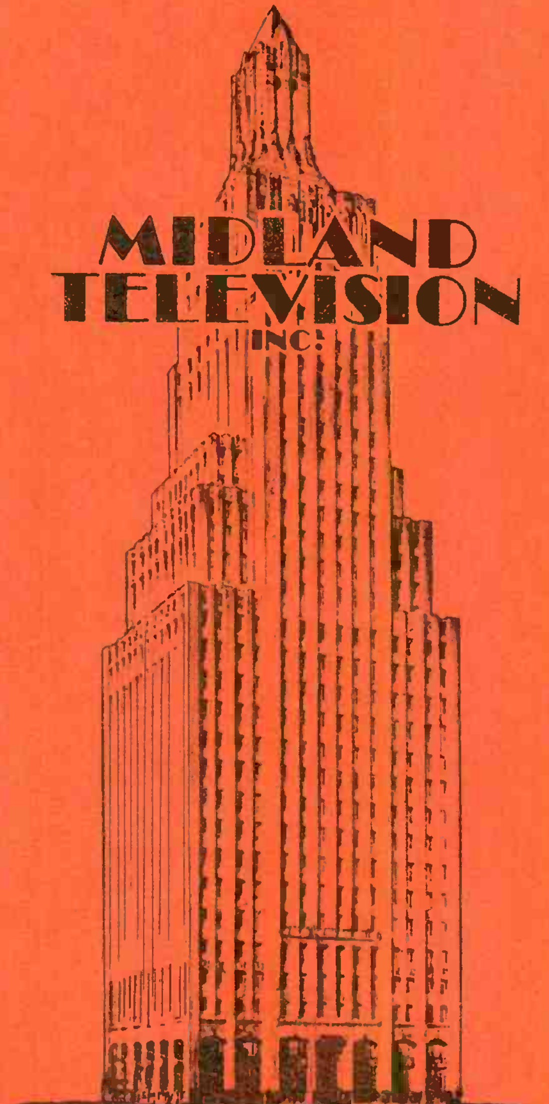
MIDLAND TELEVISION INC.



POWER & LIGHT BUILDING, KANSAS CITY, MISSOURI

UNIT NO. 6

TELEVISION RECEIVER INSTALLATION

LESSON NO. 1

"X"

.....marks the spot.

The caption of this little story may or may not sound familiar to you. It is an expression used frequently in detective or other thrilling stories, but to you who are interested in television, it will have an entirely different meaning.

The installation of a television receiver in a home is not as simple as the installation of a radio receiver. The housewife purchasing a new radio console, usually insists that it be placed in the living room so that it will present the most attractive appearance. Little thought is given to efficient operation. Very little knowledge is necessary to place the set in operation; the delivery man can hook it up.

But when Mrs. Housewife orders her new television receiver, the situation will be very much different. First of all, the installation must be made by a technician who understands television. It will be his job to seek out a "spot" in the living room where the receiver will function to best advantage. Perhaps you wonder how you will go about selecting the right "spot." Don't worry...your Midland training will take care of that.

The fact that television receivers will require the attention of men with training such as you are receiving from Midland, should encourage you tremendously. It means that television servicing will be LIMITED to men with the necessary knowledge. Consequently, fewer men will be qualified for this type of work. This, naturally should result in an increased demand for your services. And the greater the demand, the more money you can make.

By studying every lesson thoroughly so that the knowledge they contain STICKS, you will be able to put an "X" in the right spot easily.

Unit Six

SERVICING MODERN TELEVISION RECEIVERS

"As the sale of television receivers to the public increases, the serviceman will become more and more important. While all manufacturers are attempting to build their sets so that the layman will have no trouble in operating them, this tends to increase rather than decrease service complications.

"The installation of each television receiver presents an individual problem; therefore, only competent and well trained men can be used for this work. It is highly essential that you study this unit carefully so that you can qualify. Regardless of how good a set may be, its performance will depend on the type of installation you make.

"Each time a television set is moved it must be readjusted by an expert, if the best results are to be secured. You should learn your job so thoroughly that you will not have to depend on manufacturer's instructions. Remember, the untrained man will have a very difficult time.

"A radio serviceman of today without special instruction in television servicing, will find himself completely lost and unable to do satisfactory work. The information contained in this unit will provide you with the opportunity of taking advantage of the other fellow's inability. In addition, this unit will supply you with complete information on special television testing equipment. It is important that you learn how this equipment functions, and how it is used".

Lesson One

TELEVISION RECEIVER INSTALLATION

"Regardless of how excellent a television picture may be broadcast, it cannot be properly received unless the receiver is installed correctly. Since each installation will require special consideration it is highly essential that you have a thorough knowledge of the fundamentals involving proper installations.

"Radio broadcast receivers are often installed by the customers; however, this practice cannot be followed in television, if satisfactory reception is to be secured. While this is a fairly short lesson it is of considerable importance to your future success.

"In this lesson, let us assume a television receiver located in a home—the average type American home—in which the television receiver will occupy a space in the living room much the same as does the present radio receiver. Let us also assume that the receiver can show a picture of excellent quality. There are numerous considerations of varying importance which relate to the receiving antenna, the actual location of the receiver in the home, the degree of darkness in the room in which the picture is to be viewed, the distance the observers are seated from the picture screen, and the actual adjustments of the receiver controls themselves. All of these have a direct bearing upon the overall excellence of the reproduced picture, and since the receiver itself is capable of a high definition picture, the final results should not be minimized due to lack of information on the part of the operator. Such questions as, "Must the room be completely darkened?" "What is the best viewing distance?" and "What is the most desirable picture size?" will be answered in the light of scientific knowledge, and with due consideration for the personal element."

1. THE EYE AND ITS RELATION TO TELEVISION. Neglecting the requirements for good sound reproduction, since they are the same in a television receiver as in an ordinary broadcast receiver, let us assume, for the time being, that our information must come through the eye. We must not forget, however, the all-important fact that sound constantly aids the eye by supplying otherwise missing information. By this we mean that certain types of transmitted pictures will be acceptable to the eye if sound accompanies them, but they would be entirely inadequate if the sound were missing. Since the eye, therefore, is the important medium for our television picture information, we can profit by a knowledge of some of the mechanics of the eye.

The most sensitive spot in the retina of the eye is approximately .04 inch in diameter. This tiny spot is made up mainly of many little cells known as cones, (approximately .000013 inch apart) each of which communicates with the brain.

Since the focal length of the eye is approximately 1", we can calculate that the eye cannot separate objects less than about half a minute of angle apart. Actually, about one minute of angle is nearer correct, for the average, normal eye. This is further explained by reference to Fig. 1, where two points, a and b, are located some distance from the eye. When these two points are separated so that an imaginary line drawn from each point to the eye makes an angle equal to one minute of arc (any circle may be divided into 360 equal parts or degrees and each of these degrees may be divided into 60 equal parts or minutes), the eye will have difficulty in determining whether there are two spots or only one. The nearer the eye is moved to these two points, a and b, the more clearly they will be seen as two separate points and, conversely, if the eye is moved further away, a and b will appear

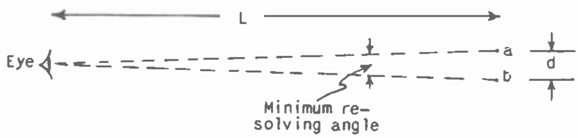


Fig.1 The acuity of the eye is measured by its minimum resolving angle.

as a single point. This explains why the further away an object is, the less detail we can observe. *The acuteness or sharpness of one's vision, therefore, is measured by the amount of detail the eye can distinguish and this is known as the resolving power of the eye.* It is sometimes called acuity. If we consider the resolving power of the eye to be one minute of arc, we may use the formula,

$$L = 3440d \quad (1)$$

to calculate how far two objects must be from the eye to appear as a single object. In the formula, L = distance from the eye to the object in inches, d = distance apart of the two objects in inches. Suppose for example, we have a certain television picture pattern whose lines are very wide apart, say $\frac{1}{8}$ inch, and we wish to know how far away from the pattern we must get in order to have the individual lines disappear. In this case, $L = 3440 \times \frac{1}{8} = 430$ inches or a little less than 36 feet. It is interesting to note that the best lenses used in taking motion pictures do not give a perfect image of a point; the smallest elements of an image that they can produce is about .001 inch. On standard 35 mm. film, this corresponds to about 800 line definition and about half that or 400 lines for 16 mm. home movies. Now, because of the great abundance of detail and the wide ranges of brightness and contrast found in nature, the eye has a tendency to demand picture resolution up to the very limit of its perception.

Variations in the intensity of light or shading is very essential to the production of a natural image. Since natural color television is only a possibility at present, we shall now concern ourselves more with the shades that lay between absolute black and white; that is, the different shades of gray. This is entirely satisfactory, because the eye is most accustomed to seeing, in books and newsprints, pictures of this general type. There are between 95 and 100 perceptible shades of gray between black and white. This means, therefore, that the eye can detect variations of between one and two per cent in reflected light, based on a total amount that could be reflected. Experience with television pictures indicates that quite excellent picture reproduction is possible with as few as ten variations of gray between black and white. From this it naturally follows that contrast distortion in television pictures is far less noticeable than frequency distortion in the video signal.

2. PERSISTENCE OF VISION. Now, insofar as television is concerned, the most important feature relating to the eye is persistence of vision. Explained in simple words, *persistence of vision is the name given to that quality of the eye which causes a sight impression to remain momentarily after the removal of the viewed object.* The length of this interval of time is determined by the *brilliance* and *contrast* in the original scene. It has been discovered that the eye will carry over any impression that is made from a brilliantly illuminated scene for perhaps .1 second after the original scene has vanished, but if the scene is weakly illuminated, the length of time which the eye retains this scene is considerably reduced, possibly to $\frac{1}{40}$ second. From this, it can be understood that the process of seeing things in motion is speeded up or slowed down according to the actual illumination. As a practical example of this, we can take a cylinder such as a dictaphone record, paste a row of small letters about its circumference, and set the cylinder in rotation so that under a bright light the letters will not be distinguishable. (The retentivity is too great at the higher illumination value). If the amount of illumination on the cylinder is reduced we will discover that the letters become quite distinguishable. Since this persistence of vision is responsible for our being able to see objects which appear to move smoothly when a series of still pictures are shown with sufficient rapidity, there must, therefore, be some point, below which this smoothness of motion will be lost. This is found to be between 15 and 20 pictures per second, depending upon the intensity of illumination. Due to the persistence characteristics of the materials composing the screen of cathode ray tubes it has been found that as the screen brilliance is increased, the number of picture repetitions required to eliminate flicker also increases. For this reason, it was necessary to select a repetition frequency for television that would be sufficiently rapid to provide satisfactory reproduction over a wide range of screen brilliances. The select-

ion of thirty complete pictures per second, or sixty half pictures or fields is more than adequate to meet this demand, being a great deal better than the motion picture which actually operates at 24 pictures per second, broken up by a "light-shutter," which gives the effect of 48 pictures per second. Naturally, we do not need 60 fields per second in television, but this was selected, because the commercial power companies in most cases supply 60 cycle alternating current. By using the same frequency, the set designer is able to reduce the amount of filtering which would normally be required to obtain a satisfactory hum level. In England where 50 cycle current is the prevailing frequency, television has adopted the 50 fields per second standard which has proved entirely adequate.

3. ROOM DARKNESS. Another very interesting feature in connection with the functioning of the eye is known as *accommodation*. This is a process by which the eye is able to adapt itself to wide variations in illumination. This is accomplished by contraction or expansion of the pupil of the eye. Since this action is not instantaneous, when we go from the light into a darkened room, such as a motion picture theatre, for a few seconds one is unable to see anything, but presently the pupils have opened sufficiently to permit more light to enter so that we are able to see various objects about the room. A particularly good example of accommodation is seen in the eye of a cat. In the bright sunlight, the pupil of a cat's eye is a very narrow slit of black, but in a darkened room or at night time, the heretofore narrow slit changes into a circle, the diameter of which equals the length of the slit. As the human eye becomes accustomed to darkness, its sensitivity rises and, in the case of complete darkness, may reach a value of 7500 times that which it normally possesses in average daylight. Since the sensitivity of the eye does vary materially with the brilliance of illumination, the question naturally arises as to the most satisfactory conditions of illumination for viewing the television picture. In this case, the amount of darkness required for satisfactory viewing will be dependent largely upon the character of the screen in the receiving tube itself. When using a screen having high brilliance and producing a black and white picture, we will find less need for total darkness than for a less brilliant screen, or one whose color produces a yellowish background. However, experience with a television receiver will soon indicate the degree of darkness necessary for satisfactory picture viewing. Comparing with daylight conditions, the amount of illumination or contrast available from the average television receiver, we find that the best contrast is obtainable when a picture is viewed in complete darkness.

Now, having some knowledge of the manner in which the eye functions, it should be easier to understand why certain requirements are necessary when viewing a television picture. There can be given only a general rule, however, regarding the various phases of picture reception, since, where there are two or more people viewing a picture, there will in all probability be two or more opinions as to the correct adjustment for the most satisfactory picture.

4. CONTRAST AND BRIGHTNESS. The one thing about which there is almost certain to be a wide range of opinions is the adjustment of the picture for contrast or brightness. Now, the matter of tonal contrast (gamma) in any picture, be it a photographic process or television, is a rather extensive subject and consequently our discussion must be limited to practical applications pertaining to adjustments of the television receiver. As previously mentioned, two of the controls on a television receiver may be termed "Contrast" and "Brightness", and it is the setting of these controls which improves or mars the tonal values of the picture. The contrast control is likened to the volume control in sound; in other words, it controls the strength of the signal; the brightness control affects the overall brightness of the picture since it changes the amount of current in the cathode ray beam by altering the bias on the CR picture tube.

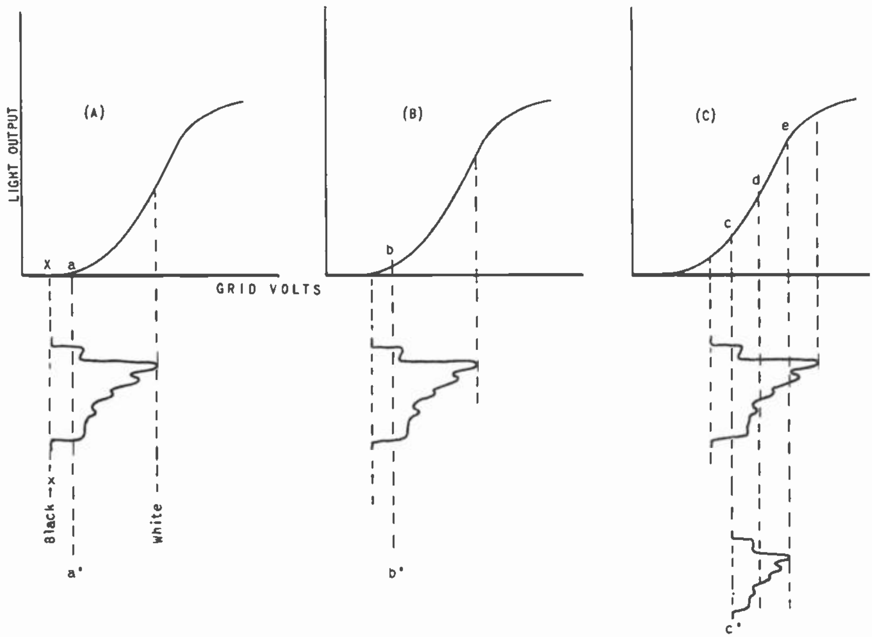


Fig.2 Characteristic curve of a cathode ray picture tube, illustrating the effects of the brightness and contrast controls on the received picture.

As has been shown in a previous lesson, the characteristic curve of a cathode ray tube is by no means linear. Hence, the received picture, like sound, will have a quality depending somewhat upon the portion of the characteristic curve, over which the signal operates during picture reception. It is extremely difficult to obtain representative photographs of television pictures, but a fair conception of the theory of operation of the contrast and brightness controls may be gained by reference to Fig. 2. Suppose, in a television receiver that we reduce the brightness control to such a value that the bias of the cathode ray tube is at some such level as aa' in Fig. 2A. This bias may be considered as cutoff for the cathode ray tube, so that this level then is black insofar as the cathode ray tube is concerned; but, the black in the picture is seen to fall in a region below aa', at some other level xx', As a result, all of these shades of gray between x and a are a total loss to the picture. If the brightness control is changed so that now the operation level occurs about bb' in (B), an improved picture will result which may be entirely satisfactory to the viewer. However, from a theoretical standpoint, the grays are not being reproduced in the same proportion as the highlights of the picture. Also, the overall brilliancy or background of the picture has been increased. Again the bias level is moved, this time to some position as shown by cc' at (C). Now the picture assumes a background of extreme brilliance wherein the highlights are all practically one tone. The gray parts of the picture have become much brighter. White is so predominant in this picture that, of the three contrast settings, this position is decidedly the least preferable.

The maximum number of true shades possible for the picture are seen to lie between points c and e, which is the straight portion of the curve, but in order to operate in this position, the brightness control must be increased and the contrast, or volume control, decreased. Of course, the blacks will certainly not be as black as in the cases of (A) and (B), but the relative shades in the picture will give a more faithful representation of the originally transmitted scene.

This manner of operation may not be so pleasing to some eyes as would the condition in (B); however, it should realize maximum results when the received picture is being transmitted from a motion picture film. Motion picture film is notably full of contrasts, which, if added to the possible contrasting effect of the cathode ray tube should become objectionable. Finally, in this discussion of brilliance and contrast, the student is reminded that some tonal distortion originates at the transmitting end because of non-linearity of response in the photoelectric device itself.

5. PICTURE SIZE AND VIEWING DISTANCE. The size of the picture and the total number of lines composing the same, determine the correct viewing distance and this, in turn, will influence the choice of the location in the home. Now, the matter of picture size is a subject open to many variations in opinion. Naturally, if we wish a television picture reproduced on a screen the size of a normal movie screen, then a room of proportions similar to a movie house should be provided, and the number of lines composing the picture should be increased accordingly. Since we have become accustomed to the size of the commercial motion picture and also the home movie size of picture, it is only natural that average public opinion should dictate a similar size for the television picture. However, if we view the facts of the case in the light of actual practice as concerns the most advantageous seating position for

viewing either the large or home movie size of picture, we shall find that we may actually obtain comparable picture results on a much smaller picture screen by viewing it at the proper distance. For example, the most satisfactory seats in any moving picture theatre, from the standpoint of easy viewing, are found in the section between the middle and back of the house. If from this location four imaginary lines were drawn from the viewer's eye to the four corners of the motion picture screen and a small cardboard having the dimensions of approximately 7" × 9" were moved out from the eye along these imaginary lines in the direction of the screen, at some point about five or six feet, depending upon the viewer's distance from the screen, the 7" × 9" cardboard corners would exactly coincide with the four imaginary lines. In other words, at this distance of five or six feet, a 7" × 9" cardboard would completely blank out our view of the large screen. Under these conditions, a picture could be reproduced on the much smaller size cardboard screen with exactly the same effect upon the eye as the one on the large size screen at a greater distance. The motion picture screen is made large in order to accommodate a large group of people, and under these conditions it is only natural that a part of them will be much too near the screen while others will be too far away; yet they can all view the picture, but with varying degrees of comfort. If we sit too near the screen, the eye cannot take in the actions of the entire picture at a glance, but must move about from point to point in following the action and, in so doing, it becomes fatigued in a short time (often a neck pain results from a prolonged and unnatural position).

Now consider the home moving picture screen and associated equipment. The average home does not have a spare room to set aside for recreational purposes, and as a result, this equipment is normally set up only when it is to be used and then the room completely darkened. The viewing distance of this screen under normal conditions varies from 10 to 20 feet and, as a rule, all the members of the family (plus several visitors) are quite easily accommodated.

The nature of the television receiver is such that to be satisfactory it must be available *for instant use at any time* for the pleasure or instruction of those interested, which in the majority of cases will not exceed 2 or 3 individuals and often-times, only one. Furthermore, the set must be capable of operation in the average living room, where at the same time, one or more floor lamps may be in use by other members of the family. Under these conditions a 3' × 4' screen would seem impractical and undesirable. In the first place, the correct viewing distance for such a picture would be sufficiently great that in most instances other members of the family would be forced to pass between the viewer and the screen in normal movement about the room. Such a picture size would also be difficult to screen from the effects of extraneous light.

It seems that our case for the correct size of television pictures in the home is fairly well summed up in the Indian's report of how a white man makes a camp fire: "White man build heap big fire and get way back and freeze, Indian build little fire, get up close and keep warm."

For *theoretical* considerations as to the proper viewing distance, let us assume a screen such as would be produced on a 12" cathode ray tube; the height in this case, of the picture, let us say is 7½" for a 441-line frame. In this calculation, the spaces between horizontal lines are considered as having a width equal to the line, (this does not make any allowance for blanked out lines during ver. B. O.) that is, there are 441 lines plus 440 spaces equal to 881 units of equal width to be divided between 7½". This figures a distance of .0085" as the width for each unit. Substituting in formula (1) we get $L = 3440 \times .0085$ or 29.24", approximately 2½ feet. This is the distance from the picture screen which the eye having an acuity of approximately 1 minute of arc will be unable to see the separate lines composing the picture. This condition is based upon the perception average of a group, and consequently may not hold for individual cases. For example, those extreme eyes having an acuity of ½ minute of arc, or the others having an acuity of 1½ minutes of arc will find in the first instance, the viewing distance will need to be lengthened, and in the second place, shortened. The assumption that the spaces between the scan lines are equal to the width of the scan line is only a working approximation and will vary with different cathode ray tubes, particularly those of different manufacturers. In some instances, the cathode ray tube may have a very fine spot, while in others it may be comparatively large. In the case of the line that is very narrow compared to the width between lines, the vanishing point is moved back; that is, it will become greater than 2½ feet, while for the spot that is large in comparison to the space separating the adjacent lines, the vanishing point would naturally be moved up to become less than 2½ feet. Likewise, if the size of the picture tube is such as to produce a picture having either greater or less height than the one under discussion, the vanishing point will be increased for the large size and decreased for the smaller. Thus, it is seen that the figure of 2½ feet is merely taken as the average point and is by no means reliable for all individual cases.

We have seen how near we may approach the screen before line structure of the picture becomes visible; this location, however, does not necessarily determine the *best* viewing distance. In fact, it merely tells us that under the given conditions we should not come any *closer* to the screen unless we wish to see the line structure of the picture. From this we may conclude, that for a picture height of 7½", 441 lines is more than adequate, and that the height of the picture may be materially increased before the line structure becomes visible at the normal viewing distance. The viewing distance for *greatest* resolution in this case is between 8" and 10" for a person having average normal eyesight; however, due to past experience, we have learned to temper our demands as to the amount of detail we require, depending largely upon what we are looking at. For example, in pictures containing a great deal of motion, particularly rapid motion, the eye is satisfied with comparatively little detail. To go further, past experiences have also taught us how certain objects should appear and, for that reason, the eye will in most instances, be satisfied with an overall picture without all of the details; the fact is, that in most cases where all details are given, the eye overlooks most of them anyway.

In this connection, we find the chief reason why television, unlike most of the other arts, had to be born full grown, so to speak. In our experiences with motion pictures we have become accustomed to a certain amount of perfection which has automatically set the standard by which we judge any similar art. Naturally, television had to approach the perfection of motion pictures in order to be accepted on a large scale by the general public.

The most satisfactory distance for the viewing of the television picture must be decided finally by actual experience. In the case of the motion picture theatre, the best viewing position seems to be a distance from the screen equal to approximately 4 to 6 times the height of the screen. In the case of home movies having less detail as a result of the smaller size film, the *most desirable viewing distance is perhaps from six to eight times the height of the screen.* If we assume television pictures to be comparable in detail to the home movies, then we are safe in saying that the best viewing distance is perhaps six to eight times the height of the picture screen. *Then in the case of the 7½", 441-line television picture, the normal viewing distance would be 45 to 60 inches.*

Under the conditions which have been outlined for satisfactory home television reception, it would seem that the size of picture available on a 12" cathode ray tube should in most cases be entirely satisfactory. If the television receiver is of the indirect viewing type in which the picture is reflected from a mirror fastened to the under side of the cabinet lid (this lid may be raised or lowered to permit correct viewing angle for the observer) it should be possible to find a location in the average living room where lights from floor lamps would not interfere, nor would other members of the household pass between the viewer and the set, since in this case, the viewers would be closely grouped about the receiver. In some instances, the actual location of the receiver in the room may be dictated by the requirements of the lead-in from the antenna.

6. "LINE OF SIGHT" RECEPTION. This brings us to a discussion of the all-important subject: the design, construction and location of the antenna. It makes no difference how excellent the facilities of the broadcasting station may be, or how expensive the receiver, maximum results in either case are dependent upon the efficiency of the antenna system. The transmitter may lay down a field strength entirely satisfactory for excellent operation in a particular locality, but poor antenna design or location may reduce the otherwise excellent system to a performance level of 50% or less. While comparatively simple in its construction, the television antenna system offers problems of considerably more magnitude than those normally encountered in antennas used for ordinary broadcast reception. In the first place, the nature of the television broadcast frequencies, occupying a portion of the region below ten me-

ters, is such that they partake of the nature of light, being referred to as "quasi-optical" waves. By this we mean that these waves tend to travel in a straight line so that the receiving and transmitting antenna should be in "line of sight" in order to give satisfactory reception. In other words, if the receiving antenna is located at such a distance from the transmitting antenna that the curvature of the earth intervenes, the transmitted signal would perhaps be of little or no service at that point. This means then that the normal range of a transmitter will be limited perhaps to a dependable service radius of from 25 to 75 miles, although freak conditions have in times past made much greater distances possible.

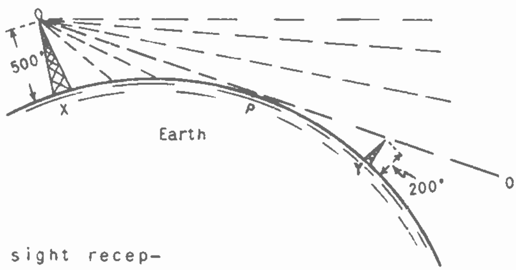


Fig. 3 Line of sight reception.

Fig. 3 illustrates the meaning of "line of sight" reception. Here OX is the transmitting antenna, and OP represents the line of sight distance from the antenna to the horizon. From this it may be seen that antennas located between points X and P should normally be able to receive signals from the transmitting antenna; those antennas located beyond P, between P and Y for example, should not be able to receive signals unless the antenna height at the receiving end is sufficiently great so that they will intersect the line OO', as in the case at Y.

This distance OP from the transmitting antenna to the horizon may be calculated by the simple formula:

$$D = 1.22\sqrt{H} \qquad (2)$$

Where D = distance in miles, and H = antenna height in feet. For example, suppose OX equals 500 feet, then the distance OP would equal $1.22\sqrt{500}$, or 27.2 miles (this, of course, assumes level ground surface). Now, if the receiving antenna has a height of 200 feet, the reception distance may be extended from OP to Y; this distance (PY) may be calculated as in the previous example and the total distance from transmitting to receiving antenna would equal the sum of the two. For example:

$$1.22\ [\sqrt{500} + \sqrt{200}] = 44.4 \text{ miles.}$$

One naturally wonders why reception of wave lengths below 10 meters is limited normally to such short distances, while we are able to receive regular radio programs hundreds and even thousands of miles away from broadcasting stations having wavelengths between 200 and 550 meters. The answer is that on the longer wavelengths, the sky wave is reflected back to earth. The sky wave is responsible for all distant reception; although the wavelengths below 10 meters have a sky wave, this sky wave is not normally reflected, consequently, reception on these low wavelengths is more or less confined to the earth wave.

The fact that the sky wave is not reflected to any great extent would seem at first to be a great hindrance to the growth of an extensive television service; actually, however, if the sky wave were reflected, we would perhaps, have another and greater handicap, as we shall presently see.

7. PROPAGATION PROBLEMS AND EFFECTS. During propagation, a radio wave is attenuated; sometimes there is a change in polarization; also there may be other phenomena such as diffraction, which will change the direction of travel. Among the more common phenonena causing a change in the direction of a wave propagation are, reflection, diffraction, and refraction. In general, the term reflection is defined the same in this instance as when used in connection with light. Diffraction and refraction also have similar definitions as when used in connection with light, but are not so generally understood. *Diffraction* is a modification of a wave when it passes the edge of a body or through a small aperture. *Refraction* is the deviating of a wave as it passes through a medium of variable characteristics such that the velocity of propagation of some portions of the wave front are faster or slower than that of other portions.

Insofar as antenna requirements are concerned, the subject of reflection is of prime importance in our present study. That reflection is quite common at these high frequencies, has been definitely established by measurements made both in the open and on the inside of buildings. The fact that these high frequencies do not, as a rule, have their sky wave reflected does not mean that they cannot be reflected at all; such is far from the case. The ground and also structures of all types reflect these frequencies to a more or less degree. In fact, reflections are found to exist in all locations except in open, flat country; even here there may be reflections from the earth's surface. These reflected waves produce what is known as "interference patterns" in the received television picture. These patterns in most instances are caused by reflections from relatively nearby objects. In many instances, particularly in industrial sections of cities, they are so severe that the changing of the receiver antenna from one point to another only a few feet away may result in a change from a very strong signal to one so weak that it is practically useless. The writer spent several days on the top of a large building located in downtown Philadelphia looking for a satisfactory location for a television receiver antenna. Finally, one spot on the roof of the building was found to be satisfactory.

The interference patterns previously referred to are the result of signals being received at the antenna from two or more paths of propagation; that is, one signal may come directly from the transmitting antenna itself, while a second and even a third or more may arrive from different directions as a result of reflection. The amount of picture distortion produced will depend upon the comparative strengths of the signals received and the difference in the length of the paths each has traveled between the transmitting and receiving antenna. Naturally, the signal that has traveled over the longest path will arrive at the receiving antenna later than signals traveling shorter paths.

As a practical example, let us suppose that an antenna is receiving television signals of very nearly the same intensity that are arriving over two different paths, one being 500 feet longer than the other. Calculating the time necessary for a radio wave to travel 500 feet, assuming the speed of such a wave to be approximately 185,000 miles per second, we have .51 micro-seconds as the difference in time required by the wave to travel the longer path. A 441-line, 30 frames per second picture may normally require approximately 68 micro-seconds for the cathode ray beam to move through a distance equal to the length of one line, which in this case we will assume to be 9", or a rate of 1" in 7.5 micro-seconds. From this we can calculate that between the time the first signal has arrived and the arrival of the second, the spot would have moved .068", or a little better than $\frac{1}{16}$ of an inch. Therefore, a double image will result, one being displaced from the other by approximately $\frac{1}{16}$ of an inch.

This, however, is only part of the story; multiple-path reception may have even much more complicated results. The reflected wave differs in phase with respect to the direct wave; and in addition to this, the frequency components of the side band may have a different phase and amplitude characteristic than existed in the original direct wave. Since the modulating frequencies in a television signal are extremely high, the difference in path length required to produce sideband distortion is surprisingly small. Just how small this distance can be may be calculated from the formula:

$$S = \frac{1}{2} \times \frac{V}{F} \qquad (3)$$

Where S is the minimum difference in propagation path length that will produce a cancellation of the modulating frequency F, and V is the velocity of light expressed in the same unit as S. Actually then, S is equal to one-half the theoretical radio wave length of the modulation frequency. (V÷F is formula for converting frequency to wave length). As an example, let us suppose a modulation frequency of 3,000,000 cycles and express the velocity of light as being 300,000,000 meters. Then:

$$S = \frac{300,000,000}{3,000,000 \times 2}$$

$$= 50 \text{ meters, or approximately 164 feet.}$$

A difference in path length of only 164 feet will cause the side band corresponding to the highest modulation frequency (3,000,000) to arrive at the receiver 180 degrees out of phase, causing partial or complete cancellation of these frequencies.

Hence, it is possible for the side bands of a transmitted signal to arrive out of phase at the receiving antenna although their carriers may be in phase; if the carriers arrive somewhat out of phase, the particular modulation frequency just discussed will not only be partially suppressed, but will also be distorted. This type of distortion phenomena is seen therefore to be very similar to a condition found in regular broadcast reception known as "selective fading". Theoretically, if a signal is received from two paths, the second being just enough longer than the first so that the signal is exactly one picture element later than the one from the first path, there will be for every dark picture element received from one path, another light picture element received from the other path. (Remember, this peculiar condition we are discussing relates to the phase of the side band frequencies). If the signals are of the same intensity, some of the sideband frequencies will exactly cancel, giving the received picture a peculiar or weird appearance. Fortunately, the conditions for this selective distortion phenomena are seldom realized to any noticeable extent in actual practice. However, as previously pointed out, if the carrier of the reflected wave arrives at the receiving antenna over a path that is, say 1,000 feet longer than the direct wave path, a second picture image will result whose intensity will depend upon the strength of the reflected signal.

8. ANTENNA INSTALLATION PROBLEMS. Thus it is quite apparent that a satisfactory antenna should receive only one signal from the transmitter to which the receiver is tuned. Naturally, this means that each antenna installation presents more or less of an individual problem. It is a safe working principle to state that in making an antenna installation for television, it should be well in the clear of nearby objects and should preferably be in actual sight of the transmitting antenna (assuming that the antenna could be seen with field glasses if not with the naked eye). When an installation is fairly near the antenna of the transmitter, satisfactory reception may be had perhaps with even an inside antenna. However, in practically every instance, the signal strength will be greatly improved if the antenna is changed from the indoors to a position in the open. In many sections of cities, maximum signal strength is desirable in order to overcome interference from ignition systems, diathermy machines, and other electrical disturbances, such as elevator motors, loose electrical wiring connections, etc. Some makes of cars and trucks have ignition systems that may cause disturbances for several blocks. This is particularly true of airplane motors which, fortunately for television, do not present a problem in many locations. Due to the increasing use of automobile radios, automobile ignition interference has been greatly decreased and the time may soon arrive when this form of interference will be completely eliminated. Ignition interference is perhaps more aggravating in the sound effects it produces in the loudspeaker than in any results seen in the picture itself. These

are sharp, staccato-like clicks which increase in frequency with increased motor speed; in the picture they are seen as narrow black or white stripes or "splotches" across the pattern. (Sometimes this effect is described as a "snowstorm.")

If the antenna is to be installed some distance from the receiver, transmission lines (between the antenna proper and the receiver) of correct design must be used in order to limit the point of signal pickup to the antenna proper. Furthermore, if the distance from the tip of the antenna to the antenna binding post on the receiver is of the order of 100 feet or more, reflections in

(A) (B) (C) (D)

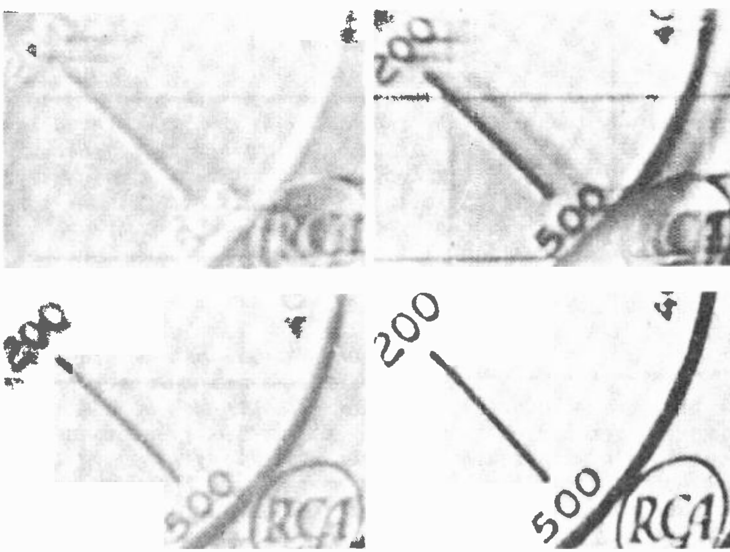


Fig.4 the effects of multiple path reception on the television picture.

the antenna system may result in a loss of picture detail unless the line is properly balanced and terminated at the receiver. If reflections from the receiver end are allowed to reflect back to the antenna and again be reflected from there so that it re-enters the receiver as a delayed signal, it will have much the same effect upon the appearance of the picture as the reception of signals from multiple paths. Anything short of the actual viewing of a condition of this kind on the receiver will not give a clear understanding of the appearance of this effect. However, the four pictures shown in Fig. 4 should serve to give some idea in this matter. These pictures were all made from the same receiver without any changes in the receiver tuning, but in each case a different antenna arrangement was used. In A, it is apparent that the reflected wave not only had the greatest signal intensity but also had its phase inverted so that the result was a negative picture. In B, the antenna adjustment has been changed so that secondary image reception is reduced; however, the picture is still far from satisfactory. Two reflected waves are quite apparent (measurements indicate these two waves arrived at the receiver antenna along paths approximately 800 feet and 2300 feet longer than that of the direct path). The picture shown at C is the result of arranging the antenna for maximum reception in one direction and thereby eliminating most of the objectionable reflected wave. This picture does not appear objectionable when operated with normal contrast similar to D.

Fig.5 A spaced transmission line.

Three general types of lead-in lines are used to reduce pick-up between the antenna and the receiver; the rubber-covered twisted pair, the spaced transmission line and the concentric cable. While the twisted pair is the simplest to install and the cheapest of the three types, considerable loss in signal strength will result if it is used over distances greater than a few wavelengths. The amount of this attenuation will vary with the grade of twisted pair used. Thus far, the average grade of twisted pair has been found to vary around 1.75 db. per wavelength at 50 megacycles. For this reason, the close-spaced transmission line is preferable since its attenuation may average, perhaps one - tenth that of the twisted pair. Construction of this type of lead-in is comparatively simple and is best described by Fig. 5. The same antenna connections cannot be used interchangeably with the twisted pair and spaced transmission line for the reason that the antenna efficiency will be decreased by the use of the higher impedance spaced transmission line unless connections to the antenna are made in such a manner that the antenna-matching is about the same for both cases. This antenna-matching is accomplished by correct location of lead-in connections, as we shall presently see. It naturally follows that matching of input impedance is also necessary, and for this reason the set manufacturer in most cases will provide an extra tap on the antenna input circuit (in the receiver). An additional precaution in the use of this type of antenna connecting link (spaced transmission line) is that unless the entire system and especially the receiver input is well balanced to ground, and lead-in may act as part of the antenna, resulting in extraneous pick-up and reflected images, such as previously explained.

The attenuation of the twisted pair is sufficient in ordinary circumstances to prevent harmful effects from reflection back and forth between the antenna and the set. The concentric cable type of lead-in, although more costly than either of the other two, is perhaps more universally desirable in that it makes for uniformity in antenna construction, and antenna circuit design. The concentric cable has a definite, predetermined impedance which makes for ease of matching the antenna and television receiver input. This impedance for a majority of the present commercial cables is around 75 ohms.

The actual design and construction of the antenna itself does not offer any particular difficulty; the main source of trouble is, as we have already seen, in finding the best location and the use of a satisfactory lead-in. The very important factor of antenna polarization (plane of signal propagation or reception) is so closely related to the antenna itself that it should be discussed at this point.

There are two general planes to consider in the positioning of antennas, depending upon whether the radiated wave is polarized in the horizontal or vertical direction. If the transmitter radiator is a vertical antenna, the receiving antenna should also be vertical; if a horizontal radiating system is used at the transmitter, then the receiving antenna should likewise be located in a horizontal position. For the reception of horizontally polarized waves, the ends of the antenna normally should point in a direction at right angles to the location of the transmitting antenna. Information that is available is not sufficiently complete to indicate which type of polarization is preferable for average receiving conditions. In some countries, vertical polarization is used, while at present the use of horizontally polarized waves seems to have a slight preference in the metropolitan areas where tests are being conducted. The theory seems to be that with this type of transmission less difficulty will be experienced from multi-path disturbances than when using vertical polarization. A horizontal receiving antenna picks up less noise signal from the street (auto ignition systems, etc.) than a vertical antenna. Other factors seem to be approximately equal for either type of polarization. Therefore, the discussion will apply equally well to either horizontally or vertically polarized waves, the only difference being in the orientation of the plane of the antenna itself. This applies also to the location of reflectors or shields.

9. ANTENNA DESIGN AND CALCULATIONS. In Fig. 6 is shown one very common type of antenna used in television reception; this is known as a *di-pole* or *doublet*. The two quarter-wave antenna pieces may be constructed of brass or copper tubing having a diameter of an eighth of an inch or better. These are insulated from the antenna support by means of standoff insulators as shown.

In many instances, in sections more remote from the transmitter, it is possible to increase the intensity of the received signal by the use of what is known as a *reflector*. Such an arrangement is shown in Fig. 7. It is important that this reflector be located in the same plane as the antenna with the receiving antenna between the reflector and the transmitting antenna. The distance from the reflector to the antenna is a quarter of a wavelength or slightly less. The reflector is generally of the same material as the antenna. The length of the reflector should be slightly greater than the overall length of the di-pole antenna for maximum results. This method of construction is very directional and must be accurately pointed in the direction of the transmitting antenna from which the signal is to be received. As a result, this type of antenna construction is limited to reception of signals from one station only unless the supporting beam is arranged so that it may be conveniently pivoted in the direction of other transmitting antennas.

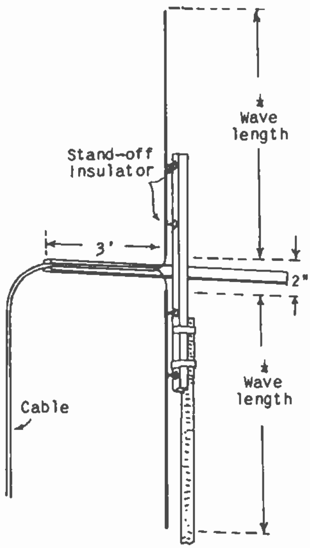


Fig. 6 A vertical di-pole antenna with concentric cable lead-in.

This reflector idea may also be used in connection with screening out unwanted reflected signals. In this case, a single pole, having a length the same as that indicated for the reflector in Fig. 7, is placed *between* the receiving antenna and the point where the reflected signals are believed to come from. The determination of the exact location for this shielding pole is one which must usually be found by trial.

Under certain conditions, reflections may arise from the ground itself and in such instances a copper screen wire has been found helpful both in screening out the unwanted reflection and in cutting down ignition noises from the street. This sort of arrangement is easily provided when the antenna is located above a flat surface such as a roof so that the screen wire may be laid flat along on the roof between the antenna and the street, or at such positions as will cut out the undesired reflection. Due to the expense involved, this procedure would be used only under extreme conditions. For a 441-line, 30 frames per second transmission, ground reflections are limited to those sets located very near the transmitting antenna. The actual distance has been found to be something in the neighborhood of six times the combined height of the receiving and transmitting antennas. In other words, if the transmitting antenna is located 500 feet above the street and the receiving antenna 50 feet, the reflection distance would be approximately 550 × 6, or 3300 feet. In other words, 3300 feet is the radius of a circle (about the transmitting antenna) whose area may be subject to this type of interference. For this reason, in all receiving locations more than a mile from the transmitter, if troublesome reflections are noticed, it is fairly certain that the reflection surface itself is in some plane other than parallel to the earth.

Where horizontal antenna installations are used, the illustrations in Figs. 8 and 9 provide a simple arrangement in which either wires or rods may be used in the antenna proper. Since the impedance varies with the point along the antenna at which it is measured, for this type of half wave antenna, it will be found to vary from around 70 ohms at the center to perhaps better than 2,000 ohms at the end. This suggests a method for matching the antenna and feeder impedances. In the case of Fig. 8, the impedance match may often be improved by fanning out the antenna end of the feed-line into a V-shape for 15 or more inches of its length, additional separator insulators being used at the same time so that the open end of the V will also be 15 inches or greater.

A second impedance matching arrangement is shown in Fig. 9. The Y section of the feeder in this case is "fanned" to have a gradually increasing impedance so that the impedance at the end of this wire where it joins the antenna will be equal to the impedance of the antenna section included between the two ends of the wire. This arrangement is very critical as to actual dimensions, since it is designed for exact impedance and frequency values. The formula for

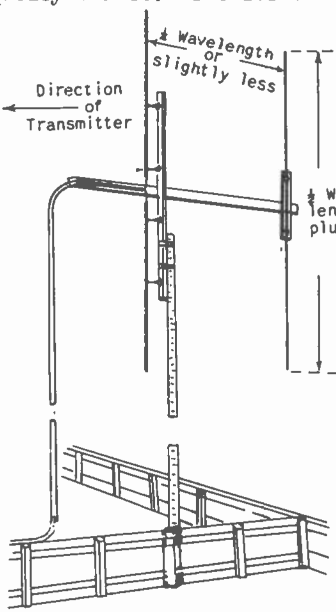


Fig.7 A di-pole antenna employing a reflector to improve the reception.

calculating the length L for the antenna to be used in *frequencies above 30 megacycles* is given to be:

$$L = \frac{462}{F} \quad (4)$$

Where L = antenna length in feet, and F = frequency in megacycles. The length of the matching section Y is calculated by the formula:

$$Y = \frac{113}{F} \qquad (5)$$

Where Y = length in feet, and F = the frequency in megacycles.

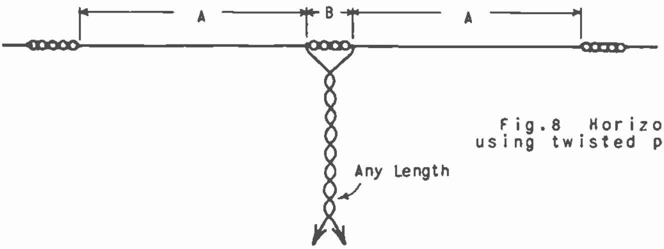


Fig.8 Horizontal antenna, using twisted pair lead-in.

The distance X (Fig. 9) is calculated by the formula:

$$X = \frac{147.6}{F} \qquad (6)$$

Where X = the distance in feet, and F = the frequency in megacycles. The above calculations are based upon a feeder line having a characteristic impedance of 600 ohms and, consequently, do not apply

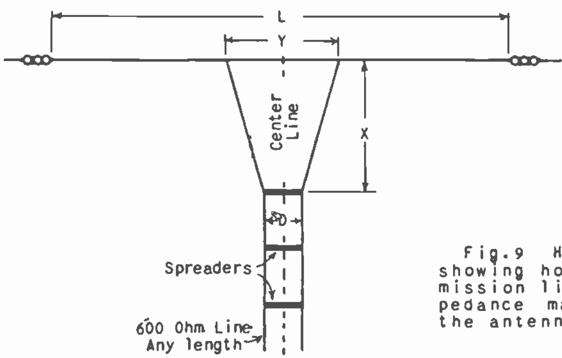


Fig.9 Horizontal antenna, showing how a spaced transmission line may have its impedance matched to that of the antenna.

to feeders having a different characteristic impedance. The formula for calculating the correct spacing for a 600-ohm transmission line may be calculated sufficiently accurate from:

$$D = 75d \qquad (7)$$

Where D = distance between the centers of the feeder wires, and d = the diameter of the feeder wire itself. These dimensions may be in millimeters or inches. For the information of those who may be more advanced in their mathematics, formula (7) is derived from the surge impedance formula for an open two-wire line which states:

$$Z = 276 \times \log \frac{b}{a} \text{ (approximation)} \qquad (8)$$

Where Z = surge impedance in ohms, b = wire spacing between centers in inches, a = wire radius in inches. This formula (8) is the answer to why the feeder shown in Fig. 9 must be of the spaced open wire type. The impedance as stated previously at the center of a half wave antenna is approximately 70 ohms and by substituting this value in formula (8), along with the radius of the wire we propose to use, and solving for Z, we shall discover that it is physically impossible to construct this type of line with a characteristic impedance as low as 70 ohms. For example, substituting, a = .03", Z = 70, and solving for b in (8) gives the required distance between wire centers to be .054". (The smallest b possible is 2 × .03", or .06").

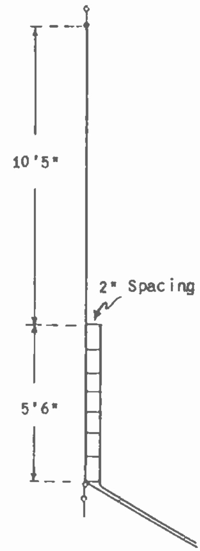


Fig.10 A method for taking the lead-in from the end of the antenna (actual measurements will change slightly, depending upon the transmission frequency).

From the foregoing, it is seen that a concentric transmission line having a surge impedance of 70 ohms may be connected directly at the center of the antenna, (Fig. 6) one section of the quarter wave being connected with the inner conductor and the other section with the outside conductor which normally is grounded. The inside diameter of the outer conductor for a line of 70 ohms impedance is approximately 3.2 × the outside diameter of the inner conductor. This is derived from the surge impedance formula for concentric cables which states:

$$Z = 138 \times \log \frac{b}{a} \qquad (9)$$

Where Z = characteristic impedance, b = inside diameter of the outside conductor, a = outside diameter of the inner conductor. These diameters may be given in millimeters or inches.

Sometimes it may not be desirable to connect the feed line at the center of the antenna. In many instances, an antenna construction may arise where space limitation, etc., would make a more satisfactory installation possible if the lead-in could be taken from one end of the antenna. The design for such an arrangement is shown in Fig. 10. If a 70 ohm feed line is to be used and we consider the impedance at the end of a half wave antenna to be in the neighborhood of 2,000 ohms, the series impedance for the matching section may be calculated by the matching formula:

$$Z = \sqrt{Z_1 \times Z_2} \qquad (10)$$

Where Z = required matching impedance, Z_1 = characteristic impedance of the feed line, Z_2 = antenna impedance. Substituting given values in this formula:

$$Z = \sqrt{70 \times 2{,}000} = 375 \text{ ohms (approximately)}$$

Now using formula (8) for an open wire line, we may calculate the spacing necessary to give this matching impedance with any given size of wire.

From the foregoing information on antennas and television receiver locations, the student should have a fair working knowledge of the subject. However, there is one further important observation, namely, all antenna design and construction has been based on the reception of a single definite frequency which, of course, will not be the actual condition encountered in normal television broadcasting service. Information on antennas to cover additional requirements is not available at the present, but this will no doubt be furnished along with the installation instructions accompanying the sets of the various television receiver manufacturers.

EXAMINATION QUESTIONS

INSTRUCTIONS. Before starting to answer these examination questions, you should have studied the lesson material at least three times. Be sure that you understand each question--then proceed to write the best answer you can. Make all answers complete and in detail. Print your name, address, and file number on each page and be neat in your work. Your paper must be easily legible; otherwise, it will be returned ungraded. Finish this examination before starting your study of the next lesson. However, send in at least three examinations at a time.

1. Insofar as television is concerned, what is the most important feature of the eye?

2. Excessive reduction in the brightness control (increased bias) will affect the television picture in what manner?

3. Explain how a 7" × 9" television picture may have the same effect on the eye as the much larger motion picture screen.

4. Theoretically, what is the desirable viewing distance for any 441-line television picture?

5. What is meant by "line of sight" reception?

6. If the receiving antenna is 64' high and the transmitting antenna is 900' high, what is the line of sight reception distance?

7. What principle effect may reception from multiple paths have on the television picture?

8. Give two reasons why the correct design and installation of the lead-in is important.

9. Name two types of lead-in construction.

10. How may a reflector be used in an antenna installation?

Notes

(These extra pages are provided for your use in taking special notes)

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PRINTED IN U.S.A.
JONES PRINTS
KANSAS CITY, MO.

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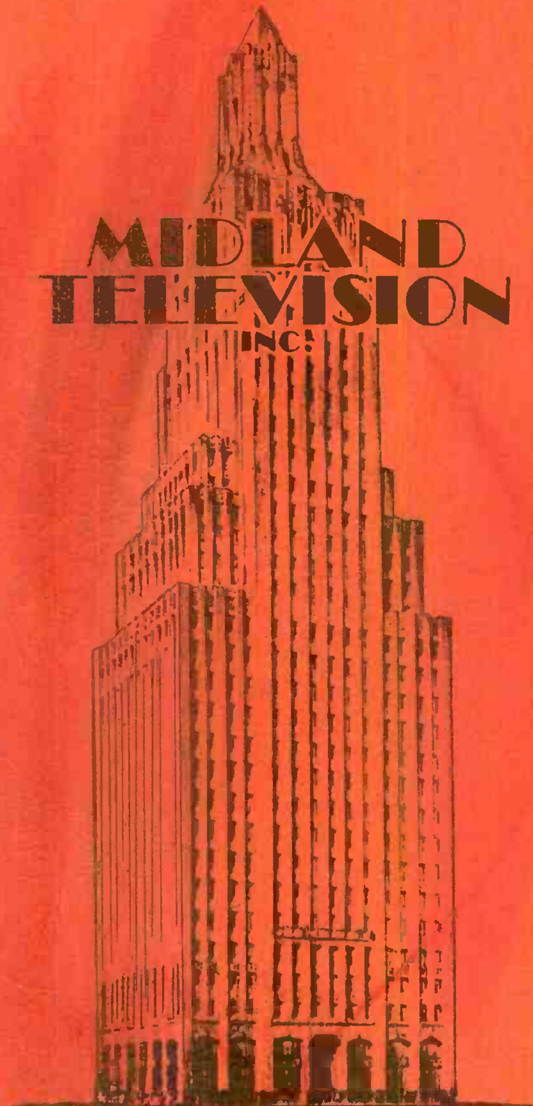

POWER & LIGHT BUILDING, KANSAS CITY, MISSOURI

UNIT NO. 6	TELEVISION PICTURE DEFECTS AND HOW TO RECOGNIZE THEM	LESSON NO. 2

DEFENSE

The perpetual strength of every nation depends entirely upon the intelligent usefulness of its citizens.

This does not mean usefulness in a military way, for, after all, the military forces must depend upon the nation as a whole if they are to ably defend the prized possessions which we Americans are so fortunate to possess.

You can do your part by preparing yourself to take a useful and creative part in the commerce of our nation. By arming yourself with specialized knowledge, you automatically accomplish a two-fold achievement. First, you make yourself more useful to your country; and, second, you defend yourself and those whom you revere, against want and financial hardships.

Stop a few moments, and consider how fortunate you are. You, as an American citizen, have the right to prepare yourself for the type of work you most enjoy. You are not TOLD 'you must do this or that'. You have ample opportunity to secure specialized training on a most liberal basis. You are not kept in ignorance for a purpose. You have the opportunity to earn as much money as your knowledge and ability will permit. You are not told you must work for certain limited wages.

We are all most fortunate to reside in a country that believes in mass education.

As a Midland student, you have demonstrated that you recognize your privileges and opportunities. We urge you to continue the construction of your defenses by continually adding to that marvelous storehouse, your brain.

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Lesson Two

TELEVISION PICTURE DEFECTS & HOW TO RECOGNIZE THEM

"It is impossible to do an efficient job of servicing television receivers unless you are capable of immediately recognizing the causes of poor reception. When you have learned what causes certain defects in the received picture, it is then comparatively simple to isolate and correct the difficulty.

"This lesson is devoted to a description of the various defects encountered in television reception and the troubles which usually cause such defects. The time spent by the student in learning to recognize the cause of faulty reception by studying the picture or pattern on the television screen, will pay him many dividends in helping to solve his problems as a television serviceman. Later lessons in this unit will be devoted to the procedures to be followed in correcting these defects."

1. USE OF THE KINESCOPE IN LOCATING FAULTS. Fortunately the serviceman does not have to carry with him his most valuable piece of test equipment; namely, the kinescope and its associated circuits. Unlike sound broadcasting, the defects in television are placed before the eye of the serviceman on the face of the picture tube. When the serviceman has learned to interpret the various types of picture distortion that appear before him, he can either diagnose the trouble immediately or relegate it to several specific parts of the television receiver.

After the serviceman has acquired sufficient practice in servicing television sets and has repaired not once, but many times, the various faults common to television receivers, he will be able to glance at the picture distortion and immediately know the source of trouble without having to reason the cause from the effect. However, in the absence of such experience, which no one will possess in the early days of television, it is essential that a serviceman have a complete knowledge of the functioning of a television receiver in order that he may be able to reason the probable cause of the picture distortion which he observes.

Fig.1 Insufficient horizontal deflection.

In order to show the approach in determining the probable cause of a particular picture defect, a few extremely simple examples will be cited. Suppose that the picture which appears on the receiver is much too narrow, as shown in Fig. 1. From a knowledge of the way a picture is formed, the television serviceman would say immediately that the trouble was due to the horizontal deflection circuit. This follows from the fact that the picture is formed by the beam scanning across the picture one line at

Fig.2 Incorrect focus.

a time. Since the picture is normal in all other respects, it is obvious that the scanning beam is making the correct number of trips and that the intensity is being modulated correctly. The only defect is that the length of travel is not great enough in traversing the width of the picture. Since this motion of the beam is determined by the horizontal deflection circuits, the picture fault obviously lies in these circuits and we say that the horizontal sawtooth deflection voltage is too small.

On the other hand, a fuzzy picture as shown in Fig. 2 could not be influenced by deflection in any way, because the picture has the right shape and size. This immediately exonerates the deflection portion of the television receiver and a serviceman can reason that the picture is either out of focus due to incorrect first anode voltage on the cathode ray tube, or else there is a fault in the video circuits which produces modulation on the grid of the kinescope. The reasoning in this case would be carried a step further. By inspection of the individual lines which compose the picture, the serviceman could tell whether the scanning beam itself was in focus. If the scanning beam is satisfactorily focused, the individual scanning lines will be clear-cut and the only alternative is that the R.F. amplifiers or video amplifiers are defective.

Occasionally, a serviceman may be called in to fix a television receiver, when in reality the imperfections of the picture are due to sources other than defects in the electrical circuits of the receiver. The serviceman must be able to recognize these faults and set about to correct them. If this is impossible, he may explain to the set owner the cause of inherent troubles and limitations in the television system.

2. INHERENT LIMITATIONS IN PICTURE QUALITY. The set owner who is not fully aware of the limitations of his receiver may move it from the position in which it was originally installed and try to operate it in a part of the room that is too brightly lighted. Under these conditions, the contrast control on the receiver would be advanced too far and the background control turned up too high; consequently spot defocusing or "blooming" would occur. The picture would be flat, out of focus, and generally unsatisfactory. It should be realized that the darkest part of the picture can be no darker than the face of the kinescope tube itself and this shade will be a long way from black if the receiver is located other than in a dark portion of the room. The highlights of the picture are limited by the maximum spot brilliance that can be obtained without defocusing. While it is the duty of the installation man to make these facts clear to the set owner during the original installation; nevertheless, the serviceman may be called upon when these facts are forgotten.

In addition to destroying the picture quality by changing the position of the receiver, the set owner may produce an unsatisfactory picture by improper use of the controls. The controls on a television receiver are quite simple and almost everyone should be able to obtain a good picture, provided the receiver and antenna

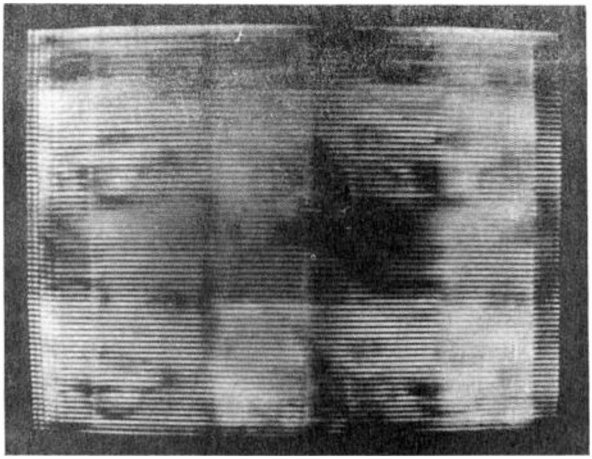


Fig.3 Incorrect adjustment of the horizontal and vertical hold controls.

are in proper working order. However, a few individuals simply lack the ability to adjust a receiver satisfactorily, just as some broadcast receiver owners will tune their sound receivers slightly off the carrier of a broadcast station to produce the well-known distortion, crosstalk, and hash which accompanies such an adjustment.

One common difficulty in adjusting the picture is for the operator to turn the wrong deflection oscillator speed control if

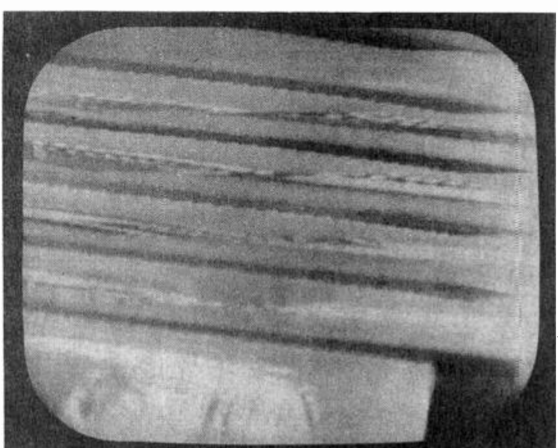


Fig.4 Incorrect adjustment of horizontal hold control.

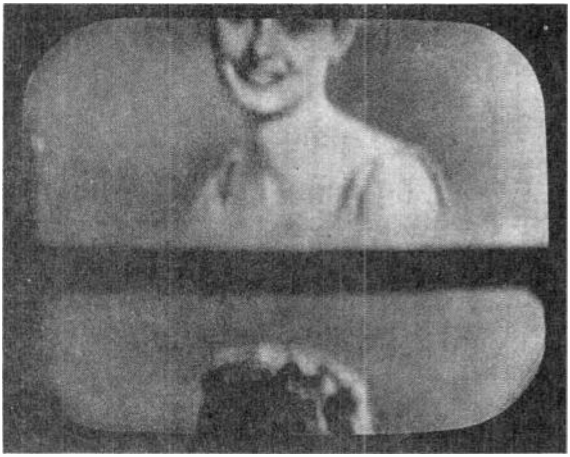


Fig.5 Incorrect adjustment of vertical hold control.

the picture should slip out of position on the screen. With both the horizontal and vertical oscillators running at the wrong frequency, the normal procedure is for the set owner to turn all of the knobs indiscriminately in trying to regain the picture. With both oscillators out of adjustment, the picture will not be regained until they are both correctly adjusted, and the set owner may be unable to tell when one of them is adjusted correctly if

Fig.6 Excessive contrast.

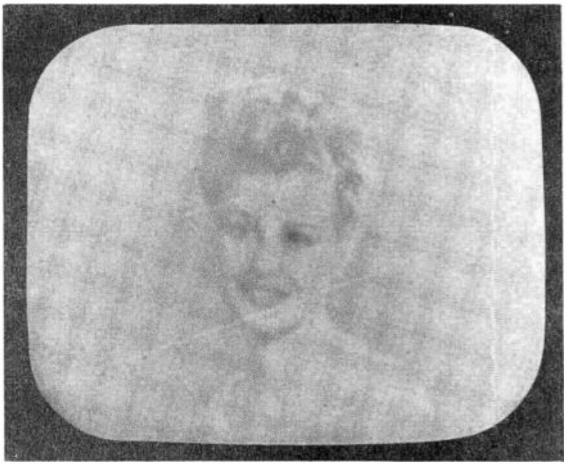


Fig.7 Insufficient contrast.

the other one is still displaced. Fig. 3 shows the general appearance of the picture when both the horizontal hold control (frequency control of the deflection oscillator) and the vertical hold control are out of adjustment. Fig. 4 is typical of the misadjustment of only the horizontal hold, and Fig. 5 is the type of picture produced when the vertical control is incorrectly set. Notice than an incorrect adjustment of the vertical hold causes perfectly *horizontal bands* across the picture, while misadjustment

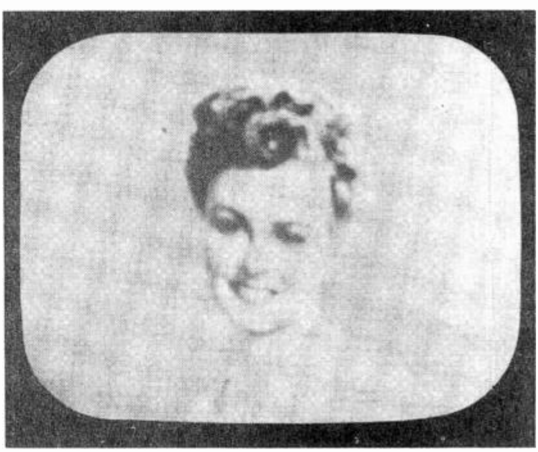


Fig.8 Background control advanced too far.

of the horizontal control causes *diagonal bands* across the picture. Therefore, the operator may easily determine whether one or both of the controls are misadjusted, and correct them accordingly.

In addition to these two controls, the receiver has a contrast or video gain control and a brightness, background, or kinescope grid voltage control. Some receivers also incorporate a focus control to adjust the first anode voltage of the kinescope. Misadjustments of the contrast control are shown in Figs. 6 and 7, while incorrect adjustment of the background control is illustrated in Fig. 8. An incorrect adjustment of the focus control has already been shown in Fig. 2.

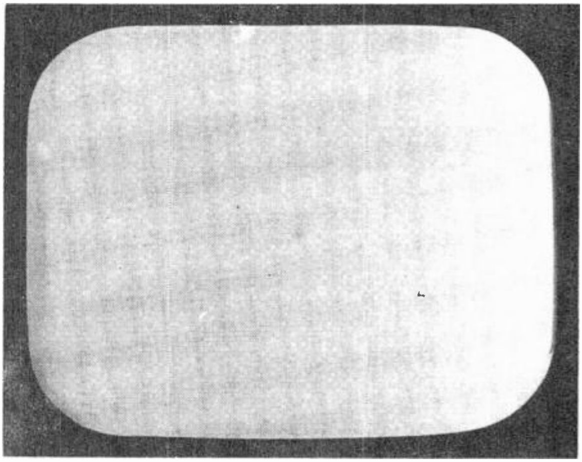


Fig. 9 Ion blemish in center of kinescope.

A picture similar to Fig. 8 is to be expected if the receiver is operated in a too brightly lighted portion of the room, because the set owner naturally will advance the background control to overcome the normal illumination on the screen. An inherent fault in the television receiver which may call for an unnecessary visit of the serviceman is the *black spot* or *ion blemish* which appears in the approximate center of the screen on certain types of kinescopes. As you should recall from a previous lesson, this blemish is due to bombardment of the screen by heavy negative ions from the cathode which are not deflected by the normal deflection system of the kinescope. The trouble is most common in black and white tubes and increases in intensity and size with age. If the tube is electrostatically focused, the ion blemish will be quite small, ranging from approximately 1/16 inch up to 1 or 2 inches in diameter. Magnetically focused tubes generally have a larger ion blemish which is not so well defined. A picture of an ion blemish or dark spot in the center of a blank screen is shown in Fig. 9. Some of the modern television tubes are built in a special way to eliminate this defect.

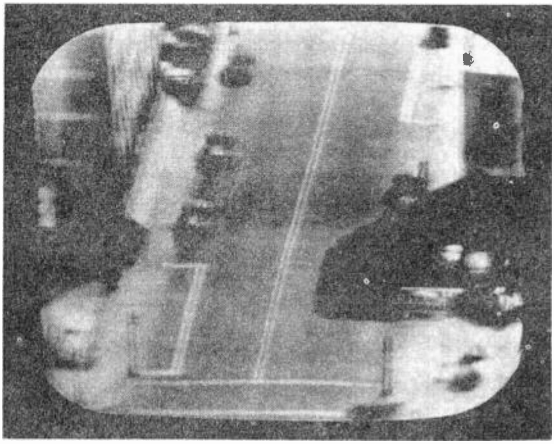


Fig.10 (A) One example of reflection due to faulty antenna.

3. DISTINGUISHING BETWEEN FAULTS IN THE RECEIVER AND FAULTS DUE TO EXTERNAL CAUSES. Poor picture reception is not always due to faults in the receiver, or to improper operation. External interference or a faulty antenna may also produce a poor picture.

The job of correctly installing the receiver antenna was covered in a previous lesson. While this is a job for the installation man, nevertheless, the effectiveness of the antenna may

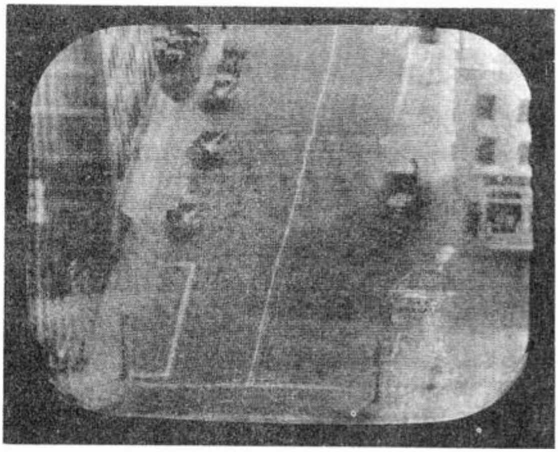


Fig.10 (B) Multiple images due to faulty antenna or improper antenna location.

change from time to time as other wires are erected in the vicinity, or it is possible that in a wind storm the antenna may be damaged or one wire of the transmission line may be broken.

The signal arriving at the receiver is a composite of the signal which goes directly between the transmitter and receiver, and several other signals which arrive via reflection from buildings, wires, etc. These various signals add up at some frequencies within the television band and subtract at others, resulting in consequent picture distortion. To obtain a good picture, the antenna is moved around until a position is found where the extraneous signals are at a minimum and the composite signal delivered to the receiver has a minimum distortion as determined by the picture quality. Usually, the location of a television antenna is quite critical and if a wire is erected near the antenna, the quality of reception may be impaired.

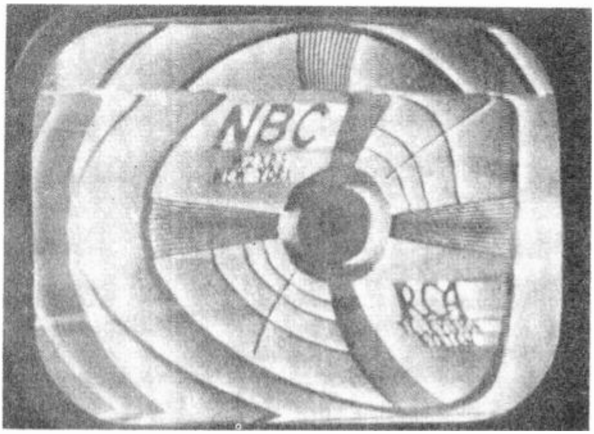


Fig.11 Effect of excessive signal strength.

Multiple images produced by the signal following several paths between the transmitter and receiver are sometimes displaced only slightly on the television screen and show up as a loss of resolution. At other times, the repeat images are quite distinct as shown in Fig. 10. A broken antenna wire would cause even worse distortion, as the feed line would be resonant at certain points within the television band.

If the receiver is located close to the transmitter, too strong a signal may overload the receiver and cause picture distortion which looks somewhat the same as the distortion encountered with a broken feed line to the antenna. Such an effect is shown in Fig. 11. On the other hand, too weak a signal will be over-ridden with noise, due to thermal agitation in the tubes in the receiver; also the picture will lack contrast. Such a picture is illustrated in Fig. 12.

Occasionally fading is encountered which changes the background and the contrast of the picture in a regular swinging manner. Such an occurrence is usually due to swinging wires in the vicinity of the receiving antenna, for which the remedy is obvious; or the effect is sometimes due to passing automobiles if the antenna is located near the street. In the latter case, a new location for the antenna should be sought.

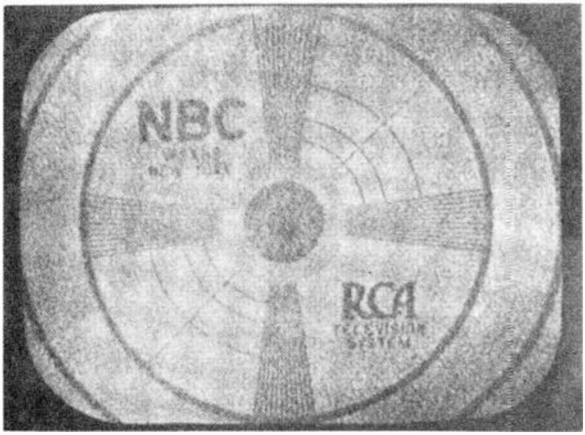


Fig.12 Tube noise in the picture due to insufficient signal strength.

It is not uncommon for modern transport airplanes in flying near a receiver location, to produce a reflection of the signal from the transmitter, which will add to the signal received directly from the transmitter, and produce two images on the screen. The second image will be fainter than the first, and displaced a half-inch or so from the main image. The *ghost image* will change position and finally fade out of the picture as the airplane recedes.

The received picture may be disagreeably marred by interference from automobile ignition, diathermy, and strong radio carriers, listed in the order of their importance. Automobile ignition interference is usually accompanied by a crackling in the received sound and shows up in the picture as white flashes, sometimes described as a snowstorm effect. This is illustrated in Fig. 13. The cure for such interference is to change the antenna location, change the type of antenna, or if the feed line is of poor quality, to replace it with a low-loss twisted pair or a concentric line.

Interference from diathermy machines often exists at a considerable distance from the doctor's office which houses the offending oscillator. A diathermy machine generates R.F. waves in miscellaneous bands of frequencies which may fall directly in the R.F. or I.F. channel of the receiver. The diathermy signal and its harmonics beat with the television signal and produce cross-modulation in the second detector of the receiver. The interference pattern produced will appear on the screen of the tube as shown in Fig. 14. Generally, this pattern is not station-

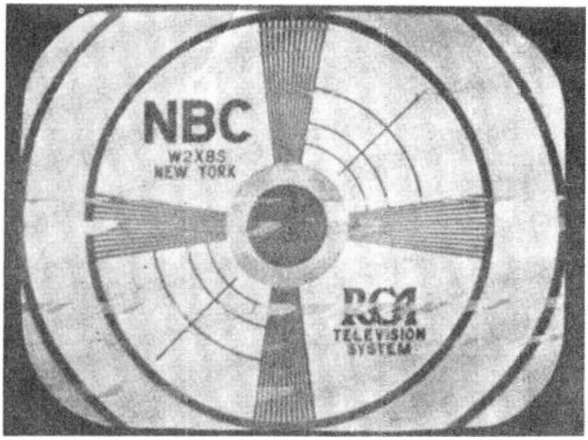


Fig.13 Automobile ignition interference.

ary, but crawls around through the picture as the frequency of the diathermy machine varies. If the location of the antenna has already been made as good as possible, the only remedy for such trouble is to locate the machine producing the interference and

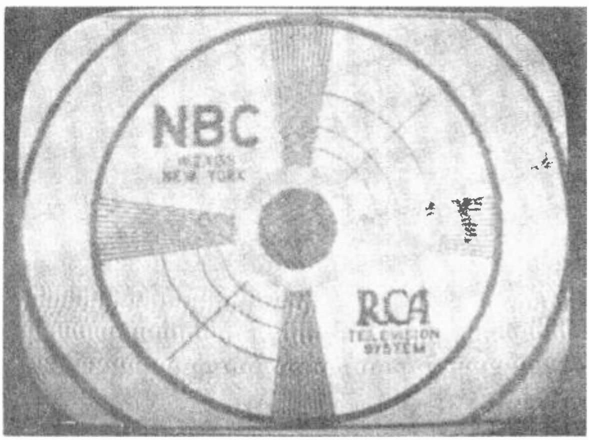


Fig.14 Diathermy interference.

secure the doctor's cooperation in applying filters to the 110 volt line, or altering grounds on the machine itself to reduce radiation to a minimum.

Interference from a strong radio carrier is not quite so common, but it should be realized that the intermediate frequencies of the receiver include a wide band of communication channels. Consequently, any extremely strong high frequency signal may be picked up in the I.F. channel directly, or capacity coupled through the mixer tube, especially if the receiver is not equipped with a pre-selector or R.F. stage. In this case, the carrier picked up will beat with the television carrier to produce a regular pattern which will appear as cross-hatching through the television picture as shown in Fig. 15. A wave trap in the antenna may be a solution to this difficulty, but in installing the wave trap, care should be taken not to spoil the quality of the picture. If the feed line is a good one, the installation of wave traps may cause a multiple image to appear. If a simple wave trap upsets the picture, two of them can be placed, one in each leg of the feed line, shielding each coil and using extremely short leads to preserve balance in the feed system.

Fig.15 Cross-hatching due to interference from a radio frequency carrier.

4. SIMPLE MISADJUSTMENTS OF THE RECEIVER. In addition to the main controls of the receiver which are exposed on the front of the cabinet, several other controls are usually provided as screwdriver adjustments; more or less accessible. If these should be changed in any way by the set owner, accidentally or through curiosity, the picture might be adversely affected. The controls usually provided are horizontal and vertical spot shifts, horizontal and vertical size, vertical linearity; and in some instances, horizontal linearity and oscillator coarse frequency controls.

Incorrect centering of the picture may not necessarily be due to a mis-setting of the centering control. Large kinescopes are not often shielded from the magnetic effects of the earth's field,

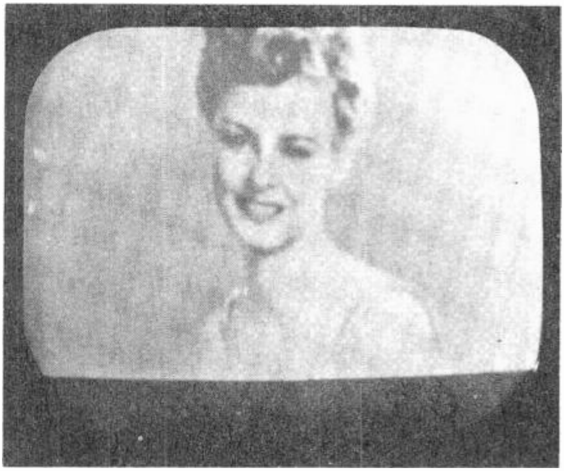


Fig.16 Misadjustment of vertical centering control.

which may play a part in determining the position of the picture by producing a constant small deflection of the cathode ray beam. In moving the set from one side of the room to the other, or merely turning the set to face a slightly different direction may cause a shift in the position of the picture. This is corrected by operating the centering controls. A misadjustment of the vertical centering control is shown in Fig. 16, while Fig. 17 shows a misadjustment of the horizontal centering control.

Fig.17 Misadjustment of horizontal centering control.

Fig.18 Incorrect vertical linearity.

The focus control should be adjusted with the proper background and contrast on the screen. The setting of the focus control will be almost, but not quite, the same for various picture intensities.

A misadjustment of the vertical linearity control will cause the top of the picture to be either compressed or expanded, or may even cause it to fold back on itself as shown in Figs. 18 and 19. In the latter case, the return lines will show in the top of the picture.

If the picture on the screen appears to be twisted, examine the individual scanning lines of the picture. They should be

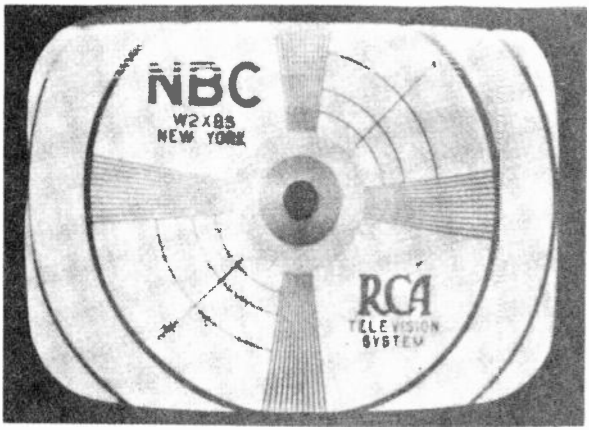


Fig.19 Return lines in the picture due to improper vertical peaking.

perfectly horizontal--parallel to the top and bottom of the kinescope viewing frame. Any deviation from this position can be corrected by rotating the deflection yoke in its mounting clamp. If this yoke should be badly out of position, the picture will appear as shown in Fig. 20.

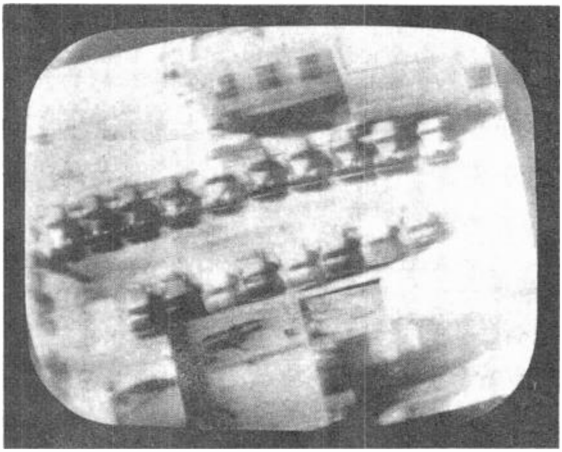


Fig. 20 Deflection yoke twisted on kinescope.

5. PARTIAL OR ZERO ILLUMINATION OF THE SCREEN. In case the screen completely fails to light up, the fault may be due to a defective kinescope, or one which is loose in its socket; a failure of the high voltage power supply, or too large a bias on the kinescope. If the tube is well placed in the socket and its filament is lighted (as observed visually, or by placing the hand on the neck of the tube to see if it is warm), the next step is to measure the high voltage and grid voltage to determine which is incorrect. It may not be practical to measure the grid voltage unless an extremely high resistance voltmeter is available. However, if the voltmeter drops the bias while the measurement is being made, it will also cause the screen of the kinescope to glow if incorrect bias is the fault. Consequently, the fault can be *detected* even though a high resistance voltmeter is not available.

The high voltages on kinescopes range up to 7500 volts, and although high impedance power supplies are generally used, nevertheless, sufficient energy can be stored in the high voltage condensers to be *dangerous to human life*. Extreme care should be exercised in measuring not only the high voltage itself, but other voltages which would bring the serviceman in the vicinity of the high voltage, such as the grid voltage on a kinescope, or in fact any voltage measurement made with the back of the cabinet removed. It is sometimes practical to determine faults in the high voltage power supply with an ohmmeter after the power supply is turned off and the *condensers discharged.* This should be done before any attempt is made to measure the high voltage pack.

The absence of high voltage could be due to a defective rectifier tube; an open circuit in the bleeder; an open circuit in the power transformer, filter chokes, or filter resistors; or a short-circuited condenser, or wiring which has arced over to ground. If the high voltage is of the correct value, the lead to the second anode should be inspected for a possible break.

If the center of the screen exhibits a stationary spot; this indicates complete absence of deflection voltages and possibly, but not necessarily, an absence of video voltage on the grid. Failure of deflection alone may be due to a loose or pulled out plug which normally connects the deflection yoke to the receiver chassis. The simultaneous failure of *deflection and video* circuits would indicate a faulty low voltage power supply, due to a burned out rectifier tube, power transformer, choke, or short-circuited filter condenser. *A stationary spot should not be allowed to remain on the screen of the tube*, as this will permanently damage the fluorescent material. The spot may be allowed on the screen if the background control is reduced to a point where the spot is barely visible. Even then, the spot should not remain on the tube longer than necessary to locate the trouble.

A single horizontal line on the face of the tube would indicate a failure of the vertical deflection circuit, whereas a single vertical line on the screen of the tube would indicate a failure of the horizontal deflection circuit. Such failure could be due to a defective tube in the deflection circuit, a broken lead to the deflection yoke, a failure in the power supply lead to one of the two deflection circuits, open resistors in either the plate circuit of the amplifier tube or in the decoupling filter resistor, or a defective oscillation transformer. An open coupling condenser will also impair the deflection, but sufficient coupling will probably exist between the stages in this case to produce a slight amount of deflection. An open in the vertical deflection circuit would allow a slight amount of vertical deflection and the horizontal line which appears on the face of the kinescope would not be sharply defined. As in the case of a stationary spot, *a single line should not be allowed to remain on the face of the kinescope* as this would produce a temporary or permanent dark line across the tube after normal deflection has been restored.

To determine whether the connections to the deflection yoke and the low voltage power supply are still intact, the centering control can be moved slightly to see if the line moves on the screen. For instance, if a horizontal line appears on the screen, the vertical centering control should be moved to determine whether the connections to the vertical coils on the yoke are intact and the power supply operative.

6. ADDITIONAL EFFECTS OF HIGH VOLTAGE POWER SUPPLY FAILURE. The most common source of high voltage power supply failure is

complete breakdown, which will result in no picture at all, as has already been pointed out. In addition to failing altogether, the high voltage may simply be reduced a certain amount by a faulty tube or leakage in the filter condenser, high voltage cables, terminals, etc.

A reduction of the power supply voltage without complete failure is possible because of the high internal impedance of the power supply. The high voltage transformers and chokes are wound with very fine wire so that they have a high resistance. Some of the high voltage rectifier tubes have a high effective resistance and some high voltage power supplies use resistors in place of chokes in the filter sections. This is done purposely for the protection of anyone coming into contact with the high voltage. As a consequence of the high resistance in the power supply circuit, any leakage will cause a reduction in the voltage applied to the kinescope. If the kinescope is operating at a low voltage, it will not be possible to obtain a brilliant picture on the screen. This effect will be particularly noticeable in a room which is not sufficiently dark. A further effect of reduced kinescope voltage is an increase in the picture size. This is due to the reduced stiffness of the electron beam at the lower second anode voltage.

Because the high voltage power supply is built with a high internal impedance, it should not be taken for granted that it is harmless to the serviceman. The shock produced is still dangerous and may cause death. A serviceman should make high voltage measurements with full caution. The procedure for making such a measurement is to shut off the receiver and then discharge the high voltage power supply. This is done by *first connecting a wire to ground* and then placing the opposite end of the wire on the high voltage terminal. After this has been done, the high voltage meter should be connected to the circuit, the grounding lead removed, and the set turned on while the operator stands clear of the meter. Throughout several of the servicing lessons, precautions are repeated in regard to handling high voltage power supplies. Repetition of these precautions should assist the student in bearing in mind the dangers involved in carelessly tampering with the high voltage while the receiver is turned on.

Unlike low voltage power supplies, an open circuit in the wiring or a burned out filter resistor may not completely remove the high voltage. A sustained arc is often formed which completes the circuit, but causes fluctuation in the high voltage power supply. This will appear as erratic modulation on the kinescope screen, causing fluttering and light flashes to occur even when the video gain control is set at minimum. Under such conditions, hum usually occurs in the picture, the effects of which will be discussed later in the lesson.

If it is impossible to distinguish the individual lines in the picture or if the individual lines seem blurred, proper adjustment of the focusing control should correct this condition. The focusing control is a potentiometer which adjusts the first anode voltage of the kinescope. If rotating this control has no effect in clearing up the blurred scanning lines of the picture, then the control has probably become defective by open-circuiting or arcing over to ground; or else the high voltage bleeder, of which this control is a part, has opened up. Such a condition is not uncommon, because the voltage supply to the first anode may range up to 2000 volts. With such high voltages involved, the leads to the potentiometer may have arced over, drawing excessive current and causing the bleeder or the potentiometer to burn out. The presence of excessive moisture or faulty insulation may cause the original breakdown in this circuit, which would possibly be followed by destruction of the potentiometer or part of the bleeder.

Inability to focus may not always be due to wrong first anode voltage on the kinescope. A soft or gassy kinescope may also prevent the tube from focusing. If the tube is gassy, it will generally pull excessive current from the high voltage power supply and lower the voltage. This can be checked with a voltmeter. In some instances, an inspection of the tube will show a purplish pencil of light emanating from the gun structure of the kinescope under normal operating conditions. The electron stream in the kinescope will ionize the residual gases, making the difficulty visible.

7. DEFECTS IN THE PICTURE BACKGROUND. The background of the picture is controlled in two ways; by the adjustment of a manual background control, and by the automatic background control circuit. Both of these circuits operate to change the bias on the kinescope. Failure in the manual background control, which is a potentiometer in the bias circuit of the kinescope, will make it impossible to adjust the brilliance of the picture to the desired level. Either the whole picture will be too dark, or the whole picture will be too light. This should not be confused with lack of contrast which has to do with the range of tones between black and white. Fig. 8, which appeared earlier in the lesson, depicts the "washed out" appearance of a picture when the background is too light.

A defect in the automatic background control circuit may make it impossible to correctly adjust the background, or cause the background to change erratically. A more subtle effect of automatic background circuit failure may be observed if the scene being televised is suddenly shifted from a generally dark toned scene to a generally light toned scene. Unless the automatic background circuits are functioning properly, the picture will appear "washed out" when the scene is shifted from one type of background to the other. If this effect occurs only rarely, the fault might lie at the transmitting station, especially if its television service has only recently been placed in operation. If the fault occurs consistently, and if the individual at the receiver must readjust the background control to obtain a good picture with shifting scenes, the fault is either in the background control circuits of the receiver, or the television re-

Fig.21 Sixty cycle hum in the video circuits.

ceiver itself is of the inexpensive variety which does not incorporate an automatic background circuit.

8. AC HUM IN THE PICTURE. Hum in the television set shows up in various ways on the screen, depending upon whether the hum is in the video amplifiers, the deflecting circuit, or other portions of the receiver.

If the hum is coming in the video amplifiers, it will not in any way effect the size or shape of the pattern on the kinescope,

Fig.22 Sixty cycle hum of opposite phase.

but will be noticed as excessive variations in background over the picture. This will show up as very broad horizontal bands of light and shade in the picture. An illustration of this effect is shown in Figs. 21 and 22, indicating the appearance when the hum is inserted with random phase relation. The hum just illustrated is due to 60 cycle pickup in the video amplifier, whereas hum at a 120 cycle rate would double the number of bands in the picture as shown in Fig. 23. Of course, both 60 cycle and 120 cycle hum could be present at the same time, resulting in a superimposition of the two sets of bands just illustrated. Notice that in all of these pictures, the shape of the picture is not distorted; the edges of the pattern are quite straight.

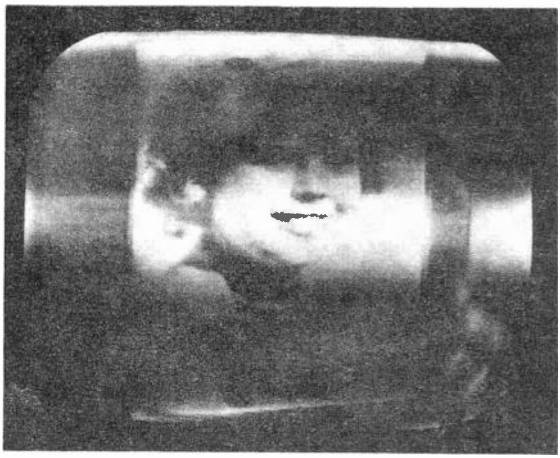


Fig.23 One hundred twenty cycle hum.

Hum in the horizontal deflection circuits, on the other hand, will not cause any variation in the background of the picture, but will cause parts of the picture to be moved on the kinescope screen to the right or left of their normal position, and some of the horizontal lines in the picture may be stretched out in comparison with other horizontal lines. Distortion of this nature is shown in Fig. 24. A picture of a group of electronic squares is also shown. Except for the distortion introduced by the receiver, each block would be perfectly square. Such picture distortion would result if hum were introduced into the horizontal oscillator or the horizontal amplifier. Hum in the oscillator, or in the synchronizing circuits, would cause the beam to fire a little sooner or a little later than normal, depending upon the polarity of the hum at that particular instance. Consequently, the horizontal deflection lines would be moved to the right or to the left of their normal position. Hum in the amplifiers would add to the deflection voltage and also cause the lines in the picture to be moved to the right or left of their normal position,

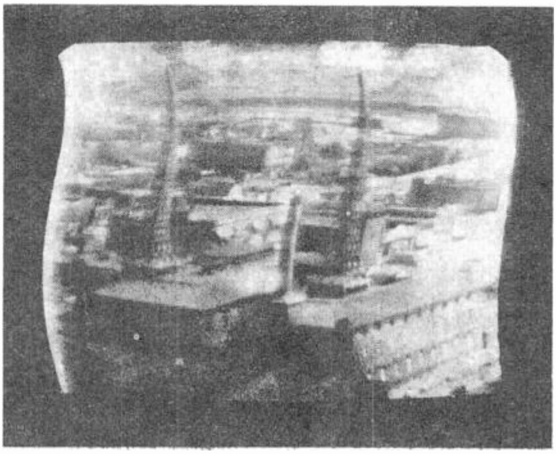


Fig.24 (A) Sixty cycle ripple in the horizontal deflection circuits.

depending upon the polarity of the 60 cycle voltage at the instant corresponding to that particular point in the picture. Since the picture is repeated at a 60 cycle rate, the distortion of the pattern remains stationary on the screen as shown in Fig. 24.

Hum introduced into the vertical deflection circuit, either the vertical discharge circuit or the vertical amplifier, will not be quite so noticeable in the picture as hum in the horizontal circuit. Since the vertical circuits are already scanning at a

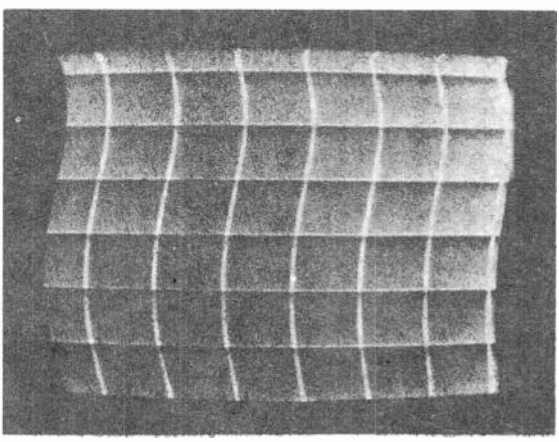


Fig.24 (B) Distortion of "electronic squares" under same conditions as in Fig. 24 (A).

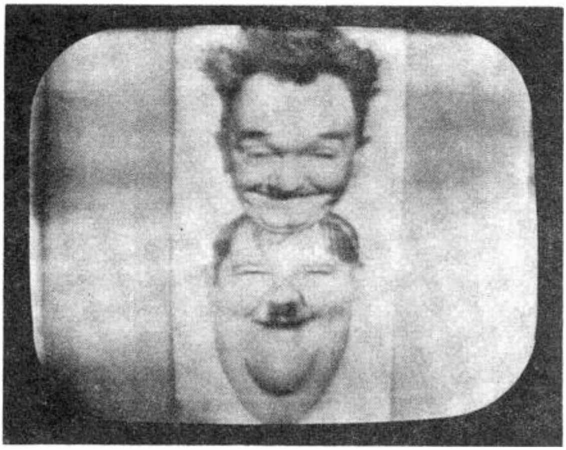


Fig.25 (A) Sixty cycle ripple in the vertical deflection circuits.

60 cycle sawtooth rate, hum introduced in these circuits will not cause distortion in the edges of the picture, but will merely increase or decrease the *velocity* of the spot as it scans from the top to the bottom of the picture. This will be noted as an elongation of part of the picture and a compression of part of the picture in the vertical direction as shown in Fig. 25. A comparison of the photograph with the distorted "electronic squares"

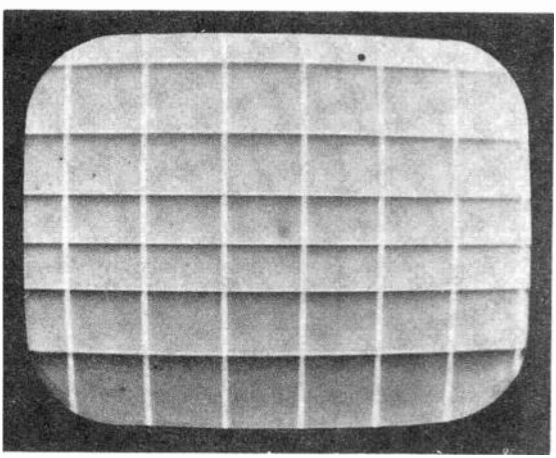


Fig.25 (B) Distortion of "electronic squares" under same conditions as in Fig.25 (A).

will indicate which portions of the picture are stretched out and which portions are compressed.

Hum may be getting into either the horizontal or the vertical deflection circuit because of a defective filter condenser in the power supply, defective decoupling condensers in the individual circuits, a filament-cathode short or otherwise defective tube, or a defective screen grid by-pass condenser.

Hum in a high voltage power supply, due to a faulty filter condenser will affect both the background of the picture and the shape of the picture simultaneously. Hum in the high voltage power supply causes the first and second anode voltages of the kinescope to fluctuate at a 60 cycle rate. This causes the background to fluctuate in a manner similar to the illustrations of Figs. 21 and 22. At the same time, the stiffness of the electron beam is changed in accordance with the 60 cycle variations and consequently, the magnitude of deflection which is produced by the normal deflecting fields will vary in proportion to the changing stiffness of the electron beam. This causes the sides of the picture to be curved rather than straight. The combined effect of pattern distortion and background variation produced by an open high voltage filter condenser is shown in Fig. 26.

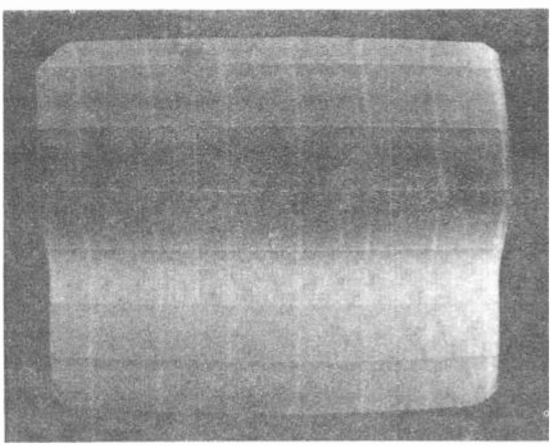


Fig.26 Defective high voltage filter condenser.

Most television receivers have a trace of residual hum in the picture, causing a faint horizontal band of gray to appear. This is entirely unnoticeable in a normal picture, but might be noticed if the shadow was set in motion instead of standing still on the screen. The band, or bands, of gray will be set in motion if the power supply frequency at the receiver differs somewhat from that at the transmitter. Assuming that the receiver is designed to operate on 60 cycles, the chance of its being supplied with a power system whose frequency differs to any extent from that at the transmitter is not very likely. Even though the transmitter and receiver are on separate power networks, the difference in frequency will normally be negligibly small. However, in rare cases, especially if the receiver is located in a small district supplying its own power, or on a farm equipped with a 60 cycle supply, there may be sufficient difference to cause the hum pattern to drift through the picture. In a good receiver, this effect will still be so faint as to be unobjectionable; but in the smaller, inexpensive models of television sets, if the drifting hum pattern is objectionable more filtering should be added by the serviceman.

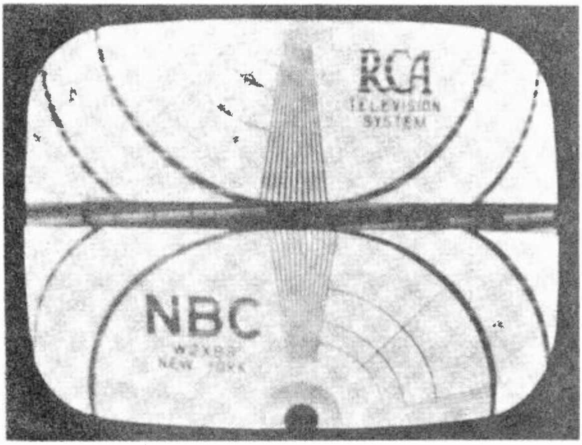


Fig.27 Picture drifting downward on the face of a kinescope.

9. POOR SYNCHRONIZATION. The extreme examples of poor synchronization shown in Figs. 3, 4, and 5, due to misadjustment of the oscillator speed controls, might also be caused by a defective control or condenser in the oscillator circuits. If these components are satisfactory and the oscillators are functioning normally, it should be possible to easily adjust the two hold controls for a stable picture. If it is not possible to secure a stable pattern, the fault may be in the vertical synchronizing circuit. If this is the case, the picture will drift slowly upward or downward on the kinescope screen, while maintaining its correct shape. Fig. 27 is a photograph of a picture which is gradually drifting downward on the face of the kinescope screen. Every time the picture gets out of the correct position, the blanking no longer occurs at the proper interval to blank out the return lines of the vertical deflection, and consequently, they appear in the picture.

It is always possible to make the picture drift downward on the face of the kinescope by misadjustment of the vertical oscillator control. This is the condition for the horizontal oscillator running too fast, and as you have learned in a previous lesson, the oscillator must run slow to synchronize correctly. If the vertical synchronizing circuit is working properly, it will not be possible to make the picture drift slowly upward. If the adjustment of the speed control is such as to cause the picture to do this, it will drift up to its normal position and then will snap into the proper place on the kinescope screen. If it does not do this, the trouble will probably be found in a faulty tube, resistor, or coupling condenser in the vertical separation circuit; or in the vertical synchronizing circuit.

Fig.28 Picture tear-out.

If the horizontal synchronizing circuits are completely inoperative, it will be possible to make the picture drift from right to left or from left to right across the kinescope screen. This is not a usual fault, as this is due to a complete failure of the horizontal synchronizing circuit. The usual difficulty is to have the picture tear out at the top as shown in Fig. 28. The picture may tear out at the center or other points for brief intervals, due to a defective resistor or potentiometer.

Tearing out at the top of the picture may be due to insufficient synchronization, or more commonly because of crosstalk between the horizontal and vertical synchronizing or deflecting circuits. Such crosstalk may be due to defective decoupling condensers in the power supply leads which feed the separation and synchronizing injection circuits, or to misplaced wiring.

Another common cause of faulty synchronizing is due to poor low frequency response in the synchronizing pickoff circuit. This causes the level of the synchronizing to be depressed immediately after the vertical synchronizing pulse. Such a situation would appear on the screen of an oscilloscope as shown in Fig. 29. Faulty synchronization of this type may exist in the complete top half of the picture. Poor low frequency response may be caused by a faulty coupling condenser in the synchronizing circuit or it may be due to crosstalk between the vertical deflection circuit and the synchronizing pickoff circuit because of poorly regulated power supplies, insufficient filtering, or faulty decoupling circuits.

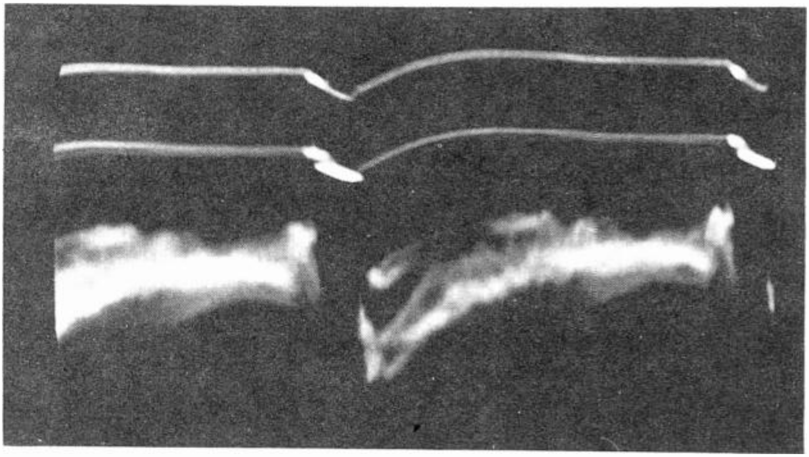


Fig.29 Poor low frequency response.

10. PATTERN DISTORTION. Figs. 16 and 17 indicate a picture which is out of position, due to misadjustment of the centering control. If rotating these controls does not place the picture in the center of the screen, then the difficulty is due to a faulty spot-shifting potentiometer, a defect in the voltage dividing resistors which supply the spot-shifting voltages to this potentiometer; or in the case where the spot-shifting currents are derived from the plate current of the deflection output stages, the difficulty may be incorrect bias on the output tubes of the deflection circuit. In the latter case, the pattern would not only be shifted on the screen, but distorted in size as well.

If the picture is too narrow, as shown in Fig. 1, or if the picture is not sufficiently high and it is impossible to secure the correct dimensions by adjustment of the horizontal and vertical gain controls, then the defect is probably due to a horizontal or vertical amplifier tube respectively which has lost emission and will not supply sufficient deflecting currents to obtain the correct size. A defective rectifier tube, or poor electrolytic condensers which would lower the power supply voltage, would cause a similar trouble.

An example of incorrect vertical linearity was shown in Fig. 18. Incorrect horizontal linearity is shown in Fig. 30. Horizontal non-linearity in moderation is not particularly apparent in a still picture and it may be necessary to compare Fig. 30A with the distorted "electronic squares" of Fig. 30B, in order to notice the

Fig.30 (A) Non-linearity of horizontal deflection.

horizontal distortion. However, if the televised scene contained horizontal motion, this amount of distortion could not be tolerated, because the moving objects would squeeze up or stretch out in crossing through the televised field.

Non-linearity in either the horizontal or the vertical direction is due to distorted deflection voltages. These may be caused by defective condensers in the discharge circuits or, more often, by incorrect bias in the sweep circuit amplifiers. Incorrect bias on an amplifier causes the sawtooth waveform to appear

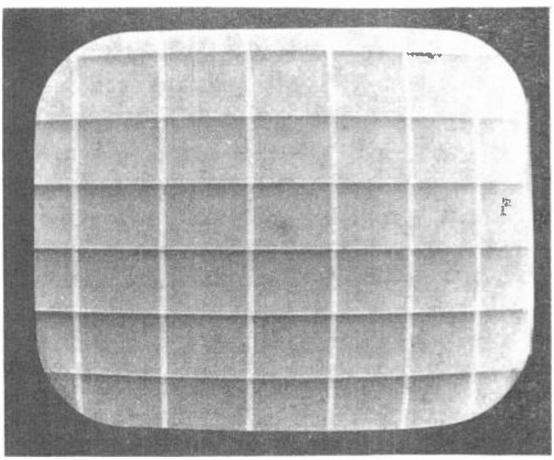


Fig.30 (B) Distortion of "electronic squares" under same conditions as in Fig.30 (A).

on a curved portion of the tube's characteristic, thereby distorting the wave from its original sawtooth form. The result is that the velocity of the beam changes as it scans across the picture. Unless the scanning beam has constant velocity in scanning across the face of the kinescope, the picture elements will not appear in their proper places, and the picture will be distorted. Improper screen or plate voltages on the amplifier would also cause them to be non-linear and distort the picture. Such a condition would arise from a defective plate or screen resistor, or a defective filter condenser.

You have learned in a previous lesson that during the return of the beam on the kinescope, the output tube in the deflection circuit draws no plate current and, due to the collapsing field in the output transformer, extremely high voltages are generated across the transformer. This would be followed by an oscillation due to the distributed capacity and the inductance of the output transformer, except that the second half-cycle is normally absorbed by a damping tube. Such an oscillation is most common in a horizontal output transformer, and may show up as a series of black vertical bands at the left-hand edge of the picture, or as a folding back of the picture at the left-hand edge. Such a situation is shown in Fig. 31, and would result if the damping tube in the horizontal output stage were defective.

Fig.31 Effect of horizontal damping tube failure.

A damping circuit is also provided in the vertical output stage, usually consisting of a series condenser and resistor across the vertical deflecting coils. Should this circuit become defective, the vertical linearity would be distorted and the vertical linearity control on the receiver could not completely correct the difficulty. The damping circuits for both the horizontal and vertical output stages are shown in one typical form in Fig. 32.

11. FAULTY INTERLACING. Every frame of the television picture appears on the kinescope screen twice. These individual appearances are called "picture fields" and each contains 220½ lines. The lines of one field lie half-way between the lines of the other. If the television picture contained only a few lines it would be formed as shown in Fig. 33A, where the solid lines represent one field and the dashed lines represent the following field. When "pairing" occurs; that is, poor interlacing, the lines of one field are displaced slightly on the screen, and so coincide, or almost coincide with the lines of the preceding and following fields. Partial pairing is shown in Fig. 33B, while complete pairing is shown in Fig. 33C. In the latter case, the lines in one field are indistinguishable from those of the preceding field.

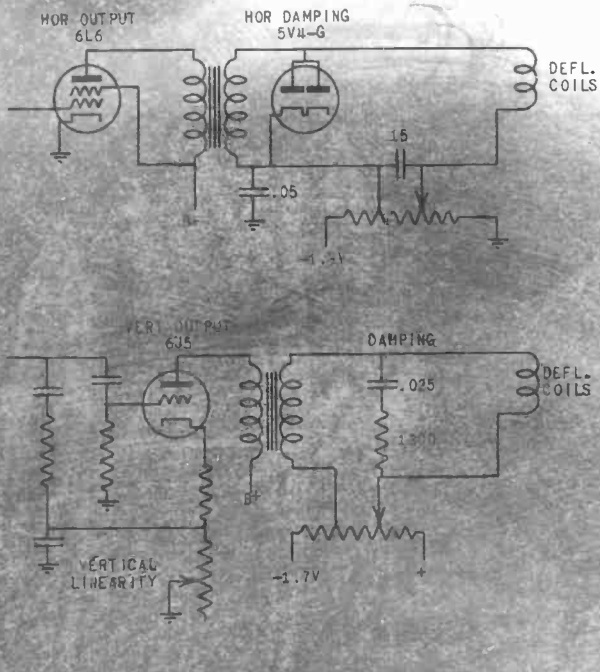
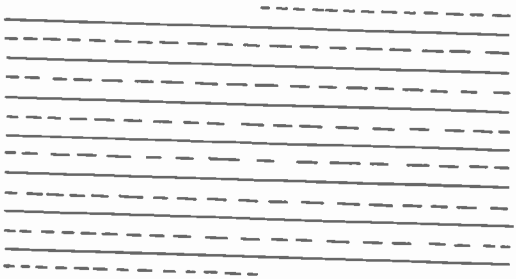


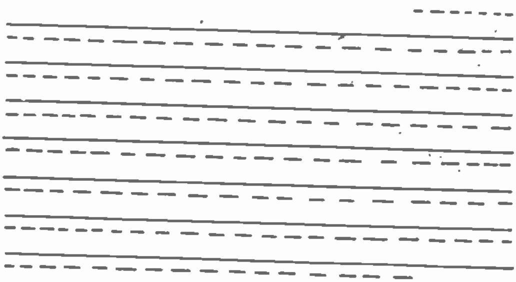
Fig. 32 Typical damping circuits.

From earlier sections of this lesson, Figs. 23, 24A, and 10B, are taken as examples of good interlacing, partial pairing, and complete pairing, respectively. These figures are duplicated in Fig. 34 which shows enlarged views of the scanning lines contained within the enclosed portions of the photograph.

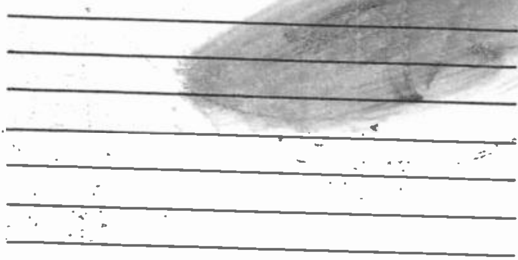
In modern television, there are so many lines in the picture that one who is not acquainted with just how pictures should appear will be unable to tell whether there are 220½ lines or 441 lines. Partial pairing can be distinguished, however, by close inspection of the individual lines in the picture. Pairing may also occur over part of the screen and not over the rest of the screen. It is generally possible to glance at a television screen, and then, upon moving your eye to another portion of the



(A) Interlacing.



(B) Partial pairing.



(C) Complete pairing.

FIG.33

screen, if the picture is interlacing, half of the lines will appear to drop out of the picture. This drop-out of half the lines occurs only while the eyes are in motion. To assist this procedure, one may place a finger at the top of the kinescope screen, and while glancing at the finger tip, move the finger down the screen at a fairly rapid rate. A little practice at this procedure, with the assistance of a properly functioning television set, will allow the serviceman to discover exactly how fast the eye should be moved to cause half the lines of the picture to drop out.

-A-

-B-

-C-

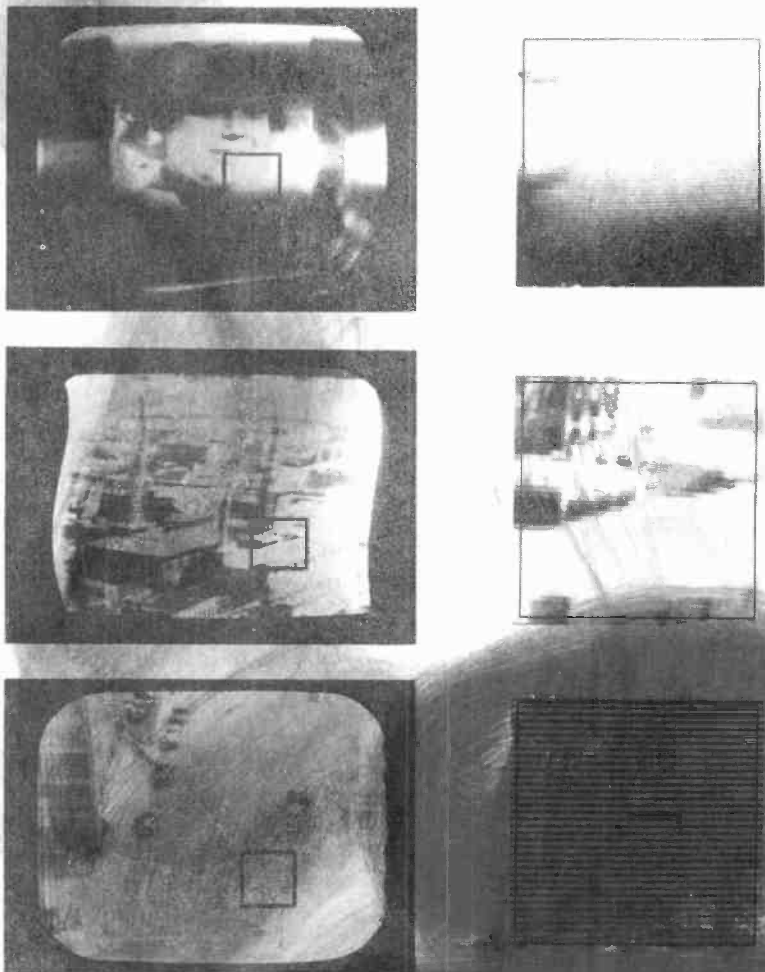


Fig.34 Photograph showing: (A) Interlacing; (B) Partial pairing; and (C) Complete pairing.

Pairing of the picture will be accompanied by loss of vertical resolution, and this will be noticed during the intervals when the television station is broadcasting its standard test pattern. While different stations will have slightly different test patterns, the serviceman should determine what part of the pattern corresponds to approximately 325-line resolution. This will be about the maximum vertical resolution that will be obtained from

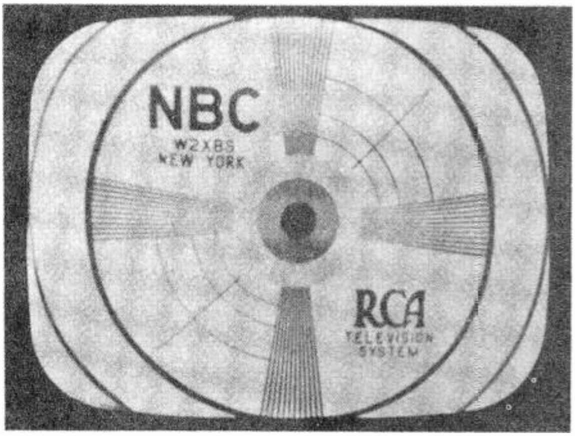


Fig.35 (A) Effect of interlacing on vertical resolution.

a correctly operating 441-line television system. In the chart of Fig. 35A, the NBC resolution chart is shown correctly resolved, while in Fig. 35B, poor interlacing results in loss of vertical resolution to the extent that an interference pattern is set up between the horizontal wedges of the test pattern and the 220 scanning lines of the picture. The interference pattern is distinguished as the curved light and dark bands which run through the horizontal wedges.

If a picture is paired over the whole screen, the fault is probably due to excessive synchronization signals resulting from incorrect bias in the pickup circuit, or cross-talk between the horizontal and vertical synchronizing circuits in the receiver, due

Fig.35 (B) Effect of pairing on vertical resolution.

to a faulty resistor or condenser, or misplaced wiring which has been incorrectly "dressed"[1] by the serviceman. Another cause of faulty interlacing is crosstalk between the horizontal and the vertical deflecting circuits or their amplifiers. Such would be the case with a faulty decoupling network or misplaced wiring in the receiver. If too much synchronizing is available, it will be found that the proper setting of the horizontal and vertical frequency controls are essential in securing correct interlacing. This effect becomes less important as the amount of synchronizing is reduced to a normal value.

12. POOR CONTRAST. A picture of low contrast, as shown in Fig. 7, is due to insufficient gain either in the R.F. amplifiers, the I.F. amplifiers, or the video amplifiers. This effect should not be confused with the reception of a weak signal, as shown in Fig. 12, as the latter is usually accompanied by noise, inadvertantly picked up by the antenna and generated in the first tubes of the receiver. If the synchronization is good and the picture can be held easily in place, then the chances are that the loss of signal is in the video amplifier rather than in the R.F. or I.F. amplifier. But in any case, the serviceman should start at the grid of the kinescope and work backward through the receiver until the trouble is located. A faulty tube will generally be found to be the cause, although too low voltage, due to a defective resistor or a fault in the power supply, will have a similar effect. Checking all the tubes in the set would be one procedure in locating the trouble. As a further step, the serviceman may apply one to two volts RMS AC to the grid of the video amplifier, which should be sufficient to completely modulate the kinescope screen if the video amplifier is normal. If the applied signal is derived from an audio oscillator, operating at less than 13,000 cycles, or from the 60 cycle filament supply in the receiver, horizontal bands will appear in the picture, whereas if an R.F. oscillator of between 400 kc. and 4 mc. is used, vertical bands will appear.

If the video amplifier is functioning properly, a serviceman's signal generator, or a Signalyst connected to the output of the first detector at a level of approximately 1 millivolt and modulated at 400 cycles should give horizontal bands in the picture if the I.F. amplifier is functioning properly. Such procedure may be repeated at the input to the first detector if a high frequency test oscillator, such as a Signalyst, is available. These instruments will be described in a later lesson.

Loss of gain in the I.F. amplifier, although probably due to a defective tube, may also be due to a misaligned I.F. transformer. This would usually be accompanied by a reduction in picture quality. Insufficient gain in the first detector could be caused by a faulty detector tube, misalignment of the first

[1] "Dressed", as applied to the wiring of a receiver, refers to the proper physical placement of the wiring.

I.F. transformer, or insufficient output from the oscillator section of the converter tube. Low oscillator output could be due to a defective tube or low plate supply voltage.

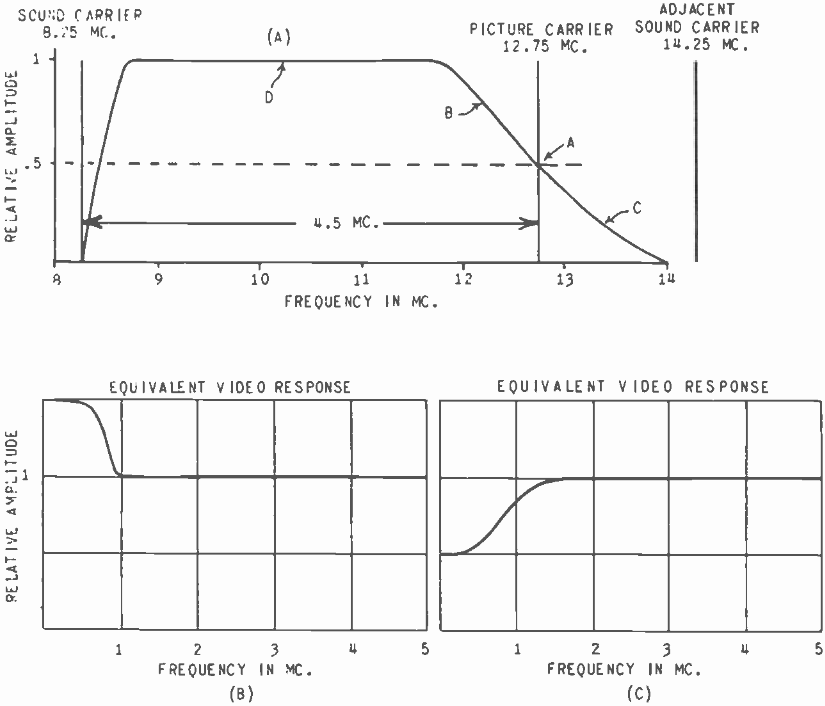


Fig.36 Effect of I.F. misalignment on the equivalent video frequency response.

13. DEFECTS IN PICTURE QUALITY DUE TO DISTORTION AT LOW VIDEO FREQUENCIES. If phase shift occurs at low video frequencies, or if the amplitude is diminished or excessively exaggerated, the picture background will not be uniform, but will vary throughout the picture. There will be a gradual change in tone from the top to the bottom of the picture, which will be particularly noticeable when a dark portion of a picture is followed by a light portion of the picture, or vice versa. This effect may be due to a defective coupling condenser in the video amplifier, defective grid resistor, or improper adjustment of the I.F. amplifier.

If the low frequency response is excessive, and attended with the usual delay of the lower frequencies, the white portions of the picture will not immediately return to the proper background level. Such an effect is generally caused by a defective decoupling condenser in the video amplifier; or it may be caused by misalignment of the I.F. amplifier.

A picture I.F. response curve of a receiver, neglecting any correction which may be made for attenuation in the R.F. circuits, is shown in Fig. 36A. In a television receiver, one oscillator is used in conjunction with the first detector to furnish two I.F. signals--one for sound and one for the picture. Normally, the sound I.F. channel is quite sharp, and in order to have good sound reception, the oscillator in the receiver must be tuned to a very definite frequency. Usually a variation of not more than 100 kc. is allowable. This fixes the position of the picture carrier at the I.F. frequency on the response curve of Fig. 36A. The normal position of the picture carrier is at point A, which is at one-half the response of the main pass-band, as represented by point D on the curve. If the I.F. response curve has the shape shown in Fig. 36A and the carrier is located at point A, all of the video frequencies which occur after demodulation in the second detector will have the same relative amplitude. If the I.F. amplifiers are misaligned so that the picture carrier occurs at point B, then the video frequencies occurring after the second detector will have a predominance of lower frequencies, as shown in Fig. 36B. Whereas, if the carrier is located at point C on the I.F. response curve, a lack of low frequencies will result after the second detector, as illustrated in the equivalent V.F. response curve of Fig. 36C. The adjustment of the I.F. amplifier to cause the carrier to fall at the proper point will be described in detail in a later lesson.

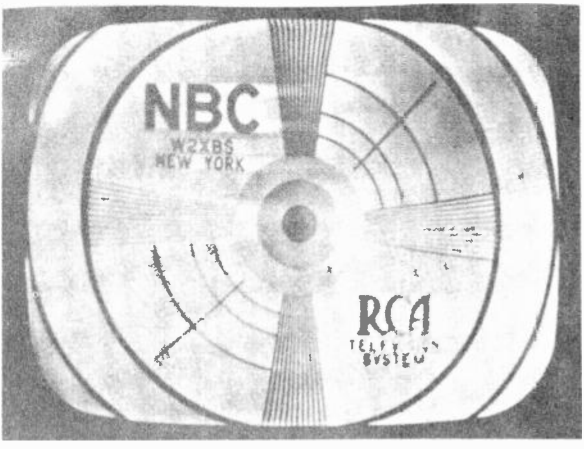


Fig.37 Phase shift of low video frequencies.

If the I.F. amplifiers are badly misadjusted, the low frequencies may be wiped out almost completely. In this instance, the synchronizing will be very poor; and when a picture is obtained, it will have a very ghostly appearance, as shown in Fig. 37. However, a more common cause for this particular type of picture distortion is an open circuit in a coupling condenser between the second detector and the video amplifier, between the stages of the video amplifier, or between the video amplifier and kinescope grid. An open-circuited condenser in any of these positions of the receiver would cause a complete loss of low frequencies in the picture, resulting in the ghostly appearing picture just shown.

14. DEFECTS IN PICTURE QUALITY DUE TO INCORRECT RESPONSE AT MEDIUM AND HIGH VIDEO FREQUENCIES. The most common defect in the high video frequency range is insufficient response at frequencies above one megacycle. The television receiver should pass up to 2½ megacycles or 4¼ megacycles, depending upon the price range of the receiver and the size of the picture tube employed. Five-inch receivers normally have a range of 2½ megacycles, whereas sets employing nine- and twelve-inch picture tubes usually extend the video response to 4¼ megacycles. Failure to pass the entire band of video frequencies will cause loss of horizontal resolution. This shows up as a fuzzy picture, somewhat similar to Fig. 2; which, as you will recall, illustrated a condition of poor kinescope focus. However, it will be easy to distinguish between poor high frequency response and poor focus by observing whether or not the individual lines in the picture can be discerned. If the individual lines in the picture are sharply defined, and the horizontal resolution is defective, then the difficulty lies in insufficient high frequency response.

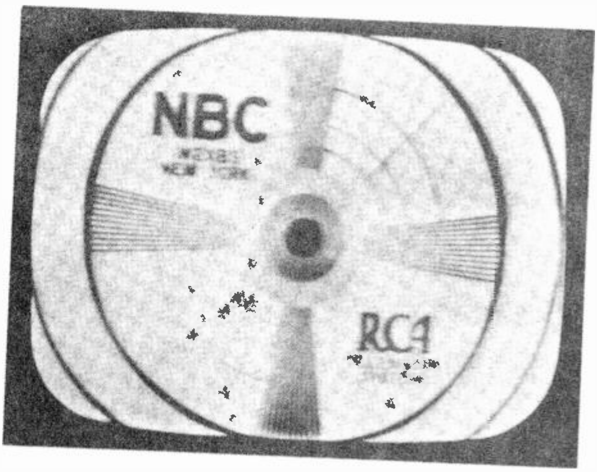


Fig.38 Loss of high video frequencies.

Poor horizontal resolution may best be inspected at the time when the television station has placed on the air a test chart. The horizontal resolution will be determined by the number of the lines that can be resolved on the vertical wedge of the chart. If the system is working correctly, approximately 250 lines will be resolved on a small receiver, and better than 400 lines will be resolved on the more expensive receivers. On the RCA chart shown in Fig. 35A, the gray circles in the center and the vertical wedges come together at a point corresponding to 350-line resolution. This should be clear-cut, as shown in Fig. 35A. If the receiver has poor high frequency response, the lines of the vertical wedge will not be distinguished down to the center circle, and the pattern will appear as shown in Fig. 38.

Poor high frequency response could be due to a defective plate resistor, a defective peaking coil in the video amplifier; or the difficulty could lie in misadjustment of the I.F. amplifier. Referring to Fig. 36, if the I.F. amplifier is misaligned so that the carrier falls at the center of the pass-band (at point D, instead of at point A), the only video frequencies which will be present after the second detector are those extending to two megacycles. Consequently, the vertical wedge of Fig. 35 could not be resolved below the first half-circle, because the receiver would lack the ability to resolve detail.

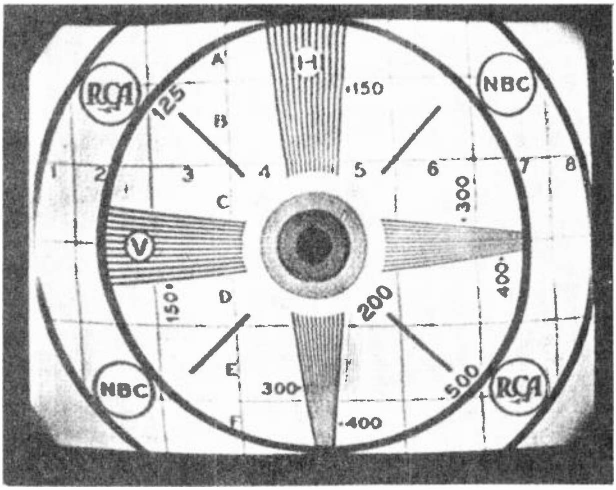


Fig.39 Transients due to a peak in the video response.

Occasionally, there appears on the screen of a defective television receiver, a series of dark and light bands, following an abrupt change from black to white in the picture. These bands may be one, two, or more in number, and always diminish in intensity as they are counted from left to right. Such distortion is observed most readily on the test pattern, which is transmitted during periods when programs are not being presented. An example of this is shown in Fig. 39. This is a picture of an early NBC test chart, and a group of about six faint vertical bands can be seen following the vertical wedge at a point equal to approximately 270 lines resolution. Bands of this nature are called "transients" and are due to a peak in the video response curve, or in the I.F. response curve. The difficulty may arise due to a faulty peaking coil, a faulty plate resistor in the load circuit of a video amplifier, or because of misalignment of the I.F. amplifier. A valley in the video response characteristic, or in the I.F. response characteristic, would have the same effect as a peak in the response, except that the polarity of the transients would be reversed; that is, all of the dark bands would be replaced by light bands. Consequently, misalignment of the trap circuits in the I.F. amplifier will result in a loss of certain video frequencies after the second detector, producing transients, as shown.

When the wedge-type test pattern is being transmitted, a definite frequency is set up in the video amplifier, corresponding to the particular portion of the wedge which is being scanned at that instant. If the generated frequency corresponds to that of the video distortion, the transient will be exaggerated in amplitude; consequently, a series of light and dark bands will lie opposite that particular part of the wedge pattern which corresponds to the frequency of the transient. To a first approximation, the number of lines of resolution indicated by the test pattern will correspond to one-ten-thousandth of the transient frequency. For instance, if the transients lie opposite the number 270, as indicated in Fig. 39, the serviceman will know that a peak or valley exists in the video characteristic at 2.7 megacycles. It should be understood, of course, that the same type of distortion can be introduced by the I.F. amplifier, in which case the distortion would occur at a point 2.7 megacycles removed from the carrier frequency. This would be typical of misalignment of a wave trap, which normally would be tuned to 8.25 or 14.25 megacycles.

15. EXTRANEOUS SIGNALS IN THE PICTURE. Misalignment of a wave trap, in addition to causing possible transients in the picture, will also allow the sound carrier to be amplified by the picture I.F. channel. The sound transmitter of the station to which the receiver is tuned will come through at an I.F. frequency of 8¼ megacycles in the case of the I.F. response curves of Fig. 36. In addition to this, the television station on the adjacent channel will have a sound carrier generated in the first detector at an I.F. frequency of 14.25 megacycles. In case the weaker of the two stations is being received, the adjacent channel sound carrier may be of extremely high intensity. Both the received channel and adjacent channel sound carriers will cross-modulate with the picture carrier in the second detector and in the R.F. amplifiers which are not perfectly linear. This cross-modulation will result in the picture being modulated at audio frequencies. Such modulation causes a multiplicity of horizontal bands of various widths to occur in the picture. The dark and light bands do not remain stationary in the picture, but move up and down and change in intensity, corresponding to the inflections in the music and voice carried on the sound transmitter. Fig. 40 illustrates an attempt to simulate this condition, although it is very difficult to photograph because of the transient, or temporary, nature of the horizontal bands which are produced.

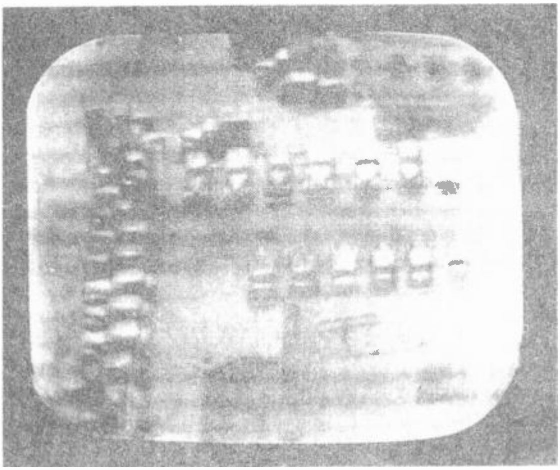


Fig.40 Sound modulation in the picture signal.

Another type of extraneous signal which is apt to occur can be generated in the television receiver itself, due to oscillations in the video amplifier, or in the I.F. amplifier. Oscillations in the video amplifier usually occur at a fairly high frequency on the order of several megacycles. One would expect this to produce a cross-hatching in the picture, as illustrated in Fig. 15. However, the oscillations are generally unstable, and for this reason, are keyed on and off by the blanking pulses. Fig. 41 shows the result of oscillations in the video amplifier.

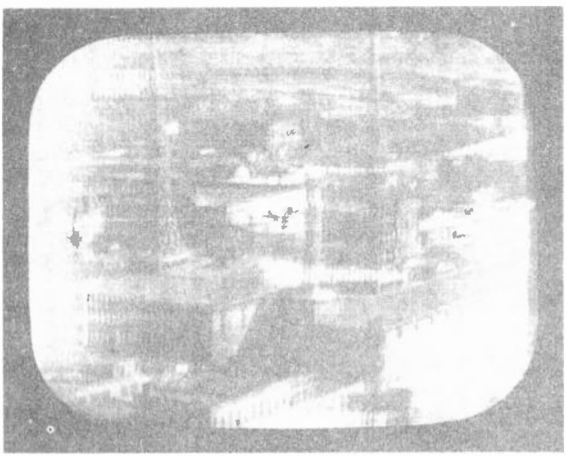


Fig.41 Oscillation in the video amplifier.

Oscillations in the video amplifier can be caused by an open circuit in a screen by-pass condenser, misplaced wiring, or insufficient grid bias.

Oscillations in the I.F. amplifier almost invariably destroy the synchronizing to such an extent that it is not possible to obtain a picture at all. Usually, the result appears as a mixture of light and dark splotches on the screen. It may also be characterized by a simple interference pattern, as shown in Fig. 15. Oscillations in the I.F. amplifier may be due to an open damping resistor across an I.F. transformer, a defective by-pass condenser on a cathode or screen, or a faulty tube. The resistance between the shell and grounding pin in the I.F. amplifier tube should be checked with an ohmmeter, or a new tube substituted, as the connection between the ground pin and the shell is sometimes defective.

In this lesson we have summed up the typical defects in the received picture and their possible causes. No attempt has been made to give detailed suggestions for analyzing or repairing the trouble, but it has been shown how to isolate the trouble to a particular part of the receiver. In later lessons, the individual portions of the receiver will be considered in detail, giving typical diagrams and a definite method of locating and repairing the trouble.

EXAMINATION QUESTIONS

INSTRUCTIONS. Before starting to answer these examination questions, you should have studied the lesson material at least three times. Be sure that you understand each question--then proceed to write the best answer you can. Make all answers complete and in detail. Print your name, address, and file number on each page and be neat in your work. Your paper must be easily legible; otherwise, it will be returned ungraded. Finish this examination before starting your study of the next lesson. However, send in at least three examinations at a time.

1. If a resolution chart has clearly defined horizontal wedges, but smeary vertical wedges, what is wrong with the receiver?

2. Describe the effect of an open high voltage filter condenser.

3. What is the effect of a damping tube failure?

4. If a uniform cross-hatching appears in the picture, what is the probable cause?

5. What will be the general appearance of the picture if the horizontal hold control is incorrectly set?

6. If a 60 cycle ripple appeared in the deflection circuit, how would you distinguish between ripple in the horizontal and vertical circuits?

7. How would you distinguish between automobile ignition interference and diathermy interference?

8. If the vertical return lines appear in the picture, what is the probable cause?

9. Illustrate by a sketch the following: (a) interlacing; (b) partial pairing; (c) complete pairing.

10. If the sound trap in the receiver were misadjusted so that cross-modulation occurred between the sound and the picture, how would this show up on the screen of the television receiver?

Notes

(These extra pages are provided for your use in taking special notes)

Notes

(These extra pages are provided for your use in taking special notes)

Notes

(These extra pages are provided for your use in taking special notes)

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UNIT NO. 6

TELEVISION SERVICING TEST EQUIPMENT

LESSON NO. 3

HISTORY

and Television.

At the time this little story was written, Television was following the same course of development that other out-of-the-ordinary scientific developments have experienced in the past.

For years, Television was in the experimental stage. At times, during this stage, it seemed certain that a new industry was to be born. For various reasons, this failed to occur. Then came improved Television and, equally important, a public demand. This demand is becoming more insistent as time goes on and will eventually bring us to the point where television reception in our homes will become commonplace. We will forget about the marvels of Television. But we will enjoy it and spend our money for receivers.

Today, radio is accepted without thought. People do not consider it wonderful that sound can be sent through the air and that intelligence can be transmitted without the aid of connecting wires.

For years the airplane struggled along much the same as Television has done. There were times when aviation seemed destined for a great boom. But such times were of short duration. Then the public awoke to the advantages of travel by air. The demand for air service skyrocketed and today the industry has shown an amazing growth.

Television is ready. The public wants Television service and is giving stronger voice to it's demands. America soon should have another new, thriving industry and you who have Television training will be most fortunate.

PRINTED IN U.S.A.
JONESPRINTS
KANSAS CITY, MO.

Lesson Three

TELEVISION SERVICING TEST EQUIPMENT

"This lesson is devoted to a discussion of the equipment required for the expert servicing of television receivers. Some of the needed apparatus was available commercially at the time this lesson was written. Constructional details are given for building other test apparatus that is valuable to the television serviceman.

"Much of the apparatus suitable for servicing the ordinary sound receiver lacks sufficient precision to be used for television servicing. Therefore, it is essential that the prospective television serviceman know the specifications that a piece of test equipment must meet in order to be usable in television servicing."

1. THE CATHODE-RAY OSCILLOGRAPH. The cathode-ray oscillograph, or oscilloscope as it is more commonly called, is undoubtedly the most valuable single piece of test equipment. It is a necessity for checking the operation of the deflecting and synchronizing circuits. It is also used in the alignment of the IF and RF amplifiers of the receiver.

However, the common types of oscilloscopes used in radio servicing are unsatisfactory for television receiver checking. The most important defect of the ordinary oscilloscope is its poor high-frequency gain and phase characteristics. The gain of the vertical amplifier in an ordinary oscilloscope usually starts to fall off at frequencies in excess of ten to fifteen thousand cycles, and is practically zero for frequencies exceeding one hundred thousand cycles. Of course, the signal could be applied directly to the deflecting plates if its magnitude were sufficient; but most of the voltages developed in television receivers lack sufficient amplitude to deflect the beam of the cathode ray tube directly.

Another defect in many of the radio servicing types of oscilloscopes is the unsatisfactory gain and phase characteristics for frequencies extending from thirty to one or two hundred cycles. Such characteristics are satisfactory for checking audio waveforms and sound IF channel alignment; but are unsatisfactory for checking television receiver waveforms and the video RF and IF alignment.

A third unsatisfactory characteristic of the common oscilloscope is the small size of the cathode ray tube screen. Practically all of them have screens of the three-inch size or smaller. To determine the frequency limits of the IF and RF response curves at the precision required in television alignment, it is advisable to use an oscilloscope with a screen five inches or more in diameter.

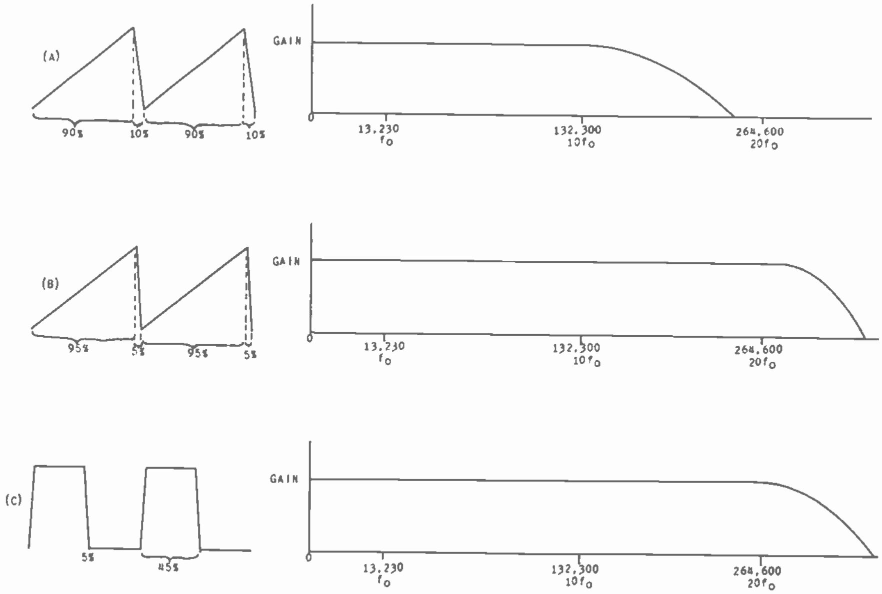


Fig.1 Amplifier frequency response required for the faithful transmission of sawtooth and square waves.

Now that the deficiencies of the ordinary oscilloscope have been discussed in terms of the television serviceman's needs, the next logical step is to discuss the design specifications of a satisfactory oscilloscope. In a previous lesson it was stated that an amplifier must have constant gain over a wide frequency range in order to transmit faithfully a sawtooth voltage wave. When the return time, or "fly-back" time, constituted ten percent of the sawtooth cycle, the amplifier had to be flat over the range of frequencies extending from the fundamental to the tenth harmonic. When the return time was reduced to five percent, the amplifier gain had to be uniform over the frequency band extending to the twentieth harmonic. In other words, the number of harmonics that must be passed by the amplifier to obtain faithful transmission of the sawtooth wave is inversely proportional to the fractional part of the cycle forming the fly-back. Thus, in order to transmit or amplify faithfully a waveform in which there are very rapid voltage changes, it is necessary to have an amplifier that has uniform gain over an extremely wide frequency range.

Fig. 1 shows the range of frequencies that an amplifier must pass with constant gain in order to transmit faithfully; (A) a 13,230-cycle sawtooth wave with a 10% return time, (B) a 13,230-cycle sawtooth with a 5% return time, and (C) a 13,230-cycle square wave in which the voltage changes between the peak values in 5% of the cycle. In this third case, the required frequency range is the same as that needed for the transmission of the sawtooth with the 5% return time.

Two of the major uses of the oscilloscope in servicing television receivers, is to check the operation of the deflecting and sync circuits, and to trace the video signal through the video portion of the receiver.

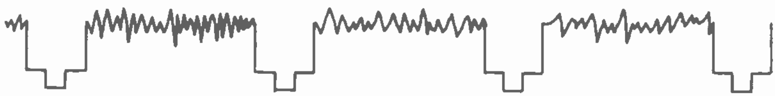


Fig.2 Video signal.

Fig. 2 shows several lines of a video signal based on the present RMA standards. It can be seen that the horizontal sync pulses have steeper slopes than the 13,230-cycle square wave shown in Fig. 1C. Therefore, faithful amplification of the sync pulses and blanking pulses requires an amplifier that has uniform gain over a wider range than that shown in Fig. 1C. Experience has shown that an oscilloscope with a vertical amplifier flat over the frequency range extending to 500,000 cycles is very satisfactory for checking the sync circuits in a receiver. This range is adequate to check the deflecting circuits as the horizontal sawtooth usually has a return time of between five and ten percent. The picture portion of the composite video signal requires a much wider frequency range for transmission, but the picture reproduced on the cathode-ray tube in the receiver is the best check on the correct operation of the video amplifier.

At the low frequencies from 30 to 100 cycles, phase distortion is more important than frequency distortion in the vertical amplifier toward limiting the usefulness of an oscilloscope for television servicing. The low-frequency phase distortion of the vertical amplifier can most easily be checked by applying a 60-cycle square wave to the input of the amplifier and viewing the output waveform on the screen of the cathode-ray tube. If the output waveform is a replica of the input waveform, the amplifier is free of low-frequency phase distortion. A simple 60-cycle square wave generator is described in a later section of this lesson.

A good measuring instrument must not change the relations between the current, voltage, and frequency existing in the circuit to which the measuring instrument is connected. This means that the measuring instrument must have a high input impedance over the entire range of frequencies in the circuit. The input impedance of an ordinary oscilloscope consists of resistance and capacitive reactance. The resistive component is the resistance of the input attenuator or gain control. The capacitive part is due to the wiring capacity to ground and the input capacity of the first amplifier tube. Then, in order to have a high input impedance over a wide frequency range, the input circuit of the oscilloscope must be designed so that the shunt capacity is reduced to a minimum.

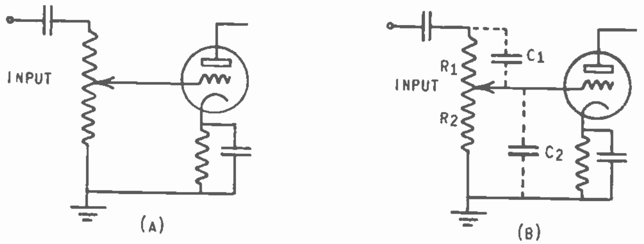


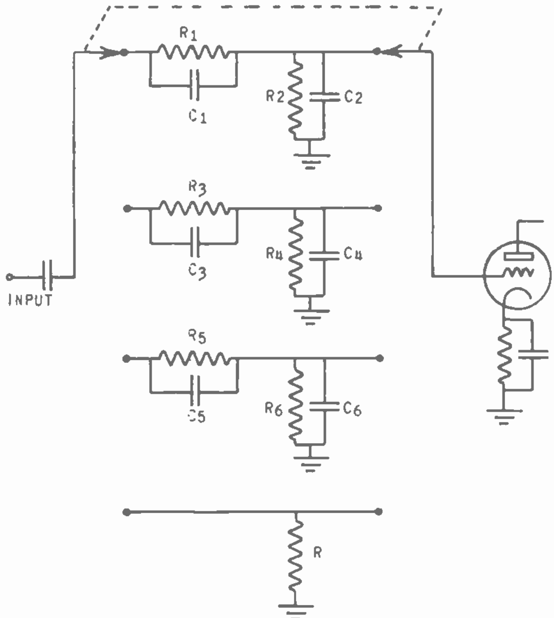
Fig.3 Simple attenuator and equivalent circuit.

A simple input attenuator, such as that shown in Fig. 3A, cannot be used with television servicing oscilloscopes. When the input capacity of the tube and the wiring capacity are considered, the circuit is actually of the form shown in Fig. 3B. The attenuator consists of two attenuators in parallel, one made of resistances, and the other of capacities. For low frequencies, the reactances of C_1 and C_2 are very large in comparison to R_1 and R_2 and can be neglected. However, at high frequencies, the reactances of C_1 and C_2 are of the same order of magnitude as R_1 and R_2, and are as important as R_1 and R_2 in determining the amplitude of the voltage applied to the grid of the tube. When the ratio between R_1 and R_2 is varied, the ratio between C_1 and C_2 remains essentially constant. Thus, the frequency characteristic of the attenuator varies with the setting of the potentiometer arm. Since C_1 and C_2 remain constant, the percentage of the high-frequency components of the input signal applied to the grid of the tube is partially independent of the ratio between R_1 and R_2. This independence becomes greater as the frequency is increased. When R_1/R_2 is small, the attenuation will increase with frequency. When R_1/R_2 is large, the attenuation will decrease with frequency. Thus, the waveform applied to the grid of the tube will not be a replica of the waveform applied to the attenuator. The type and magnitude of the distortion will depend on the setting of the attenuator.

There are two reasonably satisfactory solutions to this attenuator problem. One is a low resistance potentiometer (2000 to 5000 ohms). Then the reactances of C_1 and C_2 will be large in comparison to R_1 and R_2 over the frequency range of the oscilloscope, and can be neglected. This is not an entirely satisfactory solution because the input impedance of the oscilloscope is very low, and it can only be used to check circuits that have a much lower impedance. Thus, its usefulness becomes very limited.

The second, and more preferable, solution is to change the ratio of C_1 and C_2 when the ratio between R_1 and R_2 is changed.

The attenuation will be independent of the frequency when R_1/R_2 is equal to C_2/C_1. It is an inverse proportion because the reactance of a condenser varies inversely with the capacity. Fig. 4 is a diagram of an attenuator incorporating this method of making the attenuation independent of frequency. The attenuation is not continuously variable, but occurs in steps. Each condenser in the attenuator represents the total capacity between the points where



$$R = R_1 + R_2 = R_3 + R_4 = R_5 + R_6$$

$$\frac{R_1}{R_2} = \frac{C_2}{C_1} \qquad \frac{R_3}{R_4} = \frac{C_4}{C_3} \qquad \frac{R_5}{R_6} = \frac{C_6}{C_5}$$

$$\frac{R_2}{R} = .001 \qquad \frac{R_4}{R} = .01$$

$$\frac{R_6}{R} = .1 \qquad \frac{R}{R} = 1$$

Fig.4 Frequency compensated attenuator.

it is connected. Only sufficient additional capacity is added across each element of the attenuator to make the resistance and capacity ratios equal for each step. It is evident that the input impedance becomes less for higher frequencies. Since the capacities are in series for each step, the total input capacity will be slightly greater than the input capacity of the tube itself. The resistor R is usually about 1 megohm.

There are two other specifications that an oscilloscope should meet in order to be valuable to the television serviceman. One is that the horizontal sweep should be linear. This is necessary in order to check the linearity of the sawtooth voltages generated in the deflecting circuits of the receiver. The sweep frequency should extend beyond 13,230 cycles so that a single horizontal sync or blanking pulse can be viewed.

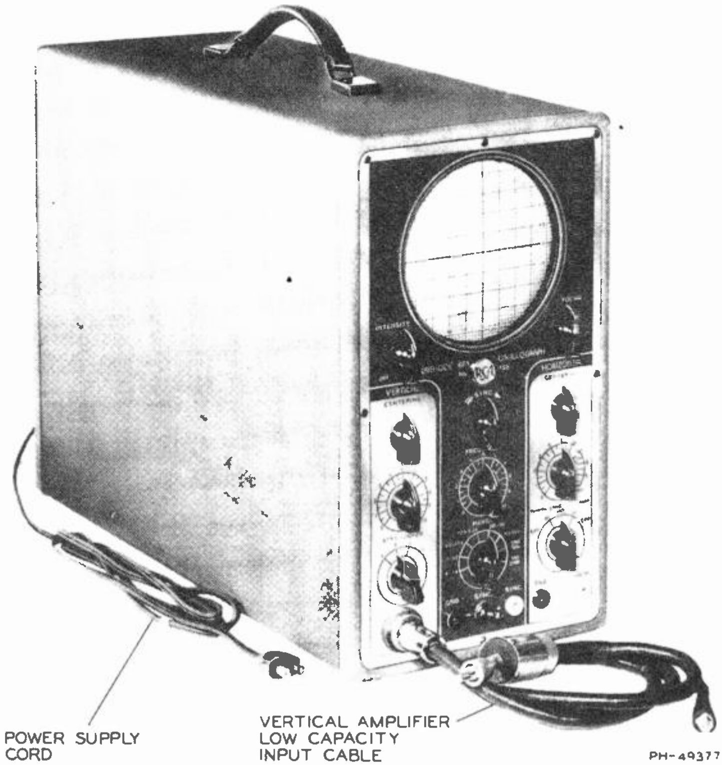


Fig.5 RCA #158 Oscilloscope.

The preceding paragraphs have listed the major design specifications that an oscilloscope must meet in order to give accurate information concerning the operation of the circuits in television receivers. Fig. 5 shows a picture of one commercial oscilloscope that meets these design specifications. It is the RCA No. 158. A circuit diagram is given in Fig. 6. This oscilloscope is equipped with a special coaxial cable for applying the signal to the input of the vertical amplifier. The equivalent input circuit of the vertical amplifier, when the cable is not used, consists of a resistance of 1 megohm in shunt with a capacity of 22 mmfds. When the cable is used, the equivalent input circuit consists of a re-

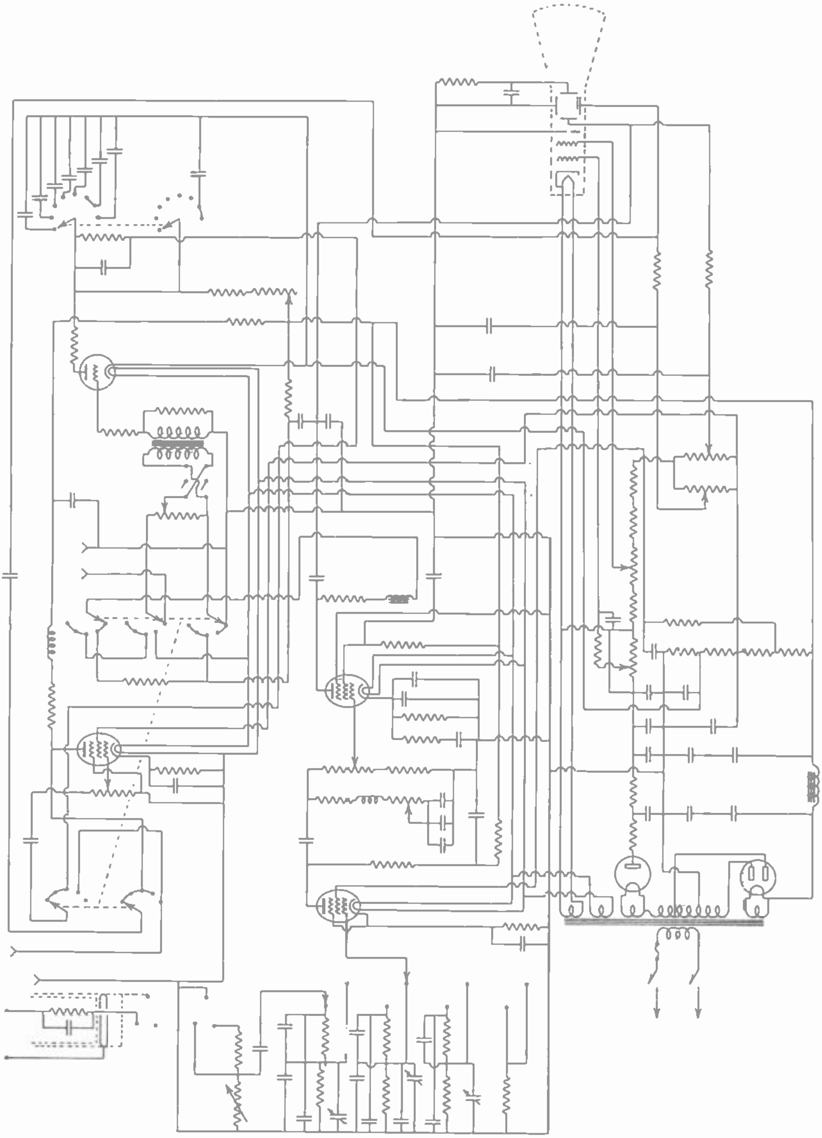


Fig.6 Circuit of RCA #158 Oscilloscope.

sistance of 1.1 megohms and 8 mmfds. The vertical amplifier has uniform gain over a frequency range from 5 to 500,000 cycles, and will amplify square waves without distortion for fundamental frequencies from 60 to 13,000 cycles. A four-step resistance-capacity attenuator, like that in Fig. 4, is used in the input circuit to the vertical amplifier. The overall gain of the amplifier is controlled by a low resistance potentiometer (10,000 ohms) in the grid of the second vertical amplifier tube. This method can be used here, as the load impedance of the preceding stage is low.

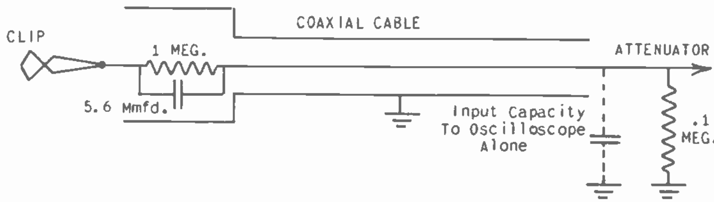


Fig.7 Frequency compensated oscilloscope cable.

In order to keep the input capacity down when the cable is used, an additional resistance-capacity attenuator stage is used, and the capacity of the cable forms part of the capacity across the output resistance of the additional attenuator. This is shown in Fig. 7. Thus, the input capacity to the oscilloscope, when the cable is used, consists of the 5.6 mmfd. condenser across the 1-megohm section of the added attenuator step in series with the cable capacity and the input capacity to the oscilloscope (when used without cable) plus the capacity between the 1-megohm resistor and its shield. With the cable, the actual input capacity is less than when the cable is not used. However, with the cable, the sensitivity is reduced by a factor of ten.

Many servicemen, when using an oscilloscope to view the waveforms generated in a television receiver, forget the nature of these waveforms, and, as a result, do not adjust the amplitude controls correctly. The waveform that they see on the screen is not the actual waveform generated in the part of the circuit to which the oscilloscope is connected. This point can best be illustrated by an example. Fig. 8A shows the waveform generated between grid and ground of the blocking tube oscillator as it is normally drawn in texts. Fig. 8B shows this same waveform as it appears on the screen of the oscilloscope. The sudden and abrupt voltage changes do not show on the screen as a bright trace, because the electron beam is moving so rapidly that there is practically no fluorescence produced along its path. As a result, the average inexperienced serviceman adjusts the amplitude controls so that the waveform appearing on the screen of the oscilloscope is like Fig. 8C. The sharp positive pulse is not seen, because the electron beam is deflected off the screen during that interval. When using an oscilloscope, it is always advisable to set the at-

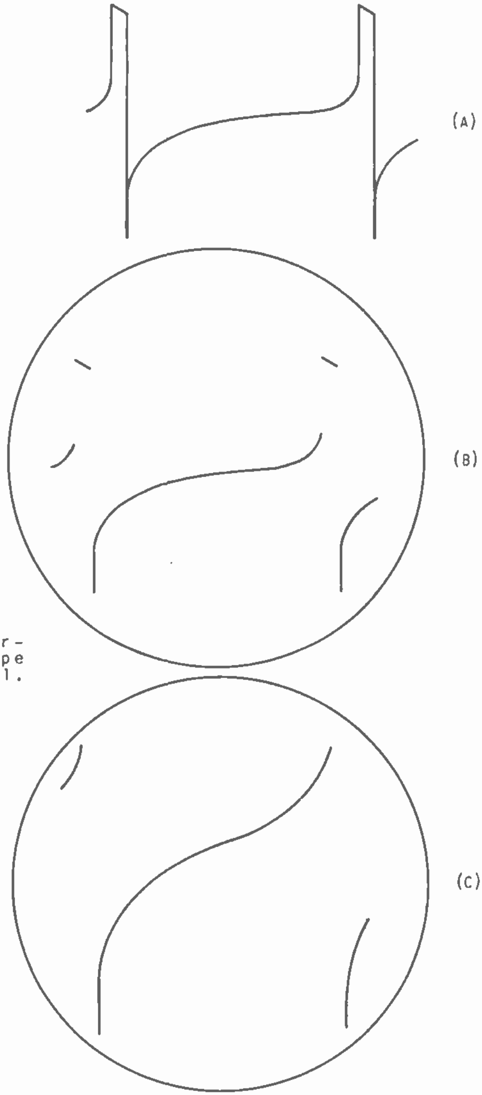


Fig.8 Correct and incorrect use of oscilloscope vertical amplitude control.

tenuator for maximum attenuation when first viewing a waveform; then gradually reduce the attenuation and carefully observe the pattern so that none of the apparently detached parts are driven off the screen.

Perhaps the last paragraph is out of place in a lesson devoted to a discussion of test equipment. However, it has been the author's experience with students that most of them neglect to consider this pertinent point when using an oscilloscope.

2. OSCILLATOR FOR CHECKING SWEEP CIRCUIT LINEARITY. The methods of checking the linearity of the sweep circuits in television receivers are described in detail in a later lesson of this unit. One of these methods is to apply two sine wave voltages simultaneously to the input of the video section of the receiver. One of these signals should have a frequency of 600 to 1200 cycles, and the other a frequency of 130,000 to 300,000 cycles. The sweep oscillators in the television receiver, which normally operate at 60 and 13,230 cycles, can be synchronized on a subharmonic of these voltages applied to the input of the video section. For example, if the low frequency signal has a frequency of 650 cycles, the vertical oscillator can be adjusted to oscillate at approximately 59.1

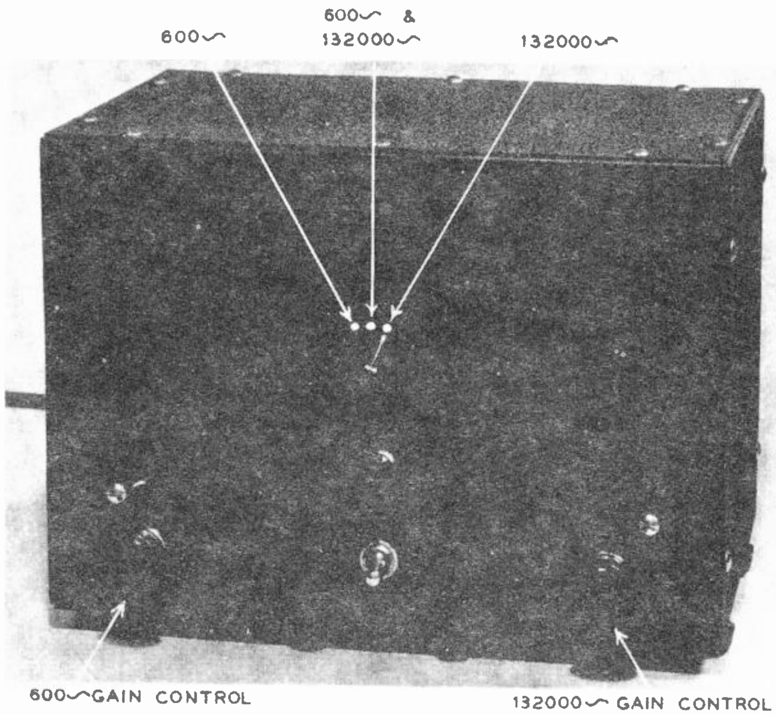


Fig.9 Linearity Test Oscillator.

cycles in synchronism with the 650 cycles, as this frequency is the eleventh subharmonic of 650 cycles. Similarly, the horizontal oscillator can be adjusted to oscillate on a subharmonic of the high-frequency component which is approximately 13,230 cycles. Since the two sweep oscillators are locked in with the frequencies being applied to the input to the video amplifier, the pattern produced on the screen of the receiver cathode ray tube will be stationary. This pattern can be used to check the linearity of the sweep or de-

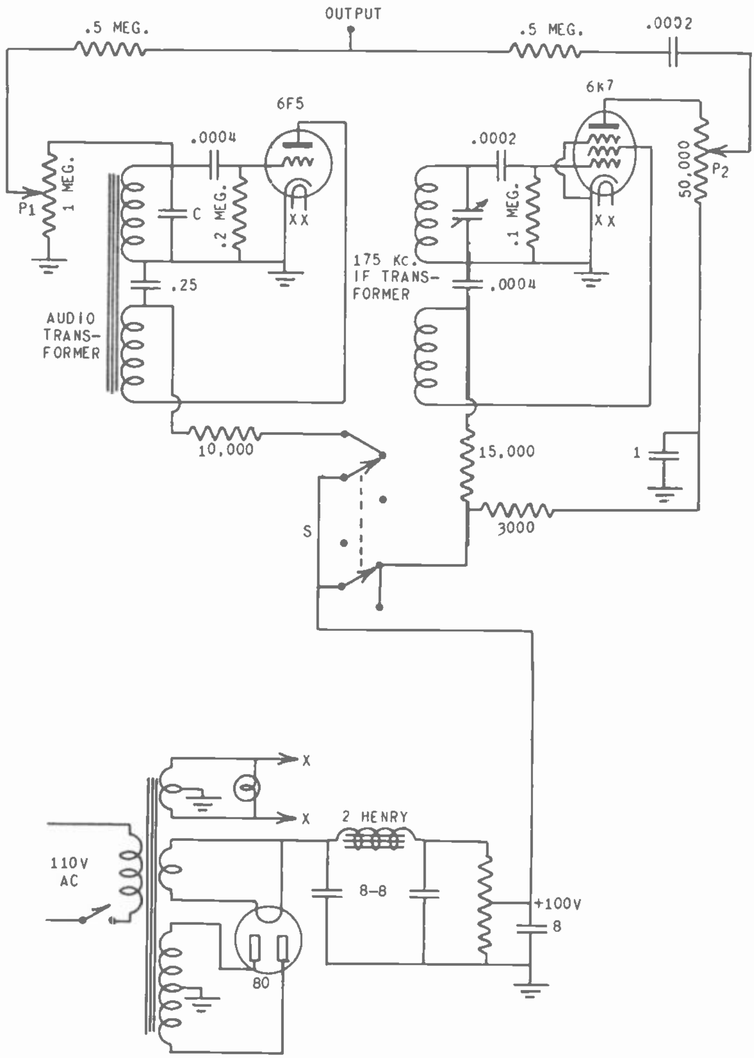


Fig.10 Circuit of linearity test oscillator.

flecting circuits and the interpretation of the pattern will be given in a later lesson of this unit. At the same time, other methods will be given for checking sweep circuit linearity.

These two checking frequencies can be obtained conveniently from the unit pictured in Fig. 9. A circuit diagram is shown in Fig. 10. The data for this test oscillator was taken from an article by J. B. Sherman, published in QST for Oct. 1938.

The circuit is self-explanatory. The two oscillators are of the simple feedback variety. Electron coupling to the load is used with the high frequency oscillator to increase the stability. The oscillator coils for the low frequency unit consist of the primary and secondary coils of an ordinary audio transformer. The constructor must, through experimentation, find the correct value of C that gives a frequency between 600 and 1200 cycles. The high frequency oscillator coils are the primary and secondary coils of a 175 kc. IF transformer. The padder on one coil is disconnected. It may be necessary to increase the coupling between the two coils in order to provide sufficient coupling between the plate and grid of the oscillator. Of course, the reader knows that the polarity of the signal induced in the grid coil by the plate coil must be regenerative, or the circuit will not oscillate. Thus, it may be necessary to reverse the connections to the plate coil in either oscillator in order to obtain oscillations.

The unit is provided with a switch S so that either frequency can be obtained separately or both obtained simultaneously. Switch S has two decks of three points each. The amplitudes of the two frequencies can be controlled by the potentiometers P1 and P2.

This circuit can be modified to suit the builder's own ideas. The unit described above will give good service.

3. DC VOLTMETERS. The reader is well aware of the importance of using a high resistance DC voltmeter when checking the DC voltages in radio receivers. He knows that in order to obtain an accurate indication of the magnitudes of the DC voltages present in

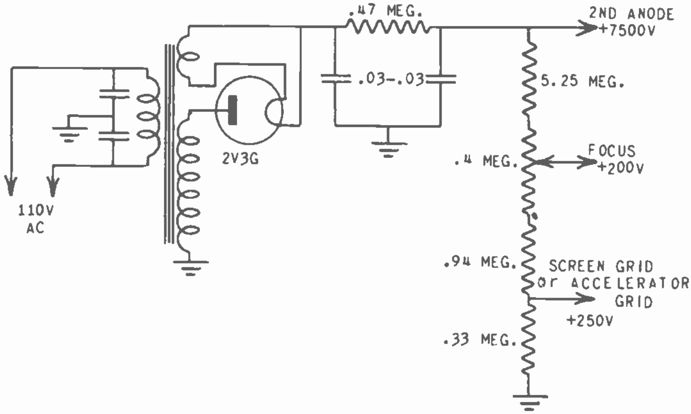


Fig.11 High voltage power supply for cathode ray tube.

receivers the power taken by the voltmeter must be a small fractional part of the power consumed by the circuit under test. It has become standard practice in radio servicing to use DC voltmeters with an internal resistance of 1000 ohms-per-volt. Such voltmeters are satisfactory for checking the DC voltages in the RF, IF, video, and deflection sections of television receivers. However, they consumed far too much power to be used in checking the voltages applied to the various electrodes in a cathode ray tube. Also most of them have a maximum range of 1000 volts, which is much too low for checking the cathode ray tube voltages. Of course, their range could be increased by the use of an external multiplier, but the meter resistance still remains 1000 ohms-per-volt.

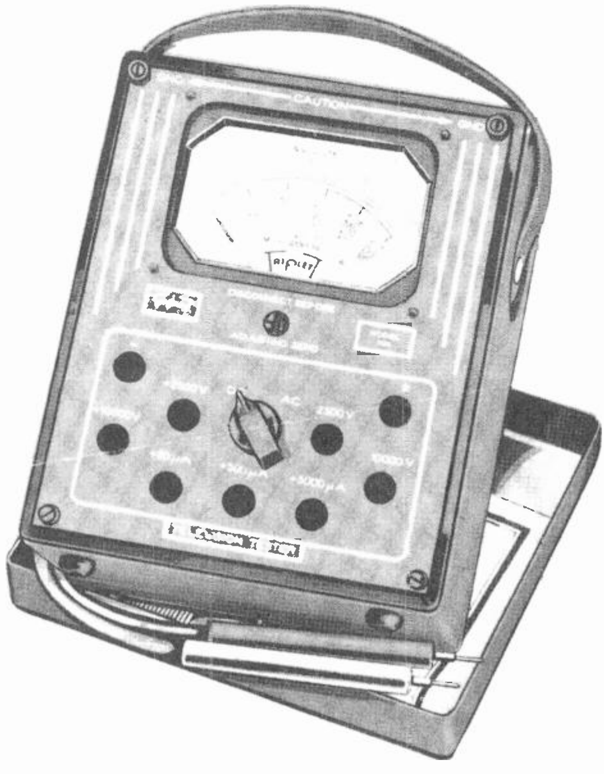


Fig.12 Triplett high range voltmeter.

Fig. 11 shows the high-voltage power supply for a modern television receiver (RCA Models TRK-9 and TRK-12). The total bleeder resistance is approximately 7 megohms. The bleeder current is 7500/7,000,000, or about 1.1 milliamperes. The total cathode ray tube current, depending on the bias, will range from 0 to perhaps a peak of 2 milliamperes. The total power supply drain is slightly over 3 milliamperes for zero bias. The total resistance of the load presented by the cathode ray tube and bleeder to the power supply will be 7500/.003, or 2.5 megohms. It will take a voltmeter with a maximum range of around 10,000 volts to measure the power supply voltage. If a 1000 ohms-per-volt meter were used, an additional load of ten megohms would be placed across the power supply and the total load resistance would become slightly more than 2 megohms. With zero bias on the cathode ray tube, this means that the voltmeter has increased the load on the power supply by 25%. Since these power supplies have a high internal impedance, the voltage indicated by the meter will be much lower than the actual power supply voltage when the meter is not connected across the output. Similarly, such a meter would give false readings for the focus and screen grid voltages.

The best type of meter for measuring the output voltage of a cathode ray tube power supply is an electrostatic voltmeter, since this type of voltmeter consumes an infinitesimal amount of power. However, electrostatic voltmeters are not available to the serviceman at a reasonable price, and therefore, they will not be considered further. Meters of conventional design are available commercially, that have an internal resistance of 20,000 ohms-per-volt. This is sufficiently high so that the meter load will not change the voltages applied to the cathode ray tube appreciably.

One of the available commercial meters is shown in Fig. 12. This is the Triplett Model 1280. This meter has a 50 microampere movement. The DC ranges are 2500 and 10,000 volts, and 50, 500, and 5000 microamperes. The AC ranges are 2500 and 10,000 volts. The meter is enclosed in a metal box. The meter movement, multiplier resistors and shunts, and the input jacks are mounted on a dielectric panel that is recessed from the front of the metal box. The meter scale is viewed through a window in the box. Connections are made to the meter jacks through holes in the front of the box by special insulated plugs on the test leads. Terminals are provided to ground the meter box so that the metal case will not acquire a high electrostatic potential. Test leads insulated for high voltages are supplied with the meter.

Some servicemen may already own a low-range DC voltmeter with an internal resistance of 20,000 ohms-per-volt, such as the Weston Model 772. It is a very simple job to build a multiplier to extend the range of the meter to 10,000 volts. The highest range of most of these meters is 1000 volts. The internal resistance of the meter for the 1000-volt range is 1000 times 20,000 ohms, or 20 megohms. To increase the range to 10,000 volts, the resistance of the meter must be increased to 10,000 times 20,000, or 200 megohms. Thus, the resistance of the external multiplier must be 180 megohms. Such a resistance can be made by connecting 18 resistors of 10 megohms each in series. The power dissipated in the multiplier will be less than one watt; therefore, one watt (or half-watt) resistors can be used. The accuracy of the voltmeter reading will depend on the value of the multiplier resistance. The error of the meter reading will be proportional to the deviation of the multiplier resistance from 180 megohms. Therefore, the resistors used in making the multiplier should be checked on a bridge and none should be used which deviate more than two or three percent from 10 megohms. Of course, it is possible to select the resistors so that their sum will be

180 megohms while the individual resistors may deviate considerably from 10 megohms. Fig. 13 suggests a method of mounting the resistors. The resistors are fastened to a strip of bakelite by drilling holes in the bakelite at the ends of the resistors to take the resistor pigtails and soldering the pigtails together on the other side. At least a half-inch should be allowed between adjacent resistors to prevent arc-over. The two extreme ends of the series combination must be well separated, as there will be a potential difference of several thousand volts between them. The multiplier must be mounted in a dust proof bakelite or wood box. The box must be dust proof, as dust collecting on the resistor panel will produce leakage paths between the resistor terminals and lower the accuracy of the multiplier. Dust may even cause an arc-over and burn out the meter used with the multiplier. Connections to the ends can be made by either jacks or binding posts.

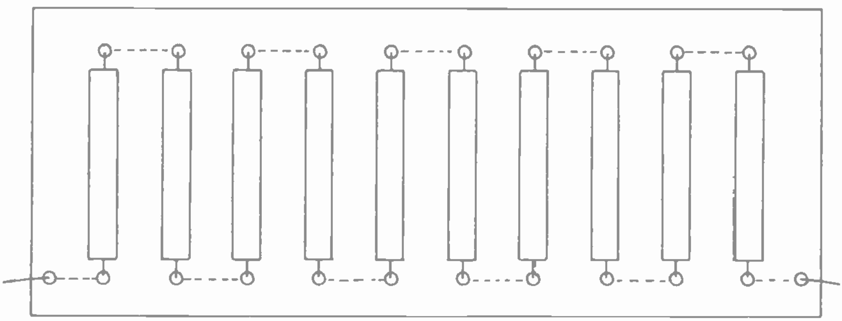


Fig.13 Arrangement of external multiplier for voltmeter.

There are a few precautions to take when using an external multiplier to increase the range of a voltmeter. In general, a meter is insulated to withstand voltages that are 50% to 100% higher than the maximum range of the meter. Therefore, when using such meters with an external multiplier, the meter must always be placed on the ground side of the circuit. For example, when measuring the voltage of a high voltage power supply which has the positive terminal grounded, the positive terminal of the meter is grounded and the multiplier is connected between the negative terminal of the meter and the negative terminal of the power supply. Then the potential difference between any part of the meter and ground will be within the voltage rating of the meter insulation. When measuring the voltage of a power supply with the negative terminal grounded, the multiplier is inserted in the positive side of the meter circuit.

There is another method that can be used to measure the output voltage of a cathode ray tube power supply without excessive loading if a vacuum tube voltmeter capable of measuring DC is available. Of course, the vacuum tube voltmeter must be of the type that has a very high input impedance. This method of measuring high DC voltages is illustrated in Fig. 14. Fig. 14A shows the circuit connections when the negative terminal of the power supply is grounded. Fig. 14B shows the circuit for the positive terminal grounded. A very large resistance is connected across the output of the power supply. The vacuum-tube voltmeter is connected across a small part of this resistance. If the whole resistor is called R, and the section feeding the vacuum tube voltmeter is R_1, the voltage developed across R is R/R_1 times the voltage indicated by the vacuum tube voltmeter. If the resistance of the measuring circuit is to exceed 20,000 ohms-per-volt the value of R will be 200 megohms or more for a meter with a maximum range of 10,000 volts. If the vacuum tube voltmeter has a maximum range of 250 volts, R_1 is chosen so that R_1 equals R multiplied by the ratio 250/10,000 or R_1 is equal to R/40. Then R_1 will be 5 megohms if R is 200 megohms. The same precautions outlined in the discussion of the multiplier previously described must be followed in building this multiplier. A circuit diagram of a satisfactory DC reading vacuum-tube voltmeter will be given later in this lesson.

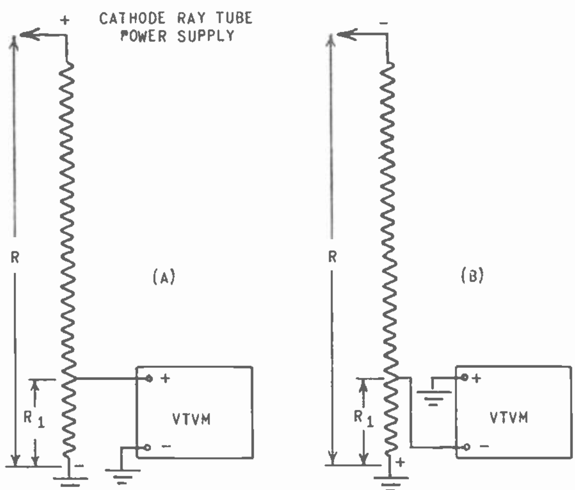


Fig.14 Measuring high DC voltages with VTVM and multiplier.

There is a third method that can be used to measure the voltage of a cathode ray tube power supply if an oscilloscope is available in which it is possible to apply a voltage direct to the vertical deflecting plates without going through a coupling network. None of the oscilloscopes that servicemen usually purchase have this feature. In many of them, the vertical amplifier can be shorted out, but there remains a resistance-capacity network between the deflecting plates and the input terminals. If an oscilloscope is available in which the signal can be applied direct to the vertical deflecting plates, the method illustrated in Fig. 15 can be used to determine the output voltage of a cathode ray tube power supply. With no input voltage to the vertical deflecting plates, the beam will trace a horizontal line across the center of the tube. The line will be shifted upward or downward when R is connected across a power supply, depending upon the polarity of the output of the power supply. In order to determine the magnitude of the shift in

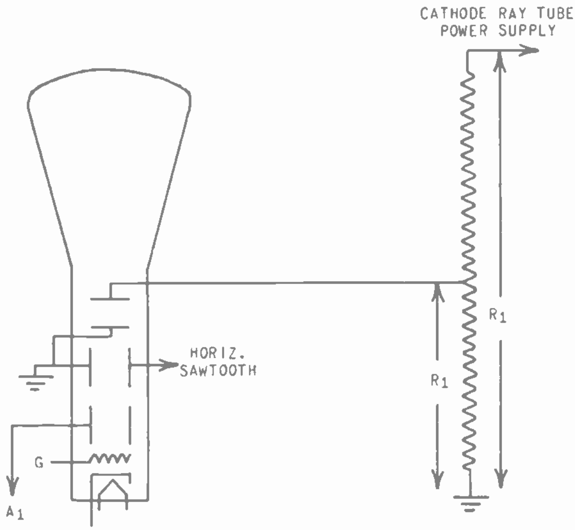


Fig.15 Measuring high DC voltages with a cathode ray tube.

terms of voltage, it will be necessary to calibrate the shift in terms of a known voltage. This can be done by applying known DC voltages across the vertical deflecting plates and noting the corresponding deflection or shift of the line. If the oscilloscope has a graduated transparent screen in front of the cathode ray tube, it is a simple problem to construct a calibration curve giving voltage in terms of shift of the cathode ray beam. If a transparent screen is not provided, one can be made to fit over the face of the cathode ray tube and calibrated directly in voltage. As in the previous method for measuring high voltages, the power supply output will be R/R_1 times the voltage indicated by the shift of the cathode ray tube beam. The same statements concerning the construction of the multiplier as given in the two previous examples apply.

Before closing the subject of methods and equipment satisfactory for measuring high voltages, it is advisable to list some of the precautions which must be observed in dealing with high voltages. High voltages are dangerous whether they are generated by a cathode ray tube power supply or the rectifier system for a 50-kw. transmitter. It was stated in a previous lesson that most cathode ray tube power supplies are designed so that their death-dealing ability is very small. However, they can give a severe shock. In many cases, serious injury results not from the shock itself but from the sudden reflex contraction of the muscles over which an individual has no control. It is possible to receive severe cuts from the sharp edges of the receiver chassis when the reflexes jerk the serviceman's hand away from the source of the shock.

Always turn off the power supply when connecting or disconnecting the measuring meter. Keep away from the meter and leads when the power is on. Use test leads that are adequately insulated for the voltages involved. Remember at all times that you are dealing with a force that can hit disasterously when you least expect.

4. DC MICROAMMETERS. A microammeter is often needed when checking cathode ray tube circuits if the current is less than 50 microamperes. For large currents, an ordinary multi-range meter with a one milliampere movement can be used. If the serviceman owns a meter like the Triplett Model 1280 previously mentioned, or a Weston Model 772 (Multi-range AC-DC meter with a 50 microampere movement), or other commercially-available multi-range meters with a 50 microampere movement, measuring these small currents is no problem. However, if he does not own such a meter, he will have to improvise a method for measuring small currents. One simple and satisfactory method is to insert a small resistance in the circuit carrying the unknown current and measuring the voltage developed across the resistance with a vacuum-tube voltmeter capable of measuring DC. The current through the circuit can then be obtained by

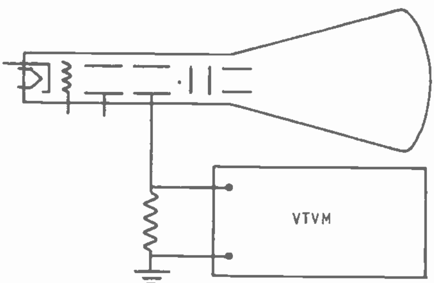


Fig.16 Measuring second anode current with a VTVM.

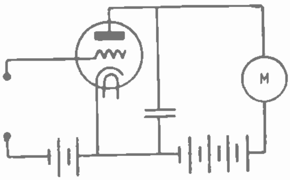
the use of Ohm's Law. Resistance values of 10,000 to 50,000 ohms are quite satisfactory to use as shunts for the vacuum-tube voltmeter. The application of this method for measuring small currents is shown in Fig. 16. *There is one important thing to remember, and that is that this method can only be used when the point in the circuit where the resistor is inserted is at ground potential unless the vacuum-tube voltmeter is battery-operated.* If an AC-operated vacuum-tube voltmeter were used to measure the voltage developed across a resistance inserted in the second anode lead of a cathode ray tube when the second anode was positive with respect to ground. the entire second anode voltage would be applied between the secondary and primary, and the core of the power transformer in the vacuum-tube voltmeter. Since the average power transformer is insulated to withstand only a few hundred volts, the insulation in the transformer would be immediately punctured and the transformer ruined. In the case of the battery-operated vacuum-tube voltmeter, it is only necessary to make sure that the voltmeter box (if metal) or the voltmeter leads are not near a ground.

A cathode ray tube is not satisfactory for measuring small DC currents by measuring the voltage developed across a resistance and calculating the current by Ohm's Law. It requires a large DC voltage to produce an appreciable deflection of the cathode ray tube beam. A large voltage can only be developed by using a large resistance in series with the circuit under test. In many cases a resistance large enough to serve the purpose would change the circuit conditions.

Another instrument that is indispensable to the television serviceman is a good ohmmeter, one that will accurately measure low resistances of 1 to 10 ohms and higher. It should also read accurately the range from one to three thousand ohms. The serviceman needs an accurate ohmmeter to check the load resistors in the video amplifiers of the receiver. In many cases, the resistance of the peaking coils are given in the receiver service data and, with a good low range ohmmeter, the serviceman can check the resistance of the coils to see if they are defective.

5. **VACUUM-TUBE VOLTMETERS.** The common types of meters that are used to measure AC voltages at power frequencies and audio frequencies cannot be used to measure voltages for frequencies in the video, IF, and RF bands. One of the most satisfactory instruments that can be used to make voltage measurements at these frequencies is the vacuum-tube voltmeter. The vacuum-tube voltmeter in its most elementary form is shown in Fig. 17. It consists of a triode, operated so that the average plate current is a function of the amplitude of the signal applied to the grid. The plate is completely

Fig.17 Simple form of vacuum tube voltmeter.



bypassed to ground. In other words, the tube is being operated as a detector. This means that the fixed bias is near the cutoff value. If the positive peak value of the unknown voltage never exceeds the fixed bias there is practically no power taken from the unknown voltage source, and thus the vacuum-tube voltmeter has a very high internal impedance. However, it can be used to measure higher voltages by the use of a multiplier. For stable operation of a triode, a complete DC path must be provided between grid and ground. If this path is not provided by the unknown voltage source, a high resistance must be connected across the input to the vacuum tube used in the voltmeter. This resistance can be made large enough so that the power dissipated in it is negligible, and thus the voltmeter will not load the voltage source.

This simple voltmeter can be used to measure either AC or DC voltages. The meter can be used to measure the AC component of a voltage containing both AC and DC if a grid condenser and grid leak is used as shown in Fig. 18. The vacuum-tube voltmeter is calibrated by recording the values of the plate current obtained when known DC and AC voltages are applied to the grid. This data, plotted in the form of a graph, will give a complete calibration over the usable range of the meter. A vacuum-tube voltmeter can be calibrated on 60 cycles and used to measure RF voltages without recalibrating.

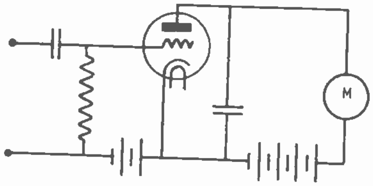


Fig. 18 Vacuum tube voltmeter to measure AC component of voltage containing AC and DC

Vacuum-tube voltmeters as simple as one shown in Fig. 17 have several unsatisfactory characteristics. The calibration is not dependable, as it is affected by variations in the heater, bias, and plate voltages. Variations in the tube's operating characteristics, resulting from aging, change the calibration. If the original calibration of the meter was based on the effective or RMS value of a sinusoidal wave, the calibration will not give the effective or RMS value when the unknown voltage has a waveform that is not sinusoidal. This is true because the meter in the plate circuit measures the average value of the plate current, and the plate current does not vary with the square of the grid voltage if the operating point is

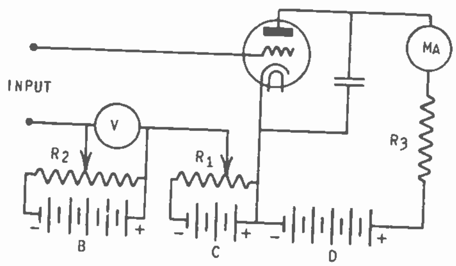


Fig. 19 Slide-back vacuum tube voltmeter.

near or at cutoff, as the negative cycle of the unknown voltage is beyond cutoff. This inability to give the effective or RMS values of voltages that are not sinusoidal is characteristic of practically all vacuum-tube voltmeters. However, in television, we are more interested in peak values, rather than RMS value, and the vacuum tube voltmeter can be designed to measure peak values accurately.

One form of vacuum-tube voltmeter, known as the slide-back vacuum-tube voltmeter, is essentially free of the drawbacks listed except the last one mentioned. It will measure peak values; however, it is not as simple to use as the vacuum-tube voltmeter shown in

Fig. 17. The slide-back vacuum-tube voltmeter is shown in Fig. 19. There are two sources of negative bias for the tube controlled by the potentiometers R_1 and R_2. The voltmeter V measures the bias applied by R_2. The meter MA in the plate circuit is a low range milliammeter or a microammeter. The resistance R_3 is to limit the peak plate current to a safe value for the tube.

The method of using the slide-back vacuum-tube voltmeter is as follows: First, R_2 is set so that V reads zero. Second, the input terminals are connected together and the potentiometer R_1 is adjusted until the tube is just biased to cutoff as indicated by the plate meter MA. Third, the input to the vacuum-tube voltmeter is connected across the unknown AC voltage source. If the unknown voltage source does not complete the grid circuit as far as DC is concerned, it is necessary to connect a high resistance across the input terminals. The positive cycle of the unknown voltage will cause a current flow in the plate circuit, the average of which is proportional to the amplitude of the unknown voltage. However, as far as determining the magnitude of the unknown voltage is concerned, the magnitude of the plate current has no significance. The fourth and final step is to increase the negative bias on the grid of the tube by means of R_2 until the plate meter again just reads zero. For this condition, the positive peak of the unknown voltage is just driving the grid of the tube up to cutoff. Thus, the additional bias applied through R_2 will just equal the positive peak of the unknown voltage. The voltmeter V, which measures the bias supplied through R_2, will then indicate the actual positive peak value of the unknown voltage. If the input voltage is sinusoidal, its RMS or effective value can be obtained by multiplying the reading of V by .707. If the unknown voltage is not symmetrical with respect to

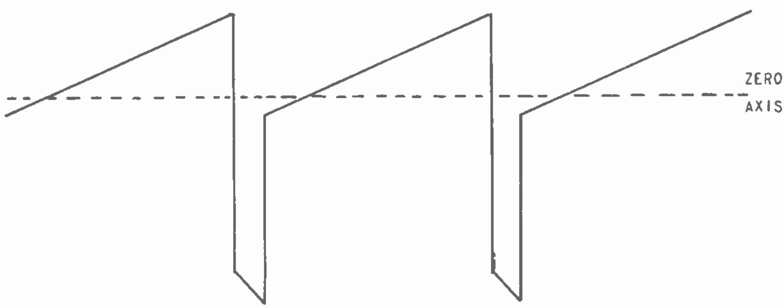


Fig.20 Voltage waveform in which the positive and negative peaks differ in amplitude.

its zero axis such as the waveform required to drive a current sawtooth through a circuit containing inductance and the resistance, (See Fig. 20), the positive and negative peaks have different amplitudes. Therefore, in order to find the peak-to-peak value of the unknown voltage, it is necessary to make a second measurement with the leads to the meter reversed in order to measure the amplitude of the negative peak. The total peak-to-peak voltage will be the sum of the voltages obtained in the two measurements.

The slide-back voltmeter can be used for measuring DC voltages as well as the peak value of AC voltages. If the unknown voltage is positive with respect to ground, the meter is used with the same procedure as outlined above. However, if the voltage is negative with respect to ground, the meter can still be used if the bias controlled by R_2 is reversed in polarity. In this case, the unknown voltage will bias the tube far beyond cutoff, and sufficient positive bias is applied by R_2 to raise the grid bias in the positive direction up to cutoff. The meter V then reads the necessary positive bias required to just neutralize the unknown negative voltage.

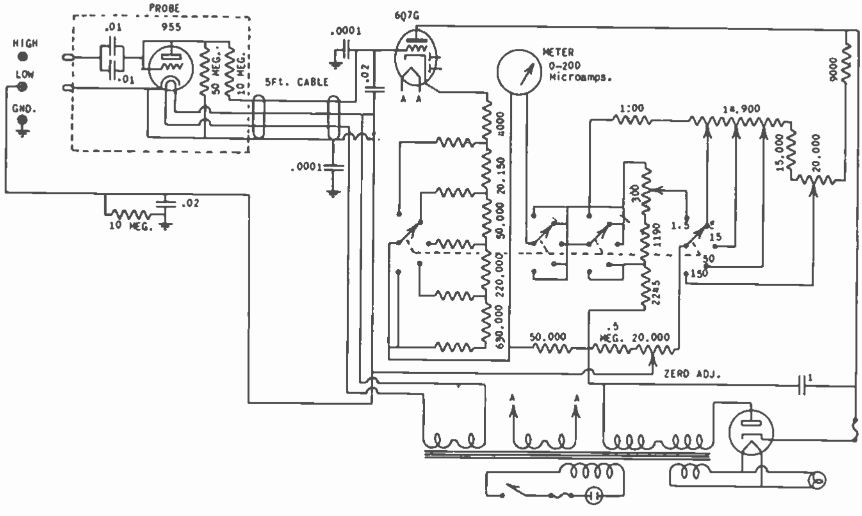


Fig.21 Circuit of General Radio Vacuum Tube Voltmeter.

When the unknown voltage source contains both AC and DC, the peak-to-peak value of the AC voltage can be measured by using an input circuit to the vacuum-tube voltmeter as shown in Fig. 18. The peak value of an AC voltage or the maximum DC voltage that can be measured by a vacuum-tube voltmeter of this kind is equal to the maximum voltage of the bias battery B in Fig. 19.

Although the slide-back vacuum-tube voltmeter is independent of tube characteristic and supply voltage changes (provided the procedure outlined above is followed before each reading), and does not require calibration except for very low input voltages, it is clumsy and inconvenient to use because of all the adjustments that must be made in taking a reading.

A vacuum-tube voltmeter that has the ease of operation of the fundamental circuit shown in Fig. 17, but lacking most of its major defects, would be a very desirable measuring instrument to the television engineer as well as to the television serviceman. Many vacuum-tube voltmeter circuits have been developed which have these desirable qualities to a greater or lesser degree.

One of the best vacuum-tube voltmeters of this type is the General Radio Model 726-A. This is an expensive instrument, and is out of reach of the ordinary television serviceman. However, a vacuum-tube voltmeter that the serviceman can build will be described a little later.

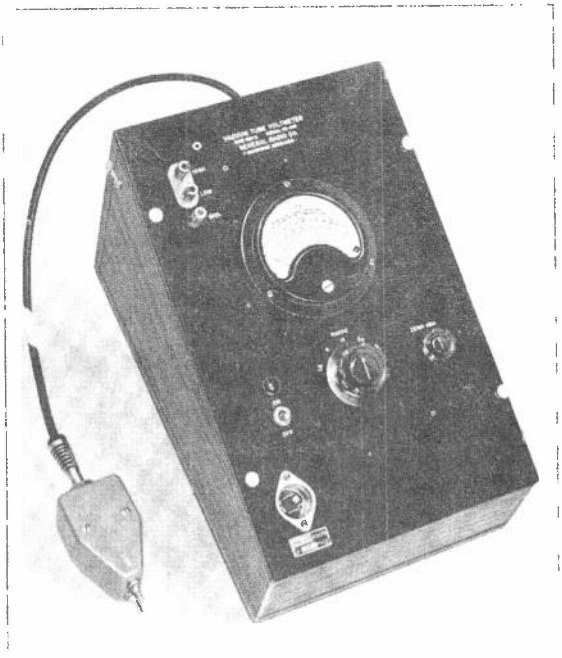


Fig.22 General Radio Vacuum Tube Voltmeter.

Fig. 21 is a circuit diagram of the General Radio vacuum-tube voltmeter. Fig. 22 is a picture of the instrument. The input tube is mounted in the bakelite probe (see Fig. 23). The amplifier tube is in the box, and the DC output from the first tube goes through the cable connecting the probe to the instrument box. With this type of construction, it is possible to connect the vacuum-tube voltmeter to the source of the unknown voltage with very short leads. When measuring low-frequency voltages where the length of the leads between the voltage source and the meter is of no consequence, the cable and probe are placed inside the box. The switch directly under the moving coil meter is the range switch. The meter has five ranges: 0-1.5, 0-5.0, 0-50, 0-150 volts. The knob to the right of the range switch is the zero adjustment.

Fig. 24 shows a simplified diagram of the vacuum-tube voltmeter so that its operation may be more clearly understood. In this vacuum-tube voltmeter, the detection or rectification of the unknown voltage is separated from the amplification. In the section of this lesson devoted to a discussion of the oscilloscope, the statement was made that the input capacity of the oscilloscope should be very low in order to make the input impedance reasonably independent of frequency. Low input capacity is just as important a design requirement for the vacuum-tube voltmeter as it is for the oscilloscope. The input capacity of an amplifier tube is quite high; especially for a triode. In this vacuum tube, the amplifier is a DC amplifier, and the high input capacity does not cause any trouble. From Fig. 24, it is seen that the input capacity of the triode amplifier merely adds to the capacity of the filter which separates the DC from the AC.

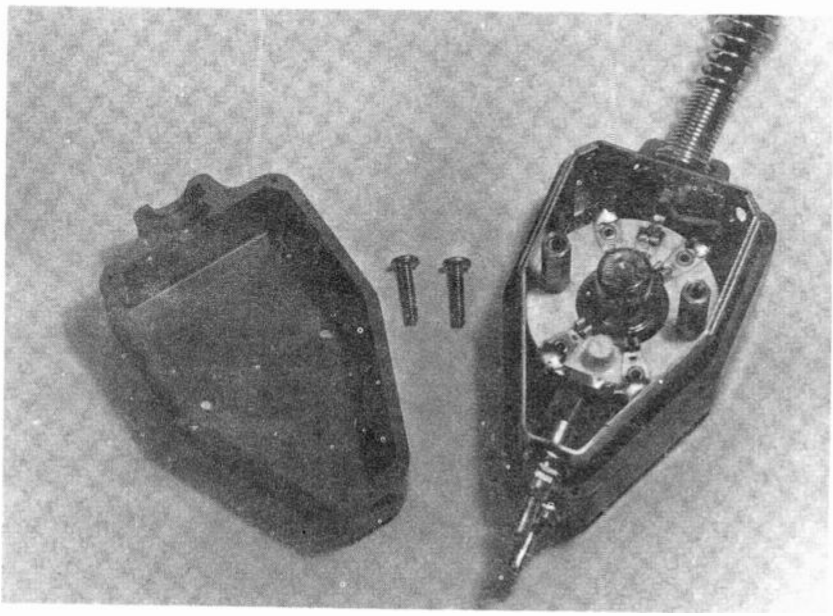


Fig.23 General Radio Vacuum Tube Voltmeter Probe.

The input tube is a type 955 operated as a diode. The 955 is an acorn type tube (See Fig. 25) which has very low interelectrode capacities. The diode is conducting on the positive part of the cycle of the input voltage, and non-conducting on the negative part. The condenser C charges through the diode during the positive peak and discharges through R during the negative part of the cycle. If C is small and R is large, C will charge to a voltage that is equal to the positive peak of the input voltage and will discharge slightly during the negative part of the cycle. After a voltage has been built up across the condenser equal to the positive peak of input voltage, the diode will conduct for a very short interval at the

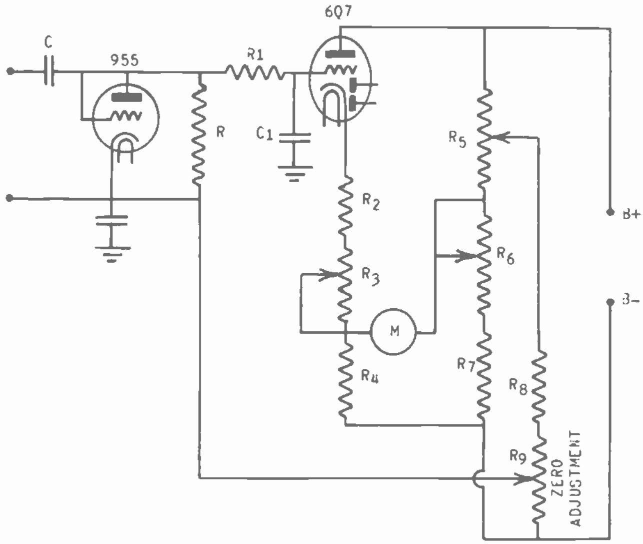
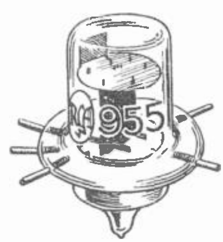


Fig.24 Simplified circuit diagram of General Radio Vacuum Tube Voltmeter.

positive peak of the input. The values of C and R should be such that the charging time constant of the condenser is very short, so that the voltmeter can be used to measure radio frequency voltages; and the discharging time constant should be very long so that the

Fig.25 Type 955 Tube.



voltage developed across R during the discharge will be constant for low frequencies, and nearly equal to the peak voltage across C. Through the use of an input circuit of this kind, the DC voltage applied to the amplifier will be independent of normal changes in the characteristics of the input tube. When the tube has lost most of its cathode emission, the vacuum-tube voltmeter will read low at high frequencies. When the tube is replaced with a new one, the original calibration will hold as far as the input circuit is concerned. This particular input circuit has a very low input capacity, approximately 6 mmfds. The input resistance R is 5 megohms.

The DC voltage developed across R is applied to the grid of the DC triode amplifier tube through the low-pass filter R_1C_1. R_1C_1 removes the small AC component resulting from the slight charging and discharging of the condenser C. This triode amplifier is the triode section of a 6Q7. The plate resistance of the triode plus the resistances R_2 and R_3 form one of the arms of a DC bridge. The degree of balance or unbalance of the bridge is indicated by the microammeter M. To use the voltmeter on any range, the input terminals are first shorted and R_9 is adjusted for balance of the bridge, which occurs for zero current through M. When an unknown voltage is fed into the vacuum-tube voltmeter, the bridge becomes unbalanced. The amount of unbalance is proportional to the input to the vacuum tube voltmeter. The meter is calibrated to read .707 of the peak voltage developed across R.

The voltage developed across R applies a negative bias to the grid of the tube. The load for the triode is in the cathode circuit. A positive bias is applied to the grid by means of R_9 to overcome the high negative self-bias due to the cathode load. Since the load for the amplifier is in the cathode circuit, the gain for the amplifier is less than one, because of cathode degeneration. You will learn in a later lesson that cathode degeneration has the effect of lowering the dynamic plate resistance of a tube by the factor $1 \div (1 + \mu)$. Also, the effective amplification factor becomes $\mu \div (1 + \mu)$. The gain of a cathode-loaded stage is given by the formula:

$$\text{Gain} = \frac{\mu}{1 + \mu} \times \frac{R}{\frac{R_p}{1+\mu} + R}$$

For a plate-loaded stage without degeneration, the gain is given by the familiar formula:

$$\text{Gain} = \mu \frac{R}{R_p + R}$$

It is evident from the formula for the gain of a cathode-loaded stage, that the gain of the stage is much less affected by changes in tube characteristics than is the gain of a plate-loaded stage. The plate resistance R_p is the only tube constant appearing in the formula for gain which changes with tube life and variations in electrode voltages. Since the plate resistance is reduced by the factor $1 \div (1 + \mu)$ for a cathode-loaded stage, normal variations in the plate resistance will have little effect on the gain of the amplifier. Therefore, the vacuum-tube voltmeter will retain its calibration over a long period. Another advantage of cathode loading is that it improves the linearity of the amplifier.

To increase the range of the meter, the cathode load is increased by increasing R_3. This increases the amount of degeneration, and therefore a greater grid voltage change is required to obtain the same plate current change. When the cathode load is increased, the positive bias applied to the grid of the tube by R_9

must be increased to overcome the increased negative bias. This adjustment is made by means of R_5. R_6 is varied with R_3 to maintain the same ratio between the arms on the two sides of the bridge. All of these changes are made by means of ganged switches as shown in Fig. 21.

This vacuum-tube voltmeter is free of variation due to supply voltage changes. One reason for this is that the plate voltage is applied across a bridge, and plate supply changes will not upset the balance of the bridge. To prevent large plate voltage variations, a self-regulating power transformer is used.

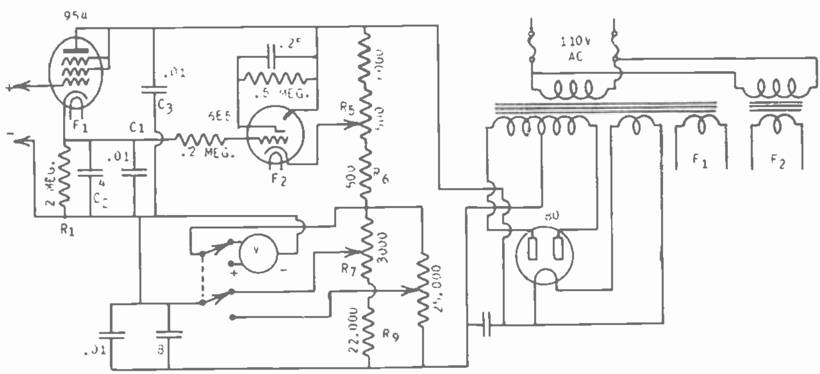


Fig. 26 Circuit of slide-back vacuum tube voltmeter.

The television serviceman can build satisfactory vacuum-tube voltmeters at reasonable cost. The simplest to build is the slide-back vacuum-tube voltmeter, as it does not require calibration except for extremely small voltages. Fig. 26 is a circuit diagram of a complete AC-operated slide-back vacuum-tube voltmeter. This particular circuit was published in the RCA Receiving Tube Manual for 1940. Although the circuit is arranged differently from the circuit shown in Fig. 19 for a slide-back vacuum-tube voltmeter, the principle of operation is the same. Actually, it is a combination of a diode to charge a condenser and a slide-back vacuum-tube voltmeter to measure the voltage built up across the condenser. The 6E5 electron ray tube is the slide-back vacuum-tube voltmeter. The voltmeter has two ranges; 0-25 and 0-250 volts. To adjust the vacuum-tube voltmeter for use, the input terminals are shorted, the control R_7 or R_9 (depending on the range) is set so that the moving coil voltmeter V reads zero, R_5 is adjusted so that the 6E5 eye is *just* closed. The input is connected across the unknown voltage and R_7 or R_9 adjusted until the 6E5 eye *just* closes again. The meter V will give the positive peak value of the unknown AC voltage. It will measure DC voltages if the grid of the input tube is connected to the positive side.

The operation of this vacuum-tube voltmeter is quite simple.

When the input terminals of the meter are shorted and R7 or R9 set for zero reading on V, the only voltage applied to the grid of the 6E5 is negative and is the drop across R5 and R6. The current of the 955 through the resistor R1 is negligible. The triode of the 6E5 will be biased near cutoff when the eye in the tube just closes. The bias is set at this required value by R5. When the input terminals of the meter are connected to the voltage source, the grid of the 954 is driven positive and the flow of plate current and grid current charge the condensers C1 and C2. These condensers will continue to charge until the voltage across them reaches the peak of the applied voltage. The condenser voltage applies a negative bias on the grid of the 954. When the condensers are charged to the peak of the input voltage the positive peak of the input voltage will swing the grid of the 954 just up to zero bias. Thus, when the condensers are charged to the peak value the resistive component of input impedance of the vacuum tube voltmeter will be very high. The condensers C1 and C2 discharge through R1 during the negative part of the cycle of the input. However, since the discharge time constant is very large (16 seconds) the voltage across the condensers changes very little during the negative grid cycle. The voltage across the condensers applies a positive bias to the grid of the 6E5 equal to the peak value of the positive cycle of the input voltage. Now if R7 or R9 are adjusted until the eye just closes again, sufficient negative bias has been added to neutralize the positive voltage across the condensers. Therefore, the meter V will read the positive peak of the input voltage. The meter V should have an impedance of 1000 ohms per volt.

The 954 is an acorn pentode identical in size with the 955 which is used in the General Radio Vacuum-tube Voltmeter. It is used in this vacuum-tube voltmeter to reduce the input capacity. In order to keep the total input capacity as low as possible, the 954 should be mounted in a shielded probe like that used with the General Radio Meter. The resistor R_1 and the condensers C_1 and C_3 (See Fig. 26) should be mounted in the probe with the 954. A 6J7 can be used in place of the 954, but the input capacity will be higher.

This vacuum-tube voltmeter can be used with a resistance to measure small currents as described earlier in the lesson provided one side of the meter can be grounded. It cannot be used to measure the second anode current of a cathode ray tube when the second anode is operated several thousand volts above ground. For this purpose, the television serviceman can build a small battery-operated slide-back vacuum-tube voltmeter like the fundamental circuit shown in Fig. 19.

It is not a simple task for the television serviceman to build a vacuum-tube voltmeter that has the simplicity of operation and the low input capacity of the General Radio instrument. However, it is not difficult to build a vacuum-tube voltmeter that is easy to operate and that has a fairly low input capacity (16 to 20 mmfds.). The circuit is shown in Fig. 27. It is a peak type vacuum-tube voltmeter. The input tube, a 6H6, is used as a voltage doubler. On the positive half-cycle, C_1 is charged through T_1, and T_2 is non-conducting. On the negative half-cycle, T_1 is not conducting, and C_2 is charged through T_2. The effective voltage for charging C_2 is the peak of the AC voltage wave plus the voltage across C_1. Thus, the voltage built up across C_2 is equal to the peak-to-peak value

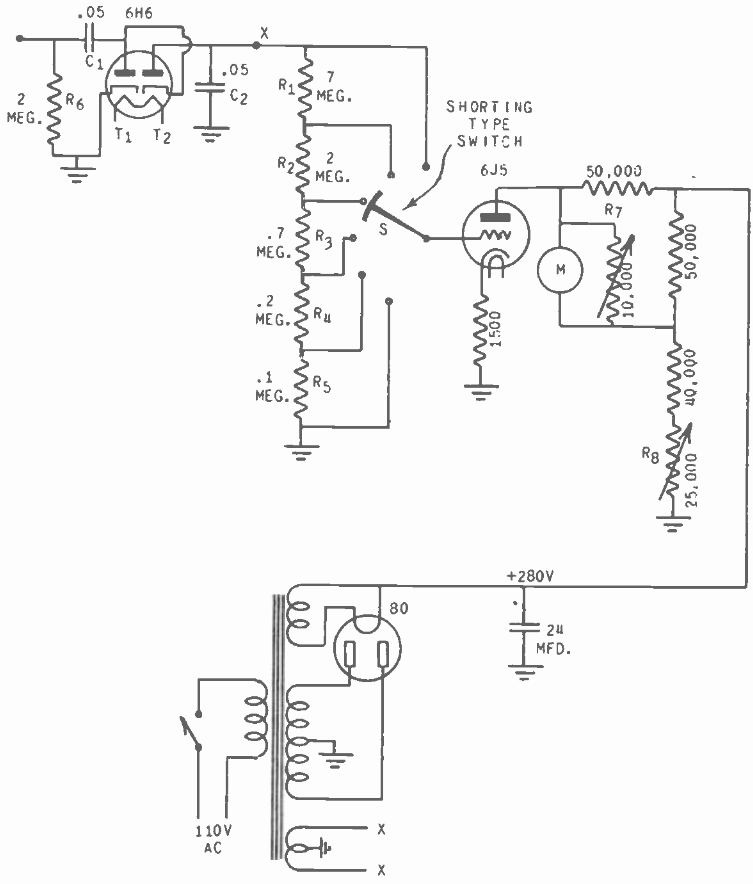


Fig.27 Peak reading vacuum tube voltmeter.

of the applied AC voltage. This vacuum-tube voltmeter has an advantage over the ordinary peak voltmeter in that it will read the same for either polarity of the applied voltage. C_2 discharges through the series combination R_1 to R_5. The voltage developed across C_2, or a definite percentage of it, is applied to the grid of the 6J5 triode amplifier. The plate resistance of the 6J5 plus the 1500-ohm degenerative cathode resistor form one arm of a DC bridge. Degeneration is used in this vacuum-tube voltmeter as it is in the

General Radio to reduce the effects of varying tube characteristics. Likewise, a bridge circuit is used to reduce the effects of power supply variation. To balance the bridge, switch S is turned to the ground position and R_8 is adjusted until the meter across the bridge reads zero. This meter has a full-scale sensitivity of 400 microamperes. This is the type movement that many of the newer multirange meters have. When an AC voltage is applied across the input to the vacuum-tube voltmeter, the DC bridge becomes unbalanced and the reading of meter M is a measure of the peak-to-peak value of the voltage applied to the input of the vacuum-tube voltmeter. To keep within the range of the meter M, and prevent biasing the 6J5 beyond cutoff, the DC applied to the grid of the 6J5 is limited in magnitude by means of the attenuator in the grid circuit. Attenuator switch S is the shorting type; that is, it does not break one circuit until the circuit for the next position is closed. This prevents the grid circuit of the tube from being opened when changing attenuator settings. The resistance values of the attenuator steps are selected so that the vacuum-tube voltmeter has the following ranges; 0-1.5, 0-5, 0-15, 0-50, and 0-150 RMS of a sinusoidal voltage wave. The resistance R_7 across the meter M is to control the sensitivity of the meter so that full-scale deflection will correspond to the ranges given above.

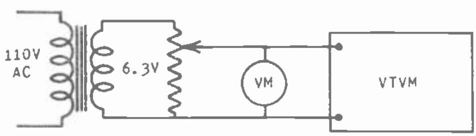


Fig.28 Calibrating a vacuum tube voltmeter.

This vacuum-tube voltmeter must be calibrated. If the resistances in the attenuator are accurate, it is necessary to calibrate one range only. The other ranges can be obtained by using the appropriate multiplier factor. Probably the easiest to calibrate is the 0-5 volt range. A satisfactory calibrating method is illustrated in Fig. 28. The voltmeter used for calibration must have an accuracy of two percent or better if the vacuum-tube voltmeter calibration is to be reasonably accurate. The first step in calibration is to find the correct setting for R_7. This is done by feeding into the vacuum-tube voltmeter exactly five volts RMS, and adjusting R_7 until the meter M reads full scale. R_7 should be an adjustable resistor rather than a rheostat, so that the adjustment will be permanent after the correct setting has been obtained. It requires changing only when the meter is recalibrated. Depending on the sensitivity and resistance of the meter M, it may be more practical to use a smaller resistance than ten thousand ohms for R_7. The next step in the calibration is to record the reading of M for all inputs from 0 to 5 volts in .5 volt steps. The resulting data, when plotted on graph paper, will give the calibration curve for the vacuum-tube voltmeter. The same curve can be used for all the other ranges by multiplying the voltage obtained from the curve by the multiplier factor given by the attenuator setting. In this particular case, since the ranges do not increase by the same factor for each attenuator step, it is more convenient to mark the voltages corresponding to each attenuator setting on the calibration curve as shown in Fig. 29.

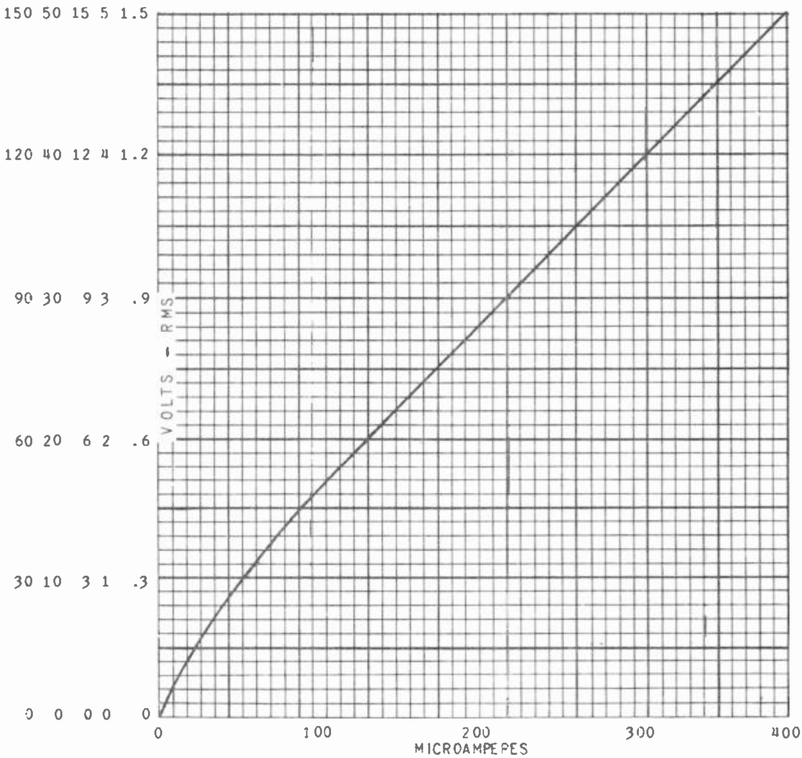


Fig.29 Calibration curve for vacuum tube voltmeter in Fig. 27.

This vacuum-tube voltmeter may be used to measure DC if the circuit is broken at the point X and the unknown DC voltage applied across the attenuator. Since the calibration curve gives .707 of the peak value applied to the input of the vacuum-tube voltmeter, it is necessary to multiply voltages obtained from the calibration curve by 2.82, in order to obtain the true value of the DC applied across the attenuator. Thus, the highest DC voltage that can be measured by the vacuum-tube voltmeter is 2.82 times 150, or approximately 425 volts. The multiplying factor 2.82 is used rather than 1.41, because the voltage developed across C_2 (Fig. 27) is the peak-to-peak value of the input AC. This vacuum-tube voltmeter can be used to measure the output voltages of cathode ray tube power supplies with the use of an external multiplier of the type previously described for that purpose.

The serviceman can use his own ideas of the physical layout and construction of the vacuum-tube voltmeter. To minimize the input capacity, it is advisable to mount the input 6H6, R_6, C_1, and C_2 in a probe. Thus, everything to the left of point X in Fig. 27 will be in the probe. The probe and its cable can be terminated by a plug and provide an easy method to convert the meter for measuring DC. When making DC measurements, it will be advisable to connect a condenser across the attenuator to keep hum out of the 6J5 grid circuit, as C_2 is in the probe and is out of the circuit.

The design of this vacuum-tube voltmeter was based on the use of a 400 microamperemeter for M. If a meter of lower sensitivity is used, an RMS input greater than 1.5 volts will be required to give a full scale deflection on the lowest range. The range covered by each attenuator step will be increased proportionately. The highest voltage measured should not exceed 150 volts RMS in order to obtain a reasonable life for the 6H6. The maximum rated voltage for the 6H6 is 117 volts RMS.

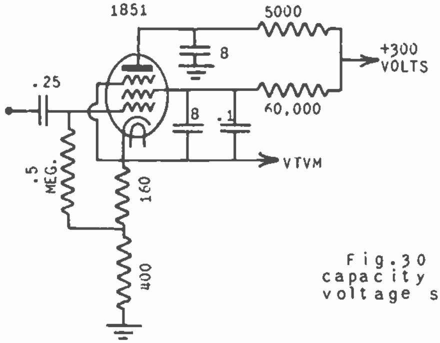


Fig.30 Circuit to reduce capacity loading on unknown voltage source.

One of the jobs that a serviceman will have is to check the frequency-versus-gain characteristics of the video amplifier in television receivers. One method used is to apply known voltages from an oscillator to the input of the amplifier and measure the output with a vacuum-tube voltmeter. Such a method is not entirely satisfactory, because the input capacity of the vacuum-tube voltmeter adds to the circuit capacity of the output stage of the video amplifier, and the curve obtained by plotting gain versus frequency will not represent the true gain-versus-frequency characteristic of the video amplifier at the high-frequency end. The vacuum-tube voltmeter capacity can increase the total capacity by as much as 50% or more. The same condition will exist if an oscilloscope is used to measure the output of the amplifier. The RCA oscilloscope described earlier in the lesson has a very low input capacity of 8 mmfds., but even this capacity will change the circuit capacity by considerable percentage. The usual effect of the added capacity of the measuring instrument is to reduce the gain at the high-frequency end of the video band. Through experience, the serviceman can judge approximately the true amplifier response.

The capacity loading on the output stage of a video amplifier can be reduced by inserting a network like that shown in Fig. 30 between the vacuum-tube voltmeter and the plate circuit of the output video amplifier stage. It consists of a cathode-loaded stage. The cathode degeneration has the effect of lowering the input capacity of the tube. The capacity from grid to ground in Fig. 30, if wiring capacity is neglected, is approximately 2 mmfds. The reason this type of circuit has the effect of reducing the input capacity of a tube will be explained in a later lesson. The effectiveness of the reduction of the input capacity by this method at the high end of the video band depends upon the amount of capacity across the cathode load. If this shunt capacity is kept below 20 to 30 mmfds., the impedance of the cathode load will be reasonably constant and cause no appreciable phase shift over the video band. The magnitude of the degeneration is proportional to the cathode load impedance.

This method of reducing the input capacity with the constants shown in Fig. 30 can be used satisfactorily, provided the input voltage does not exceed 1 or 2 volts RMS. The actual gain of the stage is about .8. When using this circuit between the vacuum-tube voltmeter and the voltage source, care must be taken to minimize all stray wiring capacity between the degenerative circuit and the voltage source. This method is effective in reducing only the input capacity of the tube; that is, the grid-to-cathode and grid-to-screen capacity.

6. LOW-FREQUENCY SQUARE WAVE GENERATOR. It was mentioned previously in the lesson that the best way to check the low-frequency phase and gain characteristics of a video amplifier was to observe the amplifier's ability to transmit a 60-cycle square wave. If the output wave is a replica of the input square wave, the amplifier is free of low-frequency phase and gain distortion. In checking the low-frequency characteristics of an amplifier by means of a square wave, the vertical amplifier of the oscilloscope used to examine the output waveform of the amplifier must be free of low-frequency phase and gain distortion.

There are several ways of producing a 60-cycle square wave. One method consists of using a relaxation oscillator to produce an output waveform that is essentially a square wave. Another method is to convert sine waves into square waves. A complete discussion of wave-shaping circuits is given in a lesson in Unit 7. Therefore, the generation of a square wave will be described only briefly in this lesson.

Fig. 31 shows the circuit diagram of a square wave generator used in the laboratories of Midland Television. The transformer is a filament transformer which has two 6.3-volt windings. The two windings are connected in series so that their output voltages add. The heaters of the two gas triodes (type 884) are in series and connected to the combined outputs of the two filament windings. Two batteries are required, one 7.5-volt "C" battery, and one small 45-volt "B" battery. The power switch is a double-pole, single-throw switch. One section controls the power input, and the other the 7.5-volt battery. The positive terminal of the 45-volt battery is grounded.

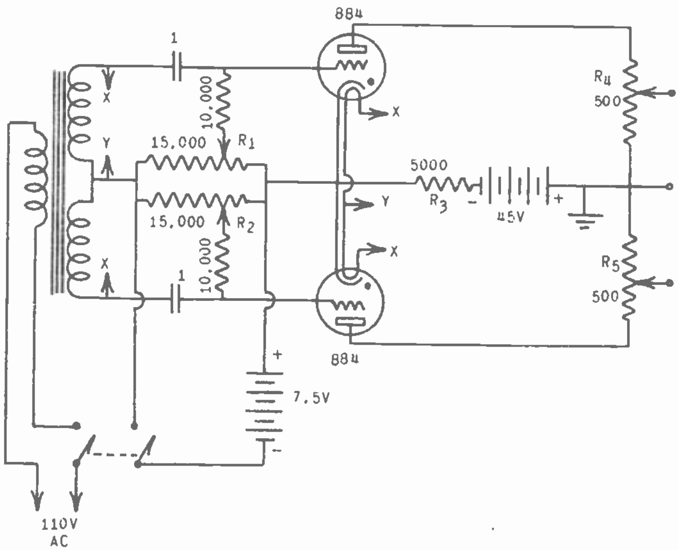


Fig.31 Circuit of square wave generator.

The reader is familiar with the operating characteristics of gas triodes, as this type of tube was discussed in a lesson in the previous unit.

The control ratio of the type 884 is 10. This means that the tube will remain non-conducting as long as the plate voltage is less than ten times the negative grid bias. If the plate or grid bias voltage is changed so that this ratio becomes ten, or greater than ten, the tube ionizes. The plate current immediately rises to a value determined by the plate supply voltage and the resistance in the plate circuit. The voltage drop across the plate resistance of the tube is 16 volts, and is independent of the plate current. Therefore, the voltage effective in causing a plate current flow through the tube and the external resistance, is the difference in potential between the tube drop and the plate supply voltage. In this particular case, this voltage will be 29 volts. After the tube ionizes, the grid no longer has any control over the plate current, and the only way that the plate current can be reduced to zero is to reduce the plate voltage below 16 volts. Sixteen volts is the minimum voltage that will keep the tube ionized.

Now let us consider Fig. 31. The square wave is generated across the resistors R_4 and R_5. The 884's conduct on alternate half-cycles in synchronism with the 60-cycle input. Since the current through the 884's is constant during the conduction period, the negative voltage developed across R_4 and R_5, due to the plate current flow, is constant. The magnitude of the plate current is equal to 29/5500, or 5.3 milliamperes. The square wave outputs across R_4 and R_5 each have a peak-to-peak voltage of 2.7 volts approximately. When either tube is conducting, there is a 26 volt drop, approximately, across the resistor R_3 which is common to the cathode circuits of both tubes.

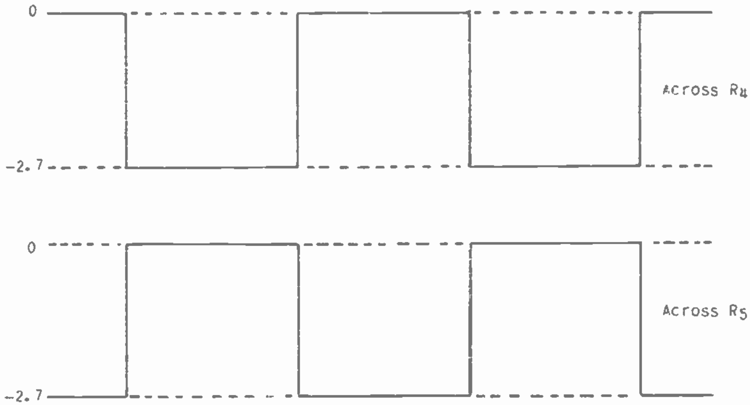


Fig.32 Output of square wave generator in Fig. 31.

Let us assume that the upper tube has just ionized. This means that the AC component of its grid voltage is increasing in the positive direction, while the AC component of the grid voltage of the other tube is increasing in the negative direction. When this half-cycle of the AC input has been completed, the phase of the AC applied to the two grids reverses, and the grid of the lower tube becomes less negative, while the grid of the upper tube becomes more negative. Since the upper tube is conducting, the actual plate voltage on the lower tube is 45 less 26, or 19 volts. When the negative grid voltage on the lower tube is reduced to -1.9 volts, the tube ionizes (control ratio is 10). The effective voltage causing plate current at that instant is 19 less 16 volts, or 3 volts. The plate current of the lower tube through R_3, caused by this small voltage, increases the voltage drop across R_3. This small increase in the voltage across R_3 is sufficient to reduce the effective voltage causing the plate current through the upper tube to drop below 16 volts, and the upper tube deionizes. Thus, the conduction cycle has been transferred from the upper tube to the lower tube. When the phase of the input AC again reverses, the conduction cycle will be transferred back to the upper tube. This periodic transfer of the conduction cycle from one tube to the other, results in voltages of square waveform being developed across R_4 and R_5. Fig. 32 shows these two voltages and their relative phase. The controls R_1 and R_2 control the ionizing point as far as the input AC is concerned. They thus control the shape of the output waveform.

The circuit shown in Fig. 31 can be used to generate square waves of other frequencies than 60 cycles by replacing the transformer feeding the grid circuits, with an audio transformer. A square wave of any frequency up to 500 or 1000 cycles can be obtained by applying a sinusoidal voltage of the required frequency, to the primary of the audio transformer. The filament supply will have to be obtained from another source.

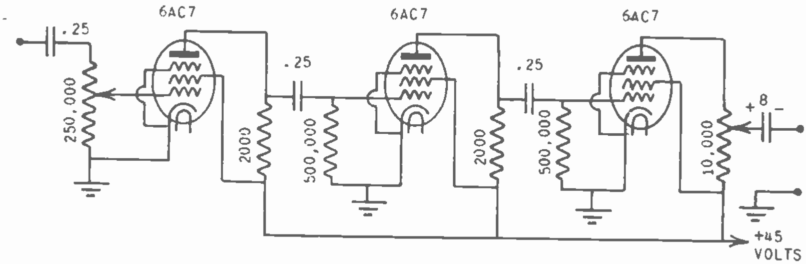


Fig.33 Circuit of square wave generator.

Fig. 33 shows a circuit that can be used to convert any frequency sine wave up to 10,000 to 15,000 cycles into a square wave. Each tube obtains its bias by means of grid current flowing through the grid leaks. The sine wave input is converted into a square wave by clipping off the positive and negative peaks of the wave. The amplitude of the signal going into each grid must be sufficient to drive the grid into grid current in the positive direction and beyond cutoff in the negative direction. Fig. 34 shows the transformation of the sine wave into a square wave as it passes through the amplifier.

7. ALIGNMENT OSCILLATORS. One of the most frequent jobs that the television serviceman will have is the realignment of the picture IF and RF amplifiers. The picture IF and RF amplifiers cannot be aligned by the simple methods that are often used for aligning conventional broadcast receivers, such as an output meter and a tone-modulated oscillator. In the vast majority of broadcast receivers, alignment consists of adjusting the IF and RF transformers for maximum output.

In television servicing, the alignment process involves the adjustment of complicated circuits so they will pass a wide band of frequencies with uniform gain. The selectivity characteristics at the two ends of the pass-band are different. Also, the IF frequency does not lie in the center of the IF band, but is at one end of the band. There are trap circuits which must be very carefully tuned.

The reader is familiar with the frequency-modulation method of aligning the IF and RF sections of broadcast receivers. The signal fed into the amplifier under adjustment is not amplitude modulated with an audio tone, but is frequency modulated at a 60 cycle rate over a frequency band from 20 to 50 kc. wide. The voltage developed across the diode load is applied to the vertical amplifier of an oscilloscope. The linear sweep of the oscilloscope is operated at 120 cycles, and is synchronized with the 60 cycle modulating frequency. If the IF frequency is in the center of the frequency

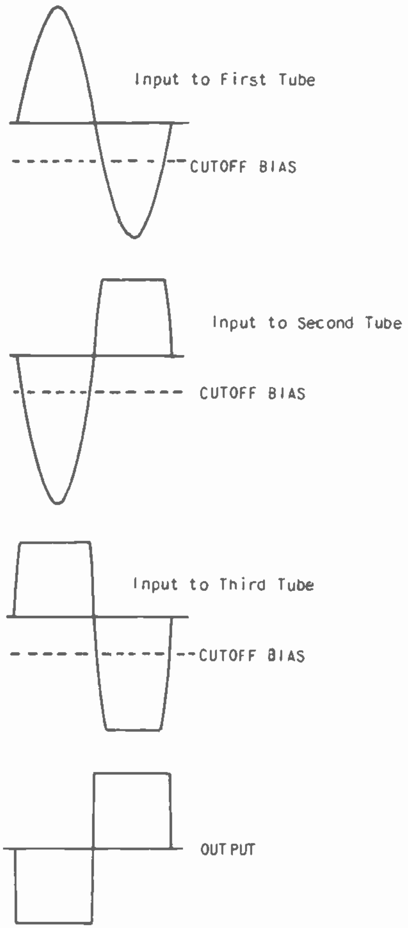


Fig.34 Formation of square wave by the square wave generator in Fig. 33.

modulation band, the voltage developed across the diode load will rise to a maximum twice for each complete frequency modulation cycle, or passes through a maximum 120 times per second. If the phase relation between the linear sweep and the modulating frequency is correct, the curves traced on the oscilloscope screen coincide for the increase and decrease in frequency change through the IF frequency. The resultant curve is the frequency-versus-gain characteristic of the IF amplifier. The bandwidth and selectivity of the IF amplifier can be determined from this curve.

The same method must be used in the alignment of the RF and IF amplifiers of television receivers. However, since the IF band of the better grade of television receivers has a bandwidth of at least four megacycles, the sweep range of the oscillator must be correspondingly greater. For the RF section, the sweep range must cover at least six megacycles.

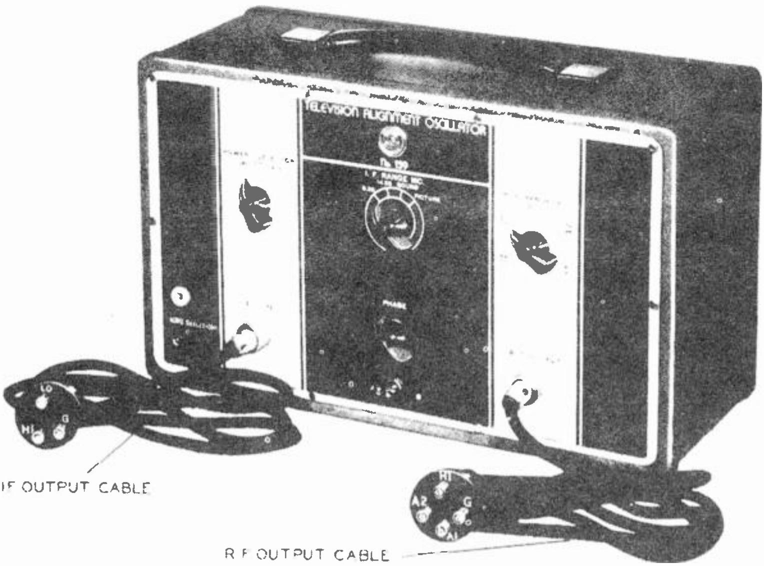


Fig.35 RCA #159 alignment oscillator.

At the time this lesson was written, there was only one alignment oscillator available commercially for television alignment. This is the RCA Television Alignment Oscillator, No. 159. Fig. 35 shows a picture of the RCA alignment oscillator. Fig. 36 is a schematic of the oscillator. The unit contains two separate frequency-modulated oscillators, one for IF alignment, and the other for RF alignment. In both cases, the oscillators are frequency-modulated by varying the capacity across the oscillator tank by means of a motor-driven condenser. The low-frequency oscillator has two frequency-modulated outputs, one for the picture IF and the other for the sound IF. It also has two fixed frequency outputs of 8.25 and 14.25 megacycles for setting the sound traps in the picture IF amplifier. The sweep range for the picture IF is from 7.5 to 15 megacycles, and the sound IF range is from 7.75 to 8.75 megacycles. The high-frequency oscillator has five frequency-modulated outputs, each 8 megacycles wide, covering the five low-frequency television

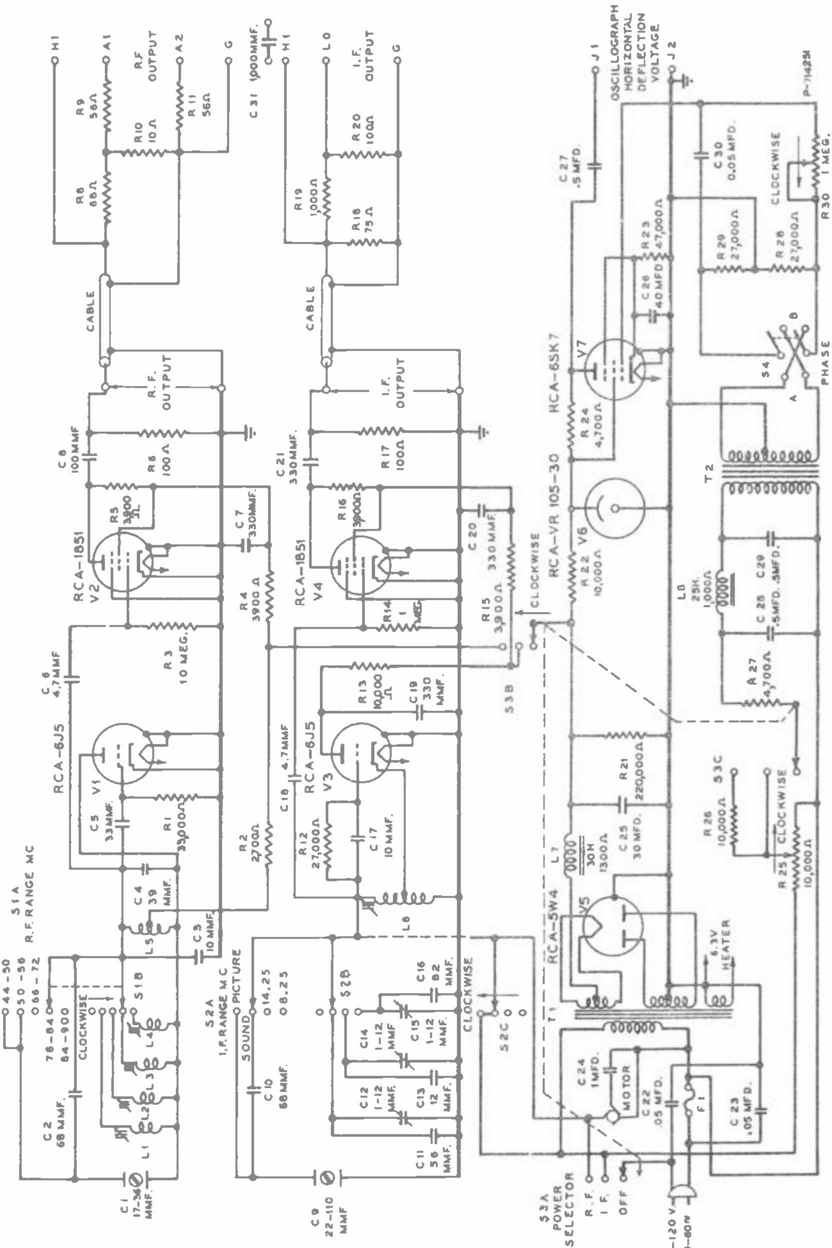


Fig.36 Circuit of RCA #159 alignment oscillator.

channels in the radio frequency spectrum. The various frequency outputs are obtained by shunting inductances of different values across the main oscillator inductance. For the low-frequency oscillator, the frequency band is changed by switching different fixed capacities across the oscillator tank.

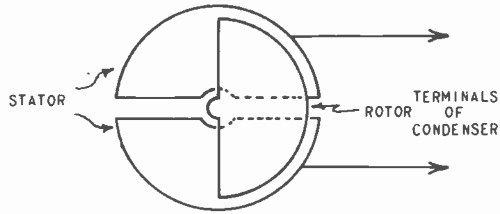


Fig.37 Schematic of frequency changing condenser.

The frequency-changing condenser is shown schematically in Fig. 37. There is no electrical connection to the rotor except through the capacity between the rotor and the two stators. The capacity goes through two maxima and two minima for each rotation of the rotor. The driving motor is a synchronous motor and has a speed of 1800 RPM. Therefore, the frequency of modulation is 60 cycles.

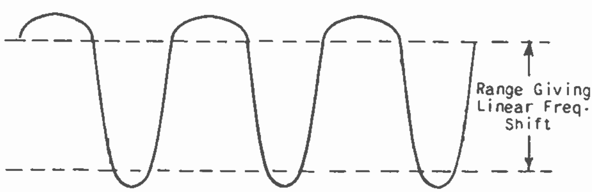


Fig.38 Sweep voltage for oscilloscope.

The horizontal sweep for the oscilloscope is obtained from the oscillator. The waveform of the horizontal sweep is shown in Fig. 38. This particular waveform is obtained by applying a 60-cycle sine wave to the grid of a 6SK7, which has a remote cutoff. The 6SK7 is self-biased with a large cathode resistor. The input sine wave has a large amplitude and the grid is swung over practically the entire negative portion of the E_g-I_p characteristic, as shown in Fig. 39. This sweep voltage, in combination with the way the frequency varies with the rotation of the condenser yields a frequency change that is directly proportional to the horizontal displacement of the beam in the cathode ray tube over the range of the horizontal sweep designated in Fig. 38. Means are provided for shifting the phase of the horizontal sweep with respect to the line voltage through approximately a range of 360 degrees. This is necessary, since a synchronous motor can lock in with the power frequency in two positions that are 180 degrees apart, to make the left-to-right trace on the oscilloscope coincide with the right-to-left.

The output of each oscillator passes through a grid-leak-biased buffer. The screen voltages for the buffers are obtained through series screen resistors. Therefore, the gain of each buffer will vary inversely with grid bias which, in turn, varies directly with the amplitude of the excitation. Thus, the output of the buffers is reasonably constant over the entire frequency range covered by the oscillators. The outputs of the two buffers are obtained through 75-ohm cables.

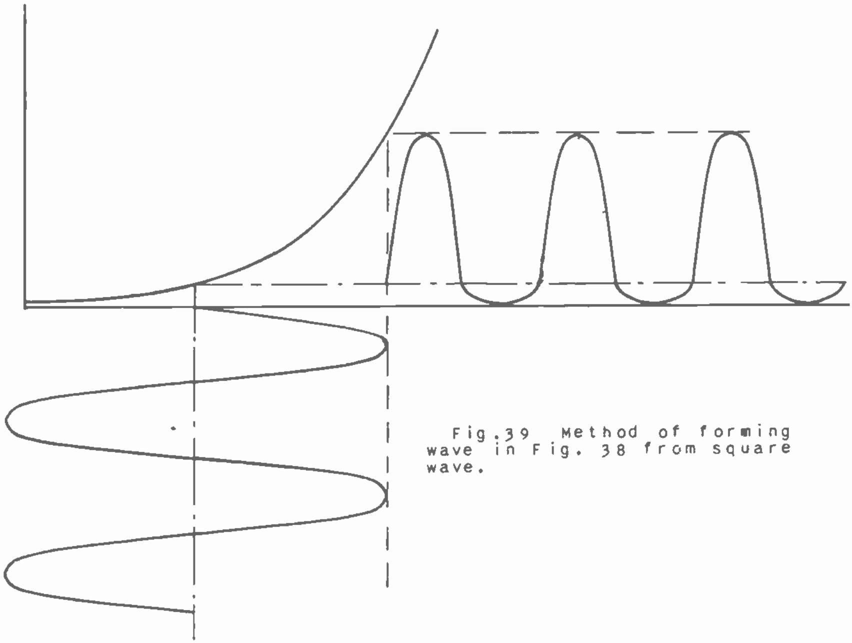


Fig. 39 Method of forming wave in Fig. 38 from square wave.

8. RF SIGNAL GENERATORS. The television serviceman has need for a signal generator which covers the frequency range from around 100 kc. to at least 120,000 kc. Such an oscillator is useful in checking the frequency-versus-gain characteristic of a video amplifier, the proper setting of the associate and adjacent channel IF sound traps, the frequency limits of the picture IF bandpass, the adjustment of the heterodyne oscillator frequency for each of the television bands, and many others.

Most servicemen possess signal generators which have a maximum output frequency of around 30 megacycles. Such an oscillator, (if it has sufficient output), is satisfactory for checking all the items listed above except the adjustment of the heterodyne oscillator. However, since the quality of the received picture is dependent on the accuracy of the oscillator frequency, it is essential to have a signal generator that will cover the oscillator frequencies for the commonly used television channels.

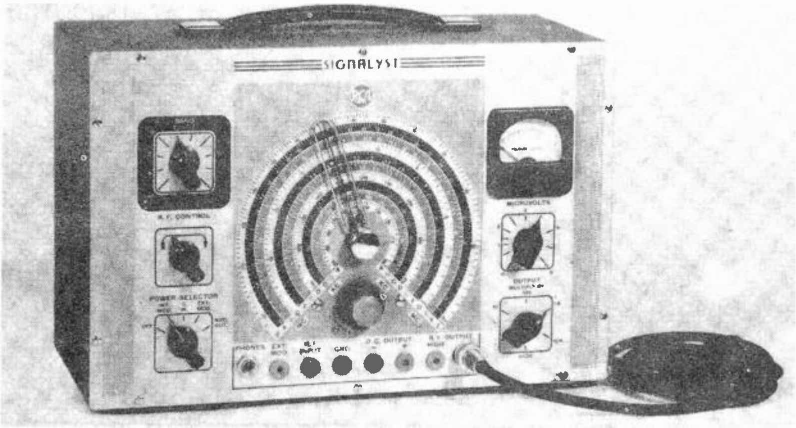


Fig.40 RCA #161 Signalyst.

At the time this lesson was written, there was only one signal generator available commercially possessing the features necessary for television receiver servicing. This is the RCA Signalyst. A picture of this instrument is shown in Fig. 40. Fig. 41 is a schematic of the Signalyst. This instrument covers the range from 100 to 120,000 kc. in ten steps. The output of a 6J5 oscillator is capacity-coupled to a 6SA7 buffer and modulator. Internal 400-cycle modulation is provided and the modulator is designed so that external modulation frequencies up to 5 mc. can be used. This means that the Signalyst can be modulated with a picture signal and the complete overall performance of a television receiver checked in the serviceman's laboratory. The buffer is capacity-coupled to a direct reading, shielded ladder-type attenuator. The input to the attenuator is measured by a vacuum-tube voltmeter that is an integral part of the instrument. The output of the attenuator is variable from a few microvolts to 50,000 microvolts. There is an additional output terminal that gives outputs up to .3 volt. This is sufficient for checking the gain-versus-frequency characteristic of video amplifiers. There is also a heterodyne detector for checking the calibration of the Signalyst against a frequency standard such as the crystal calibrator that is described later in this lesson. The method of checking the calibration by a crystal standard will be discussed in a later lesson of this unit. This same heterodyne detector can be used for comparing external frequencies. The frequency range covered by each coil is adjusted by means of an iron

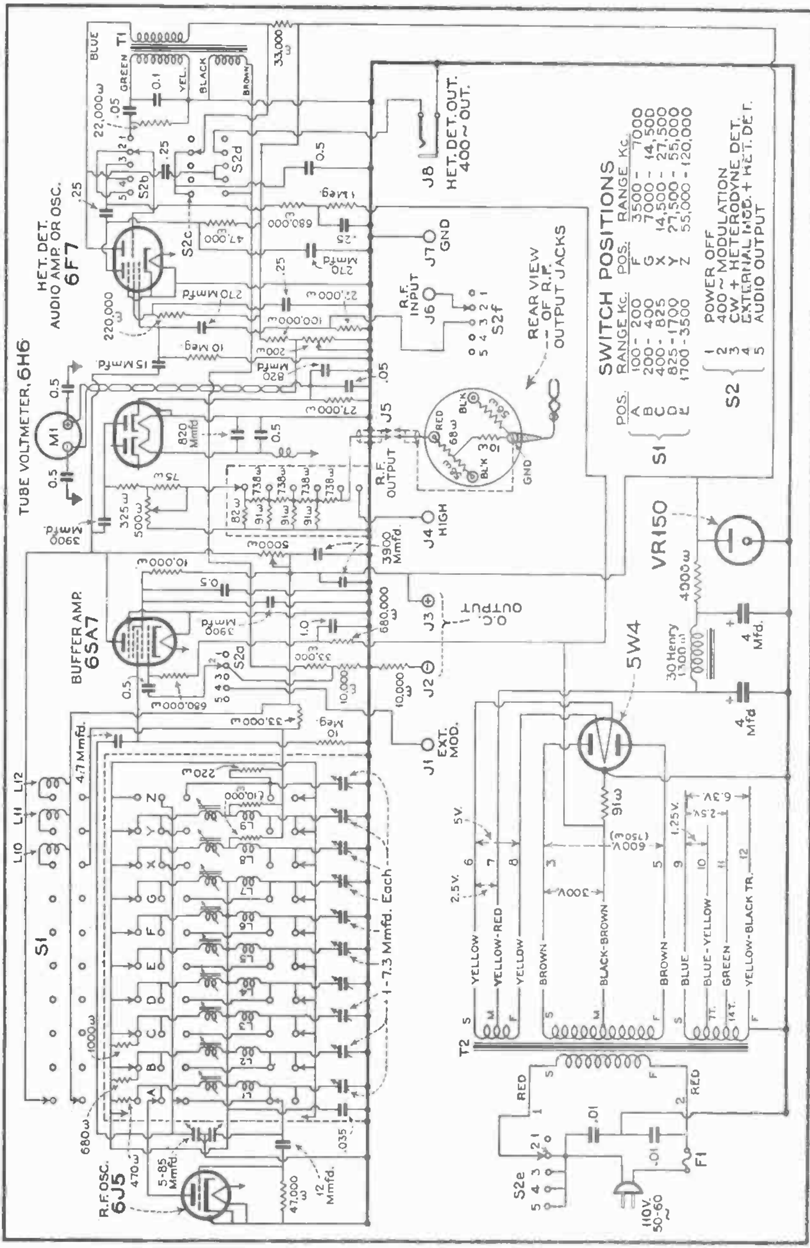


Fig.41 Circuit of RCA #161 Signalyst.

core and an air trimmer condenser. This means that the oscillator calibration will hold for a long period of time. Also, with inductance and capacity trimmers, it is easier to make the output of the oscillator fit the dial calibration. The accuracy of the original calibration is one percent. As we shall learn later, the proper adjustment of the trap circuits requires a higher accuracy than this. The heterodyne detector was incorporated in the instrument for convenience in calibrating the oscillator.

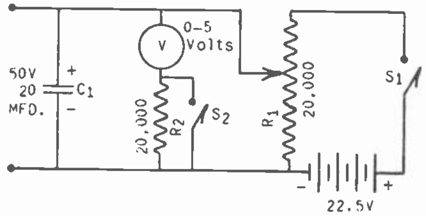


Fig. 42 Circuit of bias supply.

9. BIAS SUPPLY. Some television manufacturers specify definite values of grid bias that must be applied to the IF amplifier stages during alignment. Most of these receivers have automatic gain control and, for alignment, this feature is made inoperative. Therefore, to prevent overloading of the IF stages, an external bias supply must be used.

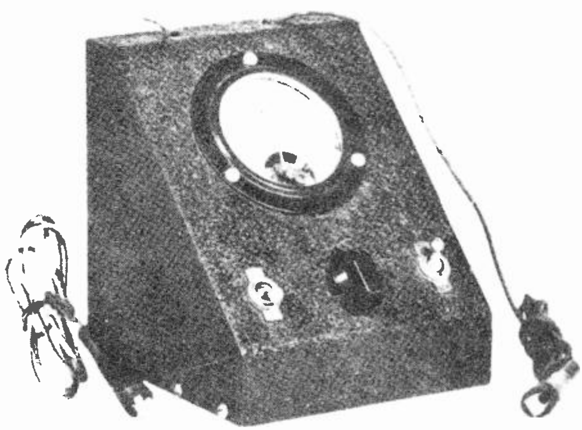
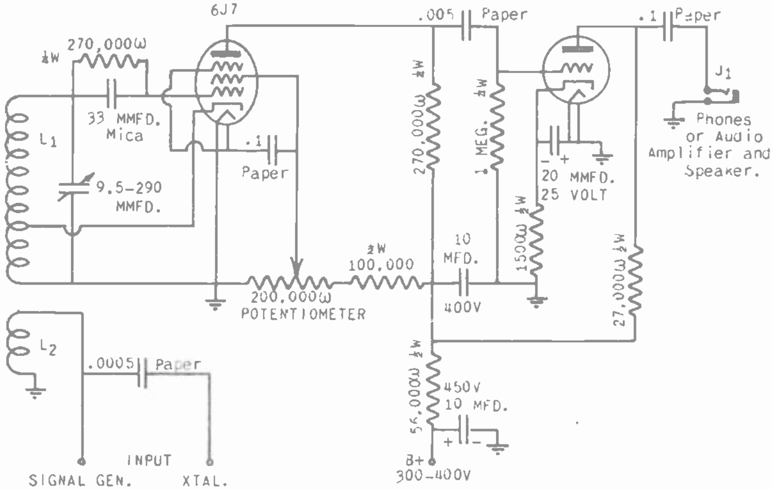


Fig. 43 Bias supply.

A very simple and easily constructed bias supply is described in the RCA alignment instructions for the RCA television receivers. The circuit for this bias supply is shown in Fig. 42. A picture of the completed instrument is shown in Fig. 43. The meter V is an 0-5 volt DC instrument with an internal resistance of 5000 ohms.

Its range is increased to 25 volts by means of the 20,000-ohm resistor R_2. R_2 should have an accuracy of plus-minus 1%. Either range can be selected by the switch S_2. The small 22.5-volt battery is placed inside the box. Connections are made to the bias supply by means of flexible leads terminated in insulated clips.

10. HETERODYNE DETECTOR. The simplest method of checking the calibration of a signal generator is to "zero beat" the signal generator frequency against a known frequency from a standard. The best standard that the serviceman can use is a crystal oscillator designed to generate a wide range of harmonics of the fundamental crystal frequencies. Such a unit will be described in the following section of this lesson.



L1- 6 Turns #22 Enameled Wire, close wound; Tap is 2 Turns from Grounded End.

L2 - 2¼ Turns #28 DSC Wire, close wound.

L1 and L2 spaced 1/16" - 1¼" Dia. Coil Form.

Fig.44 Circuit of heterodyne detector.

In order to beat two frequencies together and obtain an audible beat, the two frequencies must be applied to the grid of a tube which is biased to operate as a detector. The sensitivity of the detector can be increased by using a tuned input circuit. If the detector is made regenerative, its sensitivity will be still greater. With the detector in an oscillating condition it is much easier to tune the input of the detector to weak harmonics of the crystal standard, by zero beating the detector frequency with the crystal harmonic. Then, by reducing the regeneration below the oscillating condition, the signal generator frequency can be adjusted to zero beat with the crystal harmonic.

The Signalyst previously described has a heterodyne detector as an integral part of the instrument. However, the serviceman can readily build a heterodyne detector for calibrating his present signal generator against a crystal standard. A very satisfactory heterodyne detector is described in the RCA instructions on aligning

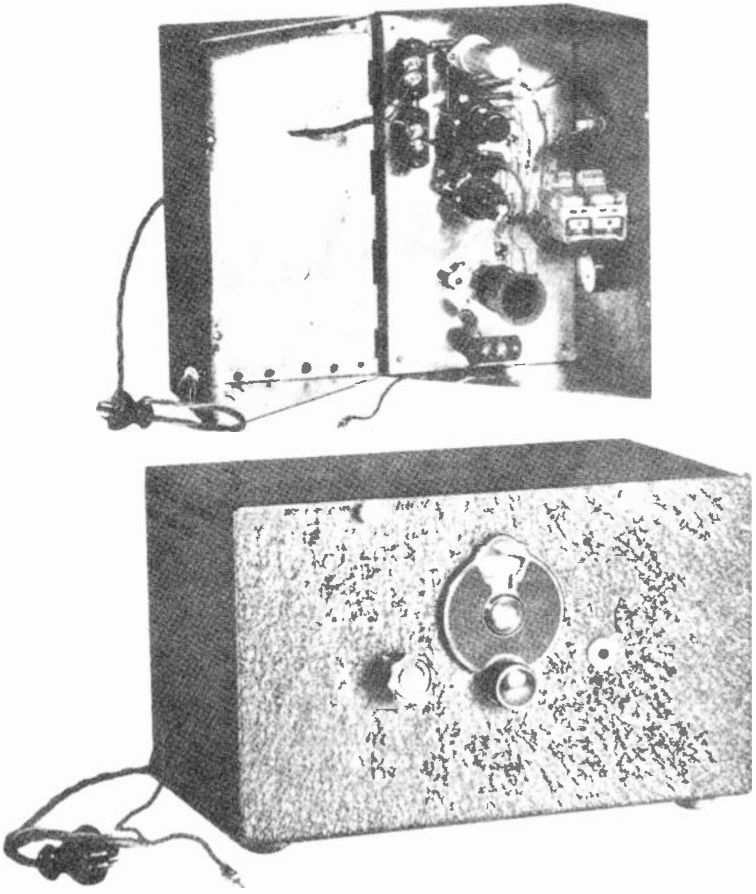


Fig. 45 Inside and outside views of heterodyne detector.

their television receivers. The schematic diagram and parts list for this heterodyne frequency meter is given in Fig. 44. Fig. 45 shows an interior and exterior view of the completed heterodyne detector. The circuit is conventional, and therefore, no discussion of its operation is required. It covers a range of 7 to 16.5 mc. Two inputs are provided, one for the signal generator and the other, for the crystal. A stage of audio amplification is included to increase the sensitivity.

11. CRYSTAL CALIBRATOR. It has been mentioned previously in this lesson that the sound IF trap circuits in the picture IF amplifier, the frequency limits of the picture IF pass band, and the heterodyne oscillator frequencies must be adjusted with a much higher precision than ordinary signal generators will hold calibration. The ordinary crystal-controlled oscillator, without temperature control, maintains its frequency within small enough limits that it can be used as a frequency standard for calibrating signal generators with the required precision. The serviceman can either buy a complete crystal standard or buy the crystal and build the standard.

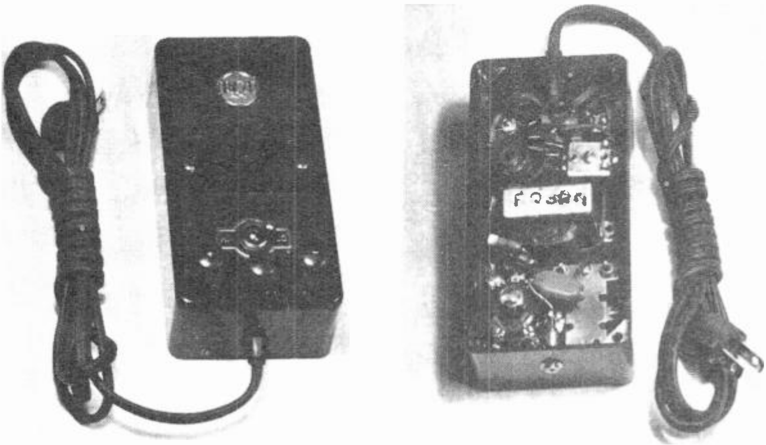


Fig.46 RCA #157 Crystal Calibrator.

A crystal oscillator is extremely rich in harmonics. If the fundamental frequency is 100 kc., the harmonics provide checking frequencies every hundred kc. up to 3 or 4 mc. Above 4 mc., the harmonics are too weak to be usable. Such a crystal would be satisfactory for checking broadcast receivers in the broadcast and IF range of frequencies. For frequencies higher than 2 or 3 mc., the close proximity of the harmonics is confusing, and the harmonics are becoming weaker. However, since the mode of oscillation of a crystal can be through the thickness or along the length, it can be ground to have at least two fundamental frequencies that are widely separated. The frequencies along any two dimensions are inversely proportional to the magnitudes of the dimensions. Thus, a crystal bar can be ground to have a fundamental frequency of 100 kc. along its length and 1000 kc. through its thickness. Such a crystal will give checking points from 100 kc. to 3 or 4 mc. in 100 kc. steps, or checking points from 1000 kc. to 30 or 40 mc. in 1000 kc. steps. Such a crystal makes an excellent standard for calibrating signal generators to be used for aligning all wave receivers. Since the top frequencies involved in television are above 100 mc., a crystal with a high-frequency fundamental of 1000 kc. produces harmonics in the

100 mc. range that are too weak for practical use. A crystal that is satisfactory for checking television receivers should have a high-frequency fundamental of about 2000 kc. Such a crystal will have harmonics extending to 100 mc. If this crystal is ground to have a low-frequency fundamental of 250 kc., it will supply checking points every 250 kc. up to 10 or 12 mc. or higher. Such a fundamental provides convenient calibrating points for the sound and picture IF ranges. The present picture IF of 12.75 mc., the sound IF of 8.25 mc., and the 14.25 mc. IF caused by the adjacent sound channel are all harmonics of 250 kc.

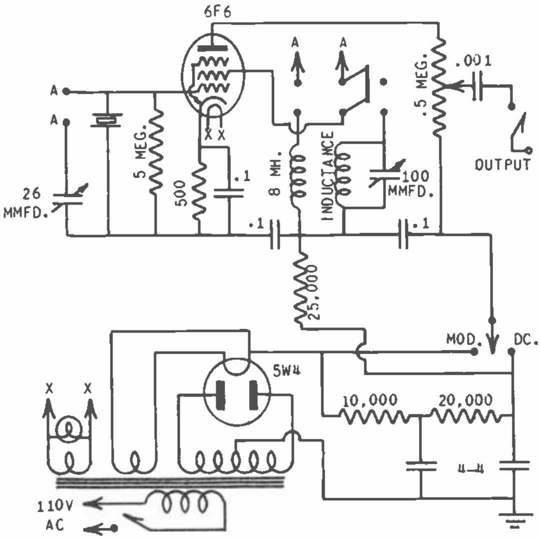


Fig.47 Circuit of a crystal calibrator.

At the present time, RCA is the only manufacturer who markets a crystal calibrator with a crystal having 2000 and 250 kc. fundamentals. This is the RCA Piezo-Electric Calibrator, Model 157. A picture of the exterior and interior of this instrument is shown in Fig. 46. There is a toggle switch on the top to select the proper inductances so that the crystal will oscillate either at 250 kc. or 2000 kc. The oscillator tube is a type 955 acorn. The calibrator is AC-operated, and the 60-cycle line voltage is applied directly to the plate of the oscillator. Therefore, the output is modulated with 60 cycles. However, terminals are provided to use an external 90-volt "B" battery when extreme accuracy in calibrating is required. There is a pin-tip jack at one end for the output.

If the serviceman desires to build his own crystal calibrator, he can obtain an X-cut crystal from the Bliley Electric Company, with fundamentals of 100 and 1000 kc. At the time this lesson was written, the Bliley Electric Company did not market a crystal with

250 and 2000 kc. fundamentals. The circuit shown in Fig. 47 is designed for the 100 and 1000 kc. fundamental crystal. It is essentially a triode crystal oscillator with a pentode amplifier. The cathode, control grid, and screen grid form the triode oscillator with the screen grid as the plate. Either mode of oscillation of the crystal can be obtained by switching in the proper plate load. The inductance L, which is tuned by its distributed capacity, has a resonant frequency favoring the 100 kc. oscillation. The circuit L_1C_1 is resonant at a frequency favoring the 1000 kc. oscillation. The values of L, L_1, and C_1 are given in Fig. 47. You will note that a small padding condenser is connected across the crystal for the low-frequency mode of oscillation. It is rather difficult to grind a crystal with the two modes of oscillation exactly 1000 and

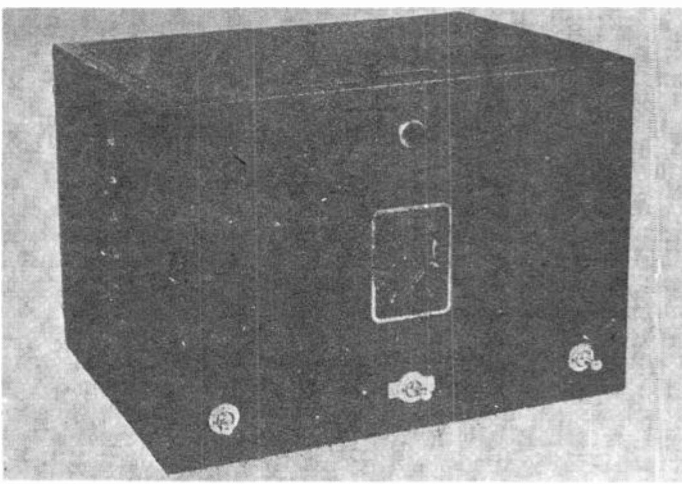


Fig. 48 Picture of crystal calibrator using circuit of Fig. 47.

100 kc. because both modes of oscillation are affected slightly by the other dimension. The greatest accuracy is required for the 100 kc. mode of oscillation, as the 100 kc. harmonics are used in checking the IF range in receivers. Therefore, the crystal is ground to be slightly high for 100 kc. and within plus-minus .05% for 1000 kc. The small padding condenser which is connected across the crystal for the 100 kc. mode of oscillation can be adjusted so the crystal will oscillate exactly at 100 kc. The simplest method of adjusting this padder is to tune a receiver to a broadcast station which operates on a harmonic of 100 kc., then adjust the padder until the corresponding harmonic of the crystal is in zero beat with the broadcast station. The output of the crystal oscillator can be modulated at 120 cycles by obtaining the plate voltage for the amplifier from the input to the filter of the power supply. Fig. 48 is a picture of the crystal calibrator. The material on the construction of the crystal calibrator was taken from an article

published in "Service" by an engineer of the Bliley Electric Company.

12. PICTURE SIGNAL GENERATORS. An indispensible piece of equipment for checking the overall performance of a television receiver is the picture signal generator. A picture signal generator is an instrument which generates a complete video signal; that is, a signal which is made up of picture signal, blanking impulses, and synchronizing impulses. The picture signal is generated by scanning a still picture incorporated in a special cathode ray tube.

The overall performance of a television receiver from the RF input to the reproduced picture on the screen of the cathode ray tube can be checked by means of the picture signal generator in conjunction with a signal generator such as the Signalyst previously described. The output of the Signalyst is modulated by the output of the picture signal generator. The modulated RF signal is then applied to the input of the television receiver. If the receiver is in perfect operating condition, the picture scanned in the picture signal generator will be reproduced exactly on the cathode ray tube screen of the receiver.

Similarly, the operation of the section of the receiver following the picture second detector can be checked by applying the output of the picture signal generator across the second detector load. In this way, the operation of the video amplifier, the sync pickoff, and separator circuits, and the deflecting circuits can be checked. The use of the picture signal generator in television servicing is explained fully in a later lesson of this unit.

A simple picture signal generator can be readily constructed by the serviceman. The heart of the picture signal generator is the cathode ray tube which generates the picture signal. The type tube available to the serviceman has the same shape as the conventional three-inch cathode ray tube. However, the end of the tube is not coated with fluorescent material. A thin metal disc is mounted inside the tube where the fluorescent screen is normally located. A half-tone picture, printed in lampblack or carbon, is on the side of the disc facing the electron gun. A connection to the metal disc is brought out through the end of the tube. The output of the tube can be obtained by connecting a resistor between this metal disc or signal plate and ground. The picture signal is developed across this load resistor. The picture on the disc is scanned by the electron beam in the same way that the fluorescent screen in the ordinary cathode ray tube is scanned. The tube is shown schematically in Fig. 49.

The picture signal developed across the load resistor is due to the difference in secondary emission from carbon coated parts of the metal disc and the uncoated parts. The secondary emission is much lower for the coated than for the uncoated sections of the disc. When the secondary emission is high, just a few of the electrons in the scanning beam are collected by the disc and flow through the load resistor to ground. The signal plate is usually operated at about 100 volts negative with respect to the second anode and deflecting plates so that the secondary electrons will be drawn away from the signal plate. When the electron beam passes over the carbon coated areas of the disc, the secondary emission is low and practically all the electrons in the scanning beam are collected by the signal plate and flow through the load resistor to ground. Thus, the voltage developed across the load resistor will be minimum when the scanning beam passes over the uncoated areas of the disc or the "whites" of the picture, and will be maximum when the scanning beam passes over the carbon coated areas of the disc or the "blacks" of the picture. The signal plate is most negative with respect to ground for the "blacks" and least negative for the "whites" of the picture. In other words, the voltage developed across the load resistor changes in the positive direction for the whites and in the negative direction for the blacks in the picture. Such a signal is called a positive picture signal.

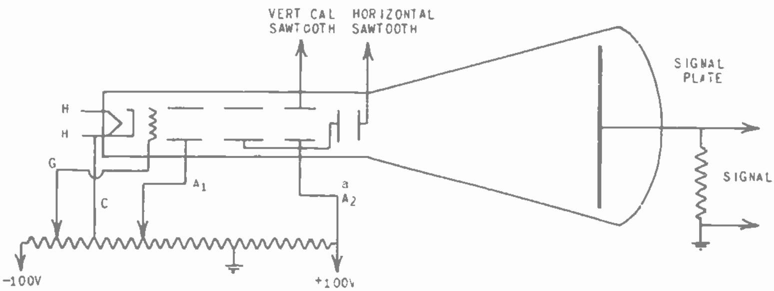
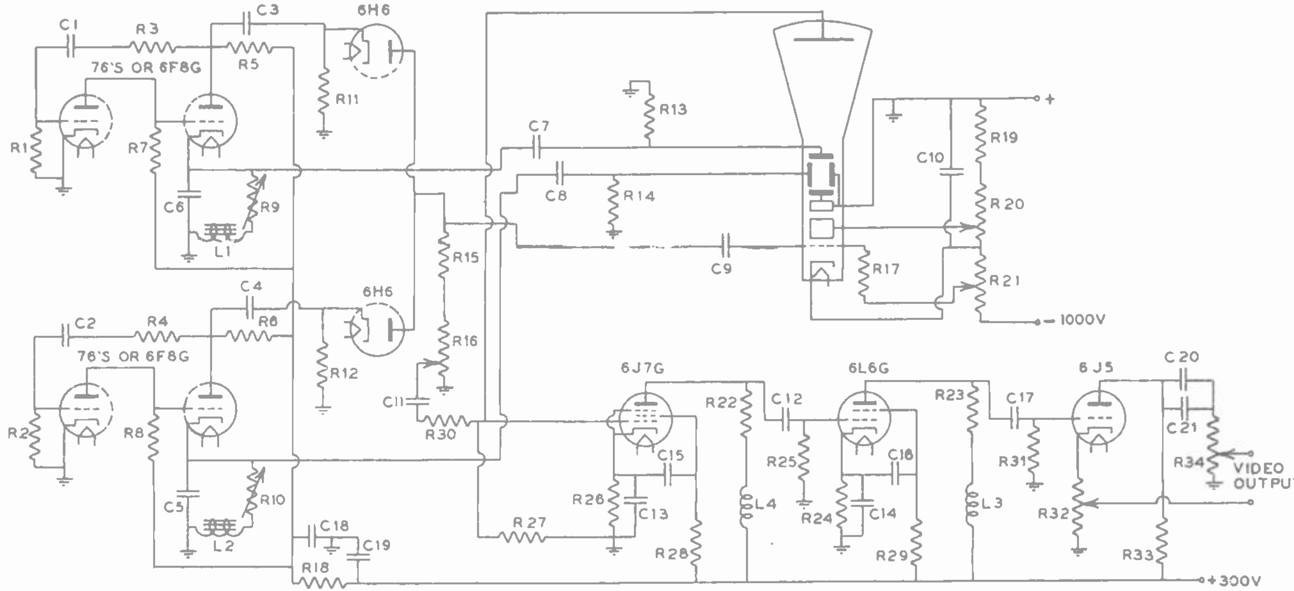


Fig.49 Schematic of picture signal generator tube.

Picture signal generator tubes are made by several manufacturers. The RCA tube is called a Monoscope, the National Union is called a Monotron, and the Dumont is called a Phasemajector. Some of these tubes have pictures of persons printed on the signal plate; others have charts which can be used to check the linearity of the receiver sweeps and the resolving power of the receiver VF amplifier and cathode ray tube.

The circuit diagram of an easily constructed picture signal generator is shown in Fig. 50. This circuit, with slight modifications, was given in an article by M. P. Wilder in the March 1938 issue of QST. The high voltage and low voltage power supplies have been omitted. The low voltage supply should produce about 300 volts at 100 milliamperes, and the high voltage supply should develop 1000 volts at two or three milliamperes. The high voltage supply is a conventional television receiver cathode ray tube supply as described in a lesson in the previous unit.

The essential parts of the picture signal generator are the picture signal generator tube, the vertical and horizontal sawtooth oscillators, and a video frequency amplifier. The sawtooth oscillators are the Bedford-Puckle multivibrators which were described in a previous lesson. The vertical oscillator is designed



R1, R2, R11, R12, R13, R14, R25 - 1 megohm.
R3, R4 - 4000 ohms.
R5, R6 - 2000 ohms.
R7, R8 - 100,000 ohms.
R9 - 50,000 ohms.
R10 - 150,000 ohms.
R15 - 200,000 ohms.
R16, R21 - 10,000 ohms.
R17 - .5 megohm.
R18 - 1500 ohms.
R19 - 150,000 ohms.
R20 - 75,000 ohms.

R22, R23 - 2500 ohms.
R24 - 220 ohms.
R26 - 1500 ohms.
R27 - 25,000 ohms.
R28 - 250,000 ohms.
R29 - 30,000 ohms.
R30 - 250,000 ohms.
R31 - 1 megohm.
R32, R34 - 1000 ohms.
R33 - 10,000 ohms.
C1, C2 - .002 mfd.
C3, C4 - .01 mfd.

C5 - .2 mfd.
C6 - .001 mfd.
C7, C8, C12, C17 - .5 mfd.
C9, C10 - 1 mfd.
C11 - .25 mfd.
C13, C14 - 50 mfd.
C15, C16, C18, C19 - 8 mfd.
C20 - 20 mfd. (Electrolytic)
C21 - .1 mfd.
L1 - 100 henrys
L2 - 2000 henrys.
L3, L4 - 100 microhenrys.

Fig.50 Circuit of picture signal generator.

to operate at 60 cycles and the horizontal at 13,230 cycles. The video amplifier uses shunt peaking to obtain uniform gain over a wide frequency range. This method of obtaining high frequency compensation was described in a previous lesson. The purpose of the video amplifier is to amplify the weak output of the picture signal generator tube. The output tube in the video amplifier is both plate and cathode loaded. Thus, a picture signal of either positive or negative polarity can be obtained; a positive from the cathode and a negative from the plate.

A complete video signal contains blanking impulses which blank out the electron beam in the picture reproducing cathode ray tube during the horizontal and vertical return times. Inserted on top of the blanking impulses are sync impulses which keep the vertical and horizontal sawtooth oscillators in step with those at the transmitter. In this simple unit, the blanking and sync impulses have been combined. These combined blanking and sync impulses are obtained from the plate circuit of the second tube in the two multivibrators. You recall that the voltage developed across the plate load of the second tube in the Bedford-Puckle multivibrator consists of sharp negative pulses occurring during the return time of the sawtooth generated across the condenser in the cathode circuit of the second tube. Thus, these sharp pulses have the correct width and occur at the right time for their use as blanking impulses for the picture signal generated by the special cathode ray tube.

In a normal video signal, (See Fig. 2), the blanking impulses are in the black direction, and the synchronizing impulses which occur during the blanking time are also in the black direction. It is sometimes said that the synchronizing impulses are "blacker than black". Thus, the negative pulses occurring across the plate loads of the second tubes in the multivibrators must be inserted into the picture signal where it has positive polarity; that is, the picture signal increases in the positive direction for white and in the negative direction for black.

In Fig. 50, the picture signal going into the video amplifier is positive in polarity. The blanking impulses from the two multivibrators are mixed through two diodes having the common load resistors R_{15} and R_{16}. The diodes are used to prevent interaction between the two multivibrators. Part of the mixed blanking and sync developed across R_{16} is fed into the grid of the first VF amplifier. The total amplitude of the mixed blanking is applied to the grid of the picture generator tube to blank out the return traces of the cathode ray beam.

The adjustment of the picture signal generator is very easy. A television receiver and an oscilloscope are required. The output of the picture signal generator is connected across the diode load of the receiver. The same polarity output from the picture signal generator is used that is normally developed across the receiver diode load. The oscilloscope is connected across the diode load also. The picture signal generator is turned on and the blanking control R_{16} is set at maximum. Since the receiver sawtooth oscillator frequency controls are probably set at the correct frequencies (if the receiver is used), the frequency controls on the picture signal generator are adjusted until the receiver oscillators lock in with the picture signal generator oscillators. Next, the blanking control R_{16} is reduced until the receiver sawtooth oscillators will just lock in with the picture signal generator oscillators. It will be necessary to readjust the picture signal generator oscillators slightly. Next, the intensity control R_{21} or grid bias control on the picture signal generator cathode ray tube is turned in the direction to reduce the bias on the grid of the tube. A blurred picture will appear on the receiver cathode ray tube screen. The focus control R_{20} is adjusted until the picture is sharply defined. If the receiver falls out of synchronism during this adjustment, turn in a little more blanking. Then the bias and focus controls on the picture signal generator tube are adjusted for the clearest and sharpest picture.

The oscilloscope horizontal sweep is set at approximately 30 cycles and synchronized internally with the signal coming from the picture signal generator. The electrical waveforms corresponding to two complete fields of the picture will be seen on the oscilloscope screen. The pattern will be similar to that shown in Fig. 60B. The purpose of the oscilloscope is to aid in the insertion of the proper amount of blanking into the picture signal. The combined blanking and sync should occupy about twenty percent of the peak to peak signal shown on the oscilloscope screen. The amount of the combined blanking and sync is controlled by R_{16}.

After these adjustments have been made, the picture signal generator is ready for use. These adjustments should be checked occasionally. The application of the picture signal generator to television receiver servicing is discussed in a later lesson of this unit.

The construction of the unit is not difficult. The cathode ray tube must be enclosed in a soft iron case to prevent stray magnetic fields from distorting the scanning pattern. In laying out the chassis, it is important to space the cathode ray tube and the power supply components as far as possible. The magnetic fields around power transformers and chokes introduce ripple into the scanning pattern. It is advisable to separate the two sawtooth oscillators as much as possible to prevent cross-talk. The video amplifier should be enclosed in a separate shield. The connection between the signal plate in the picture generator tube and the input to the video amplifier must be very short. Care must be taken to prevent energy from the sawtooth oscillators from feeding into the video amplifier.

This simple picture signal generator is very satisfactory for most of the serviceman's needs. It can be improved by the addition of amplitude controls on the vertical and horizontal sawtooth oscillators and by spot shifts for centering the electron beam in the cathode ray tube. It is also a good policy to

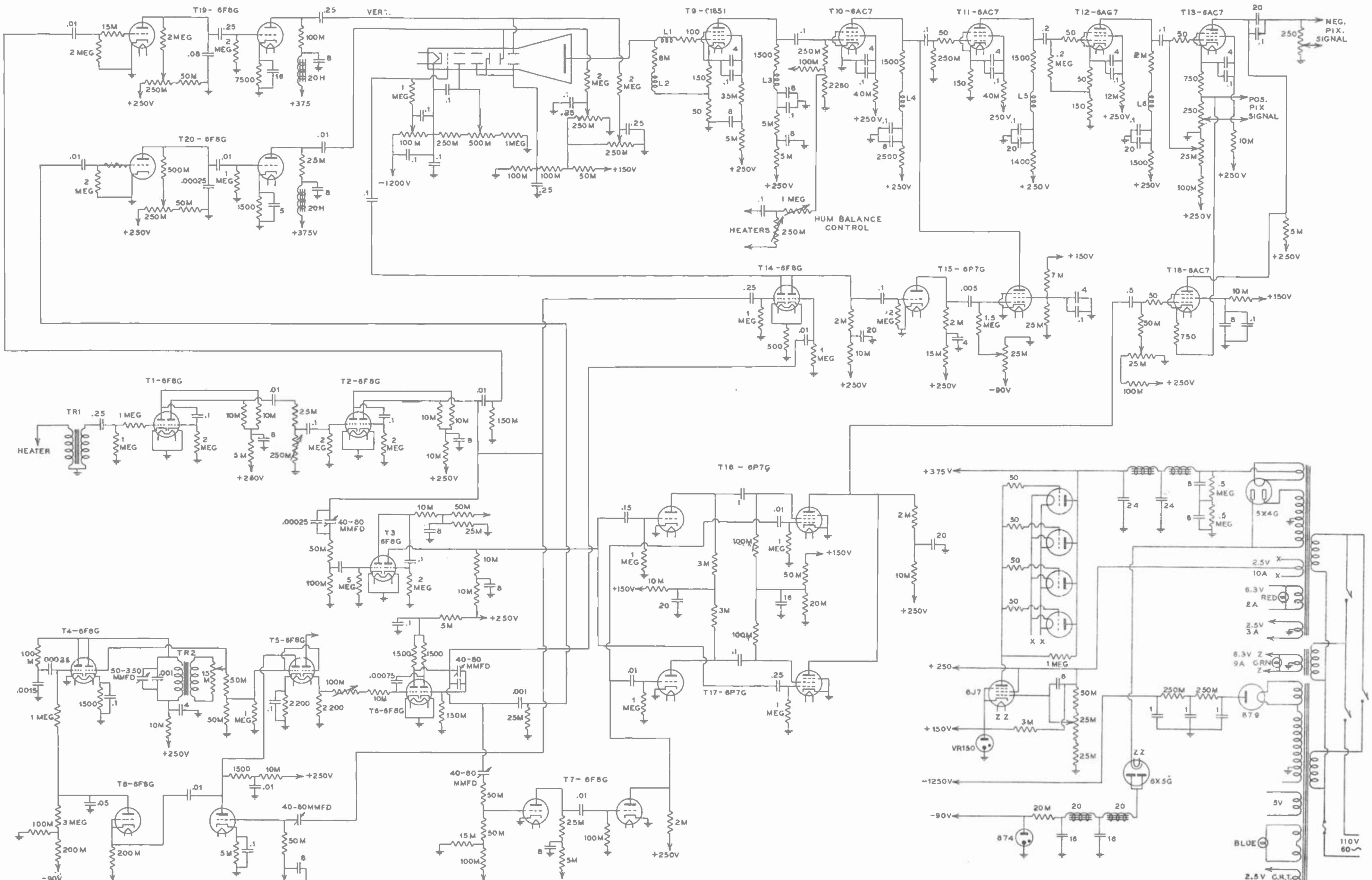


Fig.51 Circuit of Midland's picture signal generator.

check the frequency characteristic of the video amplifier. The values of the plate loads and compensating inductances given in the circuit diagram are for a uniform frequency response to 2 megacycles. However, the constructor may not have the same values of shunt capacity as the original designer, and the frequency

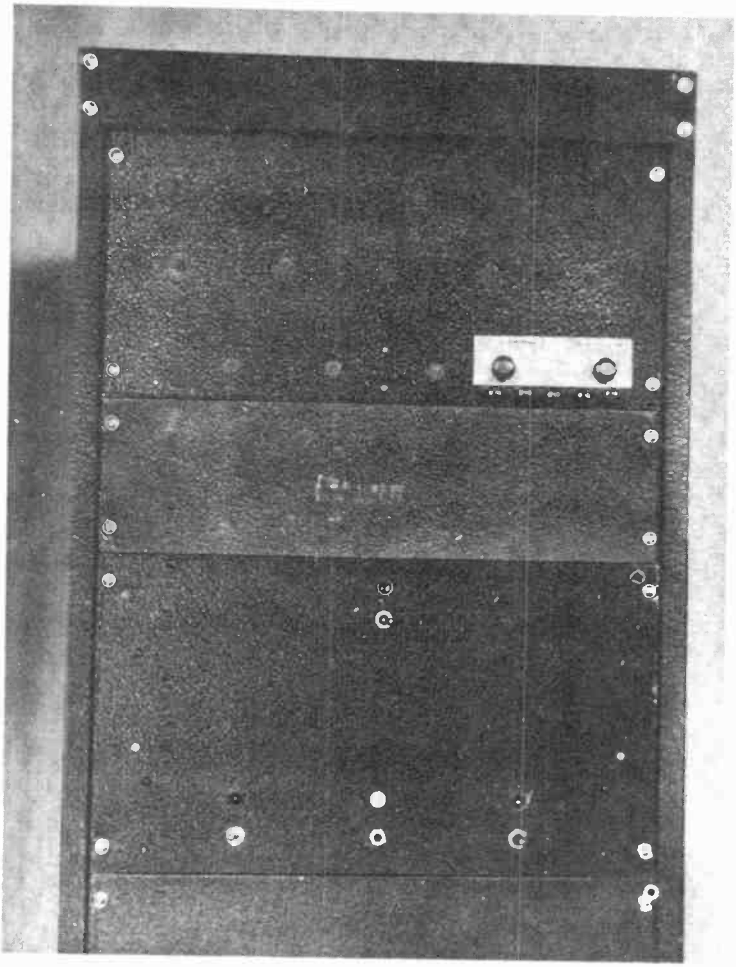


Fig.52 Midland's picture signal generator.

characteristic of his amplifier may not be flat. Methods of checking amplifier characteristics are given in a later lesson of this unit.

A picture signal generator considerably more complicated in design and adjustment has been built for use in the television laboratories of Midland Television. In this signal generator are incorporated circuits which generate some of the special waveforms required by the RMA television standards. The output is identical with the RMA standard except that there are no equalizing impulses. The vertical sync pulse is serrated as in the RMA standard signal. However, the serrations have a frequency of 13,230 cycles instead of 26,460. Also, the horizontal frequency is tied in with the vertical frequency, and the vertical frequency is tied in with the 60 cycle power supply frequency. The unit is actually a complete television transmitter except that a picture signal generator cathode ray tube is used instead of an Iconoscope or other type of tube for converting actual scenes into a picture signal.

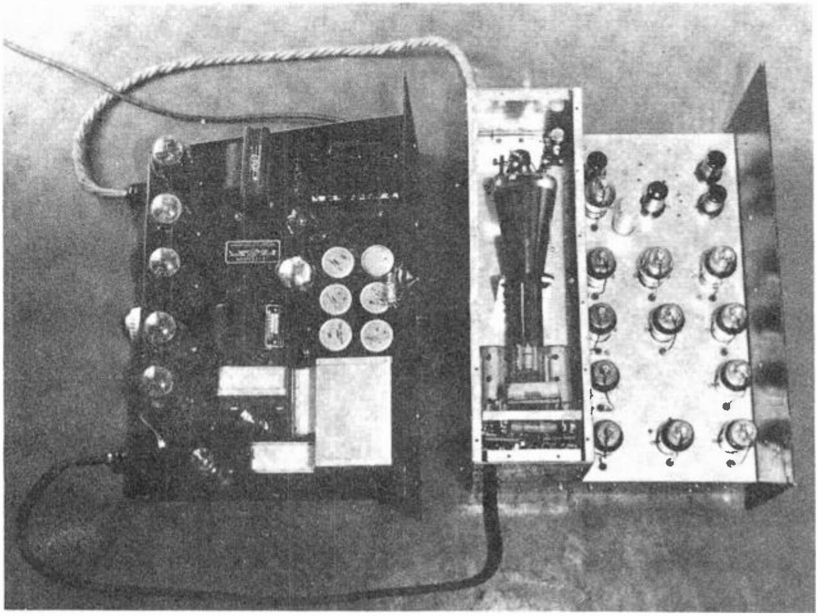


Fig.53 Power supply and picture signal generator chassis.

The circuit diagram for this picture signal generator is shown in Fig. 51. Fig. 52 is a picture of the picture signal generator mounted in a rack. Fig. 53 is a picture of the two units comprising the picture signal generator. The unit on the left is the power supply and the unit on the right is the picture signal generator. Part of the shield around the picture signal generator cathode ray tube has been removed so that the tube and the input circuit to the video amplifier can be seen. The under side of the picture signal generator chassis is shown in Fig. 54.

The operation of the specialized type of circuits used in this picture signal generator is described fully in a lesson on synchronizing generators in the next unit. Therefore, no attempt will be made in this lesson to describe in detail the function of the various components in this signal generator. Also, many servicemen lack sufficient experience to adjust these specialized circuits. However, a brief description of the operation will be given.

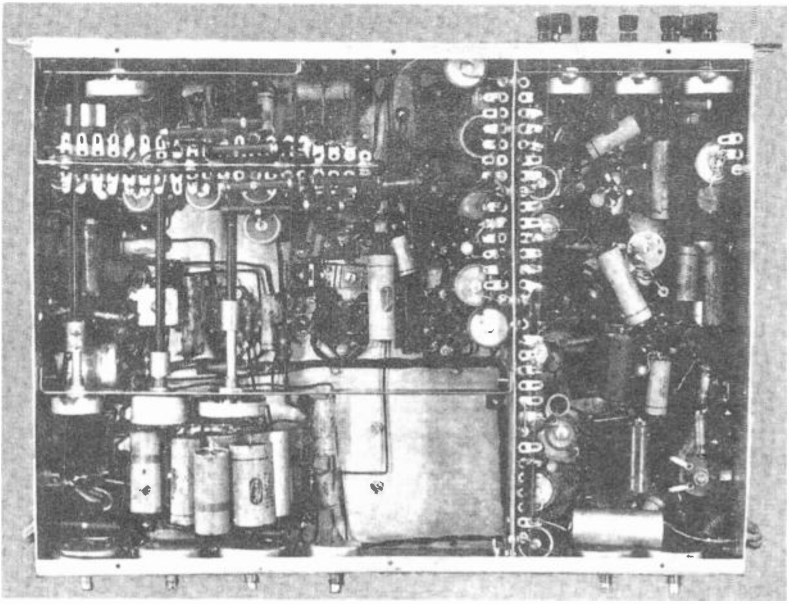


Fig.54 Underside of picture signal generator.

The power supply consists of three distinct units. There is a high voltage supply which delivers about 1250 volts for the picture signal cathode ray tube. The positive side of this supply is grounded. The second unit delivers several voltages; 375, 250, and 150. The 250 and 150 volt outputs are regulated; that is, their output voltage is constant for wide variations in load and in line voltage. The third unit delivers -90 volts regulated. This unit uses the same power transformer as the previous unit. The 150 volt supply and the -90 volt supply are regulated by glow lamps. You recall that the voltage drop across a glow lamp is relatively constant and independent of the current through the lamp. The 250 volt supply uses a type of regulator that is probably new to you. This type of regulated power supply is described fully in the lesson on synchronizing generators. The four 2A3's connected in parallel form a variable resistance in series with the load. This resistance is varied automatically with load changes and line voltage changes so that the voltage across the load remains constant. The 6J7 is called the control tube, as it controls the magnitude of the resistance presented by the 2A3's. The VR-105 glow lamp produces a fixed and constant bias voltage for the 6J7. If the voltage delivered by the 250 volt should tend to increase either through decreased load or a higher line voltage, this increase will change the voltage applied to the grid of the 6J7 in the positive direction. The 6J7 will draw more plate current and the voltage developed across the 6J7 plate load will increase. Since this load resistor is connected between the plates and grids of the 2A3's, this voltage change will shift the grid voltage on the 2A3's in the negative direction and cause their plate resistance to increase. The increased voltage drop across the 2A3's is just sufficient to absorb the increase in the output of the filter caused by either the decrease in load or the increase in line voltage. The process is reversed for an increase in load or a decrease in line voltage. The magnitude of the regulated output can be set at any value within the range of the regulator by means of the potentiometer applying voltage to the grid of the 6J7.

The video amplifier has five stages adjusted so that the frequency response is flat from 30 to 4,000,000 cycles. The blanking is introduced into the plate circuit of the second video amplifier T10. The polarity of the picture signal at this point is positive and, therefore, the blanking must be negative. The amplitude of the blanking introduced is controlled by the bias on the pentode section of the 6P7-G (T15). More blanking is introduced than is necessary, the final blanking level being controlled by the bias on T13. The synchronizing is introduced in the final video stage T13. The plates and cathodes of T13 and T18 are connected in parallel. The sync is applied to the grid of T18. The amplitude of the sync is controlled by varying the bias on T18. The bias on T13 is also made variable in order to set the black level. A discussion of this point is given in a later lesson. The polarity of the picture signal developed in the plate circuit of T13 is negative, and that developed in the cathode circuit is positive. Therefore, the sync must be positive in the plate circuit of T18 and negative in the cathode circuit. This means that the sync applied to the grid of T18 must be negative. This sync is the combined vertical and horizontal sync.

The vertical blanking, sync, and sawtooth are formed by modifying the waveform of the 60 cycle supply voltage. The horizontal blanking, sync, and sawtooth are formed by modifying the waveform of a 13,230 cycle multivibrator T6, synchronized with a 26,460 cycle oscillator, (part of T4). This oscillator is kept in step with the 60 cycle supply voltage with a modified automatic frequency control circuit. All the tubes in these pulse shaping circuits are double; that is, there are two tubes in the same envelope.

The 60 cycles for forming the vertical pulses is obtained from the heater supply. Half the heater voltage is stepped up to about 125 volts by the transformer TR1. This voltage is applied to the grid of one section of T1. The two sections of T1 clip off the top and bottom of the sine wave so that the waveform in the plate circuit of the second section of T1 is a 60 cycle square wave. This waveform is shown in Fig. 55B. The methods of clipping used here; that is, by means of a series grid resistor and grid leak bias (leveling), were discussed in a previous lesson on the sync circuits in television receivers. They are

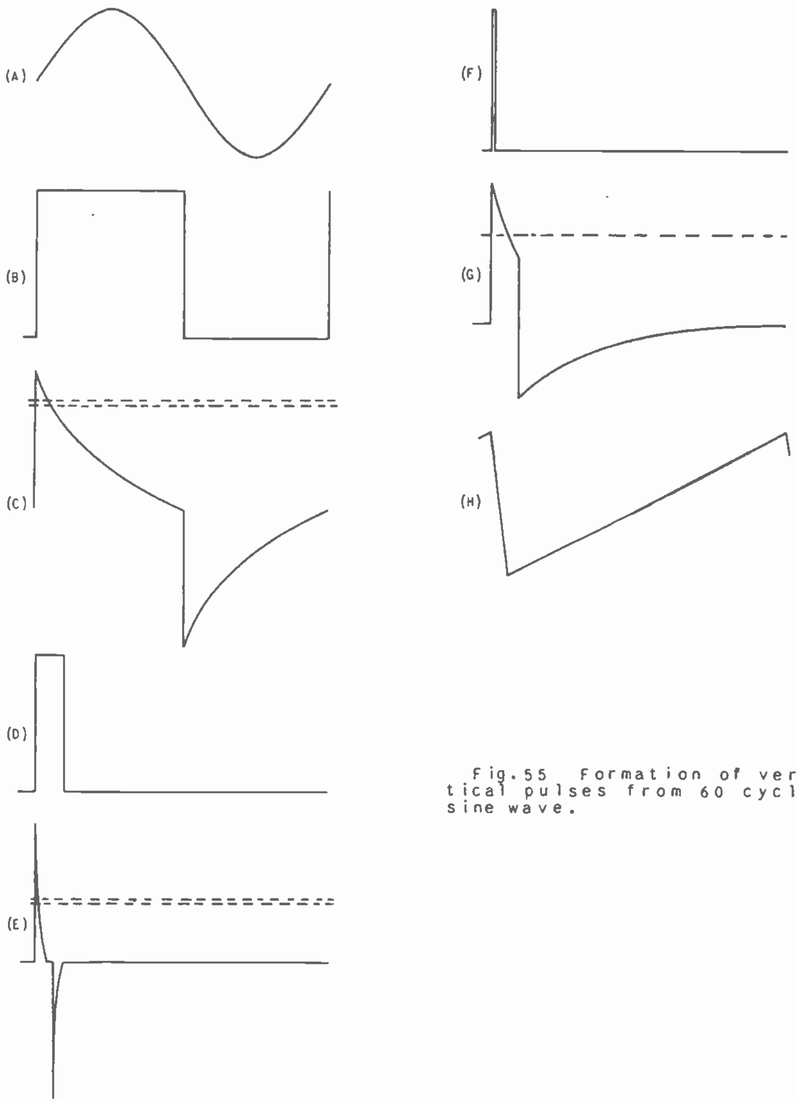


Fig.55 Formation of vertical pulses from 60 cycle sine wave.

also described in more detail in a following lesson on the synchronizing generator. The square wave from T1 is applied to the series circuit consisting of a .01 condenser, a 25,000 ohm resistor, and a 250,000 ohm variable resistor. The time constant of this combination, as you are aware from the discussion of the low frequency characteristics of amplifiers given in a previous lesson, is much too small to transmit a square wave without distortion. The output of this series circuit has the form shown in Fig. 55C. T2 is another two stage clipper which clips out a section of the input waveform as indicated by the dotted lines in Fig. 55C. The output wave has the form shown in Fig. 55D. The width of this pulse can be controlled by varying the time constant of the network connecting T1 and T2. The output of T2 has the correct shape to be used as the vertical blanking in the video signal.

The output of T2 is passed through another small time constant circuit to T3. The resultant waveform applied to the grid of T3 is shown in Fig. 55E. T3 is another double clipper which clips out a section of E as shown by the dotted lines. The output wave of T3 has the form shown in Fig. 55F. This waveform has the correct shape to be used as the vertical sync for the complete video signal. The width of this sync pulse can be controlled by varying the time constant of the circuit coupling T2 and T3.

The output of T2 is also applied through another small time constant network to the grid of T19. The waveform applied to the grid of the first section of T19 has the form shown in Fig. 55G. The cutoff bias for the first section of T19 is shown by the dotted line in Fig. 55G. These sharp positive pulses discharge periodically the condenser connected between plate and ground of the first section of T19. When T19 is biased beyond cutoff, this condenser charges. Therefore, a sawtooth voltage (Fig. 55H), is developed across this condenser as across the condenser in the discharge tube circuit of a blocking tube oscillator type sawtooth wave generator. This sawtooth is amplified by the second section of T19 and applied to the vertical deflecting plates of the picture signal cathode ray tube.

The output waveform of the 13,230 cycle multivibrator T6 has approximately the correct shape to be used for the horizontal blanking. This waveform is shown in Fig. 56A. The part of the wave below the dotted line must be clipped off. This is done in one section of T14, the tube which mixes the horizontal and vertical blanking.

The output of the T6 multivibrator is also applied through a small time constant network to the grid of one section of T7. The waveform applied to the grid of this section has the form shown in Fig. 56B. T7 is another double clipper which clips out the section of 56B shown between the dotted lines. The output waveform of T7 has the form shown in Fig. 56C. This output can be used for the horizontal sync in the complete video signal. Its width can be controlled by varying the time constant of the network coupling T6 and T7.

Part of the output of T6 is applied through another small time constant network to the grid of one section of T20. This waveform is shown in Fig. 56D. The dotted line is the cutoff bias for this section of T20. A sawtooth (Fig. 56E) is generated across the condenser in the plate circuit of the first section of T20 in the same way that the sawtooth was formed for the first section of T19. This sawtooth has a frequency of 13,230 cycles. It is amplified by the second section of T20 and applied to the horizontal deflecting plates of the picture signal cathode ray tube.

The two sections of T14 have a common plate circuit. The vertical blanking is applied to the grid of one section and the

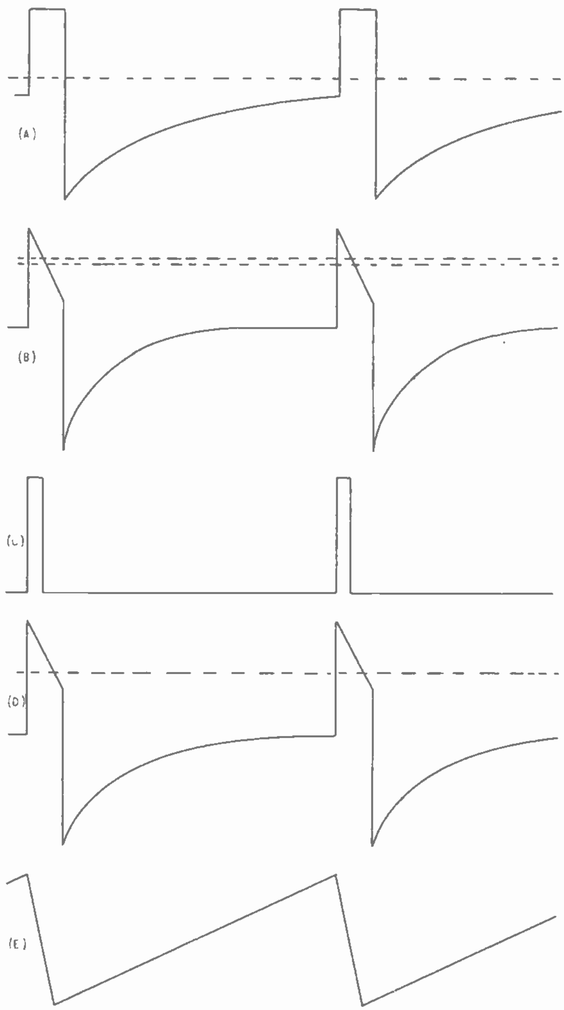


Fig.56 Formation of horizontal pulses from output of 13,230 cycle multivibrator.

horizontal blanking to the grid of the other section. The signal applied to the grid of the triode section of T15 is mixed horizontal and vertical blanking. The output of the triode section has the form shown in Fig. 57. This triode also does some clipping, and thus helps to square up the mixed blanking. The mixed

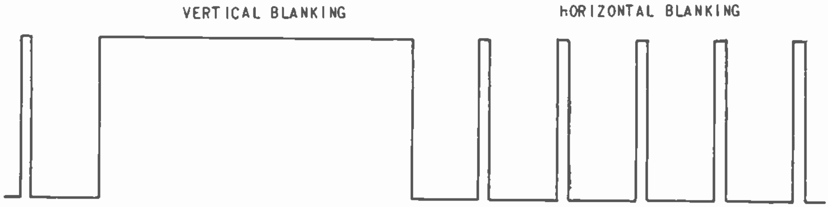


Fig.57 Mixed blanking.

blanking from the plate circuit of T14 is also applied to the grid of the picture signal cathode ray tube. This is to cut off the electron beam during the horizontal and vertical return times and prevent a picture signal from being generated.

The method of mixing the vertical and horizontal sync is more complicated, as the vertical sync pulse in the complete video signal must be serrated. You will recall that the serrations in

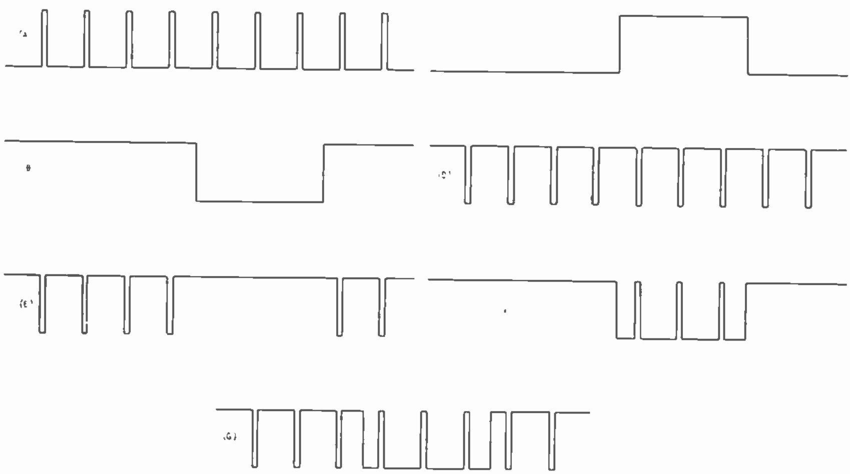


Fig.58 Formation of serrated vertical.

vertical sync pulses maintain synchronization of the horizontal sawtooth oscillator during the vertical synchronizing time. The purpose of T16 and T17 is to mix the vertical and horizontal sync and to insert the serrations into the vertical sync pulse. You will note that the horizontal sync pulses are applied to the grid of the triode section of T17 and to the grid of the pentode section of T16. Similarly, the vertical sync pulses are applied to the grid of the triode section of T16 and to the grid of the pentode section of T17. The output of each triode unit is applied to the screen grid of the pentode section of the same tube. The waveforms applied to the control grid and screen grid of the pentode section of T16 are shown in Figs. 58A and 58B. The waveforms applied to the control grid and the screen grid of the pentode section of T17 are shown in Figs. 58C and 58D. The screens of the two pentode sections have a low DC voltage (45 volts). Therefore, sharp negative pulses applied to the screens of the two pentodes can bias them to cutoff as does a sharp negative pulse applied to their grids. Keeping this point in mind, Fig. 58E shows the waveform developed in the plate circuit of the pentode section of T16 and 58F shows the waveform developed in the plate circuit of the pentode section of T17. Since these two pentodes have a common load resistor, the outputs of the two tubes are mixed and the combined output has the form shown in Fig. 58G. This is the combined horizontal and vertical sync. It is inserted into the video signal by means of T18.

One section of T4 is a 26,460 cycle oscillator. The other section acts as a variable reactance across the oscillator tank so that the frequency of the oscillator can be controlled electronically. The AC voltage applied to the grid of the reactance tube lags the voltage developed across the oscillator tank coil by 90 degrees. Therefore, the plate current of the reactance tube lags the voltage developed across the tank circuit by 90 degrees. Therefore, the reactance tube acts as inductive reactance in parallel with the oscillator tank. The magnitude of this reactance is proportional to the plate current of the reactance tube. The plate current of the reactance tube is controlled by its bias. Therefore, the frequency of the oscillator can be varied by varying the bias on the reactance tube.

The bias applied to the reactance tube is -22 volts fixed bias, plus the drop across the 3 megohm resistor caused by the current of one section of T8 operating as a diode. The AC applied to the diode is supplied by the other section of T8 in parallel with one section of T5. The signal supplied by T5 is a part of the output of the 26,460 cycle oscillator. The signal applied by the triode section of T8 consists of sharp negative pulses with a frequency of 60 cycles produced by applying the vertical blanking through a very small time constant grid leak-grid condenser combination to the grid of the triode. There is one of these negative pulses for every 441 cycles of the 26,460 cycle signal. Fig. 59A shows the waveform of the blanking applied to the input circuit of the triode section of T8. Fig. 59B shows the waveform of the signal actually applied to the grid of this tube. The cutoff bias is indicated by the dotted line. As mentioned previously, this triode and one section of T5 have a common plate load. The waveform existing across this common plate load, due to the triode of T8, is shown in Fig. 59C. The waveform existing across the common plate load due to one section of T5 is shown in Fig. 59D. The combined waveform is shown in Fig.

59E. This waveform is applied to the diode section of T8. The cutoff voltage for the diode is shown by the dotted line in Fig. 59E. Only the signal below this line will cause the diode to conduct and charge the condenser connecting the diode plate to ground. The conducting range of the diode can be controlled by varying the negative DC voltage applied to its cathode.

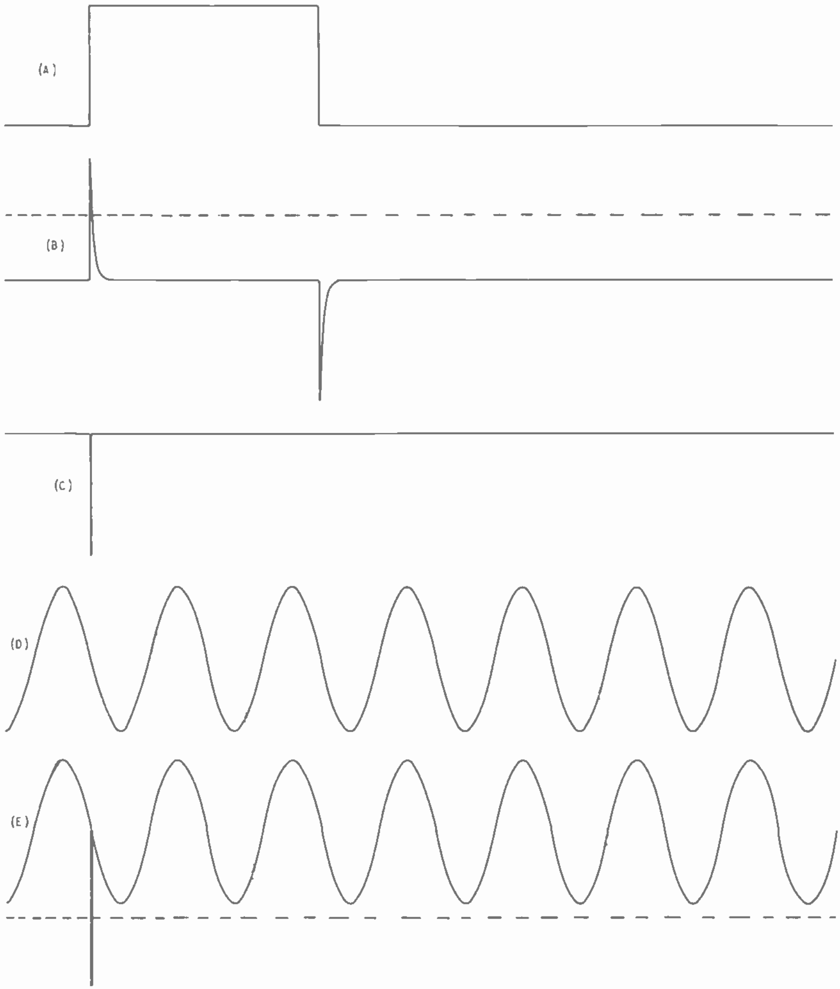


Fig.59 Formation of control signal for 26,460 oscillator.

Let us assume that when the 26,460 cycle oscillator is exactly on frequency, the waveform applied to the diode is that shown in Fig. 59E. There is a sharp pulse riding half way up the slope of every 441st cycle of the sine wave voltage applied

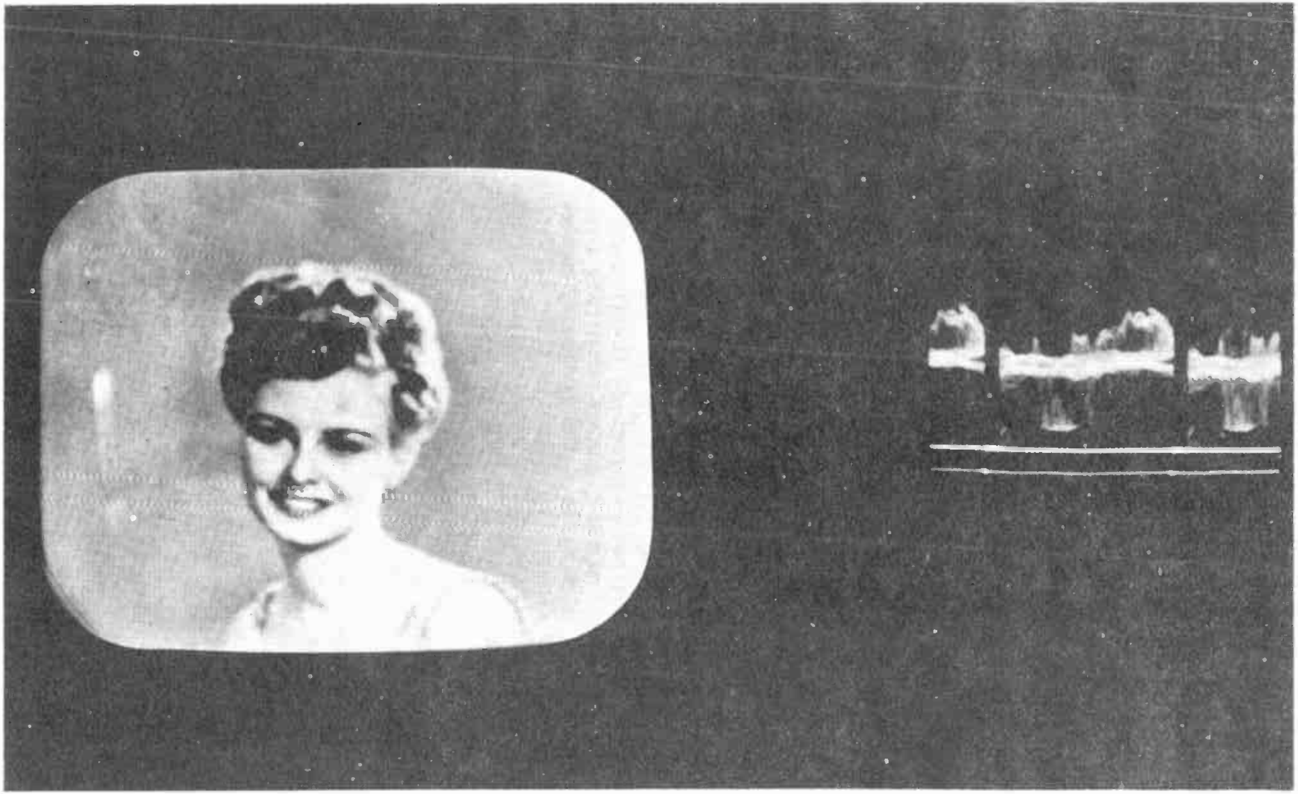


Fig.60 Photograph of television picture and oscilloscope pattern produced by Midland's picture signal generator.

to the diode. The section of the pulse below the dotted line is passed by the diode and charges the condenser in the plate circuit of the diode. This condenser discharges very slowly through the 3 megohm resistor and the bias supply for the reactance tube. This discharge current through the 3 megohm resistor applies an additional negative bias to the grid of the reactance tube. The time constant of the discharge circuit is sufficiently large that this additional bias is relatively constant over the interval of discharge. If the frequency of the oscillator tends to decrease, then the sharp pulse will tend to ride lower down on the slope of the sine wave. Less of it will be passed by the diode and the condenser in the diode plate circuit will not charge to as high a voltage as before. Therefore, the discharge current will be less, and the bias applied to the grid of the reactance tube will be changed in the positive direction. This means the reactance plate current will increase, and the inductive reactance coupled across the oscillator tank will decrease. This will result in a slightly higher oscillator frequency, and the increase will continue until the sharp pulses again ride half way up the slope of the sine wave. If the oscillator frequency tends to increase, the sharp pulse will ride higher on the slope of the sine wave, additional negative bias will be applied to the grid of the reactance tube and the frequency of the oscillator will be restored to the correct value.

The operation of this rather simple automatic frequency control circuit requires an oscillator with very low frequency drift, as the frequency control can restore the frequency to the correct value only if the frequency change occurring every 441 cycles is a small fraction of a cycle. The frequency control will not work if the frequency changes by a complete cycle during the interval between the application of the sharp negative pulses to the diode.

This picture signal generator is capable of producing a good picture when properly adjusted. This is shown in Fig. 60. This is a photograph taken of the picture reproduced on the control room monitor at Midland Television. On the right is seen the electrical waveform of two fields of the picture shown on the monitor oscilloscope.

The serviceman should not attempt the construction of a picture signal generator of this type until he is perfectly familiar with the contents of the lessons in the next unit on the equipment for generating a video signal. For satisfactory operation, the video amplifier must be well shielded from the circuits generating the blanking and synchronizing impulses. Also, the circuits generating the vertical pulses must be shielded from those producing the horizontal. All the controls are screw driver adjustments except the potentiometers in the plate and cathode circuits of T13. These control the amplitude of the output.

This lesson has listed the equipment that a good television serviceman should have to render first class service to his customers. Constructional details have been given for apparatus that is not available commercially at this time.

EXAMINATION QUESTIONS

INSTRUCTIONS. Before starting to answer these examination questions, you should have studied the lesson material at least three times. Be sure that you understand each question--then proceed to write the best answer you can. Make all answers complete and in detail. Print your name, address, and file number on each page and be neat in your work. Your paper must be easily legible; otherwise, it will be returned ungraded. Finish this examination before starting your study of the next lesson. However, send in at least three examinations at a time.

1. What are the design specifications for the vertical amplifier of an oscilloscope to be used for television servicing?

2. List several precautions which must be taken when measuring high voltages.

3. Diagram a simple slide-back vacuum tube voltmeter and explain how it is used to measure peak voltages.

4. Why is a 60 cycle square wave generator a useful piece of equipment?

5. Describe briefly the process of aligning an IF amplifier with a frequency modulated oscillator.

6. What are the characteristics of a good RF signal generator satisfactory for television servicing?

7. What is a heterodyne detector?

8. What is a crystal calibrator?

9. What is a picture signal generator?

10. Describe the construction and operation of the picture signal generator tube.

Notes

(These extra pages are provided for your use in taking special notes)

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POWER & LIGHT BUILDING, KANSAS CITY, MISSOURI

UNIT NO. 6

SERVICING TELEVISION VIDEO CIRCUITS AND POWER SUPPLIES

LESSON NO. 4

GIVE THOUGHT

to this possibility.

Television has many possibilities, some of which are so amazing that we hesitate to think of them. Yet, history has proved that man usually accomplishes what he sets out to do.

Let us imagine that scientists wish to obtain the intimate secrets of wild and native life in the jungle. They hide small portable but powerful television scanning and transmitting devices at strategic points. When animal or man comes within range of the tiny camera, transmission begins and the scientists peering at receivers witness events they could not otherwise see.

As part of our national defense program, the same type of equipment described above could be placed in remote places and transmit pictures of threatened enemy action. Or they could be placed in dangerous, advance positions and transmit pictures of military activities.

Impossible?

When you consider what man has already accomplished, the answer is no! Radio is doing many things today that were considered impossible a few years ago.

As a Midland Radio and Television student, you are studying a scientific subject possessing enormous possibilities. I safely predict that ten, even five years from now, new fields of opportunity, of which you have no conception today, will be opened to you.

PRINTED IN U.S.A.
JONESPRINTS
KANSAS CITY, MO.

Lesson Four

SERVICING VIDEO CIRCUITS & POWER SUPPLIES

"Common television receiver faults and their probable causers were described in a previous lesson of this unit. In another lesson, information was given concerning available commercial test equipment and easily constructed equipment suitable for television servicing.

"It is the purpose of this lesson and the remaining lessons in this unit, to utilize this equipment to locate the source of the television receiver defects."

1. ISOLATION OF THE DEFECTIVE SECTION OF THE RECEIVER. The location of a defect in a television receiver is simplified if the receiver is considered in terms of the main component circuits. These can be roughly classified as the antenna and transmission line, the RF and IF amplifiers, the second detector and video amplifier, the cathode ray tube and its associated power supply, and the synchronizing and deflection circuits. The source of many defects is so apparent that it is unnecessary to analyze the receiver section by section. However, many faults in the reproduced picture; such as loss of resolution, poor synchronization, transients, smears, and poor shading, can be caused by defects in one or more basic sections of the receiver.

The picture signal generator, in conjunction with a signal generator like the RCA Signalyst, provides a quick method of isolating the defective section of the receiver. The first step is to check the operation of the antenna and transmission line. The Signalyst is tuned to the picture carrier frequency of one of the television channels covered by the receiver and its output is modulated by the picture signal generator. The balanced output of the Signalyst is connected to the RF input of the receiver. If the reproduced picture is still unsatisfactory, the antenna and transmission line have been eliminated as the source of the trouble. If the picture is reproduced correctly, then the source of the unsatisfactory operation is in the antenna or its transmission line. The causes of unsatisfactory operation of the antenna and its transmission line have been adequately covered in the preceding lessons of this unit and therefore will not be considered here.

After the antenna has been eliminated, the next step is to localize the trouble in either the RF-IF section preceding the second detector or the video, sync, and deflection section following the second detector. The output of the picture signal generator is connected across the second detector load. The same polarity signal is used as that normally developed across the diode load. If the picture is reproduced correctly, the receiver trouble is in the RF-IF section of the receiver. If the picture is still unsatisfactory, the defect is in the section of the receiver following the second detector.

If the trouble has been localized in the receiver section following the second detector, inspection of the pattern reproduced on the cathode ray tube will further localize the trouble to either the video amplifier, cathode ray tube power supply, or to the sync and deflection circuits. Trouble-shooting through inspection of the pattern on the cathode ray tube screen has been completely covered in an earlier lesson of this unit.

This lesson covers the servicing of the video amplifier and the cathode ray tube circuits and the cathode ray tube power supply. The succeeding lessons in this unit cover the servicing of the sync and deflection circuits and the RF-IF amplifiers.

2. PRECAUTIONS IN HANDLING LARGE CATHODE RAY TUBES. Cathode ray tubes, especially the nine and twelve inch and larger tubes, must withstand an extremely large force on their surface caused by the atmospheric pressure. The force on the screen of a nine inch tube is approximately one-half ton. Occasionally a cathode ray tube collapses or "implodes" under this high pressure. For this reason, it is advisable to wear shatterproof goggles and heavy gloves when handling the larger cathode ray tubes. The rim of the cathode ray tube, the section around the screen area, must not be struck, scratched, or subjected to more than moderate pressure at any time. When the tube is not in the receiver, it should be stored in its packing or shipping case. If the glass near the rim is scratched, the scratch has a tendency to grow around the rim, the glass wall becomes weaker, and the tube is likely to implode. Some of the large cathode ray tubes are furnished with cardboard shields to protect the individual handling the tube from flying glass.

3. SERVICING THE TELEVISION RECEIVER POWER SUPPLIES. The power source for the DC voltages applied to the tubes in a television receiver is like that in any broadcast receiver except that it may be better filtered. For that reason, it is unnecessary to discuss the maintenance of such a power supply in this lesson. The high voltage power supply for the cathode ray tube has been discussed earlier in this unit. An amplification of this discussion is given here, as satisfactory operation of the high voltage power supply is important in determining picture quality.

The DC power supply for the cathode ray tube can be a danger to the careless or inexperienced serviceman. Information concerning the maximum current and the maximum condenser charge that the

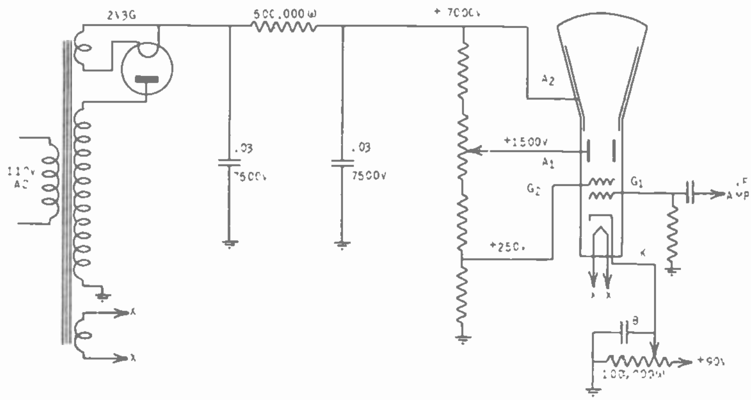


Fig.1 High voltage power supply. Negative side grounded.

body can tolerate safely is given in the appendix. Whenever checking voltages in the various circuits or when making adjustments on the receiver chassis, it is advisable to disconnect the

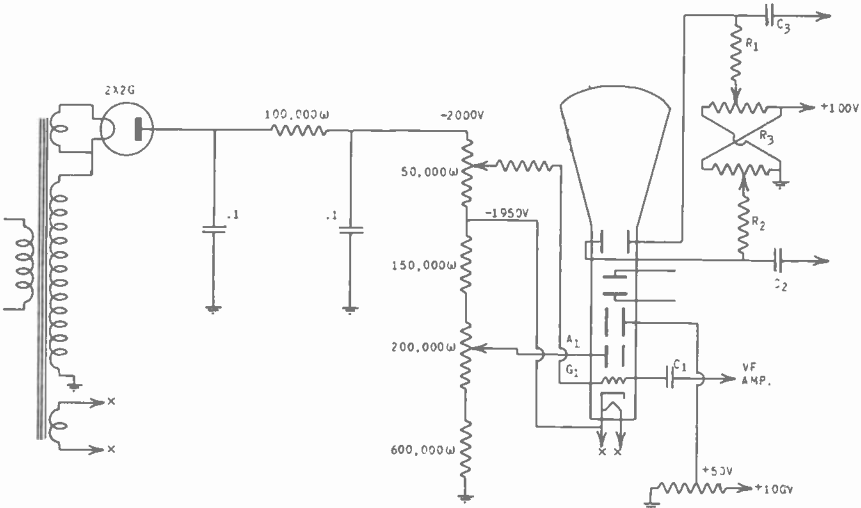


Fig.2 High voltage power supply. Positive side grounded.

primary of the high voltage transformer, and ground the output of the high voltage filter. When grounding a high voltage circuit, the grounding wire must be connected to the chassis or ground first. The serviceman should not touch the high voltage circuit until the grounded wire has been in contact with it for a second or two. This will prevent the filter condenser, if charged, from discharging through the serviceman.

Two types of high voltage power supplies are used in television receivers. In sets which use magnetic deflection of the cathode ray tube beam, the negative side of the high voltage power supply is grounded and the cathode of the cathode ray tube is operated at or near ground potential (See Fig. 1). The second anode is positive with respect to ground. In sets which use electrostatic deflection of the cathode ray tube beam, the positive terminal of the high voltage power supply is usually grounded and the cathode of the cathode ray tube is operated at a high negative potential with respect to ground (See Fig. 2). The second anode is operated at or near ground potential.

In a previous lesson in this unit on recognizing television receiver faults, most of the picture defects resulting from a defective high voltage power supply were described. These can be classified roughly into the following groups; complete failure (no screen illumination), pattern and background distortion caused by excessive ripple or hum voltage, erratic focus and pattern shape, and defocusing.

4. NO SCREEN ILLUMINATION. The lack of screen illumination (assuming that the cathode ray tube is in good operating condition) can be the result of broken leads between the power supply and cathode ray tube; defective power supply components, such as a shorted filter condenser, open high voltage transformer, open filter choke or resistor, a defective high voltage rectifier, no heater voltage for the cathode ray tube, open or grounded components in the bleeder network; or a defective bias source if the bias is obtained from a different power supply than the high voltage pack. In most receivers using magnetic deflection, the bias is obtained from a different power supply, usually a 90 volt tap on the power supply furnishing the plate voltage for the receiver tubes.

The best method of checking a defective high voltage power supply is to measure the resistance of the components and compare the measured resistance with the resistance values given by the manufacturer. Of course these measurements are made with the power off. It is also advisable to disconnect the receiver from the power line and thus prevent any possibility of the power being accidently turned on. The filter condensers must be discharged before attempting any resistance measurements. The high voltage filter condensers must be disconnected from the circuit in order to measure their leakage. An ohmmeter connected across a good filter condenser will indicate a low resistance when the meter is first connected across the condenser because of the surge of current from the ohmmeter battery into the condenser. When the con— denser is charged up to the battery voltage, the ohmmeter will show a very high or infinite resistance. The lack of an initial reading means in the case of a high capacity filter that the condenser is open. Filter condensers with resistances less than 40 to 50 megohms should be replaced. An ohmmeter capable of measuring resistances of the order of 100 megohms is almost a necessity in checking these power supplies. Any resistor or potentiometer whose measured resistance differs by more than 10% of the manufacturer's rating should be replaced.

A common cause of failure of the rectifier tubes used in these high voltage packs is the opening of the heater or filament. The tubes (2V3G and 878) used in the packs supplying 5000 to 7500 volts have tungsten filaments and there is no loss of emission during the life of the tube. The lower voltage rectifiers such as the 2X2-G have oxide coated filaments and can lose emission. Occasionally a rectifier becomes gassy. A gassy tube will show a blue glow between the filament and plate. A low emission rectifier can be checked either by means of a tube tester or by measuring the output voltage of the power supply under load.

The serviceman must be very careful when measuring the output voltage of these high voltage packs. He should never attach the voltmeter to the circuit when the power is on. When making a reading he should refrain from touching the voltmeter. If it becomes necessary to change the voltmeter range, the power must be turned off when making the change. If a voltmeter with an external multiplier is used, the multiplier should be placed between the hot side of the power supply and the meter. If the power pack has the negative side grounded, the multiplier must be placed in the positive side of the meter. If the power supply has the positive terminal grounded, the multiplier must be placed in the negative side of the meter. The voltmeter must have an internal impedance of at least 20,000 ohms per volt if accurate voltage readings are required. Voltmeters suitable for measuring the voltages produced by cathode ray tube power supplies were described in the lesson on television test equipment.

If the power supply and the bias supply for the cathode ray tube are normal, the loss of illumination may be due to a defective cathode ray tube. This condition can be easily checked either by plugging a tube known to be good into the receiver or by plugging the questionable tube into a receiver that is in perfect working order. The most probable causes of sudden failure of a cathode ray tube is a burned out heater or an air leak. The light emission falls off in cathode ray tubes after several thousand hours of service either through deterioration of the fluorescent screen or of the thermionic cathode. You are already familiar with the ion spot formed in the center of the screen during the life of the tube.

5. RIPPLE OR HUM IN POWER SUPPLY. The type of pattern distortion and the uneven background produced by excessive ripple or hum in the high voltage power supply have been described quite fully in the lesson recognizing television receiver faults. The AC component in the high voltage causes the second anode voltage to vary which, in turn, results in a variation of deflection sensitivity or beam stiffness. The resulting variation in the ampli-

tude of the horizontal deflection results in a pattern with sine wave instead of straight sides. The two bounding sine waves differ in phase by 180°. The variation of vertical deflection amplitude results in uneven spacing of the lines in the pattern or picture. The spacing is least where the pattern is narrowest. Ripple or hum in the high voltage pack can cause a dark horizontal bar across the pattern if the bias voltage is obtained from the high voltage supply (electrostatic deflected tubes). If the ripple voltage is high, this condition can exist in tubes using a separate bias supply.

The usual causes of excessive ripple or hum in the high voltage power supply are either an open filter condenser, a shorted choke or resistor (if resistance-capacity filters are used), or excessive load on the power supply. Excessive load is accompanied by a reduced output voltage. Excessive load will be especially effective in causing ripple or hum distortion if chokes are used in the filter, as these filter chokes maintain their rated inductance only when the current is normal.

6. INTERMITTENT PATTERN DISTORTION AND DEFOCUSING. The cause of intermittent pattern distortion and defocusing is sometimes difficult to find. The two sources are intermittent breakdowns to ground or intermittent opens in the high voltage circuit. Breakdowns between the wiring and socket terminals to ground can usually be found by observing the wiring in subdued light with the power on, for arcing to ground. The point of arcing can also be located by the noise radiated from the discharge.

Breakdowns inside components such as condensers, chokes, feed-through and standoff insulators, and transformers, can be located by disconnecting each suspected component and listening for the discharge. In using this method, it is essential to begin with the components at the output of the power supply and work back to the transformer. These internal breakdowns can also be located by observing the pattern on the cathode ray tube screen. The type of distortion caused by the defective component will disappear when that component is disconnected from the circuit. Of course, the removal of condensers or chokes from the filter system will introduce hum or ripple into the pattern but this distortion is constant and can be distinguished from the intermittent distortion. One cause for the apparent failure of the high voltage supply (positive terminal grounded) in a receiver using electrostatic deflection is the breakdown of the grid condenser coupling the grid of the cathode ray tube to the video amplifier (condenser C_1 in Fig. 2).

Intermittent opens in the high voltage circuit can usually be found by resistance measurements, since such opens are usually permanent when the power is off.

Breakdowns in sockets, terminal strips, and potentiometers can be located by the carbonization of the insulator along the path of the arc. Sometimes these can be eliminated by scraping the carbonized layer off the insulator and coating it with vaseline. However, it is best to replace the burned component.

Intermittent defocusing can occur in receivers using magnetic focusing of the cathode ray tube. This defocusing is probably caused by loose or intermittent connections in the focus coil or its power supply. This type of intermittent defocusing is not accompanied either by an audible or visible discharge, as the trouble is not in the high voltage power supply.

7. DEFOCUSED PATTERN. Maximum picture resolution is obtained when the cathode ray tube spot size is a minimum. Therefore, it is essential that the spot be in optimum focus. If the focus control has no effect on the sharpness of the lines there may be an open between the focus potentiometer and ground or the focus control may be defective. If the lines approach focus as the control is turned to its maximum or minimum position, the resistance values in the bleeder have changed so that the voltage across the focus potentiometer is no longer in the required focusing range for the tube. Excessive leakage from the focus supply voltage to ground can reduce the available voltage.

Lack of focus for tubes using magnetic focusing can be caused by an open focus coil, insufficient current through the focus coil caused by some defect in the low voltage power supply, or excessive ripple in the focus coil supply. In this latter case, the defocused areas will appear as horizontal bars instead of over the entire pattern.

In tubes using electrostatic deflection, defocusing results if the resistors connecting one or more of the deflecting plates back to the second anode are open (see R1 or R2 in Fig. 2). When this happens, the free deflecting plate accumulates a high negative charge and upsets the field around the second anode. You are already familiar with the change in focus as the beam is deflected away from the center of the screen in tubes which have one of each pair of deflecting plates tied to the second anode inside the tube. This same condition can exist if the DC spot shifting voltage applied to the plates of a pair becomes unbalanced through non-tracking of the spot shift dual control (see R3 in Fig. 2). This factor is not so important for the newer type tubes as they have been designed to minimize the effects of unbalanced DC potentials on the deflecting plates.

Occasionally a cathode ray tube becomes gassy. When this condition exists, the spot size is increased. Gas in a cathode ray tube shows up as a blue pencil through the electron gun. The electrons in the beam ionize the gas and the deionization radiates the blue glow.

A gassy tube can be detected in another way. Connect a microammeter in series with the grid. There will be a grid current flow in gassy tubes even when the grid is negative. This grid current increases as the grid is made more negative. The grid current is due to the collection of positive ions by the grid and naturally more ions are collected with a more negative grid. This grid current flows in the opposite direction to the grid current flow in normal tubes caused by a positive grid.

8. SERVICING THE VIDEO AMPLIFIER. Figs. 3 and 4 are circuit diagrams of the video amplifiers in two commercial television receivers. Each circuit includes all the components in the video chain from the second detector to the grid of the cathode ray tube. The pickoff points to the AVC and sync circuits are shown. Also, the DC restoration circuits are given in both cases. Fig. 3, which is an RCA circuit, has one video stage. Fig. 4, which is a General Electric circuit, has two video stages. Several methods are used in the two circuits to obtain uniform gain over a wide frequency range. You are familiar with the design formulas for shunt peaking, which is used in the plate circuit of the 6F6 in Fig. 4. Some of the other methods are described in later lessons. However, for servicing, it is not necessary to know the design formulas used by the manufacturer in obtaining uniform gain over a wide frequency range.

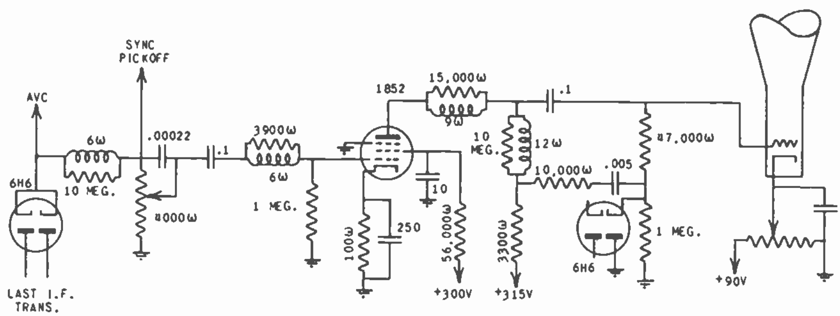


Fig.3 Video amplifier circuit used in some R.C.A. television receivers.

A good video amplifier must have uniform gain over a range of 30 cycles to 2.5 megacycles for receivers with five inch cathode ray tubes, and to 4 megacycles for receivers with nine inch or larger cathode ray tubes. This is the overall characteristic from the diode to the grid of the cathode ray tube. The effect on the picture, caused by deviations from this ideal characteristic, was given in the lesson on recognizing television receiver faults.

The first step in the servicing of the video amplifier is to check all the tubes and all the DC voltages. The correct voltages are given in the service information for the receiver. If all the voltages are low, the probable source of the trouble is a bad rectifier, a leaky filter condenser, or a defective power transformer in the low voltage power supply. There are many other sources of such a condition as the reader has learned from his study of radio. When the condition is localized in one amplifier stage, it can be due to a tube with shorted elements (which should have been discovered during the tube check), shorted screen bypass condenser, shorted plate decoupling condenser, a lack of grid bias, etc. The usual causes for the no-bias condition are well known to the reader and need not be repeated here.

The operation of the video amplifier can also be checked by observing the waveform developed in each part of the circuit from the diode load to the grid of the cathode ray tube. The test signal is supplied by the picture signal generator connected across the diode load. The operation of the second detector can be checked by a picture modulated IF signal applied to some point in the IF amplifier. The defective VF stage will either have no output or will have an output waveform which differs widely from the input.

Defective second detector circuits are most easily analyzed by measuring the magnitudes of the components and comparing the measured values with the values given in service data. The circuit should be checked for opens or grounds.

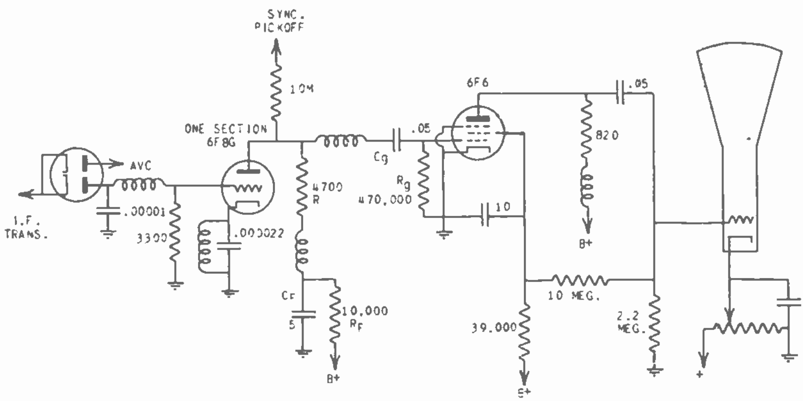


Fig.4 Video amplifier circuit used in some General Electric television receivers.

The next step is to check the gain of the amplifier against gain calculated from the circuit constants and tubes. Comparing the actual gain of the amplifier to the correct gain helps in determining the cause of an unsatisfactory amplifier frequency characteristic as shown later. The gain of a video amplifier stage for intermediate frequencies is given by the expression GmR, where Gm is the transconductance of the amplifier tube in mhos and R is the load resistance in ohms. This formula was given in an earlier television lesson on receiver video amplifiers. The transconductance for each tube is given in tube manuals. The magnitude of the load resistors is given in the service data for the receiver.

The one stage video amplifier in Fig. 3 uses an 1852 (6AC7) which has a transconductance of 9000 micromhos. The load resistor has a value of 3300 ohms. Therefore, the gain of the video amplifier is:

$$9000 \times 10^{-6} \times 3300 = 29.7$$

The actual gain of the video amplifier can be measured by any of the well known ways. The simplest is to apply a 5000 to 10,000 cycle one volt signal to the grid and measure the output developed across the plate load of the output tube with either an output meter or a vacuum tube voltmeter. The test signal frequency should be in the range given, as the gain at these frequencies is independent of most of the factors which affect the gain at either the very low or very high frequencies.

9. HUM OR RIPPLE IN THE VIDEO AMPLIFIER. Excessive ripple or hum in the picture can be caused by defects either in the high voltage power supply or in the video amplifier. If the hum is in whole or part due to a defective video amplifier, grounding the grid of the cathode ray tube will eliminate the hum completely or reduce it. If the grid potential of the cathode ray tube is several thousand volts below ground, the plate of the output video amplifier can be grounded by using a 20 to 40 mfd. electrolytic condenser.

Sixty cycle ripple or hum in the picture can be caused by a defective tube (cathode shorted to heater), excessive cathode-heater leakage in a tube, open grid circuit, or misplaced wiring. Heater-cathode leakage in the DC restoring diode (see Fig. 3) can also introduce 60 cycle ripple. An open grid condenser or an open grid leak in the earlier stages of an amplifier can cause excessive ripple. An open amplitude or contrast control can cause trouble (see Fig. 3). Hum can be introduced into the grid circuit of an amplifier by its close proximity to the heater wiring or other wiring carrying 60 cycles.

One hundred and twenty cycle ripple is usually the result of an open screen bypass, an open plate decoupling condenser, or insufficient filtering in the low voltage power supply.

10. CHECKING LOW FREQUENCY RESPONSE. Unsatisfactory low frequency characteristics in the video amplifier show up in the picture as uneven shading from top to bottom and by the presence of vertical return lines in the picture. If the gain is peaked in the low frequencies the average picture level increases in brightness toward the bottom of the picture. If the gain is deficient for the low frequencies the average picture level decreases toward the bottom. Excessive or deficient low frequency gain is always accompanied by phase shift between the component frequencies and most of the uneven shading is due to the phase shift.

The simplest and perhaps the most satisfactory method to check the low frequency characteristics of an amplifier is to apply a 60 cycle square wave to the input and observe the output waveform with an oscilloscope. If an amplifier is able to transmit a 60 cycle square wave faithfully, its low frequency characteristics are satisfactory for the transmission and amplification of a television picture. The peak-to-peak amplitude of the square wave input should be sufficiently low that none of the amplifier stages are overloaded. This condition will exist if the output is limited to five or ten volts peak-to-peak.

Fig. 5A shows two cycles of a 60 cycle square wave as gen-

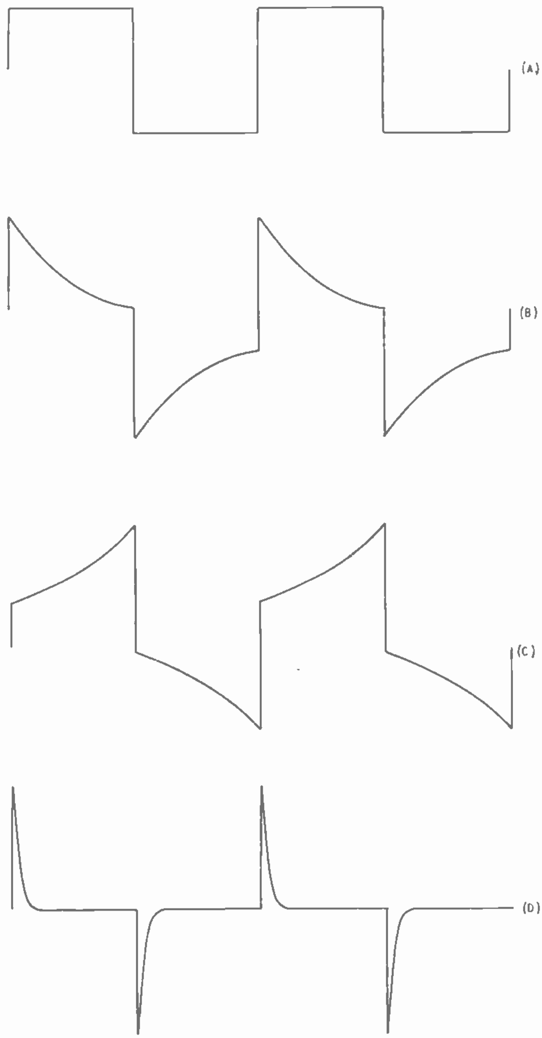


Fig.5 Distortion of a 60 cycle square wave caused by amplifiers with unsatisfactory low frequency characteristics.

erated by one of the square wave generators described in the lesson on television test equipment. A video amplifier that has satisfactory low frequency characteristics will transmit such a waveform with little or no distortion and the output waveform when viewed on an oscilloscope will also be like Fig. 5A. An amplifier that is deficient in gain over the range of frequencies from 30 to 150 cycles will distort a 60 cycle square wave and the output waveform will be like that in Fig. 5B. An amplifier that has excess gain over this range of frequencies will have an output waveform like that in Fig. 5C. The distortion shown in Figs. 5B, 5C, and 5D, is actually due to a combination of two effects; poor gain and poor phase characteristics at low frequencies. Fig. 5D shows the distortion of a 60 cycle square wave when the amplifier does not pass the intermediate audio frequencies as well as the very low frequencies. A complete discussion of gain and phase characteristics of amplifiers is given in a later television lesson on circuits used in the amplification of the camera signal.

The reader is aware of the factors which affect the low frequency response of a video amplifier. These are the time constant of the grid condenser and grid leak in the grid circuit of an amplifier and the time constant of the cathode bias resistor and its bypass, when cathode bias is used. The reader knows that the time constant of the grid condenser-grid leak combination must be at least ten times the period of one cycle of the lowest frequency square wave that must be passed by the amplifier without distortion. It isn't always feasible or advisable, as the reader knows, to use grid circuit time constants as large as required. Smaller grid circuit time constants are used and the drooping low frequency characteristic is overcome by an opposite rising low frequency characteristic obtained by the proper apportioning of the constants of the plate filter in the plate circuit of the stage preceding the low time constant grid circuit or in the plate circuit of the stage having the low grid circuit time constant. If fixed bias is used, the relation existing between the plate and grid circuit time constants is given by the expression:

$$RC_F = R_G C_G$$

provided R_F is at least ten times the reactance of C_F for the lowest frequency to be amplified by the amplifier without loss in gain and with satisfactory phase relations. This set of conditions exist in the plate and grid circuit time constants coupling the first and second video stages in Fig. 4. Any factor which upsets this set of conditions will destroy the satisfactory low frequency gain and phase characteristics of the amplifier stage.

When a bypassed cathode resistor is used for bias, the reactance of the bypass condenser should not exceed one-tenth of the magnitude of the cathode resistor at the lowest frequency to be amplified with satisfactory phase and gain characteristics. If the cathode bypass is too small the output waveform for an input square wave will be like that of Fig. 5B. The reader knows that cathode degeneration at low frequencies can be overcome by making the time constant of the plate decoupling resistor and its bypass condenser equal to the time constant of the cathode circuit. Also, the total reactance of the decoupling resistor and its bypass condenser must be selected so that the increase in the plate load at the low frequencies will overcome the loss in gain caused by cathode degeneration. Again, any factor which upsets compensation existing between the plate and cathode circuits will produce unsatisfactory low frequency characteristics.

The video amplifier shown in Fig. 3 has cathode bias, but the cathode bypass is sufficiently large that there is no degeneration over the range of frequencies required to pass a 60 cycle square wave. Also, the grid circuit time constants in Fig. 3 are sufficiently large to pass a 60 cycle square wave without distortion. Therefore, no compensating circuits are required in the plate circuit of the amplifier stage to produce satisfactory low frequency characteristics.

The first step in checking an amplifier that has unsatisfactory low frequency characteristics is to measure the resistance of all the components and compare the measured values with the values given on the service data. Any that deviate more than ten percent from the correct values should be replaced. Then the values of the grid condensers, cathode condensers, and plate decoupling condensers should be checked on a capacitance bridge. All units with a capacity different from the correct capacity as given by the service data should be replaced. When these changes have been made, the low frequency characteristics of the amplifier will be restored so that a 60 cycle square wave can be amplified without distortion.

Distortion like that shown in Fig. 5B can be caused by insufficient cathode bypassing, shorted plate decoupling resistor (R_F in Fig. 4), an open screen bypass, low resistance grid leak, low capacity coupling condenser, too high resistance plate load. Distortion like that shown in Fig. 5C can be caused by an open plate decoupling condenser (C_F in Fig. 4), too low resistance plate load, too high resistance grid leak, or a too high capacity grid condenser.

Distortion like that shown in Fig. 5B can also be caused by a gassy tube or a tube that has excessive grid emission. The input resistance of such tubes is low because of the flow of grid current. Since the input resistance is in parallel with the grid leak, the effective value of the grid leak is reduced.

Fig. 5D shows the distortion of a 60 cycle square wave when the amplifier doesn't pass frequencies below several hundred cycles. Such distortion is usually the result of an open grid condenser, an open grid circuit, or a resin joint in the grid circuit.

11. CHECKING THE INTERMEDIATE FREQUENCY RESPONSE. When a video amplifier does not amplify the very low frequencies and the frequencies up to several thousand cycles, the picture has a smeary appearance as described in the lesson on recognizing television receiver faults. Black and white areas shade into the background horizontally and are followed by a smear of the opposite shade.

An amplifier in this condition will distort a 13,000 cycle square wave in the same way as an amplifier deficient at the very low frequencies distorts a 60 cycle square wave. If the 60 cycle square wave has very steep sides (contains high frequency components) it may appear in the output of the amplifier in the form shown in Fig. 6B; a series of sharp positive and negative pulses.

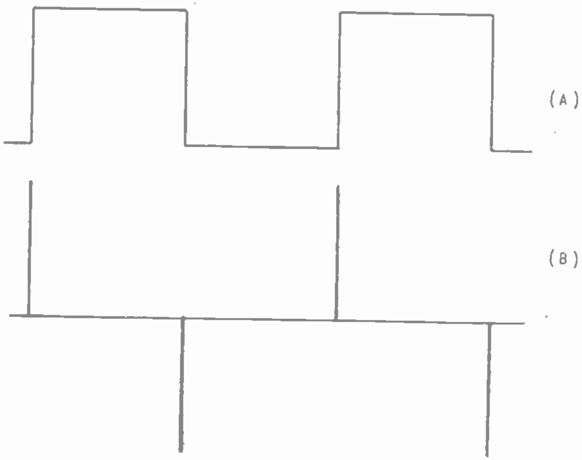


Fig.6 Distortion of a 60 cycle square wave caused by amplifiers with unsatisfactory intermediate frequency characteristics.

One way to check the frequency characteristic of an amplifier in this condition is to measure the gain for the frequencies in the range covered by the video band. The serviceman can also check the amplifier response over this range by observing the distortion of the horizontal blanking impulses from the picture signal generator. The output of the picture signal generator is connected across the diode load and the oscilloscope is connected across the grid circuit of the cathode ray tube. The linear horizontal frequency is adjusted so that three or four lines of the picture appear on the screen. The trace on the oscilloscope will be similar to that shown in Fig. 7. The defective stage can be isolated by checking the transmission capabilities of the amplifier stage by stage.

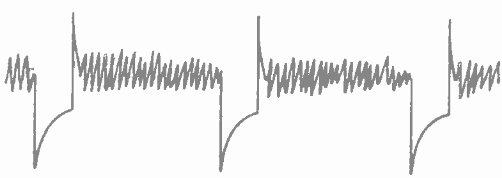


Fig.7 Distortion of picture signal caused by poor intermediate frequency characteristics.

The usual cause of this condition is an open circuit between the grid and plate circuits of two succeeding stages. The open circuit can be due to a defective coupling condenser, a resin joint, or an actual open circuit.

12. CHECKING THE HIGH FREQUENCY RESPONSE. The effects on the picture of an unsatisfactory high frequency response in a video amplifier were described in the lesson on recognizing television receiver faults. When the high frequencies are lacking, the resolution is reduced and vertical boundaries between shaded areas are not distinct. The fine detail in the picture is entirely lost. When the amplifier has a sharp peak or dip in the high frequency range, transients are generated whenever there is an abrupt change from black to white or from white to black.

Earlier in the lesson, it was stated that knowledge of the actual gain of a video amplifier as compared to the calculated gain was an aid in determining the cause of an unsatisfactory high frequency characteristic. Higher gain than normal may accompany a drooping high frequency characteristic. Lower gain than normal usually accompanies a sharp rise in the high frequency characteristic. These conditions will be true provided that the change in gain is not due to defective tubes or incorrect voltages on the tubes. It is assumed here, however, that these last two factors were previously checked and required changes or adjustments made.

If a careful resistance measurement has been made and all the components with a resistance different than the value given in the service data replaced, it is very probable that the cause of the unsatisfactory high frequency response has been removed. The resistances of the load resistors and the peaking coils should agree very closely with the design values. If the resistance of the peaking coils are not given, it is advisable to substitute new coils for those in the defective stage.

A drooping high frequency characteristic is usually caused by a load resistor higher than the correct value, defective peaking coil (shorted turns), or excess wiring capacity caused by misplaced wiring. A sharp rise in the high frequency characteristic is usually caused by a load resistor that is too low. An exceedingly low resistance grid leak can cause a rising high frequency characteristic as it is effectively in parallel with the plate load. About the only cause of a grid leak decreasing in resistance is an excessive current flow caused by a shorted coupling condenser. Similarly, the resistance of a plate load resistor can be reduced through excessive current caused by shorted tube elements.

If a careful resistance check does not locate the trouble, it is sometimes a good policy to run a frequency-versus-gain curve on the amplifier. This is done by applying a known voltage to the input of the amplifier and measuring the output voltage with a vacuum tube voltmeter. This can be done quite readily with the Signalyst and one of the vacuum tube voltmeters described in the lesson on service equipment. The Signalyst has a self contained vacuum tube voltmeter and thus the output voltage can be set to any value within the range of the attenuator. In order not to increase the capacity across the output of the video amplifier through the addition of the vacuum tube voltmeter, a degenerative coupling circuit of the type described in the lesson on test equipment must be used between the vacuum tube voltmeter and the output of the amplifier. The gain should be measured about every .5 megacycle from .1 megacycle to the top frequency that the amplifier is designed to amplify. The top frequency is usually four megacycles for receivers with nine inch cathode ray tubes or larger and 2.5 megacycles for the receivers with the smaller tubes.

If the amplifier has more than one stage, each stage should be checked separately by beginning with the last stage first. When the run on the last stage is complete, the signal generator is transferred to the input of the preceding stage and the run repeated. The vacuum tube voltmeter remains on the output of the last stage. A blocking condenser of about .1 mfd. should be used between the signal generator and the amplifier to protect the signal generator output circuits from damage through accidental application of the amplifier plate voltage.

When checking amplifier response curves by this method, it is advisable to use as small an input signal that will give an output of two or three volts RMS. Vacuum tube voltmeters are peak reading instruments and waveform distortion caused by nonlinearity in the amplifier will give readings which yield a response curve different from the actual curve.

When the offending stage has been located, check the wiring to see that conditions favoring regeneration do not exist. Check the grounds on the tube shells and actually measure the resistance between the tube shell and ground. Sometimes the connection between the grounding pin and the shell is not sufficiently low in resistance to maintain the tube shell at ground potential. The serviceman from his past experience can probably think of other trouble sources.

13. CHECKING THE DC RESTORING CIRCUIT. The purpose of the DC restoring circuit or automatic background control is to vary the bias on the grid of the cathode ray tube so that all the pulses just swing the grid of the tube to cutoff. You are familiar with the mode of operation of these circuits. If a diode is used as in Fig. 3, the coupling condenser to the diode is charged during the blanking interval through the diode to a voltage that is proportional to the blanking amplitude and discharges during the picture signal interval through the cathode ray tube grid leak. This discharge current changes the bias in the positive direction proportionally to the average light level in the picture.

In Fig. 4, the grid return of the cathode ray tube is connected to the screen of the last video amplifier. The last video amplifier depends on grid leak bias, and this bias is proportional to the average picture level (leveling). This causes a screen current variation and therefore a screen voltage variation that is proportional to the average light level. Thus, the grid voltage on the cathode ray tube is varied in proportion to the average light level.

The DC restoring circuit may fail completely or become sluggish in operation. The trouble can be usually located by measuring the magnitude of the condensers and resistors in the circuit and comparing them with the design values given in the service data. The diode should be checked on a tube tester. A defective coupling condenser to the DC restoring circuit will prevent its correct operation and the excess positive bias on the cathode ray tube will destroy focus and contrast.

In this lesson the most likely troubles that can develop in the video and cathode ray tube circuit section of a television receiver have been discussed. The serviceman will encounter others which will be characteristic of one receiver model. Through experience, the serviceman will be able to solve such problems as they arise.

EXAMINATION QUESTIONS

INSTRUCTIONS. Before starting to answer these examination questions, you should have studied the lesson material at least three times. Be sure that you understand each question--then proceed to write the best answer you can. Make all answers complete and in detail. Print your name, address, and file number on each page and be neat in your work. Your paper must be easily legible; otherwise, it will be returned ungraded. Finish this examination before starting your study of the next lesson. However, send in at least three examinations at a time.

1. What is a quick and simple method of isolating the defective section of a television receiver?

2. Why must cathode ray tubes be handled carefully?

3. State four possible causes for the lack of cathode ray tube screen illumination.

4. State several precautions which must be observed when measuring the voltage developed by the high voltage power supply.

5. What are the causes of excessive ripple or hum in the high voltage power supply?

6. What are the usual causes of intermittent pattern distortion and defocusing?

7. How can an oscilloscope be used to check the operation of a video amplifier?

8. What is the simplest method to check the low frequency characteristics of a video amplifier?

9. What is the usual cause for lack of gain in the intermediate frequency range?

10. What are the usual causes of a drooping high frequency characteristic?

APPENDIX

The current that the human body can safely pass depends on the frequency. Frequencies from 50 to 150 cycles are the most dangerous. Direct current has about the same effect on the body as an alternating current of 350 cycles. The amount of current that the body will conduct safely increases with the frequency. The maximum current that can be tolerated without discomfort for considerable periods, ranges from 8 ma. at 60 cycles to 3 amperes at 1,000,000 cycles. Sixty cycle currents exceeding 75 ma. and DC currents exceeding 150 ma. are dangerous.

The resistance of the human body depends on the skin resistance and ranges from 5000 to 100,000 ohms. The actual resistance is a function of the area and condition of the skin in contact with the current source. The average resistance is around 30,000 ohms.

Direct current usually kicks the individual away from the source, while 60 cycle current causes the victim to cling tighter to the source. Prolonged current flow causes the body resistance to decrease, due to the reduction of the skin resistance.

The human body can tolerate the discharge current from a condenser when the energy stored in the condenser does not exceed 1 joule. In the tables below are given the energies stored in various capacity condensers when charged to several different voltages. Also, the capacities which, when charged to the specified voltages, have 1 joule.

TABLE 1

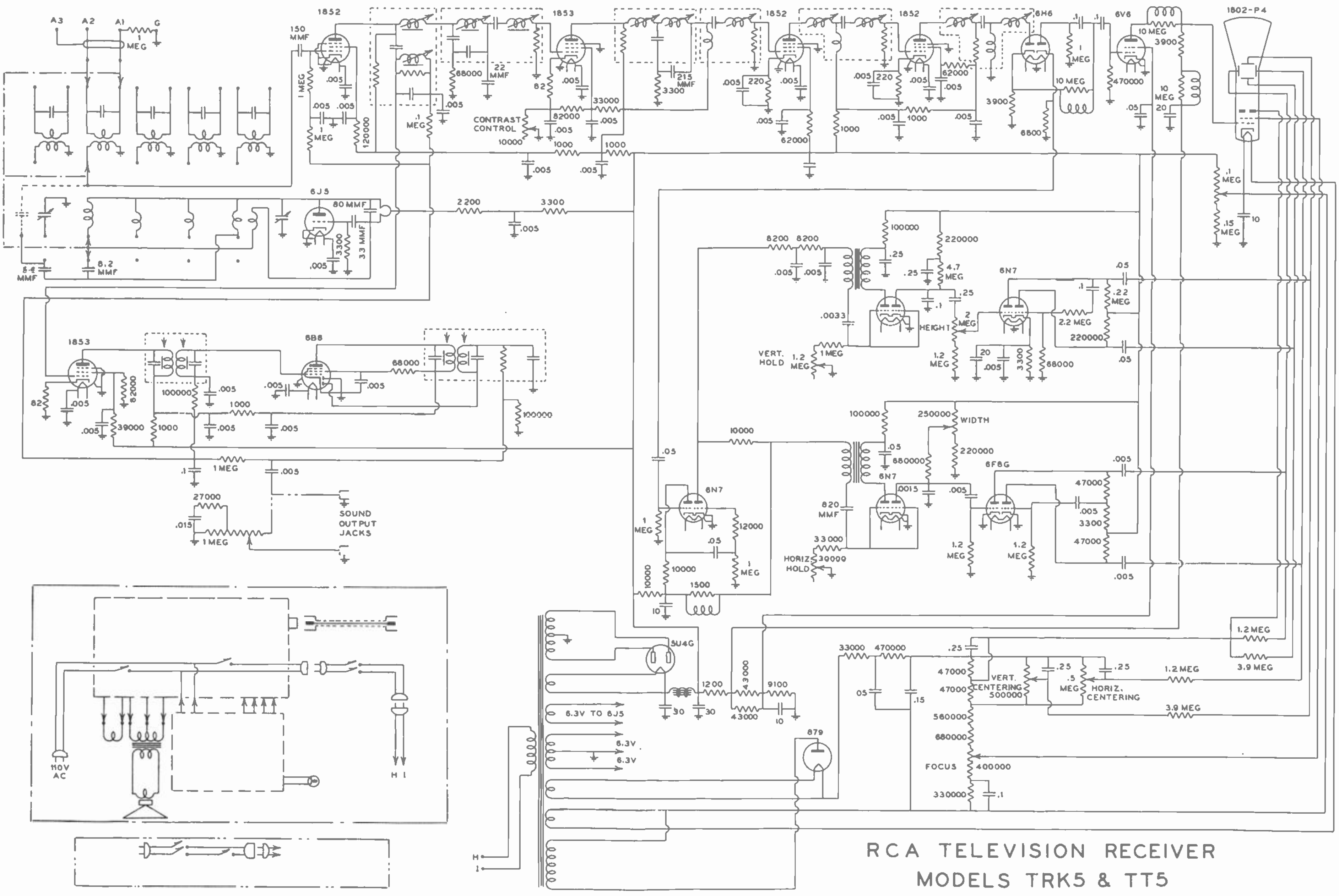
CAPACITY	JOULES AT 1000V	JOULES AT 2000V	JOULES AT 5000V	JOULES AT 10,000V
0.01 mfd.	0.005	0.020	0.125	0.50
0.03 "	0.015	0.060	0.375	1.50
0.05 "	0.025	0.100	0.625	2.50
0.10 "	0.050	0.200	1.250	5.00
0.25 "	0.125	0.500	3.125	12.50
0.50 "	0.250	1.00	6.25	25.00
1.00 "	0.500	2.00	12.50	50.00
2.00 "	1.00	4.00	25.00	100.00
4.00 "	2.00	8.00	50.00	200.00
8.00 "	4.00	16.00	100.00	400.00

TABLE 2

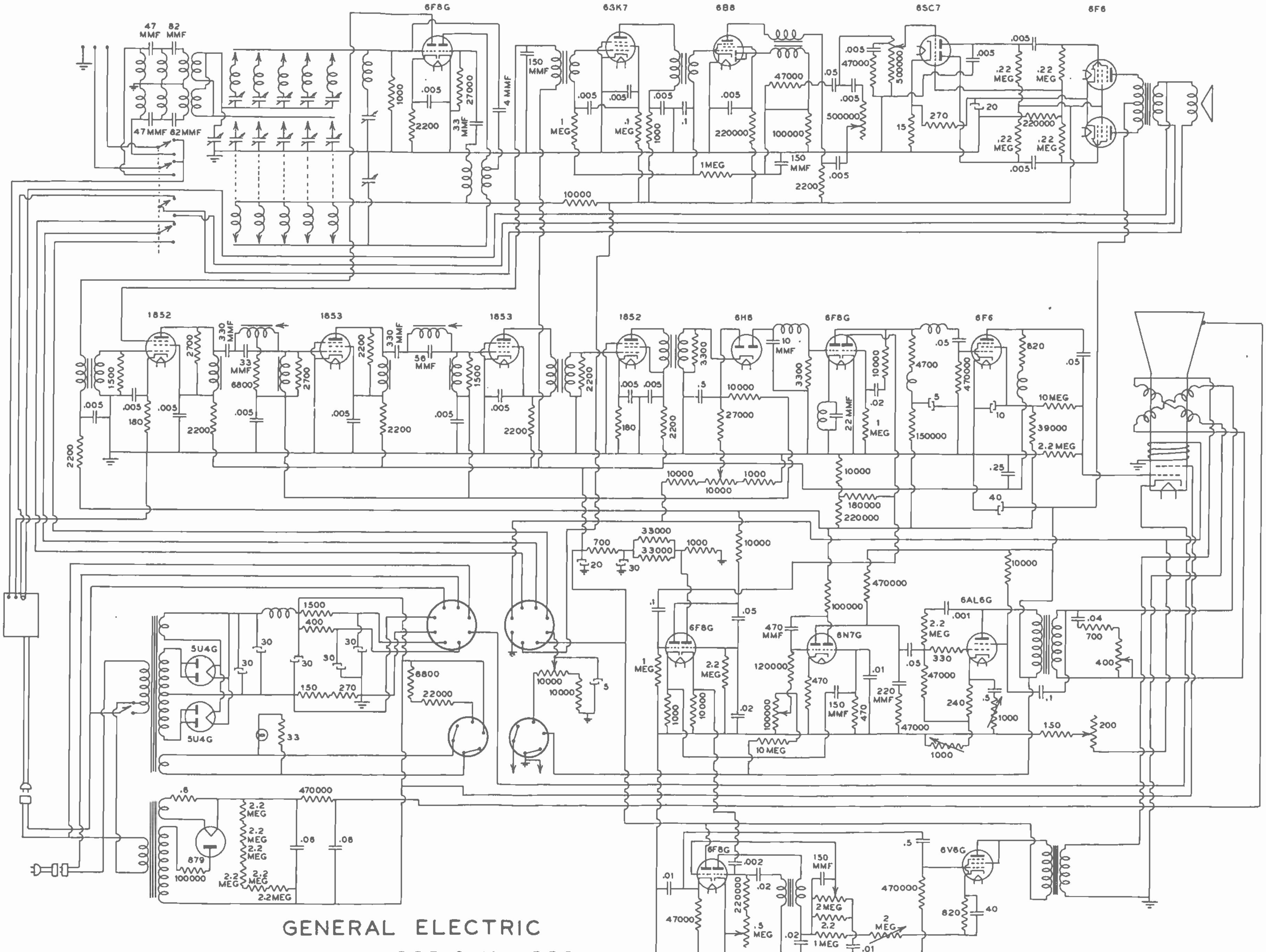
CAPACITY YIELDING 1 JOULE AT VARIOUS VOLTAGES			
1000v	2000v	5000v	10,000v
2 mfd.	0.5 mfd.	0.08mfd.	0.02 mfd.

Notes

(These extra pages are provided for your use in taking special notes)



RCA TELEVISION RECEIVER
MODELS TRK5 & TT5



GENERAL ELECTRIC

MODELS HM-225 & HM-226-7A

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UNIT NO. 6

SERVICING SYNCHRONIZING AND DEFLECTION CIRCUITS

LESSON NO. 5

A GRADUATE

always remains a student.

A short time before this lesson was prepared, a letter addressed to the staff and student body, was received from one of our Graduates who had been employed for more than eighteen months. He knows his work well; is considered efficient by his employers, while the various subjects he studied at Midland have become 'second nature' to him.

Yet that Graduate signed his letter: 'Your Brother Student'.

The letter was read to our student body during an assembly in Edison Hall. It contained words of advice and praise... words of encouragement from a Graduate who knew. When the close was reached, many of the students could not understand why a Graduate, who had been on the job for so long, should sign himself as: 'Your Brother Student'. Here is the explanation we gave them:

Although the student in question is a graduate, he was alert to the changing conditions in the world in which he lived. He realized that, as industries progress, those who are employed in them must also progress. Consequently, he still considered himself a student, because he was continuing to study and adapt himself to the requirements of his employers.

The writer of that letter should go far; and, Mr. Student, when you are a Graduate and employed, it would show excellent judgment on your part to follow in his path. Knowledge is the foundation of civilization. Get all you can, for no man can possess too much of this golden treasure.

PRINTED IN U.S.A.
JONES PRINTS
KANSAS CITY, MO.

Lesson Five

SERVICING SYNCHRONIZING & DEFLECTION CIRCUITS

"This lesson is devoted to a discussion of the faults which may arise in the synchronizing and deflection circuits of television receivers. The effect on the picture of faults in these circuits was described in a previous lesson.

"Therefore, it is essential that the prospective television serviceman study carefully the material that follows."

1. TYPICAL DEFLECTION CIRCUITS. There are only two methods used in television receivers for deflecting the electron beam in the cathode ray tube and these are electrostatic deflection and magnetic deflection. However, there are several circuits used to generate the sawtooth voltage wave. Most of these have been discussed in lessons in the preceding unit. Figs. 1 through 5 show the deflection and sync circuits for several commercial television receivers. Figs. 1 and 3 show magnetic deflection circuits. Figs. 2, 4, and 5 show electrostatic deflection circuits. Blocking tube oscillators in conjunction with a discharge tube are used to generate the sawtooth voltage wave in Figs. 1 and 2. In Fig. 3 the vertical deflecting circuit is driven by a blocking tube oscillator. However, in this circuit one tube serves as both the blocking tube oscillator and discharge tube. The horizontal sawtooth is generated by a multivibrator of the Potter type. In Fig. 4, multivibrators of the Potter type are used to drive both the horizontal and vertical deflection circuit. In Fig. 5, blocking tube oscillators of the type used for the vertical deflection in Fig. 3 are used to drive both the horizontal and vertical deflection circuits. However, in this case the oscillation transformers are equipped with a third winding for applying the synchronizing to the oscillators.

All the deflection circuits, except those in Fig. 3 are equipped with spot shifts. The circuits in Fig. 3 are from a receiver using magnetic focusing of the cathode ray tube. The pattern is centered on the cathode ray tube by the proper alignment of the focusing coil.

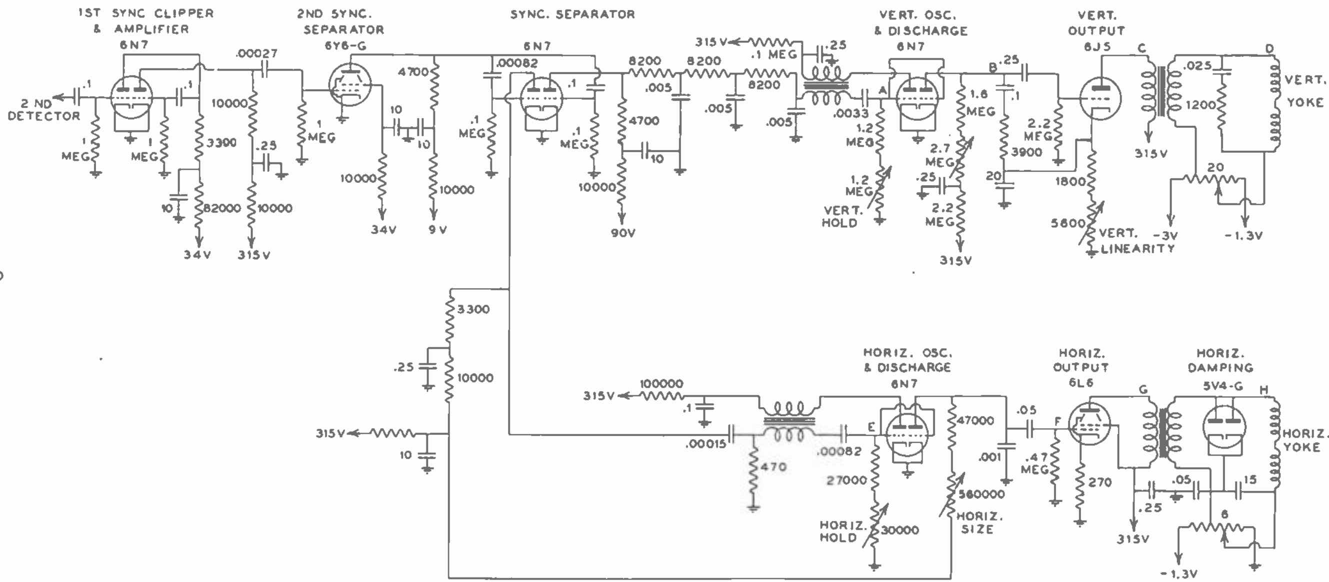


Fig.1 Sync circuits and magnetic deflection circuits for RCA Television Receiver TRK-9.

All the electrostatic deflection circuits have phase inverters so that the electrostatic deflecting field is balanced with respect to the second anode voltage. In Figs. 2 and 4, a resistance attenuator is used to feed the phase inverter with the correct amplitude signal. In Fig. 5 a capacity attenuator is used. In Fig. 5 the plate supply voltage for the push-pull stages driving the deflecting plates is 1500 volts. This is necessary for two reasons. One, the 14 inch cathode ray tube requires a high peak-to-peak sawtooth for adequate deflection of the beam. Two, the output of the sawtooth oscillator is used direct to supply one-half of the peak-to-peak voltage applied to each pair of the deflecting plates, and a high plate supply voltage is necessary to produce a sawtooth of adequate linearity.

Several methods of amplitude control are illustrated in the deflection circuits shown in Figs. 1 through 5. In Figs. 1 and 5, amplitude control is obtained by varying the charging time of the condenser that is charged and discharged periodically to form the sawtooth. Reducing the charging time constant by decreasing the resistance in the charging path increases the amplitude of the sawtooth developed across the condenser. Conversely, the amplitude of the sawtooth can be reduced by increasing the resistance in the charging path. The linearity of the sawtooth is affected by varying the amplitude in this way, and therefore the linearity control must be adjusted each time the amplitude control is changed. In Fig. 2 the vertical amplitude is controlled by varying the input to the vertical amplifier. The horizontal amplitude is controlled by varying the magnitude of the charging voltage for the condenser in the sawtooth circuit. In Fig. 3 the vertical amplitude is controlled by the same method used in Figs. 1 and 5. The horizontal amplitude is controlled by varying the amount of cathode degeneration for the output amplifier. Since the linearity of the output stage is affected by the amount of degeneration, resetting the amplitude control requires a compensating adjustment of the linearity control. In Fig. 4 the horizontal amplitude is controlled by the method used in Fig. 2. The vertical amplitude is controlled by varying the input to the vertical amplifier.

2. SERVICING THE DEFLECTION CIRCUITS. The first step in servicing the deflecting circuits of a receiver is to check all the tubes even though the apparent source of the trouble is not tube failure. This is advisable to insure optimum operation of the deflection circuits. All weak tubes should be replaced. In many receivers, 6L6's are used in the horizontal output. Ordinary 6L6's are not designed to withstand the high voltages generated during the horizontal return time. This voltage is developed across the primary of the transformer coupling the tube to the yoke. RCA 6L6's designed for deflection circuit applications can be identified by the flange sealing the envelope to the base as shown in Fig. 6. The flange in the special 6L6 has three rings or sections instead of two as in the ordinary 6L6.

The second step in servicing the deflection circuits is to check all the voltages at the tube socket with the circuit oper-

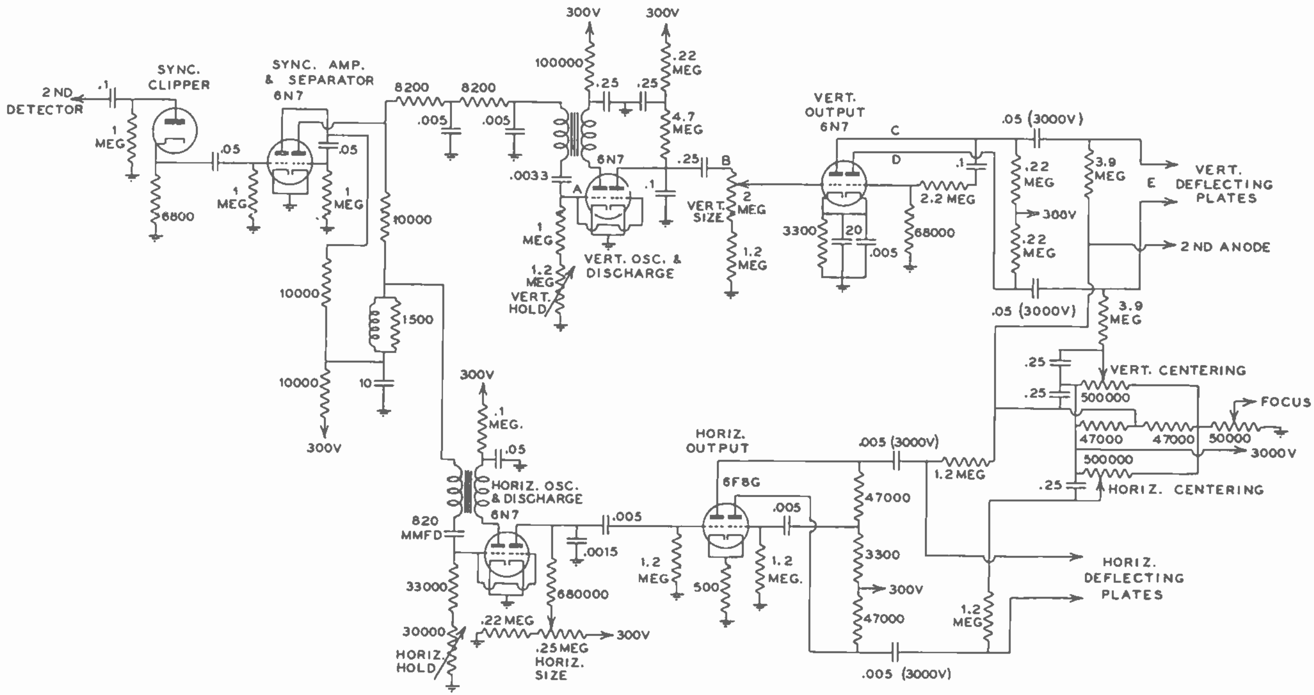


Fig.2 Sync circuits and electrostatic deflection circuits for the RCA Television Receiver TRK-5.

ating. These voltages should be compared to the correct voltages given in the service data supplied by the set manufacturer. If all the voltages are incorrect, the low voltage power supply requires investigation. Voltages in any part of the circuit which deviate from the specified values, require investigation. Usually, the cause of the deviation can be located by a resistance measurement of all the components in the defective section of the circuit. Replacement of a defective resistance with one having the same value as that specified in the service data will probably restore the deflection circuits to normal.

Sometimes incorrect terminal voltages can result from a tube which breaks down under the circuit operating conditions. Such a tube may test as satisfactory in a tube checker.

The two steps described above provide a good method for finding minor causes of deflection circuit operation below the optimum. This assumes, of course, that the cause of unsatisfactory operation is not due to misadjustment of the deflection circuit controls such as the frequency (hold), linearity, or amplitude control. The recognition of incorrect adjustments was described in the lesson on diagnosing receiver faults from picture defects.

When the deflection circuit operation deviates widely from the optimum, the source of the trouble can be located by checking the operation of the circuits with an oscilloscope designed for television receiver servicing. The waveforms developed across the various components of the circuit can be observed and compared to the correct waveform for each component. The reader knows the type of waveforms which appear in the various parts of deflecting circuits from his study of the lessons on deflection circuits in the previous unit of his television course. Waveforms developed at the points marked by capital letters for Figs. 1 and 2 are given in Figs. 7 and 8 respectively. If the reader has forgotten the waveforms developed in the other types of deflection circuits illustrated, a review of the lessons on deflection circuits is advisable.

Notes on the correct use of the oscilloscope for checking the waveforms appearing in television receivers were given in the lesson on television service equipment. The student should review this information before attempting to observe the waveforms occurring in the deflection circuits of television receivers. These notations are particularly applicable to receivers using magnetic deflection.

The statement was made previously that the voltage developed between the plate and ground of the horizontal output tube for magnetic deflection was very high. This voltage may rise to a peak of two to three thousand volts. This voltage can cause a very unpleasant shock. It is advisable to use a well insulated probe when checking the voltage or waveform on the plate terminal of the horizontal output tube. The primary of the high voltage power supply transformer should be disconnected when making measurements on the chassis. If the serviceman is checking the operation of the deflection circuits by observing the pattern on the

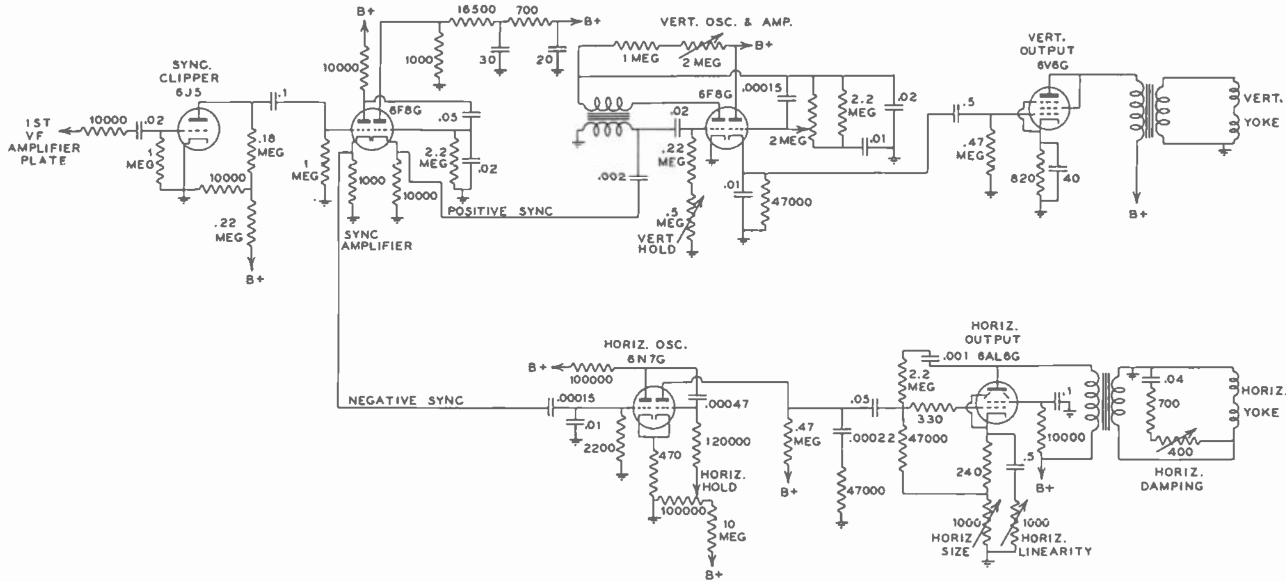


Fig.3 Sync circuits and magnetic deflection circuits for the G.E. Television Receiver HM-225.

cathode ray tube he must be extremely cautious in approaching sections of the chassis carrying the high voltage. When making an adjustment on the chassis, it is advisable to keep one hand behind your back. For safety, it is much better to disconnect the high voltage power supply when making any measurement or adjustment on the receiver. It may take a little more time to follow this procedure, but it will prevent the possibilities of injurious shocks.

3. COMPLETE OR PARTIAL FAILURE OF THE DEFLECTION CIRCUITS. Complete failure of both deflection circuits is undoubtedly due to a lack of plate supply voltage resulting from a power supply failure. For this condition, the entire receiver would be inoperative. No heater supply is another cause for complete failure. The general causes for power supply failure are well known to the reader, and do not require discussion here. The high voltage power supply may still be in operating condition after a breakdown in the low voltage unit. The undeflected cathode ray tube beam can burn the fluorescent screen and destroy its fluorescence. Therefore, it is essential to disconnect the high voltage power supply when checking failures in the low voltage supply. In some receivers the bias for the cathode ray tube is obtained from the high voltage source and the cathode ray tube can be biased to cutoff by turning the bias or background control to its most negative position. However, for safety, it is much better to disconnect the primary of the high voltage power transformer during the isolation of the cause of failure.

Complete failure of one of the deflection circuits can result from several causes. The point of failure can be found quickly by means of an oscilloscope. The path of the signal is traced progressively from the sawtooth oscillator to the deflecting yoke or deflecting plates. The tube or circuit which does not transmit the signal or transmits a signal with a waveform widely divergent from the correct waveform is the source of the deflection failure.

A complete lack of signal in any part of the deflection circuit is generally due to failure of the sawtooth oscillator. If the sawtooth oscillator can be divided into a pulse generator such as the blocking tube oscillator and a separate discharge tube, the total lack of signal is probably the result of failure in the blocking tube oscillator. The usual causes of failure of a blocking tube oscillator are a defective tube, open transformer, opens in the plate or grid circuit, shorted grid condenser, shorted plate filter condenser, and grounded grid or plate leads. If the blocking tube oscillator is working, the lack of deflection can be caused by some defect in the discharge tube circuit (no sawtooth being formed). If a double triode is used for the blocking tube oscillator and discharge tube, the section used as the discharge tube may be defective. Other causes for no sawtooth generation are opens in the plate circuit, no connection between the grids of the discharge tube and oscillator tube, grounded plate terminal caused by a shorted condenser or a defective socket or wiring, a shorted plate filter condenser, or a grounded amplitude control if located in the plate circuit of the discharge tube.

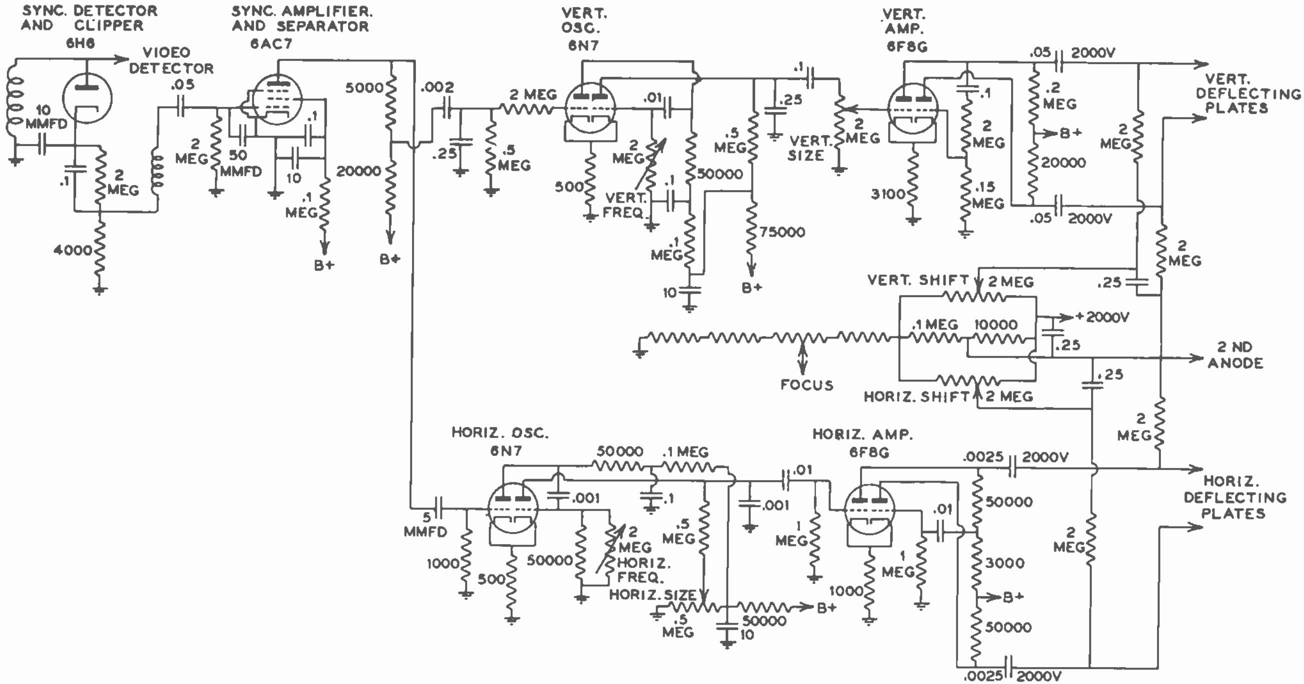


Fig.4 Sync and electrostatic deflection circuits for the Meissner Television Receiver 10-1153.

If the sawtooth generator is a single tube operating as a blocking tube oscillator and discharge tube, complete failure of the oscillator can be the result of any of the causes listed previously for oscillator failure. No sawtooth generation with normal oscillator operation can result if the sawtooth condenser is shorted.

Failure of sawtooth oscillators of the multivibrator type can be caused by defective tubes in either section of the multivibrator, grounded or open plate circuits, shorted or open coupling condensers, shorted sawtooth condenser, grounded cathode, or a lack of plate voltage.

The Kipp oscillator is quite similar to the blocking tube oscillator except that the tube draws plate current during the scan part of the cycle and is at cutoff during the return part of the cycle. Therefore, the causes for blocking tube oscillator failure will in general hold for the Kipp oscillator.

No deflection will result in an electrostatic deflection circuit when the sawtooth condenser is open. The waveform developed across the condenser for this condition consists of sharp pulses like the voltage waveform required to force a current sawtooth through a pure inductance. During the leading and trailing edges of the pulse, the cathode ray tube beam will be deflected across the tube so fast that no trace will show on the screen. If the failure is in the vertical circuit, there will be two horizontal lines, one at the top and the other at the bottom of the screen. These lines occur during the interval between the pulses and at the peak of the pulses. Therefore, the line corresponding to the interval between the pulses will be much brighter than the other. If the failure is in the horizontal circuit, two vertical lines will result, one on each side of the screen. One will be much brighter than the other, as explained before.

If the sawtooth is being generated and there is no deflection of the cathode ray tube beam, the location of the defect is probably in the deflection amplifier. Deflection amplifier failure can result from the defective tubes, lack of plate voltage caused by either opens or grounds in the plate circuit, an open grid lead, or an open cathode circuit. One cause of erratic deflection in the horizontal circuit of a magnetic deflection set is a breakdown between the plate terminal and ground of the amplifier tube socket. It is advisable to replace such a socket with one designed to withstand high voltages.

If the amplifier appears to be working normally and there is no deflection, the trouble is between the cathode ray tube and the amplifier tube. In the case of a magnetic deflection circuit, the trouble may be an open in the secondary of the coupling transformer, an open in the yoke, an open or ground in the leads to the yoke, or a ground in the damping circuit if it is located on the yoke side of the coupling transformer. In the case of an electrostatic deflection circuit, the trouble may be an open or ground in the leads going to the deflecting plates, or a breakdown inside the cathode ray tube. It is rather improbable that the circuits

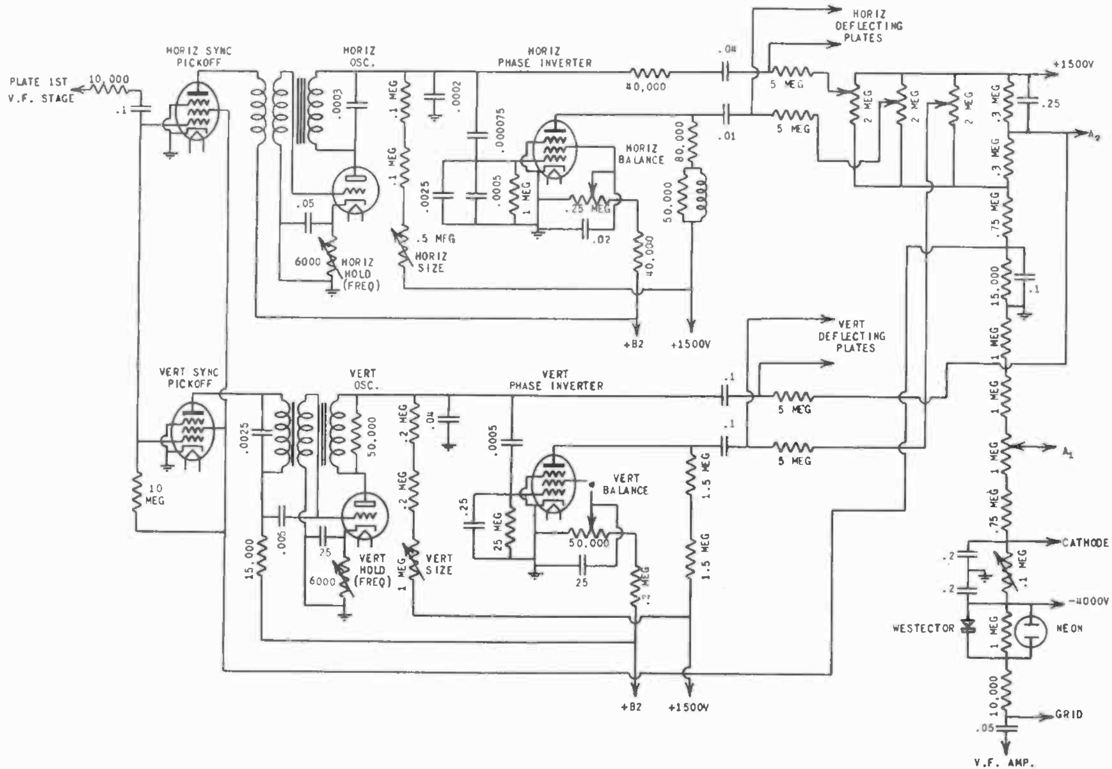


Fig.5 Sync circuit and electrostatic deflection circuits for the Dumont Television Receiver.

for the two plates of a pair will fail simultaneously, and thus there is likely to be partial deflection of the beam. If a break occurs in the deflecting plate lead between the deflecting plate and its coupling resistor, defocusing and a shift of the pattern will be present, as well as a reduction in deflection amplitude.

4. INSUFFICIENT AMPLITUDE. The cause of insufficient amplitude in deflecting circuits can usually be found through the two checks specified in the first part of this lesson. The loss of amplitude in magnetic deflection circuits is usually due to defective tubes in either the oscillator or amplifier section; insufficient plate voltage on the discharge tube or amplifier tube; incorrect bias on the amplifier, an open cathode bypass for the amplifier; excessive damping due either to incorrect adjustment or a short in the damping tube; a shorted condenser in the damping circuit; a defective yoke coupling transformer; shorted turns in the yoke; a high resistance connection to the yoke; an open grid return for the amplifier; excessive second anode voltage on the cathode ray tube; a leaky sawtooth condenser in discharge circuit; a high resistance connection in the charging circuit of the sawtooth condenser; or a change in the magnitude of the condenser in the frequency control circuit. The loss of amplitude in electrostatic deflection circuits usually due to defective tubes in either the oscillator or amplifier sections; defective phase inverter; change in the potential divider constants feeding the phase inverter; low plate voltage on the amplifier tubes; the discharge tubes, or the oscillator, incorrect bias on the amplifier tubes; open grid returns to the amplifier tubes; change in the magnitude of the amplifier load resistances; excessive second anode voltage on the cathode ray tube; a leaky sawtooth condenser in discharge circuit; high resistance connection in the charging circuit of the sawtooth condenser; or a change in magnitude of the condenser in the frequency control circuit.

5. LACK OF LINEARITY. Non-linear deflecting circuits distort the picture in a very disagreeable manner. This is especially true of pictures involving motion. Non-linear deflection results in the change in the size and shape of objects as they are shifted from one part of the picture to another. The distortion of test patterns resulting from non-linear deflection circuits was illustrated in the lesson on recognition of television receiver faults from the picture.

The best method to check the linearity of the deflection circuits is by means of a linearity test oscillator of the type described in the lesson on television test equipment. The output of the linearity test oscillator is applied across the diode load of the receiver. To check vertical linearity, the output frequency of the linearity test oscillator is set at approximately some multiple frequency of 60 cycles between the tenth and fifteenth harmonics. The vertical frequency control of the receiver is adjusted slightly, if necessary, to produce a stationary pattern. The vertical oscillator in the receiver will synchronize on a subharmonic of the output of the linearity test oscillator. The pattern produced on the screen of the cathode ray tube consists of a series of horizontal black and white bars. If the vertical deflection circuit is perfectly linear, the white bars have

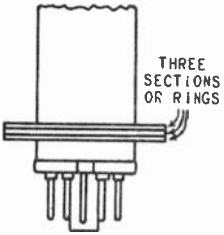


Fig.6 Identification of 6L6's satisfactory for deflection circuits.

the same width and are equally spaced. Non-linearity in the vertical deflection circuit shows up as a variation in the width of the white bars and their spacing from top to bottom of the pat-

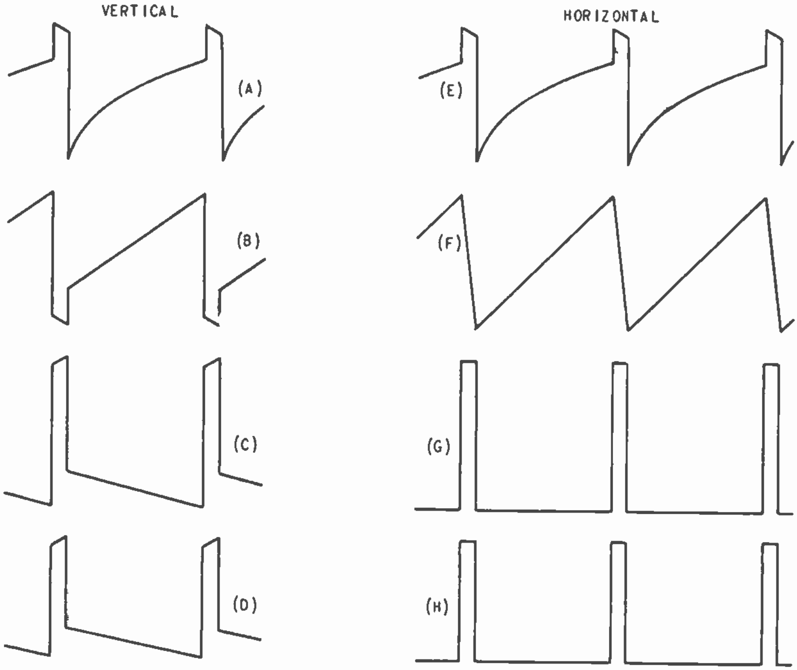


Fig.7 Waveforms developed in the deflection circuits shown in Fig. 1.

tern. Fig. 9A is a picture of the pattern produced by a linear vertical deflection circuit when checked by this method. Fig. 9B is the picture of the pattern produced by a non-linear deflection circuit.

The linearity of the horizontal deflection circuit can be checked in the same way. However, the frequency of the linearity test oscillator is set at approximately some multiple frequency of 13,230 cycles between the tenth and fifteenth harmonics. The horizontal frequency control of the receiver is readjusted slightly so that the horizontal oscillator will synchronize with a subharmonic of the linearity test oscillator frequency. A series of vertical white bars will be produced on the screen of the cathode

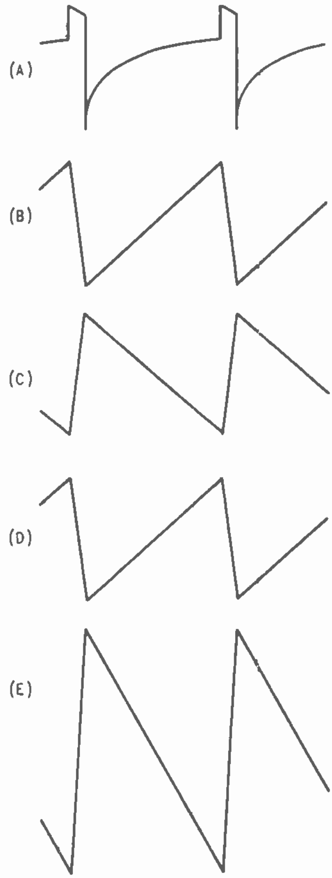
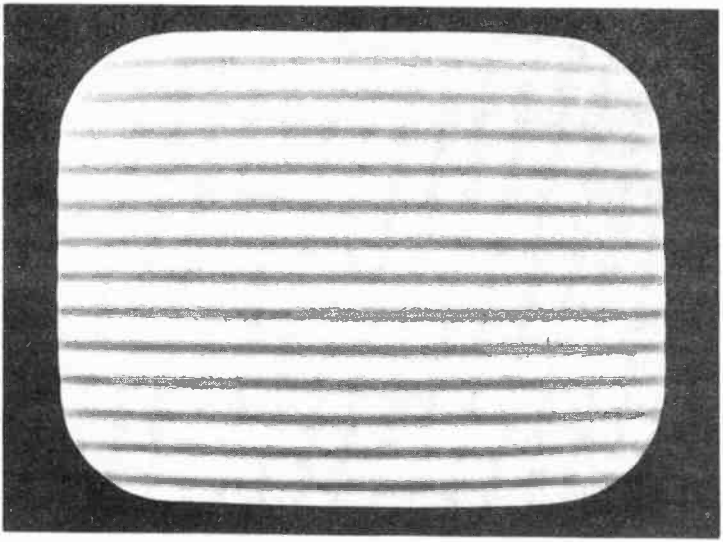


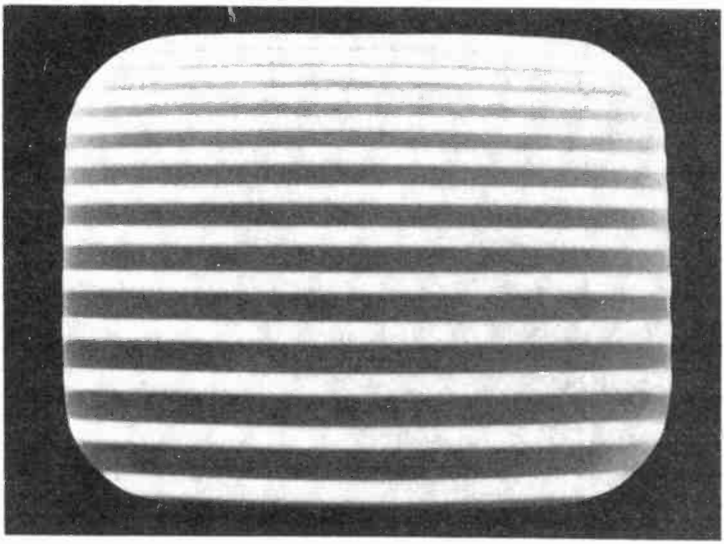
Fig. 8 Waveforms developed in the deflection circuits shown in Fig. 2.

ray tube. If the horizontal deflection is linear, the white bars will have the same width and will be equally spaced. If the horizontal deflection is non-linear, the width and spacing of the bars change across the pattern. Patterns produced by linear and non-linear deflection circuits are shown in Figs. 10A and 10B respectively.

If a linearity test oscillator is not available, an audio oscillator can be used to check the vertical linearity, and an RF



(A)

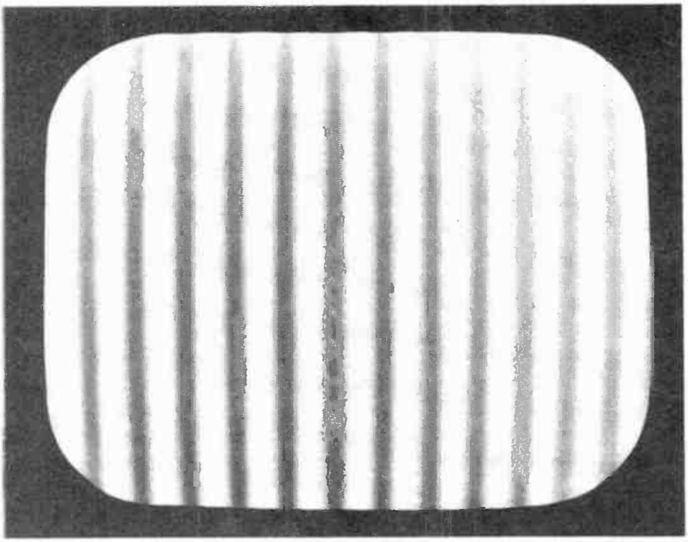


(B)

Fig.9 (A) Linear vertical sweep. (B) Non-linear vertical sweep.

signal generator used to check the horizontal linearity. If both signals from the linearity test oscillator are applied simultaneously to the receiver, a pattern of small rectangles will be produced. If both deflecting circuits are linear, all of the rectangles will have the same size.

(A)



(B)

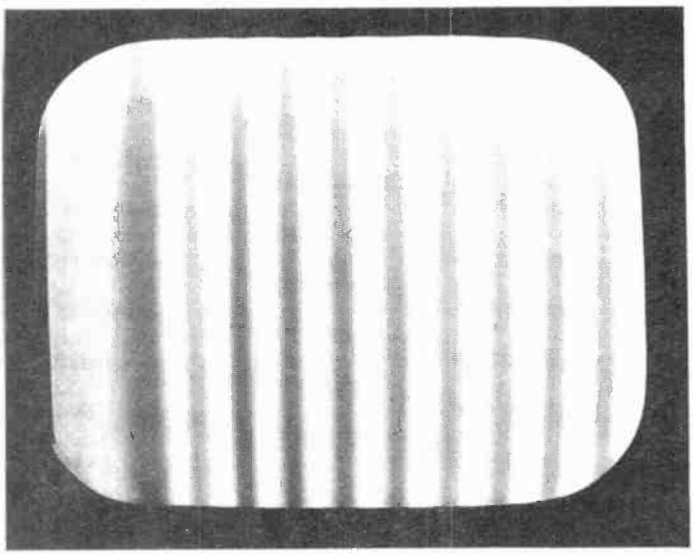


Fig.10 (A) Linear horizontal sweep. (B) Non-linear horizontal sweep.

The picture signal generator can also be used to check the linearity of the deflection circuits if the picture in the generator is a pattern designed for the purpose. Of course, the deflection circuits in the picture signal generator must be absolutely linear. The picture signal generator output is applied to the second detector load with the correct polarity. The non-linearity of the deflection circuit will distort the pattern in the way illustrated in the lesson on recognizing television receiver faults from the picture.

In discussing the causes of non-linearity, it is convenient to consider the magnetic and electrostatic deflection circuits separately. Also, it will be assumed that the lack of linearity is due to some fault in the deflection circuits, and is not due to misadjustment of the deflection circuit controls. Some of the factors which affect the linearity of the deflection circuits have the greatest effect at the top of the pattern for vertical deflection and at the left side of the pattern for horizontal deflection. Others affect the pattern most at the bottom or at the right side depending upon which circuit lacks linearity. Others control the linearity over the entire vertical or horizontal scan.

One of the factors which can cause non-linearity in the center of the pattern for magnetic deflection circuits is a change in the charging time constant of the condenser that is charged and discharged to form the sawtooth resulting from either an open condenser or a change of resistance in the charging path. Any factor which affects the frequency response of the amplifiers will cause non-linearity over the entire pattern. Open coupling condensers in the horizontal deflection circuit destroy the low frequency characteristics of the amplifier. There is usually sufficient stray capacity for the transmission of the harmonic frequencies of the 13,230 sawtooth. An open coupling condenser in the vertical circuit results in no deflection. A change in the resistance of grid leaks results in unsatisfactory low frequency characteristics especially in the vertical circuit. A leaky coupling condenser may cause the amplifier to draw grid current and low input resistance of the tube destroys the low frequency characteristics of the amplifier. This effect is also greater in the vertical deflection circuit. The flow of grid current also results in amplitude distortion. Gassy tubes destroy linearity because of the low input impedance. Electrolytic cathode bypass condensers, when old, often lose capacity. This results in degeneration of the low frequency components of the sawtooth waveform. Excessive impedance in the yoke circuit resulting from a defective spot shift control or an open bypass across the control will result in non-linearity.

The linearity of vertical deflection at the top of the pattern is affected adversely when the peaking resistance is incorrect. (The peaking resistance is the resistance in series with the condenser in the sawtooth circuit which produces the sharp pulses during the discharge period. The peaking is necessary to produce a voltage waveform that can force a current sawtooth through an inductive circuit.) Too much peaking spreads the lines out, and too little peaking crowds them. Insufficient damping in the vertical circuit may result in oscillations at the top of the pattern. This results in alternate crowding and spreading of the lines near the top. Excessive damping results in crowding at the top. Damping, when used in the vertical deflection circuit, usually consists of a condenser and resistance in series across either the primary or secondary of the coupling transformer.

The linearity of the vertical deflection at the bottom of the pattern is determined largely by the bias on the amplifier tube. Insufficient bias results in grid current flow during the positive peak of the grid swing. Excessive bias means that the tube is being operated in the curved region of its characteristic and the resulting amplitude distortion can cause non-linearity in the center of the pattern as well as at the top. Some deflection circuits are designed so that the tube curvature will compensate for non-linearity in the applied sawtooth. Therefore, the bias must be carefully adjusted to obtain linear deflection. In most receivers, the bias is adjustable on the vertical amplifier by means of the linearity control. If the non-linearity cannot be corrected by this control, it is probable that the control or its associated components are defective. The trouble can usually be isolated by measuring the values of the components and checking them against the service data for the receiver.

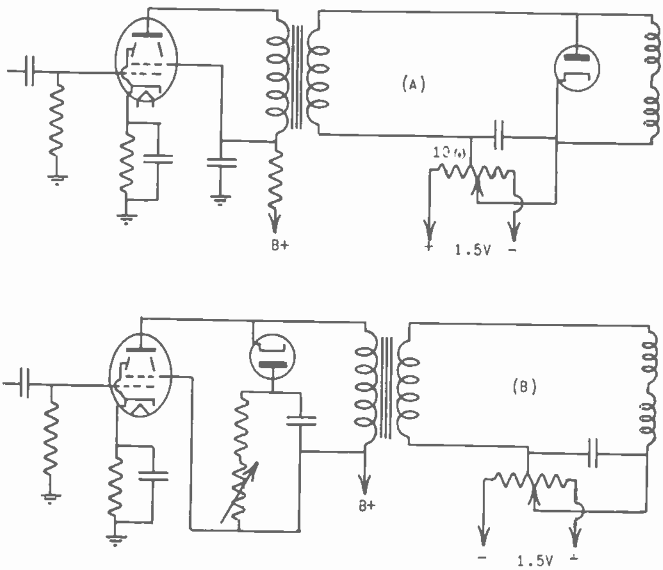


Fig.11 Damping circuits.

The linearity of the horizontal deflection at the right side of the pattern is largely determined by the bias on the tube and comments on bias for the vertical dircuit hold here. Non-linearity on the left side of the pattern results largely from incorrect damping. Diodes are generally used for horizontal damping. In some circuits, the diode is connected across the yoke. In others, the diode in series with a parallel resistance-condenser combination is connected across the primary of the coupling transformer. These two methods are shown in Figs. 11A and B. When the diode is on the primary side of the transformer, it is self-biased so that it will not conduct during the go time of the sweep.

The purpose of the damping circuit is to prevent the circuit from oscillating after the collapse of the magnetic field. The frequency of the oscillation is controlled by the leakage reactance and the distributed capacity of the transformer. On the primary side, the first positive half-cycle of the oscillation occurs during the collapse of the magnetic field, and therefore must not be suppressed. The oscillation must stop at the end of the positive half-cycle or the oscillation will be super-imposed on the start of the next horizontal line. This would cause alternate crowding and spreading of the pattern along the left edge. The presence of this type of distortion is the result of complete damping circuit failure. Complete failure is probably due to an open in the damping circuit. If the damping tube emission is low (a worn out tube) the left edge of the pattern is spread out. If the damping is excessive, the left edge of the pattern is crowded. Excessive damping is probably the result of a diode with shorted elements. It can also result if the condenser in the self-biased damping circuit is shorted. A shorted resistor will produce the same effect. When damping is done on the primary side of the transformer, the high positive peak voltage generated during the return time is applied across the diode cathode and heater supply source. Many rectifiers have a very short life when used in this type of service.

Overall non-linearity in electrostatic deflection circuits can result from the same defects in the sawtooth oscillator and amplifier frequency characteristics as in magnetic deflection circuits. In some receivers, shunt peaking is used in the horizontal amplifier in order to have a high gain with good high frequency characteristics. Trouble shooting video amplifiers was discussed in the preceding lesson of this unit and the same technique can be used to check the frequency characteristics of the horizontal amplifier. One important cause of non-linearity in electrostatic deflection circuits is unbalance in the push-pull output amplifier. Such unbalance usually is the result of a defective phase inverter. Most of the phase inverter troubles were previously discussed under amplitude considerations.

The simplest method to check the degree of balance of the push-pull output stage is to measure the output of each half of the stage with an oscilloscope. The two outputs have the same amplitude when balance exists. If unbalance exists and all the circuit components are correct, the cause is a difference in gain between the two tubes in the push-pull stage. If a double triode is used, several tubes should be tried until one is found which gives the best balance. If the two tubes receive bias from different sources, unbalance will exist when one tube is incorrectly biased.

Non-linearity can result if the connection between the coating on the inside of the cathode ray tube and the second anode is open. When this condition exists, secondary electrons from the screen are collected by the deflecting plates rather than the coating. The plate of each pair which is going positive will collect electrons and increase the loading on one side of the push-pull stage. This results in a non-linear sweep. Defocusing is likely to be present in such a tube.

6. EXCESS HUM OR RIPPLE IN THE DEFLECTION CIRCUITS. The effects of hum or ripple on the television picture were described fully in the lesson on recognizing television receiver faults. When ripple or hum is present in the horizontal deflection circuit, the sides of the pattern are not straight, but are modulated by the waveform of the hum. The horizontal deflection amplitude remains constant. This fact can be used to distinguish pattern distortion resulting from hum in the deflection circuits from that resulting from hum in the high voltage power supply. In the latter case, the horizontal amplitude changes proportionally to the increase and decrease in the second anode voltage. The sides of the pattern are modulated by the hum, but the phase of the two sides differ by 180 degrees.

Hum or ripple in the vertical deflection circuit results in uneven spacing of the lines. The line spacing is modulated according to the waveform of the hum or ripple voltage. The presence of 60 cycle hum is sometimes confused with non-linearity in the deflection circuit. Reversing the AC plug to the receiver will reverse the effect due to hum but will not change that due to non-linearity.

One of the major causes of hum in the deflection circuits is insufficient filtering in the low voltage power supply. The remedy is to increase the size of the filter condensers in the power supply or replace the low capacity units.

Hum present in the sync circuits will introduce hum into the horizontal deflection circuit. The hum in the output of the sync circuits will advance and delay the firing of the sawtooth oscillator, as the hum voltage will be superimposed on the bias for the oscillator.

Other sources of hum are defective plate filters for the various tubes in the deflection circuits. The plate supply for the sawtooth oscillator should be well-filtered.

If it ever becomes necessary to rewire the sawtooth oscillator circuits, it is essential to keep all the oscillator leads away from circuits carrying 60 cycles. Close proximity to AC circuits will result in the induction of hum into the grid circuit of the oscillator. The firing of the oscillator will be advanced or delayed according to the magnitude and polarity of the induced hum. As in the case of hum in the sync circuits, it is the horizontal deflection that is distorted.

Hum can be introduced into the pattern by direct deflection of the cathode ray tube beam by strong AC fields. Electrostatic deflection tubes are very susceptible to this type of distortion, probably because of their lower anode voltages. Sometimes it may be necessary to change the location of a receiver to reduce pattern distortion caused by this effect. AC equipment radiating strong fields should not be placed near the cathode ray tube in a television receiver.

7. SAWTOOTH OSCILLATORS OFF FREQUENCY. Sometimes defects develop in the sawtooth oscillators which change their frequency to the extent that the frequency control does not cover the required range. The deflection circuits cannot be synchronized, and a very distorted pattern results. The serviceman may assume that the difficulty is in the sync circuit and waste valuable time trying to find it.

When the condition of poor or no synchronization of one or both deflection circuits arises, the first step should be the measurement of the frequency of the sawtooth oscillators when running free. There are several methods available for checking the frequencies of the oscillators. Two of them will be described here.

The first step is to make the sync circuits inoperative. This can be done by removing the output tubes in the sync circuits. In most receivers, a double triode supplies the outputs for the horizontal and vertical sync circuits. One of the methods is to introduce a sinusoidal signal of either the vertical or horizontal frequency into the video amplifier. The corresponding

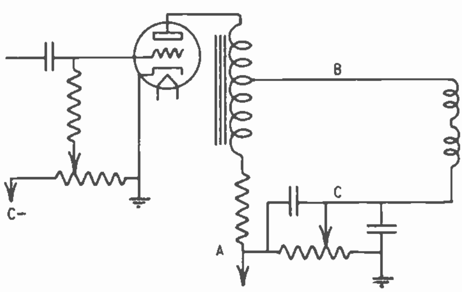


Fig.12 Spot shift with choke coupling.

oscillator frequency control is adjusted to obtain a single horizontal white bar for the vertical or a single vertical bar for the horizontal. When the oscillators are on frequency, half of the screen will be white and half black. There will be either a white bar on a black background or a black bar on a white background according to the phase relations between the signal applied to the video amplifier and the deflection circuit. Since the oscillator is running free, it will drift about, and the frequency control must be continually adjusted to obtain a well defined bar. The 60 cycle sinusoidal signal can be obtained from the heater supply of the receiver and the 13,230 cycle signal from an audio oscillator.

RMA STANDARD T-111
TELEVISION SIGNAL

441 LINES, 30 FRAMES PER SEC., 60 FIELDS PER SEC., INTERLACED

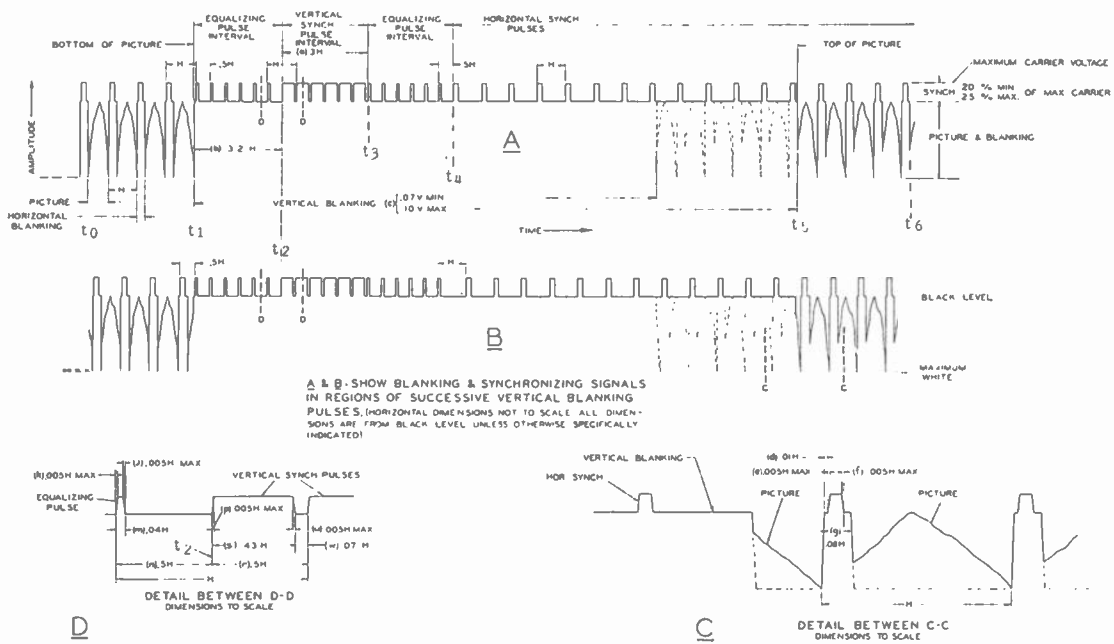


Fig.13 Standard RMA television signal.

The second method, and perhaps the least confusing method, is to compare the oscillator frequency with a known frequency by means of an oscilloscope. The vertical input to the oscilloscope is connected across the output of the sawtooth oscillator in the receiver. A sinusoidal signal of correct frequency for the oscillator under test is applied to the horizontal input of the oscilloscope. The oscillator frequency control is adjusted until a single sine wave appears on the screen of the oscilloscope tube. Since the sine wave input is on the horizontal plates and a sawtooth on the vertical plates, the axis of the sine wave will be vertical. If a single sine wave cannot be obtained over the range of the frequency control, the oscillator is off frequency. From the study of Lissajous figures in a previous lesson, it is possible to determine whether the oscillator is high or low in frequency. If the reader has forgotten how to use Lissajou figures in determining or comparing frequencies, he should review the lesson in the preceding unit covering the subject of frequency measurement.

Probably the quickest method of locating the cause of off-frequency operation is to measure the magnitudes of all the oscillator components and compare them with the values given in the service data for the receiver. The usual causes for off-frequency operation of blocking tube oscillators are defective transformers, defective resistors and condensers in the grid circuit, or an open in the grid circuit. Measuring the magnitudes of the components and the resistance to ground from all the tube terminals is the simplest way of finding the cause for off-frequency operation in multivibrator type sawtooth oscillators.

8. SERVICING SPOT SHIFTS. One rare cause for the inability of the spot shifts to center the pattern is a defective cathode ray tube. The gun elements or the entire gun may be out of alignment.

The usual causes for inoperative spot shifts in magnetic deflection circuits are open spot shift controls, no (or insufficient) current supply for the spot shift, open yoke circuits, or shorted controls. Incorrect bias on the output tube will interfere with the action of the spot shift in an output circuit of the type shown in Fig. 12. In this circuit, the direction of current through the yoke depends on the polarity of the difference between the voltage drops across AC and AB. The voltage drop across AB is proportional to the output tube current. The tube current is determined by its bias.

The usual causes of inactive or unsatisfactory spot shifts in electrostatic deflection circuits are leaky coupling condensers to the deflecting plates, opens between the deflecting plate and spot shift, open spot shift controls, shorted spot shifts, incorrect current through the spot shifts caused by defects in the circuits supplying the spot shift current. When dual controls are used to supply a balanced DC voltage to the two plates of a pair, unsatisfactory spot shift will occur if one of the sections of the

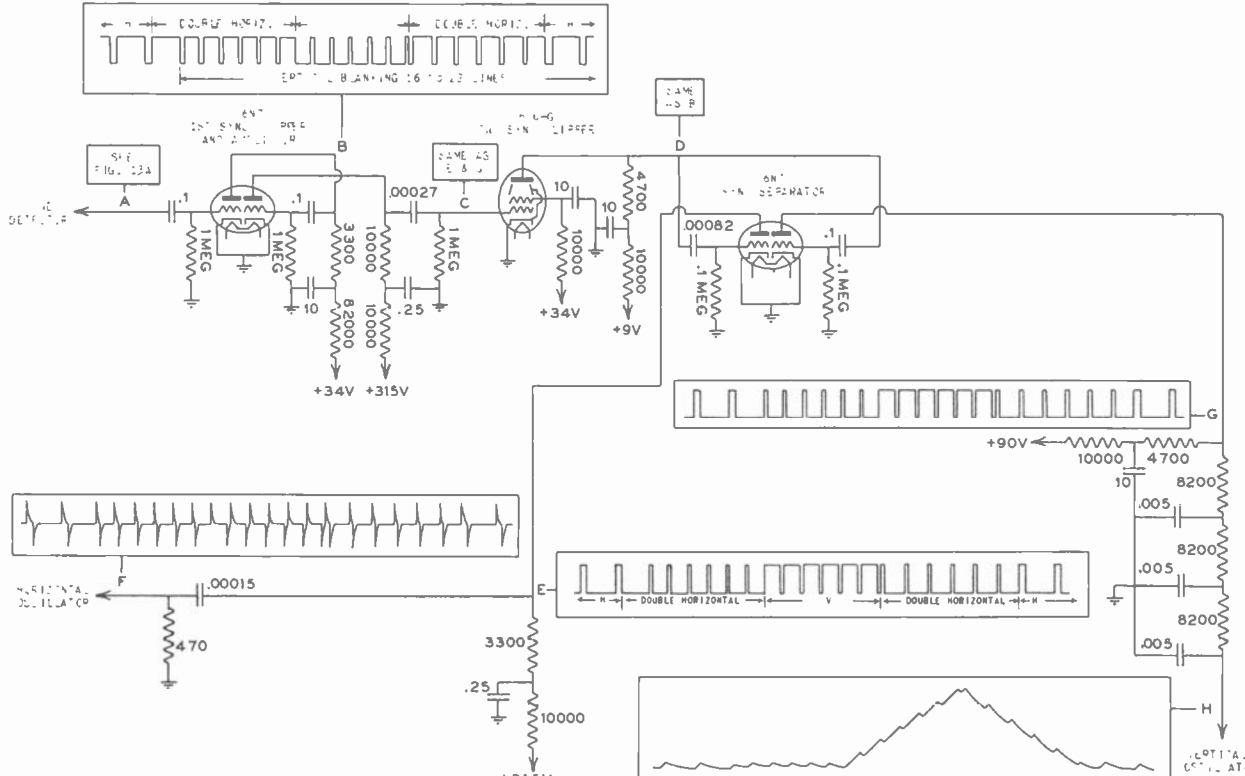


Fig.14 Sync circuit from Fig. 1.

dual control becomes defective or if the two sections become unbalanced from an open in one control.

9. PATTERN ORIENTATION. Occasionally the picture becomes rotated slightly with respect to the frame in the receiver cabinet. This can be corrected in receivers using magnetic deflection, by rotating the deflecting yoke until the pattern is squared with the frame. The yoke is held in place by a clamp. The clamp should be loosened slightly to permit easy rotation of the yoke.

It is necessary to rotate the cathode ray tube in a receiver using electrostatic deflection to square the pattern with the cabinet frame. The cathode ray tube socket is arranged to rotate slightly. The picture can be squared by loosening the socket clamp, rotating the tube for correct framing, and tightening the clamp again. It is usually necessary to make this adjustment when replacing cathode ray tubes, as the orientation between the base pins and the deflecting plates differ slightly from tube to tube.

When making repairs on the deflecting circuits, it is essential to get the polarity of the voltages applied to the deflecting yoke or deflecting plates correct so that the picture will not be reversed in one or both directions. Indirect viewing sets, when viewed directly, have the vertical deflection reversed while the horizontal is normal. The mirror reverses the vertical but does not change the horizontal.

Most of the major troubles which may develop in deflection circuits have been discussed in the last few sections. Others not mentioned may arise. The serviceman will learn through experience to reason logically from the defect to logical sources of trouble. The last sections of this lesson are devoted to a discussion of locating sync circuit troubles.

10. TYPICAL SYNC CIRCUITS. This discussion on servicing sync circuits is based on the present RMA television standards. Fig. 13 shows a standard RMA television signal for intervals from two succeeding fields which include vertical blanking and sync pulses, several horizontal lines preceding the vertical blanking, and several horizontal lines following the vertical blanking. Figs. 14 through 18 are drawings of the sync circuit sections of Figs. 1 through 5 respectively. In each figure are included the waveforms developed in the output of each tube when the input signal has the form shown in Fig. 13A or 13B. The point in the circuit where each waveform appears is marked by the same letter.

In Fig. 14, the first sync clipper is a grid leak biased triode. The plate voltage is low so that only the sync pulses drive the grid above cutoff. Since such a circuit levels on the sync pulses, the output will contain the DC component. This sync clipper requires a video signal of negative polarity. The second section of the first 6N7 is a sync amplifier. The 6Y6-G is a second sync clipper of the same type as the first and it has a very sharp cutoff because of the dynatron action. The output of the second sync clipper will have a constant amplitude for a wide variation of input amplitude to the first clipper. This is true

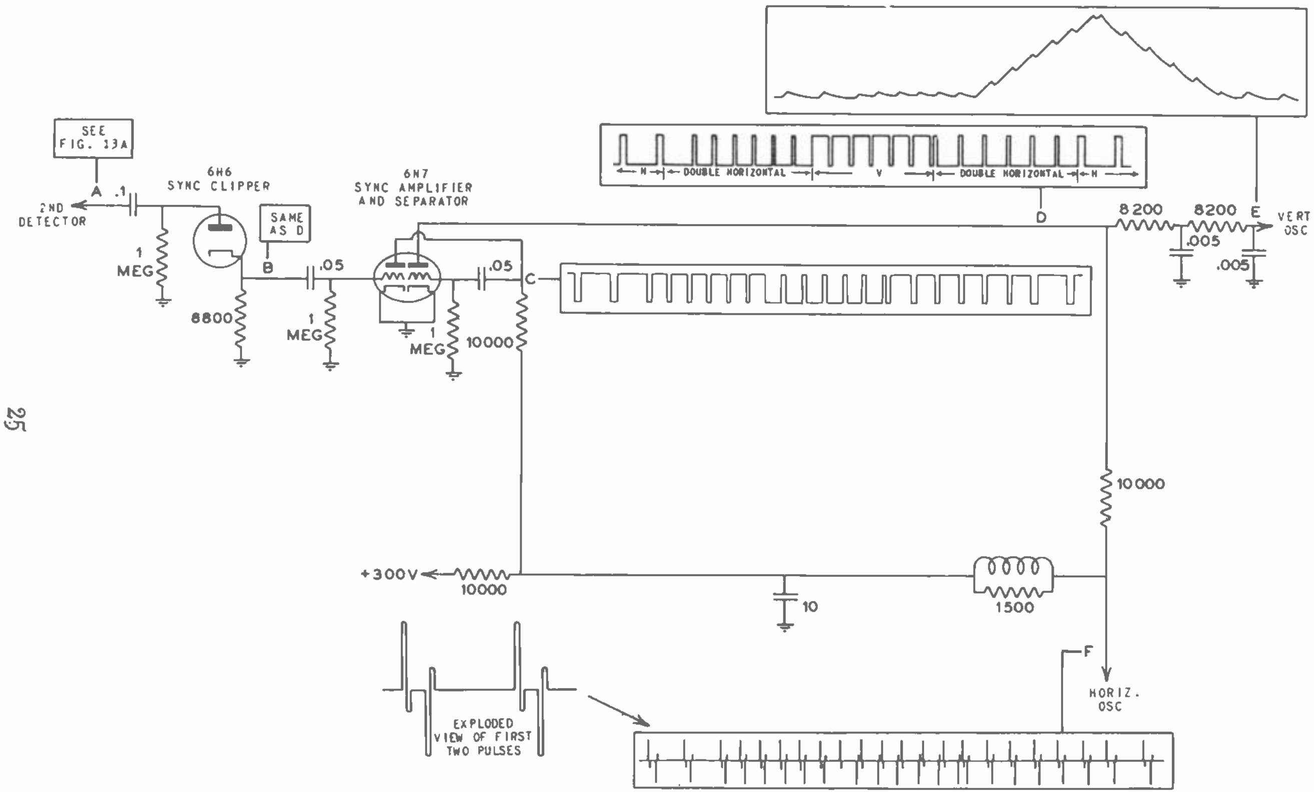


Fig.15 Sync circuit from Fig. 2.

because a grid leak biased triode has AVC action. The second 6N7 and its associated circuits is the sync separator. Section 1 feeds a high-pass filter or differentiating circuit which converts each horizontal sync pulse into a sharp positive and a sharp negative pulse. In other words, the time constant of the condenser-resistance network feeding sync to the horizontal oscillator is far too low to transmit the 13,230 cycle square wave sync pulses without phase and frequency distortion. The positive pulse developed from the leading edge of the horizontal sync pulses and the lagging edge of the serrations in the vertical sync pulse trip the horizontal oscillator. Section 2 feeds a low pass filter or integrating circuit. The output consists of triangular pulses occurring during the vertical sync time. A several stage low pass filter is essential in maintaining good interlacing.

In Fig. 15 the sync clipper is a self-biased diode. The input condenser and resistor form the biasing network. This circuit also acts as a DC restorer. The input video signal has a negative polarity. The first section of the 6N7 is a sync amplifier. It is grid leak biased. The second section is also a grid leak biased sync amplifier. The output sync has a positive polarity. The output circuit has a low pass filter for removing the horizontal sync from the vertical. The horizontal sync is obtained from the signal developed across the inductance in series with the plate load. The sharp leading and trailing edges of the horizontal sync pulses excite the inductance and its distributed capacity into a damped oscillation. The positive cycle developed during the leading edge of the horizontal sync pulses and the lagging edge of the serrations in the vertical sync pulse trip the horizontal oscillator.

In Fig. 16 the sync clipper is a grid leak biased triode. The input video signal is negative in polarity. Positive sync pulses are required to trip the vertical oscillator. Negative sync pulses are required to trip the horizontal oscillator. The negative horizontal sync is obtained from the cathode of the first section of the 6F8-G. It is applied to the grid of the first section of the horizontal oscillator through a high pass filter. The positive vertical sync is obtained from the cathode of the second section of the 6F8-G. The horizontal sync is removed by the low pass filter in the grid circuit of this second section.

In Fig. 17 a slightly different method is used to obtain the sync. In this circuit there is a separate second detector to demodulate the I.F. signal for the removal of the sync. This detector serves the double purpose of demodulating the I.F. signal and clipping the sync from the resulting video signal. The diode detector is self-biased so that only the sync pulses appear across its load. The 2 megohm grid leak and the .1 mfd. condenser act as the biasing network. The 1852 is a sync amplifier. The output circuit of the sync amplifier contains a high and a low pass filter for separating the vertical and horizontal sync. The output sync is negative in polarity.

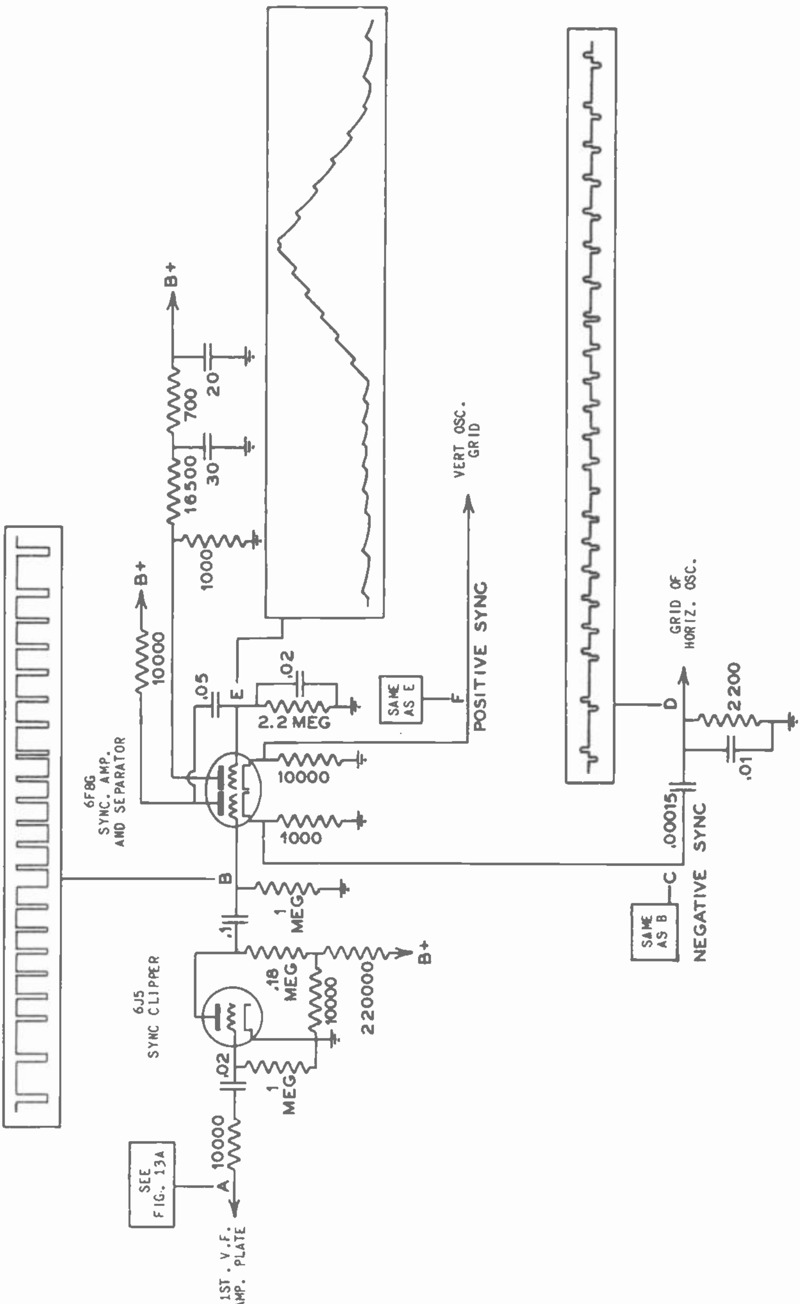


Fig.16 Sync circuit from Fig. 3.

In Fig. 18 two sync clipper tubes are used. They have a combination of negative grid leak bias plus fixed positive bias. The positive bias is required because of the extremely low screen voltage. Their input circuits are in parallel. The sync is introduced into the oscillator by means of a separate winding on the oscillation transformers. The winding on the vertical transformer is bypassed to remove the horizontal sync from the transformer. The sync is also applied to the grid of the vertical oscillator. Figs. 18B and C show the current waveforms through the transformer windings.

11. SERVICING SYNC CIRCUITS. The first step in servicing the sync circuits is to check all the tubes. The second step is to measure all the voltages at the tube terminals and compare them with the values given in the service data for the receiver. Voltages which deviate from the correct values should be investigated and the cause for the deviation removed. These two checks will probably remove the unsatisfactory sync condition.

Another method is to check the operation of the sync circuits by means of a cathode ray oscilloscope. The waveforms developed in each part of the circuit are observed and compared with the waveforms which should appear at that part. The oscillator tubes must be removed from their sockets when checking the operation of the sync circuits with an oscilloscope as the high voltages developed in the oscillators may feed back into the sync circuits, especially the output stages, and hide the sync waveforms. The sync is supplied by connecting the output of the picture signal generator with the correct polarity across the diode load. If the receiver has a sync pickoff circuit of the type shown in Fig. 18, it will be necessary to feed the I.F. amplifier of the receiver with the I.F. frequency modulated by the picture signal generator. The Signalyst in conjunction with the picture signal generator provide the best method of supplying a picture modulated I.F. frequency. When the defective sync stage has been found, the tube and the circuit components are checked to locate the defective element.

12. DEFECTIVE SYNC CLIPPER. The usual defects which may occur in the sync clipper are either no output, or incomplete clipping. Incomplete clipping occurs when part of the picture signal is present in the output of the sync clipper. Incomplete clipping usually results in erratic synchronization of the horizontal oscillator. Black areas in the picture near the end of a line will have a tendency to trip the oscillator ahead of time.

The usual causes of no output are defective tubes, lack of plate voltage resulting either from opens or grounds in the plate circuit, open grid circuit, or an open cathode. The usual causes of incomplete clipping are excessive plate voltage, a leaky coupling condenser, a gassy tube, or a low resistance grid leak. The excessive plate voltage condition may result if the bleeder supplying the low plate voltage required for clipping becomes defective. Leaky coupling condensers do not charge to the peak of the applied voltage and insufficient bias is applied to the tube.

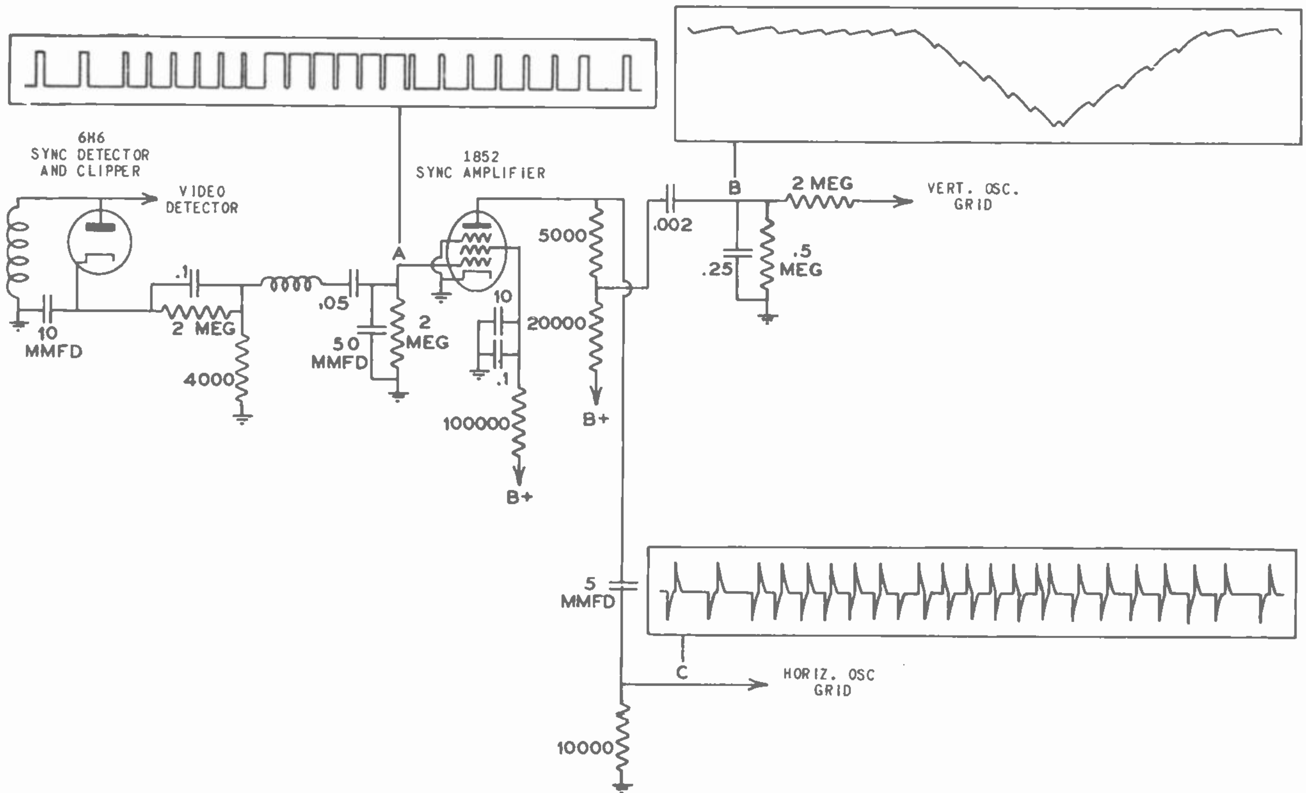


Fig.17 Sync circuit from Fig. 4.

A gassy tube has a low input impedance and the discharge time constant of the input circuit is too low to maintain a constant bias over the discharge cycle. A low resistance grid leak results in incomplete clipping for the same reason. When a self-biased diode is used as the sync clipper all trouble sources mentioned above apply, with the exception of those resulting from incorrect plate voltage.

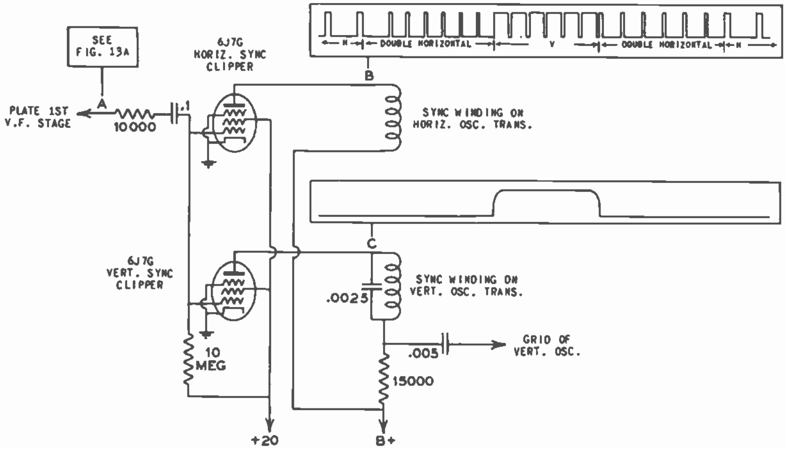


Fig.18 Sync circuit from Fig. 5.

The amplifiers used in sync circuits are conventional with the exception that they are grid leak biased. Therefore, it is not necessary to discuss them here.

13. DEFECTIVE SYNC SEPARATORS. Unsatisfactory synchronization of either or both sawtooth oscillators can result if the sync separator circuits are not functioning properly. Incomplete separation results in poor horizontal synchronization during the time of the vertical sync pulse. The picture tears out at the top. Also, the interlacing is poor. This source of trouble can be isolated by examining the output waveforms of the separator with the oscilloscope. Incorrect waveforms usually result from defective components in the separator networks. The best way of locating such components is to measure the magnitudes of all the resistors and condensers in the separator circuits and compare them with the correct values given in the service data. The condensers should also be checked for leakage. An excessively high time constant in the high pass filter which supplies the horizontal oscillator with sync will result in incomplete removal of the vertical sync. It is also advisable to check the tube voltages and the tubes in the separator circuit. Excessive plate voltage on the vertical sync tube causes erratic vertical synchronization and poor interlacing. High plate voltage results in excessive gain

and large amplitude sync pulses. Large amplitude sync pulses can upset the operating conditions of the oscillator.

14. UNSATISFACTORY INTERLACING. Unsatisfactory interlacing results in a reduction of vertical resolution. The method of checking a pattern for correct interlacing was given in the lesson on recognizing television receiver faults. Any condition which affects the amplitude and shape of the vertical sync pulse will cause poor interlacing. Noise picked up with the signal or generated within the receiver by defective components is one cause of poor interlacing. The sync circuits on the receivers using large cathode ray tubes are designed to minimize the effect of noise on the vertical sync pulse. Crosstalk between the vertical and horizontal oscillators, caused by coupling either through misplaced wiring or through insufficient filtering of the supply voltages, will result in unsatisfactory interlacing. Another source of poor interlacing is coupling between the oscillators through the sync circuits. Energy from the horizontal oscillator feeding into the vertical causes the vertical return time to be different on succeeding fields.

It is rather difficult to remove the causes of unsatisfactory interlacing, because the trouble is inherent in many receivers. If the sync circuits are operating normally and all the plate filters are in good condition and no wiring changes have been made, there is nothing the serviceman can do to improve conditions.

EXAMINATION QUESTIONS

INSTRUCTIONS. Before starting to answer these examination questions, you should have studied the lesson material at least three times. Be sure that you understand each question--then proceed to write the best answer you can. Make all answers complete and in detail. Print your name, address, and file number on each page and be neat in your work. Your paper must be easily legible; otherwise, it will be returned ungraded. Finish this examination before starting your study of the next lesson. However, send in at least three examinations at a time.

1. What is the quickest method of isolating a defect in a deflection circuit?

2. Why must the high voltage power supply be disconnected when servicing deflection circuits?

3. There is no vertical deflection in the receiver using the circuit shown in Fig. 2. The vertical blocking tube oscillator is running normally, but there is no sawtooth. List several probable sources of the trouble.

4. How can the linearity of the vertical deflection circuit be checked?

5. A receiver uses magnetic deflection. If the picture is spread out along the left edge, what is the most probable source of trouble?

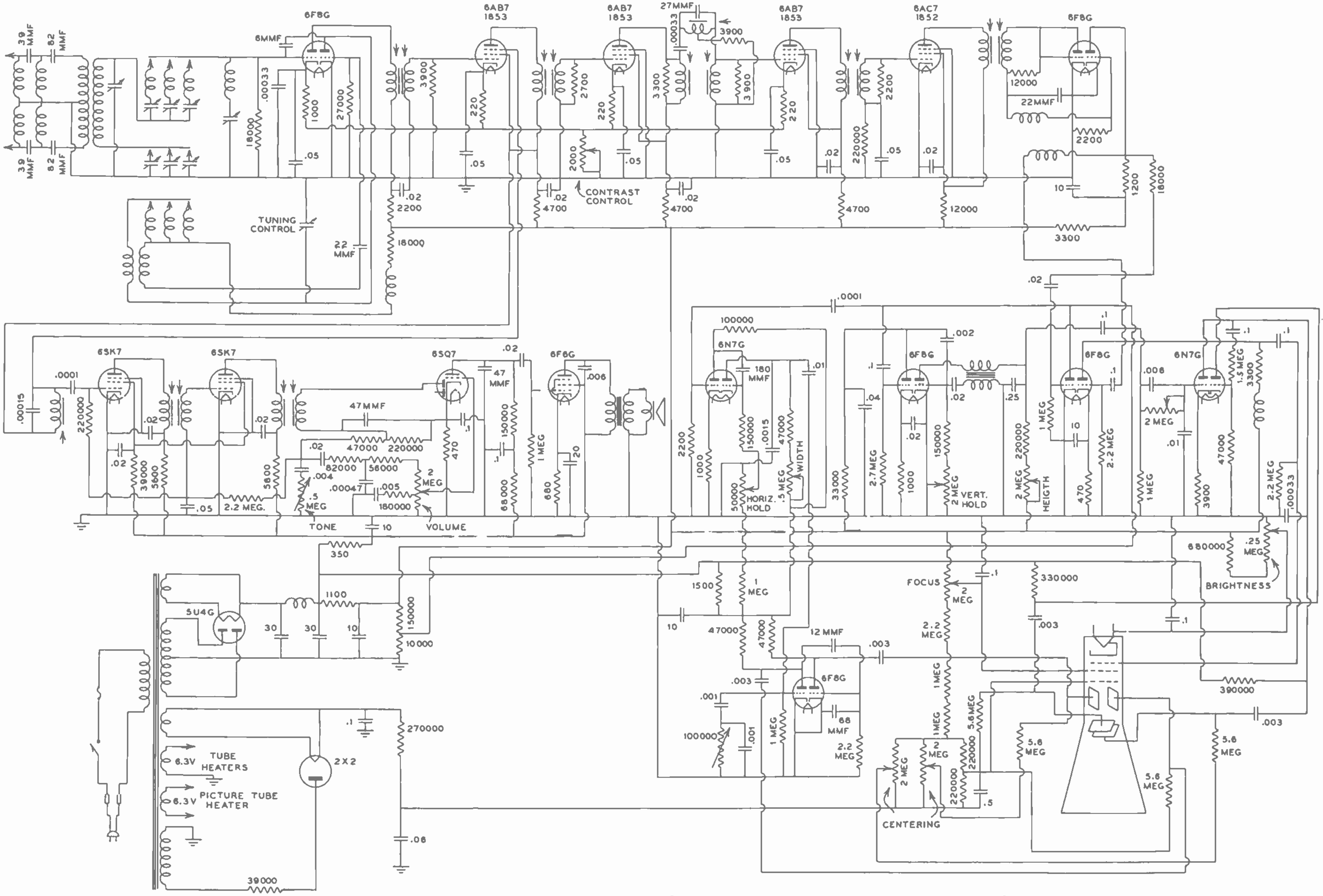
6. How can picture distortion caused by ripple in the horizontal deflection circuit be distinguished from picture distortion caused by ripple in the high voltage supply?

7. How would you check a deflection oscillator for correct frequency?

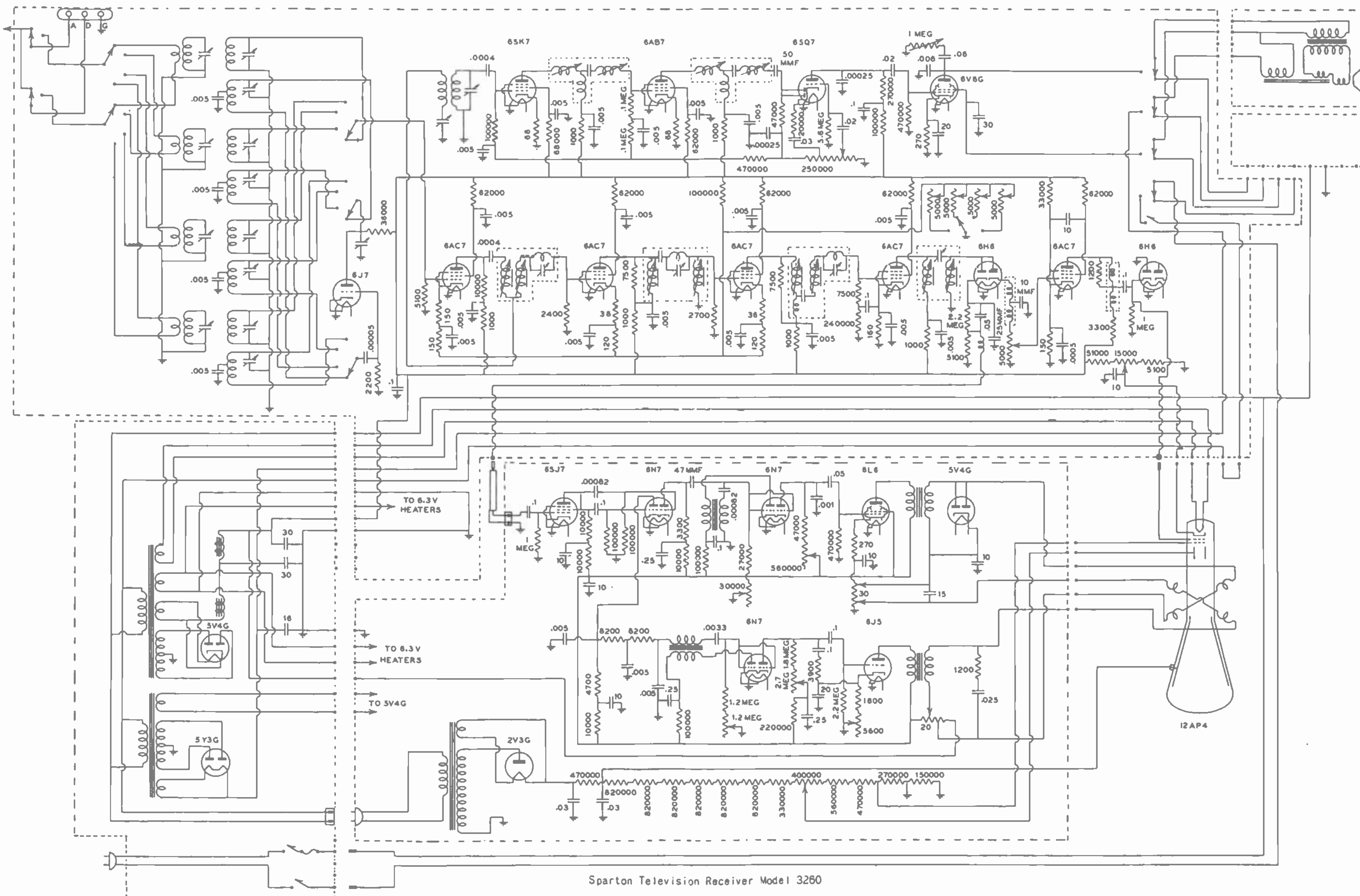
8. A receiver has a grid leak biased triode clipper. Part of the picture signal is clipped as well as the sync. What are the probable causes of this trouble?

9. What is the effect on the picture if the vertical sync gets into the horizontal sync?

10. What defects can develop in a receiver which will result in poor interlacing?



General Electric Television Receiver Model HM-185



Sparton Television Receiver Model 3260

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MIDLAND TELEVISION INC.

POWER & LIGHT BUILDING, KANSAS CITY, MISSOURI

UNIT NO. 6

SERVICING TELEVISION R.F. AND I.F. CIRCUITS

LESSON NO. 6

STRANGE EXPERIENCES

occur to those televised.

During the past months probably thousands of people from many parts of the United States have witnessed our television demonstrations in the Power and Light Building. When people come in groups, we usually televise a few of them so that the others may see how they appear on the screen of the receiver.

And how they do APPEAR!

They fail to realize that their friends are watching their every move. Many make facial expressions that are most amusing. The men will hitch their necktie and squint or attempt to attain an impressive pose. Women usually begin to primp as soon as they step before the camera. Some powder their nose, and how their friends laugh. All forget that every sound they make is reproduced in the receiver. Children invariably giggle or look frightened.

Naturally, our students operating the equipment get a big kick out of the proceedings. And they also receive excellent experience. Just imagine what an "amateur night" program would be like when you could see as well as hear the performers. Plenty of fun and laughs!

From our experience, it appears that television is going to be entertaining both for the operators and the "lookers-in". When you can combine pleasant work with a good income, you have an ideal situation. Stick to your studies and look forward to the time when your face will be serious but you will be laughing inside.

PRINTED IN U.S.A.
JONESPRINTS
KANSAS CITY, MO.

Lesson Six

SERVICING TELEVISION R.F. & I.F. CIRCUITS

"The alignment of the IF and RF sections of television receivers is not as simple or as easy as the alignment of the IF and RF sections of the conventional broadcast receiver. The quality of the picture is very dependent on the bandpass characteristics of the IF and RF amplifiers.

"Single sideband operation, which is conventional in the picture section, requires much greater alignment precision than would be necessary if double sideband operation had been used. Therefore, it is advisable that the prospective television serviceman study this lesson very carefully."

1. NECESSITY FOR PRECISION IN ALIGNMENT. The various television channels are distributed in the ultra-high radio frequency spectrum as shown in Fig. 1. Most of the present day television receivers are designed to cover just the five lowest frequency channels. Some of the higher frequency channels are used for television relay service and for experimental research. Each channel is six megacycles wide and includes both the picture and the associated sound. The method of utilizing the six megacycles in each channel for the picture and sound is the same for all the channels.

Fig. 2 shows the lowest frequency channel, the one extending from 50 to 56 megacycles. The picture carrier frequency is 51.25 megacycles, which is 1.25 megacycles higher than the low frequency limit of the channel. The sound carrier is 55.75 megacycles, which is .25 megacycle lower than the high frequency limit of the channel. The higher sideband frequencies up to 55.25 megacycles are transmitted without attenuation. Beyond 55.25 megacycles, the output of the transmitter is gradually attenuated, and at 55.75 megacycles, the sound carrier frequency, the output of the picture transmitter is essentially zero. The lower sideband frequencies down to 50.5 megacycles are transmitted without attenuation. Below 50.5 megacycles, the output of the picture transmitter is gradually attenuated so that at 50 megacycles, the lower frequency limit of the channel, the output of the transmitter is essentially zero. Thus, the upper sideband frequencies transmitted for the picture correspond to a top modulation frequency of four megacycles, while the lower sideband frequencies correspond to a top modulation frequency of .75 megacycle. Both sidebands are present for modulation frequencies up to .75 megacycle and just the upper sideband frequencies are present for modulation frequencies from .75 megacycle to 4 megacycles. Both the sound sideband frequencies are transmitted. Sound sideband frequencies corresponding to modulation frequencies of 25,000 cycles or higher can be transmitted.

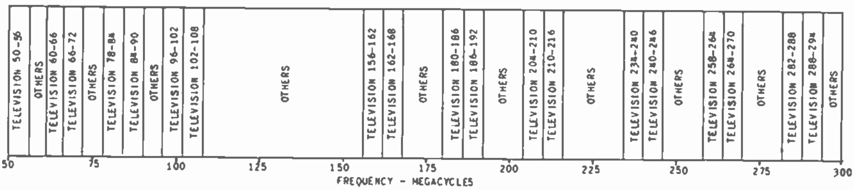


Fig.1 Location of Television Channels in the ultra-high frequency radio spectrum.

In most of the present day television receivers, the picture IF carrier frequency is 12.75 megacycles and the sound IF carrier frequency is 8.25 megacycles. If we make the assumption that the RF section of the receiver passes the entire six-megacycle channel without attenuation at the edges of the channel, the distribution of frequencies in the output of the first detector or mixer will have the form shown in Fig. 3. The picture IF carrier and all of

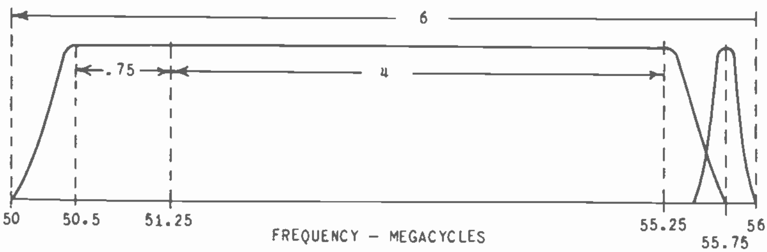


Fig.2 Lowest frequency television channel.

its lower sideband and part of the upper sideband are present. (In the case of the RF carrier, all of the upper sideband was present and part of the lower). This is true, as the oscillator frequency is higher than any of the frequencies in the television channel and the higher RF frequencies produce the lower IF frequencies. The sound IF carrier and its two sideband frequencies are present. There may also be present a 14.25-megacycle sound IF carrier and sidebands if there is a television station operating in the lower adjacent channel to the one to which the receiver is tuned. The sound RF carrier in the lower adjacent channel is only slightly lower in frequency than the lowest frequency sideband of the picture RF carrier in the received channel. Since the two sound RF carriers are six megacycles apart, the sound IF frequency resulting from the lower channel will be 8.25 plus 6, or 14.25 megacycles.

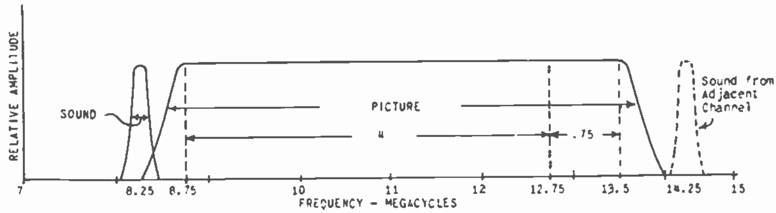


Fig.3 Frequencies in output of first detector.

The output of the second detector for the picture part of the receiver should contain all of the video frequencies with the same relative amplitudes that existed at the transmitter. If the picture IF amplifier passed all the frequencies uniformly that are present in the output of the mixer as shown in Fig. 3, it is quite apparent that the lower video frequencies up to .75 megacycles will have twice the relative amplitude that they had in the original video signal at the transmitter. This is true, because both the IF sidebands are present for modulating frequencies up to .75 megacycle, while only one sideband is present for modulating frequencies above .75 megacycle. The picture RF and IF amplifiers of television receivers are designed to have a frequency characteristic that will make the output of the second detector a replica of the video signal generated at the transmitter. If

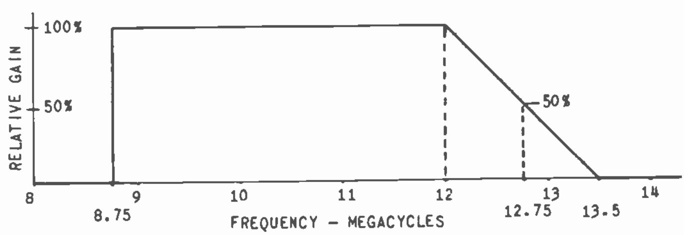


Fig.4 Ideal picture IF response curve.

we again assume that the RF section passes all the frequencies present with uniform gain, the ideal bandpass characteristic of the picture IF amplifier will have the form shown in Fig. 4. The gain is uniform from 8.75 to 12 megacycles and then tapers off to zero at 13.5 megacycles. The gain is down 50% at 12.75 megacycles, the picture IF carrier frequency. The output of the second detector will be uniform over the entire video frequency range, as the total gain for the video frequencies obtained from both sidebands for modulation frequencies below .75 megacycle will be equal to the gain for frequencies obtained from one sideband above .75 megacycle. It is necessary to have a sharp cutoff at the low-frequency end of the IF pass band so that the sound IF frequencies will not pass through the picture IF amplifier and be rectified and applied to the grid of the picture cathode ray tube. You are already familiar with the effects of sound frequencies mixed in with the video frequencies. It is also important that the gain of the picture IF amplifier be extremely low at 14.25 megacycles, the difference frequency between the heterodyne oscillator and the sound RF of the adjacent lower channel.

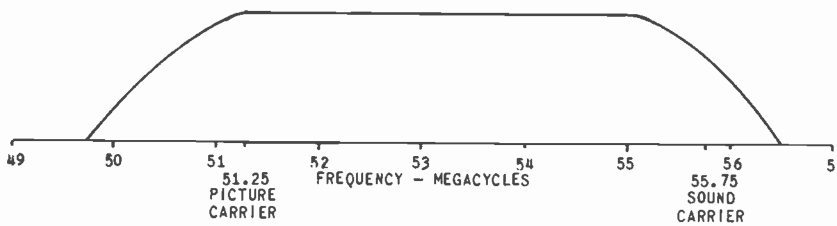


Fig.5 RF bandpass curve for the lowest television channel.

The ideal bandpass characteristic for the picture IF amplifier discussed in the preceding paragraph was based on the assumption that the RF section of the receiver amplified all the RF components in the combined picture and sound signal equally. Actually, the RF circuits in television receivers have less gain at the edges of the six megacycle band than for the central section. A typical RF bandpass curve is shown in Fig. 5 for the lowest frequency television channel. When Fig. 5 is compared to Fig. 2, it is evident that the incomplete sideband is partially attenuated. The attenuation is greater for the frequencies most remote from the carrier frequency. Also, the gain for the sound carrier is less than the gain for the complete picture sideband.

The overall response curve, including both the RF and IF sections of the receiver, must produce a uniform output from the second detector over the entire video band. The overall RF-IF response curve will have the general form shown in Fig. 6. This curve gives the output of the second detector in terms of the RF input to the receiver over any of the television channels. In this case, the gain for the picture carrier frequency is 50% of the gain for the upper sideband frequencies. Since the combined gain for the RF carrier frequency and its resulting IF carrier frequency is down 50%, it is evident that the gain for the IF carrier frequency must be more than the 50% as shown in Fig. 4. The actual gain for the IF carrier frequency depends on the design of the receiver and ranges from 50% to 75% of the gain for the IF frequencies in the center of the pass band. A typical IF response curve is shown in Fig. 7.

The major problem in aligning the IF, RF, and oscillator sections of the picture part of the receiver is to adjust the circuits so that the output of the second detector is uniform over the entire range of video frequencies, and is a replica of the

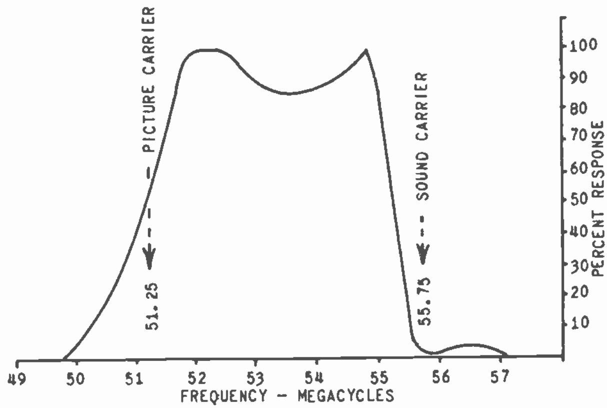


Fig.6 Overall RF-IF response curve.

original signal generated at the transmitter. Also, the picture must be free of sound interference from the associated sound channel or the lower adjacent channel for any of the television channels that the receiver covers. In order to obtain these desirable

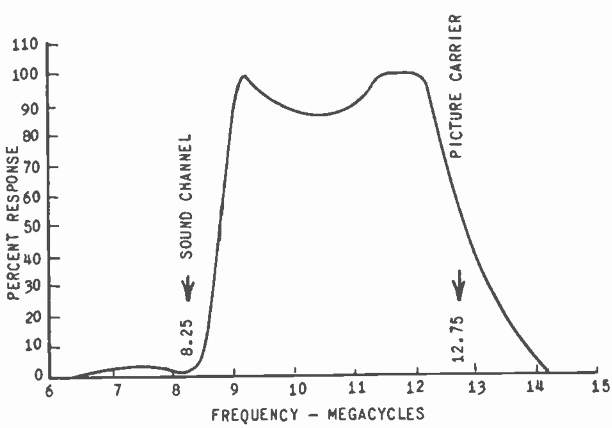


Fig.7 Typical IF response curve.

results, it is necessary to follow the manufacturers alignment instructions exactly. The picture IF amplifier must be aligned so that the response at 12.75 megacycles is correct for that particular receiver. The 8.25 and 14.25 megacycle sound trap circuits must be adjusted with a high degree of precision. Also, the oscillator frequency for each channel must be adjusted to be within 75 kilocycles of its correct value. If the oscillator frequency is off appreciably, the sound IF frequencies will not be 14.25 and 8.25 megacycles and will not be suppressed in the picture IF amplifier. However, if the receiver is designed for picture and sound IF frequencies different from 12.75 and 8.25 megacycles, the frequency limits of the IF pass band will be different. Also, the sound elimination trap circuits will have different resonant frequencies. Therefore, it is extremely important that the serviceman remember that the alignment of the RF, IF, and oscillator sections of television receivers require much higher precision than is normally required in the adjustment of conventional broadcast receivers.

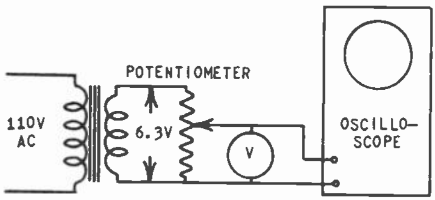


Fig.8 Method for calibrating oscilloscope.

2. APPARATUS REQUIRED FOR ALIGNMENT. A detailed description of all the apparatus for servicing television receivers was given in a previous lesson of this unit. Therefore, it is unnecessary to give complete descriptions of the apparatus needed for aligning television receivers. The equipment required for alignment is listed below:

1. A five inch oscilloscope designed for television applications.

2. A radio receiver covering the range from 7 to 24 megacycles.

3. A frequency-modulated sweep oscillator covering the RF and IF ranges of television receivers.

4. A crystal calibrator, preferably one that has 2000 and 250 kilocycle fundamentals.

5. A standard signal generator covering the range from .1 to 30 megacycles, or preferably a signal generator covering the whole range from .1 to 120 megacycles with a built-in heterodyne detector such as the Signalyst described in a previous lesson.

6. A heterodyne detector, if a signal generator like the Signalyst is not available.

7. A variable bias supply such as described in a previous lesson.

8. Miscellaneous items such as phones, output meter, tools, and assorted condensers and resistances needed for modifying various IF coupling units so that the alignment can be simplified.

3. CALIBRATION OF OSCILLOSCOPE. The signal generator used for setting the frequency limits of the picture IF amplifier must be calibrated more accurately than the dial calibration. It was stated earlier in the lesson that the 8.25 and 14.25 megacycle rejector circuits and the heterodyne oscillator must be set very accurately or else the picture quality will suffer. The other test instrument that requires calibration is the oscilloscope. This is necessary so that the output from the second detectors can be limited to the maximum permissible for minimum distortion in the sound and picture IF amplifiers during alignment.

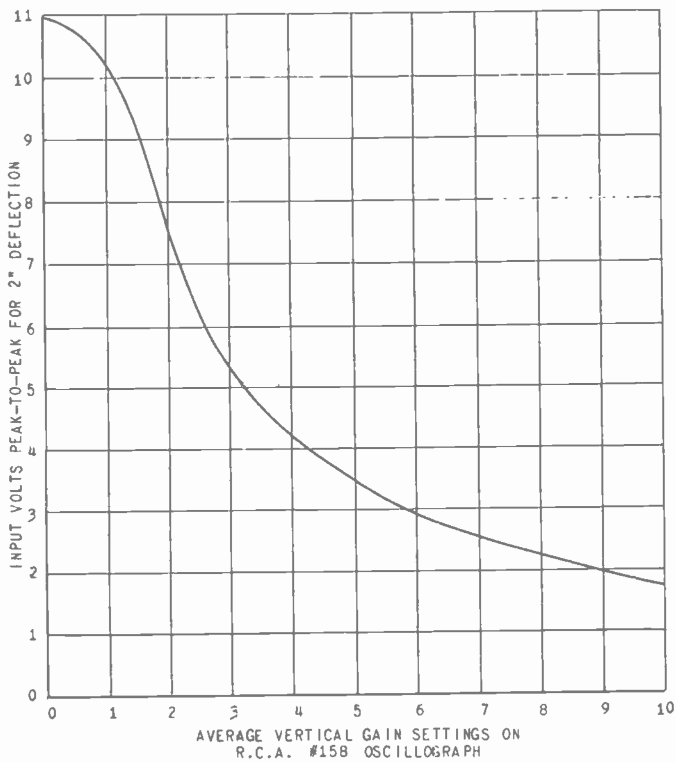


Fig.9 Calibration curve for oscilloscope.

The most convenient way to calibrate the oscilloscope is to record the gain control settings in terms of the peak-to-peak input voltage for a constant amplitude vertical deflection of the cathode ray tube beam. A vertical amplitude of two inches is suitable for a five-inch tube. A calibration covering ranges up to ten to twelve volts peak-to-peak is sufficient for television servicing. Fig. 8 shows a simple method for calibrating an oscilloscope. The AC voltmeter reads the RMS value of the input voltage. The peak-to-peak value is 2.828 times the RMS value. If a peak vacuum-tube voltmeter calibrated in peak voltages is used to measure the input voltage, the peak-to-peak value will be twice the voltmeter reading. First, the potentiometer is set so that the input to the oscilloscope is one volt peak-to-peak and then the gain control is adjusted so that the peak-to-peak amplitude of the sine wave on the oscilloscope screen is

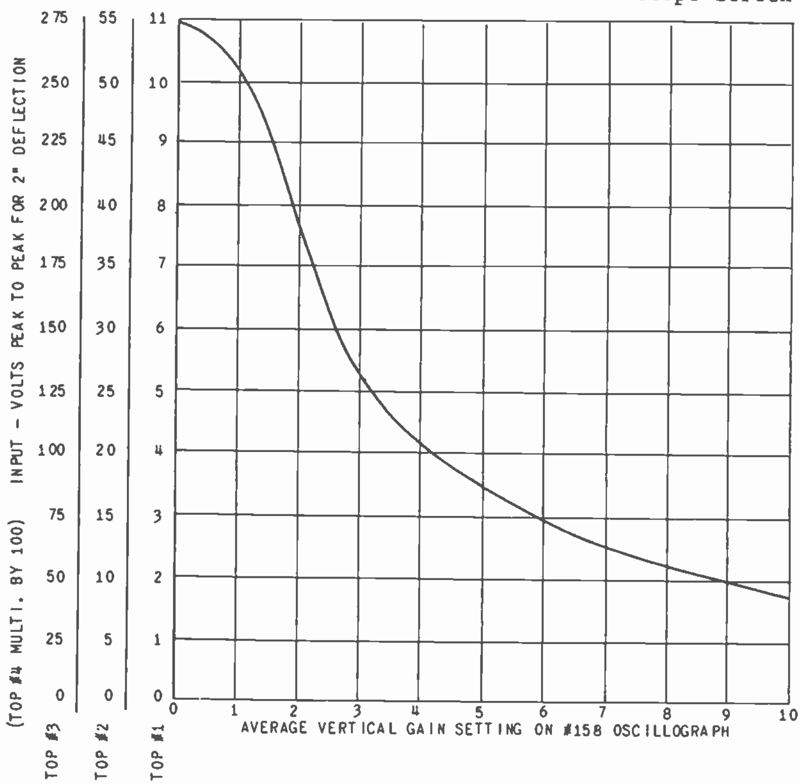


Fig.10 Complete calibration curve for oscilloscope.

two inches. The corresponding gain control setting is recorded. Next, two volts peak-to-peak are fed into the oscilloscope and the gain control again adjusted for a peak-to-peak amplitude of two inches on the screen. This process is repeated in 1-volt steps until the required range is covered. A transparent screen ruled in .2-inch squares and installed in front of the cathode ray tube screen provides a convenient method to measure the amplitude of the deflection. The data is plotted as shown in Fig. 9. With this calibration curve, it is easy to determine the peak-to-peak value of the input voltage to the vertical amplifier. The gain control is adjusted until the peak-to-peak amplitude of the waveform on the oscilloscope screen is two inches. The actual peak-to-peak voltage of the input can then be obtained from the calibration curve.

Oscilloscopes designed for television work (described in a previous lesson), have an input attenuator which changes the attenuation in steps. There is also a gain control which controls the gain of the vertical amplifier continuously over a considerable range. The input attenuator ranges multiply the input by factors of 1, .2, .04, and .01, or factors of proportional magnitudes. These attenuation factors are independent of the gain control settings. It is only necessary to calibrate the gain control for one attenuator range such as that with the multiplying factor 1. The calibration curves for the other attenuator ranges will have the same shape. The input corresponding to each gain control setting for any other attenuator range will be equal to the reading for the range with the multiplying factor 1 multiplied by the reciprocal of the multiplying factor for that range. A much simpler method is to draw a calibration curve on which the voltages corresponding to all attenuator gain control settings are given. (See Fig. 10.)

4. CALIBRATION OF SIGNAL GENERATOR. The signal generator is calibrated against a crystal. Suitable types of crystal standards were described in the lesson on television test equipment. It was stated that a crystal standard having fundamentals of .25 and 2 megacycles was most satisfactory for calibrating signal generators used in television servicing. Therefore, this discussion will be based on the use of such a crystal standard.

The method of calibrating the signal generator is to zero beat the signal generator fundamental frequency against the crystal harmonics. When zero beat exists, the signal generator frequency will be the same as the frequency of the crystal harmonic. When the two frequencies are very close, the difference frequency will be in the audio range. Therefore, a conventional detector feeding an audio amplifier and phones or loudspeaker makes a very convenient method of determining zero beat. As the signal generator frequency approaches zero beat with the crystal harmonic, the audio tone will decrease in frequency. At zero beat, there will be no audio tone. Since the cut-off frequency for most phones or speakers and amplifiers is several cycles, there will be no audible beat for difference frequencies less than 30 to 50 cycles.

An oscilloscope makes a better zero beat indicator than headphones or a loud speaker. A television oscilloscope responds to frequencies out to .5 megacycle and down to 10 to 20 cycles with uniform gain. Thus, the nearness of two frequencies can be detected when they are several hundred thousand cycles apart. As the two frequencies are brought closer together, the amplitude of the vertical deflection will increase until the difference frequency is approximately .5 megacycle. As the difference frequency becomes less and approaches the audio range, the individual sine waves become discernible. Of course, this condition depends on the horizontal sweep frequency of the oscilloscope.

When the difference frequency approaches 20 to 30 cycles, the amplitude of the vertical deflection will decrease and will become zero for frequencies less than the low-frequency cut-off of the oscilloscope. If the varying frequency is changed in the same direction, the difference frequency will increase beyond the zero beat condition and the vertical deflection will again increase. The oscilloscope is especially valuable as a zero beat detector when comparing two high frequencies where a slight adjustment of the tuning control for one frequency causes a large change in that frequency.

Information was given in the lesson on television testing apparatus for building a satisfactory heterodyne detector. A radio receiver, preferably one employing radio frequency amplification only, can be used as a sensitive detector for comparing signal generator frequency with the crystal standard. The receiver must cover the range from 7 to 16 megacycles, and preferably to 25 megacycles. A superheterodyne is unsatisfactory unless it has one or two stages of RF amplification, as the images cause confusion. The RCA Signalyst, a wide range signal generator, described in the lesson on test equipment, has a self-contained heterodyne detector. The input circuit to this detector is untuned. The heterodyne detector is preferable to a receiver as indicating instrument for zero beat.

The frequencies required with a high degree of precision are the picture IF frequency 12.75 megacycles, the 8.25 and 14.25-megacycle sound IF frequencies, the heterodyne oscillator frequencies for the five lowest frequency channels, (64, 74, 80, 92, 98 megacycles). There are other frequencies which must be known accurately in the picture IF range. These frequencies vary for different receivers and are usually given in the alignment instructions for the receiver.

In the first part of this discussion on the calibration of the signal generator it will be assumed that the dial calibration of the signal generator is approximately correct, that is, within 1% to 2%. Later, a method will be described for calibrating the signal generator when its dial calibration is off by several percent.

The detector must be loosely coupled to both the signal generator and crystal standard. The coupling should never be greater than that which will give a definite beat note. If too much signal is applied to the detector, the overloading will result in the generation of many harmonics of the two frequencies. Overloading a circuit causes amplitude distortion which results in the generation of harmonics of the frequencies involved. These additional harmonics cause confusion and make recognition of the true signal generator frequency difficult. Overloading a receiver may bias one of the input stages beyond cut-off and no signal will get through to the detector. The heterodyne detector described in the lesson on television test equipment and the heterodyne detector incorporated in the Signalyst are designed to minimize overloading.

The first step in calibrating the signal generator is to set it to one of the required frequencies such as 8.25 megacycles according to the dial calibration. If a receiver is used as the detector, the receiver is tuned to the signal generator frequency. The signal will have to be tone-modulated, as ordinary receivers are not designed for CW reception. The dial reading of the receiver is noted. Then the signal generator is turned off and the crystal standard output is applied to the input of the receiver. The crystal is made to oscillate with the 2-megacycle fundamental. Crystal harmonics will occur at 6, 8, and 10 megacycles, which are near the approximate signal generator frequency of 8.25 megacycles. The crystal output must also be modulated. Both the RCA crystal standard and the other described in the lesson on television test equipment are provided with means of modulating the crystal output by 60 cycles. The crystal harmonic tuned in on the receiver nearest to the signal generator will be the 8-megacycle harmonic, (assuming the signal generator is accurate within 1%). The receiver dial readings corresponding to the 6 and 10-megacycle harmonics should also be noted. The receiver is retuned to the 8-megacycle harmonic. The signal generator is now turned on again with the output unmodulated. The frequency of the oscillator is varied slightly until zero beat is obtained with the 8-megacycle harmonic of the crystal. The signal generator dial reading is noted. The dial reading corresponding to 6 or 10 megacycles can be found in the same way. The receiver is first tuned to the desired harmonic of the crystal.

The next step is to locate the 8.25-megacycle point on the signal generator. Both the signal generator and receiver are retuned to 8 megacycles. The signal generator is turned off. The crystal is made to oscillate with the .25-megacycle fundamental. Then crystal harmonics will occur at 6, 8, and 10 megacycle and every quarter-megacycle between these points. It was mentioned in the lesson on test equipment that the standard was adjusted most accurately for .25-megacycle mode of oscillation. Therefore, the 8-megacycle harmonics for the two modes of oscillation differ slightly. The receiver will have to be retuned slightly around 8 megacycles to pick up the 8-megacycle harmonic of the .25 fundamental. Since these harmonics are much weaker than the harmonics of the 2-megacycle fundamental, it may be necessary to increase the coupling between the crystal standard and the receiver. As the receiver is tuned over the range from 8 to 10 megacycles, crystal harmonics will be received every .25-megacycle. The first of these harmonics beyond the 8-megacycle point will be 8.25 megacycles. The signal generator is turned on again with the output unmodulated. Its frequency is increased slowly until zero beat is obtained with the 8.25-megacycle harmonic of the crystal. The signal generator dial reading is noted. The signal generator can be calibrated for the other frequencies in the IF range in the same way.

The heterodyne detector described in the lesson on test equipment is the best detector unless a tuned radio frequency receiver covering the range is available. The heterodyne detector is used the same way as the receiver. However, since the heterodyne detector can be made to oscillate, the unmodulated signal generator and crystal standard frequencies can be tuned in by the zero beat method. When tuning the signal generator to zero beat with the crystal frequencies, the heterodyne detector is adjusted so that the regeneration is just below the oscillating state. This is the condition for maximum sensitivity.

The RCA Signalyst, a signal generator designed for television servicing, has a built-in heterodyne detector. This detector is not regenerative. There is a terminal on the signal generator to feed in the crystal frequencies to the detector. There is also available 150 volts DC for the crystal standard. The output of the signal generator oscillator is coupled internally to the heterodyne detector. There is a jack provided for headphones.

The output of the crystal is connected to the RF input of the Signalyst by a *very short lead*. If the RCA crystal standard is used, the link which applies 110 volts AC to the plate of the crystal oscillator is removed and the DC input terminals are connected to the 150 volt DC output of the Signalyst. A set of headphones is plugged into the proper jack. The crystal is made to oscillate with the 2 megacycle fundamental. There will be a beat note produced every two megacycles as the Signalyst frequency is varied over the range of frequencies included in the picture and sound IF bands. Since the crystal harmonics occur at 6, 8, etc. megacycles, the zero beat obtained nearest the 6, 8, etc. points on the dial will be that frequency exactly. This will be true provided the signal generator calibration is within 1%, and the manufacturer of the Signalyst states that the factory calibration is within 1%. The points between the 2 megacycle points can be found by making the crystal oscillate with the .25 megacycle fundamental. For example, the 8.25 megacycle point can be found by increasing the frequency of the signal generator slowly from the exact 8 megacycle point until the first beat note is obtained. If the 12.75 megacycle is required, the frequency of the signal generator is increased slowly from the exact 12 megacycle point until the third beat note is reached. As mentioned previously, the even megacycle harmonics obtained from two modes of oscillation of the crystal do not coincide exactly. Thus, when switching from one mode of oscillation to the other, the signal generator frequency will have to be readjusted slightly to obtain zero beat. The two corresponding frequencies are so close together that there will be no confusion between the nearest quarter-megacycle point and the even harmonic.

Very few signal generators produce fundamental frequencies above 30 megacycles. The Signalyst is the only signal generator available commercially to the serviceman at the time this lesson was written, which went up to 120 megacycles. The high-frequency heterodyne oscillator frequencies for the five lowest frequency television channels are 64, 74, 80, 92, and 98 megacycles. The high-frequency heterodyne oscillator must be set with a high degree of precision or the 8.25 and 14.25-megacycle traps will not prevent the sound signal from getting into the picture signal.

The heterodyne oscillator frequencies are multiples of 2 megacycles. Therefore, they can be obtained from the Signalyst with a high degree of precision by calibrating the Signalyst with the crystal standard.

The high frequency heterodyne oscillator can be adjusted with a good degree of precision by using harmonics of the lower frequencies available from ordinary signal generators. The subharmonics of the heterodyne oscillator frequencies must be chosen so that they can be obtained with a high degree of precision; that is, they must be a harmonic of either .25 megacycle or 2 megacycles, the two fundamentals of the crystal standard. Since the .25 megacycle crystal frequency has the smaller error, it should be used if possible in calibrating the signal generator.

HETERODYNE OSCILLATOR FREQUENCY	HARMONIC OF SIGNAL GENERATOR FREQUENCY				
	4th	5th	6th	7th	8th
64	16.00				8.00
74	18.50				9.25
80	20.00	16.00			10.00
92	23.00				11.50
98	24.50			14.00	12.25

FIG. 11

Fig. 11 is a table giving suitable signal generator frequencies whose harmonics can be used for setting the high frequency heterodyne oscillator frequencies. These signal generator frequencies are harmonics of either the .25 megacycle or 2 megacycle fundamental crystal frequencies. These frequencies can be obtained from the signal generator with the required precision by following the methods previously given.

The calibrating equipment should form an integral part of the alignment setup. The signal generator frequency should be determined by the crystal standard each time a new frequency is required, rather than depend on calibration made before the start of the alignment. This will minimize the error caused by the signal generator drift and line voltage variations. It is a good policy to let the test equipment warm up for fifteen to twenty minutes before beginning the alignment.

If the dial calibration of the signal generator is off by several percent, the crystal with fundamentals of .25 and 2 megacycles cannot be used for checking the calibration. When this condition exists, it is advisable to adjust the signal generator so that the dial calibration is within one percent. This can be done by using another signal generator whose dial calibration is within one percent in conjunction with the crystal standard as a source of known frequencies. A heterodyne detector is used to compare the known and unknown frequencies.

If a signal generator of known calibration is not available, there is another method, and that is to use radio stations whose frequencies are known as the standard. In this case, a receiver will have to be used as the heterodyne detector. One station that is very suitable for this application is WWV. This station is operated by the Federal Government as a frequency standard. Its frequency is 5 megacycles. Harmonic frequencies can be obtained by keeping an oscillator with a frequency of 5 megacycles in zero beat with the frequency of WWV. The harmonics of this oscillator in conjunction with a separate heterodyne detector can be used to check the 5, 10, 15, etc. megacycle points on the signal generator. The intermediate points can be obtained by the use of the crystal standard.

5. GENERAL ALIGNMENT PROCEDURE. The serviceman should, before making any adjustments on television receivers, disconnect the primary to the high voltage transformer and connect the high voltage output to ground. The high voltage circuits in television receivers are dangerous, and accidental contact with such circuits may result in very serious injuries to the serviceman.

The steps in proper order for aligning television receivers are as follows:

1. Align the sound IF amplifier.
2. Adjust the 8.25 and 14.25 megacycle sound IF traps or rejector circuits in the picture IF amplifier.
3. Align the picture IF amplifier.
4. Recheck the rejector circuits in the picture IF amplifier.
5. Align the RF heterodyne oscillator.
6. Align the RF circuits.
7. Recheck the RF heterodyne oscillator adjustments.

This is the general procedure for the correct alignment of television receivers and may be modified slightly by different manufacturers.

Before beginning the alignment of a television receiver, it is necessary to remove the vertical and horizontal sawtooth oscillator tubes, the high frequency heterodyne oscillator tube, and the AVC amplifier tubes, or make the AVC circuits inoperative. Before removing the sawtooth oscillator tubes, be sure that the high voltage is completely disconnected, as the cathode ray tube screen can be ruined if the beam remains stationary on the screen. It is necessary to remove the sawtooth oscillators, as the field radiated by them may cause trouble in obtaining correct alignment of the IF amplifiers. Removal of the high-frequency heterodyne oscillator prevents the possibility of interfering signals in the IF range from being applied to the input of the IF amplifiers. The AVC circuits must be inoperative during alignment, as the response curve obtained by a frequency-modulated oscillator and oscilloscope will be affected by the AVC action.

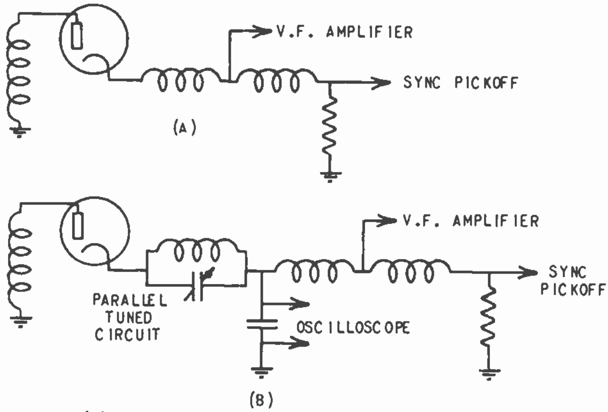
The bias box mentioned in a preceding paragraph of this section is used to supply fixed bias to the IF amplifier stages, both picture and sound. The positive side is connected to the chassis and the negative leads are connected to the sound and picture AVC leads. If the receiver is not equipped with AVC operation, the bias box is unnecessary. In many cases, the manufacturer will specify the bias that should be used on the IF amplifiers when aligning each stage. This is necessary to prevent overloading some of the amplifier stages, as overloading will distort the response curve. The shape of the response curve is affected somewhat by the amount of bias, as the input capacity of high transconductance tubes changes slightly with changes in DC plate current. Since the IF coupling units are inductively tuned, slight changes in the input capacity of the tubes will modify the shape of the response curve.

The IF amplifiers can be overloaded by feeding in too much signal from the frequency-modulated sweep oscillator. The output from the picture detector should not exceed four to five volts peak-to-peak. It is advisable to keep the output from the sound second detector below two to three volts peak-to-peak.

It is necessary to connect bypass condensers across the outputs of both the sound and picture second detectors, especially the picture second detector. A capacity of 250 mmfds. is suitable for the sound, and a capacity of around 4000 mmfds. is satisfactory for the picture. A good rule to follow in selecting the correct size condenser for the picture second detector is to select a condenser so that the time constant of the second detector load circuit will be approximately 16 microseconds. Thus, a capacity of 4000 mmfds. is suitable to use with a second detector load resistance of 4000 ohms. This condenser is necessary so that the impedance presented to the high frequency components in the detector output will be low and thus minimize the opportunities for feedback and oscillation during alignment. It also prevents the detector filter from affecting the IF response curve. One important thing to remember is that these condensers must be connected across the output of the detector tube before the IF frequency filter. If the condenser is connected across the resistance load direct, the filter will modify the IF response curve obtained on the oscilloscope. The cut-off point of the filter, which is around 8 megacycles, will insert a nick in the response curve. Thus, it is important to place this condenser before the filter. It is also advisable to connect the oscilloscope across the same place. There is another reason for the use of this condenser, which will be given in the discussion on marker frequencies.

6. MARKERS. There are two general ways used to determine the location of frequencies in the response curve of amplifiers traced on the oscilloscope screen when a frequency-modulated oscillator and oscilloscope are used for alignment. One of these is to insert a parallel-tuned circuit or wave trap in the second detector output. This tuned circuit must precede the bypass condenser connected across the input to the detector filter as

described above. The insertion of this tuned circuit is shown in Fig. 12. The tuned circuit has a frequency range of about 7 to 16 megacycles. The trap must be very accurately calibrated. This circuit has a high impedance at its resonant frequency, and inserts a notch in the response curve traced on the oscilloscope



(A) Conventional television second detector.
(B) Second detector modified for IF alignment.

Fig.12 Using a tuned circuit to check frequency limits of IF response curve.

screen. This notch shows the location of the resonant frequency of the tuned circuit in the IF response curve. This is illustrated in Fig. 13. The notch can be moved over any part of the response curve by changing the resonant frequency of the tuned circuit. This method is not recommended to the serviceman, as he lacks facilities for calibrating the tuned circuit with sufficient accuracy for television alignment. One method of reducing the calibration difficulty is to use several fixed tuned

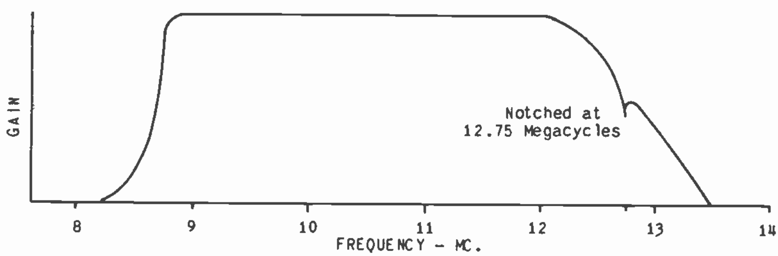


Fig.13 Notch in response curve caused by tuned circuit.

parallel circuits in series. Each circuit is tuned to a different frequency. The frequencies selected are the important frequencies in the picture IF response, such as 12.75, 8.75, 12, etc. megacycles. Using several parallel-tuned circuits complicates the alignment considerably.

The simpler, and preferable method is to inject a fixed frequency in the picture IF band from a signal generator into the same point of the IF amplifier that the output of the frequency-modulated sweep oscillator is injected. The fixed frequency and the frequency-modulated signal produce a variable beat frequency in the output of the second detector. This beat frequency will be zero when the varying frequency passes through the fixed frequency. In an earlier paragraph, it was stated that a bypass condenser was connected across the output of the second detector for aiding alignment procedure. This condenser, in combination with the detector load resistance, forms the load impedance for the detector. The impedance of this combination is essentially zero for all frequencies except those in the audio range. The impedance is maximum for zero frequency. Thus, when the variable frequency approaches zero beat with the fixed frequency, there will be a varying audio frequency superimposed on the IF response curve traced on the oscilloscope screen. The amplitude of this variable audio frequency will be maximum as it approaches zero. Since the range of frequencies covered by a left to right sweep of the oscilloscope is several megacycles, the individual audio frequency cycles are not distinguishable, and the audio beat appears as a widening of the line on the oscilloscope screen. The width will be maximum at zero beat. This is illustrated in Fig. 14.

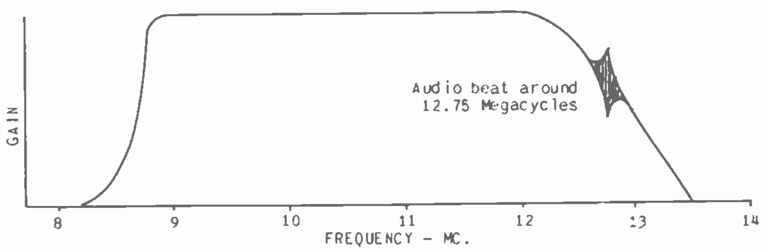


Fig. 14 Frequency marker on response curve.

If the fixed frequency is 12.75 megacycles, maximum amplitude of the audio beat will occur at the 12.75 point on the IF response curve. The audio beat or marker can be shifted over the entire IF response curve by changing the fixed frequency. The amplitude of the fixed frequency injected into the IF amplifier should be the minimum that will produce a discernible marker. A marker like that in Fig. 14 indicates that the amplitude of the fixed frequency is too large. The fixed frequencies must be determined with a high degree of precision by the methods previously outlined.

7. SOUND IF ALIGNMENT. The sound IF amplifier can be aligned either by the use of a tone-modulated signal generator and an output meter or by a frequency-modulated oscillator and

an oscilloscope. In the first method, an output meter (rectifier type or vacuum-tube type AC voltmeter fed through a condenser), is connected across the output of the audio system and a tone-modulated signal of the IF frequency is fed into the input of the sound IF amplifier. The tuning adjustments are set for maximum output. This method is well known to all servicemen.

The preferable method is the second method, as the exact shape of the IF response curve can be observed. In the second method, an oscilloscope with good low frequency characteristics is connected across the second detector load. The output of the frequency-modulated oscillator is adjusted so that it sweeps through the sound IF frequency, and is applied consecutively to the inputs of the various sound IF stages beginning with the last stage first. The tuning adjustments on the various coupling transformers are set for the required bandwidth and selectivity with the IF frequency at the center of the pass band.

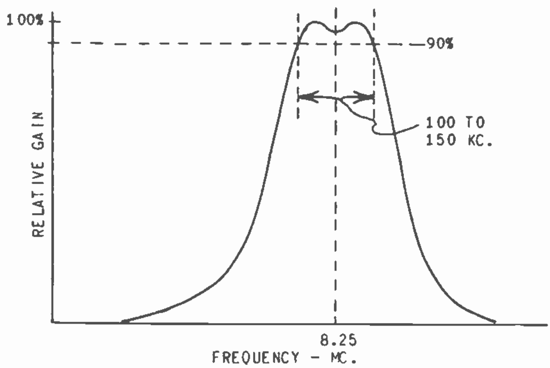


Fig.15 Typical sound IF response curve.

Fig. 15 is a typical sound IF response curve. The bandwidth of the sound IF amplifier ranges from 100 to 150 kc. For high fidelity reception, a bandwidth of 20 kc. is sufficient. The sound IF in television receivers must be considerably wider than this so there will be no sideband clipping in the sound IF amplifier, caused by normal drift of the high frequency heterodyne oscillator. Methods of determining the frequency corresponding to any part of the pass band by means of markers have already been described.

8. TRAP CIRCUIT ADJUSTMENT. The next step is the adjustment of the 8.25 and 14.25 megacycle rejector or trap circuits in the picture IF amplifier. The method to be used depends on the number of rejector or trap circuits in the amplifier. When the receiver contains two rejector circuits, one for each frequency, the simplest method is to connect a high impedance DC

voltmeter, (at least twenty thousand ohms per volt), across the second detector load for the picture section and feed a signal of the frequency to be rejected into the input of the amplifier; that is, the grid of the mixer. The rejector circuit is adjusted until the output across the detector load is a minimum. A more sensitive method is to use a radio receiver which tunes to the rejector frequencies as the indicating device. The input to the receiver is connected between plate and ground of the last picture IF amplifier. A sensitive DC voltmeter is connected across the second detector load of the receiver. The receiver is tuned to the frequency to be rejected, and the corresponding rejector circuit is adjusted for a minimum indication of the DC meter across the second detector load. This method may be necessary when more than one rejector circuit for each frequency is used, as the adjustment of the second circuit of either frequency will not produce much change in the reading of a DC voltmeter connected across the picture second detector. These rejector or trap circuits must be adjusted very accurately and accordingly the frequencies used for the adjustment must be within .05 percent of the correct value.

Some manufacturers recommend that the rejector circuits be set during the alignment of the associated picture IF amplifier stage. The method of adjusting the rejectors is the same except that the test frequency is injected into the grid of the stage under adjustment.

9. PICTURE IF ALIGNMENT. The picture IF alignment is much more complicated than the sound IF alignment. Each stage must be aligned correctly or the overall response will not have the correct shape, bandwidth, and frequency limits. Each stage will have at least two adjustments, one which controls the center frequency of the band and the other the shape and bandwidth. Of course, some of the stages have in addition adjustments for the rejector circuits.

There is only one simple and satisfactory method to align the picture IF amplifier, and that is to use a frequency-modulated oscillator in conjunction with an oscilloscope. The oscilloscope is connected across the second detector load and its input is shunted by a suitable capacity as mentioned previously. The IF output of the frequency-modulated oscillator is injected into the grid of the last IF amplifier tube. The output of the signal generator is injected into the same grid. The signal generator produces the markers for calibrating the IF response. If the frequency-modulated alignment oscillator described in a preceding lesson of this unit is used, the horizontal sweep for the oscilloscope is obtained from the oscillator. The sweep has the same frequency as the frequency of modulation of the alignment oscillator (60 cycles). If another type of television alignment oscillator is used, the horizontal sweep may be the linear sweep of the oscilloscope synchronized with the frequency of modulation of the alignment oscillator.

When the last stage of the IF amplifier has been adjusted to have the bandwidth and frequency limits given by the manufacturer, the outputs of the alignment oscillator and the signal generator are transferred to the grid of the next to the last IF stage and this stage is adjusted until the combined response curve of the last two stages fulfills the manufacturer's specifications. The process is continued until the entire IF amplifier has been adjusted. When aligning the coupling unit following the mixer, it is necessary to disconnect the grid of the mixer from the RF coupling unit; otherwise, the RF coils will short the output of the alignment oscillator. In some cases, this can be done by setting the television channel selector switch between two sets of contacts. In other cases, the grid lead must be removed. Of course, the grid circuit must be completed through a temporary grid leak. The auxiliary bias supply, if used, is set at the value recommended by the manufacturer for each stage. The overall characteristic will be like that shown in Fig. 7. The IF response curves obtained in the alignment of the IF amplifier of a commercial television receiver are given later in this lesson. If it is impossible to obtain a response curve quite similar in shape and gain to that given by the manufacturer when aligning a stage, it may mean that that particular coupling unit is defective and needs replacing. Before assuming that a coupling unit is defective, it is advisable to check all the other components in that particular circuit.

Minor deviations in the overall curve from the required curve can often be rectified by small readjustments of the individual stages. This adjustment is made while viewing the overall curve. If readjustment results in lower gain than that required by the alignment specifications, it is necessary to realign the amplifier beginning with the last stage in the method described. It is important that the 12.75 megacycle point be located at the right level on the slope of the pass band. If it does not, the entire amplifier must be re-aligned. The last two stages have the greatest effect on the location of the 12.75 megacycle point.

During the alignment, the output of the frequency-modulated oscillator must be kept sufficiently low so that the output from the picture second detector does not exceed four to five volts peak to peak. The RCA alignment oscillator previously described has two outputs, a high and a low. If the low output is still too large, it is necessary to add an external attenuator to reduce the output. The simplest and most satisfactory attenuator can be made by connecting a 1000-ohm and a 10-ohm resistor in series across the low output of the alignment oscillator. The 10-ohm resistor is placed on the ground side and the signal developed across the 10-ohm resistor is fed into the picture IF amplifier. These resistors should be ½-watt or smaller to minimize capacity loading. An ordinary potentiometer does not make a good attenuator at these frequencies because it will have a frequency characteristic due to the capacities existing between the component parts. If fixed bias, such as the auxiliary bias supply, is used for the tubes in the IF amplifier, it is necessary to feed the output of the alignment oscillator through a small condenser (.001 mfd.). Otherwise, the output circuit of the oscillator will short out the bias supply.

Leads connecting all the apparatus used in the alignment must be kept as short as possible to minimize feedback and tendencies toward oscillation in the picture IF amplifier. It is advisable to connect all the equipment, including the receiver, to a good ground.

In some cases, depending on the design of the coupling units, alignment is simplified by additional resistance loading of the coupling units and by changing the coupling in the units through the use of temporary external capacities. The alignment instructions for a given particular receiver will specify the temporary changes to be made. Sometimes alignment is simplified by disconnecting the grid lead from the coupling unit preceding the stage under alignment. If the grid circuit of the stage under alignment is completed through the coupling unit a temporary grid return must be provided. A 500-ohm resistor will serve.

Television receivers having 5-inch cathode ray tubes or smaller do not have as wide an IF band as the receivers with larger cathode ray tubes. The smaller cathode ray tubes are not capable of giving full 441-line resolution, as the spot size is too large. The IF band in such receivers usually has a width between 2½ to 3 megacycles. In these receivers the high frequency side of the IF band will have the same frequency requirements as the larger receivers. The gain at 12.75 megacycles will be 50% to 75% of the gain in the center of the band. The low frequency cut-off will occur at 10.5 to 9.75 megacycles instead of 8.75 megacycles. In some of these receivers, the low frequency cut-off is sufficiently sharp that 8.25 megacycle rejectors are not required. These receivers have fewer IF stages, as the gain per stage is greater for narrower bandwidths.

The bandwidth in IF amplifiers narrow as the alignment proceeds from the second detector back toward the mixer. This is to be expected, as the selectivity of any amplifier to frequencies near the edges of the pass band increases as the number of stages increases, even though the characteristics of all the stages are identical. This means that the relative gain for 12.75 megacycles will be near the maximum for the first stage aligned. As the alignment proceeds, the gain at 12.75 megacycles becomes less, relative to the average gain over the pass band. The 12.75 megacycle point moves down the slope of the response curve.

The next step in the alignment of the picture IF amplifier is to recheck the 8.25 and 14.25 megacycle rejector or trap circuits. This is necessary, as there is some unavoidable interaction between the adjustment of the rejector and picture IF band circuits.

10. RF HETERODYNE OSCILLATOR ALIGNMENT. The next stage in the alignment is the adjustment of the high frequency heterodyne oscillator. Most television receivers cover the five lower frequency television channels. Tuning is accomplished by means of

a switch which selects the proper oscillator and RF constants for the desired channel. Usually, a fine oscillator control is provided which permits shifting the oscillator frequency about 150 kc. above or below the correct frequency. The oscillator frequencies for the five lowest television channels are 64, 74, 80, 92, 98 megacycles.

If the serviceman owns a signal generator like the Signalyst, the problem of high frequency oscillator alignment is quite simple, as this signal generator has a frequency range up to 120 megacycles, and it has a self-contained heterodyne detector. The Signalyst is tuned to the heterodyne oscillator frequency for the channel under alignment by means of the crystal standard as previously outlined. Then some of the energy from the receiver oscillator is applied to the RF input on the Signalyst by placing a short length of wire connected to the RF input terminal on the Signalyst near the receiver chassis. The crystal calibrator is turned off and the receiver oscillator is tuned to zero beat by means of its adjusting padders. The crystal is turned on and the Signalyst is detuned by a few megacycles so that it no longer beats with the receiver oscillator frequency. There will be an audio beat between the crystal harmonic and the receiver oscillator. By a slight readjustment of the receiver oscillator padder, the receiver oscillator can be tuned to zero beat with the crystal harmonic. All of the receiver oscillator frequencies can be set in the same way. While making these adjustments, the fine oscillator control should be set about half way in its range; that is, so that the oscillator frequency can be varied the same number of kilocycles above or below the correct frequency by means of the fine tuning control.

The other method of adjusting the receiver heterodyne oscillator frequencies when a wide range signal generator is not available, is considerably more complicated. In this case, harmonics of the oscillator frequency must be used. Also, the serviceman does not possess a heterodyne detector or receiver suitable for comparing these high frequencies. Two heterodyne detectors are actually needed; one to check the signal generator fundamental frequency against the proper crystal harmonic, and the other to compare the receiver oscillator frequency with the correct harmonic of the signal generator.

An ordinary radio receiver covering the required range or the heterodyne detector described in the lesson on television test equipment can be used for checking the signal generator frequency. The simplest heterodyne detector to use for comparing the receiver oscillator and the signal generator harmonics in the first detector of the receiver under alignment. The plate circuit of the first detector or mixer must be modified for this application, as the plate load is tuned to the picture IF frequency range and offers negligible impedance to the audio frequencies produced when the input frequencies are approximately the same. The simplest method of obtaining a plate load which offers an appreciable impedance to audio frequencies is to insert a 100,000 ohm resistor in the plate lead next to the plate terminal of the mixer tube socket. A television oscilloscope connected from the plate of the mixer to ground can be used to detect the zero beat condition.

The method of alignment is as follows: The output of the signal generator is fed into the RF input to the receiver. The signal generator is tuned to a frequency by means of the crystal standard and heterodyne detector that has a harmonic equal to the receiver heterodyne oscillator frequency for the channel under alignment. The fine tuning control on the receiver oscillator is set in the middle of its range. The receiver oscillator padder is *slowly* changed until zero beat is obtained. Since the oscilloscope response is flat to .5 megacycle and falls off slowly beyond .5 megacycle, the approach to the zero beat condition can be detected quite readily.

If it is impossible to align one or more of the oscillator frequencies to the correct value, it is probable that there is a defective component in the circuit. This can be located by the conventional methods. Changing the oscillator tube may require realignment of the oscillator frequencies, as the change in tube capacities may detune the oscillator beyond the range of the fine tuning control. The serviceman should never move the oscillator inductances or leads, as the circuit constants may be shifted beyond the range of the padders to tune the oscillator frequencies to the correct values. This is especially true of the highest frequencies, as the oscillator tank usually consists of a single turn. The receiver chassis must be supported during alignment in such a way that there are no twisting strains on it. This bending or twisting will affect the oscillator alignment, as it will change the circuit capacities from the values when the chassis is unstressed.

11. RF ALIGNMENT. The next step in the alignment is to adjust the RF circuits so that the overall frequency characteristic from the antenna to the output of the second detector has the required form. The gain for the picture carrier must be 50% of the gain over the flat section of the combined RF and IF response.

The apparatus required for the RF alignment is the same as that required for the IF alignment. The receiver modifications are the same except that the high frequency heterodyne oscillator must be in operation. The RF output of the frequency-modulated alignment oscillator is applied to the input to the receiver. Since the input to a television receiver is balanced against ground, the coupling network between the alignment oscillator and the input must be designed for a balanced input. The AVC circuits are made inoperative and the required fixed bias from an external source is applied to the amplifiers.

The location of the RF carrier in the combined RF and IF response curve can be determined by injecting a marker frequency either into the RF input to the receiver or into the picture IF amplifier. When injected into the RF input, the marker frequency is equal to the RF carrier frequency for the channel under alignment. When injected into the IF amplifier, the marker frequency is equal to 12.75 megacycles, the picture IF frequency. When the latter method is used, it is essential that the signal generator supplying the marker frequency does not load the section of the IF amplifier where the marker frequency is injected. If loading occurs, the IF curve becomes distorted. Perhaps the best method of injecting the IF marker frequency is to place a lead connected to the signal generator output near the output circuit of the mixer or first detector. This lead must be short so that it will not cause coupling between the input and output of the amplifier.

The RF marker can be used conveniently only when a signal generator such as the Signalyst is available. All the RF carrier frequencies, 51.25, 61.25, 67.25, 79.25, and 85.25 are not multiples of frequencies which are multiples of the .25-megacycle mode of oscillation of the crystal. Therefore, it is not practical to use harmonics of lower frequencies as the RF marker frequencies. It is not convenient to calibrate the Signalyst, as the high-frequency harmonics of the .25-megacycle crystal frequency are too weak. However, the Signalyst can be calibrated by the 2-megacycle harmonics over the RF range and the dial positions corresponding to the RF carriers estimated quite closely.

The padders on the RF tuning units are adjusted so that the RF carrier has the correct location on the response curve and that the gain is uniform over the entire band. The receiver oscillator fine tuning control should be in the center of its range.

If it is impossible to align any of the RF bands correctly, the RF tuning unit is defective and must be replaced. On some designs of RF coupling units, the spacing between the primary and secondary coils must be within .02-inch of the correct value or the response curve of the unit is unsatisfactory. Changing of this spacing is an occasional source of alignment trouble. When such a condition arises, the best solution is to replace the unit.

After the RF circuits have been aligned, it is advisable to recheck the alignment of the RF heterodyne oscillator. There is some reaction between the RF and oscillator circuits in most receivers.

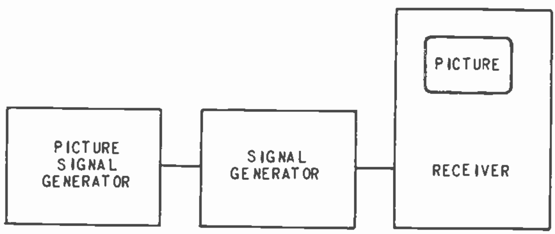


Fig.16 Method of checking overall receiver operation.

12. OVERALL CHECK OF RECEIVER PERFORMANCE. The overall operation of the receiver should be checked after alignment is com-

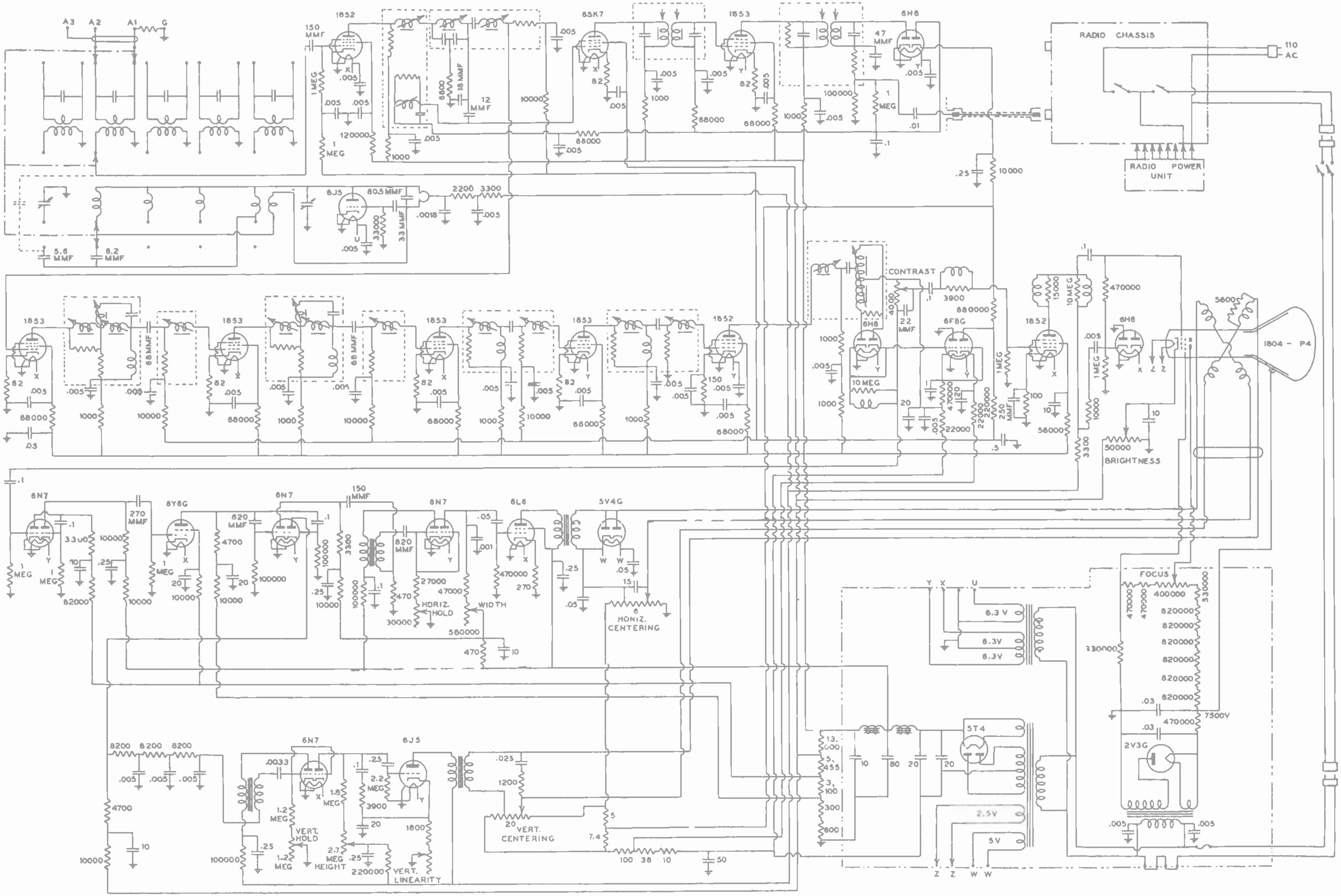


Fig. 17 Circuit diagram of RCA Victor TRK-9 television receiver.

pleted and the necessary repairs made to the video, sync, and deflection circuits either by tuning in a television station or by modulating the output of a signal generator like the Signalyst with a complete video signal that can be generated by one of the picture signal generators described in the lesson on test equipment. A block diagram of the setup for the second method is shown in Fig. 16. The generator frequency is set to the picture carrier frequency of one of the television channels by the methods previously outlined. The output of the picture signal generator is applied to the external modulation input on the signal generator. The balanced output of the signal generator is connected to the RF input to the receiver. The output of the picture signal generator is adjusted to give between 50% and 90% modulation. The picture is tuned in on the receiver in the conventional way. If the receiver is in perfect operating condition, the picture will be reproduced satisfactorily. The operation on all the television channels can be checked in the same way.

If another signal generator is available, it can be tuned to the sound RF carrier and its output modulated with an audio tone. In this way the combined picture and sound operation of the receiver can be checked.

13. ALIGNMENT OF THE RCA VICTOR MODEL TRK-9 TELEVISION RECEIVER. The remaining part of the lesson will be devoted to a description of the alignment of the two television receivers; one the RCA Victor Model TRK-9, and the other a receiver built of components available to the home constructor. Much of the following material has been taken from the alignment instructions supplied by the RCA Manufacturing Company and the F. W. Sickles Company.

The RCA Victor Model TRK-9 is a combination television receiver and an all-wave broadcast receiver. The following alignment instructions cover only the television section, as all-wave receiver alignment is not a new subject to the serviceman. A complete circuit diagram of the TRK-9 is given in Fig. 17.

The alignment apparatus used in the following discussion is that developed and manufactured by the RCA Manufacturing Co. These are the Stock No. 161 signal generator (Signalyst), the Stock No. 159 Television Alignment Oscillator, the Stock No. 157 Crystal Calibrator, and the Stock No. 158 Oscilloscope. This is the only television receiver alignment apparatus available at the time this lesson was written.

The first step in alignment is to remove the television receiver chassis and power supply from the cabinet. The cathode ray tube (Kinescope) and the all-wave receiver are left in the cabinet. The television chassis should be mounted in a frame as shown in Fig. 18. This frame must support the chassis so that there are no twisting forces applied to the chassis. This is necessary to prevent changing circuit capacities, expecially in the high frequency oscillator. The primary leads to the high-voltage transformer are disconnected and the high voltage output grounded. *The ground lead must be connected to the chassis first* *to prevent the possibility of a shock.* The following tubes are removed from the chassis: 6F8G AVC amplifier tube #9, 6N7 vertical oscillator and discharge tube #19, 6N7 horizontal oscillator and discharge tube #22, and 6J5 high frequency oscillator tube #2.

The positive lead of the bias box is connected to the chassis. One negative lead is connected to the picture AVC line (junction of R51 and C57). The other negative lead is connected to the sound AVC line (junction of R73 and C73).

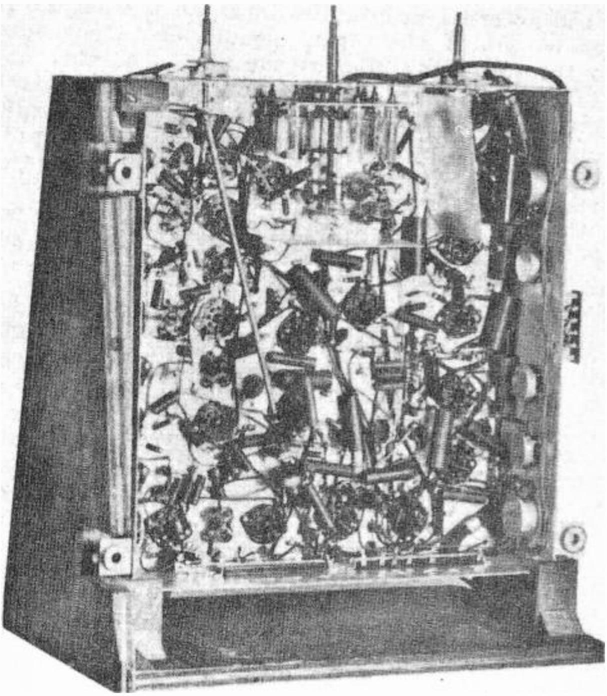


Fig.18 Television chassis mounted for alignment.

A 250 mmfd. mica condenser is connected from the junction of R72 and R73 to ground (sound second detector circuit). A 4000 mmfd. paper condenser is connected from the cathode of the picture second detector to ground.

The sound IF is aligned first. Fig. 19 is a block diagram of the receiver and apparatus required for the IF alignment. The vertical input to the oscilloscope #158 is connected from the junction of R72 and R73 to ground (sound second detector output). The horizontal sweep for the oscilloscope is obtained from the alignment oscillator. The output of the signal generator #161 and the sound IF output of the alignment oscillator #159 are fed into the grid of the tube ahead of the circuits under alignment.

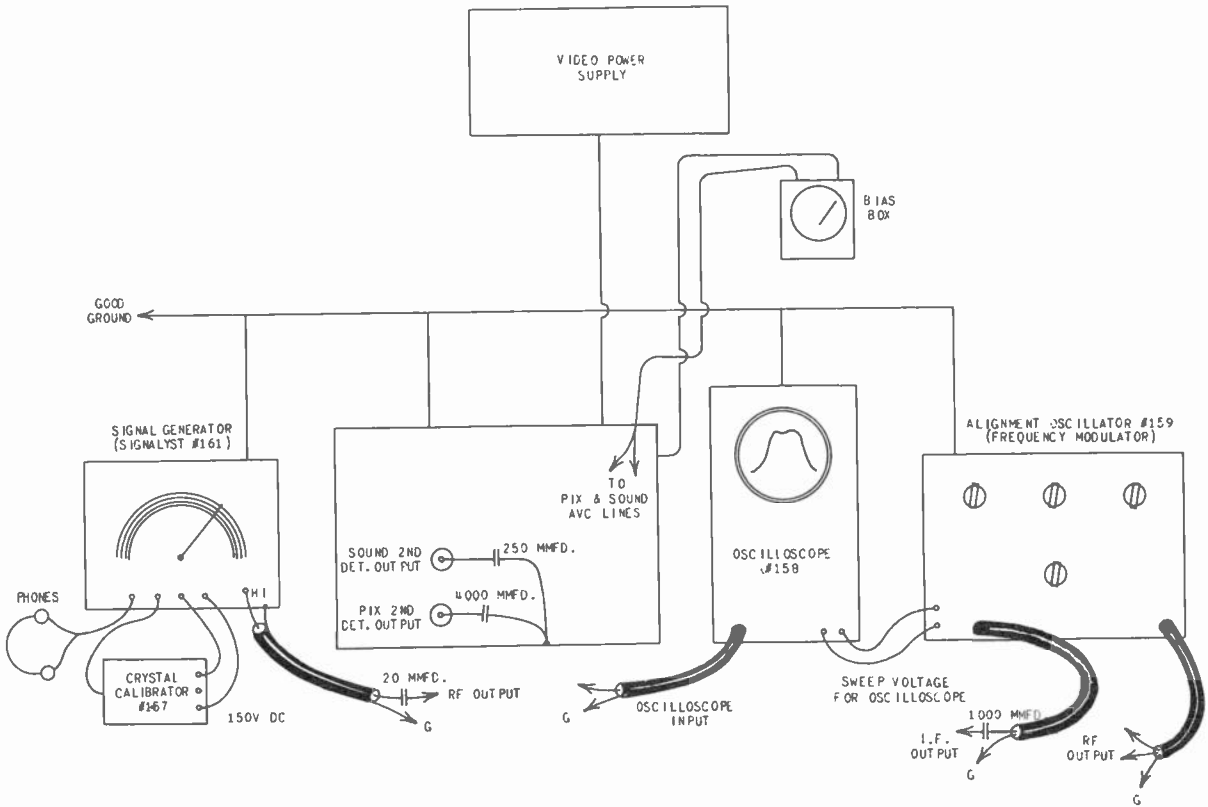


Fig.19 Block diagram of layout for IF alignment.

The high output of the signal generator is used for introducing the marker frequency. The output of the signal generator is applied to the grid of the tube through a small condenser (5 to 20 mmfd.). Just enough of the marker frequency is injected into the amplifier to produce a distinct marker. The marker frequency for the sound IF alignment is 8.25 megacycles. The alignment oscillator has two outputs marked Hi and Lo. The low output is one-tenth of the high. The correct bias for each step in the alignment is controlled from the bias box. The station selector switch on the receiver is set between bands 4 and 5. This is to disconnect the mixer from the RF and oscillator coils.

ALIGNMENT ORDER	SOUND IF TRANSFORMER NUMBER	#159 SWEEP OSCILLATOR ATTENUATOR OUTPUT	#159 SWEEP OSCILLATOR CONNECTION	ADJUST	LOCATION
1	2ND	HI	GRID OF RCA 1853 2ND SOUND IF TUBE #14	L48 . L47	TOP BOTTOM
2	1ST (1 & 2)	LO	GRID OF RCA 6SK7 1ST SOUND IF TUBE #13	L46 L45	TOP BOTTOM
3	1ST DET. (1ST DET., 1 & 2)	LO WITH ATTENUATOR	GRID OF RCA 1852 1ST DET. TUBE #2	L18	P1 BOTTOM

FIG. 20

Fig. 20 is a table giving the order of sound IF alignment, the correct input point for the alignment oscillator #159, the amplitude of the output of the alignment oscillator, and the number and location of the adjustments for each stage. Fig. 21 is a table showing the proper response curve to be obtained from each stage, the bias to be used in aligning that stage, and the alignment oscillator output amplitude. The attenuator and gain control settings on the #158 Oscilloscope for a 2 volt peak-to-peak input are given. The correct location for the 8.25 megacycle marker is shown. An additional attenuation of the alignment oscillator output is required when aligning the sound IF section of the first detector or mixer circuit. The description of a suitable attenuator is given in Fig. 21.

Referring to Figs. 20 and 21, the second sound IF stage is aligned for a symmetrical curve and maximum gain with the 8.25 megacycle marker in the center. Then the first IF stage is aligned for a combined first and second symmetrical IF response of maximum gain with the 8.25 megacycle marker in the center. Then the sound secondary on the first detector is aligned to secure a symmetrical curve and maximum gain with the 8.25 megacycle marker in the center. After this last adjustment has been made, the trimmers on the first and second sound IF are re-adjusted to get a flat-topped overall curve with approximately 100 kc. bandwidth at 90% and with the 8.25 megacycle marker in the center.

This should be done with no more than a 20% loss in gain.

The input amplitude from the alignment oscillator and the bias voltages given by Fig. 21 for aligning each stage will produce a second detector output of two volts peak-to-peak for a

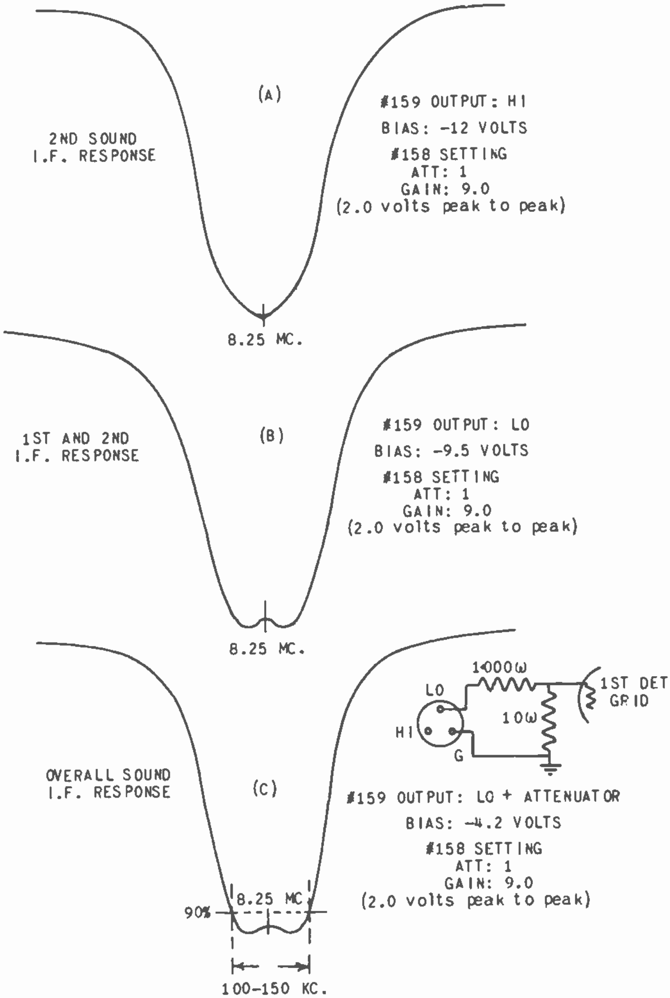


Fig.21 Response curves obtained during sound IF alignment.

normal amplifier. If the bias or input must be changed to obtain this output for any stage, the gain for that stage is not normal. Excessive gain indicates regeneration, and deficient gain can be caused by a defective tube (low Gm), or defective components in the IF transformer.

The next step in the alignment is the adjustment of the 8.25 and 14.25 megacycle trap or rejector circuits in the picture IF amplifier. There are 8.25 megacycle traps in the first and second picture IF stages controlled by variable inductors L23 and L28 respectively (See Fig. 17). There is a 14.25 megacycle trap in the first detector stage controlled by the variable inductor L19.

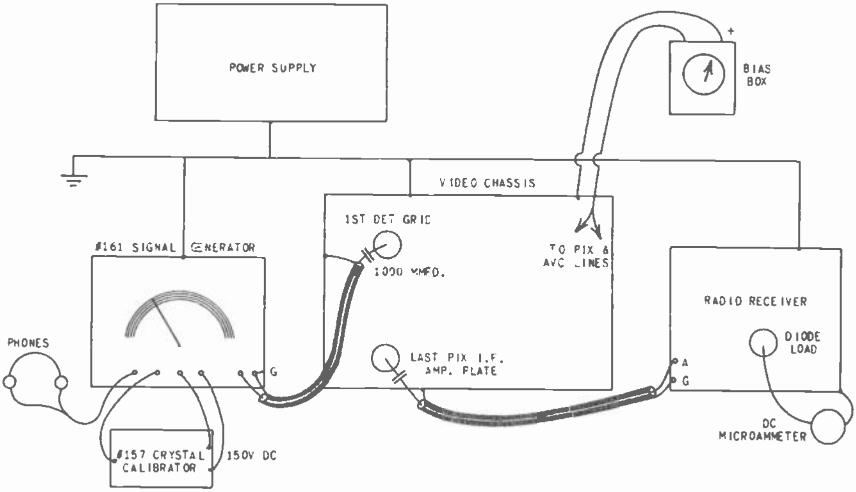


Fig. 22 Block diagram of layout for adjusting trap or rejector circuits.

A block diagram of the preferable method for adjusting the traps or rejector circuits in RCA Victor receivers is shown in Fig. 22. A radio receiver covering the range from 8 to 15 megacycles is used as the indicator for checking the setting of the traps. The antenna terminal of the receiver is connected through a 1000 mmfd. mica condenser to the plate of the last picture IF amplifier tube #7. A shielded lead is used for connecting the two receivers together. The receiver chassis is connected to the television receiver chassis. The AVC circuit in the broadcast receiver is made inoperative. A sensitive output meter is connected between plate and ground of the final audio amplifier in the broadcast receiver. The high output of the signal generator receiver through a 1000 mmfd. condenser and a shielded lead. The tuning switch on the television receiver is turned so that it rests between bands 4 and 5. The bias supply is set at -5 volts for both the picture and sound IF amplifiers in the television receiver.

The order of adjusting the rejector circuits is given in Fig. 23. The location of the adjusting screws is also given in Fig. 23. The signal generator is tuned to exactly 8.25 megacycles by means of the crystal calibrator by the method previously outlined. The signal generator output is then modulated by the internal audio tone. The broadcast receiver is tuned to the 8.25 megacycle output of the picture IF amplifier. Then the inductors L28 and L23 are adjusted for minimum output as indicated by the output meter connected across the output of the broadcast receiver. This adjustment is very critical and should be checked several times. The output of the signal generator should be increased to obtain a good indication of the minimum.

REJECTOR ALIGNMENT				
ALIGNMENT ORDER	PICTURE I-F TRANSFORMER	INPUT FREQUENCY IN MC.	ADJUST FOR MINIMUM OUTPUT	LOCATION OF ADJUSTING SCREWS
1	2ND	8.25	L28	TOP P1
2	1ST	8.25	L23	TOP P1
3	1ST DET.	14.25	L19	BOTTOM P2

FIG. 23

Next, the signal generator is tuned to exactly 14.25 megacycles by means of the crystal calibrator. The broadcast receiver is tuned to the 14.25 megacycle output of the picture IF amplifier. The output of the signal generator is again modulated and the inductor L19 is adjusted for a minimum output from the broadcast receiver.

The rejector circuits must be adjusted with a high degree of precision if the sound is to be kept out of the picture signal. If it is impossible to obtain good rejection of the sound IF frequency in any unit, that unit is defective and needs replacement.

The next step is to align the picture IF amplifier. The setup required is the same as that for the alignment of the sound IF. This time the oscilloscope is connected between the cathode of the picture second detector and ground. The high output of the signal generator which is used for introducing the marker frequencies is coupled loosely either to the last IF stage for the alignment of all the stages or to the input of the stage under alignment. The latter method eliminates any chance of the signal generator loading the last IF stage and distorting its response curve. The output of the alignment sweep oscillator is fed into the grid of the stage under alignment. The outputs of both oscillators are fed through 1000 mmfd. condensers. The oscilloscope is adjusted for a 4 volt peak-to-peak output except for the last IF stage. The range switch on the television receiver is tuned so that it is between bands 4 and 5.

Fig. 24 is a table giving the order of alignment, the amplitude of the alignment oscillator output, the input point for the aligning signal, and the adjustments and their location for all the stages. Fig. 25 shows the curves which must be obtained in each step of the alignment, the bias which will give a 2 volt peak-to-peak output for the last IF stage and a 4 volt peak-to-peak output for the other stages, the amplitude of the alignment oscillator output, and the attenuator-gain-control settings on the oscilloscope for a 4-volt peak-to-peak output. The output of the alignment oscillator is reduced by an external attenuator for the alignment of the first detector. The details for this attenuator are given in Fig. 25. The location of the 12.75 megacycle marker is shown for every stage of the alignment. The location of the 10 megacycle point in the pass band is also shown for every stage except the last, or overall IF curve. Here, the location of the 12.75 and 8.75 megacycle points are shown.

PICTURE I-F ALIGNMENT TABLE					
ALIGNMENT ORDER	PICTURE I-F TRANSFORMER NUMBER	SWEEP OSCILLATOR ATTENUATION OUTPUT	159 OSCILLATOR CONNECTION	ADJUST	LOCATION OF ADJUSTING SCREW
1	5TH	HI	GRID OF RCA 1852 5TH PIX. I-F TUBE #7	L38 L37	BOTTOM TOP
2	4TH (4&5)	HI	GRID OF RCA 1853 4TH PIX. I-F TUBE #6	L36 L34	BOTTOM TOP
3	3RD (3, 4, 5)	LO	GRID OF RCA 1853 3RD PIX. I-F TUBE #5	L33 L31	BOTTOM TOP
4	2ND (2,3,4,5)	LO	GRID OF RCA 1853 2ND PIX. I-F TUBE #4	L30 L26	P2 BOTTOM P1 BOTTOM
5	1ST (1,2,3,4,5)	LO	GRID OF RCA 1853 1ST PIX. I-F TUBE #3	L25 L21	P2 BOTTOM P1 BOTTOM
6	1ST (1ST DET. 1,2,3,4,5)	LO WITH ATTENUATOR	GRID OF RCA 1852 1ST DET. TUBE #2	L20 L17	P2 TOP P1 TOP

FIG. 24

The primary adjustment on each IF transformer has most control on the center frequency of the response curve, while the secondary adjustment has most control on the curve shape. Therefore, the primary adjustments have the greater control on the location of the 12.75 megacycle marker. Each stage should be aligned to yield a gain equal to greater than that indicated by the bias settings and alignment oscillator input for each stage. There will have to be a compromise in each adjustment between curve shape and gain, assuming that the frequency limits and bandwidth are correct. If the overall curve differs slightly from the overall given in Fig. 25, it may be possible to correct it by observing the overall curve while changing the adjustments of all the stages slightly. This should not result in a reduction in gain. If there is a loss in gain, the amplifier must be realigned from the beginning. If it is impossible to obtain the required curve from any stage it is an indication that that stage is defective and the coupling unit requires replacement. The tubes in each stage should be checked for microphonics as

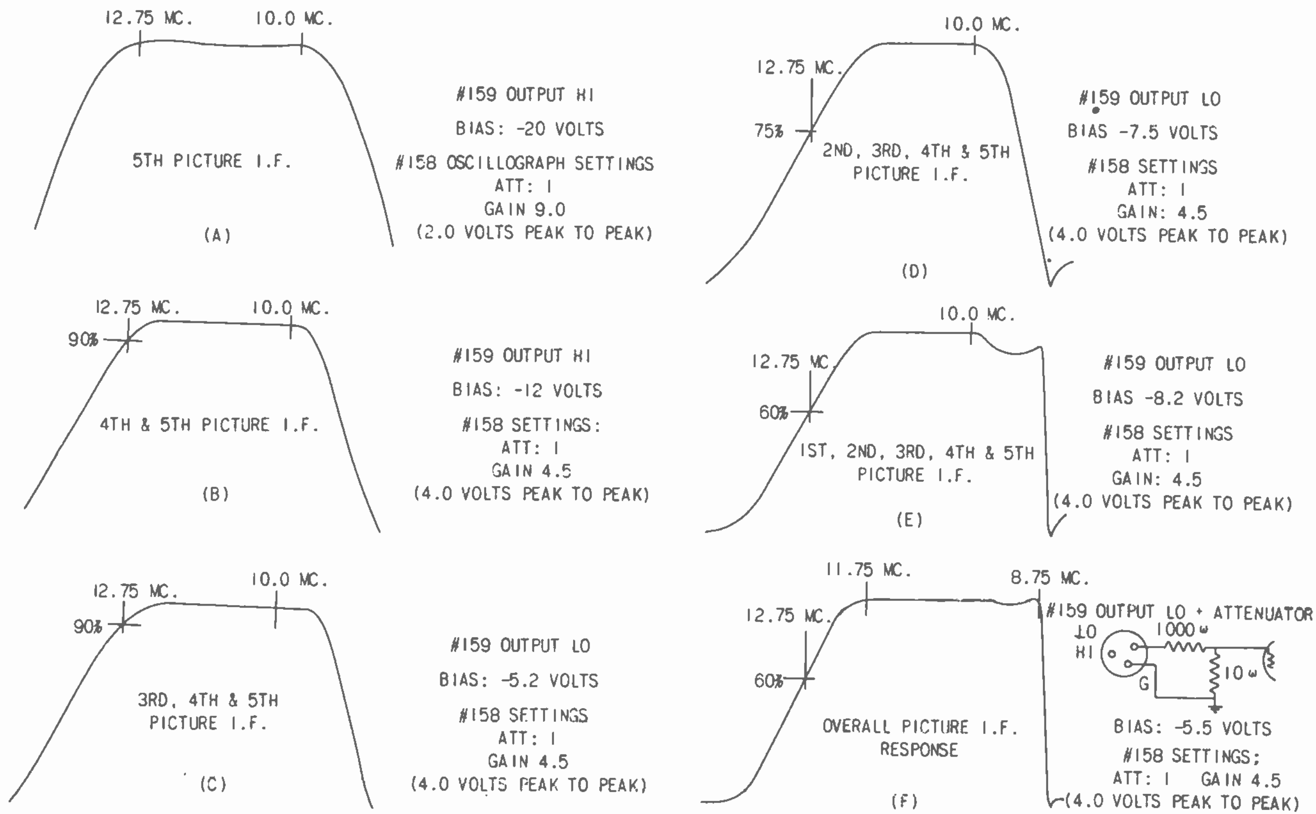


Fig.25 Response curves obtained during picture IF alignment.

the alignment progresses. All the marker frequencies should be determined accurately.

After the IF amplifier has been aligned correctly, it is necessary to recheck the rejector settings by the method given previously.

The next step in the alignment order is the adjustment of the high frequency heterodyne oscillator for the different television bands. This adjustment must be made with a high degree of precision as emphasized several times previously in this lesson.

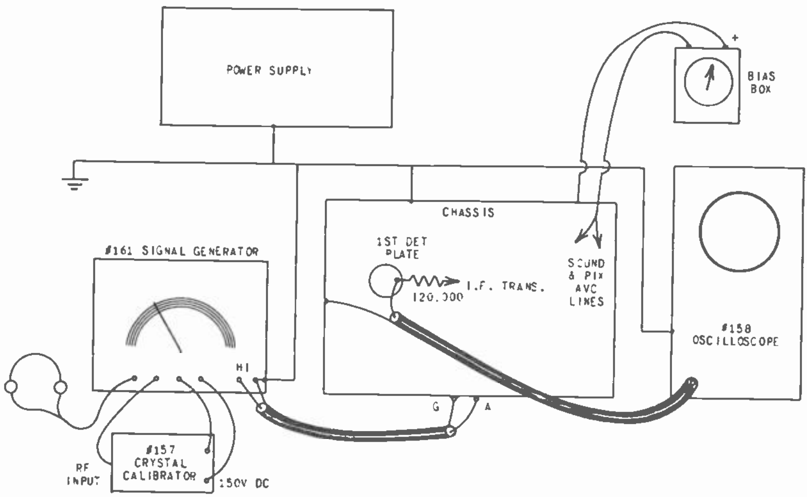


Fig.26 Block diagram of layout for heterodyne oscillator alignment.

The setup for the heterodyne oscillator alignment is shown in Fig. 26. The 6J5 oscillator tube is plugged in its socket. The blue lead is unsoldered from the plate pin of the first detector tube #1. A 120,000 ohm carbon resistor is inserted between the plate lead and the blue lead going to the IF transformer. The vertical input to the oscilloscope is connected between plate and ground of the first detector. The high output terminal of the signal generator is connected to the antenna terminal A2. The ground terminal of the signal generator is connected to the antenna terminal A1 which, in turn, is connected to ground. The internal horizontal sweep of the oscilloscope is used. Any frequency from 30 to 150 cycles is satisfactory. The attenuator and gain controls are set for maximum sensitivity. The bias for both the picture and sound IF amplifiers is set at -10 volts.

Fig. 27 shows the order of alignment, the signal generator frequency, the heterodyne oscillator frequency, and the adjustments for each band. The signal generator frequencies are determined by means of the crystal calibrator as previously outlined. Both the signal generator and the television receiver should have a fifteen to twenty minute warm-up period before commencing the oscillator alignment. The fine tuning control on the receiver oscillator is set about two-thirds full capacity. The oscilloscope is used as a zero beat indicator as explained earlier in the lesson.

SELECTOR SWITCH SETTING AND ORDER OF ADJUSTMENT	HETERODYNE OSCILLATOR FREQ. - MC.	SIGNAL GENERATOR FREQ.-MC.	TRIMMER ADJUSTMENT
1	98	98	L14 - L15
2	92	92	L13
3	80	80	L12
4	64	64	L11
5*	58	58	C6

*(Since the RCA Victor TRK-9 was built, the 44 - 50 megacycle channel was discontinued and a new 60 - 60 megacycle channel substituted.

FIG. 27

Before making the adjustment on the highest band, it is recommended that band 5 (low frequency band) be checked to make sure that the size of the tank inductance is such that the air trimmer for band 5 falls within range. Then start at the high-frequency end and follow the order shown in Fig. 27. Since there is inter-action between bands 1 and 2, it is necessary to go back and forth between these two several times to secure the proper setting of the trimmers.

There should be no strains on the receiver chassis during the oscillator alignment as the circuit capacities may be changed and the oscillator alignment upset when the receiver is restored to its cabinet. The strap inductance used in the oscillator circuit should never be bent or moved as the required frequency range may not be included within the range of the trimmers. If it is necessary to replace this inductance, care must be taken to install the new unit exactly in the same position as the old unit. Incorrect installation of this inductance can cause excessive inter-action between the various bands and make alignment difficult.

If the oscillator does not align correctly on any or some of the bands, the 6J5 oscillator tube may need replacing. If a new tube does not correct the trouble, it is probable that the tank condenser C16, which has a negative temperature coefficient, is defective and needs replacing. The oscillator will require realignment after replacing either unit.

The final step in the alignment of the television receiver is the alignment of the RF section. The first detector circuit is restored to normal (removal of the 120,000 ohm resistor inserted in the plate circuit). The apparatus setup is similar to that shown in Fig. 19, the setup for the sound and picture IF alignment. In this case, the RF output of the alignment oscillator is connected to the antenna terminals A1 and A2 of the receiver. The marker frequency can be introduced either into the IF amplifier or into the RF section. If the IF marker is used, its frequency will be 12.75 megacycles. If the RF marker is used, its frequency will be equal to the picture carrier frequency of the band under alignment.

The order of RF adjustment is given in Fig. 28. This table also gives the alignment oscillator setting, the RF marker frequency (if used), and the trimmer for each band. The trimmer is adjusted so that the combined RF and IF response has uniform gain over the pass band. If it is impossible to obtain a satisfactory overall curve in any band and the IF curve is known to be correct, then the RF unit in that band is defective and needs replacing. If the overall alignment is correct, the gain at the marker frequency will be 50% of the gain in the center of the response curve.

STATION SELECTOR SWITCH POSITION	#159 SWEEP OSCILLATOR RANGE SWITCH POSITION	RF MARKER MEGACYCLES	ADJUST
1	84 - 90	85.25	L10
2	78 - 84	79.25	L8
3	66 - 72	67.25	L6
4	50 - 56	51.25	L4
5*	44 - 50	45.25	L2

*(Since the RCA Victor TRK-9 was built, the 44 - 50 megacycle channel was discontinued and a new 60 - 60 megacycle channel substituted.

FIG. 28

One thing to remember is that the frequency of the alignment oscillator decreases for the right-to-left sweep of the cathode ray tube beam and increases for the left-to-right sweep. Therefore, the carrier frequency marker will lie on the left side of the response curve for the IF curve and will lie on the right side of the combined RF and IF curve.

After the RF alignment is completed, the oscillator alignment should be rechecked, as there is some inter-action between the RF and oscillator circuits. Then, the RF alignment should be rechecked. Realign the RF if necessary and again recheck the oscillator alignment. This process should be continued until both the RF and oscillator alignment are correct.

When the alignment is completed, the receiver is restored to complete operating condition and the units are restored to the cabinet. The overall operation of the receiver can be checked by the method previously outlined.

The rest of the lesson is devoted to a discussion of the alignment of the sound and the picture IF amplifier of a receiver using Sickles IF coupling units. Just the IF alignment will be covered, as it only is somewhat different from that of the RCA receiver just described. The circuit diagram of the sound and picture IF amplifiers using these transformers is shown in Fig. 29. The RF oscillator, video, sync, and deflection sections have been omitted.

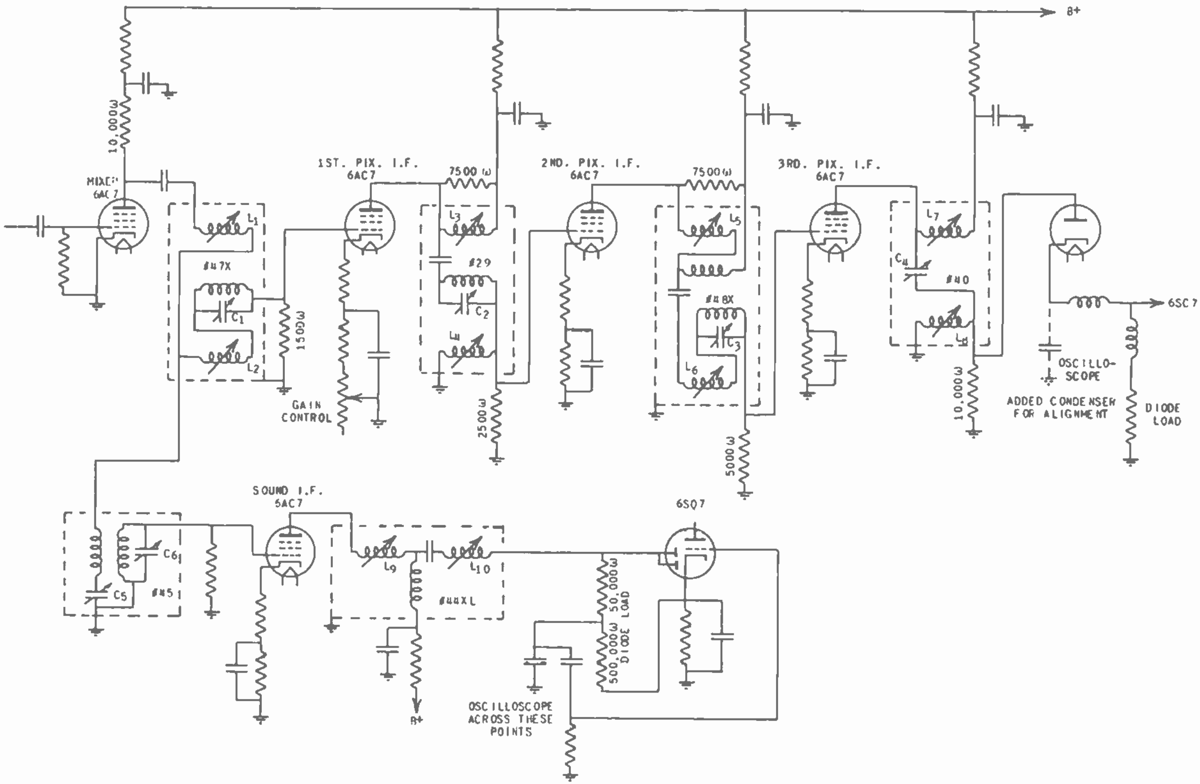


Fig.29 Circuit diagram of picture IF amplifier.

The equipment required for alignment is identical with that for the previous receiver. The general methods of alignment are also the same. However, this receiver uses self bias without AVC and therefore an auxiliary bias supply was not used. The output from the alignment oscillator was adjusted so that the peak-to-peak voltage from the picture second detector did not exceed 4 volts peak-to-peak. No attempt was made to regulate the input so that the output from the second detector was always 4 volts peak-to-peak. Thus, there was no check on the gain of the individual stages. External attenuators were used with the alignment oscillator when the output had to be reduced.

The rejector circuits are aligned by connecting a sensitive DC meter across the picture second detector diode load and adjusting the rejectors or traps for a minimum output at the required frequencies.

The sound IF is aligned in the conventional manner. The sound IF output of the alignment oscillator and an 8.25 megacycle marker from the signal generator are applied to the grid of the sound IF amplifier. L9 and L10 in transformer #44 are adjusted for maximum output at 8.25 megacycles. Unit #45 is best aligned during the alignment of the picture IF amplifier, as there is interaction between #45 and #47.

The picture IF alignment is simplified by disconnecting the grid lead from the transformer preceding the stage under alignment. For example, when aligning unit #40, the grid lead from unit #48X is disconnected. The grid resistor is left in the grid circuit so that the grid circuit of the following tube will be complete.

The first unit aligned in the picture IF amplifier is #40. A 5000 mmfd. condenser is connected from the cathode terminal of the second detector to ground. The oscilloscope is connected across these same points. The high output of the alignment oscillator and the high output of the signal generator is fed into the grid of the tube preceding the unit #40. First, the coupling capacitor is set at minimum capacity. C4 controls the coupling between L7 and L8 or the bandwidth of the response curve of #40. Then a 5000 ohm resistor is connected across the plate side of #40; that is, across L7. Both L7 and L8 are peaked at 12.2 megacycles by means of a 12.2 megacycle marker from the signal generator. The 5000 ohm resistor is removed from L7 and the coupling capacitor C4 is increased until the single peak separates into two peaks peaked at 12.75 and 8.75 megacycles. This curve is shown in Fig. 30A.

Unit #48X contains a 14.25 megacycle trap controlled by C3. This is aligned first by feeding a 14.25 megacycle signal from the signal generator into the grid of the tube preceding #48X and adjusting C3 for minimum output from the second detector. A sensitive DC voltmeter is a satisfactory instrument for detecting minimum output during the alignment of the trap in #48X. After the trap is adjusted, the output of the alignment oscillator is fed into the grid of the stage containing #48X. A .01 mfd. condenser is connected from the blocking condenser

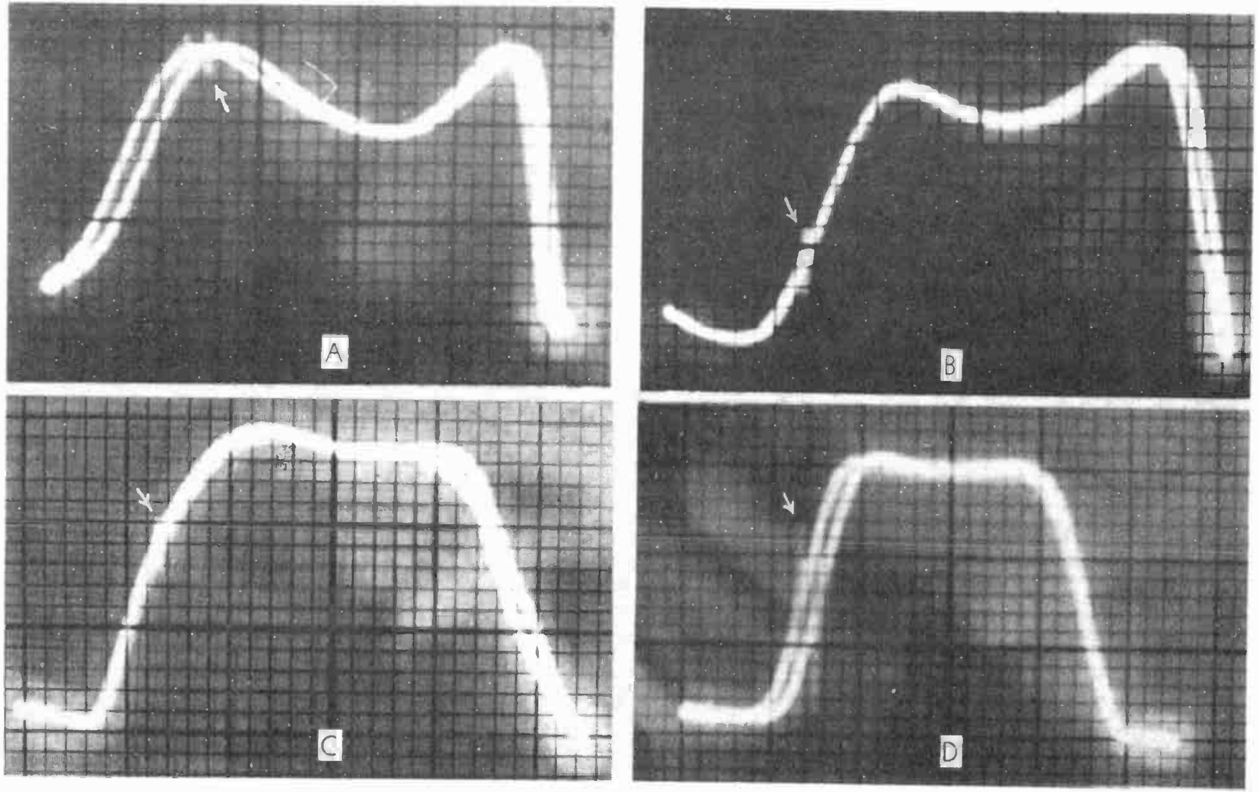


Fig.30 Response curves obtained during picture IF alignment. (A) Curve for Unit #40; (B) Curve for Units #48X and #40; (C) Curve for Units #29, #48X, and #40; (D) overall IF curve.

side of L6 to ground. This point is indicated in Fig. 29. The purpose of the condenser is to nullify the effect of the coupling inductance L11 so that a single peak can be obtained when L5 and L6 are tuned to the same frequency. L5 and L6 are peaked at 11.85 megacycles. The .01 mfd. condenser is removed. The curve is shown in Fig. 30B.

The unit #29 contains a 8.25 megacycle trap which is controlled by C2. This trap is adjusted in the same way as the trap in #48X. Then, both L3 and L4 are adjusted for an overall practically flat response with even peaks at approximately 11.85 megacycles and 9.1 megacycles. The dip should be very small. Slight correctional retouching of the plate inductor of #48X may be required. The curve is shown in Fig. 30C.

Units #47 and #45 are adjusted together as there is interaction between the two. There is a 14.25 megacycle trap in #47 controlled by the capacitor C1. This trap is adjusted first. Then the series trap in #45, which is resonant at 8.25 megacycles, is adjusted next. The third adjustment is the input circuit to the sound IF amplifier controlled by C6. This is best adjusted by tuning it for a maximum response at 8.25 megacycles. The method used for adjusting the traps is the best way to set this input circuit. For this adjustment, the DC meter is connected across the sound second detector load. Then the plate and grid inductors of #47; that is, L1 and L2 are adjusted for a flat overall response with the 12.75 megacycle marker riding 50% of the way up on the high frequency edge of the pass band. Slight retouching of the grid inductor of #29 may be required. The overall IF curve is shown in Fig. 30D.

This material on the actual alignment of typical television receivers has been presented to give the reader an idea of the complexity of the problem. It is seen that the alignment of a television receiver is not the simple process involved in the servicing of ordinary broadcast receivers.

EXAMINATION QUESTIONS

INSTRUCTIONS. Before starting to answer these examination questions, you should have studied the lesson material at least three times. Be sure that you understand each question--then proceed to write the best answer you can. Make all answers complete and in detail. Print your name, address, and file number on each page and be neat in your work. Your paper must be easily legible; otherwise, it will be returned ungraded. Finish this examination before starting your study of the next lesson. However, send in at least three examinations at a time.

1. Sketch a typical picture IF response curve and mark the location of the important frequencies.

2. What is the purpose of the 8.25 and 14.25 megacycle traps in the picture IF amplifier?

3. Why is the picture IF frequency at one end of the IF band, and why is gain at the IF frequency less than over the center of the IF band?

4. Why must the output of the signal generator be accurately determined at 8.25 and 14.25 megacycles and at the heterodyne oscillator frequencies?

5. Explain carefully the procedure in adjusting the signal generator output to exactly 14.25 megacycles.

6. What is the correct order of aligning a television receiver?

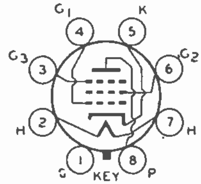
7. Why must the picture second detector output circuit be bypassed during alignment, and why must the condenser be placed before the filter in the second detector output circuit?

8. How can you determine the frequencies corresponding to any point on the response curve traced on the oscilloscope screen?

9. How are the 8.25 and 14.25 rejector or trap circuits in the picture IF amplifier adjusted?

10. What will be the result as far as the picture is concerned if the picture IF amplifier is aligned so that the 12.75 megacycle point is in the center of the IF band?

TELEVISION AMPLIFIER PENTODE



8N

6AB7/1853

METAL

The 6AB7 is a pentode of the single-ended metal type for use in television receivers. Because of its extended cut-off characteristic, it is recommended for use in the r-f and i-f stages of the picture amplifier of such receivers, particularly those employing automatic gain control. The 6AB7 can also be used as a mixer and makes a good oscillator in low-voltage applications. The shielded-construction features of the 6AB7 are similar to those of the 6AC7/1852.

CHARACTERISTICS

Heater Voltage (A.C. or D.C.)	6.3	Volts
Heater Current	0.45	Ampere
Grid-Plate Capacitance°	0.015 *max.*	μμf
Input Capacitance°	8	μμf
Output Capacitance°	5	μμf

° With shell connected to cathode.

As Class A_1 Amplifier

Plate Voltage	300 *max.*	Volts
Screen Voltage	200 *max.*	Volts
Screen Supply Voltage	300 *max.*	Volts
Grid Voltage	−3 *min.*	Volts
Plate and Screen Dissipation (Total)	4.4 *max.*	Watts
Screen Dissipation	0.65 *max.*	Watt

Typical Operation:

	Condition I ‡	*Condition II* ‡‡	
Plate Voltage	300	300	Volts
Suppressor Voltage	0	0	Volts
Screen Supply Voltage	200	300*	Volts
Screen Series Resistor	–	30000	Ohms
Grid Voltage	−3	−3	Volts
Plate Resistance (Approx.)	0.7	0.7	Megohm
Transconductance	5000	5000	Micromhos
Grid Bias for Transconductance = 50 micromhos	−15	−22.5	Volts
Plate Current	12.5	12.5	Milliamperes
Screen Current	3.2	3.2	Milliamperes

‡ With fixed screen supply ‡‡ With series screen resistor.

* Screen supply voltages in excess of 200 volts require the use of a series dropping resistor to limit the voltage at the screen to 200 volts when the plate current is at its normal value of 12.5 milliamperes.

INSTALLATION and APPLICATION

The **base** of the 6AB7 fits the standard octal socket which should be mounted to hold the tube preferably in a vertical position. Horizontal operation is permissible if the socket is positioned so that pins No. 2 and 7 are in a vertical plane. Physical characteristics of the 6AB7 are shown in Fig. 1-3, OUTLINES SECTION. For **heater** operation and **cathode** connection, refer to Type 6AG7.

Control-grid bias may be obtained by means of a cathode-bias resistor adjusted to give a plate current of 12.5 milliamperes, or from a fixed source, depending on the application.

In tubes such as the 6AB7 with a very high value of transconductance, appreciable changes in input capacitance and input conductance occur with changes in plate current. In order to minimize these changes when the 6AB7 is used as an r-f or i-f amplifier, a portion of the cathode-bias resistor may be left unby-passed. Reducing the changes of input capacitance and input conductance in this manner, however, is accomplished with some sacrifice in effective transconductance and some increase in effective grid-plate capacitance. To prevent excessive effective grid-plate capacitance, precautions should be observed to keep external plate-cathode capacitances at a minimum. It should be observed that with this method of minimization, the cathode is not at a-c ground potential. Because of this fact, the most favorable connection of the tube electrodes will be obtained with suppressor and screen at a-c ground potential as shown in the circuit diagram below.

In some installations having automatic bias control which provides a fixed minimum bias adequate to limit plate current to 12.5 milliamperes, and also using a 30000-ohm series screen resistor. the cathode may be connected through an unby-passed resistor to ground. This resistor may conveniently form part of the fixed minimum bias. Such an arrangement serves to minimize changes of input capacitance and input conductance.

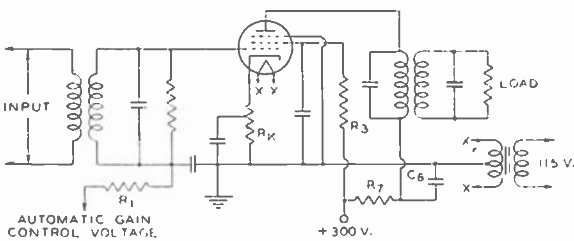
The d-c resistance in the grid circuit should not exceed 0.25 megohm with fixed bias. When full cathode bias and a series screen resistor are used, the d-c resistance may be as high as 0.5 megohm.

The **screen** voltage may be obtained from a potentiometer, a bleeder across the B-supply source. or through a series resistor. Use of the series screen resistor (Condition II) provides a somewhat more extended cut-off characteristic than is obtained with fixed screen voltage (Condition I).

The **suppressor** should be connected directly to ground in r-f and i-f circuits to minimize feedback.

As an **amplifier,** the 6AB7 is especially useful in the r-f and i-f stages of the picture amplifier of television circuits employing automatic gain control.

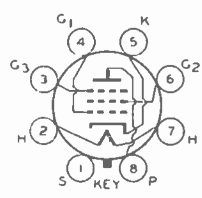
In circuits where changes of input capacitance and input conductance are not minimized by a partially unby-passed cathode-bias resistor. it will be advisable to operate the 6AB7 with circuits heavily loaded with resistance and capacitance. Although such circuits minimize the effect of the relatively small variations in tube capacitance and conductance, they also cause some sacrifice in gain.



6AC7/1852

METAL

TELEVISION AMPLIFIER PENTODE



8N

The 6AC7 is a pentode of the single-ended metal type for use in television receivers. It is recommended for use in the r-f and i-f stages of the picture amplifier of such receivers as well as in the first stages of the video amplifier. The 6AC7 can also be used as a mixer and is a good oscillator in low-voltage applications.

The 6AC7 has the same electrode assembly as the RCA-1851, but a special shielded-lead construction has been employed in the 6AC7, to permit bringing out the control-grid lead to a base pin rather than to a pin cap, without increase in the grid-plate capacitance. From a circuit standpoint, the proximity of grid pin to cathode pin simplifies wiring and decreases the size of the inductance loop connecting the input circuit to the tube. These are features important at high frequencies because they provide decreased feedback and improved circuit stability.

CHARACTERISTICS

HEATER VOLTAGE (A.C. or D.C.)	6.3	Volts
HEATER CURRENT	0.45	Ampere
GRID-PLATE CAPACITANCE°	0.015 *max.*	μμf
INPUT CAPACITANCE°	11	μμf
OUTPUT CAPACITANCE°	5	μμf

° With shell connected to cathode.

As Class A Amplifier

PLATE VOLTAGE	300 *max.*	Volts
SCREEN VOLTAGE	150 *max.*	Volts
SCREEN SUPPLY VOLTAGE	300 *max.*	Volts
PLATE AND SCREEN DISSIPATION (Total)	3.4 *max.*	Watts
SCREEN DISSIPATION	0.38 *max.*	Watt

TYPICAL OPERATION:

	*Condition I**	*Condition II***	
Plate Voltage	300	300	Volts
Suppressor Voltage	0	0	Volts
Screen Supply Voltage	150	300‡	Volts
Screen Series Resistor	–	60000	Ohms
Cathode-Bias Resistor	160 *min.*	160 *min.*	Ohms
Plate Resistance (Approx.)	0.75	0.75	Megohm
Transconductance	9000	9000	Micromhos
Plate Current	10	10	Milliamperes
Screen Current	2.5	2.5	Milliamperes

* With fixed screen supply. ** With series screen resistor.

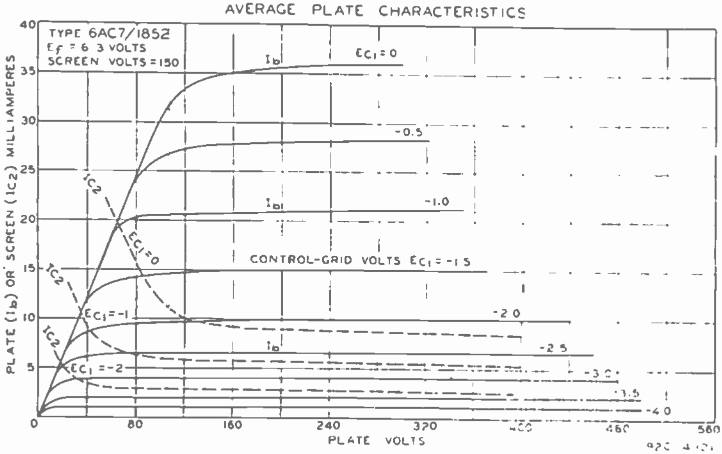
‡ Screen supply voltages in excess of 150 volts require use of a series dropping resistor to limit the voltage at the screen to 150 volts when the plate current is at its normal value of 10 milliamperes.

INSTALLATION and APPLICATION

The **base** of the 6AC7 fits the standard octal socket which should be installed to hold the tube preferably in a vertical position. Horizontal operation is permissible if the socket is positioned so that pins No. 2 and 7 are in a vertical plane. Physical characteristics of the 6AC7 are shown in Fig. 1-3, OUTLINES SECTION. For **heater** operation and **cathode** connection, refer to Type 6AG7.

Voltage supply considerations are similar to those for Type 6AB7. In video stages, the cathode-bias resistor should not be by-passed if it is desired to have degeneration and freedom from distortion. When, however, no degeneration and maximum amplitude are desired, the cathode-bias resistor should be by-passed with a large condenser (350 μμf).

AVERAGE PLATE CHARACTERISTICS



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