

DU MONT

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Allen B. Du Mont Laboratories, Inc.

Instrument Division

760 BLOOMFIELD AVENUE, CLIFTON, NEW JERSEY

Du Mont

*Cathode-ray
Oscillograph*

TYPES 304-A AND 304-AR

**OPERATING AND
MAINTENANCE
MANUAL**

Allen B. Du Mont Laboratories, Inc.

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CLIFTON . . . NEW JERSEY

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**TYPES 304-A AND 304-AR
CATHODE-RAY OSCILLOGRAPHS**

In developing this instrument, an attempt has been made to incorporate circuits the characteristics of which, we believe, will satisfy the greatest number of applications, and to this end many circuit combinations have been included to extend its flexibility and versatility.

We feel, however, that the real test of any instrument is the opinion of the man who uses it. This day-to-day test of the instrument's advantages and limitations will prove, more than any other method, just what characteristics are desirable, why the range of any given component or function of the equipment should be extended, and how important such modification is.

Because of the nature of the equipment manufactured by Allen B. Du Mont Laboratories, Inc., it is only by complete cooperation between the customer and our Engineering Department that satisfactory designs can be achieved. In an attempt to continually extend the applicability of our equipment to the problems of the engineer, we sincerely request suggestions advising in what manner the design of this equipment may be further extended to include these problems.

**ALLEN B. DU MONT LABORATORIES, INC.
INSTRUMENT DIVISION
760 BLOOMFIELD AVENUE, CLIFTON, N. J., U. S. A.**

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INTRODUCTION

This manual of operating and maintenance instructions covers information on both the Type 304-A (cabinet model) and Type 304-AR (rack mounting) Cathode-ray Oscillographs. Electrically, the two types are identical; mechanically, they are somewhat different. Wherever differences exist between the two types, these differences are clearly indicated. Otherwise, references throughout the manual to the Type 304-A pertain also to the Type 304-AR. Figures 1-1a and 1-1b show the external appearance of these instruments.

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HIGH VOLTAGE WARNING!

POTENTIALS AS HIGH AS 3000 VOLTS ARE EMPLOYED IN THIS INSTRUMENT. SUCH VOLTAGES ARE EXTREMELY DANGEROUS; AND EVERY POSSIBLE SAFETY PRECAUTION SHOULD BE TAKEN TO AVOID CONTACT WITH THIS POTENTIAL. THE INSTRUMENT SHOULD NOT BE OPERATED OUTSIDE ITS CABINET OR DUST COVER EXCEPT FOR PURPOSES OF ADJUSTMENT OR REPAIR. UNDER SUCH CONDITIONS, OBSERVE THE PRECAUTIONS GIVEN IN "MAINTENANCE" UNDER "FACTORY ADJUSTMENTS."

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FIGURE 1-1a - THE DU MONT TYPE 304-A CATHODE-RAY OSCILLOGRAPH



FIGURE 1-1b - THE DU MONT TYPE 304-AR CATHODE-RAY OSCILLOGRAPH

SECTION I GENERAL DESCRIPTION

1. INTRODUCTION

The Du Mont Type 304-A is a general-purpose cathode-ray oscillograph that enables rapid, accurate amplitude measurements of any portion of a 0-to 1000-volt signal, from d-c to over 50,000 cps. The high gain assures that the Type 304-A can be used directly with most transducers, while d-c amplification provides that the lowest frequency portions of signals will be faithfully reproduced.

To obtain the utmost from the Type 304-A, full advantage should be taken of the novel amplitude calibrating system of the instrument which permits signal amplitude measurements in volts directly from the screen. (See "Amplitude Calibration-Measurement of Signal Voltage.") Unlike electro-mechanical devices, the Type 304-A is not restricted to rms or peak-to-peak readings of voltage, as any amplitude portion of the input signal may be measured with the instrument. Moreover, these measurements may be made in a minimum of time, qualifying the Type 304-A as a quantitative as well as a qualitative instrument.

The TYPE 5ADP- Cathode-ray Tube is employed in the Type 304-A. This tube is precision-built to tolerances far more stringent than in conventional tubes, and provides a deflection sensitivity up to twice that of conventional types, as well as a smaller spot size with no sacrifice in brilliance. The Types 304-A and 304-AR differ only in that the Type 304-AR is designed for mounting in a standard, 19-inch relay rack.

2. PHYSICAL CHARACTERISTICS

Physical specifications of both the Type 304-A and the Type 304-AR are given in convenient tabular form in Table 1-1. The Type 304-A is enclosed in a blue-gray metal cabinet complete with a convenient carrying handle. The Type 304-AR employs a standard relay rack panel, a dust cover and a bottom plate. The operating controls of both instruments are conveniently located on the front panel with vertical amplifier controls on the left and horizontal sweep controls on the right. In both instruments a convenient terminal panel, accessible at the rear, provides direct access to the deflection plates of the cathode-ray tube.

To facilitate calibration, the scale of the Type 304-A is numbered and edge illuminated, with a dimmer control provided on the front panel. Unidirectional signal amplitudes are measured with the aid of the left-hand scale, symmetrical signals with the aid of scale on the right hand. These scales make it especially convenient to photograph a trace with scale superimposed. The usual double-exposure technique is normally not necessary when employing an instrument with an illuminated scale; thus, valuable time is saved, and more accurate results are obtained. The Type 304-A is also provided with a suitable color filter over the CRT screen to improve visual contrast.

Provision is made for connection of balanced, as well as single-ended vertical input signals on the 0.1 VOLT FULL SCALE range. Balanced input may be obtained merely by disconnecting a jumper to ground from the lower Y-input terminal on the front panel.

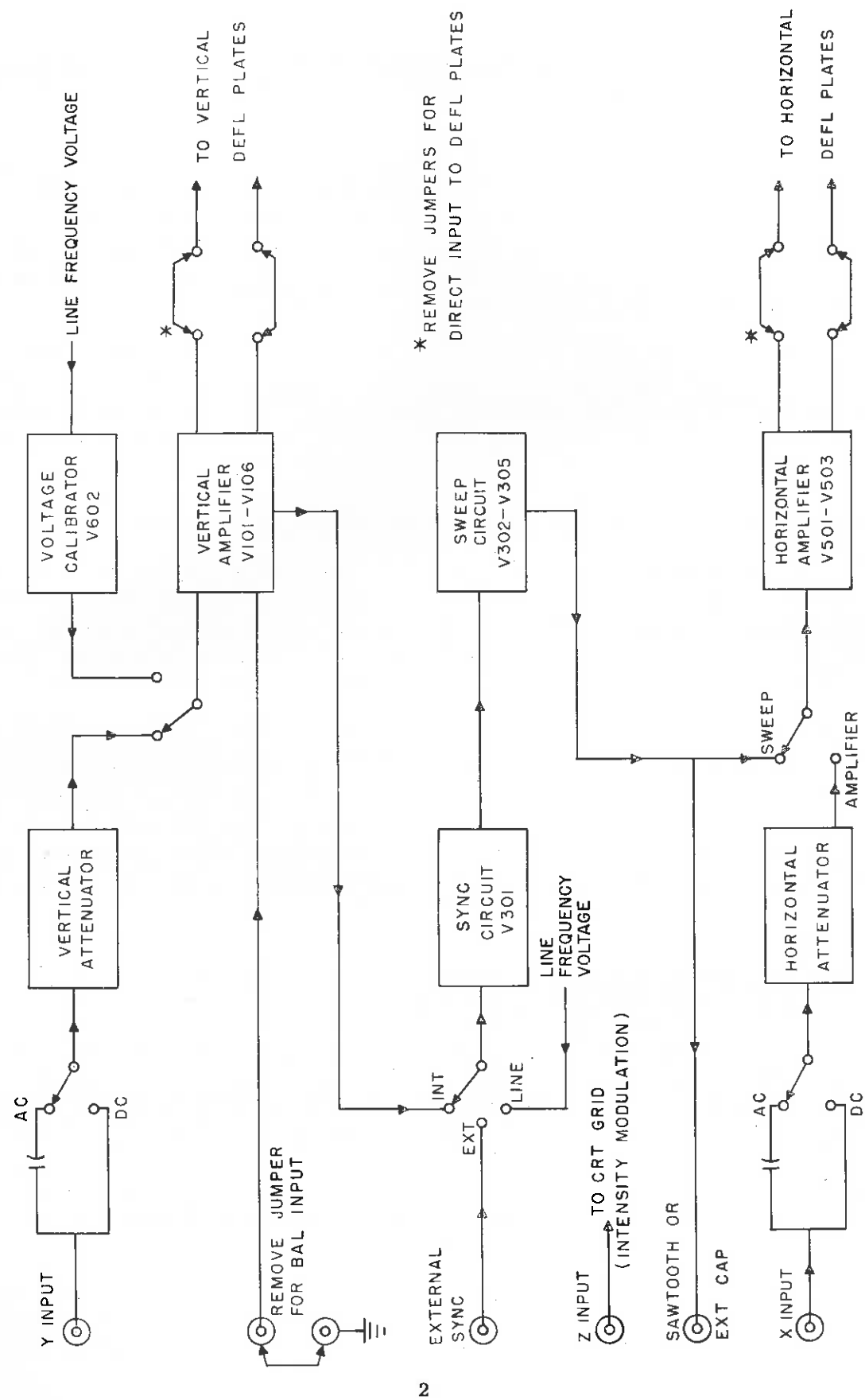


FIGURE 1-2 - SIMPLIFIED BLOCK DIAGRAM OF TYPE 304-A

Also provided on the front panel is a Z-axis input terminal for intensity modulation. This terminal connects directly to the grid of the cathode-ray tube, with positive signals increasing the intensity of the beam.

3. CIRCUITRY EMPLOYED

For a general understanding of the electrical circuits incorporated in this oscilloscope, refer to the block diagram (Figure 1-2). A detailed explanation of the circuit operation will be found in Section III, THEORY OF OPERATION.

A very sensitive vertical amplifier is employed in the Type 304-A. With the amplifier set at full gain an applied a-c or d-c signal of 0.1 volt peak-to-peak will result in full-scale deflection of the electron beam. Increased stability is assured by regulation of the heaters of the vertical amplifier input stages.

To assist in observing random phenomena or recurrent pulses having relatively low duty cycles, the sweep circuit may be adjusted, by means of a front-panel control, so that the sweep is initiated by the signal itself (DRIVEN SWEEP). Both driven and recurrent sweeps may be expanded up to six times full-screen diameter with full positioning. To obtain sweeps of extremely long duration, provision is made for attaching external capacitances to convenient terminals, 0.5 second sweep being secured for each microfarad of external capacitance employed.

Stabilized synchronization minimizes horizontal jitter of traces, while sync limiting for both driven and recurrent operation prevents spurious or distorted response from excessive synchronizing signals.

For a thorough understanding of the capabilities of the Type 304-A the following sections, OPERATION and THEORY OF OPERATION, should be read carefully.

TABLE 1-1
PERFORMANCE SPECIFICATIONS

CATHODE-RAY TUBE	
Type	5ADP-
Accelerating Potential	Second Anode: +1600 volts } with respect Intensifier } to cathode +3000 volts }
Illuminated Scale	Engraved, illuminated scale over face of tube; dimmer control provided on front panel
VERTICAL CHANNEL (Y-AXIS)	
Deflection Factor	
Amplifier (at full gain)	0.1 volt peak-to-peak full scale; or 0.025 peak-to-peak volt/inch (0.009 rms volt/inch)
Direct	32-39 peak-to-peak volts/inch (12-14 rms volts/inch)
Undistorted Deflection	At least 4 inches (limited by deflection-plate cutoff in the cathode-ray tube). Portions of expanded pattern (up to 4 times full screen) will also have negligible distortion when positioned on screen
Sinusoidal Frequency Response (Thru Ampl)	
Direct Coupling	Flat to dc; down not more than 10% at 100 kilocycles
Capacitive Coupling	Down not more than 10% from 10 cycles to 100 kilocycles
Either Type Coupling	Down not more than 50% at 300 kilocycles
Transient Response (Thru Ampl)	
Rise Time (10% to 90%)	2 μ s or less
Overshoot	2% or less
Decay	Direct Coupling - None Capacitive Coupling - Less than 10% in 45 milliseconds
Input Voltage (To Ampl) - Maximum	
Single-ended	
Capacitive Coupling	1000 (dc plus peak ac)
Direct Coupling	1000 (dc plus peak ac) on all attenuation ranges except 0.1 V where it is 100 volts (dc plus peak ac)
Balanced	May be operated up to a d-c level of +2 volts with 6 volts peak-to-peak between grids (VOLTS FULL SCALE set at 0.1)
Input Coupling (To Ampl)	Capacitive or direct
Attenuation (Ampl Connection)	By factors of 1, 10, 100, or 1000 \pm 2% as selected by the VOLTS FULL SCALE switch (0.1V, 1V, 10V, or 100V, respectively)
Input Impedance	
Amplifier	
Single-ended	2 megohms, 50 μ f

TABLE 1-1
PERFORMANCE SPECIFICATIONS (Continued)

Balanced	4 megohms, 40 μ f
Direct	
Single-ended	1.5 megohms, 20 μ f
Balanced	3.0 megohms, 20 μ f
Positioning	Permits examination on screen of any portion of signal expanded to four times full-screen diameter
HORIZONTAL CHANNEL (X AXIS)	
Deflection Factor	
Amplifier (at full gain)	0.3 peak-to-peak volt/inch (0.1 rms volt/inch)
Direct	40-50 peak-to-peak volts/inch (14-18 rms volts/inch)
Sinusoidal Frequency Response (Thru Ampl)	Same as for Vertical (Y-AXIS) Amplifier
Transient Response (Thru Ampl)	Same as for Vertical (Y-AXIS) Amplifier
Input Voltage (Maximum) to Ampl	Attenuator Setting Peak-to-Peak Volts
	1:1 18
	10:1 180
	Maximum with Attenuator in AC position 1000 volts (dc + peak ac)
Input Coupling (To Ampl)	Capacitive or Direct
Attenuation (Ampl Connection)	By factors of 1 or 10 \pm 10%, as selected
Input Impedance	
Amplifier	
Direct	
Single-ended	1.5 megohms, 20 μ f
Balanced	3 megohms, 20 μ f
Linear-sweep Time Base	
Circuit	Type 6Q5G gas triode, for both driven and recurrent sweeps. Return trace is automatically blanked.
Frequency (Recurrent Sweep)	2 to 30,000 sawtooth cps. Sweep frequencies lower than 2 cps may be obtained by attaching external capacitance between SAWTOOTH/EXT CAP terminal and ground. For each microfarad of external capacitance, approximately 0.5 seconds of sweep time is secured.
Time Duration (Driven Sweep)	0.5 seconds to approximately 30 microseconds
Expansion	To 6 times full-screen diameter with no appreciable distortion
Positioning	So any full-screen portion of expanded sweep may be examined on screen
Synchronization	INTERNAL, EXTERNAL or LINE frequency as selected, either polarity

TABLE 1-1

PERFORMANCE SPECIFICATIONS (Continued)

MAXIMUM PHOTOGRAPHIC

Writing Rates (With P-11 screen phosphor) . Du Mont Type 297 (Polaroid-Land) Camera with f/2.8 lens -- 0.08 inch/us
 Du Mont Type 296 (35mm) Camera with f/2.8 lens -- 0.8 inch/us
 Du Mont Type 295 (35mm) Camera with f/1.5 lens -- 2.8 inches/us
 Du Mont Type 321 (35mm moving-film) Camera with f/1.5 lens -- 2.8 inches /us

INTENSITY MODULATION CIRCUIT (Z AXIS)

Input Impedance 0.2 megohms, 80 uuf
 Sensitivity 2-56 volts peak-to-peak (negative) will blank the beam depending on intensity setting
 Polarity Positive signals increase the intensity of the beam

CALIBRATION VOLTAGE

Availability To input of Vertical Ampl by means of front-panel switch
 Waveshape Square Wave
 Frequency Power Line
 Amplitude 0.1 volt peak-to-peak
 Accuracy (Amplitude) Over-all $\pm 5\%$ or better

SAWTOOTH OUTPUT

Availability Front-panel terminal
 Amplitude 5 volts peak-to-peak
 Polarity Positive
 Frequency 2 to 30,000 cps, as selected. Sweep frequencies lower than 2 cps may be obtained by attaching external capacitance between this terminal and ground
 Impedance Approximately 45,000 ohms

POWER SUPPLY

Primary-power Potential 115- or 230- rms volts $\pm 10\%$
 Frequency 50-400 cps
 Power Consumption Approximately 110 watts
 Fuse Protection
 115-volt operation 1.5 amperes
 230-volt operation 0.75 amperes

TUBE COMPLEMENT

6 - 12AU7	1 - 6B2	2 - 1X2A	
2 - 6AQ5	2 - 6J6	2 - 6AL5	1 - (3-14)
1 - 6Q5G	1 - 5Y3GT	2 - 5963	1 - 5ADP-

PHYSICAL CHARACTERISTICS

Size Height - 13-1/2"
 Width - 8-3/4"
 Depth - 19-1/2"
 Weight 50 lbs.

TABLE 1-1

PERFORMANCE SPECIFICATIONS (Continued)

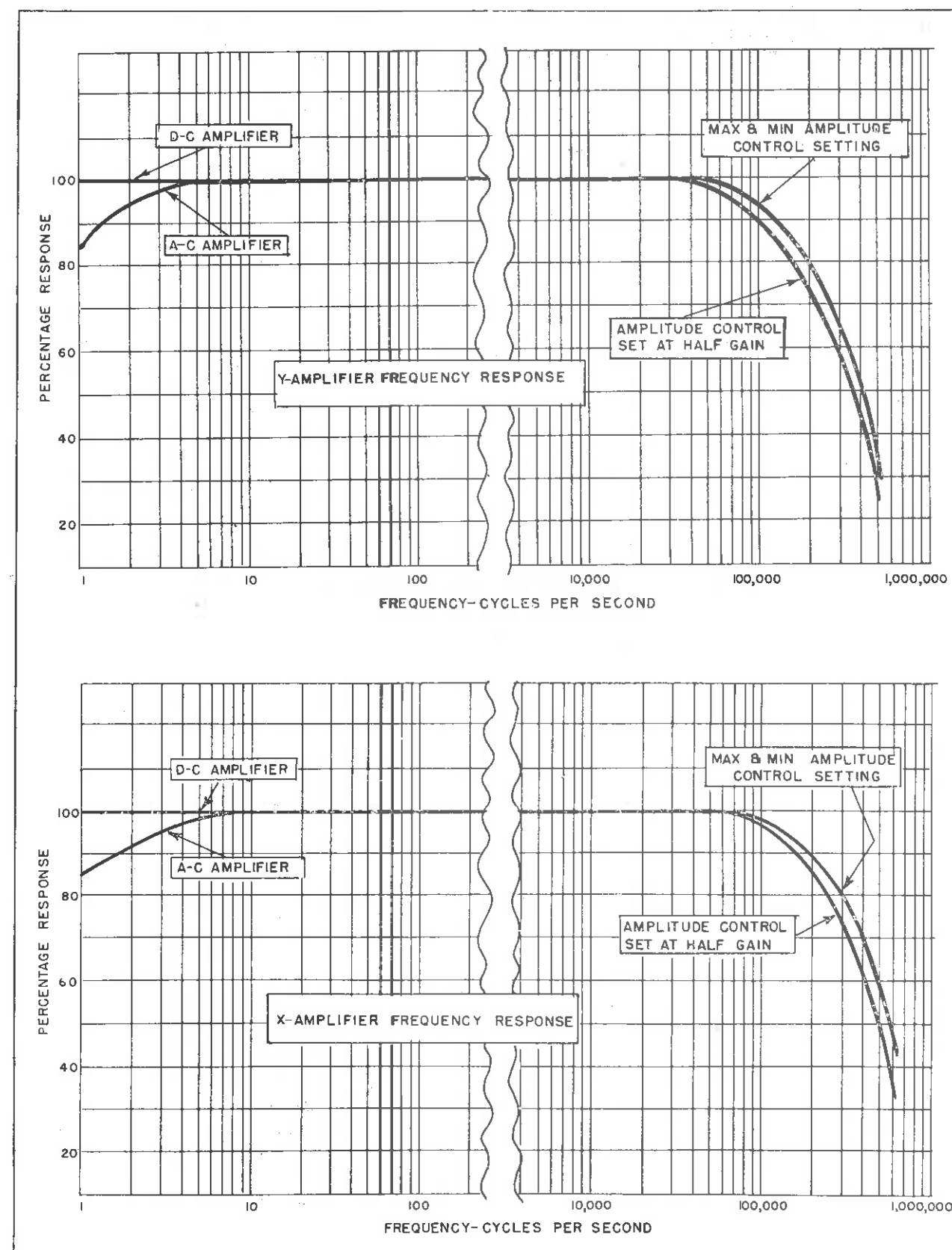




FIGURE 2-1a - FRONT PANEL VIEW OF TYPE 304-A

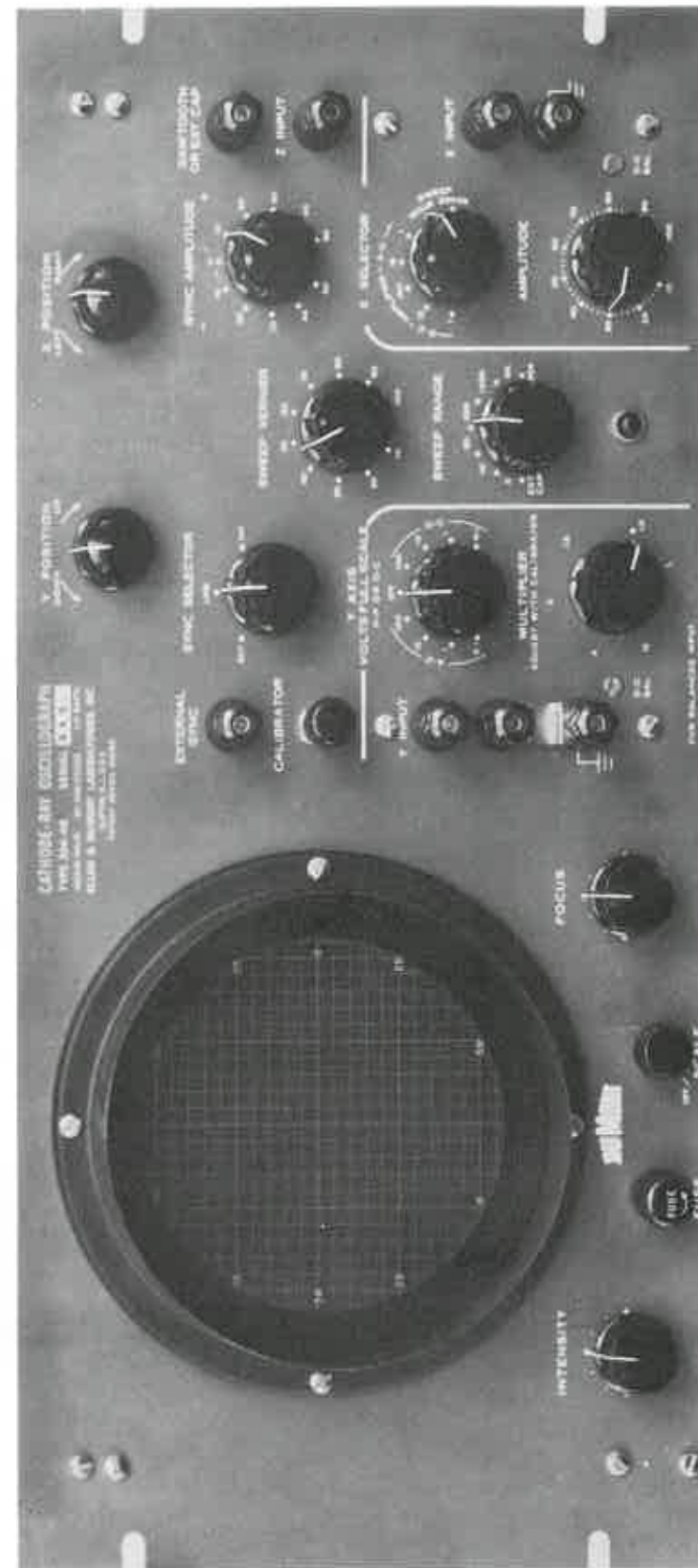


FIGURE 2-1b - FRONT PANEL VIEW OF TYPE 304-AR

SECTION II OPERATION

1. UNPACKING AND INSPECTING THE EQUIPMENT

The Du Mont Types 304-A and 304-AR Cathode-ray Oscillographs are shipped with all tubes in place and ready to operate. However, upon receipt, they should be inspected for any apparent damages, such as broken knobs, tubes, or other components. To slide the chassis of the Type 304-A out of its cabinet, remove the two screws at the back of the instrument. To remove the dust cover from the Type 304-AR, loosen the screws on either side and rear that hold the dust cover to the chassis.

2. LOCATION AND INSTALLATION

a. GENERAL

Since the Type 304-A is a portable test instrument, no special installation procedure is required. The Type 304-AR has a front panel 19 inches wide by 8-23/32 inches high for mounting the instrument in a standard relay rack or cabinet.

Normally, the Type 304-A may be placed where most convenient for viewing the screen. It is always desirable to employ the shortest possible signal leads to either instrument to avoid stray pickup.

Although magnetic and electrostatic shielding has been provided in the design of the instrument, operation in strong fields such as are found near transmitters, transformers, and power-generating equipment, etc., may introduce spurious deflections, and should be avoided.

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

b. LINE VOLTAGE AND FREQUENCY

The Types 304-A and 304-AR Cathode-ray Oscillographs are supplied for operation from a 50 to 400-cycle source of power at 115 or 230 volts rms. Unless otherwise specified by the customer when ordering, the instrument is shipped from the factory for operation on 115-volt line. A tag on the handle will specify the proper line voltage. To change from 115-volt to 230-volt line operation or vice versa, see Section IV on Maintenance.

c. POWER REGULATION

The Type 304-A will operate satisfactorily with steady line-voltage variations of $\pm 10\%$ from the specified value, due to the regulator circuits employed in the instrument. How-

ever, greater than 10 per cent variation may cause the power supply to operate erratically with consequent unsatisfactory performance of the oscillograph. Where line-voltage variations are excessive, it is recommended that a constant-voltage transformer be employed in the power line to the instrument. If such a regulator is used, precautions should be taken to avoid the effects of stray magnetic fields as discussed in paragraph 2a above.

- WARNING -

Potentials as high as 3000 volts are employed in this instrument. Such voltages are extremely dangerous; and every possible safety precaution should be taken to avoid contact with this potential. The instrument is safe when enclosed in its cabinet and should not be operated with the chassis withdrawn except for purposes of adjustment or repair. When necessary to energize the oscillograph with the chassis outside its cabinet, refer to the precautions given in paragraph 2 of Section IV, Maintenance.

3. TURNING ON THE INSTRUMENT

A dual function power switch and scale illumination control is provided; the front panel designation is SCALE. To place the instrument in operation, plug the power cord into the line outlet, and turn on the power switch. Allow approximately 30 seconds for the instrument to warm up; in the meantime, set the various controls as indicated in Table 2-1.

4. PRECAUTION AGAINST SCREEN BURNING

A sharply focused line or spot of high intensity, having short length or small area, respectively, should not be permitted to remain stationary on the screen for any considerable length of time. Under such conditions, the entire energy of the beam is concentrated over a small area, thus subjecting the screen material to burning and discoloration.

5. CONTROLS AND TERMINALS

a. GENERAL

The markings on the front panel adjacent to each control (See Figure 2-1) are essentially self-explanatory, and the operator should find it possible to master the controls with a minimum of experimentation.

b. CONTROL AND TERMINAL FUNCTIONS

Table 2-2 lists all front-panel controls and terminals and gives the function of each. Also, specific problems, which may be encountered in operating the instrument, are explained in this table.

TABLE 2-1
PRELIMINARY SETTING OF CONTROLS

CONTROL	POSITION
Y POSITION	center of range
X POSITION	center of range
INTENSITY	fully counterclockwise
FOCUS	center of range
SYNC SELECTOR	INTernal
SYNC AMPLITUDE	"0"
X SELECTOR	RECURrent SWEEP
Y AXIS VOLTS FULL SCALE	OFF
MULTIPLIER	fully counterclockwise
(X) AMPLITUDE	fully counterclockwise
SWEEP VERNIER	center of range
SWEEP RANGE	50-250
CALIBRATOR push button	released (out)

c. SYNCHRONIZATION OF SWEEP

(1) RECURRENT SWEEP

As a general rule, it is desirable to set the SYNC SELECTOR switch at INTernal. Thus, low-amplitude signals applied to the Y INPUT are amplified sufficiently before application to the sync circuits to produce stable synchronization of the sweep generators. Provision is also made for EXTERNAL sync, which is useful particularly in those cases where varying amplitudes of the same waveform are to be viewed in rapid succession. LINE-frequency sync is provided particularly as a convenience in synchronizing line-frequency signals applied direct to the deflection plates, in noting phase shifts of line-frequency signals with respect to the power line and as an aid in synchronizing line-frequency signals of low-amplitude or having a high noise content.

The proper manner of sync adjustment is as follows:

- (a) Set the X SELECTOR at RECUR SWEEP.
- (b) Set the SYNC SELECTOR at EXT, INT or LINE depending upon the signal to be synchronized as discussed above.
- (c) Set the SYNC AMPLITUDE control at "0."
- (d) Adjust the SWEEP RANGE and SWEEP VERNIER controls to obtain the desired number of cycles of the signal on the screen and to stop the travel of the pattern as nearly as possible.
- (e) Rotate the SYNC AMPLITUDE control either clockwise or counterclockwise to lock the pattern stationary, depending upon whether it is desired to have the beginning of the trace positive going or negative going, respectively.

TABLE 2-2
TABLE OF OPERATING CONTROLS AND TERMINALS

*FRONT PANEL CONTROLS		
Name of Control or Terminal	Reference Symbol	Function
INTENSITY	R407	Changes the intensity of the trace.
FOCUS	R405	Adjusts focus of the trace.
Y POSITION	R116	Changes the vertical position of the trace.
X POSITION	R510	Changes the horizontal position of the trace.
D-C BAL (Y AXIS)	R110	When properly adjusted, prevents change in the vertical position of the trace when the MULTIPLIER control is varied.
D-C BAL (X AXIS)	R506	When properly adjusted, prevents change in the horizontal position of the trace when the (X) AMPLITUDE control is varied.
Y AXIS VOLTS FULL SCALE	S101	Provides for the direct peak-to-peak reading of the input signal in steps 0.1V, 1V, 10V and 100V for both a-c and d-c inputs. OFF position also provided.
MULTIPLIER	R112	Controls amplitude of the vertical deflection.
X SELECTOR	S501	Selects internal or external signal for the horizontal deflection. The internal signal is linear sawtooth sweep, either recurrent or driven. On external signals, either d-c or a-c coupling at attenuation ratios of 1 or 10 is provided. OFF position also provided.
(X) AMPLITUDE	R514	Controls the amplitude of horizontal deflection.
SWEEP RANGE	S302	Varies sweep frequency in steps.
SWEEP VERNIER	R316	Provides continuous variation of sweep frequency when used in conjunction with SWEEP RANGE.
SYNC SELECTOR	S301	Selects synchronizing signals, internal, line-frequency, or external.
SYNC AMPLITUDE	R308	Selects phase and varies amplitude of sync voltage.
CALIBRATOR	S102	Provides 0.1 volt peak-to-peak calibration signal to vertical amplifier input.
SCALE	R411	Varies the illumination intensity of the illuminated scale. Switch attached provides means for turning power on and off.

TABLE 2-2

TABLE OF OPERATING CONTROLS AND TERMINALS (Continued)

*FRONT PANEL TERMINALS		
Name of Control or Terminal	Reference Symbol	Function
EXTERNAL SYNC	J301	Provides for connection of external sync signals when the SYNC SELECTOR is at EXT.
Y INPUT	J101 J102 J103	Provides for the connection of external signals to the Y amplifier. A jumper is provided for conventional single-ended input. Remove jumper for balanced input (no attenuation).
X INPUT	J501 J502	Provides for connection of external signals to the X amplifier.
SAWTOOTH or EXT CAP	J302	Provides for sweep sawtooth voltage at front panel. Also provides for connection of an external capacitor for low-frequency sweeps. Sawtooth output is available only when X SELECTOR is set at SWEEP.
Z INPUT	J401	Provides for connection of external signals to intensity modulate the trace.
**BACK-OF-PANEL TERMINALS (Accessible at Rear of Cabinet or Dust Cover)		
Name of Control or Terminal	Reference Symbol	Function
DEFLECTION PLATE INPUT TERMINALS "UP" and "DOWN"	J107 J111	Provides for connection of signals to vertical deflection plates direct (through capacitor).
DEFLECTION PLATE INPUT TERMINALS "RIGHT" and "LEFT"	J506 J510	Provides for connection of signals to horizontal deflection plates direct (through capacitor).
Y-AXIS	J104 J105 J106 J108 J109 J110	Provides "Direct" or "Through Amplifier" connection of vertical deflection voltages.
X AXIS	J503 J504 J505 J507 J508 J509	Provides for "Direct" or "Through Amplifier" connection of horizontal deflection voltages.
* Refer to Figure 2-1 for identification of front-panel controls. ** See Figure 2-3 for identification of deflection-plate input terminals.		

(2) DRIVEN SWEEP

The DRIVEN SWEEP mode generally is employed for viewing random or aperiodic signals, or periodic signals having a low duty cycle. When operating the instrument in this manner, one cycle excursion of the sweep occurs for each signal impulse or multiple thereof. To operate in this mode, proceed as follows:

(a) USING INTERNAL SYNC

1. Set SYNC SELECTOR at INT, SYNC AMPLITUDE at "0," X SELECTOR at OFF, and advance the (X) AMPLITUDE control approximately 1/4 turn. If necessary, position the beam to center of screen.

2. Apply signal to be observed to Y INPUT terminals, and adjust the VOLTS FULL SCALE and MULTIPLIER controls for approximately 1-1/2 inch vertical deflection.

3. Place the X SELECTOR in DRIVEN SWEEP position, and rotate the SYNC AMPLITUDE control until a steady sweep is observed. The setting of the SYNC AMPLITUDE control may be critical.

4. Adjust SWEEP RANGE and SWEEP VERNIER controls until, with periodic input signals, a steady pattern with the desired number of cycles is obtained; or, with aperiodic or low-duty cycle signals, the complete waveform appears on the sweep.

5. Adjust the X POSITION and (X) AMPLITUDE controls, if necessary, to obtain the desired portion of the trace on screen.

(b) USING EXTERNAL SYNC

When very high-frequency signals are to be observed, it may be helpful to resort to EXTERNAL sync to avoid erratic triggering of the sweeps. For EXTERNAL sync operation, proceed as follows:

1. Set SYNC SELECTOR at EXT and all other controls as described under "Using Internal Sync," paragraph 5c (2a).

2. Apply the EXTERNAL sync signal by connecting a test lead between the Y INPUT and EXTERNAL SYNC front-panel terminals; or, for most effective triggering from non-sinusoidal signals, apply the sync signal through a differentiating network having a time constant of approximately 10 per cent of the period of the sync employed. For details of the differentiating circuit, see Figure 2-2.

d. OBTAINING LOW-FREQUENCY SWEEPS

Provision is made for connecting external capacitors to the SAWTOOTH or EXT CAP terminal on the front panel to obtain lower frequency sweeps than provided for in the instrument. The lowest sweep frequency obtainable without resorting to external capacitors is two cycles per second. For lower frequency sweeps, proceed as follows:

(1) Set the SWEEP RANGE switch to EXT CAP, and position the SWEEP VERNIER control fully counterclockwise.

(2) Connect an external capacitor as determined from Table 2-3 between the SAWTOOTH or EXT CAP and ground terminals. Depending upon the value of capacitance chosen, the sweep

frequency will be approximately as shown in the table. The SWEEP VERNIER may be employed to vary the sweep frequency over a limited range.

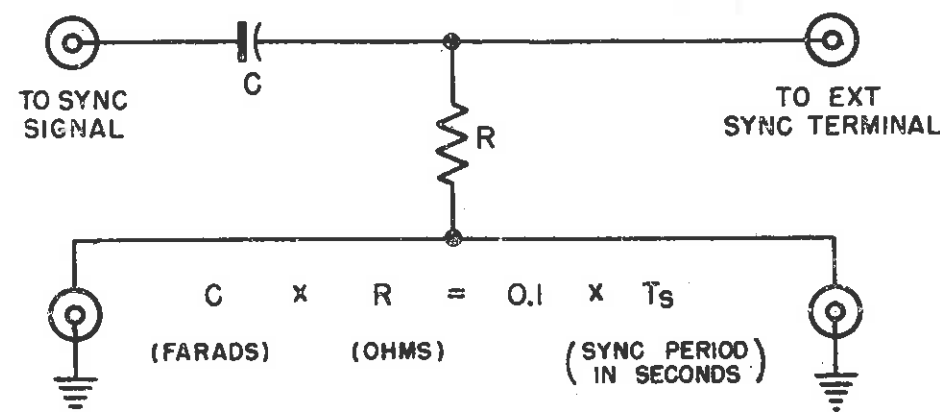


FIGURE 2-2 - DIFFERENTIATING CIRCUIT FOR USE IN ESTABLISHING STABLE DRIVEN SWEEP

TABLE 2-3

EXTERNAL CAPACITORS FOR LOW-FREQUENCY SWEEPS

Sweep Frequency	Sweep Duration	External Capacitance Required*
1 cps	1 second	2 μ f
0.5 cps	2 seconds	4 μ f
0.25	4 seconds	8 μ f
0.1	10 seconds	20 μ f

*A high-leakage-resistance capacitor must be employed such as a paper or plastic dielectric type. A 20 μ f capacitor is the highest value recommended. Too large a capacitor tends to produce a distorted sawtooth waveform.

e. AMPLITUDE CALIBRATION-MEASUREMENT OF SIGNAL VOLTAGE

Amplitude calibration on the Type 304-A Cathode-ray Oscilloscope is accomplished by the substitution method. A voltage of known amplitude is available at the input to the Vertical Amplifier at the touch of a finger on the CALIBRATOR button. This calibrator signal is substituted for the signal under test. A few moments of actual experimentation with this calibrator signal will demonstrate the ease with which amplitude measurements may be made. To become familiar with the measurements of amplitudes by means of the built-in calibrator, the following procedure is suggested.

(1) FOR SIGNALS UP TO 100 VOLTS PEAK-TO-PEAK

Step 1: Apply the calibrator voltage to the Y INPUT by depressing the CALIBRATOR button. Adjust the MULTIPLIER gain control for a peak-to-peak beam deflection of four

inches. This is best established by adjusting the Y-POSITION control along with the MULTIPLIER control to cause the negative and positive peaks of the calibrator signal to appear at 0 and 100 on the left hand scale, respectively. Note that the MULTIPLIER knob pointer is in the general vicinity of the 1.0 on the scale.

Step 2: Apply the signal under test to the Y INPUT terminal. Again depress the CALIBRATOR button (removing the calibrator signal and applying the test signal). By means of the Y-POSITION control, position the signal under test ON SCREEN and set VOLTS FULL SCALE (RANGE) switch to the position which gives maximum deflection within the scale (four-inch) limits of the screen. Do not touch or attempt to readjust the MULTIPLIER control knob. If inadvertently moved, go back and reset according to Step 1.

Step 3: Now, position the trace so that the negative peak just touches the line at 0 on the left scale. Note the deflection in terms of units from 0 to 100 as read off the scale at the left. The peak-to-peak voltage is the reading from the scale divided by 100 and multiplied by the VOLTS FULL SCALE (RANGE) switch setting. As an example, suppose the scale reading is 65 and the VOLTS FULL SCALE (RANGE) switch is on position 10. The actual peak-to-peak voltage of the waveform would be 65/100 times 10 or 6.5 volts.

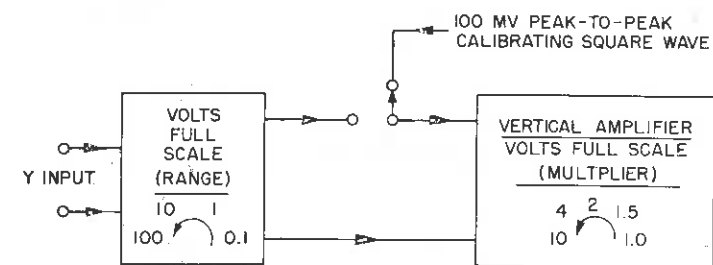
(2) FOR SIGNALS GREATER THAN 100 VOLTS PEAK-TO-PEAK

For signals of greater than 100 volts amplitude (peak-to-peak), it will be necessary to position the MULTIPLIER control knob in another position than 1.0. This will necessitate a somewhat different calibrating procedure, as follows:

Step 1: With the signal applied to the Y INPUT terminal, set the VOLTS FULL SCALE (RANGE) switch at 100 and adjust the MULTIPLIER control for a suitable deflection on the screen - preferably near full scale.

SPECIAL NOTE --

Calibration of the vertical amplifier of the Type 304-A Cathode-ray Oscilloscope is effected by the use of the CALIBRATOR push button which disconnects the applied signal and substitutes a line-frequency square wave of precisely 100 mv peak-to-peak. Reference to the figure below shows that the calibrating signal is applied directly to the input of the amplifier, so that when the MULTIPLIER amplifier sensitivity control is set to produce 4 inches (full scale) deflection with the calibrating signal applied, the Y-axis amplifier functions as a voltmeter having a sensitivity of 100 mv full scale. The input attenuator provides alternative sensitivities of 1 volt, 10 volts and 100 volts full scale. Intermediate sensitivities may be obtained by making use of the MULTIPLIER control. For example, if it is adjusted so that the 100 mv signal gives half scale (2 inches) deflection, the basic sensitivity will be 200 mv full scale and the MULTIPLIER scale will read approximately 2. This gives an alternative way of using the instrument.



Step 2: Depress the CALIBRATOR button, to apply the calibrator test signal and remove the signal under test. Note the scale marking nearest the pointer of the MULTIPLIER control knob. Take its reciprocal (i.e. 1/no.) and multiply by 100. Now readjust the multiplier control slightly, as required, until this screen deflection is obtained. As an example, suppose the MULTIPLIER knob points approximately to 1.5. It should be adjusted to give a vertical deflection on screen (using the left hand scale) of

$$\frac{1}{1.5} \times 100 \text{ or } 66\text{-}2/3 \text{ units.}$$

Step 3: Again depress the CALIBRATOR button, restoring the signal under test to the screen. Position the signal as mentioned above in "Step 3" and read peak-to-peak amplitude directly from left hand scale. Divide reading obtained by 100 and multiply by the product of the VOLTS FULL SCALE (RANGE) switch position and the MULTIPLIER setting. This gives the actual voltage of the waveform under test.

With little practice, quick and accurate readings of signal voltages having amplitudes from approximately 0.005 volts (5 millivolts) to 1,000 volts may be obtained. It should be noted that an auxiliary scale is provided at the right side of the screen for measuring peak amplitudes of symmetrical signals. Use of this scale is self-evident.

f. INTENSITY MODULATION

The Z INPUT terminal on the front panel provides the facility for brightening or blanking the beam on the screen. Positive-going signals brighten the beam while negative-going signals blank it. A negative signal of 2 to 56 volts peak, dependent upon the intensity level, will blank the beam if applied between the Z INPUT terminal and ground.

g. DIRECT CONNECTION TO DEFLECTION PLATES

(1) GENERAL

When applying signals direct to deflection plates, the highest-frequency signal that can be observed is not limited by the response of the built-in amplifiers but is dependent only upon the input capacity to the deflection plate terminals and/or transit time of the electrons between the deflection plates. Provided the impedance of the signal source is kept low, transit time is the only consideration. It should be remembered, however, that no amplification or attenuation is provided on "direct input" and that approximately 15 rms volts are required to produce an inch of beam deflection.

(2) MAKING PROPER CONNECTIONS

- CAUTION -

Turn Power Off before making any connections to the rear terminal board. Some of these terminals are at approximately 200 volts-d-c above ground.

Figure 2-3 shows the location and identification of the terminals provided for making direct connection to the deflection plates. To make connections, follow the instructions given on the terminal board. It will be necessary to move the jumpers from the "through amplifier" position to the "deflection plates" position as indicated and to connect the signal to be observed to the appropriate UP, DOWN, LEFT or RIGHT terminals. The designations, UP, DOWN, LEFT and RIGHT denote for each terminal the direction of deflection resulting from the application thereto of a positive-going signal.



FIGURE 2-3 - REAR PANEL VIEW OF TYPE 304-A

To avoid any possibility of cross-coupling effects, it is suggested that, when connecting a signal direct to deflection plates, the corresponding channel (VOLTS FULL SCALE and/or X SELECTOR) controls be switched to OFF.

(a) SINGLE-ENDED INPUT

For single-ended input, connect a jumper between UP or DOWN terminal and ground (vertical deflection plates) depending on whether a negative-or positive-going signal, applied to the ungrounded terminal, is to deflect the beam up or down, respectively. Connect the signal between the ungrounded terminal (UP or DOWN) and GROUND. In a similar manner, the horizontal deflection plates (RIGHT or LEFT) may be connected for single-ended input.

(b) BALANCED INPUT

For balanced input signals, connect the signal between the terminals designated UP and DOWN (vertical deflection plates) and/or between the terminals designated RIGHT and LEFT (horizontal deflection plates).

(c) POSITIONING

Beam positioning may be obtained by means of the appropriate POSITIONING controls on the front panel in the same manner as when employing the "amplifier" connection.

(d) RESTORING THE INSTRUMENT TO NORMAL "AMPLIFIER" OPERATION

When restoring the instrument to normal "amplifier" operation, remove the signal from the DEFLECTION-PLATE INPUT TERMINALS. Replace the jumpers as indicated in the instructions on the terminal board, and apply the signal to the front-panel terminals.

6. PHOTOGRAPHING OSCILLOGRAMS

Permanent photographic records of oscillograms, with or without the superposition of the calibrated scale, are readily obtainable from the Type 304-A. Since the calibrated scale may be illuminated, the oscillogram and scale can generally be photographed simultaneously.

Du Mont manufactures several oscillograph-record cameras, both still and moving-film types, specifically designed for effective photo-recording. Information on these cameras as well as techniques of recording is available upon request.

7. USE OF BALANCED INPUT

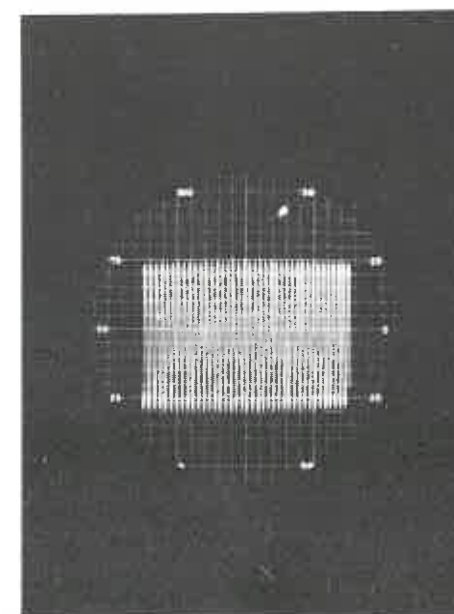
By removing the jumper between one of the Y INPUT terminals and ground, it is possible to feed a balanced-input signal to the vertical (Y-Axis) amplifier. No attenuation is provided on balanced input; however, the operator may find this feature extremely convenient for various applications. The following explanation of the balanced-input feature may help the operator to determine when this type of operation may be useful or desirable.

If there is an in-phase signal applied to both inputs (known as a "common-mode" signal) superimposed on the balanced-input signal, the maximum input signal (d-c plus peak signal a-c) will be accordingly reduced.

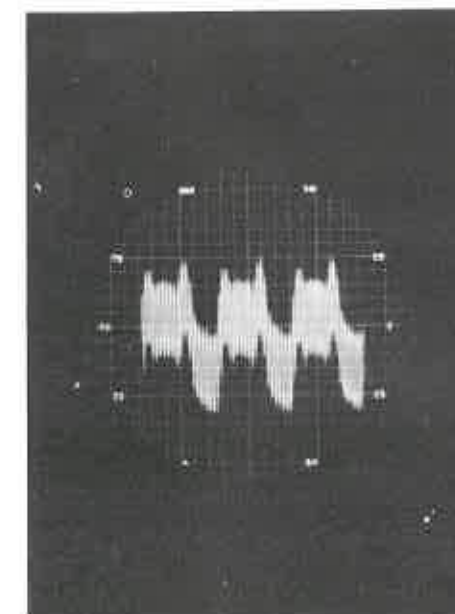
One of the features of the balanced-input circuit is the differential action of the first stage in the Y amplifier. This circuit makes it possible to reject to a considerable degree any common-mode signal while at the same time passing and amplifying the balanced-input signal. Thus, if there is any pickup of noise on test leads or in the equipment under test, such noise will be reduced materially on passing through the balanced-input circuit of the Type 304-A. The waveforms shown in Figure 2-4 illustrate the advantage of the balanced-input connection over the single-ended in such cases. In this figure, a test signal, on which a "nuisance" signal is superimposed is shown on the cathode-ray tube screen when the signal is applied to the balanced input of the Type 304-A. Then, the same signal with the same "nuisance" voltage riding on it, is passed through a network to convert it to unbalanced output and is applied to the unbalanced-input connections of the Type 304-A. Note how much greater the amplitude of the common-mode signal appears with the unbalanced-input connection.

To adjust for the best rejection of the unwanted common-mode signal, remove the jumper from the Y INPUT terminal. Feed a one-volt 60 cycle square-wave signal between both the Y INPUT terminals and ground. Set VOLTS FULL SCALE (D-C) switch at 0.1 and the MULTIPLIER control fully clockwise. Note the beam deflection produced. Vary the MULTIPLIER control for minimum deflection. If this does not reduce the amplitude of the trace to zero, set the MULTIPLIER control approximately midway, and vary the (Y) D-C BAL front-panel screw-driver adjustment for minimum deflection. (It will be necessary to adjust the Y POSITION control as the (Y) D-C BAL adjustment is being made to keep the beam centered vertically on the screen). As now adjusted, it should be possible to go through the common-mode null with either MULTIPLIER control or the (Y) D-C BAL adjustment.

NOTE: OBSERVATION OF SINGLE-ENDED SIGNALS, AFTER HAVING MADE THESE BALANCED-INPUT ADJUSTMENTS, WILL REQUIRE RESETTING OF THE D-C BAL AND Y POSITION CONTROLS.



(a) Test Signal Applied to Balanced Input



(b) Test Signal Applied to Unbalanced Input

FIGURE 2-4 - ILLUSTRATING EFFECTIVENESS OF BALANCED INPUT IN ELIMINATING "COMMON-MODE" SIGNALS

SECTION III THEORY OF OPERATION

1. GENERAL

In following the theory discussion, it is suggested that the simplified block diagram of the Type 304-A (Section I) and the over-all circuit schematic (just inside the back cover of the manual) be referred to in addition to the simplified and unit schematic in this section.

2. CATHODE-RAY TUBE CIRCUIT

a. GENERAL

A simplified schematic of the cathode-ray tube circuit is shown in Figure 3-1. A Type 5ADP- (V401) is employed, operating at a total accelerating potential of 3000 volts, with the intensifier +1600 volts above and the cathode -1400 volts below chassis ground.

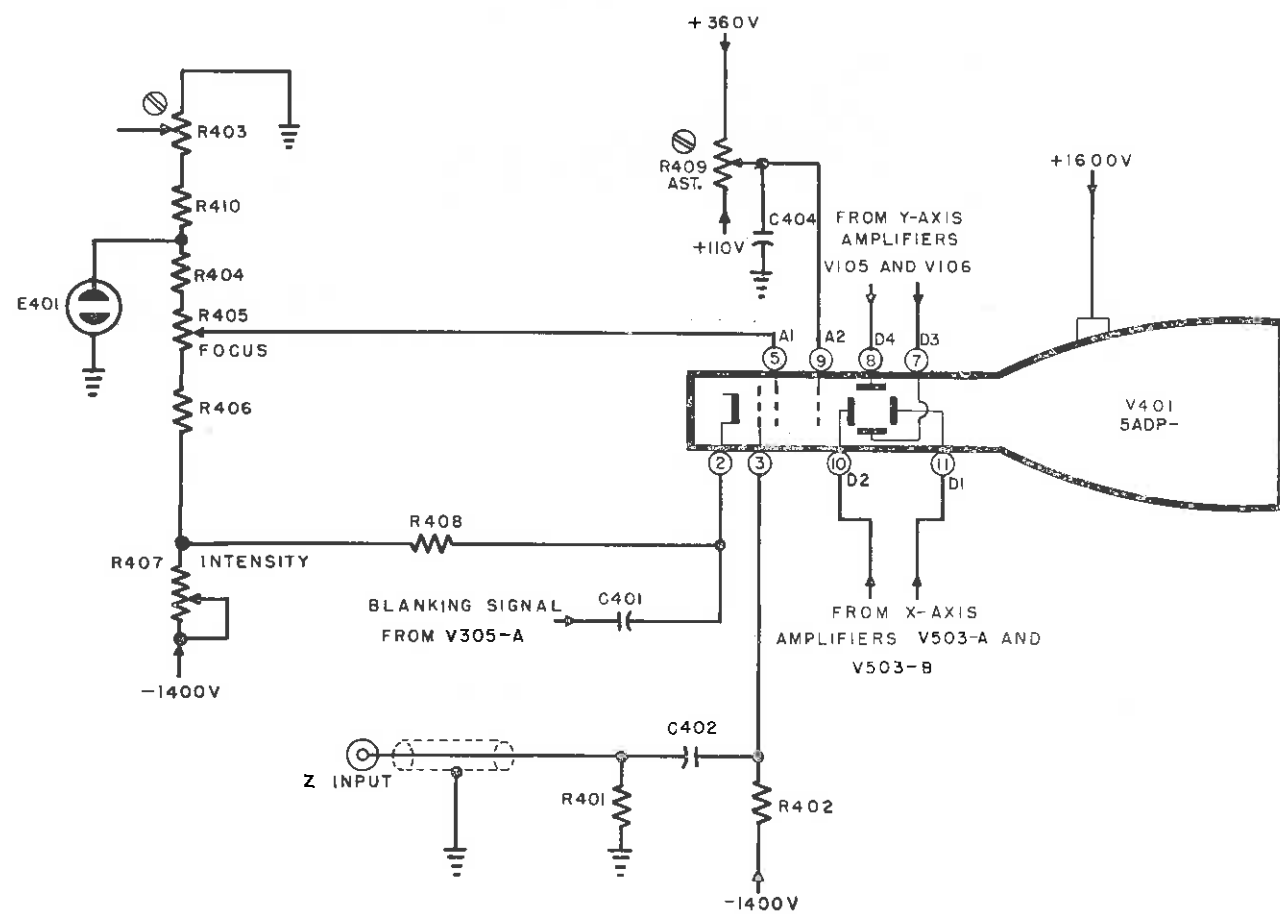


FIGURE 3-1 - CATHODE-RAY TUBE CIRCUIT (SIMPLIFIED SCHEMATIC)

b. INTENSITY

First anode and cathode potentials for the cathode-ray tube are obtained from the voltage divider (R403 through R407). The intensity of the beam is adjusted by varying the INTENSITY control (R407). This control varies the cathode potential more or less positive with respect to the grid, which is held at a fixed negative potential.

c. FOCUS

Focusing of the beam for maximum "sharpness" of trace is accomplished by adjusting the FOCUS control (R405). The setting of this control establishes the relative potential difference between anodes (A1) and (A2). The vertical-deflection plates (D3 and D4) and the horizontal deflection plates (D1 and D2) operate at an average d-c potential of approximately 200 volts above ground. To avoid beam distortion, the second anode (A2) must operate at approximately the same d-c potential. The second anode voltage is obtained from the arm of potentiometer R409.

d. INTENSITY MODULATION

For the purpose of intensity modulation of the beam traces, positive (brightening) or negative (blinking) signals may be applied from the Z INPUT terminals through coupling capacitor C402 to the grid of the cathode-ray tube.

3. VERTICAL DEFLECTION CIRCUIT (Y AXIS)

a. GENERAL

To facilitate circuit analysis, the vertical-deflection circuit may be considered as consisting of: (1) a frequency-compensated attenuator; (2) a voltage calibrator for determining input-signal amplitudes and (3) a high-gain, wide-band vertical (Y-axis) amplifier for increasing the amplitude of low-level signals for suitable display on the cathode-ray tube screen.

b. INPUT ATTENUATOR

A simplified schematic of the input attenuator (calibrated in peak-to-peak volts full scale) is shown in Figure 3-2. The decade attenuators are R-C compensated to maintain frequency and phase response and to present an impedance of 2.0 megohms in shunt with 50

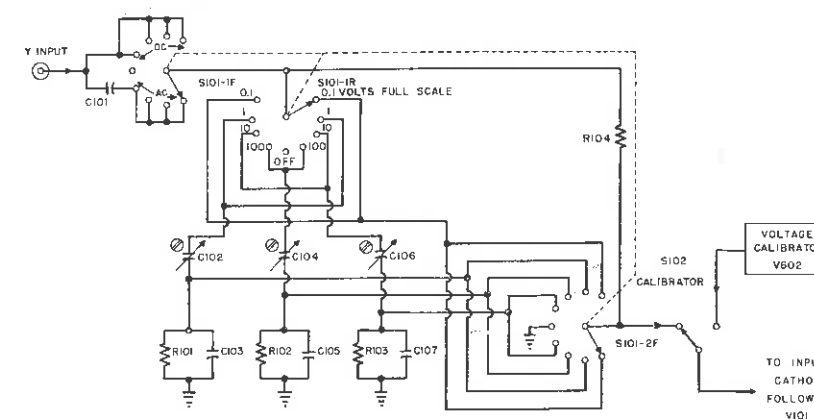


FIGURE 3-2 - INPUT ATTENUATOR--VERTICAL CHANNEL (SIMPLIFIED SCHEMATIC)

With the Y POSITION control (R116) set at its mechanical center, the Y CTR back-of-panel control (R121) is normally adjusted to equalize the voltage drops across load resistors R115 and R117 so that the beam trace will be in the vertical center of the cathode-ray tube. The positioning system provided is such that even with a vertical deflection equivalent to four times full-screen diameter, any full screen portion of this vertical deflection may be centered on the screen by the Y POSITION control. The Y SEN back-of-panel adjustment (R128) is used to set the sensitivity of the Y-deflection system to 100 millivolts peak-to-peak full scale through the amplifier. This control provides a variable low resistance path between the plates of the second push-pull amplifier, V103, and the input to the third push-pull stage, V104.

Voltage for the screen grids of V105 and V106 in the last push-pull stage is obtained from an unregulated supply source to allow the sensitivity of the circuit to rise with increased line voltage. This is designed to compensate for the reduction in the sensitivity of the cathode-ray tube caused by increased accelerating potentials resulting from the increased line voltage. Hence, variation in over-all sensitivity due to line-voltage fluctuations is minimized. The Y LIN back-of-panel control (R136) is a variable screen-dropping resistor for the output tubes (V105 and V106) thus controlling the linearity of the output signal. Additional high frequency compensation is obtained by means of degenerative feedback through resistors R123 and R124.

(3) DIRECT INPUT

Provision is made for direct input to the vertical deflection plates at rear-panel terminals through series input capacitors C110 and C111. The coupling capacitors are required since the deflection plates are maintained at approximately +200 volts with respect to ground to prevent beam distortion.

4. SYNC AND SWEEP CIRCUITS

a. GENERAL

A simplified schematic of the sync and sweep circuits is shown in Figure 3-5. Provision is made for both driven and recurrent sweeps with expansion to six times full-screen diameter; the positioning range being sufficient to allow viewing on screen of any portion of the expanded sweep. The recurrent sweep may be synchronized or the driven sweep triggered by signals of either positive or negative polarity through the incorporation of a phase-splitting stage.

b. SYNCHRONIZATION

The SYNC SELECTOR switch (S301) provides for selection of the synchronizing signal; INTERNAL (signal obtained from the Y-axis amplifier); LINE-frequency; or EXTERNAL (signal obtained from an external source). V301-A functions as a sync phase splitter. The SYNC AMPLITUDE control (R308) enables the operator to select the desired amplitude and polarity of the sync voltage. The output from the first sync amplifier (V301-B) is coupled to the grid of the sweep generator (V303) through C305 and R312. The plate of diode V302 is connected at the junction of R311 and R312; however, the cathode is connected to ground only when the X SELECTOR switch is set at RECURRENT SWEEP.

When thus connected in the circuit, this diode limits the sync voltage that can be applied to the sweep generator (V303) to prevent distortion of the sweep waveform which could result from over-sync. V302 also prevents the grid-circuit capacitance of the sweep

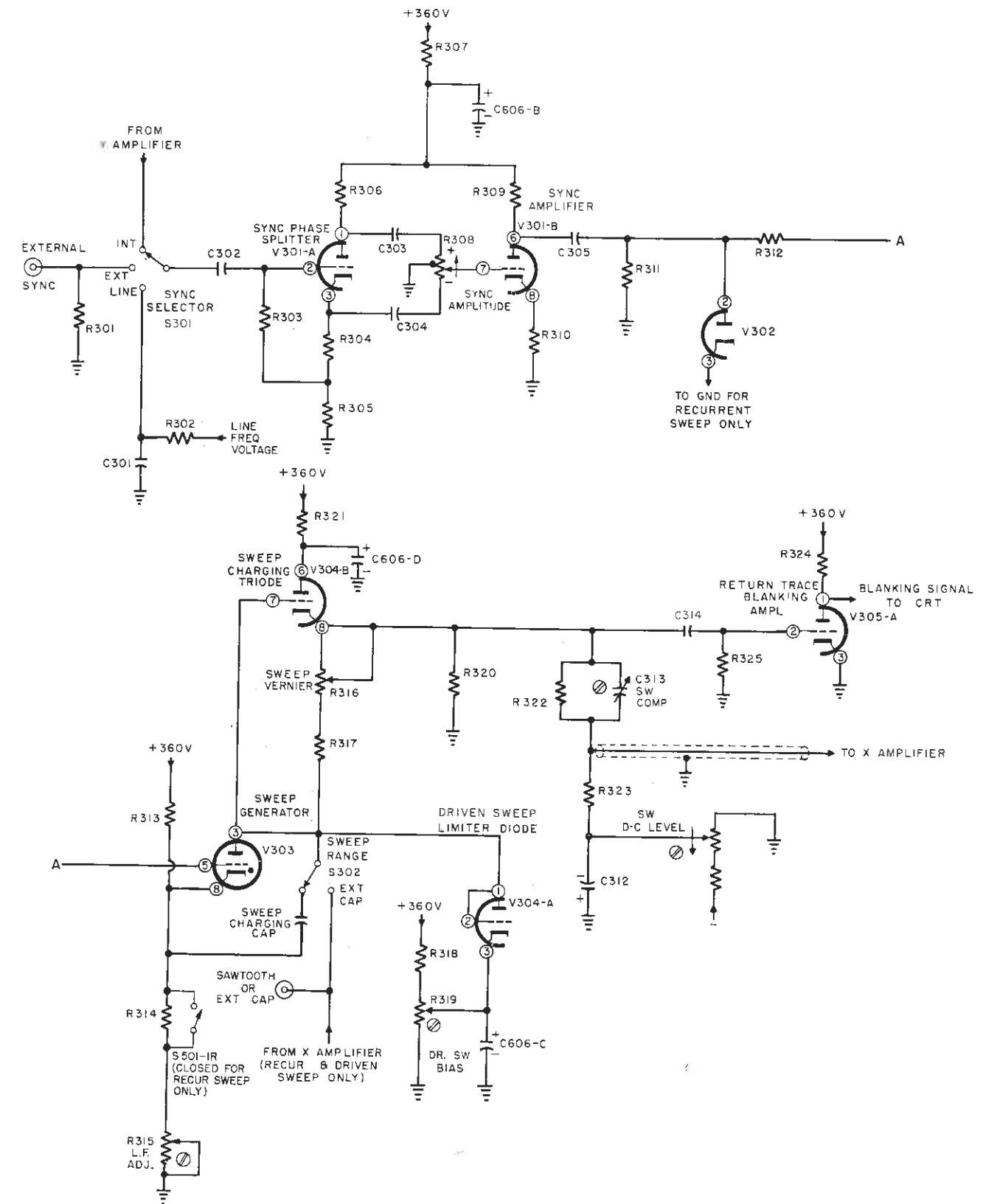


FIGURE 3-5 - SYNC AND SWEEP CIRCUITS (SIMPLIFIED SCHEMATIC)

generator (V303) from charging to a positive potential at the higher sweep frequencies which would result in premature firing and erratic operation of V303. The useful sweep range is thus extended at the high-frequency end.

c. RECURRENT SWEEP

Gas triode V303 is employed to develop the sawtooth voltage necessary to obtain the linear sweep. The cathode of this gas triode is heated and emits electrons as in the ordinary heater-type triode, but the inert gas in the tube ionizes so that when the voltage between the cathode and the plate reaches a certain value, an arc occurs causing the tube to appear as a veritable short circuit. This "breakdown" or "firing" point depends upon the bias at the grid with respect to the cathode, the bias being determined by a voltage-divider network consisting of R313 and R315. With a specific negative bias applied to V302, it will "fire" at only one value of plate voltage. To facilitate circuit analysis, only one sweep capacitor is shown in Figure 3-5, connected between the plate and cathode of the gas triode. This capacitor is charged from the +360-volt supply through sweep-charging triode (V304-B, R316, R317 and the cathode bias resistance R315) until the plate voltage becomes high enough to "fire" the tube. At this time, the sweep capacitor is discharged until the plate-to-cathode voltage falls to the arc-extinction potential (about 20 volts). When this occurs, V303 no longer conducts and the charging cycle commences all over again. The SWEEP VERNIER control (R316) provides a fine adjustment of the sweep frequency by controlling the rate at which the sweep capacitor is charged.

The circuit of V304-B serves two functions: (1) to simulate the behavior of a constant current source for the linearization of the charging rate to the sweep capacitor and (2) to function as a sweep output cathode follower. The resultant sawtooth sweep appearing across the sweep output cathode follower load resistor (R320) is applied to a frequency-compensated voltage divider (R322, C313, and R323) which attenuates the sweep to approximately one fifth of the original value. The lower end of the voltage divider is connected to an adjustable negative bias at the arm of the SW DC LEVEL control (R403). When this back-of-panel adjustment is properly set, equal sweep-trace expansion from both sides of center screen will be obtained as the X AMPLITUDE control is advanced. The output from the voltage divider is coupled to the input of the X-axis amplifier when the X SELECTOR switch is set at the SWEEP position.

It is generally desirable to view only the forward portion of the sweep trace. This requires blanking of the return trace. To accomplish this, a negative pip is generated at the end of the forward trace by the differentiating circuit composed of R325 and C314. This negative pip is applied to the grid of the return-trace blanking amplifier (V305-A). The resulting positive pulse at the plate of V305-A is coupled to the cathode of the cathode-ray tube to "turn-off" the beam during the interval of the return trace.

Certain applications may require sweep frequencies lower than two cycles per second. For such applications a very low-frequency time base may be obtained by connecting an external capacitor between the SAWTOOTH or EXT CAP front-panel terminal and ground when the SWEEP RANGE switch is set at EXT CAP. The larger the capacitor employed, the greater the R-C time constant and the lower the frequency.

d. DRIVEN SWEEP

For operation in the driven-sweep mode, the gas triode (V303) will not "fire" except when triggered by a positive pulse applied to its grid. Each positive pulse of sufficient amplitude initiates a single cycle of sawtooth voltage. When the X SELECTOR switch is at

DRIVEN, the bias on the cathode of V303 is increased because of the addition of R314 in the voltage divider network. With this additional bias, a higher plate voltage must be applied to V303 before it "fires". The driven-sweep limiter diode (V304-A) prevents the plate of the gas triode from reaching the potential necessary for ionization under steady-state conditions. The functioning of this limiter is as follows: The limiter (V304-A) will conduct when the forward portion of the sawtooth waveform reaches a certain amplitude as determined by the DRIVEN SW BIAS back-of-panel control adjustment (R319) in the cathode circuit. Upon conduction, the voltage across the sweep charging capacitor is arrested at this point; and when R319 is properly set, the voltage is of insufficient magnitude to fire that gas triode (V303).

The driven sweep is initiated by applying a positive pulse of sufficient magnitude to the grid of V303. This enables the tube to "fire" at a plate potential lower than that established by the fixed bias on the cathode. The sweep capacitor quickly discharges through the ionized conduction path of V303 to the extinction potential. At this point, conduction no longer occurs, and the sweep capacitor again charges. The driven sweep cycle is complete when the sweep capacitor is again charged to the level established by the driven-sweep limiter diode (V304-A). The beam will sweep the screen again only upon application of another positive pulse to the grid of the gas triode.

5. HORIZONTAL DEFLECTION CIRCUIT (X AXIS)

a. GENERAL

A simplified schematic of the horizontal (X-axis) amplifier is shown in Figure 3-6. The horizontal amplifier, preceded by an input attenuator, consists of an input cathode follower, a paraphase amplifier stage and an output push-pull amplifier.

b. CIRCUIT THEORY

(1) X SELECTION

By means of the X SELECTOR switch (S501) provision is made for selection of internal or external signals for horizontal deflection. The internal signal is obtained from the linear sawtooth sweep circuit previously discussed. Either d-c or a-c external signals may

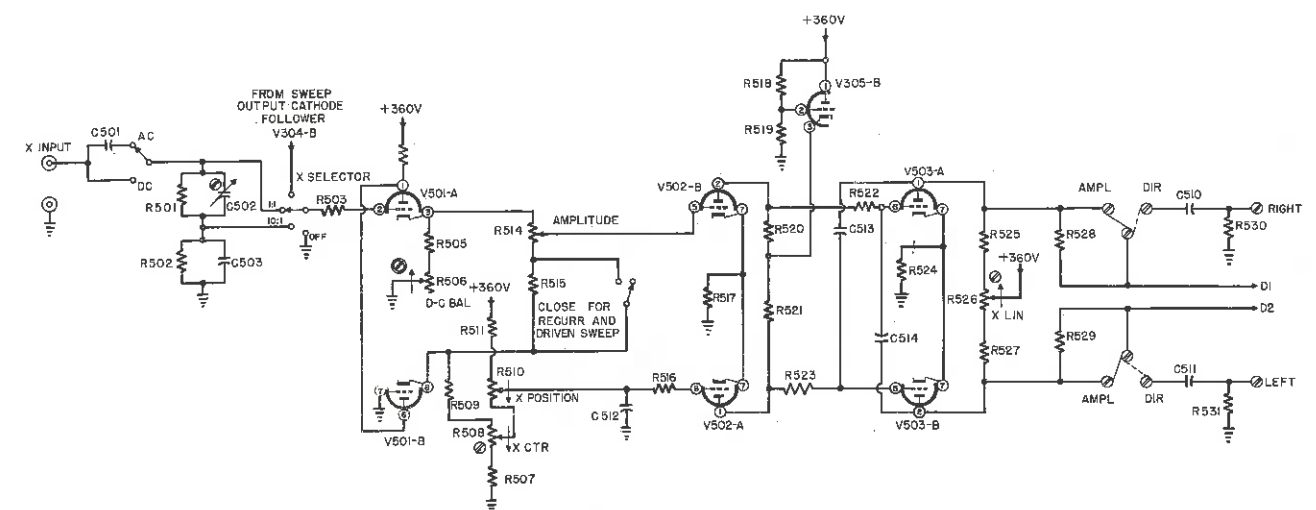


FIGURE 3-6 - HORIZONTAL AMPLIFIER CIRCUIT (SIMPLIFIED SCHEMATIC)

be applied through the X attenuator, which provides attenuation ratios of 1 or 10. An OFF position is provided on this switch, which grounds the grid of the input cathode follower (V501-A).

(2) INPUT CATHODE FOLLOWER

V501-A and V501-B are connected in a cathode-follower circuit. V501-B has no signal applied to it; its function being solely to maintain the grid (pin 6) of the paraphase amplifier stage (V502) at signal ground potential while allowing d-c positioning voltage to be applied. The d-c balance adjustment (R506, X D-C BAL) is used to equalize the d-c voltage at the ends of the AMPLITUDE CONTROL. When this adjustment is properly set, there will be no shifting (left or right) of the trace when moving the AMPLITUDE control from minimum to maximum with no input to the amplifier.

The over-all gain of the X amplifier is varied by the AMPLITUDE control (R514). To prevent the operator from inadvertently overloading the input cathode follower with resultant signal distortion, R515 is connected in series with the AMPLITUDE control. The value chosen for R515 is such that with the AMPLITUDE control set for minimum gain, a signal large enough to overload the input cathode follower (V501) will cause the beam to be deflected off the screen of the cathode-ray tube and thus require additional attenuation to be employed. The range of the AMPLITUDE control is such that a signal, which causes 5 inches deflection of the electron beam on the screen at maximum AMPLITUDE control setting, will be cut down to between 0.1 and 0.5 inch at the minimum setting.

The input cathode follower is designed so as to maintain the cathode (pin 8) of V501-B at a constant signal potential of zero volts with respect to ground. This is important if V502 is to operate as a true paraphase amplifier with low distortion.

Assume that a positive-going signal is applied to the grid (pin 2) of V501-A. This tube will conduct more heavily, causing more current through the series cathode network consisting of R514, R515, R509, R508 and R507. The total current through the latter three resistances is not only determined by the cathode current just mentioned but also in part by the current flowing through V501-B. The increased plate current of V501-A produces a voltage drop across R504 in the plate circuit, which lowers the plate voltage on V501-B, resulting in less plate current through this latter tube and the series network, R509, R508 and R507. This decrease in current through these resistances, when R504 is properly chosen, is just equal and opposite in phase to the current through the V501-A cathode network previously mentioned. Thus, the junction of R515 and R509 remains at the same (zero) potential.

(3) PARAPHASE AMPLIFIER

V502 is connected in a conventional paraphase amplifier circuit with plate voltage supplied through the series dropping stage (V305-B) from the +360-volt supply. V305-B, in addition to providing the proper voltage drop, serves as a low-impedance path to ground through the power supply.

(4) PUSH-PULL OUTPUT STAGE

The output of the paraphase amplifier is direct-coupled to a push-pull output amplifier (V503). Plate voltage for this stage is obtained from the +360-volt supply through a linearity control (R526, X LIN). This control is provided to compensate for any unbalance in the circuit caused by asymmetry of the two halves of the tube.

C513 and C514 provide sufficient feedback to cancel out the input capacitance of V502, resulting in improvement of the high-frequency response of the amplifier.

(5) BEAM POSITIONING

Beam positioning is accomplished by varying the bias voltage on V502-B with respect to that on V502-A through adjustment of the X POSITION control (R510). R508 (X CTR) is a back-of-panel adjustment in series with R510 for use in centering the beam on the screen with the X POSITION control set midway. This allows for equal positioning either side of center or may be adjusted for greater position in either direction from center, if desired.

(6) DIRECT INPUT

Connecting a signal direct to horizontal deflection plates is accomplished in the same manner as for vertical input discussed in paragraph 3d (3).

6. POWER SUPPLY

a. GENERAL

The circuit of the power supplies is shown on the over-all schematic at the back of the manual. As an aid in understanding the circuit, consider the power supply as consisting of three separate voltages: (1) low-voltage positive supply, (2) high-voltage positive and negative supply, and (3) heater supply.

b. FUNCTIONS

The low-voltage positive supply provides the necessary d-c potential for operation of the X and Y amplifiers, the sync and sweep circuits and, in addition, provides potential for the second anode of the cathode-ray tube. The high-voltage negative supply provides cathode, grid and first anode potentials for the cathode-ray tube. In addition, it furnishes the necessary bias for the SWEEP DC LEVEL control. The high-voltage positive supply provides the necessary potential at the intensifier electrode of the cathode-ray tube. The heater supply furnishes the necessary low-voltage a-c potentials for proper operation of tube heaters.

c. LOW-VOLTAGE POWER SUPPLY

The low-voltage rectifier (V605) is connected in a full-wave rectifier circuit. The rectifier output is filtered by a capacitor-input type filter (C602, L601, and C601). The full-voltage output from the filter (+360 volts) is regulated by V601 to provide +110 volts regulated. The unregulated +360-volt output supplies the Y amplifier output stages, sync, sweep, and X amplifier. In addition, this supply furnishes voltage to the second anode of the cathode-ray tube.

d. HIGH-VOLTAGE POWER SUPPLY

The high-voltage power supply contains two rectifier circuits. These rectifiers provide the cathode-ray tube intensifier-anode potential as well as operating potentials for proper intensity and focusing of the cathode-ray tube beam. V604 is employed in a -1400 volt half-wave rectifier circuit from which the cathode, grid and first anode electrodes of the cathode-ray tube are supplied. The rectified output from this stage is filtered by a single pi section of an R-C type filter (C605, R606, and C604).

V603 is also connected in a half-wave rectifier circuit, the output from which is filtered by a single section R-C type filter. Potential at the output of this filter is approximately +1600 volts and supplies the necessary potential to the intensifier electrode of the cathode-ray tube.

e. REGULATED HEATER SUPPLY

A regulated heater supply on the first and second stages of the Y-axis amplifier provides good vertical stability. A series-connected thermal regulator (V606) controls the heater temperature to stabilize cathode emission over a $\pm 10\%$ range of variation in supply voltage. In addition, a HUM BALANCE potentiometer (R144) is included in the filament circuit of V101 and V102 to reduce line-frequency modulation to a minimum.

SECTION IV MAINTENANCE

WARNING!

This equipment employs high voltages that are dangerous and may be fatal if contacted by operating personnel. Extreme caution should be exercised when working on the equipment.

1. GENERAL SYSTEM TROUBLE SHOOTING

It is assumed that maintenance personnel are thoroughly familiar with the physical make-up of the equipment, the installation and operating procedures, and the detailed theory of operation given elsewhere in this handbook.

Maintenance personnel must be prepared to repair and adjust the equipment should it fail in operation. The trouble must be located; and after repairs have been made, the equipment must be tested and adjusted to conform to the original specifications. Maintenance personnel must endeavor to find the source of the trouble that causes each equipment failure, particularly when the trouble is a recurrent one. The recurrence of a fault usually indicates the effect, not the cause, has been remedied. No back-of-panel adjustment should be undertaken except where evidence points to trouble in the particular section of the instrument affected by the control.

2. THEORY OF LOCALIZATION

The first step in correcting any trouble or failure that may occur is to isolate the section of the circuit that is causing the trouble. Such isolation can be accomplished by considering the circuit as composed of the basic sections shown in the over-all block diagram, Figure 1-2. Trouble ordinarily occurs in only one section at a time; thus, it is usually necessary to correct only the one trouble. As an aid in servicing, Trouble Shooting Chart, Table 4-1, indicates causes and remedies for certain specific troubles.

The next step after isolating the trouble to a particular section is to determine the tube circuit involved. A replacement tube should be tried before attempting any other tests. If trouble persists, voltage and resistance measurements should be made.

An over-all schematic of the circuit, together with a tube location diagram (Figure 4-5), will be found at the back of this section and should be consulted while trouble shooting. A list of component electrical parts, including descriptions, will be found following the tube location diagram.