The Cathode Ray Oscilloscope

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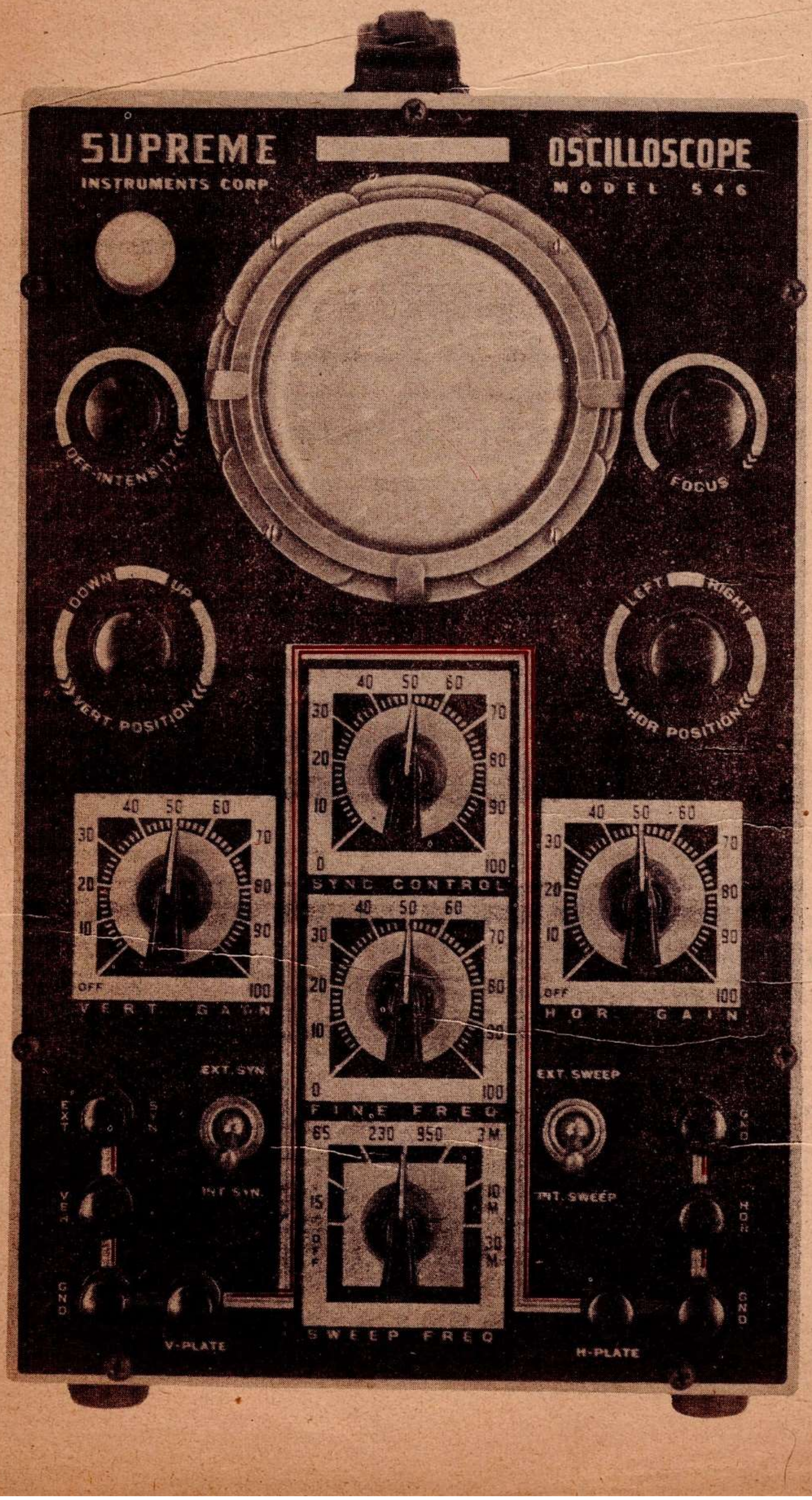
PRICE 25 CENTS


SUPREME
INSTRUMENTS CORP.
OSCILLOSCOPE
MODEL 546
OFF-INTENSITY
FOCUS
DOWN UP
VERT. POSITION
LEFT RIGHT
HOR POSITION
SYNC CONTROL
VERT. GAIN
HOR GAIN
FINE FREQ
EXT. SYN.
INT. SYN.
EXT. SWEEP
INT. SWEEP
SWEEP FREQ
V-PLATE
H-PLATE
EXT
SYN
VER
GND
HOR
GND

The Cathode Ray Oscilloscope

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.

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.

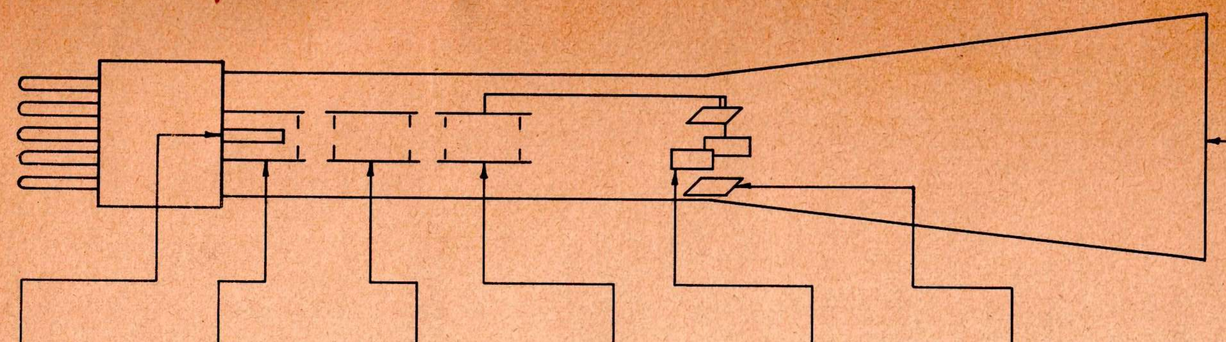
This booklet, then, is meant to be an explanation of the different circuits and functions of a representative type of cathode-ray oscilloscope which is most widely used at the present time by the radio service man and industrial laboratories. It is written for the man who does not understand how a cathode-ray 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 disappears 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.

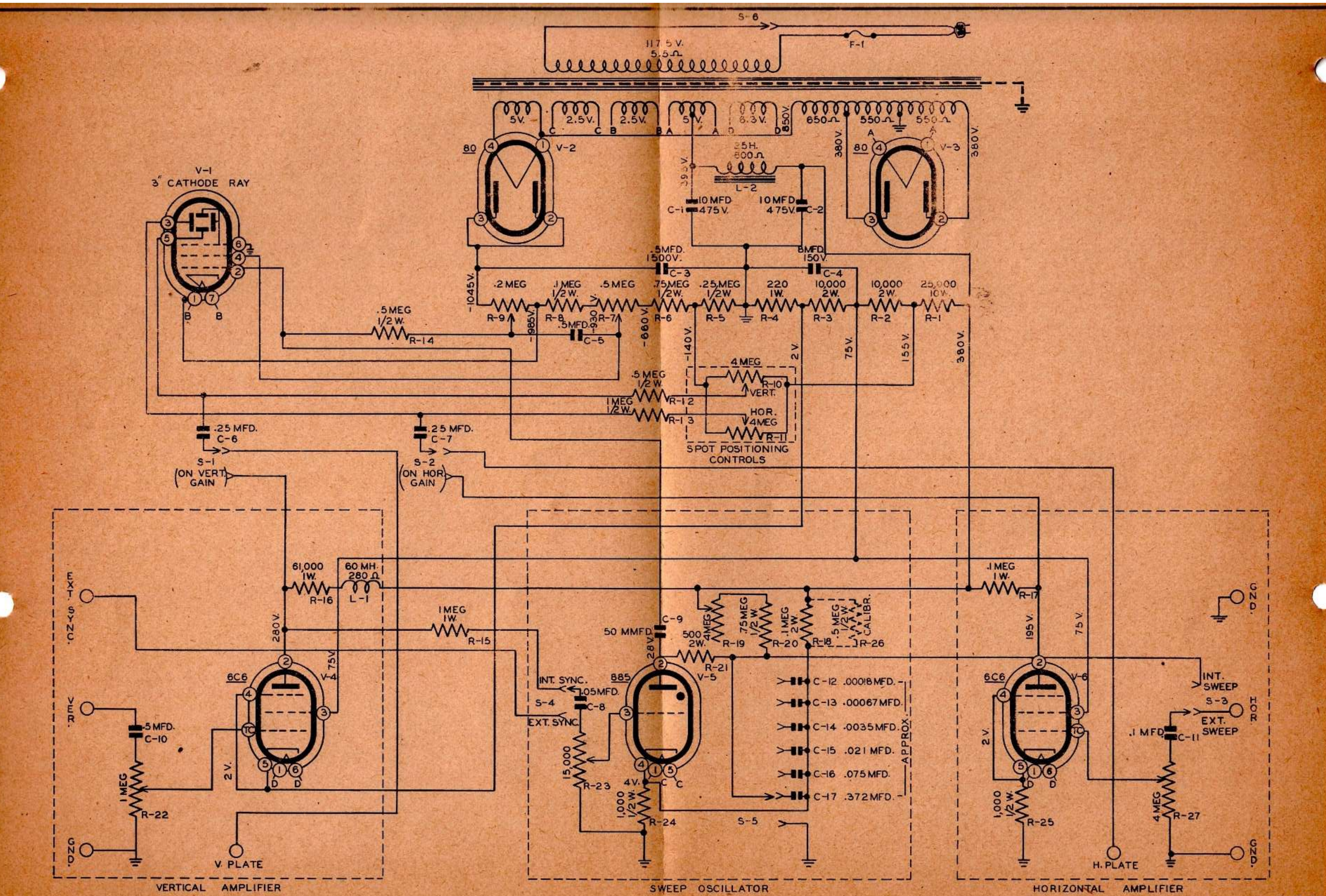
The important thing to understand at this point is the necessity of obtaining some reference to *time* in order to trace out and examine the wave form and to determine frequency. This makes it necessary for us to have some means of generating the type of voltage mentioned above which was applied to the 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 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.



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UNLESS OTHERWISE SPECIFIED DECIMAL DIMENSIONS TO BE ± ______ OTHER DIMENSIONS TO BE ± ______ SCALE ______

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SCHEMATIC DIAGRAM
MODEL 546

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