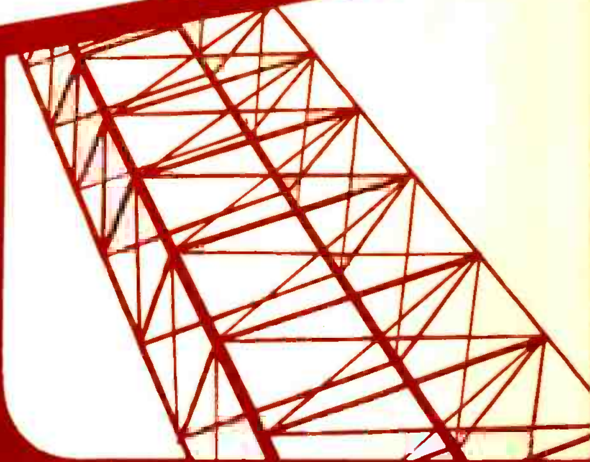
Automatic Tuning Systems

Lesson RRT-13



De Forest's Training, Inc.

2533 N. Ashland Ave., Chicago 14, Illinois

RRT-13

Radio Reception and Transmission

LESSON RRT-13

AUTOMATIC TUNING SYSTEMS

CHRONOLOGICAL HISTORY OF RADIO AND TELEVISION DEVELOPMENTS

1922—The first commercial radio program was broadcast over station WEAF.

1922—Powel Crosley, of Cincinnati, secured the first commercial broadcast station license under the call letters WLW.

1923—The first presidential message to congress to be broadcast was delivered by President Coolidge.

1923—The first chain program to be broadcast was transmitted by stations WEAF (New York) and WNAC (Boston).

1923—Pictures of President Harding transmitted by radio from Washington to Philadelphia (130 miles) by Charles F. Jenkins, American television pioneer.

DE FOREST'S TRAINING, INC.
2533 N. ASHLAND AVE., CHICAGO 14, ILLINOIS

RADIO RECEPTION AND TRANSMISSION

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AUTOMATIC TUNING SYSTEMS

INDEX

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Initiative—The men who exercise initiative are the builders of the world. All others are merely tenants or janitors.

Enterprise—People who aren't afraid to roll up their sleeves seldom lose their shirts.

Knowledge—The only jewel which will not decay.

Self-Analysis—If you're willing to admit you're all wrong when you are, you're all right.

Opportunity—Opportunity seldom calls on people who aren't worth a rap and who can't stand a knock.

—Selected

AUTOMATIC TUNING SYSTEMS

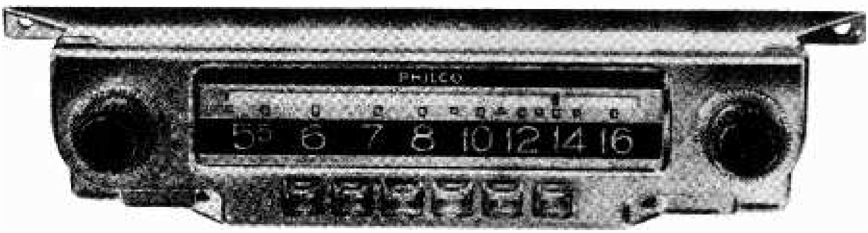
Since the introduction of the superheterodyne in 1916, there have been no important changes in the basic circuits of radio receivers. However, there has been a continuous series of developments or refinements to improve the sensitivity, increase the efficiency and simplify the operation of all types of radio and other electronic devices. Thinking of the home type of broadcast receiver, which far outnumbers all other types of radio apparatus, simplicity of control is an extremely important feature.

It is a commonly accepted fact that a large majority of listeners cannot tune their receivers properly by ear alone, therefore, automatic or push-button tuning has now been adopted by practically every manufacturer. However, automatic station selection is not new, but rather a refinement and perfection of principles which have been in use for many years.

Although the subject seems very broad, there are only three main typs of automatic station selector systems which may be classified as:

1. **Mechanically Operated Manual Types**
2. **Motor Operated Types**
3. **Tuned Circuit Substitution Types**

The object of this lesson is to give you an explanation of these basic systems so that you will readily understand the principles of operation in any automatic tuning system that you may encounter.



Pushbutton control panel, also equipped with manual tuning control at right and volume control at left.

Courtesy Philco Corporation

MECHANICALLY OPERATED MANUAL TYPE

As the heading indicates, this type of system is mechanically operated and functions without any electrical action. Due to this fact, anyone without technical training can understand the operation simply by inspecting the system.

In general, however, the tuning condenser is rotated to the desired station position by direct mechanical effort of the person operating the receiver. This is accomplished by an arrangement of push buttons, mechanically connected to a system of gears, cams and levers, which in turn are connected to the rotor of the tuning condenser gang.

The stations are pre-selected and the system is "set up" to them and locked. When this has been done, it is necessary only to push a button or lever, which then mechanically rotates the tuning condenser to the exact position to tune in the corresponding station.

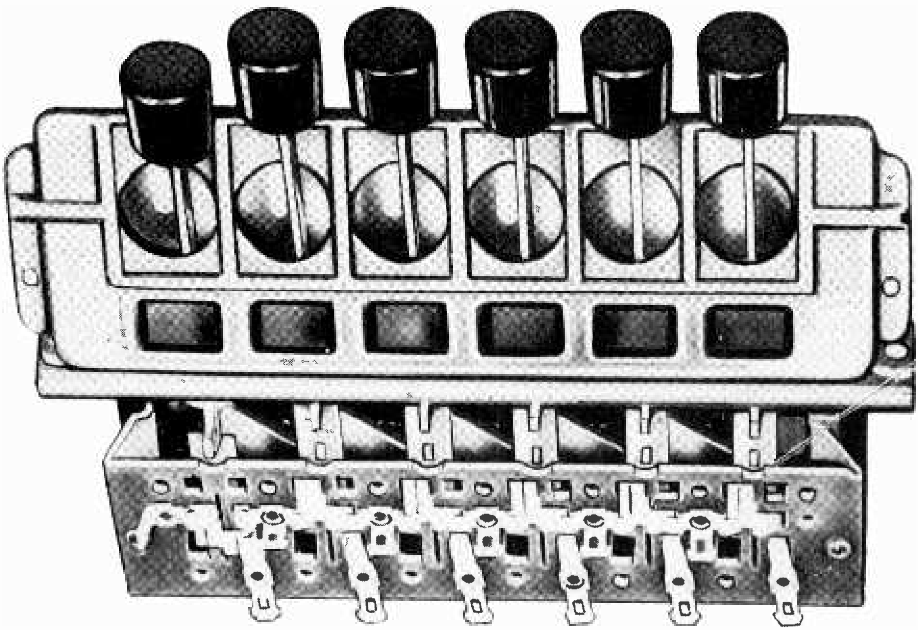
MOTOR-OPERATED TYPES

With the motor-operated type of system, the rotation of the variable condenser gang to a position corresponding to the desired station tuning point, is accomplished by means of an electric motor. Usually this system includes an electric motor, a station selector switch or group of selector buttons, a selecting commutator or other device for stopping the motor, and an audio silencing circuit which operates while the motor is running.

To describe the actual operation, in Figure 1 we show the simplified circuits of such a system in which you will find the commutator mechanically connected to the condenser gang. The selector switches are connected in the electrical circuits of the motor windings L, L_1 and L_2, the commutator and supply transformer. The motors employed in these systems are split-phase induction types which merely means that the current in L_1 or L_2 may be out of phase with the current in L. Such arrangements permit greater torque or turning effort of the armature. No direct electrical connections are made to the armature, which is not shown in Figure 1, but is coupled mechanically to the condenser shaft.

The motor circuit can be traced from the upper end of the secondary of the supply transformer, through switch 5 and the motor windings up to the commutator. From here the circuit is completed through the selector switches to ground and through it to the grounded end of the secondary. Selector switches 1, 2, 3 and 4 are normally open, but close their circuits when pushed or depressed. Switch 5, which is used to change from manual to automatic tuning, has the opposite action and is normally closed, but opens its circuit when depressed.

Mechanically, the arrangement operates so that when any one switch button is depressed, all of the others are released. Thus, in normal operation, only one switch button will be depressed at any time. However, should two or more buttons be depressed at the same time, they will remain in that position until released by the operation of another button.



Automatic pushbutton station selector as used on small radio receivers.
Courtesy Meissner Manufacturing Company

In order to follow the action, we will assume that the receiver is in operation and you desire to set up the push buttons to your favorite stations which we call A, B, C and D. As button 3 is shown depressed, your first step would be to depress push button 5, which would release button 3, and then manually tune in station A. As this is done, we will assume the insulated strip of the commutator moves to a position between contacts 1 and 2. With station A carefully tuned in, you depress push button 1 while holding in button 5, thus opening switch 5 and closing switch 1.

Under these conditions, there is a circuit from the supply secondary through the indicator lamp connected across open switch 5, through coils L and L_1 to the commutator, to contact 1 and through switch 1 to ground. Therefore, this is a complete current path which will cause the indicator lamp to light. Although carried by the motor windings, the lamp current is too small to cause the armature to rotate.

With the insulated section of the commutator between contacts 1 and 2, contact 1 is moved until it rests on the commutator insulation where it breaks the circuit and causes the indicator lamp to go out. Remember also, that this is the position of the selected station A. With this adjustment made, suppose you release push buttons 1 and 5 and manually revolve the tuning condenser and commutator to the position shown in Figure 1.

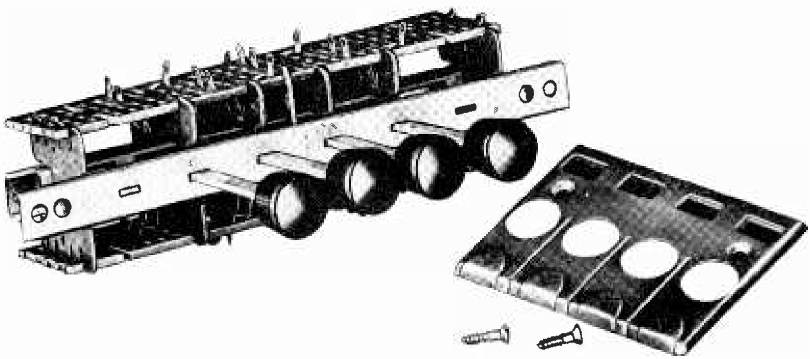
Then, as switch 5 is closed when released, the indicator lamp is shorted out of the circuit, but by depressing push button 1 only, there will be current in the motor coils L and L_1, the commutator, contact 1 and to ground through depressed switch 1. This current causes the armature of the motor to revolve in a counter-clockwise direction, and due to its mechanical connection to the condenser shaft, both the condenser and commutator revolve in the same direction. This motion will continue until the insulated segment of the commutator moves under contact 1 thus breaking the circuit and stopping the motor. As the position of contact 1 conforms to the manual setting of the tuning condenser for Station A, the motor has automatically tuned in this station.

Starting with the commutator insulation in a horizontal position, instead of vertical as shown, the motor current will be from the supply through coils L and L_2, thus making the armature and commutator revolve in a clockwise direction until the circuit is broken by the insulated segment and Station A is tuned in again.

Buttons 2, 3 and 4 are set up in exactly the same way as button 1, and will correspond to Stations B, C and D. Once these buttons are set up, it is only necessary to depress one of them, and the station corresponding to it will be tuned in automatically. In Figure 1, button 5 is used only to change from manual to automatic tuning and to assist in the original setting up of the selectors or push buttons.

In the beginning of this explanation we told you that usually, an audio silencing system is applied to this type of automatic tuning. This action is accomplished generally by positioning the armature of the motor slightly out of the center of the magnetic field set up by the motor coils. It is held in this off-center position by a flat phosphor bronze spring which is connected electrically to ground. A contact connected to the grid of the first audio tube, is placed close to the spring. When the motor windings are energized, the armature is drawn into the center of the magnetic field, pushes the spring over and closes the circuit between it and the audio contact. This grounds the grid of the first audio stage and thus silences the system. When the motor windings are not energized, the spring holds the armature out of position and opens the contacts thus allowing the audio amplifier to operate normally.

There are many variations of motor driven tuning systems, but basically they are all the same. Therefore, if you fully understand the operation of the arrangement in Figure 1, you will not have any difficulty with others. The number of push buttons will depend on the designer, and you will find systems using more or less than the number shown.



Multiple pushbutton switch used for automatic station selector tuning.
Courtesy P. R. Mallory & Company, Inc.

TUNED CIRCUIT SUBSTITUTION TYPES

In this type of automatic tuning, a latching or ladder-type push button switch selects precalibrated tuned circuits which are substituted for the usual variable condenser-tuning in the input and oscillator circuits. In general, these pre-set units are of the trimmer condenser and the iron core or "Permeability" tuning types.

Figure 2 illustrates an arrangement using trimmer-condenser tuning, and in order to simplify the explanation, only those circuits which are directly affected are included. That is, the condenser-tuned input circuit LC, and the tuned oscillator circuit C_1-L_1. In all of these circuits, a switching arrangement is necessary to change from manual to automatic tuning, and in Figure 2 this is accomplished by switch 1. The upper pair of contacts control the tuned input circuit and the lower pair of contacts control the oscillator circuit. Each pair of contacts, of course, is insulated from the other.

Auto radio receiver equipped with 5-button automatic station selector.
Courtesy General Motors Corporation

When button 1 is depressed, the upper pair of contacts is shorted, thus closing the circuit between C and L, which connects also to the input grid of V_1. This tube is a pentagrid converter, and the associated circuits serve as the 1st detector and oscillator sections of a superheterodyne receiver. Button 1 also closes the lower contacts and connects C_1 to L_1, which in turn, connects to the oscillator grid of V_1. Under these conditions, the circuits are conventional and the receiver tunes manually.

Suppose now we depress button 2, which as explained for Figure 1, releases button 1. This will disconnect condenser C from coil L and substitute trimmer condenser C_2 in its place. Likewise, in the oscillator section, condenser C_1 will be replaced by trimmer condenser C_3. However, coils L and L_1 remain in their proper circuits.

Thus, if C_2 and C_3 are adjusted and set to properly tune in some desired station, it can be received by simply depressing button 2. The other buttons, 3, 4 and 5, operate exactly the same as 2, and it is only necessary to adjust their trimmer condensers to tune the desired stations. Once this is done, the stations can be received by simply depressing a button. For manual tuning, button 1 is pushed and locks in position until another button is depressed.

Figure 3 illustrates a little different system of substitution push button tuning but before explaining the action we want to describe the operation of switch 5. This switch is made up of two parts, one of which is connected to condenser C_3 while the other, as shown by the broken line, controls a sliding contact that changes the operation of the receiver from manual to automatic tuning.

When this switch is closed, both ends of condenser C_3 are at ground potential, thus making the push button assembly inoperative. Also the sliding contact is moved so that the upper three circuits on each side are connected together while the lower contacts are open.

Tracing through these circuits, you will find this movement of the contacts simply makes connections so that the manual tuning circuits, L_2-C_2 and L_6-C_8 are operative. The resistor-condenser combination of R_1 and C_5 is employed so that the input grid circuit can be controlled by avc.

This automatic tuning system makes use of the fact that the inductance of a winding varies directly with a change in the permeability of its core material. To make use of this action, specially prepared iron slugs, which have very low loss at radio frequencies, are placed inside of the coils and arranged so that they can be moved in or out mechanically.

From your earlier lessons you know that the permeability of these iron slugs will be much higher than that of air, and as they are moved in and out of a coil, its inductance will vary accordingly. With a variable inductor and fixed capacitor, a circuit can be tuned over a definite band of frequencies, the same as with a fixed inductor and variable capacitor.

In Figure 3 we show four sets of these coils, and have indicated their functions by marking them "Antenna" and "Oscillator". It is quite easy to gang the iron slugs mechanically so that each pair may be tuned by one adjusting knob, such as indicated by the dotted line arrows. Turning this knob will move the slugs in or out of both coils as desired.

The arrangement of the push button circuit is very similar to that of Figure 2, except that here there are tuned coils instead of tuned trimmer condensers. Like the trimmer condensers, the coils are preset or tuned to the desired station, which can then be heard simply by depressing the proper button.

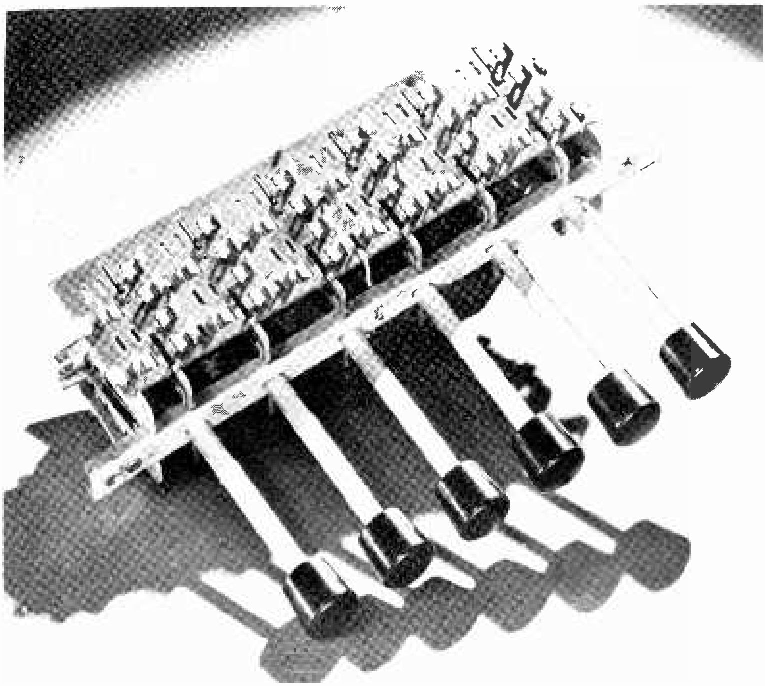
With switch 5 in the position shown, the antenna is coupled to the input grid of the first detector or mixer tube V_1, through condenser C_1, while condenser C_3 is employed to compensate for variations in antenna capacitance. In the oscillator circuit it is necessary to include adjustments which provide tracking between the oscillator and mixer input circuits.

As explained in the earlier lessons, for the condenser tuned circuits this may be accomplished by means of trimmer and padder condensers working in conjunction with the oscillator section of the variable tuning condenser. However, as no variable condenser is used with the iron-core coils, a different method must be employed.

It has been found that a small winding, connected in series with the oscillator grid end of the automatic windings, and placed so as not to be affected by the iron core, will, if properly designed, permit proper tracking at the high frequency portion of the tuning range. Also, when two inductances are connected in parallel, the maximum inductance is limited by the size of the smaller of the two, just as the equivalent resistance of two parallel connected resistors is limited by the value of the smaller.

In Figure 3, coil L_3 is the padder winding and also serves as a means of coupling to the oscillator anode coil L_4. When used in conjunction with the smaller winding mentioned above, which is L_5 in Figure 3, the arrangement allows excellent tracking. Variations of temperature and humidity are compensated by means of C_6 which is a small fixed condenser composed of silver surfaces sprayed on a special ceramic tube. Changes of capacitance due to temperature and humidity then are opposite to corresponding changes in the coil.

Another variation in the arrangement of the circuit components in Figure 3 is that of the "shunt feed" avc circuit mentioned in a former assignment. Instead of the "series feed" circuit to the control grid of the tube as illustrated by the avc "Bus" leading to coil L of Figure 2, the avc circuit of Figure 3 does not contain the tuned circuit. Instead, the control voltage is routed through R_1, while signal voltages are coupled to the control grid through C_1.



Multiple circuit pushbutton switch employed in radio receivers for automatic tuning.
Courtesy P. R. Mallory & Company, Inc.

The main advantage of the substitution type of automatic tuning, compared to the motor driven type, is that a station is tuned in as soon as the button is depressed. In the motor driven type it is necessary to wait until the commutator and condenser gang have rotated to the desired setting. Both, however, have an advantage over the mechanical systems which are sometimes difficult to tune exactly to resonance.

TUNING INDICATOR

Since the advent of avc, radio receivers have been equipped with various types of tuning indicators, practically all of which operate as a result of the avc action.

A number of factors are responsible for the widespread adoption of tuning indicators of one type or another. In addition to their usefulness in tuning to exact resonance, manufacturers realize that their incorporation constitutes an important item in increasing the attractiveness and salability of their receivers.

You have, no doubt, seen various shapes and sizes of receiver tuning indicators, and for the most part, probably each seemed separate and distinct. However, all types can be placed in one of the following three general classes:

1. **Meter type indicators**
2. **Saturable core type indicators**
3. **Cathode ray indicators**

For the remainder of this lesson, we will explain the operation of each type and show you how they are connected.

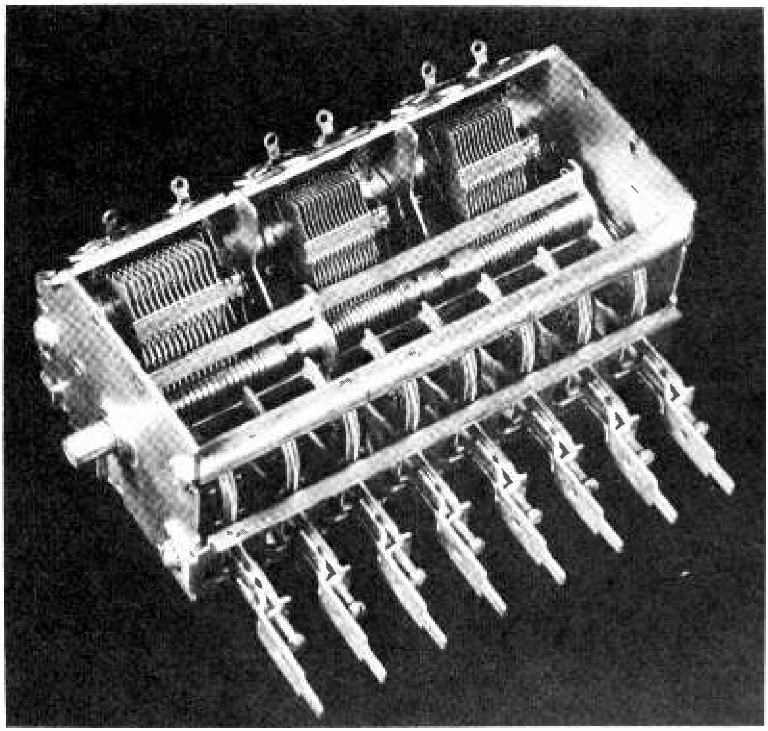
METER TYPE TUNING INDICATOR

From the explanations of the earlier lessons, you will remember that avc operates by developing a negative voltage in the grid circuits of one or more r-f, mixer, and i-f tubes. The magnitude of this control voltage depends upon the amplitude of the signal that reaches the second detector, and applied to the grids of the controlled tubes as a negative bias, it affects the plate currents. That is, when a strong signal reaches the avc rectifier, there is a high negative bias on the control grids, and the plate currents are reduced. When a weak signal reaches the second detector or avc rectifier, the controlled tubes have a minimum negative bias and comparatively high plate current.

From your former study of parallel tuned circuits, you know that at resonance, the amplitude of the a-c voltage drop across them will be maximum. Applying this action to the functioning of a receiver, as a station is tuned in, the voltage at the second detector gradually increases and becomes maximum at resonance. This causes a maximum control voltage to be applied as a negative bias to the controlled tubes, and as a result, the plate currents are reduced.

Therefore, if a sensitive current meter is placed in the plate circuits of the controlled tubes, it will register minimum current when a station is properly tuned in. The exact swing of the meter pointer will depend on the negative bias voltage applied to the controlled tubes, which, in turn, depends on the strength of the input signal.

In Figure 4 we show a simplified arrangement of such a system, and you will notice the meter is connected in series with the plate circuit of the controlled tube V_1. Tube V_2 acts as a second detector and avc rectifier, the avc control voltage being developed across R_2 and C_4, while resistor R_1 and condenser C_5 form a one-section avc filter. The control grid of V_1 is connected to the lower end of R_1 through the i-f transformer secondary L_1, and the cir-



Combination variable capacitor equipped with mechanical pushbutton tuner.
Courtesy Radio Condenser Company

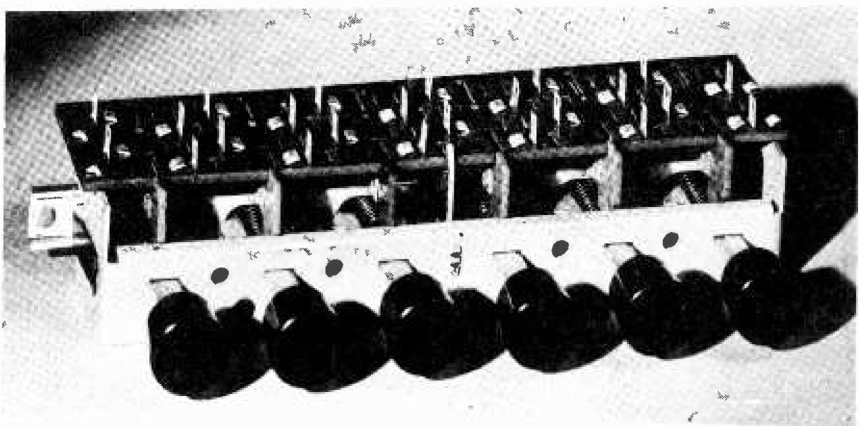
cuit is completed to ground through R_1 and R_2.

With no signal on the control grid of V_1, there will be minimum bias voltage, and maximum plate current will be registered by the meter. When a signal is tuned in, there will be a voltage drop across R_2 which will increase the negative bias on the control grid of V_1 and thus reduce the plate current. Therefore, to tune to resonance with an incoming carrier, the tuning controls are adjusted until the meter registers minimum plate current for that station.

In practice, you will find the indicating meter camouflaged in many different ways, the most common, perhaps, being the shadowgraph or shadow meter.

In its construction, the shadowgraph indicator mechanism employs a small permanent magnet which is in the form of a circular flat ring having a small air gap. The moving armature, which forms the indicating part of the system, consists of a flat disk of soft iron, with a central rectangular slit, mounted within the ring so that it pivots on two opposite supports.

A thin, black, opaque vane is mounted in the middle of the slit and rigidly attached to the iron armature so that any movement of the armature is accompanied by a corresponding rotation of the vane. A coil of wire surrounds the permanent magnet in such a way that the current it



Six-button switch used for selective tuning in radio receivers and inter-office communication systems.

Courtesy P. R. Mallory & Company, Inc.

carries sets up a magnetic field at right angles to the plane of the permanent magnet.

With this mechanical arrangement, the magnetic field of the permanent magnet tends to keep the armature in a horizontal plane because the air gap allows the leakage flux to penetrate the soft iron of the armature. Under this condition, the armature assumes a position which enables the maximum amount of leakage flux of the permanent magnet to pass through it. In other words, the permanent magnet acts as the force which holds the armature at the zero current position.

The deflection of the armature and therefore the vane, is due to the magnetic field created when there is current in the shadowgraph coil. Its field is at right angles to that of the permanent magnet, and therefore the combined field is distorted or changed in direction sufficiently to rotate the armature and attached vane. The greater the current in the coil, the greater its magnetic field and consequently the greater the angle through which the armature and vane are rotated.

Omitting the intermediate steps, the action of the shadowgraph is essentially that of a meter, and therefore it can be used in place of the meter shown in Figure 4. The only difference is that instead of an ordinary pointer indicator, it has an optical system arranged so that the reading is represented by the width of the shadow formed on a screen.

The simple optical system is composed of a pilot lamp placed so that the light is transmitted through the slit to a small screen. As the vane is located in the slit, the width of the shadow cast on the screen will be determined by the position of the vane, which in turn is controlled by the current in the coil.

In most cases, the position of the vane is such that with maximum current the shadow will have its greatest width. Therefore, when tuning in a station, the avc action will cause the shadow to narrow and become minimum at resonance.

SATURABLE-CORE TUNING INDICATORS

The operation of the saturable-core tuning indicator depends upon the variable impedance of an iron core inductor which carries a magnetizing direct current. This may seem rather complicated, but the principles involved here have already been covered. Filter chokes, as used in the ordinary power supply, carry both a-c and d-c components and usually are rated in accordance with the values of direct current they will carry safely. This value of direct current must not be exceeded if the inductance of the filter choke is to be maintained.

In other words, the inductance of the choke coil depends to a marked degree upon the value of direct current in the coil. When the direct current in an iron core coil is excessive, the core becomes "saturated" and the inductance falls to a very low value.

This is due to the fact that when the core is saturated magnetically, it is impossible for the flux to change in accordance with the variations of coil current. This means there will be less self induction and thus a lower value of reactance or impedance.

In Figure 5 we have plotted a curve of direct current against inductance, or impedance, in an iron core coil. With the origin or zero values at the lower left, as the direct current increases, the impedance of the coil decreases. We do not show any actual values, because at the present time we are interested only in the general shape of the curve.

To employ this principle for tuning indicators, generally it is found necessary to isolate the d-c winding used to saturate the core, from the a-c winding which operates the tuning indicator, by using a transformer with two windings as shown in Figure 6.

Although this is a simplified circuit, it will show the action which takes place. The primary winding L_1, connected in series with the battery and variable resistor R, is used to carry the d-c and saturate the core. The secondary L_2, in series with the lamp, is connected across a low voltage a-c supply which, in a receiver, generally consists of a winding on the power transformer.

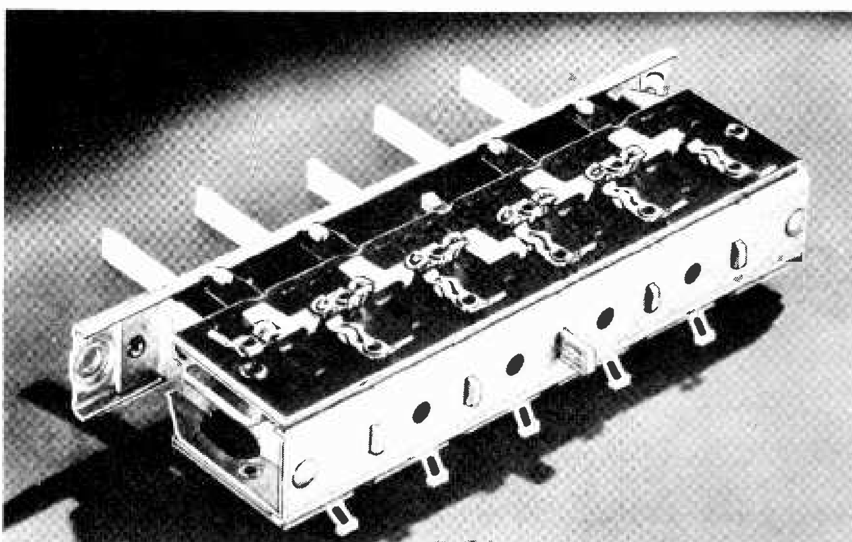
As coils L_1 and L_2 are wound on the same core, the magnetic circuit or field is the same for both therefore, changes of direct current in L_1 will cause changes in the inductance of L_2. With variable resistor R adjusted to allow but a small current in coil L_1, according to the curve of Figure 5, the inductance of coil L_2 will be high. This high value of inductance allows but a comparatively low alternating current in coil L_2 therefore the series connected lamp lights dimly, if at all.

With variable resistor R adjusted to allow a high current in coil L_1, according to the curve of Figure 5, the inductance of coil L_2 will be low. This low value of inductance allows more alternating current in coil L_2 and the series connected lamp lights more brightly. Thus, with a constant a-c voltage across L_2 and the lamp, the current in the circuit is controlled by the direct current in coil L_1. With coil L_1 connected in place of the meter of Figure 4, variations of plate current would cause corresponding changes in the brilliance of the lamp of Figure 6.

The simple transformer arrangement of Figure 6 is not satisfactory for use in radio receivers because the a-c voltage in coil L_2 will induce a voltage at the same frequency in L_1, which usually is connected in the plate circuits of the avc controlled tubes. This condition, of course, would cause an a-c hum in the speaker.

To overcome this difficulty, the windings are placed on a three-leg transformer core as shown in the lower part of Figure 7. The primary or d-c winding L_6, wound on the middle leg, has one end connected to the plates of tubes V_1 and V_2 through the primaries of their i-f transformers, and the other end is connected to B+. Thus, coil L_6 will carry the plate current of both tubes.

The secondary winding is in two sections, L_5 and L_7, wound on



Five-button multiple switch used as an automatic station selector on radio receivers.

Courtesy Oak Manufacturing Company

the outer legs of the core. These two sections are joined in such a way that the a-c in each of them will induce equal and opposite voltages in the primary L_6, and thus no net a-c voltage appears across it. The lamp and both secondary sections are connected in series across an a-c source.

The remainder of Figure 7 includes the partial circuits of two i-f amplifier tubes, V_1 and V_2, the control grids of which are connected to an avc voltage. When there is no input signal across coil L_1, the negative bias on the control grids of V_1 and V_2 will be minimum and the plate current maximum. As this current is carried by L_6, it will tend to saturate the core of the indicator transformer, lower the impedance of the secondary and allow the lamp to burn brightly.

When a signal is tuned in, the avc action will increase the negative bias on the control grids of V_1 and V_2, and cause a decrease in their plate currents. This, in turn, will increase the inductance of the secondary and dim the lamp. Therefore, with this system, resonance with an incoming signal will be indicated by a dimly lit lamp.

Another application of the saturable core principle makes use of different colored lights to indicate resonance. As far as the mechanical arrangement is concerned, the lighting is accomplished by means of four red bulbs and three green bulbs spaced alternately behind the linear dial scale.

When no signal is tuned in, the red bulbs light brilliantly and the green bulbs are so dim that the net result is a red glow over the entire scale. When the signal is accurately tuned in, the red bulbs are dim and the green bulbs are sufficiently brilliant to cast a green glow over the scale. For intermediate positions, when the signal is only partly tuned in, the illumination is a combination of green and red which combines to produce a whitish light. As a signal is tuned in, the sequence of changes will be from red to white to green, which indicates resonance.

The electrical system which provides this action is shown in the circuits of Figure 8, where coils L_1 and L_2 are the primary and secondary of a saturable core transformer like that explained for Figure 6. A separate tube V_1, employed to provide the d-c saturating current, has its control grid connected to the source of avc voltage.

The lamp network consists of seven pilot lights connected to the secondary L_2, while the a-c voltage is obtained from a winding on the power transformer of the receiver. In this explanation we will consider lamps T_1, T_2 and T_3 green, with T_4, T_5, T_6 and T_7 red.

Also, we will assume the impedance of L_2 varies from 25 ohms to 700 ohms, the exact value at any instant depending on the plate current of V_1. That is, with no signal the negative bias on V_1 will be minimum and the plate current high, resulting in an impedance of 25 ohms for L_2. With a strong signal, the negative bias on V_1 will be maximum and the plate current low, causing the impedance of L_2 to increase to 700 ohms.

With a "no signal" condition in the receiver, tube V_1 will draw its maximum plate current and cause a 25 ohm impedance in L_2. The resistance of the three series connected green lamps will be quite high in comparison and the current in them so small that they will barely light. Under these conditions, however, the total current in L_2 and the green lamps will be comparatively high and, carried by the red lamps, will cause them to light brilliantly.

When the receiver is tuned to a strong signal, increased negative avc bias voltage will reduce the plate current of V_1 and cause the impedance of L_2 to increase to 700 ohms. In comparison with the resistance of the green lamps, this value is large enough to consider L_2 as an open circuit.

With L_2 thus eliminated, in effect the green lamps are in series with the red lamps, but the total current is less than in the former "no signal" condition because the shunting effect of L_2 is removed. Not only is the total current reduced, but because of their parallel-series connection, the current in each red lamp will be only half of that in the green lamps.

The decrease in total current, and the division of current between the two parallel branch circuits of red bulbs, causes them to light dimly but the total current from the a-c source must pass through the green lamps and therefore they light to full brilliancy.

To summarize the overall action, the red lamps light brilliantly with no signal while the green lamps are brilliantly illuminated when the station is correctly tuned in, and the change depends on the variable impedance characteristic of the secondary coil L_2, controlled by the plate current in coil L_1.

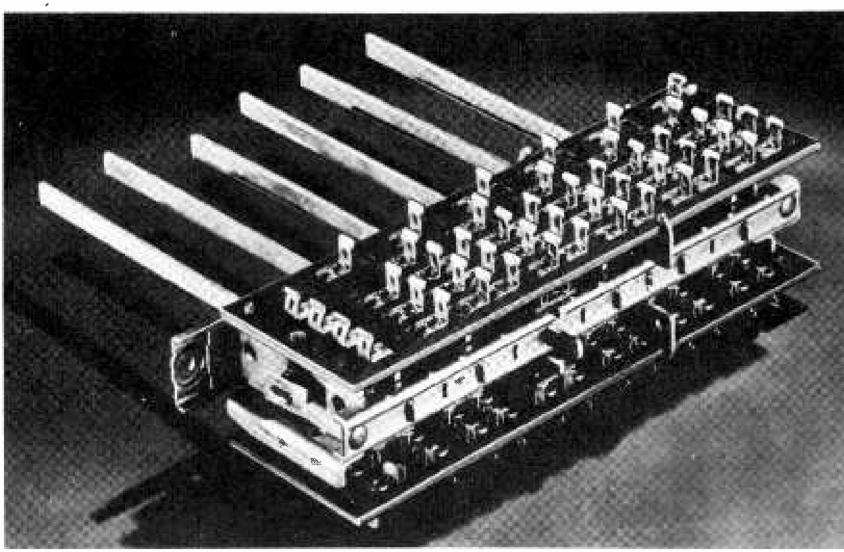
CATHODE-RAY TUNING INDICATOR

Perhaps the most common type of tuning indicator, is the "Magic Eye" tube, of which the 6E5 and 6U5 are examples. The action of this tube is very interesting but before going into detail, it is necessary to explain the location of the various elements which make up the entire assembly.

Figure 9 is a simplified cross-sectional view of this type of tube, with all of the various elements properly located and

we suggest that you review the earlier lessons.

The other section consists of the cathode with a light shield on its outer end, the ray control electrode, and the target which is coated with a material that



Multiple circuit pushbutton-operated station selector applicable to radio receivers, test instruments, communication systems, etc.

Courtesy Oak Manufacturing Company

marked. The left-hand lettering refers to external terminals, but of greater importance is the respective locations of the active elements. Essentially there are two separate tubes with a common heater and a split cathode. One of these is a triode which functions normally, and in case you have forgotten its operation,

glows or fluoresces when electrons strike it. The purpose of the target is to attract electrons from the cathode and to provide a visual indication by fluorescing over a certain part of its coated area.

The ray-control electrode, shown between the cathode and target, is tied directly to the triode plate. As we will explain later, its action controls the area of the target which is struck by the electrons emitted by the cathode.

The purpose of the cathode light shield, which is made of an opaque substance and placed directly over the outer end of the cathode, is to eliminate any of the light produced by the heater. Usually black in color, it gives the impression of being the pupil of a human "eye".

In the form of a schematic wiring diagram symbol, in Figure 10 the indicator tube is shown connected in a simplified circuit by which the action can be explained. The plus terminal of the 250 volt plate supply connects directly to the target and to the triode plate through resistor R_2, while the cathode connects to the negative of the supply as a return for the plate circuit. From the triode grid, there is a connection to the center arm of potentiometer R_1 connected across a 12 volt battery, the plus of which is tied to the negative of the plate supply.

Forgetting the visual indicating section for a moment, the connections are normal for the grid and plate voltages of a common heater type triode, with potentiometer R_1 as a means of varying the grid voltage.

From former explanations you know that if the arm of the variable resistor is at the plus side of the battery, there will be zero grid bias, the plate current will be maximum, and the voltage drop across R_2 will be high. However, if the arm is at the extreme negative position, the negative grid bias will be maximum, there will be low plate current, and the voltage drop across R_2 will be small.

Go over the above explanation several times, because as the ray-control electrode is connected directly to the plate of the triode, it is actually the triode section which controls the electrons that strike the target.

With an assumed maximum drop of 200 volts across R_2 and a 250 volt supply, there will be 250 minus 200 or 50 volts across the plate cathode of the triode. As the ray-control electrode is connected directly to the plate, the 50 volts will be applied to it also. The target is connected directly to the positive of the 250 volt supply, and thus there is a difference of potential of 250 minus 50, or 200 volts between it and the triode plate, which thus is negative with respect to the target. Go over this last statement again because it is important.

Before going further, we want you to go back to Figure 9 and notice that the ray-control electrode is placed between the target and cathode. When it is 200 volts negative with respect to the target, it will repel the electrons around it so that practically none will reach the portion of the target affected by this action.

Figure 11A is a top or end view of the "magic eye" tube with the cathode light shield removed to show the position of the elements. The shaded area is that part of the target which no electrons strike, and in actual operation it resembles a shadow, while the other portion glows or fluoresces a greenish-yellow color. This large shadow appears when the control grid bias voltage is practically zero, and is due to the repelling action of the ray-control electrode, which does not allow any electrons to strike that section of the target.

Going back to Figure 10 again, but this time with the potentiometer arm in the negative position to provide a high bias voltage, the plate current will be small, and therefore we will assume the drop across R_2 is only 5 volts.

Thus, with 245 volts on the ray-control electrode, the difference in potential between it and the target will be 250 minus 245 or 5 volts. Hence, the ray-control electrode will be but 5 volts negative with respect to the target and will have but little repelling action on the electrons.

Therefore, as shown in Figure 11B, with a high negative voltage on the control grid of the triode section of the tube, the width of the shadow will be practically as narrow as that of the physical dimensions of the ray-control electrode.

In order that you may become familiar with its applications to radio receivers, in Figure 12 we have the simplified connections of a "Magic Eye" to a diode tube V_1 which functions as a second detector and avc rectifier. Here, the 250 volt supply is connected directly to the target and through a dropping resistor R_2 to the plate of the triode section of the tuning indicator tube V_2. The grid circuit is connected across the diode load resistor R, and the drop across it, which depends on the signal strength, provides the negative avc grid bias.

With these connections, when slowly tuning in a station the voltage at point X will gradually become more negative with respect to ground, until at resonance (when the station is exactly tuned in) it will have maximum value. As this voltage is applied to the grid of the triode section, it will cause a variation of plate current which, in turn, will vary the voltage on the ray-control electrode.

Thus, when no station is tuned in, the ray-control electrode will have its greatest negative potential with respect to the target, and the shadow on the screen will look like that of Figure 11A. As resonance is approached, the ray-control electrode becomes less negative, the shadow tends to narrow, and at resonance will look like Figure 11B, the size of the minimum shadow being determined by the physical dimensions of the electrode.

There are several types of cathode-ray tuning indicators in use, but they all operate on the principles explained in this lesson. Some are arranged to give a circular shadow instead of the angular type explained here, and there are also various values of cut-off bias voltage for the triode section. For example, one type cuts off at −8 volts on the control grid while another has a −22 volt cut-off, but in both instances there are +250 volts on the target. This variation of bias voltage is to compensate for the different control voltages developed across the avc rectifier in different types of receivers.

The magic eye is not limited to use in receivers with avc since it operates to indicate a change of voltage across any part of a circuit to which it is connected. For example, it may be connected in the diode circuit of a receiver irrespective of the presence of avc, or it may be connected across the cathode bias resistor of a plate detector. The correct type of indicator tube to be selected for any position then depends on the controlling voltages available.

NULL POINT INDICATOR

The magic eye indicator has many applications in various types of test equipment, one being a null point indicator in bridge circuits. In an earlier lesson we explained the basic principles of the Wheatstone Bridge, and you will recall that some method of indicating "balance" is required. In modified bridge circuits, the use of the magic eye is preferable since it can be made very sensitive in its operation, and is capable of withstanding considerable overload voltage without damage.

Although the explanations in this lesson have been on the so-called "accessories" of a radio receiver, their wide spread application makes a complete understanding of their operation necessary. Therefore, before going to the next lesson, make sure that you know their operating principles and applications.

IMPORTANT WORDS USED IN THIS LESSON

AUDIO SILENCING SYSTEM—An arrangement for rendering the audio amplifier inoperative while a receiver is being tuned from one station to another.

AUTOMATIC TUNING—The application of a mechanical device or electromechanical system by means of which a receiver can be tuned automatically to any one of a group of stations merely by pressing a button or lever.

CATHODE RAY—A concentrated beam of electrons emitted by a cathode in a high-vacuum tube and under the influence of a high positive voltage.

COMMUTATOR—A device for reversing the direction of current in a circuit.

MAGIC EYE TUBE—A form of cathode-ray tuning indicator tube.

NULL INDICATOR—A device used to indicate a state of zero current or voltage in a circuit.

PADDER CONDENSER—A small condenser connected into an oscillator circuit to control the tuning calibration at the low frequency end. In permeability tuned circuits a small inductance coil is used for a similar purpose.

SATURABLE CORE REACTOR—An iron-core reactance or choke coil the inductance of which can be varied by changing the magnetic saturation of the iron core.

SHADOWGRAPH TUNING INDICATOR—A form of tuning meter in which the shadow of a small moving element is cast on a screen.

TARGET—That electrode within a cathode-ray tuning indicator tube to which the electrons are attracted, and that by its fluorescing action gives a visual indication of how accurately the receiver is tuned.

TRACKING—The effect of several tuned circuits operating in step with each other (in unison), and following closely the dial calibrations on the receiver.

TUNING METER—A d-c meter connected in some portion of a radio receiver circuit for use in determining when the receiver is tuned accurately to a given station.

STUDENT NOTES

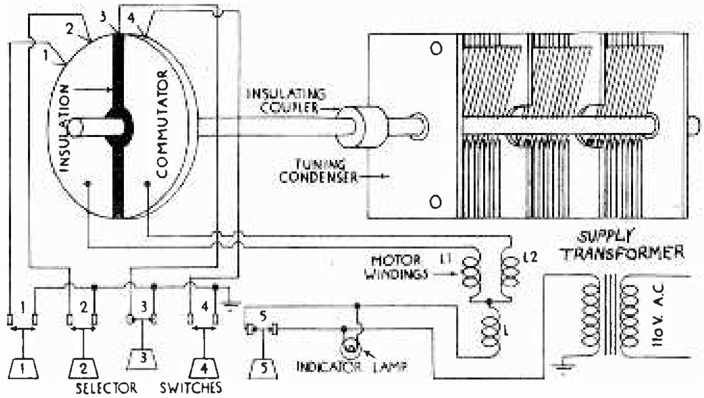


FIGURE 1

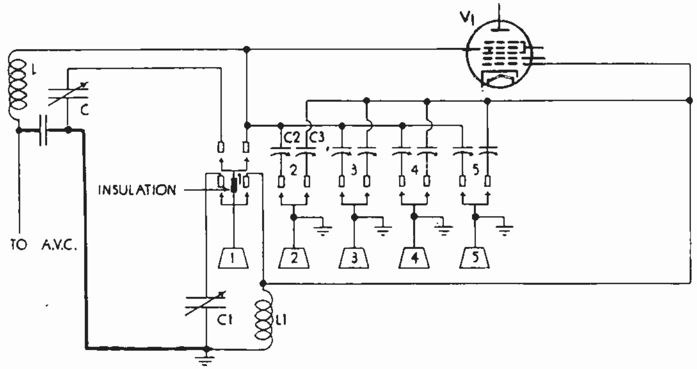
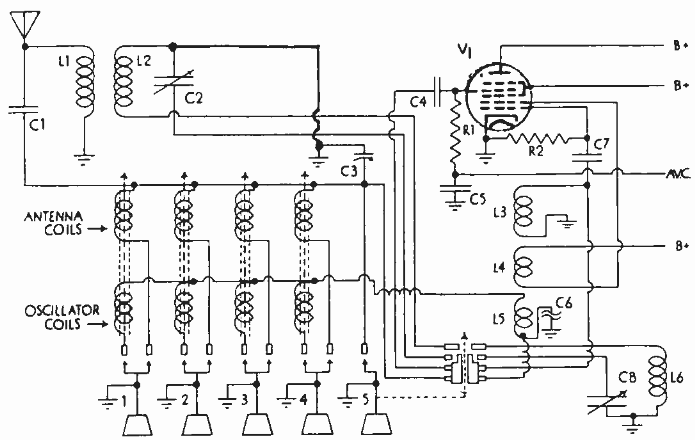


FIGURE 2



RRT-13

FIGURE 3

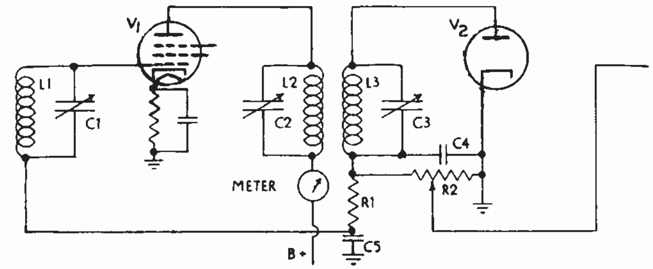


FIGURE 4

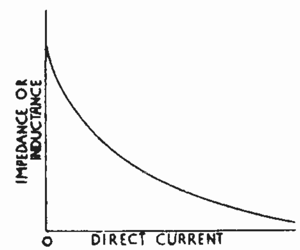


FIGURE 5

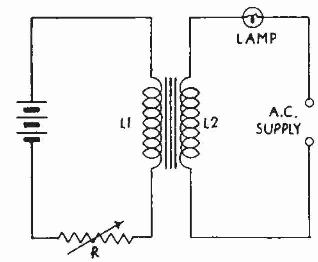


FIGURE 6

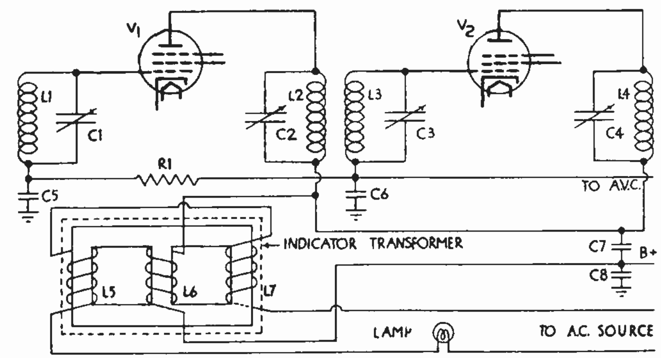
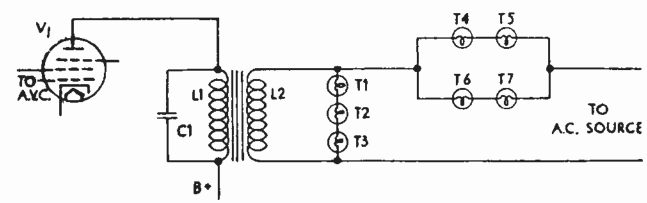


FIGURE 7



RRT-13

FIGURE 8

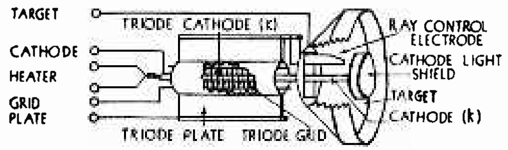


FIGURE 9

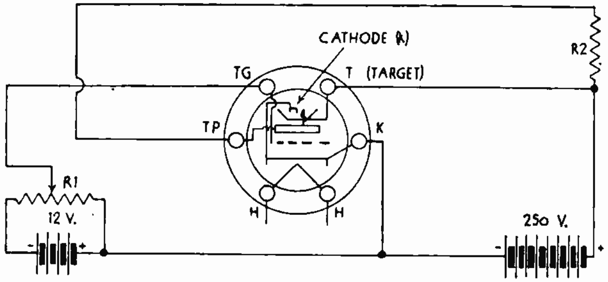


FIGURE 10

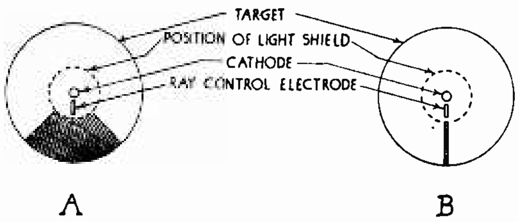


FIGURE 11

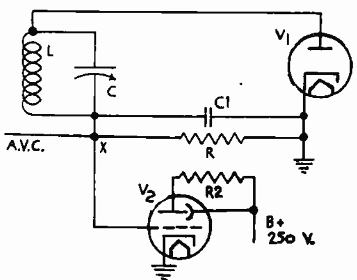


FIGURE 12

FROM OUR *President's* NOTEBOOK

POSITIVE THINKERS

The world contains two kinds of people, negative thinkers and positive thinkers—those who think failure and those who think success. Negative thinkers are afraid to venture anything for fear something might happen. The fellow who, when confronted with a problem, runs to someone else with it because he "might make a mistake." The do-nothings, the nervous wrecks, the failures—these are negative thinkers.

The positive thinkers are happier, more alive, more active, more adventuresome. They get things done. They make mistakes, they're bound to. But as long as their batting average is within reason, as long as what they do makes sense, they're more often applauded than criticized. And they try not to waste their time in fruitless efforts.

Yours for success,

E.B. deVry

PRESIDENT