The Cathode Ray Oscilloscope

By

Raymond Soward,
Chief Engineer

SUPREME INSTRUMENTS CORPORATION
Greenwood, Mississippi, U. S. A.

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RAYMOND SOWARD, Chief Engineer

Bachelor of Science, University of Wichita;
Associate Member, Institute of Radio Engineers;
Design Engineer, Supreme Instruments Corporation;
Associate Radio Engineer, Instructor Maintenance
and Repair School, Signal Corps; Several
Years Radio Repair Business.

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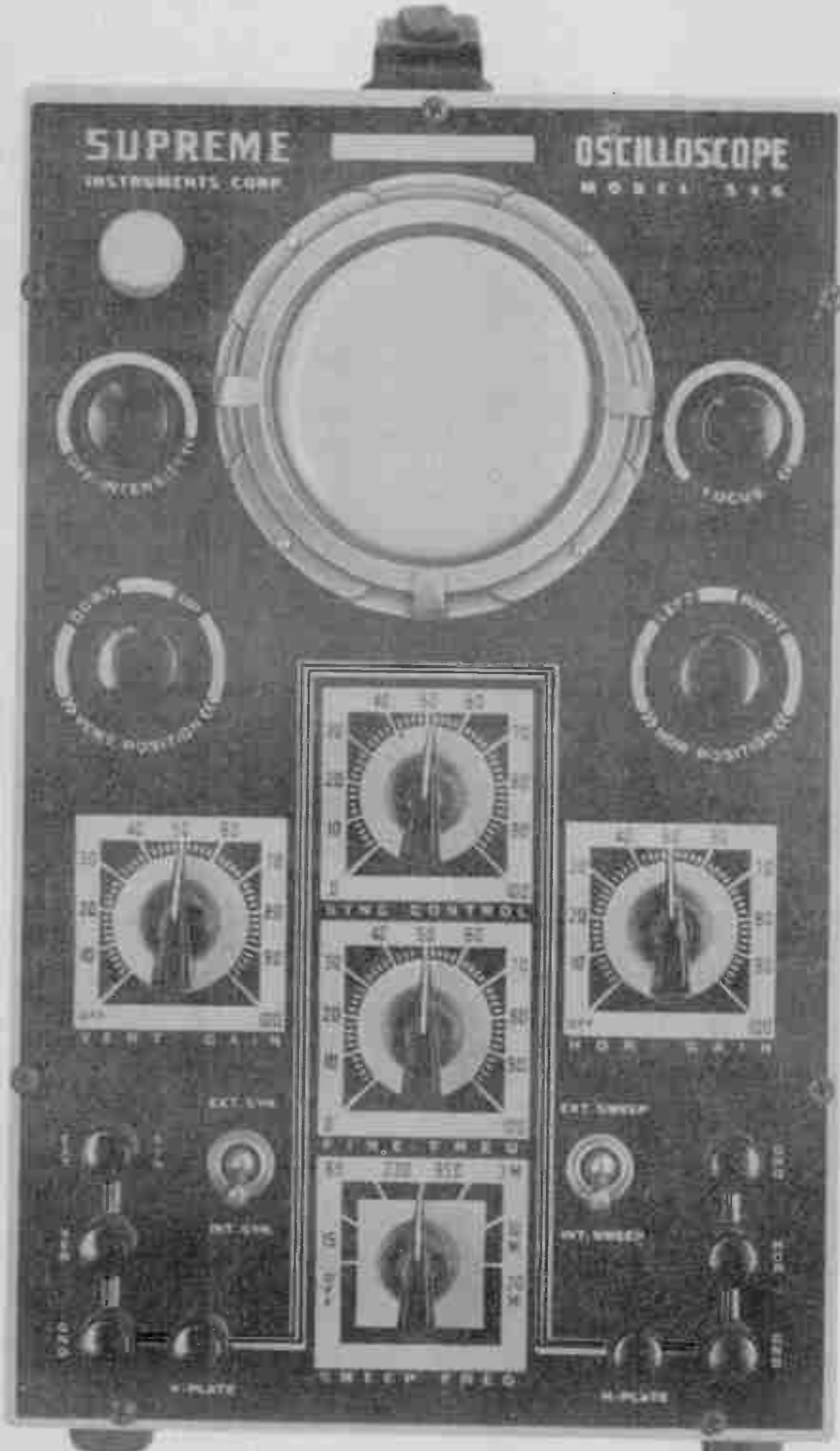
The first of a series of booklets written for the radio serviceman
on subjects about which he wants to know and
in a language which he can understand.


SUPREME
INSTRUMENTS CORP.
OSCILLOSCOPE
MODEL 546
FOCUS
SYNC CONTROL
VERT. GAIN
HOR. GAIN
FINE FREQ.
SWEEP FREQ.
EXT. SYN.
INT. SYN.
EXT. SWEEP
INT. SWEEP
V-PLATE
H-PLATE

THE CATHODE-RAY OSCILLOSCOPE

The types and sizes of cathode-ray oscilloscopes vary widely, from one using a one inch cathode-ray tube and having no amplifiers or sweep generators to the most complicated type using a ten to twelve inch cathode-ray tube and having high-gain amplifiers on the vertical, the horizontal, and the Z axes. Basically, all the different types are very similar, differing only in the size of the cathode-ray tube, the operating potentials on the tube, the number of amplifiers, and the gain and frequency response of the amplifiers. Indeed, the types are so similar that one short explanation of their operation can be written which will apply to all of them, from one which is used solely as a phase determining device to one used as the video section of a television receiver.

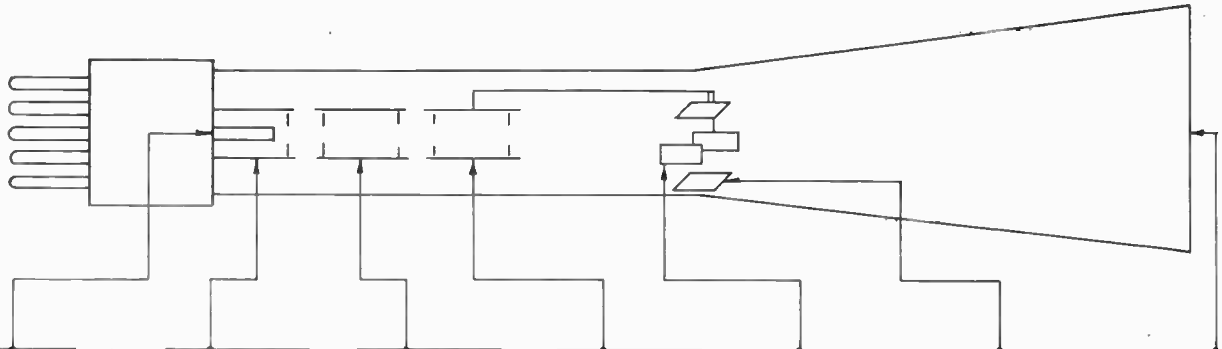
This booklet, then, is meant to be an explanation of the different circuits and functions of a representative type of cathode-ray oscilloscope which is most widely used at the present time by the radio service man and industrial laboratories. It is written for the man who does not understand how a cathode-ray oscilloscope works and is not meant to be a treatise on the various technical aspects of the methods of selection of circuits and components nor of their operation. By an extension of the descriptions of the various components in the cathode-ray oscilloscope they can be made to fit any of the other types. The particular instrument which is described herein consists of a cathode-ray tube, a power supply, a linear time base or sweep generator, and vertical and horizontal amplifiers. It is meant to be used where a three-inch cathode-ray tube will give a large enough image, where the frequencies involved do not exceed 75 to 100 kc, where there is no need for a modulation of the time or Z axis and where the sweep frequency need not extend beyond 25 to 30 thousand cycles per second. By giving a short explanation of each of the above mentioned components of the particular instrument described, it is believed that a much clearer understanding will be had of the instrument as a whole, and also of its uses.

CATHODE RAY TUBE

In a short explanation of the design and operation of a cathode-ray oscilloscope it is most important that we thoroughly understand the construction and functions of the different elements in the cathode-ray tube itself. There are many different sizes of tubes ranging from the one inch tube introduced a number of years ago to the large ten to twelve inch tubes used in television receivers on the market today. In the most popular tube used in commercial oscilloscopes a three-inch screen is used which gives a green image of medium persistence. The RCA type 906 and the Dumont 34XH are examples. This tube has a three-inch screen, is a high vacuum type and has deflection plates for obtaining deflection of the electron beam by application of electrostatic voltages to these plates and has means of focusing and controlling the intensity of the electron beam.

Referring to Figure 1 we can see, in the side view of the tube, the arrangement of the different elements. Starting from the base of the tube we find the cathode which is indirectly heated very much as in ordinary receiving type tubes but is of much heavier construction. Then around the cathode we find a small cylinder with a very small hole in the end through which the electrons liberated from the cathode can pass. Then another metal cylinder Anode #1, larger than the one around the cathode. Next a still larger tube called Anode #2, then the deflecting plates and finally the chemical coating on the inside of the large end of the tube.

As mentioned before, the function of the cathode is to emit electrons. It is the source of the electrons used to trace all the images seen on the screen. If a tube were constructed having only a heated cathode there would be no way to control the flow of electrons and very little use could be made of them. Therefore, in order to control the flow of electrons we can place the cylinder of metal call-



CATHODE	GRID	ANODE #1	ANODE #2	HOR. PLATE	VERT. PLATE	SCREEN
Indirectly heated, as in other types of receiving tubes, but much heavier construction	Turning the "Intensity" control varies the bias applied to this element and so controls the brilliance of the image. As the control is turned clockwise, value of bias is decreased, and image becomes brighter as more electrons leave the cathode	Turning the "Focus" control changes the voltage on this element and makes the image have a sharp, solid outline, instead of a "fuzzy" appearance	One Vert. Plate, one Hor. Plate, connected to chassis	Signals applied here to give deflection in a horizontal direction	Signals applied here to give deflection in a vertical direction	Electron beam strikes here and electrochemical action produces light.

TYPE 906 OR EQUIVALENT
FIGURE 1

ed the grid around the cathode and by applying a voltage to it negative with respect to the electrons, which are negative, we can effectively stop the electron emission. This is exactly the same thing which takes place in an amplifier stage when the bias on the tube (a negative voltage applied to the grid with respect to the cathode) is increased in progressive steps until the plate current is completely cut off. Since like charges repel we, in effect, apply a force opposite to that tending to force the electrons from the cathode and literally squeeze them back into the cathode. When the negative bias is low enough that electron emission can take place the electrons, which are thrown off the surface of the cathode material as a result of its high temperature, flow through the hole in the end of the grid, are attracted by the high positive voltages on Anodes #1 and #2, and are "accelerated" enormously--enough to produce light when they strike the screen. By adjustment of the ratio of the voltages on Anodes #1 and #2, (analagous to adjusting two lenses to focus a beam of light to a small spot) the beam can be brought to a point directly on the screen. We adjust Anode #1 since Anode #2 is connected to the chassis. See Figure 1 which explains the function of each element in the tube.

Now if we had a tube such as this it would have only a cathode, a grid, and two anodes and we could use it only by bringing near to the tube a magnetic field and so obtain magnetic deflection of the beam of electrons. This is cumbersome and subject to variation with frequency since the inductive reactance of the coils will vary directly with a change in frequency, and the magnetic deflecting force would vary accordingly. Therefore, four small plates are placed in the tube so that the beam passes between them. They are arranged two in a horizontal and two in a vertical plane. When a difference of potential exists between the two plates in a horizontal plane the beam is deflected up or down depending upon the polarity of the potential. Since the electrons in the beam are negative in polarity they are attracted toward the plate when the plate is positive and pushed away from the plate when it is negative. In the same way it is moved to one side or the other as the difference of potential on the horizontal plates is varied.

Then the final element in the tube is the chemical screen on the inside of the large end of the tube upon which the electron beam is focused and which produces a spot of light as the electron beam brings about an electrochemical change in the screen material. It should be remembered that every pattern produced on the screen is made by this spot moving and tracing it out. The color of the image is dependent upon the type of chemical compound which has been deposited on the inside of the tube. Red, blue, green, and white images have been produced. It is said to have a high persistence when the image remains on the screen for some time after the beam is cut off and to have a low or short persistence when it discppears very quickly. Bear in mind, however, the beam cannot be seen by looking through the glass side of the tube as there is no light until it strikes the screen.

POWER SUPPLY

Referring to Figure 2 we find a complete diagram of a SUPREME Model 546 oscilloscope. Upon close examination it can be seen that the power supply consists of a full wave rectifier with an output of about 400 volts and a half wave rectifier with an output of about 1000 volts. The full wave section is used to supply voltage for the horizontal and vertical amplifiers and for the linear time base. These pass a considerable amount of current which must be substantially free of ripple--hence the full wave rectification. The half wave section supplies voltage for the cathode-ray tube itself which passes very little current, and hence the half wave rectification is satisfactory.

In the design of a power supply it will be found very satisfactory, from the standpoint of ease of wiring, constructional considerations and application of voltages to various elements, to ground to chassis the negative side of the full wave rectifier system and the positive side of the half wave system. This makes it possible, then, to ground Anode #2 as well as one vertical and one horizontal plate. We can see from the diagram, then, that we have a bleeder system with approximately 1400 volts across it which is grounded to the chassis near the middle.

The question naturally arises, why is it necessary to have four deflection plates if two of them are to be connected to ground? The answer is that if a tube having only one vertical and one horizontal plate is built it will be found that the at-rest position of the spot will be very uncertain and the deflection will be erratic and uneven due to the electrostatic potential which will be built up on the deflecting plate. This is caused by stray electrons collecting on the sides of the tube and on the deflecting plate. One function of the resistors in series with the variable DC voltage and the deflecting plate is to leak off these electrons. By installing the second vertical and horizontal plates and by connecting them to the Anode #2, which in turn is connected to chassis, the effects of these stray electrons are eliminated. It is for this same reason, too, that the black coating of graphite is placed inside the present day tubes. This coating or shield is also grounded to Anode #2 and the two deflecting plates and helps return to ground any electrons which are not used up in creating light when they strike the fluorescent screen.

Now if we had a cathode-ray tube in which the gun assembly (heater, cathode, grid, Anodes #1 and #2) were in perfect alignment with the deflecting plates and screen the at-rest position of the spot would be exactly in the center of the screen. Since we cannot depend upon getting such perfectly aligned tubes from the suppliers of cathode-ray tubes it is necessary to provide means of applying suitable variable DC voltages to the two free deflecting plates to overcome any misalignment in the construction of the tube itself, or to position an unsymmetrical image on the screen in such a position that the desired portion of the image can be viewed better. We can see by the arrangement of the spot centering controls in Figure 2 that we can apply a voltage to either the horizontal or vertical plates which can be varied from 155 volts positive to 140 volts negative with respect to chassis ground. Varying this DC voltage which is applied to the deflecting plate then will cause the spot to be shifted up and down or from side to side to obtain the desired at-rest position. The resistors in series with the deflecting plates are for the purpose of providing a high impedance to any signals applied through the amplifier or direct to the deflecting plates. If it were not for the resistors the relatively low impedance of the bleeder network and spot centering controls would effectively short circuit any signal applied to the deflecting plates. The voltages causing deflection are built up across these resistors as the electrons surge back and forth through them charging first one plate and then the other of the coupling capacitor. One end of the resistor is connected to the plate; the other to ground through the spot centering controls. When electrons flow through the resistor from ground end to the other-- the ground end is negative and the other is positive. When electrons flow in the opposite direction the ground end is positive and the plate end negative. It can be seen that one end is connected to one plate and the other end to ground-- to which the other plate is connected. Thus one deflecting plate is plus while the other is negative and vice versa. The beam, then, is repelled by the plate which is negative and attracted by the positive plate to cause the deflection.

LINEAR TIME BASE:

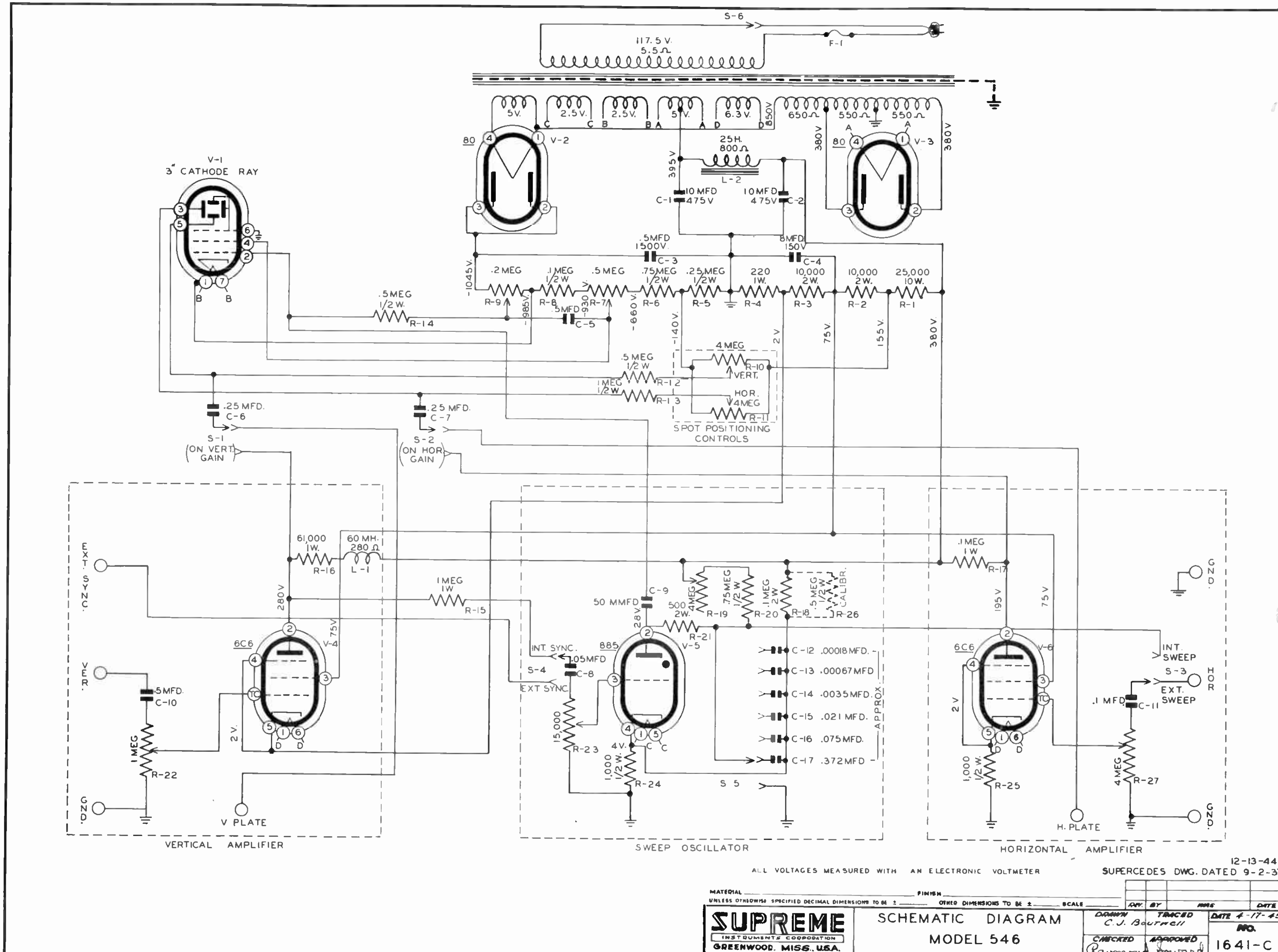
If we were to try to use the cathode-ray oscilloscope as we have thus far described it, we would find its utility very limited. We would not be able to view the wave form of an applied AC voltage but could determine only its amplitude. (We will not, at this time, consider phase relations). Let us consider Figure 2 and apply an AC voltage to the vertical deflecting plate. While we know that one cycle of AC voltage starts at 0 volts, builds up to a maximum positive, dies down to zero, falls to maximum minus, then returns to zero, we know nothing of its frequency nor the manner in which its wave form varies with respect to time. When we say an AC voltage has a sine wave form we mean that the voltage present varies at a definite rate with respect to *time*. When we say the frequency of an AC voltage is 60 we mean that there are 60 cycles completed in *one second* and the *time* needed to complete one cycle is 1/60 of one second. Now to determine whether or not a given AC voltage has a sine wave form it is necessary for us to obtain some means of showing the change in voltage with respect to *time*. To go back to the diagram again, when an AC voltage is applied to the vertical plate we will get a vertical line because the charge on the deflecting plate changes periodically and thus alternately attracts and repels the electron beam and so a line is formed as the spot moves on the screen.

If we were able to apply another voltage, which had a linear change with respect to time, to the horizontal plate at the same time, we would be able to show how the voltage applied to the vertical plate varied with respect to *time*. Let us assume we were able to move the spot from near the left horizontal deflecting plate to near the right horizontal plate at a uniform speed and that it would take just 1/60 second for the spot to move this distance. Now assume the spot almost instantaneously returns to the left and again moves toward the right at the same speed as before and keeps this movement up over and over again. If the 60 cycle voltage is applied to the vertical plate at the same time, the *spot will move from left to right at the same time it moves up and down and the wave form of one cycle* of the AC voltage will be traced out. A more detailed explanation of this formation of images will be given later.

The important thing to understand at this point is the necessity of obtaining some reference to *time* in order to trace out and examine the wave form and to determine frequency. This makes it necessary for us to have some means of generating the type of voltage mentioned above which was applied to the horizontal plates, that is, a voltage which rises in potential at a uniform rate of speed and then drops rapidly to zero. To obtain this voltage we use a circuit shown within dotted lines and labelled "Sweep Oscillator" in Figure 2. This has been called a sweep oscillator, relaxation oscillator, sweep generator, gaseous discharge circuit, thyratron oscillator; but it is probable that the name which most nearly describes the use to which the circuit is put is "linear time base generator." This is because it is a generator which gives a linear time base for the determination of frequency and wave form. To conform to usual nomenclature, however, it has been labelled "Sweep Oscillator."

The generation of the linear time base voltage is based upon the charging and discharging of a capacitor. Suppose we were to connect a capacitor, a resistor and a battery in series. At the moment we completed the circuit electrons would flow from the side of the capacitor connected to the positive of the battery, to the battery and from the negative of the battery through the resistor to the other side of the capacitor. Electrons would continue to flow until a balance was reached between the strain on the plates of the capacitor and the potential of the battery. Now let's connect the two plates of the capacitor with a wire, momentarily they will be discharged, and the electrostatic strain on the plates relieved. Immediately then, upon reconnection to the battery, electrons will flow as at first from one plate to battery, from battery to the other plate until equilibrium is reached again. Suppose we decrease the size of the capacitor and we will find that it will take *less* time to reach a balance. If we increase the size of the capacitor it will take *longer* to charge. Also if we increase the size of the battery the equilibrium will be reached *quicker* and if we decrease the size of the battery the rate of charging will be *slower*. In the same way if we increase the size of the resistor, the rate of charging will *decrease* because the charging current flowing through the resistor will cause a potential drop across it, and so less voltage will actually be present on the plates of the capacitor to cause the electrons to flow and to thus charge the capacitor.

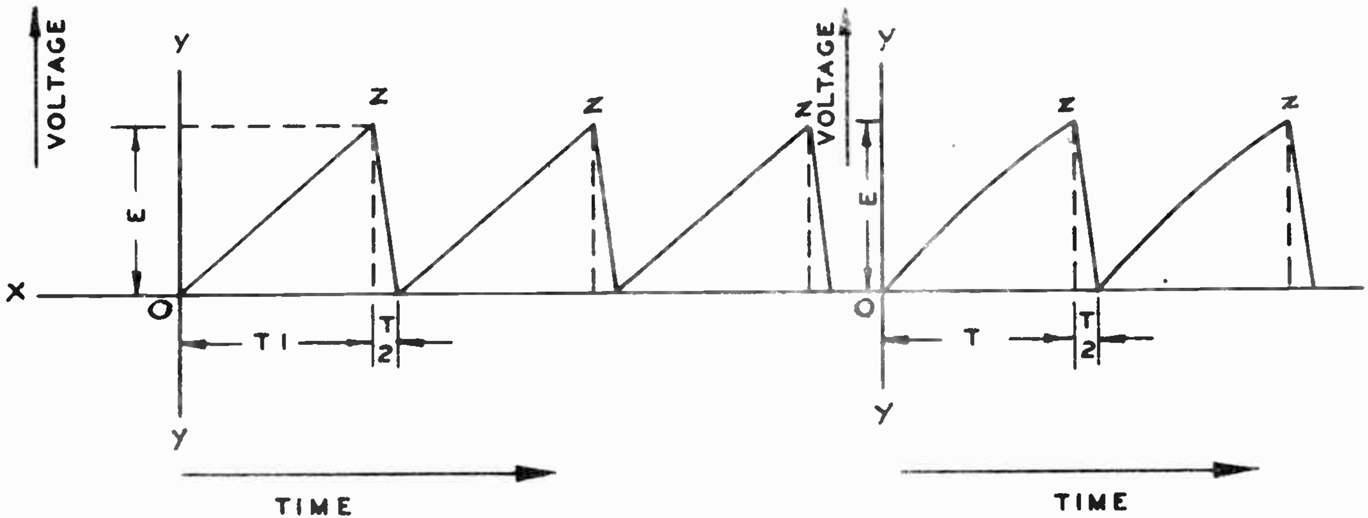
In Figure 2 we can find an exact analogy with the capacitor whose size can be changed in the "Sweep Freq." (S5), with the battery in the 400 volt supply (which, however, in this case is constant), with the variable resistor in the "Fine Freq." (R-19) and with the wire in the gas discharge tube (V-5). By the proper selection of size of capacitors a wide range of frequencies can be covered in steps and all intermediate frequencies obtained by varying the "Fine Freq." (R-19) control. The capacitor selected by the switch, "Sweep Freq." (S5) is charged by current flowing through "Fine Freq." (R-19), and through R-20. When a certain voltage is reached across them the gas discharge tube (V-5), which is filled with ah inert gas, ionizes and acts as a short circuit to the voltage across the capacitor. The charging cycle starts over again, and again the capacitor is discharged. By the proper selection of values of resistors, operating voltages and circuit design the charging of the capacitor can be made to take place at a very nearly uniform rate with respect to time. We can plot the voltage built up across the capacitor against time and obtain a graph as in Figure 3. *E* is the voltage on the capacitor. *Z* is the point of discharge. *T1* is the time needed to charge the capacitor and during this time the spot moves from


S-6
117.5 V.
5.5 Ω
F-1
5V.
2.5V.
2.5V.
5V.
6.3V.
850V
650 Ω
550 Ω
550 Ω
80
V-2
V-3
380V
380V
V-1
3" CATHODE RAY
25H.
800 Ω
L-2
395V
10 MFD
C-1 475V
10 MFD
475V C-2
.5MFD
1500V.
C-3
8MFD
150V
C-4
-1045V.
.2MEG
R-9
.1MEG 1/2W
R-8
.5MEG
R-7
.75MEG 1/2W
R-6
.25MEG 1/2W
R-5
220 1W.
R-4
10,000 2W.
R-3
10,000 2W.
R-2
25,000 10W.
R-1
-985V.
-930
.5MFD
C-5
-660V.
-140V.
2V
75V.
155V.
380V
.5MEG 1/2W.
R-14
4MEG
R-10
VERT.
.5MEG 1/2W
R-12
1MEG 1/2W
R-13
HOR.
4MEG
R-11
SPOT POSITIONING CONTROLS
.25 MFD.
C-6
.25 MFD.
C-7
S-1 (ON VERT. GAIN)
S-2 (ON HOR. GAIN)
EXT. SYNC.
VER.
GND.
61,000 1W.
R-16
60 MH. 280 Ω
L-1
280V
1MEG 1W
R-15
6C6
V-4
75V
.5MFD.
C-10
1MEG
R-22
2V.
V PLATE
VERTICAL AMPLIFIER
C-9
50 MMFD
28V
500 2W.
R-21
4MEG
R-19
.75MEG 1/2W
R-20
.1MEG 2W
R-18
.5MEG 1/2W CALIBR.
R-26
885
V-5
INT. SYNC.
.05MFD
C-8
S-4
EXT SYNC.
15,000
R-23
4V.
1,000 1/2W.
R-24
C-12 .00018MFD.
C-13 .00067MFD.
C-14 .0035MFD.
C-15 .021 MFD.
C-16 .075MFD.
C-17 .372MFD.
APPROX.
S 5
SWEEP OSCILLATOR
.1MEG 1W
R-17
195V
75V
6C6
V-6
2V
1,000 1/2W
R-25
H. PLATE
INT. SWEEP
S-3
EXT. SWEEP
.1 MFD.
C-11
4 MEG
R-27
HOR.
GND.
GND.
HORIZONTAL AMPLIFIER
ALL VOLTAGES MEASURED WITH AN ELECTRONIC VOLTMETER
12-13-44
SUPERCEDES DWG. DATED 9-2-37
SUPREME INSTRUMENTS CORPORATION GREENWOOD, MISS., U.S.A.
SCHEMATIC DIAGRAM
MODEL 546
DRAWN C.J. Bourwell
DATE 4-17-45
NO. 1641-C

one side of the screen to the other as *E* becomes larger. *T2* is the time needed to discharge the capacitor and when *E* falls to zero the spot returns to the original position. Note that at low frequencies *T1* is much larger than *T2* so that when this voltage, *which appears to the grid of the horizontal amplifier to be an AC voltage*, is amplified and applied through a coupling capacitor to the deflecting plate the spot moves across the screen, slowly during *T1* and so fast during *T2*, when the spot returns, that is seems to be moving in one direction only. As the frequency of charge and discharge increases, *T2* approaches *T1* in value and the return trace of the spot becomes more noticeable. At extremely high frequencies *T1* is practically equal to *T2* and it is difficult to distinguish one from the other on the screen of the tube. It is this limitation of the gas discharge tube which really limits the direct observation of the wave form of RF voltages.

It is possible to apply a small portion of the voltage under observation to the grid of the gas discharge tube through the "Sync. Control" (R-23) and thus help maintain the frequency of discharge in the generator to a submultiple of the observed signal. This is what is meant by "locking-in" a signal. This small voltage is obtained from the plate of the vertical amplifier (V-4). In using the "Sync. Control" it should always be run in the minimum position possible as too much voltage applied to the grid will produce not only a distorted image but can actually change the frequency of the generator.

In Figure 2, R18 is a bleeder resistor which helps stabilize the voltage supply in the generator but most important provides bias on the gas discharge tube. R21 is a resistor which limits the current through the gas discharge tube to a safe value. R20 prevents shorting the 400 volts supply by "Fine Freq." and is also the dropping resistor across which the saw-tooth voltage is developed.



LINEAR NON-LINEAR

WAVE FORM OF TIME BASE GENERATOR

FIGURE 3

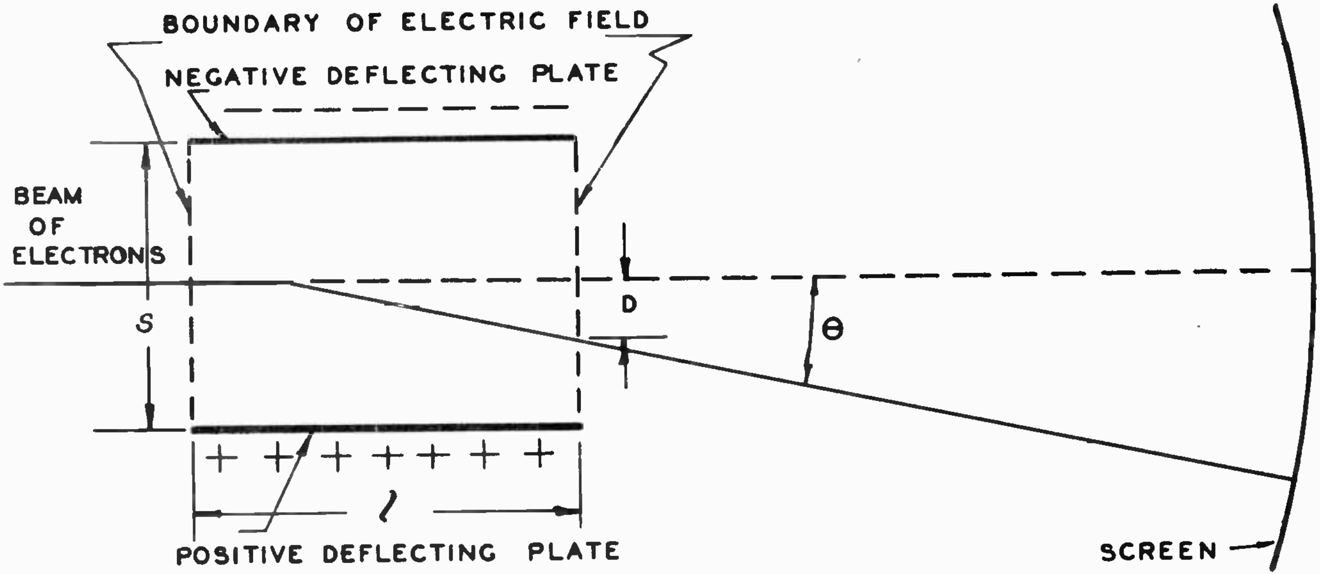
HORIZONTAL AND VERTICAL AMPLIFIERS:

Up to this point in speaking of applying a signal to one or both deflecting plates we made no mention of the amplitude of the signals necessary to give a usable deflection. The RCA type 906 or equivalent tube has an average deflection sensitivity of .55 to .58 mm per volt, when the signal is applied directly to the plates. This means it takes a signal of approximately 46 volts DC to give a deflection of one inch. Accordingly it would take approximately 140 volts DC or 70 peak volts AC to give a full scale (3 inch) deflection. This is an average deflection sensitivity and will vary with different makes of tubes and under different operating conditions. As the student will realize if he has ever run any characteristic curves on many tubes of the same or different brands, one can no more expect all cathode-ray tubes to have exactly the same deflection sensitivity than he can expect all type 76 tubes to have exactly the same plate current with a given plate voltage. This difference in sensitivity is due not only to the varying distance between the deflecting plates and the beam of electrons but also to varying operating voltages. The former affects sensitivity in that the farther the plate from the at-rest position of the beam the larger the voltage which will be required to apply the same force, acting to cause deflection, to the beam.

The force acting on an electron (and for sake of simplicity we consider one electron) is F equals $\frac{eE}{s}$, where e is the charge on the electron, E is the potential on the deflecting plates in statvolts (1 statvolt equals 300 ordinary volts) and s is the distance in centimeters between the plates. F is in dynes. It can be seen then that as s increases the force decreases. Thus with a given voltage applied to the plates there will be a different force acting to displace the beam. Now also the amount of deflection depends upon the speed of the electrons. Only during the time the electrons are between the plates are they under the influence of the force F acting to deflect the beam. Refer to Figure 4. The time then that they are under the influence of the force F is t equals $\frac{l}{v}$, where l equals length of the plates and v is the velocity of the electron in *cms/second*. An electron then is acted upon by a force F equals $\frac{eE}{s}$ for a time of T equals $\frac{l}{v}$ seconds and is deflected a distance D equals $\frac{at^2}{2}$, where a is acceleration due to the force and is equal to the force F divided by the mass m of the electron. The change in direction taken by the beam is the angle θ and tan θ equals $\frac{eEt^2}{msl}$.

From the above relations it can be seen that since the speed of the electrons is varied by varying the voltage applied between Anode #2 and cathode so the deflection sensitivity will be varied because the time they are between the deflecting plates is less and thus the force acting to deflect them has less time to act and therefore causes less deflection.

If we were working near a transmitter it is possible that we would be able to obtain high enough voltages that we could apply them direct to the plates but in ordinary practice and especially in working on receivers it is not possible to obtain such high voltages. We must point out here that not even the voltage from the linear time base has such magnitude because the amplitude must be held to a very small percentage (about 5%) of the supply voltage in order that the charging rate of the capacitor can be considered linear. The design of the two amplifiers is nearly identical and both the circuits of the two amplifiers and method of connecting them to the linear time base, to the deflecting plates in the cathode-ray tube and to the external



M = MASS OF ELECTRON = 9×10^{-27} GM
V = VELOCITY OF ELECTRON = 1×10^{9} CMS / SEC.

DIAGRAM SHOWING BENDING OF BEAM BY DEFLECTION PLATES

FIGURE 4

binding posts of the instrument are shown clearly in Figure 2. The radio frequency choke (L-1) in the plate lead of the vertical amplifier and shown on Figure 2 is for the purpose of extending the amplification range to a much higher than usual frequency. It will be relatively flat from 10 cycles to 75 kilocycles.

In applying a signal to the vertical input we can see it passes through the "Vert. Gain," is amplified by the 6C6 (V-4), and is coupled to the vertical plate by a capacitor (C-6). Likewise any signal applied to the horizontal input passes through the "Hor. Gain," is amplified by the 6C6 (V-6), and is coupled to the horizontal deflecting plate by a capacitor (C-7). If we wish to use the linear time base as a source of horizontal voltage (to use it as a sweep voltage) we set the "Int-Ext Sweep" (S-3) switch to "Int" position and the voltage present across the resistor R-20 in the sweep circuit is applied through the amplifier and to the horizontal plate. The gas discharge tube is made to keep in step or be synchronized with the signal in the vertical amplifier by setting the "Int-Ext Sync." (S-4), switch to the "Int" position and then adjusting the "Sync. Control" R-23.

APPLICATIONS OF THE CATHODE-RAY OSCILLOSCOPE

It is very important in considering the applications of the scope, to realize that although there are many different types they are basically very similar. The size of the cathode-ray tube used, the presence or absence of vertical, horizontal, and Z axis amplifiers, the frequency response of the amplifiers, and the design of the linear time base very definitely affect the uses to which the oscilloscope may be put. It is probable, though, that the factor which most limits the uses is the frequency response of the vertical amplifier. Most of the oscilloscopes manufactured today for the radio serviceman are built around almost a standard design in which the vertical amplifiers have a very poor response to signals of high RF frequency. These oscilloscopes must, in general, be used where the frequency is in the audio range, which means, in a radio receiver, only after the RF signal has been demodulated. There are special application oscilloscopes being manufactured which have a linear response to three megacycles and more and which can, because of their high gain, be used to observe even the RF signal on the input grid of the RF stage of a receiver. The basic differences between this type and the one we have been discussing are: (1) The latter has several cascaded stages of amplification using tubes which have high gain and low interelectrode capacity, and (2) The placement of every component in the circuit has been considered from the standpoint of how it will affect wide-range amplification.

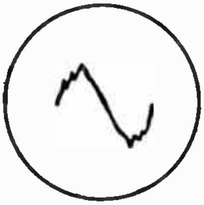


FIG.5

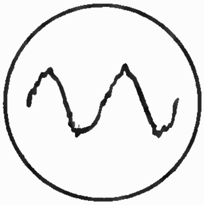


FIG.6

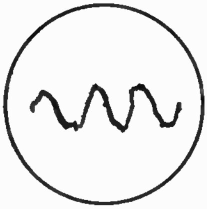


FIG.7

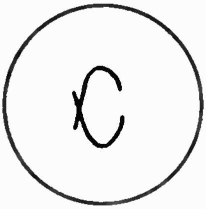


FIG.8

Suppose we were to connect a wire to the vertical input and touch this wire. With the proper adjustment of the "Intensity" and "Focus" controls a very complex image would probably appear on the screen. This signal on the operator's body is a stray voltage being radiated from the AC power lines and has a frequency of 60 cycles per second. If the linear time base is adjusted to 60 cycles per second the image will appear as in Figure 5. It shows that the voltage to the vertical input had enough time to complete just one cycle in the time it took for the sweep voltage to move the spot across the screen one time. The rough, irregular shape of the image indicates that transient voltages and harmonics of 60 cycles are present. Now readjust the sweep to 30 cycles and Figure 6 will appear. Here the vertical signal has enough time to complete two cycles to the sweep's one. Reduce the sweep to 20 cycles and Figure 7 will appear. Why? Let's adjust the sweep to 120 cycles and Figure 8 will appear. (It is very difficult to make this image stand still on the screen). To find this setting gradually increase the "Fine Freq." above 60 cycles until the image appears. This image appears because in the length of time needed for the vertical AC voltage to go from zero volts to a maximum positive and return to zero, the spot moved across the screen one time. This formed the upper half-sine-wave. Then the signal completed the lower half of the cycle and the spot again moved across the screen forming the lower arc.

The oscilloscope is a very useful instrument for determining frequency of audio signals and can be used in the following manner. Let us suppose we had an RF signal generator which had output jacks for the audio modulation voltage. Let us suppose we had to determine the frequency quite accurately at which the modulation took place in the generator. Feed this audio voltage through the horizontal amplifier to the horizontal plate and apply the output of a variable audio generator to the vertical amplifier and thence to the vertical plate. Adjust the variable audio frequency until a pattern as in Figures 9, 10, 11, 12, or 13 appears. This will indicate the signal to the vertical plate has the same frequency as the one to the horizontal plate. Now the reason this image is constantly changing from a line to a narrow ellipse into a circle and back to an ellipse and to a straight line is because the frequencies of the two signals are not absolutely constant, but are varying just a very small amount with a change in line voltage, etc. This, then, results in the two voltages being in phase at one instant and producing a line, then just slightly out of phase and producing an ellipse, then further out of phase and a broader ellipse, then 90° out of phase and a circle and then back through the ellipses and to a line at 180°. It is interesting to note that when the adjustment of the variable audio is such that there is a very definite difference the *actual* difference per second in frequency of the two signals can be determined by counting the number of circles appearing in a minute dividing by two and then by sixty.

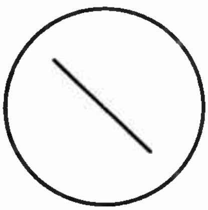


FIG.9

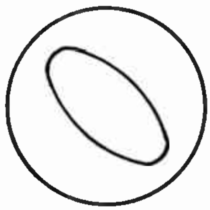


FIG.10

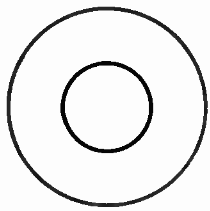


FIG.11

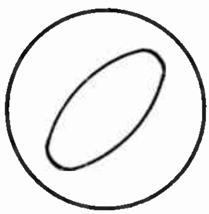


FIG.12

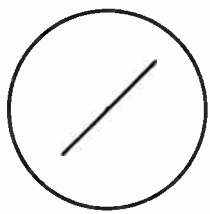


FIG.13

An oscilloscope can be used to determine phase difference between two voltages. Apply both signals simultaneously to horizontal and vertical plates and a line will appear on the screen, Figure 9 or 13. Apply the signal to horizontal through a large choke and an ellipse will appear indicating a phase shift in passing through the choke, Figure 10 or 12. Connect a capacitor and a resistor in series and across a source of voltage. Apply the source of voltage to input and the voltage across the capacitor to horizontal and an ellipse will be formed by phase shift through capacitor. The actual amount of phase shift can be determined in the following manner: place a calibrated screen having lines placed at right angles to each other and with the outer lines forming a square over the end of the tube. Observe the image through this screen and adjust the spot positioning controls and gain controls until the image just touches each of the four sides of the square calibration lines *a, b, c, d,* as shown in Figure 14. Measure distance EF. The phase angle or phase difference is equal to arcsin $\frac{EF}{FG}$. Example:

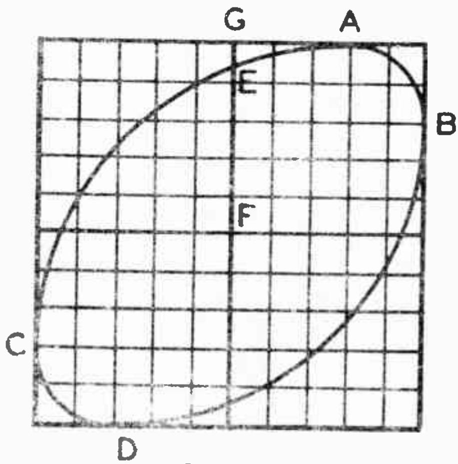


FIG. 14

at phase angle of 90° a circle will be formed and *EF* equals *FG* and sin $\frac{EF}{FG}$ equals 1. Therefore the angle whose sine is 1 is 90°. Check. At a phase angle of 0° or 180° *EF* equals zero so $\frac{EF}{FG}$ equals 0 and arcsin 0 equals 0° or 180°. Check. At a phase angle of 45° *EF* equals .707 *FG* so arcsin .707 equals 45°. Check.

An oscilloscope can be used advantageously in locating distortion in an amplifier. Apply a standard audio signal to input of amplifier. Advance volume control and assume distortion present. Adjust linear time base to submultiple of audio signal and obtain a signal for vertical deflection on plate of output tube. Distortion present as in Figure 15.

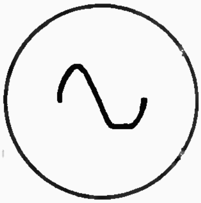


FIG.15

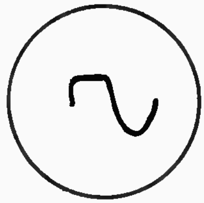


FIG.16

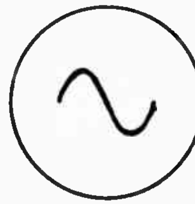


FIG.17

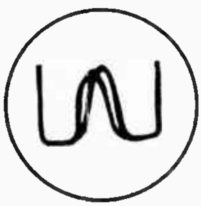


FIG.18

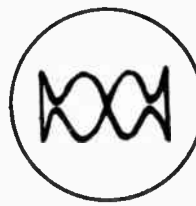


FIG.19

Obtain signal from grid of output tube. Distortion present as in Figure 16. (Phase is shifted 180° going through tube.) Obtain signal from plate of first audio. Signal as in Figure 17. Distortion absent. Distortion taking place in first audio stage. Measure voltage and current constants to determine cause of distortion.

Finally a very important use of the oscilloscope is its use in aligning the IF transformers and AFC circuits in radio receivers. In this method of alignment a frequency modulated signal is fed to the circuit to be aligned and the vertical of the oscilloscope connected to a source of the demodulated signal, for example the diode load resistor. The resonance curve of the circuit is traced on the screen as in Figure 18. The sweep used here is a 60 cycle voltage having a sine wave form and is one-half the rate of frequency modulation. The curve obtained from a discriminator alignment will be similar to Figure 19. A detailed explanation of the formation of Figures 18 and 19 would necessitate a complete explanation of the type of frequency modulated signal used, the rate of frequency modulation and the effects of the adjustment of each circuit concerned. This is beyond the scope of this booklet and will be explained fully in another.

SUPREME INSTRUMENTS CORPORATION
Greenwood, Mississippi, U. S. A.

MANUFACTURERS OF RADIO
TESTING EQUIPMENT AND
ELECTRICAL INDICATING INSTRUMENTS

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