OPERATING AND MAINTENANCE MANUAL

DU MONT

TYPES 304 and 304-H CATHODE-RAY OSCILLOGRAPHS

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Part No. 67001892
Issue 2

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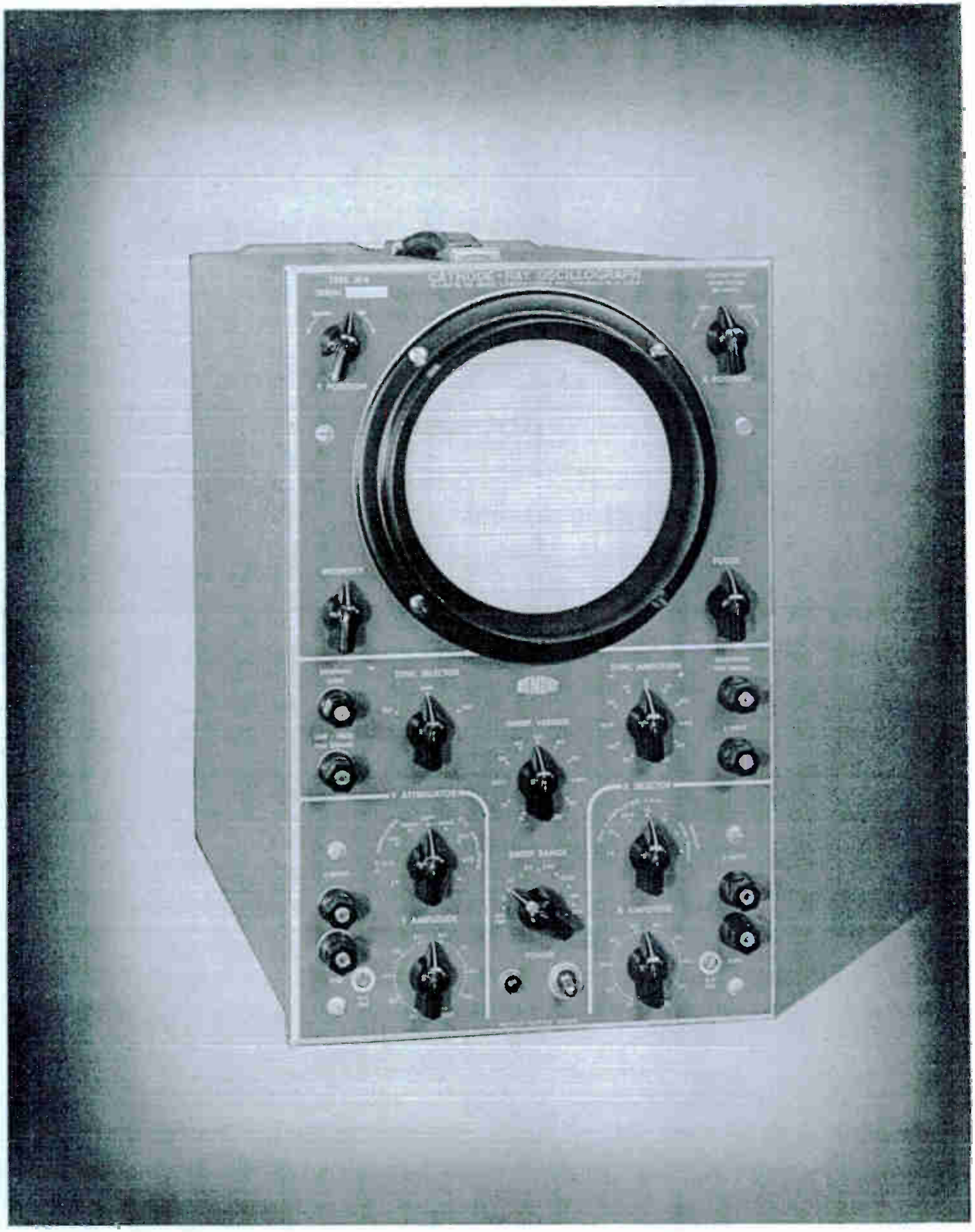


FIGURE 1-1

DU MONT TYPE 304 (or 304-H) CATHODE-RAY OSCILLOGRAPH

SECTION I

GENERAL DESCRIPTION

1. PURPOSE

The Du Mont Type 304 Cathode-ray Oscillograph is a general-purpose instrument containing extremely sensitive d-c amplifiers. The Type 304, like any other general-purpose cathode-ray oscillograph, may be employed to study any variable quantity that can be converted into electrical energy, provided that the frequency of the signal being studied is within the limits of the frequency-response characteristic of the cathode-ray oscillograph.

For example, the energy of sound can be converted into electrical energy by means of a microphone. Thus, it is possible to use the cathode-ray oscillograph in such fields as acoustics. The conversion of energy from one form to another is accomplished by means of a device which falls into the general classification of a "transducer." Thus, in the example previously given the microphone is the transducer. Further examples of transducers include such devices as photocells, vibration and displacement pick-ups, or other variable impedances designed to permit the cathode-ray oscillograph to be applied to the study of light, chemistry and all types of problems in the field of mechanical engineering. Of course, the cathode-ray oscillograph is a valuable instrument in the field of electricity and electronics because here a transducer is usually not needed in order to study such problems.

This Operating and Maintenance Manual covers both the Types 304 and 304-H Cathode-ray Oscillographs. The Type 304-H is identical to the Type 304, except that the Type 304-H contains an additional high-voltage rectifier and filter circuit for providing an additional +1200 volts to the intensifier electrode of the Type 5CP-A Cathode-ray Tube. This extra rectifier and filter circuit is not included in all instruments, because Du Mont did not wish to burden those not requiring this additional circuit with the added cost. The higher accelerating potential of the Type 304-H is necessary only for applications requiring the use of long-persistence cathode-ray-tube screens, where the fullest advantage is being made of the instrument's d-c amplifiers and very-low-frequency sweeps.

2. CIRCUITS

a. GENERAL.—In general, the cathode-ray oscillograph is employed to plot the dynamic relationship of a variable unknown quantity as a function of some known variable quantity. It is general practice to plot the unknown quantity along the vertical, or Y axis, with the known quantity plotted along the horizontal, or X axis.

b. AMPLIFIERS.—The cathode-ray tube in itself is a relatively insensitive device, since potentials of about 300 volts are required to produce full-scale deflection of the electron beam across the face of the cathode-ray tube. In order, then, for the cathode-ray oscillograph to be a versatile instrument, amplifiers are employed in both the vertical and horizontal channels to increase the sensitivity of the cathode-ray tube so that it may be used to plot signals from sources of relatively low potential. The characteristics of the amplifiers included in this instrument are given in Table 1-1.

c. TIME BASE.—Since it is very convenient in many applications to plot an unknown variable as a function of time, a linear time-base generator is included as an integral part of this instrument. The characteristics of this time-base generator are given in Table 1-1.

d. INTENSITY MODULATION.—Provision is made in this instrument so that the intensity of the trace may be modulated, or varied in accordance with some electrical potential. A terminal is provided, on the front panel of the instrument, which is capacitively coupled to the control grid of the cathode-ray tube to permit the connection of an external signal to this electrode of the cathode-ray tube. Positive pulses applied to this terminal will intensify the trace at time intervals corresponding to the intervals between pulses. Negative pulses of approximately 15 peak volts will blank the beam from normal intensity settings.

e. POWER SUPPLY.—A self-contained power supply furnishes all the necessary voltages at the currents required for the satisfactory operation of both the Types 304 and 304-H Cathode-ray Oscillographs. The Type 304-H contains an extra high-voltage rectifier and filter circuit for providing an additional +1200 volts to the intensifier electrode of the Type 5CP-A Cathode-ray Tube. The Type 304 does not contain this additional rectifier, but space is provided so that it may be added later, if desired, with a minimum of effort.

3. PHYSICAL DESCRIPTION

The Type 304 Cathode-ray Oscillograph is shown in Figure 1-1. The Type 304-H Cathode-ray Oscillograph has the same external appearance as the Type 304, except for the type number designation. The instrument is enclosed in a metal cabinet with a convenient carrying handle attached to the top. All controls that are necessary for the operation of the instrument are located on the front panel.

TABLE 1-1
QUICK REFERENCE DATA

CATHODE-RAY TUBE

Type 5CP-A

Accelerating Potentials ....Type 304—E_{b2} + 1600 volts with respect to cathode. Intensifier + 1780 volts with respect to cathode

Type 304-H—E_{b2} + 1600 volts with respect to cathode. Intensifier + 3000 volts with respect to cathode

Y AXIS

Deflection Factor

Direct .... 18 rms volts /inch ±17%

Amplifier

Y Attenuator at 1:1, Y Amplitude Maximum = 10 rms millivolts/inch

Y Attenuator at 1:1, Y Amplitude Minimum = 115-190 rms millivolts/inch

FREQUENCY RESPONSE	*DC Amplifier*	*AC Amplifier*
10% Response Point	100 kc	100 kc
50% Response Point	300 kc	300 kc
20 kc Squarewave	Good	Good
10 cycle Squarewave	Good	17% Saw.

Maximum Input Potential........ 1000 volts peak

Input Impedance

Direct

Balanced .... 3 meg; 20 $\mu\mu f$

Unbalanced .... 1.5 meg; 20 $\mu\mu f$

Amplifier .... 2 meg; 50 $\mu\mu f$

X AXIS

Deflection Factor

Direct .... 21 rms volts/inch ±17%

Amplifier

X Selector at 1:1, X Amplitude Maximum........ .05 rms volts/inch

FREQUENCY RESPONSE	*DC Amplifier*	*AC Amplifier*
10% Response Point	100 kc	100 kc
50% Response Point	300 kc	300 kc
20 kc Squarewave	Slight Overshoot	Slight Overshoot
10 cycle Squarewave	Good	17% Saw.

Maximum Input Potential........ 1000 volts peak

Input Impedance

Direct

Balanced .... 3 meg; 20 $\mu\mu f$

Unbalanced .... 1.5 meg; 20 $\mu\mu f$

Amplifier .... 2.2 meg; 50 $\mu\mu f$

TYPE 316 PROBE

The Types 304 and 304-H Cathode-ray Oscillographs may be used with the Type 316 Probe as an accessory. (The type 316 Probe is not supplied with the Type 304 or Type 304-H). The probe is supplied with 5 feet of cable, and it increases the input resistance to 4.7 megohms and decreases the input capacity to 10 $\mu\mu f$ with an attenuation of 10:1. The small 3-12 $\mu\mu f$ capacitor under the name plate band is accessible for frequency compensating the probe. The capacitor should be adjusted so that a 10-kc squarewave passing through the probe will show up as a perfectly flat-topped squarewave.

LINEAR TIME BASE—RECURRENT SWEEP & DRIVEN SWEEP

Gas Triode ....Type 6Q5G

Sweep-Frequency Range ....2 cps to 30 kc with provision for connecting external capacitor for sweeps of lower frequency (.5 sec. sweep per microfarad).

Expandable Sweep:

The sweep of this instrument is expandable to an equivalent of six times the full-screen diameter of the cathode-ray tube; the positioning circuits are broad enough to examine any portion of the sweep on the screen without distortion. The expanded sweep is capable of a sweep writing rate of one inch per microsecond or faster.

TABLE 1-1—Cont'd

INTENSITY-MODULATION CIRCUIT

Input Impedance	0.2 meg; 80 $\mu\mu f$
Sensitivity	15 volts peak to blank the beam

TEST SIGNALS

Line-Frequency Test Signal—A test signal of approximately 0.5 rms volts at the power-line frequency, is available at a front-panel terminal.

Sawtooth Test Signal—A sawtooth test signal of about 7.5 volts peak amplitude at 47 K output impedance, at the frequency of the time-base generator, is available at a front-panel terminal.

POSITIONING AND UNDISTORTED DEFLECTION

The d-c positioning system permits the equivalent of four times full-scale expansion of the signal for Y axis, with no on-screen distortion present. For the X deflection, the d-c positioning system permits the equivalent of six times full-scale expansion of the signal with no on-screen distortion present.

POWER SUPPLY

Primary—Power Potential	115 or 230 rms volts ±10%
Frequency	50-60 cycles
Power Consumption	100 watts approx.
Fuse Protection	1.5 ampere

TUBE COMPLEMENT

8—12AU7	1—OB2
2—6AQ5	1—5Y3
1—6Q5G	1—2X2A
1—5CP-A	1 additional 2X2A for 304-H
2—6J6	

PHYSICAL SPECIFICATIONS

Height	13½"
Width	8¾"
Depth	19½"
Weight	50 lbs.

A rear panel is also available for connecting signals directly to the deflection plates.

4. FREQUENCY RANGE

a. TRANSIT TIME.—The cathode-ray tube is essentially an indicating device with a pointer of negligible inertia. For this reason its only frequency limitation occurs at deflection frequencies where the transit time of the electron beam across the face of the deflection plates must be considered. Since the electron velocity through the deflection-plate space has a finite value, it is possible that a deflecting potential could reverse in polarity during the transit time of the electron through this space, with the result that only a highly distorted representation, if any, of the original signal would be displayed on the screen of the cathode-ray tube. For example, assume that a 1000 megacycle sinewave is applied to the vertical-deflection plates. The period of one cycle will be 0.001 microsecond. Assume further, that the transit time of the electron beam across the face of the deflection plates is 0.001 microsecond. The beam will then become acted upon by equal positive and negative deflection forces as it travels across the face of

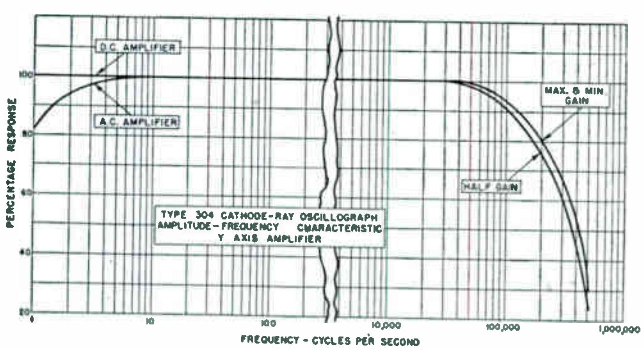


FIGURE 1-2
FREQUENCY-RESPONSE CURVE OF Y-AXIS AMPLIFIER

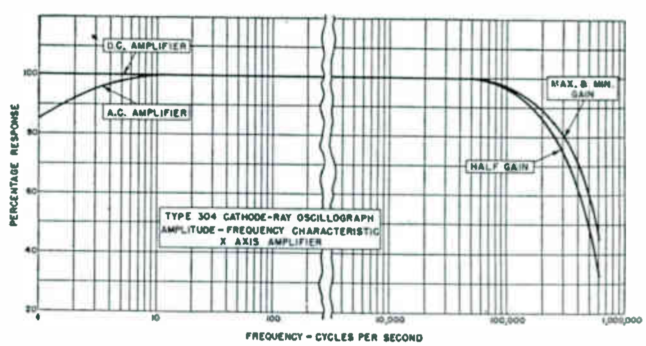


FIGURE 1-3
FREQUENCY-RESPONSE CURVE OF X-AXIS AMPLIFIER

:he plates, with a resulting deflection of zero. In the modern cathode-ray tube, as customarily used, this effect is not .pparent at frequencies below 100 megacycles per second, and may normally be disregarded at the lower frequencies. These frequency limitations apply when the cathode-ray-tube beam is deflected directly from the signal source without employing any type of vacuum-tube amplifier. If an amplifier of the oscillograph is used in any application, the frequency-response characteristics of the amplifier are the limiting factors.

5. TYPE OF INDICATION

a. LIMITATIONS.—It should be emphasized that the cathode-ray oscillograph does not offer the solution to a problem but that it merely supplies information and data regarding the characteristics of the problem. This information is meant to serve as a guide in analyzing the phenomenon under study. The cathode-ray oscillograph is not designed to be a corrective instrument, which, in itself, performs a specific operation on an electrical signal or on its source. It should rather be considered an auxiliary instrument which indicates visually the essential characteristics of a signal, thus enabling the operator to make a rapid check on the functioning of equipment, or to isolate the causes of any malfunction.

b. INTERPRETATION.—One of the most perplexing problems besetting the inexperienced operator of a cathode-ray oscillograph is the correct interpretation of an oscillographic pattern. It should be borne in mind that the unknown signal is always plotted as a function of some signal whose characteristics are known. If the characteristics of the signal on at least one axis are not known, it will be impossible to identify the characteristics of the signal under investigation on the other axis. For this reason, the horizontal variable is generally either a sinusoidal signal of known frequency, or a sawtooth signal, varying linearly with respect to time, which has been synchronized to the same or some integral sub-multiple of the frequency of the unknown signal. The sinusoidal signal is often used in applications such as phase, frequency, and rate determination. The sawtooth signal gives horizontal deflection which is linearly proportional to time, and it therefore gives a familiar plot of the waveshape of the unknown signal against time.

c. APPLICATIONS.—Information gained from analyzing oscillograms in the above manner is of great value in determining the characteristics of a device under study. A known signal can be followed through an amplifier, and the gain and distortion characteristics of the amplifier quickly and easily determined; the point at which the circuit may be faulty can also be determined. Using the linear time-base as the known function, an unknown waveform may be plotted and analyzed, or the dynamic characteristics of an unknown circuit may be studied. The waveform of a signal plotted as a function of the linear sawtooth-sweep will indicate the presence of undesirable harmonics or parasitic oscillations, and will show how closely a device is following a desired cycle of operation.

A familiar case of operation where a sinusoidal standard signal is employed for horizontal deflection is found in the application of the cathode-ray tube for frequency comparison of two signals. The unknown signal is fed into the vertical input and the known sinusoidal standard frequency is fed into the horizontal input. In this way, the frequency of the unknown signal may be measured by the correct interpretation of the resulting Lissajous pattern (see Section III).

Another common practice is to impress a modulated carrier upon the vertical input, and the modulation voltage on the horizontal. This results in the pattern known as the modulation trapezoid pattern which is used for studying percentage modulation (see Section III).

SECTION II
THEORY OF OPERATION

1. THE CATHODE-RAY TUBE

a. FUNCTION.—As an indicating instrument, the cathode-ray tube may be compared to the galvanometer, with the electron beam which is projected from the hot cathode analogous to the galvanometer needle. However, the cathode-ray, or electron beam, has great advantages over the needle, since the electron beam is practically without weight, and it therefore possesses minimum inertia, which results in infinitely greater flexibility of operation. The beam itself requires negligible power for deflection, so that accurate readings are obtained without loading the circuit under test. The beam can be moved vertically or horizontally, or the vertical and horizontal movements may be combined to produce composite patterns on the tube screen. Thus the block diagram, Figure 2-1, shows the cathode-ray tube as the recipient of signals from both the vertical and horizontal amplifiers.

b. OPERATION.

(1) Figure 2-2 shows the internal details of the cathode-ray tube. Electrons emitted from the cathode flow through the control grid in a beam toward anodes 1 and 2, and are accelerated and focused by the high positive potentials on these anodes. The electron beam continues between two sets of deflection plates, horizontal and vertical, and strikes the screen, causing it to fluoresce at the point of impact. With no potential applied to the deflection plates, the electron beam will strike the screen at the center and appear as a bright spot. If a positive voltage is applied to the right horizontal deflection plate, the electron beam, which is made up of electrons and therefore negatively charged, is attracted to the right. Should a negative charge be applied to the same plate, the beam would be repelled to the left.

(2) An a-c voltage applied to the horizontal deflection plates will cause the spot to move alternately to one side and then the other. This motion will be repeated continuously until the voltage is removed. The visual indication, except at very low frequencies, will appear to be a straight line, due to the effect of persistence of the screen phosphor and of visual persistence (see paragraph c).

(3) Vertical deflection is obtained in precisely the same way when the voltage is applied to the vertical plates.

(4) As a general rule the deflections representing signal amplitude are produced by applying voltage to the ver-

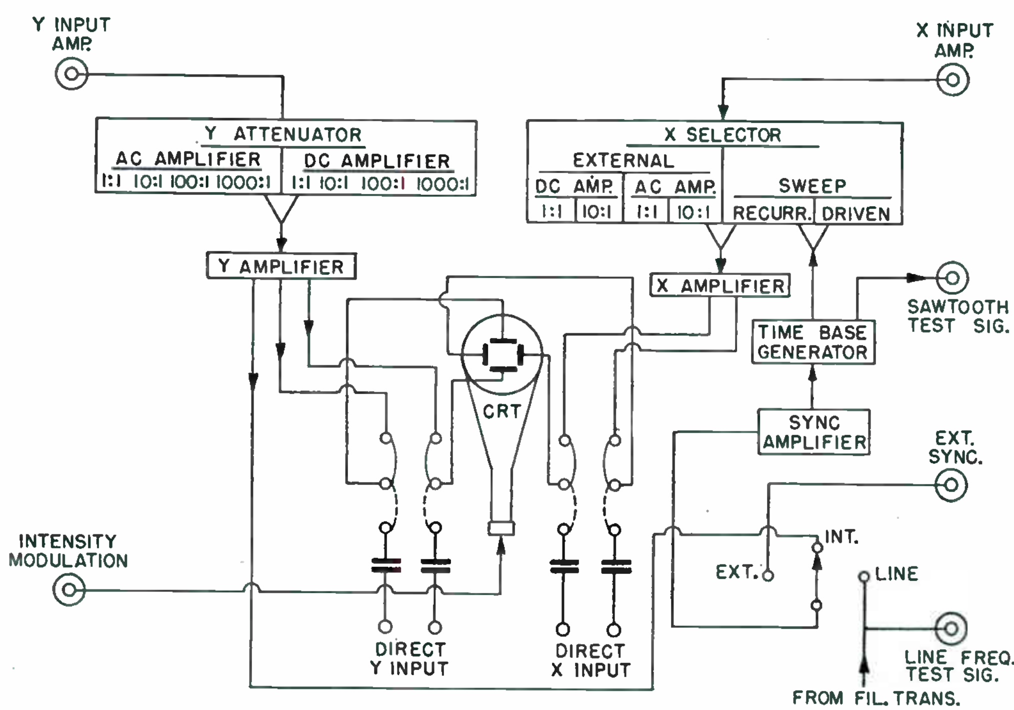
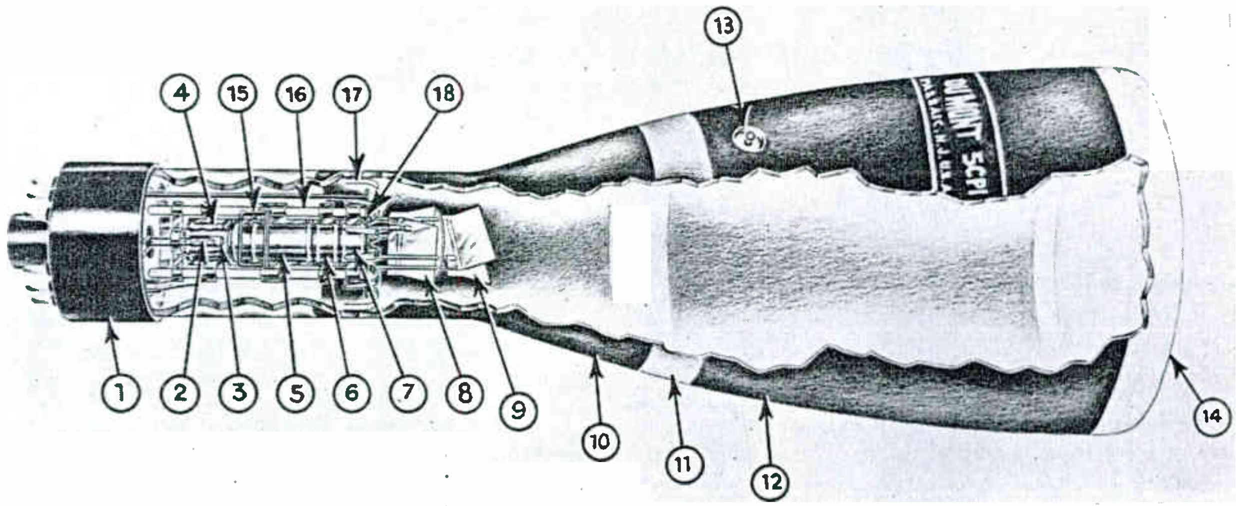


FIGURE 2-1

BLOCK DIAGRAM, TYPE 304 CATHODE-RAY OSCILLOGRAPH



1. Base
2. Heater
3. Cathode
4. Control Electrode Grid (G)
5. Pre-accelerating Electrode (connected internally to A_2)
6. Focusing Electrode (A_1)
7. Accelerating Electrode (A_2)
8. Deflection Plate Pair (D_3D_4)
9. Deflection Plate Pair (D_1D_2)
10. Conductive Coating (connected internally to A_2)
11. Intensifier Gap
12. Intensifier Electrode (A_3)
13. A_3 Terminal
14. Fluorescent Screen
15. Getter
16. Ceramic Gun Supports
17. Mount Support Spider
18. Deflection Plate Structure Support

FIGURE 2-2

INTERNAL CONSTRUCTION OF A TYPICAL CATHODE-RAY TUBE

tical deflection plate, and the pattern resulting from these deflections is said to be along the Y axis.

(5) Deflections representing the known quantity, usually time, are produced by applying a voltage to the horizontal deflection plate. The patterns resulting from these deflections are said to be along the X axis.

(6) The intensity of the trace may be modulated in order to obtain reference markers indicating time, angle, distance, etc. This is achieved by applying either positive (to brighten) or negative (to darken) marker signals to the grid of the cathode-ray tube. These marker signals may be supplied by an external source of known frequency. Intensity modulation is said to be performed on the Z axis of the cathode-ray tube.

A further use of this grid connection is to intensify the beam over portions of the trace where the writing rate of the spot is so rapid that the fluorescent screen is not sufficiently excited. Thus the intensity may be made more uniform over the entire trace. This feature facilitates photographic recording particularly. It should be emphasized that the screen excitation, and therefore the pattern intensity, is a function of both the beam current and the writing rate. The intensity of the spot at any instant, regardless of its position on the screen, may be controlled by a variation of the control-grid (modulating electrode) bias.

c. PERSISTENCE OF VISION.—Any image reaching the retina of the eye registers and persists there for an appreciable period of time, even though the object producing the image disappears almost at once from the field of vision. If an intermittently appearing image is reregistered at the rate of approximately 16 or more times per second, the image will appear continuous. As an example, "moving" pictures are really a series of "still" pictures projected successively at the rate of 16 or more per second. Similarly, if a cathode-ray spot is moved back and forth over the same path on the screen at the rate of 16 or more cycles per second, the movement or trace will appear to be continuous due to this persistence of vision.

d. CIRCUIT.—A Type 5CP-A Cathode-ray Tube is used in this instrument. As shown in the simplified schematic, Figure 2-3, the necessary potentials for operating this tube are obtained from a voltage divider made up of resistors R71, R72, R73, R74, R75, R76 and R79. The intensity of the beam is adjusted by moving the contact on R79. This adjusts the potential on the cathode more or less negative with respect to the grid which is operated at the full negative voltage, –1400 v. Focusing to the desired sharpness is accomplished by adjusting the contact on R75 to provide the correct potential for anode No. 1. Interdependency between the focus and the intensity controls is inherent to some degree in all electrostatically focused cathode-ray tubes, but is minimized in the Type 5CP-A by the design of the electron gun. In short, there is an optimum setting of the focus control for every setting of the intensity control. It can be seen in Figure 2-3 that each pair of deflection plates of the 5CP-A in this instrument are directly coupled to the plates of the output tubes of the deflection amplifiers. This brings each pair of deflection plates to an average potential of about 200 volts

above ground. To avoid distortion, the second anode must also operate at this same potential of 200 volts. This potential is maintained by the divider made up of resistors R81 and R82. The intensity of the trace is increased as the intensity control is turned in a clockwise direction, which reduces the bias at the cathode. If the control is turned too far in a clockwise direction, bringing the bias too close to zero, both size and intensity of the spot become too great, and no setting of the focus control will bring the spot into focus. In general, it is most satisfactory to use as low an intensity setting as possible. Excessive brightness of trace is obtained at the sacrifice of a small spot size.

The cathode of the cathode-ray tube is operated at a high negative potential (approximately 1400 volts). With the 200 volts applied to the second anode, the second-anode-to-cathode potential becomes 1600 volts. But since the intensifier of the cathode-ray tube operates at 380 volts above ground, the total overall accelerating voltage of this tube is 1780 volts.

2. Y-AXIS DEFLECTION

The signal may be applied to the vertical-deflection plates either directly or through a high-gain amplifier.

a. Y AMPLIFIER.—For low-level signals, the Type 304 is provided with a stable, high-gain, d-c amplifier (Figure 2-4). The input system to the Y amplifier utilizes an attenuator which retains the high-gain d-c characteristics. It can be seen from Figure 2-4 that the input attenuator is of the decade type, using RC-compensated, stepped attenuators and a linear gain control (R1). Either a-c or d-c input may be made by means of the input-attenuator switch and the input terminals marked "Y Input" and "Gnd." The "Off" position on the switch may be used to remove the signal from the grid of the amplifier. Thus, the signal leads need not be disconnected from the input terminals when changing to direct connections to the deflection plates. Attenuation ratios of 1:1, 10:1, 100:1, and 1000:1 are available for both a-c and d-c inputs.

The input cathode follower (V1) precedes the continuously variable Y-Amplitude control (R7). The Y-Amplitude control has an attenuation ratio of more than 10:1 it its output. Resistor R8 has been put in series with the Y-Amplitude control (see Figure 2-4). This prevents the operator from cutting the gain down completely to zero so that any portion of a signal that saturates the input cathode follower will be deflected beyond full screen on the cathode-ray tube, and can be observed only after setting the input-attenuator switch in a position of greater attenuation. It may be seen from the Quick Reference Data Table 1-1, that a sensitivity of 10 rms millivolts per inch with the Y attenuator at 1:1 and the Y-amplitude at maximum becomes 115 to 190 rms millivolts per inch with the Y-amplitude setting at minimum. Therefore, a full-screen deflection of 5 inches at maximum amplitude setting can be reduced to between .26 and .43 inch deflection at minimum Y-amplitude setting. For a-c input, the input capacitor has a voltage rating of 1000 volts. The 220K resistor (R6) in series with the grid of V1 is used to protect V1 and V2 and their associated components from damage due to excessive input voltage. The 6800 $\mu\mu$f shunting capacitor across R6 maintains the high-frequency response.

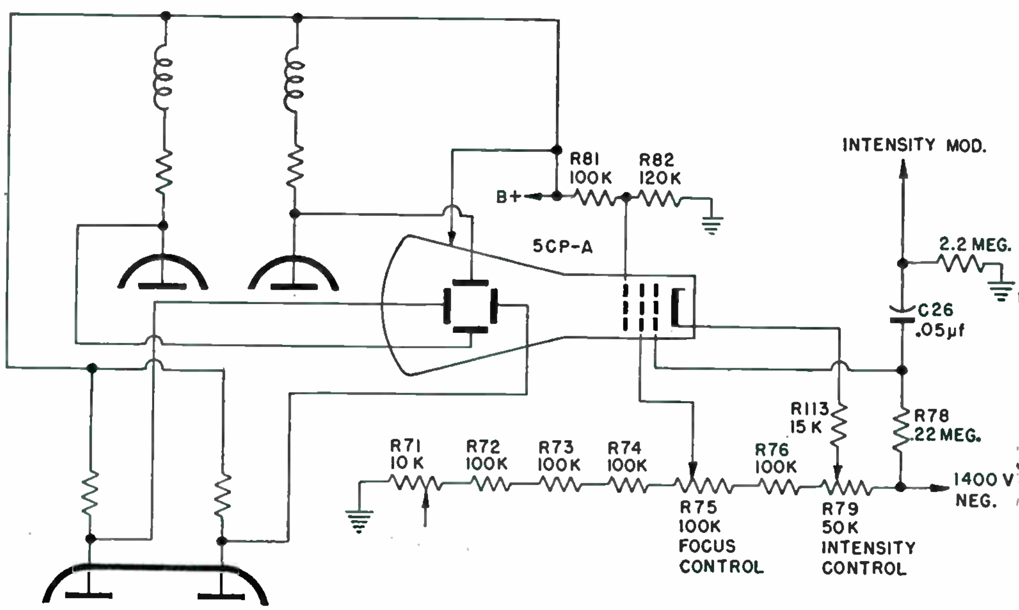


FIGURE 2-3

SCHEMATIC OF CATHODE-RAY TUBE CIRCUITS

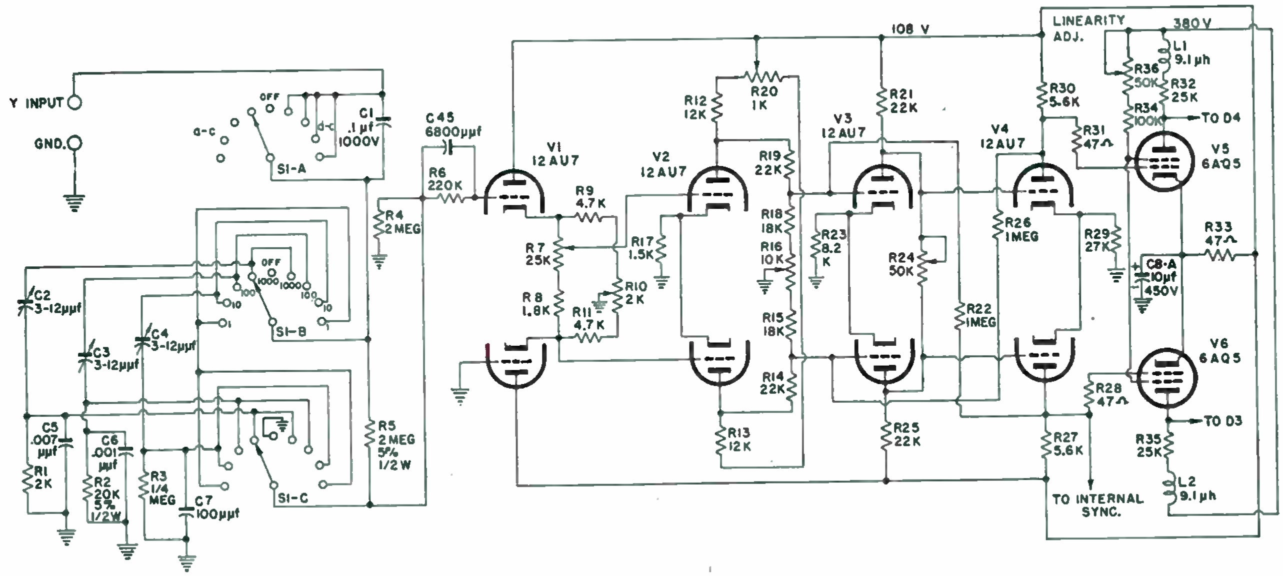


FIGURE 2-4

Y-AMPLIFIER SCHEMATIC

The details of the Y amplifier are shown in Figure 2-4. The balanced arrangement of the tubes gives great stability to the amplifier. For proper operation there should be no change in d-c position with variations of the gain control (R7). This requirement is fulfilled by use of the twin-triode circuit of V1 (Figure 2-4). The balance potentiometer R10 is adjusted so that the d-c levels are equal at the ends of the gain potentiometer (R7). This adjustment can be accomplished very quickly by adjusting R10 so that there is no vertical positioning of the cathode-ray tube trace on moving the Y-amplitude control from minimum to maximum with no input to the amplifier. For convenience, the balance adjustment is accessible with a screwdriver from the front panel.

D-C positioning is obtained by use of R20. From Figure 2-4 it can be seen that the d-c levels at the plates of V2 are varied by moving the arm of potentiometer R20, resulting in positioning of the trace on the face of the cathode-ray tube. The trace should be approximately in the vertical center of the cathode-ray tube when the positioning control is at its center. This condition can be achieved by use of the factory adjustment R16. The positioning system is such that even with a vertical deflection equivalent to 4 times full-screen diameter, any 5-inch portion of the 20-inch vertical deflection may be centered on the screen.

The factory adjustment R24 is used to set the sensitivity of the Y-deflection system to 10 millivolts per inch rms through the amplifier. The potentiometer R24 provides a variable partial short between the push-pull plates of the amplifier stage V3. It is desirable to avoid an excess of sensitivity, since such a condition would result in poorer stability.

The last stage of the amplifier is made up of two Type 6AQ5 pentodes. The screens of these pentodes are operated from the unregulated supply, so that the sensitivity of the system rises with increases in line voltage, due to increased amplifier gain. This essentially compensates for the reduction in cathode-ray tube sensitivity which is experienced at higher accelerating potentials resulting from higher line voltages. As a result of these two compensating factors the sensitivity of the system (through the amplifier) is almost independent of line-voltage variations. Factory-adjusted potentiometer R36 connected as a variable screen resistor for the output tubes, is provided for linearity adjustment. When the sensitivity at the top and bottom of the screen is greater than in the middle, the resistance is increased; and, as might be expected, the resistance is decreased when the sensitivity at the top and bottom of the screen is less than in the middle. When the sensitivity at the top and bottom of the screen is different the two output tubes are too far mismatched and one should be changed. The 9.1 mH. fixed peaking coils (L1 and L2) help maintain the high-frequency response of the amplifier. Additional high-frequency compensation is obtained by means of degenerative feedback through the 1-megohm resistors, R22 and R26.

b. DIRECT INPUT.—Input may be made directly to any set of deflection plates through terminals and series input capacitors of 1000-volt rating located at the rear of the instrument. The method of utilizing the direct input is discussed in Section III, i. Only a-c input may be made since the deflection plates normally are about 200 volts above ground. Direct input may be made by means of the amplifier and input-attenuator combination.

3. X-AXIS DEFLECTION

For deflection along the X axis, either the internal sweep signal or an external signal may be used.

a. As with the Y axis, an external signal may be applied to the X axis either directly or through the amplifier.

(1) Direct input. The direct input for the X axis is made in the same way as for the Y axis, as discussed in Section III, i.

(2) X Amplifier. External signals may be applied to the X amplifier by setting the X-selector switch in one of the four amplifier positions. Either direct or capacitive coupling at 1:1 or 10:1 attenuation ratios is available. As with the Y amplifier, an "Off" position is provided on the X-selector switch to ground the input grid of the amplifier.

As seen in Figure 2-5, the X-axis amplifier is very similar to that employed on the Y axis. The X-amplitude control, too, is similar to that of the Y axis. The d-c balance adjustment for the X axis is accessible as a screwdriver adjustment on the front panel.

The gain of the X-axis amplifier cannot be reduced to zero, since it is limited by resistor R94 which is in series with the X-amplitude control. The reason for this, as in the case of the Y axis, is to deflect off the screen any portion of a signal which saturates the input cathode follower. A horizontal deflection which occupies 5 inches on the screen at maximum gain can be cut down to between .1 and .5 inch at the minimum gain setting.

The X-axis positioning system is somewhat different from that employed on the Y axis. Here the positioning voltage is applied to one grid of the first amplifier stage; the input signal is applied to the grid of the other half of this stage. The positioning potentiometer is returned to a point near the cathode end of the cathode load of the cathode follower. This tends to increase amplifier stability, since variations in line voltage now produce about the same variations in voltage at the two grids of the first stage of amplification (V12).

A small portion of the input signal to V11 appears at the pin-8 cathode of V11. About 10% of the low-frequency component of the signal at the pin-8 cathode is lost through the divider network before it can reach the pin-5 grid of V12. To equalize the losses of high- and low-frequency components, the capacitive divider, C34 and C36, has been added. To afford additional improvement, the two halves of the cathode-follower, V11, are supplied with a common plate resistor, R113. This 8.2K resistor is of proper value to produce a signal, at the pin-8 cathode, almost equal in amplitude and opposite in phase to the sig-

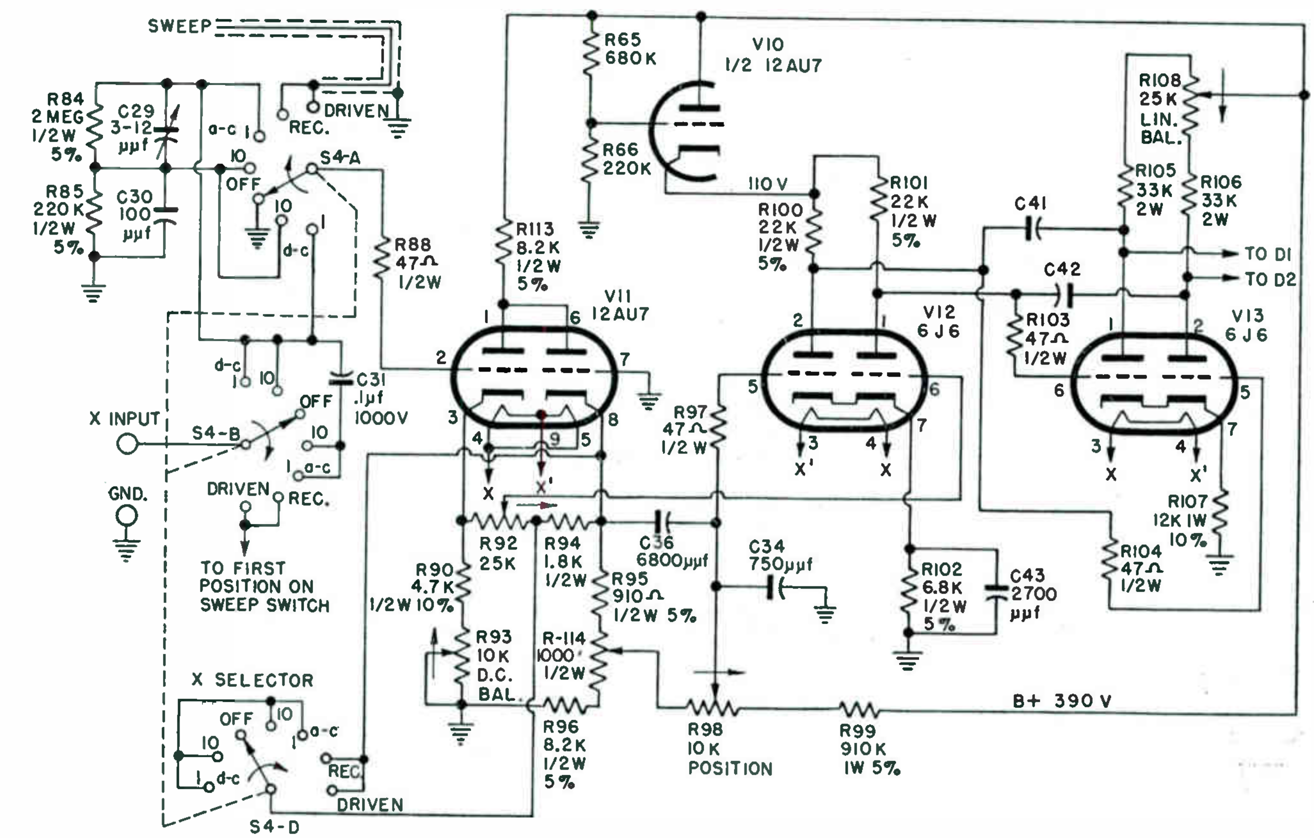


FIGURE 2-5

X-AMPLIFIER SCHEMATIC

nal which is already present at that point, thus resulting in cancellation. This assures better high-frequency response at the low end of the X-amplitude control, and it also facilitates reduction of the sweep amplitude to less than 0.1 inch.

In the sweep position resistor R94 is shorted out. Were this not done, approximately 2% of the sweep voltage would appear between the grids of the following stage, with gain at minimum. Hence, too much residual deflection would be visible.

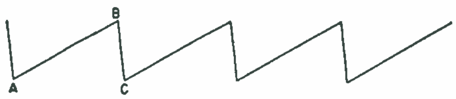


FIGURE 2-6

SAWTOOTH WAVEFORM

The horizontal d-c positioning system is such that even with 6 times full-screen expansion, any portion of the pattern can be positioned on the screen. Thus, as far as horizontal deflection is concerned, the instrument is the equivalent of a 30-inch oscillograph having a movable 5-inch mask which permits any 5-inch portion of the trace to be examined.

The output stage of the horizontal amplifier is a twin triode. Good linearity is maintained in this output stage by the linearity adjustment potentiometer, R108, a factory adjustment located in the rear, vertical chassis. R108 functions by arranging the relationship between the load resistors in the two halves of the output stage in such a way as to compensate for the variations between the two sections of the output tube.

The capacitors, C41 and C42, are merely four turns of wire from the grid looped around the plate leads. These provide feedback to cancel out the input capacitance of V13, and hence improve the high-frequency response of the horizontal amplifier.

a. TIME-BASE GENERATOR.

(1) GENERAL.—Investigation of electrical waveforms with the cathode-ray tube frequently requires some means for determining the variation in the amplitudes of these waveforms with respect to time. When such a timebase is used, the patterns presented on the cathode-ray-tube screen show the variation in amplitude of the input signal with respect to time. Such an arrangement is made possible by the use of the timebase generator. In operation, it moves the spot across the screen at a constant rate from left to right, between selected points, returns the spot almost instantaneously to its original position, and repeats the operation. The rate at which this voltage repeats the cycle of sweeping the spot across the screen is referred to as the sweep frequency. The sweep voltage necessary to produce the motion described above must be of a sawtooth waveform such as that shown in Figure 2-6.

The sweep occurs as the voltage varies from A to B, and the return trace occurs as the voltage varies from B to C. If AB is a straight line, the sweep generated by this voltage will be linear with respect to time.

It should be realized, however, that the sawtooth-sweep signal is used only to plot variations in the vertical signal with respect to time. For specialized studies, other waveforms may be applied to the horizontal axis.

(2) CIRCUIT.—The sawtooth voltage necessary to obtain the proper sweep is generated by means of the electronic circuit shown in Figure 2-7. The gas triode used for this purpose is a Type 6Q5G (V8). The cathode is heated and emits electrons as in the ordinary heater-type triode. This tube contains an inert gas which ionizes when the voltage between the cathode and the plate reaches a certain value. The voltage at which breakdown will occur depends upon the bias with respect to grid potential at the cathode of the thyratron, which bias in turn is determined by a voltage-divider network. With a specific negative bias applied to the tube in this way, the tube will fire at a specific plate voltage.

Capacitors C18 to C22 are selectively connected in parallel with this tube. The plate voltage on this tube is obtained through resistors R55 and R57. The capacitor charges until the plate voltage becomes high enough to ionize the gas in the tube. At this time, the thyratron starts to conduct and the capacitor discharges through it until its voltage falls to the extinction potential. When the tube stops conducting, the capacitor voltage starts to build up, and the cycle of events is repeated. As this action continues, the resultant sawtooth waveform (see Figure 2-6) appears at the plate of V8.

The sweep must be attenuated before being applied to the X amplifier; otherwise saturation would occur in the cathode-follower stage of the X amplifier. The plate of the thyratron must not be loaded down with an attenuator since this would distort the low-frequency sweeps. Therefore the sweep is directly coupled to a cathode-follower stage. From the cathode follower the sweep is applied to a compensated voltage divider, where it is cut down to about one-fifth of its original value. The lower end of the attenuator is returned to an adjustable, negative bias at the arm of the potentiometer (R71), in the cathode-ray-tube bleeder. The negative bias brings the average level of the attenuated sweep to zero-voltage level, so that equal expansion from both sides of center will be observed as the gain is turned up. The sweep is fed from the attenuator to the horizontal amplifier, provided the input-selector switch is in one of the sweep positions. From the horizontal amplifier, the sweep is applied to the horizontal-deflection plates of the cathode-ray tube.

For convenience it is desirable to view only the forward trace of the sweep, and to blank out the return trace. This

is accomplished by applying a positive pulse to the cathode of the cathode-ray tube, to cut off the beam during the interval of the return trace. This positive pulse is obtained by differentiating the sweep at the cathode of the cathode follower (V9A) and amplifying it through V9B. With the sweep vernier potentiometer (R54) and the sweep capacitors, C18 to C22, the sweep may be varied from 2 cycles to 30 kc per second. But with the sweep range switch in the first position, a capacitor may be connected externally across the horizontal-input binding posts to produce sweeps of very low frequency. Whereas this first position is intended primarily for low-frequency sweeps, it may be used without an external condenser to provide sweeps if higher than 30 kc per second.

Table 2-1 will help the operator select the proper capacitor necessary to bring the sweep down to the desired frequency.

It should be borne in mind that the capacitors used should have a very high leakage resistance in order to obtain good linearity. Electrolytic capacitors are not recommended because their leakage resistance is relatively low.

There are two sweep positions, single and repetitive. The circuit described so far explains the operation of the repetitive sweep only. A full understanding of the single sweep can be had only after acquiring a familiarity with the

TABLE 2-1

EXTERNAL CAPACITORS FOR LOW FREQUENCY SWEEPS

Sweep Frequency	*Sweep Duration*	*Capacitance*
1 cycle	1 sec	2 μf
.5 cycle	2 sec	4 μf
.25 cycle	4 sec	8 μf
.1 cycle	10 sec	20 μf

principles of synchronization, discussed in the following paragraphs.

(3) SYNCHRONIZATION.—Provision has been made so the sweep generator may be synchronized from the vertical amplifier, from an external source, or from the power line. The switch, S2, shown in Figure 2-7, is mounted on the front panel to be easily accessible to the operator.

If no synchronizing voltage is applied, the discharge tube will begin to conduct when the plate potential reaches the value of E_f (Firing Potential). When this breakdown takes place and the tube begins to conduct, the capacitor is discharged very rapidly through the tube, and the plate voltage decreases until it reaches the extinction poten-

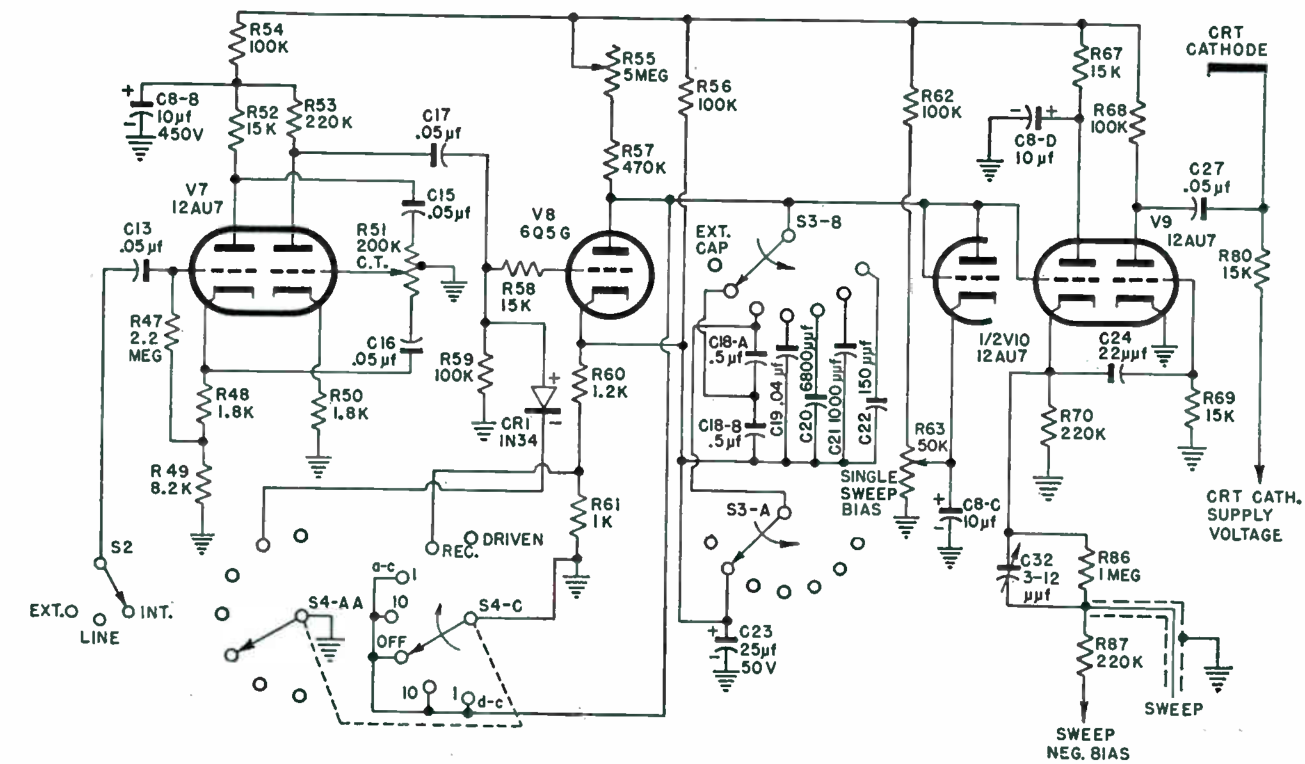


FIGURE 2-7

SCHEMATIC OF SWEEP GENERATOR

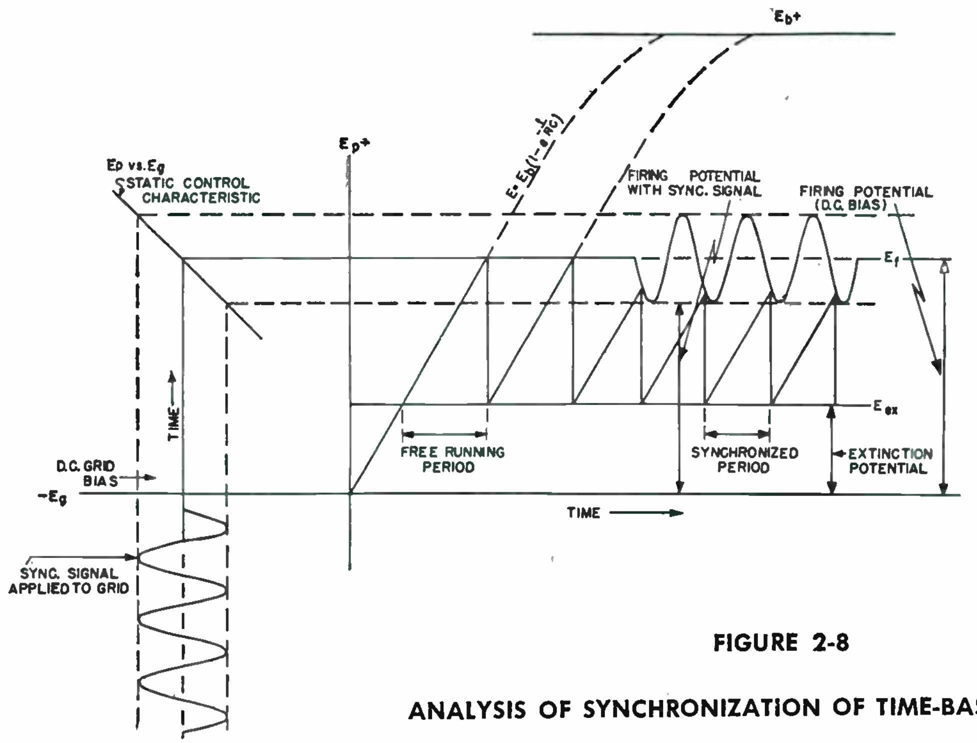


FIGURE 2-8

ANALYSIS OF SYNCHRONIZATION OF TIME-BASE GENERATOR

tial E_x. At this point conduction ceases, and the plate potential rises slowly as the capacitor begins to charge through R55 and R57. The plate potential will again reach a point of conduction and the circuit will start a new cycle. The rapidity of the plate-voltage rise is dependent upon the circuit constants R55, R57, and the sweep-range capacitor selected, C18-C22, as well as the supply voltage E_b. The exact relationship is given by:

$$E_c = E_b \left(1 - e^{\frac{-t}{RC}}\right)$$

Where E_c=capacitor voltage at time t

E_b=supply voltage (B + supply — cathode bias)

E_f=firing potential or potential at which time-base gas-triode fires

E_x=extinction potential or potential at which time-base gas triode ceases to conduct

e=base of natural logarithms

t=time in seconds

R=resistance in ohms (R55 + R57)

C=capacitance in farads (C18, C19, C20, C21, or C22)

The frequency of oscillation will be approximately:

$$f = \frac{E_b}{E_f - E_x} \cdot \frac{1}{RC}$$

Under this condition (no synchronizing signal applied) the oscillator is said to be "free running."

When a positive synchronizing voltage is applied to the grid, the firing potential of the tube is reduced. The tube therefore ionizes at a plate potential lower than it will when no grid signal is applied. Thus, the applied synchronizing voltage fires the gas-filled triode each time the plate potential rises to a sufficient value, so that the sweep recurs at the same or an integral sub-multiple of the synchronizing-signal rate. The necessary positive synchronizing voltage at the grid of the thyratron may be obtained from either a positive or negative input signal to the first sync. amplifier (first half of V7). This first sync. amplifier is a phase inverter which enables the operator to select varying amounts of synchronizing voltage from either the plate or cathode of the amplifier by the use of a 200K center-tapped potentiometer (R51) connected between the plate and cathode through coupling capacitors. The center tap of the potentiometer is connected to ground. The output from this stage is fed into a second stage of amplification; the output of this second amplifier is applied to the grid of the thyratron. The 1N/34 germanium diode, connected between the grid and ground of the thyratron, limits the synchronization voltages and thus avoids distortion resulting from too much synchronizing signal. The diode also

prevents the grid of the thyratron from charging to too high a positive potential at higher sweep frequencies, and thus avoids premature firing of the thyratron which would reduce sweep amplitude. A graphic representation of this is shown in Figure 2-8.

(4) SINGLE SWEEP.—In the single-sweep position, the sweep is normally not operating except when triggered by a synchronizing pulse. Each pulse produces one single sweep. With the input-selector switch in the Single Sweep (or Driven Sweep) position, the bias at the cathode of the thyratron is increased by the addition of resistor R61. With this additional bias, the thyratron must reach a higher plate voltage before it can conduct. The tube, V10, connected as a diode does not permit the thyratron plate to reach the potential necessary for conduction. When a positive synchronizing potential (of sufficient amplitude) is applied to the grid, however, the firing potential of the tube is reduced sufficiently to start it conducting. The sweep capacitor immediately discharges until the plate voltage of the thyratron drops to the extinction point. Conduction no longer occurs and the capacitor again begins to charge and produce the single sweep. The charging continues until the diode-limiting voltage is reached. The plate of the thyratron then remains at this voltage until the next synchronizing pulse triggers off the single sweep.

The spot is normally at rest at the end of the sweep traverse, at the extreme right side of the screen. On triggering, the capacitor discharges and its voltage level drops. The spot moves toward the left very rapidly. During the time the spot moves from rest position to the extreme left, it is blanked out. The spot then begins the sweep from left to right as the capacitor begins to recharge.

Frequently, it is objectionable to have the visible spot at rest on the screen. This condition can easily be remedied by increasing the sweep amplitude so that the spot is deflected off the screen when it is in the rest position.

4. POWER SUPPLY

a. GENERAL.—Figure 2-9 shows the power supply of the Type 304 which is made up of two sections: (1) a low-voltage positive supply which provides the power for operating the amplifiers, the time base generator, and the positioning circuits of the cathode-ray tube, and (2) the high-voltage negative supply which provides the potentials necessary for operating the various electrodes of the cathode-ray tube and furnishes a negative voltage to the positioning controls. In addition to these two sections, the Type 304-H contains a high-voltage positive supply to provide an additional voltage to the intensifier electrode of the cathode-ray tube.

b. THE LOW-VOLTAGE POWER SUPPLY.—The low-voltage power supply consists of a full-wave rectifier, V15. The output of this rectifier is filtered by a capacitor-input filter consisting of C40, L3, and C39. It furnishes B+ at approximately 390 volts (positive) at sufficient current to supply the tubes of the instrument. In addi-

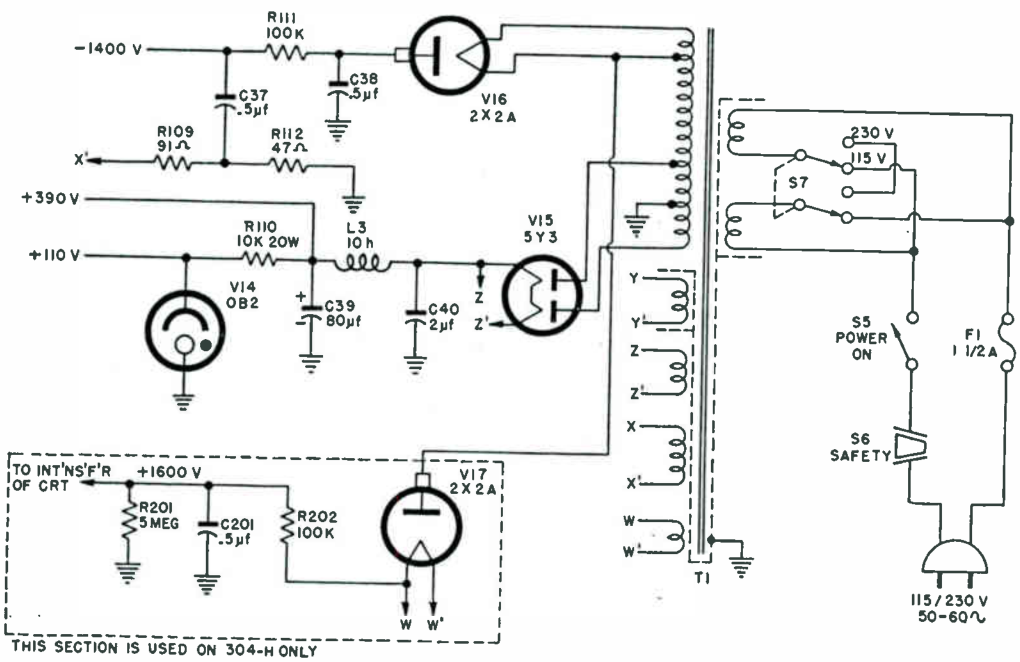


FIGURE 2-9

SCHEMATIC OF POWER SUPPLIES

tion, this +390 volts provides voltage for the intensifier electrode of the cathode-ray tube in the Type 304.

c. THE HIGH-VOLTAGE POWER SUPPLY.—The high-voltage power supply employs a half-wave rectifier, V16. The output of this rectifier is filtered by a resistance-capacitance filter consisting of C38, R111, and C37. A voltage-divider network, attached from the output of this filter, determines the proper operating potentials for the various electrodes of the cathode-ray tube.

d. AUXILIARY INTENSIFIER SUPPLY.—The Type 304-H contains a separate high-voltage positive supply of approximately 1600 volts to supply the intensifier electrode. Since the Type 304 operates the intensifier at approximately 400 volts, the difference between third anode potentials in the Type 304 and the Type 304-H is 1200 volts with respect to ground.

The Type 304 may be easily converted to a Type 304-H. The power transformer of the Type 304 is equipped with an additional 2.5-volt winding, already wired to a 4-pin tube socket, for the extra high-voltage rectifier. (See portion of Figure 2-9 enclosed by dotted line.) The filter system required consists of a 100K resistor, a 0.5 μf 2000-volt capacitor, and a 5 megohm bleeder across the capacitor. The bleeder should be a special high-voltage type, or should consist of five 1-megohm composition resistors in series. The additional high-voltage capacitor may be mounted in a hole already provided in the chassis.

For best results, the auxiliary intensifier supply should be shielded.

WARNING

OPERATION OF THIS EQUIPMENT INVOLVES THE USE OF HIGH VOLTAGES WHICH ARE DANGEROUS TO LIFE. OPERATING PERSONNEL SHOULD OBSERVE ALL SAFETY REGULATIONS. DO NOT CHANGE TUBES OR MAKE ADJUSTMENTS INSIDE THE EQUIPMENT WITH THE HIGH-VOLTAGE SUPPLY "ON". DO NOT DEPEND UPON THE SAFETY SWITCH FOR PROTECTION, BUT ALWAYS REMOVE THE POWER CORD FROM THE LINE OUTLET. UNDER CERTAIN CONDITIONS DANGEROUS POTENTIALS MAY EXIST IN THE CIRCUITS WITH POWER CONTROLS IN THE "OFF" POSITION DUE TO CHARGES RETAINED BY CAPACITORS. TO AVOID SHOCK AND SEVERE BURNS ALWAYS DISCHARGE AND GROUND CIRCUITS PRIOR TO TOUCHING THEM. NEVER SERVICE OR ADJUST THE INSTRUMENT WITHOUT THE PRESENCE OR ASSISTANCE OF ANOTHER PERSON CAPABLE OF RENDERING AID.

SECTION III

OPERATING INSTRUCTIONS

1. INSTALLATION

In most instances, the Types 304 and 304-H Cathode-ray Oscillographs are shipped with all tubes in place and ready for operation. In some instances, however, the cathode-ray tube may be packed separately.

To install the cathode-ray tube, the chassis must be removed from the cabinet. Two screws near the bottom in the rear of the cabinet hold the chassis in place. Remove these two screws, and unwind the power cord from its bracket. The instrument will now slide forward out of the cabinet. The power cord and its plug will conveniently feed through the hole provided in the rear of the cabinet.

Remove the bezel and calibrated scale and insert the cathode-ray tube through the front panel and tube shield as far as the socket. The socket prongs are then inserted into their correct position in the socket. A gentle push, with one hand on the face of the tube and the other hand supporting the tube base and socket will seat the tube in the socket. Fasten the tube, and base clamp, snap on the intensifier contact, and replace the calibrated scale. The cathode-ray tube should be rotated so the horizontal trace will be parallel to the horizontal lines of the calibrated scale. After the chassis has been placed in its cabinet, the instrument can be turned on. If the trace appearing on the tube is not parallel to the horizontal lines on the calibrated scale, the instrument must be removed from the cabinet, the cathode-ray tube clamp loosened, and the cathode-ray tube rotated to its proper position.

Before replacing the chassis in the cabinet, it is advisable to see that all tubes are properly seated in their sockets. All tube locations are clearly indicated on the chassis. It is also advisable to inspect the instrument for any mechanical damage which may have occurred in transit.

As soon as these operations have been completed, place the instrument back in its cabinet, and replace the screws.

2. PRECAUTIONS

WARNING

IT IS NOT ADVISABLE TO OPERATE THIS CATHODE-RAY OSCILLOGRAPH WITH THE CASE REMOVED. DANGEROUS POTENTIALS AS HIGH AS 3000 VOLTS ARE EMPLOYED IN THIS INSTRUMENT AND SHOULD BE TREATED WITH PROPER CAUTION.

a. MAGNETIC AND ELECTRIC FIELDS.—Magnetic and electrostatic shielding adequate for all ordinary applications has been provided in this instrument. However, operation of the instrument in strong fields such as are found near transmitters, transformers, and power generating equipment, etc., may introduce spurious deflections.

Electrostatic pick-up may be minimized by the use of shielded input cables with connections that make a good electrical ground on the chassis of the instrument. Spurious magnetic deflections may be eliminated or reduced to a degree that is unobjectionable by removing the instrument from the immediate vicinity of the disturbance; by orienting the instrument in the field so that spurious deflection is at a minimum; or, in extreme cases, by adding magnetic shielding in the form of a large iron or steel container in which the entire instrument may be placed.

b. POWER REGULATION.—The Types 304 and 304-H are designed to operate at a power-line voltage of 115 or 230 volts rms at a frequency of 50 to 60 cycles per second. Steady variations of $\pm 10\%$ from the normal line voltage will cause little change in the operation of this instrument. Greater changes than this may cause the power supply, and thus the instrument, to operate erratically. For conditions where power-line variations are excessive, the use of constant-voltage transformers placed in the power line leading to the instrument is recommended. If such a regulator is used, the precautions outlined in the previous paragraph should be observed.

c. SCREEN BURNING.—When a small spot or line of high intensity is allowed to remain stationary on the screen of the cathode-ray tube, the entire energy of the beam is concentrated over a very small area, and the power input per unit of screen area is high. Under such conditions the screen is susceptible to burning and discoloration.

It is well to note that burning of the screen, until carried to excess, will in no way impair the operation of the tube, since the burning is localized to small areas and the burned area is not completely insensitive.

3. OPERATION OF CONTROLS

a. GENERAL.—The operation of the various controls of the Types 304 and 304-H is presented in brief tabular form in Table 3-1. Figure 3-1 shows the location of the controls on the front panel of the instrument.

TABLE 3-1

TABLE OF OPERATING CONTROLS AND TERMINALS

Name of Control	*Circuit Desig.*	*Component*	*Function*
Y POSITION	R20	1000 ohm potentiometer	Changes the Vertical Position of the trace.
X POSITION	R98	10K potentiometer	Changes the Horizontal Position of the trace.
INTENSITY	R79	50K potentiometer	Varies voltage on the cathode of the cathode-ray tube and thus the intensity of the trace.
FOCUS	R75	100K potentiometer	Varies the voltage on the focusing electrode of the cathode-ray tube and thus adjust the focal point of the beam.
Y ATTENUATOR	S1	3 Pole—9 Position Switch	Select d-c or a-c coupling for Y-Input signal at attenuation ratios of 1:1, 10:1, 100:1, or 1000:1. "OFF" position grounds the grid of the Y amplifier.
Y AMPLITUDE	R7	25K potentiometer	Varies the amplitude of the vertical signal after passing through the input cathode follower, thus controlling the amplitude of vertical deflection.
X SELECTOR	S4	4 Pole—7 Position Switch	Selects between internal or external signal for horizontal deflection. The internal signal is linear sweep and selection of either recurrent or driven sweep may be made with the X Selector. For external signals either d-c or a-c coupling at 1:1 or 10:1 attenuation may be made. "OFF" position grounds the grid of the X amplifier.
X AMPLITUDE	R92	25K potentiometer	Varies amplitude of the horizontal signal, after the signal has passed through the input cathode follower. Thus it controls the amplitude of horizontal deflection.
D-C BALANCE (Y-side)	R10	2K potentiometer	This control, available as a screwdriver adjustment on the front panel, is used to equalize the voltage at the ends of the vertical-amplitude control so that there will be no change in the position of the trace when the Y amplitude control is varied.
D-C BALANCE (X-side)	R93	10K potentiometer	This control, available as a screwdriver adjustment on the front panel, is used to equalize the voltage at the ends of the horizontal amplitude control so there will be no change in the d-c level of the trace when the X amplitude control is varied.
SWEEP RANGE	S3	2 Pole, 7 Throw	Switches to various sweep capacitors to obtain step variations in sweep frequency.
SWEEP VERNIER	R55	5-meg. potentiometer	Provides a fine adjustment of the sweep frequency by controlling the rate at which the selected sweep capacitor is charged.
SYNC. AMPLITUDE	R51	200K C. T. potentiometer	Varies the amplitude of the synchronizing voltage applied to the time-base generator, thus enabling the operator to "lock-in" the signal being viewed, or to trigger off the driven sweep. This control enables the selection of signals of either negative or positive polarity, depending on whether the control is turned to the left or to the right of the zero mark.
SYNC. SELECTOR	S2	1 Pole, 3 Throw	Provides means for selecting as a synchronizing signal, the vertical signal, a line-frequency signal, or an external signal.
Y INPUT		Binding Post	Provides a terminal for the connection of an external signal to the vertical amplifier.
X INPUT		Binding Post	Provides a terminal for the connection of an external signal to the horizontal amplifier, or for an external capacitor for obtaining low frequency sweeps.
Z INPUT		Binding Post	Provides a terminal for the connection of an external signal to the grid of the cathode-ray tube for the purpose of modulating the intensity of the trace.
EXT. SYNC.		Binding Post	Provides a terminal for connecting an external synchronizing or triggering signal.
LINE FREQ. TEST SIGNAL		Binding Post	Provides a terminal at which a line frequency output voltage of approximately 0.5 volts rms is available.
SAWTOOTH TEST SIGNAL		Binding Post	Provides a terminal at which the sweep sawtooth voltage is available.
GROUND		Binding Post	The two ground binding posts are available to ground the chassis of the Type 304 and 304-H to the ground of any input signals.

FIGURE 3-1

FRONT PANEL VIEW OF TYPE 304 AND 304-H CATHODE-RAY OSCILLOGRAPH

For the operator who is well acquainted with cathode-ray oscillographs, this table will probably furnish sufficient instructions to operate the instrument. For the new operator, however, the following discussion lists a step-by-step procedure for the efficient operation of the instrument. It is suggested that the new operator follow this procedure for learning the use of each of the operating controls.

b. PREPARING THE EQUIPMENT FOR OPERATION.

Step 1. Place the oscillograph on a level table or bench so the screen of the cathode-ray tube is in full view and a minimum amount of light is incident upon the face of the tube. The location must be sufficiently near a 115- or 230-volt a-c power source to be reached easily by the line cord provided with the instrument.

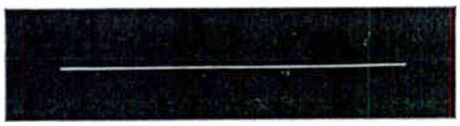


FIGURE 3-2
TRACE "IN FOCUS"

FIGURE 3-3
TRACE "OUT OF FOCUS"

Step 2. Set the controls as follows:

Y Position	— center of range
X Position	— center of range
Intensity	— fully counterclockwise
Power Switch	— down (off)
Focus	— center of range
Y Attenuator Switch	— off
Y Amplitude	— fully counterclockwise
X Selector	— recur. sweep
X Amplitude	— at 100
Coarse Frequency	— between 10 and 50
Fine Frequency	— at 100
Sync. Amplitude	— at 0
Sync. Selector Switch	— ext.

Step 3. Plug the line cord into a power source.

c. OBTAINING THE TRACE.

Step 1. Throw the POWER switch to the "On" position.

Step 2. Allow 30 seconds for the instrument to warm up.

Step 3. Advance the INTENSITY control until a trace is visible on the cathode-ray tube screen. If no trace becomes visible, rotate the Y-POSITION control in both directions to bring the trace onto the screen.

WARNING

NEVER ADVANCE THE INTENSITY CONTROL TO A POSITION WHICH CAUSES AN EXCESSIVELY BRIGHT SPOT TO APPEAR ON THE SCREEN. A VERY BRIGHT SPOT MAY BURN THE SCREEN AND DECREASE THE LIFE OF THE CATHODE-RAY TUBE. FOR THIS REASON A SHARPLY FOCUSED TRACE OR SPOT OF HIGH INTENSITY MUST NEVER BE PERMITTED TO REMAIN STATIONARY FOR ANY LENGTH OF TIME. THIS IS ESPECIALLY TRUE OF THE TYPE 304-H.

Step 4. Rotate the FOCUS control as required to the position where the trace is clear and sharp (least "fuzzy"). The trace then is described as being "in focus." Once in focus, either clockwise or counterclockwise movement of the FOCUS control defocuses the trace. Having reached a clear focus, the operator may decide that the trace is too bright. If such is the case, reduce the setting of the INTENSITY control and refocus. Figures 3-2 and 3-3 show a trace respectively "in focus," and "out of focus."

Note

The action of the INTENSITY and FOCUS controls are inherently dependent on each other. Therefore, it may be necessary, whenever varying one control, to adjust the other control to obtain the best definition of the trace. When the INTENSITY control is turned too far clockwise, an extremely defocused trace is observed. The instrument should not be operated under these conditions. Proper setting of the INTENSITY control under normal operating conditions should fall between 45 and 90 degrees rotation to the right of center range (with the knob pointing directly upward).

Step 5. Rotate the Y-POSITION control counterclockwise (DOWN) and clockwise (UP). The trace moves down and then up as the control is turned. Center the trace in the vertical plane.

Step 6. Rotate the X-AMPLITUDE control counterclockwise and observe decrease in amplitude of the sweep trace. Set the sweep amplitude to about 3 inches.

Step 7. Rotate the X-POSITION control, first counterclockwise (left) and then clockwise (right). The trace moves left and then right as the control is turned. Center the trace in the horizontal plane. The trace is centered horizontally when the edges of the trace are equally distant from their respective edges of the tube screen.

d. CONTROL OF HORIZONTAL FREQUENCY OF THE TRACE.—The trace that has now been obtained and positioned is actually a single spot which is repeatedly being caused to move across the screen from left to right. As this beam moves across the screen the persistence of the human vision plus the persistence of the screen, cause the movement of this spot to blend into a continuous line as has been previously explained in Section II, paragraph 1 c. The operator may prove this point to his own satisfaction by the following procedure:

Step 1. Set the X-SELECTOR switch to the OFF position. A very small spot should appear on the face of the cathode-ray tube. This spot will remain stationary.

CAUTION

Immediately after this spot has been observed, turn the X-Selector switch back to the recurrent-sweep position. This precaution eliminates the danger of the stationary spot burning the screen of the cathode-ray tube.

Step 2. With the Sync Selector at EXT and the Sweep-Range switch set between 2 and 10, turn the SWEEP VERNIER control to zero.

The operator will observe that the spot which was obtained in the preceding step is now being caused to sweep across the face of the cathode-ray tube.

Step 3. By advancing the SWEEP VERNIER control slowly, the operator can observe that this spot is caused to sweep more and more rapidly across the screen. As the SWEEP VERNIER control reaches about 80 or 90 this spot will have blended into a solid line which appears to be flickering (varying in intensity).

On turning the SWEEP RANGE switch to the next range (10 to 50) and starting with the SWEEP VERNIER control at 10, the flickering line may again be observed. But now, as the SWEEP VERNIER is advanced, the flicker becomes less and less noticeable. As the VERNIER control approaches 100, the flicker of the trace becomes negligible, due to the fact that the frequency of the sweep generator is now equal to or above that which produces persistence of human vision.

By means of the two controls, the SWEEP VERNIER control, and the SWEEP RANGE switch, the frequency of the sweep generator can be adjusted to any frequency between 2 and 30,000 cycles per second.

e. DISPLAYING A SINEWAVE.—
Preliminary Setting: Y Attenuator — 10:1
Y Amplitude — 50

Step 1. Connect a short wire from the LINE FREQUENCY TEST SIGNAL terminal to the VERTICAL INPUT terminal. The test signal is an a-c signal of approximately .5 rms volts amplitude.

Step 2. With the SWEEP RANGE control set at the 10-50 position, rotate the SWEEP VERNIER control until a sinewave (Figure 3-4) of one or more cycles can be identified on the screen. As the SWEEP VERNIER control is set towards the low frequency end of its scale (0), more cycles of the sinewave should appear.

Step 3. Stop the drifting of this wave as nearly as possible with the SWEEP VERNIER control. Regardless of this setting there will nearly always be a slight drift.

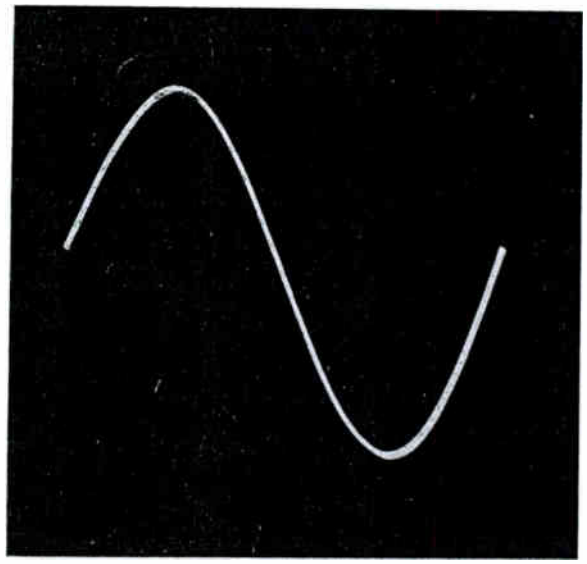


FIGURE 3-4

OSCILLOGRAM OF A 60-CYCLE SINE WAVE

Step 4. Set SYNC SELECTOR switch to INT. This setting permits part of the signal which is passing through the vertical amplifier to be impressed on the grid of the time-base generator, thereby synchronizing the time-base generator to a submultiple of the wave passing through the vertical amplifier. The amplitude of the synchronizing voltage applied depends upon the setting of the SYNC AMPLITUDE control. The theory of synchronization is explained more fully in Section II.

Step 5. Turn the SYNC AMPLITUDE control clockwise (to the + side) until the pattern "locks in." Notice that the positive cycle is at the left side of the trace.

Step 6. Turn the SYNC AMPLITUDE control counterclockwise (to the — side) until the pattern "locks in." Notice that the negative cycle is now at the left side of the trace. This illustrates the difference between synchronizing on the positive and negative signals.

Step 7. Synchronize the sweep to produce about 10 cycles of the 60-cycle test-signal on the screen. Observe how any one of these cycles may be expanded to full-screen diameter and, by means of the wide-range positioning circuits, be brought on-screen and examined.

Step 8. Set the SYNC AMPLITUDE control at zero, and the X-SELECTOR switch to the Driven-Sweep Position. It should be observed that the sweep does not function in this position. However, the sweep can be made to trigger from a synchronizing signal supplied internally by turning up the sync amplitude control.

f. MODULATING THE INTENSITY OF THE TRACE.

Step 1. Obtain a repetitive trace with the SWEEP RANGE switch at the 10-50 position and with the SWEEP VERNIER control at 100.

Step 2. Connect a short wire between the Z input and the Sawtooth Test Signal.

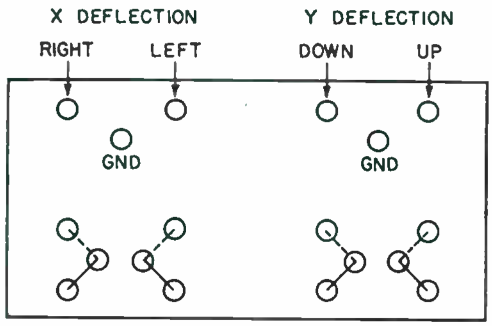


FIGURE 3-5

REAR TERMINAL BOARD SHOWING AMPLIFIER AND DIRECT CONNECTIONS

Step 3. Reduce the intensity of the trace with the Intensity control (while maintaining focus with the FOCUS control) until the left-hand portion of the sweep disappears. By intermittently connecting and disconnecting the Sawtooth Test Signal from the Z input it can be seen that the sawtooth signal brightens the right-hand portion of the trace and dims the left-hand portion. The sawtooth applied is capacitively coupled so that half of it may be considered positive, thus causing brightening of the trace and the other half (starting half) negative thus dimming the trace. The result just described is called *intensity modulation* and is discussed more fully under Laboratory and Lecture Applications.

WARNING

NEVER APPLY AN INTENSITY MODULATING SIGNAL LARGE ENOUGH TO SWING THE GRID OF THE CATHODE-RAY TUBE POSITIVE WITH RESPECT TO THE CATHODE. THIS UNWANTED, DANGEROUS CONDITION MAY CAUSE A SERIOUS REDUCTION IN THE LIFE OF THE CATHODE-RAY TUBE. AN INDICATION OF THE GRID SWINGING POSITIVE WITH RESPECT TO THE CATHODE IS RECOGNIZED BY MARKED DEFOCUSING ON THE SCREEN DURING THE POSITIVE PHASE OF THE INTENSITY MODULATING SIGNAL.

g. CONTROLLING THE SIZE OF THE PATTERN.—It is frequently desirable to examine more closely a particular part of a pattern or trace. In that event the pattern or trace may be expanded both horizontally and vertically by increasing the setting respectively of the X AMPLITUDE and Y AMPLITUDE controls. These expanded traces may then be positioned to any part of the screen to obtain better definition of the part in question.

Note

All signals applied to the oscillograph from external sources require two wires to complete the connection. One wire carries the signal and the other wire serves as a ground, or return path. In this manner, all signals, those being observed or those performing a function in the oscillograph, are referred to a common ground.

h. THE USE OF EXTERNAL SYNC.—In many cases, an external signal is more suitable for synchronizing than the signal applied to the vertical channel, particularly when varying amplitudes of the same waveform are to be viewed in rapid succession. When using internal sync, the amplitude of the waveform passing through the vertical amplifiers affects the amplitude of the synchronizing voltage; too much or too little voltage will be applied to the sync generator with different amplitudes of input signals. Thus, the setting of the SYNC AMPLITUDE control will require adjustment with each different amplitude of signal applied.

When using an external synchronizing voltage of sufficiently constant amplitude, connection is made from the external source to the EXT. SYNC terminal and the SYNC SELECTOR switch is thrown to the EXT. position. Once the SYNC AMPLITUDE control has been adjusted to apply the correct amount of synchronizing signal to the sweep generator, it will not be necessary to reset it as the various amplitudes of the signal are applied to the vertical channel. It will be necessary to use an external synchronizing voltage whenever the vertical amplifier is not used and the signal is capacitively or directly coupled to the deflection plates.

It should be observed that the SYNC AMPLITUDE control is calibrated in both directions from the center zero position. One side marked (+) provides a positive synchronizing signal at the grid of the thyratron for a positive signal applied to the sync.-input terminals. In the direction marked (—), a negative input signal is required for producing the necessary positive sync at the grid of the thyratron.

i. DIRECT DEFLECTION.

It has already been pointed out that signals may be applied directly to the deflection plates through .1 μf, 1000 v capacitors. Connections are made to binding posts on the Rear Terminal Board (Figure 3-5). *Before any connections are made to the Rear Terminal Board, the power should be turned off, since some of the terminals normally operate at about 200 volts above ground.* For normal operation, when the horizontal and vertical amplifiers are used, the two bottom rows of terminals on the Rear Terminal Board are connected by jumpers as shown in Figure 3-5 by the solid lines. If it is desirable to use the direct connections to the Y-deflection plates, the two jumpers in the lower-right-hand portion of the Rear Terminal Board are disconnected and reconnected to the position shown by the dotted lines. If direct connections to the X-deflection plates are to be made, the two jumpers in the lower-left-hand portion of the Rear Terminal Board are disconnected and reconnected to join the terminals connected by the dotted lines in Figure 3-5.

The direct connections are then made to the top terminals. The two right-hand top terminals are used for direct connections to the vertical deflection plates; and the two left-hand top terminals are used for direct connections to the horizontal deflection plates. (Caution! Connect *only* external leads to the Top Terminals.)

The designations RIGHT, LEFT, DOWN and UP adjacent to Direct-Input terminals (Figure 3-5) denote for each terminal the direction of the deflection that will be produced by a positive a-c signal connected between that terminal and ground.

It should be borne in mind that only a-c input is available with this system since the deflection plates are capacitively coupled and operate at a mean potential of about 200 volts above ground; however, the high-frequency response of this system is much better than through the amplifier. When using direct deflection, the input to the amplifier should be removed. This can be accomplished quickly by setting the Y-attenuator or X-Selector switch, whichever the case may be, in the "Off" position. The Direct Input system has no attenuator, but the positioning circuits will still function. The high-gain d-c amplifiers of the instrument may be used in external applications. The vertical amplifier output is available at the two terminals at the bottom right; the horizontal-amplifier output is taken from the terminals at the bottom left (See Figure 3-5).

It has been previously mentioned that only capacitively coupled connections could be made directly to the deflection plates, and that d-c connections could be made only through the d-c amplifiers. However, direct connections to the deflection plates can be made at the terminals second from the left at the bottom, although some distortion will occur. The left-hand pair is connected to D_1D_2; the the right-hand pair is connected to plates D_3D_4. To make direct connections, the jumpers should either be in the dotted position or removed entirely. Since the voltage level of the second anode is 200 volts above ground, no distortion will occur if the external signal is kept at approximately the same level (200 $\pm$ 50 volts).

j. VERTICAL AMPLIFIER PRODUCING HORIZONTAL DEFLECTION

HORIZONTAL AMPLIFIER PRODUCING VERTICAL DEFLECTION

When using the Du Mont Type 314-A Oscillograph-record Camera, the input signal is applied to the vertical amplifier and the amplified output of the vertical amplifier is applied to the X-deflection plates to produce a horizontal deflection, which will photograph as a swept pattern on the vertically moving film.

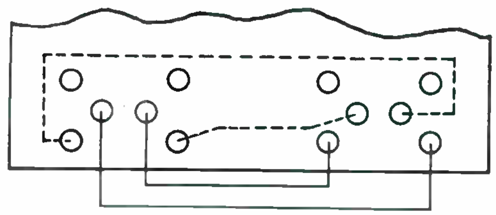


FIGURE 3-6

JUMPER CONNECTIONS FOR Y-AMPLIFIER PRODUCING HORIZONTAL DEFLECTION AND X-AMPLIFIER PRODUCING VERTICAL DEFLECTION

4. DISPLAY OF WAVEFORMS

Together with a working acquaintance of the controls of the oscillograph, an understanding of how the patterns are traced on the screen must be obtained for a thorough knowledge of oscillograph operation. With this in mind a careful analysis of two fundamental patterns is diccussed under the following headings:

a. Patterns plotted against time (using the sweep generator for horizontal deflection)
b. Lissajous Figures (using a sinewave for horizontal deflection)

a. PATTERNS PLOTTED AGAINST TIME.

(1) Preliminary.—A sinewave is typical of, and convenient for this study. The connections necessary for producing a sinewave on the screen were previously discussed. This wave is amplified by the vertical amplifier and impressed on the vertical (Y-axis) deflection plate. Simultaneously the sawtooth wave, as discussed in Section 2, from the time-base generator, is amplified and impressed on the horizontal (X-axis) deflection plates.

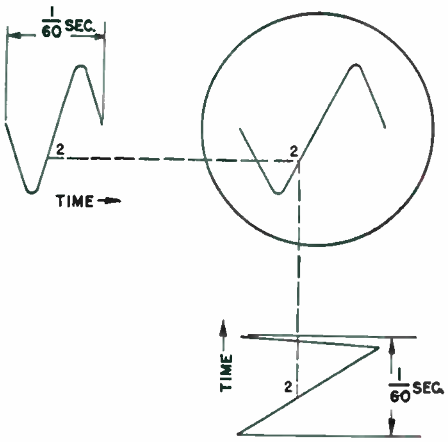


FIGURE 3-7

PROJECTION DRAWING OF A SINEWAVE APPLIED TO THE VERTICAL AXIS AND A SAWTOOTH WAVE OF THE SAME FREQUENCY APPLIED SIMULTANEOUSLY ON THE HORIZONTAL AXIS

(2) Theory.—The electron beam moves in accordance with the resultant of the sine and sawtooth signals. The effect is shown in Figure 3-7 where the sine and sawtooth waves are graphically represented on time and voltage axes. Points on the two waves that occur simultaneously are numbered similarly. For example, 2 on the sine and 2 on the sawtooth waves occur at the same instant. Therefore, the position of the beam at instant 2 is the resultant of the voltages on the horizontal and vertical deflection plates in instant 2. Referring to Figure 3-7, by projecting lines from point 2, the position of the electron beam at instant 2 can be located. If projections were drawn from every other instantaneous position of each wave to intersect on the circle representing the tube screen, the intersections of similarly timed projections would trace out a sinewave.

(3) Conclusion.—In summation, Figure 3-7 illustrates the principles involved in producing a sinewave trace on the screen of a cathode-ray tube. Each intersection of similarly timed projections represents the position of the electron beam acting under the influence of the varying voltage waveforms on each pair of deflection plates. Figure 3-8 shows the effect on the pattern of decreasing the frequency of the sawtooth wave. Any recurrent waveform plotted against time can be displayed and analyzed by the same procedure as used in these two examples.

(4) Other Patterns.—The sinewave example just illustrated is typical of the method by which any waveform can be displayed on the screen of the cathode-ray tube. Such waveforms as squarewave, sawtooth wave, and many other more irregular, recurrent waveforms can be observed by the same method explained in the preceding paragraphs.

b. LISSAJOUS FIGURES.

(1) Preliminary.—Another fundamental pattern is the Lissajous figure, named after the 19th century French scientist. This type of pattern is of particular use in determining the frequency ratio between two sinewave signals. If the frequency of one of these signals is known, the other can be quickly calculated from their ratio. Common practice is to connect the known signal to the horizontal channel and the unknown to the vertical channel. The amplifiers may or may not be used depending upon the amplitude and frequency of the signals.

(2) Theory.—The presentation of Lissajous figures can be analyzed by the same method as previously used for sinewave presentation. A simple example is illustrated in Figure 3-9. The frequency ratio of the signal on the horizontal axis to that on the vertical axis is 3 to 1. If the known signal on the horizontal axis is 60 cycles per second, the signal on the vertical axis is 20 cycles.

The Lissajous pattern is traced by joining intersections of projections from like numbered points on the signals. The frequency relationship, determined by the ratio of the number of loops touching two mutually perpendicular sides, is calculated most readily when the two signals are out of phase. For example, Figure 3-10 shows a complex Lissajous figure. The vertical line, AB is touched by 5 loops and the

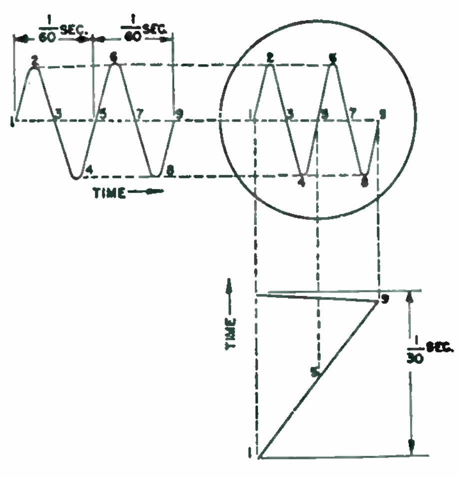


FIGURE 3-8

PROJECTION DRAWING SHOWING THE RESULTANT PATTERN WHEN THE FREQUENCY OF THE SAWTOOTH IS ONE-HALF OF THAT EMPLOYED IN FIGURE 3-7

horizontal line BC is touched by 3 loops. The ratio of the frequency on the horizontal axis is to the frequency on the vertical axis as the number of loops which intersect line AB is to the number of loops which intersect line BC.

Algebraically:

$$\frac{\text{Frequency on horizontal Axis}}{\text{Frequency on vertical Axis}} = \frac{\text{Number of loops tangent to AB}}{\text{Number of loops tangent to BC}}$$

(3) Obtaining a Lissajous Pattern on the screen. Preliminary Settings:

SWEEP RANGE—Any position except extreme counterclockwise

X SELECTOR—AC amplifier

Y ATTENUATOR—AC amplifier

Step 1. Connect a wire from the LINE FREQ. TEST SIGNAL terminal to the X-INPUT terminal.

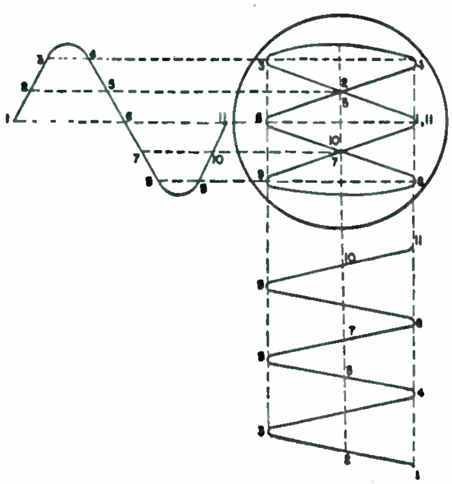


FIGURE 3-9

PROJECTION DRAWING SHOWING THE RESULTANT LISSAJOUS PATTERN WHEN A SINE WAVE APPLIED TO THE HORIZONTAL AXIS IS THREE TIMES THAT APPLIED TO THE VERTICAL AXIS

Step 2. Place an audio oscillator conveniently near the oscillograph, and connect its output and ground terminals to the Y-INPUT and GROUND terminals of the oscillograph.

Step 3. Switch the oscillograph and the audio oscillator into operation.

Step 4. Locate a pattern of convenient size in the center of the screen by adjusting the positioning and amplitude controls.

Step 5. By adjusting the frequency of the audio oscillator obtain a pattern that is nearly stationary. It is not necessary to stop the pattern, but merely to slow it up enough to count the loops at the sides of the pattern.

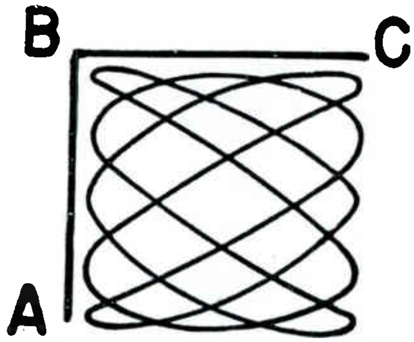


FIGURE 3-10

METHOD OF CALCULATING FREQUENCY RATIO OF LISSAJOUS FIGURES

Step 6. Count the number of loops which intersect an imaginary vertical line AB and the number of loops which intersect the imaginary horizontal line BC as in Figure 3-10. The ratio of the number of loops which approach AB is to the number of loops which approach BC as the frequency of the horizontal signal is to the frequency of the vertical signal.

(4) More examples of Lissajous Patterns.—Figure 3-11 shows other examples of Lissajous figures. In each case the frequency ratio shown is the frequency ratio of the signal on the horizontal axis to that on the vertical axis.

(5) Phase Difference Patterns.

(a) Introduction.—Coming under the heading of Lissajous figures is the method used to determine the phase

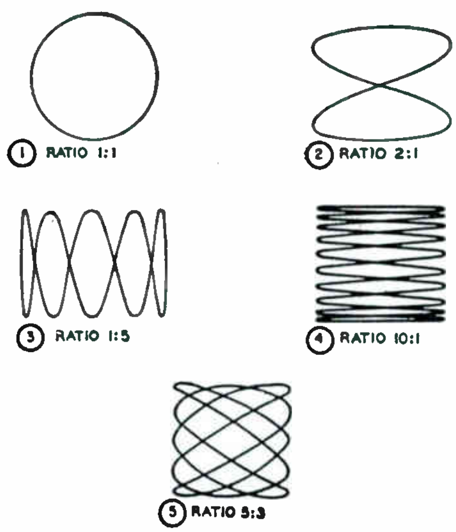


FIGURE 3-11

OTHER LISSAJOUS PATTERNS

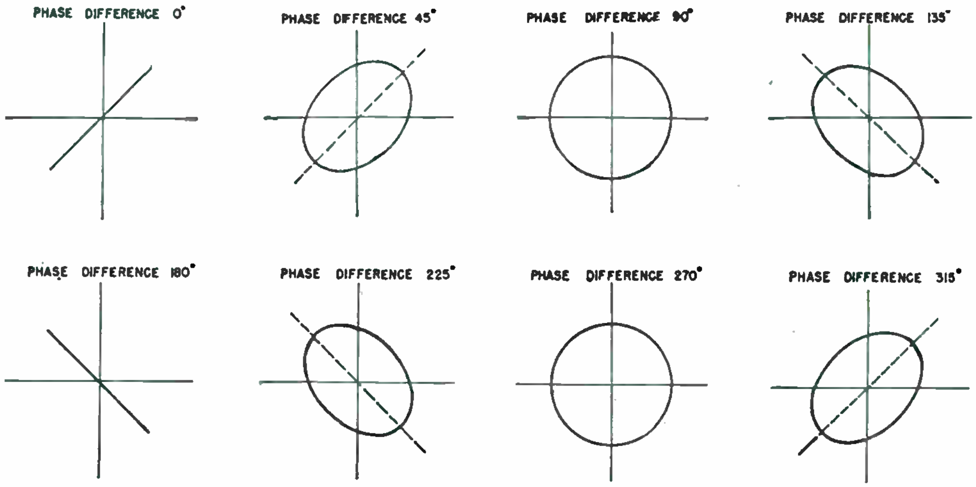


FIGURE 3-12

LISSAJOUS PATTERNS OBTAINED FROM THE MAJOR PHASE DIFFERENCE ANGLES

difference between signals of the same frequency. The patterns involved take on the form of ellipses with different degrees of eccentricity.

(b) Obtaining the Phase-Difference Pattern. To obtain an accurate pattern from which phase difference can be determined, the following procedure must be followed:

Step 1. Turn the Y ATTENUATOR and X SELECTOR controls to 0 and with the calibrated screen in place, center the spot on the screen of the cathode-ray tube.

Step 2. Connect one signal to the Y INPUT terminal and the other signal to the X INPUT terminal.

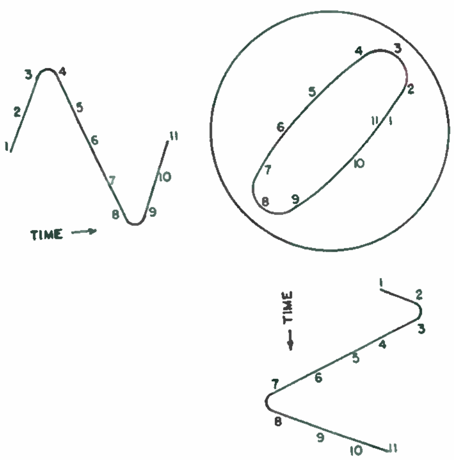


FIGURE 3-13

PROJECTION DRAWING SHOWING THE RESULTANT PHASE DIFFERENCE PATTERN OF TWO SINEWAVES 45° OUT OF PHASE

Step 3. Connect a common ground between the two frequencies under investigation and the oscillograph.

Step 4. Adjust the Y ATTENUATOR and Y AMPLITUDE controls to give approximately 3 inches of vertical deflection. To facilitate this adjustment the X SELECTOR switch is set in the "Off" position.

Step 5. Being very careful not to change the Y-Amplitude setting, throw the Y Attenuator to the "Off" position and position the spot to the exact center of the calibrated scale.

Step 6. With the X Selector in one of the amplifier positions adjust the X-Amplitude control to produce the same deflection as was produced in the Y direction (3").

Step 7. Throw the Y-attenuator switch back to the position it occupied when the 3" of Y deflection was adjusted.

The resulting pattern will give an accurate picture of the exact phase difference between the two waves. If these two patterns are exactly the same frequency but different in phase and maintain that difference, the pattern on the screen will remain stationary. If, however, one of these frequencies is drifting slightly the pattern will drift slowly through 360°. The phase angles of 0°, 45° 90°, 135°, 180°, 225°, 270°, 315° are shown in Figure 3-12.

(c) Presentation.—Each of the eight patterns in Figure 3-12 can be analyzed separately by the previously used projection method. Figure 3-13 shows two sinewaves which differ in phase being projected on to the screen of the cathode-ray tube. These signals represent a phase difference of 45°.

Note

It is extremely important: (1) that the spot has been centered on the screen of the cathode-ray tube, (2) that both the horizontal and vertical amplifiers have been adjusted to give exactly the same gain, and (3) that the calibrated scale be originally set to coincide with the displacement of the signal along the vertical axis.

(d) Determination of the Phase Angle.—The relation commonly used in determining the phase angle between signals is:

$$\text{Sine } \theta = \frac{\text{Y intercept}}{\text{Y maximum}}$$

where θ = phase angle between signals
Y intercept = point where ellipse crosses vertical axis measured in tenths of inches. (Calibrations on the calibrated screen)
Y maximum = highest vertical point on ellipse in tenths of inches

Several examples of the use of the formula are given in Figure 3-14. In each case the points Y intercept and Y maximum are indicated together with the sine of the angle and the angle itself.

For higher frequency signals it is necessary to take into consideration the phase shift between the X- and the Y-amplifiers themselves. By connecting the same signal to both amplifiers the phase shift between the two can be measured by the method already described.

In order to determine which signal is leading, an additional operation is necessary. The Y-input signal is made to pass through an RC high-pass network. With the RC time constant very large, the new signal obtained at the Y-input is changed very little by the network. Then, as R is made smaller the Y signal will shift in phase in the negative direction, and cause the phase angle between the X and Y signals to become greater when the Y signal lags the X signal, and smaller when the Y signal leads the X signal.

(e) Phase Shifters.—For the operator to observe these various patterns with a single signal source such as the test signal, there are many types of phase shifters which can be used. Circuits can be obtained from a number of radio and electronics text books. The procedure is to connect the original signal to the horizontal channel of the oscillograph and the signal which has passed through the phase shifter to the vertical channel of the oscillograph, and follow the procedure set forth in this discussion to observe the various phase shift patterns.

c. OTHER TIME BASES.

Numerous new applications have been developed and are being developed almost daily. Many of these applications require time bases which are different from either the sawtooth time base or the sinewave time base just discussed. These applications are too numerous and too specialized to be considered to any great extent in this instruction book. However, some special types of time bases are listed as follows: 1. Circular sweep. 2. Spiral sweep. 3. Radial sweep. 4. Delayed sweeps. 5. Expanded sweeps.

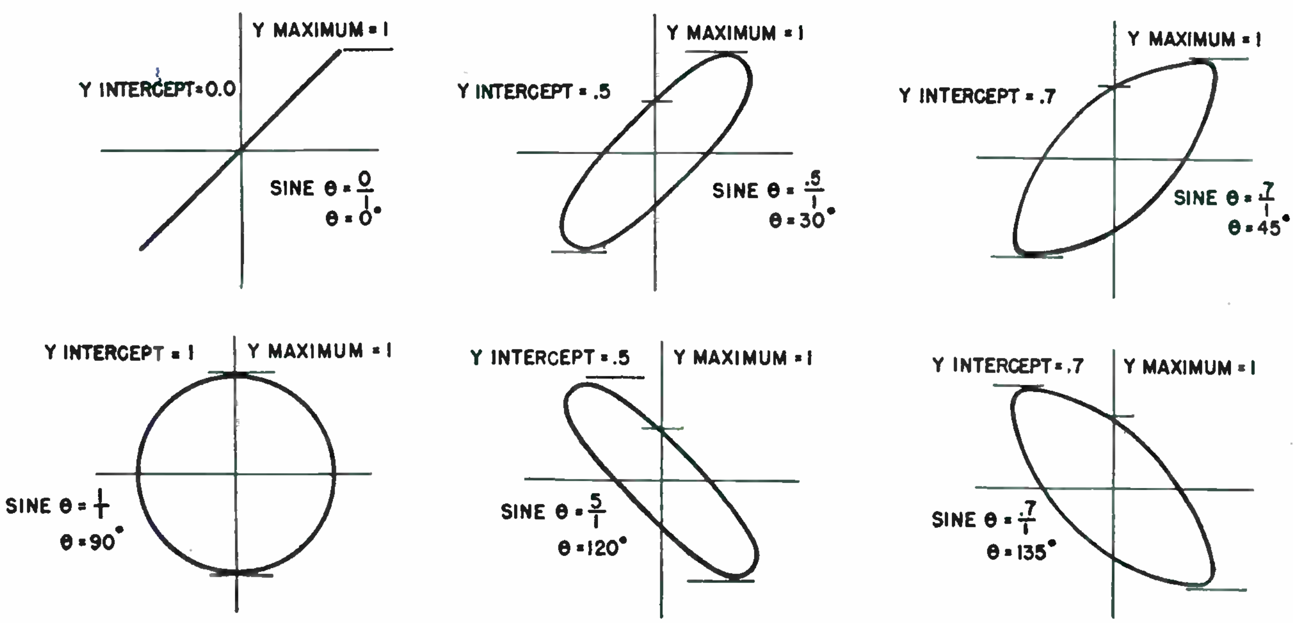


FIGURE 3-14

EXAMPLES SHOWING THE USE OF THE FORMULA FOR DETERMINATION OF PHASE DIFFERENCE

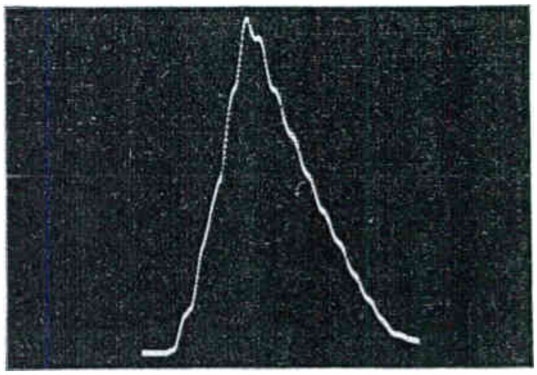


Figure 3-15. Indication of variation of volume of liquid in a retort. Signal, applied through d-c amplifier channel, was displayed on a 10-second sweep

The goal in designing the Types 304 and 304-H Cathode-ray Oscillographs has been to create instruments which would serve over the widest possible range of applications, within the limits of practicality.

For example, to extend the use of the instrument to include low-frequency phenomena, sweep frequencies as low

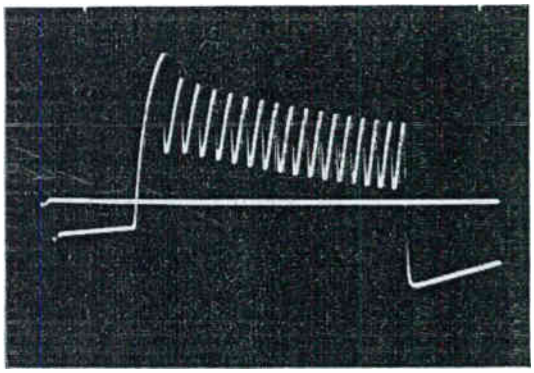


Figure 3-17. Waveform similar to that of Fig. 3-16, passed through a-c amplifier. Note tilt due to time constant of coupling circuit, and shift of reference axis

as two cycles per second are provided, and sweeps of considerably lower frequencies are possible by the use of additional capacitance attached between the X-input terminals at the front panel. Since, however, a conventional a-c coupled amplifier would not reproduce the low-frequency signals that are frequently displayed on sweeps of such long duration, a d-c amplifier is provided. The oscillogram of

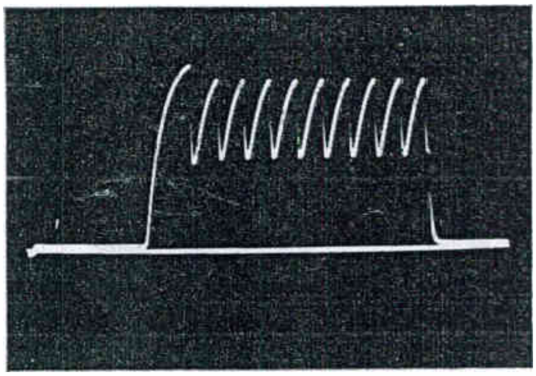


Figure 3-16. Voltage from oscillating neon bulb, applied through d-c amplifier channel. D-C voltages may be measured directly (base line represents zero volts)

Figure 3-15 illustrates such an application. It is an indication of the volume of liquid in a reaction vessel, plotted as a function of time. It was recorded on a ten-second sweep, with the signal applied through the d-c amplifier.

The d-c amplifier is also essential in cases where the d-c level of signals of higher frequencies must be reproduced. An instance of this is seen in the oscillograms of Figures 3-16 and 3-17, both of which are representations of an oscillating neon bulb. In Figure 3-16 where the signal was passed through the d-c amplifier, the d-c level is maintained. The base line represents zero volts. Note that the ignition and extinction voltage may be measured easily. In Figure 3-17, where the signal was applied through the a-c amplifier, the reference axis shifted, making quantitative measurements of absolute potentials impossible.

To facilitate the use of long-persistence screens, customarily employed for the observation of low-frequency phenomena, the cathode-ray tube of the Type 304-H is operated at an overall accelerating potential of 3000 volts. This higher accelerating potential lengthens considerably the decay time of the persistence, thus increasing the utility of the long-persistence screens.

This higher potential also facilitates the observation and recording of phenomena that exhibit high writing rates, by increasing the light output from the screen. The photographic capabilities of the Type 304-H are greater by a factor of 10 than those of the Type 304. The oscillograms

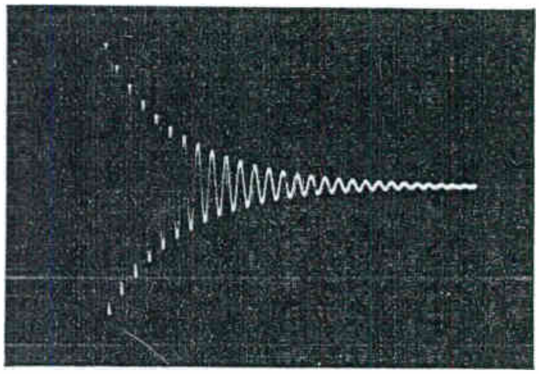


Figure 3-18. Relatively-high-speed transient in form of damped oscillation. With accelerating potential of 1780 volts, high-speed portion of trace was not recorded

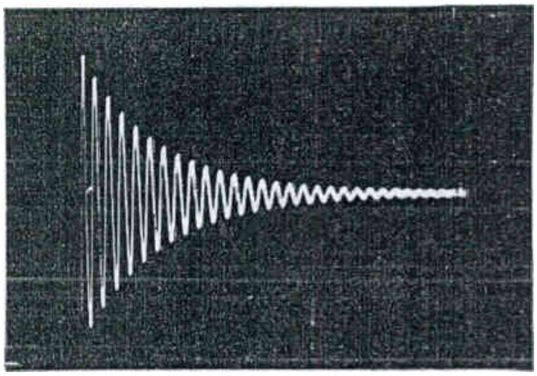


Figure 3-19. Waveform similar to that of Fig. 3-18. Increased accelerating potential of Type 304-H (3000 volts) rendered entire pattern visible

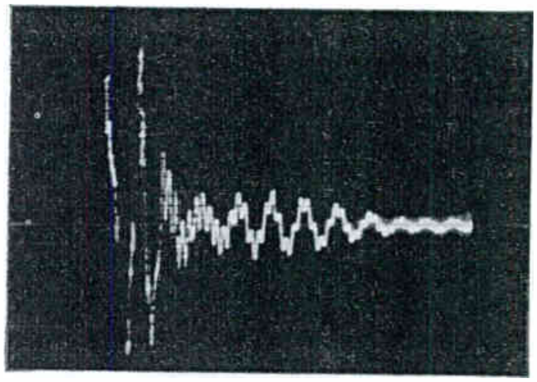


Figure 3-20. Random vibration in metal beam, recorded with Type 304 operating on single sweep. Note that entire phenomenon was recorded on the trace

of Figures 3-18 and 3-19, showing a relatively high-speed transient in the form of a damped oscillation, clearly demonstrate the importance of this increased potential. In Figure 3-18, where an accelerating potential of 1780 volts was employed, the portions of the trace where the spot moves most rapidly, were not recorded. In Figure 3-19, photographed from the screen of the Type 304-H operated with an accelerating potential of 3000 volts, the entire trace was clearly recorded.

For the observation of phenomena occurring at random intervals, driven sweeps, triggered by the signal under investigation, are provided. An example of this is seen in the oscillogram of Figure 3-20, an indication of sporadic vibrations in a metal beam. Were the sweep not initiated by the first impulse from the vibration, there would be no assurance that the beginning of the sweep would coincide with the start of vibration. (See Figure 3-21). Thus it would be only through an occasional chance that the entire signal would appear on the trace.

Figures 3-22 and 3-23 illustrate the sweep-expansion feature of the Types 304 and 304-H. Figure 3-22 shows the voltage field in the vicinity of a fluorescent lamp. Figure 3-23 is a portion of the same pattern, identified by the square on Figure 3-22, expanded to full-screen diameter.

An application requiring many of the features of the Types 304 and 304-H is the observation and recording of nerve potentials. (See Figure 3-24). The differentiated sawtooth test signal triggers the stimulating pulse. And

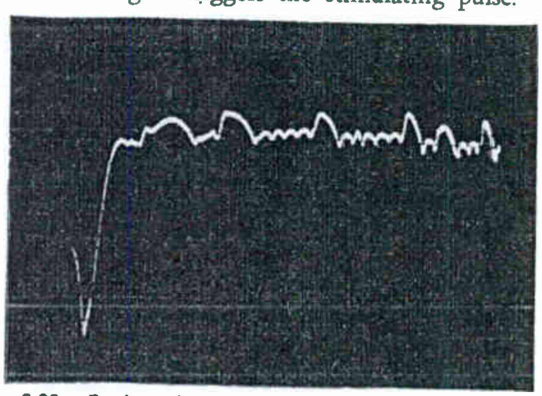


Figure 3-23. Portion of pattern outlined by square on Fig. 3-22, expanded to full-screen diameter. Even at maximum expansion, no on-screen distortion is present

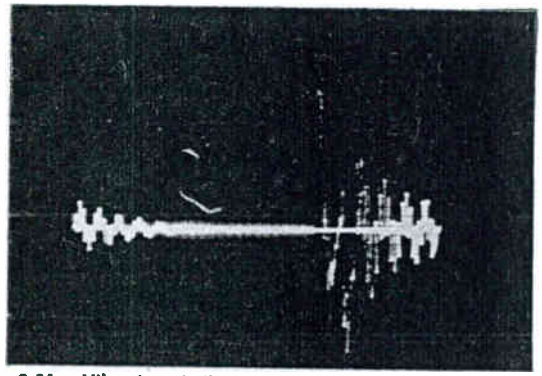


Figure 3-21. Vibration similar to that of Fig. 3-20, displayed on recurrent sweep. Phenomenon begins toward end of trace, with much of the signal lost entirely

since the nerve may be stimulated only once every few seconds, a driven sweep must be employed. Sweeps of 10-second duration or longer must be used if the time required for the nerve to transmit the stimulus is to be observed. Because of the low signal levels and the long time duration of the pulse, a high-gain d-c amplifier is required. While the gain of the amplifier of the Type

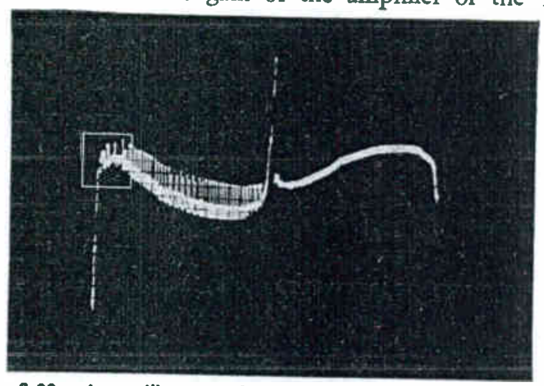


Figure 3-22. An oscillogram of the voltage field in the vicinity of a fluorescent lamp, displayed with no expansion of sweep. Compare with Fig. 3-23

304 or 304-H may not be sufficient for such applications, this amplifier's characteristics greatly simplify the problem of designing a satisfactory preamplifier for such specialized work.

Every feature of the Types 304 and 304-H was conceived and designed with an eye toward versatility. Each was engineered to complement the others, so that fullest possible advantage could be taken of all.

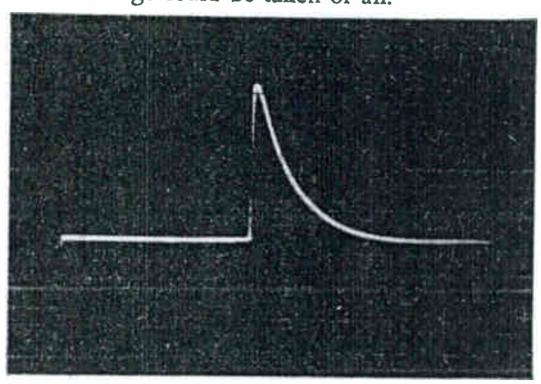


Figure 3-24. Observation of nerve potentials is an application requiring many features of the Types 304 and 304-H. Nerve potential below was recorded from Type 304

SECTION IV

MAINTENANCE

1. GENERAL

The components used in both the Type 304 and Type 304-H Cathode-ray Oscillograph have been selected and tested to provide long, trouble-free operating life. It must be recognized, however, that trouble may be expected at some time during the life of the instrument. This section is included to provide useful information for the location and correction of such trouble.

2. DRAWINGS

The schematic of the circuit located just inside of the back cover give the complete information as to how the various components are connected. A list of parts with their descriptions is given on the page accompanying the schematic diagrams.

WARNING

DANGEROUS POTENTIALS AS HIGH AS 3000 VOLTS ARE FOUND IN THIS INSTRUMENT. SINCE THESE POTENTIALS MAY BE DANGEROUS TO HUMAN LIFE, THEY SHOULD BE TREATED WITH PROPER CAUTION.

3. CIRCUIT VOLTAGES

Table 4-2 is included to give the voltages and resistances that are found between the socket connections of the various tubes and ground. The meter used for these measurements has an internal resistance of 20,000 ohms per volt. Naturally voltages or resistance measurements taken with a meter having a lower internal resistance will differ from the values of this table.

It should be remembered that the values given are nominal and considerable variation may be experienced due to various line voltage conditions and component tolerances. Generally, a variation of $\pm 10\%$ is to be expected and 20% may not be uncommon. Judgment is often required to determine if a particular deviation is indicative of trouble.

4. WARRANTY

DU MONT INSTRUMENTS.

All instruments manufactured by Allen B Du Mont Laboratories, Inc., are guaranteed to equal or exceed all specifications for that particular instrument as published by the company. They are further guaranteed against defective materials, other than the cathode-ray tube, and workmanship for a period of one year from date of sale, and we will promptly repair the instrument or replace it, at our discretion, at any time within the guarantee period should any defect develop from these causes or the instrument be not as represented, upon our inspection of the equipment.

In order that this guarantee be effective, it is necessary that the enclosed guarantee card be properly filled out and mailed to the factory immediately upon receipt of the equipment. Complete information should be given, since a record of every instrument is maintained at our office. This record constitutes our source of information when any correspondence is necessary. Both the *type number and the serial number* of the instrument must be given on this card in order that the information be complete.

DU MONT CATHODE-RAY TUBES.

All industrial cathode-ray tubes manufactured and sold by Allen B. Du Mont Laboratories are guaranteed for a life of 1,000 hours or for six months, depending upon which expires first. The only exceptions to this guarantee are burned-out heaters and broken glass. Cathode-ray tubes will be promptly replaced within the guarantee period if, upon our inspection, the tube has failed within less than its normal expected life.

In order that this guarantee be effective, it is necessary that the enclosed guarantee card be properly filled out and mailed to the factory immediately upon receipt of the equipment. Complete information should be given in order that the records which we maintain on your particular tube will be accurate. When correspondence is necessary, both *type number and serial number* of the tube should be mentioned. The serial number of Du Mont cathode-ray tubes will be found on the glass stem of the electron gun.

5. SERVICE

Du Mont equipment is designed and manufactured in accordance with the best practices of modern engineering, and it is fully inspected before it leaves our factory. Under normal operation it may be expected to give long, trouble-free service. In order to insure factory service and proper consideration within the guarantee period, the enclosed guarantee card should be properly filled out and mailed to the factory immediately upon receipt of the equipment.

In many cases, equipment has been returned to us, without authorization, and without any need for our examination, resulting in unnecessary shipping costs. In the event that you feel you have not received satisfactory operation from this equipment, you should immediately contact our

Instrument Service Department, mentioning the *type number and serial number,* completely outlining all characteristics of the failure, and describing the method in which the equipment has been used.

It is important that such information be given, since much time often can be saved when all operating conditions are known. With such information we often are able to make decisions and suggestions which will avoid returning it to our plant. The foregoing applies also to Du Mont cathode-ray tubes.

All equipment returned to our plant should be shipped, carefully packed, via express prepaid. Cathode-ray tubes larger than five inches screen diameter should be shipped separately and should not be left mounted in their socket within the instrument. In addition, all equipment should be properly identified either by a packing slip or, preferably, by a suitable tag affixed to it. Unidentified equipment which has been returned to us is a serious source of needless errors and delays.

6. REPLACEMENT PARTS

When ordering replacement parts, always give the *type number and serial number* of the instrument and refer to the part by its symbol designation and its description on the schematic.

7. SPECIFICATIONS

The right is reserved to change the specifications of any equipment, without notice, at any time. This right shall not incur any liability to Allen B. Du Mont Laboratories, Inc., to change equipment previously sold, or to supply new equipment in accordance with earlier specifications.

8. THE DU MONT "OSCILLOGRAPHER"

The Du Mont "Oscillographer," a quarterly publication, is published regularly by the Allen B. Du Mont Laboratories. It is sent free of charge to engineers, research workers, and those engaged in the use and application of cathode-ray equipment. When sending requests for subscriptions and address-change notice, please supply the following: name, company name, company address, type of business, and title of individual.

WARNING

EXERCISE EXTREME CARE WHEN HANDLING THE CATHODE-RAY TUBE. IT MAY BE SCRATCHED AND THEREBY WEAKENED TO THE POINT WHERE IT MAY EASILY BE BROKEN. THE BREAKING OF THIS TUBE MAY CAUSE AN IMPLOSION AND RESULT IN PERSONAL INJURY FROM FLYING GLASS PARTICLES.

9. FACTORY ADJUSTMENTS

a. Because of the unusual nature of the circuits in this instrument and the requirement that pre-selection of components be avoided, several more factory adjustments than usually found on cathode-ray instruments have been incorporated. Some factory adjustments may need to be reset when replacing certain tubes. Three of the factory adjustments, the Y-Position Balance, the Y-Sensitivity adjustment, and the Single-Sweep bias adjustment, are accessible through an access hole fitted with a snap-button on the right side of the cabinet. Before making any adjustments, a 10-minute warm-up period should be allowed.

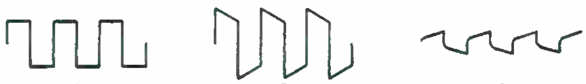
b. FACTORY ADJUSTMENTS FOR Y AMPLIFIER.

(1) Y-Position-Balance Adjustment. This potentiometer (R16) is the second from the front on the small vertical bracket over the shock-mounted chassis. This adjustment is set to bring the trace on the cathode-ray tube to the vertical center of the screen with no signal input (Y attenuator at "Off") and with the Y-Position control at the mechanical center of its range (Pointing up).

(2) Sensitivity Adjustment.—This potentiometer (R24) is the third from the front on the small vertical bracket over the shock-mounted chassis. It should be set to give the amplifier a sensitivity of precisely 10 millivolts per inch rms or 28 millivolts per inch d-c at full gain. For standards, a d-c voltage of known amplitude or a Type 264B Voltage Calibrator may be used.

(3) Linearity Adjustment.—The Y-Linearity adjustment (R36) is located in the top left hand portion of the vertical composition-board chassis at the rear of the instrument. To make this adjustment, apply the Line Freq. Test Signal to the Y Input and adjust to 1 inch of vertical deflection at the center of the screen. Position pattern about 1-1/2 inches up and 1-1/2 inches down, and observe whether the vertical size of pattern becomes greater, or smaller away from the center of the screen. If the size becomes greater rotate the arm of the Linearity potentiometer in a clockwise direction. When this adjustment is made it may be necessary to go back and readjust the Sensitivity and Position Balance adjustment.

(4) D-C Balance Adjustment.—In addition to the internal factory adjustments, the amplifier is supplied with a D-C Balance adjustment (R-10), accessible as a screwdriver adjustment in the lower-left portion of the front panel. When this adjustment is properly set, and with the Y-attenuator in the "Off" position, there will be no shifting in the zero position (up and down) with changes in the Y-Amplitude setting. This adjustment requires occasional resetting, due to aging of components. To set the D-C Balance adjustment, set the Y-attenuator switch in the "Off" position and set Y-Amplitude control at 10 and position the trace to the vertical center of the cathode-ray tube. Turn up Y-Amplitude to 100 and adjust D-C Balance to return the trace to its previous position. Clockwise rotation of the D-C Balance potentiometer moves the trace up and counterclockwise rotation moves the trace down. It should now be possible to move the Y-Amplitude control from 10 to 100 without any vertical displacement resulting.



A B C

FIGURE 4-1
WAVEFORMS ENCOUNTERED IN ADJUSTING THE Y-INPUT ATTENUATOR

Repeat procedure if any vertical displacement is observed, and continue until it is eliminated.

(5) Y-Attenuator Compensating Capacitors.—The trimmer capacitors C2, C3, and C4 are used for compensating the Y Attenuator in the 1000:1, 100:1, and 10:1 positions respectively. Compensation should be made by applying a 5-kc squarewave to the Y input and adjusting the capacitor corresponding to each position to pass the squarewave without distortion.

In Figure 4-1 above, A represents a proper adjustment and B and C represent conditions of overcompensation and undercompensation respectively for any of these capacitors.

c. FACTORY ADJUSTMENT FOR X AMPLIFIER.

(1) Linearity Adjustment.—The X-Linearity Adjustment (R108) is located in the top-right-hand portion of the vertical composition-board chassis at the rear of the instrument. To set this adjustment apply the Line Freq. Test Signal to the X Input and adjust to 1 inch of horizontal deflection at the center of the screen. Position the pattern about 1-1/2 inches to the left and 1-1/2 inches to the right of the center and observe whether the horizontal size of the pattern is greater at the left side or the right side of center. Then by use of the X-Linearity adjustment, adjust the pattern to have the same amplitude on both sides of the center. This can be done by using the X-Linearity adjustment to position the pattern in the direction of the reduced sensitivity.

(2) D-C Balance Adjustment.—As with the vertical amplifier the horizontal amplifier has a D-C Balance adjustment (R93), accessible as a screwdriver adjustment on the front pannel (in the lower right hand corner). The adjustment of this control is similar to that for the Y-amplifier.

(3) X Position Balance—As with the vertical amplifier the horizontal amplifier has a position balance adjustment located on the shock mounted chassis. This adjustment is set to bring the spot to the horizontal center of the cathode-ray tube with the X position control at the center of its range, with no input signal and X selector in the OFF position.

d. FACTORY ADJUSTMENTS FOR THE SWEEP.

(1) Single Sweep Bias Adjustment (R63).—To adjust the single sweep place the Sweep Range switch at the 2-10 position, the Sync Control to "Ext." and the Sync

TABLE 4-1

Tube No.	*Tube Type*	*1st Readjustment*	*2nd Readjustment*	*3rd Readjustment*
V1	12AU7	D-C Balance (R10)		
V2	12AU7	Position Balance (R16)	Sensitivity (R24)	
V3	12AU7	Sensitivity (R24)	Position Balance (R16)	*Position Balance (R16)
V4	12AU7	Linearity (R36)	Sensitivity (R24)	
V5	6AQ5	Linearity (R36)	Sensitivity (R24)	Position Balance (R16)
V6	6AQ5	Linearity (R36)	Sensitivity (R24)	Position Balance (R16)
V7	12AU7			
V8	6Q5G	Single Sw Bias (R63)	D-C Sweep Level Ads (R71)	
V9	12AU7			
V10	12AU7			
V11	12AU7	D-C Balance (R93)	X Position Balance R114	
V12	6J6	X Position Balance R114		
V13	6J6	Linearity (R108)		
V14	OB3			
V15	5Y3			
V16	2X2			
**V17	2X2			
V18	5CPA	Y Sensitivity (R24)	Y Position Balance (R16)	

* The Position Balance needs to be readjusted here because Y position is slightly dependent on sensitivity adjustment. The sensitivity cannot be listed as the 1st readjustment instead of the second, because a change in V2 may put the pattern so far off screen that the Y-position control will be unable to bring it back.

** V17 is provided only with the Type 304-H.

Amplitude "O." The line-frequency test signal is fed into the Y Input to produce about 1 inch of deflection. Set the X-Selector switch to "Single." Adjust the Single Sweep bias potentiometer (the rear potentiometer of the vertical bracket above the shock-mounted chassis) until the sweep stops and a vertical bar appears. Check this setting on the low end of the Sweep Vernier and also be certain that this adjustment has not caused the continuous sweep to stop. It should be possible to trigger the single sweep with sync amplitude control when the sync switch is set on internal. At zero sync, the sweep should not be triggered. Check the triggering of single sweep at the low end of the vernier also. If the sweep fails to trigger here, increase the Y Amplitude to a maximum of 1.5 inches. If the sync control still does not trigger the single sweep, the thyratron may be defective.

(2) Sweep d-c Level Adjustment (R71).—This adjustment sets the sweep to expand equally in both directions as the horizontal amplitude is turned up. The potentiometer is the first on the vertical bracket above the shock-mounted chassis.

(3) Sweep-output-attenuator Trimmer (C32).—The sweep-output-attenuator trimmer (C32) should be adjusted, using a sweep of approximately 300 cps, for best linearity and a minimum "tail." This trimmer may be found in the lower-right-hand corner of the bakelite card running across the width of the chassis in the middle.

e. It has already been mentioned that some factory adjustments may need to be reset when replacing certain tubes. Table 4-1 has been prepared as a guide to indicate which adjustments may need resetting when each tube is changed.

TABLE 4-2
TABLE OF VOLTAGE AND RESISTANCE
K = 1000 OHMS

Pin No.	*Res. to Gnd. in Ohms*	*D-C Voltage to Gnd.*	*Control Affecting Reading*
	V-1 12AU7—Y Amplifier Input		
1	18K	110	
2	2 Meg.—220K—19.8K—2K—0	0	
3	4.85K	5.7	
4	.03	3.15 RMS (AC)	
5	.03	3.15 RMS (AC)	
6	18K	108	
7	0	0	Y ATTENUATOR
8	4.85K	5.7	
9	.03	3.15 (AC)	
	V-2 12AU7—Y Amplifier		
1	20K	63	
2	4.85K—9.6K	5.7	Y AMPLITUDE
3	1.5K	7.0	
4	.03	3.15 AC	
5	.03	3.15 AC	
6	20K	63	
7	4.85K	5.7	
8	1.5K	7.2	
9	.03	3.15 AC	
	V-3 12AU7—Y Amplifier		
1	28K	67	
2	15K	31.0	Y POS. AND Y D-C BAL.
3	8.2K	32.0	
4	.03	3.15 AC	
5	.03	3.15 AC	
6	28K	67	
7	15K	31.0	Y POS. AND Y D-C BAL.
8	8.2K	32.0	
9	.03	3.15 AC	
	V-4 12AU7—Y Amplifier		
1	20K	104	
2	28K	67	
3	27K	68	
4	.03	3.15AC	

TABLE 4-2—Cont'd

Pin No.	*Res. to Gnd. in Ohms*	*D-C Voltage to Gnd.*	*Control Affecting Reading*
		V-4 12AU7—Y Amplifier (Continued)	
5	.03	3.15AC	
6	20K	104	
7	28K	67	
8	27K	68	
9	.03	3.15AC	
		V-5 6AQ5 V-6 6AQ5—Output Stage Y Amplifier	
1	20K	104	
2	18K	110	
3	.03	3.15AC	
4	.03	3.15AC	
5	42K	195	
6	150K	213	
7	20K	104	
		V-7 12AU7—Sync. Amplifier	
1	130K	100	
2	2.2 Meg	15*	
3	10K	19	
4	.03	3.15AC	
5	.03	3.15AC	
6	330K	17	
7	0 to 100K	0	SYNC. AMPLITUDE CONTROL
8	1.8K	.8	
9	.03	3.15AC	
		V-8 6Q5G—Sweep Generator	
1			
2	.03	3.15AC	
3	0, 500K—4.5 Meg	0, 4.2—5.0, 34-50, 85	X SELECTOR SWEEP VERNIER SYNC. AMP.
4			
5	115K	0	
6			
7	.03	3.15AC	
8	2.2K or 1.2K	4.3—5, 7.5—8	SWEEP VERNIER, SWEEP RANGE X-SELECTOR
		V-9 12AU7—Sweep Cathode Follower—Blanking Amp	
1	40K	385	
2	0, 500K—4.5 Meg.	0, 4.2-5.0, 34–50, 85	X SELECTOR, SWEEP VERNIER, SYNC. AMP.
3	180K	65–70, 107, 35	X SELECTOR, SWEEP VERNIER, SYNC. AMP.
4	.03	3.15 AC	
5	.03	3.15 AC	
6	110K	40	
7	15K	–.1	
8	0	0	
9	.03	3.15 AC	
		V-10 12AU7—Single Sweep Clipper—Regulated Supply Voltage	
1	20K	390	
2	167K	95	
3	INFINITE	110	
4	.03	3.15 AC	
5	.03	3.15 AC	

* This value can be measured only with a vacuum-tube voltmeter.

TABLE 4-2—Cont'd

Pin No.	*Res. to Gnd. in Ohms*	*D-C Voltage to Gnd.*	*Control Affecting Reading*
V-11 12AU7—X Amplifier Input (Continued)			
6	0, 500K—4.5 Meg.	0, 4.2–5.0, 34–50, 85	X SELECTOR, SWEEP VERNIER, SYNC AMP.
7	2.2K, 500K—4.5 Meg.	0, 4.2–5.0, 34–50, 85	X SELECTOR, SWEEP VERNIER, SYNC AMP.
8	25K	75	
9	.03	3.15 AC	
V-11 12AU7—X Amplifier Input			
1	28K	360	
2	0, 220K, 2.2 Meg, 190K	0 –18	X SELECTOR
3	7.5K	21	
4	.03	3.15 AC	
5	.03	3.15 AC	
6	28K	360	
7	0	0	
8	6.4K	21	
9	.03	3.15 AC	
V-12 6J6—X Amplifier			
1	INFINITE	75	
2	INFINITE	75	
3	.03	3.15 AC	
4	.03	3.15 AC	
5	5.8K—15.5K	21	X POSITION
6	9.4K—7K	21	X AMPLITUDE
7	6800	22	
V-13 6J6—X Amplifier Output Stage			
1	67.5K	222	
2	67.5K	222	
3	.03	3.15 AC	
4	.03	3.15 AC	
5	INFINITE	75	
6	INFINITE	75	
7	12K	79	
V-14 OB2—Regulator			
1, 5	20K	110	
2, 4, 7	0	0	
V-15 5Y3—Low Voltage Rectifier			
1	20K	410	
2	20K	410	
3	Open	Open	
4	150	375 AC	
5	Open	Open	
6	150	375 AC	
7	Open	Open	
8	20K	410	
V-16 2X2—High Negative Rectifier			
3	1600	1230 AC	
4	1600	1230 AC	
Cap	660K	1630	
V-17 2X2—For Auxiliary Intensifier Supply (304-H Only)			
3	5 Meg.	1600 Negative	
4	5 Meg.	1600 Negative	
Cap	1620	1230 AC	

TABLE 4-2—Cont'd

Pin No.	*Res. to Gnd. in Ohms*	*D-C Voltage to Gnd.*	*Control Affecting Reading*
		V-18 5CP—Cathode-ray Tube	
1	525K—575K	1230-1300 (Negative)	INTENSITY
2	525K—575K	1230-1300 (Negative)	INTENSITY
3	780K	1300-1350 (Negative)	INTENSITY
4			
5	310K—410K	720-990 (Negative)	FOCUS
6			
7	36K—4.74 Meg.	195	AMP—DIRECT
8	36K—4.74 Meg.	195	AMP—DIRECT
9	58.5K	200	
10	61.5—4.76 Meg.	222	AMP—DIRECT
11	61.5—4.76 Meg.	222	AMP—DIRECT
12			
13			
14	525K—575K	1230-1300 (Negative)	INTENSITY

PATENT NOTICE

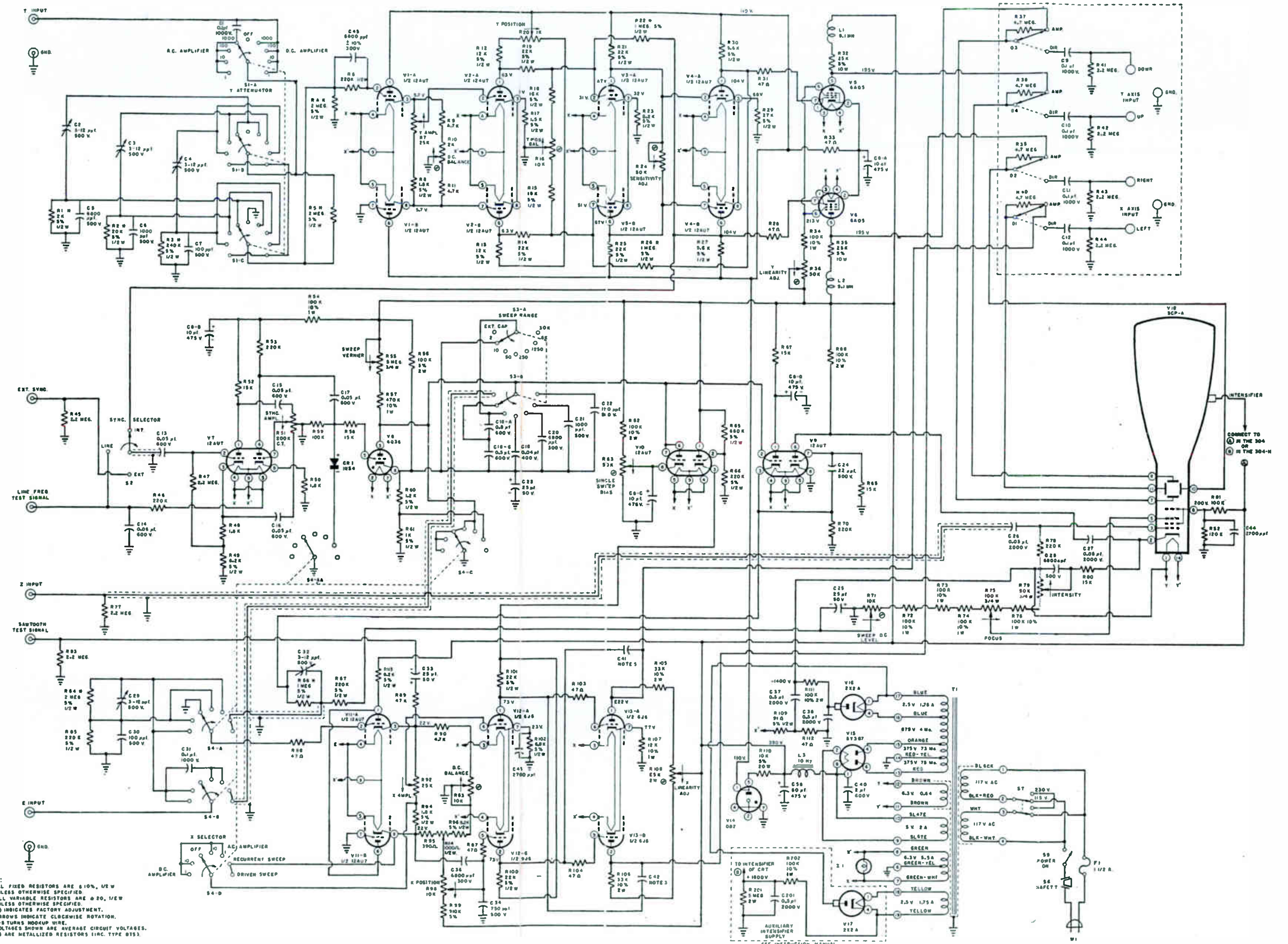
Manufactured under one or more of the following U. S. Patents:

1,844,117	1,960,333	1,999,407	2,000,014	2,014,106
2,067,382	2,082,327	2,085,576	2,087,280	2,098,231
2,153,800	2,157,749	2,162,009	2,163,256	2,164,176
2,185,705	2,186,634	2,186,635	2,190,020	RE. 21,326
2,201,309	2,207,048	2,208,254	2,209,507	2,221,398
2,225,099	2,227,822	2,229,556	2,245,409	2,245,428
2,249,942	2,249,943	2,269,115	2,269,129	2,280,700
2,280,738	2,290,592	2,297,742	2,297,752	2,299,471
2,299,510	2,315,848	2,319,691	2,321,149	2,328,259
2,331,401	2,337,980	2,338,336	2,338,646	2,343,630
2,345,549	2,346,509	2,347,933	2,355,363	2,356,733
2,364,687	2,365,476	2,372,455	2,372,901	2,373,114
2,379,488	2,384,931	2,389,025	2,391,082	2,391,090
2,391,273	DES. 143,796	2,396,014	2,398,535	2,398,959
2,404,185	2,408,193	2,409,419	2,410,920	2,414,319
2,414,634	2,419,118	2,419,177	2,423,362	2,426,419
2,429,824	2,435,564	2,435,680	2,436,265	2,437,173
2,438,668	2,438,706	2,438,717	2,439,186	2,440,597
2,441,334	2,442,138	2,442,264	2,442,545	

Other Patents Pending

ALLEN B. DU MONT LABORATORIES, INC.

CLIFTON, N. J., U. S. A.



NOTES:
1. ALL FIXED RESISTORS ARE ±10%, 1/2 W UNLESS OTHERWISE SPECIFIED
2. ALL VARIABLE RESISTORS ARE ±20, 1/2 W UNLESS OTHERWISE SPECIFIED.
3. ⊘ INDICATES FACTORY ADJUSTMENT.
4. ARROWS INDICATE CLOCKWISE ROTATION.
5. 3-5 TURNS HOOKUP WIRE.
6. VOLTAGES SHOWN ARE AVERAGE CIRCUIT VOLTAGES.
7. (M) ARE METALLIZED RESISTORS (IRC. TYPE BTS)

SCHEMATIC OF CIRCUIT OF THE DU MONT TYPES 304 AND 304-H CATHODE-RAY OSCILLOGRAPHS

Ref. Dwg. 98000111-4 Issue 7