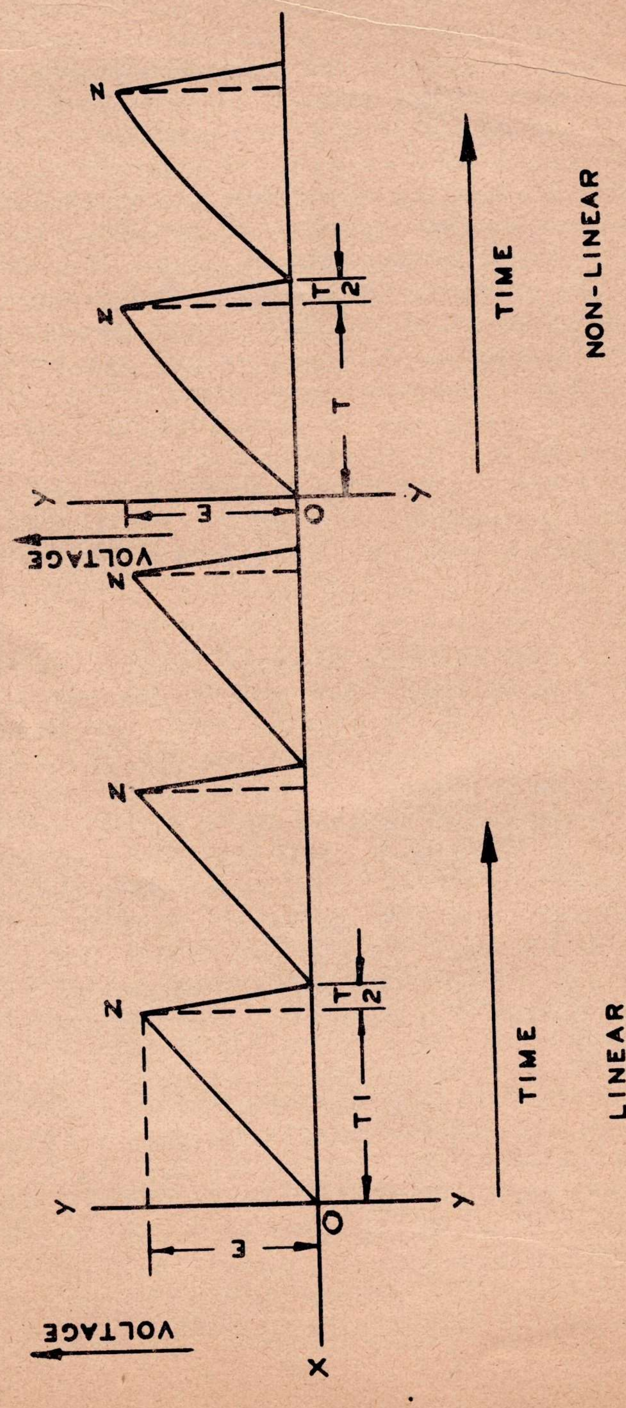


WAVE FORM OF TIME BASE GENERATOR
FIGURE 3

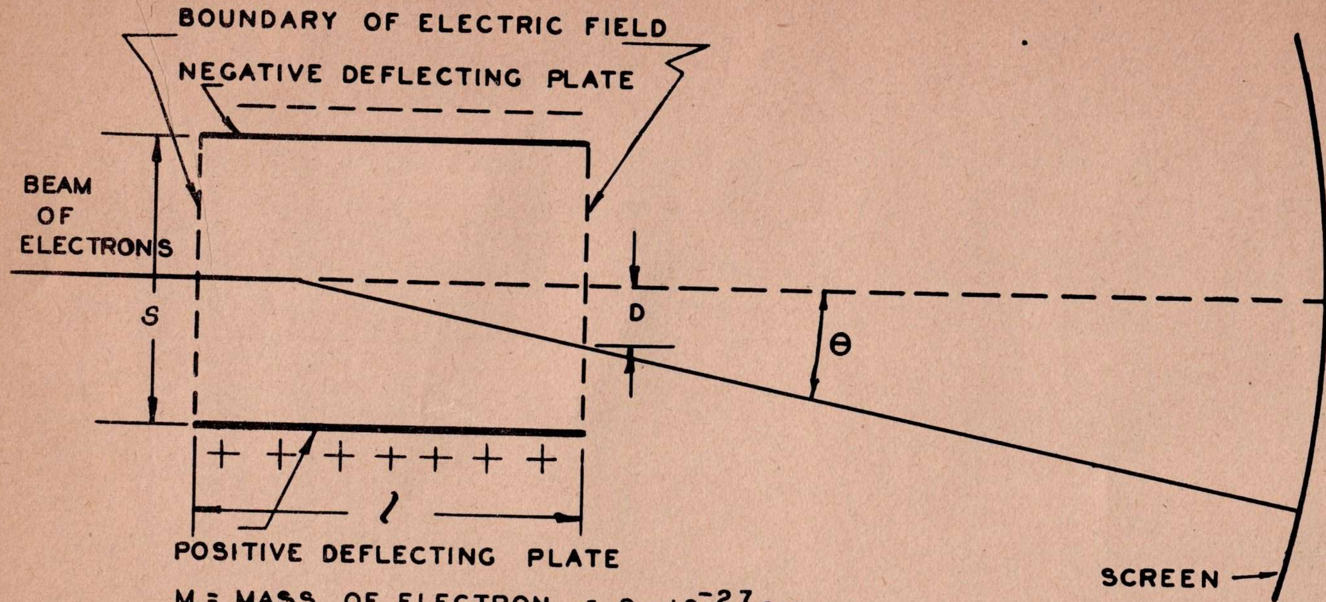
HORIZONTAL AND VERTICAL AMPLIFIERS:

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.

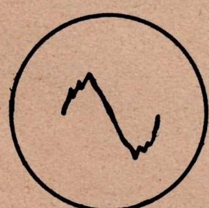


FIG.5

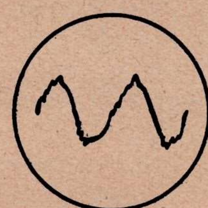


FIG.6

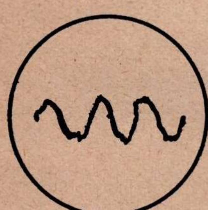


FIG.7

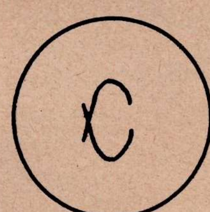


FIG.8

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.

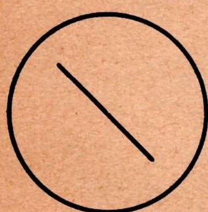


FIG. 9

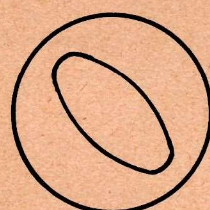


FIG. 10

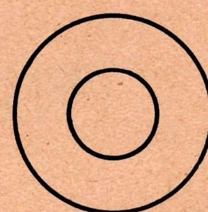


FIG. 11

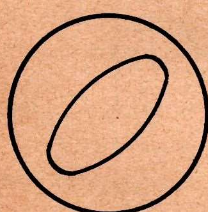


FIG. 12

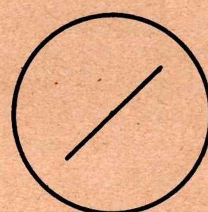


FIG. 13

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:

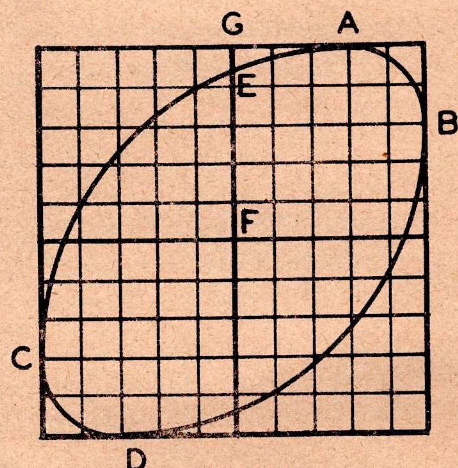


FIG. 14

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.

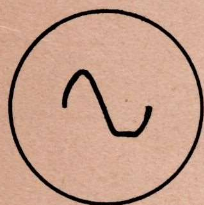


FIG.15

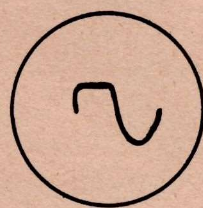


FIG.16

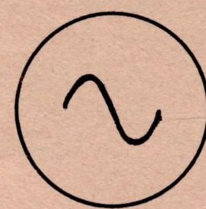


FIG.17

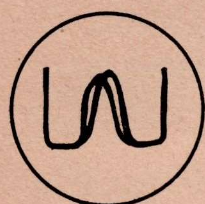


FIG.18

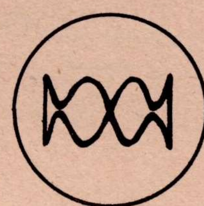


FIG.19

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.

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