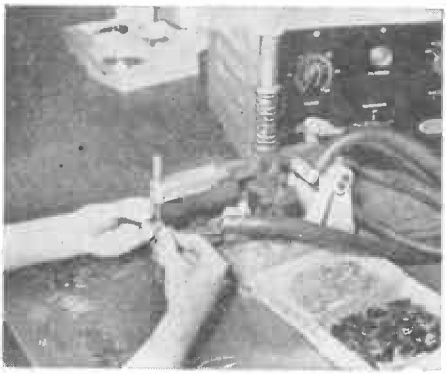
Hum in a p.a. system is most usually caused by a defective filter condenser or by cathode-to-heater leakage in a tube. In some amplifiers, hum may also become evident if the output stage becomes unbalanced because of differences in the characteristics of the tubes. This can happen, of course, only in an amplifier in which the balanced characteristic of the output stage is depended upon to remove some hum.

Hum in the output of a p.a. system may also be caused by pickup from external sources. Microphone and loudspeaker cables are supposed to be completely shielded; if a poor connection develops between the shield and the amplifier chassis, however, hum may be picked up. Perhaps the most common cause of faulty shielding is a poor, high-resistance contact between the amplifier and the plug at the end of the shielded cable.

Hum may also be picked up directly by a microphone that is near some device that hums. Even an electric clock has been known to cause enough hum to be picked up and amplified by a microphone located near it.

NOISE

Noise is another condition that may be caused by something completely separate from the p.a. system. For example, a customer may complain that there is a great deal of noise in the system when one of his favorite records is played over it. You can almost be sure when you hear a complaint of this sort that the record has simply been played too often and is noisy. The system itself, of course, is not to blame, unless noise is present all the time.



Courtesy The Astatic Corp.

In a microphone factory, the leads of crystal microphones are spliced by spot welding. This procedure, which is very quick, does not heat up the crystal enough to damage it. It is easy to get a crystal hot enough to ruin it, however, if you attempt to solder the leads, because the soldering iron must be held against the leads for an appreciable time.

The customer may also complain that

the system is noisy when the noise is actually picked up by the microphone. This, too, is a condition that cannot be blamed upon the system.

You yourself would not be likely to make a mistake in diagnosis of the difficulty in either of these cases. Remember, however, that the owners and users of p.a. systems are not necessarily technical men, and they often have a marked tendency to blame every difficulty upon the system instead of looking for possible outside causes.

stage or by an open input circuit. Noise results from a defect of this sort because the grid of the amplifier stage is then able to "float"—that is, it develops a very high impedance to ground. Even very small noise currents developed through this impedance will produce an appreciable grid signal. This trouble may be caused by a poor connection at a microphone cable plug such that the cable shield does not ground satisfactorily to the amplifier chassis.

Noisy operation is often caused by defective faders or variable attenuators. You can determine whether a control is defective by adjusting it throughout its range at varying rates of speed. If you hear a crashing noise when you do so, the control is at fault.

Courtesy The Astatic Corp.

At the factory, skilled technicians inspect damaged microphones minutely, using special equipment like the microscope shown here. A microphone is too delicate a piece of equipment to be pryed into by someone who does not know exactly what he is doing.

There are many defects that can cause noise in a p.a. system. A defective tube is a frequent offender, particularly one that has loose elements that may intermittently short-circuit if the tube is vibrated. A noise resulting from this cause usually consists of a loud crashing sound that occurs only at intervals.

A more or less steady, roaring sound may be caused by an open grid circuit in a voltage amplifier

If you hear a rattling noise from the cone loudspeaker, the chances are that the cemented edge of the cone has come loose. It is, of course, easy to determine whether or not this has happened by inspecting the loudspeaker. If you are within the range of two loudspeakers, however, it is often rather difficult to tell from which the sound is coming. The easiest way to do so is to reduce the volume until you can hear a loudspeaker only when you are very close to it; unfortunately, doing so may mean that the loudspeaker will be driven so little that it does not rattle appreciably even though it is loose. In this case, disconnect one of the two loudspeakers from the amplifier. (Of course, the amplifier should be turned off before you do so.) Operate the system then at a fairly high volume level to be sure that rattling will occur if the cone is loose. Do not, however, allow the volume level to become so high that the loudspeaker will be overloaded; remember that there is now more power available because the other loudspeaker is disconnected.

With the loudspeaker removed, there will be an impedance mismatch at the output of the amplifier that may cause distortion. Pay no attention to the distortion, since it will be removed when the proper impedance match is made again.

LOW OUTPUT

Low output in a p.a. system may be caused by any of the defects that cause the audio amplifier section of a radio to be weak. In addition, there are some defects that may be found in a p.a. system that you would not ordinarily find in a radio. For example, many of the more complicated p.a. systems have terminal boards to which the leads from the loudspeakers are brought. It is always possible that one of the connections in this terminal board has become poor, either through corrosion or through someone's accidentally having loosened it. There may also have been some mechanical injury to one of the loudspeaker cables that broke some of the strands of wire in the cable and so increased its resistance considerably. The loudspeaker itself or the input device may also be to blame. Later on, in a section on microphones, we shall discuss some of the defects that may cause the microphone output to be reduced.

Remember, also, to look for some very obvious cause of reduced volume, such as a failure by the user to adjust the volume control correctly.

In an installation in which multiple speakers are used, a defect that causes a short circuit or partial short circuit across the line to one loudspeaker reduces the overall volume output of the system for two reasons: first, because the output from the shorted loudspeaker is lost, and second, because the impedance of the speaker combination is changed, causing a mismatch that wastes power. You can locate a defect of this kind by listening carefully to each loudspeaker to determine which has the lower output.

If a great many loudspeakers are used, it is sometimes helpful to disconnect them all from the amplifier and feed a signal from some other source, such as a signal generator, into each line individually to determine which one is at fault.

DEAD SYSTEM

When you receive a complaint that

a p.a. system is dead, your first step should be to make sure that the amplifier is plugged in and that the power is turned on. It is surprising how often such a simple and obvious cause for a dead system is overlooked by the owner.

Next, if the system has multiple inputs, check each of them. Sometimes the user of a p.a. system will assume that the whole system is dead when he gets no response from one input. If all inputs are dead, the trouble is in the amplifier or in some common connection to the loudspeaker system. If only one input circuit is dead, the defect must be in the preamplifier channel employed for this input device, in the input device itself, or in the cables connecting it to the amplifier. The easiest way to tell which is to blame is to try another input device (microphone or phono pickup) on the input terminals of the defective channel. If the test device works, then the original device or its cables is to blame. In this case, apply a test signal to the cable with the input device removed; if the system then operates properly, the original input device must be defective. Incidentally, it would be a good idea for you to include with your servicing equipment a test microphone that you know is in good condition, a record player, and perhaps an audio oscillator, for use when you want a test signal source.

Courtesy The Astatic Corp.

Precision and care are required to reassemble a microphone after it has been repaired. The man who does so must be experienced if he is to do a good job.

If all the input circuits are dead, check the connections between the amplifier and the loudspeaker. If the loudspeakers appear to be connected properly to the amplifier, very likely the amplifier itself is defective. You can then follow the usual service procedure to locate the defective part. If the amplifier has a fuse, check it first before looking for other components that may be defective. If you do find that a fuse is blown, install another and then operate the amplifier for a reasonable length of time to make sure the fuse does not blow again. If it does, there is some other defect in the amplifier that you must locate. If, however, a replacement fuse does not blow within about five minutes, check the leakage of the filter condensers and the plate voltages of all tubes. If the filter condensers are not excessively leaky, and the plate voltages are not above normal, it is unlikely that there has been any long-time overload that has caused the fuse to blow. In this case, you can assume that some defect of a temporary nature, such as a power surge on the line, caused the original trouble.

If the fuses in a given place

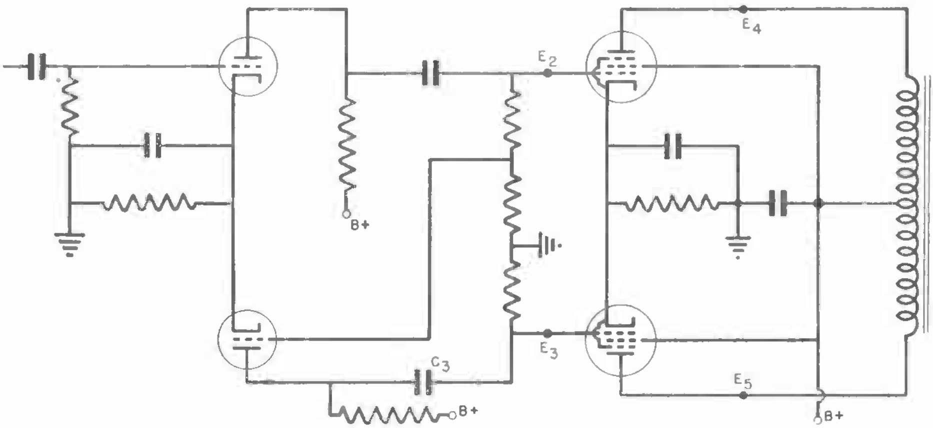


FIG. 3. Typical output stage of a p.a. amplifier.

blow rather frequently, you should check the line voltage to make sure that it is not excessively high. If the line voltage is above 130 volts, report the fact at once to the power company, because there is very possibly some defect in the power line itself. If the line voltage is slightly under 130 volts, the chances are that the amplifier is a little too sensitive to supply voltage variations, although it would work perfectly well in the usual supply voltage range of 110 to 115 volts. In such a case, you should consider installing a voltage-dropping resistor in the supply line to the amplifier if it appears that the high line voltage is to be present constantly. If you do use such a voltage-dropping resistor, be sure that its dissipating ability is sufficient for the power it must handle.

DISTORTION

We mentioned distortion earlier in the section on system renovation. Since we described there the defects outside the amplifier that might cause distortion, we shall deal here only with the internal defects that may cause a system to distort.

Distortion may be caused in a p.a. amplifier by any of the defects that will cause distortion in the audio amplifier of a radio. In addition, an unbalanced output stage, which would usually cause relatively little distortion in a radio, will produce very appreciable distortion in a p.a. amplifier because of the high power levels in such equipment.

Fig. 3 shows a typical output stage in a p.a. system. Any defect that could cause an unbalance in this stage could cause distortion. If condenser C_3 were to open, thus reducing the signal fed to one of the output tubes, the output of the amplifier would be very much distorted because of the loss of push-pull action. There would also be a loss in volume, although this would not be noticeable until the volume control was turned well up; at low volume levels, either output tube could supply sufficient signal.

A vacuum tube voltmeter can be used to determine how well the output stage is balanced. While a test signal is applied to the input of the amplifier from a sine-wave audio generator, measure the voltages between the circuit components and ground at the points marked E_2, E_3, E_4, and E_5 on the diagram. If the stage is well balanced, E_2 should equal E_3, and E_4 should equal E_5.

An oscilloscope is also a useful instrument when you are trying to locate the source of distortion. The method of using the oscilloscope for this purpose was described earlier in your Course.

Again, the use of multiple pickups and loudspeakers gives a p.a. system possible sources of distortion that do not exist in a radio.

If a p.a. system uses two or more pickup devices and two or more loudspeakers, you will be able to localize the source of the distortion rather easily. If the distortion is heard when one microphone or record player is used but not when the other is used, then almost certainly the source of the distortion is in the first device. Similarly, if the distortion is heard on one loudspeaker and not on others, then the one on which it is heard must be defective. If the distortion is the same regardless of which pickup device or which loudspeaker is used, the amplifier is probably to blame.

INTERMITTENT DEFECTS

A p.a. system is subject to all the intermittent defects that the audio system of a radio has. Going dead intermittently is probably the most common defect, but any of the others we have described can also occur intermittently.

Loose connections, frequently the cause of intermittent defects, are more common in p.a. systems than in radio receivers. One reason is that there are usually many more connections of the sort that are frequently made and broken in a p.a. system—connections to loudspeakers or microphones, for example. Such connections are naturally much more likely to become defective.

Most intermittent defects have only one symptom: That is, a system hums intermittently, or goes dead intermittently, but does not do both. Occasionally, however, a system will have dual defects—for example, an intermittent loss of output accompanied by distortion. This is usually caused by a voice coil circuit that opens intermittently. If the voice coil is slightly off-center, it may rub against the pole piece enough to wear off the enamel insulation from the coil wire; the coil may then short circuit intermittently to the pole piece and, through it, to the voice coil terminal that is grounded to the frame of the loudspeaker. This is much the same thing as putting a short across the secondary of the coupling transformer feeding the voice coil. As a result, the output from the defective loudspeaker is reduced or killed completely. The changed impedance of this loudspeaker will also destroy the impedance match between the amplifier and the loudspeaker system, and will therefore probably reduce the output of all the loudspeakers to some extent.

Even though the output of each loudspeaker will be reduced by such an occurrence, the output of the defective loudspeaker will be affected by far the most. Therefore, you can locate the defective loudspeaker by listening to each of them and determining which is the worst. This may, of course, be difficult if the intermittent operation occurs for only a short period of time.

If you have a sensitive ohmmeter, you can check the suspected loudspeaker rather easily. All you need do is measure the resistance of the voice coil circuit and see whether it changes when the voice coil is moved in and out. You will need a good ohmmeter to do this, since the resistances involved may be of the order of 1 ohm. If the ohmmeter is not quite this sensitive, you can disconnect the voice coil from the output transformer and measure the voice coil resistance alone. Doing so lets you measure a somewhat higher resistance, since then the very low resistance of the secondary of the line-matching transformer is removed from the circuit.

Alternatively, you can open the voice-coil circuit and place the ohmmeter in series with the voice-coil transformer and the voice-coil. In this case, the resistance you measure will be slightly higher than that of the voice-coil. Whatever method you choose, the indication of voice-coil trouble is a change in resistance as the voice-coil is moved.

Courtesy The Astatic Corp.

Highly specialized equipment is needed to calibrate a microphone after it has been repaired. This picture shows a calibration run being made on a microphone at the Astatic factory. Don't attempt microphone repairs yourself—send the microphone back to the manufacturer.

ALIGNING A WIRELESS INTERCOM

As you recall, a wireless intercom uses the power line as a means of propagating a modulated carrier signal. The carrier frequency on most is around 100 kc. This frequency can be changed up or down by a factor of 25% so that as many as three systems can be used near one another without interfering with each other. For example, the units in one system may be tuned to 120 kc., the units in the second system to 100 kc., and those in the third to 80 kc. Since all three carrier signals will be present in one power line, it is necessary for each unit to accept a bandwidth considerably less than 20 kc. to make sure it will not pick up a carrier that is not intended for it.

It is easy enough to align a wireless intercom to a specified frequency if you have a signal generator. Simply connect the signal generator to the input of the intercom, set the generator to the desired frequency, and turn the tuning trimmer condenser until you get a maximum response. (Most wireless intercoms use trimmer condensers to tune their input circuits.) Tune the other unit of the pair in exactly the same manner. Then, check your work by transmitting from one unit to the other and back from the second unit to the first. While one unit is operating, make small adjustments of the trimmer on the other to make sure that you have the point of maximum response. Do not adjust both units, however, since doing so may get you too far away from the frequency you want.

If you do not have a signal generator when you are attempting to align a wireless intercom, you can probably do a satisfactory job by turning the trimmers on both units all the way in, backing both off a quarter of a turn, and then adjusting one unit for maximum response while someone talks steadily into the other unit. When you have peaked one unit in this manner, reverse the procedure and peak the other while someone is talking into the one you have already adjusted. If you wish to add another system, turn the trimmers on both units on that system until they are a quarter of a turn from being all the way out and repeat the tuning procedure. Finally, if you wish to add a third system, set the trimmers of the two units half-way between the full-in and full-out position and again repeat the tuning procedure. In each case, be sure that you make only small adjustments during the alignment procedure so that you will stay fairly close to the point at which you initially set the condensers.

MICROPHONES

Microphones are extremely delicate devices and must be handled with great care. In fact, it is almost impossible for you to service one successfully unless you have had some special training in this delicate work. It is not even possible to test them successfully without special equipment. Therefore, never open a microphone on the assumption that you can poke around in it, find out how it works, and fix it. If the microphone is dead, return it to the manufacturer for repairs.

As a matter of fact, it is impossible to make a direct test of a microphone without special equipment normally used only in factories. About the only practical test that a serviceman can make is to install a microphone he knows to be good in place of one that he suspects of being defective. If the response of the system improves when the good microphone is installed, then either the original microphone is defective or its matching transformer and connecting cable are defective. Of course, the test microphone you install should be of the same type as

This is the service shop of an NRI graduate who does p.a. work as a sideline. Notice the trumpets and microphone at the right of the picture.

the one of which you are suspicious.

It is possible to test the microphone cable for continuity, but the microphone should be disconnected from the cable before you make such a test. An ohmmeter must never be connected to a microphone, because even the relatively small d.c. voltage of an ohmmeter can damage certain types of microphones severely or even ruin them.

Substitution of a good microphone is the only way you can tell whether or not a suspected microphone is deficient in its frequency response or in its output. These qualities of a microphone are tested by the manufacturer, but the method used is not practical for a serviceman. At the factory, the microphone under test and a standard test microphone are placed in a room that has had special acoustic treatment. Pre-determined amounts of sound power at various frequencies are then fed into both microphones, and the outputs of the two are compared as to amplitude and frequency response. No method that is less elaborate has been discovered for checking microphones accurately.

As you can see, a microphone that is bad is not something you can service. There are, however, certain practices that you can follow that will extend the useful life of microphones. We shall tell you what they are, and you can pass along the information to the owner of a p.a. system so that he can make his microphones last longer.

Microphone Precautions. Every velocity or dynamic microphone has a powerful magnet built into it. For this reason, none of these microphones should be placed on a workbench or any other place where it might pick up iron filings. The housing contains a metal screen around the diaphragm of such a microphone to prevent bits of metal from entering it, but iron dust or very small filings can work their way in if given a chance.

Care should be taken to keep any velocity or dynamic microphone away from alternating current fields, because such fields can partially demagnetize the magnet, thereby causing reduction in output and narrowing of the frequency range. For this reason, keep such microphones well away from power transformers and power lines, particularly lines carrying heavy current.

Velocity microphones of the ribbon type, which are normally used only when extremely high fidelity of pickup is required, are very delicate. They must be handled with great care. For example, they should always be carried or moved in a normal operating position—that is, held upright so that the ribbon is in a vertical plane. Carrying such a microphone horizontally lets the ribbon sag and stretch. Any jarring or rough handling may cause the ribbon to move so far that it will be stretched out of shape or stick to one of the magnets between which it is suspended.

The magnets of a velocity microphone may themselves shift in position if the microphone is jarred or roughly handled. The location of these magnets with respect to the ribbon is very important to the proper operation of the microphone, so even a very slight shift in position of one or more of the magnets may destroy the fidelity of the microphone or even prevent it from operating altogether.

A strong blast of air on a ribbon microphone is certain to damage the ribbon and perhaps ruin it. Such a microphone must, therefore, be well protected from the wind if it is used outdoors. No one should be allowed to speak into it from very close range. In particular, you should never whistle directly into a ribbon microphone to test its operation.

The crystal unit in a crystal microphone can be damaged by heat, excessive humidity, or mechanical jarring. Therefore, such microphones should be kept away from extreme heat and dampness and should be kept out of direct sunlight as much as possible. They should be protected, also, from excessive shock and vibration.

Let us repeat one important warning. *Do not try to repair a microphone; return it to the manufacturer for repairs.* It is almost invariably less expensive to have a microphone repaired than to buy a new one.

THOUGHT

Many years ago, Carlyle wrote this tribute to *thought*—to men who think—to institutions which help men think:

"How noiseless is thought! No rolling of drums, no tramp of squadrons or immeasurable tumult of baggage-wagons, attends its movements. In what obscure and sequestered places may the head be meditating, which is one day to be crowned with more than imperial authority. It will rule not over, but *in*, all heads, and with its combinations of ideas, as with magic formulas, bend the world to its will! The time may come when the victory of Waterloo prove less momentous than the opening of the first Mechanics' Institute."

How true Carlyle's observations have proved to be! Waterloo is still famous in history—but of much less importance to the world's progress, than are hundreds of modern developments made possible by men trained to *think!*

J. E. Smith

TV INTERFERENCE ELIMINATION AND SPECIAL TV INSTALLATIONS

62RH-2

PIONEER HOME STUDY RADIO SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 62RH-2

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

JD3M652 1952 Edition Printed in U.S.A.

TV INTERFERENCE AND SPECIAL INSTALLATIONS

CONVENTIONAL TV receiver installations have been discussed in previous Lessons. The instructions given in those Lessons cover most of the problems you will meet. However, you may run into some special problems—heavy and constant interference, for example—that make an installation particularly difficult. This Lesson will show you what to do when you meet these unusual conditions.

First, let's take up the problem of eliminating ghosts.

GHOSTS

You have already learned that ghosts may be caused when a signal reaches the antenna over two or more paths or when the receiver and the transmission line are not matched in impedance. Ghosts of the first sort can often be eliminated by orienting the antenna so that it does not pick up the reflected signals; and those of the second kind can be gotten rid of by matching the line impedance to that of the receiver.

There are, however, some conditions under which orienting the antenna will not eliminate the ghosts completely. One of these occurs when the object that reflects signals to the antenna is close behind the antenna. In this case, it may well be that the reflected signal is so strong that even a very directive array cannot ignore it completely. You have probably noticed that the antenna radiation patterns shown in earlier Lessons always have at least a small back lobe. The presence of this lobe indicates that the antenna picks up from its rear to some extent. If the signal coming from the backward direction is very strong, therefore, it will be picked up by the antenna sufficiently well to cause a ghost.

The remedy for this condition is to use a large reflector to shield the antenna from the undesired signal. A large screen of chicken wire will often serve the purpose. Of course, you should not go to the trouble of erecting such a screen unless it is absolutely necessary to do so.

A ghost that is very difficult if not impossible to eliminate is caused when the reflected signal comes from almost the same direction as the direct signal. An example of the conditions that can cause such a ghost is shown in Fig. 1. Here there may be as many as six ghosts caused by reflections from six different structures.

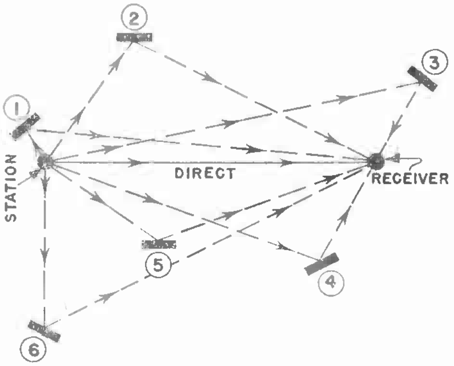
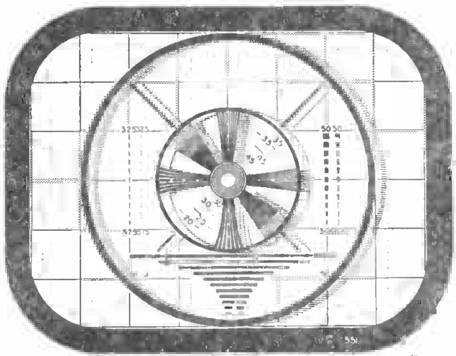


FIG. 1. A set in the location shown may receive as many as 6 reflected signals in addition to the direct signal, making it possible for there to be 6 ghosts.

If we use a directive antenna and point it for maximum pickup from the TV station, the chances are that the signals bouncing off the buildings marked 3 and 4 will be eliminated. We may even be able to eliminate the signals reflected from the buildings marked 2 and 6. However, we will not be able to eliminate the reflection from the buildings marked 1 and 5, because the reflected signals come from practically the same direction as the transmitted signal.

The only hope of getting ghost-free reception in a location of this sort lies in using a highly directive antenna array and aiming it so that it will pick up one of the reflected signals and nothing else. In the situation shown in Fig. 1, it might be possible to prevent ghosts by aiming the array at building 3. If the array were highly directive, you could probably eliminate pick-up of all other signals—including the direct one—by doing so.

A ghost may be either a "positive" or a "negative" ghost. A negative ghost is reversed with respect to the original image. In other words, the black portions are white, and the white portions are black. Whether a ghost is positive or negative depends upon the phase relationship of the direct and reflected signals, which, in turn, depends upon the relative lengths of the direct and reflected paths. Changing these path lengths by moving the antenna will make the ghost change from positive to negative or vice versa. The usual type of ghost is called a "trailing" ghost because it appears on the right-hand side of the picture (see Fig. 2). The ghost appears on the right side because the reflected signal travels a longer path than the direct signal and therefore arrives at the set later than the direct signal. Under certain conditions, however, one or more of the images may appear on the



Courtesy Belmont Radio Corp.

FIG. 2. An example of a single trailing ghost.

left-hand side of the main picture, producing what is called a "leading" ghost.

This type of ghost may appear in locations where conditions like those shown in Fig. 3 exist. The location is comparatively close to the transmitter; as a result, it is possible to pick up a fairly strong signal in the r.f. or first detector circuit of the receiver even with the antenna disconnected. This direct pickup in the front end of the set may produce a ghost to the left of the main picture because the path from the TV station directly to the front end of the receiver is shorter than the path from the TV station to the antenna and down the transmission line. If the transmission line is less than 100 feet long, the direct signal may not produce a separate image but may instead blend with the antenna signal to create a picture of poor quality.

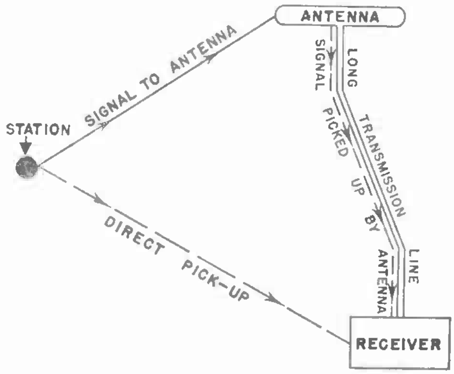


FIG. 3. Under the conditions shown here, a leading ghost may be produced.

The remedy for such a condition is: (a) to reduce the direct signal pickup in the receiver by shielding the r.f. and detector circuits or by shielding the entire chassis; or (b) to increase the signal from the antenna. Of the two, reducing the direct signal pickup in the receiver is the more effective, because usually in a location close to the transmitter the signal picked up by the antenna is already extremely high.

In many cases where direct signal pickup by a receiver causes a leading ghost, the picture will vary in quality when people move around the room near the receiver. Movement close to an unshielded transmission line may also alter the picture quality, particularly if the input impedance of the receiver does not match the impedance of the transmission line.

Another situation that can produce a leading ghost is shown in Fig. 4. In this case, the strength of the direct signal from the transmitter is greatly reduced by the intervening object. For this reason, the reflected signal reaching the receiver is stronger than the direct signal and therefore produces the main picture. However, since the direct signal route is the shorter of the two, the direct signal will arrive before the reflected signal and produce a leading ghost.

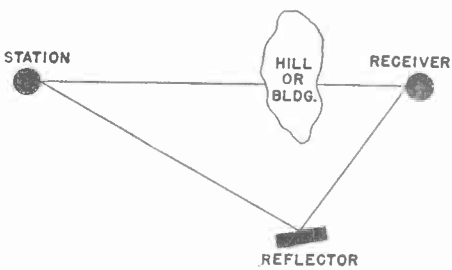


FIG. 4. Here, a leading ghost is produced because the reflected signal is much stronger than the direct signal, although the latter reaches the set first.

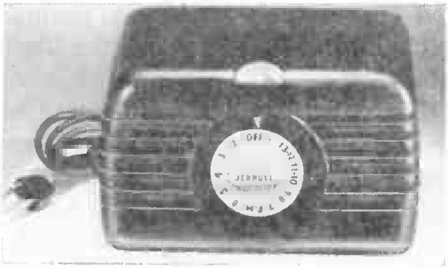
To eliminate this undesirable effect, the direct signal pickup must be eliminated. This can be done by using a directive antenna and orienting it properly.

In one actual case where leading ghosts were encountered, more than 10 distinct images were seen on the picture tube with the antenna connected to the receiver and the controls adjusted properly. Disconnecting the antenna without changing the setting of the contrast control reduced the number of images. This indicated that the antenna was contributing little and that the pickup was mostly in the r.f. and detector circuits—the numerous images probably being due to signals reflected from buildings or other objects in the vicinity.

In this particular case, shielding the r.f. and detector circuits did not help. Further experimentation indicated that there was a defect in the r.f. stage of the receiver that had reduced its gain very considerably; as a result, the signal picked up by the antenna was not being amplified very much, so the antenna was contributing very little to the picture. When the defect in the r.f. stage was corrected, it was found that the signal picked up by the antenna was so much stronger than the reflected signals that the ghosts were no longer noticeable.

Thus, it is not always wise to blame a ghost on the location or on the orientation of the antenna. Unusually heavy ghosting may be caused by a receiver defect.

If you find "tunable" ghosts—ghosts that vary in number and in intensity as the tuning control of the set is adjusted—you can be sure that the receiver itself is to blame. These ghosts may be caused by incorrect alignment of the i.f. amplifier or by regeneration.



Courtesy Jerrold Electronics Corp.

The Jerrold booster, shown in schematic form in Fig. 5.

BOOSTERS

In this and earlier discussions of the various methods of eliminating ghosts, we have pointed out that frequently ghosts can be eliminated only by using a highly directive antenna and pointing the antenna to pick up one of the reflected signals rather than a direct signal. Almost always such a reflected signal will be weak. If so, the signal can generally be brought up to usable strength by using a booster. The schematic diagram of a typical booster is shown in Fig. 5.

A booster is nothing more than a broad-band r.f. amplifier, much like the r.f. amplifier used in the front end of the television receiver. In fact, it is used as an extra r.f. stage ahead of the one in the receiver: the transmission line is connected to its input terminals and the receiver to its output terminals. It may give more than one extra stage of r.f. amplification: although many booster amplifiers, like the one illustrated in Fig. 5, use only one tube, others use two or more.

Some boosters have a continuous fine-tuning control that permits the device to be tuned over an entire TV band, with a switch being provided to change from one band to the other.

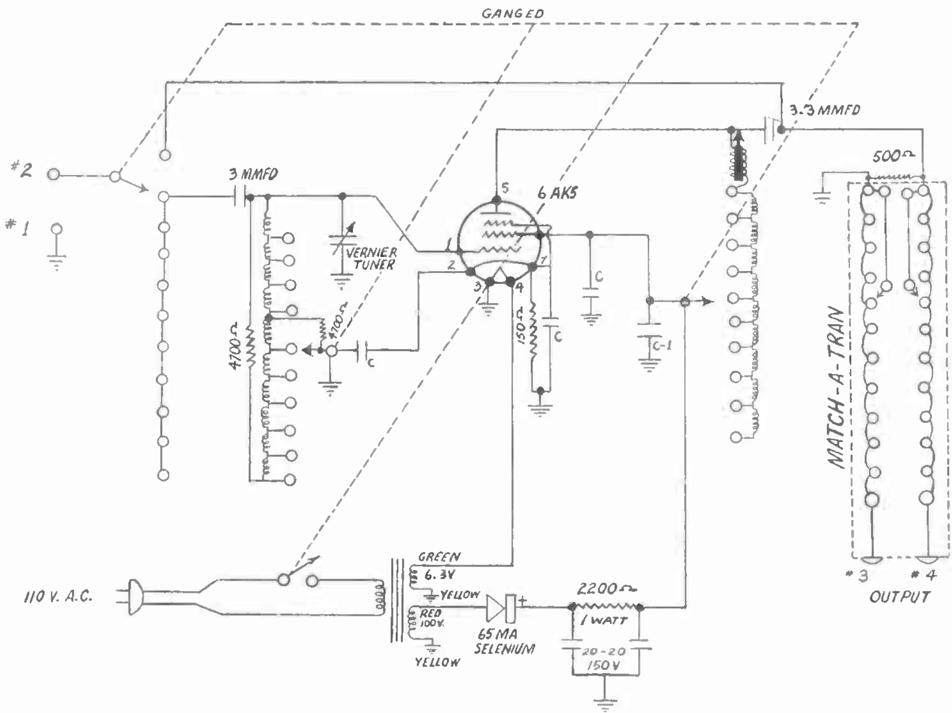
The tuning control usually consists of a variable condenser that is shunted across the coil for the particular band.

Other types of boosters, like the one shown in Fig. 5, are switched from one channel to another in the range from 2 through 7 and from one group of channels to another group above channel 7. Each channel (or group of channels) is individually tuned, the tuning arrangement being quite similar to those used for tuning the front end of a TV set.

There is enough variation between different brands of boosters to make it worth your while to be careful in selecting one. Some of the first booster amplifiers manufactured and some of those on the market at the present time do not give a gain in signal strength on all of the channels. On some channels an actual loss of signal strength might occur.

Of course, the fact that a certain booster does not give a gain on all channels may not be any disadvantage. If it gives a gain on all the channels that can be picked up where the installation is made, the fact that it may cause a loss on some other channel is unimportant (unless, of course, that channel is slated to go on the air in your location in the future).

To make sure that a booster will be suitable for a particular installation, get specific data from the manufacturer or the distributor of the amplifier concerning its gain on each chan-



Courtesy Jerrold Electronics Corp.

FIG. 5. The schematic diagram of a typical all-channel booster. It is essentially a broad-band, single-stage r.f. amplifier.

nel. Be sure that the booster will actually give a gain on all the available channels.

A booster is most commonly used in fringe-area installations where the signal strength is comparatively low. In these installations, two boosters are often used. When this is done, the transmission line from the antenna is connected to one booster, the output of that booster is connected to the input of the second booster, and the output of the second booster is connected to the receiver. If a gain of 5 or 6 can be realized from each booster, the total gain of the two boosters in cascade will be between 25 and 30. Such a gain, of course, will often produce a very great improvement in the picture quality.

There are many other uses for a booster. Sometimes one is used with an indoor antenna. In fact, indoor antennas combined with booster amplifiers are commercially available. In some locations, the use of an indoor antenna and a booster amplifier will make an outdoor antenna unnecessary.

A booster amplifier is sometimes used, not to increase the signal strength, but to prevent feedback from the TV receiver to the antenna. A signal from the local oscillator in the TV receiver may be feeding back to the antenna, radiating, and causing interference with other sets. Under such conditions, a booster amplifier may be installed in series between the antenna and TV set to isolate the local oscillator of the TV receiver from the antenna and thus to eliminate this radiation and reduce interference with other people's sets. One may also be used to increase the selectivity of the TV receiver when it is necessary to eliminate interference from services operating on frequencies near the TV channels. Image interference may also be eliminated or greatly reduced by the use of a booster. These uses of the booster will be discussed in more detail later.

Interference Traps

To use "effect-to-cause" reasoning when you are working on a TV set, you must be familiar with how the picture is formed and be able to recognize what will cause certain distinctive changes or patterns in the picture. When interference is the problem, a careful examination of the picture—particularly a test pattern—will often furnish excellent clues to the cause of the interference.

With the TV set operating normally and with no station being received, a raster should appear on the screen when the brightness control is advanced. This raster consists of many very fine horizontal lines and several vertical retrace lines. The latter slope diagonally upward from left to right.

As you will remember, a scanned field consists of 262.5 lines. The entire group of lines is repeated at a frequency of 60 cycles per second. Thus, the frequency of the sweep producing the horizontal deflection is 60x262.5 or 15,750 cycles per second, and the frequency of the sweep producing the vertical deflection is 60 cycles per second.

If an a.c. signal is introduced in the grid circuit of the picture tube, the brightness of parts of the raster will be varied in accordance with the signal. As the grid is made more positive with respect to the cathode, parts of the raster will become brighter; as it is made less positive, other parts of the raster will become darker. If the a.c. signal is of a fixed frequency, the pattern produced will depend, to a large extent, upon the signal frequency and amplitude. If the amplitude is sufficient to drive the grid of the picture tube very far negative, part of the raster will be darkened.

If the frequency of the a.c. signal applied to the grid circuit of the picture tube is less than the frequency of the sweep producing the horizontal lines, several adjacent lines may be blacked out at one time; as a result, horizontal bars will be produced across the face of the picture tube, as shown in Fig. 6.

Therefore, any defect or interference that causes horizontal bars on the screen is occurring at a frequency of less than 15,750 cycles per second. A rough indication of the frequency of the interfering signal can be obtained from the number of bars seen. If only one large bar is seen, for example, the frequency must be the same as that for a field—in other words, 60 cycles per second. If two complete bars are produced, the frequency producing them is 120 cycles per second.

Thus, if you find an interference pattern similar to the one shown in Fig. 6, you can be sure that the interfering signal applied to the grid of the picture tube has a frequency falling within the audio range. However, this does not mean that the interfering signal is an audio signal: it may be produced by the beating together of two r.f. signals.

If, on the other hand, the frequency of the signal applied to the grid circuit of the picture tube is greater than the horizontal frequency, parts of each horizontal line will be made alternately dark and bright; as a result,

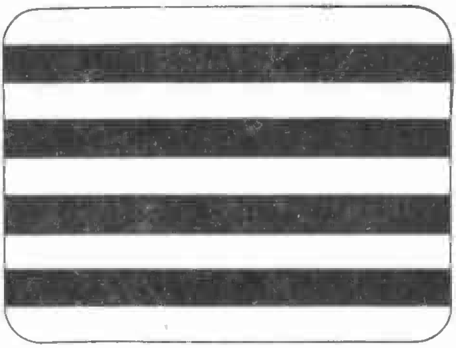


FIG. 6. Horizontal bars of this sort are produced by interference having a frequency when it is applied to the picture tube that is less than that of the horizontal sweep. Roughly, the frequency of the interference in cycles is equal to 60 times the number of bars.

vertical bars more or less like those shown in Fig. 7 will be formed. Here again, it may be possible to determine from the number of bars the approximate frequency of the interfering signal.

An interfering signal with a frequency higher than the horizontal sweep may cause lines that are perfectly vertical, as shown in Fig. 7, or that slope to either the left or the right. Whether the lines are vertical or sloping will depend upon the frequency and phase relationships of the interfering signal to the horizontal sweep signal.

If the frequency of the interfering signal is constantly changing, a series

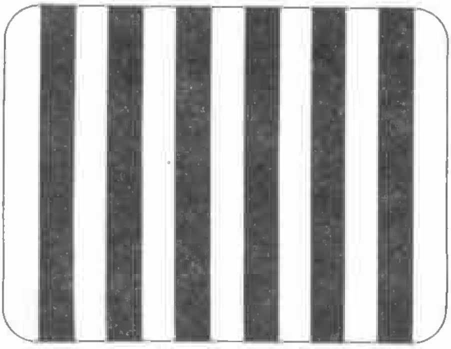


FIG. 7. Vertical bars of this sort are produced when the frequency of the interference applied to the picture tube is higher than the horizontal sweep frequency. The frequency of the interference is roughly equal to the horizontal sweep frequency times the number of bars.

of wavy lines, somewhat like those shown in Fig. 8, rather than stationary vertical lines or bars, will be set up. An f.m. signal, for example, will cause such a pattern.

Whatever the frequency of an interfering signal that is being picked up by the antenna or transmission line, it can usually be kept out of the set with the aid of a tuned circuit. Let's see what such interference eliminators are like.

STUBS AND TRAPS

You already know that the resistance of a series resonant circuit is low at resonance. We can, therefore, use a series resonant circuit to eliminate an undesired signal by connecting it across the antenna terminals of a television receiver and tuning it to the frequency of the interfering signal. The resonant circuit will then act as practically a short across the set terminals as far as the interfering signal is concerned, and the interference will either be eliminated completely or greatly reduced.

A parallel resonant circuit presents a high impedance across its terminals at the frequency to which the circuit is resonant. Another way of removing interference, therefore, is to connect a parallel resonant circuit tuned to the interfering signal in series with one of the leads to the receiver. Most of the interfering signal will then be dropped across the parallel resonant circuit and very little will be applied to the input of the TV receiver.

A piece of transmission line cut to the correct length will act as a series resonant circuit. Such a piece of line (which, since it is rather short, is called a "stub") can therefore be connected across the antenna terminals

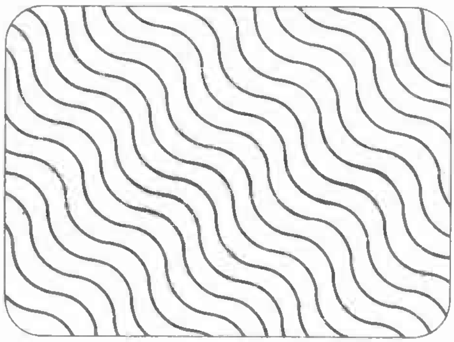


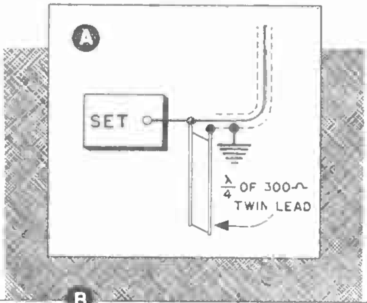
FIG. 8. Wavy lines show that the frequency of the interference is changing.

of a set to eliminate interference. The connection of such a stub is illustrated in Fig. 9A.

Two types of stubs may be used: the "open" and the "shorted" stub.

The shorted stub is about a half wave length long at the frequency of the station to be eliminated. The open stub, on the other hand, is approximately one quarter of a wave length long.

To make a shorted stub, the ends of the transmission line are stripped clean of insulation, twisted together, and soldered to form a short circuit



CHANNEL CAUSING INTERFERENCE	STARTING LENGTH OF STUB	
	OPEN 300-Ω LINE TO SET	SHORTED 300-Ω LINE TO SET
2,3	45"	90"
4	40"	80"
5,6	35"	70"
FM	30"	60"
7-13	16"	32"

FIG. 9. Part A shows how a stub should be connected to a transmission line; part B shows the starting lengths of open and shorted stubs made of 300-ohm line for use with different channels.

at the end of the line. An open stub is made simply by cutting off the correct length of transmission line, leaving the ends open. Obviously an open stub is much easier to make. Further, it is easier to work with, because a stub must be adjusted in length to make it perform properly after it has been connected to the set; and it is much simpler just to snip a bit off the end of an open stub than it is to connect the ends of a shorted stub again after cutting a piece off of it.

When you use a stub, start with one that is somewhat longer than is needed. The starting lengths for stubs made of 300-ohm twin-lead line are given in Fig. 9B for various channels. Connect the stub to the antenna terminals of the set, then cut off half-inch sections from its end until there is some noticeable effect upon the interference. As soon as you begin to notice an effect, reduce the length of the sections you cut off to a quarter inch or less. If you reach a point where the interference is completely eliminated, stop.

In most cases, however, it will be impossible to eliminate the interference completely. Instead, as you continue to cut off lengths of the stub, you will find that the interference first decreases, then begins to increase again. When this happens, you will have made the stub too short, and you will have to start over again. This time, however, you will know approximately how long the stub should be, and you will be able to recognize when you have made it the length that produces maximum interference elimination.

During your adjustments of its length, the stub should be placed as nearly as possible in the position that it will occupy after you have finished. Changing the position of the stub frequently has an effect upon its performance. Thus, if you stretch it out on the floor in front of the set for convenience while you are shortening it, you may find that it does not work properly when you place it behind the set afterwards. Another reason

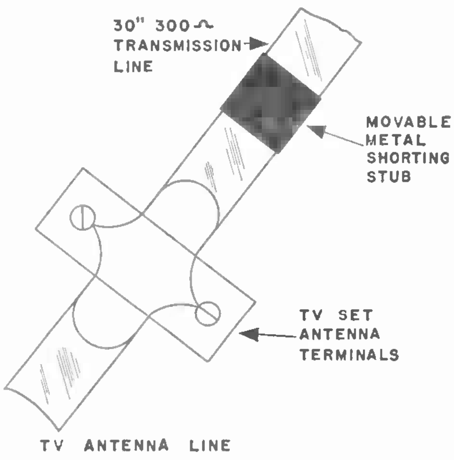


FIG. 10. How a piece of foil can be used to make an adjustable shorted stub.

for not changing the position of the stub as you adjust its length is that its performance may be affected by nearby objects.

An adjustable transmission line stub may also be made as shown in Fig. 10. Here the transmission line is connected to the antenna terminals of the TV set, and a piece of aluminum or tin foil is wrapped around the line. The piece of foil effectively shorts the line, even though it does not actually touch the conductors of the line. Therefore, the effective length of the stub can be adjusted by sliding the foil back and forth along the stub line until a position is found that clears up or minimizes the interference.

The use of a stub will cause a change in the r.f. response curve of the front end of a set on channels close to the frequency to which the stub is tuned. In some cases, this will cause smearing of the picture.

It has been found that this effect can be prevented by inserting a small condenser in series with each line of the stub at the point where it fastens to the front end or antenna input of the receiver. These condensers should have capacities of 5 mmf. for stubs used in the low TV band and the f.m. band and about 2 mmf. for stubs used in the high band. Inserting these condensers makes the stub a series-parallel tuned trap that is much sharper in response and will not affect the response curve of the front end of the set unless the stub is tuned directly to the channel. The addition of condensers may make it necessary to use a longer piece of line for the stub.

If a coaxial transmission line is used between the antenna and the receiver, it is sometimes desirable to use a coaxial line stub. Fig. 11 shows how to terminate the end of a coaxial line that is to be used as a shorted stub.

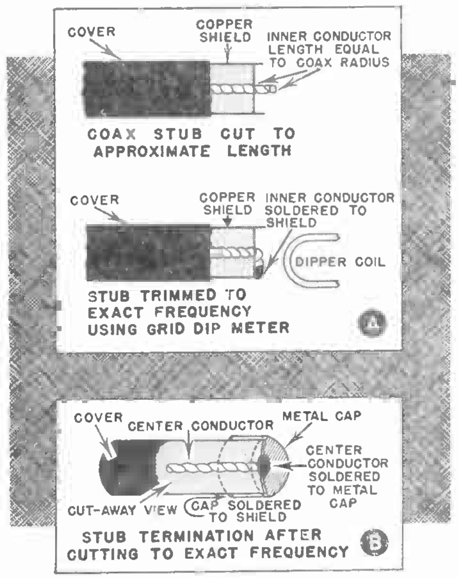
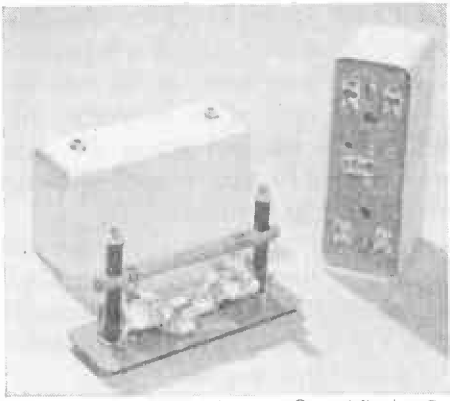


FIG. 11. A coaxial stub should be terminated as shown in part A. It should then be capped (part B) to prevent radiation from its end.



Courtesy Crystal Devices Co.

FIG. 12. A commercial wave trap.

Wave Traps. If the station causing the interference is comparatively low in frequency, a transmission line stub may have to be impracticably long to eliminate the interference. In such cases, you should use a wave trap tuned to the frequency of the interfering station instead of a stub. Wave traps are even used for some of the higher-frequency stations to avoid the need for having an extra piece of transmission line hanging from the set. Commercial wave traps are available; one is illustrated in Fig. 12.

Electrically the wave trap may take one of several different forms. Fig. 13A is the schematic diagram of the commercial wave trap in Fig. 12.

The transmission line from the antenna is connected to the terminals marked "in" on the wave trap and the transmission line running from the receiver is connected to the terminals marked "out." Thus, with the wave trap connected, coils L_1 and L_3 are inserted in series with the transmission line. Coil L_2, tuned by condenser C_1, is coupled to coil L_1; and coil L_4, tuned by condenser C_2, is coupled to L_3. L_2-C_1 and L_4-C_2 thus act as absorption wave traps, absorbing energy from the line at the frequency to which they are tuned. To use this trap, therefore, all you need to do is insert it in the transmission line and adjust C_1 and C_2 until the interference is minimized.

Slightly different arrangements of absorption wave traps are shown in Figs. 13B and 13C.

A series resonant wave trap that is connected directly across the antenna input terminals is shown in Fig. 14. Electrically, this is approximately the same as the quarter-wave open stub or the half-wave shorted stub previously described.

A wave trap of this sort is often not as effective as an absorption trap, because the attenuation it produces in the undesired signal depends upon how

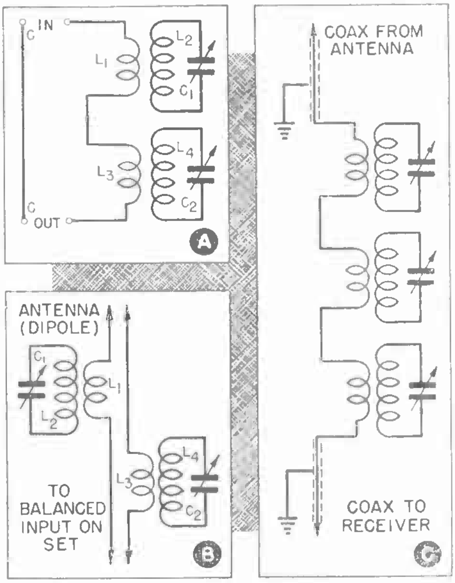


FIG. 13. Three forms of absorption wave traps. The one in part A is pictured in Fig. 12.

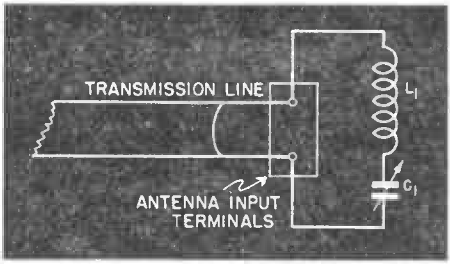


FIG. 14. A series resonant wave trap. As the text shows, this is often not as effective as an absorption trap is.

low its impedance becomes at resonance in comparison to that of the receiver. Since the input of a receiver has a comparatively low impedance, a series trap may not be able to become low enough in impedance to produce sufficient attenuation of the undesired signal.

Fig. 15 shows how parallel resonant wave traps can be used. Notice that a trap is connected directly in series with each conductor of the transmission line. Since each wave trap has a very high impedance at its resonant frequency, most of the interfering signal will be dropped across the traps and very little will be applied to the receiver input terminals.

Now that you know how stubs and traps are used, let's see which kinds of r.f. interference they can eliminate and which kinds must be eliminated by some other means.

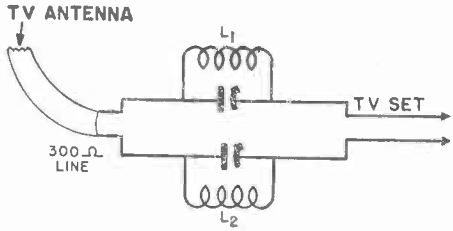


FIG. 15. A pair of parallel resonant wave traps. The inductance and capacity should be chosen to make the traps resonant at the frequency of the interfering signal.

Eliminating R.F. Interference

F.M. signals can interfere with both low-band and high-band TV signals. Interference with high-band stations may occur because of radiation of second harmonics by an f.m. station. The f.m. band, as you know, extends between the frequencies of 88 and 108 mc. The second harmonics of these frequencies lie between 176 and 216 mc. Thus, the range of these second harmonics coincides almost exactly with the range of the upper TV band (which is 174 to 216 mc.). If an f.m. station does not have good second-harmonic suppression (and some do not), therefore, it can easily interfere with one of the high-band stations. A typical example of the effect produced by f.m. interference is shown in Fig. 16.

If you find f.m. interference on one of these channels, about the only thing that you can do is use a highly directive antenna and attempt to orient it so that the pickup from the f.m. station will be reduced to a minimum. It is impossible to use a stub or a wave trap to eliminate interference of this sort, because these devices must be tuned to the frequency of the interfering signal to be effective. Since second-harmonic f.m. interference comes in on top of a TV signal, the use of a stub or a wave trap to eliminate the interference will eliminate the desired signal as well.

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FIG. 16. Wavy interference of this sort that is continually changing is characteristic of f.m. interference. The variations in the pattern produced are caused by the continually changing frequency of the interfering signal.

An f.m. signal can also produce image interference, particularly on channel 2. To see why, let's suppose we have a typical TV receiver having a picture i.f. of 25.75 mc. On channel 2, the picture carrier frequency is 55.25 mc. The local oscillator of our set will therefore be operating at a frequency of 81 (55.25 plus 25.75) mc. when the set is tuned to this channel.

If a signal exactly 25.75 megacycles higher than the frequency of the local oscillator is picked up by the set, it can very easily beat with the signal from the local oscillator to produce an i.f. signal. Such a signal, as you know, is called an image. Adding 25.75 mc. to the oscillator frequency of 81 mc., we find that the image frequency for channel 2 is 106.75 mc., which is within the f.m. broadcast band.

Thus, a strong f.m. station can cause image interference on channel 2 if the front end of the TV set does not have sufficient selectivity to reject the image frequency. As you learned in your earlier studies of TV input tuners, many sets do not have this much selectivity.

There are several methods that may be used to reduce or eliminate f.m. image interference. A series wave trap, an absorption trap, or a stub (either a quarter-wave open stub or a half-wave shorted stub) may be used. A quarter-wave open stub is perhaps the most commonly used of these, because it is as effective as any other device in the elimination of this type of interference, and it is comparatively easy to make and adjust. If you wish to use an open stub to eliminate f.m. image interference, start with a section of line about 32 inches long, then shorten it as previously described until the interference is minimized.

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Another form of interference pattern caused by f.m. pickup.

In addition to using a stub or a wave trap to knock out this type of interference, try reorienting the antenna. You may find that there is a position for the antenna where pickup from the f.m. station is at a minimum but where there is still satisfactory signal pickup from the TV station.

Also, a booster may be helpful. It will increase the gain at the frequency of the TV signal and improve the image rejection of the receiver. If the previous suggestions are not successful, try a booster.

INTERFERENCE FROM LOCAL OSCILLATORS

Interference may be caused by radiation from the local oscillator of a nearby TV or f.m. receiver. A TV receiver with an i.f. of between 21 and 27 mc. in which the local oscillator operates above the incoming signal may often cause interference with other sets. When the set is tuned to channels 2, 3, 7, 8, and 9, the local oscillator will be operating on channels 5, 6, 11, 12, and 13 respectively.

When the set is operating on channel 2 (54-60 mc.), for example, and the i.f. is 21 mc., the operating frequency of the local oscillator is approximately 81 mc., which is within channel 5 (76-82 mc.). Similar examples may easily be set up to show how interference can be caused on other channels.

The local oscillators of some f.m. sets operate at a frequency lower than the incoming signal. As a result, the local oscillator of such a set may operate within television channels 5 or 6.

Interference will be caused in a receiver by radiation from a nearby TV or f.m. set having a local oscillator operating at a TV frequency if there is not sufficient isolation between the mixer stage and the antenna of the offending set. If the isolation is insufficient, the signal from the local oscillator will be fed back to the antenna and radiated. If this radiated signal is picked up by a TV set, it will produce an interference pattern like that shown in Fig. 17.

There is little that can be done at the TV receiver itself to eliminate this interference unless the pickup is direct and not through the receiving antenna. If there is a direct pickup from a nearby set (in another apartment, for example), it is sometimes possible to cut down the interference or to eliminate its effect by using a shielded transmission line or by carefully shielding the TV receiver. In some instances, it has been found necessary to cover the inside of the TV cabinet with shielding screen.

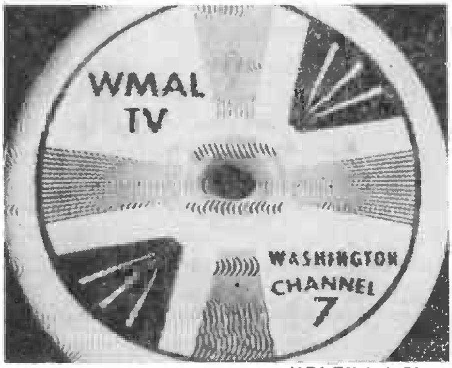

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FIG. 17. Interference of this sort can be produced by the local oscillator of a nearby TV or f.m. set. You can distinguish it from other kinds of r.f. a.m. interference by the fact that the number and positions of the lines will change when the tuning of the interfering oscillator is changed. When the tuning operation stops, the pattern may change to that in Fig. 18.

In most cases, however, steps for eliminating this type of interference must be taken at the *interfering* receiver. The easiest way to eliminate this trouble is to use a booster amplifier between the antenna input of the set and the antenna.

Of course, you are likely to find it difficult to persuade the owner of an interfering TV receiver to spend the money for a booster. He will probably decide that since his set is working all right, the fact that somebody else's set is having trouble is due to a defect in that receiver rather than in his. Even if he can be convinced it is due to a defect in his receiver, or perhaps we should say to poor design in his receiver, very often he will not be willing to go to the expense of installing a booster.

AMATEUR INTERFERENCE

There are three possible ways in which an amateur transmitter may cause interference in a TV set. First, there may be excessive harmonic radiation from the amateur transmitter at a TV frequency. Second, the amateur signal may be able to get directly into the i.f. stages. Third, the amateur station may be operating on a frequency near the TV channels and simply be getting through the set because of the strong signal from the station and the poor selectivity of the TV receiver.

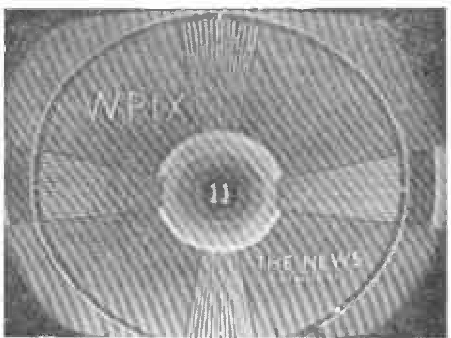
Two amateur bands, the 21-mc. and 28-mc. bands, operate near the i.f. frequencies of modern TV receivers. A signal from a nearby amateur station in one of these bands may get through the front end of the TV set into the i.f. amplifier. Many TV sets have i.f. traps in the front end that can be adjusted to eliminate such interference or to reduce it to a minimum.

If a set suffering from such interference does not have an i.f. trap, you should add one. Install it across the transmission line if you use series resonant traps. For these amateur bands, 14 turns of No. 22 enameled wire on a form ¾ of an inch in diameter with the windings spaced to fill about ¾ of an inch will make a suitable trap coil. Use a variable tuning condenser having a capacity rating of 15 to 20 mmf.

Harmonics from the amateur transmitter are probably the most common cause of amateur interference. These may affect the test pattern as shown in Fig. 18. In some instances, horizontal lines like those shown in Fig. 19 may be produced.

The chart shown in Fig. 20 shows the relationship of the most widely used amateur bands to the TV channels. Harmonics that fall into any of the assigned TV channels have asterisks beside them.

Interference from harmonics of the



Courtesy Sylvania Electric Products, Inc.

FIG. 18. Harmonics from an amateur or any other a.m. transmitter may produce regular lines of this sort. They will not change if the frequency of the transmitter does not change.

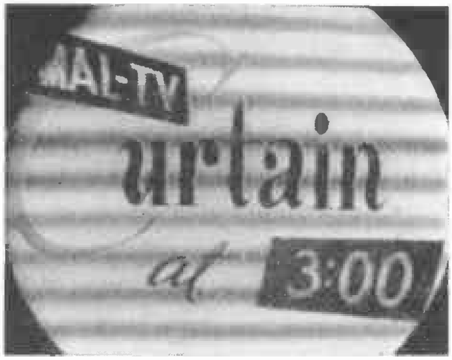


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FIG. 19. Another form of interference that may be produced by an amateur or other a.m. transmitter.

amateur station may best be reduced or eliminated at the transmitter itself. A quarter-wave shorted stub is very effective in the elimination of even-harmonic interference. The quarter-wave shorted stub is cut to the fundamental frequency of the transmitter. It will then act as a parallel resonant circuit (high impedance) at the fundamental. At even-harmonic frequencies (second, fourth, etc.), the stub will act as a series resonant circuit (low impedance) and will effectively reduce the even-harmonic radiation.

The harmonic radiation may not necessarily be coming from the amateur antenna. It may be radiating from one of the buffer stages in the transmitter. The remedy in this case is to shield the transmitter completely. All shielding should be properly bonded, and the shield should be grounded at one point. In addition, a power line filter similar to the one shown in Fig. 21 should be used.

In some cases, key-clicks may be noticeable from an amateur station. They may be eliminated by the use of a better key-click filter and by the use of an r.f. filter (as shown in Fig. 21) in the power line. They can also be eliminated by redesigning the transmitter to use a vacuum tube to key the equipment.

Of course, you cannot do anything about curing the trouble at the transmitter end unless the amateur is willing to cooperate. Most of them will be. Most, too, will know what steps should be taken to eliminate the trouble, because the amateur magazines are continually running articles on eliminating amateur interference.

Incidentally, when harmonic interference is encountered on channel 2,

AMATEUR FREQ. (mc.)	X 2 (mc.)	X 3 (mc.)	X 4 (mc.)	X 5 (mc.)	X 6 (mc.)	X 7 (mc.)	X 8 (mc.)	X 9 (mc.)	X 10 (mc.)
3.5	7	10.5	14.0	17.5	21.0	24.5	28.0	31.5	35.0
7.0	14	21	28	35	42	49*	56*	63*	70*
14.0	28	42	56*	70*	84*	98	112	126	140
21.0	42	63*	84*	105	126	147	168	189*	210*
27.0	54*	81*	108	135	162	189*	216*	243	
28.0	56*	84*	112	140	168	196*	224		
50.0	100	150	200*						

FIG. 20. Chart of the harmonics of the most popular amateur frequencies. Those that have an asterisk beside them fall in one of the TV channels.

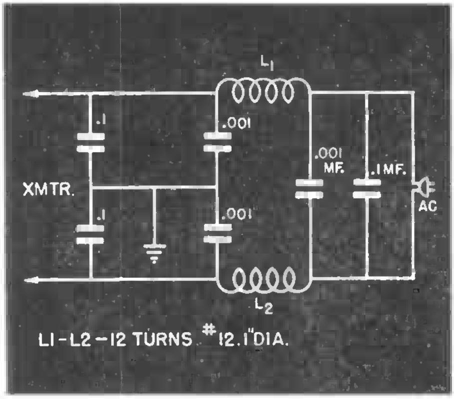

FIG. 21. This r.f. filter will help keep amateur harmonic radiation out of the power line.

it is due to harmonics from an amateur transmitter that is operating in the 28-mc. band. Remember, the amateur transmitter has a legal right to be operating in that band; and the FCC recognizes that certain harmonics will be radiated. Recent studies indicate that interference from second-harmonic radiation of a 28-mc. transmitter can be expected on channel 2 up to a mile from a 750-watt transmitter having a harmonic suppression of 42 db. Interference from the third harmonic of a transmitter usually will not cause any trouble except in the immediate vicinity.

Amateur stations operating on the 6-meter band also cause TV interference. This band is located directly beside television channel 2. As a result, amateur stations operating in this band will get through the front end of a nearby TV set, because the set does not have sufficient selectivity to reject the undesired signal. A 6-meter transmitter will cause considerable interference on channel 2 on nearby TV receivers and may even affect the entire low band.

A quarter-wave open stub used on the receiver transmission line may be helpful in reducing this type of interference. There is nothing that can be done at the transmitter, because the fundamental of the transmitter causes the trouble.

In addition to using the quarter-wave stub, using a highly directive antenna array and orienting it for minimum pickup from the amateur station may be helpful. However, if the amateur station is located in the same direction as a television station, the chances are that this solution will be impractical.

Fortunately, the 6-meter amateur band is not as popular as the lower-frequency amateur bands—in fact, the number of stations operating on 6 meters is small in comparison to the number on the other amateur bands. As a result, interference from 6-meter stations is not very widespread.

The previous information on reducing amateur interference can also be applied to the lessening of interference caused by commercial short-wave stations operating on frequencies near the TV channels or on frequencies having harmonics that fall in TV channels. Harmonic interference from these commercial stations is likely to be less severe than it is from an amateur station. The commercial stations have had the benefit of good reliable design by competent engineers, whereas some of the amateur stations are lacking in this respect.

INTERFERENCE FROM BROADCAST STATIONS

Interference may be caused by nearby a.m. broadcast stations. This interference will look something like a wire mesh across the face of the cathode ray tube.

Moving and redirecting the TV antenna usually does not help too much in this case, because the trouble is due to the fact that the signal blankets the area. The most effective method of reducing this interference is to use a high-pass filter like that shown in Fig. 22.

It is not usually sufficient simply to connect this filter between the transmission line and the antenna terminals of the receiver. Usually there is a fairly long piece of transmission line between the antenna terminals of the receiver and the input to the tuner. When there is a strong signal from a local a.m. broadcast station, sufficient signal may be picked up in this short length of line to cause considerable interference. The best thing to do is to disconnect the transmission line at the point where it is connected to the front end of the receiver. Then connect one side of the high-pass filter directly to the tuner input, and connect the transmission line coming from the antenna terminals of the receiver to the other side of the high-pass filter.

If the TV signal is weak, increasing its strength may be helpful in reducing the effect of this interference. Using a better antenna, raising the antenna, or using a booster may prove helpful.

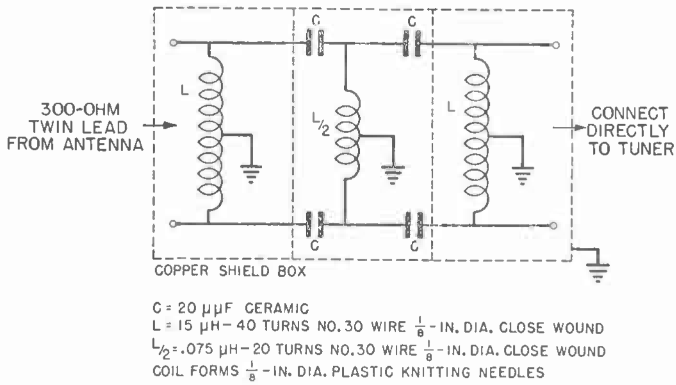

FIG. 22. Use of this high-pass filter will reduce interference caused by a powerful nearby a.m. broadcast station.

CO-CHANNEL INTERFERENCE

When the FCC originally assigned the television channels, it was assumed that a TV signal would not travel a very great distance beyond the line of sight. The geographical separation of stations on the same channel was set with this assumption in mind. Experience has proved, however, that there is a certain amount of bending of a TV signal; and, as a result, signals travel a good distance beyond the horizon. Consequently, the problem of co-channel interference has arisen in some locations.

Such interference occurs when it is possible to pick up signals from two different stations that are on the same channel. Let's say that a set is located between two channel 4 stations that are 175 miles apart and is 50 miles from one station and 125 miles from the other. If conditions are favorable, it will be possible to pick up the nearer channel 4 station well. The other channel 4 station may not be received well enough to give a satisfactory picture, but it may be possible to pick up enough signal from it to cause inter-

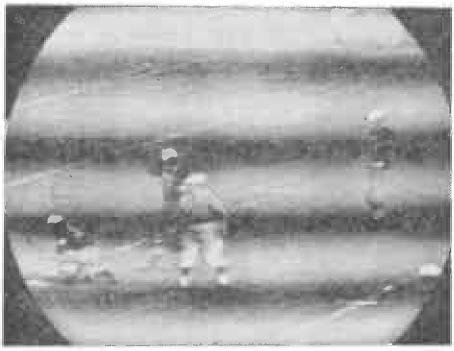

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FIG. 23. The "venetian blind" effect produced by co-channel interference may look like this.

ference with the signal from the first station.

Such interference occurs whenever the signals from the two stations differ in frequency by a small amount. Theoretically, both stations should be operating on exactly the same frequency, but they may easily differ by a few hundred cycles and still be well within the frequency tolerance limits set by the FCC. When both signals are received, a beat note having a frequency equal to their frequency difference will be produced and eventually applied to the picture tube, causing an interference pattern like that shown in Fig. 23. This interference produces a series of alternate black and white bars across the image, for which reason it is called the "venetian blind effect." The number of bars depends, of course, on the difference in frequency of the two carriers. If this difference is less than 60 cycles, no visible bars will be produced; but, unless the two carriers are exactly synchronized in frequency, there will be an annoying variation in brightness of the picture.

The only hope of eliminating such interference at the receiver is to use a more directive antenna in an effort to attenuate the undesired signal so much that it will produce no appreciable effect. If this does not work, there is nothing else that can be done at the receiver to eliminate the interference.

Fortunately, however, a simple method of adjusting the transmitter to eliminate this interference completely has been worked out. It is likely that it will be adopted very soon, in which case co-channel interference will no longer be a problem.

This method consists of adjusting the two transmitters so that they are exactly 10,500 cycles different in frequency. When the frequency difference is this great, the bars produced are so numerous and so thin that they disappear completely.

ADJACENT-CHANNEL INTERFERENCE

Adjacent-channel interference is not likely to occur in large cities to which TV channels have been assigned, because such cities are generally located so far from others to which adjacent channels have been assigned that it is impossible to pick up the adjacent-channel signals. A receiver located between two cities to which adjacent channels have been assigned may suffer from interference of this sort, however.

To take a specific example, let's suppose that a set is located between a city to which channel 3 has been assigned and another city to which channels 2 and 4 have been allocated. Let's suppose further that reception is such that all three of these channels can be picked up. If so, the broad response of the front end and the i.f. stages of the set will probably permit the set to pick up interference from both channel 2 and channel 4 when it is tuned to channel 3.

Such interference will probably be caused by the sound carrier of channel 2 and the picture carrier of channel 4. The sound carrier frequency of channel 2, for example, is 59.75 mc., and the local oscillator of the set (assuming it has the usual sound i.f. of 21.25 mc. and picture i.f. of 25.75 mc.) will be operating at 87 mc. when the set is tuned to channel 3. The beat between the sound carrier of channel 2 and the local oscillator frequency when the set is tuned to channel 3 will therefore have a frequency of 27.25 mc., which is near enough to the i.f. frequencies to get through the set and cause interference.

Similarly, the picture carrier frequency of channel 4 (67.25 mc.) will beat with the local oscillator of a set tuned to channel 3 to produce a frequency of 19.74 mc. This will probably also pass through the i.f. stages and produce interference.

There are several things that might be done to reduce adjacent-channel interference. Some receivers contain adjacent-channel sound traps and adjacent-channel picture traps that are designed to eliminate it. Properly adjusted, such traps are very effective.

The use of a more directive antenna should be tried. It may be possible to reduce the pickup from the interfering station to such a low level that the interference will not be objectionable.

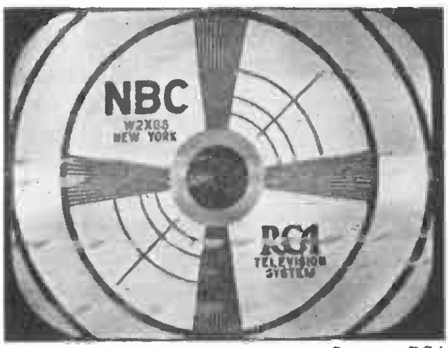
It may also be possible to use a stub cut to a frequency near that of the interfering station to attenuate the interference. This is practicable, of course, only if the presence of the stub does not reduce the strength of the desired signal too much.

Sometimes the use of a pad that reduces the signal strength of all incoming signals will prove helpful. We shall discuss pads a little farther on in this Lesson.

NOISE

Noise produces dark spots or streaks across the picture tube. Probably the most common source of this kind of interference is automobile ignition systems. The effects of light and heavy interference of this sort are shown in Figs. 24A and 24B respectively. Notice that heavy ignition interference may destroy the horizontal sync action.

Frequently a great deal of auto ignition interference is picked up by the



Courtesy RCA

Interference caused by some form of noise.

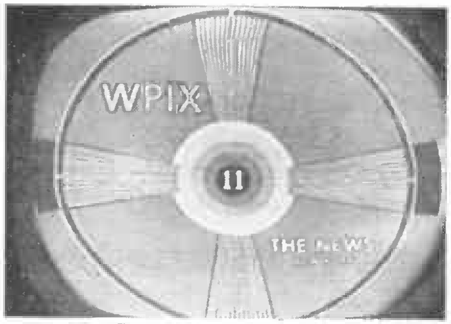
transmission line rather than by the antenna. If such interference is severe, you should try a shielded transmission line. If the interference is light, it may be possible to use an unshielded line provided it is placed as far as possible away from the street. Even if the interference is light, the use of shielded line is preferable from every standpoint except that of cost.

Placing the antenna as high as possible is helpful. In addition, if the interference is being picked up by the antenna itself, it is often worth while to use a stacked array. As you know, a stacked array picks up much less noise from a source below it than a dipole does.

Automobile manufacturers are cooperating with TV manufacturers, and the new cars do not cause nearly as much ignition interference as do the older ones. In time, therefore, as the older cars go off the roads, ignition interference will probably be reduced considerably.

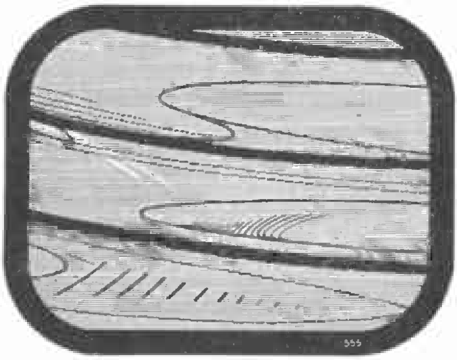
Noise may also be produced by various other electrical devices. Any device in which a motor is used may produce interference if the motor is not properly adjusted or if sparking occurs between the brushes and the commutator. In addition, ultra-violet lamps, neon signs, electric razors, and similar spark-producing devices may cause considerable interference.

In each of these cases, the use of a line filter should prevent interference from getting into the set through the power line. Of course, to be most effective, the filter should be placed at the interfering piece of equipment. When the device cannot be located or if it is impractical to place the filter at this point, however, try installing



Courtesy Sylvania Electric Products, Inc.

FIG. 24A. Light ignition interference causes streaks of this kind across the picture.



Courtesy Belmont Radio Corp.

FIG. 24B. Heavy ignition interference may make the set lose horizontal sync, as shown here.

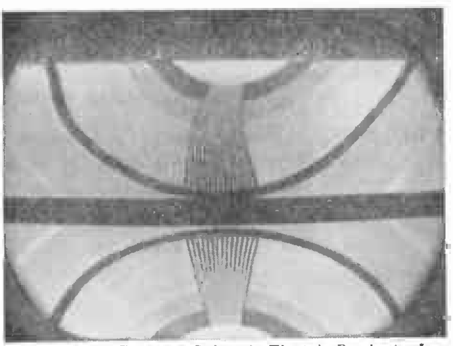
the filter between the receiver and the power outlet.

Again, as in the case of auto ignition, much of the interference may be picked up by the transmission line, so the use of shielded line may help to reduce the interference. Getting the antenna higher to keep it as far away as possible from the interference may do some good.

A booster is sometimes useful in reducing noise interference if the interference is noticeable simply because the signal from the TV station is weak. In this case, increasing the signal from the TV station by the use of a booster will reduce the effect of the noise. If the interference is being picked up by the antenna, however, a booster will do little good, because the noise will be amplified along with the desired signal.

DIATHERMY INTERFERENCE

Diathermy interference is caused by radiation from the oscillator of a diathermy machine (a piece of equipment used by doctors in giving heat treatments). The newer machines are designed to minimize such radiation: in some, second-harmonic radiation (which is the most troublesome, because it is in the TV spectrum) is kept as low as 5 microvolts per meter. However, older equipment radiates very strongly, causing interference that often cannot be eliminated.

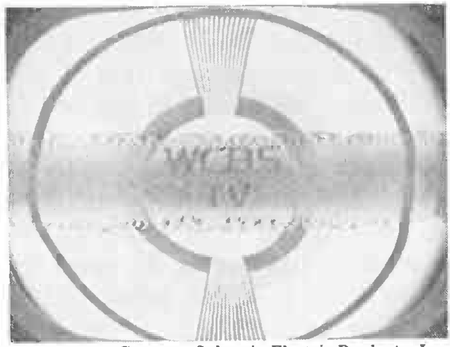


Courtesy Sylvania Electric Products, Inc.

Loss of vertical sync caused by diathermy interference.

The effect of diathermy interference on the test pattern is shown in Fig. 25. The herring-bone pattern may move vertically, or it may remain stationary as shown. If the interference is extremely strong, it may completely blank out the test pattern on one or more stations.

Filtering the antenna circuit with a high-pass filter may help to some extent if the interference is very broad. Repositioning the antenna to reduce pickup from the interfering source to a minimum and using an antenna with



Courtesy Sylvania Electric Products, Inc.

FIG. 25. A typical example of diathermy interference. Usually such interference will cause either one or two bands across the picture, since diathermy machines (which are essentially h.f. and v.h.f. oscillators) are usually modulated at either 60 or 120 cycles, depending on whether a half-wave or a full-wave rectified power supply is used. The modulation occurs because the power supply is not usually filtered.

a sharper pattern may also be helpful. Sometimes a stacked array will not pick up this interference to the extent that an ordinary dipole or folded dipole will. If the pickup occurs in the transmission line, the use of a shielded line should eliminate it.

Diathermy interference can best be eliminated at the source, if the source can be found. Usually you can find out which doctors in the neighborhood have diathermy equipment. Then, when the interference is present, you can telephone each doctor to see if his equipment is turned on at that moment.

If the doctor is willing to permit you to take steps to eliminate the interference, shield the diathermy oscillator completely. This will keep radiation from the oscillator itself to a minimum.

In addition, filter the power supply to the equipment. Use an r.f. filter like the one shown in Fig. 21.

Fortunately, diathermy equipment is usually not used too much during the evening hours when television programs are on the air.

IDENTIFYING R.F. INTERFERENCE

Since the measures you take to eliminate r.f. interference often depend on what kind of interference is being picked up, it is usually necessary for you to identify the interference before you can remove it. Fortunately, it is generally easy to do so by observing the effect produced on the picture by the interference.

We have illustrated most of these effects in the preceding sections of this Lesson. Study the pictures carefully so that you will be able to identify each type. Most of them are distinctive enough so that you will have very little difficulty in telling them apart. Noise, for example, causes streaks or dots across the face of the tube; diathermy produces a herring-bone pattern; and so on.

Interference from amateur stations and from f.m. stations may be somewhat difficult to distinguish between, since both cause diagonal lines across the face of the tube. The lines caused by an amateur station are usually straight, however, whereas those caused by an f.m. station are not. Further, the number of lines caused by an f.m. station varies constantly, because the frequency of the station is continually changing; but an interfering amateur station will usually produce a constant number of lines.

Another distinguishing feature is that amateur interference is not present all the time, because amateur stations are operated intermittently. On the other hand, interference caused by an f.m. station is usually present throughout practically the entire day and evening.

If interference is caused by a radio station, try to pick up its call letters. Doing so will let you find out what the fundamental frequency of the interfering frequency is, which may make it easier for you to determine why the interference is occurring. If it is the picture rather than the sound that is interfered with, you will not hear the interfering frequency when the set is correctly tuned. However, you may find it possible to hear it if you misadjust the fine tuning control (if the set has one) so as to increase the frequency of the local oscillator, thereby making the beat frequency of the interfering signal and the oscillator signal fall within the sound i.f. range. Even if the interference is amplitude modulated, you will probably be able to hear it through the f.m. sound system of the TV set; it will undoubtedly be distorted, but you should be able to make out what is being said.

SIGNAL STRENGTH

In many cases, the success you will have in eliminating interference will depend upon the strength of the signal from the TV station. The stronger the signal, the better your chance of eliminating the interference. If the signal is relatively weak, it may be difficult or impossible to eliminate the interference without also attenuating the signal from the television station to such an extent that it is unusable.

When the signal from the TV station is weak, therefore, it is usually worth while to spend some time attempting to increase its strength before trying to knock out the interference. Use a high-gain antenna and a booster to build up the signal strength in such a case. Then you can use traps or stubs to knock out the interference with some assurance that you will not reduce the strength of the desired signal too much.

INTERFERENCE CAUSED BY TV RECEIVERS

Several of the circuits in a TV set may interfere with other broadcast services. In addition to being called upon to eliminate interference in a TV receiver, therefore, you may also be called upon to eliminate interference that is caused by the TV receiver.

Direct radiation from the video circuit may cause trouble in an a.m. broadcast receiver, for example. Remember, the video circuits in a receiver handle frequencies all the way from about 15 or 20 cycles up to 4.5 megacycles. As a result, there are strong signals present in the video circuits that fall within the frequency range of the standard broadcast band. If there are any long leads in the video circuits, there may be considerable radiation that will affect nearby broadcast receivers.

Such interference makes the a.m. set sound mushy. Considerable background noise of variable intensity is present. In some cases, the noise can be severe enough to obliterate weak stations completely. There may also be "birdies" caused by beating of some video components with broadcast carriers.

The most effective method of eliminating such interference is to shield the TV receiver. It may be necessary to build a wire mesh shield completely around the inside of the TV receiver cabinet. This shield should then be grounded.

In receivers using the intercarrier sound system, the 4.5-mc. sound may radiate, causing trouble with services on or near this frequency, if the leads in the set are long and unshielded. Shielding any long leads should be effective in eliminating this difficulty.

The scanning systems in a TV receiver may cause trouble because they are rich in harmonics. The vertical sweep is usually not troublesome, since it operates at the low frequency of 60 cycles per second. The horizontal sweep circuits, however, operate at a frequency of 15,750 cycles and have an output that is very rich in harmonics. These harmonics may cause "birdies" about every 15 kc. all over the dial of an a.m. set as they beat with broadcast station carriers.

In most sets in which electromagnetic deflection is used, the horizontal sweep circuit is shielded along with the high-voltage rectifier and the damping circuits. If you should find that these components are not shielded in a set that causes interference in a nearby radio receiver, shielding these circuits should be helpful.

In addition, radiation may occur from the yoke. An additional shield may be made that can be slipped on over the yoke and grounded to the receiver chassis. Such a shield is usually quite effective in eliminating radiation from the yoke. If it doesn't remove the interference completely, it will be necessary to use a screen shield over the entire inside of the set (with the exception of the face of the picture tube).

We mentioned earlier that radiation from the local oscillator of the TV set may cause interference in nearby TV or f.m. sets. The best way to eliminate such radiation by the TV receiver is to install a booster between the offending receiver and its antenna.

There is one possible difficulty you should keep in mind if you are attempting to eliminate interference by shielding the inside of a TV receiver cabinet with a grounded wire mesh. Some TV receivers use power supplies that resemble the a.c.-d.c. circuits used in many of the lower-priced a.m. broadcast radios. In such sets, one side of the power line may be connected directly to the chassis.

Obviously, you must not ground the chassis in a set of this kind—if you do, you may put a short directly across the power line. Therefore, if you install a shield in one of these sets, be very careful not to allow the grounded shield to come into contact with the receiver chassis.

SUMMARY

There are two main kinds of external r.f. interference—"blanket" interference and "station" interference. Blanket interference, such as diathermy, ignition, etc., can best be eliminated by going to the equipment causing the interference. The use of appropriate filters and shielding will usually eliminate the interfering radiation.

On the other hand, interference caused by a particular station, whether it be an f.m., an amateur, a shortwave, or some other station, can usually be eliminated by using wave traps or stubs at the receiver. Of course, if the interference is caused by excessive harmonic radiation from an amateur station, the elimination or the suppression of that harmonic at the station will be the most effective means of combating the trouble. When the interference is due to nearby stations that are operating on frequencies near the TV channel or near the TV i.f. frequency, however, the best way to eliminate the interference is to trap the interfering signal at the receiver.

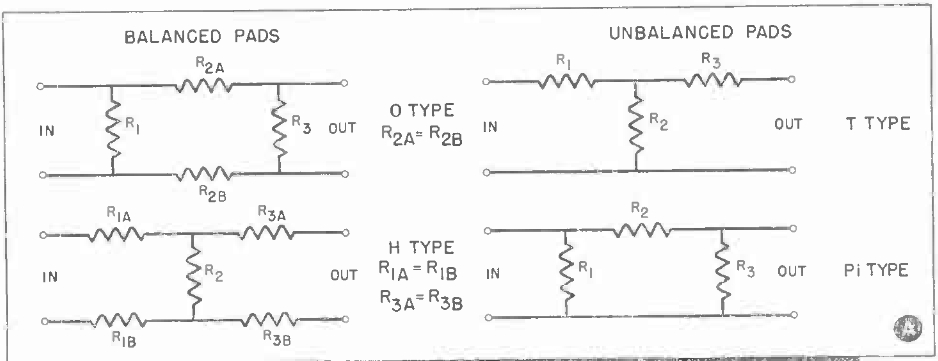
Special TV Installations

In this section, we are going to take up some special installation problems. One of these is the use of pads or some other means of cutting down extremely strong signals when the receiver is located close to the transmitter. Another is the installation of a receiver in an area where the correct type of power is not readily available. A third is making commercial installations—in taverns or restaurants, for example. The fourth is setting up a multiple-installation system for an apartment house or a dealer's store.

STRONG SIGNAL AREAS

When you make a TV installation in an area where the signal strength is excessive, you should use a pad to reduce the amount of signal fed to the set from the antenna to prevent the first stages in the set from being overloaded. Fig. 26 shows the circuits of four types of pads and the resistor values that should be used in the two most common of them to produce various amounts of attenuation. The balanced pads are used with 300-ohm twin-lead line, and the unbalanced pads are used with 72-ohm coaxial line.

In an area where there are several stations, it is unusual to find a location where the signals from all of them are too strong. It is somewhat more common to have the signal from one



DB ATTENUATION	300-OHM IMPEDANCE O PAD			72-OHM IMPEDANCE Pi PAD		
	R_1	R_2	R_3	R_1	R_2	R_3
6	1000	100	1000	150	100	150
12	470	300	470	100	220	100
18	390	560	390	82	470	82
24	330	1000	330	---	---	---
30	310	2200	310	---	---	---

(ALL R VALUES ARE IN OHMS)

B

FIG. 26. The diagrams of O, H, T, and Pi pads are shown in part A, and design factors for O and Pi pads are given in part B.

station be extremely strong but those from other stations be only normal in strength. This condition occurs when the set is located very close to one transmitter but considerably farther from the others.

Since a pad will reduce the strength of all signals equally, a pad would be unsuitable in a location of this latter kind because we do not want to reduce the signal strength from the weaker stations. Instead, you should install a parallel resonant wave trap in the transmission line (one trap in each lead of the line if twin-lead is used), tuning it to the frequency of the over-strong station. This arrangement will usually attenuate the strong signal enough to prevent overloading.

Incidentally, you may wonder why we go to all of the trouble of designing pads to attenuate signals instead of simply inserting resistors in the leads between the transmission line and the antenna terminals of the receiver. The reason is that the transmission line would no longer be terminated with the correct impedance if we just installed resistors to attenuate the signals. The pads shown in Fig. 26, however, are designed so that they will have no effect on the impedance matching. In other words, when the resistances given in Fig. 26 are used, the impedance at the input and at the output of either of the balanced pads is 300 ohms; and, similarly, the input and output impedance of the unbalanced pads is 72 ohms.

INSTALLATIONS IN D.C. AREAS

In some of the larger and older cities, there are areas in which d.c. power rather than the more common 60-cycle a.c. power is supplied over the power lines. When public distribution of electric power was first undertaken by power companies, d.c. was the only kind used. Later, when the advantages of a.c. power became apparent, most new installations were equipped to deliver it. In some areas of the older cities, however, the expense of converting to a.c. was so great that the power companies continued and still continue to supply only d.c. to them.

A power transformer will not operate on d.c. As a result, TV sets using power transformers cannot be operated on d.c. If you are going to install a TV set in a d.c. area, you must either use a set designed for a.c.-d.c. operation or use some means of converting the d.c. from the power lines to 60-cycle a.c.

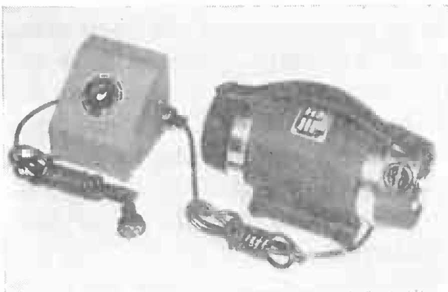
There are several devices that make it possible to change d.c. to a.c. You may use an inverter, a rotary converter, or a motor driven generator.

An inverter consists of a vibrator, a transformer, and a suitable filter assembly. One is shown in Fig. 27A. Commercially manufactured inverters are available from most wholesale supply houses.

The inverter has a few disadvantages. One of the most important, in this case, is that one large enough to supply a TV set that draws 300 to 350 watts is very expensive. Another is that some have a tendency to vary in frequency, an effect that may cause undesirable voltage variations in a TV set. There are inverters commercially available that can be synchronized with the field frequency of the TV signal so that their outputs are constant in frequency. Such devices are also very expensive, however.

Courtesy Cornell-Dubilier Electric Co.

FIG. 27A. A typical inverter used to change d.c. to 60-cycle a.c.



Courtesy Carter Motor Co.

FIG. 27B. This rotary converter is used to change d.c. to 60-cycle a.c. The small box contains a speed control device that permits the frequency of the output to be regulated.

The other commonly used device that may be employed is a rotary converter. One is illustrated in Fig. 27B.

Essentially, a rotary converter consists of a d.c. motor and an a.c. generator assembled on a common shaft so that the motor drives the generator. Most are designed to deliver 60-cycle a.c. power. The converter shown in Fig. 27B has a small speed-control device that can be used to regulate the frequency of the a.c. obtained. This is the small box into which the power cord of the converter is plugged in the illustration; it is called a "picture-control unit" by the manufacturer.

It is also possible to change d.c. to a.c. by using a motor-generator assembly. This assembly is much the same thing as the rotary converter except that the motor and the generator are built separately and mechanically coupled together. Most such assemblies are designed to deliver large amounts of power and are too expensive to use if a TV set is to be the only load.

In selecting a device to convert d.c. to a.c., make sure that the unit can supply the a.c. at the proper voltage and frequency and also that it is large enough to furnish the current needed to operate the TV set. A TV receiver usually has a current requirement of several amperes at approximately 115 to 120 volts, 60-cycle a.c.

Many inverters and converters are given both an intermittent-duty and a continuous-duty rating. Be sure that the continuous-duty rating is high enough to handle the requirements of the TV set, because the set will probably be used for several hours during an evening. A device designed to supply the required current under intermittent conditions only would not be capable of handling the load.

INSTALLATIONS IN 25-CYCLE AREAS

Some American cities supplied by hydro-electric plants have 25-cycle rather than 60-cycle power. A TV receiver that uses a power transformer designed for 60-cycle operation will not work satisfactorily on 25 cycles: there is not sufficient iron and copper in the power transformer, and the transformer will burn out. Even if the power transformer would work, the chances are that there would not be sufficient filtering in a 60-cycle receiver to give satisfactory performance on 25 cycles.

Therefore, if the customer's set is designed for 60-cycle operation and he wishes to use it in a 25-cycle area, about the only practical thing to do is to replace the power transformer with one designed for 25-cycle operation. It will probably also be necessary to increase the filter capacity to reduce the hum. This can be done by installing larger filter condensers or by connecting additional condensers across those already on the set. Be sure that the condensers being installed in the set have a working voltage that is at least as high as the working voltage of the condensers they are replacing.

If a suitable power transformer cannot be obtained, it may be possible to have one wound specially for the job. Such a transformer will be fairly expensive; however, about the only alternative is to use a frequency converter, which is considerably more costly.

The kind of frequency converter we refer to consists of a 25-cycle synchronous motor that drives a 60-cycle generator. This device has a constant-frequency output, because the output frequency is determined by the speed of the motor. Since it is a synchronous motor, its speed is determined by the frequency of the power line, which is practically constant.

Not all TV sets use a power transformer. Many sets use voltage-doubler and voltage-tripler circuits to obtain the necessary B-supply voltages. These circuits will not work on d.c., but they will work on 25-cycle a.c. power. When a receiver of this type is to be installed in a 25-cycle area, therefore, satisfactory performance can usually be obtained simply by increasing the size of the filter condensers without making any other alterations in the set. For this reason, a customer buying a set for use in a 25-cyle area will find it cheaper to get a transformer-less type if a set with a 25-cycle transformer is not available. You may wish to point this fact out to customers or potential customers living in such an area.

COMMERCIAL INSTALLATIONS

In general, commercial installations are handled in the same manner as home installations. The problems encountered are very similar. One difference between them, however, is that there is seldom a high electrical noise level in a private home, whereas there is very apt to be one in a commercial location. A tavern or restaurant usually contains many electrical devices —automatic phonographs, refrigerators, electric washing machines, neon signs, and fluorescent lights, for example. Considerable interference may be radiated by one or more of these devices. If you notice that the noise level is comparatively high in the TV set, the interfering device can be identified by shutting off the various electrically operated machines one at a time. If you notice that the noise goes down when a certain machine is shut off, that machine is generating at least part of the interference. You can probably reduce the interference from each such machine by using a suitable filter in the power line to the device.

Noise pick-up in the transmission line from such devices or from nearby automobiles can be kept to a minimum by using shielded transmission lines. For this reason, a shielded line is far superior to an unshielded line for a commercial installation. Since the charge for a commercial installation is usually somewhat higher than that made for a home installation, it is practicable from the cost viewpoint to spend the extra money for the shielded line.

Since people are often more careless about equipment in a commercial establishment than they are in a private home, make sure that the transmission line is securely fastened in place. If it is not, it may be kicked or pulled loose accidentally or someone may be injured by tripping over it. It is also a good idea to run the transmission line in such a manner that it will be as inconspicuous as possible.

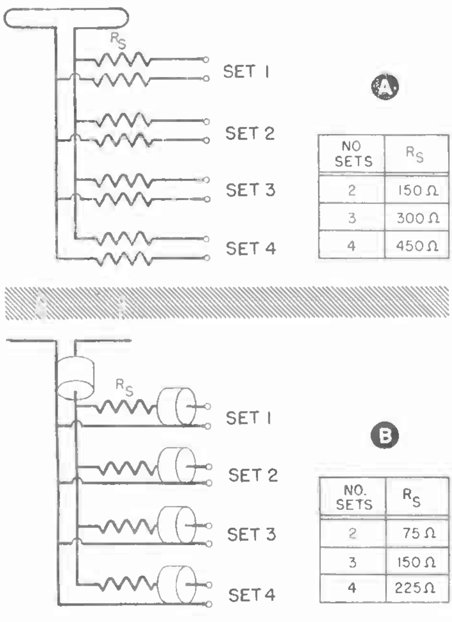


FIG. 28. Methods of connecting several sets to the same transmission line. The resistive networks permit the lines to be terminated in their characteristic impedances, thus eliminating line reflections.

Another difference between home and commercial installations is that there is usually only one set in a home but there may be several in a large commercial establishment. The use of several sets brings up the problem of connecting them to an antenna. Of course, one way of solving this problem is to use a separate antenna for each set. There may not be room for several antennas, however, or the proprietor may not want to use more than one. In this case, a distribution network must be used to feed the signal from a single antenna to several receivers.

Fig. 28 shows a simple way in which several receivers can be connected to a 300-ohm line (Fig. 28A) or a 72-ohm line (Fig. 28B). The matching networks shown permit the transmission line to be terminated in its characteristic impedance with the result that ghosts resulting from mismatch are avoided.

It is necessary to know the relative signal strength in a particular area before you can tell whether it is practical to connect 2, 3, or 4 receivers to the same antenna, because the total signal delivered by the antenna is divided equally among the sets. If there are two sets, for example, only half the signal fed to the line by the antenna is applied to each of them; if there are three, only one-third the signal is applied to each; and so on.

If the receivers are installed in a primary service area where the signal strength is comparatively high, it may be possible to connect many sets to the same antenna without any difficulty. In other cases, it may be nec-

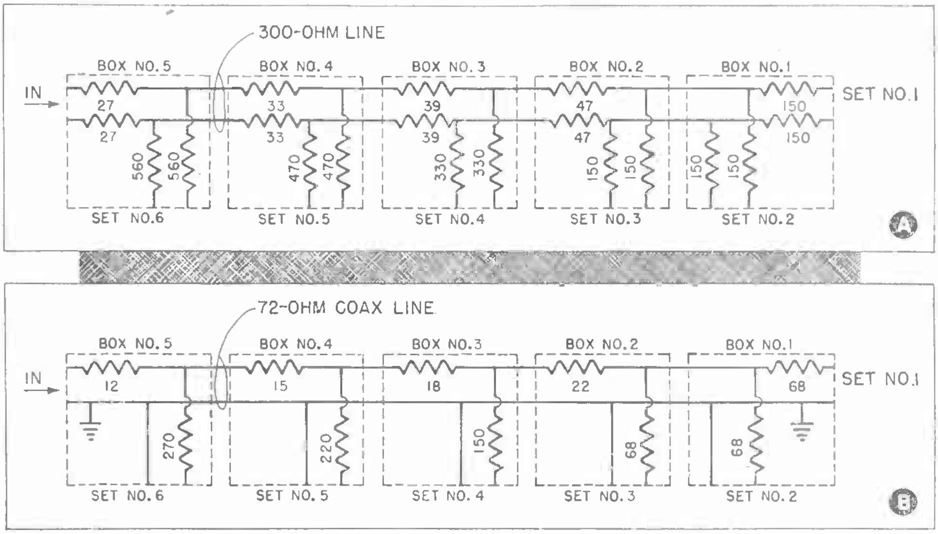


FIG. 29. These matching networks can be used to permit as many as 6 sets to be connected to the same line.

essary to use a high-gain antenna array or an array plus a booster to make up for the loss of signal strength as additional sets are connected to the antenna, even though such a high-gain system would not normally be required to get reception on a single receiver.

The circuit in Fig. 29 shows a complete matching network that can be used to connect as many as six separate receivers to the same transmission line. The network constants are such that signals of equal strength will be delivered to each receiver.

If fewer than six sets are to be connected to this network, the extra distribution boxes should be disconnected to keep the network in balance. For example, if only five sets are to be used, box No. 1 should be removed. The sets should then be connected to the positions marked set No. 3, set No. 4, set No. 5, and set No. 6. The fifth set should be connected to the leads that went to box #1. Similarly, if only four receivers are to be used, boxes No. 1 and No. 2 should be removed, and so forth.

The circuit shown in Fig. 29A should be used for receivers having 300-ohm balanced inputs. The one in Fig. 29B is a similar network for use with a 72-ohm unbalanced system in which a coaxial cable is used.

APARTMENT-HOUSE INSTALLATIONS

Many landlords will not permit tenants to install individual TV antennas on the roofs of their apartment houses. In cases of this sort, the TV set owner must generally use a window or an indoor antenna unless he has a set having a built-in antenna.

The effectiveness of such antennas, including built-in ones, depends on the location. In many places they work well, in others they are satisfactory if boosters are used with them. Very often, however, a TV receiver will fail to give satisfactory performance unless it is connected to a suitable outside antenna.

Usually an apartment-house owner who will not permit each tenant to erect an outdoor antenna will allow one master antenna to be put up. For that matter, it may not be desirable for every tenant to put up his own antenna even if he is permitted to do so, because each antenna will have a certain effect on any other antenna near it. For this reason, antennas cannot be placed too close together; if they are, the result is that none of them works well. This fact creates a problem when there are a great many television sets in one apartment house, because it is impossible to erect enough antennas on the roof to take care of all of them without having the antennas so close together that all of them will be affected.

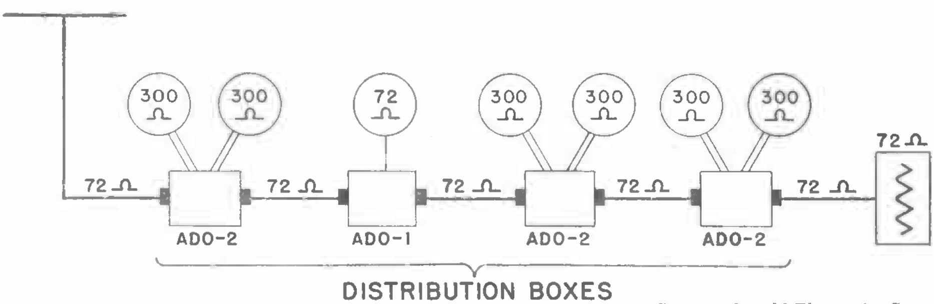
There is, therefore, a demand in apartment-house installations for a master antenna system that will furnish a signal for several receivers. In small apartment houses, systems like those shown in Figs. 28 and 29 may be suitable. A more elaborate system must generally be used for a large apartment house, however.

Several systems have been devised to answer the problem of apartment house installations. One of these is the Jerrold "Mul-TV Antenna System," which we shall describe briefly.

The simplest form of the Jerrold system is shown in block diagram form in Fig. 30. As you can see, it consists of a series of distribution boxes coupled to each other and to the antenna by 72-ohm coaxial transmission line. (For convenience in reference, we shall call this the distribution line.) A 72-ohm terminating resistor is connected across the end of the line.

Two kinds of distribution boxes, called ADO-1 and ADO-2 by the manufacturer, are used in this system. The ADO-1 is used to couple one 72-ohm set to the line, the ADO-2 to couple two 300-ohm sets to it. Either kind of box can be used anywhere in the system, so 72-ohm and 300-ohm receivers can be connected to the line in any proportion.

Each distribution box contains a cathode-follower amplifier and its power supply. The input of each box is connected across the distribution line; since this input consists of the grid circuit of the cathode follower



Courtesy Jerrold Electronics Corp.

FIG. 30. A block diagram of the Jerrold Mul-TV antenna system intended for use in apartment installations. Either 72-ohm or 300-ohm receivers can be connected to this system. One or two sets can be connected to an ADO-2 box.

and therefore has a high impedance, it attenuates the signal in the distribution line only slightly. For this reason, a great many boxes can be connected to the line without attenuating the signal too much.

The output of each box is taken from the cathode circuit of the cathode follower. Therefore, the only connection between the input and the output is through the internal capacities of the tube, which are low. For this reason, there is practically no backward transmission (from output to input) of signals through the distribution boxes. This means that any signal feeding back from the local oscillator of a set that is connected to the output of a distribution box will be very severely attenuated before it is applied to the distribution line of the system. The distribution boxes thus act as decoupling devices to prevent the receivers connected to them from interfering with each other.

The manufacturer of this system offers several accessories that can be used to adapt it to meet various needs. For example, there is a matching transformer that permits the 72-ohm distribution line of the system to be matched to a 300-ohm line if it is necessary to use the latter with the antenna selected.

Another accessory device is a channel amplifier that is intended for use in low-signal areas or in installations in which the run of the coaxial distribution line is so long that the signal is attenuated too much. This amplifier contains four plug-in amplifier strips, each of which is a 6-tube r.f. amplifier that is designed to handle a particular channel. There is an individual gain control for each strip, an arrangement that permits the outputs of all the strips to be adjusted to the same level. These individual outputs are applied to a mixing network from which they are fed to the main distribution line of the system.

Each amplifier strip of this device has its own input. If an individual antenna is used for each station that is to be picked up, the transmission line from each antenna can be connected to the appropriate amplifier input. If a single antenna is to be used for all stations, however, an antenna matching network offered by the manufacturer must be used. This network consists of six tuned circuits connected in parallel across an input terminal that is connected to the transmission line from the antenna. Each circuit can be tuned over a range of 20 mc., and their basic frequencies are staggered so that their combined range covers all the TV and f.m. frequencies. When this network is used, the antenna transmission line is connected to its input, and the proper outputs are connected to the individual inputs of the channel amplifier. The unused outputs of the network can then be used to trap interference if desired.

Another network offered by the manufacturer is the reverse of the one just described. It is intended to be used to couple the transmission lines from as many as six individual antennas to the single coaxial distribution line of the system. It is used only with unamplified systems, of course.

Finally, the manufacturer offers noise filters for each TV channel. These are intended for use only with amplified systems. Each is installed just ahead of the amplifier for the channel for which it is designed.

The choice of the antenna to be used with this master system depends upon the location. If several stations lying in different directions are to be picked up, it is usually best to use an individual antenna for each, aiming it for best pick-up and minimum ghosting. If all the local stations can be picked up well with one antenna, however, there is no need to use a separate antenna for each.

In an apartment-house installation, the use of an antenna system of this sort is very desirable. Not only does it furnish each tenant an adequate signal for his set on each channel, but also it practically eliminates interference between receivers. Its cost is fairly high but not excessively so, particularly if it is installed while the house is being built, since it is simple at that time to run the necessary distribution cable from one apartment to the next.

DEALER INSTALLATIONS

Dealer installations may be divided into two categories. One is the installation used for demonstrating TV sets to prospective purchasers, the other is the kind that may be used in the service shop to assist the technicians in servicing TV receivers.

An installation that is to be used to demonstrate receivers to prospective buyers should be as good as it can be made. When a customer comes into a dealer's store to watch a television receiver, it should be working as well as possible. Many sales have been lost because of a poor demonstration caused by a slip-shod installation. Every available local channel should give a good clear picture. It is not sufficient to pick up one or two channels well and the rest poorly. The customer may appear willing to accept the explanation that this condition is due to the antenna, but inwardly he may think that the inability of the set to produce good pictures on all channels is due to some fault in the set. Even if he believes that the defective operation should be blamed on the installation, he will probably not have a high opinion of a serviceman who cannot make a satisfactory installation in his own store.

There is another reason why the antenna installation should be the best possible. It is easier to tune in a television set on a strong signal than it is on a weak signal. When the signal is strong and free from interference, there is little chance that the set will lose sync. Most customers like to operate a TV set themselves before purchasing it. If there is a strong signal available, they should be able to obtain a good clear picture very easily. This will impress them with the ease with which the receiver operates, which should be an excellent selling point for an aggressive salesman.

For these reasons, a master antenna system of the sort we just described is by all odds the best kind to use for dealer demonstrations. A small dealer, however, may not feel he can afford to install an elaborate system. In such a case, you can make a fairly inexpensive installation for him by using a single antenna and a distribution system like that shown earlier in Fig. 29 if his store is located in an area where the signal strength is high.

Before connecting two or more television sets to the same antenna, however, check the sets carefully to make sure there will not be any interaction between them caused by radiation or feedback from their local oscillators. Incidentally, remember that sets having balanced and unbalanced inputs should never be operated together from the same antenna unless some device like the distribution boxes of the Jerrold antenna system is used.

If the signal strength is not high enough to make it possible to operate several sets at once from the same antenna, the arrangement shown in Fig. 31 can be used. Here all the sets are connected to the single transmission line through toggle switches. When one set is to be demonstrated, close the switch that connects it to the line, and open the other switches.

The antenna should be located as far as possible away from the street and from any electrical devices to reduce the noise pickup to the minimum. Shielded transmission line should be used so that there will be no line pickup from noise-producing devices or from radiation of the local oscillators in nearby TV sets or f.m. receivers. Noise coming in through the power line can be reduced to a minimum by installing power-line filters at the outlets to which the sets are connected.

The transmission line should be tacked neatly in place and kept as much out of the way as possible. If the transmission line is left lying around loose, not only will it appear unsightly, but also there is the danger that someone may trip over the line and be injured.

It is just as important to have a good antenna installation for a service shop as it is to have one for a dealer's showroom. The antenna must be capable of producing ghost-free pictures on all available TV channels. This is important to you as a serviceman because ghosts can be caused by improper alignment of the TV receiver. If the antenna installation in the shop is a poor one that produces ghosts, you may attribute ghosts to the installation when they are really caused by improper alignment. If so, you will find that the ghosts are still present when you return the set to the customer, and all attempts to orient the antenna to eliminate them will be useless.

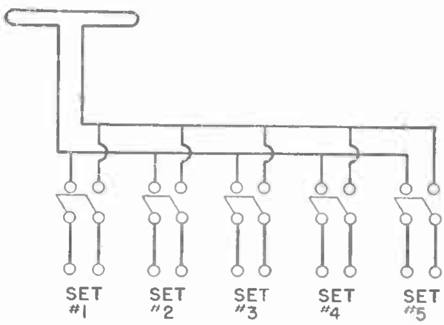


FIG. 31. This multiple installation is designed to permit several different sets to be connected to the same line one at a time.

Another reason for having a good antenna is that the customer will frequently come into the shop to look at his set. Sometimes a customer believes his set is defective when the real trouble is that he made the installation himself and failed to do it properly. If such a customer comes into your shop and sees the set operating properly, giving clear, sharp pictures on all available TV channels, it will be much easier to convince him that the trouble is due to his installation. On the other hand, if ghosts are present and the picture is poor in your shop as well as in his own location, it's going to be rather difficult to convince him that his installation is at fault.

Again, a master antenna system like the one described earlier is the best kind to use in a service shop. If you do not want to use such a system for some reason, you should install two sets of antennas—a high-band-low-band folded dipole and a similar plain dipole. Use 300-ohm (preferably the shielded kind to eliminate line pick-up) for the folded dipole, and 72-ohm line for the plain dipole.

In either case, there should be connection terminals at various convenient points along the service bench. At each point, there should be a connection both to the 300-ohm balanced transmission line and to the 72-ohm coaxial line. This arrangement makes it possible to service either kind of set at any location along the bench.

Lesson Questions

Be sure to number your Answer Sheet 62RH-2.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next Lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of Lessons before new ones can reach you.

1. When a leading ghost is caused by direct pickup in the front end of a set, what two steps should be taken to get rid of it?
2. Name two causes of tunable ghosts.
3. If a number of vertical bars appear on the face of the picture tube, is the frequency of the interfering signal (a) *lower than,* (b) *equal to,* or (c) *higher than* that of the horizontal sweep?
4. Which kind of resonant circuit does an open quarter-wave stub act like: (1) a *parallel* resonant circuit; or (2) a *series* resonant circuit?
5. If it proves impossible to eliminate f.m. interference on channel 2 by using a stub or a trap and re-orienting the antenna, what other remedy should you try?
6. If a carrier of the channel *below* the one to which the set is tuned causes interference, which ONE of the following traps should you adjust: (a) *the sound trap,* (b) *the adjacent-channel sound trap,* or (c) *the adjacent-channel picture trap?*
7. What kind of antenna should you use, even in a strong signal area, if ignition noise is a problem?
8. When interference from a TV set causes a nearby a.m. set to have birdies about every 15 kc., what circuits in the TV set are likely to be causing the trouble?
9. If the signal from one station is excessively strong at a particular location, how can you reduce its strength without affecting the response of the set for other stations?
10. If several sets are to be operated from the same antenna, but the addition of the extra sets reduces the signal strength too much, what two things should you try before considering the use of a special master-antenna system?

Be sure to fill out a Lesson Label and send it along with your answers.

Why Do You Want to Succeed?

There are several answers to this question. You may want to succeed for the very human reason that you want more money with which to enjoy life, or you may have a family for whom you want to provide those comforts they so well deserve—a home, a new car, good clothes, life insurance, and financial security.

Your ambition to succeed may be prompted by the desire to bring happiness to an aged father, mother or relative whose chief hope in life is to see you enjoy prosperity and prestige, to see you on the pinnacle of success.

Pause for just a minute and think—*what is your reason for wanting success?* With this reason in mind, resolve firmly that you will never allow your ambition to weaken. Resolve that you will never swerve from the direct path to your goal. Make this resolution now and keep it, so the years to come will be happier and more prosperous for you.

J. E. Smith

TV RECEIVER
SERVICING TECHNIQUES

63RH-2

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 63

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. **Introduction** . . . . **Pages 1-5**

In this section, you learn some basic facts about television servicing.

☐ 2. **Test Procedures and Instruments** . . . . **Pages 5-12**

The methods and servicing instruments used to locate defects in TV sets are described in this section.

☐ 3. **Handling TV Service Calls** . . . . **Pages 12-18**

Here you review the safety precautions you should take in servicing TV sets and learn how to handle the various kinds of TV chassis, then study the various servicing procedures involved in determining and confirming complaints.

☐ 4. **Effect-to-Cause Reasoning Applied to Dead Sets** . . . . . **Pages 18-27**

In this section, you learn how effect-to-cause reasoning can be used to determine the probable location of the defect causing various dead-set complaints.

☐ 5. **Sync and Sweep Defects** . . . . **Pages 28-36**

Here you learn what effects common defects in the sync and sweep circuits have on the performance of a set. You also learn how to use effect-to-cause reasoning in locating such defects.

☐ 6. **Answer Lesson Questions and Mail Answers to NRI for Grading.**

☐ 7. **Start Studying the Next Lesson.**

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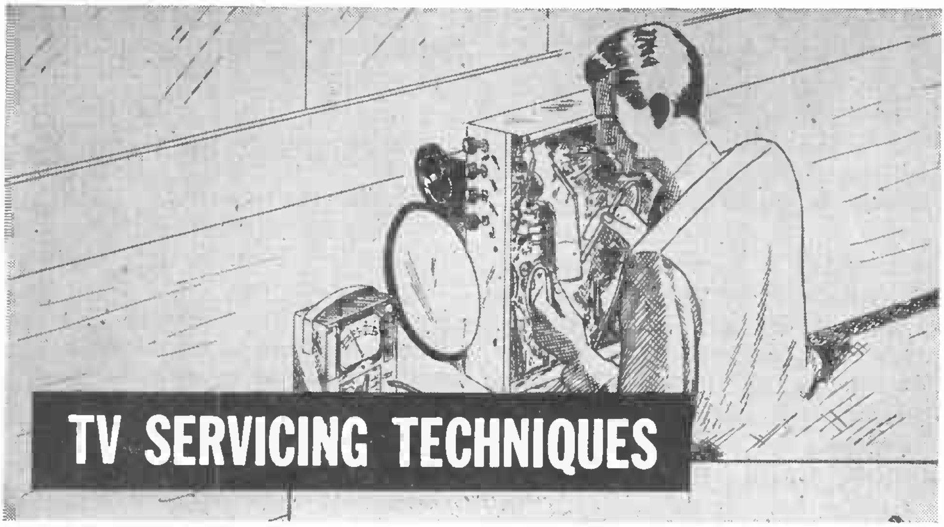
BP5M951 1951 Edition Printed in U.S.A.



TV SERVICING TECHNIQUES

TELEVISION RECEIVER servicing is in general the same as sound-radio receiver servicing. The same basic troubles exist, the same tools and test equipment are used, and the same general servicing procedures are followed in localizing the troubles. Once the successful *radio* serviceman has learned the fundamentals of television circuits, therefore, he can adapt himself to television servicing without too much trouble. The most successful TV servicemen are today being drawn from the upper ranks of radio servicemen, and this practice will probably continue indefinitely.

We strongly recommend, therefore, that you become an expert radio serviceman before doing any television servicing. Obviously, you will be able to find your way around easier in a 5- or 10-tube sound receiver than in a 20- or 30-tube TV set. Once you have developed your ability to use effect-to-cause reasoning and professional isolation procedures on sound receivers to such a point that servicing them becomes routine, you will be ready to apply your knowledge to the more elaborate television receiver. When you do, you will find that TV sets contain the same kinds of resistors, coils, condensers, and tubes as do sound receivers, plus a few special parts. The same troubles—open circuits, short circuits, and changes in value—occur in all these parts, and the same basic methods of testing them are used.

The use of a large number of stages in a television set makes it somewhat difficult at times to localize the trouble, but in many cases the very complexity of a television set is helpful. As we shall show later in this Lesson, the fact that you have separate paths for the sound, sync, and picture signals will often let you identify the section or even the stage containing the trouble just by watching the picture and listening to the sound. Before you can do so, however, you must have a complete understanding of the circuits involved.

As you know, there are many possible variations of the basic TV circuits. Obviously, you must determine what arrangement of stages is in use in the set on which you are working. In television servicing, therefore, even the expert must rely heavily on circuit diagrams. As we shall show later in this text, the circuit diagram can be used to speed up the service procedure to a remarkable extent.

However, it is important to have the *proper* circuit diagram. Many sets having the same model number are radically different from each other because improvements have been incorporated in the model after a few thousand sets were produced and shipped. It is not uncommon to find five or six different runs of the same model, some using as many as two or three tubes more or less than others bearing the same model number. Eventually, of course, such radical changing of sets during production will die out; but in the meantime, the serviceman in the television business must make an effort to keep up-to-date with the latest service information. If you handle only one particular line, you can get the information from the manufacturer. If you run or work in a general service shop in which you may be called upon to fix all types of sets, however, you need the television service manuals that cover all sets. These are similar to the radio receiver service manuals with which you are familiar.

In this Lesson, we shall assume that you are a radio serviceman and know the professional procedures that have been described in your Lesson on radio servicing. If you have not yet become expert in these procedures, you must do so to get the fullest use from this Lesson. Even if you are not yet ready for TV servicing, however, you will find the basic procedures understandable and can learn what to expect.

Table 1

6AG5	**6BA6**	**6BG6G**
6AU6	**6K6GT**	**6V6G**
6AL5	**5U4G**	**5V4G**
6SN7GT	**1B3G**	**6AC7**
6J6	**12AU7**	**6W4GT**

Now let's review TV parts and learn more about the kinds of defects that may occur in them.

TV RECEIVER PARTS

Most of the tubes used in television receivers are of the miniature type, because they have low inter-electrode capacities and permit the use of compact circuit arrangements. Two of these are likely to be different from any tubes used in even late-model sound receivers. One is the high-voltage rectifier; the other is the horizontal output tube, which in an electromagnetic sweep system is usually a special type in which the plate lead is brought to a top cap. Table 1 gives a list of the 15 tubes most commonly found in TV receivers; this list will be helpful in arranging a stock. Of course, this list refers to *present* receivers, and there may be changes in the future. Further, these are the *most-used* tubes—not all that are used. TV sets generally use more different tube types per set than is common in sound receivers. In a 30-tube TV set, for example, there may be 17 or more different types of tubes used—only one of most types, but three or four of some of the others. Obviously, your stock must contain all the tubes that are used in the sets you may have to service.

Because tube capacities are made use of in some television circuits, it sometimes happens that a tube will operate in one circuit but will not in another in the same set. A typical example is the case in which tubes of the same type are used as the local oscillator and as an r.f. amplifier. A tube that is used as a replacement for the r.f. oscillator must have internal capacities somewhat like those of the original tube if it is to operate without requiring a realignment of the set. On the other hand, much of the capacity difference is swamped when the same tube is used as an r.f. amplifier. A tube tester does not show tube capacities, so only a trial of several tubes will permit you to find the best one. Those that aren't usable in one place can be saved for the circuits in which their capacities are less important.

Certain stages are hard on tubes. For example, some of the sweep amplifiers pass rather high peak currents, although their average currents are not much greater than normal for the tube type. However, a tube that is operated in this manner may have a shorter life than it would have in some of the other circuits in the receiver.

Tube defects are by far the most common difficulty encountered in a TV set—far more so than in a radio, both because TV circuits are more critical in their operation, and because many of the other parts that might be expected to break down occasionally are quite commonly oversize in TV sets. For example, it is very common to find practically all of the resistors to be 1-watt or 2-watt sizes instead of the familiar ½- and ¼-watt types that are ordinarily used in radio sets.

Engineers were quite cautious in setting the original ratings for early TV sets because they did not want parts failures and consequent repair bills to set back the introduction of television too much. In addition, not too much was known about the exact limits of parts values for television purposes. It was well known that the eye is quite sensitive to changes in the picture, but it was not very well realized how great a difference in certain part values could occur before the picture was seriously affected. Therefore, most of the resistors were made oversized in their wattage ratings to avoid drifting and changes in value caused by temperature rises. (Heat is more of a problem in a TV set than it is in a radio, because a TV set contains many more tubes, all of which radiate heat.) It has since been discovered that some resistors were made unnecessarily high in rating.

On the other hand, it has been found that certain circuits are even more critical than was originally expected, with the result that some parts have to be held to closer tolerances than is usual in radio receivers. It is rather common to find resistors having 5% and 10% tolerances instead of the 20% tolerances that are acceptable in most radio circuits.

Another change is that the electrolytic condensers used in TV sets are designed to operate under higher surrounding temperatures than are normally found in radio receivers—in fact, they are given temperature ratings in addition to the usual capacity and voltage ratings. For this reason exact duplicates should be used for replacements of electrolytic condensers in TV receivers.

Many of the paper by-pass condensers used in TV circuits have high voltage ratings—some of them extremely high. An example is the coupling condenser used between the sweep output stage and the deflection plates of an electrostatic tube system, which may be rated at 6000 to 10,000 volts.

The insulation between the plates of most of the coupling condensers and of many of the by-pass condensers is ceramic rather than paper. Ceramic condensers are preferred because they can be very small and yet have high capacity. Their smallness makes it easier to fit them into a crowded television chassis, and minimizes the stray capacity between the condenser itself and the chassis. In addition, their smallness makes it possible to use very short leads, thus reducing the inductive effects of these leads and permitting the condenser to be a more effec-

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tive high-frequency by-pass. Some of these condensers, incidentally, look just like resistors. Others are wafers that look like dimes with leads.

Finally, there are a few parts that are found only in TV sets, such as deflection yokes, focus coils, sweep output transformers and blocking-oscillator transformers, to name the most important ones. These special parts are often designed for one particular receiver and must be replaced by exact duplicates if they fail.

Because any disturbance of wire position can be disastrous in high-frequency circuits, you must be sure to put in replacement parts that are of the same physical sizes as the originals and be certain that they are in the same positions and have the same lead dress (position) as the original parts. Because of this requirement, you cannot follow the common radio practice of installing a new part anywhere in the circuit that the proper electrical connections can be made. Further, if there is a defect in only one section of a multi-section part, such as a multiple filter condenser, you must sometimes replace the whole part so that the replacement can be installed in the right position.

It is particularly important to connect a replacement part to exactly the same points as the original. As you learned elsewhere, many tube circuits use separate cathode leads to reduce cathode inductance effects. In such cases, the by-pass condensers must be brought back to the proper cathode terminal to prevent circuit interaction.

Of course, in making a replacement, it is important not to move the wires that are already in the circuit any more than is necessary, because the positions of many of these wires will be quite critical.

At first it may seem that you will need hundreds of special sizes of parts to be able to service the many different TV models. Fortunately, however, TV sets in general follow five or six basic designs used by the leaders, such as RCA, DuMont, GE, Admiral, and Philco; as a result, a stock of replacement parts does not have to be too extensive. Furthermore, television is now chiefly restricted to the larger cities, where the presence of wholesale distributors simplifies the stocking problem. By the time television stations are in the smaller communities, in all likelihood the circuits will be much more standardized than they are now so that not too great a stock will meet most service emergencies.

Although picture tubes have proved to have much longer life than was anticipated at first, they must be replaced from time to time. Since picture tubes are expensive, it is not wise to stock them if replacements are readily available from any nearby supply house or distributor.

Naturally, if you work for or become an official service center for a particular brand of receivers in a particular locality, you will be expected to stock a rather complete assortment of parts for that brand. The manufacturer or his distributor for your locality will help you to select the proper assortment.

TV TROUBLES

In this and the following Lessons, we shall assume that you have been called upon to fix a set that has a definite service complaint. In practice, you will often be asked to fix a set that is simply out of adjustment or that is bothered by outside interference. We shall not, however, repeat here the information given in earlier Lessons on adjusting TV sets and eliminating TV interference.

One thing you must keep in mind is that different brands of sets may differ considerably in their picture reproduction and sound quality. Some sets have very high sensitivity and are intended to operate well in the fringe areas. Others will operate acceptably only in areas where the signal strength is high. If you find that a customer's set is not the type he should have for his particular desires or location, you should recommend a more appropriate one. Don't try to modify his set to make it work—set designing is not your job.

You are quite likely to get a number of calls from customers who misinterpret operating instructions or do not understand the limits of their sets. When you start in business, therefore, familiarize yourself as quickly as possible with the characteristics of the receivers that are sold in your locality so you will be able to set these customers right.

Of course, a TV set amounts to a double receiver containing both a sound and a picture section. Ordinarily, if the picture is normal, but the sound is absent, distorted, or otherwise affected, you can consider that only the sound channel is defective, and you can service it much as if it were just an f.m. sound receiver. In general, we shall assume that you have the ability to run down any such complaints as these, and we shall confine our discussion to service complaints in which the picture is affected.

There are really only two service complaints as far as the video section of a TV set is concerned. Either the set is dead (by which we mean that there is no picture, whether or not part of the set is operating) or the picture is distorted in some manner. There are so many ways in which a picture can be distorted, however, that we shall divide this complaint into the following three classes:

Class 1—picture distortions that are caused by improper adjustment of the controls on the set or by defects that produce the same effect on the picture as a misadjustment does. In this class are all conditions involving sync and sweep defects in which the picture would be normal if the proper synchronization or the proper linearity in the sweep could be obtained. Also included are conditions in which the picture is out of focus, not centered, or tilted.

Class 2—picture distortion in which the picture is normal except for an overlaid pattern or smear that is caused by a defect in the set. A picture that has hum in it or that lacks detail because of loss of low- or high-frequency response caused by defects is in this category.

Class 3—picture distortion caused by receiver mis-alignment. Included here are i.f. oscillation and lack of high-frequency response caused by mis-alignment.

Now, let's take up the basic servicing procedures.

Test Procedures and Instruments

Television receiver servicing can be treated in the same straightforward, logical manner as sound-radio servicing; as a matter of fact, the basic service procedure is the same for both. Fig. 1 gives the 10-step plan for quickly localizing the trouble. Let's consider each of these steps:

1. Determine the Complaint. Your time as a TV serviceman is too valuable to be wasted in unnecessary service calls, so it is important that

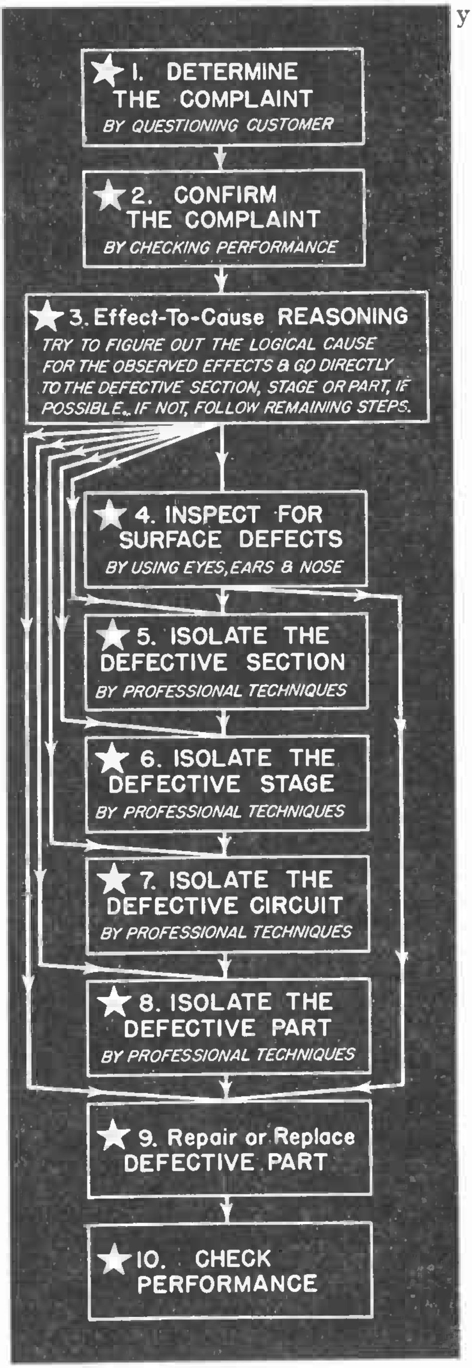


FIG. 1. You will find that this 10-step servicing procedure is as effective when you are locating and repairing defects in TV receivers as it is for radio sets.

you first determine that an actual service complaint exists. If the set owner has called you on the telephone, a little careful questioning may let you diagnose the trouble as something as simple as the fact that the set is not plugged into a power outlet or that the customer is trying to operate the receiver improperly.

In questioning the customer, remember that he does not speak your language; ask questions that will give you the information you need. By asking him to describe exactly what it is he can see on the screen of the tube or can hear from the loudspeaker, you can get a much better idea of the exact nature of the complaint.

If it is impossible to suggest anything over the telephone that the customer might do to localize the trouble himself, you need to know the make and model number of the set (if you do not have this information on file) and must make a service call.

If the customer brings his set into your shop, you will ordinarily plug it in and go on to step 2 at once. Even so, question the customer carefully to determine how the set was performing just before the breakdown that he is complaining about occurred. Some defects will mask others that existed previously. Be particularly suspicious of a dead set, because when you have restored it to life, you may find that another trouble is present that was hidden by the one complained about.

2. Confirm the Complaint. It is best to have the customer himself operate the receiver to demonstrate the complaint. By watching him, you can tell if he just needs further instruction or if an actual defect exists. Once you are sure that the customer has made no error in describing the difficulty and that he is operating the set properly, you can go on to localize the trouble.

You should make sure at this time that the trouble is caused by a defect in the set and not by outside interference. This should not be particularly difficult, since oscillation and internal noise are about the only set defects that will produce an effect on the picture that will resemble the pattern caused by outside interference. The best way to tell whether outside interference is to blame, when you see such patterns, is to try the set in a different location (such as your shop). You might also try a test receiver at the customer's location; however, if the responses of your test receiver and the customer's set are very different, such a test may be misleading. When you have learned enough about the responses of the sets that are common in your vicinity, you will be able to compare the picture on your test receiver with that on the customer's set and determine at once whether any differences you observe are caused by a defect or by the difference in response.

3. Effect-to-Cause Reasoning. Once you have determined and confirmed the complaint, you should try to apply reasoning just as you would in radio service work. Often the indications given by the picture or the sound will lead you directly to the section, stage, circuit, or even part that is defective. Of course, if these indications are so general that reasoning is inconclusive, you must make isolation tests. During such tests, and after each test, however, don't fail to try to re-apply reasoning; every step you can cut out means that you will service the set that much quicker.

4. Inspect for Surface Defects. Although this is given as a separate step, it may well be a part of the confirmation of the complaint or the effect-to-cause reasoning processes. Look for such possibilities as a burned-out tube, plug out of the wall socket, antenna disconnected, etc., before you make any effort to remove the chassis from the cabinet. You will want to see if the tubes light or get warm, sniff for odors indicating overloaded parts, and listen for noises and watch the screen of the picture tube as you rotate the controls while trying the set.

If you find it necessary to remove the chassis, again make a careful inspection. A burned-out resistor or shorted condenser may be entirely obvious once you have the chassis in a position where you can examine the parts underneath it.

5. Isolate the Defective Section. As we shall point out later in this text, many clues may be present that will help to determine what section of the set may be at fault. The fact that both the picture and the sound may be affected by some complaints, whereas other complaints will affect only one or the other, means that you can determine quickly the approximate location of many common troubles. By reapplying effect-to-cause reasoning once you have learned which section is defective, you may be able to go at once to the defective stage, circuit, or part. On the other hand, it may be necessary to make further tests to determine just where the defect is.

6. Isolate the Defective Stage. The same basic professional servicing techniques that are used in radio receiver servicing can be used to check through the defective section to isolate the stage at fault. Once you have localized the trouble to the stage, effect-to-cause reasoning will lead you to make certain definite tests. In particular, unless the trouble is obviously not due to a tube defect, another tube should be tried. Do not depend solely on a test in a tube tester. A tube tester cannot be expected to show if a tube will work as a blocking oscillator or as a horizontal sweep amplifier, for example.

7. Isolate the Defective Circuit. If the trouble proves not to be the tube, and effect-to-cause reasoning does not disclose the circuit or part, then proceed with the usual voltage measurements, continuity tests, and other service procedures for determining the defective circuit.

8. Isolate the Defective Part. Once you have run the trouble down this far, it is usually possible to go right to the most logical part that could be the cause of the trouble. However, it may be necessary to continue the testing procedure within the circuit you have found to be defective until you actually do localize the part. We'll go into these localization procedures in more detail elsewhere, but in general they are identical with the procedures that you have been using on sound radio receivers.

9. Repair or Replace the Defective Part. In most cases, you should use an exact duplicate replacement for the defective part. In some circuits, in particular, the physical size of the replacement is important; you would do well to use the same brand of part in such places. In other circuits, you will not need to use the same brand as long as the electrical characteristics of the replacement are identical with those of the original one. Remember that the tolerances of TV parts are often closer than those of parts used in radio sets.

10. Check Performance. Try the receiver to make sure the customer's complaint has been eliminated. It is always desirable to demonstrate to the customer that his complaint has been corrected and, in cases involving possible misadjusment, to have the customer try out the set in your presence. This will give you an additional opportunity to instruct the customer in the operation of the set and to clear up misunderstandings about the characteristics of the set or its operation

After you have completed the repair, it is an excellent idea to allow the set to play for a fair length of time to be sure no intermittent defect is present. However, this procedure is not practical when the set is serviced in the home of the customer, (which is a common occurrence in TV servicing), so you may be forced to leave the set in the hands of the customer and thus face a possible call-back in some cases.

SERVICING PROCEDURES

The procedures that are used to localize the defect and to check for the defective part are the same as those you would use in radio service work. That is, you have circuit disturbance, signal injection, signal tracing, stage blocking, etc., as your means of localizing the defect. Naturally, these tests do not operate even in a radio receiver for every single complaint in exactly the same manner, and this is even more true in television.

Circuit Disturbance. For example, the circuit disturbance test can be performed only on a set that has a power transformer and no tube circuits or tube filaments in series, just as in the case of a sound receiver. Anywhere in the path containing the sound system, the circuit disturbance test will operaate just as it would for a radio receiver. In the video circuits, however, the circuit disturbance caused by pulling out a tube will result in a flash of light on the picture tube screen. The flash won't get any brighter as you interrupt circuits farther along in the signal chain, so such a test is of value only in the case of a dead set. The test is not greatly used even on a dead set, however, because as we shall show, effect-to-cause reasoning will usually lead right to the defective section.

Signal Injection. Signal injection may be used in the video circuits even though there is no picture, as long as there is a raster on the picture tube. Even a tone-modulated signal generator will produce a pattern (a series of bars) on the picture-tube screen. Generators designed specifically for television service work are modulated so that their signals produce certain characteristic patterns on the picture-tube screen that are useful for television servicing. One such generator, for example, has an output that will produce a series of dots of light that will completely cover the screen if the signal gets through from the point of injection to the grid of the picture tube.

Signal Tracing. The signal tracer with which a great deal of sound radio service work is done does not ordinarily tune to frequencies sufficiently high to be fully useful on TV sets. We can expect that TV tracers will be made available eventually, however. In the meantime, crystal detectors built into probes provide a way of obtaining a signal from a TV carrier that can be amplified by the audio stages of the tracer.

Most of the signal tracing that is being done in TV is with the cathode-ray oscilloscope, because it can be used not only to find out whether a signal is present or not but also to show the wave shape; hence, it is quite useful in running down sources of distortion as well as in locating the defect causing a dead set. A crystal detector probe is used for tracing in the stages ahead of the video detector, but the oscilloscope is used directly in the video, sync, and sweep circuits. A schematic of a typical crystal probe is shown in Fig. 2; more details on the use of the oscilloscope will be given elsewhere.

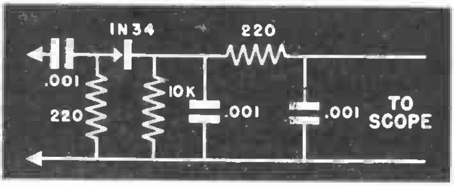


FIG. 2. Schematic of a crystal probe.

As we shall point out, the division of a television receiver into sections in itself provides a certain amount of "signal tracing," and certain other checks can be made within the set to secure the results that signal tracing would give. For example, on a dead set, it is possible to connect a d.c. voltmeter across the video detector load and then to switch from channel to channel by tuning the set. If there is any change in the voltage across the load as the various channels are tuned in, you know that a signal is reaching this point and is being rectified by the detector. The trouble must then be between this point and the picture tube.

Even better, the audio amplifier itself can be used for signal tracing to a certain extent. For example, the sweep circuits produce audio frequencies. It is possible to use an audio signal tracer to follow from the oscillator through the output of the sweep circuit when trouble is encountered in this section. Alternatively, by using a blocking condenser and a test lead, you can feed the signal into the grid of the first audio tube and thus use the audio amplifier of the television receiver as a tracer.

TV TEST EQUIPMENT

Once trouble has been localized to a stage, you will use a multimeter to measure voltages and to check resistance just as you would in a radio receiver. As a matter of fact, you can take voltage readings throughout the set to locate the defective section and stage if no other test suggests itself.

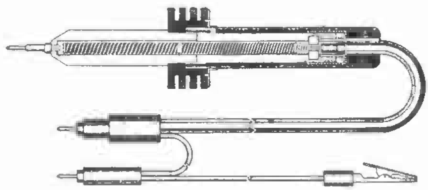
The ordinary multimeter that is designed for radio service work is entirely adequate for most of the checking that needs to be done in a television set. In general, it is advisable to have a multimeter that has extended low and high ohmmeter ranges, because TV resistors vary from just a few ohms to 10 megohms and more Most of the modern 20,000-ohm-per-volt multimeters are capable of giving the required ohmmeter ranges.

Vacuum-tube voltmeters are also popular, because their high input resistance makes it possible to obtain more accurate readings in high-resistance circuits.

High-Voltage Readings. The multimeter cannot ordinarily be used to measure the high voltage that is supplied to the second anode of the picture tube. Servicemen get around this in two ways; they make a rough check by determining how long an arc they can draw from the power supply, or else they buy a high-voltage multiplier to go with their multimeter.

In checking a voltage by drawing an arc, a screwdriver with a well-insulated handle is used. The screwdriver blade is touched to some grounded bracket or part on the chassis, then the tip of the screwdriver is brought near the high-voltage terminal, and the spark that jumps the gap from the high-voltage terminal to the screwdriver tip is observed. The distance the spark will jump is proportional to the voltage, and with experience it is possible to guess roughly what the voltage is by this method.

Of course, there is some danger in this method, and it is far more accurate to make an actual measurement. For this purpose, a multiplier like the one shown in Fig. 3 is used. Such a multiplier consists of a high resistance built right in the tip of a test probe made especially for the purpose. This resistance acts as a voltage divider with the internal resistance of the multimeter so that the multimeter range is extended. Of course, the amount of resistance needed in a test probe depends on the sensitivity and ranges available on the multimeter. In general, however, these multipliers are designed to go with 20,000-ohm-per-volt meters or vtvm's and extend the range to as much as 50,000 volts.



Courtesy Precision Instruments Co.

FIG. 3. High-voltage multiplier probe.

It is extremely important to realize that this multiplier is engineered for the purpose. The resistance is right at the tip, so that the high voltage is beyond the hand holding the test probe. A ring is on the probe to prevent the fingers from slipping down and possibly touching the high-voltage terminal.

In addition to this high-voltage test probe, it is desirable to use test leads that are intended for use in high-voltage circuits. After a few years of use, most test leads have frayed insulation. Since there is always the chance that a lead will make contact with the high-voltage circuit when you are making measurements, you should replace your test leads from time to time with new ones that have insulation capable of withstanding such voltages. We shall later refer to these as leads with high-voltage insulation. Be sure to remember the difference between these and the high-voltage multiplier lead that has the built-in resistor.

Tube Tester. A vitally necessary piece of equipment for TV servicing is a tube tester. This can be of the same type as those used for radio receiver servicing, since the tubes are similar. However, it must be a late model, capable of testing the newest tubes, because television receivers use the latest miniature types. As we have said, a tube that tests good in a tube tester will not always work in TV circuits in which the interelectrode capacities of the tube are used as part of the circuit capacity. However, when a tube registers bad in a tube tester, it definitely should be replaced; for this reason, a tube tester is a handy instrument for finding defective tubes.

Oscillators. A signal generator like that commonly used for radio service work is a standard piece of equipment for TV servicing. A man going into television service work should purchase a high-grade signal generator capable of producing frequencies in the TV i.f. ranges from 10 to 50 mc. and of covering the TV bands from 60 to 215 megacycles. When you buy a signal generator for TV service and alignment, get the best one that you can afford. A high degree of accuracy in the frequency calibration is necessary; in fact, some of the best ones are crystal oscillators with crystal selectors or exchangeable crystals. One with a calibrated attenuator, giving output in microvolts, is helpful.

In addition to the standard signal generator, a wobbulated or sweep signal generator is highly desirable because of its ability to produce a trace pattern of the over-all frequency response. We shall discuss both types of oscillators in more detail in the textbook on alignment.

In addition to the r.f. oscillators, a good audio oscillator is desirable, and certain other special signal generators such as a cross-hatch unit will prove helpful in many instances. (These instruments will be covered elsewhere.)

R-C Tester. Another standard service instrument that is very much used in TV service work is the R-C tester. It is particularly important to be able to check TV condensers for their capacity and leakage values. The resistances used in many circuits are so high that even a very small amount of leakage in condensers is objectionable. There are only two effective ways of testing for leakage: one is to use an R-C tester, and the other is to measure the voltage developed across a known resistance in the circuit. An ohmmeter is not of much use in measuring leakage: for one thing, leakage resistance is so high that an ordinary ohmmeter cannot measure it; and for another, the leakage will often disappear unless the normal operating voltage is across the condenser.

Signal Tracer. As we said earlier, the signal tracer is not of as wide use in TV work as it is in sound-receiver servicing. However, as demand grows, it is quite likely that signal tracers more useful for TV service work will be developed.

Oscilloscope. An oscilloscope that has sufficient sensitivity and that can pass the wide range of frequencies involved can be very useful in TV servicing. Such an oscilloscope makes it possible for you to see the wave shape in a great number of the TV circuits and thus to determine more definitely what is wrong in many of the troubles encountered. In general, the better the high-frequency response of the sweep amplifiers, the better able you will be to see the square and trapezoidal wave shapes. For alignment work, a high-frequency response out to 100 kc. is adequate, but if the oscilloscope is to be used for examining the video and horizontal sweep signals, it will be necessary to go out at least to 2 mc. and preferably to 4 mc. The low-frequency response must be good down to 30 cycles also if you are to observe the vertical sweep and sync voltages.

The oscilloscope should be especially designed for television work; in particular, it must have a low-capacity input so it can be connected to circuits without upsetting them too greatly.

Monitor. Finally, a very important piece of test equipment for the shop is a monitor receiver, which can be any TV receiver of good quality. In use, the monitor and the set being repaired are tuned to the same station. By comparing the pictures on the two screens, you can tell whether any distortion you see on the screen of the set that is being repaired is caused by a defect in that set or by the signal being transmitted. Because the quality of the transmitted picture often varies considerably, such a monitor receiver has considerable use.

For some complaints, it may even be desirable to have a small portable set that can be carried along to the home of the customer. However, only practical experience will determine whether an investment in such a set is really worth while in your locality. We shall suggest several uses for monitor receivers as we go along.

Handling TV Service Calls

Before we discuss examples of typical calls to indicate the procedure that you should use in determining and confirming the complaint, let us review the safety precautions that should be taken in working on TV receivers and also point out how the chassis-handling procedures that you must use with TV sets differ from those you have used with radio receivers.

SAFETY PRECAUTIONS

There are two basic dangers in a television receiver: the picture tube may shatter because of the very high forces existing on its surfaces; and the voltage applied to the picture tube is high enough to give a severe shock—perhaps even a fatal one. Early texts have given warnings about both these, which we shall summarize here.

Picture Tube. Do not open the picture tube shipping carton or install, remove, or handle the tube in any manner unless you wear shatter-proof goggles and heavy gloves. People not so equipped should be kept away while you are handling the picture tube. Keep the picture tube away from your body when you are handling it.

The large end of the picture tube bulb—particularly that part at the rim of the viewing surface—must not be struck, scratched, nor subjected to more than moderate pressure at any time. If the tube sticks or fails to slip smoothly into its socket or deflection yoke when you are installing it in a set, investigate and remove the cause of the trouble. Do not force the tube. Refer to the text on the installation of receivers for details on how the tube is installed.

Picture tubes come from the factory in special shipping cartons and should be left in these cartons until you are ready to install them in receivers. This carton can then be used for storing or carrying any defective tubes that you may remove in service work.

Disposing of defective tubes is

somewhat of a problem. Of course if the tube is still within its guarantee, you will probably send it back to the manufacturer. However, when tubes are worn out and are out of guarantee, they must be disposed of so that they will not create a hazard to other people. Distributors may take back the tubes and dispose of them for you. If not, it will be up to you to get rid of the tube. One manufacturer suggests that the tube be sealed in its standard shipping carton and that a long spike then be driven into the face of the tube through the carton. The tube will shatter, but the shipping cartons are able to withstand the force of the implosion.

You may see TV servicemen who do not take these precautions. These men are taking the risk of being badly disfigured or blinded by a shattered tube. Don't take chances—follow the manufacturer's recommendations in handling the tube.

Also, don't arrange a window display using an evacuated picture tube. Tube distributors can furnish tubes for this purpose that are not evacuated, or which have had air let in. These tubes cannot then implode, so they are safer for this purpose.

High Voltage. The voltages used in TV receivers are in some instances very dangerous, and any high-voltage supply can deliver at least a severe shock.

It is important to remember that a large charge is built up between the coatings on the inside and outside of the glass of a magnetic picture tube when the high voltage is applied to it. These coatings, which are insulated from each other, form a condenser; in fact, this is used as the output filter condenser in many cases. When the high voltage is removed from the tube, the charge remains, since there is no way for it to leak off. As a result, if you ever touch the high-voltage terminal of the tube at a time when you are in contact with the outer coating or with ground, you can get quite a shock. This shock is severe enough to cause you to drop the tube.

It is necessary to be careful about this charge storage even with tubes that are still in their factory shipping cartons. These tubes are tested at the factory and may not have been discharged—and they are capable of storing a charge for a long period of time. Therefore, the fact that a tube is not in a receiver is no guarantee that it will not have such a charge on it. As a safety precaution, before handling any picture tube of this kind, short it by connecting a test lead (with high-voltage insulation) between the external coating and the high-voltage connector on the tube.

When the high-voltage supply is one of the older types operating from a 60-cycle source, it can cause a fatal shock. The flyback or r.f. supplies used in modern receivers are not as dangerous, but they can give a very unpleasant and severe shock that may cause you to hurt yourself by making you fall or jump back against something.

As a matter of fact, the regular B+ supply in most TV receivers is more dangerous than the high-voltage supply, because so much charge is stored in the filter condensers. As a result of this storage, these supplies can furnish a high current; if you happen to connect yourself across the supply at a time when your skin is damp, it is possible to get a very dangerous shock even though the voltage levels are not excessively high. In other words, you should observe safety precautions constantly when you are working anywhere on a television receiver—not just on a high-voltage supply. Among these precautions are:

When working on a TV set, do not stand on a concrete floor. If the shop has such a floor, stand on a board or other insulating material.

Be very careful not to get yourself in the circuit by having both hands any place where they may complete a circuit through your body. As a safety precaution, "keep one hand in your pocket"—that is, force yourself to use only one hand in making measurements. This is easy to do if you clip one test lead to the chassis, then use just one hand to move the other lead about.

It is extremely dangerous to grab a chassis or part if it starts to fall while you are making a measurement. Therefore, always securely support the chassis and other parts so that there is no danger of making this mistake.

It is advisable to use a high-voltage test probe for measuring in the high-voltage supply rather than going through the risky practice of guessing at the voltage by drawing an arc with a screwdriver. The latter process can easily result in your getting a severe shock.

Watch out for the unusually high voltages in the output tube circuits at the ends of the sweep chains. Not only is there danger of shock—if you forget that the voltages there are high, you can easily ruin your multimeter.

The high-voltage supply is ordinarily enclosed in a shield, except, of course, for the lead that comes out to the tube. If there is a reason for you to work on the high-voltage supply, be very certain that the set is turned off before you remove this shield. The shield in many sets has an interlock switch that will automatically disconnect the set from the power line when the shield is open. When the shield is opened, discharge the high-voltage filter condensers before you touch anything. In discharging the filter condensers, be very certain that you use a test lead having high-voltage insulation and that you use only one hand to do so.

HANDLING THE CHASSIS

A major difficulty in television servicing is getting the television chassis and the picture tube out of the cabinet and setting them up to work on them. (For this reason, it is standard practice to do as much servicing as possible with the chassis in the cabinet.) The easiest set to handle in this respect is one in which the picture tube is supported by brackets on the chassis so that the tube and chassis come out of the cabinet together. More difficult is a set in which the front of the picture tube front is supported by the cabinet; here the picture tube must be removed from the cabinet before the chassis can be taken out. In a set in which the picture tube is completely cabinet supported, the chassis can usually be removed without taking out the picture tube. However, for many service procedures the picture tube must be plugged in and operating, so you must find a way to support the tube in an appropriate position outside the cabinet or to bring the chassis close enough to the cabinet so that you can make the proper connections to the tube.

Finally, there are sets in which the chassis itself is divided into a number of sections, each of which is mounted separately. Once the defect has been localized, it may be possible in such a set to remove and service only the defective section without having to take the tube and all the rest of the set out of the cabinet. In other instances, it will be necessary to remove the complete assembly.

Some manufacturers have recognized the problem and have arranged their sets for relatively easy servicing. Some models have cut-outs on the bottom of the cabinet that make it possible to service the sets to a great extent without even taking them from their cabinets.

Removing the Chassis. If it proves necessary to remove the chassis, you should follow the reverse of the installation procedure.

When the picture tube is supported on the chassis, it is usually possible to leave it there and to prop up the chassis so that servicing is possible.

If the tube is partly supported by the cabinet, the tube must be removed before the chassis can be removed for servicing. If the tube is completely supported in the cabinet, it is usually possible to unplug the leads from the chassis to the deflection yoke and focus coil and to remove the chassis without removing the tube. WARNING: In either of these cases, don't operate the set with the coils unplugged or without a picture tube in place. You can service the set (using an ohmmeter), but don't turn on the power until everything is reconnected.

When the trouble requires that the tube be connected and watched during the service procedure, you will have to use your ingenuity to connect parts together and to support the tube. It is necessary to set the chassis up on end so that you can work underneath it. It must be solidly supported in this position so that it cannot fall, and it must be held in such a way that no strain is placed on the picture tube, particularly on its neck.

An important factor to remember in servicing sets with the picture tube in place is the fact that you must never drop tools on the picture tube. Because of this ever-present danger, you should carry out your service procedure with the picture tube well removed from where you are working if it is at all possible to do so. Then, when the defective part has been localized and replaced, you can put the receiver back together to try it out.

You may find it practical in some cases to make up a set of extension cables so that the tube can remain in the cabinet or be at a point away from the chassis. Since the cable arrangement depends on the receiver, this system is practical only if most of your work is concentrated on one line of receivers.

TV SERVICE IN THE HOME

Because of the difficulty in getting a set in and out of the cabinet and the possibility of damaging the set or cabinet in carrying it to the shop, it is common practice for a great percentage of TV service work to be carried on in the home.

Occasionally a customer may bring his set to you, but in general the size and weight of the set and its value make the customer reluctant to handle it himself. Therefore, most of your calls will be to homes anyway, and it is logical to carry out as much of the service there as is practical. This is just the opposite of the usual procedure followed in servicing sound receivers, in which it is customary to examine the set in the home only enough to be able to quote a price, and then to take the set to the shop for the repair.

The fact that a great deal of your TV servicing will be carried out in the home of the customer means that you must carry along not only a set of tubes but also a fair stock of generally used replacement parts when you go out on a call. You will need a multimeter with a high-voltage multiplier probe, a tube tester, and an R-C checker as basic equipment. You should also take along a large sheet of canvas or similar material to put down to protect your customer's furniture and rugs while you work. It is becoming a fairly common practice to have practically a completely equipped service shop built into a truck to go out on calls. Of course, such an elaborate set-up is expensive, particularly for a beginning serviceman.

The bulk and weight of a receiver are usually great enough to make it desirable to have an assistant to help you handle the set. Some service shops do hire assistants for their servicemen. However, the salary of even a laborer is high enough to prevent many from adopting this practice.

Of course, if the repair must be attempted and the necessary parts are not available, or if more extensive test equipment and test procedures are necessary, the set obviously must go into the shop for servicing. The smaller table models are usually carried to the shop in their cabinets, but only the chassis and any other necessary parts of large table models and consoles are taken in.

One item that is not commonly taken along on a service call unless the complaint obviously indicates the need for it is a picture tube. Picture tubes represent a considerable investment, so it is unwise to subject them to possible breakage by carrying them in a truck any more than is necessary.

DETERMINING THE COMPLAINT

When you answer the telephone or talk with a customer about his receiver, remember that he is probably a non-technical man and will probably be unable to describe the complaint accurately until you ask rather direct questions. For example, the customer may say that there is "no picture" when the actual complaint may be that there is no raster whatever, that there is a raster but no picture, or that the horizontal or vertical sync is out of adjustment so that the picture cannot be locked in. Therefore, you'll have to find out from the customer by careful questioning whether he means that he can see nothing whatever, a raster, or a jumbled picture on the face of the tube. Incidentally, the customer won't know what a raster is—he'll probably just say that the picture tube lights up if a raster is present. Additional questioning may be necessary to bring out whether the customer hears a sound or not, and also whether this action is something that is occurring at the moment, happened last night, happened on only one station, or happened on all of them.

Of course, if the customer brings the receiver to you, you will naturally plug it in and see for yourself how it is operating while you are questioning the customer. This questioning isn't a waste of time, because you want the customer to bring out details of the past history of the set so that you will know how it has been operating. It is important to know whether the set has been exhibiting troubles that may be hidden by the present one but that will be apparent when you again get the set into operation.

When you are discussing the set over the phone, you won't have this opportunity to make tests, but you should certainly suggest any test or check the customer might make that will help prevent an unnecessary call. If the set is completely dead, have the customer see that the power cord is plugged in and that the antenna is connected. Suggest that he rotate the front-panel controls—children may turn the controls from their proper settings without the knowledge of the set owner, and he may well believe that something has gone wrong with the set the next time he turns it on. For example, the screen may be blank if the contrast control has been set too high or the brilliancy control too low. The picture may be torn up or completely jumbled if the settings of the hold controls have been changed.

Ordinarily, if the screen of the receiver is completely blank so that no raster or snow can be seen, there is likely to be a defect in the receiver if it is getting power. However, if the set is a radio-TV combination, the picture tube may be cut off because the function switch has been set on radio or phono. Have the customer check this.

On the other hand, if the set is picking up some kind of a signal, and that signal is out of sync or is otherwise distorted or torn up, you should check quickly on your shop receiver to see just what is coming from the station at that time. In many instances a station will be having trouble. Ordinarily, the station will make an announcement that it is having difficulty very shortly after the trouble starts, but once in a while the announcement may be delayed so long that the customer will believe his set is defective. This is most likely to happen when the customer first gets a television receiver and is unfamiliar with television programming.

Of course, in localities where there are other stations that are on the air at the time, you can always suggest to the customer that he try another station if there is any question about whether the trouble is in the station to which he is listening at the time. When reception is poor from only one station, that station is usually at fault.

Of course, if your shop receiver shows that the station is sending out an entirely normal signal, and the customer complains about his reception, something has gone wrong at the receiving location. It is possible for a trouble to appear on only one station if the signal is either very weak or excessively strong at the receiving location. Also, poor contacts in a station-selector switch may cause trouble on only one station.

In questioning the customer, you may find that he turned off his set after some apparent trouble the evening before. Here too, the trouble may have been at the station and the customer may not have waited long enough to find this out. If you know that the station had some trouble the evening before, you can suggest that the customer turn on the set and try it out if the station is on the air at the time he calls. You may suggest this anyway, even when you do not know just what might have happened the night before.

Once your questioning has made it clear that the set is defective, you must make a service call. Here again, TV servicing differs somewhat from radio servicing. There is practically certain to be some radio station on the air at almost any hour at which you are likely to be working. Television stations, however, often present regular programs only during the evening hours and put on programs of test patterns at irregular intervals during the day. You must therefore know exactly when the local stations will be on the air so that you can arrange to make your calls during such times.

If the particular complaint is one that would be easiest to clear up when there is a test pattern on the air, the hours during which you can make your calls will be even more limited. You will have to arrange to carry out your television service calls to suit the station hours; then the rest of your working day can be spent in making such repairs as can be made without a signal or in doing regular radio service work if you are conducting a dual business.

It would be well for you to become familiar with the transmitting habits of the local stations so that you will not be led into assuming a non-existent trouble. For example, many stations send a test pattern that is usually accompanied by a tone or other sound modulation. However, this sound modulation may be cut off for a period of about five minutes every half hour or every hour. Therefore, don't think that no sound always means trouble, because the sound may not be being transmitted.

Once in a while you may find that a station is transmitting no picture but is sending out the sync pulses. Either some technical difficulty may have cropped up or the station may be engaged in switching patterns at such times.

You will, of course, become familiar with the characteristics of your local stations after you have been engaged in TV servicing for a while.

CONFIRMING THE COMPLAINT

When you are confirming the complaint, it is best to have the customer demonstrate exactly how he operates the set so that you can see if the complaint could possibly be the result of mis-operation. If the contrast control is turned up too high, the picture will be distorted, or the screen may go completely blank because of overloading. On the other hand, if the contrast control is not turned up high enough, the picture may not sync properly.

Once you have observed the exact operation of the set, you can determine just what class of difficulty exists. This may let you go to effect-to-cause reasoning. You may also look for surface defects, such as unlit tube filaments, and, of course, you should check up to make certain that the set is plugged in, that the antenna is connected, and that any radio-television switch is in the TV position.

Effect-to-Cause Reasoning Applied to Dead Sets

Before it is possible to do much reasoning, it is necessary to know something about the receiver itself. As we said earlier, schematic diagrams of television receivers are important service tools and should be secured if at all possible. Diagrams are necessary because sets often vary considerably in their circuit arrangements and consequently in their defects. For example, a set having one particular kind of high-voltage supply may be able to have a defect that it could not possibly have if a different kind of supply were used.

Therefore, before you can logically reason that there is a defect in a particular section of the set, you must know something about the set itself, which you can learn best from the service data.

Of course, you can make some rather logical assumptions just from the fact that the picture tube is an electromagnetic or an electrostatic type. If it is electrostatic, the set may have a transformerless power supply, it is quite likely to have an r.f.-type high-voltage supply, and may have an intercarrier sound system. On the other hand, if the set uses an electromagnetic tube, it is more common to find a flyback power supply, although a pulse high-voltage supply may be used. The standard sound system is much more likely to be used with such a set also. There are exceptions to all these rules, however, and it is best to *know* just what circuits are in use.

In all complaints involving a dead set, it is important to know what kind of sound system is used and where the sound signal is separated from the video signal.

Fig. 4 illustrates what is known as the standard system. In this kind of set, the sound signal i.f. carrier is 4.5

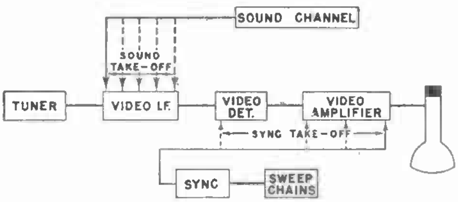


FIG. 4. Block diagram of a standard set.

mc. below the video i.f. carrier, and the sound signal is extracted from the combined signal at some point between the output of the first detector and the last video i.f. stage. The sound take-off point is usually ahead of or immediately following the first video i.f. tube, but it can be after the second or even the third tube. In localizing trouble, it is important for you to know just where this take-off point is, because that tells you just which stages can be involved in particular complaints.

Similarly, it is important to know where the take-off point for the sync signal is. In the most recent receivers, the sync signal is taken from the output of the video amplifier. However, there are many receivers in which the sync take-off is at some earlier point, even as far back as the video detector.

Fig. 5 is a block diagram of a set in which an intercarrier sound system is used. Here, the sound and video i.f. signals come through the same i.f. amplifier to the video detector, where the two i.f. signals beat to produce a 4.5-mc. carrier that has the sound signal on it. It is becoming common practice for the sound take-off to be at the output of the video amplifier, but it may be earlier, at any point beyond the video detector. In such sets, the sync take-off may be at any point between the video detector and the output, with the output connection being the most common in recent receivers.

As an example of why it is important to know where these take-off points are, let's suppose that some defect in a set cuts off both the picture and the sound. The trouble must be between the antenna connection and the sound take-off point or at some point in a low-voltage power supply to which both the sound and video stages are connected. If the power supply is not to blame, you must know the number of stages from the input to the point of sound take-off to make the proper check. On the other hand, if the trouble is with the picture alone and not with the sound, the defect must be between the sound take-off point and the picture tube.

Obviously, the standard set shown in Fig. 4 breaks more handily into sections this way. In a set in which an intercarrier sound system is used,

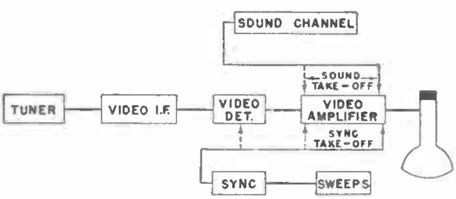


FIG. 5. Block diagram of an intercarrier set.

any trouble in the stages handling the video signal is practically certain to affect the sound signal as well. If the sound take-off is at the output of the video amplifier, there is practically nothing except a defect in the picture tube or in its power supply that could block the picture signal and not affect the sound.

In a similar manner, the presence or absence of a synchronized raster will help to show whether the defect is between the sound take-off and sync take-off points.

It is well to be extremely cautious in your analysis of TV complaints, because there is a great deal of interlocking of circuits through the power supply in some sets and very much less in others. In sets in which there is considerable interlocking, a defect in one section may affect another entirely separate section.

In one receiver, for example, the audio amplifier stages and the video control of the power supply and brightness control. If d.c. coupling is used, however, an upset in the bias of one of the video amplifier stages may blank out the screen of the picture tube. For example, a lack of bias on the output tube or too much bias on the tube preceding the output tube would cause an increase in the voltage drop across the load resistance of the output tube, thereby driving the grid of the picture tube so far negative that the picture would be blanked out.

The extensive use of decoupling in the plate supply leads also may result in some interesting servicing condi-

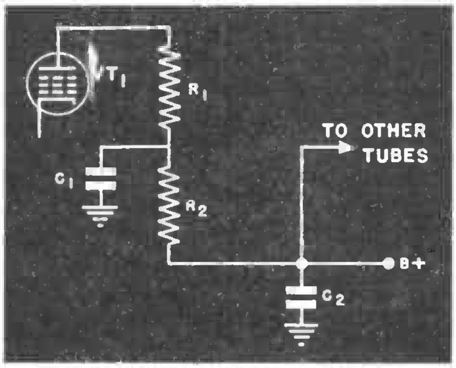


FIG. 6. A short in C_1 may affect other stages.

amplifier stages get their bias from the same source. A leaky coupling condenser in the audio stage will cause distortion; but it will also upset the bias, for which reason the picture will be completely torn up. Since the picture circuits are more sensitive than the sound circuits, you may not even notice the sound distortion at first and may believe that you have only picture trouble.

In another receiver, the focus coil current is made up mostly of current from the sound stages, so a defect in the sound stages will again affect the picture.

If the video stages are a.c. coupled, the brightness is completely under the tions. If condenser C_1 in Fig. 6 short-circuits, for example, the plate voltage will be removed from tube VT_1. If R_2 is a low resistance, and does not burn out, this short in C_1 will reduce the voltage on the other tubes because of the common coupling back through the B supply. In effect, we have shunted R_2 across the B supply in this case.

If R_2 is of high resistance, or burns out, on the other hand, plate voltage will be removed from VT_1 only and the other tubes will be unaffected. Should R_2 burn out, the plate of VT_1 will be grounded through R_1-C_1 and will also show no continuity back to B+. Watch for dual defects of this kind.

A more elaborate filtering arrangement is shown in Fig. 7. Here, not only does each stage have its own R-C filter, but also there are other filters for groups of stages. Thus, C_3-R_3 acts as a filter for all of the i.f. stages, each of which also has its own filter. Similarly, C_6-R_6 filters the sweep stages.

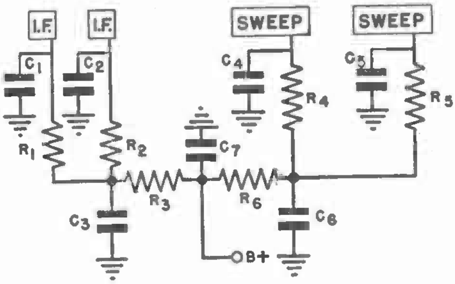


FIG. 7. Filter arrangements as elaborate as this are fairly common in TV sets.

In a case of this kind, a short in condenser C_3 would remove the plate voltage from all the i.f. stages, but a short in either C_1 or C_2 would be most likely to affect only the stage with which it is associated. Similarly, in the sweep side of this circuit, a short in C_6 would remove all the voltage from the sweep circuits. However, if either C_3 or C_6 should short, the other stages in the set may be unaffected if the series resistors R_3 or R_6 are sufficiently high in resistance or burn out as a result of the short.

Another case in which service information can be helpful to you occurs when you get a set in which another serviceman or the set owner has had the tubes out and has replaced them in the wrong sockets. The layout of the set will let you determine whether any such peculiar condition as this exists. Misplacing the tubes may not completely prevent the set from operating but may cause some very unusual operation. For example, in one well-known set, interchanging certain tubes results in apparently normal operation except that the picture is reversed—it is white where it should be black, and vice versa. This comes about because the plate and cathode terminals of the video detector come out to pins that are exactly opposite to the plate and cathode pins of another tube that is used in this set; if these tubes are interchanged, the phase of the output voltage of the video detector will be reversed.

The manufacturers themselves, however, very frequently change tube types because they find that a tube with somewhat different characteristics works better or lasts longer in the set than the one they chose at first. By examining their service notes, you will soon learn which manufacturers are likely to change sets in production this way. Don't always assume that the wrong tubes have been used.

Now that you know some of the reasons why it is necessary to obtain and use complete service information, let's turn now to a consideration of what we shall class as a dead set. First we shall consider the case in which there is no sound but the picture is okay, then we shall take up the cases in which the picture is absent.

NO SOUND—PICTURE OKAY

Most generally, if a TV set reproduces a picture properly, but there is no sound, the trouble is in the sound path between the take-off point and the loudspeaker. Therefore, the trouble must be in the sound i.f., sound detector, audio stages, or loudspeaker. You must remember, however, that misalignment or misadjustment of the fine-tuning control of a standard TV receiver could cause the sound to be absent and yet permit you to get almost a normal picture (unless the set has a.f.c., in which case misalignment or mistuning cannot cut out the sound without cutting out the picture also). This can happen because the sound i.f. channels are much more sharply tuned than are the picture channels. Therefore, misalignment of the first oscillator or misadjustment of the fine-tuning control may be sufficient to cause the sound carrier to drop out without greatly affecting some pictures. (Naturally, if the picture is a test pattern from which you can determine whether the high or low frequencies are missing, you will see that the picture is really not all that it should be.)

This condition can occur only in the standard set—in a set using an intercarrier sound system, misalignment of the oscillator will not ordinarily be able to remove the sound signal without causing severe distortion of the picture as well. This comes about because the sound i.f. carrier passes through the picture i.f. amplifier in such a set. A misalignment may move the sound carrier off the skirt of the i.f. amplifier response, but such a shift will also cause severe attenuation of the higher frequencies in the picture signal, which is a readily observable condition.

You will sometimes find that the picture is distorted when there is a no-sound complaint. In such cases, look for interaction between sections through the power supply. The audio power output tube, for example, draws a fair amount of current; if this tube becomes defective, the current flow through the power supply may change enough to change the bias on some of the video stages. This could distort the picture.

In general, therefore, if the picture is present and of such quality that the set is apparently not mistuned, but there is no sound, the trouble is probably in the sound section; and it can be run down by any of the methods of localization that you would use on any ordinary sound receiver. This is an example of the use of effect-to-cause reasoning—since the picture is present, we must have high voltage, the picture tube is all right, at least most of the low-voltage supply is operative, and any stages that handle the picture but not the sound signal are apparently working to some extent at least.

If you decide the trouble is in the sound system, you can turn the volume control full on and use circuit disturbance or a similar means of localizing the trouble.

NO PICTURE

The complaint of "no picture" may mean anything from a totally blank screen to a screen showing a controlled raster but no image. The sound may or may not be present.

The various conditions that may be found are summarized in Fig. 8. In brief, this table shows how effect-to-cause reasoning can be used when you have no indications other than what you see on the picture tube and the presence or absence of sound. Let's take a few examples to show how this table was developed.

Blank Screen. When we say that the screen is blank, we mean that there is no image, pattern, raster, line, or spot of light on the face of the picture tube, even when the brilliancy control is fully advanced. Depending on whether or not you get sound, this is the condition that most truly represents a dead set.

If there is no sound, and the screen is blank, the defect has to be one that causes the picture tube to be blanked at the same time that the sound is cut off. This almost certainly means that it is in the low-voltage supply or in the filament circuits. It could not be

FIG. 8. The table at right shows possible causes of various no-picture conditions.

NO PICTURE

Picture Tube Indication	Sound	Defect
1. Blank screen No image, pattern, raster, line, or spot even when brilliancy control is fully advanced.	NO	Defect in LV supply or filament circuit.
	YES	Defect in picture tube or in its supplies (LV, HV, or filament).
2. Only a spot of light No image, raster, or line when brilliancy control is advanced. (Indicates picture tube has LV and HV but both sweeps are inoperative.)	NO	Unlocked HV*—Trouble in LV common to both sweeps and to stages between antenna and sound take-off—but not to HV or picture tube. Locked HV**—Combination of shorted horizontal yoke, plus vertical sweep or yoke defect, plus defect between antenna and sound take-off. (Very rare to have triple defect.)
	YES	Unlocked HV*—LV supply to both sweeps. Locked HV**—Horizontal yoke shorted, plus vertical sweep or yoke trouble.
3. Vertical line only No image or raster when brilliancy control is advanced. (Indicates picture tube has LV, HV, and vertical sweep but no horizontal sweep.)	NO	Unlocked HV*—LV supply at some point common to horizontal sweep and to stage between antenna and sound take-off (or to stage in sound section). Locked HV**—Horizontal yoke shorted, plus trouble between antenna and loudspeaker (or in LV supply to these stages).
	YES	Unlocked HV*—Horizontal sweep. Locked HV**—Horizontal yoke.
4. Horizontal line only No image or raster when brilliancy control is advanced. (Indicates picture tube has LV, HV, and horizontal sweep, but no vertical sweep.)	NO	Vertical sweep plus trouble between antenna and loudspeaker (check LV supplies).
	YES	Vertical sweep or yoke.
5. Uncontrolled Raster No image; back-traces visible when brilliancy is advanced. Back traces moving and cannot be locked by hold control.	NO	Trouble between antenna and sync take-off, or between antenna and sound take-off, whichever occurs earlier.
	YES	Trouble between sound take-off and sync take-off or double trouble in sync and video sections.
6. Controlled Raster No image; back traces visible when brilliancy is advanced. Back traces hold or can be locked definitely when hold control is set.	NO	Trouble between sync take-off and sound take-off (requires sync take-off to be first, as in a few intercarrier systems), or defect in both the sound and video sections.
	YES	Trouble betwen sync take-off and picture-tube grid (in video-restorer section).

* Unlocked HV—an r.f. or 60-cycle supply, not tied to sweep.

** Locked HV—a flyback or pulse type that is keyed to the horizontal sweep.

a trouble in one of the video or sound stages, because the picture tube should still exhibit a raster even if these stages are defective.

Obviously, you should first check to be sure that the set is plugged into a power outlet and that the outlet is delivering power. You can make this check quickly just by looking at the tubes. If the tubes in the set light, power is getting to the set. If the set uses a power transformer, and you observe light in most of the tubes, you can assume that the filament circuits are normal and can go to work on the B supply. If the set uses a filament string, however, it is possible that one string is lighted but that the other one is out because of a burned-out tube or a break somewhere in the string; in this case, it may be that the emission in the picture tube as well as in a sound-handling stage has been affected.

On the other hand, if you have a blank screen but get sound, the defect is almost sure to be in the picture tube or in its supply. When the picture tube filament is in a string with the other tubes, you can usually assume that its filament supply is all right when you get sound, although an unusual arrangement of filaments may be found in some cases that would permit the sound stages but not the picture tube to work. Also, when the low-voltage supply for the picture tube is obtained from the common supply for the other tubes, and the sound section works, you can expect the low-voltage supply to be normal.

There is the possibility, however, that a burn-out at one end of the brilliancy control may not affect the low-voltage supply to any stage other than the picture tube. Don't overlook the possibility of a burn-out of this kind when you find that the picture tube is apparently all right and is otherwise receiving normal voltages. You can be sure that such a burn-out has occurred if a voltage check on the picture tube shows that it is over-biased, and rotating the brilliancy control does not change the bias.

If you suspect the high-voltage supply, you can check it quickly by making an attempt to measure the high voltage at the second-anode connection. Also, if you can see the high-voltage rectifier through the power supply shield, notice whether or not its filament is lighted. If not, either the tube is bad or there is a defect in the circuit that should be driving the tube. If the set has a fly-back supply, something wrong in the sweep circuit would prevent the high voltage from being produced. Watch for fuses in the plate circuit of the sweep amplifier in such cases—if such a fuse has blown, the circuit will not work.

If the high-voltage supply is of the r.f. type, a shorted filter condenser may produce such a drain on the oscillator that the oscillator will stop working, in which case the rectifier tube filament will be unlighted.

On the other hand, if the rectifier tube filament in an r.f. high-voltage supply appears to be normally lighted, but you do not find a high voltage, something is probably wrong in the filter circuit. Since the rectifier filament supply and the high voltage come from the same source (the oscillator tank circuit), this is a logical assumption. However, there is always the possibility that there is a defect in the transformer feeding the plate of this rectifier.

If you find high voltage, and apparently find the low voltages to be normal, and there is no indication of trouble in the filament string, the picture tube itself is about the only remaining possibility if the set uses a.c. coupling in the video amplifier. In this case, try a new picture tube.

If d.c. coupling is used in the video amplifier of the set, however, it is possible for an excessive voltage across the plate-load resistor of the output tube to over-bias the picture tube so much that the screen will be blank. Such an excessive voltage may be the result of a defect in the output tube, a lack of bias on this tube, or an over-bias on a previous stage that is d.c. coupled to the output stage. Voltage readings will usually disclose the source of trouble in this case. Don't overlook the possibility of a defect of this kind in a set that uses d.c. coupling if nothing appears to be wrong with the picture tube and its power supplies.

Spot of Light. In another kind of no-picture complaint, there is no image, raster, or line when the brilliancy control is advanced, but there is a bright spot in the center of the screen. When you observe this condition, turn the brilliancy control down at once—the tube screen will be burned in the center if you allow this spot to be present more than a few seconds.

Since a spot of light can be produced, both low and high voltages are applied to the picture tube to form a beam, but both sweeps are inoperative.

Let's assume that we have no sound with this spot-of-light condition. We next have to determine whether we have a locked or an unlocked high-voltage supply. As you have learned, a locked high voltage is a fly-back or pulse type that operates from a sweep circuit; an unlocked type, such as an r.f. supply, is independent of the sweep.

As shown in the table in Fig. 8, if we have no sound and an unlocked high-voltage supply, the defect has to be in a low-voltage circuit that is common to both sweeps and to the stages between the antenna and sound take-off, but not to the high-voltage circuit nor to the low-voltage supplies for the picture tube (because the latter defects would prevent the spot from being formed). Such a defect might be a shorted by-pass or filter condenser in one of the B+ circuits that does not cut off the low voltage applied to the picture tube. Wherever the short exists, it must have cut off the supply to both the sweep chains and to at least one stage handling both picture and sound signals.

If the set has a locked high-voltage supply, the horizontal sweep circuit must be working up to the point where the high-voltage supply is taken off. If it is a fly-back supply, the only trouble that could exist in the horizontal supply that would not block the high voltage would be a shorted horizontal yoke. In addition, there would have to be a defect in the vertical sweep chain or the vertical yoke and a defect between the antenna and the sound take-off. Thus, there would have to be a double or triple defect to produce the conditions of no sweeps and no sound in a set using a locked high-voltage supply, for which reason such a set is unlikely to exhibit this complaint.

If there is a spot of light and the sound is reproduced normally, the trouble must be in the low-voltage supply to both sweep circuits in a set having an unlocked high-voltage supply. This could be the result of a condition like the one we mentioned in connection with Fig. 7—in which a short in condenser C_6 cuts off the voltage to the sweep circuits, but because R_6 has sufficient resistance or burns out, the voltage supply in the other stages is unaffected. Of course, this kind of trouble can occur only if the two sweep circuits come from a common point, as they do in Fig. 7, and is therefore likely to be rare.

In a set that uses a locked high-voltage supply, the horizontal sweep circuit must be working up to the high-voltage supply for a spot to be produced on the picture tube screen. The lack of a sweep again means that there must be a short in the horizontal yoke plus some defect in the vertical sweep chain or yoke. It is likely that both the vertical and the horizontal yoke windings are short-circuited.

Vertical Line Only. If there is no picture or raster when the brilliancy control is advanced, but a thin, bright, vertical line is formed on the picture-tube screen, the picture tube has low voltage and high voltage, and the vertical sweep signal is present, but there is no horizontal sweep.

If the set uses a locked high-voltage supply, the lack of a horizontal sweep combined with the presence of high voltage again means that the horizontal yoke must be shorted. If there is no sound, there must also be some other defect.

If no sound is present, and the set has an unlocked high-voltage supply, a defect in the low-voltage supply is blocking operation of the horizontal sweep chain and of some stage between the antenna and the sound take-off or of some stage in the sound section. If sound is present, the trouble must be in the horizontal sweep chain.

Horizontal Line Only. In the converse of the previous condition, there is no picture nor raster when the brilliancy control is advanced, but a bright horizontal line is formed. The presence of this line indicates that the picture tube has low voltage and high voltage, and that the horizontal sweep is working, but that the vertical sweep is not working.

If sound is produced, the trouble is definitely localized to the vertical sweep or the vertical yoke. If there is no sound, there may be some defect in the B supply circuit, or there may be a defect in the vertical sweep plus some other defect in one of the sound-handling stages.

In any of these cases in which the trouble is apparently in the sweep circuits, voltage measurements may disclose the difficulty, or you can use an oscilloscope as a signal tracer, working from the sweep oscillator to the output. In the latter case, you can observe the wave shape as well as determine whether the signal is getting through each stage of the sweep chain.

Since the sweep voltage is an a.c. signal, it can be followed by an a.c. vacuum tube voltmeter. The sound section itself can be used as a signal tracer to a certain extent, particularly through the vertical sweep circuits. If you connect a test lead fitted with a blocking condenser between the grid of the first sound amplifier and your test point, you will hear a 60-cycle hum from the vertical sweep circuit and a very high-pitched squeal from the horizontal circuit if they are working properly. You can start from the sweep oscillator and follow the signal through to the output with your signal-tracing test lead.

Uncontrolled Raster. In still another no-picture complaint, there is neither a picture nor "snow," but the screen is covered by a normal raster when the brilliancy is advanced sufficiently. The back traces for the vertical sweep are easily visible, and these back traces are moving and cannot be locked by the hold control.

The presence of the raster indicates that the picture tube is getting normal low and high voltages and that both sweep circuits are working. However, since the raster is uncontrolled, the sync signal is not reaching the sweep circuits or is not able to control them.

If there is no sound, the trouble must be in some stage between the antenna and the sync signal take-off or between the antenna and the sound take-off, whichever occurs earlier. Thus, in a standard set, in which the sound take-off is in the video i.f. section and the sync take-off is somewhere in the video amplifier, the trouble has to be between the antenna and the sound take-off to block the sound channel. On the other hand, if the set uses the intercarrier system, and the sync take-off is ahead of the sound take-off, the trouble has to be ahead of the sync take-off to produce the uncontrolled raster. An open antenna lead or an oscillator tube that is not working are obvious possibilities that you should check first.

On the other hand, if you find an uncontrolled raster and no picture, but the sound is normal, the trouble is probably between the sound take-off and the sync take-off points. Otherwise, there must be a double defect—one in the sync chain and one in the video stages as well.

Trouble between the sound take-off and the sync take-off is more likely than a double defect in a standard set, in which the sound take-off is at or near the first i.f. stage and the sync take-off is at or near the output of the video section. A dead stage in the video i.f., video detector, or video amplifier sections would be what you should look for.

Controlled Raster. Finally, it is possible to have a no-picture complaint that is like the previous one except that the vertical retrace lines hold or can be locked by manipulating the hold controls. In this case, we say the raster is controlled.

It is particularly important to learn by experience the difference between an uncontrolled and a controlled raster. If the set has very stable sweep circuits, an uncontrolled raster may look like a controlled one because the back traces will stand still for an appreciable period.

If there is a controlled raster but no sound, the stages up to the point of the sync take-off must be all right, so the defect must be between the sync take-off and the sound take-off. Such a condition can occur as the result of a single defect only in a set in which the sync take-off occurs first—in other words, only in a set in which an intercarrier system is used. In a standard set, in which the sound take-off is first, the fact that there is a controlled raster but no sound means that there must be trouble in both the sound and the video sections. If there is any low-voltage supply common to these two sections that might become defective without affecting other stages, you should check this supply and its bypass condensers first.

If sound is present, along with the controlled raster, only the picture signal is missing. There must therefore be trouble somewhere in the video amplifier or restorer stages between the sync take-off and the grid of the picture tube.

In this discussion, we have gone into considerable detail to show you just how reasoning can be used when the complaint is "no picture." As you have learned, the characteristics of the pattern produced on the picture tube indicate at least which sections are not defective and may indicate which one is. The presence or absence of sound and the type of power supply (which you can find out from the diagram) are also sometimes helpful in showing what is wrong.

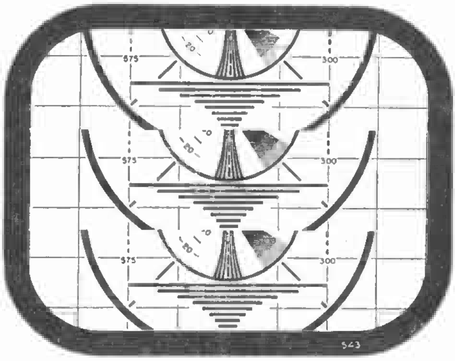
Sync and Sweep Defects

There are a number of defects that occur in TV sets in the sync and sweep circuits. The complaints that we are going to cover in this Lesson are all conditions in which a picture is present in some form on a direct-view set but is jumbled, rolling, non-linear, or otherwise distorted. Although these are not the only complaints that are caused by the sync or sweep circuits, they are by far the most common ones. In general, the sound should be normal in each of these conditions.

Many of these complaints can be caused by a misadjustment of a control. When you are attempting to clear up such a complaint, therefore, your first step should be to try adjusting the control that might cause it before condemning any portion of the set. If such an adjustment cannot clear up the trouble, or if it can be cleared up only at the very end of the control's range, you can safely assume that either some other adjustment is needed or there is an actual defect.

In the following section, we shall describe the complaint and indicate to what extent the defect causing it can be located by using effect-to-cause reasoning. The exact method of running down the trouble will depend on conditions. Obviously, if you can locate the defective section at once, there is little need for making a series of tests elsewhere. If you must run it down, on the other hand, an oscilloscope will probably be the quickest means of localization. The use of the oscilloscope for this purpose will be described in another Lesson.

Let us now discuss some typical troubles and find out just what may be indicated by each of them.



Courtesy Belmont Radio Corp.

FIG. 9. Rapid vertical rolling.

VERTICAL ROLLING

When the vertical sweep chain is working but is not synchronized, either because of a sync chain defect or because of improper adjustment of the hold control, the picture will move up or down. This is usually called "vertical rolling." If the hold control is far out of adjustment, the vertical movement will be quite rapid, and there will appear to be a number of picture segments moving (see Fig. 9). As the control is brought nearer to the proper setting, the picture will drift slowly up or down on the screen. Its appearance at an instant when it is just halfway out of position will then be as shown in Fig. 10.

Obviously, the first step to make in attempting to correct vertical rolling is to try adjusting the vertical hold control. If readjusting this control causes the image to lock in properly, and it remains locked, in all probability the vertical hold control was just misadjusted.

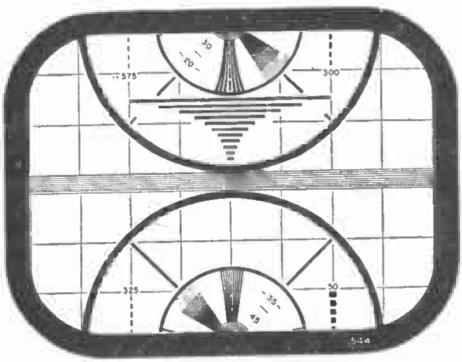
On the other hand, if you can get it to hold for only a short period of time, or if it tends to hold very near the end of the control's range, one of several possible defects may exist.

If the vertical hold control must be adjusted to one end of its range before the picture will hold, probably the value of some part in the grid circuit has changed. On the other hand, if it syncs near the center of the control range, but then does not hold, either the sync pulses are not reaching the vertical sweep oscillator because of a sync chain defect, or poor low-frequency response somewhere in the circuit is causing trouble.

The vertical sync signal, as you know, is a 60-cycle pulse. If the low-frequency response is reduced in any section handling this sync pulse, it may be wiped out; if so, a vertical hold cannot be obtained for very long. In such a case, adjust the hold control until the picture stands still, and carefully examine the test pattern you see. If there is a smearing or blurring of this pattern, the video amplifier probably has poor low-frequency response of the kind that may be caused by an open low-frequency compensating condenser or by a defective coupling condenser.

On the other hand, if the picture is not excessively smeared, but the retrace lines are visible while the picture is standing still (they will show while the picture is moving), observe the vertical and horizontal wedges of the test pattern. If the lines that are vertical in the test pattern are blacker than those that are horizontal, poor low-frequency response is indicated again, but this time it is more likely to be caused by improper alignment of the video i.f. amplifier. This may come about either because the trimmers are incorrectly adjusted or because an adjacent channel trap has drifted out of adjustment so much that it is too near the picture carrier frequency and is therefore reducing the low-frequency response. (We are assuming proper tuning and normal settings of the brilliancy and contrast controls.)

If the picture appears relatively normal as long as it is holding in sync, but vertical sync is not maintained, there is some trouble in the sync chain itself. Since the horizontal sync is



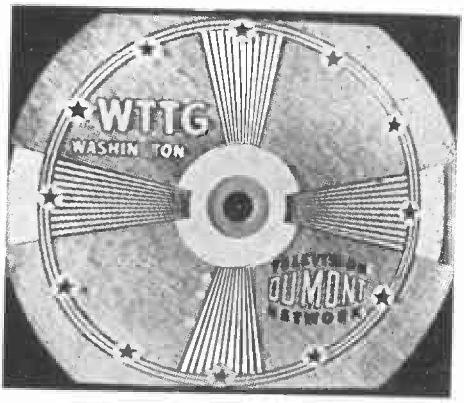
Courtesy Belmont Radio Corp.

FIG. 10. Slow vertical rolling.

apparently holding in all right, the defect must be in a circuit that handles the vertical sweep only or in a coupling condenser. Remember that stray capacity across an open coupling condenser may be able to pass the relatively high-frequency horizontal sync pulses but would offer too much impedance to the lower-frequency vertical sync pulses.

Interlace. An improper setting of the vertical-hold control or a lack of vertical sync may also cause poor interlacing. When this condition occurs, the horizontal lines "twin": that is, the lines of one field trace over those of the preceding field instead of falling between them. This gives a coarser picture and produces a moire pattern on the lines in the horizontal wedges of a test pattern, as shown in Fig. 11.

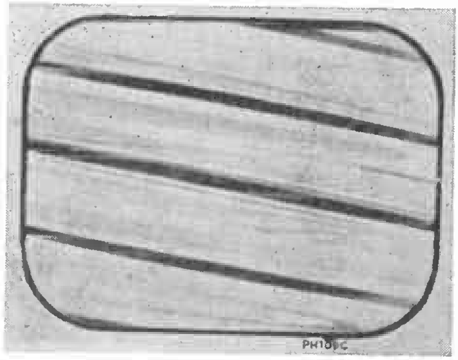
As we said, this effect can be caused by improper adjustment of the vertical-hold control, in which case it can be remedied by a slight readjustment of the control. However, it can also



NRI TV Lab Photo

FIG. 11. Poor interlace.

be the result of a defect. If the horizontal sweep output can get back to the input of the vertical sweep through a common coupling—perhaps through a power supply connection—it may throw off the vertical sync so that this condition occurs. If the set did not originally exhibit poor interlacing, a loss of capacity in a by-pass or filter condenser may cause it to appear. The small 7″ electrostatic sets, which have very high horizontal-sweep voltages and perhaps not too much filtering,



Courtesy RCA

FIG. 12. Extreme misadjustment of the horizontal hold.

often exhibit poor interlacing even when they are new. Fortunately, it is rather difficult to notice the effect on a 7″ tube.

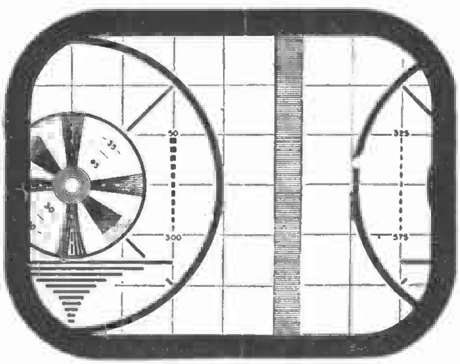
HORIZONTAL ROLLING

Lack of horizontal sync will cause the picture to roll to the right or left. If the horizontal sweep is far off, the picture will be torn up rather completely—to such an extent, in fact, that there will be practically no semblance of a picture on the screen.

As the horizontal-hold control is brought nearer the right adjustment, the picture tube will exhibit a number of black, slanting, roughly horizontal lines with extremely distorted pictures between them, as shown in Fig. 12. The number of these lines will decrease as the correct adjustment is approached. In a set using a locked horizontal hold, the number of lines can be reduced to 3 or 4; then further adjustment of the hold circuit will make the picture snap into sync. In a set using an unlocked hold, it may be possible to eliminate all lines and produce a series of pictures moving slowly sideways, as shown in Fig. 13, before the picture is brought into sync. In some sets, you may get a tearing at the very top of the picture, as shown in Fig. 14, when the picture is almost but not quite perfectly synchronized. (Excess contrast will also cause this; be sure the contrast control is set properly.)

The possible causes of loss of horizontal sync are much like those causing loss of vertical sync. If the hold control will lock the picture in near the middle of its range and will hold it in over a suitable range, misadjustment of the hold control is probably all that was the matter.

The range over which the horizontal-hold control should hold the picture in is usually considerably wider than that of the vertical control, because most modern sets have some form of locking circuit for the horizontal sweep. With any of these locking circuits, a misadjustment of the locking-range control or of the horizontal

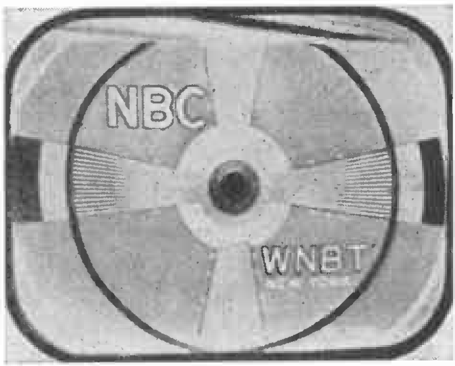


Courtesy Belmont Radio Corp.

FIG. 13. Slight misadjustment of unlocked horizontal hold.

a.f.c. circuit (where one is used) may produce the same effect as a severe misadjustment of the hold control. In such instances, the first thing to do is to set the hold control as recommended in the manufacturer's instructions, then to adjust the locking-range control to see if the picture can be made to fall into sync. If so, then this is all that is the matter, and the manufacturer's instructions for completing the adjustment should be followed.

On the other hand, if no adjustment of the locking-range or horizontal-hold



Courtesy RCA

FIG. 14. Slight misadjustment of locked horizontal hold (or excessive contrast).

control will let you sync the picture more than momentarily, the sync pulses are probably not reaching the locking circuit. If the picture is normal during the moments you are able to keep it in sync, there is a defect in the sync chain, because anything that would wipe out the horizontal sync pulses in the video circuits would affect the picture very severely.

If the trouble is just a tearing at the top of the picture, it may be that improper operating voltages in the video amplifier or in the sync chain are causing clipping of the sync pulses. The cause of the tearing can usually be located by checking these voltages. If this fails to reveal the defect, trace the sync pulses through the video and sync circuits with an oscilloscope to find where their shape changes.

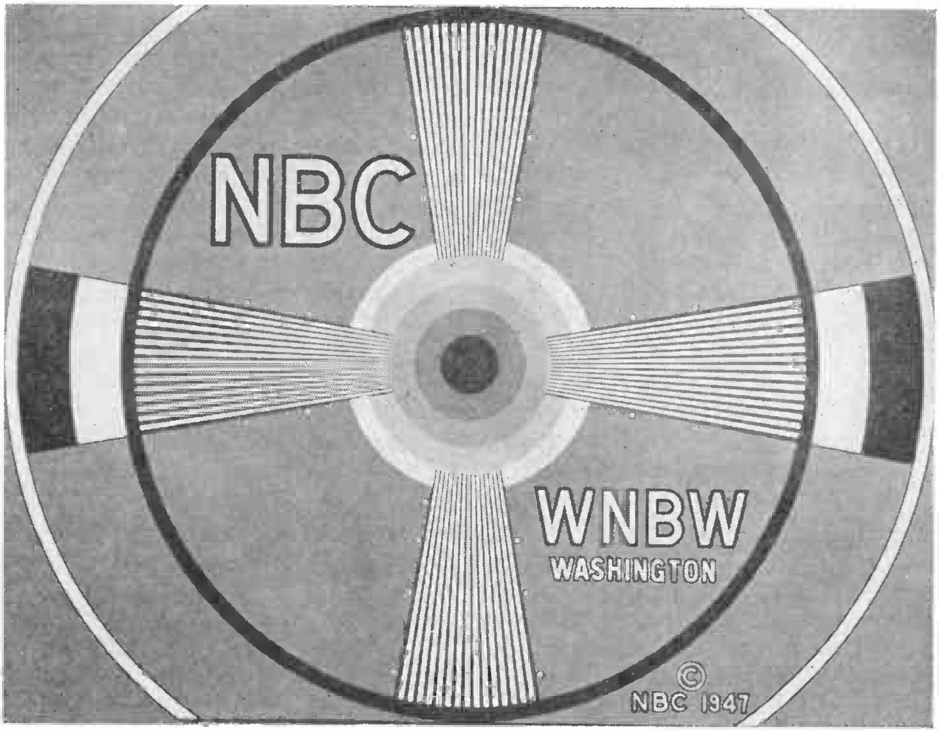
Of course, it is always possible for both the vertical and horizontal sweeps to be out of sync at the same time. A dual defect of this kind is almost certain to be something in the sync chain.

NON-LINEAR PICTURE

Fig. 15 shows a "perfect" test pattern. When the size and linearity controls are adjusted properly, as shown here, the line wedges are all equal in length, and the circles are perfectly round. When this test pattern is adjusted by means of the size controls to be perfect for the mask of the set, the large black circle should exactly fit the viewing mask in the vertical direction. and the outermost white circle should approximate the width of the picture.

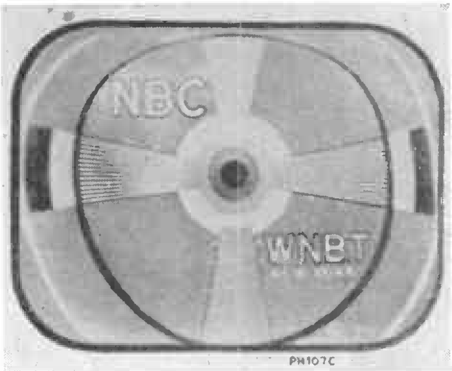
Adjusting the size controls of an electromagnetic set may throw the pattern into a distorted shape, because there is an interlocking between certain linearity controls and the size controls. Poor vertical and poor horizontal linearity are shown in Figs. 16 and 17 respectively. The outer circles are anything but round in these figures. Ordinarily, a careful readjustment of the linearity and size controls will allow you to correct such conditions. If you find that it is impossible to correct the distortion, however, the vertical or horizontal amplifier tube is defective in some respect or is not receiving proper operating voltages.

Incidentally, remember that you cannot check the plate voltage of the horizontal output tube in a set using electromagnetic deflection. You can make a check of the B+ voltage but not of the voltage at the plate, because the operating voltage at the plate is masked by the very high pulses fed back from the fly-back transformer. In fact, it is dangerous to make such a measurement—these pulses are high enough to ruin an ordinary multimeter and give you a severe shock. Pay particular attention to the bias and screen voltages as well as to the B+ voltage applied to this tube.



Courtesy NBC

FIG. 15. A photograph of the standard test pattern used by many stations.

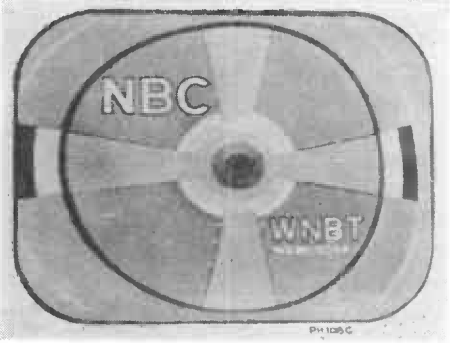


Courtesy RCA
FIG. 16. Poor vertical linearity.

In sets using electrostatic deflection, both the horizontal and vertical linearity may be poor if any of the coupling condensers used to couple the sweep circuits to the picture tube are defective.

A sort of dual non-linearity in both directions, producing a picture in which neither the sides nor the top and bottom are parallel, may be the result of an improper adjustment of the focus coil or ion trap magnets. Check the positioning of these as well as that of the deflection yoke if you observe such a condition.

Of course, you should not expect absolutely perfect linearity on any set. The picture tube itself may introduce a certain slight amount of non-linearity, and you have no absolute assurance that the station is transmitting a perfect pattern.

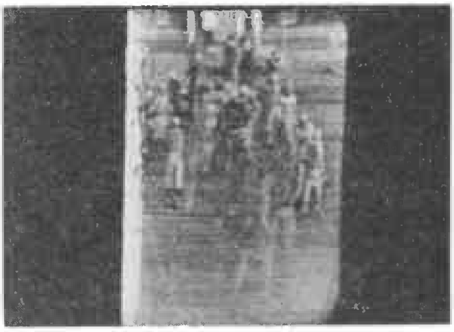


Courtesy RCA
FIG. 17. Poor horizontal linearity.

MULTIPLE OR FOLDED IMAGES

A rather rare but nevertheless possible complaint is one in which either the horizontal or the vertical sweep operates at half or twice the normal frequency. If the horizontal sweep opates at a half-normal frequency, you will get two complete pictures of full height, side by side. If the vertical sweep operates at half-normal frequency, you will have two short, full-width pictures, one above the other. Such an effect can be produced by an increased resistance in the grid circuit of the sweep oscillator or by a radical change in the value of some other part in the oscillator circuit.

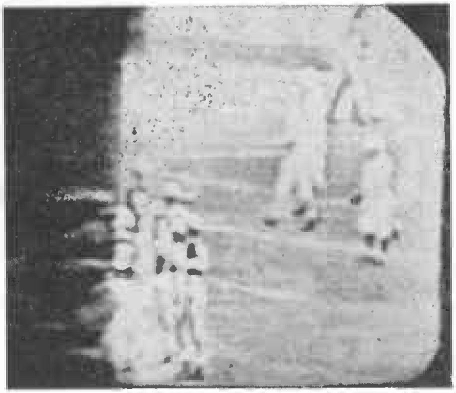
If the horizontal oscillator speeds up so much that it operates at twice its normal frequency, the right-hand half



NRI TV Lab Photo
FIG. 18. Folding caused by reduced plate voltage on horizontal output tube.

of the picture will be folded over on the left-hand half. Similarly, if the vertical oscillator operates at twice normal frequency, the bottom of the picture will be folded over on the top. A drop in the resistance of the hold-control network or some unusual tube defect are the only likely causes of this condition.

There are several other defects that will cause a partially folded picture. Fig. 18 illustrates one example. In this

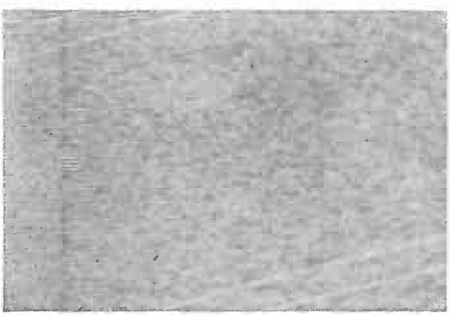


NRI TV Lab Photo
Folding caused by a defective damper tube.

case, the picture becomes smaller than normal and there is a folding over on the left edge. This is the result of a reduction in the plate voltage applied to the horizontal output tube. A somewhat similar effect can be caused by a defective damping tube or by an improperly shaped horizontal sweep voltage (which would normally occur only because of changes in part values or operating voltages in the sweep chain).

A somewhat similar partial fold at the very top of the picture is usually due to an improperly shaped vertical sweep voltage.

In receivers using electromagnetic deflection, a fold-over in the form of a heavy white vertical line at the right edge of the picture may occur when the horizontal drive control is misadjusted so much that the output tube is overdriven. However, if the picture is out of focus and perhaps oversized at the same time, it may well be that the drive control setting is normal but that the output tube of the horizontal sweep circuit is not delivering sufficient output. Try a new tube in this case.



NRI TV Lab Photo
FIG. 19. Oscillation in horizontal output tube.

VERTICAL BAR IN LEFT HALF OF PICTURE

When a black bar somewhat resembling a rope appears at the left side of the picture, as shown in Fig. 19, the horizontal sweep amplifier output tube is oscillating in the v.h.f. range. This oscillation may cause interference on only one or on several channels.

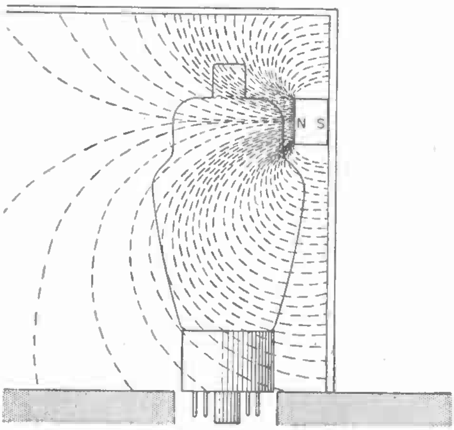


FIG 20. A magnetic field can be used to eliminate oscillation in the horizontal output tube.

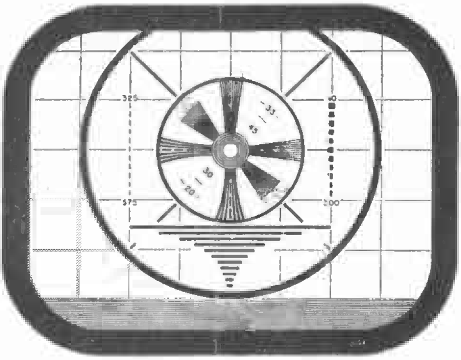
Oscillation may sometimes be cured by readjusting the horizontal drive control to reduce the signal applied to the horizontal output tube. At other times, making a slight change in the screen-grid voltage will be helpful.

A positive cure is to distort the electron path within this tube by means of a magnetic field. One way of getting this field is to mount a bar magnet near the tube on the shield of the high-voltage container. When the magnetic field for this magnet passes through the tube, as shown in Fig. 20, the electron paths are distorted so that oscillation is unlikely to occur. Some servicemen use ion-trap magnets around the tube or near the tube to produce the desired field.

Remember—for your own safety, do not open the shield around the high-voltage supply while the circuit is on. Install a magnet only when the supply is not working.

PICTURE NOT FITTING THE VIEWING MASK

When the picture is not centered properly in the viewing mask, so that



Courtesy Belmont Radio Corp.

FIG. 21A. Picture off center vertically.

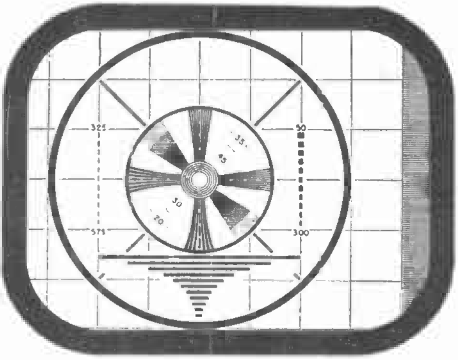


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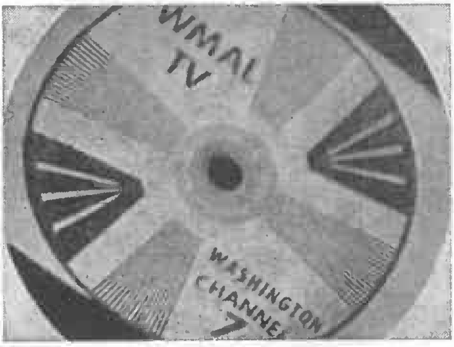
FIG. 21B. Picture off center horizontally.



NRI TV Lab Photo

FIG. 22. Tilted picture.

it is too high (or too low), as shown in Fig. 21A, or is off-center to the left or right, as shown in Fig. 21B, you can usually bring it back to the right position by adjusting the centering controls. If not, it is possible that either too little or too much current is flowing through these controls. In a few receivers, the condition of the audio tubes may affect this adjustment because their plate currents pass through the centering controls.

In sets that use electrostatic tubes, leakage in the coupling condensers between the sweep output tubes and the picture tube will also cause an off-center picture that you may not be able to bring back to the right place with the centering controls. Suspect that such leakage exists if the picture is centered properly when the set is first turned on but then gradually drifts off center.

If much leakage develops in these condensers, the sweep output tubes are likely to be damaged. Damaged tubes are usually indicated by the fact that the sweep is not wide enough to give a full-size picture in one direction or the other.

A tilted picture (Fig. 22) usually means that the deflection yoke is rotated from its correct position or, if an electrostatic tube is used, that the tube is not oriented properly with respect to the mask.

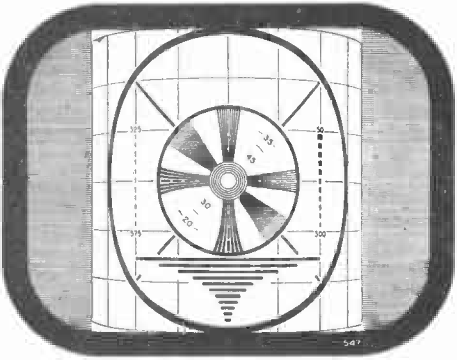


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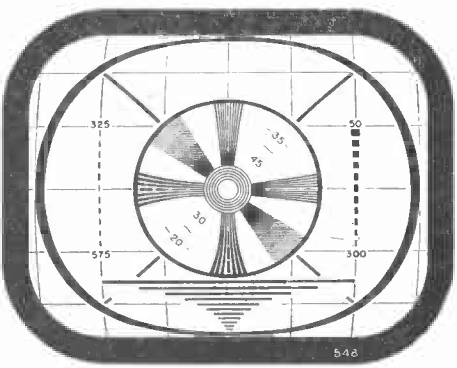
FIG. 23A. Picture too narrow.



Courtesy Belmont Radio Corp.

FIG. 23B. Picture too wide.

IMPROPER SIZE

Pictures too narrow (A) and too wide (B), but proper in height are shown in Fig. 23. Notice that the picture is relatively linear; it is "spread" one way or the other, but the wedges in each pair are equal in length. When the horizontal size control is adjusted, the picture may become non-linear, but the linearity controls should restore the image to normal.

If an adjustment of the size control will not bring the picture up to normal, the output from the sweep involved must be below normal. Improper operating voltages or defective amplifier tubes are the likely causes.

Similarly, the picture may be too short or too high if the vertical size control is misadjusted.

A picture too small in both directions usually indicates a low-voltage supply defect.

In practically all of the cases we have described, the complaint is caused by a misadjusted control or by a defect in the sync or sweep chain. Localizing these defects is, as we have said, most easily done with an oscilloscope. The oscilloscope not only lets you determine whether or not a.c. signals are present—you can also see the wave shape and thus determine when it gets distorted or changed in any manner. For these reasons, the oscilloscope is rather widely used in TV servicing, as we shall point out in another Lesson.

Lesson Questions

Be sure to number your Answer Sheet 63RH-2.

Place your Student Number on every Answer Sheet.

***Send in your set of answers for this Lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. Why are ceramic condensers widely used in TV receivers?

2. If the screen of a TV set is completely blank even with the brilliancy control fully advanced, and there is no sound, what section or sections of the set are probably defective?

3. If only a spot of light is produced on the screen of a TV set that uses a locked high-voltage supply, but there is sound, what is the most probable defect?

4. If only a horizontal line is produced on the screen of a TV set, but there is sound, what section or sections are defective?

5. In what kind of a set can a single defect produce a controlled raster but no sound?

6. If a coupling condenser opens in a circuit that handles both the vertical and the horizontal sync pulses, which kind of pulse is more apt to be blocked?

7. What effect is produced on a test pattern by poor interlacing?

8. If no adjustment lets you sync the picture horizontally for more than a few moments, but the picture is all right when it is in sync, where is the defect?

9. What simple remedy will cure the condition that produces a rope-like black bar at the left side of the picture?

10. If the picture is properly centered when a set using an electrostatic picture tube is first turned on, but it then drifts off-center and cannot be brought back with the centering controls, what is probably wrong?

Be sure to fill out a Lesson Label and send it along with your answers.

DANGER AHEAD!

Today, events move at a rapid pace. New ideas, new processes, new products are brought forth daily. You must keep abreast of this tide if you are to stay in business, because nothing is more fatal than to become out-of-date.

To understand new developments, you must learn the fundamentals in your chosen field and must *remember* them. And, *remembering* facts is the catch—how many things have you learned with great difficulty only to forget them within a short time? How much do you remember *clearly* from your early "school days?"

There is only one way to fix ideas in your mind and that is to USE them! If your work does not make full use of your knowledge, then you must review and review and review. You cannot afford to stop the processes of memorizing and learning. If you do, you will find facts slipping away from you; your key of knowledge will become rusty and useless —it won't open the door to your future!

J. E. Smith

SERVICING TV RECEIVERS FOR PICTURE DISTORTION

64RH-3

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 64

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

Form 1—64RH-3

- ☐ 1. **Introduction** .... **Pages 1-11**
  The causes of smears, blurs, and other aberrations in a picture are described in this section.

- ☐ 2. **Interference Overlays** .... **Pages 11-18**
  Here you learn to distinguish between sources of interference from the effects they produce on the picture.

- ☐ 3. **Oscilloscope Characteristics** .... **Pages 18-26**
  This section contains a discussion of the characteristics that an oscilloscope must have to be useful for TV servicing and shows you why they are necessary.

- ☐ 4. **Using an Oscilloscope in TV Servicing** .... **Pages 26-36**
  Here you learn how to use an oscilloscope to locate defects in a TV receiver.

- ☐ 5. **Answer Lesson Questions, and Mail your Answers to NRI for Grading.**

- ☐ 6. **Start Studying the Next Lesson.**

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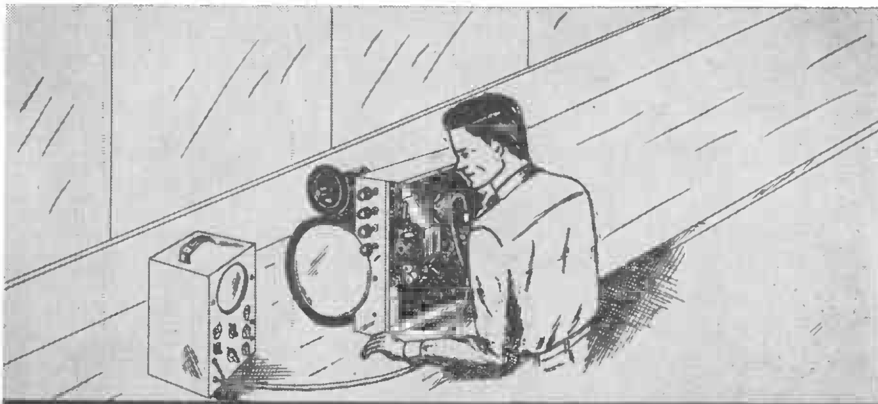


SERVICING FOR PICTURE DISTORTIONS

IN ANOTHER LESSON, we have described the various conditions that cause what might be called a dead receiver, and have shown how effect-to-cause reasoning can be used to localize the trouble. We have also described various defects that may occur in the sweep and sync systems. We shall now discuss the servicing of TV sets to remove picture distortions.

Sweep and sync defects may be said to cause picture distortions of one form or another. In this Lesson, however, we shall refer to distortions as being cases in which the picture is normal except that it is blurred, or is covered by some pattern that indicates a receiver defect.

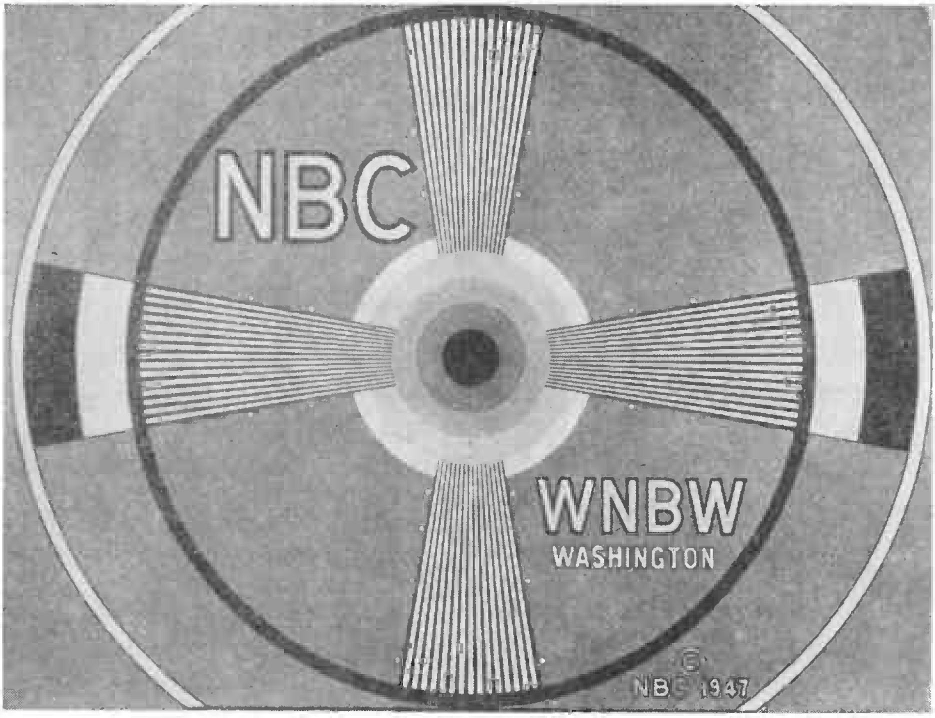
Once again, we shall find that an examination of a test pattern will show at least which section, and possibly even which stage or part, is defective. If you can do no better than locate the defective section by examining the pattern, you can use the usual testing methods to locate the actual defect. Since one of the most useful devices for making such tests is an oscilloscope, we shall devote a section of this text to showing you how to use it for this purpose.

Now, let's learn what causes various kinds of picture distortions and how you can determine what the source of a particular distortion is.

BLURRED PICTURE

A good description of what we call a "blurred" picture is that it looks somewhat like a drawing that has been smeared by someone's running his hand over it while the drawing ink was still wet. Some of the blurring, particularly when it occurs across a white area, appears to be a shadow streak across the picture. Because several defects create blurred pictures that look very much alike, it is usually necessary to study the test patterns very carefully to reach a logical conclusion as to the source of trouble.

There are four basic troubles that will cause a blurred or smeared picture. One is improper focusing. Another is a loss of low-frequency re-



Courtesy NBC

FIG. 1. Normal pattern.

sponse, which is always accompanied by an excessive phase shift. A third is a loss of high-frequency response, and a fourth is a strong ghost that is only slightly misplaced from the original image. Let's consider each of these.

IMPROPER FOCUS

A very definite blurring of the entire image occurs if the focus control is misadjusted or if any defect causes the focus to be abnormal.

Perhaps the best way to determine exactly what an out-of-focus picture looks like is to throw the focus control out of adjustment on a set with a test pattern tuned in. The general effects can also be observed by examining Figs. 1 and 2, which show a normal and a blurred pattern respectively.

As we said a moment ago, it isn't always easy to determine whether blurring is due to improper focusing or to some other cause. One basic test is to examine the image from a position a few inches away from the face of the tube. At close range you should be able to distinguish the individual lines. If you cannot see the individual lines, either the set is not properly focused or the blurring is caused by a ghost. Other sources of blurring cause smear *along* the lines, but not between them.

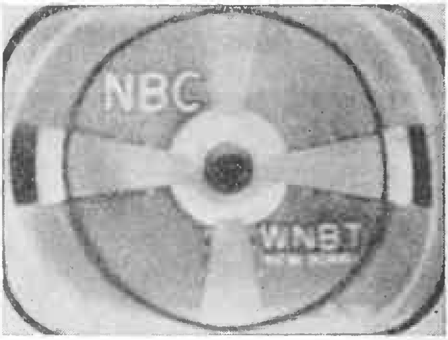
Another general test is to turn down the contrast control until a picture cannot be seen (or to tune to a channel that does not have a signal), then turn up the brightness control enough to let you see the raster. (Don't turn the brightness up too high, however, because doing so will naturally defocus the electron beam.) Poor focusing is indicated if the raster appears to be a smear of light rather than sharply-defined individual lines. This is easiest to see in the vertical retrace lines, which will tend to be broad and fuzzy, rather than sharp if the focusing is improper.

Another simple and quick test is to try a readjustment of the focus control. If this clears up the trouble, obviously the only thing wrong was that the control was improperly adjusted. If readjusting the control tends to make matters better, but you reach the end of the control's range before the picture becomes normal, some defect is producing an improper current flow through the focus network.

In a set that uses an electrostatic picture tube, the focus adjustment usually varies the voltage on one of the anodes in the gun. Voltages that are higher or lower than normal on this element (or, for that matter, on any other element in the gun) will prevent proper focusing. In a set that uses an electromagnetic picture tube, either an excessive current or too little current through the focusing coil will disturb the focus. An incorrect positioning of the coil will also affect the focus—in some receivers, in fact, the focus is adjusted by moving the coil. (In a few sets, p.m. focus magnets are used instead of an electromagnetic coil. Loss of magnetism may make it impossible to focus with such units; try a replacement.)

A multiple ghost may produce a pattern very similar to that caused by improper focusing, but if the blurring shows up on the raster when there is no picture, the focus is to blame.

If you attempt to improve the focus by adjusting the focus control, you may find that one setting of the control gives best definition on the vertical wedges of a test pattern, whereas a different setting gives best definition on the horizontal wedges. There is not much that you can do about this condition, because it is a result of the basic design of the focus coil and of the picture tube itself. By orienting the tube differently (if it is electromagnetic), and possibly by moving the focus coil, you may be able to



Courtesy RCA

FIG. 2. Out of focus.

correct the condition somewhat. Usually, however, the best you can do is make a compromise adjustment. It is the general practice in such a case to use the adjustment that gives the best definition for the vertical wedges.

SMEARING

As we just said, you can be sure that blurring is caused by improper focusing or possibly by a multiple ghost rather than by a loss of either the high or the low video frequencies if you cannot see the individual lines in the picture even at close range. Conversely, if you can see the lines, but the picture is blurred, you can be sure that the set is properly focused, but that there is a loss of low or high frequencies within the set. Loss of such frequencies causes blurring along each line, but not between the lines.

We are talking about a direct-view tube when we make this statement. Even at best focus, the lines tend to overlap somewhat in the picture on a projection set. This effect is deliberately introduced so that the enlarged image will not exhibit too much of the line structure. Therefore, this test does not hold very well for projection sets.

When you suspect that there is a loss of high or low video frequencies, you can usually confirm or dispel your suspicions by examining the horizontal and the vertical wedges in a test pattern. Both wedges will be sharp and clear if the low- and high-frequency responses are normal. If both responses are not normal, one wedge or the other will be affected, as we shall now see.

High-Frequency Loss. The vertical wedges consist of lines that cross the scanning lines. The frequency needed to produce each line properly becomes increasingly higher as the wedges taper toward the center circles. If the high-frequency response of the set falls off, therefore, these lines tend to blur together as they approach the center circles. As a matter of fact, the actual point at which the high-fre-

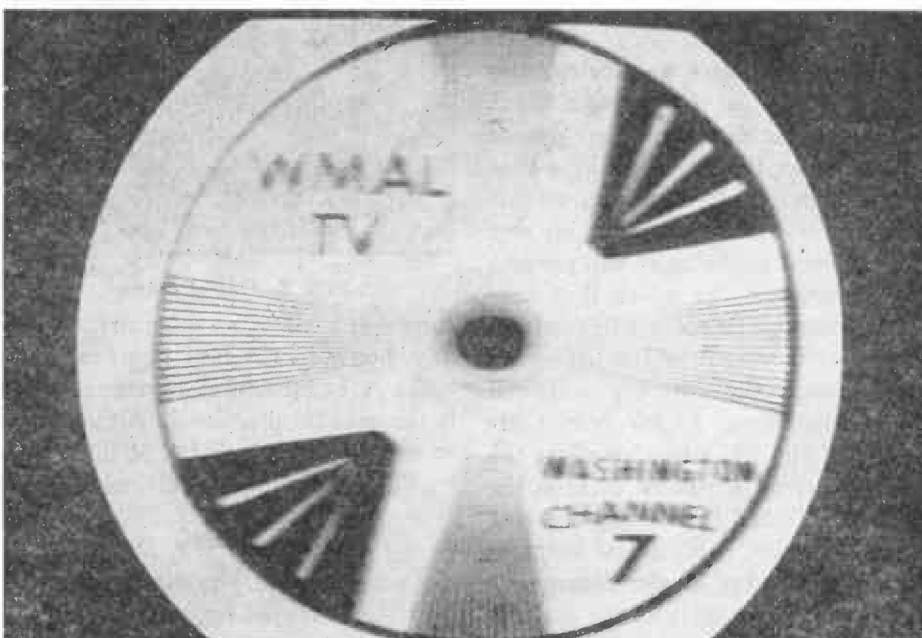


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FIG. 3. Loss of high frequencies.

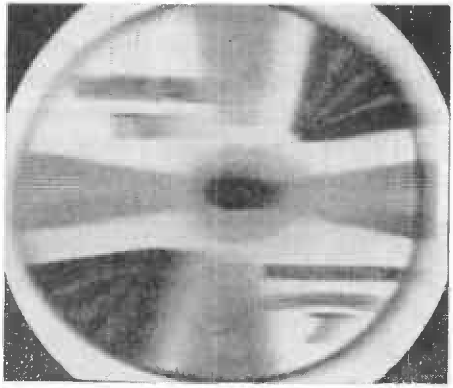

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FIG. 4. Loss of low frequencies.

quency response falls off can be judged by how far down you can see the lines of the vertical wedges on a *standard* test pattern like the one shown earlier in Fig. 1. It is not always possible to determine the fall-off point on a non-standard pattern, however; and, unfortunately, many stations use test patterns that are non-standard. If the test patterns of your local stations are not standard, you will have to learn to judge from them whether or not a set is defective in its high-frequency response.

The effect produced on a typical test pattern if the high-frequency response of the video i.f. or the video amplifier is reduced for any reason is shown in Fig. 3. Notice that the lines in the vertical wedges tend to blend together, and appear more smeared than do those in the horizontal wedges. Such a loss of high-frequency response may be caused by a drift in the alignment or by defects in the video section, such as shorted peaking coils or an increase in the load resistance.

Low-Frequency Loss. On the other hand, if the difficulty is caused by a loss of low frequencies (which will be accompanied by a phase shift if the trouble is in the video amplifier), the horizontal wedges will appear grayer than do the vertical wedges, and the letters in the test pattern will be followed by smears at their right. Fig. 4 shows one example of loss of low frequencies. Study these first four figures carefully, comparing them point by point, to see just how each of these defects is made apparent by a test pattern.

There are many possible causes of a loss of low video frequencies. Such a loss may occur because of an open coupling condenser or an open by-pass condenser in a low-frequency compensating filter. It can also be caused by a misalignment of the video i.f. stages that brings the video i.f. carrier too far down on the skirt of the response curve. If such drifting occurs, the low-frequency response may be decreased so much that the set will lose vertical sync as well as exhibit a smeared picture. Incidentally, the synchronization may also be affected if the trouble is in the video amplifier, and the sync take-off is beyond the point where the trouble exists.

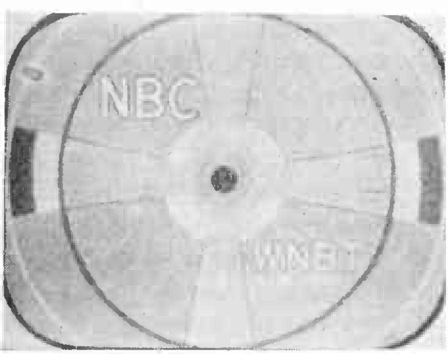
Thus, if you find it difficult to maintain vertical sync in a set that has a smeared picture, you can be reasonably sure that the smearing is caused by a loss of low-frequency response rather than by poor focusing, or by a loss of high-frequency response.

Remember that it is possible for transmission difficulties to produce smeared pictures. It is always advisable to refer to a monitor set to be certain that the set that you have for repair is really to blame. Also, careful questioning of the customer may give you helpful clues to the general nature of the defect. Any difficulty that has come on quite gradually, over a long period of time, probably is caused by failing tubes or by a shift in the alignment. On the other hand, any very sudden change probably means that some part has broken down.

If you suspect that the alignment of a set is faulty, the quickest general test is to use a sweep generator and an oscilloscope to view the response curve of the video i.f. amplifier and the front end to determine whether or not alignment is needed. We shall describe alignment procedures elsewhere.

IMPROPER CONTRAST

If the contrast of a picture is considerably higher or lower than normal,

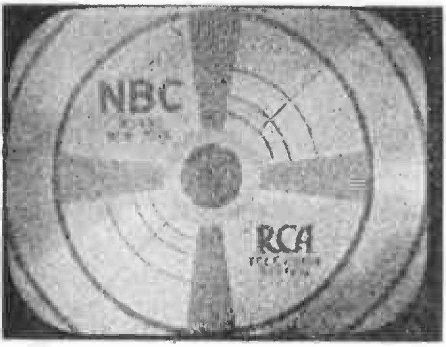


Courtesy RCA

FIG. 5. Low contrast.

probably all that is wrong is that the contrast control is improperly adjusted. However, improper contrast may also be caused by a fault within the receiver.

Low Contrast. If the contrast is below normal, as shown in Fig. 5, and increasing the setting of the contrast control does not make the picture more than light gray in appearance, see if there is an excessive amount of snow or noise in the picture. A typical



Courtesy RCA

FIG. 6. Snow.

picture with snow is shown in Fig. 6. The fact that a picture lacks contrast and has considerable snow in it may indicate that the signal being picked up is weak or is not being transferred properly from the antenna to the set. On the other hand, this kind of picture may be caused by a reduction in the overall gain of the set, which may be the result of improper operating voltages or a defective tube.

As a first step toward locating the trouble, you should find out if the contrast is low on all signals. If the contrast is low on only one station, the difficulty must be in the alignment of the front end if there is anything wrong with the set. (You must be careful about this; in some locations, the response to one or more stations may be below normal because of some local reception condition.) If the contrast is low on all stations, however some more general defect is indicated.

If the set has been installed properly and has the proper type of antenna for reception at its location, and if normal results were once obtained, you should first check the installation for defects if you find that the contrast is low on all stations. To do so, disconnect the transmission line and connect an indoor antenna to the set instead. If reception improves, or at least gets no worse, when the indoor antenna is substituted for the outdoor one, there may be a defect in the outdoor installation. Look first for an open or a shorted transmission line, as these are the most common defects.

Incidentally, if the set has automatic gain control, you must use the signal-to-noise ratios as your basis for comparing the reception with one antenna to that with the other. Signal strength alone is not a good point of comparison, because the a.g.c. system will attempt to bring the signals to about the same levels. If the a.g.c. system is able to equalize the signal strengths, the antenna that produces less audible noise—if any gets through the f.m. system—and less snow in the picture is the one that gives the better reception.

Once you are satisfied that the antenna and transmission line are normal, carefully observe the effect produced by operating the contrast control. If the picture tends to tear up as the control is advanced, much as is shown in Fig. 7, but it remains gray and washed out, two facts are immediately obvious. One is that a normal signal is passing the point or points at which the contrast control operates, since the control is able to produce overloading of some later stage (which is the reason why the picture tears up). Since the picture remains gray, however, it must be that either this signal is not reaching the picture tube properly, or the picture tube or its supply voltages are not normal.

If you find this condition, you can localize the defect more closely by examining the set to determine what type of contrast control is used. If it is one of the kinds that vary the bias on the i.f.-r.f. stages, it is quite likely that the overloading is occurring in the last i.f. stage, and that the defect lies somewhere in the video amplifier. If the set uses a.g.c., determine whether the contrast control varies the a.g.c. voltage or is located in the video amplifier. If it is in the video amplifier, the trouble has to be near the picture tube or output video stage. On the other hand, if the control varies the a.g.c. threshold, something may be wrong with this network.

Courtesy RCA

FIG. 7. Excessive signal (may be caused by setting contrast control much too high).

High Contrast. It is just as possible for the picture to have too much contrast as it is for it to have too little contrast. Figs. 7 and 8 show different degrees of excessive contrast. In Fig. 7, the signal is so strong that some stage has been overloaded; here a strong signal is further indicated by an excessive blackness. (Compare with the over-all grayness of a weak signal.) If this happens in an inter-carrier set, a buzzing sound may be heard, because the overloading produces cross-modulation products.

In some cases, the overloading may be so severe that the picture becomes inverted—black becomes white, and vice versa. Such an inversion does not always mean that overloading has occurred, however. This condition can be caused by improper tuning, for instance. It may also occur if you happen to interchange tubes while you are servicing a set. In some sets, it is possible to put the wrong tube in the video detector socket; the tube will still work as a detector, but its plate and cathode connections may be reversed, with the result that the picture phase will be inverted. Ordinarily, of course, such a change will cause other peculiarities in the picture at the same time, but the first characteristics you notice may be the reversed image. You should suspect that an interchange of tubes has occurred if the picture phase is inverted suddenly during servicing of the set, and nothing is apparently wrong with the contrast control.

Generally speaking, a set can be

Courtesy Philco

FIG. 8. Excessive contrast (usually caused by setting contrast control somewhat too high).

Courtesy Philco

FIG. 9. Excessive brightness.

overloaded only if it is located where the signal is very strong. Of course, this condition would have existed since the set was placed in operation in that location, in which case it may have been corrected before by an attenuating pad in the transmission line. If this pad becomes defective, the set will be overloaded. If the pad is not defective, or if none was needed previously, and the station has not increased its power, the fact that a set overloads means that the contrast control has lost its ability to cut down the signal sufficiently. This may be the result of an open bleeder network that makes it impossible for the control to apply sufficient bias.

IMPROPER BRIGHTNESS

The brightness control is almost the opposite of the contrast control in its effect on the picture. If the brightness control is set too low, the picture appears quite dark and has a very compressed range of shades of gray from light to black. In fact, the picture appears almost over-contrasty. On the other hand, if the control is set too high, the picture becomes washed out and resembles an under-contrasty picture. The vertical retrace lines become visible, as shown in Fig. 9, if the brightness control is set slightly too high.

There are several defects within a receiver that may affect the brightness. Whenever you find difficulty in setting the brightness to the proper level, you should first determine what kind of video amplifier the set has. If a d.c.-coupled amplifier is used, any abnormality in the operating voltages on any of the stages in the video amplifier may make it impossible to set the brightness control properly. If the amplifier is a.c. coupled, on the other hand, the only defect in the amplifier that can produce this effect is leakage in the coupling condenser between the picture tube and the output video stage. If this condenser is not leaky, the only other possibilities are improper operating voltages on the picture tube, a defect in the brightness control itself or in its supply, or a defective picture tube.

If you find that rotating the brightness control of an a.c.-coupled set seems to have no effect on the brightness, most likely the control is defective, although it is possible that cathode-to-heater leakage in the picture tube may be the source of trouble. If the control is part of a voltage-dividing arrangement in the power supply, don't overlook the fact that an open in the voltage-dividing circuit could cause the loss of control action.

PICTURE DISCOLORATION

The black-and-white image produced on a direct-view tube is achieved by depositing a mixture of several different phosphors on the tube face. By themselves, some of these phosphors would produce a blue image, others would produce a yellow image. The proper combination of the two phosphors gives an acceptable white. If something goes wrong during the manufacture of a tube so that one or the other of the phosphors predominates, however, the picture on that particular tube may appear to have a blue-white, a yellow, or a brown tint. In a good tube, any tint should be barely noticeable, and it should not change appreciably during the useful life of the tube.

If a customer complains that the picture on his set has *turned* yellow or brown, you will usually find that this is the result of a decrease in the output of the high-voltage supply. Such a decrease causes the electrons in the cathode beam to strike the phosphor with less energy than is normal, with the result that the phosphor is not excited sufficiently to glow white. If this occurs, the picture will also become somewhat enlarged, because a reduction in the high voltage decreases the stiffness of the beam so that the deflection system can over-sweep it. The image may also appear somewhat fuzzy and out of focus around the edges of the picture.

Since all these indications point to some defect in the high-voltage supply, a check of the high voltage and a check of the components should bring you to the trouble. If the set uses an r.f. high-voltage supply, the decreased output may have been caused by a frequency drift. If the set uses a fly-back supply, a reduced output from the horizontal sweep output tube may be the cause. The latter condition can be caused by a weak tube, by lower-than-normal operating voltages, or by a reduced amount of drive from the horizontal sweep shaper circuits. A check of the tube, its voltages, and the drive will show whether or not any of these is at fault.

About the only other condition that may affect the ability of the face of the tube to reproduce a picture properly is that a black or brownish spot may develop in the center of the tube face. Very little or no picture will be visible in the affected area. This spot is the result of ionic bombardment of the center of the tube face. This condition is likely only on those few large tubes that have no ion traps. On these tubes, ion traps were omitted because it was assumed that the ions would spread out so that this burning of the screen would not occur; this doesn't always happen.

When an ion spot develops, the tube must be replaced. If the tube has lasted a reasonable length of time, the fact that it has developed a spot should not be considered surprising. If the spot occurs within a short period of time after the tube has been put into use, however, it would be well to consult the set or tube manufacturer to learn whether or not the particular set or tube requires special treatment to prevent the development of a spot.

While we are discussing picture tube troubles, let us mention that you may find that the picture tends to "bloom" or grow larger as the set warms up. If the blooming is excessive, you will usually find that it is caused by a shift in the operating potentials applied to the picture tube. A gradually developing cathode-to-heater leakage, or changes in the low-voltage or high-voltage supplies may change the operating characteristics. Incidentally, it is normal for the picture to bloom somewhat if you increase the brightness by turning up the brightness control.

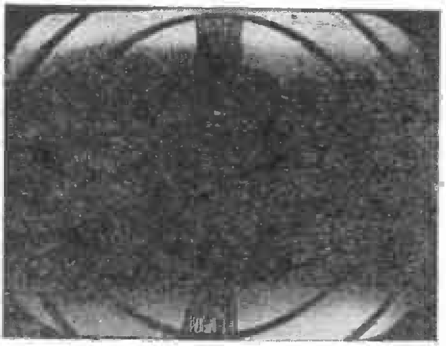
Interference Overlays

So far, we have covered cases involving a dead set, troubles with the sweep circuits, and difficulties that cause smearing and other aberrations in the picture. We shall now discuss cases in which the picture is normal except that it is overlaid by some interference pattern. If hum or sound bars appear in the picture, for example, their characteristic interference patterns will be seen as an overlay on the picture. Various other forms of interference, such as those produced by diathermy and ignition noises, and by beats between r.f. signals and ghosts, may also be seen.

HUM

The normal sources of hum or ripple in a TV set are the same as in a radio receiver: cathode-to-heater leakage in a tube, or defective filter condensers in the power supply. Cathode-to-heater leakage is the most common source, because TV receivers have such high-capacity, multiple-section filters that defective filtering is rather rare.

If the trouble arises in the power supply, the hum signal is likely to get into a number of sections of the receiver at the same time, and may therefore cause rather complex effects.



Courtesy RCA

FIG. 10. 60-cycle hum.

Naturally, if an audio stage is involved, you will be able to hear hum from the loudspeaker.

The exact nature of the hum pattern produced on a picture depends on just where the hum is getting in, and on its source. If the hum is primarily in the video amplifier section and arises from cathode-to-heater leakage or from a filter defect in a set using half-wave rectification, half of the picture will be blanked once each frame in synchronism with the 60-cycle hum. Therefore, approximately half the picture will disappear behind a broad black bar. It is rather rare to find that the bar covers exactly the top or the bottom half of the picture; instead, you are much more likely to find that the bar blanks the middle of the picture as shown in Fig. 10, or that it blanks the top and the bottom as shown in Fig. 11. The exact position of the bar depends on the relative phasing of your 60-cycle power supply and that of the transmitter. If there is any drift in the frequency of either of these power supplies, this bar may move gradually up or down the picture.

Of course, if the hum is caused by

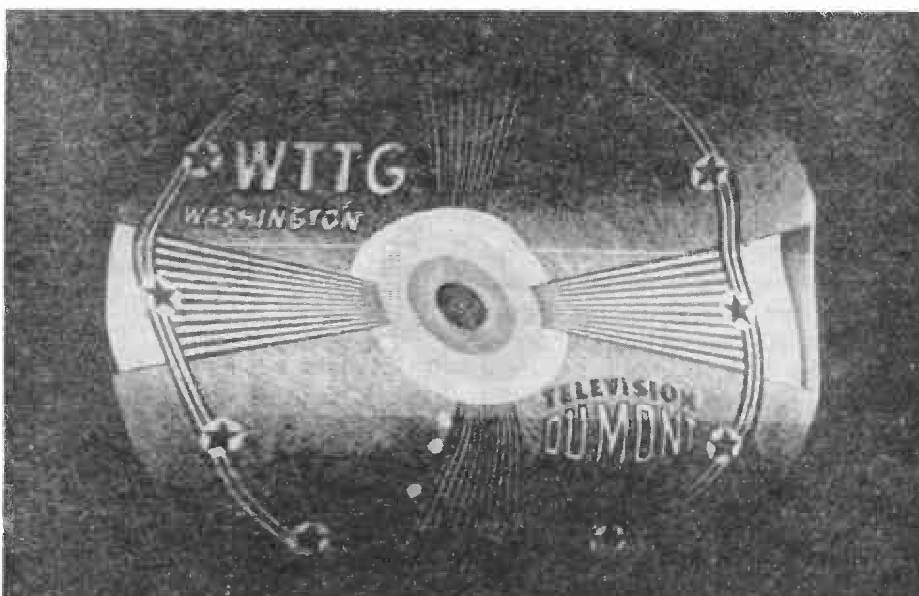


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FIG. 11. Another effect caused by 60-cycle hum.

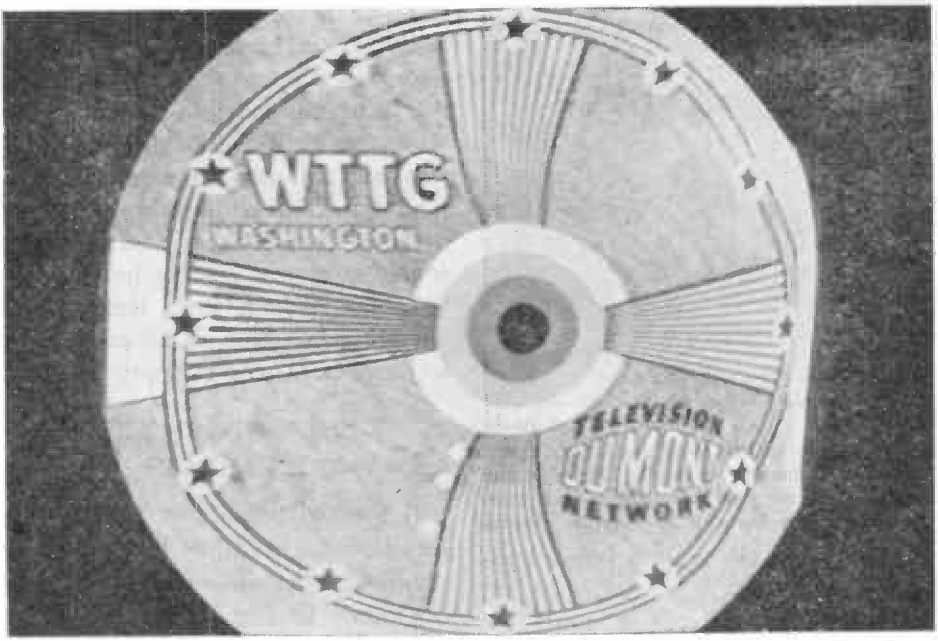

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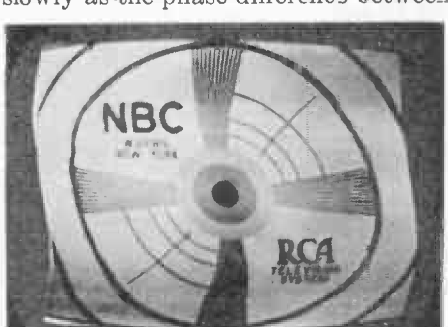
FIG. 12. Hum in horizontal deflection circuit.

poor filters in a set that uses full-wave rectification, the ripple frequency will be 120 cycles, so there will be two bars across the picture. This clue points at once to a filter defect. A 60-cycle pattern in a set that uses full-wave rectification normally indicates cathode-to-heater leakage, but in a set that uses half-wave rectification, you must check to find the source of the 60-cycle hum.

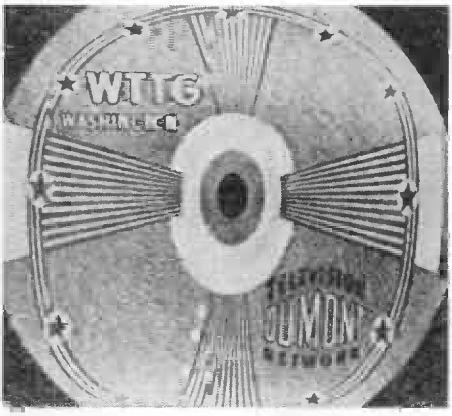
If very much hum gets into the deflection circuits, the picture will exhibit an unusual form of distortion. Fig. 12 shows hum ripple in the horizontal deflection circuit. Notice that there is apparently a ripple from the top to the bottom of the picture along each edge. When this ripple is extreme, the distortion somewhat resembles the overloading that is seen when the contrast control is set too high.

If the ripple gets into the vertical deflection system, the picture will have a wave in it that will resemble poor vertical linearity; however, you can distinguish between the two by the fact that this wave is likely to move slowly as the phase difference between



Courtesy RCA

One momentary effect produced by hum in the horizontal sweep.



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Hum in the vertical sweep will produce a ripple that moves vertically through the picture. Here you see the effect produced for an instant by such a ripple.

the local and the station power supplies shifts.

Obviously, the ripple must be rather high in amplitude to cause so much difficulty in the deflection circuits, where the voltages are ordinarily fairly high. If hum of such an amplitude is developed in the power supply, it will usually get into the video amplifiers as well as the deflection circuits and will produce hum bars in the picture in addition to a ripple. If only a ripple is produced, therefore, the source is almost sure to be cathode-to-heater leakage in a tube in the offending deflection circuit rather than an ineffective power-supply filter.

SOUND BARS AND R.F. BEATS

If a sound signal gets into the picture circuits, the effect it produces on the picture is similar to that produced by hum. As Fig. 13 shows, a tone signal in the picture circuits produces several bars across the picture, the

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FIG. 13. Sound bars.

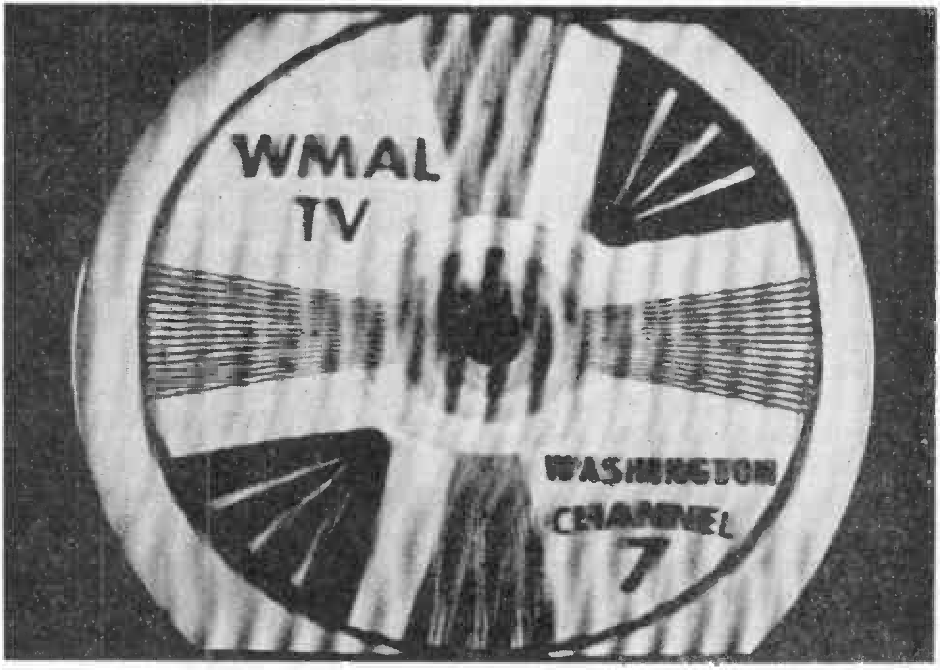

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FIG. 14. R.F. interference.

number depending on the frequency of the interference. Each alternate half-cycle of the interfering signal will produce a dark bar. Therefore, since the picture is created 60 times a second, the number of bars will be equal to the number of cycles per second of the interfering signal divided by 60. (Or, the interfering frequency is 60 times the number of bars.) If the interfering frequency is an exact multiple of 60 cycles, the pattern will stand still; if not, the pattern will appear to run up or down the picture, as long as the frequency is less than the line-scanning frequency of 15,750 cycles.

In the example shown in Fig. 13, the interference may represent the tone modulation that is transmitted along with the test pattern. The presence of 9 bars shows the frequency to be about 540 cycles (60 × 9); at least it is between this value and 600 cycles which would be shown by 10 bars. If the tone is not exactly 540 cycles, the pattern will run up or down on the picture.

If the sound is voice or music instead of a single tone, the number of bars in the pattern will vary rapidly, but will be exactly in step with the frequencies in the sound signal.

The presence of sound bars in the picture usually indicates improper tuning or that the set has gotten somewhat out of alignment. If the sound traps in the video i.f. amplifier are out of adjustment, for example, too much of the sound signal may reach the video detector, where slope detection may produce an audio signal that will then accompany the picture signal to the output. As we said, all such alignment problems will be discussed later.

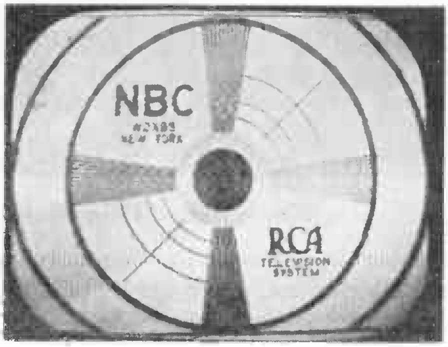
An r.f. beat between two different signals also produces a series of bars, but in most cases they are nearly vertical, as shown in Fig. 14. This comes about because the position of the bars (horizontal or vertical) depends on the frequency of the interference with respect to the horizontal or line frequency of a TV receiver. When the frequency of the interfering signal is less than 15,750 cycles, the bars are horizontal; when it exceeds the line frequency, the bars become vertical, because the interference occurs at least once every line. As you know, the number of horizontal bars is equal to the interfering frequency divided by 60; similarly, the number of vertical bars is equal to the interfering frequency divided by 15,750 (the line frequency).

The exact number of vertical bars that will be seen, therefore, depends on the frequency difference that is producing the beat note. If this difference varies (as it will, for example, if one of the beating signals is frequency modulated), the number and position of the bars will vary likewise. As you learned in an earlier Lesson, r.f. interferences may be produced by beats between signals from nearby stations, or may be the result of beats between harmonics of the local oscillator and other signals. In general, the only effective cures are re-alignment of the receiver, re-orientation of the antenna, and the installation of traps tuned to the interfering signals.

MAN-MADE INTERFERENCE

Among the most common sources of man-made interference are diathermy and ignition systems. Figs. 15 and 16 show what the patterns produced by these interferences look like.

Ordinarily, no defect within the receiver can produce these patterns. To remove diathermy interference, as you know, you may have to re-orient the antenna, shield the lead-in, install traps, and perhaps run down the source of the trouble. Re-orienting or re-locating the antenna and shielding the lead-in are also the methods used to attempt to clear up interference from auto ignition systems and similar sources.



Courtesy RCA

Effect produced by weak diathermy interference.

Excessive noise produced within a set may tear up the picture in somewhat the same manner that auto ignition interference does. Such noise can be caused by a poor connection or a defective tube in a video circuit. Poor contacts in the selector assembly of the input tuner are also capable of causing it. A certain amount of aud-

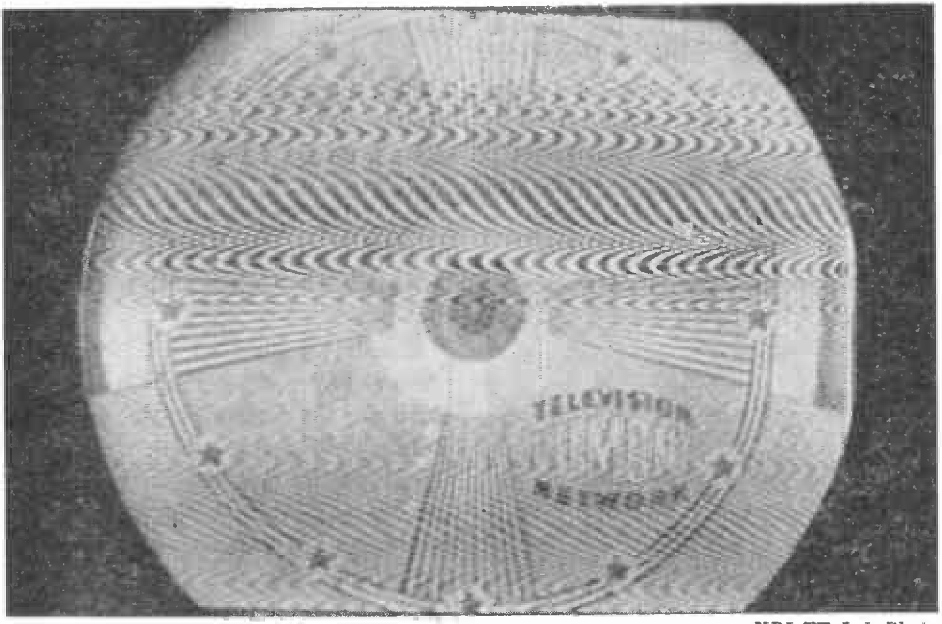


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FIG. 15. Diathermy interference.

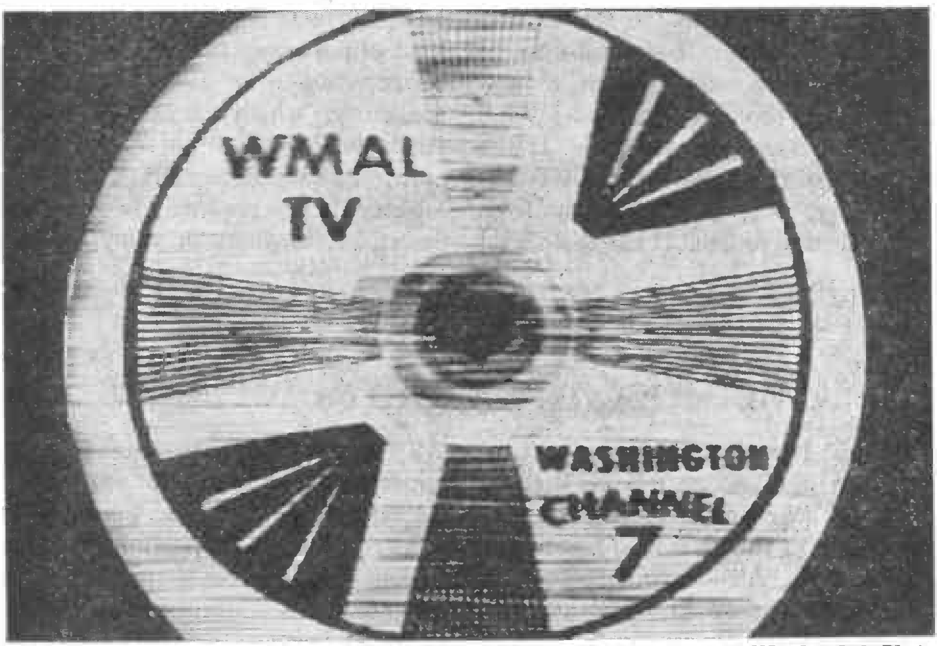

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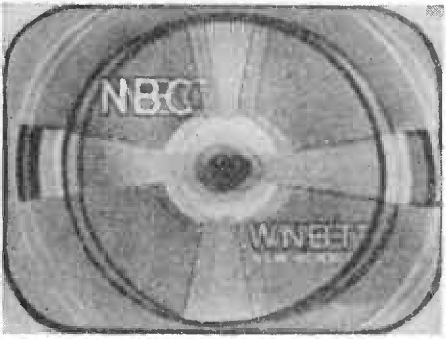
FIG. 16. Auto ignition interference.

ible noise may also be produced if this latter defect exists, but the fact that you do not hear any noise does not mean that the contacts are all right. After all, the sound channel is intended for f.m. signals, so it will tend to wipe out much of the noise.



Courtesy RCA

FIG. 17. Ghosts.

You can find out whether or not the noise is produced in the set, if it is not necessary for the picture to be present for the noise to occur, by disconnecting the antenna lead-in and observing the picture raster. If the level of the visible noise then decreases markedly, it is coming chiefly from some outside source. If the noise level does not drop much when the lead-in is disconnected, either the noise is being produced within the set or it is coming in over the power line. You can use an r.f. filter in the power line to find out if it is the source of the interference; if not, the noise is being produced in the set, and its source can be located by following an isolation procedure.

Finally, a kind of interference is produced by ghosts. Fig. 17 shows one example. Such ghosts are generally a result of reception over multiple signal paths, and the only effective cure is to re-orient the antenna or to change its location so as to avoid the reflected signal.

Ghosts can be caused by extreme misalignment, however, and may also be produced if there is a path that will cause a regeneration of the signal with an appreciable phase delay. The latter kind of path may be the result of loss of capacity of a filter or by-pass condenser, which may then permit feedback through a power-supply circuit. The conditions under which misalignment may produce ghosts will be described elsewhere in your Course.

Oscilloscope Characteristics

As you have learned in earlier Lessons, an oscilloscope can be used in servicing sound radio receivers, but it is not one of the vital instruments for this purpose. A good oscilloscope is an absolute necessity in television servicing, however.

The signals in the various circuits of a TV set are often required to have unusual shapes that must be closely maintained if the set is to work properly. It is often possible for them to depart from these shapes in such a way that an amplitude-measuring instrument (such as a v.t.v.m.) will not indicate any change. Hence, the oscilloscope is particularly valuable, because it not only acts as a measuring device to show you the amount of signal, but it also lets you *see* the shape of the signal.

For this reason, an oscilloscope is much used in isolating trouble to a specific stage or circuit in TV servicing. Also, as we have said, it is an extremely useful piece of equipment for alignment.

An oscilloscope also helps you to learn what actually happens in different stages of a working TV receiver, and helps you to grasp more easily the action of the different stages, and thus obtain a more thorough understanding of the operation of the set.

TYPICAL OSCILLOSCOPE

You studied the workings of the cathode-ray oscilloscope in earlier Lessons. Let us briefly review the subject now to refresh your memory.

Fig. 18 shows a block diagram of the major sections of a service oscilloscope. The signal that you want to analyze is fed to the deflecting plates that move the beam vertically. If the voltage is large enough, switch SW_4 should be thrown to position 2 so that the signal will be applied directly to the deflecting plates. If the signal is small, on the other hand, switch SW_4 should be thrown to position 1 so that the signal will be fed through the vertical amplifier. A gain control in the vertical amplifier can be adjusted to keep the deflection within the limits of the tube face.

The signal that is applied to the vertical plates, if it is an a.c. signal, will deflect the electron beam up and down in a straight line, thus producing

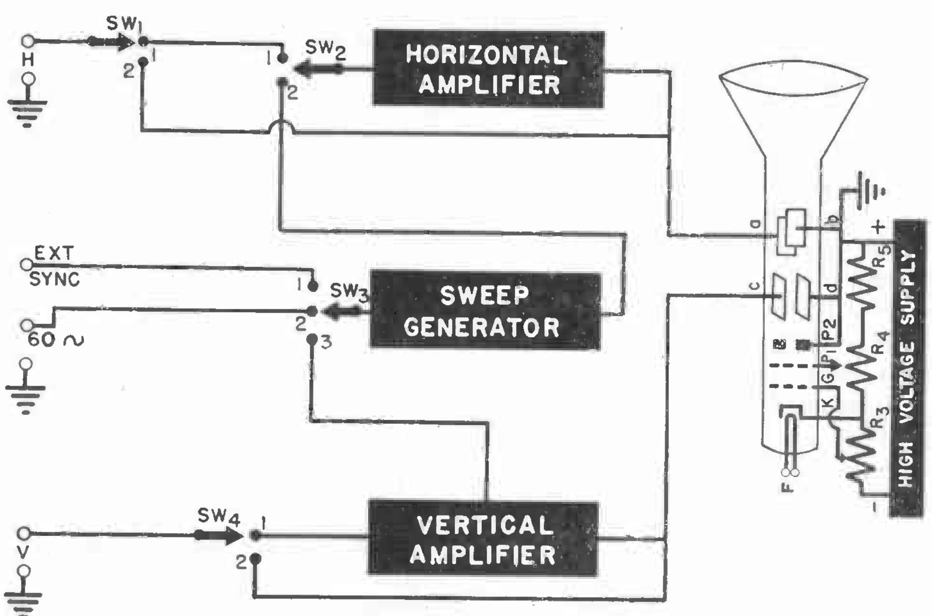


FIG. 18. Block diagram of a typical oscilloscope.

a vertical trace on the face of the tube. The height of the deflection will be proportional to the peak value of this voltage, but, of course, we cannot see its shape unless we spread out the wave trace horizontally. Therefore, we need another signal applied to the horizontal deflecting plates. This signal may come from an external source or from an internal sweep generator.

When switches SW_1 and SW_2 (Fig. 18) are in position 1, any external signal applied to the horizontal input terminals of the oscilloscope will be fed through the horizontal amplifier. If this signal is large, switch SW_1 should be thrown to position 2, in which case this external signal will be applied directly to the horizontal deflecting plates.

If the sweep generator is to be used, switch SW_2 should be thrown to position 2 so that the output of the sweep generator will be fed through the horizontal amplifier. All oscilloscopes offer three ways to provide synchronization of the sweep generator. In the one shown in Fig. 18, throwing switch SW_3 to position 1 will permit an external synchronization voltage to be fed to the sweep generator. If it is thrown to position 2, the sweep generator will be locked to a 60-cycle source, which is a very commonly used sweep rate. If it is thrown to position 3, a portion of the signal applied to the vertical amplifier will be tapped off and used to synchronize the sweep generator with the incoming signal.

In brief, this is the procedure that you should follow to operate a c.r.o. of this kind. First, turn it on and adjust the intensity and focus the controls to give a fine, bright spot. If necessary, adjust the horizontal and the vertical centering controls to center this spot in the center of the screen. Then, apply the signal to be analyzed to the vertical deflecting system, and apply either the sweep signal or an external horizontal signal to the horizontal amplifier.

If the wave shape is to be reproduced exactly, the sweep generator must produce a saw-tooth voltage that will sweep the beam from left to right at a rate that will reproduce at least one cycle of the signal to be observed. As a matter of fact, the sweep generator is most commonly synchronized to a frequency one-half, one-third, or one-quarter the frequency of the voltage being observed, because this gives more than one cycle on the face of the tube. This is desirable, because a small part of the first cycle will be blanked while the sweep generator is getting into sync with the incoming signal. By having more than one cycle, and by viewing the cycles after the first one on the screen, you can get a much more exact idea of the wave shape.

If the wave shapes are to be reproduced accurately, the sweep should have a high degree of linearity.

We mentioned applying voltages directly to the deflecting plates. Naturally, the voltage being observed has to be quite high if it is to be applied in this manner. Most oscilloscope tubes have deflection sensitivities of from 25 to 40 volts per inch per thousand volts on anode 2. Thus, if the second-anode voltage is 1000 volts, and the sensitivity is 30 volts per inch, 30 volts applied to the vertical plates will give 1 inch of deflection. However, with 2000 volts on this anode, it will take 60 volts to give an inch of deflection on this same tube. Therefore, although such an increase in the anode voltage will give a brighter trace, it will also increase the amount of voltage necessary to give a fixed amount of deflection.

For this reason, there is usually a compromise in the oscilloscope design—enough second anode voltage is used to give a reasonably bright image, but not so much that an excessive deflection voltage will be required. After all, the signals with which you are dealing are, in many cases, quite low in amplitude. As a matter of fact, you will rarely be able to apply a signal directly to the deflection plates; you will almost always use the amplifier.

Ordinary a.c.-coupled amplifiers are used in most oscilloscopes intended for service work. In a very few, however, the amplifiers are d.c. coupled. The chief advantage of the latter kind is that it can be used to measure d.c. as well as a.c. voltages, because the application of a d.c. voltage to the input terminals will cause a deflection of the spot from its center location, the amount of deflection being proportional to the voltage. Application of a d.c. voltage to an a.c.-coupled amplifier will cause a momentary deflection of the spot as the coupling condensers charge, but the spot will return to the center of the screen as soon as the charging is completed.

When an a.c. voltage is applied to either kind of oscilloscope, the spot is moved back and forth between the limits determined by the amplitude of the signal and the setting of the level control of the vertical amplifier.

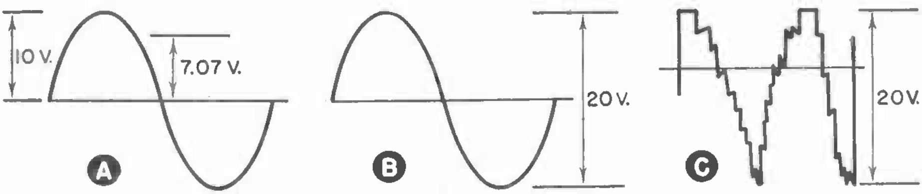


FIG. 19. Part A shows the relationship between the peak and r.m.s. values of a sine wave. Parts B and C show that the peak-to-peak amplitudes of a sine wave and a complex wave may be the same, even though the shapes of the two waves are very different.

PEAK VOLTAGES

In servicing sound receivers, in which sine-wave signals or sine-wave signals plus a few harmonics are all that we are dealing with, we rarely have to worry about peak-voltage values. We know that our meters are calibrated to read r.m.s. (or effective) values, and that the peak value for a sine wave is about 1.4 times the r.m.s. reading. Conversely, the r.m.s. value is equal to the peak value multiplied by .707. Thus, if the peak value of a signal is 10 volts, as shown in Fig. 19A, the r.m.s. value that will be indicated by a voltmeter will be slightly over 7 volts. Since the peak of a sine wave reaches the same value on either side of the reference line, as shown in

Fig. 19B, the peak-to-peak value of a sine-wave voltage (which is the sum of the two peaks) is twice either of the peaks.

In TV work, however, we are dealing with waves that are not sine waves. The wave shapes of the signals in a TV set include many combinations of square and rectangular forms, and often contain a d.c. component as well. If we try to measure the voltage of any such wave with an ordinary voltmeter or a vacuum-tube voltmeter, we shall find that our readings do not mean very much, because the relationship between the peak, r.m.s., and average values of a wave depends on the wave shape, and our instruments are calibrated for sine waves only.

We must, therefore, use some other instrument to measure the amplitudes of the signals in TV circuits. The oscilloscope is ideal for this purpose, since it can be calibrated to indicate the peak-to-peak voltage of any wave, regardless of its shape, and will let us see the wave shape at the same time. Generally speaking, peak-to-peak voltages are the only characteristics of such waves that we are interested in as far as amplitude measurements are concerned. Such factors as r.m.s., average, and single-peak amplitudes mean little when we are dealing with a wave that is not a sine wave and that may, as Fig. 19C shows, be of different peak amplitudes on the two sides of the reference line. The peak-to-peak amplitude of a complex wave, however, shows us how much signal the wave represents, regardless of its shape and of its position with respect to the zero reference line. For these reasons, service instructions dealing with circuits in which complex signals exist always give peak-to-peak values when they discuss signal-voltage amplitudes.

Calibration. If an oscilloscope is to be used as a voltage-measuring device, it must be calibrated so that we will know just what voltage is indicated by the deflection we see. Of course, the amount of deflection that is produced by any applied voltage depends on the deflection sensitivity of the oscilloscope tube. If the applied voltage is fed to the tube through the vertical amplifier, the deflection also depends on the gain of the amplifier.

To calibrate an oscilloscope so that it will measure peak-to-peak voltage, proceed as follows. First, place a transparent graph scale over the face of the oscilloscope tube as shown in

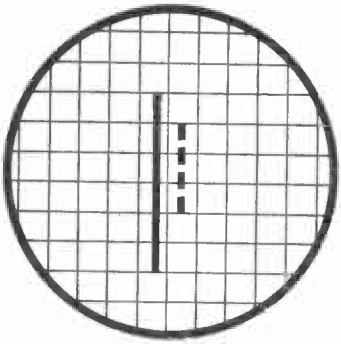


FIG. 20. Use of a grid to indicate relative amplitudes of oscilloscope deflections.

Fig. 20, if one is not already on your tube. Next, apply a sine-wave voltage having a known peak-to-peak value to the input of the vertical amplifier. Reduce the horizontal gain to zero so that only a vertical line is produced. Next, adjust the vertical gain control until as many blocks as you wish are filled by this line. This completes the calibration process for the particular setting of the vertical gain control that you have chosen. If you now remove the known signal and apply any other signal to the vertical plates, *leaving the vertical gain control in the same position*, the amount of deflection produced will be proportional to the deflection caused by the known voltage.

For example, let us suppose that you apply a sine-wave a.c. signal of 6.3 volts r.m.s. to the vertical input as the known calibrating voltage. This signal has a peak-to-peak value of approximately 18 volts. You can find the peak-to-peak value from the r.m.s. value by multiplying the latter by 2.8 (multiply by 1.4 first to obtain the peak voltage, then by 2 to obtain the sum of the voltage of both peaks). If you adjust the vertical gain control so that the line produced by this signal includes exactly 6 blocks as illustrated by the solid line in Fig. 20, each block must then represent a deflection equal to 3 volts.

To measure an unknown voltage. all you need to do is to remove the calibrating signal and apply the signal that is to be measured to the vertical input. The deflection produced will depend on the peak-to-peak amplitude of this new signal. If a total deflection of three blocks is produced, as shown by the broken line in Fig. 20, the peak-to-peak amplitude of the new signal is 9 volts. If the deflection is 4 blocks, the peak-to-peak amplitude of the signal is 12 volts.

If the signal you are trying to measure has a much higher amplitude than your calibrating signal has, it may produce a line that goes off the screen. If so, apply the calibrating voltage again, and adjust the vertical gain control until the 18-volt signal covers only 2 or 3 blocks. Each block will now represent a higher voltage as long as the vertical gain control is at its new position, and therefore a higher unknown voltage can be measured before the deflection trace it produces goes off the screen.

Let's summarize the procedure you should follow to use an oscilloscope as a peak-to-peak voltmeter. First, measure your calibrating signal with a reliable a.c. voltmeter, then convert the r.m.s. reading that the voltmeter gives you into a peak-to-peak voltage. Next, set the gain control of the vertical amplifier of the oscilloscope to give you a convenient deflection for this voltage, and leave the control at this position when you check the unknown voltage you are measuring. If the unknown voltage is so large that it produces a deflection that goes off the screen, reduce the gain of the vertical amplifier and recalibrate the oscilloscope. If you move the gain control after a calibration before you measure the unknown voltage, your readings will be meaningless until you recalibrate.

TURNOVER

In the preceding example, we have shown how to measure a voltage to determine its peak-to-peak amplitude. Although we suggested that the horizontal amplifier be turned off so that you get a line, you can, if you wish, observe the voltage at the same time by having it deflected from left to right. Doing so will not prevent you from measuring the peak-to-peak voltage, but does make it a little more difficult.

When you are observing a signal, either to measure its amplitude or to see its shape, you may find that it is upside down compared to the picture shown in the manufacturer's test manual. This is entirely normal—whether or not it happens depends on the number of stages and the methods of coupling between stages in your oscilloscope compared to those in the oscilloscope used by the manufacturer. Thus, the manufacturer's service information may show that the signal at a certain point should look like wave A in Fig. 21, but on your oscilloscope the signal at that point may look like wave B. Since these two waves are exactly alike except that one is inverted with respect to the other, you should consider that the wave you have found is of the correct shape.

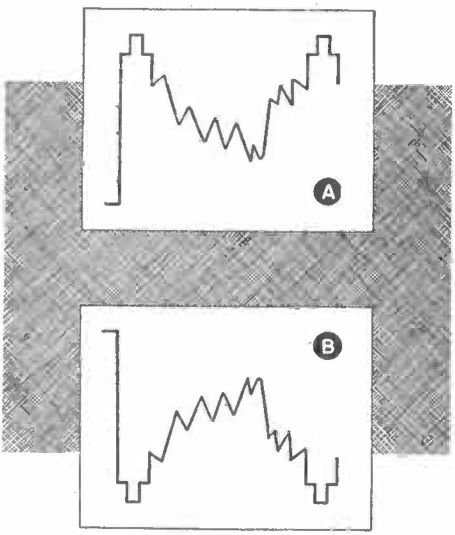


FIG. 21. Either an upright (A) or an inverted (B) trace can be used to determine the shape of a signal.

Some oscilloscopes have a phase-reversing switch that interchanges the connections between the cathode-ray tube and the vertical amplifier. If yours has such a switch, you can invert the image if it happens to be upside down. However, once you are used to it, an upside-down image is just as useful as a "normal" one is.

Of course, as you move along stage-by-stage in tracing a signal, the wave picture is naturally going to turn over every time you pass through another stage, since you invert the signal 180° in phase when you do so. In general, therefore, you should be interested only in the basic shape of the wave, and you should expect it to be upside down part of the time.

SENSITIVITY

The term "sensitivity," when it is applied to an oscilloscope, refers to the amount of signal that must be applied to the input of the vertical amplifier to produce a standard deflection. Ordinarily, this sensitivity is expressed in terms of volts-per-inch (or volts-per-centimeter), just as the deflection sensitivity of a c.r. tube is. The fact that an oscilloscope has a maximum sensitivity rating of 1 volt-per-inch, for example, means that a 1-inch deflection will be produced on the face of the oscilloscope when a 1-volt signal is applied to the input of the vertical amplifier with the latter adjusted to give maximum gain.

An oscilloscope that is to be used for TV service work must be fairly sensitive, because it must operate from rather low voltage levels in certain cases. For example, if you are signal-tracing through the sync chain, you are going to find some voltages that have very low peak-to-peak values. Also, in aligning a TV set, you will sometimes find it necessary to measure a signal after it has been fed through only one stage, the gain of which may be quite small.

In rating the vertical amplifiers of oscilloscopes, manufacturers use either an *r.m.s.* volts-per-inch, or a *peak-to-peak* volts-per-inch rating. You will have to be careful to notice which rating is used when you are comparing the characteristics of two oscilloscopes. For example, if one instrument is rated at .5 volt r.m.s. per inch, and another at 1.4 volts peak-to-peak per inch, the sensitivities of the two are the same. (Multiply the r.m.s. value by 2.8 to get the peak-to-peak, or divide the peak-to-peak value by 2.8 to get the r.m.s.)

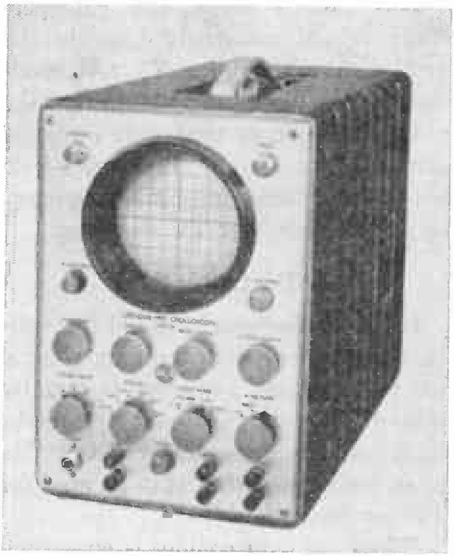
When the rating is in volts per centimeter, multiply the rating by 2.54 to find the volts per inch.

A rating of .2 volt peak-to-peak per inch is considered very good; this corresponds to about .07 volt r.m.s. per inch and to about .079 volt peak-to-peak per centimeter. Any rating smaller than these shows even more sensitivity (that is, a rating of .1 volt peak-to-peak per inch is better than one of .2). An oscilloscope having a sensitivity rating of .6 volt peak-to-peak per inch or better will be satisfactory for TV servicing use.

FREQUENCY RESPONSE

Most ordinary service oscilloscopes can be used in aligning TV sets as long as they have a good response to frequencies in the neighborhood of 60 cycles. A good high-frequency response is not needed for alignment. In fact, as you will learn in another Lesson, it is desirable to have the oscilloscope response cut off at a fairly low frequency (50 to 100 kc.) if it is to be used as an output indicator during the alignment of a set.

On the other hand, if you are going to use your oscilloscope to trace signals that may contain components ranging up to 4 megacycles in frequency, and particularly if you are going to use it for square-wave testing



Courtesy RCA

A typical oscilloscope that can be used in TV servicing.

of a TV receiver, it must have a very good high-frequency response. For square-wave testing, the response should extend to a frequency at least 10 and preferably 20 times as great as the highest-frequency square-wave test signal that will be used. For signal tracing, it is desirable to have the frequency response extend practically as high as the highest frequency that may be expected in the signal that is being traced. Therefore, oscilloscopes intended for TV work quite generally have responses extending to one or two megacycles and even more. Of course, getting the necessary gain over so wide a frequency band calls for the use of TV circuit techniques in the vertical amplifier (which is quite similar, as a matter of fact, to the usual video amplifier). The same techniques must also be used to get the good low-frequency response needed for alignment.

For these reasons, the gain-per-stage is not extremely high in the vertical amplifier of a TV test oscilloscope. Further, you will find that the older oscilloscopes that were designed primarily for sound radio servicing do not have the sensitivity and frequency response needed for TV servicing.

GAIN CONTROL

In an oscilloscope intended for ordinary radio servicing, the gain control for the vertical amplifier is usually placed right at the input terminals. Such an arrangement is not desirable in an instrument that is to be used for TV servicing, however.

When the gain control is connected directly across the input terminals, there is a fairly high capacity between the terminals. When the oscilloscope is connected to the circuits that are being tested, this shunting capacity may reduce the frequency responses of the circuits and thus affect the shapes of the waves that you are trying to see.

One way out of this difficulty is to connect the oscilloscope input terminals directly to the grid of the first tube in the vertical amplifier, and then to put the gain control between the first and the second amplifier stages. This arrangement reduces the input capacity but also makes it possible for a strong signal to overload the first tube in the vertical amplifier.

There are several methods of reducing the danger of overloading. In one design, a cathode-follower circuit is used for this purpose: the load for the first tube in the vertical amplifier is placed in the cathode circuit, and the resulting degeneration makes it possible for the grid to handle a fairly high input signal. Another arrangement makes use of an input voltage divider having very low capacity that can be switched in when necessary to reduce the strength of the input signal to some fraction of its original value—usually to one-tenth. Thus, when the divider is switched in, only one-tenth the signal is applied to the grid of the first tube.

In summary, we can say that you are not likely to overload the oscilloscope if the gain control is across the input terminals, but the input capacity may affect the circuits that are being tested. If the gain control is between the stages, on the other hand, the input capacity will be too low to cause trouble, but you will have to be careful to limit the input signal so that it cannot overload the first tube. Read the manufacturer's instructions accompanying the oscilloscope you buy to learn what is said on this subject.

Incidentally, it is possible to overload an oscilloscope if you run the gain control so high that the trace sweeps beyond the face of the tube.

You should try to keep the deflections in both the vertical and the horizontal directions well within the edge of the face. Because of this, an oscilloscope using a c.r. tube smaller than 3 inches in diameter is not practical, and those with 5-inch or 7-inch tubes are better because they permit you to use images of reasonable size without fear of causing excessive distortion because of overloading.

To sum up these requirements, an oscilloscope that is to be used in television servicing must have: high sensitivity; good low-frequency response (down to 60 cycles or better); good high-frequency response (up to 1 megacycle or more is the oscilloscope is to be used for square-wave testing or for signal tracing); and, finally, a low input capacity so that it will not affect the circuits that are being checked.

Using an Oscilloscope in TV Servicing

As we have said, an oscilloscope can be used in TV service work to examine the wave shape and to measure the peak-to-peak values of the signal voltages in various stages. It is also useful when you are aligning a TV set.

In addition, the oscilloscope can be used to check the frequency of any signals seen. This is possible because the frequencies of the sweep generator of the oscilloscope are either marked on the sweep control, or can readily be determined by a calibration process. When the sweep generator frequency exactly matches the frequency of the incoming signal, you will see one cycle of the wave being analyzed. By referring to the calibration of the sweep generator when only one cycle is visible, therefore, you can determine the frequency of the incoming signal. If you see two cycles of the incoming signal, the sweep generator is operating at half the frequency of the signal, and so on. In each case, the frequency of the incoming signal is equal to the sweep generator frequency multiplied by the number of cycles visible. If the calibration of the sweep generator is not exact, you can determine the unknown frequency by comparison with known frequencies. The method of doing so has been described elsewhere in your Course.

Signal Tracing. The oscilloscope is directly usable for signal tracing in the audio, video, sync, and sweep sections. By this statement, we mean that it can be used throughout the audio amplifier just as a signal tracer would be used in a sound receiver. It can also be used to trace the video signal from the video detector through the video amplifier to the grid of the picture tube if the oscilloscope has a sufficiently wide frequency response. Finally, it can be used to follow the synchronizing signal through the sync chain and the sweep signals through the vertical and horizontal sweep chains. In each of these uses, no special equipment that is not already incorporated in the instrument is required.

Let us remind you, however, that the sweep voltages reach very high values, so it is quite easy to overload the in-

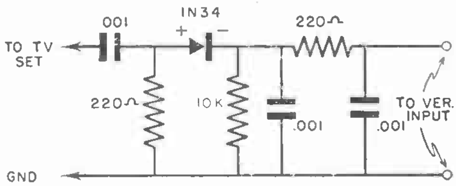


FIG. 22. Schematic diagram of a crystal detector probe.

put of the oscilloscope when you are using it to examine the shapes of sweep signals. Also, you will have to be careful about d.c. voltage levels. There may be blocking condensers in your oscilloscope that cannot withstand some of the high voltages that are found in many sweep circuits. For these reasons, you will have to measure the sweep signals with caution. In particular, unless you use a voltage divider of a kind to be described later to protect your oscilloscope, do not attempt to use it to make a direct measurement of the sweep output voltage in a set using electrostatic deflection, of the voltage at the plate of the horizontal sweep output amplifier in a set using electromagnetic deflection, or of the a.c. voltage across the horizontal deflection yoke.

The oscilloscope cannot give a useful indication of a signal too high in frequency to pass through its vertical amplifier, so it cannot be used directly in the i.f. stages. However, by rectifying the incoming signal so that the modulation is available for the oscilloscope, you can use it to trace through the video i.f. and the sound i.f. amplifiers. For this purpose, you must buy or build a special detector probe that has an extremely low input capacity. (This probe must have a low capacity so that it will not upset the resonant circuits of the i.f. amplifiers.) A diagram of a typical probe of this kind is shown in Fig. 22. The 1N34 crystal detector rectifies the i.f. signal so that the oscilloscope can follow the modulation on the signal. This probe may also be used in alignment, as we shall show elsewhere.

EFFECTS OF WAVE SHAPE

You can learn a great deal about the operation of various sections in a TV receiver by examining the wave shapes that are found in each section. You are already familiar with the fact that the particular sweep-voltage shapes desired are obtained by carefully shaping the output of an oscillator. As another Lesson pointed out, any change in the characteristics of the wave-shaping network will affect the shape of the sweep voltage, and will therefore produce non-linearity in the sweep. In turn, this will cause the picture to be non-linear in one form or another.

Your earlier Lesson on the sweep circuits showed you what the ideal wave shapes are. In a practical set, it is possible for the sweeps to depart *somewhat* from these ideal shapes without producing too much distortion. When you are examining the sweep shapes in an actual set, therefore, you should find out what the service manual on that set nas to say about them. The tracings in such manuals are those that are obtained from a set in good working order, and indicate just how much variation from the theoretically perfect shape you can expect to find.

As an example of what you can learn from a careful examination of wave shapes, let's suppose that we have an oscilloscope that is connected in the video amplifier, and that we have it adjusted so that we can see the horizontal line pulses and their blanking pedestals.

If the pulse and the blanking pedestal are normal, as shown in Fig. 23A, the over-all frequency response of the receiver is about what it should be, and the picture should also be normal unless some defect exists beyond the point at which the oscilloscope is connected.

On the other hand, let's suppose that the wave is distorted as shown in Fig. 23B. Such a distortion is caused by a poor high-frequency response. Compare this carefully with the correct wave shown in part A of this figure. Notice that the pedestal of the latter has a front and back porch, and that the sync pulse is properly placed on the pedestal. When the high frequencies are lost, it is impossible for the circuit to follow the sharp frequency changes that are needed to produce the porches, and the slope or rise of this nearly square pulse is rounded off. When this condition occurs, the loss of high frequencies may result in a loss of picture detail. This condition may correspond to a misalignment of the sort shown by the alignment curve in Fig. 23B.

On the other hand, if the high frequency response of a receiver is excessive, there will be an over-shoot on each vertical rise (Fig. 23C). When this occurs, the oscilloscope tracing will indicate that the voltage goes beyond the correct point, and must then fall back to the right level. Such a condition will produce a form of reversed ghost effect, because any sudden change in shading in the picture will become even more abrupt than it should be. If the picture is supposed to change from black to light gray, for example, it may, instead, change from black to white, then to gray. Conversely, if it is supposed to change from white to dark gray, it may change from white to black before it becomes gray. As a result, each sharp change in shade in a picture will be

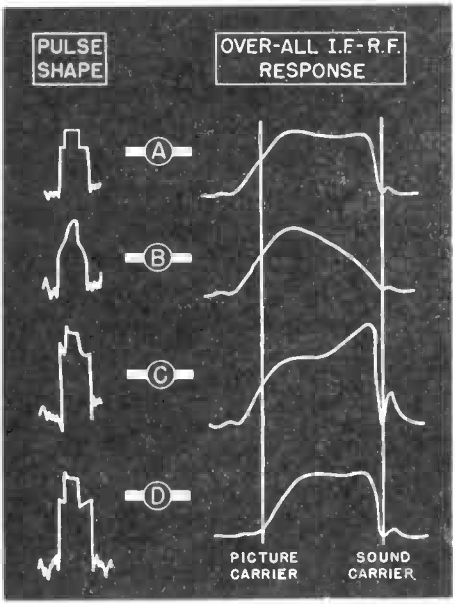


FIG. 23. Various possible shapes of the horizontal sync pulse and the over-all frequency responses that produce them.

followed by a line that is lighter or darker than it should be. If there is much "bounce" or oscillation before the voltage settles down to the required value, there may be a series of black and white lines or striations following sharp changes in the picture shading.

Finally, as shown in Fig. 23D, the set may be deficient in its low-frequency response. This deficiency is indicated by the fact that the portions of the pulses that should be horizontal or level tend to slope off instead. This condition can be caused by a misalignment that has shifted the video i.f.-response curve in such a way that the picture carrier is way below the 50% response point. Such a misalignment is shown by the response curve in Fig. 23D. (Of course, this loss of low frequencies can also be due to a defect in the video amplifier.) If the low-frequency response of a set is below normal, large picture areas that should be all of one shade will, instead, gradually trail off into a gray. Also, if the very low frequencies are lost, there will be a smeared picture, and perhaps a loss of vertical synchronization.

Frequency Response Check. If the pulse that we are viewing is the horizontal pulse, it will not indicate a loss of low frequencies under 15 to 20 kilocycles. Therefore, we will not be able to determine if there is any loss in the very low frequencies by examining the horizontal pulse.

There are, however, several other ways in which we can use an oscilloscope to check the low- and high-frequency response of a set. If you suspect that the set is misaligned, you can find out if your suspicions are correct by using a sweep signal generator and an oscilloscope to see exactly what the response of the front end and the i.f. stages is like. The method of using these instruments for this purpose will be covered when we study alignment.

If you believe that the loss is occurring in the video amplifier, you can feed signals at the frequencies you suspect through the amplifier, and determine its gain at each frequency by direct measurement. Alternatively, if a square-wave signal generator is available, you can feed a square-wave signal of about 60 cycles through the video amplifier and examine the response. If the trace produced on the oscilloscope is square, the low-frequency response of the video amplifier is normal. However, if it slopes off as does the top of the sync pulse in Fig. 23D, the low-frequency response of the amplifier is falling off, and there is a low-frequency phase shift.

SIGNAL TRACING

Most servicemen depend on a TV station for a signal source when they use an oscilloscope as a signal tracer, primarily because test equipment that is capable of simulating a TV signal is rather costly. However, the demand for such equipment is causing less expensive models to be put on the market, and eventually, the average serviceman may have a TV signal generator of his own. In such a case, the signal seen on the oscilloscope will depend on what the output signal of his equipment is.

If you do not have such a generator, but instead trace a broadcast TV signal, there are certain basic kinds of signals that you will find in each section of every TV set. The exact forms of these signals do depend, however, upon just what is coming in and upon the design of the set. Therefore, you must consult the manufacturer's service information to find out exactly what you should see when you trace through his sets.

When you examine a signal with an oscilloscope, as you learned earlier, it is desirable to have at least two cycles visible on the screen, since you can then get a better idea of the actual wave shape than you could by examining just one. The composite signal passing through the video amplifier contains not only the video signal itself, but also the line and frame-blanking pedestals on which are the line and frame sync signals—in fact, the entire modulation transmitted in the composite signal. The video signal itself is, of course, constantly changing, and it would be impossible to synchronize this to any satisfactory degree. However, the horizontal or line-blanking pulse that occurs at the end of each line, and the vertical or field-blanking pulse that occurs at the end of each field are fixed and regular in frequency; the line frequency being 15,750 cycles, and the field frequency, 60 cycles. The oscilloscope can be synchronized with either of these pulses. Since we want two complete cycles, we must set the oscilloscope sweep to half the frequency of the blanking pulse that we want to sync with. Thus, a 30-cycle sweep rate will cause a trace of the voltages that occur in two complete cycles of the vertical sweep to be produced, whereas a rate of 7875 cycles will cause a similar trace of the voltages in two complete horizontal sweeps.

Video Amplifier Tracing. The signals shown in Fig. 24 are typical of those that you might see in the video amplifier. The trace in part A of this figure shows what you will see if the oscilloscope sweep rate is 30 cycles; therefore, the two major traces seen in this figure represent two fields, and the empty area between them represents the blanking that occurs between fields. All of the lines in each field are mixed up in this kind of trace, so it gives you little information about the true nature of the video signal itself. It does give you a general idea of the appearance of the signal, however, and records the vertical blanking period with reasonable faithfulness. Also, you can use such a trace to measure the peak-to-peak value of the signal. It is

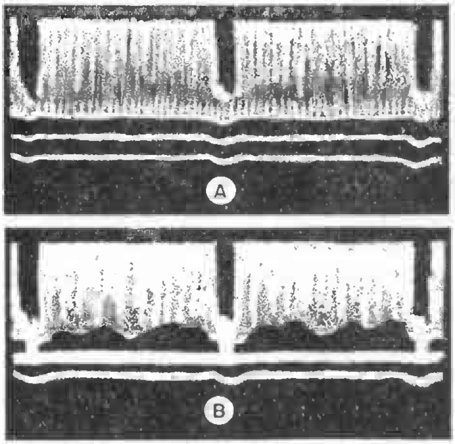


FIG. 24. Traces representing two fields (A) and two lines (B), taken from the video amplifier.

useful for you to know what this value is, because the service manual for the set will usually tell you what it should be at various points in the video amplifier. If you do not find the right value (which may be as low as 1 or 2 volts at the output of the video detector, or as much as 60 volts at the grid of the picture tube), you will know, of course, that some defect exists.

The trace shown in Fig. 24B is what you will see if the oscilloscope sweep is adjusted to be half the horizontal sweep rate of the signal. This represents two lines and the blanking space between them. Actually, of course, the trace is produced by all the lines that occur during the time that the oscilloscope is connected to this point in the amplifier, each pair of lines being superimposed on the pair that occurred before it. Since each line usually differs somewhat from all the others, the trace is not a clear representation of a pair of lines, but rather a mixture of the traces produced by a great many lines.

The peak-to-peak voltage in this case is essentially the same as that represented by the trace shown in Fig. 24A, since the peak-to-peak signal depends primarily on the height of the sync pulses above the zero level, a factor that will remain relatively constant even though the signal content itself does change.

As you move along through the video amplifier, this trace will be inverted as you pass each stage, but its appearance should remain relatively the same except that it will be amplified. Of course, if the signal itself changes during the time it takes you to move the oscilloscope probes, the part of the trace that represents the video portion of the signal—the "smear" between the blanking intervals—will tend to change in characteristics somewhat.

The peak-to-peak value of the signal you find at any point should correspond to the value given by the manufacturer, if the local signal strength is normal. Regardless of this strength, you can determine the gain of any stage by dividing the peak-to-peak voltage at the output of the stage by its peak-to-peak input voltage.

Sync Chain Tracing. The signals seen in the sync chain vary a great deal in their characteristics. If there is an input sync amplifier, it is quite likely to handle the entire signal, including the video portions. However, there may be some leveling or clipping in this stage to restrict amplitude changes caused by noise, so the signal may look somewhat different from that found in the video stages.

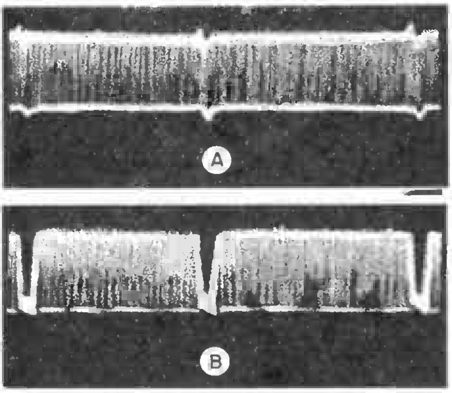


FIG. 25. Traces representing two vertical (A) and two horizontal (B) pulses, taken from the output of the clipper.

At the output of the clipper, the video signal should be almost entirely removed, and you should get a series of pulses that consist mostly of the sync pulses. Once again you can get your oscilloscope to sync with either the vertical or the horizontal pulses, and can therefore view them individually. A typical example is shown in Figs. 25A and 25B, the former showing two vertical and the latter two horizontal pulses.

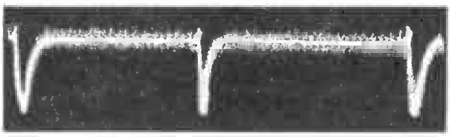


FIG. 26. Trace representing the output of the vertical integrating network.

Any sync amplifier following the clipper will increase the amplitude of these signals if it is arranged as a straight amplifier. However, a second sync amplifier is often actually a second clipper, arranged to square off the pulses, and get rid of any stray noise, and any vestiges of the video signal. In such a case, the output may be below that of the first clipper, but the pulses should be more nearly square in their shapes. The voltages at the output of the clipper are usually somewhere around 50 to 75 volts, since a fairly strong signal is needed for the integrating and differentiating networks.

The output of the vertical integrating network consists of a series of pulses representing the vertical sync signal. As you will recall, this pulse is relatively broad in comparison to a line pulse (in fact, its duration is equivalent to that of three or more complete lines), but it looks rather narrow on an oscilloscope when compared to the over-all sweep time of the complete field, as shown in Fig. 26.

The pulse found in the output of the integrating network may be anywhere from 10 to perhaps 40 volts in peak-to-peak amplitude, depending on the set design. As you will recall, this pulse is used in most receivers either to unblock a blocking oscillator or to drive a multivibrator.

The wave form to be seen in and around this oscillator depends upon the characteristics of the circuit. A typical example of the wave shape at the grid of a vertical blocking oscillator is shown in Fig. 27. Here, the peak-to-peak voltage may be rather high—as much as 300 volts or more in some sets, depending on the inductive kickback of the blocking oscillator transformer. The peak-to-peak voltage at the input of a multivibrator will be considerably less.

The vertical sync signal will look somewhat like the trace shown in Fig. 28 when it is applied to the input of the vertical sweep output stage in a set that uses an electromagnetic picture tube. Here, too, the peak-to-peak voltage may be surprisingly high, perhaps as much as 150 volts or so. Of course, only the tips of the positive

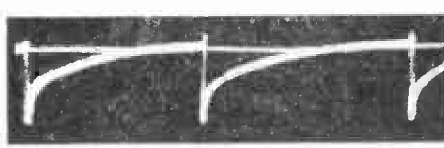


FIG. 27. Trace representing the wave shape at the grid of a vertical blocking oscillator.

peaks (which may be only about 20 volts positive) are used to drive the vertical output tube.

The signal that finally reaches the vertical deflection coils in a set in which electromagnetic deflection is used has the shape shown in Fig. 29. The peak-to-peak amplitude depends on the design of the coils; it is usually around 50 to 75 volts.

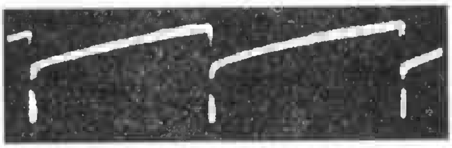


FIG. 28. Trace representing the vertical sync signal at the input of the vertical sweep output stage.

Horizontal Sweep Tracing. The shapes of the signals coming through the horizontal sync chain depend on whether the set has an a.f.c. horizontal hold system or one of the pulse-shaping types. You should consult the service manual for the set you are working on to learn what wave shapes you should expect the sync signals to have.

The wave shapes in the horizontal sweep chain depend on the kind of horizontal oscillator that is used. The horizontal oscillator is often a blocking oscillator or a multivibrator, but it is quite possible for it to be a sine-wave oscillator, particularly if it is in a set that uses a horizontal a.f.c. system.

In this last case, you will find a sine wave across the grid circuit of the oscillator but are quite likely to find a squared wave in its plate circuit. If the set uses a blocking oscillator or a multivibrator, the horizontal sweep signal will probably be shaped very much like the vertical sweep signal, except, of course, that its frequency will be 15,750 cycles instead of 60 cycles. To reproduce two cycles of this signal on the oscilloscope, therefore, you must set the oscilloscope sweep frequency at 7875 cycles.

An example of the changes that occur in a horizontal sweep circuit that starts from a sine-wave oscillator is given in Fig. 30. The grid input signal of the oscillator is shown in part A of this figure. Part B shows the signal in the plate circuit.

After shaping, the wave resembles the one shown in part C, which represents the signal that is fed to the grid of the horizontal-sweep output tube.

A signal much like that in part D may be found at the plate of the horizontal output tube, but you should not attempt to measure this pulse without using special equipment—it may be as much as 6000 volts peak-to-peak! The coupling condensers in your oscilloscope cannot withstand such voltages; even if they could, these signals would drive the spot far off the screen. About the only way you can measure a voltage of this kind is to use a capacitive voltage divider that is set up to deliver a very small portion of the total signal to your oscilloscope. Any such capacitive voltage divider must use

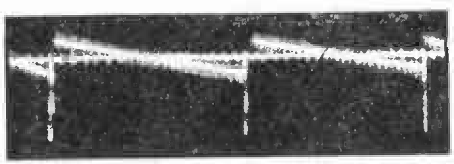


FIG. 29. Trace representing the signal applied to the vertical deflection coils.

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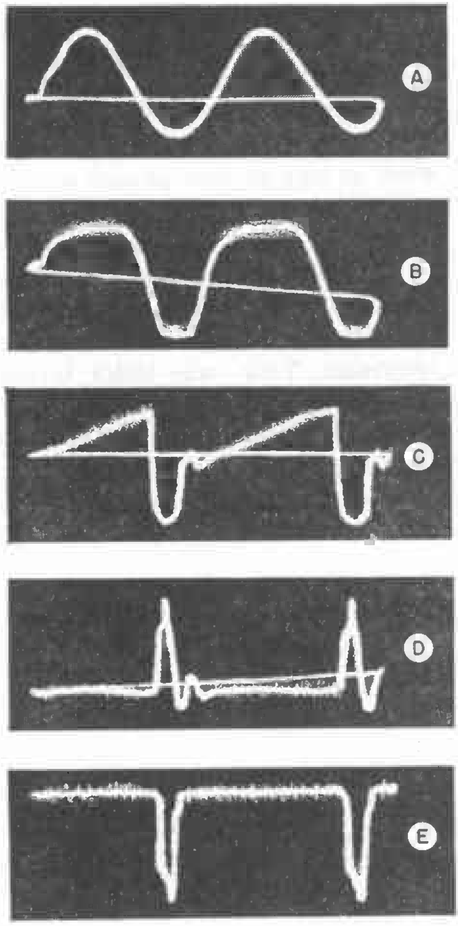

FIG. 30. Generation of a horizontal sweep signal from a sine-wave oscillator.

fixed condensers rated at 10,000 volts or more, of course.

The signal across the vertical deflection coils is shown in Fig. 30E. Here, because of the resonant kickback, we again have a high peak voltage; it may be 1000 or more volts peak-to-peak. Once again, a capacitive voltage divider, made up of high-voltage condensers, must be used if the voltage is to be measured.

Summary. Keep in mind that the oscilloscope traces we have shown in Figs. 24 to 30 are typical for only one kind of set. You will find quite different signals in other sets, and until you become accustomed to the signals that are to be seen, you should always refer to the manufacturers' information to learn what the typical wave shapes and peak-to-peak voltage values are.

In our example, we have shown the wave shapes that exist in a receiver using electromagnetic deflection. Many of the same signals exist in a set in which electrostatic deflection is used; however, the signals in the sweep chains of the latter will be different, because a saw-tooth voltage must be applied to the deflection plates of the electrostatic picture tube. This saw-tooth wave is formed in the saw-tooth generator in the sweep chain, then amplified in a linear fashion to a very high voltage level. It is common to find a deflection voltage of 800 or more volts peak-to-peak applied to an electrostatic picture tube. Once again, you must use a capacitive voltage divider to measure this voltage.

As we have pointed out, the oscilloscope is particularly useful as a signal tracer, because it lets you measure the peak-to-peak voltage of a signal of any shape and also makes it possible for you to see the wave shape of the signal. When this wave shape departs radically from what it should be, you have a definite indication of trouble in the section or stage in which the change of shape occurs. Thus, the oscilloscope is an extremely valuable instrument for use in localizing a defect to a particular section or stage.

Most standard radio service equipment (except the signal tracer) is useful for TV servicing if it has the proper characteristics. Thus, you will not need a special multimeter for TV work as long as your present one has a meter with a high enough ohms-per-volt rating to provide high ohmmeter ranges. A high-voltage multiplier probe is the only extra equipment that is needed to extend its usefulness to television. Your tube tester is perfectly satisfactory for TV work if it can test the latest tube types. A standard R–C tester is far more useful for TV servicing than it is for radio work. Your signal generator may or may not be useful, depending on the ranges it covers; we shall discuss such generators in detail in the Lesson on alignment.

In general, most of the basic servicing procedures that you have learned to use in repairing radio receivers can be applied directly to TV service work as long as you are careful in interpreting the results of your tests. For this reason, once you obtain a certain amount of practical experience, and have learned to recognize the effects produced on test patterns by various defects, you will find it rather easy to service TV receivers successfully.

Lesson Questions

Be sure to number your Answer Sheet 64RH-3.

Place your Student Number on *every* Answer Sheet.

***Send in your set of answers for this Lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. If the individual lines in a raster are not sharp when the contrast control is turned down so that no picture is visible, which one of these possible causes is to blame: 1, poor focus; 2, ghosts; 3, poor high-frequency response; 4, poor low-frequency response?

2. If it is difficult to keep a set in vertical sync, and the picture is blurred, which one of these possible causes is to blame: 1, poor focus; 2, ghosts; 3, poor high-frequency response; 4, poor low-frequency response?

3. If a set that originally showed a black-and-white picture later shows a brown-toned one, what is probably the matter?

4. If a set uses full-wave rectification in its power supply, what defect is indicated if (*a*) one bar and (*b*) two bars appear on the picture?

5. If a picture has 10 bars across it horizontally, what is the approximate frequency of the interference?

6. If a sine-wave a.c. source rated at 5 volts r.m.s. is used for calibrating an oscilloscope, what is the peak-to-peak voltage?

7. What four requirements are essential for an oscilloscope that is to be used in TV servicing?

8. Why is a detector probe needed with a TV scope to search through the video i.f. stages?

9. Why is it desirable to arrange for more than one cycle of the signal to be visible on the oscilloscope?

10. In viewing the horizontal pulse on a TV oscilloscope, what is wrong with the receiver response if the porches and flat top of the pulse are rounded instead of square?

Be sure to fill out a Lesson Label and send it along with your answers.

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The road of human welfare lies along the old highway of steadfast well-doing. The men who are most persistent will usually be the most successful.

"Fortune" has often been blamed for her blindness. But "fortune" is not as blind as men are. "Fortune" is usually on the side of the industrious—just as the wind and waves are on the side of the best navigator.

J. E. Smith

TV RECEIVER ALIGNMENT

65RH-4

PIONEER HOME STUDY RADIO SCHOOL

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

☛ THIS IS THE LAST LESSON OF YOUR COURSE ☚

STUDY SCHEDULE NO. 65

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. **Introduction** .... **Pages 1-7**
Here you learn why sections may get out of alignment, what indicates that alignment is necessary, and what the responses of the various sections of a TV set should be.

☐ 2. **Methods of Alignment** .... **Pages 7-13**
The general procedures followed in aligning TV sets and the equipment and tools needed in them are discussed in this section.

☐ 3. **Video I.F. Alignment** .... **Pages 13-23**
Here you learn how to align the video i.f. section in standard and intercarrier sets.

☐ 4. **Sound I.F. Alignment** .... **Pages 23-26**
The manner of aligning the sound i.f. section is described here.

☐ 5. **Front End Alignment** .... **Pages 26-28**
The few adjustments that a serviceman can make on the front end of a TV set are described here.

☐ 6. **Answer Lesson Questions and Mail Your Answers to NRI for Grading.**

☐ 7. **This is the LAST Lesson of your Course. Your next step will be to answer the Final Examination. (If you have misplaced your examination questions, write in at once for another copy.) It is advisable to review the Course to prepare for this examination. A quick reading of the Lessons, one right after another, will refresh your memory on many vital points, and should enable you to answer the examination questions with ease.**

65 RH-4

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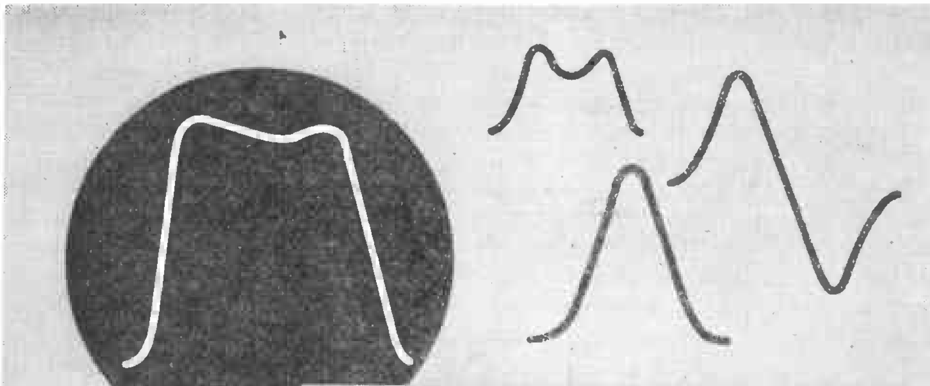


TV RECEIVER ALIGNMENT

ALIGNING a standard sound receiver is a relatively simple process: the proper i.f. or r.f. signal is inserted and the corresponding circuits are tuned for a maximum output indication. (Band-pass adjustments are found only in a few high-fidelity sets.) The indications of the need for alignment of a sound receiver are quite definite — reduced output, stations coming in at incorrect points on the tuning dial, or distortion due to sideband cutting. Since sound receivers are relatively stable, the need for alignment is rather infrequent.

Aligning a TV set is not a great deal more difficult, but the indications pointing to the need for alignment are not as definite. In many cases, a set will exhibit exactly the same symptoms when some part is defective in it as it will when it needs re-alignment. In such cases, either you should prove that no defect exists before you decide that alignment is needed or you should use a sweep generator and an oscilloscope to show the response curve and thus determine whether alignment is needed.

Because many of the circuits of a TV set are heavily loaded so that they will have low Q and a broad response, there is seldom enough drift to make a complete over-all alignment necessary. On the other hand, because certain changes in the alignment affect the picture in a manner that is rather noticeable to the eye, relatively small amounts of drift, which may occur fairly often, can make spot or section alignment necessary. Tuned-circuit drift is more common in a TV set than in a radio because more heat is developed—heat that will warp coil forms and distort tuning capacitors—and because tube capacities, which are subject to change, make up part of the capacity in some tuned circuits.

In general, the sharper the selectivity (the higher the Q), the sooner alignment may be needed, because even small amounts of drift affect the outputs of high-Q circuits remarkably. On the other hand, low-Q circuits can drift considerably before the output changes greatly.

Relatively high-Q circuits are used as oscillator tank circuits and as sound and adjacent-channel rejection traps. In some of the stagger-tuned i.f. circuits, the Q is higher than the width of the pass-band might lead you to expect. It is quite possible that any of these circuits may need touch-up adjustments even when the rest of the receiver requires no alignment.

Oscillator Drift. It is rather common to find that the oscillator of a TV set has drifted so much that stations come in too near the end of the range of the fine tuning control or outside its range altogether. In a set that does not have a fine tuning control but instead depends on automatic frequency control (a.f.c.) to hold the oscillator, it is possible for the drift to cause the signal to fall outside the range of the a.f.c. network and thus for the station to be lost completely.

A certain amount of drift of the oscillator at the high frequencies involved in television is natural. It can be tolerated as long as it can be corrected by the fine tuning control or by the a.f.c. system. If the drift becomes excessive, however, it will be necessary to re-align the oscillator.

Because the oscillator circuits used in TV sets depend on the internal tube capacities for much of the tuning capacity needed, replacing the original oscillator tube with one that has different internal capacities may easily throw the oscillator section completely out of alignment. Therefore, if it proves impossible to find a replacement tube that matches the original in its capacities, a certain amount of re-alignment may be required.

Traps. Trap circuits also frequently drift out of proper adjustment. There are many traps in the average TV set. Some are tuned to the accompanying sound channel, some are tuned to the adjacent sound or picture carriers, some are used to reduce i.f. interference, and still others are used (particularly in sets using the intercarrier sound system) to reduce the 4.5-mc. grain pattern in the picture. Because these traps are sharply tuned and have much to do with the over-all response, slight shifts in their tuning may produce large increases in interference and can affect the low- or high-frequency response as much as or more than the stagger-tuned or band-pass circuits do.

Sound-Video Drift. The sound and video carriers are 4.5 mc. apart. If either or both of these i.f. sections in a conventional set drift appreciably, you may find that best sound and best picture are not obtained at the same setting of the tuning control. That is, if the picture carrier is moved up or down on the slope of the video i.f. response, the low-frequency response will be better or worse than it should be, and consequently the picture quality will be affected. A shift of the carrier may also result in a loss of high-frequency response.

In any of the above cases, you can make a touch-up alignment of the particular circuit that needs it without re-aligning any of the rest of the set. This is similar to what you do when a radio does not track the dial properly, in which case you re-align the oscillator but leave the i.f. and r.f. adjustments alone.

Of course, there will eventually come a time when an over-all alignment will be desirable. Such a general over-all alignment is called for when you are overhauling a receiver or remedying any of the characteristic conditions described in the following section.

MISALIGNMENT INDICATIONS

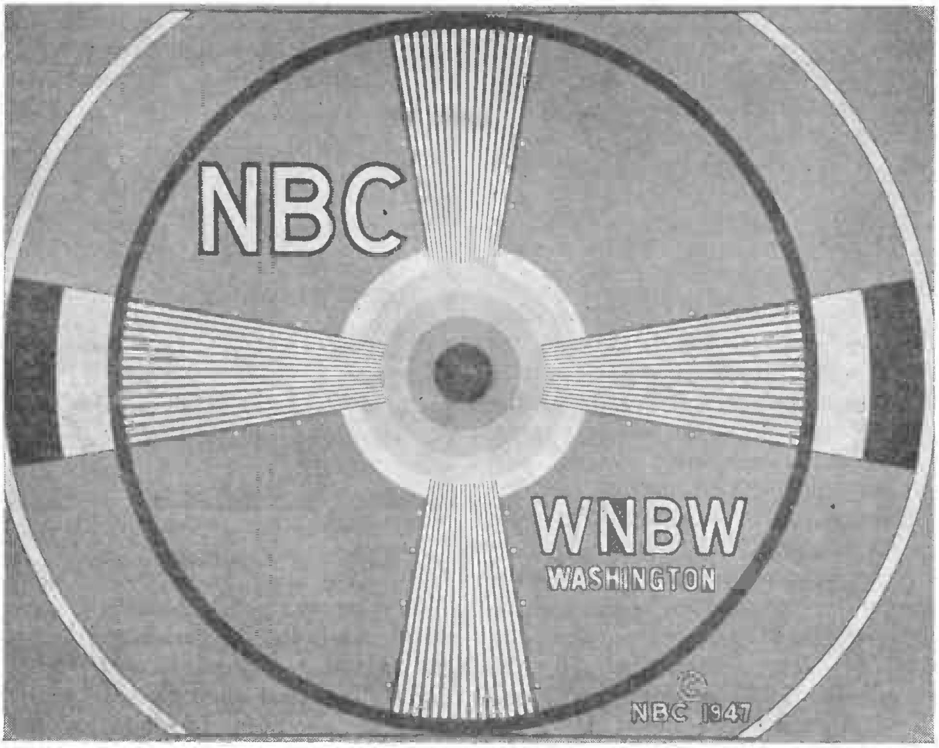
One of the most obvious conditions indicating a need for alignment is weak reception. However, unless the oscillator drifts, the alignment must shift markedly (usually in more than one stage) to produce weak reception. It is more common to find that the first indication of the need for TV alignment is a loss of the low- or high-frequency response. This is most easily seen by observing a test pattern.

Fig. 1 shows a typical test pattern. As we have shown elsewhere, this test pattern gives considerable information about the adjustment of the focus, linearity, and size controls, and also indicates when the correct contrast and brilliancy control settings have been made.

The contrast setting is indicated by the center circles: proper setting gives the complete tone range from black to white. The wedge-shaped groups of lines show many things. The vertical wedges show the high-frequency response, because they represent elements along the scanning lines. The horizontal wedges show other things, including the low-frequency response.

When we are aligning a set, we are primarily interested in how the test pattern will show high- and low-frequency response. When the set is operating normally and has a frequency response going out to 4 or 4.25 mc., the separate lines in the *vertical* wedges should be distinguishable all the way down to the center circle at which they end. If they appear to blend together short of their ends, the response of the set is less than 4 mc., either because it is intended to be or because it is out of alignment. In this case, the actual high-frequency response can be determined by observing where the lines in the vertical wedges appear to blend.

In the standard test pattern of Fig. 1, the four pairs of white dots along the lower vertical wedge are markers that indicate approximately the frequency response needed to reproduce the lines in the wedge between each pair. Thus, the first pair, nearest the bottom of the test pattern, represents



Courtesy NBC

FIG. 1. The standard test pattern broadcast by many stations.

a frequency response of 2 mc. If the lines are distinguishable between this pair but not between the next pair of dots, 2 mc. is the limit of the high-frequency response. The next pair is for 2.5 mc., the next, 3 mc.; the next, 3.5 mc.; and the ends of the wedges represent a response of 4 mc. In other words, if the vertical lines can be distinguished sharply all the way to their inner ends, the horizontal resolution corresponds to an over-all frequency band width in the video amplifier, video i.f., and front end of 4 mc.

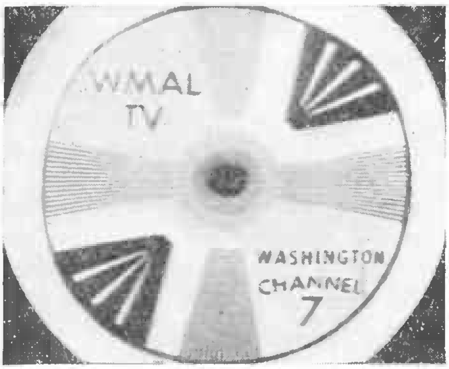


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FIG. 2. Poor high-frequency response.

It may happen that the test patterns of your local stations do not have calibration marks, or that non-standard wedges made with fewer or thicker lines are used. In the latter case, the frequency response may be less than 4 mc. even though the ends of the wedges are clearly distinguishable. Check with your local stations and use the best local test pattern for your alignment check.

The *horizontal* wedges do not show anything about the band width of the receiver response. Whether or not the lines in these wedges can be distinguished depends on the focus, the roundness of the scanning spot, and the interlacing of the fields. If the set is deficient in low-frequency response, however, the horizontal line wedges will be gray when the vertical wedges are black and white.

Examples. Before you can tell much about the test pattern, you must adjust the focus for maximum sharpness and set the contrast and brilliancy controls to normal positions. If the set is very close to a powerful station, overloading may occur, or you may not be able to get normal contrast without turning the control down so far that overbiasing produces a distorted response. In such cases, use another signal, or use a resistive pad in the transmission line to reduce the strength of the input signal.

Fig. 2 illustrates poor high-frequency response. Notice that the lines in the vertical wedges join well outside the inner circle.

Excessive response to any frequency, an effect that may be caused by regeneration or misalignment, may be indicated by a smearing or blurring at the position in the wedge corresponding to that frequency. This is shown in Fig. 3.

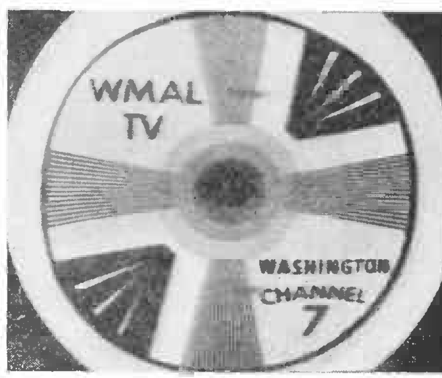

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FIG. 3. Peak in high-frequency response.

Another common indication of misalignment is the appearance of sound bars across the picture as shown in Fig. 4. This may mean that the sound traps are not properly aligned or are aligned to the wrong frequencies, but it may also indicate merely that the fine tuning control on the set is misadjusted. If the set uses a.f.c., sound bars may be caused by excessive drifting of the oscillator or by a misalignment of the discriminator from which the a.f.c. voltage is obtained.

The grain pattern shown in Fig. 5

NRI TV Lab Photo

FIG. 4. Sound bars.

may be the result of a misadjustment of a grain trap, but it may also indicate that the co-channel sound traps in the i.f. amplifier are misaligned if the set is a conventional type.

Many of the distorted test patterns that we have just shown may be caused by other defects in the set or by external causes as well as by misalignment. Therefore, you should not try re-alignment until you have checked the other possible causes of trouble.

Before we take up the methods of aligning a TV set, let's learn what frequency response we can expect each section to have.

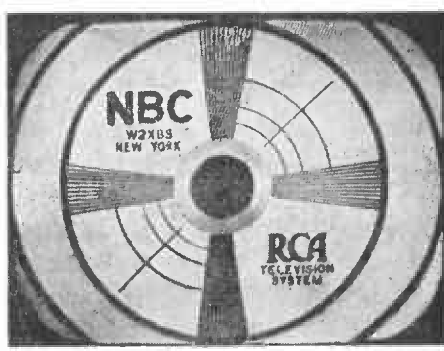
CIRCUIT RESPONSES

Front End. In general, the front-end response will be a band-pass response about 6 mc. wide so that the picture and sound signals can go through simultaneously.

Video I.F. The response of the video i.f. amplifier varies considerably in different receivers. One reason for the variation is that this response is often designed to correct for dips or peaks in the front-end response. Another is that the manufacturer may intend to locate the picture carrier higher or lower than the 50% response point, depending on whether he wants the low-frequency response to be raised or lowered. And, of course, the response of the video i.f. amplifier to the sound carrier will depend upon whether it is a conventional or an intercarrier system. Because of these wide differences, it is very desirable to have the manufacturer's alignment instructions before attempting to adjust a TV receiver.

Fig. 6A shows a typical front-end response. The exact shape of the response curve depends on the design of the set and even on the channel to which it is tuned.

If the set has a separate sound channel, the sound carrier will be suppressed. A typical i.f. response for such a set is shown in Fig. 6B. The



Courtesy RCA

FIG. 5. Grain.

over-all r.f.-i.f. response is a combination of the two, which may be somewhat like that shown in Fig. 6C.

The shape of the response curve can be varied considerably, as shown in Fig. 7A, without making any difference in the output. In other words, the output will be constant if the picture carrier is located exactly half way up any slope that is symmetrical on both sides of the carrier, regardless (within limits) of what the angle of the slope may be. Thus, the curves 1, 2, and 3 all will give approximately the same output. Because of the design of the peaking circuits and traps, however, it may be that only one of these curves can be made symmetrical, so it is necessary for you to learn from the manufacturer's instructions just what slope is to be obtained on the particular set on which you are working.

The position of the picture carrier on the slope affects the low-frequency response. If it is above the mid-point

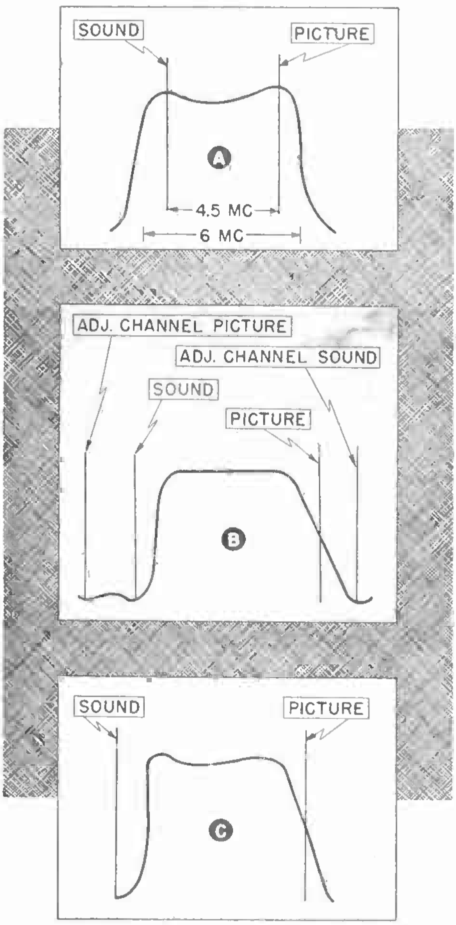


FIG. 6. The combination of the front-end response (A) with the i.f. response (B) produces the over-all response of the set (C).

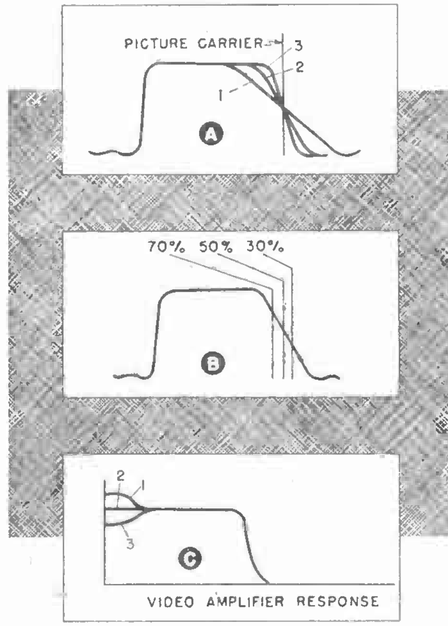


FIG. 7. The shape of the i.f. response curve (A) has little effect on the output, but the position of the sound carrier on the curve (B) can be used to compensate for variations in the video amplifier response (C).

of the curve, the low-frequency output is higher than normal; if below, the low-frequency output is lower than normal. This fact is helpful when the video amplifier response is to be compensated for. If the video amplifier response is flat as shown by curve 2 in Fig. 7C, for example, the carrier should be at the 50% point on the response curve in Fig. 7B. On the other hand, if the video amplifier response peaks at the low frequencies as shown by curve 1 in Fig. 7C, the carrier should be lower down on the curve, perhaps near the 30% point (Fig. 7B). This arrangement will reduce the amount of low-frequency signal applied to the video amplifier, thus compensating for the peak in the response of the latter. Similarly, if the video amplifier response is deficient at the low frequencies (curve 3 in Fig. 7C), the carrier should be

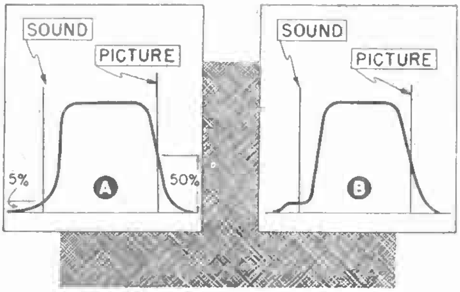


FIG. 8. Typical video i.f. responses of intercarrier sets.

farther up the slope, perhaps near the 70% point (Fig. 7B), to compensate. Once again, the manufacturer's alignment instructions must be followed.

Of course, if the receiver uses the intercarrier sound system, in which the sound signal must get through the picture i.f. along with the video signal, the response curve of the i.f. amplifier will be quite different. Fig. 8 shows two typical intercarrier video i.f. responses. The curve in Fig. 8A is nearly symmetrical on the sides, but the picture carrier is much farther up the slope than is the sound carrier. In some sets, traps are used to create a small plateau at the point where the sound carrier intercepts the response curve (see Fig. 8B). Once again, you will have to learn from the manufacturer's instructions what adjustments must be made.

Sound I.F. The response of the sound i.f. amplifier has the shape shown in Fig. 9A. The response is rather narrow, since a band of frequencies only 50 to 100 kc. wide is all that has to be passed. Hence, a response characteristic that is 200 to 300 kc. wide is entirely sufficient for most purposes and will even permit a reasonable amount of oscillator drift.

Since the sound is f.m., the discriminator response has the standard S-curve shape shown in Fig. 9B. The distance between the peaks on this S curve varies from set to set; once again, your adjustments must be guided by the manufacturer's information.

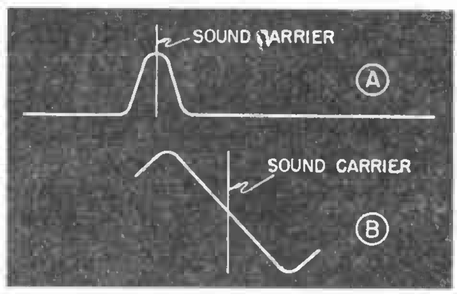


FIG. 9. Sound i.f. (A) and discriminator (B) responses.

Methods of Alignment

The pass band of a TV set, as you have learned, must be wide and flat and have very carefully shaped skirts. Either band-pass or stagger-tuned circuits are used in the front end and video i.f. amplifier sections to make the response sufficiently wide and flat, and traps are commonly used both to eliminate undesired carriers and to shape the response. Any one or all of these circuits may need to be aligned.

It is possible to align stagger-tuned circuits with an ordinary signal generator by adjusting each for maximum output at its proper frequency. The combined response curve of all the circuits will then have the desired shape.

A signal generator can also be used to align band-pass circuits fairly well, but a sweep signal generator is far better for the purpose. This same sweep signal generator can also be used to align stagger-tuned circuits if a cathode-ray oscilloscope is used as the output indicator; the oscilloscope will make the response curve visible, and any defects shown in the curve can easily be remedied.

Before we learn just how to align the various sections of a TV receiver, let's see what requirements the equipment used to do so must meet.

SWEEP SIGNAL GENERATORS

The sweep signal generator used in television resembles the frequency-modulated or "wobbulated" signal generator that is used to align high-fidelity sound receivers. The only basic difference is that the television sweep signal generator covers a wider sweep band.

As you know, the output of a wobbulated signal generator consists of a signal voltage that is swept back and forth over a range of frequencies on each side of a tunable operating or center frequency. For television use, this sweep must extend over a rather wide range—it is common to use sweeps 10 mc. (or more) wide for TV alignment.

This sweep can be obtained either mechanically or electronically. Three kinds of mechanical sweep generators are shown in Figs. 10A, B, and C. In the one shown in Fig. 10A, a motor rotates a tuning condenser plate so that the capacity in the L-C circuit is continuously varied. In that in Fig. 10B, a vibrator vibrates one plate of the condenser with respect to the fixed plate so that the capacity is varied. In that in Fig. 10C, a vibrator moves a disc with respect to the tuning coil so that the inductance is varied.

An electronic generator is shown in Fig. 10D. Here a reactance tube (like the one used in a.f.c. systems) is connected across the oscillator tank circuit. The grid of the reactance tube is fed from an a.c. source. As a result, its reactance varies at the a.c. frequency and therefore varies the frequency of the oscillator.

A major defect of the motor system shown in Fig. 10A is that there is no easy way to vary the width of the range over which the signal frequency

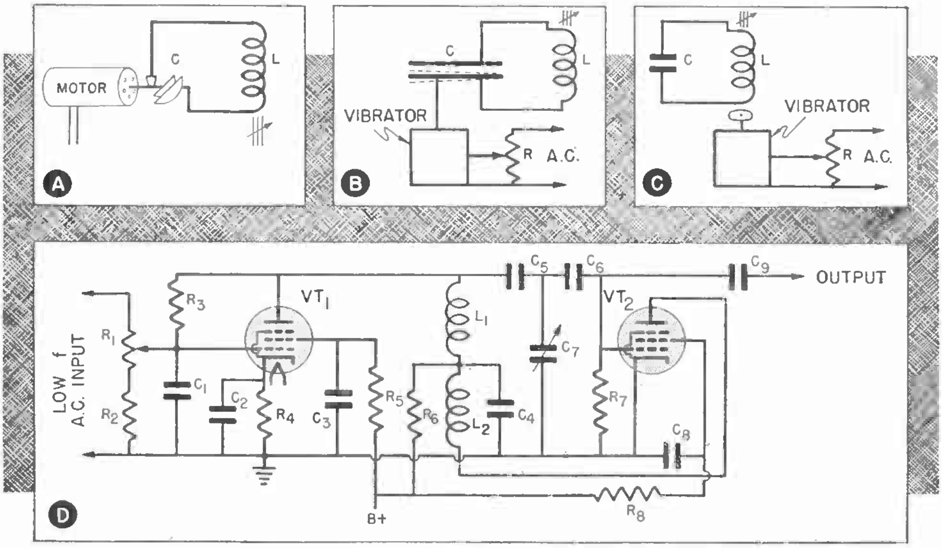


FIG. 10. Sweep generators used in sweep signal generators.

is swept. In the other systems, we can vary the range over which the frequency change occurs by varying the amplitude of the a.c. voltage applied to the vibrator or to the grid of the reactance tube. An increase in the voltage will cause an increased change

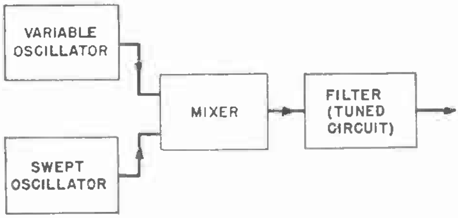


FIG. 11. Block diagram of a sweep signal generator.

in capacity or inductance and consequently an increase in the width of the sweep. Conversely, a decrease in the voltage will cause a decrease in the width of the sweep. It is very desirable to be able to vary the width of the sweep, since we want a width of less than 1 mc. for f.m. and audio section alignment, and a width of 10 or 15 mc. for video alignment.

The sweep *rate* is equal to the frequency of the a.c. signal used to vary the output frequency of the generator. In other words, it is the number of times per second that the output of the generator is swept through its range and returned to its starting point. This sweep rate need be only high enough to be within the response range of an oscilloscope. A 60-cycle a.c. is readily available from the power line or from a filament winding, and 120-cycle a.c. can be obtained from the ripple output of a full-wave rectifier. Either can be used for the sweeping signal if the oscilloscope has a reasonably good response at these frequencies.

The heterodyne principle is used in all practical sweep signal generators to simplify the problem of getting sweeps of adequate width at any desired center frequency. The block diagram in Fig. 11 shows the general arrangement of such an oscillator. As you can see, it consists of two oscillators, a mixer stage in which the outputs of the two oscillators beat together, and a filter circuit that passes only the difference frequency produced by the beating process.

One oscillator, called the swept oscillator, has a fixed center frequency that is sweep-modulated over the desired range. Since the center frequency of this oscillator is very high—usually well over 100 mc.—it is easy to vary the reactance in its tank circuit enough to produce a sweep range of 10 or 15 mc. The frequency of the other oscillator, called the variable oscillator, can be adjusted to any desired single value within a fairly wide range.

To see how this sweep signal generator works, let's suppose that the swept oscillator has an output of 125 mc. that is swept over a range of 15 mc. The center frequency of the output of the generator will be equal to the difference between 125 mc. and the frequency of the variable oscillator. If we adjust the variable oscillator to a frequency of 100 mc., for example, the generator output will have a center frequency of 25 mc. (125 − 100), which will be swept over a 15-mc. range.

To be useful for television servicing, a sweep signal generator should have an output voltage that is practically flat over the entire tunable frequency range, or at least over the range over which the signal is swept. This output voltage should be high, because as much as .5 volt may be necessary to give a usable response on an oscilloscope when the signal is fed through a single i.f. stage. There should be some provision for attenuating this output, however, since only 500 microvolts or less may be wanted when you are checking the over-all response of a set that has high gain.

It is necessary, of course, to synchronize the horizontal sweep of the oscilloscope with the sweep of the generator to produce a steady pattern on the oscilloscope face. Some generators supply a synchronizing signal that can be used to lock the sweep of the oscilloscope to the right frequency; others furnish the horizontal deflection voltage for the oscilloscope directly. (The latter is applied through the horizontal amplifier instead of the oscilloscope sweep voltage.)

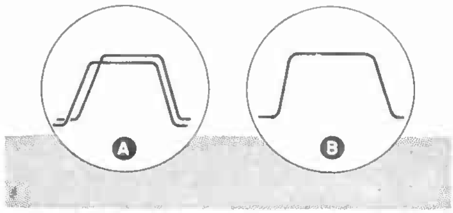


FIG. 12. A double trace (A) should be overlapped to produce a single trace (B) by adjusting the phasing control of your sweep signal generator.

It is possible for a sweep signal generator to produce a single trace pattern, but whenever a.c. is used to produce the sweep, the output will be a double trace. Thus, if the center frequency is 25 mc. and there is a 10-mc. sweep, the signal will be swept from 20 through 25 to 30, then back from 30 through 25 to 20. Thus, it goes over the frequency range twice for each complete sweep—once from the low end up, and once from the high end down—and therefore produces a double trace on an oscilloscope. For easiest observation, these two traces should exactly overlap each other as shown in Fig. 12B instead of appearing as separate traces as in Fig. 12A. This overlapping will be produced if the phase of the output is arranged properly; therefore, a control is incorporated in the sweep generator to permit the phase to be adjusted.

In general, therefore, a sweep signal generator will have a frequency control to adjust the operating frequency, an attenuator to control the output, a phasing control to permit the sweep image to be overlapped properly, and a sweep width control to vary the width of the swept band.

MARKERS

The manner in which a sweep generator produces its output makes its calibration subject to rather large errors. For example, let's suppose that two oscillators operating at 125 mc. and 100 mc. respectively are being used to produce a 25-mc. beat output frequency. Assuming a 1% accuracy for each oscillator, the output of one may be between 126.25 and 123.75 mc., and that of the other may be between 99 and 101 mc. The beat may therefore be anywhere between 22.75 and 27.25 mc., meaning that it may be as much as 9% away from the desired 25-mc. frequency. Further, there is no guarantee that the sweep will be exactly the same width on either side of the resting frequency or that the width of the sweep will be accurately known.

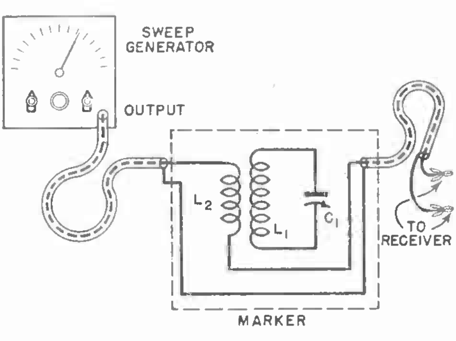


FIG. 13. How to connect a dipper marker.

Since it is important to know exactly what frequencies are produced by a signal generator, it is necessary to use some "marker" with the generator that will produce accurate frequency indications on the sweep trace on the oscilloscope. This marker must be accurately calibrated; an accuracy of .1 mc. is not good enough, even though this represents 1/10 of 1% at 100 mc.

Dipper. Perhaps the simplest form of marker is an absorption wavemeter like that shown connected to the cable of a sweep generator in Fig. 13. Some

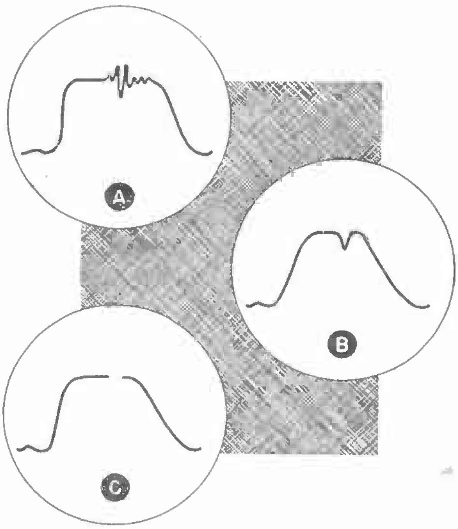


FIG. 14. Frequency indications produced by a sweep generator marker (A), a dipper marker (B), and a blanker marker (C).

sweep generators have a marker of this kind built in.

Essentially, this marker is a tuned circuit made with high precision from quality parts. It has a calibrated dial that indicates accurately the frequency to which it is tuned. When it is connected between a generator and a receiver as shown in Fig. 13, the tuned circuit will absorb energy at its resonant frequency from the coil L_2 and hence will produce a drop in the voltage supplied to the receiver at this particular frequency. This gives a "dip" in the response curve like that shown in Fig. 14B. If you change the resonant frequency of the absorption marker by turning its tuning condenser to some other position, the dip will move along the response curve to a position corresponding to the new resonant frequency. Thus, the marker dip can be used to indicate exactly the frequency to which any particular point on the curve corresponds.

Pipper. It is also possible to use an accurately calibrated signal generator as a marker. If the output of the signal generator is fed into the circuit in parallel with the output from the sweep generator, a "pip" will appear on the response curve seen on the oscilloscope, as shown in Fig. 14A. However, whereas the absorption tank circuit produces a single dip, a marker signal generator will produce a number of "wiggles" along the response curve, since there will be beats between the signals of the signal generator and the sweep signal generator that will cover an infinite band. All that limits the number of beats that are visible are the band-width response of the video output with the oscilloscope connected and the response of the vertical amplifier of the oscilloscope. An oscilloscope with a limited response produces a limited series of beats (Fig. 15A), but one with a wide-range re-

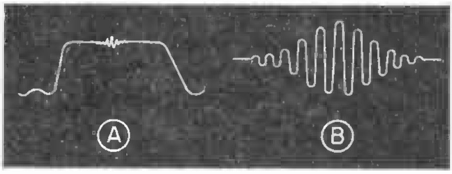


FIG. 15. Marks produced by a signal generator marker on an oscilloscope with a narrow response (A) and on one with a wide response (B).

sponse passes a number of beats (Fig. 15B). As we shall point out later, it is necessary to have only a narrow band of beats reproduced if the pip marker is to be used. If the oscilloscope response is too good, therefore, the response must be narrowed at the point where the oscilloscope is connected to the set. In this case, an inexpensive oscilloscope with a reduced response is as useful as a wide-band, high-quality instrument. (For other TV uses, of course, the more expensive instrument is better.)

Incidentally, the marker can be any good signal generator that covers the frequencies involved, provided that it is accurate in its calibration or that a crystal calibrator is used with it. Since few service generators cover the right frequencies, however, TV markers are usually bought especially for this use.

Blanker. A third way to produce a mark is to mix the marker and sweep signals and to utilize the beat output to produce a high negative voltage that is applied to the grid of the oscilloscope. In this case, the response curve will be blanked out, as shown in Fig. 14C, at the point corresponding to the marker frequency.

At the present time, blanking markers are not commonly available.

Calibrators. A dipper marker must be accurately calibrated. Once this has been done properly, the calibration should remain accurate if the instrument is of reasonable quality. The calibration of a signal generator may become inaccurate after a time, however. If such an instrument is to be used as a marker, therefore, it must be re-calibrated frequently.

A very accurate crystal oscillator is often used for this purpose (in fact, some TV marker generators have such crystal oscillators built in). The fundamental and harmonic frequencies of the crystal can be used as calibration points. If a 5-mc. crystal is used, for example, its output will contain harmonics every 5 mc. This fact makes it possible to locate points at 5, 10, 15, 20, 25 (etc.) mc. accurately. If you adjust the marker generator so that it zero-beats accurately with the oscillator output at these points, you can be reasonably sure that it will be accurately calibrated between these points. The exact method of producing and detecting the zero beats depends upon the equipment you have: the manufacturer of your marker generator will supply calibration instructions with the instrument.

THE OSCILLOSCOPE

The oscilloscope used for alignment can be any of the standard types used for radio receiver servicing. It must have a fairly good response down around 60 cycles and a reasonable sensitivity, but it need not have a good high-frequency response. Of course, if the oscilloscope is to be used for other TV servicing uses, it should have a very good high-frequency response, high gain, and low input capacity.

The oscilloscope is absolutely necessary for making a band-pass alignment or for checking the over-all frequency response. However, when you are peak-aligning stagger-tuned circuits, you can measure the output with a vacuum-tube voltmeter or a 20,000-ohms-per-volt multimeter (preferably the former) instead of an oscilloscope.

ALIGNMENT TOOLS

TV alignment tools are very similar to those used in ordinary receiver alignment. It is important to use nonmetallic alignment tools insofar as possible, and the types with long, thin shanks may be needed to reach some of the adjustments. Any special alignment tool needed for a particular set can be obtained from the manufacturer, his local distributor, or your regular supply house.

When you align over-coupled or band-pass circuits, it is sometimes advisable to use two tools and to adjust the primary and secondary of each transformer more or less simultaneously. Of course, it is possible to adjust first one and then the other, but you will waste a lot of time moving a tool rack back and forth between the adjustments. (Usually, one adjustment is above the chassis and the other below.)

Now that you have a general idea of the tools, equipment, and procedures involved in alignment of a TV set, let's discuss the alignment of each of the sections of a TV set. As we said, most of the time you can remedy alignment defects merely by readjusting one or two circuits; however we shall give the complete procedure so you will know just what needs to be done if the set should need complete alignment. Once again we must caution you to follow the manufacturer's instructions carefully.

In making a complete alignment, it is quite common to align the sound system first, then the video i.f., and finally the front end. Some manufacturers, however, recommend that the video i.f. be aligned before the audio system. Actually, unless the sound signal passes through one or more of the video stages, it makes little difference which section is aligned first. It is wise to follow the order suggested by the set manufacturer, however.

Video I. F. Alignment

Before we discuss the processes involved in aligning the video i.f., there are several preliminary matters we must take up. Let's do so now.

Obviously, you must be able to identify each adjustment you are going to use. Unless you are quite familiar with the set, therefore, you must have the manufacturer's layout so that you can locate these adjustments.

Fixing the Bias. In aligning the video i.f. amplifier, we have to consider the fact that the contrast control (or the a.g.c. system, if the set has one) varies the gain of the video amplifier by varying the bias on some of the stages. The over-all response of a group of stages depends, of course, on their individual gains. If the gains of some of the stages are changed, as they will be if there is change in bias, obviously the over-all response of the i.f. amplifier will be greatly affected. For this reason, the bias on each stage that is to be aligned must be kept constant during the alignment procedure.

Manufacturers usually recommend the use of a moderate bias voltage so that the alignment will be made under the conditions that would exist if a reasonable local signal were being received. In sets without a.g.c., the contrast control is set to produce the desired bias, which is measured with the aid of a vacuum-tube voltmeter. As the alignment progresses, this voltage is remeasured from time to time, and, if necessary, the contrast control is reset to bring the voltage back to the right value.

Most manufacturers of sets in which a.g.c. is used recommend that the system be blocked either by removing a tube in the a.g.c. chain or by connecting a large condenser to the a.g.c. network. This condenser must make the time constant so long that it will be impossible for the a.g.c. to follow the variations in output caused by the alignment.

If a set is constructed so that the a.g.c. system or the contrast control cannot be adjusted to produce a fixed voltage of the desired value, the manufacturer may recommend the use of a bias from a separate source. Fig. 16 shows a typical arrangement. The potentiometer across the 4.5-volt battery can be used to adjust the bias. When

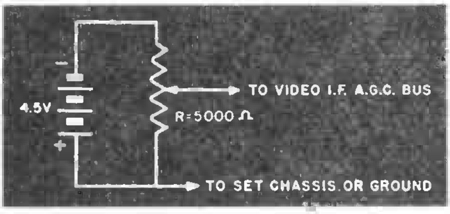


FIG. 16. Alignment bias source.

such a separate bias is used, the a.g.c. network or the contrast control is usually disconnected at some point. The manufacturer's instructions will tell you where.

COUPLING TO VIDEO I.F. STAGES

An important point to remember is that a signal generator can never be connected directly across a tuned circuit that is to be aligned. It must always be decoupled from this circuit. The simplest way of doing this is, of course, to connect the signal generator to a stage that is nearer the antenna than the one that is being aligned. If you connect your signal generator to the grid circuit of the tube ahead of the tuned circuit you are going to align, for example, the tube will act as a decoupler and prevent the generator from detuning the circuit.

Manufacturers recommend two basic approaches to video i.f. alignment: 1, a stage-by-stage process; and 2, an over-all technique. In a stagger-tuned section, the over-all technique is usually followed unless the stages are very far out of adjustment because of excessive drift or of tampering. An over-all technique will work on band-pass circuits also, but here the response curve depends so much on exact amounts of coupling (which may vary from stage to stage) and on precise adjustments, that the stage-by-stage method may be recommended.

Over-all Video I.F. For over-all alignment of the video i.f. amplifier, the signal generator can be connected to the grid circuit of the mixer stage or even to the antenna connections of the set. Although a signal fed from the antenna will be reduced by the r.f. stage, its level at the input to the video i.f. amplifier may be about as high as it would be if it were fed to the grid of the mixer, because the grid circuit of the mixer may contain a trap tuned to the i.f. frequency that would reduce the input to a low level. In such cases, the manufacturer may give special instructions for making connections in the input tuner, because it is necessary to feed the signal through the mixer to align the i.f. transformer in its plate circuit properly.

Getting a simple connection to the circuit is sometimes a problem. In some instances, the manufacturer will instruct you to make up a dummy tube—one with one or more pins cut off—that will provide the necessary connection for the signal generator.

Another and even simpler method of connection is shown in Fig. 17. There will be sufficient capacitive coupling between a shield of this sort and the tube elements to transfer the signal without greatly upsetting the circuit to which the tube is connected. Of course, the shield must fit so snugly that it will not slip down the tube and touch the chassis; if it did, the hot side of the signal generator output would be grounded.

When you are making an over-all alignment, you can connect the output indicator to the plate load of the video detector (or even to the output of the video amplifier if a modulated signal is used.) The kind of output indicator will depend on what you use as a signal source—if it is a standard signal generator, as it will be when you align a stagger-tuned i.f., you should use a vacuum-tube voltmeter or a multimeter as the output indicator. On the other hand, if you use a sweep signal generator in making an over-all check on alignment, the output indicator should be an oscilloscope. We shall describe the connections of these devices in more detail a little later.

Stage-by-Stage Video I.F. Alignment. There are two methods of getting a stage-by-stage alignment. In the more popular one, the output indicator is connected to the detector plate load, and the signal source is moved from the last i.f. stage back toward the converter stage, a stage at a time. However, a few manufacturers recommend that the signal source be connected to the converter or to the antenna connections and that the output indicator be moved from the first video i.f. stage back toward the video detector, a stage at a time. Essentially the same results will be obtained by either method. You must follow the manufacturer's instructions, however, particularly when you align band-pass circuits, because that is the only way you can duplicate the curves that he shows in his service manual.

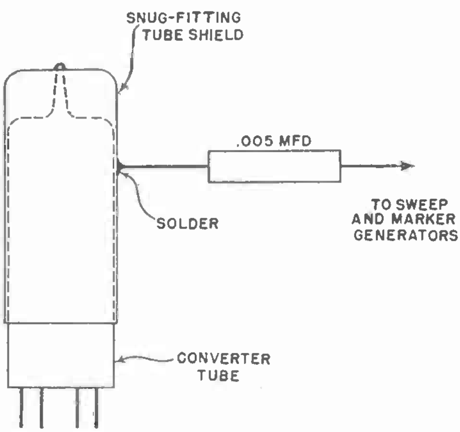


FIG. 17. Simple method of coupling a signal generator to a set.

As far as making connections is concerned, it is somewhat more difficult to align by moving from the output back toward the input, since you must move both the sweep generator connections and the marker signal generator connections each time you align a stage. Going in the other direction, you need to move only the oscilloscope connection, but a special coupling device consisting of a rectifier and an R-C decoupling network must be attached to the end of the oscilloscope cable to make it possible to use it this way. We'll describe a simple coupling device that can be used for this purpose a little later in this text.

CONNECTION HINTS

When you align any section of a TV receiver, you must make sure that good ground connections exist between all of the pieces of equipment that are connected together. Some manufacturers even recommend the use of a metal-topped bench to insure good common grounding; such a bench is dangerous from other standpoints, however, so you should use some other means to make the ground connections. If you find at any time that moving the cables or bringing your hand near them causes the signal strength to vary or the frequency to change, you do not have an adequate ground connection between the set and equipment.

Although all of the cables that are commonly used for making connections have clips for grounding, these may prove insufficient. Pieces of shielding braid with heavy clamps on the ends can be used to connect various pieces of equipment together.

You must take special precautions if

any piece of your test equipment or the set on which you are working is of the a.c.-d.c. type that has a direct connection to the power line. If you have a piece of a.c.-d.c. test equipment, it is advisable to install an isolating transformer between it and the power line. (An isolating transformer has a one-to-one turns ratio: it does not change the voltage, but it does separate the device from the power line.) Such a transformer is needed when you work on sets that use filament strings and voltage-doubling power supplies so that there will be no chance of short circuits developing through your grounding connections.

When you align a set that does not have a series filament string, you can leave the picture tube out if it interferes with easy handling of the set chassis. (Leave the deflecting yokes plugged in, however.) If the filament of the picture tube is in series with others in a filament string arrangement, either leave it in the set or connect a 5-watt, 10-ohm resistor across the filament terminals of its socket to take its place. Of course, you should never attempt to remove the tube while the receiver is on.

If you remove an electromagnetic tube, you must do something to make the high-voltage lead safe. Either fasten this lead in a position where you will not be able to touch its terminal and where the terminal will not be able to touch the chassis, or make the high-voltage supply inoperative. The latter may be accomplished either by removing the high-voltage rectifier tube (or tubes) from its socket or by removing the r.f. oscillator tube or the horizontal output tube, depending on what kind of power supply is used in the set.

It is very important not to use too strong a signal for aligning any section of the TV set, the video i.f. in particular. If the input signal is too strong, some of the stages will be overloaded to such an extent that they will act as limiters and thus produce a false flattening in the trace of the over-all response on the face of the oscilloscope. The alignment cannot be properly made under such conditions. To prevent overloading, limit the input enough to keep the voltage across the video detector load under 2 volts.

If you align the i.f. stages with the signal generator connected to or ahead of the converter, it is always possible for the local oscillator in the receiver to beat with the signal and thus give a number of spurious frequency indications. If this proves annoying, you may have to kill the local oscillator completely by removing the tube, replacing it with a dummy tube to complete the filament circuit if the set has a series filament string. (A dummy tube for this use is a regular tube from which the grid and plate prongs have been removed, leaving only the filament operative.)

Of course, if the oscillator is a section of a dual tube, you may not be able to remove it. In such a case, it may be practical to tune to some channel far removed from the i.f. frequency (one of the upper channels on the high band) so that the oscillator frequency will be as far removed as possible from the signal you are using.

Now let's learn how to align video i.f. stages.

STAGGER ALIGNMENT

When the video i.f. amplifier uses stagger-tuned circuits, the most usual method of alignment is to adjust the tuned circuits, one at a time, with the aid of a standard signal generator and an output meter. The manufacturer's instructions will usually have you start with the traps, which are adjusted to give minimum responses, after which you adjust the regular tuned circuits for maximum outputs at their resonant frequencies.

Using such a system, and of course changing the signal generator to the proper frequency for each alignment adjustment you make, you can be reasonably sure that you will get the desired over-all results. If you have any doubts after you have completed the stagger-tuned alignment, you can always use a sweep generator, a marker, and an oscilloscope to check the over-all response and make any necessary corrections in it. As a matter of fact, you can use the sweep generator and the marker combination to align these circuits in the first place by adjusting each trimmer until the over-all response is that desired for the particular set you are working on. The difficulty with this arrangement is that if the trimmers are far out of adjustment, you may find it very difficult to get the proper over-all response with maximum output. In such a case, you will probably have to align the stages to approximately their right frequencies before making a sweep alignment.

Let us run through the adjustment procedure you should use to align stagger-tuned circuits, first with a standard signal generator and an output meter, and then with a sweep generator and an oscilloscope.

Standard Generator. Aligning the video i.f. amplifier with a standard signal generator and an output meter is a process that is very similar to the one you use to align a radio receiver. If the circuits are not too badly out of alignment, the signal generator may be connected to the grid circuit of the mixer or even to the antenna terminals of the set.

The output meter may be either a vacuum-tube voltmeter or a multimeter of high sensitivity. Connect it across the load of the video detector. You will often find that the receiver is equipped with a convenient terminal on the top or rear of the chassis for making this connection. Refer to the manufacturer's instructions to see if this is true of the set you are working on.

If you are using a standard signal generator, you can use it modulated or not, as you wish. In either case, a d.c. voltage will be developed across the video detector load; measuring this voltage with your output meter will give your output indication. Of course, the proper polarity for your output meter connections depends upon the picture phase for which the video detector is adjusted. If the video detector load resistor is in its cathode circuit (cathode to ground), connect the negative lead of the voltmeter to ground. If the video load is in the plate circuit, connect the positive voltmeter lead to ground.

You can also measure the a.c. voltage produced by the modulation of the signal generator if you wish, but since most signal generators are modulated only about 30% to 50%, the a.c. output voltage will be rather low.

If you are using a marker signal generator, you may find that there are no provisions for modulating it. In this case, you must depend on the d.c. indication.

You must, of course, refer to the manufacturer's instructions to learn exactly what frequencies each of the traps and the tuned circuits must be set to and in what order the stages should be aligned. Follow this order exactly. If you do not, you may get two of the circuits aligned to the same frequency, in which case feedback may be set up, and some stage may go into oscillation. If you make the alignment in the proper order, the normal staggering of the tuning arrangement will prevent the resonant frequencies of the circuits from crossing each other in this manner.

A stagger-tuned video i.f. amplifier always has several traps, each of which must be adjusted to the frequency specified for it in the manufacturer's instructions. To align a trap, set the signal generator to the proper frequency and then adjust the trap to produce a minimum output indication.

Usually, though not always, the manufacturer's instructions will tell you to adjust the various traps first.

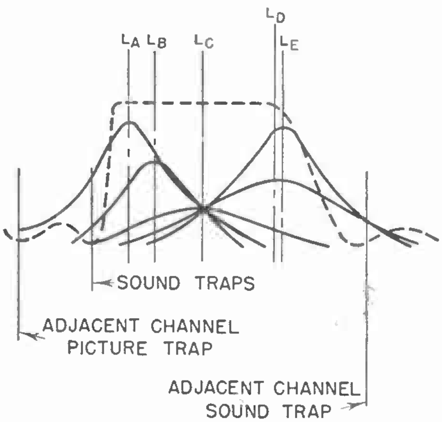


FIG. 18. Individual and over-all responses of a stagger-tuned i.f. section.

When you have adjusted them, proceed to align the various stages in the specified order. To align a stage, set the signal generator to the proper frequency and turn whatever adjustment the stage has until you get maximum output.

When each trap and stage has been properly adjusted, the over-all response should have the form shown by the broken line in Fig. 18. This response curve is the resultant of the responses of the individual stages (shown by the solid lines), and the notches cut by the various traps.

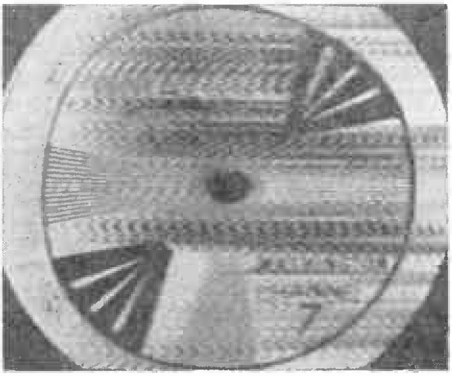
The proper response curve may not be produced by this method of alignment, however, if there has been a change in the bias applied to one or more stages or if the characteristic of some tube has changed because of aging. Either of these causes will affect the gain of a stage; and, unless the gains of all the stages are affected equally, the over-all response of the i.f. section will therefore be changed from what it was at the time the set was made. An incorrect response curve may also be produced, as we pointed out earlier, if too strong a signal is used. You can avoid this possibility by following the manufacturer's instructions carefully.

Oscillation. A severe misalignment may produce oscillation. If you suspect the alignment, and have another set like it, move all the adjusting screws of the set on which you are working to approximately the positions of those in the set that is working normally; the circuits should then be somewhere near the right adjustment —perhaps near enough so that you can go on to make a proper alignment. If not, you may have to align the circuits, one at a time, by aligning the last i.f. stage first and working back toward the input. In such a case, it is necessary to block the oscillation. If the receiver has four i.f. tubes, for example, remove the third i.f. tube to block all signals coming from stages nearer the antenna. Then connect your signal generator to the grid circuit of the fourth i.f. stage and align this stage for maximum output. Next, put the third tube back in place, remove the second tube, and connect the signal generator to the grid of the third tube. Progressing in this manner, you should be able to reach an adjustment that will stop the oscillation, after which you can make the final adjustment in the proper order.

Incidentally, when a set is severely

out of alignment, a procedure of this type may be necessary whether or not oscillation occurs. When you are feeding a signal into the grid of one tube, the tuned circuits that are between the plate of the preceding tube and the point where your signal is applied may act as an absorption trap and reduce the output from your signal generator to a low level. By removing the preceding tube, you remove that tube's capacity and so detune the circuit that such absorption is unlikely. Of course, any procedure that involves the removal of a tube cannot be used in a set that has a series filament string unless you can put a dummy in place of the one you wish to remove.

Sweep Alignment. If you want to see the over-all response after having aligned the circuit in the manner just described, or if you want to align with the sweep generator, you can connect a sweep generator and a marker in place of the standard generator and connect an oscilloscope as the output indicator.



NRI TV Lab Photo

One type of i.f. oscillation.

If the oscilloscope has an excellent high-frequency response, the beat between the marker and the signal generator will spread over such a wide band that it will not be practical to use it. In such a case, the high-frequency response must be reduced. One way of doing this is to connect a resistance of 10,000 to 25,000 ohms in series with the hot lead going to the oscilloscope. This will cause the cable capacity (between the point of connection and the oscilloscope) to act with the resistance as an R-C low-pass filter, thereby reducing the input to the oscilloscope at high frequencies. Another way to reduce the response is to shunt the detector load with a small condenser. The size of such a condenser would have to be determined by experiment if there is no recommendation in the oscilloscope instructions.

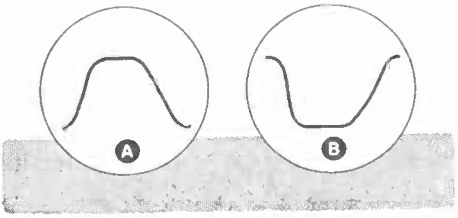


FIG. 19. A "normal" (A) and an inverted (B) trace of the same signal.

You may sometimes find that the oscilloscope picture is upside down, as shown in Fig. 19B, instead of having the normal position shown in Fig. 19A. Some oscilloscopes have a switch that permits you to turn over the trace by reversing the oscilloscope connections.

An upside-down picture is just as useful for alignment as a normal one is, so if your oscilloscope has no phasing switch, you can use the trace, or if you prefer, you can get the picture to turn over by inverting the picture phase, which you can do by connecting your oscilloscope to the output of the first video stage following the detector. If you do so, remember that you must not short-circuit the B supply. If your oscilloscope does not have a blocking condenser in its input lead, you must connect one in series with this lead to prevent such a short circuit.

The proper method of connecting the sweep and the marker depends on the equipment you have. If the marker is an absorption wavemeter or dipper, it will just be connected in the output lead from the sweep signal generator to produce a dip in the response. If the marker is a signal generator, however, it may be connected in parallel with the sweep generator, it may be connected at another point in the circuit, or it may be connected directly to the oscilloscope, depending on its type.

You may get into some trouble because the marker output may be far higher than is necessary. If its attenuator cannot reduce the output sufficiently, you may have to include a resistance in series with the hot lead from the marker generator. A 100,000-ohm resistor is generally used.

Some of the newest marker signal generators are quite different from the kind we have already described. These contain a built-in mixer-detector stage in which the marker signal is mixed with a small amount of energy taken from the output of the sweep generator. The resulting beat output is then fed directly to the oscilloscope, where it is connected in parallel with the sweep output that is coming from the set. In other words, only the sweep generator signal goes through the receiver, but the output of the marker unit has the necessary beat at the right point (since it is in synchronism with the sweep) to indicate the frequencies on the curve shown by the oscilloscope. Instruments of this kind have crystal calibrators built in them for checking the marker generator alignment from time to time.

Some servicemen couple a marker generator to a receiver capacitively simply by placing the marker lead near the mixer circuit. In general, you should follow the instructions accompanying your marker and generator combination in connecting them to a receiver.

As a simple check on whether the marker is properly connected, set up the sweep signal generator and oscilloscope and get a response. Next, connect the marker and turn it on. The response curve should then have the characteristic wiggles of a pip on it, but should otherwise be unchanged. If it does change, either the marker output must be reduced or the marker must be connected at a different point so that it does not upset the sweep output.

The sweep generator-marker-oscilloscope method of alignment has two advantages: it lets you see whether the over-all response curve has the right shape, and lets you determine whether the curve covers the right frequency range. It is always possible for the response to have exactly the right shape but to be shifted above or below the correct frequency range. You can tell whether this has hap-

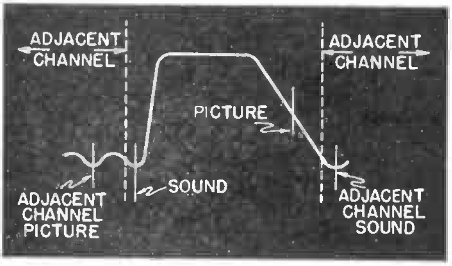


FIG. 20. Position of carriers on a response curve.

pened by using your marker to locate various frequencies—such as the carrier frequencies—whose relationship to the curve is known. Fig. 20 shows where the various carriers are supposed to occur in many sets. If you find, with the aid of your marker, that the picture carrier is not half-way down the slope of the response, you know at once that the response curve does not have the frequency range it should have. The manufacturer's instructions will show you where the various carriers should be with respect

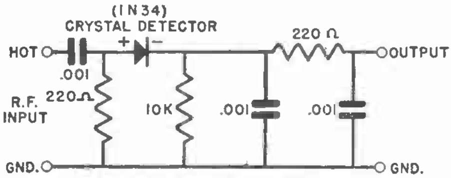


FIG. 21. Schematic of a crystal detector probe.

to the response curve for the set you are interested in.

BAND-PASS ALIGNMENT

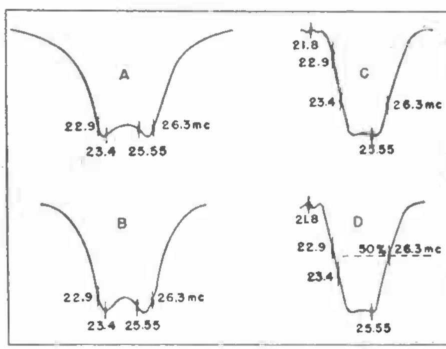
Two basic kinds of band-pass circuits are used in video i.f. stages. In one, each circuit covers practically the full band width, in the other, the circuits are band passed but are also somewhat stagger tuned in their arrangement.

It is sometimes possible to align either kind of band-pass circuit fairly well with a standard signal generator (we will show you how later on). It is far better, however, to use a sweep generator and an oscilloscope for the purpose.

Band-pass circuits, because they are overcoupled, are critical in their adjustment. It is very easy to get them out of adjustment so that the response curve is lopsided or consists of two widely separated peaks having a valley between them. The best way to avoid such difficulties is to adjust the primary and secondary simultaneously on each transformer as you move along.

As we have pointed out, there are two basic ways in which you can make the alignment. One is to connect the oscilloscope to the detector load and then move the sweep generator and marker back a stage at a time toward the input. The other is to connect the marker and sweep generator to the converter stage and move the oscilloscope from the input toward the output, a stage at a time. In the latter case, the oscilloscope must be connected to the set through a rectifier and decoupling network like that shown in Fig. 21. You can buy such a coupling unit made up in an enlarged probe, or you can make one if you are careful to arrange it to take a minimum of space.

No matter which way you move through the video i.f. amplifier in a stage-by-stage alignment, you must have the manufacturer's instructions so that you will know what response curves you should see for the various groupings of the stages that you have.



Courtesy General Electric Co.

FIG. 22. Partial and over-all responses of a band-pass i.f. section.

That is, you will need to know what the response curve for one stage alone looks like, then what shape the curve for two should have, and so on.

A typical example of such curves is shown in Fig. 22. Part A of this figure shows the curve for one stage (the output stage); B, that for two stages; C, for three; and D, the over-all response. Notice that the other curves do not closely resemble the one showing the over-all response.

It may be possible to make an over-all alignment adjustment of a band-pass i.f. when the trimmers are not very far out and when the coupling need not be disturbed. If the coupling has to be adjusted, however, the proper pass-band shape can usually be obtained only by making a stage-by-stage adjustment.

Notice that the various marker positions are very carefully indicated in Fig. 22. It is quite important to make sure that the various points on the response curve occur at the right frequencies.

If you do not have a sweep signal generator, you may be able to use the method shown in Fig. 23 to align a stage in which an over-coupled transformer is used. A load resistor of the size recommended by the manufacturer (usually 1000 ohms or less) is connected across one of the circuits; then the other is aligned. Next, the resistor is moved to the other circuit, and the circuit across which it was first placed is aligned. As shown in Fig. 23A, for example, a resistor is used to load the primary, and the secondary is tuned to resonance. Then, as shown in Fig. 23B, the resistor is moved to the secondary, and the primary is tuned to resonance. When the resistor is removed from both windings, the over-coupling that will be present without the resistor should give the band-pass response shown in Fig. 23C.

INTERCARRIER RECEIVERS

Receivers that use the intercarrier method of obtaining the sound may either be stagger tuned or have band-pass circuits. The alignment procedures for these sets are quite similar to those that we have just described. One difference is that you seldom align the sound i.f. amplifier of a conventional set unless it actually needs it, whereas it is customary to align the sound i.f. amplifier of an intercarrier set as a matter of course before aligning the video i.f. amplifier. About the only difference between the two kinds of sets in the alignment of the video i.f. amplifier is that you want to get an over-all response curve in an intercarrier set that is somewhat different from the one you want in a conventional set, since the video i.f. amplifier of the former must pass at least a small portion of the sound carrier.

In general, the over-all video response curve of an intercarrier set is more symmetrical on the two sides than that of a conventional set is. If there are any traps for the accompanying sound signal, they will not

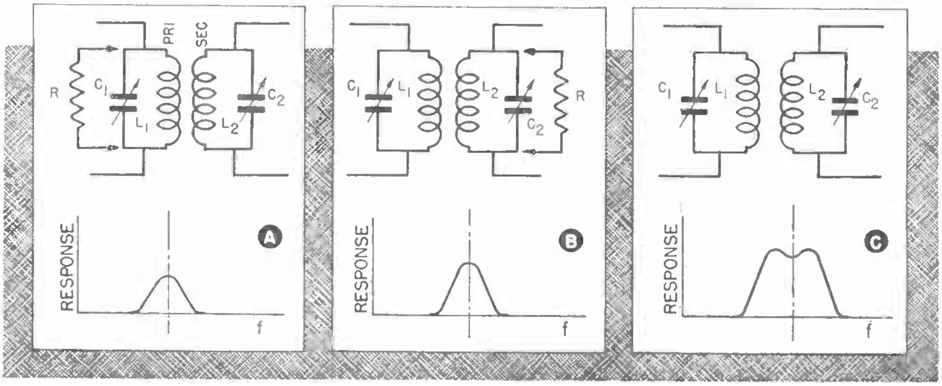


FIG. 23. Method of aligning a band-pass i.f. section with a non-sweeping generator.

have the high Q of those used in conventional sets or will be detuned sufficiently to permit a certain amount of the sound carrier to go through.

Once again, you should follow the manufacturer's instructions concerning the exact order of the trimmer adjustments and the response curves that should be obtained.

Grain Traps. A grain trap is commonly used in an intercarrier set at the point of sound take-off (and sometimes also in any following video stage) to remove the 4.5-mc. beat from the picture signal before it is applied to the picture tube. Such traps are also used in some conventional sets.

The adjustment of a grain trap is quite simple. Just apply a 4.5-mc. signal to the first video amplifier, then adjust the trap until a minimum amount of grain is visible on the picture tube of the set. If you prefer, you can connect an oscilloscope having a rectifying probe to the output of the video amplifier and adjust the trap for minimum signal on the oscilloscope. This adjustment must be made with the contrast control in its maximum position if the contrast control is located in the video amplifier. If the contrast control is located in the video i.f. amplifier, its setting is immaterial, unless you are watching a picture on the picture tube to determine when the grain is minimized instead of using a signal generator.

Although this trap is in the video amplifier, not in the video i.f. amplifier, we have included its adjustment here because it is usually adjusted after the video i.f. amplifier has been aligned.

Sound I. F. Alignment

The sound i.f. section of a TV receiver is aligned in just the same way that the i.f. section of an f.m. radio is. We shall sketch the method briefly here; full details were given earlier in your Course.

The sound i.f. amplifier itself consists of from 1 to perhaps 3 stages that are tuned to the sound i.f. frequency. In an intercarrier receiver, this frequency is 4.5 megacycles. In a conventional set, this frequency is 4.5 megacycles below whatever the video i.f. carrier frequency may be.

Although these amplifier stages may be coupled by semi-band-pass circuits, the pass band is usually narrow enough for them to be peak aligned. Therefore, you can use either a signal generator and a vacuum-tube voltmeter (peak alignment) or a sweep signal generator, a marker, and an oscilloscope (sweep alignment).

You must connect your signal generator to some point ahead of the place where the sound signal is taken off. In a conventional set, a logical place is at the grid of the mixer-converter. In an intercarrier set, you can feed the signal in anywhere in the video amplifier ahead of the sound take-off.

The point to which you should connect your output indicator depends upon whether the set uses a limiter-discriminator or a ratio detector.

If the set uses a limiter, it is considered best to adjust the sound i.f. circuits for a maximum indication across the grid resistor of the limiter, so that is the logical place to connect your vacuum-tube voltmeter or oscilloscope. If you use an oscilloscope, connect a decoupling resistor of about 50,000 ohms in series with the hot lead to prevent the input of the oscilloscope from affecting the time constant of the limiter circuit too much.

After the circuits up to the input of the limiter have been adjusted for maximum response, you must move your output indicator to the output of the discriminator. At that time, you can make the proper adjustment of the transformer that connects the limiter to the discriminator. We shall say more about this adjustment in a moment.

A set that uses a ratio detector has no limiter stage (or has only partial limiting). In such a set, the proper place to put the output indicator is across the ratio circuit, as we shall show. Once again, the purpose of the adjustment is to produce maximum output.

F.M. DETECTOR ALIGNMENT

Although it is possible to adjust a discriminator or a ratio detector with a signal generator and an output meter, it is better to use a sweep signal generator and an oscilloscope. We'll describe both methods.

Peak Adjustment. The transformer that feeds the f.m. detector must be very carefully adjusted if best results are to be obtained. You must first set the signal generator to produce the sound i.f. center frequency, then tune the primary to obtain maximum output, and then tune the secondary to get a minimum output. Be careful in adjusting the secondary—a slight misadjustment beyond the correct point will cause a reversal of the polarity of the output voltage. Since many vacuum-tube voltmeters will not indicate a reversed voltage, you have to be careful in approaching zero output to be sure you do not go too far. If you suspect that you have, reverse the test leads and see if you get a reading. If you do, readjust the secondary slightly. You will have gotten the right adjustment when the reading remains as near zero as possible when you reverse the leads.

The output meter connections for this adjustment depend on the type of detector circuit. If the set uses the standard discriminator circuit shown in Fig. 24, connect the v.t.v.m. between point Y and ground, and adjust the primary trimmer C_1 until you get a maximum reading. Then connect the v.t.v.m. between point X and ground, and adjust the secondary trimmer C_2

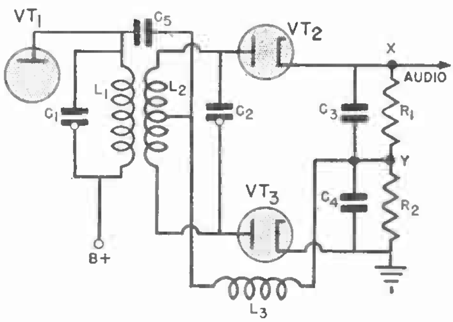


FIG. 24. Output meter connection points in a standard discriminator circuit.

until you get a minimum output. You may have to go back and forth, repeating each adjustment one or more times, because of interlocking between these circuits.

When the ratio detector is used, the connections will depend on the design of the circuit. In the balanced detector shown in Fig. 25, there is a center-tapped resistor network across the charge-storing condenser C_3. Connect the v.t.v.m. between point Y and ground to align the primary for maximum output, and connect it between point X and ground to align the secondary for minimum output. You should also connect it between point Y and ground for use as an output meter when you align the preceding i.f. amplifier circuits. These circuits should be adjusted to produce maximum output when the v.t.v.m. is connected in this manner.

The ratio detector shown in Fig. 26 is unbalanced. When you align this

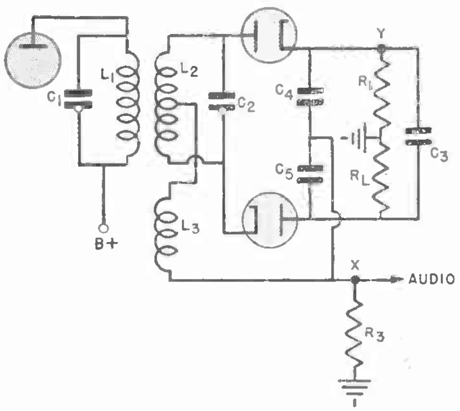


FIG. 25. Output meter connection points in a balanced ratio detector circuit.

kind of detector, you should connect the v.t.v.m. between X and ground to align the primary circuit L_1-C_1 and the preceding i.f. amplifier circuits to produce maximum output, just as you do when you align a balanced detector.

To adjust the secondary circuit L_2-C_2, however, you must establish an artificial balance point, because the load resistor R_1 has no center tap. To do so, connect two resistors of about 100,000 ohms (R_2 and R_3) across R_1 as shown. These resistors should have the same resistance within 5%. Then connect the v.t.v.m. between the junction point W and point Y, and adjust the secondary to get a minimum reading.

Notice that two core adjusters are indicated for L_2 in Fig. 26. These are provided so that the secondary can be adjusted to feed the proper signal to each diode. Adjust them simultaneously for minimum output between W and Y.

This peak adjustment procedure does not necessarily give a symmetrical response curve. For this reason, sweep alignment (which does give a symmetrical curve) is preferred.

Sweep Alignment. When you use a sweep signal generator, you must connect the oscilloscope to the point in the output circuit of the discriminator to which the audio frequency take-off lead is connected. You will then get an "S" curve somewhat like that in Fig. 27A if the oscilloscope is swept from the sweep generator. If the sweep generator furnishes a sync voltage instead of a sweep voltage to the oscilloscope, you can get the double response curve shown in Fig. 27D by reducing the horizontal sweep frequency to one-half that of the sweep generator. This pattern is sometimes useful in obtaining perfect balance in the discriminator response, because it is easier to determine whether the two sections of the double "S" curve are

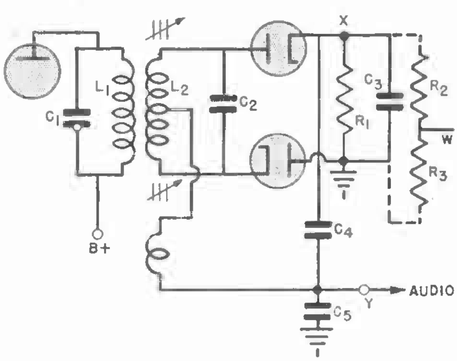


FIG. 26. Output meter connection points in an unbalanced ratio detector circuit.

alike than it is to compare halves of a single curve.

You should use a marker signal generator to determine the exact midpoint of the S curve (point 1 in Fig. 27A). This marker should be modulated by an audio tone. If the marker is not modulated, the pip it produces will be visible if it occurs near one of the peaks of the discriminator curve (at point 2 in Fig. 27B, for example), but it will not be easily visible if it occurs at the midpoint of the S curve. If the marker signal generator is modulated by an audio tone, however, a series of beats will show up on either

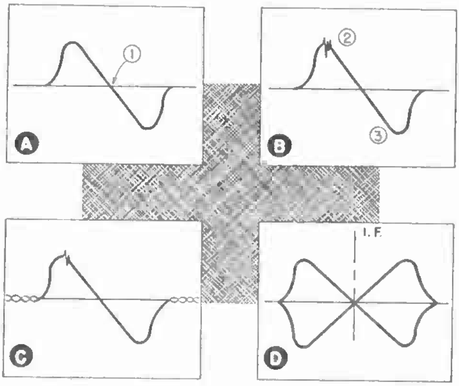


FIG. 27. The text describes the use of these curves in aligning a discriminator.

side of the S curve, as shown in Fig. 27C, *except when the marker is tuned exactly to the midpoint of the curve.* In other words, as long as the beat pattern appears outside the S curve, the marker frequency is not the same as the center frequency of the S curve. The beats will disappear when the two frequencies are the same. Incidentally, this is practically the only case in TV alignment in which it is desirable to modulate a marker.

As you adjust the secondary of the discriminator transformer, you will move the S curve from side to side. When the transformer is properly adjusted, the positive and negative peaks should be equally distant from the reference line, the S curve should be straight between the two peaks, and the frequency separation of the two peaks should be what the manufacturer recommends. This separation (which represents the pass band of the discriminator) may be anywhere from 200 to 500 kc., depending on the set. Use your marker to determine exactly where these peaks occur.

You should align the sound system as accurately as the video section. If you happen to align the sound system to the wrong center frequency, the points of best picture and best sound may not be at the same setting of the fine tuning control. If it is necessary to make any great change in the alignment of the sound circuits, and the set uses automatic frequency control (a.f.c.), it may be necessary to readjust the oscillator as well to make it possible for the a.f.c. system to maintain control.

Front End Alignment

Because it drifts so much, the oscillator circuit needs re-alignment more frequently than does any other TV circuit. The fine tuning control or the a.f.c. system used in most sets has a wide enough range to compensate for a rather large drift. Sooner or later the drift will exceed the adjustment range of these compensators, however, and then the oscillator alignment must be touched up.

It may also be necessary to realign the oscillator if the oscillator tube burns out, because the interelectrode capacities of this tube affect the tuning, and a replacement tube is very unlikely to have exactly the same capacities. Before you make the realignment, however, you should try a number of different tubes to see if you can find one that is exactly right. If you are not lucky enough to find such a tube, use the one that comes nearest to being right so that a minimum of readjusting will be necessary.

Once again, you should be guided by the instructions furnished by the manufacturer of the set. In some sets, the oscillator circuits are entirely independent of each other, which makes it possible for you to re-align only the channel or channels that are improperly adjusted. More commonly, however, the oscillator coils for the various channels are in series, which means that adjusting one channel will affect the adjustments of all of the channels having lower frequencies. If you re-align channel 9, for example, you will find that the adjustments for stations on channels 7, 5, and 4 will be off. When you re-align the front end of a set in which the oscillator coils are in series, therefore, you must align all channels, starting at the highest-frequency channel and working downward.

A skilled serviceman may be able to find a reasonably good adjustment by using the stations themselves as signal sources. In general, however, it is best to use a standard signal source of considerable accuracy for this purpose.

Getting accuracy at such high frequencies is not easy. For this reason, the most practical signal generator for TV front-end alignment consists of a crystal-controlled oscillator having separate crystals for each channel. It is possible to connect such an instrument to the input of the set and to adjust the oscillator, channel by channel, for maximum output. Then, if necessary, you can make a final touch-up adjustment by using the available stations as signal sources on the stations themselves.

When you adjust the oscillator, you must set the fine tuning control somewhere near the middle of its range. If the set uses a.f.c., you must disable the a.f.c. circuit temporarily in the manner recommended by the set manufacturer.

R.F. ALIGNMENT

The r.f. circuits of the average input tuner are rarely adjustable. In general, the original adjustment that was made at the factory was made by spacing the coil turns and by making other physical adjustments to give the proper band-pass response. Factory equipment must ordinarily be used to re-adjust such circuits. If the r.f. end is badly out of alignment for any reason (a very rare occurrence), you should remove it and return it to the factory for re-adjustment.

There are usually one or two adjustments, however, that can be made in the r.f. section. These usually consist of adjustments for channels 6 and 13, the highest channels in the two bands. If there are local stations on these channels, it is usually possible to set each of these adjustments correctly by turning it to produce maximum output with the set tuned to the appropriate station. Use a v.t.v.m. across the load of the video detector to measure the output. If there are no local stations on these channels, you can use a signal generator to furnish the necessary input signal.

A disadvantage of this maximum-output method of aligning the front end is that it may upset the band-pass characteristics of the receiver. It is therefore a good idea to check the response with a sweep signal generator after making a maximum-output adjustment. You can check the response on all channels this way. If you want to see what the r.f. band-pass characteristic looks like, connect your oscilloscope with a crystal detector probe to the output of the mixer circuit. If you want to check the over-all response instead, connect your oscilloscope to the video detector output; the resulting characteristic curve will include the response of the r.f. circuit and of the video i.f. amplifier as well. Of course, make sure that the video i.f. amplifier is properly aligned before making this latter check.

Should you ever check the response of a TV receiver in this manner, you may be surprised to see how much difference there is in the responses that are obtained on the different channels. Don't worry about such differences as long as the responses are within the tolerances specified by the manufacturer. As a general rule, you will find that the tuned circuits for the upper-frequency channels are far wider and give lower outputs than do those for the lower channels, because most manufacturers find it impossible to prevent the Q of a tuned circuit from decreasing as the frequency to which it is tuned increases.

R.F. TRAPS

There may be several adjustable traps associated with a front end. For example, there is often an i.f. trap associated with the grid circuit of the mixer. To adjust such a trap, connect a signal generator or marker to the antenna terminals, tune the generator to the video i.f., and adjust the trap to produce a minimum output across the load of the video detector.

There may be other traps that are intended to eliminate interfering signals, such as those from f.m. stations. If you wish to use such a trap to eliminate an interference having a known frequency, you can use a signal generator to supply a signal of that frequency while you adjust the trap for a minimum output. If you do not know the frequency of the interference you want to eliminate, wait until the interference is present, then tune the trap through its range to see if it has any effect on the picture as far as the interference is concerned.

We have advised you many times in this Lesson to follow the manufacturer's instructions. This applies both to the instructions for the receiver you are working on and to those that accompany your servicing equipment. You will find a number of important hints for speeding up your alignment work and for carrying it out in the proper order given in these manuals. If you follow the set manufacturer's instructions faithfully and use your test equipment as it is supposed to be used, you should have little difficulty in getting the desired alignment.

Most of this text has been devoted to the video i.f. stages because we wanted to give the methods of sweep and stagger-tuning alignment in detail. Much of this information also applies to the alignment of the sound i.f. stages and of the front end.

Lesson Questions

Be sure to number your Answer Sheet 65RH-4.

Place your Student Number on every Answer Sheet.

Send in your set of answers for this Lesson immediately after you finish them, **as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. If, after focusing a receiver properly, you find that the lines in the vertical wedges of a standard test pattern blend together short of their ends, in what respect is the receiver deficient?

2. If, after focusing a receiver properly, you find that the lines in the horizontal wedges of a standard test pattern are gray while those in the vertical wedges are black, in what respect is the receiver deficient?

3. What is the purpose of the "phasing" control that is found on sweep generators that are swept sinusoidally?

4. Why is it necessary to reduce the frequency response of a wide-range oscilloscope to use it with a marker generator for alignment?

5. What will happen if the bias on the stages being aligned is not kept constant during alignment?

6. Why is it desirable to connect your signal generator to the grid circuit of the tube ahead of the tuned circuit you are going to align?

7. If you find that moving the cables that connect your test instruments to the set that you are aligning causes the signal strength to change, what is the matter?

8. What may happen if too strong a signal is used in aligning the video i.f. section?

9. In what way does the video i.f. response for an intercarrier set differ from that of a standard set?

10. Where are grain traps used in an intercarrier TV set?

Be sure to fill out a Lesson Label and send it along with your answers.

COMMENCEMENT—AND YOUR FUTURE

This is your last regular Lesson in the NRI Course. With it, you have received a thorough basic training in Radio and Television Servicing. But more than this, you have learned to think for yourself; you have acquired the ability to locate and use printed information which has been prepared by others; you have learned to answer questions precisely, briefly, and clearly—you have learned to do exactly the type of work which leaders of men must do to gain their successes.

With all these added qualifications, new developments in your chosen field should be no obstacle; you are equipped to keep in step with future developments.

It has been a real thrill for me to watch your progress through this Course, to see you tackle and hurdle even the toughest Lessons in the Course. My admiration — my heartiest congratulations — my wishes for happiness and speedy success go to *you*—a man *who will not quit* when new problems arise!

J. E. Smith

PRACTICAL ELECTRONIC CONTROL EQUIPMENT

REFERENCE TEXT 64RX

NATIONAL RADIO INSTITUTE
WASHINGTON, D. C.
ESTABLISHED 1914

PROPHECIES

Training in a new and specialized field like Electronic Control is peculiar in that it prepares you to be a better man in your chosen profession rather than for a new job in a new field. Later, when Electronic Control assumes its rightful position of importance alongside the other professions, you will be ready. Study and experience will gradually make you an expert, and a steadily increasing reputation for ability can very easily build up your business to the point where you will be able to devote full time to Electronic Control jobs, should you so desire.

This reference book and the preceding books dealing with electronic subjects together give you a thorough knowledge of the basic ideas—the fundamental principles of practical electronic control equipment. In the near future you will recognize these books as among the most important you have ever studied—that you will refer to them continually, regardless of what your field of endeavor may be.

In the years to come, the electronic control systems which today appear as miracles to the uninitiated public will form the very backbone of our civilization—of an electronic civilization in which man's ingenuity will bring about greater happiness, better health, more comfort and more leisure to mankind.

A LESSON TEXT OF THE N. R. I. COURSE
WHICH TRAINS YOU TO BECOME A
RADIOTRICIAN & TELETRICIAN
(REGISTERED U. S. PATENT OFFICE) (REGISTERED U. S. PATENT OFFICE)

FM4M252 1952 Edition Printed in U.S.A.

Practical Electronic Control Equipment

OPPORTUNITIES IN A NEW FIELD

JUST as electrical power has largely replaced human muscles, so is the "electric eye" gradually replacing the human eye in industry, the "electric feeler" replacing the human sense of touch, the "electric taster" replacing the human sense of taste, and the "electric nose" replacing the human nose. Since electronic tubes play an important part in making these electrical senses carry out desired control operations, we call the entire field *electronic control.*

Electronic control is a new and fast-growing field, and pioneering will be in order for many years yet. Because of your thorough training in radio, you are now in a position to take a leading part in the development of this field and in the application of the already-available electronic devices to industrial needs. There will be only a few precedents to guide you in individual electronic applications (most of these being given in this book), but with an understanding of the standard circuits and setups, you can become an electronic control specialist—*if you want to.*

Opportunities for the application of practical electronic control equipment exist in almost every industry. If you are now working for an organization which has a need for improved machine controls, you can make your knowledge of electronic control serve as a key to promotions and salary boosts.

Like the field of public address systems, electronic control can be at first simply a side-line for an active, progressive Radio-Trician; eventually it may become even more important than your servicing business. In order to gain the attention of those who need electronic control equipment, make your store or shop "the showroom of modern industrial magic"; install electronic devices which will arouse the interest of your regular customers, who in turn will tell their friends, giving you free advertising. Study the needs of store owners and others in your neighborhood, sell them electronic controls and gradually your ability will attract the attention of factory owners and industrial agents in your town. Remember, though, that while merchants may want only trick devices to attract customers, industry accepts new devices only when they can profitably perform a definite, desired task accurately and dependably.

As the electronic control industry expands, manufacturers of electronic equipment and the agencies which specialize in selling, installing and maintaining the equipment will need more men; those trained in both radio and electronics, as you are, will get first chance at these jobs and will command the highest salaries.

ADVANTAGES OF ELECTRONIC CONTROLS

A few of the more common advantages and reasons for installing electronic control equipment are listed below, to give you some idea of the great variety of projects covered by this new field.

1. Reduction in the cost of producing a product.
2. Reduction in equipment maintenance costs.
3. Insuring more uniform quality of manufactured products.
4. Safeguarding and protecting life and property.
5. Speeding up industrial operations.
6. Counting objects accurately.
7. Inspecting and adjusting manufactured products with greater accuracy and speed than is possible even with the best workers.
8. Acting as a constant attendant in supervising actions which occur at irregular intervals or when least expected.
9. Attracting and holding the attention of prospective customers.
10. Controlling things which cannot be detected by the human senses.
11. Controlling objects too fragile for mechanical controls.
12. Improving the efficiency of human workers.

ANALYZING THE JOB

No matter what application of electronic control equipment you may be considering, first study and analyze the job. Be absolutely fair; will a simple mechanical or electrical control work as efficiently and be less expensive? If it will, suggest it even though this may mean less profit to you. If a simple push-button set into a door frame will set off an alarm when the door is opened, it is unwise to recommend a light beam and photocell control device for this purpose. If an overflow of liquid can be detected by a floating ball on a hinged arm, it is folly to recommend a photoelectric control here. The customer will eventually discover the least expensive way, and if you have erred, intentionally or not, you will lose prestige. Be fair and you will go far in this field.

If the request for a control originates with some one else, be sure to get a clear statement of what is to be accomplished; if the control is to be a part of an existing machine or process, study the machine or process. You must not upset the existing conditions. If the job originates with you, then you should already have all necessary data. Place your ideas and plans on paper, work out the design, study the results, and when you are convinced that your project will prove valuable, prepare a written report, giving: *1, the purpose of the control; 2, the advantages; 3, the design; 4, the estimated cost; 5, savings to be gained by its use; 6, estimated time required to make the installation*. This report constitutes your bid for the job; always secure the written approval of the customer on the entire job and on your price, and secure an advance payment when you think it necessary. When the job is finished and in operation, call back periodically to inspect its operation. Purchase commercially available equipment made by reliable concerns, making full use of their engineering consultation service; construct only those parts which are not standard or readily obtained.

BASIC PARTS OF A CONTROL SYSTEM

In every electronic control system you will find some or all of the following important parts:

1. *The detector,* which converts the physical change being controlled into a desired electrical change, either directly or by means of mechanically actuated contacts. With photoelectric controls the electric eye is the detector; with temperature controls, a thermostat, mercury column thermometer, or some other device which responds to changes in temperature serves as detector; with humidity controls a special indicator using one or more pieces of blonde human hair may be the detector.

2. *The introductory system,* which brings before the detector the object or agent to be analyzed. For example, the introductory system may be a conveyer belt which makes the packages being counted pass in front of the electric eye; it may be the railing on each side of the approach to a door, which compels a person to walk through the light beam; it may be a special pipe or wire which makes the liquids, gases or the electric current being supervised pass in front of or through the detecting device. We must include in the introductory system all of the devices which insure proper operation of the detector; for example, with the electric eye the entire optical arrangement is a part of the introductory system.

3. *Amplifying and power relay devices* are often essential components of an electronic control system. In one sense the amplifier is the "automatic brain" of the system, building up the weak current changes produced by the detector to give sufficient energy for a positive control, and at the same time selecting and handling in an orderly, prescribed manner the controlling impulses. Vacuum and gas amplifier tubes, relays of all kinds, circuits with unique characteristics, and electromechanical "gear switching" systems play vital parts in the final control operation.

4. *The device being controlled* is naturally the most important part of an electronic control system, for it must perform the desired action. The operation of this device is of far more importance to its owner than the means of controlling the device. If the device is to open and close a door automatically, we must consider the electric motor, the worm and drive gears, the reversing switch, the limit-of-travel switches and the door itself.

PHOTOELECTRIC CONTROL SYSTEMS

Photoelectric control holds an important position in the field of electronic control; commercial apparatus for all standard photoelectric jobs has been on the market for many years, and is available at reasonable prices in a wide range of models. Existing equipment is easily modified by electronic engineers to meet special requirements of individual applications, when necessary. For these reasons we will pay special attention to the photoelectric branch of electronic control.

In analyzing the average light-sensitive control circuit, you will find the following basic units: *1, the light-sensitive cell; 2, the light source with its associated optical system; 3, the amplifier and sensitive relay (or super-sensitive relay with sensitive relay); 4, the power relay; 5, the device being controlled.* Before going into specific photoelectric applications, a general discussion of these essential units will be helpful.

The Light-Sensitive Cell, This is the detector in a photoelectric system, changing its electrical characteristics in response to changes in the quantity and quality (color) of light. The three basic types of cells are the *photoemissive, photoconductive,* and *photovoltaic cells.* When the light beam is to be invisible to the human eye, infra-red light is generally utilized; photoconductive (selenium) cells and photoemissive cells are generally used with "invisible" beams, for they have high infra-red response.

Light Source and Optical System. A source of artificial light and an optical system for directing the greatest possible amount of this light on the light-sensitive cell are necessary in all photoelectric control systems except those which are designed especially to respond to general illumination.

The 6-8 volt, 32 candlepower automobile headlight bulb has become more or less standardized as a photoelectric light source, but in some units a 110 volt home movie projector type of lamp is used in order to permit operation of the bulb on either 110 volts A.C. or D.C. With the low voltage lamp a step-down transformer is needed, the secondary having several taps. The lamp should always be operated at the lowest voltage which gives sufficient illumination, to secure long lamp life. Twin filament lamps are generally used; when one filament burns out, the position of the lamp in its bayonet type socket is merely reversed. These lamps have a high infra-red output and can, therefore, be used with an infra-red filter to produce an invisible beam.

Either parabolic mirrors or convex spherical lenses can be used to concentrate light from the source into a narrow beam. Lenses are more widely used than reflectors for this purpose, since lenses are lower in cost, simpler to adjust, and permit focusing of the beam to any desired position.

Photoelectric light sources must be rugged in construction, for they are often subjected to considerable abuse. In some cases, as in door-opening installations, persons or trucks may bump the unit or its support; inquisitive persons will seek to discover what is inside that "cute little box," and in outdoor installations snow, rain, ice and sleet will batter the unit. Representative commercial light sources are shown in Figs. *1A, 1B, 1C* and *1D*; in each, a step-down transformer is built into the lamp housing, and a spherical lens is placed in front of the lamp. The position of either the lamp socket or the lens is adjustable; the lamp is set at the focal point of the lens when an approximately parallel beam is wanted, and back of the focal point (but at *less than twice* the focal distance) when the converging beam is to be focused on the light-sensitive cell. In general, the beam of light is adjusted to have a greater diameter (at the light-sensitive cell) than the cell cathode; this prevents vibration in any part of the optical system from throwing the beam off the cell and causing improper operation of the control system.

The average photoelectric control unit requires an illumination of about 5-foot candles on the light-sensitive cell; the maximum distances at which this intensity can be obtained for the light sources shown in Figs. *1B* and *1D*, and for two sizes of ordinary incandescent lights without lenses or reflectors are given on the graph in Fig. *2*. With ordinary 110-volt lamps the illumination varies inversely as the square of the distance, and therefore drops off rapidly as the light-sensitive cell is moved away from the lamp. Ordinary lamps are unsuited for producing powerful beams, principally because their filaments have too large an area.

The photograph in Fig. 3 illustrates a practical photoelectric application, where a beam of light directed across the punch press prevents the press from operating until the operator's hands are out of danger. The light-sensitive cell, placed in the dust-proof metal housing at the right, has a tubular visor to keep out all light except that reaching it from the light source at the left. When the distances involved are as short as this, no

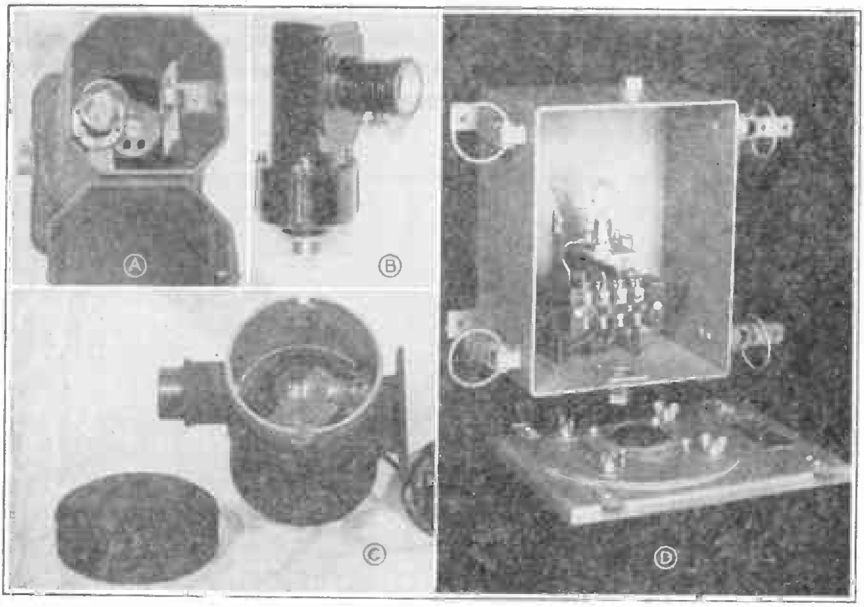


FIG. 1A. This light source, a *Western Electric* product, has a light filter (two panes of colored glass) held in place between the lamp and the lens barrel by a spring clip. Careful design of the castings used for the housing gives a sturdy, weather-proof unit.

FIG. 1B. *Westinghouse* type F general purpose light source, designed for indoor use. The transformer is housed in the lower casting; the adjusting screw on the lens barrel is loosened while focusing, then tightened to hold the lens in the desired position. Provisions are made for attaching metal conduit at the base, through which the wires to the transformer can be run.

FIG. 1C. Another simple light source with transformer, in a weather-proof cast iron housing. Adjusting screw clamps lens tube in desired position.

FIG. 1D. View of interior of *Westinghouse* type B long range light source, designed for either indoor or outdoor use. Light-concentrating lens is rigidly mounted in cover, but lamp socket can be moved backward or forward for focusing. Unit is designed to deliver a parallel beam which is about 5 inches in diameter at a point 10 feet away from lens. Note that in each of these four light sources, a step-down transformer is mounted below the lamp, and no reflectors are used.

light-collecting lens is needed, and even the light-concentrating lens on the source can often be dispensed with if a simple reflector is used back of the lamp. When protecting the operators of machines against their own carelessness in this way, electromagnetic devices are usually attached to the operating lever of the machine to prevent release of the lever when the operator's hands are in the danger zone; a careful study of each installation is necessary, for the machine must not be slowed up unless the operator actually is in danger.

A photoelectric control unit utilizing a light-collecting lens is shown in Fig. 4; this lens concentrates a large-diameter beam on the photocell cathode. Light-collecting lenses like this are generally required where the light beam is transmitted for distances greater than 15 to 40 feet (depending upon the type of light source used).

Mirrors can be placed in the path of a light beam to change its direction, but each reflection from an ordinary mirror results in a loss of about 40% of the light reaching the mirror. This loss can be compensated for by using a stronger light source and better optical system. The mirror used must be large enough to reflect all of the light beam.

Some light is also lost (through reflection) when a beam is directed through a plate glass window or a pane of glass; the loss is about 5% for zero angle of incidence (at right angles to the glass), and increases to 25% for a 45 degree angle of incidence.

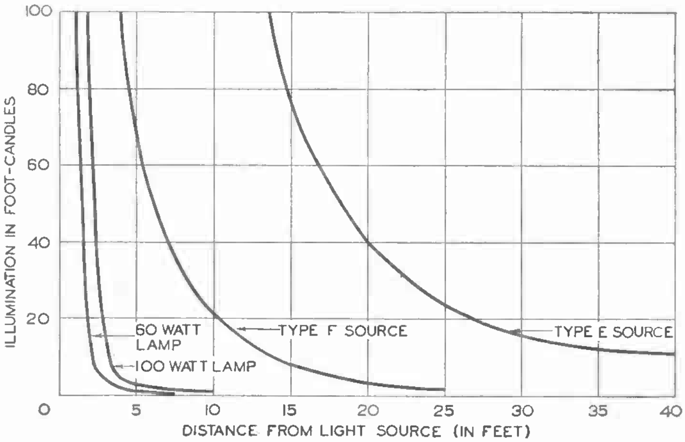


FIG. 2. This graph gives maximum intensities of illumination at different distances from the type F *Westinghouse* light source (pictured at *B* in Fig. 1), from the type E *Westinghouse* unit (pictured at *D* in Fig. 1) and from two sizes of ordinary incandescent lamps.

The light-sensitive cell may either be housed in the amplifier and relay box, as shown in Fig. *4*, or may be placed in a special housing similar to the housing used for light sources. A separately mounted photocell is pictured in Fig. *5*, connections being made between cell and amplifier by wires running through a grounded BX cable; since the photocell is essentially a high impedance device, these precautions must be taken to reduce undesirable pickup in the connecting leads. Manufacturers supply special cable for making connections to photocells like this.

Visors of the forms shown in Figs. *4* and *5* are essential where a beam of light is directed on a photocell, for these visors exclude light from other sources and thus prevent improper operation of the equipment.

Amplifier and Relay Unit. This is the "brain" of the control system, interpreting what the light-sensitive cell sees; it can be made to act on impulses of light, on gradual changes, or on differences in the color of light; it can be made to ignore anything but slow permanent changes; it can be made selective in its action. All the peculiarities of radio and electrical circuits can be put to use to get actions which appear nothing short of magical to the general public.

It is customary to place the amplifier stages and sensitive relays in a single housing; the photocell is often placed in this housing too, as it is in Fig. *4*. The power pack, the special circuits and the circuit-adjusting controls are housed in the same box, giving a compact, easily serviced unit. Heavy-duty relays are usually placed in a separate housing mounted close to the device being controlled. Bear in mind that when photovoltaic cells are used, only relays are needed; the cell feeds directly into a supersensitive relay which may control motor-operated switches or relays.

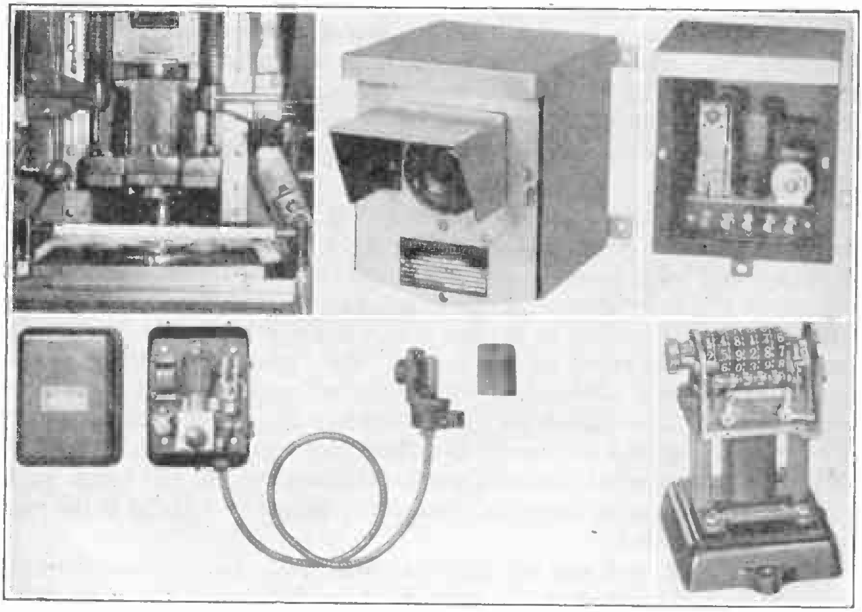


FIG. 3 (upper left). A beam of light may here save a worker's hand some day. The powerful punch press cannot operate while the beam of light is interrupted, for the photoelectric amplifier and relays are interlocked with the press controls.

FIG. 4 (upper center and right). Two views of *General Electric* CR7505-M1 outdoor photoelectric relay with self-contained photocell and light-collecting lens. Light intensities as low as 3 foot-candles will cause relay to pull up; light beam should be completely intercepted for relay to drop out. Note metal visor over lens to keep out slanting rays of sun.

FIG. 5 (lower left). *General Electric* CR7505-A5 indoor type photoelectric relay with covers removed. Photocell is in separate housing, connected to relay unit by BX armored cable.

FIG. 6 (lower right). Typical electromagnetic counter (made by *Production Instrument Co.*) with cover removed to show the six number wheels. The maximum operating speed is here 25,000 counts per hour.

The Device Being Controlled. Photoelectric equipment is essentially designed to control electrical apparatus, the largest relay in the system being connected to start and stop the electrical device which is to be controlled. Where the desired operation is of a mechanical nature, additional devices are sometimes needed; for example, when the flow of gas or water to a device is to be controlled, the final relay would be connected to an electromagnetic valve. In some cases, as in automatic door openers, motors are used to give the required mechanical motion.

Basic Considerations. In applying photoelectric controls to industrial or commercial jobs, the manner in which the optical system will react should be given full consideration. In fact, the types of light-sensitive controls can be grouped according to whether: *1*, the light beam is cut *off* or *on*; *2*, the light beam merely varies in intensity; *3*, the color content of the light beam varies. A better understanding of photoelectric control systems will be obtained if typical systems are studied according to these classifications.

CONTROLS WHERE LIGHT IS CUT OFF OR ON

The commonest type of photoelectric control is that which involves interruption or turning on of a beam of light which is directed on a light-sensitive cell. Standard photoelectric units are available from various manufacturers; with the correct unit at hand, there remains only the installation and connection of the various components to give the desired results. A few examples will be taken up to show how simple this is in most cases.

Counters (Slow Speed). The movement of an object through the light beam of a photoelectric system produces an electrical impulse which, if amplified and fed to an electromagnetic counter of the type shown in Fig. *6*, will cause the counter to read one number higher. The speed of the control equipment (number of objects it can count per minute) is governed essentially by the speed of the counter; 600 "counts" per minute is an average top speed. Electromagnetic counters require about 5 watts of power and can be obtained for use with either A.C. or D.C. power of any practical voltage and frequency. Standard counters will count up to 9,999 or 999,999, but special counters can be obtained which will count up to any desired amount, automatically reset themselves to zero and in the reset process trip a switch.

When objects on a moving conveyer belt are to be counted, the light beam is directed across the belt; each object interrupts the beam once, and the photoelectric amplifier sends one impulse to the counter. The conveyer here places the objects in the proper position for counting, and no other introductory devices are needed. On the other hand, when persons are being counted, it is necessary to design the introductory system so that only one person can pass through the beam at a time. This is done by constructing a passageway or entrance just wide enough for a single person.

Another interesting photoelectric counter application is that where definite quantities of some small object are to be placed in containers. The reset type of counter can be used here, the final switch action being used to control a conveyer which will bring an empty container into position ready for a new count.

One-Way Counter. When objects pass through the beam in both directions, as in the case of automobiles going over a highway or bridge, a special counting circuit can be used to count only the cars moving in one direction. This circuit, given in Fig. *7*, uses either selenium cells or photocells. With the cells connected as shown, *illumination on a cell* lowers the cell resistance, makes the amplifier tube grid more negative and thus *lowers the plate current; interruption* of a light beam therefore *increases* the plate current of the associated amplifier tube.

With a circuit like that shown in Fig. 7, only objects moving *upward* will be counted. When light is on both cells, the plate currents of the two tubes are a minimum and all three relays are in their drop-out positions as shown; an object moving upward first interrupts the beam on P_B, causing relay R_B to pull up. The contacts of R_A and R_B are both closed now, but R_C cannot pull up for the simple reason that plate current in VT_A is still a minimum and is insufficient to operate both R_A and R_C, now *in parallel* with each other. The object moves farther up, to a position where it interrupts *both* beams; the plate current of VT_A increases, but—and here is the secret of this circuit—the coil of R_C has so much *lower* a resistance than the coil of R_A that only R_C pulls up. In other words, relay R_A cannot get sufficient current for its operation when R_C is in parallel with it. The pulling up of R_C closes the contacts which control the electromagnetic counter, and one count is registered. As the object moves on, the beam of

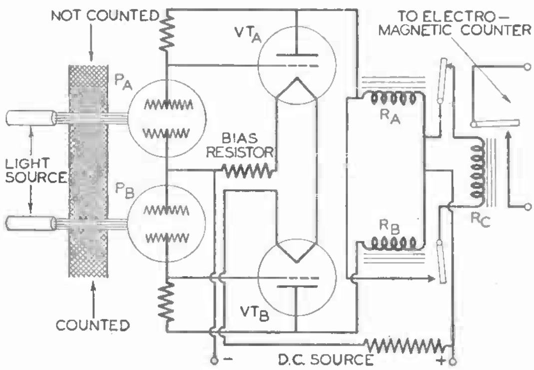


FIG. 7. One form of selective circuit for a one-way photoelectric counter. Objects moving upward over the shaded path are counted; those moving down do not give a count. In some installations the electromagnetic counter can be connected in place of R_C, eliminating one relay, provided that the operating coil of the counter has the same electrical characteristics as the coil of R_C.

P_B is restored first, causing R_B and R_C to drop out; with R_C no longer "stealing" current from R_A, the latter relay pulls up, but nothing else can happen. When the object leaves the last beam, restoring light to P_A, R_A drops out, closing its contacts, and the system is ready for another count.

Now let us see why no count is made for an object moving in a downward direction. The beam of P_A is interrupted first, and R_A pulls up. Nothing else happens until the object moves into the lower beam, cutting off light to P_B; relay R_B now closes, but since the contacts of R_A are open, R_C is not energized and there is no count. When light is restored to P_A, the contacts of R_A close; R_C cannot pull up now because VT_A has minimum current and the electromagnetic counter does not operate. Finally, when light is restored to P_B, the contacts of R_B open, and the system is restored to its original condition.

Objects shorter than the separation between the two beams are not counted, since both beams must be interrupted at some instant, and in the proper order. Special counting systems like this are usually built to order by electronic equipment manufacturers, since they are required only for specialized applications.

High-Speed Counters. In industries where small products such as cigarettes, nuts, bolts, etc., are produced at speeds far in excess of the counting ability of an ordinary electromagnetic counter, special circuits have been developed which will "memorize" impulses and operate the counter once for a definite number of impulses.

One type of high speed counting arrangement, shown in Fig. *8*, uses one small size gas triode for each impulse which is to be "memorized"; the multiplying factor for the registered count is therefore four when four tubes are used. The grids of all tubes are fed simultaneously by impulses from the light-sensitive cell amplifier, through coupling condensers C, but the cathode bias resistances and connections are such that only one tube is "fired" (passes current) at any time, and this "firing" primes the following tube so it can be "fired" by the next impulse. The plates of the tubes are connected to a D.C. source; you will remember that once a gas triode in a D.C. circuit fires, the grid loses control and plate current can be stopped only by interrupting the plate current or removing the plate voltage.

Let us trace through the operation of the circuit from the time it is turned on. The D.C. voltages applied to the plates and the grid bias batteries are of such values that no tube can fire when voltage is first applied, even when signal impulses come through. The circuit must therefore be initially primed (one tube made to fire) by throwing switch SW momentarily to position *1*, placing zero bias on tube VT_A and causing it to fire; the switch is then thrown to position *2* permanently, applying the bias voltage of battery B_D to tube VT_A. With tube VT_A passing current, the voltage drop in the lower part of potentiometer R_A opposes the bias voltage of battery B_A (applied to the grid to VT_B) and the net bias on VT_B is made *less negative*. The first signal impulse to come from the photocell circuit will fire tube VT_B now, but will not affect tubes VT_C and VT_D, which are still biased highly negative, or tube VT_A, which is passing current. The firing of tube VT_B causes condenser C_A to act momentarily as a short circuit, drawing a large current through R_A. The voltage drop across R_A momentarily becomes so great that the voltage between plate and cathode of VT_A is insufficient to maintain ionization. Current flow in VT_A stops, and its grid regains control.

The first signal impulse has thus fired tube VT_B, extinguished VT_A and "primed" the grid circuit of VT_C; the next impulse will fire VT_C, extinguish VT_B and prime VT_D; the third impulse will fire VT_D, making the electromagnetic counter read one digit higher, and will extinguish VT_C and prime VT_A, completing the cycle. Since the first impulse was created artificially by manipulating SW, the total number of actual impulses will be (in this circuit) one less than four times the counter reading (provided VT_D is firing when the reading is taken).

Photoelectric Alarms. It has often been suggested that photoelectric controls be used as burglar alarms or for announcing the arrival of a person or car, the interruption of either a visible or invisible light beam causing the alarm to sound; in the majority of such cases, however, it is cheaper and more practical to use simple mechanical switches for the purpose. These switches might be simple make-and-break affairs mounted on all doors and windows which must be opened to enter a room or, in the case of filling stations, might be metal plate switches in the driveway or a pneumatic switch which operates when a car drives over a rubber hose. Capacity controls utilizing feedback-controlled oscillators, to be described shortly, should be considered.

Where open passageways or definite areas in a room are to be guarded, and where mechanical systems are impractical, undesirable or too costly, photoelectric controls can be used to advantage. Standard photoelectric amplifier units can be used, with an ordinary power relay if the alarm is to operate only when the beam is interrupted, or with a latch-in type relay if the alarm is to operate until the relay is reset manually.

Many unique photoelectric alarm systems have been devised. In one case the interruption of the light beam opened and closed the shutter of a camera and set off a photoflash bulb, taking a picture of the intruder; an

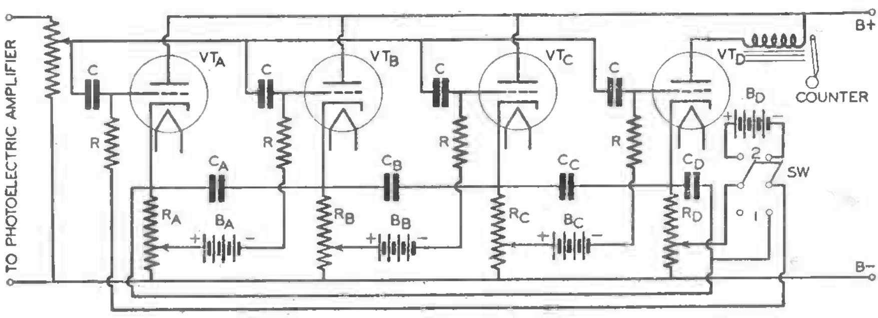


FIG. 8. High speed photoelectric counter circuit, which "memorizes" impulses fed to it by a photocell and amplifier, and operates the electromagnetic counter once for every four impulses.

alarm gong was also set into operation, scaring off the intruder before he could locate and wreck the camera.

Effortless Action Switches. Where an action is desired with no effort on the part of the operator and no mechanical pressure on the product or object being controlled, the photoelectric control fills an important need. Standard photoelectric control equipment can generally be used, the introductory system being designed to meet the requirements of each particular application.

An automatic sanitary drinking fountain is a good example of an effortless action switch. It is a simple matter to arrange the light source and light-sensitive cell so that a person bending over the fountain interrupts the light beam. The regular fountain valve is replaced by an electromagnetic valve which is controlled by the contacts of the power relay in the photocell amplifier circuit. The light beam can be made invisible when a mystery effect is desired.

The general appearance of an electromagnetic water valve is shown in Fig. *9;* the mechanism is usually quite simple, consisting of a soft steel plunger with a conical bronze point which is normally held against the orifice (water outlet) by a spring. When the solenoid or coil surrounding the plunger is energized, the plunger is pulled away, allowing water to flow through the valve.

Effortless controls find many uses in manufacturing plants. Where strips of cloth, cellophane and similar materials which are subject to shrinkage have woven patterns or printed designs whose positions are critical, shrinkage causes errors in cutting and considerable waste when automatic cutting machinery is used. Errors due to shrinkage accumulate rapidly, especially in high-speed machinery, with the result that the machine must be stopped and reset at frequent intervals. Photoelectric control of the position of the printed pattern with relation to the cutting knife completely eliminates these troubles. A dot or other mark woven or printed in the margin of the sheet at each point where a cut is to be made is all that the electric eye needs to do its work. Light source and electric eye are mounted close to each other in a manner similar to that shown in Fig. *10,* so that the

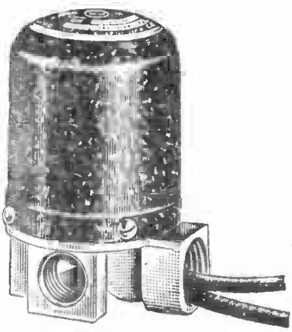


FIG. 9. A typical electromagnetic water valve.

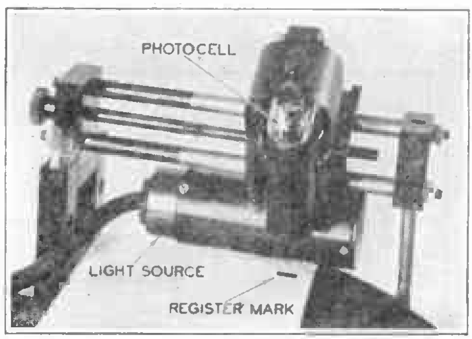


FIG. 10. The "detecting" section of a photoelectric register control.

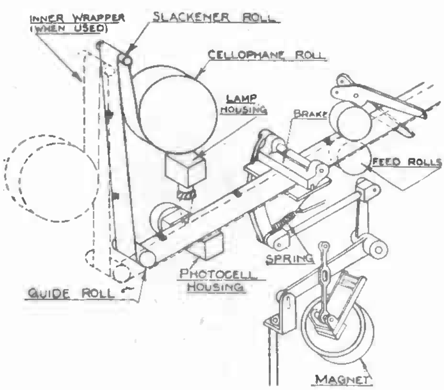
light-sensitive cell can detect the changes in light reflected from the moving sheet of material.

Photoelectric register controls like this are now being used extensively in connection with package wrapping machinery like that shown in Fig. *11;* here a friction brake is used to correct the speed of the moving paper at the command of the photoelectric control system, to insure correct register.

Automatic Door Openers. The opening of doors automatically as a person or vehicle approaches is becoming a very popular job for photoelectric controls. Doors in garages, stores, hospitals, restaurants, factories and public buildings are today controlled by interruption of beams of light.

Door opening mechanisms are available for the opening and closing of three general types of doors: *1, doors which open inwardly or outwardly, or swing in both directions; 2, sliding doors; 3, overhead doors.* The door opening mechanisms can be divided into two general groups: *1,* those using electric motors operating worm gear drives, cables running over pulleys, or a link motion mechanism; *2,* pneumatically operated openers, in which the motion of one or more pistons under the action of compressed air is transferred into motion of the door by link mechanisms.

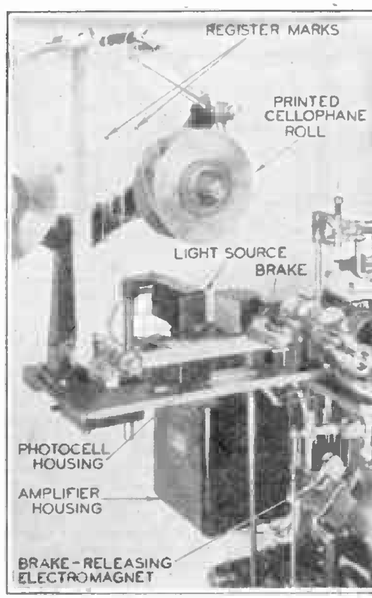
Each door opening installation requires a complete photoelectric control at the approach, to cause the door to open when some one enters the introductory system, and generally another complete photoelectric control to close the door after the person or vehicle has passed through and interrupted a light beam on the other side. In many installations, of course, it is more feasible to arrange a manual control for closing the door; in private garages this especially holds true, for here the door must remain open as long as the engine of the car is running, to prevent an accumulation of deadly carbon monoxide gas. In this particular case the driver must get out of his car anyway, so it is no hardship for him to turn a switch on the wall to close the doors.



Courtesy Package Machinery Co.

FIG. 11A (above). Simplified sketch of photoelectric registry control mechanism.

FIG. 11B (right). View of modern packing machine; cellophane rolls containing printed designs are accurately cut to required size sheets by means of photoelectric registry control, insuring that the pattern is perfectly centered on each sheet.



When very long objects, such as a truck and trailer or a long string of trailers, may pass through a door, the truck may intercept the closing light beam before the last car has cleared the door; in cases like this it is necessary to use an additional light beam or some other means of indicating to the "brain" of the photoelectric system that the doorway is being blocked. One solution to this problem, a light beam directed diagonally through the doorway, is shown in Fig. *12*.

In Fig. *13* is shown a typical photoelectric door opening installation; a photoelectric cell and light source are mounted inside the railings placed on either side of the entrance, while the pneumatic door opening mechanism is mounted above the door. A motor driven air compressor and storage tank, located in a remote place, provide air pressure at the correct value. Interrupting one beam opens the doors and interrupting the beam on the other side of the door closes the doors.

The advantage of a pneumatic door opener lies in its ability to open and close doors almost instantly, with a minimum of noise. Where slower acting doors are permissible, as in garages and in industrial plants, motor driven mechanisms can be employed; typical examples of these are shown in Figs. *14A*, *14B*, *14C* and *14D*. A reversible motor is generally used; note that in Fig. *14A* the cable actuates a link mechanism; in Fig. *14B* an endless cable running over two pulleys moves the sliding doors in and out; in Fig. *14C* a gear box operates levers connected to the two swinging doors; in Fig. *14D* an endless cable pulls the door up overhead. Worm and screw mechanisms driven by electric motors are also widely used for these types of doors. The possibility of power failure must always be considered in a door opening

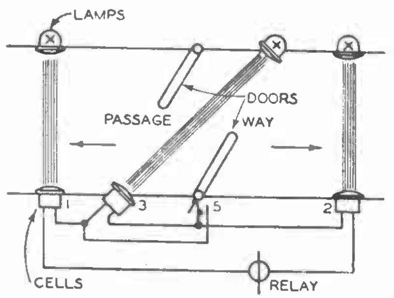


FIG. 12 (above). Arrangement of light beams for fool-proof photoelectric door-opening system. Three photovoltaic cells connected in series feed into one super-sensitive relay whose contacts in turn control a rotary switch, power relays and finally the door-operating mechanism. Cell *3* is shorted out by switch *5* when the doors are closed. Interruption of either cross-beam increases the resistance of a cell about five times, lowering circuit current enough to cause relay operation and make the doors open. Relays and a rotary switch are so interconnected that interruption of the other cross-beam closes the doors only if nothing is blocking the diagonal beam.

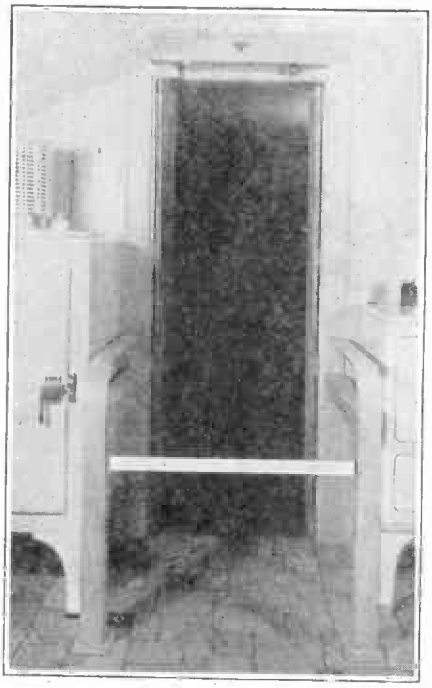


FIG. 13 (right). Installation of Stanley automatic door opener in kitchen of modern home.

mechanism; it should be possible to open and close the doors manually when power is off. Detailed information on door opening mechanisms can best be obtained from the literature supplied by the various manufacturers.

Automatic Inspection. Photoelectric controls can be applied to practically any automatic inspection application, but as a rule considerable ingenuity is required to design and install the system. A description of a typical application will give some idea of the problems involved. In the automobile manufacturing industry it is necessary to test a large number of steel parts for hardness. The instrument ordinarily used for testing hardness contains a diamond pointed weight which is dropped on the object from a fixed height, the hardness of the object being determined by the height of rebound of the weight. The higher the rebound, the harder is the material. The weight (often called the hammer) moves inside a vertical glass tube alongside which is a scale indicating the height; the hammer is drawn to the top of the tube by suction, then allowed to drop. Objects which do not give a rebound to a certain definite height are rejected. To make the hardness inspection automatic, a light beam is focused so its cross-over point is inside the glass tube; if this beam is intercepted by the hammer on the rebound, the object is considered okay and is moved along by the conveyer system; if the hammer does not reach the light beam, a rejecting mechanism kicks the object into a basket for further treatment

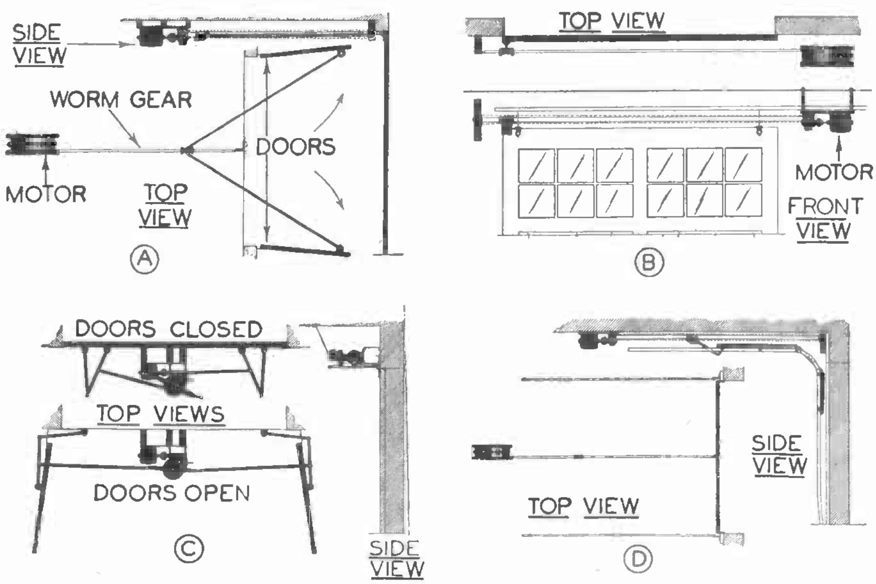


Fig. 14. Types of electric door-operating mechanisms. A—top and side views of motor-driven worm gear mechanism for opening outward-swinging double doors; B—motor-driven endless cable for opening single-section sliding door; C—motor-driven crank and link mechanism for opening inward-swinging double doors; D—motor-driven endless cable type opener for overhead doors.

or scrapping. A second light beam directed through the glass tube below the first beam is so connected to the amplifiers and relays that the descending hammer resets the latch-in relays in readiness for another monitoring operation as the hammer ascends. Naturally the rejecting mechanism must be carefully designed to give the desired results and make the entire testing procedure automatic.

CONTROLS FOR VARIABLE LIGHT INTENSITIES

Variations in the *amount* of light reaching the light-sensitive cell (rather than complete cut-off of the light beam) cause relay operation in a number of photoelectric control systems. Controls like these are possible because relays can be made to pull up or drop out at definite values of coil current corresponding to definite values of illumination on the cell; general illumination in a room or outdoors, which is gradually changed by movement of clouds or the sun, can be utilized to actuate the photoelectric control system. The passage of dust, smoke or fog through a light beam, the change in opacity of a liquid through which the light beam is directed, or the partial blocking of a light beam by a moving object are a few other examples of variable illumination. Some practical applications where variable light intensity is used will now be taken up.

Spark Plug Gap Adjustments. As automotive spark plugs are now manufactured and assembled, it is necessary to adjust the gap between the points to the correct value by a separate operation after assembly. Previously an accurate thickness gauge was held in the gap and a vibrating hammer used to bend the outer electrode against this gauge; unless the operator was very careful in stopping the hammer, a few extra blows would be delivered, cracking the porcelain insulator. At least one spark plug manufacturing plant has now replaced the steel thickness gauge with a light beam gauge, so arranged that when the outer electrode blocks off the light by an amount corresponding to the correct gap, the photoelectric control system automatically stops the vibrating hammer. Naturally a very small diameter but high intensity light beam is needed; this is obtained by focusing light to a cone having a minimum diameter at the gap. All light passing through the gap is collected by a light-sensitive cell, which is connected to an amplifier in such a way that a definite decrease in light intensity actuates the relay.

Smoke Detectors. Many towns and cities now have laws limiting the amount of smoke which factories, apartment buildings and other large users of coal and other fuels can release from chimneys and smoke stacks. Aside from the fact that smoke is a nuisance to the public, its presence indicates incomplete combustion and wastage of fuel, the amount of smoke being a direct indication of the inefficiency of combustion. If a beam of light is directed through the chimney or smoke stack to a photoelectric cell, as shown in Fig. *15A*, increases in smoke will reduce the light reaching the photoelectric cell. If this cell is connected to an amplifier, the plate current of the amplifier tube will change in value according to the amount of smoke. A relay can be inserted in the circuit and adjusted to close its contacts and sound an alarm when the amount of smoke exceeds a certain definite value. A meter can be inserted in the plate circuit of the amplifier stage to indicate the relative amount of smoke present at all times, or a recording instrument can be connected to the amplifier to give a continuous record of the amount of smoke passing up the chimney. Various combinations of relays can be used for special indicating purposes; in one system, shown in Fig. *15B*, a red light is made to flash on to indicate improper combustion, and a green light is illuminated when combustion efficiency is satisfactory. Relays can also be connected to correct the excessive smoke condition automatically; this is usually done by having the relay start a blower which feeds more air to the furnace and improves fuel combustion.

In most cases, the light beam intensity and the amplifier circuit must be adjusted, after the equipment is first installed, by making an analysis of the gases going up the chimney, and computing the percentage of efficiency of combustion for various amplifier settings. Special measuring instruments are available for this purpose. In general, combustion efficiency is at a maximum when a haze appears at the top of the chimney. Since the correct installation of a photoelectric smoke detector requires considerable knowledge of steam engineering, these systems are generally installed by firms which specialize in this one field. While some manufacturers of smoke detectors prefer to carry out the entire installation themselves, others will cooperate with you and your customer in working out a satisfactory system for a particular location.

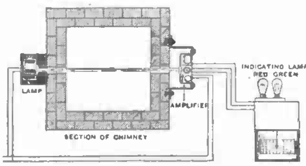
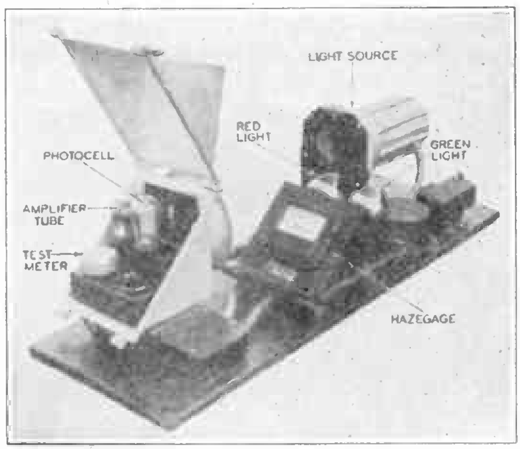


Fig. 15A (above). Simplified diagram of a representative photoelectric combustion efficiency recorder and smoke alarm.



Courtesy Ess Instrument Co.

Fig. 15B (right). All parts of the Ess Model HGL-4 Combustion Indicator system appear here, mounted on a "breadboard" for display purposes. Hazegage with signal lights is ordinarily mounted in boiler room.

In some photoelectric smoke detectors, the panes of glass which protect the light source and the photoelectric cell are kept clean continually by a motor driven wiping mechanism, while in others some provision is made for adjusting the voltage of the light source to compensate for dust and smoke on the glass. In the latter case it is generally necessary to clean the glass windows about once a week.

Turbidity and Opacity Measuring Devices. The turbidity of a solution (the amount of foreign material in the liquid) is easily estimated by measuring the reduction in the intensity of a beam of light which is directed through a sample of the solution, the emerging light beam being directed on a light-sensitive cell which is connected to a suitable amplifier and indicating meter. Where a continuous indication or record of the turbidity of a solution is required, as in chemical processes, or where pure water is required for drinking purposes or for manufacturing processes, it is customary to by-pass a small portion of the main water supply, allowing this water to run through a short length of glass tubing through which the light beam can be directed. One light beam is directed through this glass tube which carries water to be analyzed, and another light beam is directed through a similar tube carrying pure distilled water. The two light-sensitive cells are connected to a special linear amplifier circuit known as a differential circuit, which responds to the difference in the outputs of the two cells and causes an indicating meter to register the amount of turbidity in the solution being analyzed. Recording instruments and alarm devices may also be connected to the amplifier if desired. Colored liquids or dyes can be continually monitored in this way; sometimes color filters are used in the optical system to make the photocell respond to changes in the most important color present in the liquid under test.

Opacity, the ability of a material to block light, and transparency, the ability of a material to transmit light, can both be measured in a manner similar to that used for checking turbidity. The material to be inspected is either placed in the light beam or drawn slowly through it; the associated amplifier is connected to a meter which reads from zero to 100 per cent, the system being adjusted to give full-scale percentage transparency directly. Films of soot or dust can be measured if deposited on a clear pane of glass;

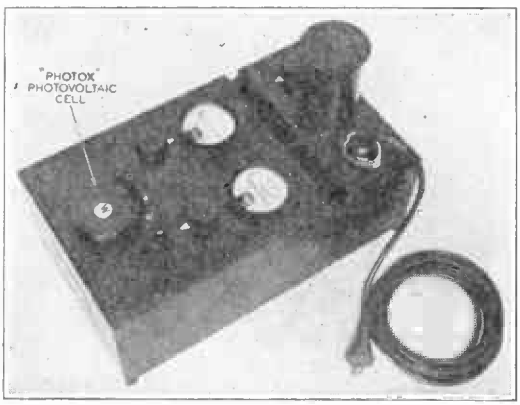


FIG. 16. *Westinghouse* Trans-O Meter, a simple portable device for measuring the percentage of transparency of paper, films, fabrics or any other thin flat material. Housing of photovoltaic cell raises so material can be slipped under it.

the meter is adjusted to read 100 per cent with only the glass in the light beam, to counteract losses of light in the glass itself.

A representative transparency measuring instrument is shown in Fig. *16;* this can also be used to measure opacity and turbidity by following the directions supplied with the instrument. The photovoltaic cell used here is corrected with filters to have the same color response as the human eye.

Photoelectric egg candling systems operate on much the same principle as the transparency measuring instrument. The eggs are first sorted by operators for size and color of the shell, and are then placed on a conveyer system which carries them through the egg candling machine. A rejecting mechanism controlled by an electromagnetic lever pushes eggs of inferior quality off the conveyer belt.

Illumination Controls. The importance of adequate illumination in securing maximum efficiency of workers is rapidly becoming recognized. Today we want light when it is needed, and not necessarily when it is time for the sun to set or when some one suddenly notices "it is getting pretty dark." If sunlight returns after artificial lights have been on for a while, the effects of the sun so greatly overshadow the effects of the artificial sources that no one realizes lights are on and power is wasted. Ad-

vertising signs, highway lights, window display lights and school room lighting systems are just a few examples where automatic control of illumination is today being used to great advantage. It is generally recognized that for working purposes, between fifteen and thirty foot-candles of illumination are ordinarily required; for street illumination between .5 and 2 foot-candles are sufficient, while about 6 foot-candles are needed for proper illumination of advertising signs. It is the light-sensitive cell with its discriminating control apparatus which makes automatic control of illumination at different levels possible. Various types of commercial illumination controls are now on the market, these being adjustable to turn lights on at a certain minimum level of illumination, and to turn the lights off again when illumination exceeds a prescribed maximum value.

Illumination controls are, as a rule, quite easy to install. The control box containing the light-sensitive cell is, of course, placed in the room whose illumination is to be controlled, it being so located that the cell sees the average light coming from the area being monitored. The contacts of the illumination control relay are connected into the circuit containing the lights being controlled.

There are many different types of illumination control circuits, each manufacturer generally showing a preference for a particular circuit. That shown in Fig. *17* is a good example, however, and will therefore be studied in detail. In this circuit, P is a photocell connected between cathode and grid of vacuum tube VT, while potentiometers R_2 and R_3 control the negative grid bias of VT. Although the plate of this tube receives A.C. power, the circuit is in operation only for that half of each cycle when the plate is positive (when transformer polarity is as indicated). Since the photocell anode and the plate are positive at the same time, the photocell passes current and acts like a variable resistance during the active half-cycle.

The operation of this circuit is as follows: When the photocell is dark (insufficient illumination), the resistance of the cell is high and the grid bias (determined by the ratio of the resistances $R_1 + R$ to the cell resistance) is highly negative. Plate current of VT is therefore a minimum, and relay A is in the drop-out position, as shown. Contacts a are closed; relay B is getting power directly from the A.C. line, and is therefore in the pull-up position shown. Contacts *3*, controlling the load, are closed, and artificial lights are on. Note that under these conditions R_3 is out of the circuit; R_2 therefore determines the level, as natural illumination increases, at which plate current is sufficient to actuate relay A.

When natural illumination increases to the level at which the customer decides artificial lights are no longer needed, the increasing illumination on P has lowered its resistance, making the grid of VT less negative (closer to the cathode in potential), and thus increasing the plate current of VT to a value which causes relay A to pull up. Armature K now moves to contact b and relay B now receives its current through time delay button (or time delay relay) M, whose contacts were closed. Current passing through the heater resistance in M causes its contacts to open in a definite time interval. With relay armature K pulled up and the contacts at M open, relay B drops out; contacts *3* open, turning off the artificial lights.

contacts *2* open, and time delay button N is now in series with the coil of relay B; contacts *1* close, connecting potentiometer R_3 in the circuit. The moving arms of R_3 and R_2 are thus connected together through resistor R, which has a sufficiently high ohmic value to prevent overloading of the transformer, and the grid bias will be determined solely by the setting of R_3.

The lights are now off; when natural illumination drops below the level determined by the position of R_3, the resistance of the photocell increases, plate current of VT decreases to the drop-out value for relay A, and armature K drops out to make contact with a. Remember that relay B is still in the drop-out position; the coil of B now gets its power through the heater resistor of time delay button N (whose contacts are open when cold), but this heater resistance keeps the current through B below its pull-up value. In a definite time interval the contacts of N close, allowing relay B to pull up. Now contacts *3 turn on* the lights; contacts *2 close,* shorting out N and allowing it to cool in readiness for the next cycle of operation, contacts *1* open, cutting out R_3 and allowing R_2 to take control again.

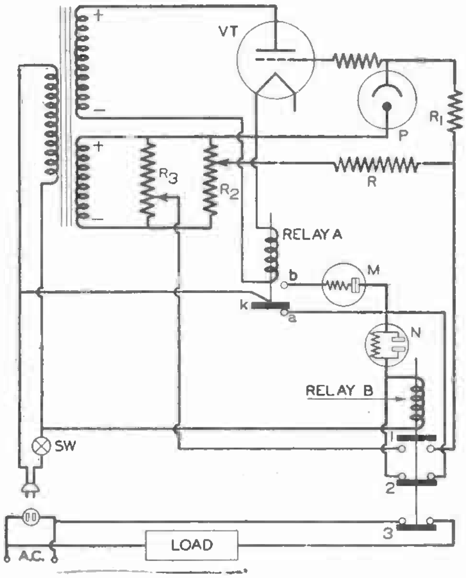
This system provides separate adjustments for low and high values of illumination, eliminating any need for adjusting the relays to certain pull-up and drop-out values. The two time delay buttons act to prevent flashing of lights on and off where changes in illumination are temporary, such as changes caused by passing clouds in the daytime, flashes of lightning at night, or persons walking directly in front of the light-sensitive cell.

Sorting According to Size. Objects having a definite geometrical shape but different sizes can be accurately sorted according to size if passed through a beam of light which is a part of a photoelectric control system. In some cases the light is beamed through a tunnel whose cross-section corresponds to the shape of the largest object being inspected, the inside of the tunnel being painted black to prevent reflections of light. The objects being inspected are carried through this light-tunnel by a conveyer system, and the amount of light passing around the object is condensed onto a photoelectric cell by a collecting lens. The smaller the object, the more light will reach the photocell; the amplifier and a rejecting circuit can be adjusted to reject all objects under a certain size. One form of rejecting mechanism, which can be used to "kick" objects off a moving belt, is shown in Fig. *18*.

When more than two sizes of objects are to be sorted, one photoelectric analyzer is usually required for each size. The objects are passed through each analyzing position in turn, a separation into two sizes being made at each position. Even tape, ribbon or wire can be monitored for size in this way; the material is made to pass through the analyzing beam, and when its width exceeds certain dimensions, an alarm or signal system either warns the operator or stops the machine. Thousands of other photoelectric sorting and inspection applications are possible, but in general, standard photoelectric amplifier circuits can be used. Your job is to choose the correct relays and the optical system.

CONTROLS WHERE COLOR OF LIGHT VARIES

Photoelectric cells, as you know, have varying responses to light of different colors, each type of cell having its own peculiar color response characteristic. It is therefore possible to use photoelectric controls in sorting objects like beans, eggs, sliced pineapple, cigars and sheets of paper as to shades of whiteness or color; similar photoelectric controls can be used to supervise the roasting of coffee, the baking of cake and bread, the preheating of steel before treatment for tempering, and the control of any other products whose final quality is determined by the color of light which it reflects or emits.



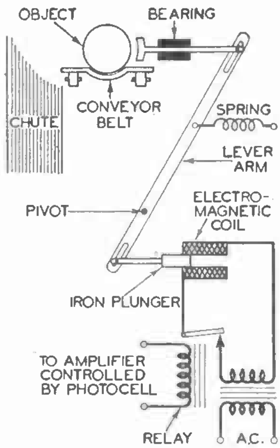


FIG. 17 (left). Photoelectric illumination control circuit.

FIG. 18 (above). One type of mechanism which kicks objects off a conveyer belt in response to impulses from a light-sensitive cell. A special mechanism must be developed for each installation.

Sorting Closely-Related Colors. Sorting of light and dark objects is comparatively simple, for here the difference in the amount of light reflected from the object is quite appreciable; ordinary photoelectric control units are generally quite satisfactory for sorting objects which differ greatly in color. When there are only slight variations in the color of a certain product, and the variations in the amount of white light reflected are not sufficient for accurate photoelectric sorting, an expert sorter first separates a large number of samples of the product into the desired number of groups according to shades of color; in other words, this expert sets an example which the photoelectric color sorter must follow. The products in each group are now put through a special color-analyzing process which determines the average percentages of the primary colors, red, blue and green, in that group. The controlling color for all groups (that color which varies greatest in amount in all objects sorted) is then determined, and a filter is selected which will allow only the one particular color to pass.

Since one photoelectric color sorter can ordinarily separate objects into only two groups (corresponding to relay pull-up and relay drop-out positions), an extra sorter is needed for each extra group (above two) into which a product is to be sorted; a filter of the selected color is inserted in each of the light beams, so that the different shades of color produce the greatest possible differences in light-sensitive cell response. Each sorting unit is then adjusted to "pick out" objects belonging in one of the groups originally set up by the expert sorter.

Only a single photoelectric color analyzing system is needed when controlling a process where the color of the object changes gradually, such as in the roasting of coffee. When the electric eye "sees" the correct color, it causes relays to cut off the heat and sound an alarm.

Color Analyzing. In many manufacturing processes where the color of a product is important, the sensitivity of the human eye to shades of a color is not sufficiently accurate for production purposes. Photoelectric color analyzers have been designed to replace the human eye for this purpose; although many different types of analyzers are on the market, the basic principles of these can be secured by studying the simplified diagram shown in Fig. *19*. Here a photovoltaic cell whose color response has been corrected with filters to approximate that of the human eye is arranged to "see" light which is reflected from the object being analyzed by a lamp which is filtered to make it approximate sunlight. The meter connected across the photovoltaic cell gives a minimum deflection when a pure white surface is being analyzed, and for other colors gives readings which are proportional to the amount of light reflected. By inserting red, blue and green filters in the path of the light beam in turn, the amounts of each primary color reflected from the product can be determined.

Photoelectric Installation Questionnaire. To be certain that you are ordering the proper equipment for a particular photoelectric job, it is wise to check over the following list of questions, making sure that each factor has been properly considered:

LIGHT BEAM

1. Can visible light be used, or must the light be practically invisible?
2. Will the light beam be horizontal or at an angle?
3. How many mirrors, if any, are required for the beam?
4. What is the total length of the light beam?
5. What is the size of the intercepting object?
6. How far will the intercepting object be from the light source?

LIGHT-SENSITIVE CELL

1. Will the cell be in the relay housing?
2. If the cell is mounted separately, how far is it from the relay?
3. Will direct or reflected sunlight or strong artificial light enter the cell housing?
4. What is the temperature range at the location of the installation?
5. Is the equipment subject to excessive dampness?
6. Will any housings be subject to direct heat of the sun?
7. If equipment is used outdoors, in what direction will light be sent from source to cell?

RELAYS

1. What is the maximum number of relay operations per minute?
2. What is the voltage, current and frequency of the circuit to be controlled?
3. What is the nature of the load? (Is it highly inductive?)
4. Will relay be in pull-up or drop-out position when light is on cell?
5. What is minimum duration of complete light change which is to actuate relay?

INSTALLATION

1. Are there any limits on size of housings?
2. Are cell and light source housings readily accessible for cleaning?
3. Are units to be mounted on floor, walls or ceilings?
4. What are maximum and minimum values of line voltage?
5. What is the power line frequency?
6. If unit is to be used at night, what is the night voltage range?
7. Is one side of the power line solidly grounded?
8. How many hours a day, days a week and weeks a year is unit to be in use?

OTHER TYPES OF DETECTORS

It has already been pointed out that many of the other human senses besides that of sight can be replaced by man-made devices which produce a change in electrical or mechanical characteristics, corresponding to a change in the effect being supervised. These detectors can be used with all of the circuits just described, where they replace only the light-sensitive cell. Each type of dector will be considered in turn, and a few of the practical applications taken up in each case.

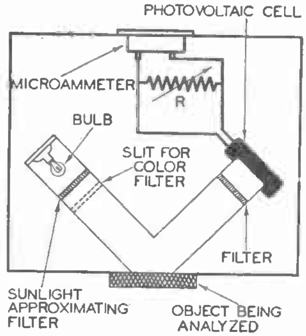


FIG. 19. Simplified sketch of one form of photoelectric color analyzer. Photovoltaic cell has filter which gives it color response of human eye. *R* adjusts meter sensitivity.

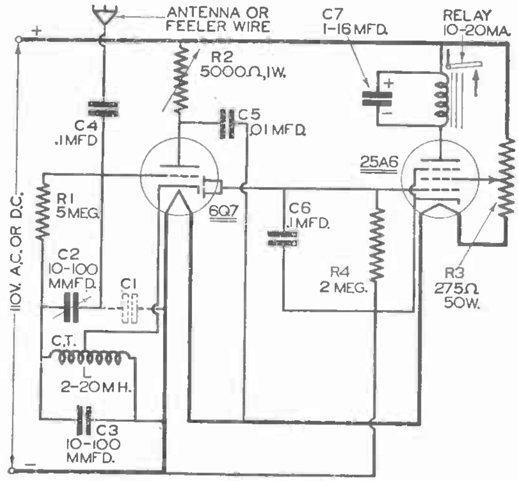


FIG. 20. Schematic circuit diagram of capacity control circuit. Condenser *C7* is needed only for A.C. operation, to prevent relay chatter; the indicated polarity must be observed if an electrolytic condenser is used. Any external capacity between antenna wire and ground has the same effect as would a condenser at *C1*.

Feeler (Capacity) Controls. It is often desirable to have an alarm system which will operate when a person or object approaches within a definite distance of the object or area being protected. Photoelectric alarm systems are impractical for protecting areas of irregular size, since the light beam can travel only in a straight path, and reflection by mirrors introduces heavy losses in light. The solution to the problem lies in a feeler or capacity control, which consists essentially of a feed-back oscillator in which the degree of oscillation is controlled by the feed-back capacity introduced by the feeler or antenna circuit. The feeler may be a single wire stretched around the area being protected, at a height of about three feet above ground; it may be a metal plate located underneath a display table containing valuable jewelry or other articles, or it may be a metal object such as a safe.

A simple and practical feeler control circuit, designed by F. H. Shepard, Jr., of R. C. A. Mfg. Co., is shown in Fig. *20;* the triode section of a 6Q7 duo-diode triode tube forms an oscillating circuit with coil *L* and condenser *C3*, the feed-back voltage of which is controlled by variable condenser *C2* and the capacity existing between the feeler wire and ground (represented by *C1* in Fig. *20*). The antenna is simply an insulated wire acting alone or connected to the metal object being guarded. Condenser *C4* is inserted in series with the antenna lead to prevent a direct connection to the power supply, since no transformer is used. The diode sections of the 6Q7 tube, connected in parallel, rectify the oscillator current; the resulting D.C. output, which is proportional to the strength of the oscillations, is fed to the grid of the 25A6 amplifier tube. Potentiometer *R3* varies the screen voltage applied to the amplifier tube.

The circuit is initially adjusted to give maximum oscillator output when nothing is near the antenna. The output of the diodes is therefore a *maximum,* the bias on the amplifier tube is *highly negative,* plate current through the relay is *low* and the relay armature is in its *drop-out* position. When a person or vehicle approaches the antenna, increasing the antenna-to-ground capacitance (*C1*), the intensity of oscillation is reduced and the diodes feed a less negative bias to the amplifier; the amplifier plate current goes up, operating the relay. When first adjusting the circuit, potentiometer *R3* is adjusted until the relay just drops out when nothing is near the antenna; the next step is to adjust condenser *C2,* with a person in the position at which operation of the control is desired, until the relay pulls up.

Temperature Controls. Millions of temperature control devices of various types are in use today, opening and closing contacts in response to changes in temperature. Some of these devices actuate the contacts either directly or through mechanical levers, while others require amplifiers followed by relays. Let us study a few typical detectors.

The bi-metallic strip type of temperature control, in which two dissimilar strips of metal (welded together) curl and uncurl, causing a lever arm to move from one contact to another in response to changes in temperature, is pictured in Fig. *21A*. This detector is extensively used in room heating control systems and in other applications where a large movement but only a relatively small force is required.

Another temperature detector, one which depends upon the expansion and contraction of a liquid with changes in temperature, is shown in Fig. *21B;* here considerable force is exerted by the expanding liquid. The liquid is placed in a specially constructed metal bellows which readily changes its shape as the liquid changes in volume. One side of the bellows is fixed, while the other presses against a lever arm which is held down by a small spring. Contacts mounted on this arm may move between fixed contacts, or the arm can be made to tilt a mercury type switch.

The change in the resistance of a wire with temperature is the operating principle of the temperature detector shown in Fig. *21C*. The resistor here forms one arm of a Wheatstone bridge, the circuit being balanced for a definite temperature. Deviations from this temperature produce an unbalanced circuit; the resultant voltage and current are used as a means of controlling the heat-producing device or for operating an alarm or indicating system.

The thermocouple shown in Fig. *21D* must be connected either to a supersensitive relay or to an amplifier circuit. The temperature range of the thermocouple can be changed by adjusting the pull-up current value of the relay or by changing the bias on the grid of the amplifier tube.

When the temperature being controlled varies between definite known limits, mercury column thermometers having wire contacts imbedded in the glass walls can be used as temperature controls; the arrangement is shown in Fig. *21E*. The rise and fall of the column of mercury makes and breaks the circuit between the two contact wires.

When the temperature being controlled is subject to change from time to time, the photoelectric scheme shown in Fig. *21F* is sometimes used. Here the rising column of mercury intercepts the coned beam of light at its cross-over point.

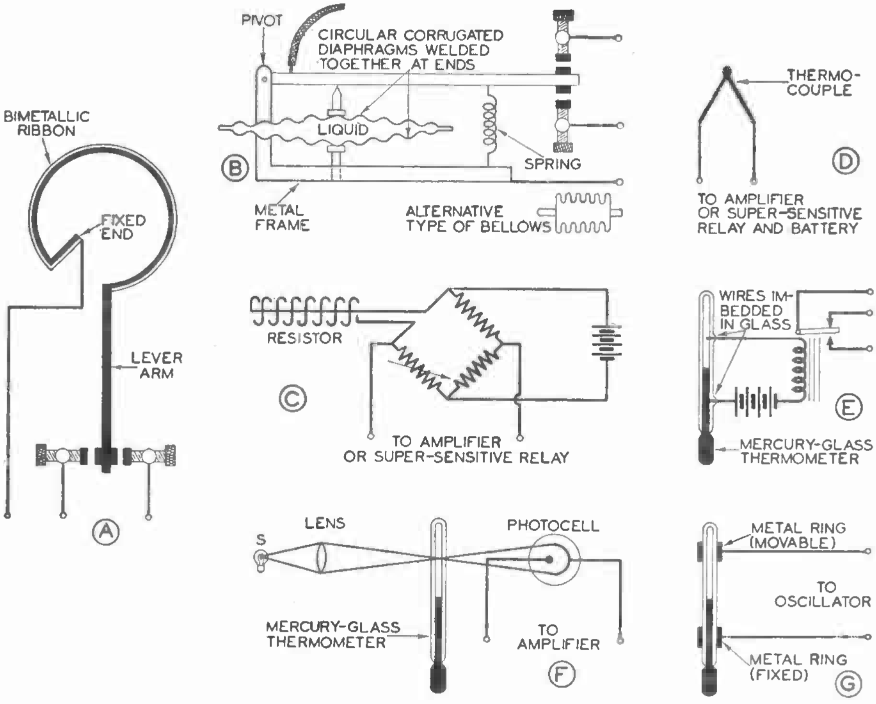


Fig. 21. Seven different methods of converting changes in temperature into electrical changes.

An alternative adjustable thermometer method is pictured in Fig. *21G*. The column of mercury varies the capacity between two metal rings slipped over the thermometer, this change in capacity changing the intensity of oscillation of a capacity control like that shown in Fig. *20*, and thus causing a relay to pull up.

Humidity Controls. All practical humidity controls operate upon the principle that a porous detecting material, such as paper or human hair, will stretch more when damp than when dry. A humidity control depending upon the expansion of paper when damp is shown in Fig. *22A;* a thin layer of the paper is cemented carefully to a very thin coiled strip of hard brass. The paper keeps the coil spring under tension (wound up) when dry, but when humidity rises the paper becomes damp and offers less resistance to the uncoiling of the spring, thus closing the contacts. Naturally, in a system like this, high contact pressures are difficult to obtain; this scheme is used extensively, however, in direct indicating humidity meters.

A more reliable humidity control, which in one case is used to tilt a heavy-duty mercury switch, is pictured in Fig. *22B*. Human hairs arranged in bundles are here kept under tension by a spring; as the hairs become damp with rising humidity, the spring stretches the hairs to a greater length, moving the lever arm and tilting the mercury switch. By adjusting the position of the switch pivot, the control can be set for any desired humidity value within its range, and by changing the position of the pivot on the lever arm the sensitivity of the control can be adjusted.

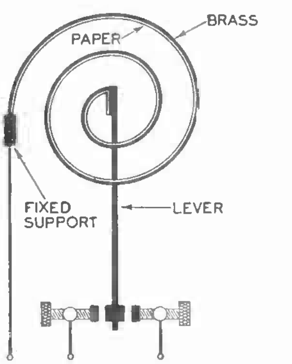


FIG. 22A. Humidity detector using special moisture-absorbing paper cemented to spring brass strip.

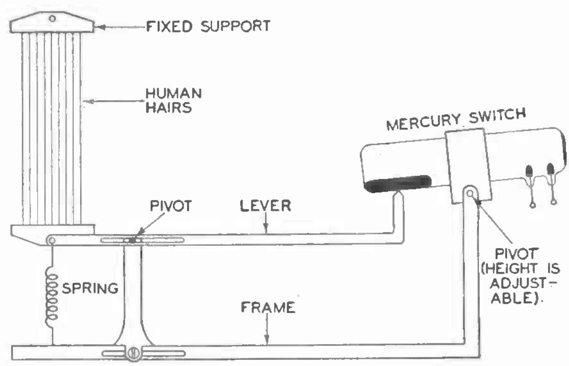


FIG. 22B. Humidity detector for heavy duty operation, using stretched human hairs whose lengths vary with the amount of moisture in the air.

Sound Controls. An ordinary radio microphone serves as a detector in a system where a sound is to start or stop a certain device or machine. The output of the microphone must be amplified and then passed to a vacuum tube stage whose output is practically independent of the frequency of the sound, but is dependent upon the signal intensity.

A self-rectifying A.C.-D.C. audio amplifier circuit for a sound control system is given in Fig. *23;* the type 38 output tube is here highly negatively biased by variable resistor *R6*. The relay is of the latch-in type, so any sound whose duration is greater than the pull-up speed of the relay will operate the relay and give the desired control. This sound control system can be used, for example, to make garage doors open when an automobile horn is blown. A directional microphone is in this case placed above the doors, and directed outward toward the driveway. Potentiometer *R5* is adjusted to give relay operation with the lowest horn noise which will be encountered. With this adjustment completed, extraneous noise from the street or shouting will have no effect upon the system.

Taste Testers. At present it may be stretching the imagination a little too far to say that a simple detecting device can tell you whether one chocolate bar has more of the chocolate taste than another bar, but it is perfectly possible to tell whether one food product is more sour than another. For example, we can tell whether one lemon, apple, grapefruit, pineapple, or even a glass of vinegar is more sour than another, since all these products contain acids. A taste detecting device consists simply of two probes, one of copper and the other of zinc, which are inserted in the product to be tasted. In an acid fruit or solution these two probes generate an e.m.f., and a microammeter connected across the probes indicates a current flow which is proportional to the acid concentration. By fixing the separation of the probes and the depth of immersion, citrus fruits can be accurately compared as to taste. The sensitivity of the taster can be increased by using a D.C. amplifier.

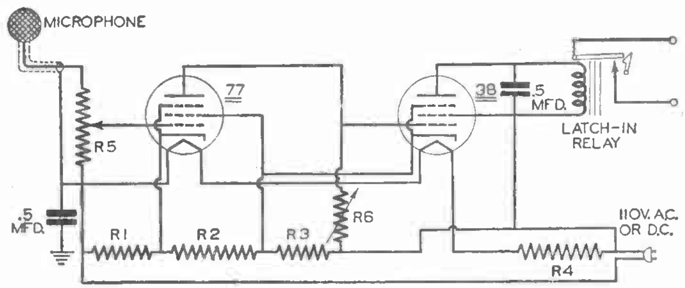


Fig. 23. Two stage audio frequency amplifier for sound control circuit. Circuit constants are: *R1*—75 ohms, 2 watts; *R2*—500 ohms, 5 watts; *R3*—500 ohms, 5 watts; *R4*—325 ohms Cordohm; *R5*—.5 megohm potentiometer; *R6*—.5 megohm variable resistor.

The water content of any product can be checked in much the same manner, if the microammeter is replaced with a megohm meter (an ohmmeter capable of measuring resistance up to about 50 megohms, sometimes called a *megger*). The moisture content of wood is readily checked in this way by driving steel needles into the wood a short distance apart and measuring the resistance between the needles.

Automatic control of the taste of a product can be secured simply by connecting suitable amplifiers and relays to the taste detecting device.

Gas Detectors. It is a well-known fact that gases like carbon monoxide, illuminating gas and hydrogen can cause wires or discs made of platinum black (spongy platinum) to become very hot. This is due to an action called adsorption or surface combustion of gas. Flameless cigarette and gas stove lighters operate on this principle. Naturally the resistance of the material increases with its temperature; this change in resistance can be utilized in a Wheatstone bridge circuit to give any desired control or to operate an alarm when gas is present. A thermocouple placed in contact with the spongy platinum to measure its temperature can also be used as a means of detecting gas.

A wire made with a platinum-iridium alloy exhibits slight surface combustion effects in the presence of various gases (becomes warm), but is not sufficiently sensitive by itself for gas detection purposes. If the wire is primed, however, by sending a steady heating current through it, combustion of the gas increases and temperature changes in the wire become sufficiently great for detection. Platinum is the essential element here; iridium is included only to harden the platinum and make it more resistant to the high temperatures involved.

Unfortunately, spongy platinum makes no distinction between various kinds of gas; this gas detector is therefore limited in its use to conditions where only one kind of gas exists. If hydrogen is a component of the gas in question and the detector is to be operated cold (without a priming current), a mixture of palladium and platinum gives considerably greater sensitivity to gas. Practical applications include searching for leaks in gas pipes and monitoring the amount of hydrogen escaping from alkaline (Edison) storage batteries. Where a selective device is required, such as for detecting the presence of deadly carbon monoxide gas in airplanes, automobiles and garages, a chemical converter type of detector must be used. The chemist sets up a system which causes the carbon monoxide gas to change from one form to another, this action producing a change in heat which can be detected by a thermocouple.

Radio Off-On Controls. Many different schemes have been devised for operating small devices or even airplanes and battleships by radio from distant points. The principle of remote controlled radio operation is quite simple; a low-power, high frequency (about 50 megacycles) oscillator is used at the control station, and a simple tuned input detector receiver whose output feeds a relay is located at the receiving end of the system. The starting of the oscillator causes the plate current in the receiver to rise or fall, depending upon how connections are made, thus actuating the relay which starts or stops the device being controlled. In more complicated systems the oscillator sends out different code signals, and a selective relay connected into the output of the receiver responds to these various codes and performs the desired switching operation. If the codes are kept secret, only the correct transmitter can actuate the selective relay.

Conclusion. Although no attempt has been made in this book to analyze all possible forms of detectors, sufficient information to stimulate your imagination has been given. Radio and mechanical experience, together with an inventive mind, are the requirements for developing electronic controls to replace man's natural senses of seeing, hearing, feeling, tasting and talking.

SINCERITY

We are often told that a man must rely on himself for success. In one way this is true—but it is not true that a man can become successful in any line of work without the cooperation of others. Were it not for the fact that we are all living together in associations of various kinds, there would be no point in striving for success, or in being successful.

For this reason, men who desire to become successful can not ignore other people; they can not ride rough-shod over the feelings of others; they must be considerate, courteous, fair, honorable.

Possibly we can sum up all this in two words—be sincere. If you are really sincere, you will be honest, fair, kind and considerate.

All truly successful men are sincere. Success built on insincerity is not success; it can not last, nor is it complete and satisfying. Only merited success is complete and satisfying. Be sincere—if you want the kind of success that brings happiness.