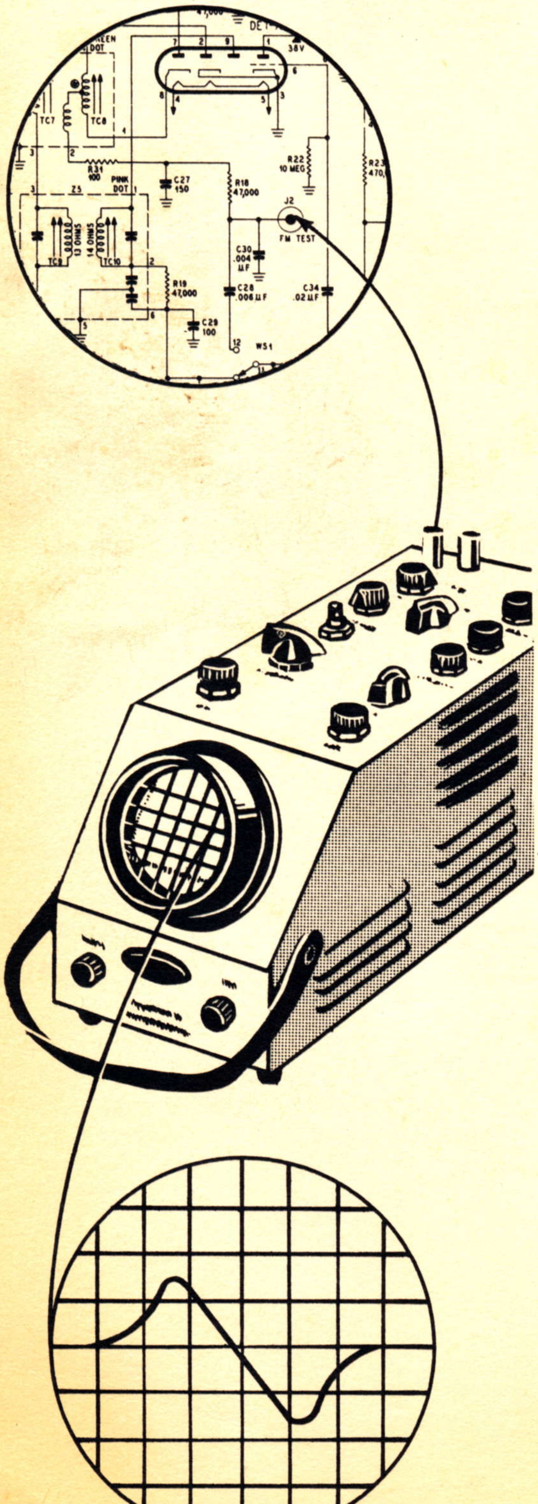
PHILCO SERVICE

PHILCO Factory-Supervised Service

RADIO HOME STUDY



PHILCO

OSCILLOSCOPE APPLICATIONS FOR RADIO

MEASUREMENTS
ALIGNMENT
SIGNAL TRACING

OSCILLOSCOPE APPLICATIONS FOR RADIO

PR-2206

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FOREWORD

Through the close contact with the servicing industry made possible by Philco Factory-Supervised Service, the results of an extensive survey have indicated that the subject of using the oscilloscope in radio servicing is of vital interest at this time. Therefore, this handbook is presented to acquaint the serviceman with a practical knowledge of the cathode-ray oscilloscope, with particular emphasis on its use in diagnosing and correcting troubles in circuits of modern radio receivers.

PART I

PRINCIPLES OF THE OSCILLOSCOPE

The cathode-ray oscilloscope is an instrument designed for the visual observation of varying electrical voltages or currents. The visual presentation is usually in the form of a graph or curve. Such a graph is called a "waveform" of voltage or current, and is composed of all the instantaneous values, plotted against time. By means of the waveform presentations obtainable with an oscilloscope, it is possible to observe and measure the following simultaneously:

1. The value of voltages or currents.
2. Variations in voltages or currents, with respect to time.
3. The repetition rate, or frequency of voltages or currents.
4. Phase relations existing between voltages or their corresponding currents.

The oscilloscope finds wide application in all phases of electronics, and readily lends itself to radio servicing.

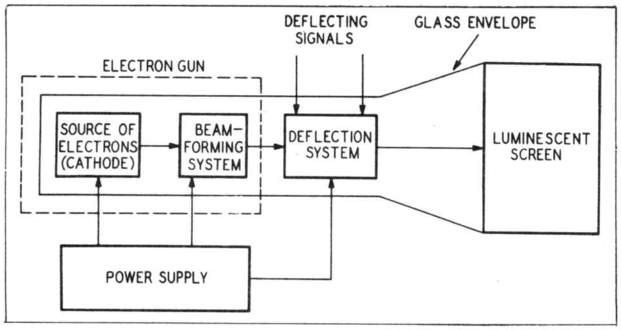

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Figure 1. Block Diagram of Cathode-Ray Tube

However, to use an oscilloscope intelligently, it is necessary to understand its theory, operation, and applications. The information presented in the following pages should prove valuable in developing this understanding.

THE CATHODE-RAY TUBE

The cathode-ray tube is the heart of an oscilloscope, and as such should be treated separately. A block diagram of a cathode-ray tube is shown in figure 1; this diagram gives a basic conception of the sequence of events that occur within the tube. The electrons given off by the cathode are formed into a thin beam, and are deflected in such a manner as to cause the beam to draw a picture of the deflecting voltage waveshape on the luminescent screen. As shown in figure 2, the tube contains an electron-gun assembly, which literally "shoots" the beam of high-speed electrons into space. This electron beam is directed toward the face of the tube, which is called the screen, the inner surface of which is coated with a phosphor that gives off light wherever the beam is allowed to impinge upon it. Between the phosphor-coated luminescent screen and the electron-gun assembly are interposed two pairs of deflecting plates, one pair displaced 90 degrees from the other.

When a potential difference is applied between either set of plates, a corresponding electrostatic field is set up between the pair of opposing plates somewhat like that which occurs within a capacitor under similar conditions. This electrostatic field exerts a force upon the electron beam passing through it. The magnitude of

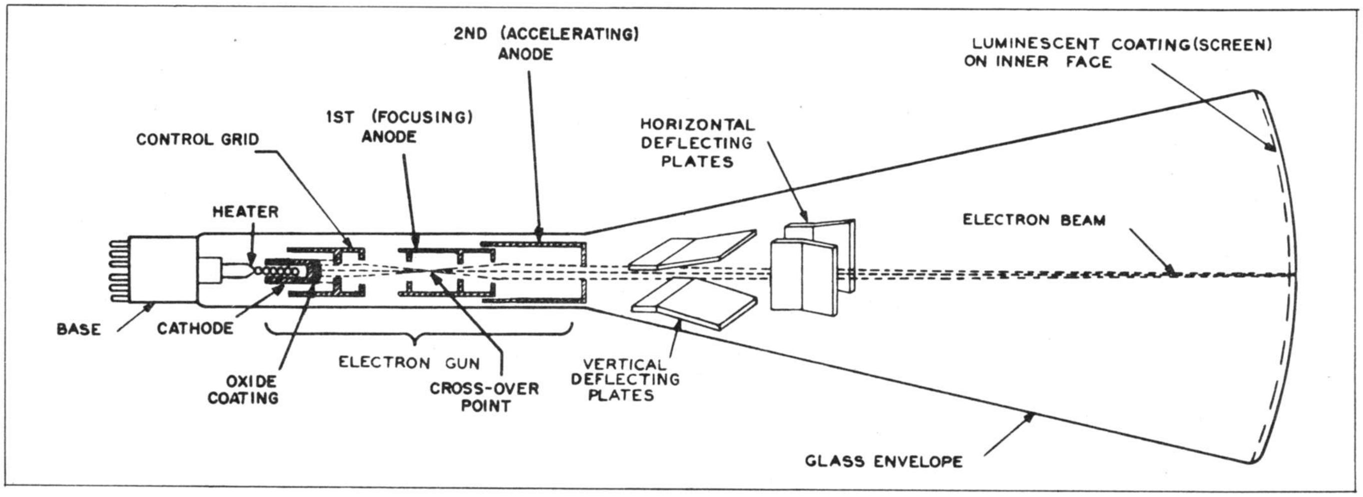

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Figure 2. Location of Elements in Cathode-Ray Tube

the force depends directly upon the intensity of the electrostatic field, which in turn depends upon, and is directly proportional to, the voltage difference between the two opposing plates. Since the deflecting plates are supported rigidly and the electron beam is free to move, it follows that the beam is deflected by an amount proportional to the voltage applied to the deflecting plates.

Since there are two sets of plates, 90 degrees apart, the point of impact of the beam on the screen can be moved either up or down, or to the right or left. In addition, if the proper combination of voltages is applied to both sets of plates simultaneously, the beam can be made to assume any desired position on the screen.

The distance the beam is displaced for a given applied voltage depends on several factors, which will now be discussed. The action of the deflection plates on the electron beam is similar to that of a comb, charged with static electricity, held near a fine stream of water from a faucet. If the water is running at a very slow rate, the stream is deflected more than it would be if the water were running faster. In cathode-ray-tube terminology this phenomenon is called deflection sensitivity. The sensitivity is usually designated as "so many volts per inch," or the d-c potential difference required between two opposite plates to displace the electron beam one inch at the screen. The deflection sensitivity of the vertical-deflecting plates is usually greater than that of the horizontal plates, because the vertical plates are located farther away from the screen, and do not have to deflect the beam over as great an angle to get the same amount of deflection.

Further examination of the water analogy would lead one to believe that if the velocity of the electron beam were decreased, greater deflection sensitivity would result, and that is exactly what happens. If the second anode voltage is decreased, the deflection sensitivity becomes greater; if it is increased, the deflection sensitivity becomes less.

It is apparent from the preceding discussion that the velocity of the electron beam has a great effect on the deflection sensitivity. For this reason, manufacturers list the deflection sensitivity obtainable under certain optimum conditions, taking into consideration such factors as best over-all focus, spot size, etc.

The electron-gun assembly consists of five basic parts: heater, cathode, control electrode (grid), first anode (focusing anode), and second anode (accelerating anode). (Refer to figure 2.) The heater is similar to that used in ordinary vacuum tubes. However, the cathode is made in the form of a thimble with an oxide coating on its end; the coating merely serves to increase the emission efficiency, and is of the same type used in receiving tubes. Because of the construction of the cathode, most of the emission is in the forward direction. The control electrode does not even resemble a grid, but is more like a cylinder with a baffle. In the center of the baffle is a hole through which the electrons must pass to reach the screen. In spite of its odd construction, the control electrode has the same effect as the control grid of a triode or pentode, and is therefore generally referred to as the grid, or control grid.

The first anode is similar in construction to the grid; however, it is somewhat larger, and is operated at a positive potential of 600 to 1000 volts. This anode attracts the electrons from the cathode and gives them their initial acceleration. By the time the electrons reach the first anode they are going too fast to be turned aside; hence, they go through the aperture and into the field of the second anode.

The second anode is very similar in construction to both the grid and the first anode, but is slightly larger and usually overlaps the first anode by a small amount. In the overlapping region the anodes are not allowed to contact each other, as this would obviously short-circuit the elements. The second anode is operated at a high positive potential, ranging from approximately 1000 to 3000 volts, depending upon the tube type. It is

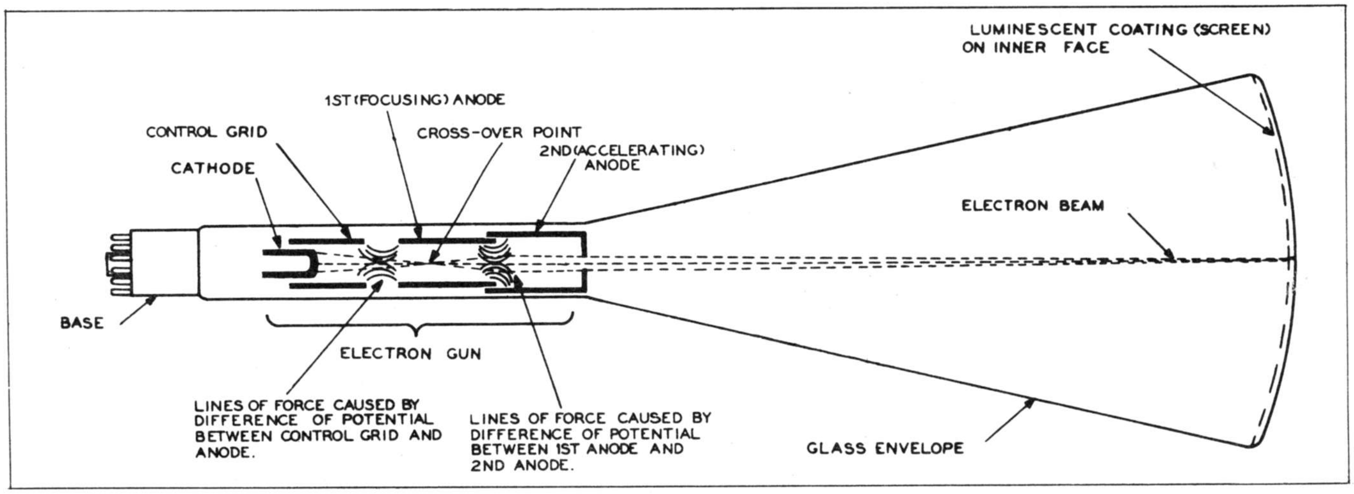

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Figure 3. Focusing Action in Cathode-Ray Tube

by means of this potential that the electrons receive their final acceleration and are sped out of the gun assembly into the space beyond.

For satisfactory operation, the electron-gun assembly must incorporate a provision for focusing the electron beam on the screen. If the apertures in the grid and anodes were made small enough to restrict the electrons to a very fine beam, the system would lack efficiency, because very few emitted electrons would ever reach the screen. Therefore, a relatively large portion of the electron beam must be concentrated in much the same way as sunlight is focused with a magnifying lens. The method of obtaining this focusing effect can be explained with the aid of figure 3.

The electron beam is forced to converge at a point, between the grid and the first anode, by electrostatic lines of force set up by the difference between the voltages applied to these two electrodes. This point, called the crossover point, may be considered as the reference starting point for the beam. From here it progresses in a divergent fashion into the region between the first and second anodes. In this region the fields are such that the electrons in the system are forced together again. (See figure 3.) Because of the increased velocity and certain other factors, the focal point of this second "lens" is at the surface of the viewing screen. The focal points are normally changed by adjusting the voltage of the first anode and keeping the potentials of the other elements constant.

A good idea of the physical construction and placement of the elements within the cathode-ray tube can be had by examination of figure 4, which shows a cutaway pictorial view of a cathode-ray tube, showing the electron-gun assembly and deflecting plates.

HOW A PATTERN IS TRACED ON A CATHODE-RAY-TUBE SCREEN

Perhaps the best way to understand just how a pattern is traced out on a cathode-ray-tube screen is actually to trace a few patterns. The electron gun dispenses a beam of electrons, which strike the screen material and cause a spot of light to appear where the beam strikes. Since the beam travels directly through the space between the four deflecting plates, if the voltages at all plates are the same, the spot rests in the center of the screen. Looking in from the face of the tube, the four deflecting plates are seen equally spaced at 90-degree intervals, as illustrated in figure 5. The horizontally positioned plates, A and B, control deflection in the vertical direction; and the vertically positioned plates, C and D, control deflection in the horizontal direction. This is so because like charges repel and unlike charges attract. The electron beam is charged negatively because electrons are negative charges; therefore, if plate A is

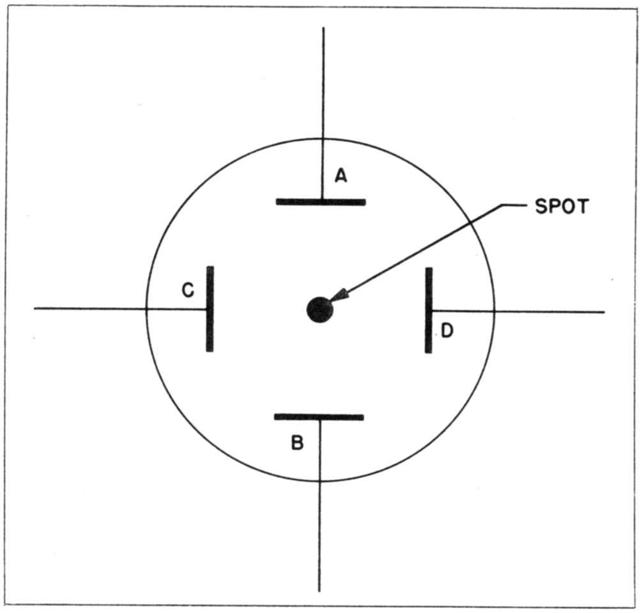

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Figure 5. Resting Position of Spot

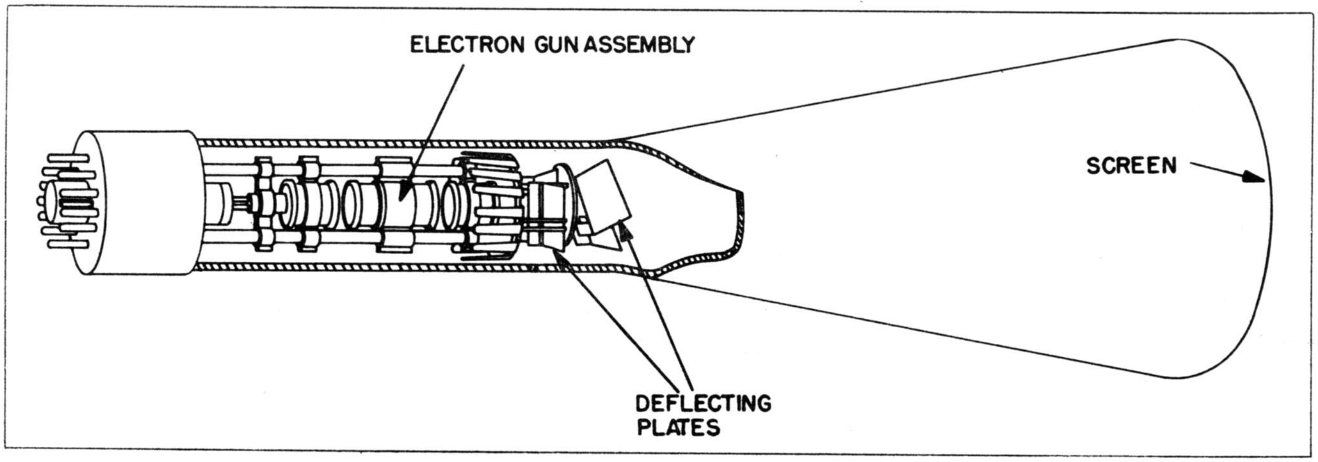

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Figure 4. Cutaway Drawing of Cathode-Ray Tube

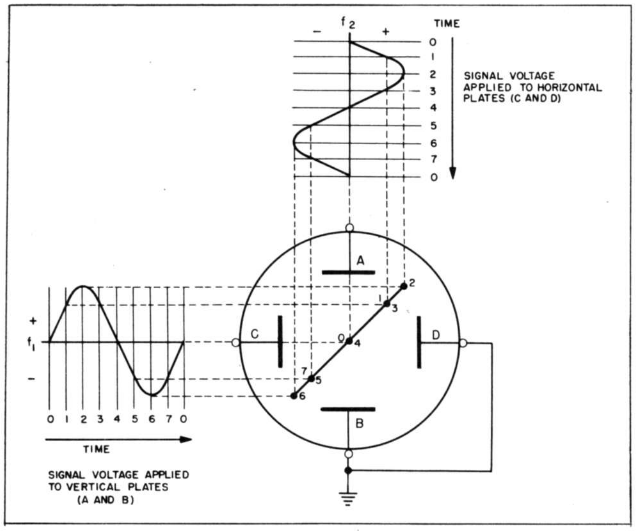

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Figure 6. Pattern Development, Voltages in Phase

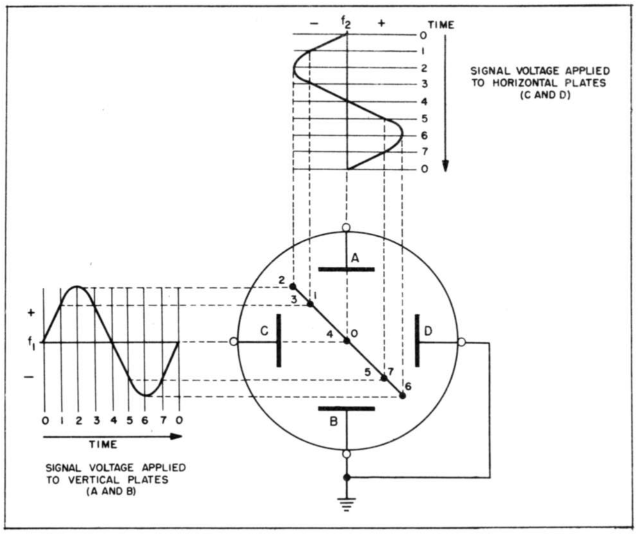

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Figure 7. Pattern Development, Voltages 180° Out of Phase

positive, assuming the other three plates to be grounded, the spot moves upward by an amount proportional to the applied voltage; also, if plate D is made negative with A, B, and C grounded, the spot moves to the left. If plates B and D are grounded, and sinusoidal voltages of the same frequency and in phase are applied to plates A and C, the beam traces a straight line diagonally from the upper right-hand corner to the lower left-hand corner. Figure 6 indicates the deflection sequence. In order to locate the spot at each instant, the sine waves are divided into eight equal time elements, and the instantaneous values at each time increment are projected until the lines cross. Where several numbers are shown, the spot falls in the same place at different points through the cycle. If the two voltages are 180 degrees out of phase, the diagonal line slants downward from left to right, as shown in figure 7. If the voltages are only 90 degrees out of phase a circle results, as evidenced by figure 8. However, it is necessary that the applied voltages be of such an amplitude as to cause equal deflection in both the vertical and horizontal directions, or a vertical or horizontal ellipse will result. Figure 9 illustrates the effect with two sine waves of 45 degrees phase displacement; the pattern is an ellipse. Further discussion of phase displacement is included in the section on Lissajous figures.

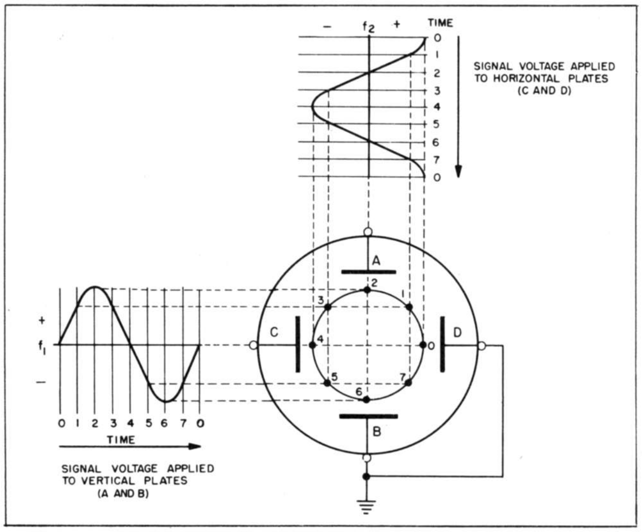

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Figure 8. Pattern Development, Voltages 90° Out of Phase

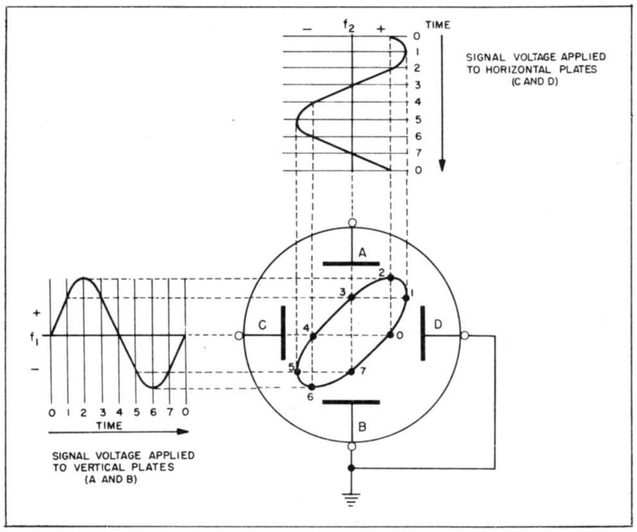

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Figure 9. Pattern Development, Voltages 45° Out of Phase

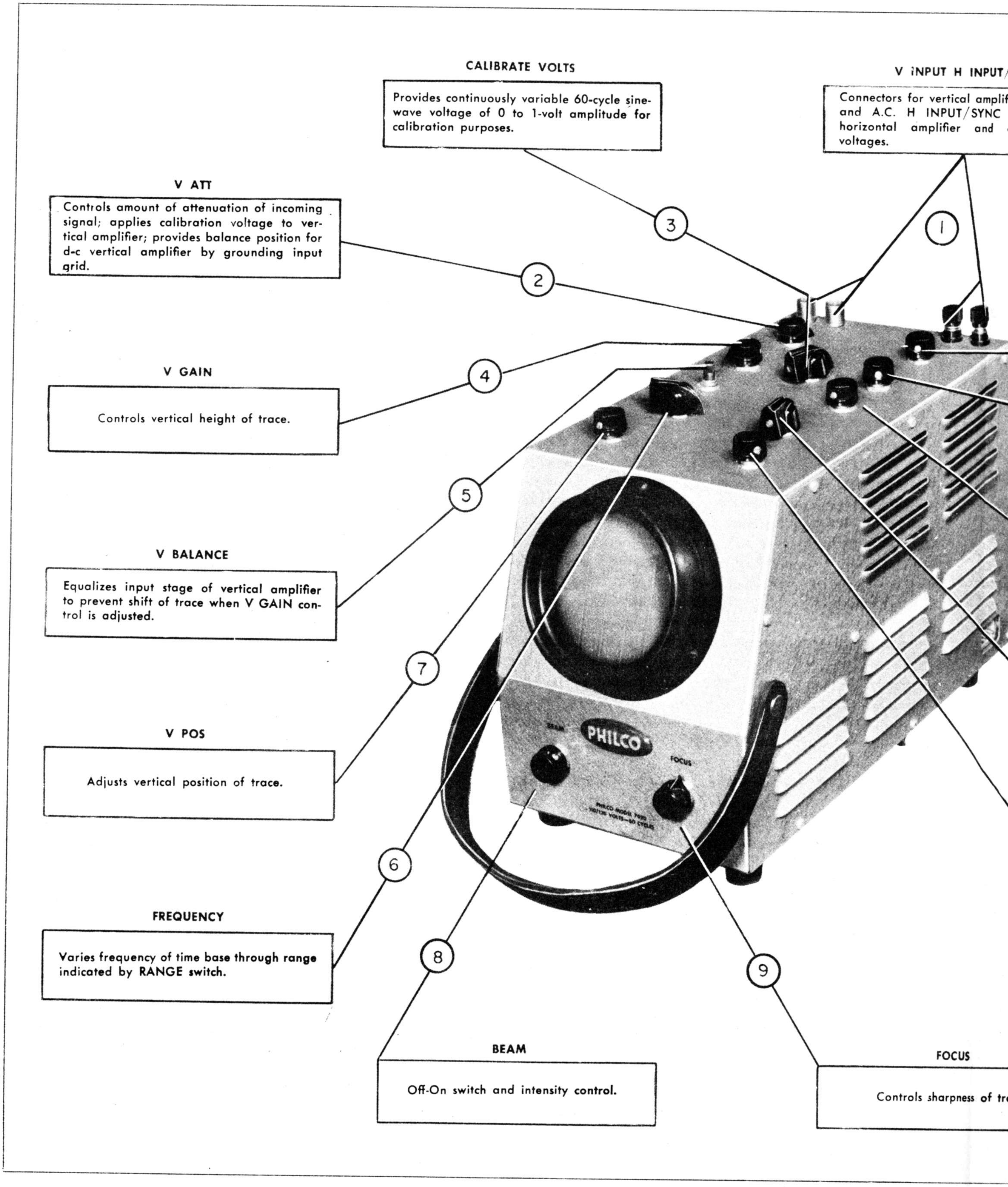

Figure 10. The Philco Model 7020 Oscilloscope

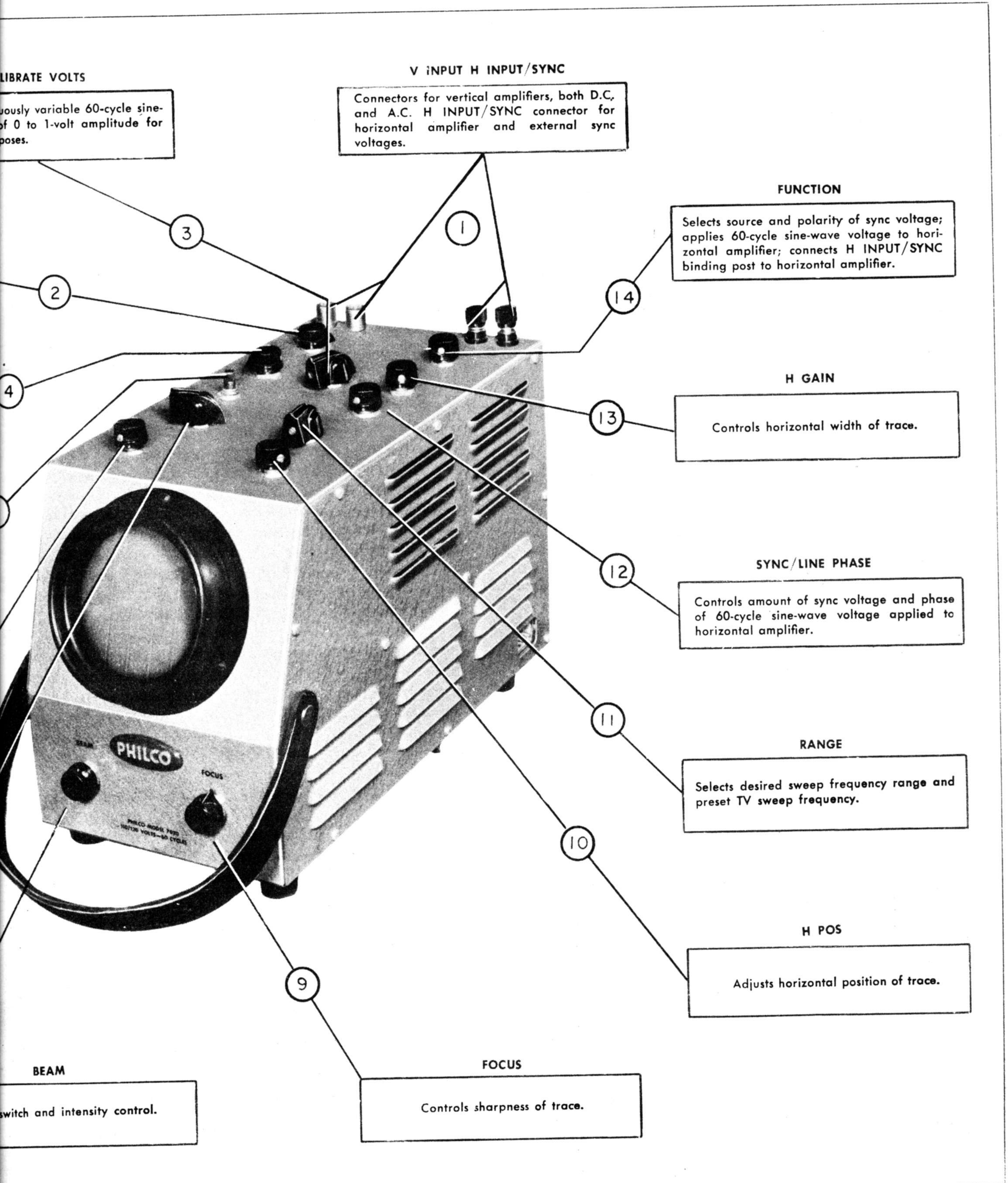

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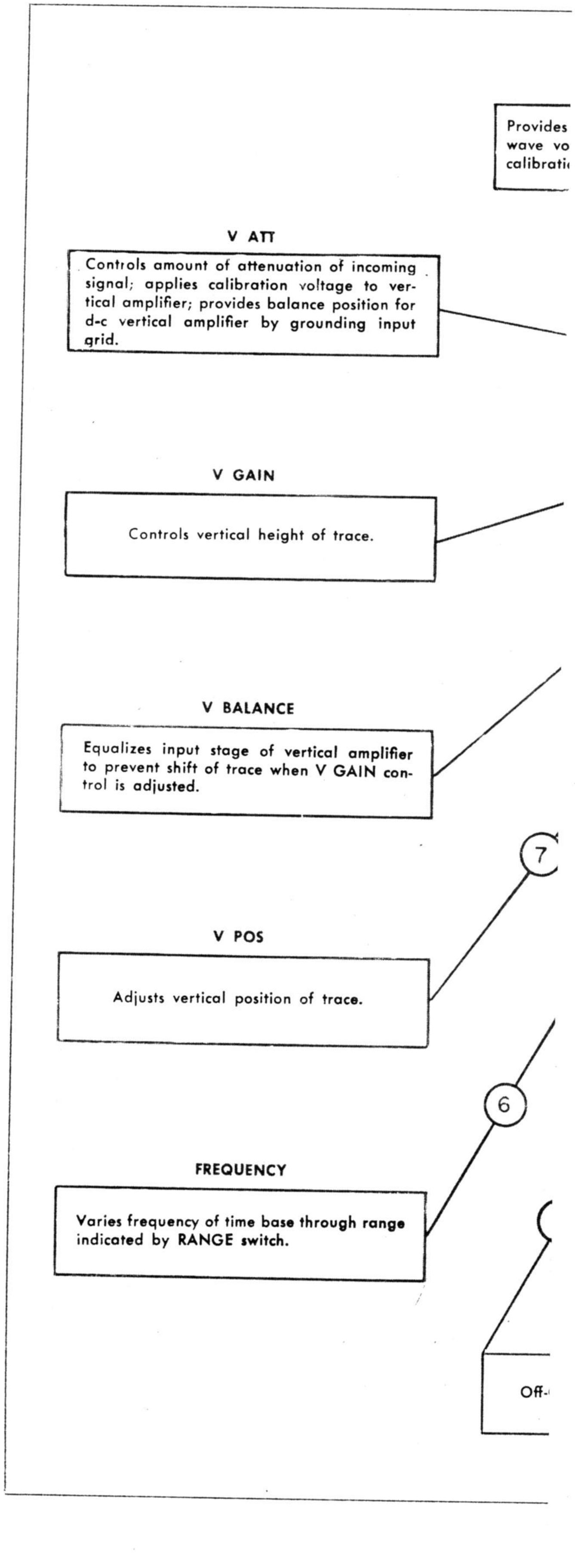
Figure 10. The Philco Model 7020 Oscilloscope



FUNCTIONS OF THE CONTROLS

An operational description of the various inputs and controls of the Philco Model 7020 Oscilloscope is given in the following paragraphs. The reference numbers used here are associated with figure 10.

Before applying power to the scope, make the preliminary adjustments indicated below. These initial settings will aid in making the final adjustments for use.

1. Set V ATT switch (2) to its extreme counterclockwise position, marked OFF.
2. Turn FUNCTION switch (14) to either INT(—), INT(+), or EXT.
3. Set H GAIN control (13) to mid-position.
4. Turn SYNC/LINE PHASE control (12) fully counterclockwise.
5. Turn V POS control (7) to mid-position.
6. Turn H POS control (10) to mid-position.
7. Set FOCUS control (9) to mid-position.

With the a-c cord connected to a 110/120-volt, 60-cycle outlet, turn the instrument on by rotating the control marked BEAM (8) clockwise from the OFF position. Allow a few minutes for the equipment to warm up, and then advance the BEAM control until a horizontal line is observed on the screen. Do not set the BEAM control higher than necessary for a clear pattern, as the screen material may be damaged, especially if a high-intensity spot remains stationary on the screen too long. Adjust FOCUS; when changing settings of the BEAM control, it may be necessary to readjust the FOCUS control slightly. If the horizontal line does not fall in the center of the screen, it may be centered by turning the V POS control (7). Centering in the horizontal direction is accomplished by adjusting the H POS control (10).

Turn the V GAIN control through its range; if the horizontal line moves upward or downward as this control is operated, the vertical amplifiers are out of balance. The vertical circuits may be balanced by following the procedure outlined below:

1. Rotate V GAIN control (4) fully counterclockwise.
2. Adjust V POS control (7) until trace is centered vertically.
3. Rotate V GAIN control fully clockwise.
4. Adjust V BALANCE control (5) until trace is centered vertically.
5. Repeat above procedure until there is negligible shift of trace when V GAIN control is rotated.

When the instrument is ready for use, the signal voltage to be observed may be connected to either the AC or DC V INPUT connector (1), depending on the nature of the voltage to be observed. Adjust both the V ATT and the V GAIN controls to secure the desired height of the pattern. It is best to set the V GAIN control to approximately mid-position, and then select the V ATT setting which gives a pattern height closest to that desired. Then readjust the V GAIN control.

observation is normally passed through the vertical attenuator, vertical-input switching system, and vertical amplifiers, before application to the vertical-deflecting plates of the cathode-ray tube. A portion of the signal from the vertical amplifier is fed into the time-base generator to synchronize the oscillator. A linear, sawtooth sweep voltage is generated in the time-base oscillator, and fed through the horizontal-input switching system to the horizontal amplifier, from which it is applied to the horizontal-deflecting plates of the cathode-ray tube. A calibrated 60-cycle voltage, taken from the power supply, is applied to the vertical amplifiers through the vertical-input switching system. The power supply, of course, furnishes plate and filament power for the various circuits.

CIRCUIT DESCRIPTION OF PHILCO MODEL 7020 OSCILLOSCOPE

The Power Supply

It will be noted upon examination of the diagram, figure 12, that the power supply furnishes low-voltage B+, high-voltage B—, and filament voltages for the various stages. By use of a multiwinding power transformer, 660 volts, center-tapped, is fed to the plates of a 6X4 tube connected as a full-wave rectifier. The output voltage of this rectifier is smoothed by a resistance-capacitance filter network, and supplies B+ of 355 volts to the amplifiers and to the time-base oscillator.

The high-voltage supply for the cathode-ray tube operates as a positive-grounded, half-wave rectifier system, and supplies negative 590 volts through a resistance-capacitance filter circuit to a bleeder network. This bleeder network is tapped at various points by means of potentiometers, to obtain the correct variable voltages necessary for control of the focus, brightness, and deflection of the beam. The filament of the 1V2 high-voltage rectifier tube is supplied from a 0.625-volt winding located at the extreme end of the high-voltage winding. By this arrangement the filament of the 1V2 is placed at 565 volts, a.c., above ground. On the negative half-cycle of input voltage to this rectifier, the filament reaches an approximate maximum peak value of 795 volts negative with respect to ground. Since the plate is connected to ground through the high-voltage bleeder network, the tube conducts, and a current of approximately ½ ma. flows through the bleeder network to ground, developing voltage drops of the polarities shown in figure 12. The second-anode voltage for the 3RP1 cathode-ray tube is obtained from the +355-volt supply through a small bleeder system, which makes the second anode approximately 260 volts positive with respect to ground. The deflecting plates should be operated at the same voltage as the second anode, so that the deflecting plates do not defocus the electron beam when deflection voltages are applied. The system described here enables the amplifier tubes to be directly coupled to the deflecting plates, because the average voltage at the amplifier plates is of the same value as that applied to the second anode.

The filament circuit consists of three separate windings on the power transformer. One winding supplies 12.6 volts (balanced to ground by means of a potentiometer) to the three tubes in the vertical-deflecting circuits. Another, a 6.3-volt winding, supplies the heater of the cathode-ray tube; and the remaining winding,

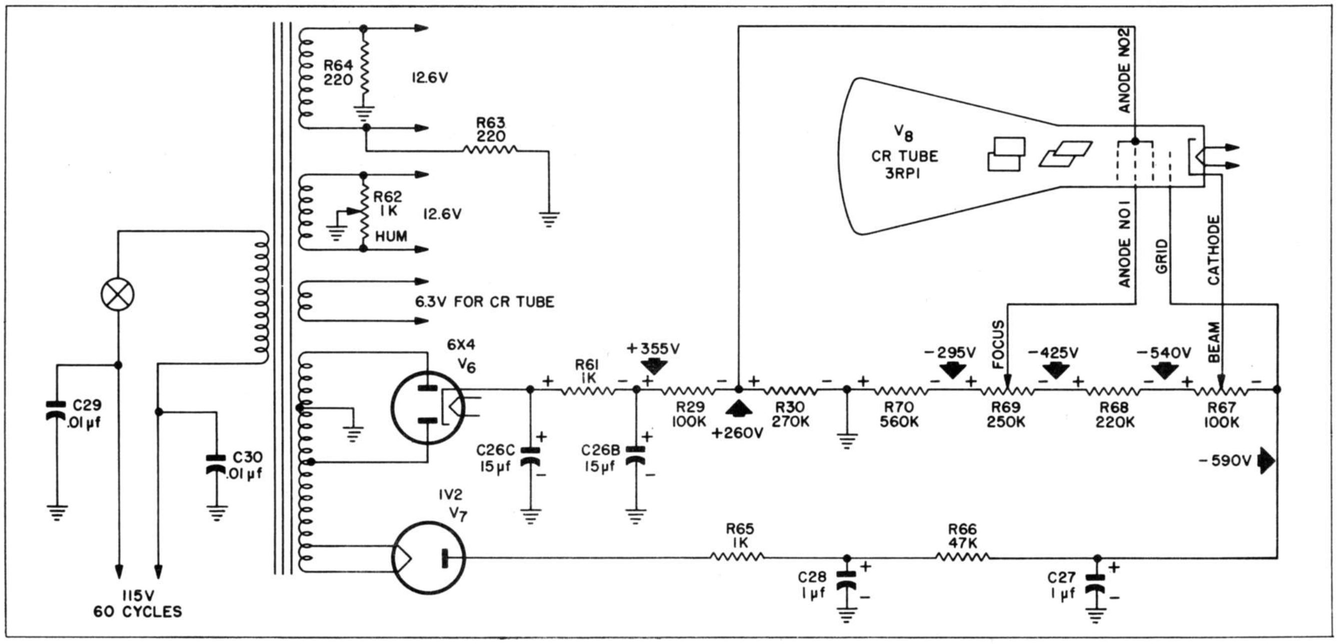


Figure 12. Power-Supply Circuit

which is balanced to ground by means of two 220-ohm resistors, supplies heater power to the time-base oscillator, the horizontal amplifier, and the low-voltage rectifier tube.

The Vertical Input and Attenuator

In order to read d-c values, direct coupling is required in the vertical-deflecting circuits. It will be seen from figure 13 that the d-c input jack connects directly to the switch arm, whereas the a-c input is applied in series with a 0.1-μf. capacitor. This is the only difference in the circuits for the a-c and d-c inputs. The vertical-attenuator switching is accomplished by means of a 2-pole, 6-position switch, shown in simplified view to facilitate explanation. Switches S1 and S2 are ganged, and must be on corresponding contacts at all times. When on position 6, the signal is fed straight through to the input of the amplifier; therefore, in this position there is no attenuation; that is, the signal transfer is 1:1. When the switch is on position 5 the input is applied to a voltage divider, and 1/10 of the voltage is fed to the amplifier. The capacitors which appear across the resistors are frequency-compensation elements, and will not enter into this discussion. Disregarding these capacitors, the amount of attenuation depends upon the ratio of the resistances in the divider network. For example, on position 5 the total resistance from the S1 connection to ground is 1 megohm. The resistance from S2 to ground is 100,000 ohms. Since the divider is composed of two resistors in series, and there is a resistance ratio of 10:1, it follows that there is also a voltage division of 10:1. The principle is the same for all attenuator settings, the difference of course being in the ratios of resistance required to give the proper attenuation.

When the vertical-attenuator switch is set to position 2, the contact arm of S2 connects to the contact arm of the calibration control, which is mounted on the control panel of the scope. The voltage across the calibration control is set for 1.0 volt by means of an internal adjustment. Since this control is of the linear type, it is possible to determine, from the relative position of its shaft, the voltage that is being applied to the vertical amplifier. This feature provides a convenient means for checking the calibration accuracy and sensitivity of the scope (by noting and recording the control settings for a pattern of certain amplitude when the instrument is new). When S1 and S2 are on position 1, the input of the vertical amplifier is grounded; this is done for convenience in making the necessary balancing adjustments.

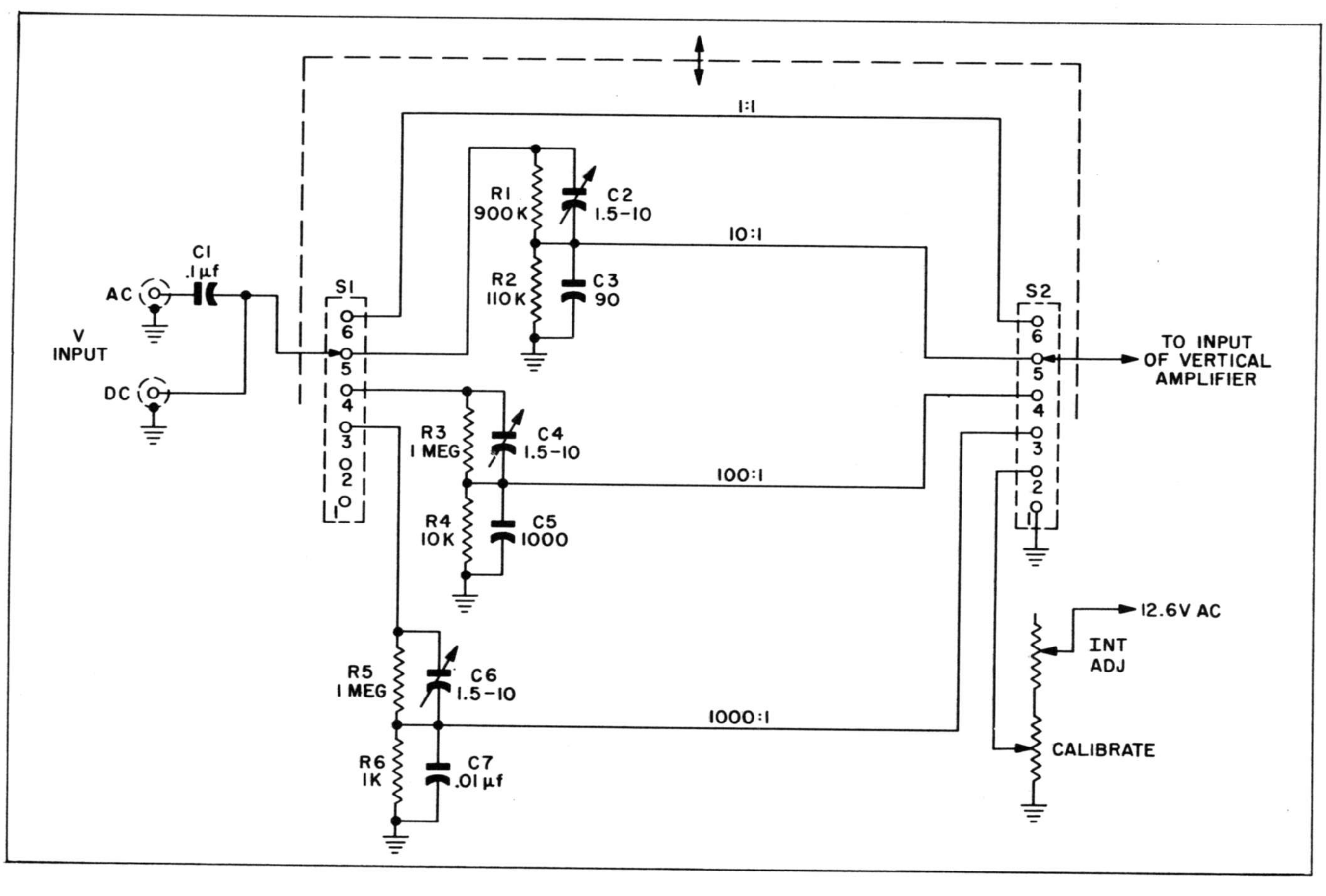


Figure 13. Vertical-Attenuator Circuit

The Vertical Amplifier

Because of the fact that the input to an oscilloscope is not always a simple sine wave, but may be a variety of waveforms, it is necessary that the vertical amplifiers have an extended pass band in order to avoid frequency distortion and the resulting change in the waveshape to be viewed on the screen.

All nonsinusoidal waveforms can be broken down into a number of sine waves of different frequencies, all added together in the proper proportions to produce the complex pattern. Among the waveforms deemed complex are the square, triangular, trapezoidal, parabolic, and saw-tooth variety, as well as audio and video. The waveforms first mentioned are generally repetitious in nature, while the latter two are usually constantly changing, and, therefore, more complex.

In order to reproduce any of these waveforms with the maximum degree of accuracy, the vertical amplifiers in the oscilloscope must be capable of amplifying equally all the frequencies represented by the waveform. However, since it is virtually impossible to make an amplifier respond to all the frequencies contained in some waveforms, it is usually acceptable to include only those which will characterize the particular waveshape. It has been found that if the fundamental and at least 7 harmonics are amplified uniformly, the waveform will be essentially unchanged for all practical purposes. For horizontal sync pulses to appear reasonably square, the response of the vertical amplifier should be flat to at least 2 mc. To observe composite video (both sync and video combined), the response of the vertical amplifier should be much greater.

The complete vertical-amplifier circuit shown in figure 14 makes use of three dual triodes. Starting from the output and working toward the input, tube V3 functions as a push-pull voltage amplifier, the plates of which are directly connected to the vertical-deflecting plates of the cathode-ray tube. This amplifier also employs cross-neutralization to suppress unwanted oscillations. These oscillations may be set up through tube and wiring capacitances. The plates of V3, the vertical-deflecting plates, and also the second anode are operated at about +260 volts above ground. These voltages are kept alike to prevent the spot from becoming egg-shaped at the screen. This defect is referred to as astigmatism. Centering of the beam is accomplished by varying R22, which makes one plate or the other more positive than its mate, while the average voltage between the pair of plates and the second anode remains the same. As an example, assume the second anode voltage to be +260 volts, and the voltage at each vertical plate to be +260 volts. Then the voltage difference between both plates and the second anode is zero. If the upper plate is then made 270 volts positive and the lower plate 250 volts positive, the average is still +260 volts. The grids of V3 are directly coupled to the plates of the preceding stage through two 220-ohm resistors, which serve only to suppress parasitic oscillations. The grids of V3 therefore operate at +90 volts; however, the cathode bias is +92 volts, and the net bias on the grids is —2 volts.

The second amplifier, V2, operates in much the same manner as the output stage. The exception is in the grid circuit, where the gain is varied by adjusting the amount of resistance between the grids.

The input stage, V1, functions as a cathode follower and phase splitter. It consists of two cathode followers, fed from an unbalanced input and giving outputs which are 180 degrees out of phase with each other, to supply the two push-pull amplifier stages described above. A simplified schematic diagram is shown in figure 15. For descriptive purposes, V1 of figure 14 is broken down into two separate tubes, V1 and V2. Resistors R12 and R13 are combined into R_c, and the cathode resistors and

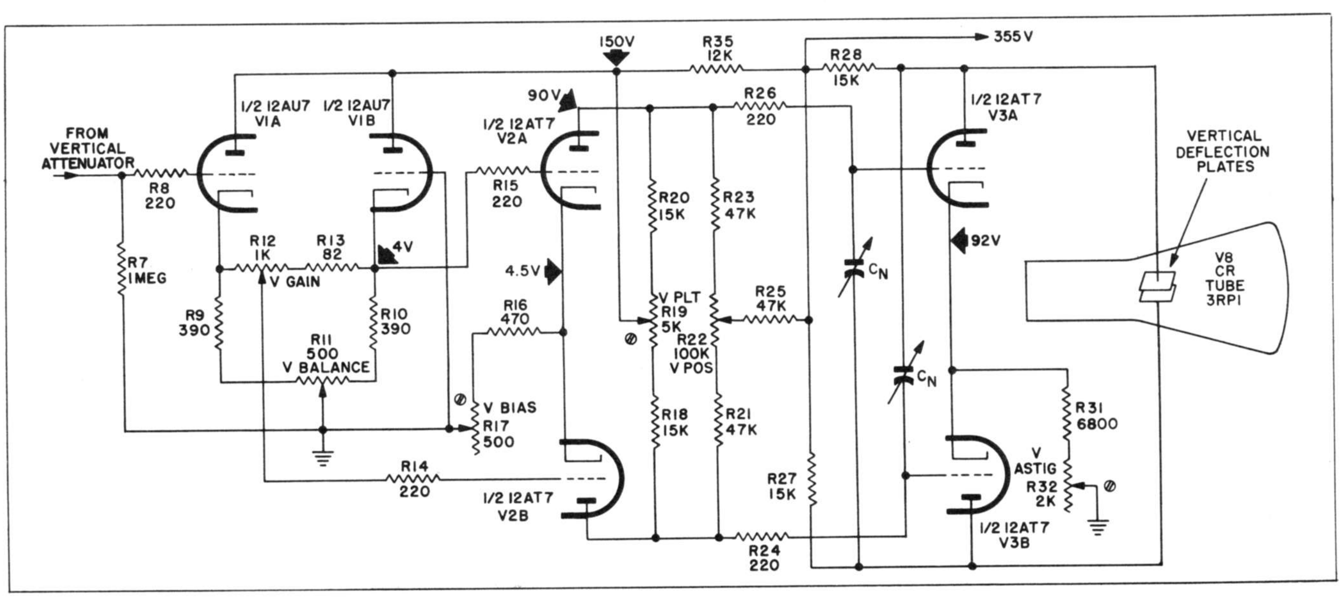


Figure 14. Vertical-Amplifier Circuit

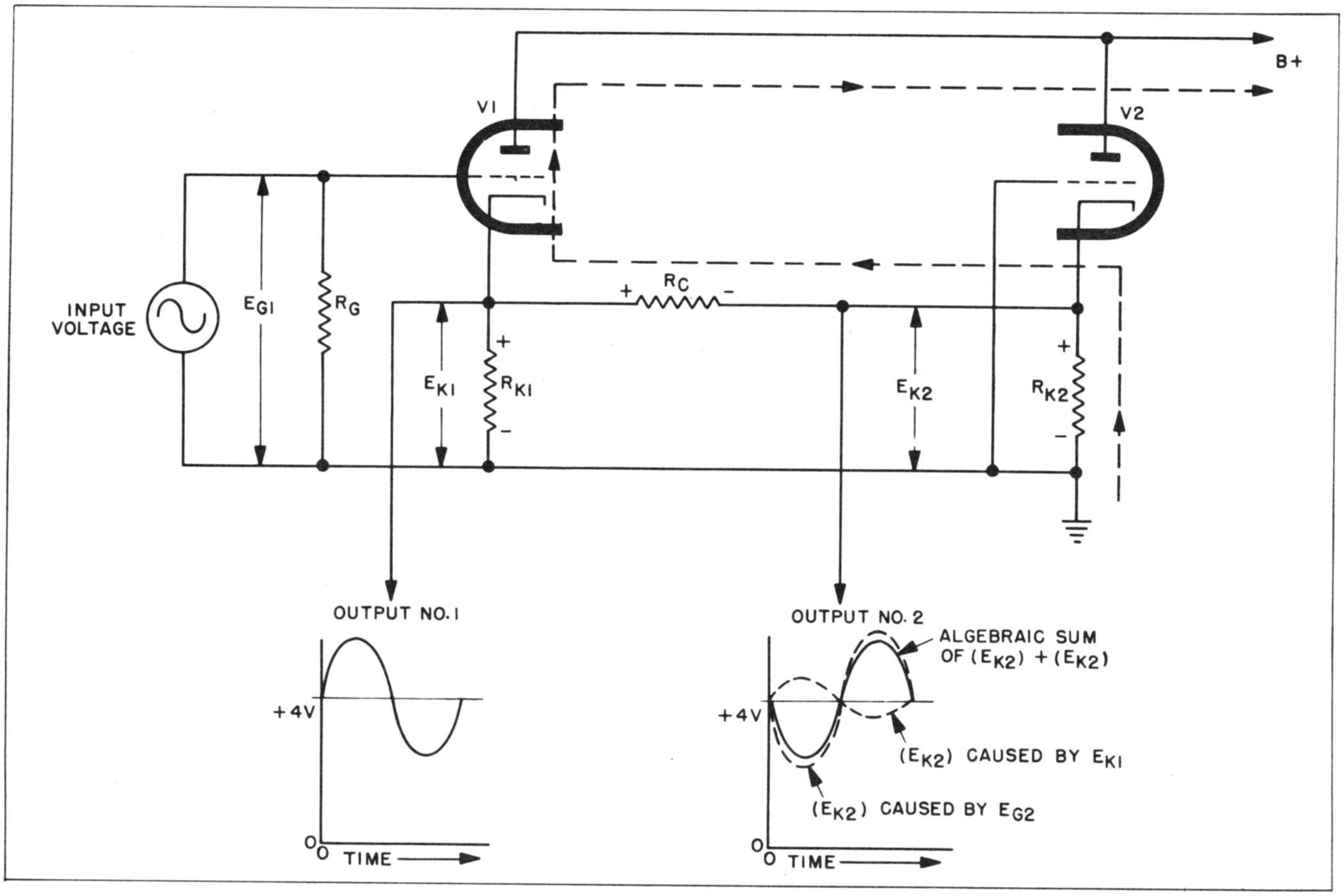


Figure 15. Simplified Schematic of Vertical-Amplifier Input Circuit

balance potentiometer are replaced by two separate cathode resistors, R_{k1} and R_{k2}. R8, the 220-ohm parasitic suppression resistor, is omitted, R_g is substituted for R_7, and a signal source is added.

Referring to figure 15, assume both plate currents to be equal, giving a cathode potential of +4 volts in each tube. During the positive half-cycle of input voltage (when E_{g1} swings in a positive direction), the plate current through tube V1 increases, causing a greater drop across R_{k1}. At the instant E_{k1} starts changing with respect to E_{k2}, a voltage difference is impressed across R_c, and, as a result, a current flows through R_c in the direction shown by the dotted arrow. Thus, R_c and R_{k2} act as a voltage divider, and the change in E_{k2} is not as great as that produced at R_{k1}. This is shown by the dotted sine wave in figure 15 labeled "E_{k2} caused by E_{k1}." Since V2 is connected as a grounded-grid amplifier, an increase in E_{k2} makes the grid swing in a more negative direction with respect to its cathode, because these elements are connected to opposite ends of R_{k2}. As the grid of V2 swings more negative with respect to its cathode, I_{p2} decreases, causing E_{k2} to decrease. This is shown by the dotted sine wave labeled "E_{k2} caused by E_{g2}." The net voltage appearing across the cathode resistor equals the algebraic sum of the two voltages just described, and is shown as a solid-line waveform in the diagram, 180 degrees out of phase with E_{k1}. In figure 15, the action of "E_{k2} caused by E_{k1}" subtracting from "E_{k2} caused by E_{g2}" can be compared to the degenerative action of an unby-passed cathode resistor in a standard amplifier circuit.

It should be understood that the preceding circuit description does not apply to all oscilloscopes, as the circuits differ widely. Some oscilloscopes employ resistance-coupled single-ended amplifiers, but the circuit may vary from a standard audio amplifier to what closely resembles the video amplifier in a television receiver.

The Time-Base Oscillator

A linear sawtooth sweep voltage is generated by the time-base oscillator circuit. The sawtooth voltage output is introduced into the horizontal-deflecting circuits, and appears as a horizontal line on the face of the cathode-ray tube. If this line is, for example, 2 inches in length, and is linear (the spot moving at a constant rate of speed), this 2-inch length can be subdivided into a number of equal segments, each representing an equal time element. If the sweep is not linear, the spot does not move across the face of the tube at a constant rate of speed, and if the line is then divided into a number of equal segments, each segment will not represent the same amount of time. As a result, any waveform impressed on the vertical input will appear to be compressed in some places and expanded in others, in a horizontal direction.

The circuit employs a cathode-coupled multivibrator, shown in simplified form in figure 16. The simplification involves only omission of the range switching, as the operation is the same on all ranges. For purposes of explanation, assume that the combination of C13, C14, R40, and C19 is taken out of the circuit by opening the connection at point A. When the power is first applied to the circuit, capacitor C20 charges to a value somewhere between zero and B+ voltage, with the polarity shown. As the cathodes come up to operating temperature, both sections of the 6J6 tube conduct. Because of the unbalance in the plate circuits, V5A conducts slightly more than V5B. This increase in plate current causes an increased voltage drop across the plate-load resistors (R44 and R45) of this tube. As the plate potential of V5A drops, coupling capacitor C20 must discharge through grid-leak resistors R72 and R46A, cathode resistor R42, and tube V5A. By making R46A variable, the discharge rate of C20 can be controlled. The discharge-current flow through the grid-leak resistances causes voltage drops of the polarities shown. The grid of V5B is driven highly negative, plate current in V5B is cut off, and V5A conducts heavily. Nothing else happens until the charge on C20 leaks off enough to raise the grid of V5B above cutoff. During this time the voltage across the cathode resistor, R42, is only that developed by the plate current of V5A. When tube V5B rises above cutoff, the total current through R42 increases, the voltage drop increases, the plate current in V5A decreases, and the plate voltage of V5A increases sharply. This sharp increase of E_{p1} is transferred to the grid of V2, and C20 charges through R42, through V5B from cathode to grid (grid current), through R44 and R45, to B+. The action continues in this manner, and the plate waveforms are approximately as shown in figure 16. The frequency of these pulses is determined essentially by the time constant of the RC circuit formed by C20, R72, and R46A. The range switch selects different values for C20 for large changes in frequency, while the frequency control (R46A) makes fine adjustment possible.

If the free-running frequency of this oscillator is made slightly lower than that of the synchronizing frequency, the multivibrator can be made to "lock-in" with the sync signal in the following manner: If a sync voltage is applied to V5A in such a way as to make grid 1 go positive just before the tube rises above cutoff, the tube can be made to fire at this instant instead of at its normal time. If, however, a negative pulse is applied to this grid when tube V5A is normally conducting, just before it is cut off by the action of E_k, the tube is immediately cut off and C20 starts to charge an instant

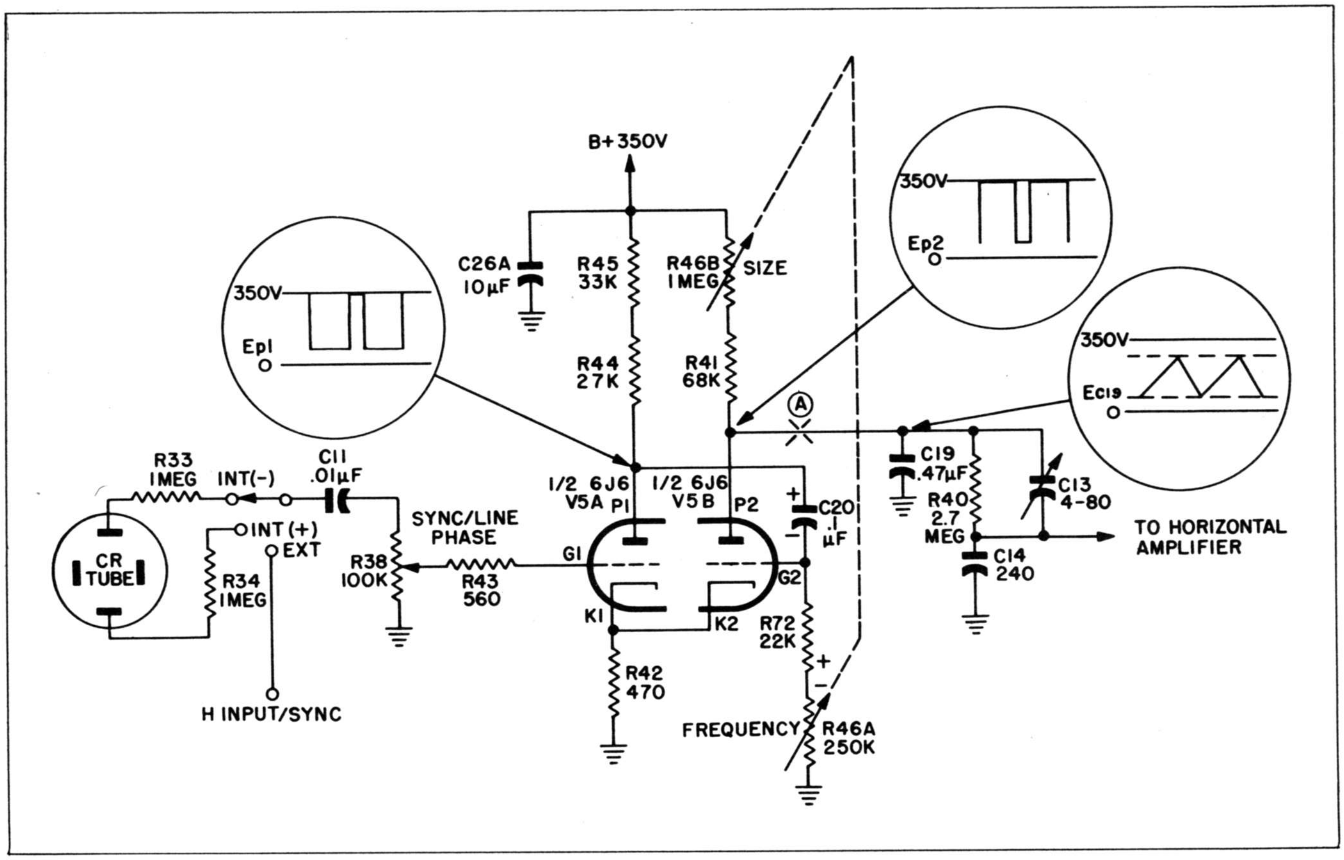


Figure 16. Time-Base-Generator Circuit

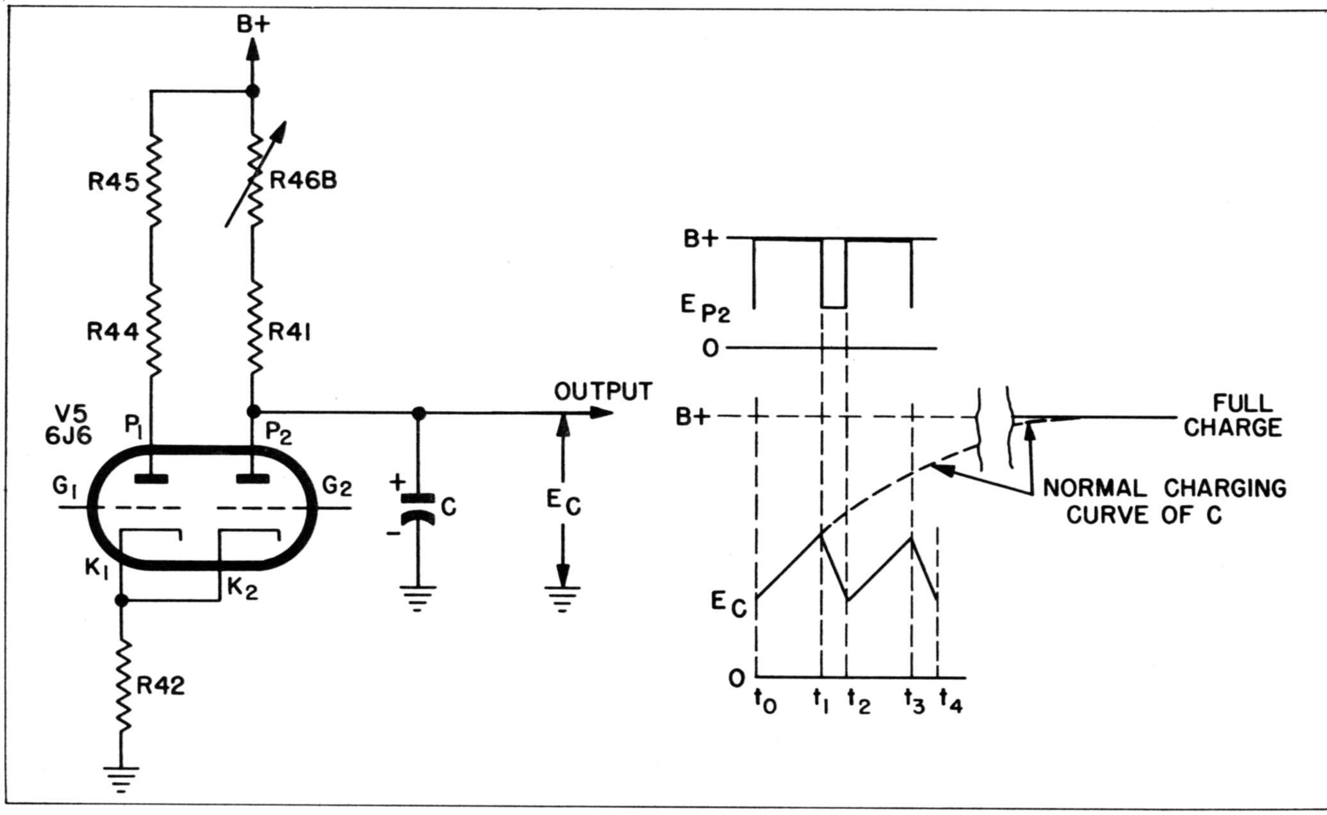


Figure 17. Simplified Schematic of Time-Base Generator

sooner than it normally would. It is very important that the amplitude of this synchronizing voltage be held to a minimum, while maintaining good synchronization, because of the amplifying action of the tube. If the sync signal is too great in amplitude, it will distort the time-base signal, and therefore appear as distortion in the pattern being viewed on the cathode-ray tube screen.

When connected at point "A" in figure 16, the combination of R40, C13, and C14 make up a coupling circuit that transfers the saw-tooth voltage to the horizontal-amplifier circuits with negligible distortion of the waveform and minimum loading of the sweep oscillator. For simplicity, capacitor C19 is shown as C in figure 17. Referring to this figure, the voltage at plate 2 is seen to be maximum for the period from t_0 to t_1, dropping to a low value from t_1 to t_2. At time t_0 the capacitor starts charging to the polarity shown across C in the diagram. The charging path is through R41 and R46B to B+, and C charges in the manner shown by the dotted curve marked "normal charging curve of C" in figure 17. However, at time t_1, before the capacitor has charged to an appreciable percentage of B+, V2 conducts, and C discharges through the tube and cathode resistor R42. When the next cycle begins at time t_2, the capacitor has not had time to fully discharge, and the voltage swing across C is consequently only a small portion of the total applied voltage. By properly proportioning the time constant of R41, R46B, and C with respect to the frequencies involved, the slope of the saw-tooth voltage can be made very nearly linear. By making R46B variable and ganging it to the frequency control, R46A, the time constant can be made to keep the correct proportions when the frequency is varied. Likewise, C19 and C20 are switched in unison to retain the necessary proportions.

The Horizontal Amplifier

The horizontal amplifier consists of one stage, using a 12AX7 high-gain dual triode. The circuit is essentially a standard paraphase (resistance-coupled push-pull) amplifier, and is shown in figure 18. The input is developed across the combination of C15 and R53, and a portion of this voltage is fed to the grid of V4A, is amplified, and then applied to one of the horizontal-deflecting plates. The signal is also coupled from the plate of V4A to the grid of V4B through a voltage-divider network which reduces the signal voltage coupled to the grid of V4B to approximately the amplitude of the signal on the grid of V4A. Because of the 180-degree phase shift through the amplifier, the signal applied to the grid of V4B is 180 degrees out of phase with that applied to V4A. The plate of V4B is coupled to the other horizontal-deflecting plate in the cathode-ray tube, and balanced push-pull deflection is obtained.

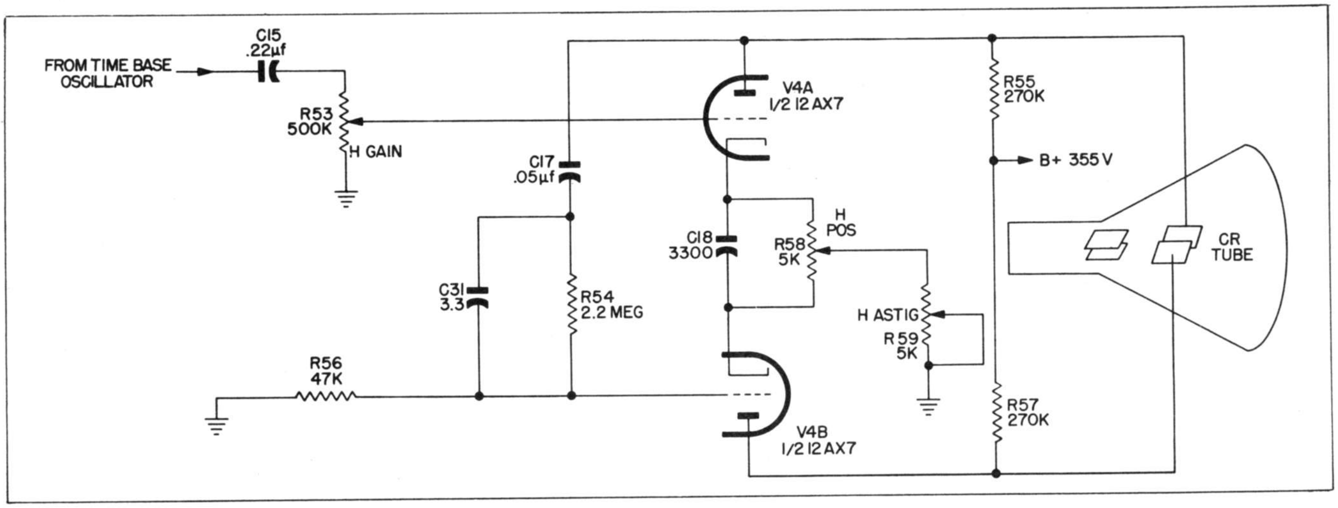


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Figure 18. Horizontal Amplifier Circuit

The horizontal amplifier in some oscilloscopes may also be of the single-ended variety, as discussed under "The Vertical Amplifier"; however, the pass band of the horizontal amplifier need not be so great. Generally speaking, the horizontal amplifier should be capable of amplifying the highest frequency of its associated time-base oscillator (usually about 30 kc.) uniformly, indicating that the response should extend to at least 210 kc.

THE R-F PROBE

A signal from an r-f or i-f circuit must be demodulated, or detected, before it is applied to the oscilloscope, as the frequency response of the oscilloscope amplifiers is limited, and signals in these frequency ranges would be greatly attenuated. Moreover, the input capacities of the oscilloscope would tend to by-pass these signals.

Detection of the signal is accomplished by the use of a specially designed probe containing a detector circuit. Modern r-f probes generally make use of germanium crystal diodes, because of their small size, light weight, and simple circuit. Moreover, the sensitivity of the crystal diode is greater than that of the vacuum-tube diode. The schematic representation of such a probe, illustrated in figure 19, is seen to be that of a half-wave detector.

In use, the probe cable is attached to the oscilloscope by means of a coaxial connector, and the ground clip from the probe is clipped to a ground point on the chassis as close as possible to the point of measurement, in order to ensure a short r-f path. The probe tip is then applied to the point in the circuit at which observations are to be made.

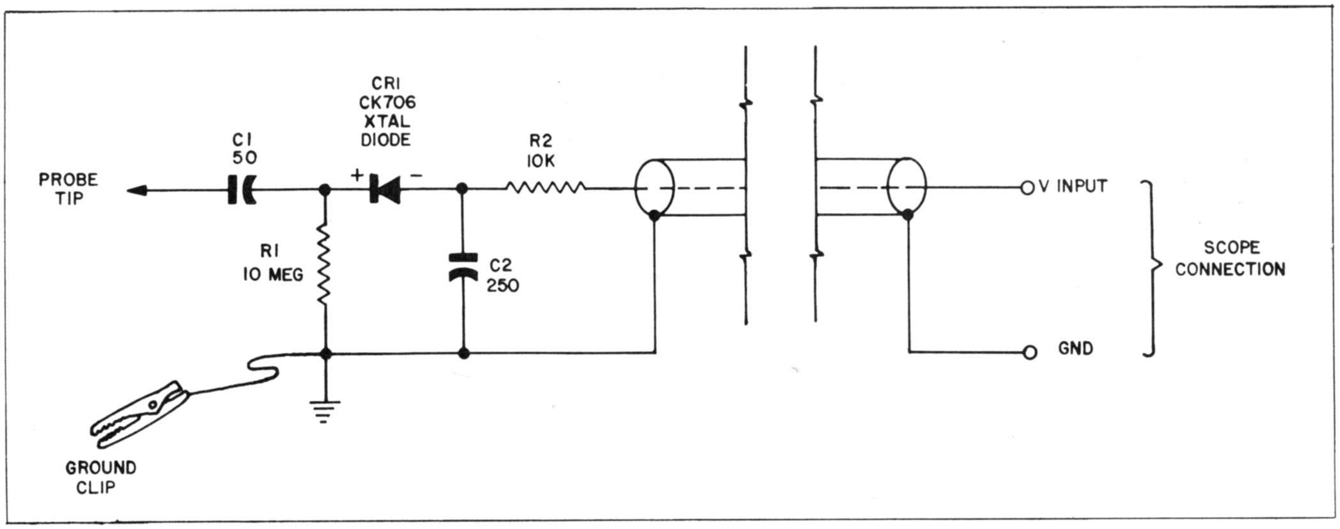

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Figure 19. Typical R-F Probe (Detector)

PART II
GENERAL USES OF THE OSCILLOSCOPE

In order to become proficient in the use of any test equipment, it is essential that some time be devoted first to practicing with the instrument, by making tests for which the results are already known. For example, if an oscilloscope is connected to a known source of pure sine waves, a perfect sine-wave pattern can be expected to appear on the screen. If at first the presentation does not look like a sine wave, but rather like a maze of lines, it is necessary to readjust the range and frequency controls until a stable display is obtained on the screen. This section is devoted to practice exercises that the reader can perform to familiarize himself with the operation of the scope, in order to be able to interpret the results and gain confidence in the accuracy of his conclusions. After familiarity is gained, it will be found that no more effort is required to use a scope properly than to use a voltmeter or a signal generator. Radio servicing requires the use of the voltmeter, ohmmeter, and similar test equipment; however, because of its versatility, the use of the oscilloscope greatly speeds the trouble-shooting process.

PRACTICE EXERCISES

With the oscilloscope connected to the a-c power line and warmed up, connect the vertical input of the scope to a source of 60-cycle voltage, such as across the filament winding of a power transformer. Observing the pattern on the screen, adjust the range and frequency controls to display two cycles, or two complete sine waves. The pattern may be found to drift slowly to the right or left; to correct for this effect, advance the sync control just far enough to steady the pattern. It is best to keep the sync control at the lowest setting that still allows the pattern to be stabilized. With a 60-cycle input voltage, if two cycles are displayed, it follows that the sweep rate must be one-half of this frequency, or 30 cycles per second.

Adjust the time-base controls to produce one complete cycle; the sweep rate will be the same as the frequency applied to the vertical input, or 60 cycles per second. As the time base is speeded up, an "X" pattern appears on the screen; this pattern indicates that the sweep frequency is twice as high as before, or 120 cycles per second. If a 120-cycle sine wave is then applied, with the sweep rate still set at 120 cycles, a single sine wave will result. Sometimes it is possible to make use of this characteristic, as in determining whether a hum has a frequency of 60 or 120 cycles. In this case, simply set the time base to display one cycle of the hum voltage (a good spot to examine this is at the speaker voice coil). Next, connect the probe to the filament circuit. If one cycle is shown on the oscilloscope screen, the hum is 60 cycles. If an "X" pattern is displayed, the hum is 120 cycles (full-wave rectifier), in which case a check of the power-supply filtering components is indicated. For a half-wave rectifier, the hum is of course 60 cycles.

Connect the vertical input of the oscilloscope to the a-c power line. A 60-cycle sine-wave pattern similar to that obtained from the filament winding of the power transformer should now appear on the screen, differing only in the relative amplitude of the two signals. When observing the 117-volt waveform, it will probably be necessary to readjust the vertical attenuator and vertical-gain control settings, to avoid overloading of the vertical amplifiers with a signal of this amplitude.

VOLTAGE MEASUREMENT

A procedure for making amplitude measurements of waveforms with the Philco Model 7020 Oscilloscope is outlined in Part I under the heading, FUNCTIONS OF THE CONTROLS. While some oscilloscopes have built-in calibration circuits, many do not; therefore, a procedure is given here for making amplitude measurements by means of an external calibrating circuit used with an oscilloscope.

Measure the unknown peak-to-peak amplitude of the waveform on the oscilloscope screen, using a flexible rule or the calibrated overlay supplied with the instrument. Then transfer the scope input lead from the signal source to a variable source of accurately metered voltage, and adjust this voltage to give the same deflection as obtained with the voltage being measured. The meter reading gives the unknown voltage. The accuracy of the result is determined by the precision of the meter and the accuracy of the measurements.

While there are many excellent voltage calibrators commercially available, a circuit will be described here that will enable the service technician to make amplitude measurements that will be sufficiently accurate for service purposes. The circuit diagram is given in figure 20.

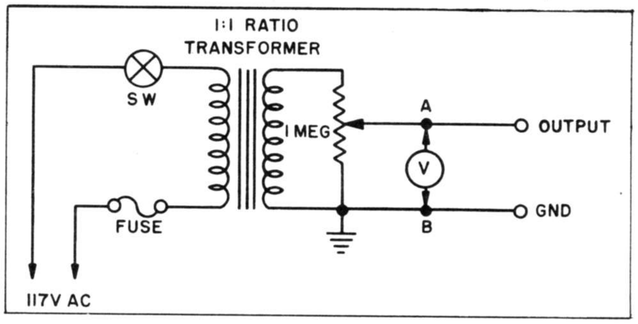

Figure 20. Simple Voltage Calibrator

The voltmeter (V) in the diagram can be any a-c voltmeter of the proper range, and points A and B can terminate in tip jacks so that the regular shop v.t.v.m. or multimeter can be connected into the circuit when it is desired to use the calibrator.

Most waveform measurements are made peak to peak; therefore, a multiplying factor must be used to determine the peak-to-peak voltage from the calibrator. As an example, assume V in figure 20 to be an r-m-s voltmeter; the peak-to-peak output voltage of the calibrator is then the meter reading multiplied by 2.82. However, if the meter being used is calibrated in terms of peak values, the peak-to-peak value is simply double the meter reading. The meter reading should be taken with the oscilloscope connected to the calibrator, in order to avoid the possibility of an error in meter reading due to possible loading effects of the scope on the calibration circuit.

As a practice exercise, try measuring the amplitudes of various waveforms, using the oscilloscope and a suitable calibration circuit such as that just described. Measure the peak-to-peak amplitude of the various windings of a typical receiver-type power transformer. To avoid the possibility of electrical shock, remove the power from the transformer while making the necessary oscilloscope connections. When working with sine waves, as in this case, the r-m-s reading at the calibrator is equal to the r-m-s value of the unknown voltage, if the peak-to-peak amplitudes of each are equal.

In going through the procedure outlined above, it will be found impossible to make the calibrating voltage equal in amplitude to that of the transformer high-voltage secondary. A simple solution is to set the amplitude of the calibrator at some submultiple of the amplitude of the unknown voltage, and multiply by the ratio of the amplitudes. As an example, suppose that the unknown voltage amplitude is set to cover 20 blocks on the screen overlay, and the calibrating voltage is adjusted to give an amplitude of 2 blocks. If the voltmeter at the calibrator indicates 75 volts, r.m.s., then multiplying this by the amount of reduction (which in this case is 20 divided by 2, or 10 to 1) gives 750 volts, r.m.s., across the transformer secondary. In this manner the oscilloscope can be used to measure voltages greater in amplitude than that of the calibrating source.

LISSAJOUS FIGURES

A method developed by Lissajous, a French scientist, makes it possible to determine the frequency ratio and phase relationship between two sine-wave signals by means of the cathode-ray tube. The patterns produced in this manner bear his name. The method consists simply of applying one signal to the horizontal-deflecting plates and the other signal to the vertical-deflecting plates, and interpreting the resulting configuration of loops and lines appearing on the screen of the cathode-ray tube.

For a Lissajous pattern to remain stationary on the screen of the oscilloscope, the two numbers comprising the ratio of the applied frequencies must be integers; that is, 1:1, 3:1, 3:2, 3:4, and so on. When the ratio is 1:1, or unity, the pattern will be a straight line, a circle, or an ellipse, depending on the phase relationship between the signals and their respective amplitudes. Figure 21 illustrates some of the various possibilities.

In patterns of this type, there is frequently a slow drift from one pattern shape to the next, despite all efforts to keep the display stationary. This condition is attributable to a slight frequency instability in at least one of the signals, and creates the illusion that the pattern is being traced around the outside of a revolving glass cylinder.

In practice, the maximum frequency ratio whose pattern can be interpreted without the aid of photography is about 10:1. Some possible combinations are shown in figure 22. If the frequency of one of the applied signals is known, it is possible to determine the frequency of the other by applying the ratio, determined from the pattern on the screen.

There are several methods of determining the frequency ratio represented by a particular Lissajous pattern. One of the simplest of these is described below. Extend a vertical line down through the pattern at a location where it will intersect with the maximum number of pattern lines. Do not draw the line through the individual intersections of the pattern lines. Extend a horizontal line through the pattern in the same manner. Then, referring to figure 22(b), the vertical and horizontal phantom lines shown are those just described. The ratio that the pattern represents can then be determined by counting the number of intersections of the pattern lines with the phantom lines. The number of intersections with the horizontal line just drawn relates to the frequency at the vertical input, and the number of intersections with the vertical line relates to the frequency at the horizontal input; the number of intersections in each plane comprises the ratio between the

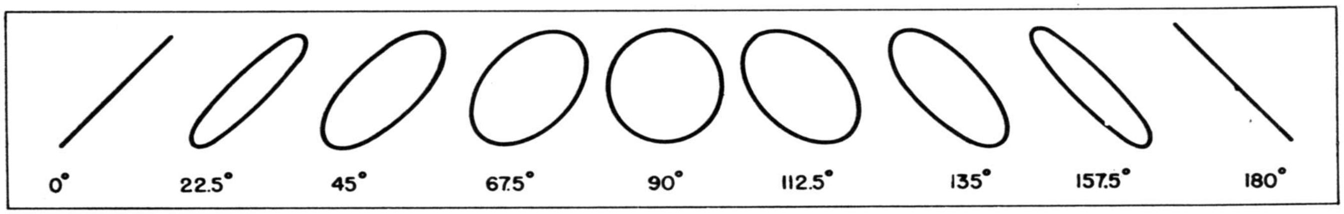

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Figure 21. Various Phases of a 1:1 Lissajous Pattern

two applied frequencies. Using figure 22(b) as an example, twelve intersections can be counted along the horizontal line, and two intersections along the vertical line. The ratio is therefore 12 to 2, or, reducing to lowest terms, 6 to 1. If the signal applied to the horizontal plates is known to be 60 cycles, from the ratio just determined the frequency applied to the vertical plates must be 6 times greater, or 360 cycles.

Another example is given in figure 22(e). Here 10 intersections appear along the horizontal line, and 6 along the vertical line, giving a ratio of 5 to 3. If the frequency of the signal on the horizontal plates is still 60 cycles, the frequency at the vertical plates is 5/3 as great, or 100 cycles.

For an actual measurement, the pattern can be centered under the plastic ruled overlay on the screen by use of the centering controls provided on the oscilloscope. This method eliminates the need for drawing the vertical and horizontal lines.

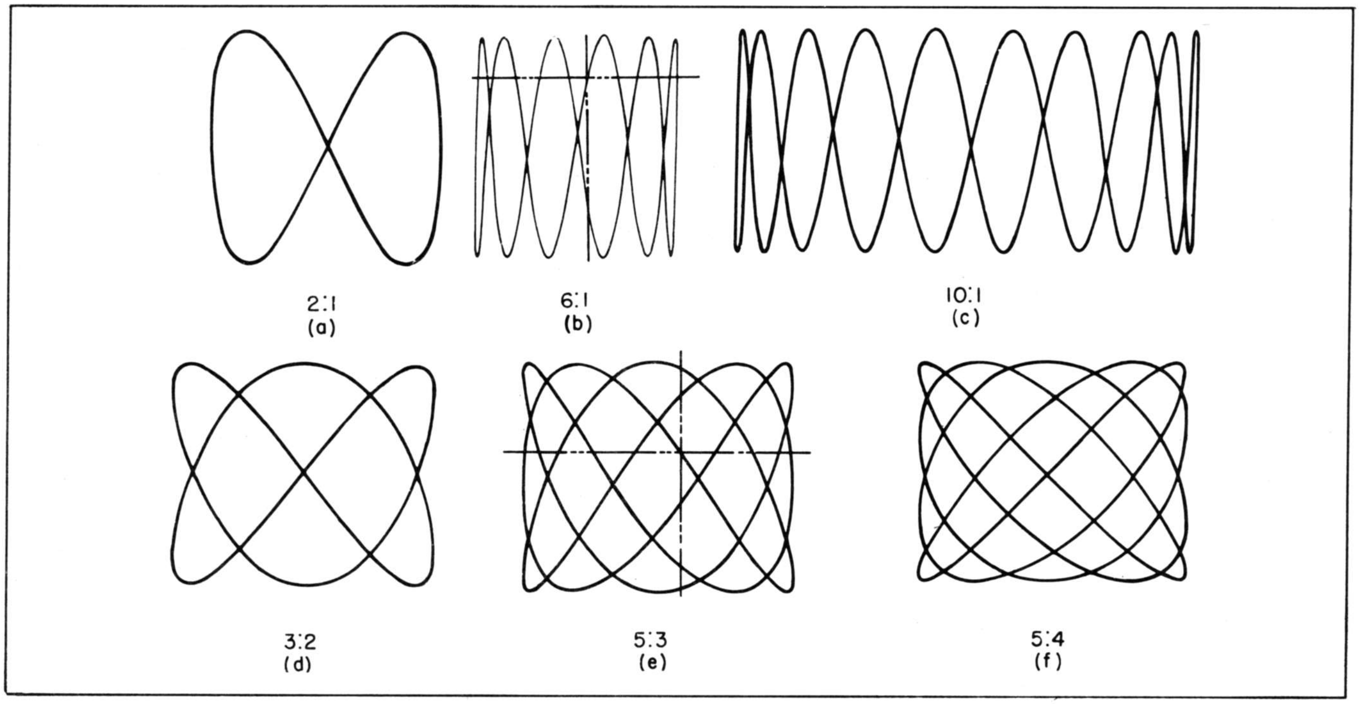


Figure 22. Frequency Comparison with Lissajous Figures

PART III
APPLICATIONS OF THE OSCILLOSCOPE TO HOME RADIO SERVICING

The oscilloscope is no longer to be considered a laboratory instrument; it has proven itself to be adaptable to all phases of electronics, including the servicing of home radios. In this section, several of the more important applications of the oscilloscope to the field of radio servicing are outlined, together with a few time-saving short cuts. In the course of daily work routine, the service technician will undoubtedly find many uses for this versatile instrument, in addition to the few outlined here.

VISUAL ALIGNMENT

Perhaps one of the most important applications of the oscilloscope is the sweep-generator method of aligning tuned circuits. When a scope is used in conjunction with a sweep alignment generator and an r-f marker generator, a very clear picture of the frequency response of a circuit can be obtained. The point-by-point process for determining the frequency response of a circuit is performed by applying a series of individual signals at various frequencies, all of the same amplitude, to the circuit input, and measuring the output amplitude at each frequency. By plotting a graph of amplitude versus frequency, a response curve of that circuit is obtained. This time-consuming process can be superseded by an instantaneous method, using an equipment setup similar to that shown in figure 23. This method will give as accurate results as the point-by-point method if the precautions given in the service manual are observed.

The sweep alignment generator gives an output of constant amplitude while sweeping through a range of frequencies. The sweep rate generally used is 60 sweeps per second, each sweep starting at the lowest frequency, progressing to the highest frequency, and then back

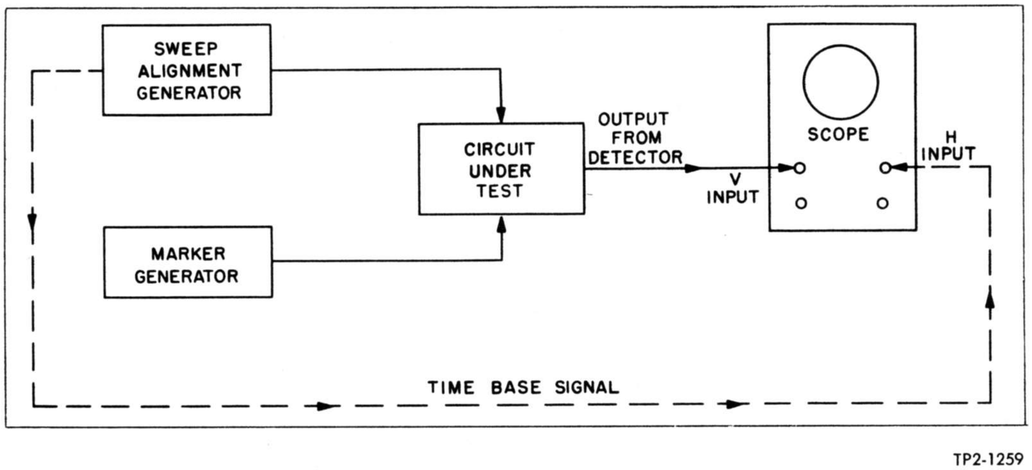


Figure 23. Equipment Setup for Visual Alignment

again. The range of frequencies swept is usually variable by means of front-panel controls. As a rule, the same 60-cycle voltage used to operate the frequency modulator within the sweep alignment generator is also brought out by means of connectors, so that the horizontal input of the oscilloscope can be supplied with a time base that is properly phased with the frequency variations of the sweep alignment generator.

If the sweep alignment generator supplies horizontal-deflection voltage to the oscilloscope, it generally incorporates a phasing control so that the pattern can be properly adjusted for best viewing conditions. The effects of this are shown in figure 24. In some oscilloscopes, 60-cycle sine-wave voltage is made available to the horizontal input by means of the horizontal-input switching system for visual alignment purposes. In these oscilloscopes, a phasing control is generally incorporated for the same reason.

It will be observed that the alignment pattern illustrated in figure 24 represents relative response versus frequency. The only accurate way in which frequency can be indicated on the response curve is by injecting a marker signal into the circuit being examined simultaneously with the signal from the sweep alignment generator. The marker-signal generator should be very accurate in calibration, or the accuracy of the entire alignment process may be seriously impaired. Another method is sometimes employed for markers; this consists of having an absorption-type wavemeter circuit incorporated in the sweep alignment generator, and coupled to the sweep oscillator in such a manner as to provide a small marker in the output. In both cases, the marker is made continuously variable. In practice, the marker is moved along the trace to the desired point, and the marker dial consulted to determine the frequency; or the marker dial is set for the desired frequency, and the resulting pip on the trace then identifies that frequency on the response curve. When using a separate signal generator to supply markers, care must be taken not to distort the response curve by the loading effect of the marker generator on the circuit, or by overloading the circuit with too high a signal output from the generator. The output of the marker generator should be adjusted to give as small a pip as practicable. When it is necessary to inject a marker from a separate signal generator, a good rule to follow is to observe the response pattern before injecting the marker, and then try adding the marker by capacitive coupling in several places until one is found at which the response curve does not become distorted. Some good methods

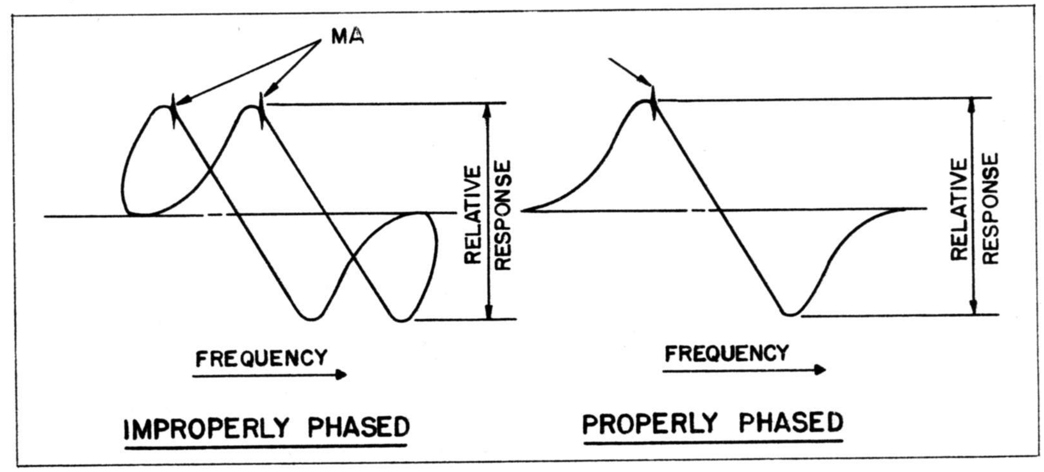


Figure 24. Effects of the Phasing Control

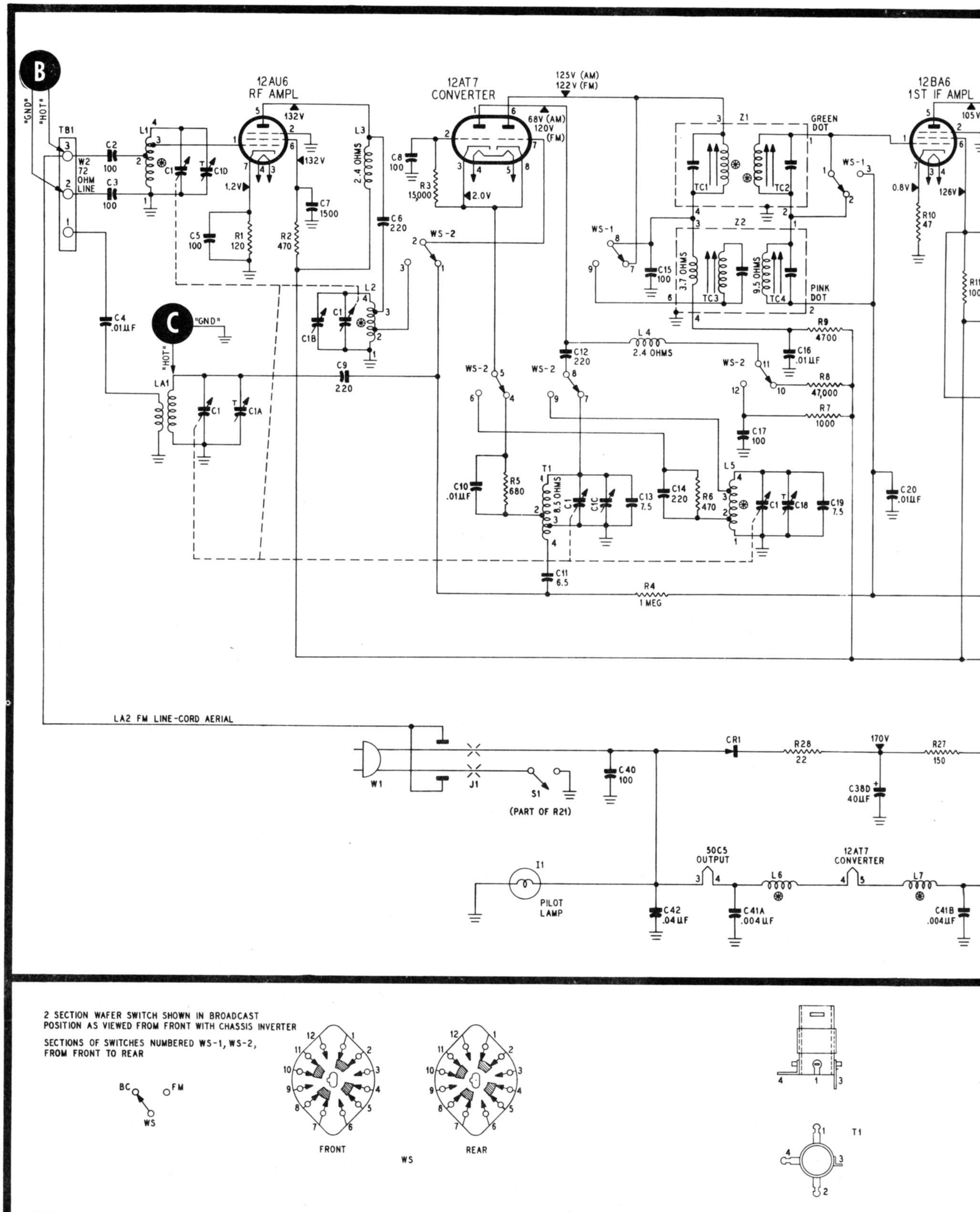
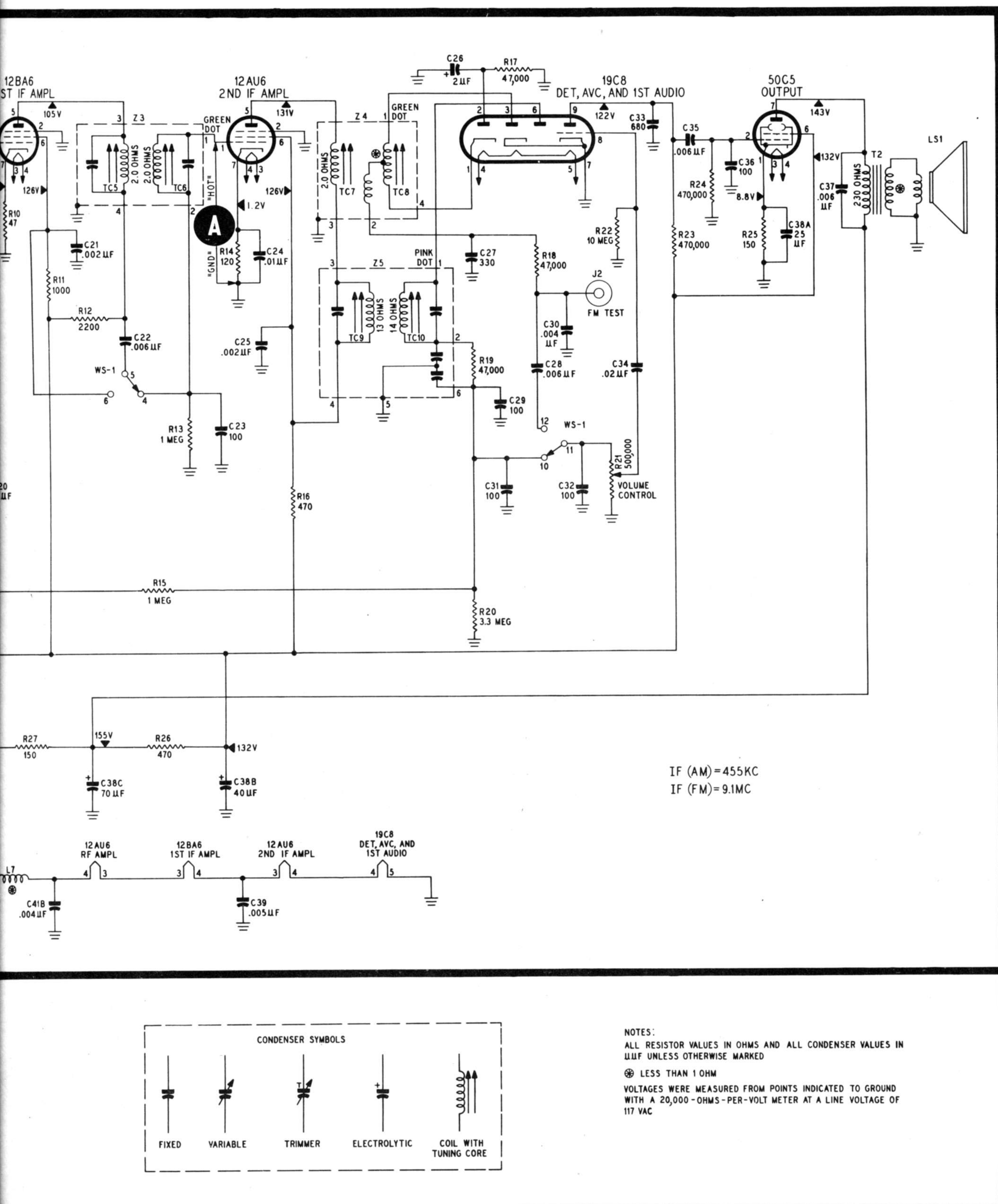


Figure 25. Schematic Diagram of



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agram of a Typical AM-FM Receiver

for injecting markers include clipping the marker-generator lead to the exhaust stem on the top of a miniature tube, over the insulation on a filament lead, or over the body of an insulated-type composition resistor.

ALIGNMENT OF FM RECEIVERS

In the alignment of FM radio receivers, the system of visual alignment described above is usually employed. The receiver should have a comparatively wide pass band, so that the frequencies covered by the FM signal are all amplified uniformly. If, for example, the i-f amplifiers of an FM receiver are aligned with an AM signal generator, the bandwidth may be rather difficult to define. With the visual-alignment method, the response curve can be observed continuously as the adjustments are being made, and it is therefore a simple matter to obtain the proper response curve with a minimum of time and effort.

Because of the many types and variations of FM circuits, no one procedure gives unexcelled results in all cases; however, the general method given here is a typical alignment procedure. In all cases, the procedure recommended by the manufacturer should be followed.

A typical AM, FM receiver is shown schematically in figure 25. The switching is shown in the AM position. However, only the FM alignment will be discussed at this point. Alignment of the AM circuits will be considered later.

Allow the receiver and sweep alignment generator to warm up for 15 minutes; then connect the vertical input of the oscilloscope to the audio output from the FM detector (readily accessible at the FM TEST JACK, J-2,) and connect the ground lead of the scope to the receiver chassis. Connect the horizontal input of the scope to the time-base output of the sweep alignment generator. Tune the receiver to 88 mc. (plates of ganged tuning capacitors fully meshed), with the band switch set in the FM position, so that no signal will be received to interfere with the alignment. Couple the output of the sweep alignment generator through a 0.01-μf. capacitor to the grid of the second i-f amplifier, point A in figure 25, and connect the ground lead from the generator to the chassis of the receiver. Set the generator to sweep a band of frequencies about 600 kilocycles wide, with a center frequency of approximately 9.1 mc. At this point some sort of a response curve should be observed on the screen of the oscilloscope.

Set the r-f marker-generator dial to produce a pip on the trace at exactly 9.1 mc. If no pip can be observed detune the secondary of the discriminator transformer (TC8) until the pip can be seen on the response curve. Adjust the primary of the discriminator transformer (TC7) for maximum response about the 9.1-mc. marker. Next adjust the secondary of the discriminator transformer to obtain a symmetrical "S" curve similar to that shown in figure 26. When the discriminator is tuned correctly, the center frequency is equidistant from the peaks of the curve. When the marker is at zero center frequency, it is not seen at all, because there is no output from the discriminator at this frequency. Repeat the adjustments with TC7 and TC8 for maximum gain and symmetry, as indicated by the oscilloscope. The marker should now be moved along the curve to make sure that the response curve is at least 150 kc. wide at the points indicated in figure 26.

With the scope still connected to the FM test jack, and without disturbing the settings on the sweep generator, move the sweep-generator lead to the lug on the mixer-grid section of the FM tuning gang (junction of C1 and lug 4 of L2), still using the 0.01-μf. capacitor in series with the generator "hot" lead. Adjust the primary and secondary of the 2nd i-f transformer (TC5 and TC6) for maximum amplitude on the scope, in keeping with good symmetry. The primary and secondary windings of the 1st i-f transformer (TC1 and TC2) should now be adjusted for maximum amplitude and symmetry, to obtain a waveform similar to that shown in figure 26.

NOTE

In the foregoing procedure, care should be exercised to avoid overloading of the i-f circuits; otherwise, the response will APPEAR broader than it actually is. The manufacturer's service data should always be consulted. Usually, a maximum output voltage at the detector or speaker voice coil is specified, and instructions are given to adjust the input from the signal generator to keep the output voltage at or below this specified value.

The local oscillator should now be adjusted to track with the dial calibrations and the i-f amplifier. The sweep alignment generator should be connected to the antenna input terminal board (TB1) in the following manner: Connect the "hot" lead from the output of the sweep alignment generator to terminal 3 of TB1 (hot side of the antenna input circuit), and the ground lead to terminal 2 of TB1 (ground side of antenna input circuit). This is shown as point "B" in figure 25. The input impedance at TB1 is 300 ohms; to obtain proper results, the sweep alignment generator should be matched to this input. If the output impedance is 300

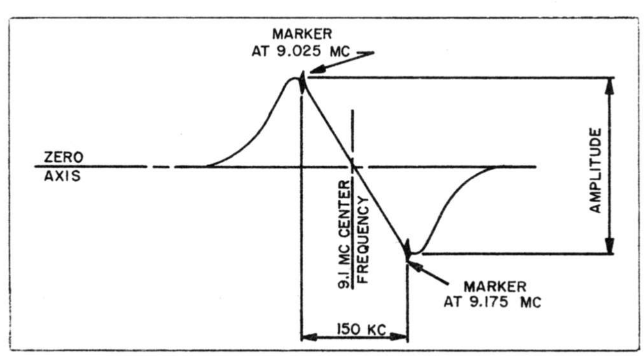

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Figure 26. Discriminator Response Curve

ohms, the generator may be connected directly. If the impedance is less than 300 ohms, it will be satisfactory to insert a noninductive resistor in series with the "hot" lead, to make up the total of 300 ohms. As an example, assume that the output impedance of the sweep alignment generator is 150 ohms; then a 150-ohm carbon resistor should be inserted in series with the generator "hot" lead. With the receiver tuning dial still set for 88 mc. (at the first index mark from the left on the dial backing plate), and the oscilloscope still connected to the FM test jack, turn the horizontal-gain control down to a minimum so that just a vertical line is seen on the scope. Set the sweep alignment generator at a center frequency of 99 mc., with a total sweep width of 150 kc., and adjust the FM oscillator coil (L5) for a maximum indication on the scope. Reset the sweep alignment generator to a center frequency of 108.5 mc., set the receiver tuning dial to 108.5 mc. (the first index mark from the right-hand end of the dial backing plate), and adjust the FM oscillator trimmer capacitor (C18) for a maximum indication on the scope.

To align the r-f circuits, the sweep alignment generator remains connected to TB1 (antenna input), and the scope is still left at the FM test jack. Adjust the sweep alignment generator for a center frequency of 105 mc., with the total sweep width still 150 kc., with the receiver tuning dial at 105 mc. (the third index mark from the right-hand end of the dial backing plate), and adjust the FM r-f trimmer (C1B) for maximum indication while rocking the tuning gang slightly about the 105-mc. index mark. Adjust the FM aerial trimmer (C47) for maximum response at this same frequency. The FM r-f coil is then adjusted by changing only the center frequency of the sweep generator to 92 mc., setting the radio tuning dial to 92 mc. (the third index mark from the left-hand end of the dial backing plate), and adjusting the FM r-f coil (L2) for maximum amplitude on the oscilloscope. Tuning the FM aerial coil (TC11) for maximum response at this frequency completes the alignment.

ALIGNMENT OF AM RECEIVERS

In the alignment of AM radio receivers, the methods employed will necessarily vary to suit different receivers. However, in all cases the equipment used is more or less standard; the setup usually consists of an AM signal generator and an indicating device, which may be either an output meter or an oscilloscope. The oscilloscope can be used for an output indicator in any type of alignment, and since this book is concerned primarily with the practical application of the oscilloscope, its use in this application will be considered here.

The general procedure for aligning an AM receiver is first to align the i-f amplifiers, then the converter, then the r-f amplifier (if one is used), and finally the aerial tuning circuits. The actual equipment connections may vary from one receiver to another, but the steps always follow this general pattern. In an FM, AM receiver, the AM circuits are generally aligned completely before the FM circuits are adjusted. An alignment procedure for the AM section of the receiver, depicted schematically in figure 25, is described below.

The first step in the alignment procedure is to check the position of the tuning-dial pointer relative to the setting of the ganged tuning capacitors. This is accomplished by setting the pointer over the first index mark at the left-hand end of the dial backing plate, with the tuning capacitor plates fully meshed. Allow 15 minutes for the equipment to warm up; then set the volume control to maximum and the band switch for broadcast reception, and turn the tuning gang to the fully unmeshed position. Set the vertical-gain control of the oscilloscope for a good-sized pattern, using a 1.25-volt, 60-cycle input signal from such a source as the calibrating circuit described in Part II of this handbook. The pattern size for a 1.25-volt input with a specific gain-control setting should be noted for reference throughout the alignment procedure. Turn the horizontal-gain control of the scope to minimum, so that only a vertical line appears on the screen. Connect the scope across the speaker voice coil without disturbing the setting of the vertical-gain control.

Connect the ground lead of the AM signal generator to the receiver chassis, and connect the "hot" lead from the generator through a 0.1-μf. capacitor to the junction point between LA1 and L8 in the mixer grid circuit, designated in figure 25 as point C. Set the generator to produce a tone-modulated AM signal of 455 kc., and adjust the primary and secondary of the 2nd i-f transformer (TC10 and TC9) for maximum indication on the oscilloscope. If the amplitude at the oscilloscope exceeds the 1.25-volt limit, as previously calibrated, reduce the r-f output of the generator. This is done to prevent overloading of the receiver circuits; throughout the AM alignment procedure the output of the signal generator should be reduced whenever necessary to keep the voltage output at the speaker voice coil from exceeding 1.25 volts. After peaking the second i-f transformer, adjust the 1st i-f transformer (TC4 and TC3) for maximum indication on the oscilloscope. Repeat the tuning adjustments on both i-f transformers until no further increase in output is obtained. This completes the alignment of the i-f circuits.

For alignment of the converter stage, it will be necessary to make up a radiating loop for the purpose of radiating a test signal from the signal generator which can be received by the loop aerial of the receiver. This is made from 6 to 8 turns of insulated wire, the completed loop being about 6 inches in diameter. A small amount of cellophane tape can be used to bind the turns together. Connect the loop to the signal-generator output, and place it near the loop aerial of the receiver. Set the signal generator for a modulated output at 1620 kc., set the receiver tuning gang for 1620 kc. (the second index mark from the right-hand end of the dial backing plate), and adjust the local-oscillator trimmer (C1C) for a maximum indication on the oscilloscope.

Set the signal generator to 1500 kc., tune the receiver gang to pick up this signal, and adjust the aerial trimmer (C1A) for a maximum indication on the scope. This completes the alignment of the AM receiver.

DETERMINING THE PERCENTAGE OF RIPPLE IN POWER SUPPLIES

The oscilloscope is useful in determining the percentage of ripple at the output of a power supply. Measure the r-m-s value of the ripple component with the oscilloscope, using a suitable voltage calibrator. If the scope will also indicate d-c values, as is possible with the Philco Model 7020, measure the d-c output of the power supply in the same manner. If the oscilloscope is not designed for d-c measurements, it will be necessary to measure the d-c output voltage of the power supply with a voltmeter.

With the r-m-s value of the ripple voltage known, it is only necessary to divide this value by the value of d-c output voltage, and multiply the quotient by 100 to find the percentage of ripple. In the example of figure 27, the power supply delivers 150 volts, d.c. The ripple component, as measured with the aid of an oscilloscope, is found to be 15 volts, r.m.s. Dividing 15 by 150 gives a quotient of 0.1, and multiplying this by 100 gives the percentage of ripple, which in this case is 10%. In actual practice, however, the percentage ripple will be much smaller than this unless the power supply has one or more defective components.

SIGNAL TRACING

The process of signal tracing is not new, but a brief review is included here because this system of localizing trouble is very useful in many cases. Usually, it is performed with a special test instrument known as a signal tracer. This instrument consists of a detector circuit and a high-gain audio amplifier provided with a speaker or headphones. A jack is brought out from the detector, and another from the audio amplifier, for attaching test leads or cables. In practice, the signal-tracer test lead is applied systematically to the input and output of each stage of the receiver, actually monitoring the signal at each point for amplitude and also for distortion or hum, until the faulty stage is located.

Depending on which way the signal-tracing process is performed—that is, from speaker to antenna or from antenna to speaker—the sound is either heard in the signal tracer when the defective stage is passed, or is cut off when the defective stage is passed. The choice of progressing forward from the audio stages toward the antenna of the receiver, or vice versa, will depend upon the individual preference of the service technician. Some troubles are more readily located by tracing in one direction rather than the other.

In this discussion, however, it will be shown how an oscilloscope equipped with a detector probe can be used for signal tracing; in order to obtain the best results, the oscilloscope used for this purpose should have a high-gain vertical amplifier.

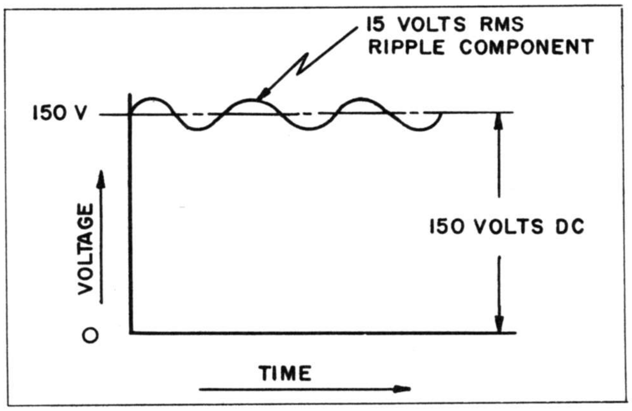

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Figure 27. Power-Supply Ripple Voltage

One advantage of using the oscilloscope in signal tracing lies in the ability of this instrument to give a visual presentation of the relative gain from stage to stage, as well as distortion. If a signal generator with tone modulation is used also, the process of tracing the signal through the r-f and i-f circuits is very effective, and the pattern on the screen of the oscilloscope is the modulation frequency of the signal generator. In practice, the signal generator is connected to the input of the receiver, and the signal tracing is carried out in the manner described in the following paragraphs.

NOTE

Before starting the signal-tracing procedure, it is recommended that the receiver be checked for physical signs of trouble, such as unlit or obviously gassy tubes, odors of burning parts, arcing sounds, no B+, tubes not in correct sockets, etc.

Referring to the block diagram of figure 28, apply the r-f probe of the oscilloscope to the input of the r-f stage (point A). A signal should be observed at this point; if a normal signal is not obtained, check the aerial coupling circuits. If a normal signal is obtained, apply the probe to the output of the r-f stage (point B). If a normal signal is not present here, check the r-f stage. If the signal is normal at this point, proceed to point C, the input of the converter stage. If a normal signal is not obtained at this point, look for an open coil or capacitor in the coupling circuit between the r-f plate circuit and the converter grid circuit. Assuming the signal at the converter grid circuit to be normal, proceed to the converter plate (point D). If a normal signal does not appear here, first check the local oscillator. A simple way to do this is to measure the negative grid bias at the oscillator, and compare it with the normal value. If the local oscillator is operating correctly, check the remaining parts of the converter circuit, including correct tuning of the i-f transformer.

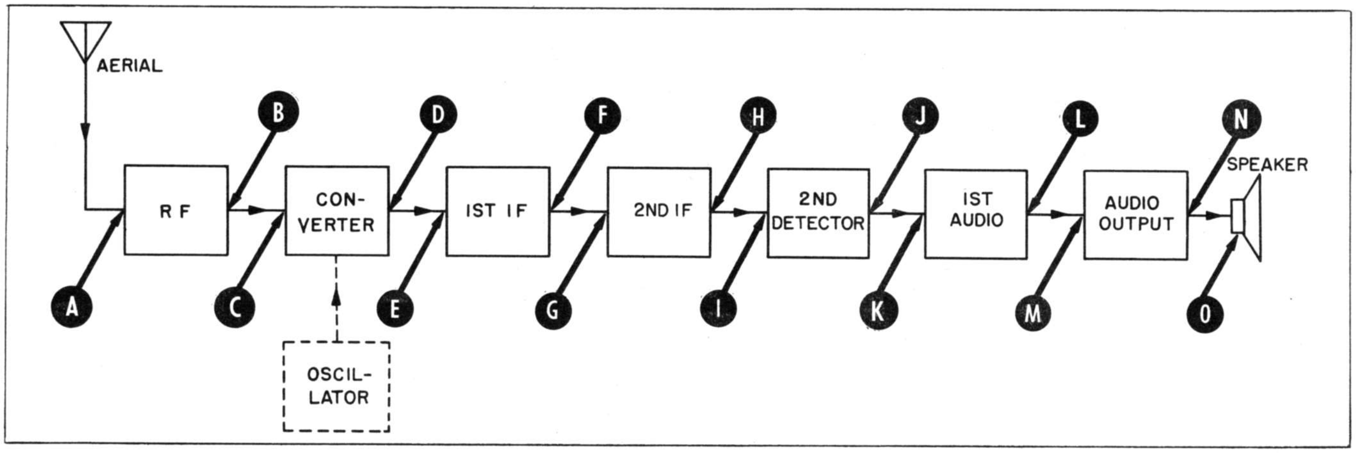

Figure 28. Block Diagram of AM Receiver

For purposes of explanation, assume the signal to be normal at the converter output. If a normal signal is not obtained at the grid of the first i-f amplifier (point E), a defective or detuned i-f transformer between the converter and the first i-f stage is indicated. Checking the signal in this manner at each succeeding grid and plate circuit should point out the faulty stage. Voltage and resistance checks should then be used to locate the defective component. After reaching the second-detector circuit, it is no longer necessary to use the detector probe, as the oscilloscope can be applied directly to the audio circuits.

Referring again to figure 28, assume the receiver to have a modulation hum. This trouble can be distinguished from similar effects by the fact that the hum appears only when the receiver is tuned to a station. If an unmodulated r-f signal is applied to the input of the receiver, and the receiver tuned to the applied frequency, isolation of the defective stage will be facilitated. With the unmodulated r-f signal generator connected to the receiver aerial, apply the oscilloscope (using the detector probe to the input and output of the r-f and i-f stages successively, until an output waveform appears on the screen of the oscilloscope. The waveform will be that of the hum modulation, and will appear at a point in the circuit immediately following its point of origin. In cases of this type it is sometimes helpful to note the frequency of the hum pattern produced on the oscilloscope screen, as this may give a valuable clue as to the cause of the hum.

For another example of the value of the oscilloscope in signal tracing, consider the case of a receiver in which the noise level is abnormally high at all times, regardless of tuning or whether an aerial is connected. Starting at the input, with a normal modulated signal applied, the detector probe is applied to the input and output of each stage as before. Assume that at the grid of the first i-f stage (point E in figure 28) the signal is normal; that is, no noise is present on the waveform. If, as the detector probe is moved to the first i-f plate, noise suddenly appears on the waveform, the first i-f stage can be considered at fault. In this case, replace the first i-f tube with another that is known to be good. If changing the tube does *not* eliminate the noise, *replace the original tube,* and proceed to check the i-f transformer in the plate circuit of the first i-f stage. This may be accomplished by voltage and resistance measurements, or by substituting a new part. The scope can also be applied, without the detector probe, directly across the primary of the i-f transformer; since noise of this nature varies at an audio rate, only the noise will be seen on the oscilloscope. Cases have been found where a noise of as much as 18 to 20 volts has been developed across the i-f-transformer primary. This can usually be attributed to electrolysis, which causes pitting and possibly breaks in the wire. In most cases, however, this process takes years to cause the effects described, and, therefore, is generally found only in older receivers.

Another use of the oscilloscope is in checking for amplitude distortion in an audio-amplifier circuit. A fixed audio-frequency signal is applied to the input of the amplifier, and the scope used to observe the signal after it passes through each stage. Using the same block diagram as before (figure 28), the audio signal generator is connected to point K (the input of the first audio stage), and the scope is applied to points L, M, N, and O, successively. If the waveform is undistorted at the plate of the first audio stage (point L) and distortion appears in the following grid circuit (point M), a check of the coupling circuit between these two stages should be made. An indication of the type just described can usually be attributed to a leaky coupling capacitor, which causes grid current to flow in the following stage. If the signal waveform shows no distortion up to and including the voice coil of the speaker (point O), but the speaker output still sounds harsh and distorted, the voice coil is probably rubbing against the pole piece in the speaker. In this case the speaker cone must be re-centered, or a new speaker installed.

It can be easily seen that the systematic method of signal tracing has a definite place in the trouble shooting of home radios, and also that the oscilloscope, because of its versatility, is very adaptable to this type of service.

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