INSTRUCTION MANUAL

Serial Number ____________

TYPE 310A OSCILLOSCOPE

Tektronix, Inc.
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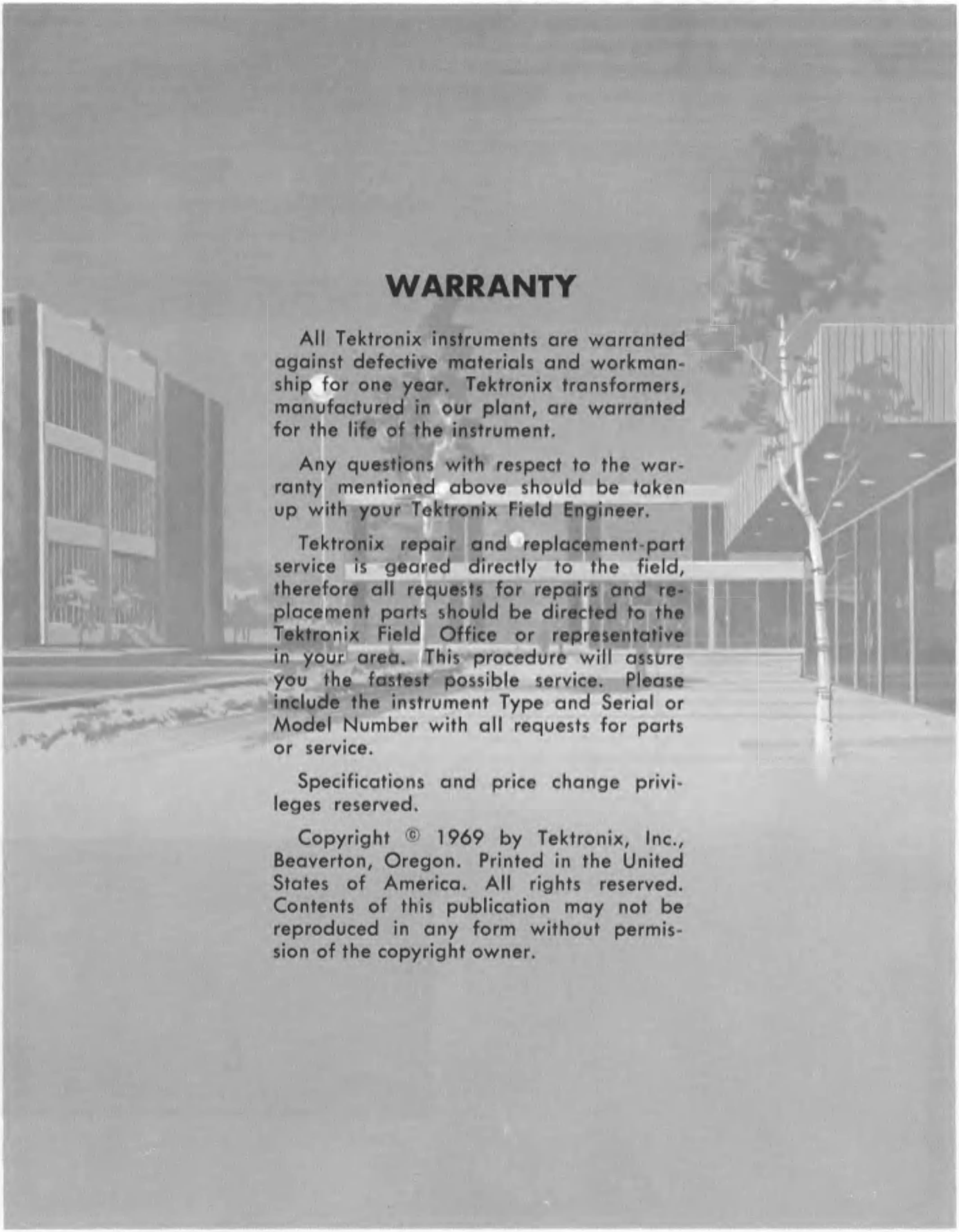
070-0893-00 **669**



WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our plant, are warranted for the life of the instrument.

Any questions with respect to the warranty mentioned above should be taken up with your Tektronix Field Engineer.

Tektronix repair and replacement-part service is geared directly to the field, therefore all requests for repairs and replacement parts should be directed to the Tektronix Field Office or representative in your area. This procedure will assure you the fastest possible service. Please include the instrument Type and Serial or Model Number with all requests for parts or service.

Specifications and price change privileges reserved.

CONTENTS

Abbreviations and symbols used in this manual are based on or taken directly from IEEE Standard 260 "Standard Symbols for Units", MIL-STD-12B and other standards of the electronics industry. Change information, if any, is located at the rear of this manual.

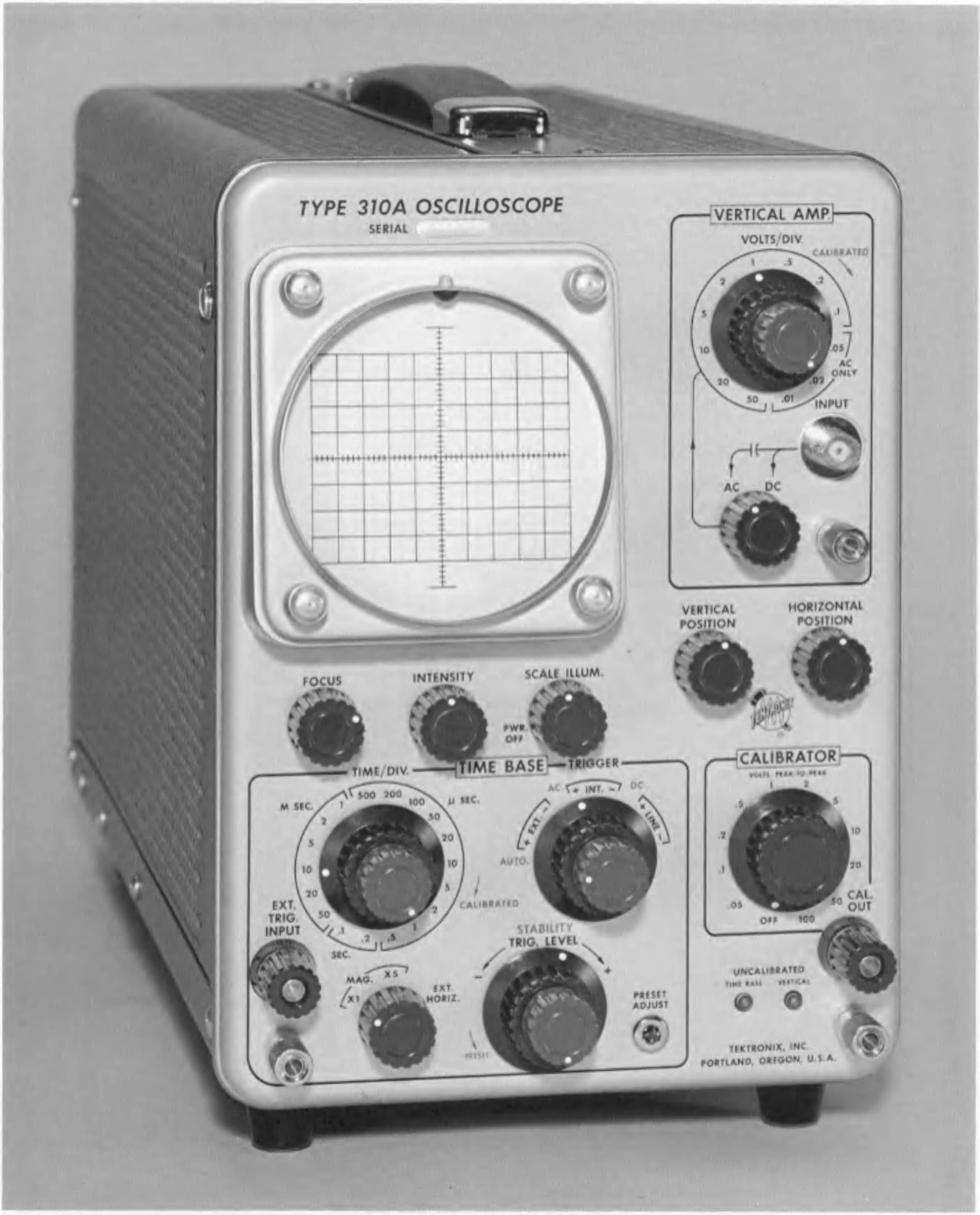


Fig. 1-1. The Type 310A Oscilloscope.

SECTION 1
TYPE 310A SPECIFICATION

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

The Tektronix Type 310A Oscilloscope is a portable precision instrument designed for equipment maintenance or calibration at its point of use. A DC to four megahertz vertical system provides calibrated deflection factors from 0.01 to 50 volts/division (0.01 to 0.05 volts/division AC coupled only). The trigger circuits provide stable triggering over the full vertical bandwidth. The horizontal deflection system provides calibrated sweep rates from 0.2 second to 0.5 microsecond/division. A X5 magnifier allows each sweep rate to be increased five times and provides a maximum sweep rate of 0.1 microsecond/division in the .5 μSEC position. X - Y measurements can be made by applying the vertical (Y) signal to the vertical INPUT connector and the horizontal (X) signal to the EXT HORIZ INPUT binding post on the rear panel (Horizontal Display switch set to EXT HORIZ). The regulated DC power supplies maintain constant output over a wide variation of line voltages and frequencies. Total power consumption is about 175 watts.

This instrument will meet the electrical characteristics listed in Table 1-1 following complete calibration as given in Section 5. The performance check procedure given in Section 5 provides a convenient method of checking instrument performance without making internal checks or adjustments. The following electrical characteristics apply over a calibration interval of 500 hours after a warmup time of 20 minutes.

TABLE 1-1

ELECTRICAL

Vertical Deflection System

Characteristic	Performance
Deflection Factor	
Calibrated range	
DC coupled	0.1 volt/division to 50 volts/division in 9 steps. Steps in 1-2-5 sequence.
AC coupled	0.01 volt/division to 50 volts/division in 12 steps. Steps in 1-2-5 sequence.
Accuracy	Within 3% of indicated deflection factor.
Uncalibrated (variable) range	Continuously variable between steps. Extends maximum uncalibrated deflection factor to at least 125 volts/division.
Bandwidth	
Upper −3 dB point, AC (capacitive) and DC (direct) coupled	
.1 to 50 volts/division	Four megahertz or greater.
.01, .02 and .05 volts/division (AC only)	3.5 megahertz or greater.
Lower −3 dB point, AC (capacitive) coupled	
Without probe	Two hertz or less.
With probe	0.2 hertz or less.
Risetime	
.1 to 50 volts/division	Approximately 90 nanoseconds.
.01, .02 and .05 volts/division (AC only)	Approximately 100 nanoseconds.
Input Coupling	AC (capacitive) and DC (direct) coupled. Selected by front-panel Input Coupling switch.
Maximum Input Voltage	600 volts + peak AC.
Input RC Characteristics	
Resistance	One megohm.
Capacitance	40 picofarads.

Characteristic	Performance
Triggering	
Trigger Source	Internal, external, or line. Selected by TRIGGER switch.
Trigger Coupling	AC (capacitive) or DC (direct) coupled. Selected by Trigger Coupling-Mode switch.
Trigger Polarity	Sweep can be triggered from positive-going or negative-going portion of trigger signal. Selected by TRIGGER switch.
Trigger Mode	Manual trigger adjustable for desired level or automatic triggering at average level of triggering waveform with free-running sweep at 50 hertz repetition rate in absence of adequate trigger signal. Selected by Trigger Coupling-Mode switch.
Trigger Sensitivity	
Internal (minimum for stable triggering)	
AC	0.25 division of deflection minimum, 30 hertz to one kilohertz; increasing to two divisions at four megahertz. Typical −3 dB point, 16 hertz.
DC	0.25 division of deflection minimum, DC to one kilohertz; increasing to two divisions at four megahertz.
AUTO	0.25 division of deflection minimum, 60 hertz to one kilohertz; increasing to two divisions at two megahertz.
External (minimum signal for stable triggering)	
AC	0.2 volt minimum, 30 hertz to one kilohertz; increasing to two volts at four megahertz. Typical −3 dB point, 16 hertz.
DC	0.2 volt minimum, DC to one kilohertz; increasing to two volts at four megahertz.
AUTO	0.2 volt minimum, 60 hertz to one kilohertz; increasing to two volts at two megahertz.
External Trigger Input	
Input Resistance	Approximately one megohm.

Characteristic	Performance
Time Base	
Sweep Rate	
Calibrated range	0.5 microsecond to 0.2 second/division in 18 steps. Steps in 1-2-5 sequence. Each sweep rate can be increased five times with the X5 magnifier. Extends fastest sweep rate to 0.1 microsecond/division.
Unmagnified time measurement accuracy over center eight divisions of graticule	Within 3% of indicated sweep rate.
Magnified time measurement accuracy over center eight divisions of graticule (equivalent magnified sweep rates given)	
0.2 microsecond to 40 millisecond/division	Within 4% of equivalent magnified sweep rate.
0.1 microsecond/division	Within 5% of equivalent magnified sweep rate.
Uncalibrated (variable) range	Continuously variable sweep rate between steps. Extends slowest uncalibrated sweep rate to at least 0.5 second/division.
External Horizontal Operation	
Deflection Factor	1.5 volt/division, or less, with HORIZ GAIN control fully clockwise.
X Bandwidth at Upper −3 dB Point, DC (direct) coupled	At least 500 kilohertz.
Input Resistance	Approximately 100 kilohms.
Calibrator	
Wave shape	Square wave.
Output Voltage	0.5 to 100 volts peak to peak in 11 steps. Steps in 1-2-5 sequence.
Voltage Accuracy	Within 3% of indicated output voltage.
Repetition Rate	Approximately one kilohertz.

Characteristic	Performance
Power Supply	
Line Voltage Range	
110 volts nominal	99 to 117 volts.
117 volts nominal	105 to 124 volts.
124 volts nominal	111 to 132 volts.
220 volts nominal	198 to 234 volts.
234 volts nominal	210 to 248 volts.
248 volts nominal	222 to 264 volts.
Line Frequency	50 to 800 hertz (increase line voltage about 4% for correct regulation at 800 hertz).
Power Consumption	Approximately 175 watts.
Cathode-Ray Tube (CRT)	
Graticule	
Type	External with variable edge lighting.
Area	Eight divisions vertical by 10 divisions horizontal. Each division equals 0.25 inch.
Beam Modulation	20 volts peak to peak connected to CRT CATHODE binding posts provides trace modulation at normal intensity.

TABLE 1-2

PHYSICAL

Dimensions (measured at maximum points)	
Height	10 7/8 inches (27.6 centimeters).
Width	6 15/16 inches (17.6 centimeters).
Depth	17 11/16 inches (44.9 centimeters).
Finish	Anodized front panel and chassis. Blue vinyl painted cabinet.

STANDARD ACCESSORIES

Standard accessories supplied with the Type 310A are listed in the Mechanical Parts List at the rear of this manual. For optional accessories available for use with this instrument, see the Tektronix, Inc. catalog.

NOTES

SECTION 2
OPERATING INSTRUCTIONS

Change information, if any, affecting this section will be found at the rear of the manual.

General

To effectively use the Type 310A, the operation and capabilities of the instrument must be known. This section describes the operation of the front-panel controls, gives first-time and general operating information and lists some basic applications.

Power Requirements

The Type 310A can be operated from either a 117-volt or a 234-volt nominal line-voltage source. Two auxiliary windings in addition to the standard windings allow the nominal primary voltage to be increased or descreased in steps of seven volts from 117-volts nominal (to provide 110, 117 or 124 volt nominal operation) or 14 volt steps from 234-volts nominal (to provide 220, 234 or 248-volt nominal operation). As the nominal operating voltage is changed, the regulating range of the power supply changes also, to provide regulated output voltages with input line voltages about 10% lower and 6% higher than the nominal voltage. The regulating range for each line voltage that this instrument can be wired for is as follows:

110-volts nominal	99 - 117 volts
117-volts nominal	105 - 124 volts
124-volts nominal	111 - 132 volts
220-volts nominal	198 - 234 volts
234-volts nominal	210 - 248 volts
248-volts nominal	222 - 264 volts

This instrument will regulate over a line frequency range of 50 to 800 cycles. For correct regulation at 800 cycles, increase the minimum line voltage requirement about 4%. Power consumption is approximately 175 watts. To convert to a different line voltage than the one for which the instrument is wired, use the following procedure.

1. Disconnect the instrument from the power source.

2. Connect the transformer for the desired line voltage as shown in Fig. 2-1.

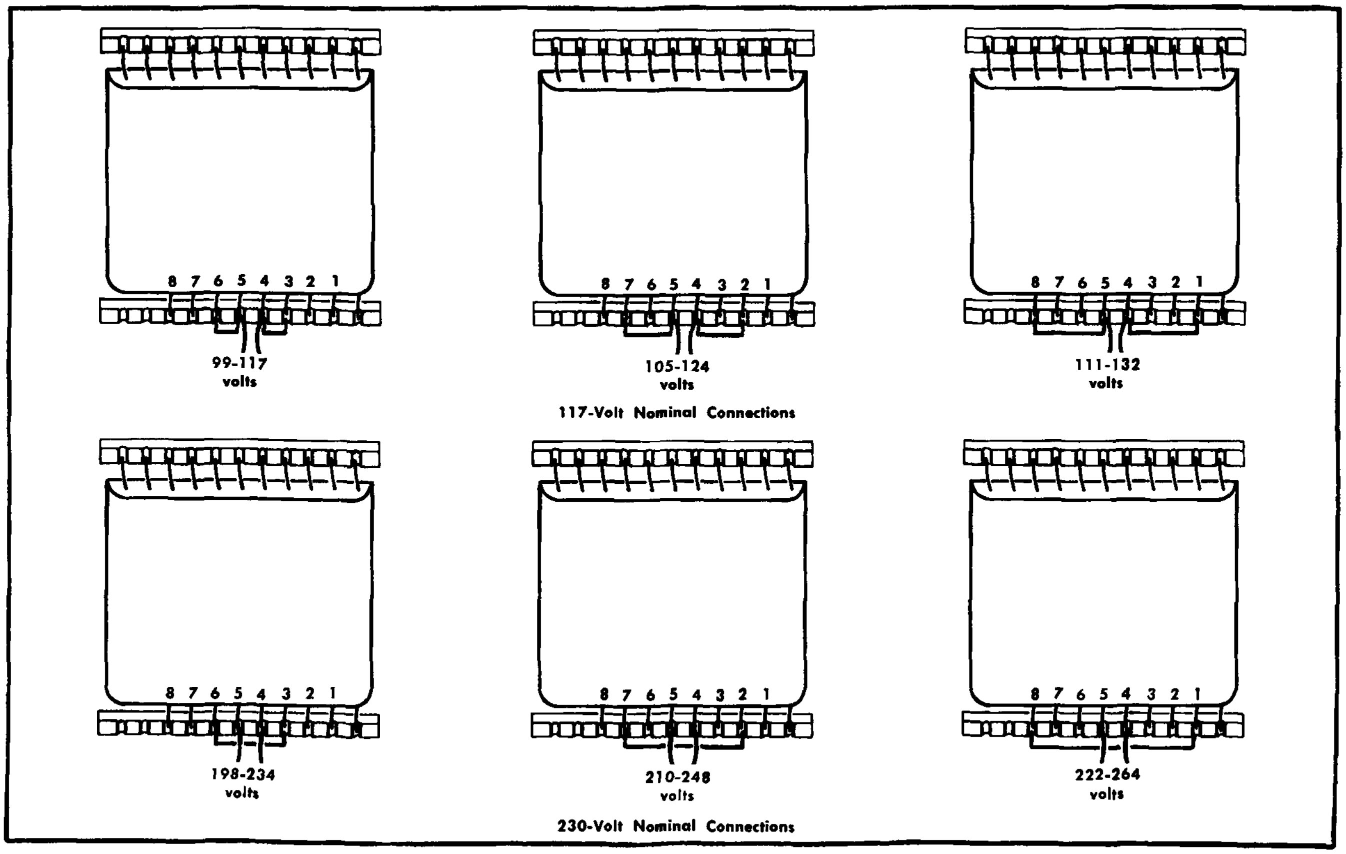


Fig. 2-1. Power transformer primary connections.

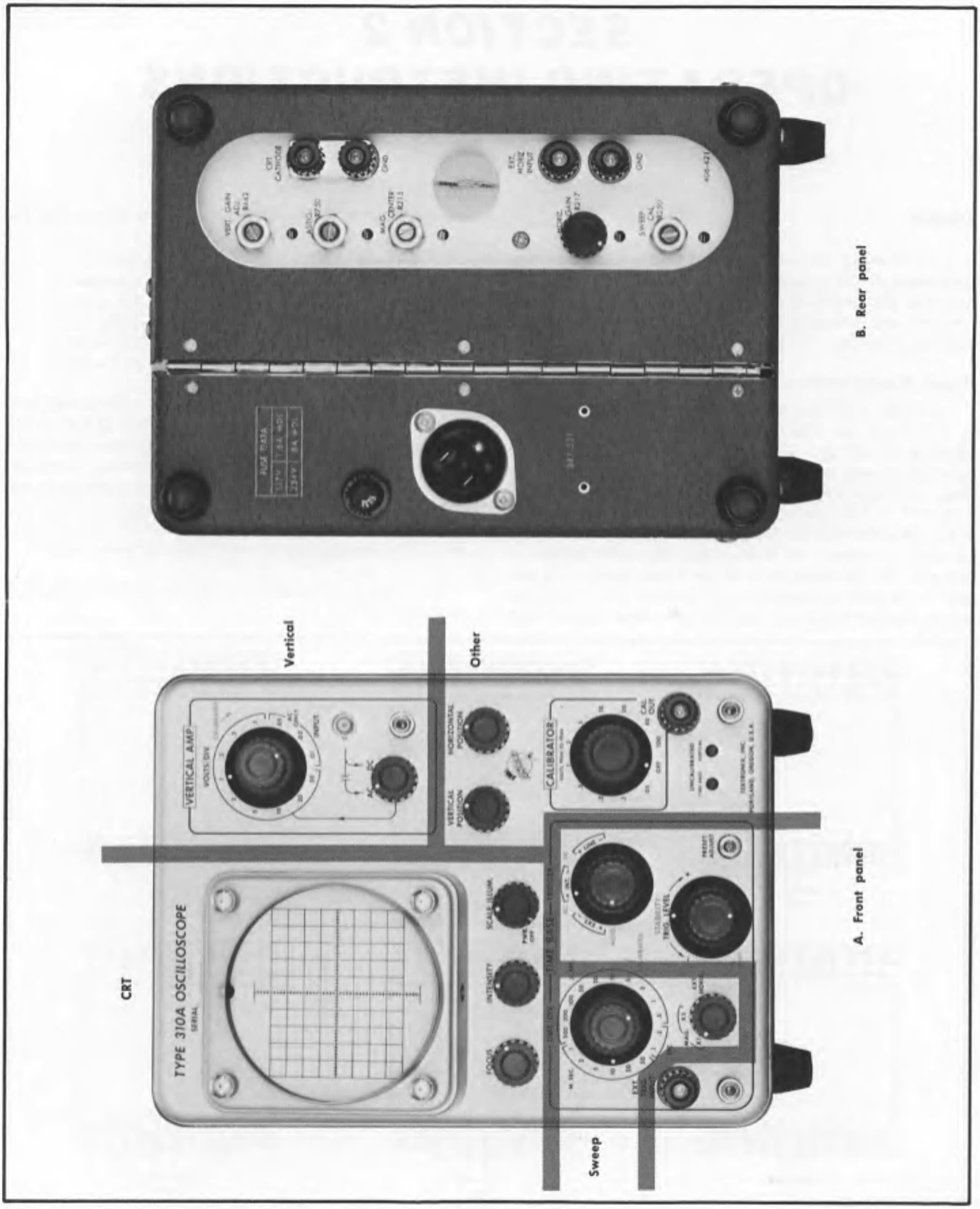


Fig. 2-2. Front- and rear-panel controls and connectors.

3. If converting from 117-volt to 234-volt nominal line voltage or vice versa, change the line-cord power plug to match the power-source receptacle or use a suitable adapter.

4. If converting from 117-volt to 234-volt nominal line voltage or vice versa, change the line fuse as follows:

117-volts nominal	1.6 ampere, slow-blow
234-volts nominal	0.8 ampere, slow-blow

5. Change the voltage tag on the rear of the instrument to indicate the correct regulating range. The new tag can be obtained from your local Tektronix Field Office or representative. State the regulating range desired.

This instrument is designed to be used with a three-wire AC power system. If a three- to two-wire adapter is used to connect this instrument to a two-wire AC power system, be sure to connect the ground lead of the adapter to ground. Failure to complete the ground system may allow the chassis to be elevated above ground potential and pose a shock hazard.

Operating Temperature

The Type 310A is cooled by convection air flow through the holes in the cabinet. For this reason, it is important to choose a location for the instrument where the air flow is not restricted or the temperature of the cooling air is not higher than the ambient temperature. The clearance provided by the feet at the bottom and rear should be maintained. Allow several inches clearance on the sides.

A thermal cutout provides thermal protection and disconnects the power to the instrument if the internal temperature exceeds a safe operating level. If the thermal cutout opens frequently, choose a different location for the instrument which provides better air circulation, or provides forced-air cooling. An accessory fan base is available for use with the Type 310A. This fan base is particularly useful when the Type 310A is placed in a permanent location. In addition to providing forced-air cooling, the fan base elevates the front of the instrument. This makes it easier to view the display and adjust the front-panel controls. The fan base can be ordered through your local Tektronix Field Office or representative.

Operating Position

Rubber feet are provided both on the bottom and rear of the Type 310A. In some locations, it may be easier to view the display when the instrument is set on the rear feet. However, the air flow through the instrument is restricted in this position reducing the cooling effeciency. Therefore, the instrument may overheat.

CONTROLS AND CONNECTORS

General

A brief description of the function and operation of the front- and rear-panel controls and connectors follows. Fig. 2-2 shows the front and rear panels of this instrument. More detailed information is given in this section under General Operating Information.

Cathode-Ray Tube (CRT)

FOCUS	Provides adjustment for a well defined display.
INTENSITY	Controls brightness of display.
SCALE ILLUM	Dual purpose control to determine graticule illumination and to apply power to the instrument. In the fully counterclockwise position, power is off. As the control is rotated clockwise out of the detent, power is applied to the instrument and the graticule lights come on at maximum intensity. Continued rotation of the control reduces the graticule illumination.

Vertical

VOLTS/DIV	Selects vertical deflection factor in 1-2-5 sequence (Variable VOLTS/DIV control must be in CALIBRATED position for indicated deflection).
Variable VOLTS/DIV (not labeled—red knob concentric with VOLTS/DIV switch)	Provides continuously variable uncalibrated deflection factors between the calibrated settings of the VOLTS/DIV switch. UNCALIBRATED VERTICAL light at lower right corner of front panel indicates when the Variable VOLTS/DIV control is not in the CALIBRATED position.
INPUT	Input connector for vertical deflection signals.
Input Coupling (AC-DC)	Determines method of coupling input signal to vertical amplifier. AC: DC component of input signal is blocked. Low frequency −3 dB point is about two hertz. DC: All frequency components of the input signal are passed to the vertical amplifier.

Trigger

TRIGGER — Selects the source and slope of the trigger signal which starts the sweep. The sweep can be triggered from either the positive-going or negative-going portion of the trigger signal in each of the following source positions:

+ EXT —: Trigger signal obtained from an external signal applied to the EXT TRIG INPUT binding post.

+ INT —: Trigger signal obtained from vertical deflection system.

+ LINE —: Trigger signal obtained from a sample of the line voltage applied to this instrument.

Trigger Coupling-Mode (AUTO AC DC) — Determines the method of coupling the trigger signal to the trigger circuit, or the trigger mode.

AUTO: Sweep automatically triggered at the average level of the applied trigger signal when the trigger signal repetition rate is above about 60 hertz. For lower repetition rates or when an adequate trigger signal is not applied, the sweep free runs at about a 50 hertz rate. TRIG LEVEL control is inoperative.

AC: Rejects DC and attenuates signals below about 30 hertz. Accepts signals between about 30 hertz and four megahertz. Triggering point determined by TRIG LEVEL control.

DC: Accepts all trigger signals from DC to four megahertz or greater. Triggering point determined by TRIG LEVEL control.

TRIG LEVEL — Selects amplitude point on trigger signal where sweep is triggered.

STABILITY — Sets the time-base generator for triggered or free-running operation. In the fully counterclockwise PRESET position, the time-base is automatically set for triggered operation.

PRESET ADJUST — Screwdriver adjustment to provide correct operation of the instrument in the PRESET position of the STABILITY control.

EXT TRIG INPUT — Input binding post for external trigger signal.

Sweep

TIME/DIV — Selects sweep rate of the time-base generator (Variable TIME/DIV control must be in CALIBRATED position for indicated sweep rate).

Variable TIME/DIV (not labeled—red knob concentric with TIME/DIV switch) — Provides continuously variable uncalibrated sweep rates between the calibrated settings selected by the TIME/DIV switch. UNCALIBRATED TIME BASE light at lower right corner of front panel indicates when Variable TIME/DIV control is not in CALIBRATED position.

Horizontal Display (MAG-EXT HORIZ) — Determines horizontal mode of operation.

X1 MAG: Normal sweep at sweep rate selected by the TIME/DIV switch.

X5 MAG: Magnified sweep at sweep rate five times faster than setting of TIME/DIV switch.

EXT HORIZ: Horizontal deflection provided by an external signal connected to the rear-panel EXT HORIZ INPUT binding post.

Other

VERTICAL POSITION — Controls vertical position of the trace.

HORIZONTAL POSITION — Controls horizontal position of the trace.

CALIBRATOR — Selects the peak-to-peak amplitude of the square wave available at the CAL OUT binding post.

CAL OUT — Calibrator output binding post.

UNCALIBRATED — TIME BASE: Light indicates that the horizontal sweep rate is uncalibrated.

VERTICAL: Light indicates that the vertical deflection factor is uncalibrated.

Rear Panel

VERT GAIN ADJ — Screwdriver adjustment to set the gain of the vertical amplifier.

ASTIG	Screwdriver adjustment used in conjunction with the FOCUS control to obtain a well-defined display.
CRT CATHODE	Input binding post for intensity modulating signals.
GND	Ground terminal to establish a common ground between this instrument and the source of the intensity modulating signal.
MAG CENTER	Screwdriver adjustment to set the DC level of the horizontal amplifier so deflection at the center of the display does not move when the horizontal Display switch is set to X5 MAG.
HORIZ GAIN	Control to set the gain of the horizontal amplifier for external horizontal operation.
EXT HORIZ INPUT	Input binding post for external horizontal deflection signals.
GND	Ground terminal to establish a common ground between this instrument and the source of the external horizontal deflection signal.
SWEEP CAL	Screwdriver adjustment to set the gain of the horizontal amplifier for correct normal sweep timing.

FIRST-TIME OPERATION

General

The following steps demonstrate the use of the controls and connectors of the Type 310A. It is recommended that this procedure be followed completely for first time familiarization with this instrument.

Setup Information

1. Set the front-panel controls as follows:

CRT controls	
FOCUS	Midrange
INTENSITY	Counterclockwise
SCALE ILLUM	PWR OFF
Vertical controls	
VOLTS/DIV	.1
Variable	CALIBRATED
Input Coupling	DC
Trigger controls	
TRIGGER	+ INT
Trigger Coupling-Mode	AUTO
TRIG LEVEL	Midrange
STABILITY	PRESET
Sweep controls	
TIME/DIV	500 μSEC
Variable	CALIBRATED
Horizontal Display	X1 MAG
Other controls	
VERTICAL POSITION	Midrange
HORIZONTAL POSITION	Midrange
Rear Panel controls	
HORIZ GAIN	Clockwise

2. Connect the Type 310A to a power source that meets the voltage and frequency requirements of the instrument.

3. Turn the SCALE ILLUM control clockwise from the PWR OFF detent to turn on the instrument. Allow several minutes warmup so the instrument reaches a normal operating temperature before proceeding.

CRT Controls

4. Advance the INTENSITY control until the trace is at the desired viewing level (about midrange).

5. Connect the CAL OUT binding post to the vertical INPUT connector with the 18-inch BNC-to-banana plug patch cord (supplied accessory). For instruments between SN10,000 and 20,474 use an 18-inch banana-plug patch cord.

6. Adjust the FOCUS control for a sharp, well-defined display over the entire trace length. If focused display cannot be obtained, see Astigmatism Adjustment in this section.

7. Rotate the SCALE ILLUM control throughout its range and notice that the graticule lines are illuminated as the control is turned counterclockwise (most obvious with tinted filter installed). Set the control so the graticule lines are illuminated as desired.

Vertical Controls

8. Center the display about the center horizontal line with the VERTICAL POSITION control. The display is a square wave, five divisions in amplitude with about five cycles displayed. If the display is not five divisions in amplitude, see Vertical Gain Adjustment in this section.

9. Temporarily disconnect the input signal and position the trace to the center horizontal line with the VERTICAL POSITION control.

10. Reconnect the input signal to the vertical INPUT connector. Notice that the baseline of the square wave is near the center horizontal line.

11. Set the Input Coupling switch to AC. Notice that the waveform is centered about the center horizontal line (ground reference).

12. Turn the Variable VOLTS/DIV control throughout its range. Notice that the UNCALIBRATED VERTICAL light in the lower right corner of the front panel comes on when the Variable VOLTS/DIV control is moved from the CALIBRATED position (fully clockwise). The deflection should be reduced to about two divisions in the fully counterclockwise position. Return the Variable VOLTS/DIV control to the CALIBRATED position.

Triggering Controls

13. Rotate the TRIG LEVEL and STABILITY controls throughout their range. Notice that neither control has any effect on the display in the AUTO position of the Trigger Coupling-Mode switch. Set the TRIG LEVEL control counterclockwise and the STABILITY control to PRESET.

14. Temporarily disconnect the input signal. Notice that a reference trace is presented. Reconnect the input signal.

15. Set the Trigger Coupling-Mode switch to AC. Slowly rotate the TRIG LEVEL control clockwise until a display appears. Notice that the display starts near the bottom of the square wave. Continue rotating the TRIG LEVEL control clockwise and notice that less of the leading edge of the square wave is shown as the TRIG LEVEL control is turned toward + (it may be difficult to observe this effect due to the fast rise of the calibrator waveform).

16. Set the TRIG LEVEL and STABILITY controls fully clockwise. Notice that the display drifts across the display area, indicating that the time-base generator is free running.

17. Slowly rotate the STABILITY control counterclockwise until the display disappears. Now rotate the TRIG LEVEL control counterclockwise until a stable display appears. This setting of the TRIG LEVEL and STABILITY control provides a stable display of this signal, but may need readjustment if the signal changes amplitude or repetition rate.

18. Set the STABILITY control to the PRESET position. The display should again be stable (if not, readjust the TRIG LEVEL control for a stable display). This position of the STABILITY control automatically provides the correct STABILITY setting, and can be used for most applications. Now, when the input signal changes amplitude or repetition rate, only the TRIG LEVEL control needs readjustment.

19. Set the TRIGGER switch to –INT. The trace starts on the negative-going part of the square wave. Return the TRIGGER switch to +INT; the display starts with the positive-going part of the square wave.

20. Set the Trigger Coupling-Mode switch to DC. Turn the VERTICAL POSITION control clockwise until the display becomes unstable or disappears completely (only part of square wave may be visible). Return the Trigger Coupling-Mode switch to AC; the display is again stable. Since changing vertical position of the trace changes the DC level of the internal trigger signal, this demonstration shows how DC level changes affect DC trigger coupling. Return the display to the center of the display area.

21. Connect the 10X probe (supplied accessory) to the vertical INPUT connector. Connect the probe tip to a line-voltage source. Set the TRIGGER switch to – LINE and set the VOLTS/DIV switch for a display about four divisions in amplitude. If necessary, adjust the TRIG LEVEL control for a stable display. Notice that the display starts on the negative-going part of the sine wave. Set the TRIGGER switch to + LINE; the display starts with the positive-going part of the sine wave. Disconnect the probe.

22. Connect the CAL OUT binding post to the vertical INPUT connector with the 18-inch BNC-to-banana plug patch cord (supplied accessory) and to the EXT TRIG INPUT binding post with an 18-inch banana-plug patch cord (for instruments between SN10,000 and 20,474 use two banana-plug patch cords). Set the TRIGGER switch to +EXT and the VOLTS/DIV switch to .1. Operation of the Trigger Coupling-Mode, TRIG LEVEL and STABILITY controls are the same as described in steps 12 through 20.

23. Disconnect the patch cord from between the CAL OUT and EXT TRIG INPUT binding posts. Set the TRIGGER switch to +INT.

Normal and Magnified Sweep

24. Set the TIME/DIV switch to 1 MSEC and note the CRT display. Then set the TIME/DIV switch to 5 MSEC and set the Horizontal Display switch to X5 MAG. The display should be similar to that obtained with the TIME/DIV switch set to 1 MSEC and the Horizontal Display switch set to X1 MAG.

25. Turn the HORIZONTAL POSITION control throughout its range and note that the sweep is magnified in both directions from the center vertical line. Any 10-division portion of the magnified sweep can be positioned onto the viewing area with the HORIZONTAL POSITION control. Return the TIME/DIV switch to 500 μSEC, the Horizontal Display switch to X1 MAG and return the start of the trace to the left edge of the graticule with the HORIZONTAL POSITION control.

26. Turn the Variable TIME/DIV control throughout its range. Notice that the UNCALIBRATED TIME BASE light in the lower right corner of the front panel comes on when the Variable TIME/DIV control is moved from the CALIBRATED position (fully clockwise). The sweep rate is reduced as the Variable TIME/DIV control is turned counterclockwise as indicated by more cycles displayed on the CRT. Return the Variable TIME/DIV control to the CALIBRATED position.

External Horizontal

27. Connect the CAL OUT jack to the EXT HORIZ INPUT binding post on the rear panel with two 18-inch

banana-plug patch cords. Reduce the INTENSITY control setting to protect the CRT phosphor.

28. Set the VOLTS/DIV switch to 1, the Horizontal Display switch to EXT HORIZ and the CALIBRATOR switch to 5. Advance the INTENSITY control setting until a display is visible (two dots displayed diagonally). The display should be five divisions vertically and about four divisions horizontally.

29. Turn the HORIZ GAIN control on the rear panel throughout its range and notice that the display decreases horizontally as this control is rotated counterclockwise. This control can be used to provide calibrated external horizontal deflection. Disconnect the patch cords and set the Horizontal Display switch to X1 MAG.

Z-Axis Input

30. If an external signal is available (20 volts peak-to-peak minimum), the function of the CRT CATHODE input on the rear panel can be demonstrated. Remove the ground strap from between the CRT CATHODE and GND binding posts and connect the external signal to both the vertical INPUT connector and the CRT CATHODE binding post. Set the TIME/DIV switch to display about five cycles of the waveform and, if necessary, adjust the INTENSITY control to show blanking. The positive peaks of the waveform should be blanked and the negative peaks intensified.

31. Disconnect all equipment and replace the ground strap between the CRT CATHODE and GND binding posts.

This completes the basic operating procedure for the Type 310A. Instrument operations not explained here, or operations which need further explanation are discussed under General Operating Information.

TEST SETUP CHART

General

Fig. 2-3 shows the front and rear panels of the Type 310A. This chart can be reproduced and used as a test-setup record for special measurements, applications or procedures, or it may be used as a training aid for familiarization with this instrument.

GENERAL OPERATING INFORMATION

Intensity Control

The setting of the INTENSITY control may affect the correct focus of the display. Slight readjustment of the FOCUS control may be necessary when the intensity level is changed. To protect the CRT phosphor, do not turn the INTENSITY control higher than necessary to provide a satisfactory display. The light filters reduce the observed light output from the CRT. When using these filters, avoid advancing the INTENSITY control to a setting that may burn the phosphor. When the highest intensity display is desired, remove the filter and use the clear graticule only. Apparent trace intensity can also be improved in such cases by reducing the ambient light or using a viewing hood. Also, be careful that the INTENSITY control is not set too high when changing the TIME/DIV switch from a fast to a slow sweep rate, or when switching to the external horizontal mode of operation.

Astigmatism Adjustment

NOTE

To check for proper setting of the ASTIG adjustment, slowly turn the FOCUS control through the optimum setting. If the ASTIG adjustment is correctly set, the vertical and horizontal portions of the display will come into sharpest focus at the same setting of the FOCUS control. This setting of the ASTIG adjustment should be correct for any display. However, it may be necessary to reset the FOCUS control slightly when the INTENSITY control is changed.

If a well-defined display cannot be obtained with the FOCUS control, adjust the ASTIG adjustment on the rear panel as follows:

1. Connect the CAL OUT binding post to the vertical INPUT connector and set the VOLTS/DIV switch to present a two-division display.

2. Set the TIME/DIV switch to 200 μSEC.

3. With the FOCUS and ASTIG adjustments set to midrange, adjust the INTENSITY control so the rising portion of the display can be seen.

4. Set the ASTIG adjustment so the horizontal and vertical portions of the display are equally focused, but not necessarily well focused.

5. Set the FOCUS control so the vertical portion of the trace is as thin as possible.

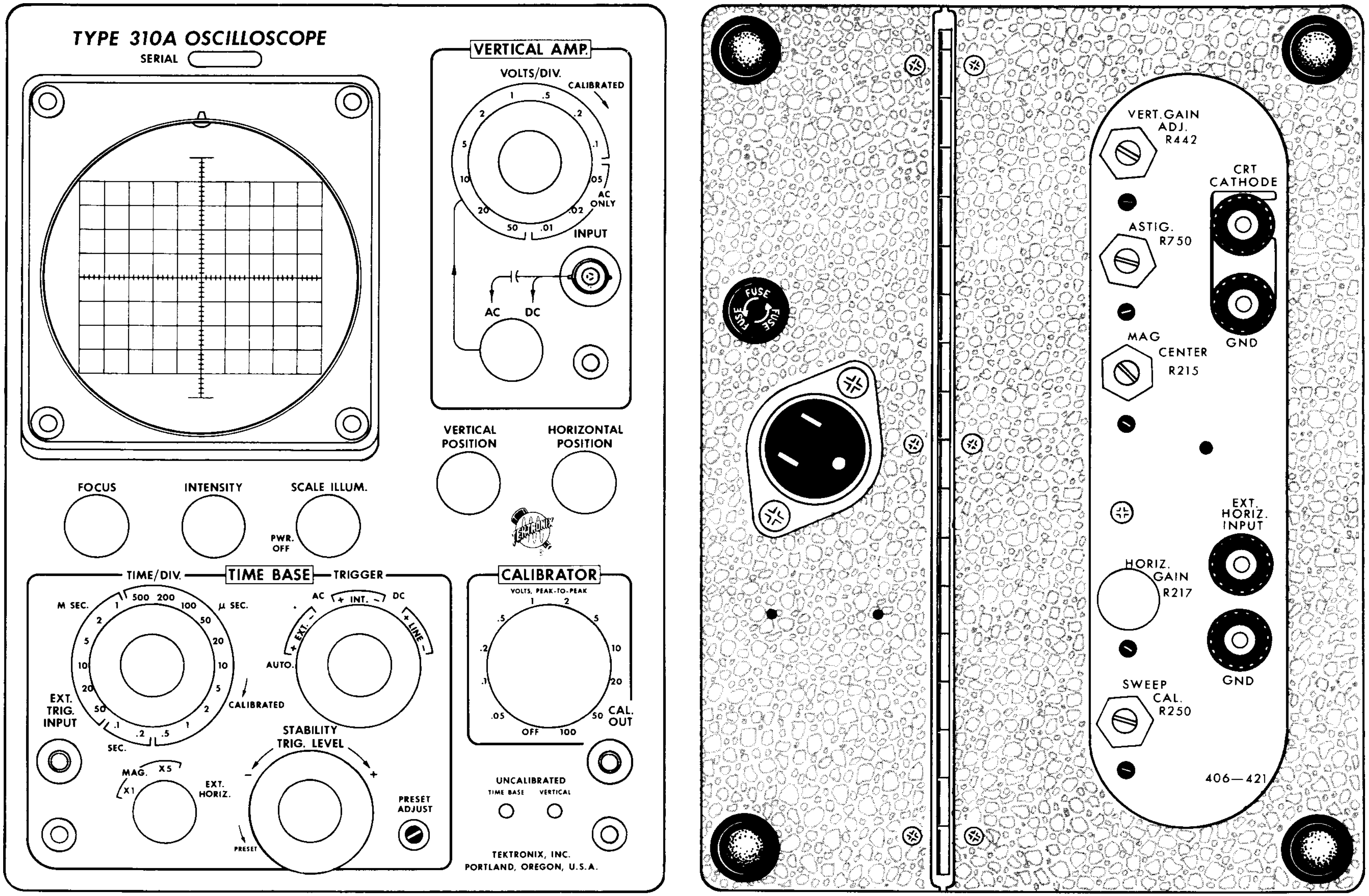
6. Repeat steps 4 and 5 for best overall focus. Make final check at normal intensity.

Graticule

The graticule of the Type 310A is scribed on the clear plastic faceplate protector. The graticule is marked with eight vertical and 10 horizontal divisions. Each division is 1/4-inch square. In addition, each major division is marked off in five minor divisions at the center vertical and horizontal lines. The vertical gain and horizontal timing are calibrated to the graticule so accurate measurements can be made from the CRT. The illumination of the graticule lines can be varied with the SCALE ILLUM control. Fig. 2-4 shows the graticule of the Type 310A and defines the various measurement lines. The terminology defined here is used in all discussions involving graticule measurements.

When making waveform measurements using the graticule, be careful that errors are not introduced into the

TYPE 310A TEST SETUP CHART



(A) Front Panel

(B) Rear Panel

Fig. 2-3.

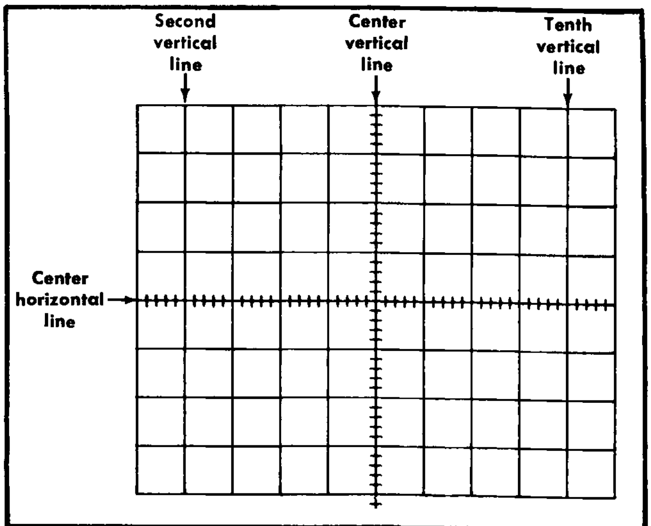


Fig. 2-4. Definition of measurement lines on Type 310A graticule.

measurement due to parallax. Fig. 2-5 illustrates how parallax affects a measurement. To minimize measurement errors due to parallax be sure that the graticule is installed so the scribed side is toward the CRT face. Also, when making the measurement, attempt to position your eye on a viewing plane perpendicular to the CRT face. The graticule, tinted filter or similar clear plastic protector should be used at all times to prevent permanent damage to the CRT face.

Light Filter

The tinted light filter provided with the Type 310A minimizes light reflection from the face of the CRT to improve contrast when viewing the display under high ambient light conditions. To install the filter, remove the four bezel nuts on the graticule cover and remove the cover. Place the filter on the mounting studs and replace the graticule cover and bezel nuts. The filter can be used with or without the graticule.

Vertical Gain Check

To check the vertical gain, set the VOLTS/DIV switch to .1 and the CALIBRATOR switch to .5. Connect the CAL OUT binding post to the vertical INPUT connector with the 18-inch BNC-to-banana plug patch cord (supplied accessory). (For instruments between SN 10,000 and 20,474 use an 18-inch banana-plug patch cord.) The vertical deflection should be exactly five divisions. If not, adjust the rear panel VERT GAIN adjustment for exactly five divisions of deflection

NOTE

For the most accurate vertical gain adjustment and best measurement accuracy, use the vertical gain adjustment procedure given in the Calibration section.

The best measurement accuracy when using a probe is provided if the VERT GAIN adjustment is made with the probe installed. This compensates for any inaccuracies of the probe. Also, to provide the best measurement accuracy, calibrate the vertical gain of the Type 310A at the temperature at which the measurement is to be made.

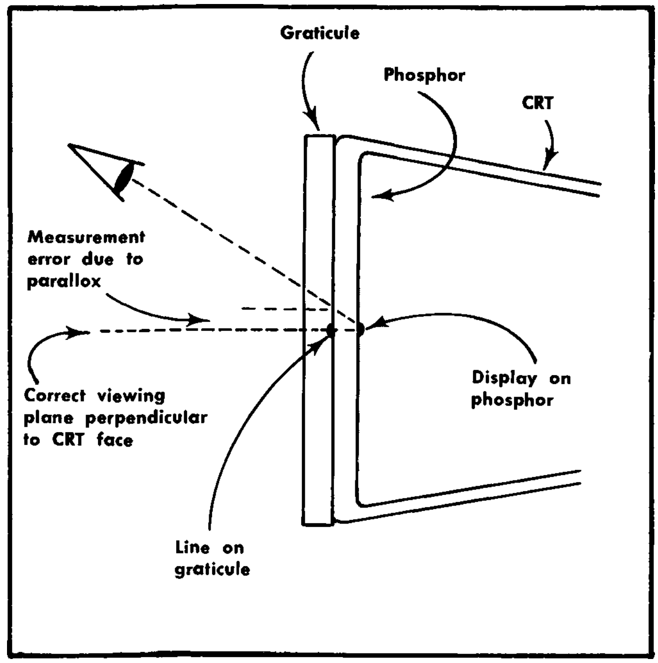


Fig. 2-5. Effect of parallax on measurement accuracy.

Signal Connections

In general, probes offer the most convenient means of connecting a signal to the vertical INPUT connector of the Type 310A. Tektronix probes are shielded to prevent pickup of electrostatic interference. A 10X attenuator probe offers a high input impedance and allows the circuit under test to perform very close to normal operating conditions. However, a 10X probe also attenuates the input signal 10 times. A 1X probe can be used for signal connection, although it does not provide as high an input impedance and may result in a lower overall bandwidth. Specialized probes are also available from Tektronix, Inc. for high-voltage measurement, current measurement, etc. See the Tektronix, Inc. catalog for characteristics and compatibility of probes for use with this system.

In applications requiring maximum overall bandwidth, use coaxial cables terminated in their characteristic impedances at the Type 310A vertical INPUT connector. High-level, low-frequency signals can be connected directly to the Type 310A vertical INPUT connector using the BNC-to-BNC patch cord or BNC-to-banana plug patch cord (supplied accessory). This coupling method works best for signals below about one kilohertz and deflection factors above one volt/division. When this coupling method is used, establish a common ground between the Type 310A and the equipment under test. Attempt to position the leads away from any source of interference to avoid errors in the display. If interference is excessive with unshielded leads, use a coaxial cable or a probe.

Loading Effect of the Type 310A

As nearly as possible, simulate actual operating conditions in the equipment under test. Otherwise, the equipment under test may not produce a normal signal. The 10X attenuator probes mentioned previously offer the least circuit loading. See the probe instruction manual for loading characteristics of the individual probes.

When the signal is coupled directly to the vertical INPUT connector of the Type 310A, the input impedance is about one megohm paralleled by about 40 picofarads. When the signal is coupled to the vertical INPUT connector through a coaxial cable, the effective input capacitance is increased. The actual input capacitance depends upon the type and length of cable used and the frequency of the signal.

Ground Considerations

Reliable signal measurements cannot be made unless this oscilloscope and the unit under test are connected together by a common reference (ground) lead in addition to the signal lead or probe. Although the three-wire AC power cord provides a common connection when used with equipment with similar power cords, the ground loop produced may make measurements impossible. The ground straps supplied with the probes provide an adequate ground. The shield of a coaxial cable provides a common ground when connected between two coaxial connectors (or with suitable adapters to provide a common ground). When using unshielded signal leads, a common ground lead should be connected from the Type 310A chassis to the chassis of the equipment under test.

Input Coupling

The Input Coupling switch (AC DC) allows a choice of the input coupling method. The type of display desired and the applied signal will determine the coupling used.

The DC coupling position can be used for most applications. This position allows measurement of the DC component of a signal. It must also be used to display signals below about 20 hertz (two hertz with a 10X probe) as they will be attenuated in the AC position.

In the AC coupling position, the DC component of the signal is blocked by a capacitor in the input circuit. The low-frequency response in the AC position is about two hertz (−3 dB point). Therefore, some low-frequency attenuation can be expected near this frequency limit. Attenuation in the form of tilt will also appear in square waves which have low-frequency components. The AC coupling position provides the best display of signals with a DC component that is much larger than the AC component.

Deflection Factor

The amount of vertical deflection produced by a signal is determined by the signal amplitude, the attenuation factor of the probe (if used), the setting of the VOLTS/DIV switch and the setting of the Variable VOLTS/DIV control. The calibrated deflection factors indicated by the VOLTS/DIV switch apply only when the Variable VOLTS/DIV control is set to the CALIBRATED position.

The Variable VOLTS/DIV control provides variable (uncalibrated) vertical deflection factors between the calibrated settings of the VOLTS/DIV switch. The Variable VOLTS/DIV control extends the maximum vertical deflection factor of the Type 310A to at least 125 volts/division in the 50 position.

Trigger Source

INT. For most applications, the sweep can be triggered internally. In the INT position of the TRIGGER switch, the trigger signal is obtained from the vertical deflection system. The sweep is triggered from the same waveform that is displayed on the CRT.

EXT. An external signal connected to the EXT TRIG INPUT binding post can be used to trigger the sweep in the EXT position of the TRIGGER switch. The external signal must be time-related to the displayed signal to produce a stable display. An external trigger signal can be used to provide a trigger display when the internal signal is too low in amplitude for correct triggering, or contains signal components on which it is not desired to trigger. It is also useful when signal tracing in amplifiers, phase-shift networks, wave-shaping circuits, etc. The signal from a single point in the circuit under test can be connected to the EXT TRIG INPUT binding post. Then the sweep is triggered by the same signal at all times. This allows amplitude, time relationship or wave shape changes of signals at various points in the circuit to be examined without resetting the trigger controls.

LINE. The LINE position of the TRIGGER switch connects a sample of the power- line frequency to the trigger circuit. Line triggering is useful when the input signal is time-related to the power-line frequency. It is also useful for providing a stable display of a line-frequency component in a complex waveform.

Trigger Coupling

AC. In the AC position of the Trigger Coupling-Mode switch, the DC component of the trigger signal is blocked. Signals with low-frequency components below about 30 hertz are attenuated. In general, AC coupling can be used for most applications. However, if the sweep is to be triggered at a low repetition rate or a DC level, use the DC position of the Trigger Coupling-Mode switch.

The triggering point in the AC position depends upon the average voltage level of the trigger signal. If the trigger signals occur in a random fashion, the average voltage level will vary, causing the triggering point to vary also. This shift of the triggering point may be enough to make it impossible to maintain a stable display. In such cases, use DC trigger coupling.

DC. DC trigger coupling can be used to provide stable triggering with low-frequency signals which should be attenuated in the AC position, or with low-repetition rate signals. It can also be used to trigger the sweep when the trigger signal reaches a DC voltage level selected by the setting of the TRIG LEVEL control. When using the internal trigger source, the setting of the VERTICAL POSITION control affects the DC triggering point.

Trigger Slope

The TRIGGER switch selects the triggering slope as well as the source. Each source selected by the TRIGGER switch provides both + and – slope selection. When the TRIGGER switch is in a + (positive-going) position, the trigger circuits respond to the positive-going portion of the triggering waveform; in a – (negative-going) position, the trigger circuits respond to the negative-going portion of the triggering waveform (see Fig. 2-6). Since this instrument does not have an internal delay line, the display may not start on the selected slope, particularly when the displayed waveform has a high repetition rate. When several cycles of a signal appear in the display, the triggering slope is often unimportant. However, if only a certain portion of a cycle is to be displayed, correct setting of the TRIGGER switch is important to provide a display of the desired portion of the input signal.

Stability Control

The STABILITY control determines whether the time-base generator is free-running, triggerable, or not triggerable when the Trigger Coupling-Mode switch is set to AC or DC. When the STABILITY control is set fully clockwise, the time-base generator is free-running at a repetition rate determined by the setting of the TIME/DIV switch. As the STABILITY control is turned counterclockwise, the free-running condition ends when the control is near midrange (TRIG LEVEL control set fully clockwise). At this setting of the STABILITY control, a triggered display can be obtained with the TRIG LEVEL control (adequate trigger signal applied). In the fully counterclockwise position (not in PRESET detent), the time-base generator is inoperable and cannot be triggered. The PRESET position automatically sets the time-base generator for triggerable operation with most trigger signals. In this position, only the TRIG LEVEL control needs to be adjusted to obtain a stable display. The STABILITY control is inoperable in the AUTO position of the Trigger Coupling-Mode switch.

Trigger Preset Adjustment

The PRESET ADJUST is normally adjusted during instrument calibration (see Calibration section) and should not need readjustment during normal use. However, the following procedure can be used to set the PRESET ADJUST if the Type 310A cannot be triggered correctly. Before readjusting the PRESET ADJUST, be sure the triggering controls are correctly set and the applied trigger signal is within the required limits.

1. Set the TIME/DIV switch to 1 MSEC.

2. Set the Trigger Coupling-Mode switch to AUTO.

3. Turn the PRESET ADJUST fully counterclockwise.

4. Slowly turn the PRESET ADJUST clockwise until the trace first appears. Note the position of the PRESET ADJUST.

5. Continue to slowly turn the PRESET ADJUST clockwise until the trace brightens. Again note the position of the PRESET ADJUST.

6. Set the PRESET ADJUST halfway between the point where the trace first appeared in part 4 and where the trace brightened in part 5.

Trigger Level

The TRIG LEVEL control determines the voltage level on the triggering waveform at which the sweep is triggered (Trigger Coupling-Mode switch set to AC or DC). When the TRIG LEVEL control is set in the + region, the trigger circuit responds at a more positive point on the trigger signal. In the – region, the trigger circuit responds at a more negative point on the trigger signal. Fig. 2-6 illustrates this effect with different settings of the TRIGGER switch. The TRIG LEVEL control is inoperative in the AUTO position of the Trigger Coupling- Mode switch.

To set the TRIG LEVEL control, first select the trigger source, slope and coupling. Then set the STABILITY control to the PRESET position. Now, rotate the TRIG LEVEL control fully counterclockwise and slowly turn it back clockwise until a stable display appears. Further rotation in the clockwise direction causes the sweep to trigger at a more positive point on the triggering waveform. If a stable display cannot be obtained in this manner with the STABILITY control set to the PRESET position, use the following procedure: (be sure an adequate trigger signal is available):

1. Set the TRIG LEVEL control fully clockwise.

2. Set the STABILITY control fully clockwise and then rotate it counterclockwise until the free-running display just disapppears.

3. Rotate the TRIG LEVEL control counterclockwise until a stable display is obtained.

Trigger Mode

The Trigger Coupling-Mode switch (concentric with the TRIGGER switch) selects the operating mode of the triggering circuits. When this switch is in the AC or DC positions, the trigger circuits operate in the normal triggering mode. The TRIG LEVEL and STABILITY controls must be adjusted to obtain a stable display. When a trigger signal is not present, there is no display. Use the normal triggering mode to display signals with repetition rates below about 60 hertz, or when it is desired to select the triggering point on the displayed waveform. This mode provides an indication of an adequate trigger signal as well as the correctness of trigger control settings, since there is no display without correct triggering. For information on selecting the trigger

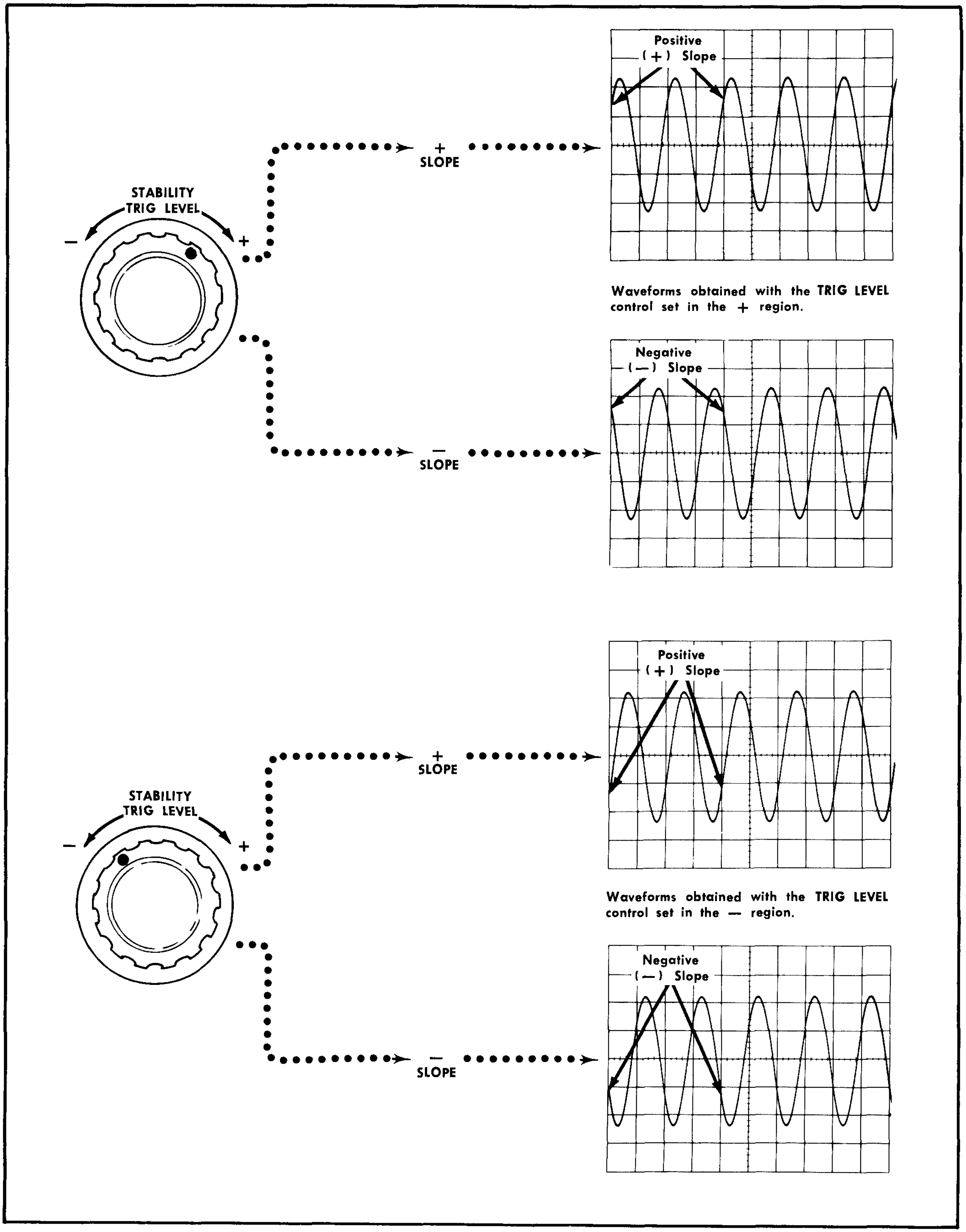


Fig. 2-6. Effect of the TRIG LEVEL control and triggering slope selection on the CRT display.

coupling, see the discussion titled Trigger Coupling in this section.

Automatic triggering is obtained in the AUTO position of the Trigger Coupling- Mode switch. In this position, triggering occurs at the average voltage level of the applied waveform. If a trigger signal is not present, the sweep is automatically retriggered at about a 50-hertz rate to provide a reference trace. Automatic triggering can be used with both internal and external trigger signals with repetition rates between about 60 hertz and two megahertz.

Automatic triggering is particularly useful when observing a series of waveforms since it is not necessary to set the TRIG LEVEL and STABILITY control for each observation. Therefore, this mode can be used for most applications and the normal triggering mode used when special applications are necessary or stable triggering is not obtainable in the AUTO mode.

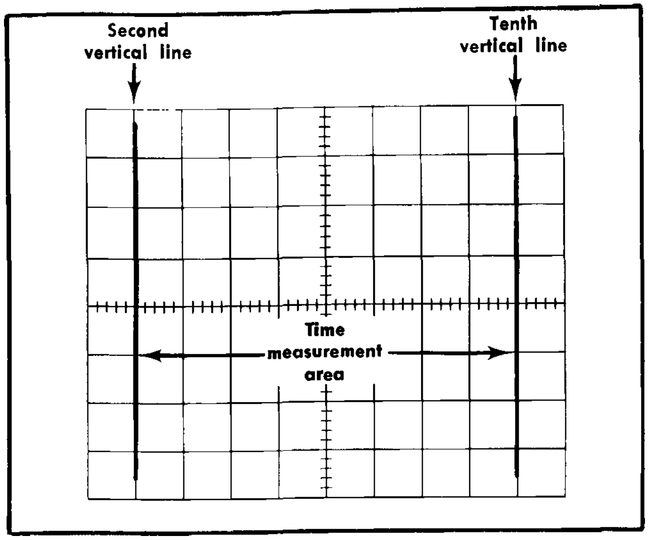


Fig. 2-7. Area of graticule used for accurate time measurements.

Horizontal Sweep Rate

The TIME/DIV switch provides 18 calibrated sweep rates ranging from 0.5 microsecond to 0.2 second/division. The Variable TIME/DIV control provides continuously variable sweep rates between the settings of the TIME/DIV switch. Whenever the UNCALIBRATED TIME BASE light in the lower right corner of the front panel is on, the sweep rate is uncalibrated. This light is off when the Variable TIME/DIV control is set fully clockwise to the CALIBRATED position.

When making time measurements from the graticule, the area between the second and tenth vertical lines provides the most linear time measurement (see Fig. 2-7). Therefore, the first and last division of the display should not be used when making accurate time measurements. Position the start of the timing area to the second vertical line and adjust the TIME/DIV switch so the end of the timing area falls between the second and tenth vertical lines.

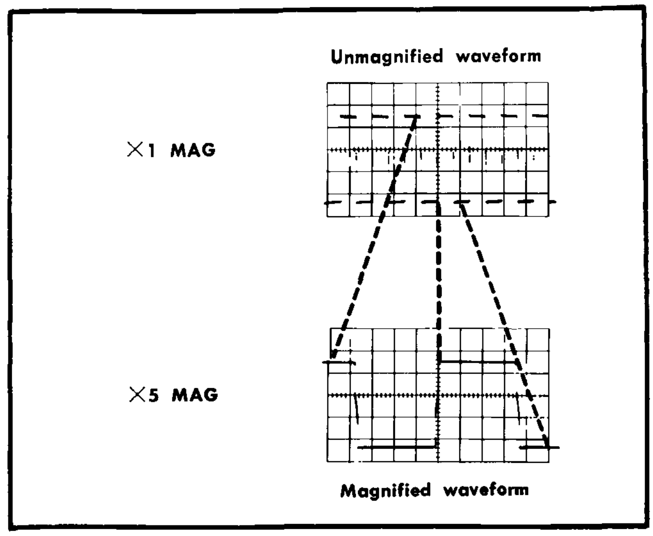


Fig. 2-8. Operation of the sweep magnifier.

Sweep Calibration and Mag Center Adjustments

The SWEEP CAL and MAG CENTER adjustments on the rear panel are adjusted as part of the calibration procedure and should not be adjusted during normal operation. See the Calibration section for complete adjustment procedure.

Sweep Magnification

The sweep magnifier can be used to increase each sweep rate five times. The center two divisions of the unmagnified display is the portion visible on the screen in magnified form (see Fig. 2-8). Equivalent length of the magnified sweep is more than 50 divisions; any 10-division portion can be viewed by adjusting the HORIZONTAL POSITION control to bring the desired portion onto the viewing area.

To use the magnified sweep, first move the portion of the display which is to be expanded to the center of the graticule. Then set the Horizontal Display switch to X5 MAG. Adjust the HORIZONTAL POSITION control for exact positioning of the magnified portion. When the Horizontal Display switch is set to X5 MAG, the sweep rate is determined by dividing the TIME/DIV switch setting by five. For example, if the TIME/DIV switch is set to 1 μSEC, the magnified sweep rate is 0.2 microsecond/division. The magnified sweep rate must be used for all time measurements when the Horizontal Display switch is set to X5 MAG. The magnified sweep rate is calibrated when the Variable TIME/DIV control is set fully clockwise to the CALIBRATED position (UNCALIBRATED TIME BASE light off).

External Horizontal Operation

In some applications, it is desirable to display one signal versus another signal (X-Y) rather than against time (internal sweep). The external horizontal mode of operation provides a means for applying an external signal to the horizontal amplifier for this type of display.

To use the external horizontal mode of operation, connect the external signal to the EXT HORIZ INPUT binding post on the rear panel and set the Horizontal Display switch to EXT HORIZ. External horizontal deflection factor with the HORIZ GAIN control (rear panel) set fully clockwise is 1.5 volts/division, or less. The HORIZ GAIN control provides variable attenuation of the external horizontal signal. This control can be adjusted to provide calibrated external horizontal deflection. The X and Y channels of this instrument are not time matched and some inherent phase shift is apparent, particularly at highter frequencies. Take this inherent phase shift into account when making measurements. For aid in interpreting lissajous displays, refer to the reference books listed under Applications.

Intensity Modulation

Intensity (Z-axis) modulation can be used to relate a third item of electrical phenomena to the vertical (Y-axis) and the horizontal (X-axis) coordinates without changing the wave shape. The Z-axis modulating signal applied to the CRT circuit through the CRT CATHODE and GND binding posts on the rear panel changes the intensity of the displayed waveform to provide this display. "Gray scale" intensity modulation does not completely blank the display. This type of display can be obtained by applying signals which are not high enough in amplitude to completely blank the display. Large amplitude positive-going signals completely blank portions of the display and negative-going signals intensify portions of the display. The sharpest display is provided by signals with a fast rise and fall. The voltage amplitude required to blank the display depends upon the setting of the INTENSITY control. At normal intensity level, a positive ten-volt signal will blank the display. When the CRT CATHODE binding post is not in use, keep the ground strap in place to prevent changes in trace intensity due to extraneous noise.

Time markers applied to the CRT CATHODE binding post provide a direct time reference on the display. With uncalibrated horizontal sweep or external horizontal mode operation, the time markers provide a means of reading time directly from the display. However, if the markers are not time-related to the displayed waveform, they will appear to be unstable.

Calibrator

The square-wave calibrator of the Type 310A provides a convenient signal source for checking basic vertical gain. However, to provide maximum measurement accuracy, the adjustment procedure given in the Calibration section should be used. The calibrator output signal is also very useful for adjusting probe compensation as described in the probe instruction manual. In addition, the calibrator can be used as a convenient signal source for application to external equipment.

APPLICATIONS

General

The following information describes the procedures and techniques for making basic measurements with a Type 310A Oscilloscope. These applications are not described in detail since each must be adapted to the requirements of the individual measurement. This instrument can also be used for many applications which are not described in this manual. Contact your local Tektronix Field Office or representative for assistance in making specific measurements with this instrument. Also, the following books describe oscilloscope measurement techniques which can be adapted for use with this instrument.

Harley Carter, "An Introduction to the Cathode Ray Oscilloscope", Phillips Technical Library, Cleaver-Hume Press Ltd., London, 1960.

J. Czech, "Oscilloscope Measuring Technique", Phillips Technical Library, Springer-Verlag, New York, 1965.

Robert G. Middleton and L. Donald Payne, "Using the Oscilloscope in Industrial Electronics", Howard W. Sams & Co. Inc., The Bobbs-Merrill Company Inc., Indianapolis, 1961.

John F. Rider and Seymour D. Uslan, "Encyclopedia of Cathode-Ray Oscilloscopes and their uses", John F. Rider Publisher Inc., New York, 1959.

John F. Rider, "Obtaining and Interpreting Test Scope Traces", John F. Rider Publisher Inc., New York, 1959.

Rufus P. Turner, "Pratical Oscilloscope Handbook", Volumes 1 and 2, John F. Rider Publisher Inc., New York, 1964.

Peak-to-Peak Voltage Measurements—AC

To make a peak-to-peak voltage measurement, use the following procedure:

1. Connect the signal to the vertical INPUT connector.

2. Set the VOLTS/DIV switch to display about five divisions of the waveform.

3. Set the Input Coupling switch to AC.

NOTE

For low-frequency signals below about 16 hertz, use the DC position.

4. Set the Triggering controls to obtain a stable display. Set the TIME/DIV switch to a position that displays several cycles of the signal.

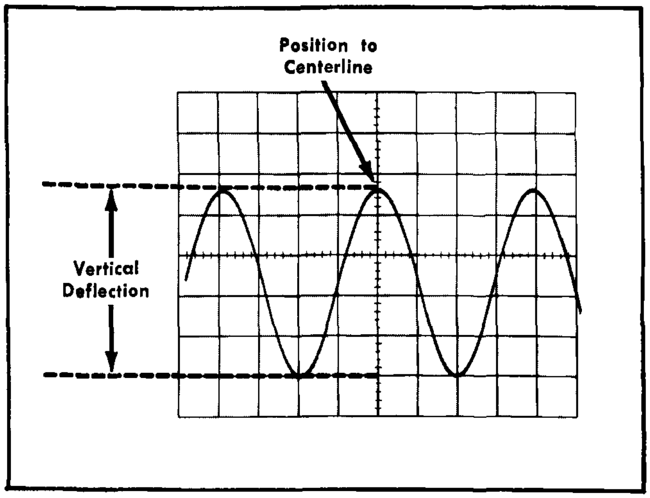


Fig. 2-9. Measuring peak-to-peak voltage of waveform.

5. Turn the VERTICAL POSITION control so the lower portion of the waveform coincides with one of the graticule lines below the center horizontal line, and the top of the waveform is on the viewing area. Move the display with the HORIZONTAL POSITION control, so one of the upper peaks lies near the center vertical line (see Fig. 2-9).

6. Measure the divisions of vertical deflection from peak to peak. Make sure the Variable VOLTS/DIV control is in the CALIBRATED position.

NOTE

This technique may also be used to make measurements between two points on the waveform, rather than peak to peak.

7. Multiply the distance measured in step 6 by the VOLTS/DIV switch setting. Also include the attenuation factor of the probe, if used.

Example. Assume a peak-to-peak vertical deflection of 4.6 divisions (see Fig. 2-9) using a 10X attenuator probe and a VOLTS/DIV switch setting of .5. Using the formula:

$$\text{Volts Peak to Peak} = \text{Vertical deflection (divisions)} \times \text{VOLTS/DIV setting} \times \text{probe attenuation factor}$$

Substituting the given values:

Volts Peak to Peak = 4.6 X 0.5 V X 10

The peak-to-peak voltage is 23 volts.

Instantaneous Voltage Measurements — DC

To measure the DC level at a given point on a waveform, use the following procedure:

1. Set the Trigger Coupling-Mode switch to AUTO.

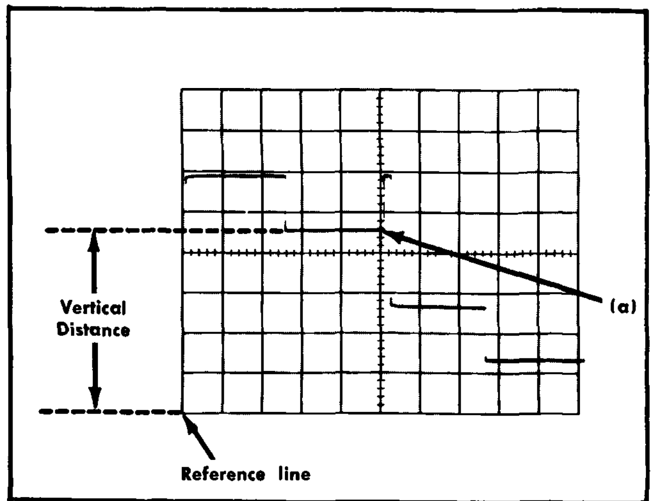


Fig. 2-10. Measuring instantaneous DC voltage with respect to a reference voltage.

2. Position the trace to the bottom line of the graticule or other reference line. If the voltage to be measured is negative with respect to ground, position the trace to the top line of the graticule. Do not move the VERTICAL POSITION control after this reference line has been established.

NOTE

To measure a voltage level with respect to a voltage other than ground, make the following changes in step 6: Set the Input Coupling switch to DC and apply the reference voltage to the vertical INPUT connector. Then position the trace to the reference line.

3. Connect the signal to the vertical INPUT connector.

4. Set the VOLTS/DIV switch to display about five divisions of the waveform.

5. Set the Input Coupling switch to DC.

6. Set the Triggering controls to obtain a stable display. Set the TIME/DIV switch to a setting that displays several cycles of the signal.

7. Measure the distance in divisions between the reference line and the point on the waveform at which the DC level is to be measured. For example, in Fig. 2-10 the measurement is made between the reference line and point A.

8. Establish the polarity of the signal. If the waveform is above the reference line, the voltage is positive; below the line, negative.

9. Multiply the distance measured in step 7 by the VOLTS/DIV switch setting. Include the attenuation factor of the probe, if used.

Example. Assume that the vertical distance measured is 4.6 divisions (see Fig. 2-10), the waveform is above the reference line, using a 10X attenuator probe and a VOLTS/DIV switch setting of 2.

Using the formula:

$$\text{Instantaneous Voltage} = \text{vertical distance (divisions)} \times \text{polarity} \times \text{VOLTS/DIV setting} \times \text{probe attenuation factor}$$

Substituting the given values:

$$\text{Instantaneous Voltage} = 4.6 \times +1 \times 2\text{ V} \times 10$$

The instantaneous voltage is +92 volts.

Comparison Measurements

In some applications it may be desirable to establish arbitrary units of measurement other than those indicated by the VOLTS/DIV switch or TIME/DIV switch. This is particularly useful when comparing unknown signals to a reference amplitude or repetition rate. One use for the comparison-measurement technique is to facilitate calibration of equipment (e.g., on an assembly-line test) where the desired amplitude or repetition rate does not produce an exact number of divisions of deflection. The adjustment will be easier and more accurate if arbitrary units of measurement are established so that correct adjustment is indicated by an exact number of divisions of deflection. Arbitrary sweep rates can be useful for comparing harmonic signals to a fundamental frequency or for comparing the repetition rate of the input and output pulses in a digital count-down circuit. The following procedure describes how to establish arbitrary units of measure for comparison measurements. Althouth the procedure for establishing vertical and horizontal arbitrary units of measurement is much the same, both processes are described in detail.

Vertical Deflection Factor. To establish an arbitrary vertical deflection factor based upon a specific reference amplitude, procede as follows:

1. Connect the reference signal to the vertical INPUT connector. Set the TIME/DIV switch to display several cycles of the signal.

2. Set the VOLTS/DIV switch and the Variable VOLTS/DIV control to produce a display an exact number of graticule divisions in amplitude. Do not change the Variable VOLTS/DIV control after obtaining the desired deflection. This display can be used as a reference for amplitude comparison measurements.

3. To establish an arbitrary vertical deflection factor so the amplitude of an unknown signal can be measured accurately at any setting of the VOLTS/DIV switch, the amplitude of the reference signal must be known. If it is not known, it can be measured before the Variable VOLTS/DIV control is set in step 2.

4. Divide the amplitude of the reference signal (volts) by the product of the vertical deflection established in step 2 (divisions) and the setting of the VOLTS/DIV switch. This is the vertical conversion factor.

$$\text{Vertical Conversion Factor} = \frac{\text{reference signal amplitude (volts)}}{\text{vertical deflection (divisions)} \times \text{VOLTS/DIV switch setting}}$$

5. To measure the amplitude of an unknown signal, disconnect the reference signal and connect the unknown signal to the vertical INPUT connector. Set the VOLTS/DIV switch to a setting that provides sufficient vertical deflection to make an accurate measurement. Do not readjust the Variable VOLTS/DIV control.

6. Measure the vertical deflection in divisions and calculate the amplitude of the unknown signal using the following formula.

$$\text{Signal Amplitude} = \text{VOLTS/DIV switch setting} \times \text{vertical conversion factor} \times \text{vertical deflection (divisions)}$$

Example. Assume a reference signal amplitude of 30 volts, a VOLTS/DIV switch setting of 5 and the Variable VOLTS/DIV control is adjusted to provide a vertical deflection of four divisions. Substituting these values in the vertical conversion factor formula (step 4):

$$\text{Vertical Conversion Factor} = \frac{30\text{ V}}{4 \times 5} = 1.5$$

Then, with a VOLTS/DIV switch setting of 10, the peak-to-peak amplitude of an unknown signal which produces a vertical deflection of five divisions can be determined by using the signal amplitude formula (step 6):

$$\text{Signal Amplitude} = 10\text{ V} \times 1.5 \times 5 = 75\text{ volts}$$

Sweep Rates. To establish an arbitrary horizontal sweep rate based upon a specific reference frequency, proceed as follows:

1. Connect the reference signal to the vertical INPUT connector. Set the VOLTS/DIV switch for four or five divisions of vertical deflection.

2. Set the TIME/DIV switch and the Variable TIME/DIV control so one cycle of the signal covers an exact number of horizontal divisions. Do not change the Variable TIME/DIV control after obtaining the desired deflection. This display can be used as a reference for frequency comparison measurements.

3. To establish an arbitrary sweep rate so the repetition rate of an unknown signal can be measured accurately at any setting of the TIME/DIV switch, the repetition rate of the reference signal must be known. If it is not known, it can be measured before the Variable TIME/DIV switch is set in step 2.

4. Divide the repetition rate of the reference signal (seconds) by the product of the horizontal deflection established in step 2 (divisions) and the setting of the TIME/DIV switch. This is the horizontal conversion factor.

$$\text{Horizontal Conversion Factor} = \frac{\text{reference signal repetition rate (seconds)}}{\text{horizontal deflection (divisions)} \times \text{TIME/DIV switch setting}}$$

5. To measure the repetition rate of an unknown signal, disconnect the reference signal and connect the unknown signal to the vertical INPUT connector. Set the TIME/DIV switch to a setting that provides sufficient horizontal deflection to make an accurate measurement. Do not readjust the Variable TIME/DIV control.

6. Measure the horizontal deflection in divisions and calculate the repetition rate of the unknown signal using the following formula:

$$\text{Repetition Rate} = \text{TIME/DIV switch setting} \times \text{horizontal conversion factor} \times \text{horizontal deflection (divisions)}$$

NOTE

If the horizontal magnifier is used, be sure to use the magnified sweep rate in place of the TIME/DIV switch setting.

Example. Assume a reference signal frequency of 455 hertz (repetition rate 2.19 milliseconds), a TIME/DIV switch setting of .2 ms and the Variable TIME/DIV control is adjusted to provide a horizontal deflection of eight divisions. Substituting these values in the horizontal conversion factor formula (step 4):

$$\text{Horizontal Conversion Factor} = \frac{2.19 \text{ milliseconds}}{.2 \times 8} = 1.37$$

Then, with a TIME/DIV switch setting of 50 μs, the repetition rate of an unknown signal which completes one cycle in seven horizontal divisions can be determined by using the repetition rate formula (step 6):

$$\text{Repetition Rate} = 50\,\mu s \times 1.37 \times 7 = 480\,\mu s$$

This answer can be converted to frequency by taking the reciprocal of the repetition rate (see application on Determining Frequency).

Time-Duration Measurements

To measure time between two points on a waveform, use the following procedure:

1. Connect the signal to the vertical INPUT connector.

2. Set the VOLTS/DIV switch to display about four divisions of the waveform.

3. Set the triggering control to obtain a stable display.

4. Set the TIME/DIV switch to the fastest sweep rate that displays less than eight divisions between the time measurement points (see Fig. 2-11). (See the topic entitled Horizontal Sweep Rate in this section concerning non-linearity of first and last divisions of display.)

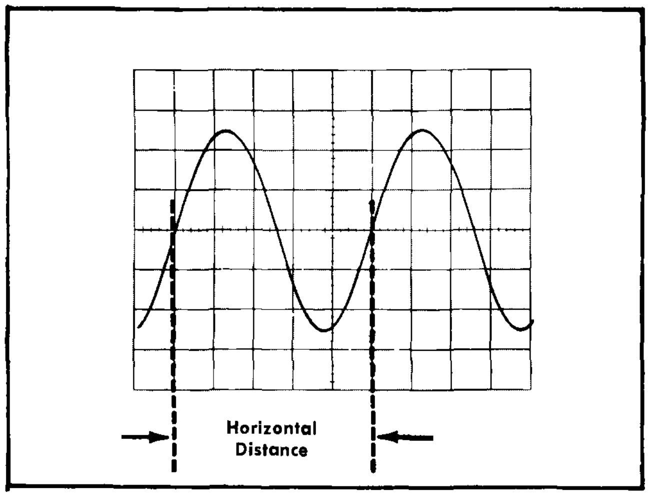


Fig. 2-11. Measuring the time duration between points on a waveform.

5. Adjust the VERTICAL POSITION control to move the points between which the time measurement is made to the center horizontal line.

6. Adjust the HORIZONTAL POSITION control to center the time-measurement points within the center eight divisions of the graticule.

7. Measure the horizontal distance between the time measurement points. Be sure the VARIABLE TIME/DIV control is set to CALIBRATED.

8. Multiply the distance measured in step 7 by the setting of the TIME/DIV switch. If sweep magnification is used, divide this answer by 5.

Example. Assume that the distance between the time measurement points is five divisions (see Fig. 2-11) and the TIME/DIV switch is set to .1 MSEC with the magnifier off. Using the formula:

$$\text{Time Duration} = \frac{\begin{matrix}\text{horizontal}\\ \text{distance}\\ \text{(divisions)}\end{matrix} \times \begin{matrix}\text{TIME/DIV}\\ \text{setting}\end{matrix}}{\text{magnification}}$$

Substituting the given values:

$$\text{Time Duration} = \frac{5 \times 0.1 \text{ ms}}{1}$$

The time duration is 0.5 milliseconds.

Determining Frequency

The time measurement technique can also be used to determine the frequency of a signal. The frequency of a periodically recurrent signal is the reciprocal of the time duration (period) of one complete cycle.

Use the following procedure:

1. Measure the time duration of one complete cycle of the waveform as described in the previous application.

2. Take the reciprocal of the time duration to determine the frequency.

Example. The frequency of the signal shown in Fig. 2-11, which has a time duration of 0.5 milliseconds is:

$$\text{Frequency} = \frac{1}{\text{time duration}} = \frac{1}{0.5 \text{ ms}} = 2 \text{ kilohertz}$$

Risetime Measurements

Risetime measurements employ essentially the same techniques as time-duration measurements. The main difference is the points between which the measurement is made. The following procedure gives the basic method of measuring risetime between the 10% and 90% points of the waveform. Falltime can be measured in the same manner on the trailing edge of the waveform.

1. Connect the signal to the vertical INPUT connector.

2. Set the VOLTS/DIV switch and the Variable VOLTS/DIV control to produce a signal an exact number of divisions in amplitude.

3. Center the display about the center horizontal line with the vertical POSITION control.

4. Set the triggering controls to obtain a stable display.

5. Set the TIME/DIV switch to the fastest sweep rate that displays less than eight divisions between the 10% and 90% points on the waveform.

6. Determine the 10% and 90% points on the rising portion of the waveform. The figures given in Table 2-1 are for the points 10% up from the start of the rising portion and 10% down from the top of the rising portion (90% point).

TABLE 2-1

Vertical display (divisions)	10% and 90% points	Divisions vertically between 10% and 90% points
4	0.4 and 3.6 divisions	3.2
5	0.5 and 4.5 divisions	4.0
6	0.6 and 5.4 divisions	4.8
7	0.7 and 6.3 divisions	5.6
8	0.8 and 7.2 divisions	6.4

7. Adjust the HORIZONTAL position control to move the 10% point of the waveform to the second vertical line of the graticule. For example, with a five-division display as shown in Fig. 2-12, the 10% point is 0.5 division up from the start of the rising portion.

8. Measure the horizontal distance between the 10% and 90% points. Be sure the Variable TIME/DIV control is set to CALIBRATED.

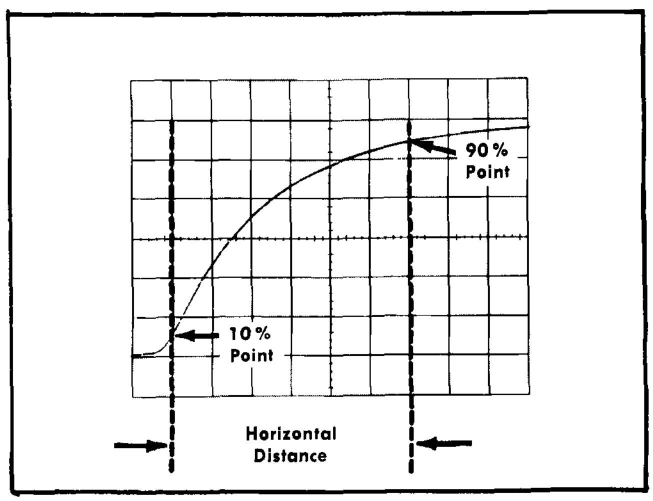


Fig. 2-12. Measuring risetime.

9. Multiply the distance measured in step 8 by the setting of the TIME/DIV switch. If sweep magnification is used, divide this answer by 5.

Example. Assume that the horizontal distance between the 10% and 90% points is four divisions (see Fig. 2-12) and the TIME/DIV switch is set to .5 µSEC with the Horizontal Display switch set to X5 MAG. Applying the time duration formula to risetime:

$$\text{Time Duration} = \frac{\begin{matrix}\text{horizontal}\\ \text{distance}\\ \text{(divisions)}\end{matrix} \times \begin{matrix}\text{TIME/DIV}\\ \text{setting}\end{matrix}}{\text{magnification}}$$

Substituting the given values:

$$\text{Risetime} = \frac{4 \times 0.5\ \mu s}{5}$$

The risetime is 0.4 microsecond.

NOTES

SECTION 3
CIRCUIT DESCRIPTION

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

This section of the manual contains a description of the circuitry used in the Type 310A Oscilloscope. The description begins with a discussion of the instrument using the basic block diagram shown in Fig. 3-1. Then each circuit is described in detail using a detailed block diagram to show the interconnections between the stages in each major circuit and the relationship of the front-panel controls to the individual stages. A complete block diagram is located in the Diagrams section at the back of this manual. Complete schematics of each circuit are also given in the Diagrams section. Refer to these diagrams throughout the following circuit description for electrical values and relationship.

BLOCK DIAGRAM

General

The following discussion is provided to aid in understanding the overall concept of the Type 310A before the individual circuits are discussed in detail. A basic block diagram of the Type 310A is shown in Fig. 3-1. Only the basic interconnections between the individual blocks are shown on this diagram. Each block represents a major circuit within the instrument.

Signals to be displayed on the CRT are applied to the vertical INPUT connector. Large signals can be attenuated the desired amount by the attenuator networks to prevent overdriving the input stage of the Vertical Amplifier. Low-amplitude signals can be amplified by the Vertical Preamplifier to provide adequate vertical deflection. The signal connected to the Vertical Amplifier circuit is amplified and converted to a push-pull signal to drive the vertical deflection plates of the CRT. This circuit contains vertical position, variable attenuation and vertical gain controls to produce the desired display. A trigger-pickoff stage in the Vertical Amplifier supplies a sample of the applied signal to the Time-Base Trigger circuit for internal triggering.

The Sweep Trigger circuit produces an output pulse which initiates the sweep signal produced by the Sweep Generator circuit. The input signal to the Sweep Trigger circuit can be selected from the internal trigger signal from the Vertical Amplifier circuit, an external signal connected to the EXT TRIG INPUT binding post, or a sample of the line voltage applied to this instrument. The Sweep Trigger circuit contains level, slope, coupling, source and mode controls to select the desired triggering.

The Sweep Generator circuit produces a linear sawtooth output signal when initiated by the Sweep Trigger circuit. The slope (sweep rate) of the sawtooth produced by the Sweep Generator circuit is controlled by the TIME/DIV switch. The Sweep Generator circuit also produces an unblanking gate signal to unblank the CRT so a display can be presented. The gate signal is coincident with the sawtooth output from this circuit.

The sawtooth output signal from the Sweep Generator circuit is connected to the Horizontal Amplifier to produce the horizontal deflection for the CRT in all positions of the Horizontal Display switch except EXT HORIZ. In the EXT HORIZ position, external signals connected to the EXT HORIZ INPUT binding post can be applied to the Horizontal Amplifier circuit to produce horizontal deflection on the CRT. The Horizontal Amplifier circuit amplifies the applied sawtooth or external horizontal deflection signal and produces a push-pull output signal to drive the horizontal deflection plates of the CRT. The Horizontal Amplifier circuit also contains a X5 magnifier circuit to increase the gain of the Horizontal Amplifier five times. When the Horizontal Display switch is set to the X5 MAG position, the sweep rate is five times faster than indicated by the TIME/DIV switch.

The CRT Circuit provides the voltages and contains the controls necessary for the operation of the cathode-ray tube. The CRT CATHODE binding post allows external signals to be connected to the cathode of the CRT to provide intensity modulation of the display. The Calibrator circuit produces a square-wave output which can be used to check the compensation of attenuator probes or for application to external equipment. The LV Power Supply circuit provides the low-voltage power necessary for operation of the instrument. This circuit is regulated to maintain constant output with changes in line voltage or frequency.

CIRCUIT DESCRIPTION

General

The following circuit analysis is written around detailed block diagrams which are given for each major circuit. These detailed block diagrams give the names of the individual stages within the major circuits and show how they are connected together to form the major circuit. The block diagrams also show the inputs and outputs for each circuit and the relationship of the front-panel controls to the individual stages. The names assigned to the individual stages on these block diagrams are used throughout the following discussion. The circuit diagrams from which the detailed block diagrams are derived are shown in the Diagrams section.

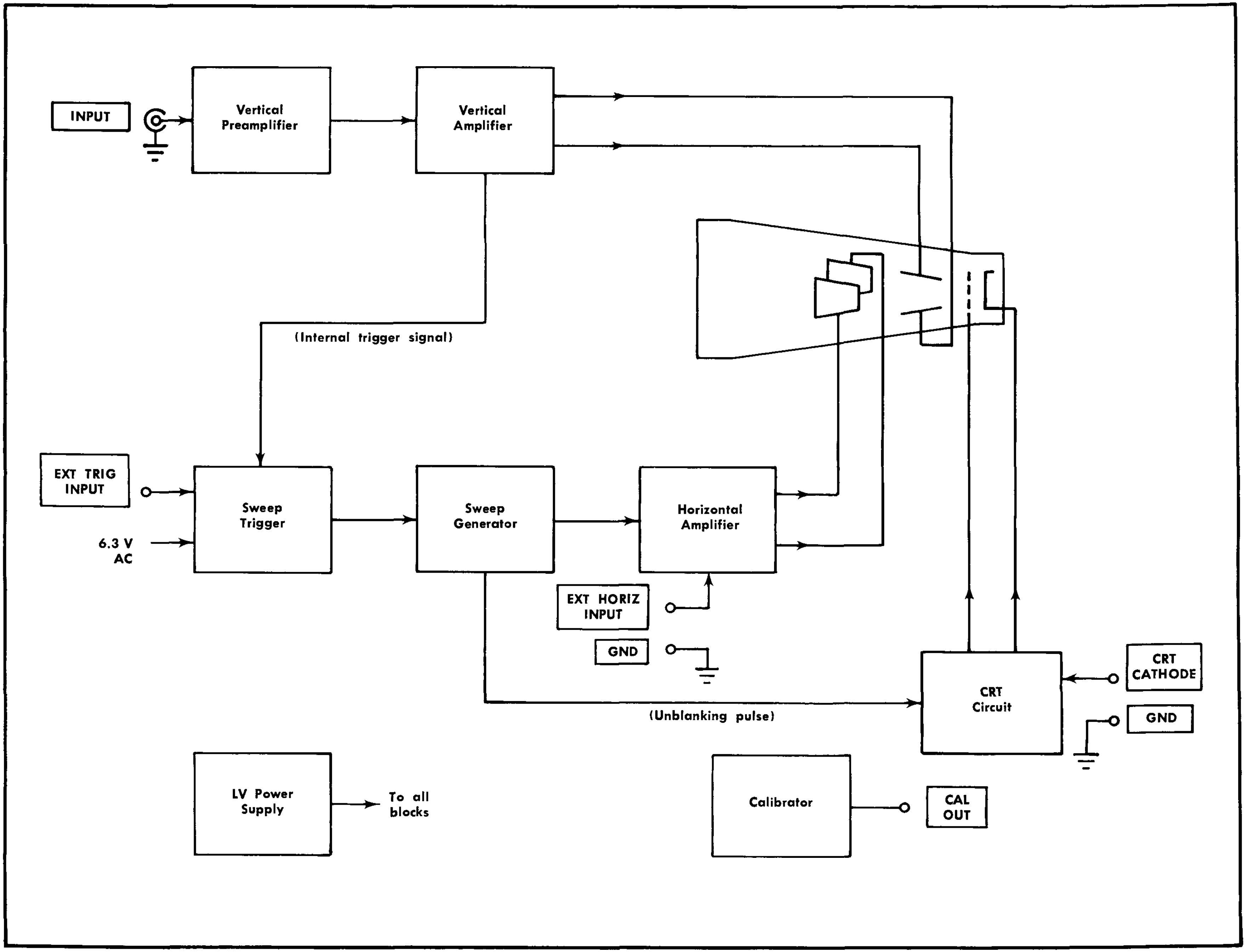


Fig. 3-1. Basic block diagram of the Type 310A Oscilloscope.

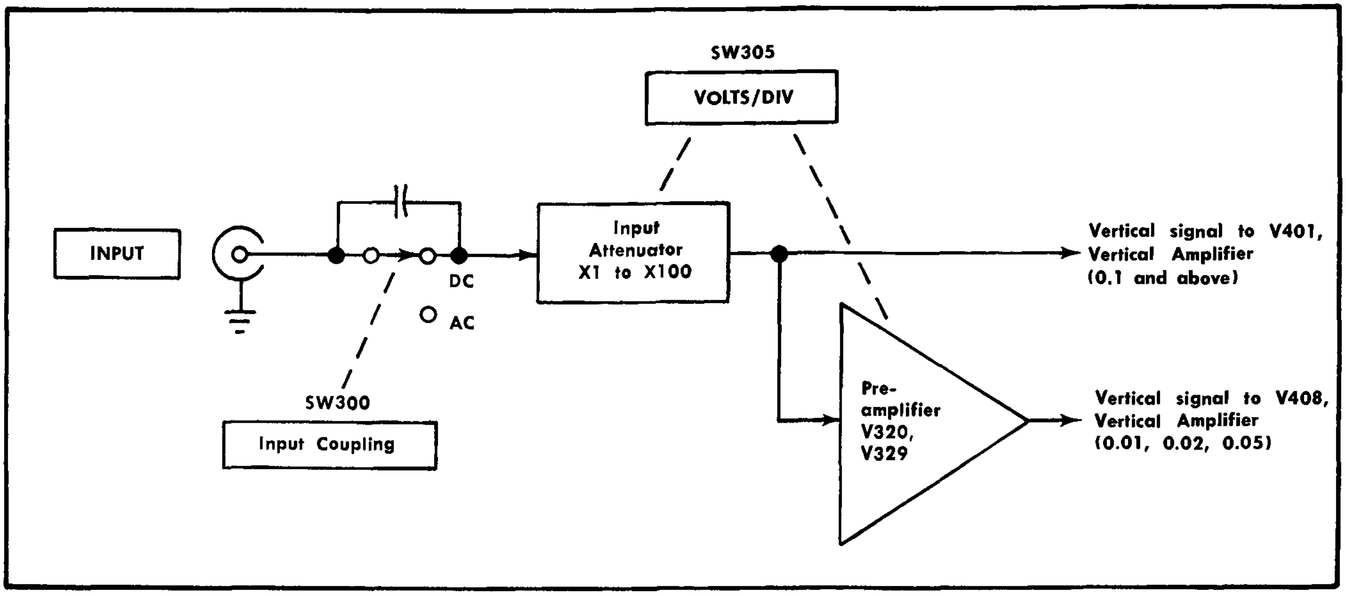


Fig. 3-2. Vertical Preamplifier detailed block diagram.

VERTICAL PREAMPLIFIER

General

Input signals for vertical deflection on the CRT can be connected to the vertical INPUT connector. This circuit provides control of input coupling, vertical deflection factor and DC balance. Fig. 3-2 shows a detailed block diagram of the Vertical Preamplifier circuit.

Input Coupling

Input signals connected to the vertical INPUT connector can be AC coupled or DC coupled to the Input Attenuator. When Input Coupling Switch SW300 is in the DC position, the input signal is coupled directly to the Input Attenuator stage (except when the VOLTS/DIV switch is in the .01, .02 and .05 positions). In the AC position or when the VOLTS/DIV switch is set to the .01, .02 or .05 positions, the input signal is connected through capacitors C315 and C316. These capacitors prevent the DC component of the input signal from passing to the Input Attenuator.

Input Attenuator

The effective overall vertical deflection factor of the Type 310A is determined by the VOLTS/DIV switch, SW305. In the VOLTS/DIV switch positions above .05, the basic deflection factor is 0.1 volt per division of CRT deflection, and in the .01, .02 and .05 positions the basic deflection factor is 0.01 volt per division. To increase the basic deflection factor to the values indicated on the front panel, precision attenuators are switched into the circuit. These attenuators are switched into the circuit singly or in pairs to produce the vertical deflection factor indicated on the front panel. These attenuators are frequency compensated voltage dividers. For DC and low-frequency signals, they are primarily resistance dividers and the voltage attenuation is determined by the resistance ratio in the attenuator. The reactance of the capacitors in the circuit is so high at low frequencies that their effect is negligible. However, at higher frequencies, the reactance of the capacitors decreases and the attenuator becomes primarily a capacitance voltage divider. Each attenuator contains an adjustable series capacitor to provide optimum response for the high-frequency components of the signal and an adjustable shunt capacitor for optimum response for the lower-frequency components. In addition to providing constant attenuation at all frequencies within the bandwidth of the instrument, the Input Attenuator is designed to maintain the same input RC characteristics (one megohm X 40 picofarads) for each position of the VOLTS/DIV switch. The signal from the Input Attenuator is connected directly to the Vertical Amplifier circuit in the positions of .1 and above. In the .01, .02 and .05 positions of the VOLTS/DIV switch, the output signal is connected to the Preamplifier stage.

Preamplifier

In the .01, .02 and .05 positions of the VOLTS/DIV switch, the signal from the Input Attenuator stage is connected to the control grid of V320. The gain of this stage is determined by Preamp Gain adjustment R322, which sets the cathode degeneration of V320. The signal at the plate of V320 is connected to the control grid of V329. V329 is connected as a cathode follower stage and the output at its cathode is connected to the Vertical Amplifier circuit through C340, L341 and R341. C320, L325, L341 and R345 are adjustable to provide the correct signal response. The preamplifier is by-passed at VOLTS/DIV positions of .1 and above.

DC Bal adjustment R344 sets the grid level of V408 (on Vertical Amplifier schematic). This adjustment is set to establish the same DC voltage level at the cathode of V408 as at the cathode of V401. Then, with the cathodes of V401 and V408 at the same DC voltage level, there is no current flow through the Variable VOLTS/DIV control and the position of the trace will not shift as this control is rotated.

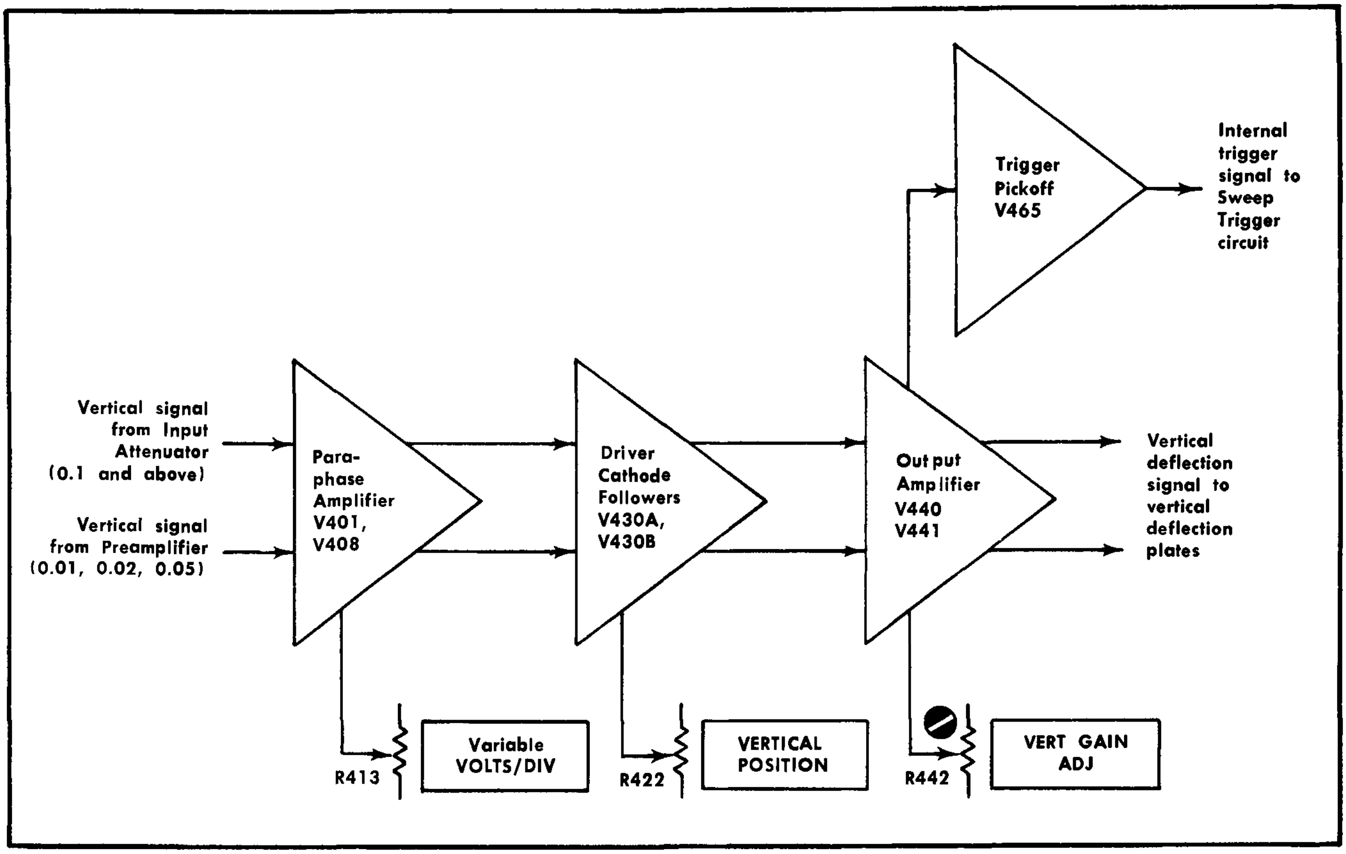


Fig. 3-3. Vertical Amplifier detailed block diagram.

VERTICAL AMPLIFIER

General

The Vertical Amplifier circuit provides amplification for the vertical deflection signal. This circuit provides control of variable deflection factor, vertical position and vertical gain. The Trigger Pickoff stage provides a sample of the vertical signal to the Sweep Trigger circuit for internal triggering. Fig. 3-3 shows a detailed block diagram of the Vertical Amplifier circuit.

Paraphase Amplifier

The signal from the Input Attenuator is connected to the control grid of V401 in the .1 and above VOLTS/DIV switch positions. In the .01, .02 and .05 positions of the VOLTS/DIV switch, the output signal from the Preamplifier stage is connected to the control grid of V408. V401 and V408 are connected as a common-cathode phase inverter (paraphase amplifier) to convert the single-ended input signal to a push-pull output signal. The push-pull output is obtained from the single-ended input signal in the following manner: Assume that the signal voltage at the grid of V401 is increasing. This produces a corresponding increase in current through V401, and its plate voltage goes negative. At the same time, the cathode of V401 goes positive and this change is connected to the cathode of V408 through Variable VOLTS/DIV control R413. The level at the control grid of V408 is determined by the DC Bal adjustment in the Vertical Preamplifier circuit. As far as signal changes are concerned, V408 is connected as a grounded grid stage so that it operates as the cathode-driven section of the paraphase amplifier. The positive-going signal connected to the cathode of V408 decreases the conduction of V408 and its plate voltage goes positive by about the same amount that the plate of V401 went negative. Thus the single-ended input signal at the grid of V401 has been amplified and is available as a push-pull signal at the plates of V401 and V408. Variable components C413, L409 and L418 determine the frequency response of this stage.

In the .01, .02 and .05 positions of the VOLTS/DIV switch, the output signal from the Preamplifier stage is connected to the grid of V408 and the grid of V401 is at signal ground. Circuit operation is the same as just described except that a negative-going signal is produced at the plate of V408 and a positive-going signal is produced at the plate of V401 with a positive-going input signal. This is necessary to offset the 180° phase inversion which occurs through the Preamplifier stage.

Variable VOLTS/DIV control R413 determines the degeneration between the cathodes of V401 and V408. When the Variable VOLTS/DIV control is set fully clockwise to the CALIBRATED position, there is minimum resistance between the cathodes of V401 and V408 and they are at maximum gain to provide calibrated deflection factors (with correct setting of VERT GAIN ADJ). As the Variable

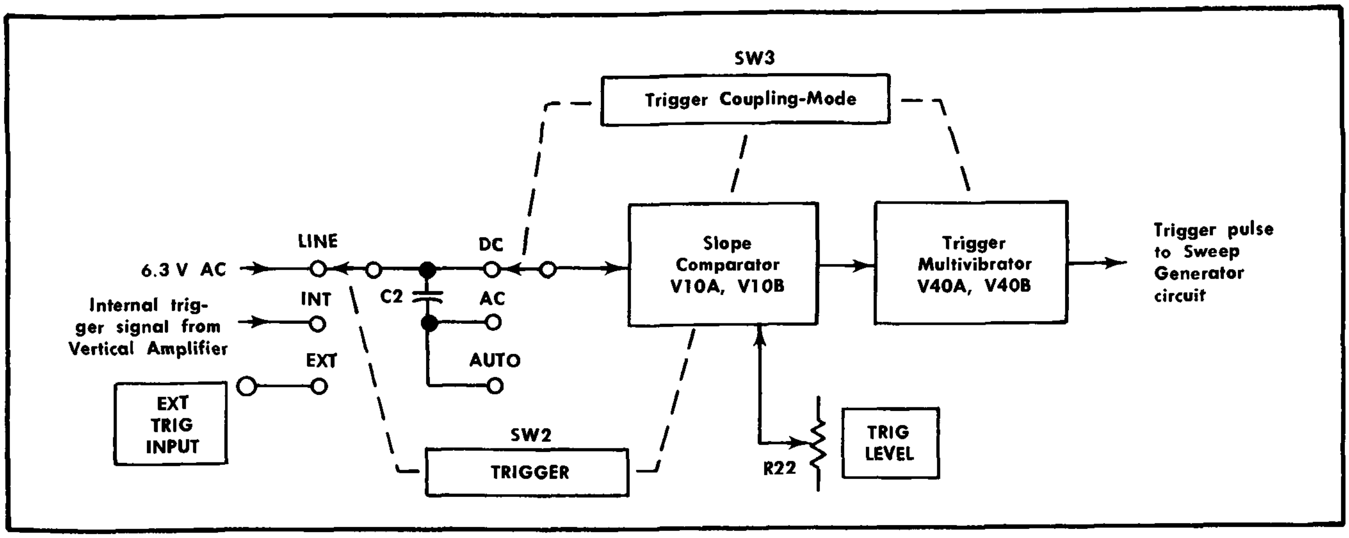


Fig. 3-4. Sweep Trigger detailed block diagram.

VOLTS/DIV control is rotated counterclockwise, the resistance between the cathodes increases to reduce the gain and provide continuously variable deflection factors between the calibrated settings of the VOLTS/DIV switch. Switch SW413, ganged with the Variable VOLTS/DIV control, is open when this control is set to the CALIBRATED position. As the Variable VOLTS/DIV control is rotated counterclockwise from the CALIBRATED position, SW413 is closed and UNCALIBRATED VERTICAL light B400 ignites to indicate that the vertical deflection factor is uncalibrated.

Driver Cathode Followers

The output signal from the Paraphase Ampifier stage is connected to the Output Amplifier stage through the Driver Cathode Followers, V430A and V430B. VERTICAL POSITION control R422 sets the DC level at the grids of these tubes to determine the vertical position of the trace. The output signals at the cathodes of V430A and V430B are connected to the Output Amplifier stage through LR433 and LR432.

Output Amplifier

The Output Amplifier, V440 and V441, is a push-pull amplifier to provide the final amplification for the vertical signal before it is connected to the vertical deflection plates of the CRT. Gain of the Output Amplifier stage is set by VERT GAIN ADJ R442 to provide calibrated vertical deflection factors. L450 and L451 are set to provide correct frequency response from this stage. The output signal at the plate of V440 is connected to the upper vertical deflection plate through LR440, and the signal at the plate of V441 is connected to the lower vertical deflection plate through LR441.

Trigger Pickoff

The signal at the plate of V440 in the Output Amplifier stage is connected to Trigger Pickoff stage V465 through C460-R460. This sample of the vertical signal provides internal triggering from the signal displayed on the CRT. V465 is connected as a cathode follower to provide isolation between the Vertical Amplifier circuit and the Sweep Trigger circuit. It also provides a minimum load for the Output Amplifier stage while providing a low output impedance to the Sweep Trigger circuit.

SWEEP TRIGGER

General

The Sweep Trigger circuit produces trigger pulses to start the Sweep Generator circuit. These trigger pulses are derived from an internal trigger signal from the Vertical Amplifier circuit, an external trigger signal connected to the EXT TRIG INPUT binding post or a sample of the line voltage applied to the instrument. Controls are provided in this circuit to select trigger level, slope, coupling, source and mode. Fig. 3-4 shows a detailed block diagram of the Sweep Trigger circuit.

Trigger Source

TRIGGER switch SW2A selects the source of the trigger signal. Three trigger sources are available; internal, external and line. The internal trigger signal is obtained from the Vertical Amplifier circuit. This signal is a sample of the signal applied to the vertical INPUT connector. An external signal connected to the EXT TRIG INPUT binding post can be used to produce a trigger in the EXT positions of the TRIGGER switch. Input resistance (DC) is about one megohm as established by R2. The line trigger is a sample of the line voltage applied to the instrument. This 6.3-volt RMS signal is connected to the Sweep Trigger circuit in the LINE position of the TRIGGER switch.

Trigger Coupling

Trigger Coupling-Mode switch SW3A allows selection of the portion of the trigger signal from which the trigger pulse is derived. In the DC position of this switch, the trigger signal is coupled directly to the Slope Comparator stage. This position provides equal coupling for all trigger signals from DC to four megahertz. When the Trigger Coupling-Mode switch is set to the AC or AUTO positions, the trigger signal must pass through C2. This capacitor blocks the DC component of the trigger signal and attenuates AC signals below about 30 hertz.

Slope Comparator

V10A and V10B are connected as a comparator to provide selection of the slope and level at which the sweep is triggered. Output signal from the Slope Comparator stage is always obtained from the plate of V10A and the sweep is started from the negative-going portion of the signal at this point. To provide selection of the trigger slope, TRIGGER switch SW2B connects the trigger signal to the grid of V10A for positive-slope triggering or to the grid of V10B for negative-slope triggering. Circuit operation is as follows:

For positive-slope triggering, the trigger signal is applied to the grid of V10A and a reference voltage from TRIG LEVEL control R22 is connected to the grid of V10B. R13 establishes the cathode current of both V10A and V10B. In this configuration the tube with the most positive grid controls conduction of the comparator. For example, with a positive-going trigger signal, V10A conducts when its grid level rises more positive than the grid of V10B as established by the TRIG LEVEL control. When V10A conducts, its plate level goes negative. Notice that the output signal from the Slope Comparator stage is 180° out of phase with the input trigger signal. The sweep is started on this negative-going output, which is coincident with the positive-going portion of the input trigger signal. However, the displayed waveform on the CRT may not start on the selected slope at fast sweep rates since, there is no delay line in the Vertical Amplifier circuit.

TRIG LEVEL control R22 sets the grid level of V10B for positive-slope triggering. This in turn determines the level on the trigger signal at which the comparator switches. With the TRIG LEVEL control set near midrange and a positive-going signal applied, V10B conducts until the applied trigger signal raises the grid of V10A more positive than the grid of V10B (tube with the most positive grid always controls conduction of the comparator). V10B is then reverse biased and V10A is forward biased to produce the negative-going output as discussed previously. V10A remains on and V10B off until the applied trigger signal drops the level at the grid of V10A more negative than the grid of V10B. Then the circuit returns to the original conditions. Now, assume that the TRIG LEVEL control is turned clockwise to produce a display which starts at a more positive level. A more positive level is established at the grid of V10B by the TRIG LEVEL control. Now the trigger signal must rise more positive before the grid of V10A is positive enough to bias this tube on to produce the negative-going output which triggers the sweep. The resultant CRT display starts at a more positive point on the displayed signal, since the sweep is started later. When the TRIG LEVEL control is turned counterclockwise toward −, the effect is the opposite to produce a resultant CRT display which starts at a more negative point on the trigger signal.

To start the sweep on the negative slope of the trigger signal, TRIGGER switch SW2B reverses the connections to the grids of V10A and V10B. Now, the trigger signal is connected to the grid of V10B and the reference level from the TRIG LEVEL control is connected to the grid of V10A. The TRIG LEVEL control establishes the point at which the comparator switches as discussed for positive-slope triggering. Assume that V10B is not conducting with a positive-going signal applied. As the grid of V10B goes positive with the applied trigger signal, V10B will be forward biased when its grid voltage exceeds the level at the grid of V10A set by the TRIG LEVEL control. When this occurs, V10A shuts off and its plate rises positive. Note that the signal at the plate of V10A is now in phase with the applied trigger signal. Since the sweep is always started on the negative-going portion of the signal at the output of the Slope Comparator, the sweep will not start until the trigger signal goes negative to turn V10B off and V10A on. Then, the output of this stage goes negative to trigger the sweep.

In the AUTO position of the Trigger Coupling-Mode switch SW3B, the TRIG LEVEL control is by-passed to ground. This sets the grid of the reference tube of the comparator at ground level. The signal must also pass through C2 in the AUTO mode. Now, triggering occurs very near the average level of the applied trigger signal.

Trigger Multivibrator

Normal Triggering. The output from the slope Comparator stage is connected to Trigger Multivibrator stage V40A and V40B. These tubes are connected as a Schmitt bistable multivibrator for normal triggering (Trigger Coupling-Mode switch SW3D set to AC or DC). To understand the operation of this circuit, assume that the TRIG LEVEL control is set near midrange, TRIGGER switch set to a + position and the circuit is ready to receive a trigger signal. These conditions produce a positive output level from the Slope Comparator stage (see Slope Comparator discussion) which holds V40A in conduction and its plate is negative from the supply voltage. The quiescent level on the plate of V40A is determined by divider R41-R46-R48 between +300 volts and −150 volts. This divider also sets the quiescent level at the grid of V40B negative enough so that V40B is held off. The plate of V40B rises positive toward the supply voltage to set the quiescent output level of this stage.

When a trigger signal applied to the Sweep Trigger circuit produces a negative-going output from the Slope Comparator stage, V40A is reverse biased. The plate of V40A rises positive and the voltage at the grid of V40B is pulled positive through divider R46-R48. V40B is forward biased and its plate drops negative as the current through V40B increases. This negative-going change at the plate of V40B is connected to the Sweep Generator circuit to start the sweep. Capacitor C46 improves the response of this circuit for fast changes to produce an output signal with a fast rise. This stage remains in the condition just described until the output from the Slope Comparator stage returns positive and V40A is again forward biased. Then the grid of V40B goes positive to turn V40B off. The output level of this stage returns to the quiescent level near the supply voltage.

Auto Triggering. When the Trigger Coupling-Mode switch is in the AUTO position, SW3C and SW3D change the circuit configuration. SW3C opens the signal path to the grid of V40A through R30 and R31 so that the signal must pass through C30. Resistor R42 is added to the plate circuit of V40A to increase the plate load of V40A and effectively lower the plate voltage of V40A when it is on. The circuit can operate in one of two modes dependent upon the trigger signal.

When there is no trigger signal present, or if the repetition rate of the trigger signal is less than about 60 hertz, the Trigger Multivibrator stage operates as an astable multivibrator with C30 determining the repetition rate. To understand the operation of the circuit under this condition, assume that there is no trigger signal applied to the instrument and V40A has just turned on. When V40A is on, its plate drops negative. This places less voltage across divider R46-R48 and the voltage at the grid of V40B is negative enough to hold V40B off. The voltage at the junction of R46-R48 is also connected to the grid of V10A through R55, SW3C, R31 and R40. The grid of V40A starts to go negative toward the level at the junction of R46-R48 as C30 charges. The cathode of V40A follows the voltage change at its grid and the cathode level of V40B follows also, since the cathodes of V40A and V40B are connected together. The cathode level of V40B continues to go negative as C30 charges, until it drops negative enough to forward bias V40B. Then V40B comes on and its plate drops negative to produce a trigger pulse to the Sweep Generator circuit. V40A is reverse biased since its grid continues to go negative with the charging of C30 and its cathode level is set by the conduction of V40B. When V40A turns off, its plate rises positive and this voltage level is connected back to the grid of V40A through R46, R55, SW3C, R31 and R40. Now the grid of V40A begins to rise positive as C30 discharges toward the level at the junction of R46-R48. When C30 has discharged sufficiently to forward bias V40A, it turns on and its plate goes negative. Now the cycle begins again. As long as the instrument is in the AUTO mode and there is no trigger signal, or the trigger signal repetition rate is too low, the Trigger Multivibrator stage free runs at about a 50 hertz rate as just described to automatically retrigger the sweep and provide a reference trace.

Whenever a trigger signal with a repetition rate higher than about 60 hertz is applied to the grid of V40A, the Trigger Multivibrator stage operates in much the same manner as described with the Trigger Coupling-Mode switch set to AC or DC. The display is triggered at the average voltage level of the trigger signal (trigger signal always AC coupled in AUTO trigger mode). The switching rate of the Trigger Multivibrator stage when it is triggered at a repetition rate faster than 60 hertz is such that C30 does not charge or discharge enough to affect the grid level of V40A.

SWEEP GENERATOR

General

The Sweep Generator circuit produces a sawtooth voltage which is amplified by the Horizontal Amplifier circuit to provide horizontal sweep deflection on the CRT. This output signal is generated on command (trigger pulse) from the Sweep Trigger circuit. The Sweep Generator circuit also produces an unblanking gate to unblank the CRT during sweep time. Fig. 3-5 shows a detailed block diagram of the Sweep Generator circuit.

Sweep Gate Multivibrator

The trigger pulse from the Sweep Trigger circuit is applied to the Sweep Generator circuit through C101. The trigger pulse applied to C101 is a fast-rise square wave with the repetition rate and duty cycle determined by the Trigger Multivibrator stage. C101 differentiates this square wave to produce positive and negative going pulses which are very fast (trigger pulses at grid of V102A are difficult to see at normal test oscilloscope intensity; it may be necessary to increase the test oscilloscope intensity when viewing this waveform). The positive-going pulses produced from the trigger square wave are shunted by D129 (above SN 15221 only) to prevent them from switching the Sweep Gate Multivibrator during a sweep. V102A and V110 are connected as a multivibrator with V102B providing the coupling between the plate of V102A and the control grid of V110. Quiescently, V102A is conducting and V110 is off. This produces a positive level at the plate of V110 which allows V150A and V150B to conduct. The function of these diodes is discussed under Disconnect circuit. With V102A conducting, its plate is negative from the supply voltage and this produces a negative level at the cathode of V102B. This negative level at the cathode of V102B is connected to the CRT circuit to blank the CRT until a trigger pulse is received (more details on unblanking given in the CRT circuit discussion). It is also connected to the control grid of V110 through divider R106-R107 to hold V110 off until the trigger pulse is received. STABILITY control R125 determines the quiescent grid level of V102A so it is near the forward bias point in the AC and DC positions of the Trigger Coupling-Mode switch. In the PRESET (fully counterclockwise) position of the STABILITY control, or in the AUTO position of the Trigger Coupling-Mode switch, the quiescent grid level of V102A is determined by PRESET ADJUST R126. The PRESET ADJUST is calibrated to set the grid of V102A at the correct level for best triggering operation.

The negative-going trigger pulse applied to the grid of V102A turns V102A off and its plate goes positive toward the supply voltage. This produces a corresponding positive-going change at the cathode of V102B. The positive-going change at the cathode of V102B unblanks the CRT through the CRT circuit so a trace can be displayed, and it turns V110 on through divider R106-R107. When V110 turns on, its plate goes negative enough to reverse bias diodes V150A

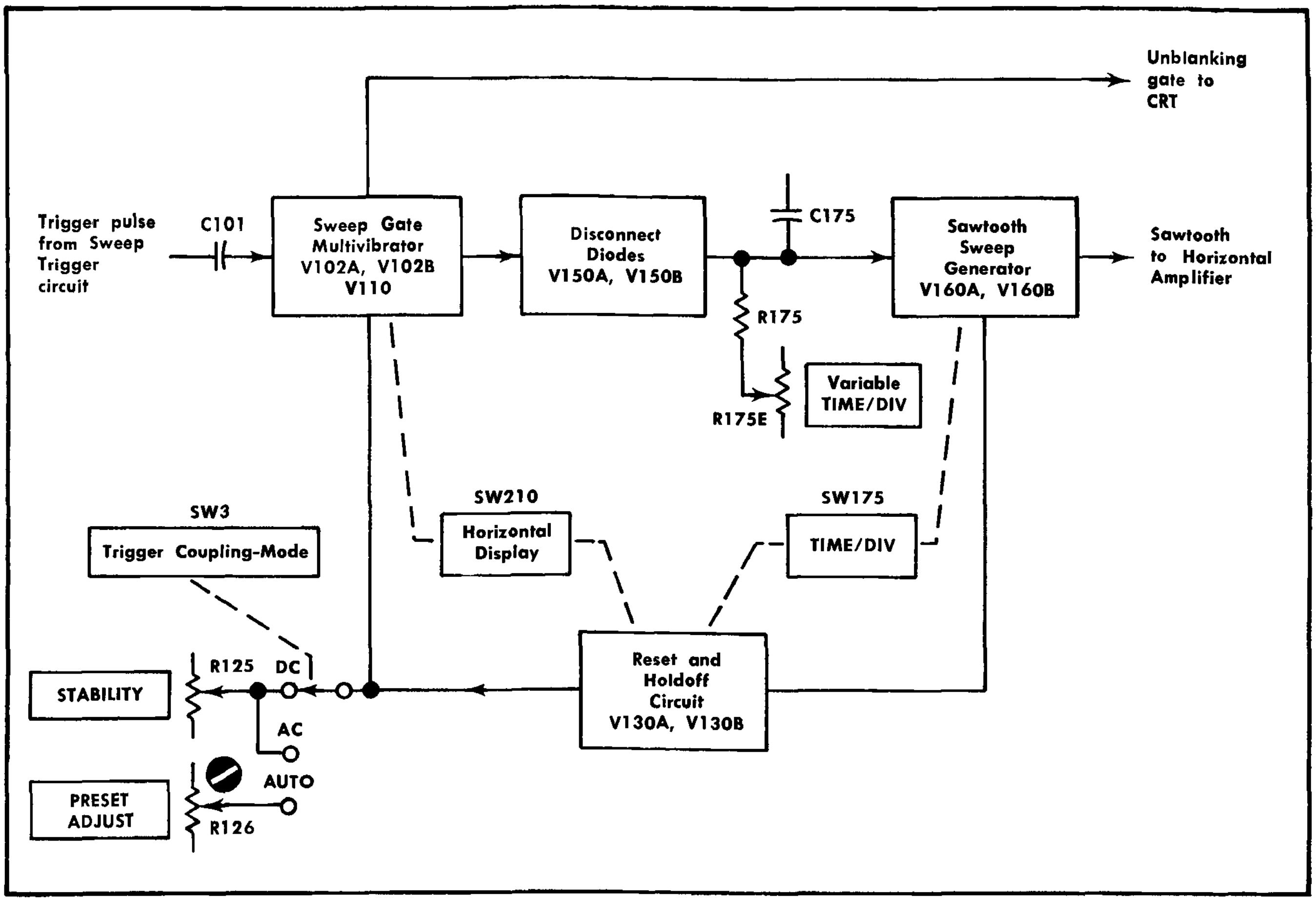


Fig. 3-5. Sweep Generator detailed block diagram.

and V150B. The circuit remains in this condition with V102B off and V110 on until it is reset by the Reset and Holdoff circuit at the end of the sweep. The reset action is described under the Reset and Holdoff circuit discussion.

When Horizontal Display switch SW210B is set to the EXT HORIZ position, the cathode voltage is disconnected from V102A and V110. This allows the grid of V102B to rise positive toward the supply voltage to produce a positive output pulse which unblanks the CRT. Since the cathode voltage is disconnected from V102A and V110, they lock out the incoming trigger pulses to prevent the Sweep Generator from operating in this mode. To further lock out the Sweep Generator circuit, the cathode voltage for V130B in the Reset and Holdoff circuit is also disconnected by SW210B.

Disconnect Diodes

Disconnect Diodes V150A and V150B are quiescently forward biased by the positive level at the plate of V110. These diodes are quiescently conducting timing current through the timing resistor R175 and they prevent timing capacitor C175 from charging in this quiescent condition.

When a trigger pulse is received, the output level at the plate of V110 goes quickly negative. This reverse biases diodes V150A and V150B and interrupts the current which was quiescently flowing through them. Now the timing current from timing resistor R175 begins to charge the timing capacitor C175. As the timing capacitor charges, the Sawtooth Sweep Generator stage can produce a sawtooth output signal.

Sawtooth Sweep Generator

The basic sweep generator circuit is a Miller Integrator circuit. When the quiescent current flow through the Disconnect Diodes is interrupted by the sweep gate, timing capacitor C175 begins to charge through R175. The timing capacitor and timing resistor are selected by TIME/DIV switch SW175 to provide the various sweep rates listed on the front panel. A complete diagram of the TIME/DIV switch is shown on the Sweep-Timing Switch diagram. Variable TIME/DIV control R175E provides continuously variable, uncalibrated sweep rates by varying the charging current to the timing capacitor. UNCALIBRATED TIME BASE light B177 (see Sweep-Timing Switch diagram) is turned on by SW175F whenever the Variable TIME/DIV control is not in the CALIBRATED position to indicate when the sweep rate is uncalibrated.

As the timing capacitor begins to charge negative towards the voltage applied to the timing resistor, the control grid of V160B goes negative also. This produces a positive-going change at the plate of V160B which is connected to the grid of cathode follower V160A. The positive-going signal at the cathode of V160A is connected to the Horizontal Amplifier circuit to provide the sweep signal for the CRT. It is also connected to the positive side of timing capacitor C175. This feedback to the timing capacitor maintains a constant charging current for C175 to produce a linear sawtooth output signal. The actual voltage change at the grid of V160B is very small compared to the sawtooth output signal produced by this stage. The output voltage continues to go positive until the circuit is reset through the Reset and Holdoff Circuit. Divider R160-R161-R162 in the cathode circuit of V160A determines the level at which the sweep is reset. Sweep Length adjustment R161 is adjustable to provide the correct sweep length. Complete operation of this action is discussed under Reset and Holdoff Circuit.

Reset and Holdoff Circuit

The positive-going sawtooth from the cathode of V160A is connected to the grid of V130B through R162 and R161. Sweep Length adjustment R161 determines the DC level and amplitude of the signal applied to the grid of V130B to set the length of the sweep. The positive-going sawtooth at the grid of V130B produces a similar positive-going change at the cathode of V130A, which charges holdoff capacitor C135. The level at the cathode of V130B is also connected to the grid of V102A through V130A. During sweep time, V102A in the Sweep Gate Multivibrator stage is off and V110 is on. The positive-going signal from V130A raises the grid of V102A positive toward the turn-on point as the sawtooth produced by this circuit rises positive. When V102A comes on, its plate goes negative and it resets the Sweep Gate Multivibrator to the quiescent state. The level on the positive-going sawtooth at which this stage is reset can be adjusted with Sweep Length adjustment R161. When R161 is turned clockwise (toward −150 volt supply) a more negative quiescent level is connected to the grid of V130B. Also, due to the divider action of R160-R161-R162, less of the positive-going sawtooth is applied to the base of V130B. Therefore, the sawtooth must rise farther positive before the Sweep Gate Multivibrator can be reset through V130B and V130A which produces a longer sweep length. The action is the opposite when R161 is turned counterclockwise to produce a shorter sweep.

When the Sweep Gate Multivibrator stage resets, the output level at the plate of V110 quickly rises positive to forward bias V150A and V150B. Timing capacitor C175 discharges rapidly and the control grid of V160B follows to produce the retrace portion of the sweep. Since the resistance of the discharge path for C175 is less than the charging path, the retrace portion of the sweep has a steeper slope to quickly return the CRT beam to the left side of the display area. The unblanking gate to the CRT goes negative also, so this retrace is not visible on the display area. Now the Disconnect Diodes and the Sawtooth Sweep Generator stage have returned to their quiescent conditions and are ready to produce another sweep as soon as the Sweep Gate Multivibrator stage is ready to receive the next trigger pulse.

As the cathode of V130B goes positive along with the positive-going sawtooth, holdoff capacitor C135 charges positive also. However, when the circuit is reset to produce the retrace portion of the sawtooth signal, the grid of V130B drops negative with the retrace but the cathode is clamped by the charge level on C135. The charge level on the holdoff capacitor clamps the grid of V102A at a positive level also, through V130A. This action blocks the incoming trigger pulses at the grid of V102A for a period of time to establish a holdoff period and allow all circuits to return to their quiescent condition before the next sweep is produced. This holdoff time is determined by the discharge rate of the holdoff capacitor. As the holdoff capacitor discharges, the grid of V102A drops negative until it reaches the level established by STABILITY control R125 or PRESET ADJUST R126 as described for the quiescent condition of the Sweep Gate Multivibrator stage. Now the Sweep Gate Multivibrator stage is ready to accept the next positive-going trigger pulse. Holdoff capacitor C135 is changed by the TIME/DIV switch to provide the correct holdoff time for the sweep rate selected (see Sweep-Timing Switch diagram).

When the STABILITY control is turned fully counterclockwise with the Trigger Coupling-Mode switch set to AC or DC, the grid of V102A is at its most negative level. Now, when the Sweep Gate Multivibrator stage is reset and the holdoff period ends, the grid of V102A goes negative enough to turn V102A off again. The result is that the Sweep Generator circuit is retriggered at the end of each holdoff period to produce a free-running sweep. This sweep free-runs at the sweep rate selected by the TIME/DIV switch to produce a bright reference trace at fast sweep rates. This is in contrast to the 50-hertz free-running repetition rate in the AUTO mode.

HORIZONTAL AMPLIFIER

General

The Horizontal Amplifier circuit provides the output signal to the CRT horizontal deflection plates. In all positions of the Horizontal Display switch except EXT HORIZ, the horizontal deflection signal is a sawtooth from the Sweep Generator circuit. In the EXT HORIZ position, the horizontal deflection signal is provided by an external signal applied to the EXT HORIZ INPUT binding post on the rear panel. This circuit also contains the horizontal magnifier circuit and the horizontal positioning network. Fig. 3-6 shows a detailed block diagram of the Horizontal Amplifier circuit.

Sawtooth Input CF

The input signal for the Horizontal Amplifier in the X1 and X5 positions of the Horizontal Display switch is the sawtooth produced by the Sweep Generator circuit. The sawtooth is applied to the grid of Sawtooth Input CF

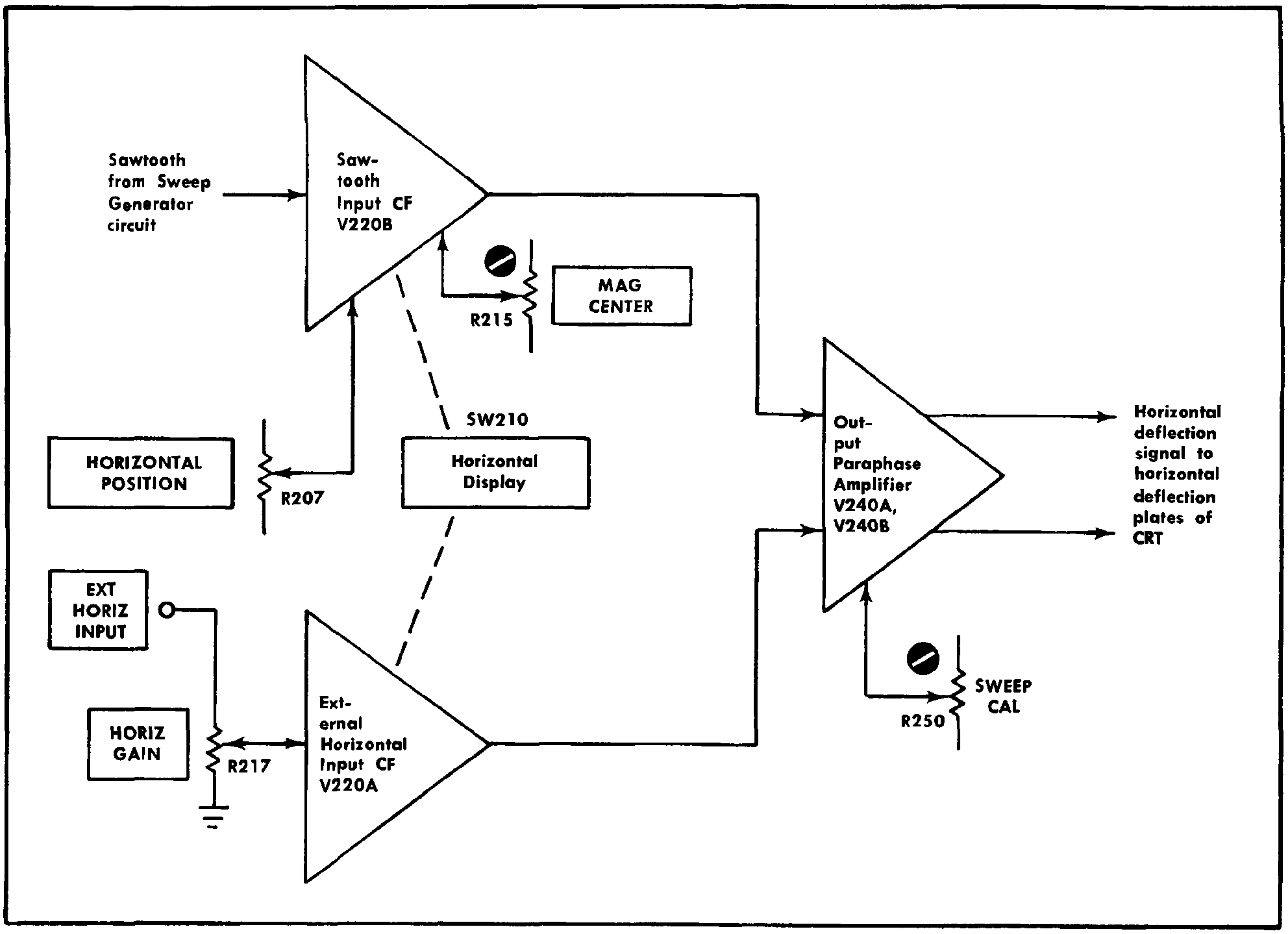


Fig. 3-6. Horizontal Amplifier detailed block diagram.

V220B. HORIZONTAL POSITION control R207 sets the DC level at the grid of V220B to determine the horizontal position of the display on the CRT. Variable capacitors C205 and C213 provide adjustment for a linear horizontal sweep. The Horizontal Display switch SW210A disconnects network C213-C214-R213-R214-R215 in the X5 MAG position. This allows about five times more sawtooth signal to reach the grid of V220B and provide a sweep rate which is magnified five times. MAG CENTER adjustment R215 balances the current in this stage so that a center-screen display does not change position when the Horizontal Display switch is changed from X1 MAG to X5 MAG. In the EXT HORIZ position of the Horizontal Display switch, a bias voltage is connected to the grid of V220B through R210 to position the display to the right side of the CRT. Since the sweep is disabled in this position (see Sweep Gate Multivibrator discussion) there is no signal at the grid of V220B for external horizontal operation. The HORIZONTAL POSITION control provides horizontal positioning of the display as for sweep operation. The output signal at cathode of V220B is connected to the grid of V240B in the Output Paraphase Amplifier stage.

External Horizontal Input CF

In the X1 MAG and X5 MAG positions of the Horizontal Display switch, the grid of V220A is connected to ground by SW210C. In the EXT HORIZ position, the grid of V220A is disconnected from ground to allow an external signal connected to the EXT HORIZ INPUT binding post to be applied to the Horizontal Amplifier. HORIZ GAIN control R217 provides continuously variable attenuation of the external horizontal input signal. The output signal at the cathode of V220A is connected to the grid of V240A in the Output Paraphase Amplifier stage.

Output Paraphase Amplifier

V240A and V240B are connected as a paraphase amplifier to convert the single-ended input signals to a push-pull output signal. For the X1 MAG and X5 MAG positions of the Horizontal Display switch, the signal from the Sawtooth Input CF is connected to the grid of V240B to produce the push-pull output signal at the plates of V240A and V240B. This occurs as follows: The positive-going sawtooth at the output of the Sawtooth Input CF forward biases

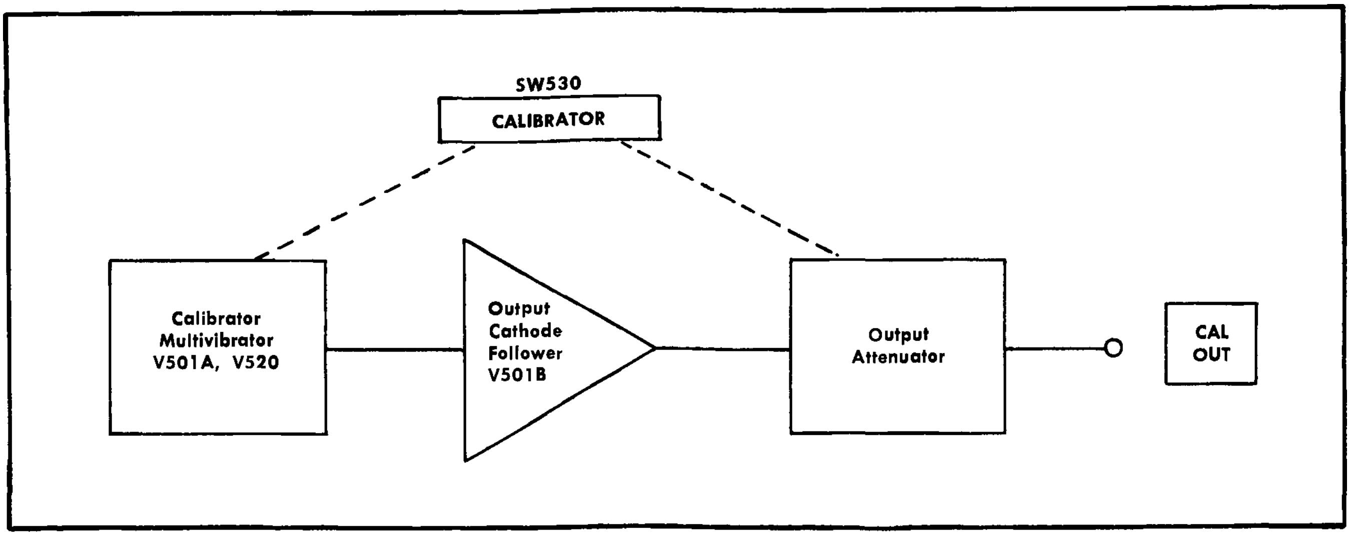


Fig. 3-7. Calibrator circuit detailed block diagram.

V240B and the current through it increases. This increase in current through V240B produces a negative-going sawtooth at its plate which is connected to the left horizontal deflection plate of the CRT. At the same time the increase in current through V240B produces a positive-going sawtooth at its cathode. The cathodes of V240B and V240A are coupled together through C250-R250. SWEEP CAL adjustment R250 sets the gain of this stage to provide calibrated horizontal sweep rates. Variable capacitor C250 is adjusted to provide correct horizontal sweep rates at the faster sweep rates. The positive-going sawtooth coupled to the cathode of V240A through the degeneration network reverse biases this tube. For X1 MAG and X5 MAG operation there is no signal connected to the grid of V240A, so it operates as a grounded grid stage. Since the positive-going sawtooth at its cathode reverse biases V240A, its plate rises positive toward the supply voltage to produce a positive-going sawtooth output. This signal is connected to the right horizontal deflection plate of the CRT.

When the Horizontal Display switch is set to the EXT HORIZ position, the conditions of the Output Paraphase Amplifier are reversed. Now, the output signal from the External Horizontal Input CF is connected to the grid of V240A and the grid of V240B is at signal ground. Operation is similar to that just described for sawtooth input except that the output signals are inverted. For example, if the external signal applied to the EXT HORIZ INPUT binding post is positive-going, V240A is forward biased. This produces a negative-going signal at the plate of V240A which is connected to the right horizontal deflection plate. At the same time, a positive-going signal is coupled to the cathode of V240B which produces a positive-going signal at the plate. This signal is connected to the left horizontal deflection plate.

CALIBRATOR

The Calibrator circuit produces a square-wave output voltage. The CALIBRATOR switch selects the attenuation of the output signal to provide square-wave voltage outputs between 0.5 and 100 volts peak to peak. Fig. 3-7 shows a detailed block diagram of the Calibrator circuit.

Calibrator Multivibrator

V501A and V520 are connected as an astable multivibrator. The frequency at which this multivibrator changes states is determined by time-constant networks C502-R502 and C506-R506. The plate supply voltage for V520 is set by Cal Adj R510 to determine the accuracy of the calibrator amplitude. CALIBRATOR switch SW530A connects the cathodes of V501A and V520 to −150 volts in all positions except OFF. In the OFF position the cathode supply voltage is disconnected so this stage is inoperative. The one-kilohertz output square wave at the plate of V520 is connected to the Output Cathode Follower stage.

Output Cathode Follower and Output Attenuator

The output square-wave from the Calibrator Multivibrator stage controls the conduction of the Calibrator Cathode Follower stage. When V520 in the Calibrator Multivibrator stage is off, its plate rises positive to the voltage set by the Cal Adj. When this adjustment is set correctly, V501B is forward biased and its cathode rises positive to +100 volts. Then, as the Calibrator Multivibrator stage switches states, V520 turns on and its plate level goes negative enough to cut V501B off. Now the cathode of V501B drops negative to the ground level. This 100-volt peak-to-peak square wave is connected across the Output Attenuator. The Output Attenuator is made up of a voltage divider composed of 11 resistors selected to provide the voltage outputs listed on the front panel. CALIBRATOR switch SW530B selects the point on the divider which is connected to the CAL OUT binding post. In the fully counterclockwise position of the CALIBRATOR switch, the CAL OUT binding post is disconnected from the divider (Calibrator circuit inoperative; see Calibrator Multivibrator discussion).

LV POWER SUPPLY

General

The LV Power Supply circuit provides the operating power for the instrument from three regulated supplies and one unregulated supply. Electronic regulation is used to provide stable, low-ripple output voltages. Fig. 3-8 shows a detailed block diagram of the LV Power Supply circuit.

Power Input

Power is applied to the primary of transformer T600 through line fuse F600, POWER switch SW600 and thermal cutout TK600. The primary of T600 is composed of two main windings with four taps on each winding. The main windings are connected in parallel for 117-volt nominal operation or in series for 234-volt nominal operation. The taps on each main winding can be connected to either aid or oppose the main windings. This provides compensation for line voltages slightly higher or lower than normal.

Thermal cutout TK600 provides thermal protection for this instrument. If the internal temperature exceeds a safe operating level, TK600 opens to interupt the applied power. When the temperature returns to a safe level, TK600 automatically closes to re-apply the power.

−150-Volt Supply

The following discussion includes the description of the −150-Volt Rectifier, −150-Volt Series Regulator, −150-Volt Error Amplifier and the Reference Voltage stages. Since these stages are closely related in the production of the −150-Volt regulated output voltage, their operation is most easily understood when discussed as a unit.

The −150-Volt Rectifier stage, D601A-D, rectifies the output at the secondary of T600 to provide the unregulated voltage source of this supply. Rectifier D601A is connected as a bridge rectifier and the output voltage is filtered by C601A-C before it is applied to −150-Volt Series Regulator stage V607. The Series Regulator can be compared to a variable resistor whose value is automatically changed to maintain a constant output voltage. The Error Amplifier stage provides this change by varying the conduction of the Series Regulator stage to provide regulated output voltage.

−150-Volt Error Amplifier V602 compares the output voltage of this supply against a reference voltage to maintain a constant output. Reference voltage is provided by voltage-reference tube V613, which sets the cathode of V602 at about −66 volts. The control grid level of V602 is determined by voltage divider R609-R610-R611 connected between the output of this supply and ground. R610 is adjustable to set the output voltage of this supply to −150 volts. The output current of the Error Amplifier controls the conduction of the −150-Volt Series Regulator stage. This output current changes to provide a constant, low-ripple −150-volt output level. This occurs as follows: The difference in voltage between the cathode and control grid of V602 determines its conduction. For example, if −150V Adj R610 is turned clockwise toward a more negative potential, the control grid of V602 goes more negative also to reduce the conduction of V602. This allows its plate to go more positive along with the grid of −150-Volt Series Regulator V607. When the grid of V607 goes positive, this tube is forward biased and more current flows through it and through the external load of the supply. More current through the load increases the output voltage from this supply. Resistor R608 in parallel with series regulator tube V607 allows some current to bypass the tube so that all of the current for the supply does not go through V607. However, the current through R608 remains constant and only the current through V607 is changed to provide a change at the output. When R610 is turned counterclockwise, a similar but opposite action takes place to reduce the output voltage of this supply. −150V Adj R610 is set to provide a −150-volt level at the output of this supply.

The output voltage of this supply is regulated to provide a constant voltage to the load by feeding a sample of the output voltage back to −150-Volt Series Regulator V607. For example, assume that the output voltage increases (more negative) because of a change in load or an increase in line voltage. This negative-going change at the output appears at the cathode of −150-Volt Error Amplifier V602 since a DC level change at the cathode of voltage reference tube V613 produces a similar change at its plate. A more negative voltage also is applied to the control grid and screen grid of V602 through dividers R609-R610-R611 and R602-R603. However, the voltage change at the grids is less than at the cathode so that the overall effect is to forward bias V602. More current flows through V602 and its plate goes negative to reduce the conduction of −150-Volt Series Regulator V607. With less current flowing through V607, the voltage across the load decreases and the output voltage returns to −150 volts. To regulate the output voltage of this supply to eliminate changes due to ripple, a sample of the unregulated voltage from the −150-Volt Rectifier is connected to the screen grid of V602 through divider R603-R604. The voltage at the cathode of V602 remains constant, since voltage reference V613 is bypassed by C613 to eliminate voltage changes at this point due to ripple in the output. The change at the screen grid is in a direction to oppose the ripple voltage in the output.

+100-Volt Supply

Rectified voltage for operation of the +100-Volt Supply is provided by D630A-D. This voltage is filtered by C630 and connected to +100-Volt Series Regulator V633 and to the negative side of the +300-Volt Rectifier stage. Reference voltage for this supply is provided by voltage divider R637-R638 between the regulated −150-volts and the output of this supply. The −150 volts is held stable by the −150-Volt Supply as discussed previously. If the +100-volt output changes, a sample of this change appears at the grid

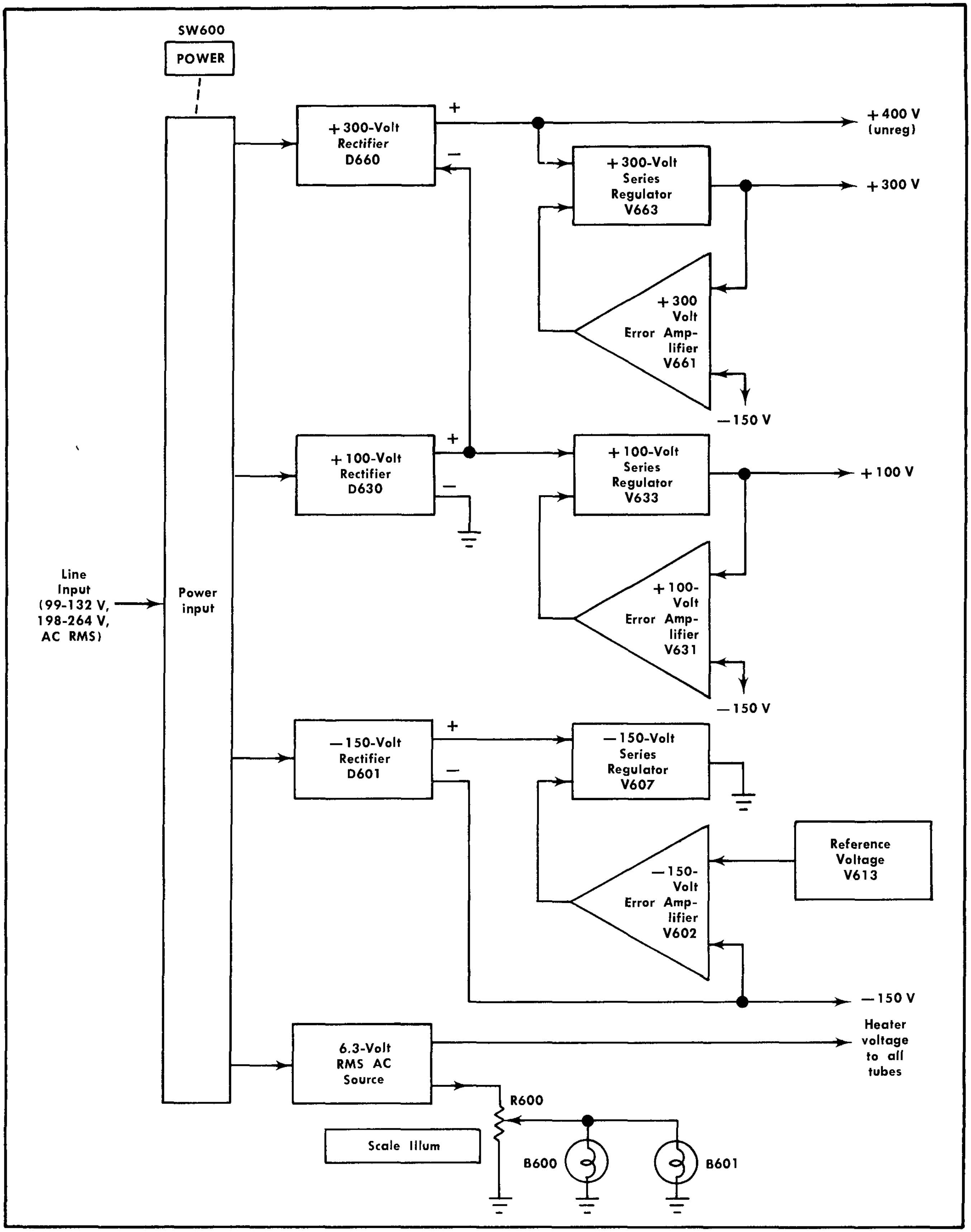


Fig. 3-8. LV Power Supply detailed block diagram.

of +100-Volt Error Amplifier V631 as an error signal. Regulation of the output voltage is controlled by +100-Volt Series Regulator V633 in a similar manner to that described for the −150-Volt Supply. Ripple regulation is provided by divider R631-R632 between the +100-volt output of this supply and ground. This divider applies a ripple voltage to the screen grid of V631 which changes the conduction of the +100-Volt Series Regulator in such a way as to oppose the ripple at the output.

+300-Volt Supply

D660A-D provides the rectified voltage for the +300-Volt Supply. The unregulated output from the +100-Volt Rectifier stage is connected to the negative side of the +300-Volt Rectifier to elevate the output level to +100 volts. C660 filters the rectified voltage which is connected to the +300-Volt Series Regulator. This unregulated voltage also provides the +400-volt unregulated output from the supply. The remainder of this circuit operates as described for the +100-Volt Supply.

CRT CIRCUIT

General

The CRT Circuit provides the high voltage and control circuits necessary for the operation of the cathode-ray tube (CRT). Fig. 3-9 shows a detailed block diagram of the CRT Circuit.

High-Voltage Oscillator

V704, T700 and C705 form an oscillator which operates at a frequency of about 25 kilohertz. The amplitude of oscillations in the primary of T700 is determined by the level at the screen grid of V704. This level is set by the High-Voltage Regulator stage and the operation is described in the High-Voltage Regulator discussion. The voltage induced into the secondary of T700 provides the high voltage for the CRT.

Control-Grid and Cathode Supplies

The high-voltage transformer has four output windings. Two of these windings provide filament voltage for rectifier

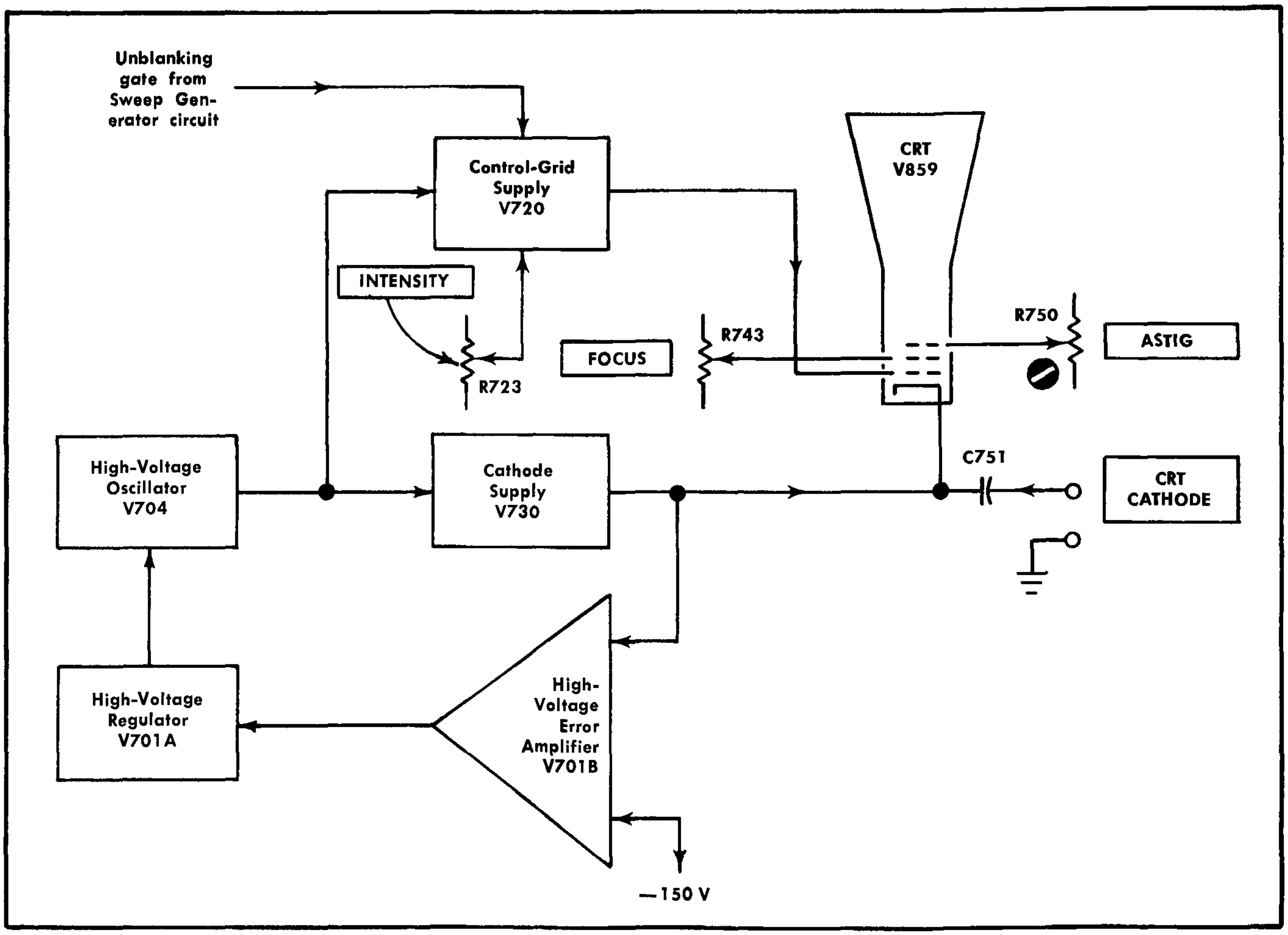


Fig. 3-9. CRT Circuit detailed block diagram.

tubes V720 and V730. The two remaining windings provide the control grid and cathode potential for the CRT. Both of these supplies are regulated by the High-Voltage Error Amplifier and High-Voltage Regulator stages in the primary of T700 to hold the output voltage constant. Half-wave rectifier V720 provides a negative voltage for the control grid of the CRT. The output level of this supply is variable by INTENSITY control R723 to determine the brightness of the CRT display. The unblanking gate from the Sweep Generator circuit is connected to the positive side of this supply to unblank the CRT so a trace can be displayed. This positive-going pulse coincident with the sweep (except for external horizontal operation when a positive bias level is applied) raises the control grid of the CRT positive to forward bias the CRT with the correct setting of the INTENSITY control. Between sweeps, the output level of the Control Grid Supply drops negative to reverse bias the CRT and blank the display.

The cathode-potential for the CRT is provided by half-wave rectifier V730. A sample of the output voltage from this supply is connected to the High-Voltage Error Amplifier to provide a regulated high-voltage output (see High-Voltage Error Amplifier Discussion).

High-Voltage Error Amplifier

The output voltage from the Cathode Supply is connected across divider R740-R741-R742-R743-R744. HV Adj R741 is adjusted to select the proper amount of feedback voltage to provide correct high-voltage output. The sample of the high-voltage obtained from R741 is connected to the grid of V701B. The cathode of V701B is connected to −150 volts. Since this supply is regulated by the LV Power Supply, any change in voltage at the grid of V701B appears at the plate as an amplified error signal. This error signal is connected to High-Voltage Regulator V701A.

High-Voltage Regulator

The error signal from the High-Voltage Error Amplifier is connected to the grid of the High-Voltage Regulator stage, V701A. V701A amplifies the error signal and produces a control signal to the High-Voltage Oscillator stage. This control signal is in such a direction as to correct the original error. Also, the DC level set by HV Adj R741 determines the quiescent output from this supply by setting the conduction of V701A and V701B which determines the amplitude of oscillation from High-Voltage Oscillator stage V704. Changes in output level are controlled as follows: Assume that the output from this supply tends to increase (cathode voltage goes more negative). This produces a more negative sample to the grid of V701B which reduces the conduction of this tube and its plate rises positive. When the grid of V701A rises positive, it conducts harder and its plate drops negative. The negative going signal at the plate of V701A is connected to the screen grid of V704 and it reverse biases V704 to reduce its conduction. This results in less oscillation in the primary and therefore less induced voltage into the secondary of T700. Since there is less signal induced into the secondary of T700, the output from the Cathode Supply will be less negative to correct the original error.

CRT Control Circuits

Focus of the CRT display is controlled by FOCUS control R743. Divider R740-R741-R742-R743-R744 is connected between the CRT Cathode Supply and ground. Therefore, the voltage on FOCUS control R743 is more positive (closer to ground) than the voltage on the CRT cathode. ASTIG adjustment R750, which is used in conjunction with the FOCUS control to provide a well-defined display, varies the positive level on the astigmatism grid. The intensity of the CRT display is determined by INTENSITY control R723.

External CRT Cathode Input

An external signal applied to the CRT CATHODE binding post on the rear panel is coupled to the CRT cathode through C751. This signal produces an increase or decrease in trace intensity, depending upon polarity, to provide Z-axis modulation of the display.

NOTES

SECTION 4
MAINTENANCE

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

This section of the manual contains maintenance information for use in preventive maintenance, corrective maintenance or troubleshooting of the Type 310A.

Panel Removal

The side panels of the Type 310A are held in place by slotted fasteners. To remove the panels, turn each fastener counterclockwise several turns with a screwdriver. Then, pull the panel out at the top and lift away from the instrument. For best overall operation and safety, leave the panels on this instrument except during calibration or maintenance.

WARNING

Dangerous potentials exist at several points in the instrument. When this instrument is operated with the covers removed, do not touch exposed connections or components. Disconnect power before cleaning the instrument or replacing parts.

Access to Internal Components

The components of the Type 310A are mounted on two separate chassis which are hinged at the rear. The chassis on the right side of the instrument may be swung out to gain access to components mounted on the inner sides of the chassis. To separate the chassis, loosen the slotted fastener, located at the lower front corner on the right side, several turns and swing the chassis open. The instrument can be operated with the chassis open for troubleshooting. However, overall instrument performance may be somewhat lower when operated in this manner.

PREVENTIVE MAINTENANCE

General

Preventive maintenance consists of cleaning, visual inspection, lubrication, etc. Preventive maintenance performed on a regular basis may prevent instrument breakdown and will improve the reliability of this instrument. The severity of the environment to which the Type 310A is subjected determines the frequency of maintenance. A convenient time to perform preventive maintenance is preceding recalibration of the instrument.

Cleaning

General. The Type 310A should be cleaned as often as operating conditions require. Accumulation of dirt in the instrument can cause overheating and component breakdown. Dirt on components acts as an insulating blanket and prevents efficient heat dissipation. It also provides an electrical conduction path and may result in instrument failure.

CAUTION

Avoid the use of chemical cleaning agents which might damage the plastics used in this instrument. Avoid chemicals which contain benzene, toluene, xylene, acetone or similar solvents.

Exterior. Loose dust accumulation on the outside of the Type 310A can be removed with a soft cloth or small paint brush. The paint brush is particularly useful for dislodging dirt on and around the front-panel controls. Dirt which remains can be removed with a soft cloth dampened in a mild detergent and water solution. Abrasive cleaners should not be used.

CRT. Clean the plastic light filter, graticule and the CRT face with a soft, lint-free cloth dampened with denatured alcohol.

Interior. Dust in the interior of the instrument should be removed occasionally due to its electrical conductivity under high-humidity conditions. The best way to clean the interior is to blow off the accumulated dust with dry, low-pressure air. Remove any dirt which remains with a soft paint brush or a cloth dampened with a mild detergent and water solution. A cotton-tipped applicator is useful for cleaning in narrow spaces or for cleaning ceramic terminal strips.

The high-voltage circuit should receive special attention. Excessive dirt in this area may cause high-voltage arcing and result in improper instrument operation.

Lubrication

General. The reliability of potentiometers, rotary switches and other moving parts can be maintained if they are kept properly lubricated. Use a cleaning-type lubricant (e.g., Tektronix Part No. 006-0218-00) on switch contacts. Lubricate switch detents with a heavier grease (e.g., Tektronix Part No. 006-0219-00). Potentiometers which are not permanently sealed should be lubricated with a lubricant which does not affect electrical characteristics (e.g., Tektronix Part No. 006-0220-00). The pot lubricant can also be used on shaft bushings. Do not over lubricate. A lubrication kit containing the necessary lubricants and instructions is available from Tektronix, Inc. Order Tektronix Part No. 003-0342-00.

Visual Inspection

The Type 310A should be inspected occasionally for such defects as broken connections, broken or damaged ceramic strips, improperly seated tubes, and heat-damaged parts.

The corrective procedure for most visible defects is obvious; however, particular care must be taken if heat-damaged components are found. Overheating usually indicates other trouble in the instrument; therefore, it is important that the cause of overheating be corrected to prevent recurrence of the damage.

Tube Checks

Periodic checks of the tubes in the Type 310A are not recommended. The best check of tube performance is its actual operation in the instrument. More details on checking tube operation is given under Troubleshooting.

Recalibration

To assure accurate measurements, check the calibration of this instrument after each 500 hours of operation or every six months if used infrequently. In addition, replacement of components may necessitate recalibration of the affected circuits. Complete calibration instructions are given in the Calibration section.

The calibration procedure can also be helpful in localizing certain troubles in the instrument. In some cases, minor troubles may be revealed and/or corrected by recalibration.

TROUBLESHOOTING

Introduction

The following information is provided to facilitate troubleshooting of the Type 310A. Information contained in other sections of this manual should be used along with the following information to aid in locating the defective component. An understanding of the circuit operation is very helpful in locating troubles. See the Circuit Description section for complete information.

Troubleshooting Aids

Diagrams. Complete circuit diagrams are given on foldout pages in the Diagrams section. The component number and electrical value of each component are shown on the diagrams. Each main circuit is assigned a series of component numbers. Table 4-1 lists the main circuits in the Type 310A and the series of component numbers assigned to each. Important voltages and waveforms are also shown on the diagrams.

TABLE 4-1

Component Numbers

Component numbers on diagrams	Circuit
1-49	Sweep Trigger
101-179	Sweep Generator
201-249	Horizontal Amplifier
300-399	Vertical Preamplifier
400-480	Vertical Amplifier
500-549	Calibrator
600-675	Power Supply
700-760	CRT Circuit

Wiring Color-Code. All insulated wire and cable used in the Type 310A is color-coded to facilitate circuit tracing. Signal carrying leads are identified with one or two colored stripes. Voltage supply leads are identified with three stripes to indicate the approximate voltage using the EIA resistor color code. A white background color indicates a positive voltage and a tan background indicates a negative voltage. The widest color stripe identifies the first color of the code. Table 4-2 gives the wiring color-code for the power-supply voltages used in the Type 310A.

TABLE 4-2

Power Supply Wiring Color Code

Supply	Background Color	First Stripe	Second Stripe	Third Stripe
−150 Volt	black	brown	green	brown
+100 Volt	white	brown	black	brown
+300 Volt	white	orange	black	brown
+400 Volt (unreg.)	gray	orange	red	

Troubleshooting Equipment

The following equipment is useful for troubleshooting the Type 310A.

1. Multimeter

Description: Voltmeter, 20,000 ohms/volt and 0 to 500 volts range; ohmmeter, 0 to 50 megohms. Accuracy, within 3%. Test probes must be insulated to prevent accidental shorting.

Purpose: To check voltages and for general troubleshooting.

2. Test Oscilloscope

Description: DC to 5 MHz frequency response, 50 millivolts to 50 volts/division deflection factor. A 10X probe should be used to reduce circuit loading.

Purpose: To check waveforms.

Troubleshooting Techniques

This troubleshooting procedure is arranged in an order which checks the simple trouble possibilities before proceeding with extensive troubleshooting. The first few checks assure proper connection, operation and calibration. If the trouble is not located by these checks, the remaining steps aid in locating the defective component. When the defective component is located, it should be replaced following the replacement procedures given under Corrective Maintenance.

1. Check Control Settings. Incorrect control settings can indicate a trouble that does not exist. If there is any question about the correct function or operation of any control, see the Operating Instructions section.

2. Check Associated Equipment. Before proceeding with troubleshooting of the Type 310A, check that the equipment used with this instrument is operating correctly. Check that the signal is properly connected and that the interconnecting cables are not defective. Also, check the power source.

3. Visual Check. Visually check the portion of the instrument in which the trouble is located. Many troubles can be located by visual indications such as unsoldered connections, broken wires, damaged components, etc.

4. Check Instrument Calibration. Check the calibration of the instrument, or the affected circuit if the trouble appears in one circuit. The apparent trouble may only be a result of misadjustment or may be corrected by calibration. Complete calibration instructions are given in the Calibration section.

5. Isolate Trouble to a Circuit. To isolate trouble to a circuit, note the trouble symptom. The symptom often identifies the circuit in which the trouble is located. For example, poor focus indicates that the CRT circuit is probably at fault. When trouble symptoms appear in more than one circuit, check affected circuits by taking voltage and waveform readings.

Incorrect operation of all circuits often indicates trouble in the power supply. Check first for correct voltage of the individual supplies. However, a defective component elsewhere in the instrument can appear as a power-supply trouble and may also affect the operation of other circuits. Table 4-3 lists the tolerances of the power supplies. If a power-supply voltage is within the listed tolerance, the supply can be assumed to be working correctly. If outside the tolerance, the supply may be misadjusted or operating incorrectly. Use the procedure given in the Calibration section to adjust the power supplies.

TABLE 4-3
Power Supply Tolerance

Power Supply	Tolerance	Maximum ripple (peak to peak)
−150 Volts	±4.5 Volts	10 millivolts
+100 Volts	±3 volts	10 millivolts
+300 Volts	±9 Volts	40 millivolts

After the defective circuit has been located, proceed with steps 6 through 8 to locate the defective component(s).

6. Check Voltages and Waveforms. Often the defective component can be located by checking for the correct voltage or waveform in the circuit. Typical voltages and waveforms are given on the diagrams.

NOTE

Voltages and waveforms given on the diagrams are not absolute and may vary slightly between instruments. To obtain operating conditions similar to those used to take these readings, see the first diagram page.

7. Check Individual Components. The following procedures describe methods of checking individual components in the Type 310A. Components which are soldered in place are best checked by disconnecting one end. This isolates the measurement from the effect of surrounding circuitry.

A. TUBES. The best check of tube operation is actual performance under operating conditions. If a tube is suspected of being defective, it can best be checked by substituting a new component or one which has been checked previously. However, be sure that circuit conditions are not such that a replacement tube might also be damaged. If substitute tubes are not available, use a dynamic tester. Static-type testers are not recommended, since they do not check operation under simulated operating conditions.

B. DIODES. A diode can be checked for an open or shorted condition by measuring the resistance between terminals. With an ohmmeter scale having an internal source of between 800 millivolts and 3 volts, the resistance should be very high in one direction and very low when the meter leads are reversed.

CAUTION

Do not use an ohmmeter scale that has a high internal current. High currents may damage the diode.

C. RESISTORS. Check the resistors with an ohmmeter See the Electrical Parts List for the tolerance of the resistors used in this instrument. Resistors normally do not need to be replaced unless the measured value varies widely from the specified value.

D. INDUCTORS. Check for open inductors by checking continuity with an ohmmeter. Shorted or partially shorted inductors can usually be found by checking the waveform response when high-frequency signals are passed through the circuit. Partial shorting often reduces high-frequency response (roll-off).

E. CAPACITORS. A leaky or shorted capacitor can best be detected by checking resistance with an ohmmeter on the highest scale. Do not exceed the voltage rating of the capacitor. The resistance reading should be high after initial charge of the capacitor. An open capacitor can best be detected with a capacitance meter or by checking if the capacitor passes AC signals.

8. Repair and Readjust the Circuit. If any defective parts are located, follow the replacement procedures given in this section. Be sure to check the performance of any circuit that has been repaired or that has had any electrical components replaced.

CORRECTIVE MAINTENANCE

General

Corrective maintenance consists of component replacement and instrument repair. Special techniques required to replace components are given here.

Obtaining Replacement Parts

Standard Parts. All electrical and mechanical part replacements for the Type 310A can be obtained through your local Tektronix Field Office or representative. However, many of the standard electronic components can be obtained locally in less time than is required to order them from Tektronix, Inc. Before purchasing or ordering replacement parts, check the parts lists for value, tolerance, rating and description.

NOTE

When selecting replacement parts, it is important to remember that the physical size and shape of a component may affect its performance in the instrument, particularly at high frequencies. All replacement parts should be direct replacements unless it is known that a different component will not adversely affect instrument performance.

Special Parts. In addition to the standard electronic components, some special components are used in the Type 310A. These components are manufactured or selected by Tektronix, Inc. to meet specific performance requirements, or are manufactured for Tektronix, Inc. in accordance with our specifications. These special components are indicated in the Electrical Parts List by an asterisk preceding the part number. Most of the mechanical parts used in this instrument have been manufactured by Tektronix, Inc. Order all special parts directly from your local Tektronix Field Office or representative.

Ordering Parts. When ordering replacement parts from Tektronix, Inc., include the following information:

1. Instrument type.
2. Instrument serial number.
3. A description of the part (if electrical, include circuit number).
4. Tektronix Part Number.

Soldering Techniques

WARNING

Disconnect the instrument from the power source before soldering.

Ceramic Terminal Strips. Solder used on the ceramic terminal strips should contain about 3% silver. Use a 40- to 75-watt soldering iron with a 1/8-inch wide wedge-shaped tip. Ordinary solder can be used occasionally without damage to the ceramic terminal strips. However, if ordinary solder is used repeatedly or if excessive heat is applied, the solder-to-ceramic bond may be broken.

A sample roll of solder containing about 3% silver is mounted on the rear of the instrument. Additional solder of the same type should be available locally, or it can be purchased from Tektronix, Inc. In one-pound rolls; order by Tektronix Part No. 251-0514-00.

Observe the following precautions when soldering to ceramic terminal strips.

1. Use a hot iron for a short time. Apply only enough heat to make the solder flow freely. Use a heat sink to protect heat-sensitive components.

2. Maintain a clean, properly tinned tip.

3. Avoid putting pressure on the ceramic terminal strip.

4. Do not attempt to fill the terminal-strip notch with solder; use only enough solder to cover the wires adequately.

5. Clean the flux from the terminal strip with a flux-remover solvent.

Metal Terminals. When soldering metal terminals (e.g., switch terminals, potentiometers, etc.), ordinary 60/40 solder can be used. Use a soldering iron with a 40- to 75-watt rating and a 1/8-inch wide wedge-shaped tip.

Observe the following precautions when soldering metal terminals:

1. Apply only enough heat to make the solder flow freely. Use a heat sink to protect heat-sensitive components.

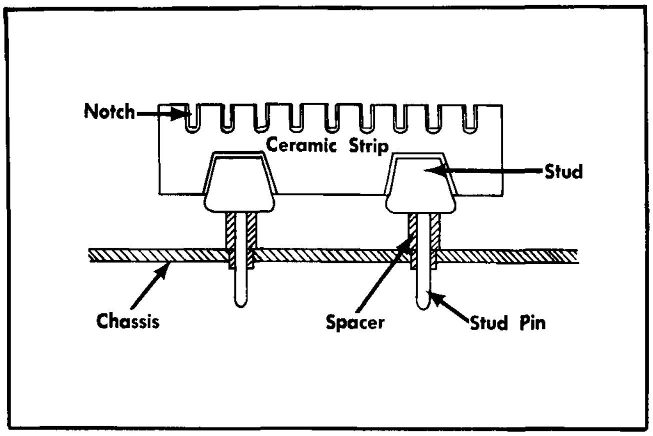


Fig. 4-1. Ceramic terminal strip assembly.

2. Apply only enough solder to form a solid connection. Excess solder may impair the function of the part.

3. If a wire extends beyond the solder joint, clip off the excess.

4. Clean the flux from the solder joint with a flux-remover solvent.

Component Replacement

WARNING

Disconnect the instrument from the power source before replacing components.

Ceramic Terminal Strip Replacement. A complete ceramic terminal strip assembly is shown in Fig. 4-1. Replacement strips (including studs) and spacers are supplied under separate part numbers. However, the old spacers may be re-used if they are not damaged. The applicable Tektronix Part Numbers for the ceramic strips and spacers used in this instrument are given in the Mechanical Parts List.

To replace a ceramic terminal strip, use the following procedure:

REMOVAL:

1. Unsolder all components and connections on the strip. To aid in replacing the strip, it may be advisable to mark each lead or draw a sketch to show location of the components and connections.

2. Pry or pull the damaged strip from the chassis. Be careful not to damage the chassis.

3. If the spacers come out with the strip, remove them from the stud pins for use on the new strip (spacers should be replaced if they are damaged).

REPLACEMENT:

1. Place the spacers in the chassis holes.

2. Carefully press the studs of the strip into the spacers until they are completely seated. If necessary, use a soft mallet and tap lightly, directly over the stud, to seat the strip completely.

3. If the stud extends through the spacers, cut off the excess.

4. Replace all components and connections. Observe the soldering precautions given under Soldering Techniques in this section.

Cathode-Ray Tube Replacement. Use care when handling a CRT. Protective clothing and safety glasses should be worn. Avoid striking it on any object which might cause it to crack or implode. When storing a CRT, place it face down on a smooth surface with a protective cover or soft mat under the faceplate to protect it from scratches.

The CRT shield should also be handled carefully. This shield protects the CRT display from distortion due to magnetic interference. If the shield is dropped or struck sharply, it may lose its shielding ability.

The following procedure outlines the removal and replacement of the cathode-ray tube:

A. REMOVAL:

1. Remove the side panels and separate the chassis as described previously.

2. Remove the four bezel nuts and remove the graticule cover, light filter and graticule.

3. Remove the CRT socket.

4. Loosen the CRT clamp at the base of the CRT shield.

5. Place one hand on the CRT faceplate and push forward on the CRT base with the other. As the CRT starts out of the shield, grasp it firmly. When the CRT is free of the clamp, slide the CRT completely out of the shield.

B. REPLACEMENT:

1. Insert the CRT into the shield.

2. Replace the CRT socket.

3. Replace the graticule, light filter, graticule cover and the four bezel nuts.

4. Push the CRT forward against the graticule. Tighten the base clamp.

5. Check the CRT alignment and geometry adjustments as given in the Calibration section. Also check the basic vertical and horizontal gain.

Tube Replacement. Tubes should not be replaced unless actually defective. If they are removed from their sockets during routine maintenance, return them to their original sockets. Unnecessary replacement of tubes may affect the calibration of this instrument. When tubes are replaced, check the operation of that part of the instrument which may be affected. Replacement tubes should be of the original type or a direct replacement.

CAUTION

POWER switch must be turned off before removing or replacing tubes.

Fuse Replacement. The line fuse for this instrument is located on the rear panel. The fuse requirements are:

117-volts nominal	1.6 ampere slow-blow
234-volts nominal	0.8 ampere slow-blow

Rotary Switches. Individual wafers or mechanical parts of rotary switches are normally not replacable. If a switch is defective, replace the entire assembly. Replacement switches can be ordered either wired or unwired; refer to the Electrical Parts List for the applicable part numbers.

When replacing a switch, tag the leads and switch terminals with corresponding identification tags as the leads are disconnected. Then, use the old switch as a guide for installing the new one. An alternative method is to draw a sketch of the switch layout and record the wire color at each terminal. When soldering to the new switch be careful that the solder does not flow beyond the rivets on the switch terminals. Spring tension of the switch contact can be destroyed by excessive solder.

Power Transformer Replacement. The power transformer in this instrument is warranted for the life of the instrument. If the power transformer becomes defective, contact your local Tektronix Field Office or representative for a warranty replacement (see the Warranty note in the front of this manual). Be sure to replace only with a direct replacement Tektronix transformer.

When removing the transformer, tag the leads with the corresponding terminal numbers to aid in connecting the new transformer. After the transformer is replaced, check the performance of the complete instrument using the Performance Check procedure.

Recalibration After Repair

After any electrical component has been replaced, the calibration of that particular circuit should be checked, as well as the calibration of other closely related circuits. Since the low-voltage power supply affects all circuits, calibration of the entire instrument should be checked if work has been done in the low-voltage supply or if the power transformer has been replaced. The Performance Check procedure provides a quick and convenient means of checking instrument operation.

SECTION 5 PERFORMANCE CHECK/CALIBRATION

Change information, if any, affecting this section will be found at the rear of this manual.

Introduction

To assure instrument accuracy, check the calibration of the Type 310A every 500 hours of operation, or every six months if used infrequently. Before complete calibration, thoroughly clean and inspect the oscilloscope as outlined in the Maintenance section.

As an aid to calibration, a Short-Form Procedure is given prior to the complete procedure. To facilitate instrument calibration for the experienced calibrator, the Short-Form Procedure lists the calibration adjustments necessary for each step and the applicable tolerances. This procedure also includes the step number and title as listed in the Complete Performance Check/Calibration Procedure and the page number on which each step begins. Therefore, the Short-Form Procedure can be used as an index to locate a step in the complete procedure. Another feature of the Short-Form Procedure is the spaces provided to record performance data or to check off steps as they are completed. This procedure can be reproduced and used as a permanent record of instrument calibration.

The Complete Performance Check/Calibration Procedure can be used to check instrument performance without removing the covers or making internal adjustments by performing all portions except the ADJUST- part of a step. Screwdriver adjustments which are accessible without removing the covers are adjusted as part of the performance check procedure. A note titled PERFORMANCE CHECK ONLY gives instructions which are applicable only to the performance check procedure and lists the next applicable performance check step.

Completion of each step in the Complete Performance Check/Calibration Procedure insures that this instrument meets the electrical specifications given in Section 1. Where possible, instrument performance is checked before an adjustment is made. For best overall instrument performance when performing a complete calibration procedure, make each adjustment to the exact setting even if the CHECK- is within the allowable tolerance.

NOTE

Limits and tolerances in this procedure are given as calibration guides and should not be interpreted as instrument specifications except as specified in Section 1.

A partial calibration is often desirable after replacing components or to touch up the adjustment of a portion of the instrument between major recalibrations. To check or adjust only part of the instrument, start with the nearest equipment required picture preceding the desired portion. To prevent unnecessary recalibration of other parts of the instrument, readjust only if the tolerance given in the CHECK- part of the step is not met. If readjustment is necessary, also check the calibration of any steps listed in the INTERACTION- part of the step.

TEST EQUIPMENT REQUIRED

General

The following test equipment and accessories, or its equivalent, is required for complete calibration of the Type 310A. Specifications given are the minimum necessary for accurate calibration. Therefore, some of the recommended equipment may have specifications which exceed those given. All test equipment is assumed to be correctly calibrated and operating within the given specifications. If equipment is substituted, it must meet or exceed the specifications of the recommended equipment.

Special Tektronix calibration fixtures are used in this procedure only where they facilitate quick and more accurate calibration. These special calibration fixtures are available from Tektronix, Inc. Order by part number through your local Tektronix Field Office or representative.

Test Equipment

1. Variable autotransformer.[1] Must be capable of supplying about 200 volt-amperes over a range of 99 to 132 volts (198 to 264 volts for 234-volt nominal line). (If autotransformer does not have an AC voltmeter to indicate output voltage, monitor the output with an AC RMS-reading voltmeter.) For example, General Radio W10MT3W Metered Variac Autotransformer.

2. DC voltmeter[1] Minimum sensitivity, 20,000 ohms/volt; range, 0 to 1750 volts; accuracy, checked to within 1% at 100, 150, 300 and 1675 volts. For example, Triplett Model 630-NA.

3. Test Oscilloscope.[1] Bandwidth, DC to 500 kilohertz; minimum deflection factor, 10 millivolts/division; accuracy, within 3%. Tektronix Type 561A Oscilloscope with Type 3A72 Amplifier unit and Type 2B67 Time Base unit recommended.

[1] **Not required for performance check only.**

4. Standard amplitude calibrator. Amplitude accuracy, within 0.25%; signal amplitude, 50 millivolts to 100 volts; output signal, square wave and positive DC; must have mixed display feature. Tektronix calibration fixture 067-0502-00 recommended.

5. Square-wave generator. Must have the following output capabilities (may be obtained from separate generators): 120 volts amplitude at 50 hertz and one kilohertz repetition rate with a 120 nanosecond or less risetime; 500 millivolts into 50 ohms at 400 kilohertz with a five nanosecond risetime. Tektronix Type 106 Square-Wave Generator recommended (meets both output requirements).

6. High-frequency constant-amplitude sine-wave generator. Frequency, 350 kilohertz to above four megahertz; reference frequency, 50 kilohertz; output amplitude, variable from five millivolts to five volts peak to peak into 50 ohms; amplitude accuracy, output amplitude constant within 3% of reference at 50 kilohertz as output frequency changes. Tektronix Type 191 Constant Amplitude Signal Generator recommended.

7. Low-frequency constant-amplitude sine-wave generator. Frequency, two hertz to 500 kilohertz; output amplitude, variable from 0.4 to 20 volts peak to peak; amplitude accuracy, output amplitude constant within 3% of reference at one kilohertz as output frequency changes. For example, General Radio Model 1310-A Oscillator.

8. Time-mark generator. Marker outputs, 0.1 microsecond to 0.2 second; marker accuracy, within 0.1%. Tektronix Type 184 Time-Mark Generator recommended.

Accessories

NOTE

For instruments between SN 10,000 and 19,119 use comparable accessories which fit UHF connectors or use suitable adapters.

9. 1X probe for test oscilloscope.[1] Tektronix P6011 Probe recommended.

10. Patch cord. Length, 18 inches; connectors, BNC plug-jack and banana plug-jack. Tektronix Part No. 012-0091-00 (supplied accessory for instruments above SN 20,475).

11. 10X probe for test oscilloscope.[1] Tektronix P6006 Probe recommended.

12. Cable. Impedance, 50 ohms; type, RG-58/U; length, 42 inches; connectors, BNC. Tektronix Part No. 012-0057-01.

13. Adapter. Adapts GR874 connector to BNC male connector. Tektronix Part No. 017-0063-00.

[1]**Not required for performance check only.**

14. 5X attenuator. Impedance, 50 ohms; accuracy, ±3%; connectors, BNC. Tektronix Part No. 011-0060-00.

15. Termination. Impedance, 50 ohms; accuracy, ±3%; connectors, BNC. Tektronix Part No. 011-0049-00.

16. 2X attenuator. Impedance, 50 ohms; accuracy, ±3%; connectors, BNC. Tektronix Part No. 011-0069-00.

17. 10X probe for Type 310A. Tektronix P6012 recommended (supplied accessory).

18. Adapter. BNC-to-post. Tektronix Part No. 012-0092-00 (supplied accessory for instruments above SN-20,475).

19. Adapter. Adapts BNC male to dual binding posts. Tektronix Part No. 013-0094-00.

20. BNC T connector. Adapts two BNC male connectors to one BNC female connector. Tektronix Part No. 103-0030-00.

21. Patch cord. Length, 18 inches; connectors, banana plug-jack both ends. Tektronix Part No. 012-0031-00.

Adjustment Tools

22. Screwdriver. Three-inch shaft, 3/32-inch bit for slotted screws. Tektronix Part No. 003-0192-00.

23. Screwdriver.[1] Three-inch shaft, #1 Phillips bit. Tektronix Part No. 003-0341-00.

24. Low-capacitance screwdriver.[1] 1 1/2-inch shaft. Tektronix Part No. 003-0000-00.

25. Tuning rod[1] Five inch for 0.100-inch (ID) hex slugs. Tektronix Part No. 003-0301-00.

SHORT-FORM PROCEDURE

Type 310A, Serial No. __________

Calibration Date ______________

Calibrated By ________________

1. Adjust −150-Volt Power Supply (R610) Page 5-7

REQUIREMENT: −150 volts, ±4.5 volts.

PERFORMANCE: −150 volts, ± ____ volts.

2. Check +100-Volt and +300-Volt Power Supplies Page 5-8

REQUIREMENT: +100 volts, ±3 volts. +300 volts, ±9 volts.

PERFORMANCE: +100 volts, ± ____volts. +300 volts, ± ____ volts.

3. Check Low-Voltage Power Supply Regulation — Page 5-8

Output voltage tolerances over line voltage range (from reference at center of regulating range):

Power supply	REQUIREMENT: Voltage tolerance.	PERFORMANCE: Output voltage change.
150 volt	±4.5 volts	____ volts
+100 volt	±3 volts	____ volts
+300 volt	±9 volts	____ volts

4. Adjust High-Voltage Supply and Check Regulation (R741) — Page 5-8

REQUIREMENT: Output voltage, −1675 volts ±49 volts. Output level changes less than ±49 volts over line voltage range.

PERFORMANCE: Output voltage, ____ volts. ____ volts change over line voltage range.

5. Check Low-Voltage Power Supply Ripple — Page 5-9

REQUIREMENT: −150 volt and +100 volt, 10 millivolts maximum ripple over line voltage range; +300 volt, 40 millivolts maximum ripple over line voltage range.

PERFORMANCE: −150 volt, ____ millivolts maximum ripple; +100 volt, ____ millivolts maximum ripple; +300 volt, ____ millivolts maximum ripple.

6. Check/Adjust DC Balance (R344) — Page 5-9

REQUIREMENT: Less than one division vertical trace shift as the Variable VOLTS/DIV control is rotated throughout its range.

PERFORMANCE: ____ division maximum shift.

7. Check/Adjust Preset Stability (R126) — Page 5-9

REQUIREMENT: Correct operation of trigger circuit; see procedure.

PERFORMANCE: Correct ____ ; incorrect ____ .

8. Check/Adjust Astigmatism (R750) — Page 5-9

REQUIREMENT: Sharp, well defined display.

PERFORMANCE: Correct ____ ; incorrect ____ .

9. Check/Adjust CRT Alignment (Reposition CRT) — Page 5-9

REQUIREMENT: Trace parallel to center horizontal line within 0.5 division/10 divisions.

PERFORMANCE: Within ____ division.

10. Check/Adjust Vertical Gain (R442) — Page 5-12

REQUIREMENT: Five divisions vertical deflection at .1 VOLTS/DIV with 0.5-volt square-wave input.

PERFORMANCE: Correct ____ ; incorrect ____ .

11. Check/Adjust Vertical Preamplifier Gain (R322) — Page 5-13

REQUIREMENT: Five divisions ±0.15 division vertical deflection at .01 VOLTS/DIV with 50-millivolt square-wave input.

PERFORMANCE: Five divisions ± ____ division.

12. Check Vertical Deflection Factor Accuracy — Page 5-13

REQUIREMENT: Vertical deflection factor within 3% of VOLTS/DIV switch indication at all settings.

PERFORMANCE: Correct ____ ; incorrect (list exceptions) ________________________ .

13. Check Variable Volts/Division Control Range — Page 5-13

REQUIREMENT: Continuously variable between the calibrated settings of the VOLTS/DIV switch.

PERFORMANCE: Correct ____ ; incorrect ____ .

14. Check Input Coupling Switch Operation — Page 5-13

REQUIREMENT: Correct signal coupling in each position of the Input Coupling switch.

PERFORMANCE: Correct ____ ; incorrect ____ .

15. Check Low-Frequency Linearity — Page 5-14

REQUIREMENT: 0.1 division or less compression and 0.15 division expansion of a center-screen two-division signal when positioned to the vertical extremes of the graticule area.

PERFORMANCE: ____ division maximum compression; ____ division maximim expansion.

16. Adjust Hum Balance (R470) — Page 5-14

REQUIREMENT: Minimum hum.

PERFORMANCE: Correct ____ ; incorrect ____ .

17. Check/Adjust Volts/Division Switch Series Compensation (C300, C303, C306, C309, C310, C413) — Page 5-15

REQUIREMENT: Optimum square corner within 3%.

PERFORMANCE: Correct ____, incorrect (list exceptions) ____

18. Check/Adjust Volts/Division Switch Shunt Compensation (C301, C304, C307, C320) Page 5-16

REQUIREMENT: Flat top within 3%.

PERFORMANCE: Correct ____ ; incorrect ____ .

19. Check/Adjust Low-Frequency Compensation (R345) Page 5-17

REQUIREMENT: Correct waveform response at 50 hertz; see procedure.

PERFORMANCE: Correct ____; incorrect ____ .

20. Check/Adjust Vertical Amplifier High-Frequency Compensation (L409, L418, L450, L451) Page 5-17

REQUIREMENT: Square corner and flat top on 400 kilohertz square wave within ±0.15 division at .1 VOLTS/DIV.

PERFORMANCE: Correct ____ ; incorrect ____ .

21. Check/Adjust Preamplifier High-Frequency Compensation (L325, L341) Page 5-18

REQUIREMENT: Square-wave display at .01 VOLTS/DIV similar to that obtained at .1 (previous step).

PERFORMANCE: Correct ____ ; incorrect ____.

22. Check Upper Vertical Bandwidth Limit Page 5-19

REQUIREMENT:
.1, not more than −3 dB at four megahertz.
.05 to .01, not more than −3 dB at 3.5 megahertz.

PERFORMANCE:
.1, −3 dB point ____ megahertz.
.05, −3 dB point ____ megahertz.
.02, −3 dB point ____ megahertz.
.01, −3 dB point ____ megahertz.

23. Check AC-Coupled Lower Vertical Bandwidth Limit Page 5-19

REQUIREMENT: Not more than −3 dB at two hertz.

PERFORMANCE: Correct ____; incorrect ____ .

24. Check High-Frequency Triggering Operation Page 5-19

REQUIREMENT: Internal, stable display in the AUTO position with a two-division display at two megahertz; stable display in the AC and DC positions with a two-division display at four megahertz. External, stable display in the AUTO position with a two-volt signal at two megahertz; stable display in the AC and DC positions with a two-volt signal at four megahertz.

PERFORMANCE: Correct ____ ; incorrect (list exceptions) ____ .

25. Check Low-Frequency Triggering Operation Page 5-20

REQUIREMENT: Internal, stable display in the AUTO, AC and DC positions with a 0.25 division display at one kilohertz; stable display in the AUTO position with a 0.25-division display at 60 hertz; stable display in the AC and DC positions with a 0.25-division display at 30 hertz. External, stable display in the AUTO, AC and DC positions with a 0.2-volt signal at one kilohertz; stable display in the AUTO position with a 0.2-volt signal at 60 hertz; stable display in the AC and DC positions with a 0.2-volt signal at 30 hertz.

PERFORMANCE: Correct ____; incorrect (list exceptions) ____.

26. Check Triggering Slope Operation Page 5-20

REQUIREMENT: Stable triggering on the correct slope of trigger signal.

PERFORMANCE: Correct ____; incorrect ____.

27. Check Line Triggering Operation Page 5-20

REQUIREMENT: Stable display of line-frequency signal, triggered on the correct slope.

PERFORMANCE: Correct ____; incorrect ____.

28. Check/Adjust Normal Timing (R250) Page 5-20

REQUIREMENT: Correct timing within 0.24 division at 1 MSEC/DIV over middle eight divisions of display.

PERFORMANCE: Within ____ division over center eight divisions.

29. Check/Adjust Sweep Length (R161) Page 5-21

REQUIREMENT: Between 10.2 and 10.8 divisions.

PERFORMANCE: ____ divisions.

30. Check/Adjust Magnifier Registration (R215) Page 5-21

REQUIREMENT: Less than one-division shift of marker at center vertical line when Horizontal Display switch is changed from X5 MAG to X1 MAG.

PERFORMANCE: ____ division shift.

31. Check Variable Time/Division Control Range — Page 5-21

REQUIREMENT: Continuously variable between calibrated TIME/DIV switch settings.

PERFORMANCE: Correct ____ ; incorrect ____ .

32. Adjust High-Speed Linearity (C205, C213) — Page 5-22

REQUIREMENT: Correct operation at 10 μSEC/DIV; see procedure.

PERFORMANCE: Correct ____ ; incorrect ____ .

33. Adjust 10-Microsecond Timing (C175B) — Page 5-22

REQUIREMENT: Correct timing within 0.24 division over center eight divisions.

PERFORMANCE: Within ____ division.

34. Adjust One-Microsecond Timing (C175A) — Page 5-22

REQUIREMENT: Correct timing within 0.24 division over center eight divisions.

PERFORMANCE: Within ____ division.

35. Adjust 0.5-Microsecond Timing (C250) — Page 5-22

REQUIREMENT: Correct timing within 0.4 division over center eight divisions of total magnified sweep length.

PERFORMANCE: Within ____ division.

36. Check Normal Sweep Timing Accuracy — Page 5-23

REQUIREMENT: Correct timing within 0.24 division over center eight divisions at each TIME/DIV switch setting.

PERFORMANCE: Correct ____ ; incorrect (list exceptions) ____________________ .

37. Check Magnified Sweep Timing Accuracy — Page 5-23

REQUIREMENT: Correct timing within 0.32 division (0.4 division at 0.5 μSEC/DIV) over center eight divisions of total magnified sweep length at each TIME/DIV switch setting.

PERFORMANCE: Correct ____ ; incorrect (list exceptions) ____________________ .

38. Check/Adjust Calibrator Amplitude (R510) — Page 5-24

REQUIREMENT: Correct calibrator output within 3% at all CALIBRATOR switch positions.

PERFORMANCE: Correct ____ ; incorrect (list exceptions) ____________________ .

39. Check Calibrator Repetition Rate — Page 5-25

REQUIREMENT: Approximately one kilohertz.

PERFORMANCE: Correct ____ ; incorrect ____ .

40. Check External Horizontal Deflection Factor — Page 5-25

REQUIREMENT: Minimum horizontal deflection of 6.67 divisions.

PERFORMANCE: ____ division horizontal deflection.

41. Check External Horizontal Bandwidth — Page 5-25

REQUIREMENT: Not more than −3 dB at 500 kilohertz.

PERFORMANCE: Correct ____ ; incorrect ____ .

42. Check External Blanking — Page 5-26

REQUIREMENT: 20 volt peak to peak signal blanks trace.

PERFORMANCE: Correct ____ ; incorrect ____ .

PERFORMANCE CHECK/CALIBRATION PROCEDURE

General

The following procedure is arranged so the Type 310A can be calibrated with the least interaction of adjustments and reconnection of equipment. A picutre of the test equipment required for each group of steps is given to aid in identification of the necessary equipment. Control settings and test equipment setup throughout the procedure continue from the preceding step(s) unless noted otherwise. A complete list of control settings is given following this picture. To aid in performing a complete calibration procedure controls must be changed for the next step are printed in bold type.

NOTE

Control titles which are printed on the front-, side- or rear-panel of the Type 310A are capitalized in this procedure (e.g., VOLTS/DIV). Internal adjustments are initial capitalized only (e.g., Vert Gain Adj).

The following procedure uses the equipment listed under Equipment Required. If other equipment is substituted, control settings or calibration setup may need to be altered to meet the requirements of the equipment used. For detailed operating instructions for the equipment, refer to the instruction manual for the test equipment.

NOTE

This instrument should be calibrated at any ambient temperature of +25°C ±5°C for best overall accuracy. Performance can be checked at any temperature within the 0°C to +40°C range. If the ambient temperature is outside the given range, see Section 1 for the applicable tolerances.

Preliminary Procedure for Performance Check Only

1. Connect the Type 310A to a power source which meets the voltage and frequency requirements of this instrument.

2. Turn the SCALE ILLUM control clockwise to turn the power on. Allow at least 20 minutes warmup before proceeding.

3. Begin the performance check with step 6.

Preliminary Procedure for Complete Calibration

1. Remove the side panels from the Type 310A.

2. Connect the autotransformer to a suitable power source.

3. Connect the Type 310A to the autotransformer output.

4. Set the autotransformer output voltage to the center of the voltage range for which the Type 310A is wired.

5. Turn the SCALE ILLUM control clockwise to turn the power on. Allow at least 20 minutes warmup before proceeding.

NOTES

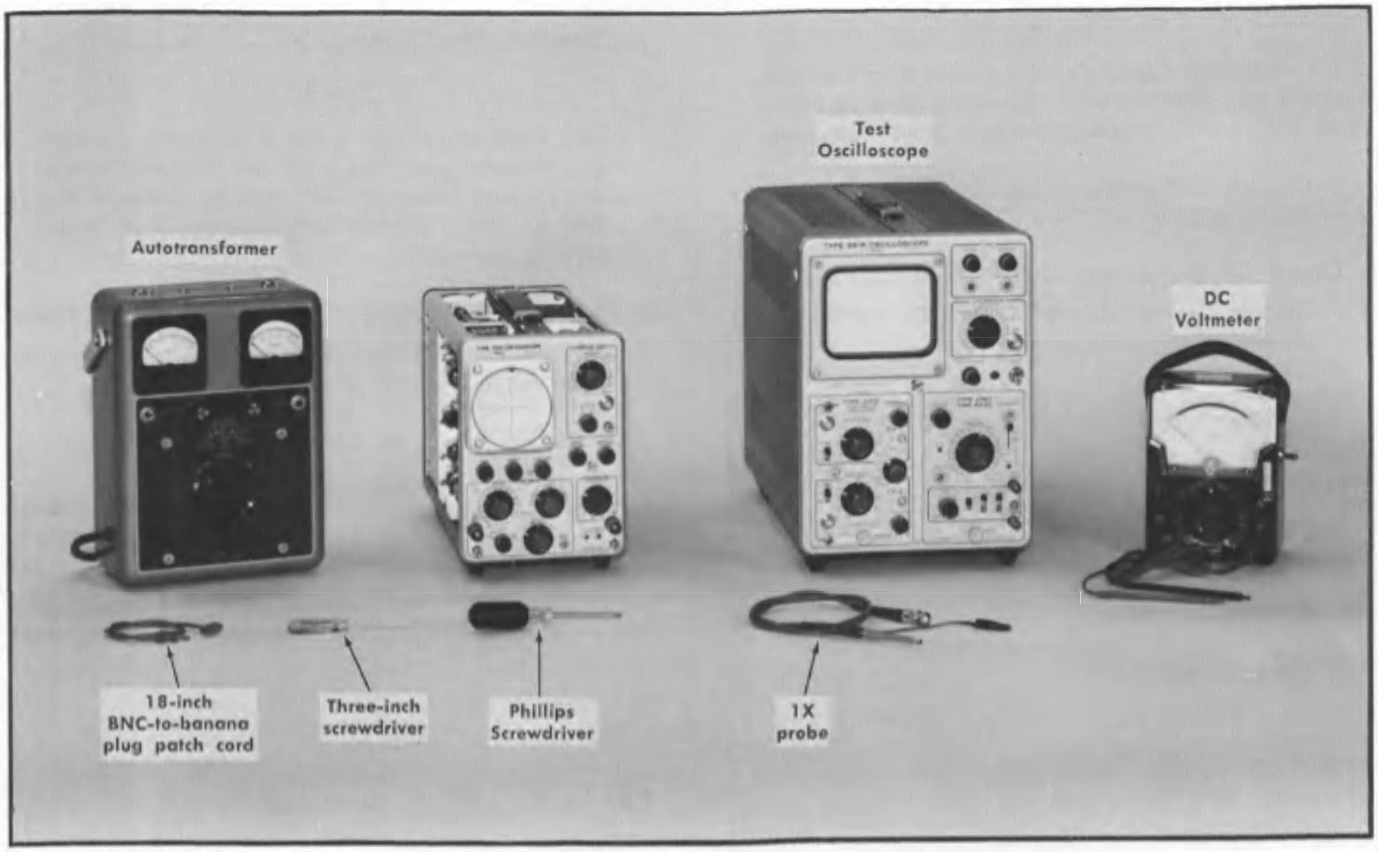


Fig. 5-1. Equipment required for steps 1 through 9.

CRT controls

FOCUS	Midrange
INTENSITY	Counterclockwise
SCALE ILLUM	As desired (power on)

Vertical controls

VOLTS/DIV	.1
Variable	CALIBRATED
Input Coupling	DC

Trigger controls

TRIGGER	+INT
Trigger Coupling-Mode	AC
TRIG LEVEL	Clockwise
STABILITY	Counterclockwise (not in PRESET detent)

Sweep controls

TIME/DIV	100 μSEC
Variable	CALIBRATED
Horizontal Display	X1 MAG

Other controls

VERTICAL POSITION	Midrange
HORIZONTAL POSITION	Midrange
CALIBRATOR	OFF

Rear-panel controls

HORIZ GAIN	Clockwise

1. Adjust −150-Volt Power Supply

PERFORMANCE CHECK ONLY

Steps 1 through 5 are not applicable to a performance check. Set controls as given following Fig. 5-1 and begin with step 6.

a. Equipment required for steps 1 through 9 is shown in Fig. 5-1.

b. Separate the chassis of the Type 310A and swing the right chassis open.

c. Connect the DC voltmeter from the −150-volt test point (see Fig. 5-2A) to chassis ground.

NOTE

Power supply voltage and ripple tolerances given in steps 1 through 5 are typical values, provided as guides to correct instrument operation. They are not instrument specifications. The actual values may be greater than those listed, without loss of measurement accuracy, if the instrument meets the specifications given in Section 1 as tested in this procedure.

d. CHECK—Meter reading; −150 volts ±4.5 volts.

e. ADJUST— −150-V Adj, R610 (see Fig. 5-2B) for −150 volts.

NOTE

The —150-Volt supply can be adjusted to any voltage within the —150-volt ±4.5 volts range to bring either the +100-volt or +300-volt supply within tolerance.

f. INTERACTION—May affect operation of all circuits within the Type 310A.

2. Check +100-Volt and +300-Volt Power Supplies

a. Connect the DC voltmeter from the +100-volt test point (see Fig. 5-2A) to chassis ground.

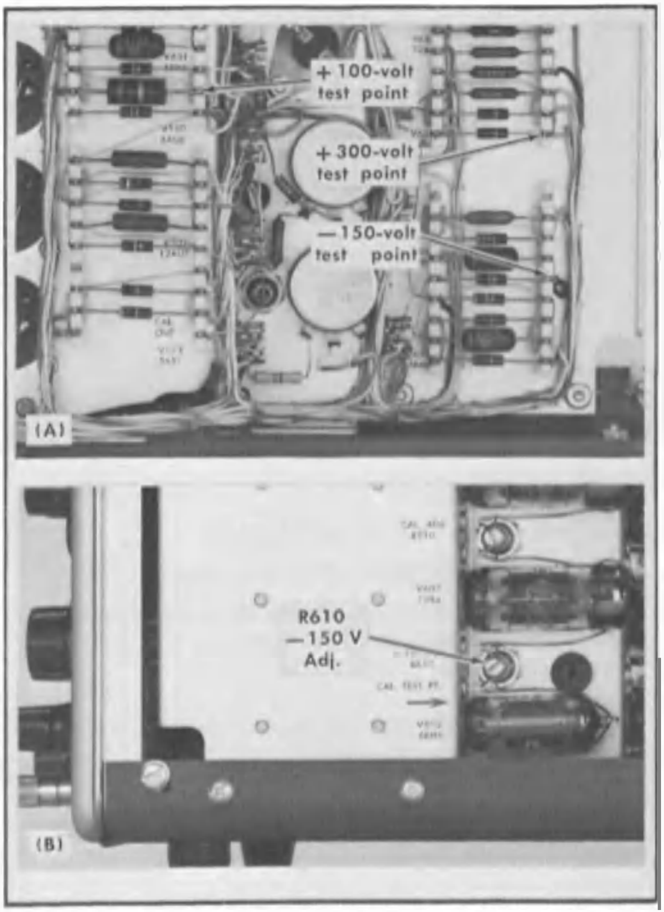


Fig. 5-2. (A) Location of power supply test points (inside swing-out chassis), (B) location of —150-volt adjustment (right side).

b. CHECK—Meter reading; +100 volts ±3 volts.

NOTE

If the +100-volt supply is out of tolerance, readjust the —150-volt supply to bring the +100-volt supply into correct tolerance. Be sure to recheck the —150-volt supply for correct tolerance after adjustment.

c. Connect the DC voltmeter from the +300-volt test point (see Fig. 5-2A) to chassis ground.

d. CHECK—Meter reading; +300 volts ±9 volts.

NOTE

If the +300-volt supply is out of tolerance, readjust the —150-volt supply to bring the +300-volt supply into correct tolerance. Be sure to recheck the —150-volt and +100-volt supplies for correct tolerance after adjustment.

3. Check Low-Voltage Power Supply Regulation

a. Connect the DC voltmeter from the —150-volt test point (see Fig. 5-2A) to chassis ground.

b. Note the output voltage of the —150-volt supply.

c. CHECK—Vary the autotransformer output voltage throughout the regulating range for which this instrument is wired and check for less than ±4.5 volts change from the voltage noted in part b.

d. Return the autotransformer to the center voltage of the regulating range.

e. Connect the DC voltmeter from the +100-volt test point (see Fig. 5-2A) to chassis ground.

f. Note the output voltage of the +100-volt supply.

g. CHECK—Vary the autotransformer output voltage throughout the regulating range and check for less than ±3 volts change from the voltage noted in part f.

h. Return the autotransformer to the center voltage of the regulating range.

i. Connect the DC voltmeter from the +300-volt test point (see Fig. 5-2A) to chassis ground.

j. Note the output voltage of the +300-volt supply.

k. CHECK—Vary the autotransformer output voltage throughout the regulating range and check for less than ±9 volts change from the voltage noted in part j.

l. Return the autotransformer to the center voltage of the regulating range.

4. Adjust High-Voltage Supply and Check Regulation

a. Connect the DC voltmeter from the high-voltage test point (see Fig. 5-3) to chassis ground.

b. CHECK—Meter reading; —1675 volts ±49 volts.

c. ADJUST—HV Adj, R741 (see Fig. 5-3) for —1675 volts.

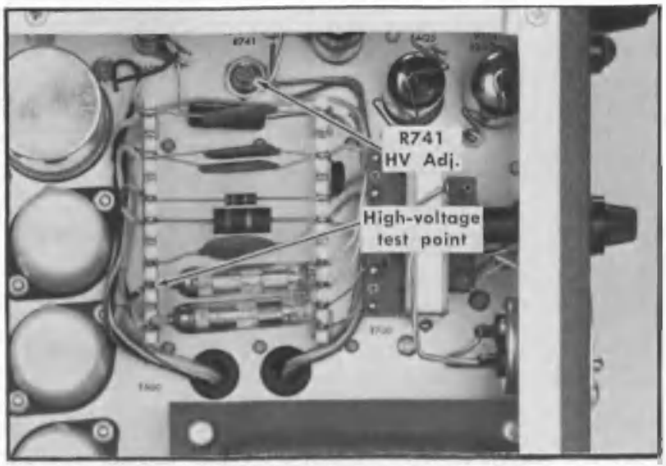


Fig. 5-3. Location of high-voltage test point and adjustment (right side).

d. CHECK—Vary the autotransformer output voltage throughout the regulating range for which this instrument is wired and check for less than ±49 volts change in the high-voltage output level. Also set the INTENSITY control fully clockwise at minimum line voltage and fully counterclockwise at maximum line voltage; check that regulation remains within given limits.

CAUTION

If a spot or trace appears on the screen when the INTENSITY control is turned clockwise, position it off the viewing area to protect the CRT phosphor.

e. INTERACTION—May affect operation of all circuits within the Type 310A.

f. Disconnect the DC voltmeter.

5. Check Low-Voltage Power Supply Ripple

a. Connect the 1X probe to the test oscilloscope input connector.

b. Set the test oscilloscope for a vertical deflection factor of 10 millivolts/division, AC coupled, at a sweep rate of five milliseconds/division.

c. Connect the probe tip to the −150-volt test point (see Fig. 5-2A). Connect the probe ground lead to the Type 310A chassis near the test point.

d. CHECK—Test oscilloscope display for less than one division vertical deflection (10 millivolts ripple) while varying the autotransformer output voltage throughout the regulating range for which this instrument is wired.

e. Connect the probe tip to the +100-volt test point (see Fig. 5-2A). Connect the probe ground lead to the Type 310A chassis near the test point.

f. CHECK—Test oscilloscope display for less than one division vertical deflection (10 millivolts ripple) while varying the autotransformer output voltage throughout the regulating range.

g. Connect the probe tip to the +300-volt test point (see Fig. 5-2A). Connect the probe ground lead to the Type 310A chassis near the test point.

h. CHECK—Test oscilloscope display for less than four divisions vertical deflection (40 millivolts ripple) while varying the autotransformer output voltage throughout the regulating range for which this instrument is wired.

i. Return the autotransformer to the center voltage of the regulating range. (If the line voltage is near the center of the regulating range, the Type 310A can be connected directly to the line; otherwise, leave the instrument connected to the autotransformer for the remainder of this procedure.)

j. Disconnect all test equipment.

6. Check/Adjust DC Balance

a. Connect the vertical INPUT connector to one of the ground posts on the front panel with the 18-inch BNC-to-banana plug patch cord.

b. Turn the TRIG LEVEL and STABILITY controls fully clockwise.

c. Advance the INTENSITY control until a trace is visible. If the trace is not visible with the INTENSITY control set near midrange, preadjust the DC Bal adjustment to bring the trace on screen (VERTICAL POSITION control must be set to midrange).

d. Adjust the FOCUS control for as well-focused a display as possible (trace may not focus well since the ASTIG adjustment has not been performed yet).

e. Position the trace to the center horizontal line with the VERTICAL POSITION control.

f. CHECK—Rotate the Variable VOLTS/DIV control throughout its range. Trace should not move more than one division vertically.

g. ADJUST—DC Bal adjustment, R344 (see Fig. 5-4), for minimum trace shift as the Variable VOLTS/DIV control is rotated.

h. Return the Variable VOLTS/DIV to the CALIBRATED position.

7. Check/Adjust Preset Stability

a. Set the Trigger Coupling-Mode switch to Auto.

Fig. 5-4. Location of DC Bal adjustment (left side).

PERFORMANCE CHECK ONLY

The remainder of this step is not applicable to a performance check. If there is no trace on the CRT at this point, adjust the PRESET ADJUST as follows (this procedure may not provide correct instrument performance under all operating conditions): (1) Rotate the PRESET ADJUST fully counterclockwise and then slowly rotate it clockwise until a trace first appears on the CRT; note the physical rotation of the adjustment. (2) Continue rotating the PRESET ADJUST until the trace brightens; again note the rotation. (3) Set the PRESET ADJUST midway between the position noted in parts (1) and (2). (4) Proceed to next step.

b. Connect the 10X probe to the test oscilloscope input connector.

c. Set the test oscilloscope for a vertical deflection factor of 0.5 volts/division (5 volts/division at probe tip), DC coupled, at a sweep rate of one millisecond/division.

d. Connect the 10X probe tip to the preset test point (junction of C101-R100; see Fig. 5-5A). Connect the probe ground strap to the Type 310A chassis near the test point.

e. Rotate the PRESET ADJUST, R126 (see Fig. 5-5B), fully counterclockwise. Then, slowly rotate it clockwise until the trace first appears on the Type 310A CRT. Adjust the test oscilloscope vertical position control to move the trace to a graticule line near the center horizontal line.

f. Continue rotating the PRESET ADJUST clockwise until the trace on the Type 310A CRT brightens. Note the location of the trace on the oscilloscope CRT.

g. ADJUST—Rotate the PRESET ADJUST counterclockwise until the trace on the test oscilloscope is located half way between the trace location in parts e and f.

h. Disconnect all test equipment.

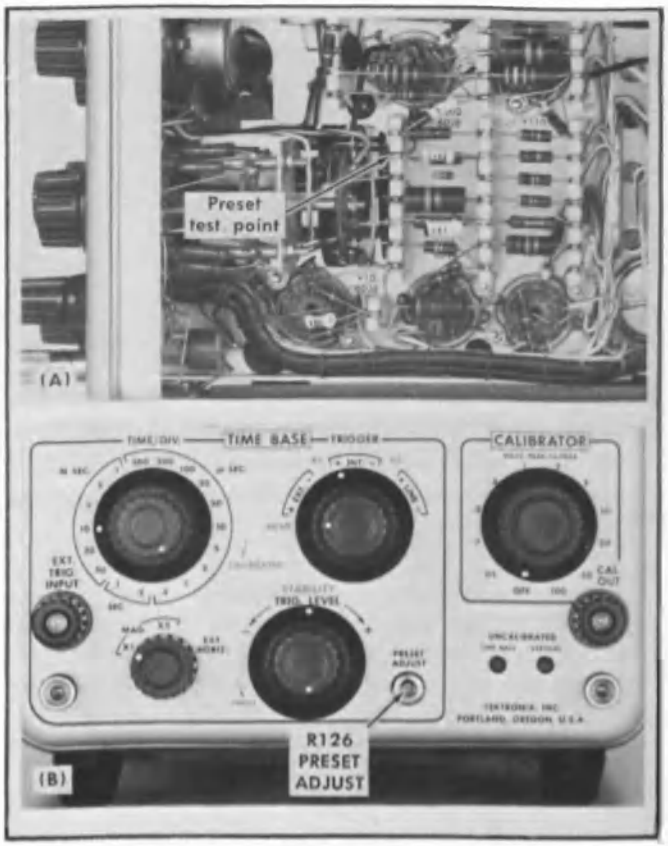


Fig. 5-5. (A) Location of preset test point (inside swing-out chassis), (B) location of PRESET ADJUST (front panel).

8. Check/Adjust Astigmatism

a. Connect the CAL OUT binding post to the vertical INPUT connector with the 18-inch BNC-to-banana plug patch cord.

b. Set the CALIBRATOR switch to .5.

c. Center the display on the CRT area with the VERTICAL POSITION and HORIZONTAL POSITION controls.

d. CHECK—CRT display should be well defined with optimum setting of the FOCUS CONTROL.

PERFORMANCE CHECK ONLY

Rear-panel operational adjustment; can be adjusted as part of a performance check.

e. ADJUST—FOCUS control and ASTIG adjustment, R750 (see Fig. 5-6), for best definition of the CRT display.

9. Check/Adjust CRT Alignment

a. Connect the vertical INPUT connector to one of the ground posts on the front panel with the 18-inch BNC-to-banana plug patch cord.

b. Position the trace to the center horizontal line with the VERTICAL POSITION control.

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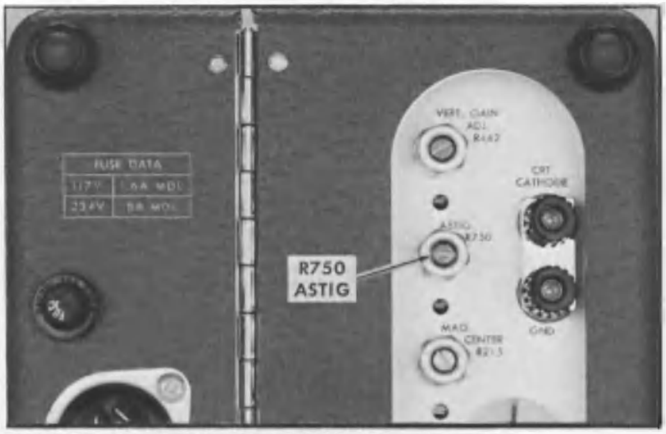


Fig. 5-6. Location of ASTIG adjustment (rear panel).

c. CHECK—The trace should be parallel to the center horizontal line within 0.5 division/10 divisions (i.e., with trace positioned to center horizontal line at the farthest left vertical line of the graticule, the trace must be within 0.5 division of the center horizontal line at the farthest right vertical line).

d. ADJUST—Loosen the CRT base clamp with the Phillips screwdriver. Push the CRT forward so the CRT face is firmly against the external graticule. Then rotate the CRT until the trace is parallel to the center horizontal line and re-tighten the base clamp.

e. Disconnect the patch cord. Close and latch the swing-out chassis.

NOTES

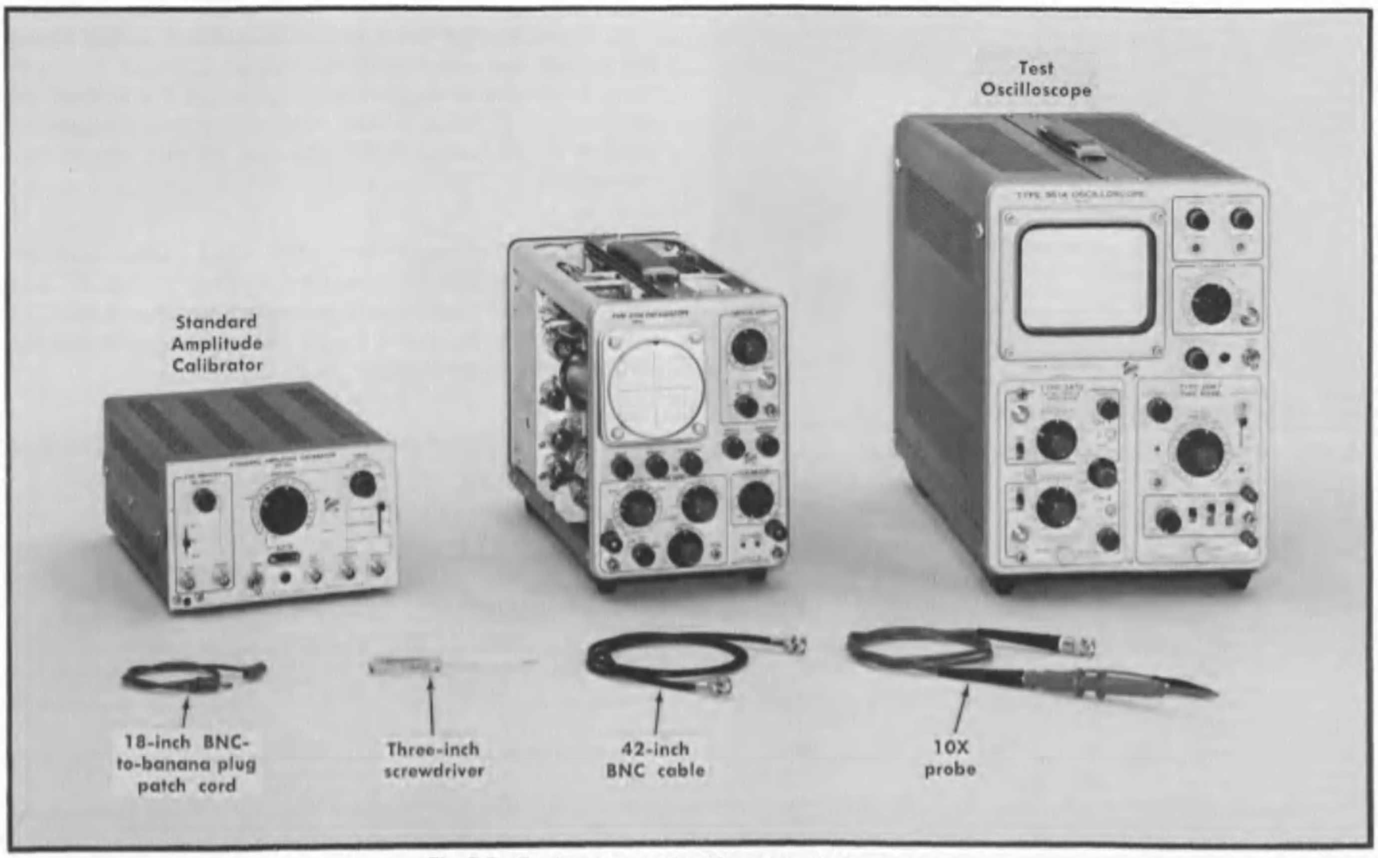


Fig. 5-7. Equipment required for steps 10 through 16.

CRT controls

FOCUS	Adjust for well defined display
INTENSITY	Adjust for visible display
SCALE ILLUM	As desired (power on)

Vertical controls

VOLTS/DIV	.1
Variable	CALIBRATED
Input Coupling	DC

Trigger controls

TRIGGER	+ INT
Trigger Coupling-Mode	AUTO
TRIG LEVEL	**Midrange**
STABILITY	**PRESET**

SWEEP controls

TIME/DIV	**1 MSEC**
Variable	CALIBRATED
Horizontal Display	X1 MAG

Other controls

VERTICAL POSITION	Midrange
HORIZONTAL POSITION	Midrange
CALIBRATOR	**OFF**

Rear-panel controls

HORIZ GAIN	Clockwise

10. Check/Adjust Vertical Gain

a. Equipment required for steps 10 through 16 is shown in Fig. 5-7.

b. Connect the standard amplitude calibrator (067-0502-00) output connector to the vertical INPUT connector with the 42-inch BNC cable.

c. Set the standard amplitude calibrator for a 0.5-volt squarewave output.

d. Center the display about the center horizontal line with the VERTICAL POSITION control.

e. CHECK—CRT display for five divisions vertical deflection.

PERFORMANCE CHECK ONLY

Rear-panel operational adjustment; can be adjusted as part of a performance check.

f. ADJUST—VERT GAIN ADJ, R442 (see Fig. 5-8), for exactly five divisions vertical deflection at the center vertical line.

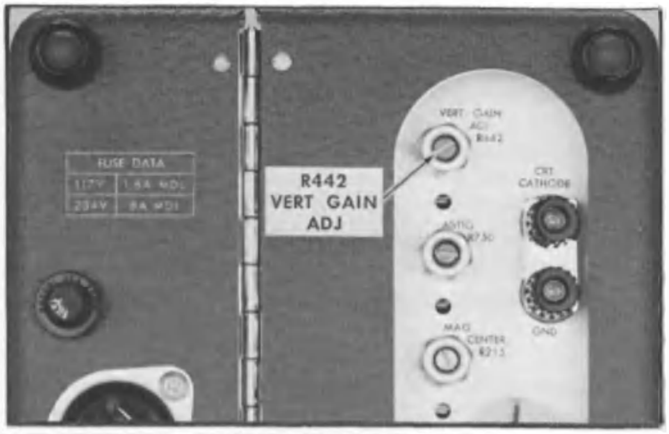


Fig. 5-8. Location of VERT GAIN ADJ (rear panel).

11. Check/Adjust Vertical Preamplifier Gain

a. Set the VOLTS/DIV switch to .01.

b. Set the standard amplitude calibrator for a 50-millivolt squarewave output.

c. Center the display about the center horizontal line with the VERTICAL POSITION control.

d. CHECK—CRT display for five divisions ±0.15 division vertical deflection (within 3%). Since the signal is AC coupled in this position, some waveform tilt is evident in the CRT display. Measure the amplitude between the front corners of the positive and negative portions of the square wave to eliminate amplitude errors due to the tilt.

e. ADJUST—Preamp Gain adjustment, R322 (see Fig. 5-9), for exactly five divisions vertical deflection at the center vertical line.

12. Check Vertical Deflection Factor Accuracy

a. CHECK—Using the VOLTS/DIV switch and standard amplitude calibrator settings given in Table 5-1, check vertical deflection within 3% in each position of the VOLTS/DIV switch.

Fig. 5-9. Location of Preamp Gain adjustment (left side).

TABLE 5-1
Vertical Deflection Accuracy

VOLTS/DIV switch setting	Standard amplitude calibrator output	Vertical deflection in divisions	Maximum error for ±3% accuracy (divisions)
.01	Checked in previous step		
.02	0.1 volt	5	±0.15
.05	0.2 volt	4	±0.12
.1	0.5	5	±0.15
.2	1 volt	5	±0.15
.5	2 volts	4	±0.12
1	5 volts	5	±0.15
2	10 volts	5	±0.15
5	20 volts	4	±0.12
10	50 volts	5	±0.15
20	100 volts	5	±0.15
50	100 volts	2	±0.06

13. Check Variable Volts/Division Control Range

a. Change the following control settings:

VOLTS/DIV	.1
Input Coupling	AC

b. Set the standard amplitude calibrator for a 0.5-volt square-wave output.

c. Center the display about the center horizontal line with the VERTICAL POSITION control.

d. CHECK—Rotate the Variable VOLTS/DIV control fully counterclockwise. Display must be reduced to two divisions or less (indicates adequate range for continuously variable deflection factor between the calibrated steps). UNCALIBRATED VERTICAL light must be on when Variable VOLTS/DIV control is not in the CALIBRATED Position.

14. Check Input Coupling Switch Operation

a. Set the Variable VOLTS/DIV control to CALIBRATED.

b. Set the standard amplitude calibrator for a 0.2-volt square wave output.

c. Center the display about the center horizontal line with the VERTICAL POSITION control.

d. Set the Input Coupling switch to DC.

e. CHECK—Bottom of the displayed square wave near the center horizontal line.

f. Disconnect the input signal.

g. CHECK—CRT display for straight line near the center horizontal line.

15. Check Low-Frequency Linearity

a. Reconnect the standard amplitude calibrator to the vertical INPUT connector with the 42-inch BNC cable.

b. Set the standard amplitude calibrator for a 0.5-volt square-wave output.

c. Position the display to the center of the graticule with the VERTICAL POSITION control.

d. Reduce the display to exactly two divisions with the Variable VOLTS/DIV control (keep display centered about the center horizontal line).

e. Position the top of the display to the top horizontal line of the graticule.

NOTE

Tolerances given in this step are typical values provided as guides to correct instrument operation, and are not instrument specifications.

f. CHECK—Vertical compression of display does not exceed 0.1 division or expansion does not exceed 0.15 division.

g. Position the bottom of the display to the bottom horizontal line of the graticule.

h. CHECK—Vertical compression of display does not exceed 0.1 division or expansion does not exceed 0.15 division.

i. Set the Variable VOLTS/DIV control to CALIBRATED.

j. Disconnect all test equipment.

16. Adjust Hum Balance

PERFORMANCE CHECK ONLY

This step is not applicable to a performance check. Proceed to next equipment required picture (Fig. 5-11).

a. Set the VOLTS/DIV switch to .01.

b. Connect the vertical INPUT connector to one of the ground posts on the front panel with the 18-inch BNC-to-banana plug patch cord.

c. Connect the 10X probe to the test oscilloscope input connector.

d. Set the test oscilloscope for a vertical deflection factor of 0.05 volts/division (0.5 volts/division at probe tip), AC coupled, at a sweep rate of five milliseconds/division.

e. Connect the 10X probe tip to the hum balance test point (see Fig. 5-10A). Connect the probe ground strap to the Type 310A chassis near the test point.

f. ADJUST—Hum Balance adjustment, R470 (see Fig. 5-10B), for minimum vertical deflection on the test oscilloscope.

g. Disconnect all test equipment.

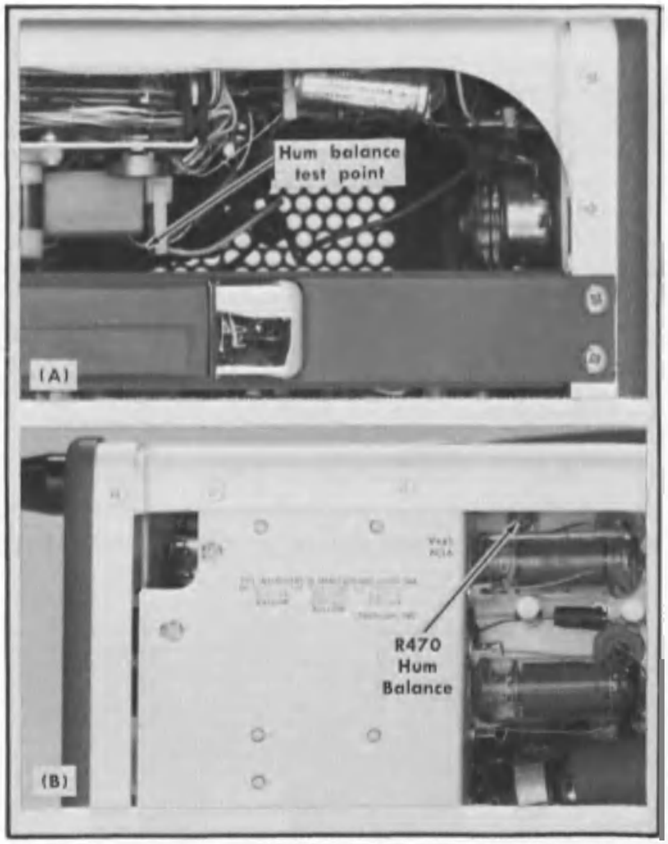


Fig. 5-10. (A) Location of hum balance test point (top), (B) location of Hum Balance adjustment (left side).

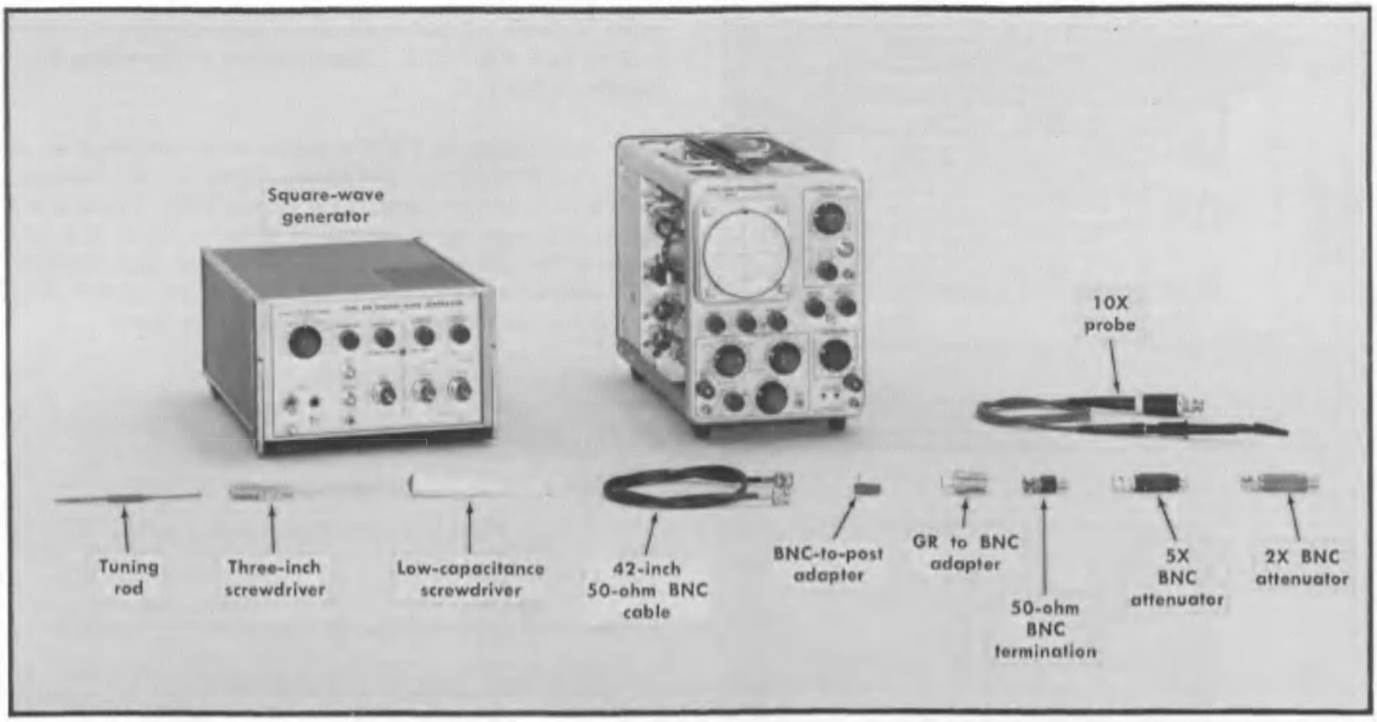


Fig. 5-11. Equipment required for steps 17 through 21.

CRT controls

FOCUS	Adjust for well defined display
INTENSITY	Adjust for visible display
SCALE ILLUM	As desired (power on)

Vertical controls

VOLTS/DIV	**.2**
Variable	CALIBRATED
Input Coupling	DC

Trigger controls

TRIGGER	+ INT
Trigger Coupling-Mode	AUTO
TRIG LEVEL	Midrange
STABILITY	PRESET

Sweep controls

TIME/DIV	**200 μSEC**
Variable	CALIBRATED
Horizontal Display	X1 MAG

Other controls

VERTICAL POSITION	Midrange
HORIZONTAL POSITION	Midrange
CALIBRATOR	OFF

Rear-panel controls

HORIZ GAIN	Clockwise

17. Check/Adjust Volts/Division Switch Series Compensation

a. Equipment required for steps 17 through 21 is shown in Fig. 5-11.

b. Connect the square-wave generator to the vertical INPUT connector through the GR to BNC adapter, 42-inch 50-ohm BNC cable, 5X BNC attenuator and the 50-ohm BNC termination, in given order.

c. Set the square-wave generator for a four-division display at one kilohertz.

NOTE

Tolerances given in steps 17 through 21 are not instrument specifications, but are provided only to determine if recalibration is necessary.

d. CHECK—CRT display for square corner within 3%.

e. ADJUST—C310 (see Fig. 5-12A) for best square corner on the displayed waveform (use low-capacitance screwdriver).

f. Rotate the Variable VOLTS/DIV control fully counterclockwise.

g. Set the square-wave generator for a four-division display.

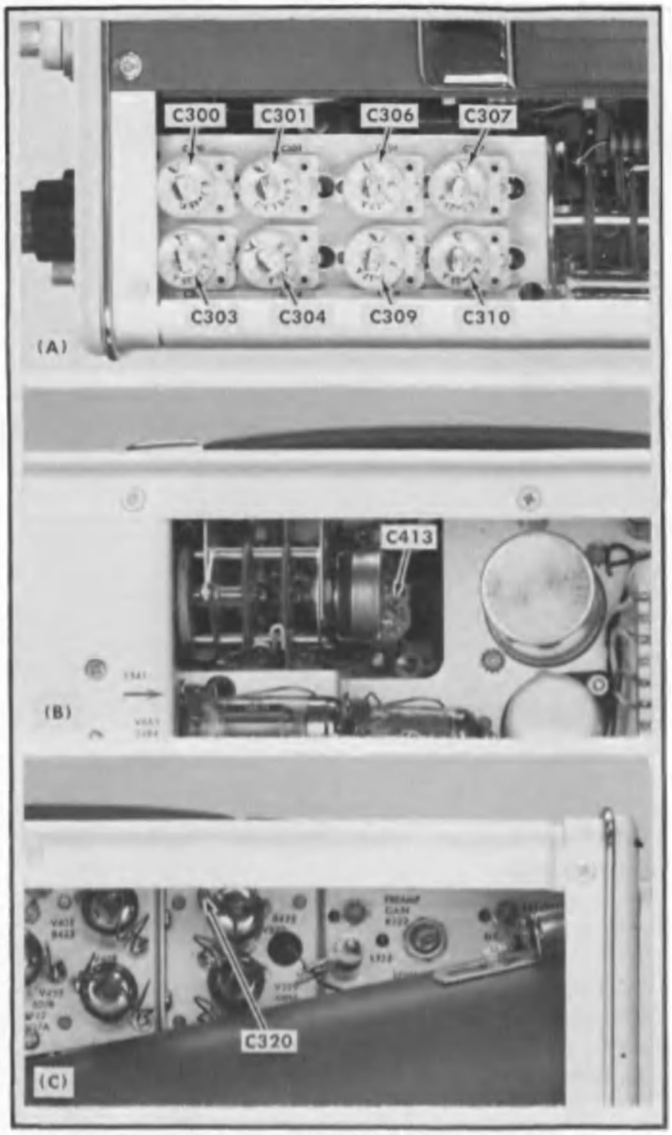


Fig. 5-12. Location of compensation adjustments (A) top, (B) right side, (C) left side.

h. CHECK—CRT display for square corner within 3%.

i. ADJUST—C413 (see Fig. 5-12B) for best square corner on the displayed waveform (use low-capacitance screwdriver).

j. Return the Variable VOLTS/DIV control to CALIBRATED.

k. Repeat parts c through j until best response is obtained.

l. Connect the 2X attenuator between the BNC cable and the 5X attenuator.

m. CHECK—CRT display at each calibrated VOLTS/DIV switch setting listed in Table 5-2 for square corner within 3%. Remove the attenuators and termination as given in Table 5-2 and readjust the generator output amplitude at each VOLTS/DIV switch setting to maintain a four-division display.

n. ADJUST—VOLTS/DIV switch series compensation as given in Table 5-2 for best square corner on the displayed waveform (use low-capacitance screwdriver). Remove the attenuators and terminations as given in Table 5-2 and readjust the generator output amplitude at each VOLTS/DIV switch setting to maintain a four-division display. Fig. 5-12 shows the location of the variable capacitors.

o. Disconnect the BNC cable.

TABLE 5-2

VOLTS/DIV Switch Series Compensation

VOLTS/DIV switch setting	Series compensation adjustment
.01	C320
Remove 10X attenuator	
.5	C307
Remove 5X attenuator and termination	
1	C304
10	C301

18. Check/Adjust Volts/Division Switch Shunt Compensation

a. Set the VOLTS/DIV switch to .1.

b. Connect the 10X probe (P6012) to the vertical INPUT connector.

c. Install the BNC-to-post adapter on the output of the GR to BNC adapter.

d. Connect the 10X probe tip to the BNC-to-post adapter. Connect the probe ground strap to the ground post on the square-wave generator.

e. Set the square-wave generator for a four-division display at one kilohertz.

f. Compensate the probe as described in the probe instruction manual.

g. CHECK—CRT display at each VOLTS/DIV switch setting listed in Table 5-3 for flat top within 3%. Reset the generator output amplitude at each VOLTS/DIV switch setting to maintain a four-division display, or for maximum vertical deflection in the 10 position.

h. ADJUST—VOLTS/DIV switch shunt compensation as given in Table 5-3 for best flat top on the displayed waveform (use low-capacitance screwdriver). Readjust the generator output amplitude at each setting to maintain a four-division display, or to provide maximum vertical deflection in the 10 position. Fig. 5-12 shows the location of the variable capacitors.

i. Disconnect the 10X probe and the BNC-to-post adapter.

TABLE 5-3

VOLTS/DIV Switch Shunt Compensation

VOLTS/DIV switch setting	Shunt compensation adjustment
.1	Compensate probe
.2	C309
.5	C306
1	C303
10	C300

19. Check/Adjust Low-Frequency Compensation

a. Change the following control settings:

VOLTS/DIV	.1
Input Coupling	AC
TIME/DIV	5 MSEC

b. Connect the square-wave generator high-amplitude output connector to the vertical INPUT connector through the GR to BNC adapter, 42-inch 50-ohm BNC cable, 5X BNC attenuator, 2X BNC attenuator and the 50-ohm BNC termination, in given order.

c. Set the square-wave generator for a six-division display at 50 hertz.

d. Note the amount of tilt in the displayed waveform and then set the VOLTS/DIV switch to .01.

e. Set the square-wave generator for a six-division display.

f. CHECK—CRT display for the same amount of tilt in the displayed waveform as noted in part d.

g. ADJUST—Low Freq Adj, R345 (see Fig. 5-13) for the same amount of tilt in the displayed waveform as noted in the .1 position.

h. Disconnect the 50-ohm cable, attenuators and the termination.

20. Check/Adjust Vertical Amplifier High-Frequency Compensation

a. Change the following control settings:

VOLTS/DIV	.1
TIME/DIV	.5 μSEC

Fig. 5-13. Location of low-frequency compensation adjustment (left side).

b. Connect the square-wave generator fast-rise + output connector to the vertical INPUT connector through the GR to BNC adapter, 42-inch 50-ohm BNC cable and the 50-ohm BNC termination.

c. Set the square-wave generator for a six-division display at 400 kilohertz in the fast-rise mode.

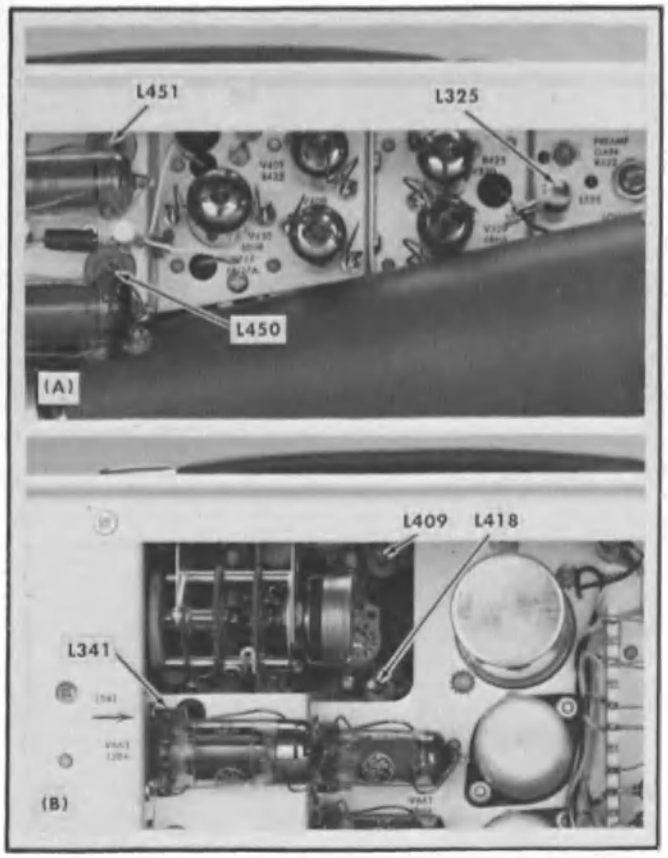


Fig. 5-14. Location of high-frequency compensation adjustments. (A) Left side, (B) right side.

d. If necessary, adjust the triggering controls for a stable display.

e. CHECK—CRT display for square corner and flat top within 0.15 division.

f. ADJUST—L409, L418, L450 and L451 (see Fig. 5-14) for best square-wave display. L409 and L418 affect the leading edge of the square wave and L450 and L451 affect the area just following the leading edge. Adjust L409 and L418 so the slugs in the coils are in about the same positions. L450 and L451 may provide best response in either of two positions; the desired adjustment is with the slugs in most of the way and in about the same positions. The top of the waveform will not necessarily be flat when final adjustment is achieved. The desired adjustment should provide the best risetime with the flattest waveform top.

21. Check/Adjust Preamplifier High-Frequency Compensation

a. Set the VOLTS/DIV switch to .01.

b. Set the square-wave generator for a six-division display at 400 kilohertz.

c. CHECK—CRT display for a square-wave display similar to that obtained in previous step with a square corner and flat top within 0.15 division.

d. ADJUST—L325 and L341 (see Fig. 5-14) for best square wave display. Adjust for the best risetime with the flattest waveform top. L341 affects the leading edge and L325 affects the general level of the waveform top.

e. Disconnect all test equipment.

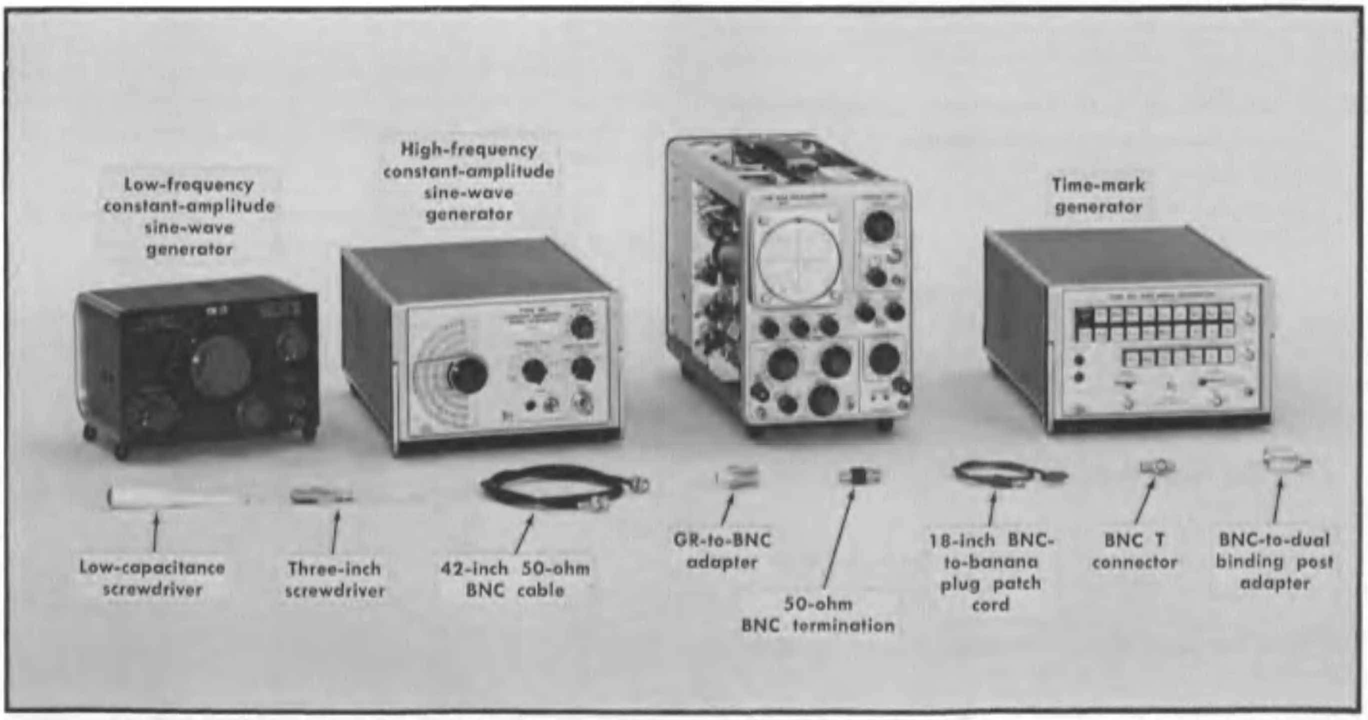


Fig. 5-15. Equipment required for steps 22 through 37.

CRT controls

FOCUS	Adjusted for well defined display
INTENSITY	Adjusted for visible display
SCALE ILLUM	As desired (power on)

Vertical controls

VOLTS/DIV	**.1**
Variable	CALIBRATED
Input Coupling	AC

Trigger controls

TRIGGER	+ INT
Trigger Coupling-Mode	AUTO
TRIG LEVEL	Midrange
STABILITY	PRESET

Sweep controls

TIME/DIV	**1 MSEC**
Variable	CALIBRATED
Horizontal Display	X1 MAG

Other controls

VERTICAL POSITION	Midrange
HORIZONTAL POSITION	Midrange
CALIBRATOR	OFF

Rear-panel controls

HORIZ GAIN	Clockwise

22. Check Upper Vertical Bandwidth Limit

a. Equipment required for steps 22 through 37 is shown in Fig. 5-15.

b. Connect the high-frequency constant-amplitude sine-wave generator to the vertical INPUT connector through the GR to BNC adapter, 42-inch 50-ohm BNC cable and the 50-ohm BNC termination, in given order.

c. Set the constant-amplitude generator for a four-division display centered on the graticule at its reference frequency (50 kilohertz).

d. Without changing the output amplitude, increase the output frequency of the generator until the display is reduced to 2.8 divisions (−3 dB point).

e. CHECK—Output frequency of generator must be four megahertz or higher.

f. Set the VOLTS/DIV switch to .05.

g. Set the constant-amplitude generator for a four-division display, centered on the graticule, at its reference frequency (50 kilohertz).

h. Without changing the output amplitude, increase the output frequency of the generator until the display is reduced to 2.8 divisions (−3 dB point).

i. CHECK—Output frequency of generator must be 3.5 megahertz or higher.

j. Repeat parts g through i with the VOLTS/DIV switch set to .02 and .01.

k. Disconnect all test equipment.

23. Check AC-Coupled Lower Vertical Bandwidth Limit

a. Change the following control settings:

VOLTS/DIV	.1
TIME/DIV	1.2 SEC

b. Connect the low-frequency constant-amplitude sine-wave generator to the vertical INPUT connector through the BNC-to-dual binding post adapter, 42-inch 50-ohm BNC cable and the 50-ohm BNC termination.

c. Set the low-frequency generator for a four-division display, centered on the graticule, at a reference frequency of one kilohertz.

d. Without changing the output amplitude, reduce the output frequency of the generator to two hertz.

e. CHECK—CRT display 2.8 divisions or greater in amplitude (not more than −3 dB).

f. Disconnect all test equipment.

24. Check High-Frequency Triggering Operation

a. Change the following control settings:

VOLTS/DIV	1
Input Coupling	DC
TIME/DIV	1 μSEC

b. Connect the high-frequency constant-amplitude sine-wave generator to the vertical INPUT connector through the GR-to-BNC adapter, 42-inch 50-ohm BNC cable, 50-ohm BNC termination and the BNC T connector. Connect the output of the BNC T connector to the EXT TRIG INPUT binding post with the 18-inch BNC-to-banana plug patch cord.

c. Set the high-frequency generator for a two-division display at two megahertz.

d. CHECK—Stable CRT display is presented.

e. Set the high-frequency generator for a two-division display at four megahertz.

f. Set the TIME/DIV switch to .5 μSEC.

g. CHECK—Stable CRT display can be obtained with the Trigger Coupling-Mode switch set to AC and DC (TRIG LEVEL control may be adjusted as necessary to obtain a stable display).

h. Change the following control settings:

TRIGGER	+ EXT
Trigger Coupling-Mode	AUTO
TIME/DIV	10 μSEC

i. Set the high-frequency generator for a two-division display (two volts) at its reference frequency (50 kilohertz).

j. Set the TIME/DIV switch to .5 μSEC.

k. Without changing the output amplitude, set the constant-amplitude generator to two megahertz.

l. CHECK—Stable CRT display is present.

m. Without changing the output amplitude, set the constant-amplitude generator to four megahertz.

n. CHECK—Stable CRT display can be obtained with the Trigger Coupling-Mode switch set to AC and DC (TRIG LEVEL control may be adjusted as necessary to obtain a stable display).

o. Disconnect the high-frequency generator.

25. Check Low-Frequency Triggering Operation

a. Change the following control settings:

VOLTS/DIV	0.2
TRIGGER	+ INT
Trigger Coupling-Mode	AUTO
TIME/DIV	1 MSEC

b. Connect the low-frequency constant-amplitude sine-wave generator to the vertical INPUT connector through the BNC-to-dual binding post adapter, 42-inch 50-ohm BNC cable, 50-ohm termination and the BNC T connector. Connect the output of the BNC T connector to the EXT TRIG INPUT binding post with the 18-inch BNC-to-banana plug patch cord.

c. Set the low-frequency generator for a 0.25-division display at one kilohertz.

d. CHECK—Stable CRT display can be obtained with the Trigger Coupling-Mode switch set to AUTO, AC and DC (TRIG LEVEL control may be adjusted as necessary to obtain a stable display).

e. Set the TRIGGER switch to + EXT.

f. Set the low-frequency generator for a one-division display (0.2 volt) at one kilohertz.

g. CHECK—Stable CRT display can be obtained with the Trigger Coupling-Mode switch set to AUTO, AC and DC (TRIG LEVEL control may be adjusted as necessary to obtain a stable display).

h. Set the TIME/DIV switch to 10 MSEC.

i. Set the low-frequency constant-amplitude generator for an output frequency of 60 hertz (output amplitude remains at 0.2 volt).

j. Set the Trigger Coupling-Mode switch to AUTO.

k. CHECK—Stable CRT display is presented.

l. Set the low-frequency constant-amplitude generator for an output frequency of 30 hertz (output amplitude remains at 0.2 volt).

m. CHECK—Stable CRT display can be obtained with the Trigger Coupling-Mode switch set to AC and DC (TRIG LEVEL control may be adjusted as necessary to obtain a stable display).

n. Set the TRIGGER switch to + INT.

o. Set the low-frequency generator for a 0.25-division display at 30 hertz.

p. CHECK—Stable CRT display can be obtained with the Trigger Coupling-Mode switch set to AC and DC (TRIG LEVEL control may be adjusted as necessary to obtain a stable display).

q. Set the Trigger Coupling-Mode switch to AUTO.

r. Set the low-frequency generator for a 0.25-division display at 60 hertz.

s. CHECK—Stable CRT display is presented.

26. Check Triggering Slope Operation

a. Set the TIME/DIV switch to 200 μSEC.

b. Set the low-frequency generator for a four-division display at one kilohertz.

c. CHECK—CRT display starts on the positive slope of the waveform.

d. Set the TRIGGER switch to – INT.

e. CHECK—CRT display starts on the negative slope of the waveform.

f. Set the TRIGGER switch to + EXT.

g. CHECK—CRT display starts on the positive slope of the waveform.

h. Set the TRIGGER switch to – EXT.

i. CHECK—CRT display starts on the negative slope of the waveform.

j. Disconnect all test equipment.

27. Check Line Triggering Operation

a. Connect the 10X probe to the vertical INPUT connector.

b. Change the following control settings:

VOLTS/DIV	10
TRIGGER	+ LINE
TIME/DIV	2 MSEC

c. Connect the probe tip to the same line-voltage source which is connected to this instrument.

d. CHECK—Stable CRT display triggered on the positive slope.

e. Set the TRIGGER switch to – LINE.

f. CHECK—Stable CRT display triggered on the negative slope.

g. Disconnect all test equipment.

28. Check/Adjust Normal Timing

a. Change the following control settings:

VOLTS/DIV	.5
TRIGGER	+INT
TIME/DIV	1 MSEC

b. Connect the time-mark generator (Type 184) to the vertical INPUT connector through the 42-inch 50-ohm BNC cable and a 50-ohm BNC termination.

c. Set the time-mark generator for one-millisecond markers.

NOTE

Unless otherwise noted, use the middle eight horizontal divisions (between second and tenth vertical lines of the graticule) when checking or adjusting timing.

d. CHECK—CRT display for one marker each division between the second and tenth vertical lines of the graticule. Tenth marker must be within 0.24 division (within 3%) of the tenth vertical line with the second marker positioned exactly to the second vertical line.

PERFORMANCE CHECK ONLY

Rear-panel operational adjustment; can be adjusted as part of a performance check.

e. ADJUST—SWEEP CAL adjustment, R250 (see Fig. 5-16), for one marker each division. The second and tenth markers must coincide exactly with their respective graticule lines (reposition the display with the HORIZONTAL POSITION control if necessary).

f. INTERACTION—Check steps 29 through 37.

29. Check/Adjust Sweep Length

a. Move the eleventh marker to the tenth vertical line of the graticule with the HORIZONTAL POSITION control.

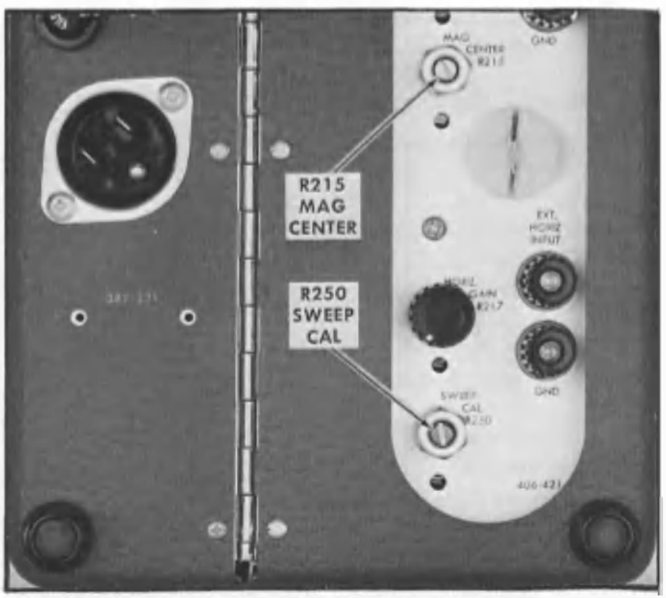


Fig. 5-16. Location of Sweep Cal adjustment (rear panel).

b. CHECK—Sweep length between 10.2 and 10.8 divisions as shown by 0.2 to 0.8 division of horizontal deflection to the right of the tenth vertical line.

c. ADJUST—Sweep Length adjustment, R161 (see Fig. 5-17), for a sweep length of 10.5 divisions (0.5 division of deflection to the right of the tenth vertical line).

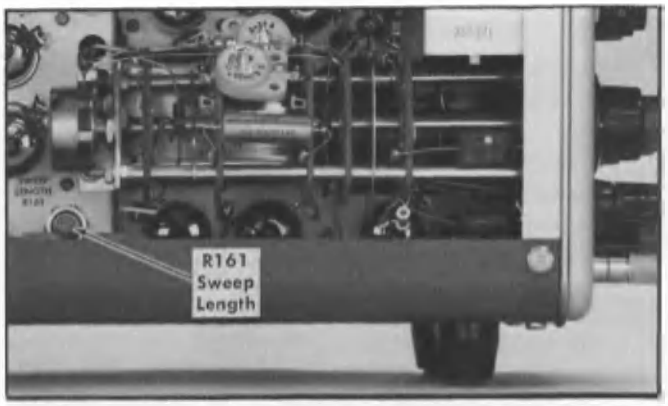


Fig. 5-17. Location of Sweep Length adjustment (left side).

30. Check/Adjust Magnifier Registration

a. Set the Horizontal Display switch to X5 MAG.

b. Set the time-mark generator for five-millisecond markers.

c. Position the middle marker (three markers on total magnified sweep) to the center vertical line.

d. Return the Horizontal Display switch to X1 MAG.

e. CHECK—Middle marker should be within one division of the center vertical line.

PERFORMANCE CHECK ONLY

Rear-panel operational adjustment; can be adjusted as part of a performance check.

f. ADJUST—MAG CENTER adjustment, R215 (see Fig. 5-16), to position the middle marker to the center vertical line.

31. Check Variable Time/Division Control Range

a. Set the time-mark generator for 10-millisecond markers.

b. Position the markers to the far left and right vertical lines of the graticule with the HORIZONTAL POSITION control.

c. Turn the Variable TIME/DIV control fully counterclockwise.

d. CHECK—CRT display for four-division maximum spacing between markers (indicates adequate range for continuously variable sweep rate between the calibrated steps). UNCALIBRATED TIME BASE light must be on when Variable TIME/DIV control is not in the CALIBRATED position.

32. Adjust High-Speed Linearity

PERFORMANCE CHECK ONLY

Complete accuracy of the TIME/DIV switch is checked in Table 5-4. Proceed to step 36.

a. Change the following control settings:

Variable VOLTS/DIV	CALIBRATED
Trigger Coupling-Mode	AC
STABILITY	Fully counterclockwise (not in PRESET detent)
TIME/DIV	10 μSEC
Horizontal Display	X5 MAG

b. Set the time-mark generator for 10-microsecond markers.

c. Increase the INTENSITY control setting until a vertical line is visible on the CRT.

d. Position the vertical line to the center vertical line of the graticule with the HORIZONTAL POSITION control.

e. Turn the STABILITY control counterclockwise to the PRESET position. If a marker display is not present, adjust the TRIG LEVEL control for a stable display.

f. CHECK—First marker of display at the center vertical line.

g. ADJUST—C205 (see Fig. 5-18) to move the first marker to the center vertical line (use low-capacitance screwdriver).

h. Change the following control settings:

STABILITY	Fully counterclockwise (not in PRESET detent)
Horizontal Display	X1 MAG

i. Position the vertical line to the center vertical line with the HORIZONTAL POSITION control.

j. Turn the STABILITY control counterclockwise to the PRESET position. If a marker display is not present, adjust the TRIG LEVEL control for a stable display.

k. CHECK—First marker of display at the center vertical line.

l. ADJUST—C213 (see Fig. 5-18) to move the first marker to the center vertical line (use low-capacitance screwdriver).

33. Adjust 10-Microsecond Timing

a. Position the first marker to the left vertical line of the graticule with the HORIZONTAL POSITION control.

b. CHECK—CRT display for one marker each division between the second and tenth vertical lines of the graticule. Tenth marker must be within 0.24 division (within 3%) of the tenth vertical line with the second marker positioned exactly to the second vertical line.

c. ADJUST—C175B (see Fig. 5-18) for one marker each division (use low capacitance screwdriver). The second and tenth markers must coincide exactly with their respective graticule lines (reposition the display with the HORIZONTAL POSITION control if necessary).

d. INTERACTION—If C175B is adjusted, recheck step 32.

34. Adjust One-Microsecond Timing

a. Set the TIME/DIV switch to 1 μSEC.

b. Set the time-mark generator for one-microsecond markers.

c. CHECK—CRT display for one marker each division between the second and tenth vertical lines of the graticule (notice that first marker of display is not visible). The marker at the tenth vertical line must be within 0.24 division (within 3%) of the line when the marker at the second vertical line is positioned exactly.

d. ADJUST—C175A (see Fig. 5-18) for one marker each division (use low-capacitance screwdriver). The markers at the second and tenth vertical lines must coincide exactly with their respective graticule lines (reposition the display with the HORIZONTAL POSITION control if necessary).

e. INTERACTION—Recheck steps 32, 33 and 34 and readjust if necessary.

35. Adjust 0.5-Microsecond Timing

a. Change the following control settings:

VOLTS/DIV	.1
TRIGGER	+ EXT
TIME/DIV	.5 μSEC
Horizontal Display	X5 MAG

b. Set the time-mark generator for 0.1-microsecond markers and one-microsecond trigger output.

c. Connect the time-mark generator trigger output connector to the EXT TRIG INPUT binding post with the 18-inch BNC-to-banana plug patch cord.

d. Adjust the TRIG LEVEL control for a stable display.

e. CHECK—CRT display for one marker each division between the second and tenth vertical lines of the graticule. The marker at the tenth vertical line must be within 0.4 division (within 5%) of the line when the marker at the second vertical line is positioned exactly.

f. ADJUST—C250 (see Fig. 5-18) for one marker each division (use low-capacitance screwdriver). The markers at the second and tenth vertical lines must coincide exactly with their respective graticule lines (reposition the display with the HORIZONTAL POSITION control if necessary).

36. Check Normal Sweep Timing Accuracy

CAUTION

To prevent burning of the CRT phosphor at slow sweep rates, position the baseline of the marker display below the viewing area.

a. Change the following control settings:

TRIGGER	+ INT
Horizontal Display	X1 MAG

b. CHECK—Using the TIME/DIV switch and time-mark generator settings given in Table 5-4, check normal sweep timing within 0.24 division (within 3%) over the center eight divisions of the display. Set the TRIG LEVEL control as necessarv for a stable display.

TABLE 5-4

Normal Sweep Timing Accuracy

TIME/DIV switch setting	Time-mark generator output	CRT display (markers/division)
.5 μSEC	0.5 microsecond	1
1 μSEC	1 microsecond	1
2 μSEC	1 microsecond	2
5 μSEC	5 microsecond	1
10 μSEC	10 microsecond	1
20 μSEC	10 microsecond	2
50 μSEC	50 microsecond	1
.1 MSEC	0.1 millisecond	1
.2 MSEC	0.1 millisecond	2
.5 MSEC	0.5 millisecond	1
1 MSEC	1 millisecond	1
2 MSEC	1 millisecond	2
5 MSEC	5 millisecond	1
10 MSEC	10 millisecond	1
20 MSEC	10 millisecond	2
50 MSEC	50 millisecond	1
.1 SEC	0.1 second	1
.2 SEC	0.1 second	2

37. Check Magnified Sweep Timing Accuracy

a. Change the following control settings:

TRIGGER	+ EXT
Horizontal Display	X5 MAG

b. Set the time-mark generator for one-microsecond trigger output.

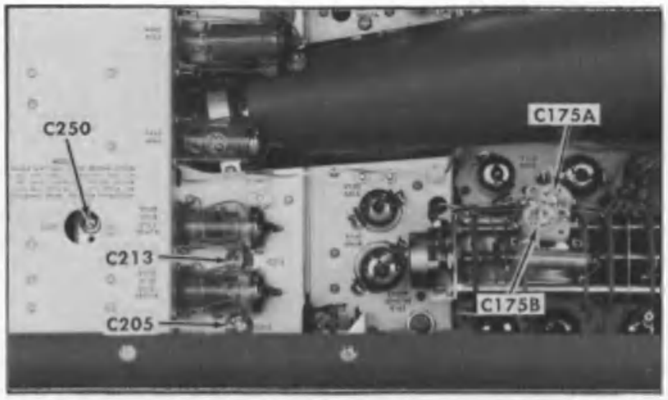


Fig. 5-18. Location of high-frequency adjustments (left side).

c. Connect the time-mark generator trigger output connector to the EXT TRIG INPUT binding post with the 18-inch BNC-to-banana plug patch cord.

d. CHECK—Using the TIME/DIV switch and time-mark generator settings given in Table 5-5, check magnified sweep timing within the given tolerances over the center eight divisions of the total magnified sweep length. Set the TRIG LEVEL control as necessary for a stable display and set the TRIGGER switch for + INT source as given in Table 5-5.

e. Disconnect all test equipment.

TABLE 5-5

Magnified Sweep Timing Accuracy

TIME/DIV switch setting	Time-mark generator output	CRT display (markers/division)	Allowable error for given accuracy
.5 μSEC	.1 microsecond	1	0.4 division (within 5%)
1 μSEC	.1 microsecond	2	0.32 division (within 4%)
2 μSEC	.1 microsecond	4	
Set TRIGGER switch to + INT			
5 μSEC	1 microsecond	1	
10 μSEC	1 microsecond	2	
20 μSEC	1 microsecond	4	
50 μSEC	10 microsecond	1	
.1 MSEC	10 microsecond	2	
.2 MSEC	10 microsecond	4	
.5 MSEC	.1 millisecond	1	
1 MSEC	.1 millisecond	2	
2 MSEC	.1 millisecond	4	
5 MSEC	1 millisecond	1	
10 MSEC	1 millisecond	2	
20 MSEC	1 millisecond	4	
50 MSEC	10 millisecond	1	
.1 SEC	10 millisecond	2	
.2 SEC	10 millisecond	4	

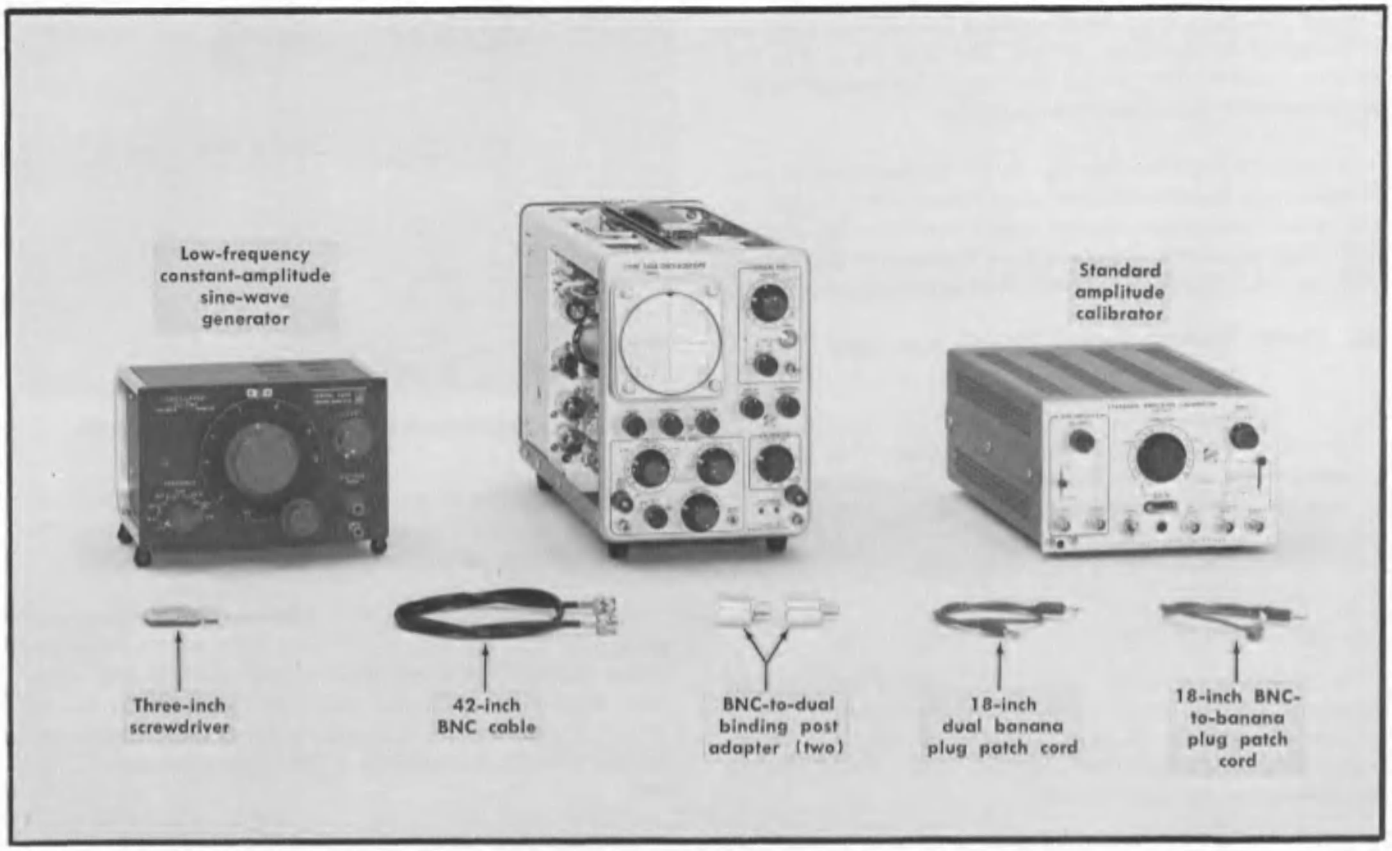


Fig. 5-19. Equipment required for steps 38 through 42.

CRT controls

FOCUS	Adjust for well defined display
INTENSITY	Adjust for visible display
SCALE ILLUM	As desired (power on)

Vertical controls

VOLTS/DIV	**10**
Variable	CALIBRATED
Input Coupling	DC

Trigger controls

TRIGGER	**+ LINE**
Trigger Coupling-Mode	AC
TRIG LEVEL	Midrange
STABILITY	PRESET

Sweep controls

TIME/DIV	**5 MSEC**
Variable	CALIBRATED
Horizontal Display	X1 MAG

Other controls

VERTICAL POSITION	Midrange
HORIZONTAL POSITION	Midrange
CALIBRATOR	OFF

Rear-panel controls

HORIZ GAIN	Clockwise

38. Check/Adjust Calibrator Amplitude

a. Equipment required for steps 38 through 42 is shown in Fig. 5-19.

b. Connect the CAL OUT binding post to the unknown input connector of the standard amplitude calibrator with the 18-inch BNC-to-banana plug patch cord.

c. Set the standard amplitude calibrator for a positive 100-volt DC output in the mixed mode.

d. Connect the standard amplitude calibrator output connector to the vertical INPUT connector with a 42-inch BNC cable.

e. Position the top of the waveform onto the display area with the VERTICAL POSITION control.

f. CHECK—CRT display for difference between the standard amplitude calibrator output level and the Type 310A calibrator output level is 0.3 division (three volts) or less (calibrator output amplitude, 100 volts ±3%). The standard amplitude calibrator output level is the solid portion of the trace and the Type 310A calibrator output level is the segmented portion.

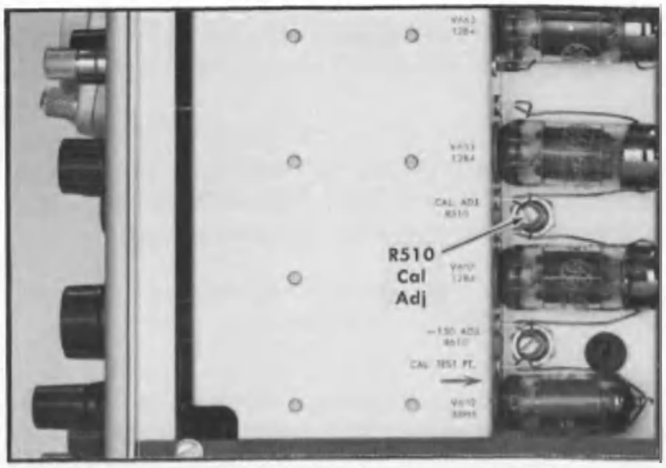


Fig. 5-20. Location of calibrator amplitude adjustment (right side).

g. ADJUST—Cal Adj, R510 (see Fig. 5-20), for no difference between the standard amplitude calibrator output level and the Type 310A calibrator output level.

h. CHECK—Using the CALIBRATOR switch, VOLTS/DIV switch and standard amplitude calibrator settings given in Table 5-6, check the accuracy of the remaining CALIBRATOR switch positions. Adjust the VERTICAL POSITION control as necessary to keep the top of the waveform on the display area. For the CALIBRATOR switch positions of 0.5 and below, ignore the waveform tilt and measure the accuracy at the point where the display switches from the standard amplitude calibrator level (solid portion) and the Type 310A calibrator output level (segmented portion).

i Disconnect all test equipment.

TABLE 5-6

Calibrator Accuracy

Type 310A CALIBRATOR switch setting	VOLTS/DIV switch setting	Standard amplitude calibrator output	Allowable difference for ±3% accuracy (divisions)
50	5	50 volts	0.3
20	2	20 volts	0.3
10	1	10 volts	0.3
5	.5	5 volts	0.3
2	.2	2 volts	0.3
1	.1	1 volt	0.3
.5	.05	0.5 volt	0.3
.2	.02	0.2 volt	0.3
.1	.01	0.1 volt	0.3
.05	.01	50 millivolts	0.15

39. Check Calibrator Repetition Rate

a. Change the following control settings:

VOLTS/DIV	.5
TRIGGER	+ INT
TIME/DIV	200 μSEC
CALIBRATOR	2

b. Connect the CAL OUT binding post to the vertical INPUT connector with the 18-inch BNC-to-banana plug patch cord..

c. Position the start of the trace to the first vertical line of the graticule with the HORIZONTAL POSITION control.

d. CHECK—CRT display for duration of one complete cycle about five divisions (repetition rate approximately one kilohertz).

e. Disconnect all test equipment.

40. Check External Horizontal Deflection Factor

a. Change the following control settings:

TIME/DIV	2 μSEC
Horizontal Display	EXT HORIZ

b. Connect the standard amplitude calibrator to the EXT HORIZ INPUT and GND binding posts on the rear panel with the 42-inch BNC cable and the BNC-to-dual binding post adapter.

c. Set the standard amplitude calibrator for a 10-volt square-wave output.

d. Center the display (two dots) on the display area. If necessary, increase the INTENSITY control setting to view the display.

e. CHECK—CRT display for minimum horizontal deflection of 6.67 divisions (1.5 volt/division, or less, external horizontal deflection factor).

f. Disconnect all test equipment.

41. Check External Horizontal Bandwidth

a. Connect the low-frequency constant-amplitude generator to the EXT HORIZ INPUT binding post through the BNC-to-dual binding post adapter, 42-inch BNC cable and the BNC-to-dual binding post adapter.

b. Set the low-frequency constant-amplitude generator for a six-division display at one kilohertz.

c. Without changing the output amplitude, increase the output frequency of the generator to 500 kilohertz.

d. CHECK—CRT display for 4.2 divisions or greater horizontal deflection (not more than −3 dB).

e. Disconnect all test equipment.

42. Check External Blanking

a. Change the following control settings:

VOLTS/DIV	5
TIME/DIV	500 μSEC
Horizontal Display	X5 MAG

b. Connect the low-frequency generator to the vertical INPUT connector through the BNC-to-dual binding post adapter, 42-inch BNC cable and the BNC T connector.

c. Set the low-frequency generator for a four-division display (20 volts peak to peak) at one kilohertz.

d. Remove the ground bar from between the CRT CATHODE and GND binding posts on the rear panel.

e. Connect the output of the BNC T connector to the CRT CATHODE binding post with the 8-inch BNC-to-banana plug patch cord and 18-inch dual banana plug patch cord.

f. CHECK—CRT display for blanking of a portion of each cycle of the waveform. The INTENSITY control setting may need to be changed to show blanking.

g. Replace the ground strap between the CRT CATHODE and GND binding posts.

This completes the Calibration Procedure for the Type 310A. Disconnect all test equipment and replace the side panels. If the instrument has been completely checked and/or calibrated to the tolerances given in this procedure, it will meet the electrical characteristics given in Section 1.

NOTES

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix, Inc. Field Office or representative.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number, instrument type or number, serial or model number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix, Inc. Field Office or representative will contact you concerning any change in part number.

SPECIAL NOTES AND SYMBOLS

×000	Part first added at this serial number
00×	Part removed after this serial number
*000-0000-00	Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, Inc., or reworked or checked components.
Use 000-0000-00	Part number indicated is direct replacement.

PARTS LIST ABBREVIATIONS

BHB	binding head brass
BHS	binding head steel
cap.	capacitor
cer	ceramic
comp	composition
conn	connector
CRT	cathode-ray tube
csk	countersunk
DE	double end
dia	diameter
div	division
elect.	electrolytic
EMC	electrolytic, metal cased
EMT	electrolytic, metal tubular
ext	external
F & I	focus and intensity
FHB	flat head brass
FHS	flat head steel
Fil HB	fillister head brass
Fil HS	fillister head steel
h	height or high
hex.	hexagonal
HHB	hex head brass
HHS	hex head steel
HSB	hex socket brass
HSS	hex socket steel
ID	inside diameter
inc	incandescent
int	internal
lg	length or long
met.	metal
mtg hdw	mounting hardware
OD	outside diameter
OHB	oval head brass
OHS	oval head steel
P/O	part of
PHB	pan head brass
PHS	pan head steel
plstc	plastic
PMC	paper, metal cased
poly	polystyrene
prec	precision
PT	paper, tubular
PTM	paper or plastic, tubular, molded
RHB	round head brass
RHS	round head steel
SE	single end
SN or S/N	serial number
S or SW	switch
TC	temperature compensated
THB	truss head brass
thk	thick
THS	truss head steel
tub.	tubular
var	variable
w	wide or width
WW	wire-wound

SECTION 6
ELECTRICAL PARTS LIST

Values fixed unless marked Variable.

Bulbs

			Tektronix Part Number
B165		Neon, NE-23	Use 150-027
B166		Neon, NE-23	Use 150-027
B177	10,001-21,331	Neon, NE-23	Use 150-027
B177	21,332-up	Neon, NE-2 V	150-0030-00
B400	10,001-21,331	Neon, NE-23	Use 150-027
B400	21,332-up	Neon, NE-2 V	150-0030-00
B600		Incandescent, #47	150-001
B601		Incandescent, #47	150-001

Capacitors

Tolerance ±20% unless otherwise indicated.

C2		.01 μf	PT		400 v		285-510
C3		.001 μf	Cer.		500 v	GMV	283-000
C13		.001 μf	Cer.		500 v	GMV	283-000
C15		100 μμf	Cer.		350 v	±20 μμf	281-523
C30		.01 μf	PT		400 v		285-510
C46	10,001-12,419	22 μμf	Cer.		500 v	10%	281-511
	12,420-up	27 μμf	Cer.		500 v	10%	281-512
C101		27 μμf	Cer.		500 v		281-513
C102		8 μf	EMC		450 v	−10%+50%	290-002
C103		4.7 μμf	Cer.		500 v	±1 μμf	281-501
C106		3.3 μμf	Cer.			±.25 μμf	281-534
C115		180 μμf	Mica		500 v	5%	283-510
C135A		220 μμf	Mica		500 v	10%	283-536
C135B		.0022 μf	PT		400 v		285-543
C135C		.022 μf	PT		400 v		285-515
C135D		.22 μf	PT		400 v		285-533
C140		47 μμf	Cer.		500 v		281-518
C166		.001 μf	Cer.		500 v	GMV	283-000
C168		470 μμf	Cer.		500 v		281-525
C175A		3-12 μμf	Cer.	Var.	500 v		281-007
C175B		4.5-25 μμf	Cer.	Var.	500 v		281-010
C175C		82 μμf	Mica		500 v	5%	283-534
C175D		.001 μf	Mylar			±½%	*291-008
C175E		.01 μf	Mylar Timing Series				*291-012
C175F		.1 μf					
C175G		1 μf					
C176		4.7 μμf	Cer.		500 v	±1 μμf	281-501
C205		4.5-25 μμf	Cer.	Var.	500 v		281-010
C210		.001 μf	Cer.		500 v	GMV	283-000
C213		7-45 μμf	Cer.	Var.	500 v		281-012
C214		150 μμf	Mica		500 v	10%	283-508

Capacitors *(continued)*

							Tektronix Part Number
C218		.02 μf	Cer.		150 v	GMV	283-004
C220		12 μμf	Cer.		500 v	10%	281-506
C240		6.25 μf	EMC		300 v	−10% +100%	290-025
C250		9-180 μμf	Mica	Var.	500 v		281-023
C300		7-45 μμf	Cer.	Var.	500 v		281-012
C301		1.5-7 μμf	Cer.	Var.	500 v		281-005
C302		250 μμf	Mica		500 v	5%	283-543
C303		4.5-25 μμf	Cer.	Var.	500 v		281-010
C304		4.5-25 μμf	Cer.	Var.	500 v		281-010
C305		150 μμf	Mica		500 v	10%	283-544
C306		3-12 μμf	Cer.	Var.	500 v		281-007
C307		4.5-25 μμf	Cer.	Var.	500 v		281-010
C308		47 μf	Mica		500 v	5%	283-501
C309		3-12 μμf	Cer.	Var.	500 v		281-007
C310		4.5-25 μμf	Cer.	Var.	500 v		281-010
C312		10 μμf	Cer.		500 v	10%	281-504
C314		10 μμf	Cer.		500 v	10%	281-504
C315		.1 μf	PT		600 v		285-528
C316		.001 μf	Cer.		500 v	GMV	283-000
C320		.7-3 μμf	Tub.	Var.	500 v		281-027
C321		275 μf	EMT		6 v	−10% +250%	290-020
C323		4.7 μμf	Cer.		500 v	±1 μμf	Use 281-501
C325	10,001-22639	6.25 μf	EMT		300 v	−10% +100%	290-000
C325	22640-up	6.25 μf	EMT		300 v	**−10% +100%**	**290-0025-00**
C340	10,001-11,169	.1 μf	Cer.		500 v		Use 285-572
	11,170-up	.1 μf	PTM		200 v		285-572
C342		.01 μf	Cer.		500 v	GMV	283-002
C347		.01 μf	Cer.		500 v	GMV	283-002
C349		.001 μf	Cer.		500 v	GMV	283-000
C402	10,001-22639	6.25 μf	EMC		300 v	−10% +100%	290-000
C402	22640-up	6.25 μf	EMT		300 v	**−10% +100%**	**290-0025-00**
C403	10,001-22639	6.25 μf	EMC		300 v	−10% +100%	290-000
C403	22640-up	6.25 μf	EMT		300 v	**−10% +100%**	**290-0025-00**
C405		.02 μf	Cer.		150 v	GMV	283-004
C407		6.25 μf	EMT		300 v	−10% +100%	290-025
C413		1.5-7 μμf	Cer.	Var.	500 v		281-005
C414		2.2 μμf	Cer.		500 v	±½ μμf	281-500
C446		.001 μf	Cer.		500 v	GMV	283-000
C447		.001 μf	Cer.		500 v	GMV	283-000
C454		.01 μf	Cer.		500 v	GMV	283-002
C460		1.5 μμf	Cer.		500 v	±½ μμf	281-526
C470		.01 μf	Cer.		500 v	GMV	283-002
C471		.001 μf	Cer.		500 v	GMV	283-000
C472		.001 μf	Cer.		500 v	GMV	283-000
C502		330 μμf	Mica		500 v	10%	283-518
C506		330 μμf	Mica		500 v	10%	283-518
C521		.005 μf	Cer.		500 v	GMV	283-001
C601A		2 x 15 μf	EMC		350 v	−10% +100%	Use 290-006
C601B		2 x 15 μf	EMC		350 v	−10% +100%	Use 290-006
C601C		2 x 15 μf	EMC		350 v	−10% +100%	Use 290-006
C612		.01 μf	PT		400 v		285-510
C613		.01 μf	PT		400 v		285-510
C630		150 μf	EMC		250 v	−10% +100%	Use 290-0019-00

Capacitors *(continued)*

						Tektronix Part Number
C639		.01 μf	PT	400 v		285-510
C660		40 μf	EMC	350 v	−10%+100%	Use 290-0088-00
C661	10,001-10,122	.02 μf	Cer.	600 v		Use 283-022
	10,123-14453X	.02 μf	Cer.	1400 v		283-022
C671		.01 μf	PT	400 v		285-510
C701		.022 μf	PTM	400 v		285-515
C702	10,001-11,529	.001 μf	PTM	1000 v	GMV	285-502
	11,530-up	.001 μf	Cer.	500 v	GMV	283-000
C704		.001 μf	Cer.	500 v	GMV	283-000
C705		.001 μf	PTM	1000 v	GMV	285-502
C720	10,001-11,529	.015 μf	PTM	3000 v		285-513
	11,530-15,059	.01 μf	Cer.	2000 v		283-011
	15,060-21,879	.015 μf	Cer.	2500 v		283-030
C720	21,880-up	.015 μf	Cer.	3000 v		283-0042-00
C722	10,001-12,419	.0068 μf	PTM	3000 v		285-508
	12,420-up	.01 μf	Cer.	2000 v		283-011
C730		.01 μf	Cer.	500 v	GMV	283-002
C731	10,001-12,419	.0068 μf	PTM	3000 v		285-508
	12,420-up	.01 μf	Cer.	2000 v		283-011
C732	10,001-12,419	.0068 μf	PTM	3000 v		285-508
	12,420-up	.01 μf	Cer.	2000 v		283-011
C733	10,001-12,419	.0068 μf	PTM	3000 v		285-508
	12,420-up	.01 μf	Cer.	2000 v		283-011
C751		.01 μf	Cer.	2000 v		283-011

Fuses

F600	1.6 Amp	3 AG	Slo-Blo	117 V operation	159-034
F600	.8 Amp	3 AG	Slo-Blo	234 V operation	159-018

Inductors

L325		82-140 μh	Var.	core 276-503	*114-033
L341		22-46 μh	Var.	core 276-511	*114-116
L409		50-70 μh	Var.	core NOT REPLACEABLE	*114-106
L418		50-70 μh	Var.	core NOT REPLACEABLE	*114-106
LR432		18 μh on 2.2 K, 1 W resistor			*108-089
LR433		18 μh on 2.2 K, 1 W resistor			*108-089
LR440		40 μh on 1.8 K, 2 W resistor			*108-116
LR441		40 μh on 1.8 K, 2 W resistor			*108-116
L450	10,001-11,459	77-140 μh	Var.	core 276-503	Use *114-129
	11,460-up	90-150 μh	Var.	core 276-503	*114-129
L451	10,001-11,459	77-140 μh	Var.	core 276-503	Use *114-129
	11,460-up	90-150 μh	Var.	core 276-503	*114-129

Resistors

Resistors are fixed, composition, ±10% unless otherwise indicated.

							Tektronix Part Number
R2		1 meg	½ w				302-105
R3		470 k	½ w				302-474
R10		47 Ω	½ w				302-470
R11		8.2 k	½ w				302-822
R12		47 Ω	½ w				302-470
R13		22 k	2 w			5%	Use 305-223
R15		8.2 k	½ w				302-822
R20		220 k	½ w				302-224
R21		1 meg	½ w				302-105
R22*	10,001-24,019	100 k	½ w	Var.	Comp.	TRIG. LEVEL	311-096
R22*	24,020	100 k	½ w	Var.	Comp.	TRIG. LEVEL	311-0096-02
R23		22 k	½ w				302-223
R30		220 k	½ w				302-224
R31		220 k	½ w				302-224
R40		100 Ω	½ w				302-101
R41		2.7 k	½ w				302-272
R42		1.2 k	½ w				302-122
R45		2.7 k	½ w				302-272
R46		390 k	½ w		Prec.	1%	309-056
R47		100 Ω	½ w				302-101
R48		400 k	½ w		Prec.	1%	309-126
R50	10,001-12,419	22 k	1 w				304-223
	12,420-up	18 k	1 w				304-183
R55	10,001-12,419	2.7 meg	½ w				302-275
	12,420-up	2.2 meg	½ w				302-225
R100		100 Ω	½ w				302-101
R101		5.6 k	½ w			5%	301-562
R102		4.7 k	½ w			5%	301-472
R103		100 Ω	½ w				302-101
R106		39 k	1 w			5%	303-393
R107		33 k	1 w			5%	303-333
R110		100 Ω	½ w				302-101
R111		1.8 k	½ w			5%	301-182
R112		15 k	2 w			5%	305-153
R115		330 Ω	½ w				302-331
R116		47 k	½ w				302-473
R125**	10,001-24,019	100 k	½ w	Var.	Comp.	STABILITY	311-096
R125**	24,020	100 k	½ w	Var.	Comp.	STABILITY	311-0096-02
R126		100 k	½ w	Var.	Comp.	PRESET STABILITY	311-110
R128		100 k	½ w				302-104
R129		4.7 k	½ w				302-472
R132		27 k	½ w			5%	301-273
R133		47 k	½ w			5%	301-473
R134		100 Ω	½ w				302-101
R135A		470 k	½ w				302-474
R135B		4.7 meg	½ w				302-475
R140		2.2 meg	½ w				302-225

*Concentric with R125 and SW125.

**Concentric with SW125 and R22.

Resistors *(continued)*

							Tektronix Part Number
R150	X21880-up	22 meg	¼ w				316-0226-00
R160		8.2 k	1 w				304-822
R161		5 k	2 w	Var.	Comp.	Sweep Length	311-011
R162		15 k	2 w				306-153
R165		100 Ω	½ w				302-101
R166		220 k	½ w				302-224
R167		1.5 meg	½ w				302-155
R168		56 k	½ w				302-563
R169		56 k	½ w				302-563
R170		100 Ω	½ w				302-101
R175A		1.2 meg	½ w		Prec.	1%	309-149
R175B		600 k	½ w		Prec.	1%	309-004
R175C		600 k	½ w		Prec.	1%	309-004
R175D		39 k	½ w				302-393
R175E		100 k	2 w	Var.	Comp.	Var. Time/Div.	311-059
R176		12 k	½ w			5%	301-123
R177		100 k	½ w				302-104
R205		1.75 meg	½ w		Prec.	1%	309-019
R206		1.55 meg	½ w		Prec.	1%	309-018
R207		50 k	2 w	Var.	Comp.	HORIZONTAL POSITION	311-023
R210		2.2 meg	½ w				302-225
R213		220 k	½ w		Prec.	1%	309-052
R214		3.1 meg	½ w		Prec.	1%	309-027
R215		500 k	2 w	Var.	Comp.	MAG. CENTER	311-034
R217		100 k	2 w	Var.	Comp.	HORIZ. GAIN	311-026
R218		100 k	½ w				302-104
R220		18 k	½ w				302-183
R224		100 Ω	½ w				302-101
R226		100 k	½ w				302-104
R228		47 Ω	½ w				302-470
R229		20 k	8 w		Mica Plate	1%	*310-510
R240		47 Ω	½ w				302-470
R241		100 k	½ w				302-104
R242		25 k	8 w		Mica Plate	1%	*310-503
R245		47 Ω	½ w				302-470
R247		27 k	2 w				306-273
R248		27 k	2 w				306-273
R250		2 k	2 w	Var.	Comp.	Sweep Cal.	311-008
R300		47 Ω	½ w				302-470
R301		990 k	½ w		Prec.	1%	309-013
R302		10.1 k	½ w		Prec.	1%	309-034
R304		900 k	½ w		Prec.	1%	309-111
R305		111 k	½ w		Prec.	1%	309-046
R307		800 k	½ w		Prec.	1%	309-110
R308		250 k	½ w		Prec.	1%	309-109
R310		500 k	½ w		Prec.	1%	309-003
R311		1 meg	½ w		Prec.	1%	309-014
R320*		1 meg	½ w		Prec.	1%	*312-583
R321		33 k	2 w				306-333
R322		500 Ω	.2 w	Var.	Comp.	Preamp Gain	311-066
R323		47 Ω	½ w				302-470

*R401 and R320 are matched 0.1%. Furnished as a unit.

Resistors *(continued)*

						Tektronix Part Number
R325	6 k	½ w		Prec.	1%	309-099
R326	16 k	½ w			5%	301-163
R329	18 k	½ w				302-183
R340	470 k	½ w				302-474
R341	4.7 k	½ w				302-472
R342	4.7 k	½ w				302-472
R343	470 k	½ w				302-474
R344	500 k	.2 w	Var.	Comp.	D.C. Bal.	311-068
R345	2 meg	2 w	Var.	Comp.	Low Freq. Adj.	311-042
R347	100 Ω	½ w				302-101
R400	100 k	½ w				302-104
R401*	1 meg	½ w		Prec.	1%	*312-583
R402	33 k	2 w				306-333
R403	68 k	½ w				302-683
R404	1.5 k	½ w				302-152
R405	100 k	½ w				302-104
R406	47 Ω	½ w				302-470
R407	47 Ω	½ w				302-470
R408	3.3 k	½ w				302-332
R409	2.2 k	½ w			5%	301-222
R410	3.3 k	½ w				302-332
R411	3.3 k	½ w				302-332
R412	33 k	2 w			5%	Use 305-333
R413	1 k	2 w	Var.	Comp.	Var. Volts/Div.	311-058
R414	33 k	2 w			5%	Use 305-333
R415	33 k	2 w				306-333
R416	47 Ω	½ w				302-470
R417	1.5 k	½ w				302-152
R418	2.2 k	½ w			5%	301-222
R419	3.3 k	½ w				302-332
R420	150 k	½ w				302-154
R422	2 x 100 k	2 w	Var.	Comp.	VERTICAL POSITION	311-028
R423	150 k	½ w				302-154
R426	47 Ω	½ w				302-470
R427	47 Ω	½ w				302-470
R430	18 k	½ w				302-183
R431	18 k	½ w				302-183
R432	47 Ω	½ w				302-470
R433	47 Ω	½ w				302-470
R440	4 k	5 w		WW	5%	308-051
R441	4 k	5 w		WW	5%	308-051
R442	200 Ω	2 w	Var.	Comp.	Vert Gain Adj.	Use 311-004
R444	5.6 k	2 w				306-562
R446	470 k	½ w				302-474
R447	470 k	½ w				302-474
R450	4.7 k	4 w		Mica Plate	1%	*310-509
R451	4.7 k	4 w		Mica Plate	1%	*310-509
R454	750 Ω	5 w		WW	5%	308-067
R460	183 k	½ w		Prec.	1%	309-050
R461	220 k	½ w				302-224

*R401 and R320 are matched 0.1%. Furnished as a unit.

Resistors *(continued)*

							Tektronix Part Number
R462		147 k	½ w		Prec.	1%	Use 323-0401-00
R465		47 k	½ w				302-473
R470		1 k	.2 w	Var.	WW	Hum Balance	311-060
R480		27 Ω	½ w				302-270
R501		150 k	½ w				302-154
R502		3.9 meg	½ w			5%	301-395
R505		1 k	½ w				302-102
R506		2.7 meg	½ w			5%	301-275
R507		68 k	½ w				302-683
R508		33 k	½ w				302-333
R509		50 k	½ w		Prec.	1%	309-090
R510		10 k	2 w	Var.	WW	Cal. Adj.	311-015
R520		1 k	½ w				302-102
R521		47 Ω	½ w				302-470
R530		10 k	½ w		Prec.	1%	309-100
R531		6 k	½ w		Prec.	1%	309-099
R532		2 k	½ w		Prec.	1%	309-098
R533		1 k	½ w		Prec.	1%	309-115
R534		600 Ω	½ w		Prec.	1%	309-097
R535		200 Ω	½ w		Prec.	1%	309-073
R536		100 Ω	½ w		Prec.	1%	309-112
R537		60 Ω	½ w		Prec.	1%	309-067
R538		20 Ω	½ w		Prec.	1%	309-064
R539		10 Ω	½ w		Prec.	1%	309-096
R540		10 Ω	½ w		Prec.	1%	309-096
R600		50 Ω	2 w	Var.	WW	SCALE ILLUM.	311-057
R601		10 Ω	1 w				304-100
R602		5.6 k	½ w				302-562
R603		100 k	½ w				302-104
R604		470 k	½ w				302-474
R607		2.2 meg	½ w				302-225
R608		2.5 k	10 w		WW	5%	308-018
R609	10,001-20599	56.5 k	½ w		Prec.	1%	309-040
R609	20600-up	36.5 k	½ w		Prec.	1%	323-0343-00
R610		10 k	2 w	Var.	WW	—150V Adj.	311-015
R611	10,001-20599	68 k	½ w		Prec.	1%	309-042
R611	20600-up	49.9 k	½ w		Prec.	1%	323-0356-00
R612		1 meg	½ w				302-105
R613		33 k	½ w				302-333
R630		10 Ω	1 w				304-100
R631		100 k	½ w				302-104
R632		68 k	½ w				302-683
R633		2.2 meg	½ w				302-225
R636		5.6 k	2 w				306-562
R637		333 k	½ w		Prec.	1%	309-053
R638		490 k	½ w		Prec.	1%	309-002
R639		2.2 meg	½ w				302-225
R660		10 Ω	1 w				304-100
R661		270 k	½ w				302-274
R662		47 k	½ w				302-473
R663		270 k	1 w				304-274
R664		1 meg	½ w				302-105

Resistors *(continued)*

								Tektronix Part Number
R668		2 k	20 w		WW		5%	308-031
R669		1 meg	½ w		Prec.		1%	309-014
R670		490 k	½ w		Prec.		1%	309-002
R671		2.2 meg	½ w					302-225
R701		1.5 meg	½ w					302-155
R702		150 k	1 w					304-154
R703		47 k	½ w					302-473
R704		4.7 k	½ w					302-472
R720	10,001-11,669	68 k	½ w					302-683
	11,670 15,059	15 k	½ w					302-153
	15,060-up	68 k	½ w					302-683
R721		5.6 meg	2 w					306-565
R722		5.6 meg	2 w					306-565
R723	10,001-22,349	1 meg	2 w	Var.	Comp.	INTENSITY		311-041
R723	22,350-up	1 meg	2 w	Var.	Comp.	INTENSITY		311-0041-02
R724	10,001-11,669	1.5 meg	½ w					302-155
	11,670-up	2.2 meg	½ w					302-225
R725	X21,880-up	1 meg	½ w					302-0105-00
R726	X21,880-up	10 k	¼ w				5%	315-0103-00
R730		3.3 k	½ w					302-332
R740		1.5 meg	½ w		Prec.		1%	309-017
R741		2 meg	2 w	Var.	Comp.	HV Adj.		311-042
R742		3.9 meg	2 w					306-395
R743	10,001-22,349	2 meg	2 w	Var.	Comp.	FOCUS		311-043
R743	22,350-up	2 meg	2 w	Var.	Comp.	FOCUS		311-0043-02
R744		1.5 meg	½ w					302-155
R745		27 k	½ w					302-273
R750		50 k	2 w	Var.	Comp.	ASTIGMATISM		311-023
R751		1 meg	½ w					302-105

Diodes *

D129	X15221-up	Germanium Diode	152-008
D150	X21,500-up	Silicon Low Leakage 0.25 w, 40 v	152-0246-00
D321		Germanium Diode	152-008
D601A,B,C,D	10,001-21,499	Silicon Diode	Use 152-047
D601A,B,C,D	21,500-up	Silicon 1N3194	152-0066-00
D630A,B,C,D	10,001-21,499	Silicon Diode	Use 152-047
D630A,B,C,D	21,500-up	Silicon 1N3194	152-0066-00
D660A,B,C,D	10,001-21,499	Silicon Diode	Use 152-047
D660A,B,C,D	21,500-up	Silicon 1N3194	152-0066-00

Switches

				Wired	Unwired
SW2 } SW3 }	10,001-12,419	rotary	Trig. Slope/Mode	*262-200	*260-252
	12,420-up	rotary	Trig. Slope/Mode	*262-361	*260-252
SW125	10,001-24,019	SPDT	Preset W/R125 & R22		311-096
SW125	24,020	SPDT	Preset W/R125 & R22		311-0096-02
SW175		rotary	Time/Div.	*262-199	*260-093
SW210		rotary	Display		*260-096
SW300		rotary	AC-DC	*262-217	*260-097
SW305 } SW413 }		rotary	VOLTS/DIV.	*262-198	*260-206
SW530		rotary	CALIBRATOR	*262-120	*260-098
SW600		rotary	ON-OFF SPST		Part of R600

* Even though the diodes may be different in physical size, they are direct electrical replacements for the diodes in your instrument.

Thermal Cut-Out

			Tektronix Part Number
TK600		Thermal Cutout 165°F.	260-227

Transformers

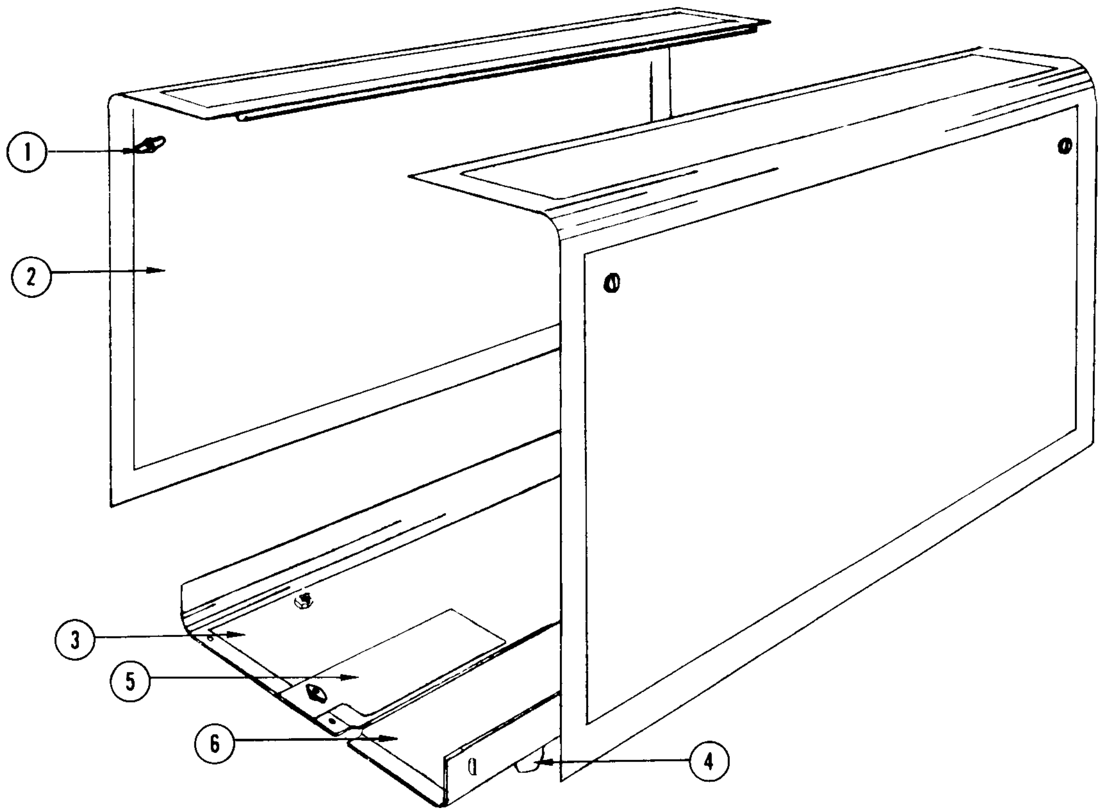
T600		Plate and Heater Supply	*120-118
T700		CRT Supply	*120-121

Electron Tubes

V10		6DJ8	154-187
V40		6DJ8	154-187
V102		6DJ8	154-187
V110		6AU6	154-022
V130		12AT7	154-039
V150		6AL5	154-016
V160		6AN8	154-078
V220		6DJ8	154-187
V240		6DJ8	154-187
V320	10,001-21,429	6AU6	154-0022-00
V320	21,430-up	8425	154-0022-07
V329		6BH6	154-026
V401	10,001-21,429	6AU6	154-0022-00
V401	21,430-up	8425	154-0022-07
V408	10,001-21,429	6AU6	154-0022-00
V408	21,430-up	8425	154-0022-07
V430		6DJ8	154-187
V440		6CL6	154-031
V441		6CL6	154-031
V465		6BH6	154-026
V501		12AU7	154-041
V520		6AU6	154-022
V602		6BH6	154-026
V607		12B4	154-044
V613		5651	154-052
V631		6BH6	154-026
V633		12B4	154-044
V661		6BH6	154-026
V663		12B4	154-044
V701		12AU7	154-041
V704		6AQ5	154-017
V720		5642	154-051
V730		5642	154-051
V859		CRT T3100-31 Standard Phosphor	Use *154-366

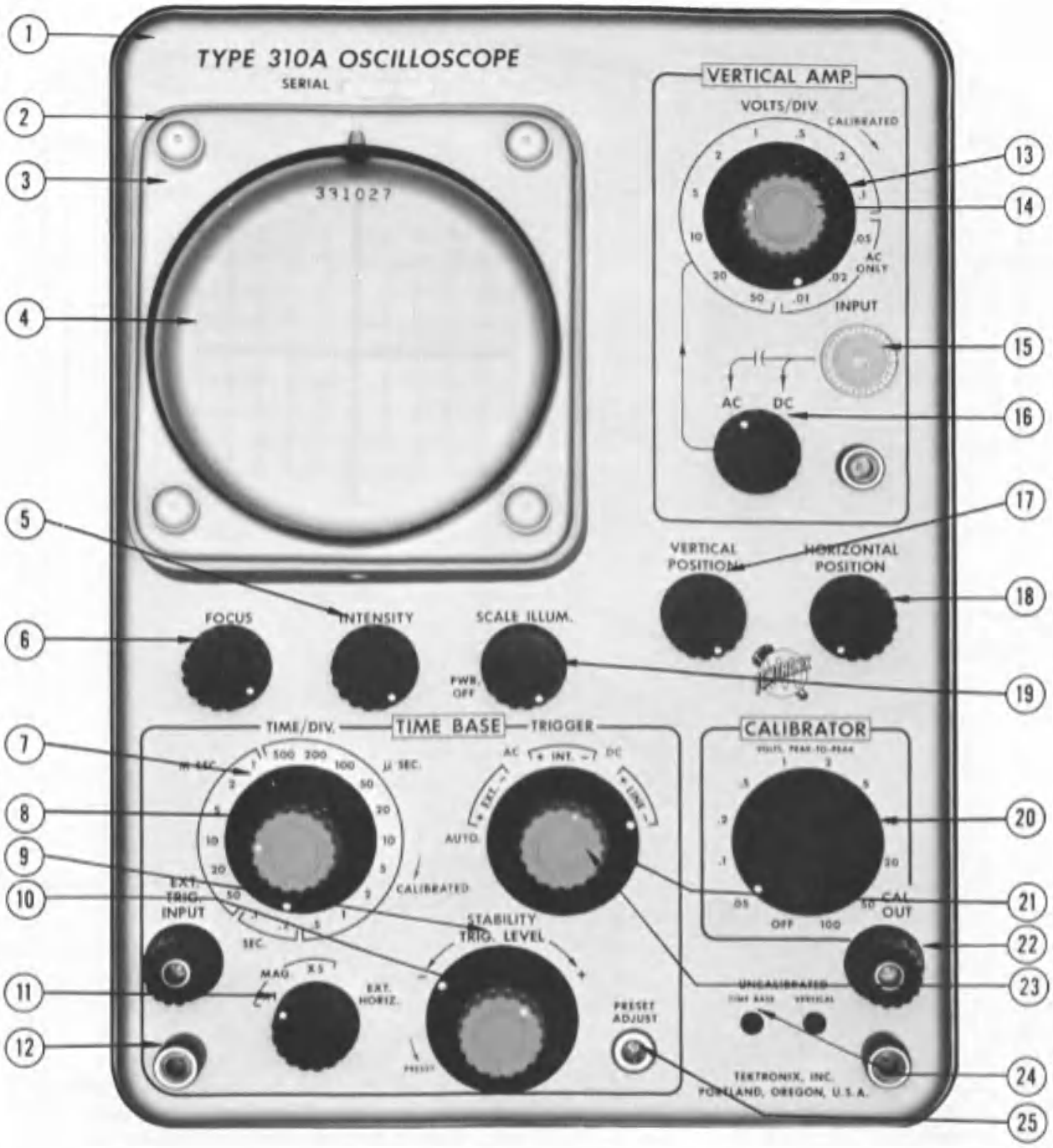
SECTION 7
MECHANICAL PARTS LIST

CABINET



REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	QTY.	DESCRIPTION
1	213-0040-00			6	SCREW, fastening, steel, 6-32 x 3/8 x 1/2 inch
	105-0009-00			6	STOP, steel, 5/32 ID x 11/32 inch OD
	210-0870-00			6	WASHER, steel, 9/64 ID x 5/16 inch OD
	210-0470-00			6	NUT, cabinet, fastener, small with insert
2	386-0874-00	10001	12578	2	PLATE, cabinet side, left or right, blue wrinkle
	387-0045-00	12579		2	PLATE, cabinet side, left or right, blue vinyl
3	386-0953-00	10001	12578	1	PLATE, cabinet bottom, vertical amplifier half,
	- - - - - -			-	blue wrinkle
	387-0047-00	12579		1	PLATE, cabinet bottom, vertical amplifier half,
	- - - - - -			-	blue vinyl
4	348-0015-00			4	CUSHION, rubber ball, 7/16 inch, blue
	348-0014-00			4	FOOT, molded, black, 3/4 OD x 11/16 inch high
	- - - - - -			-	Mounting Hardware For Each: (not included)
	210-0458-00			1	NUTS, keps, 8-32 x 11/32 inch
	210-0008-00			1	LOCKWASHER, steel, internal #8
	212-0010-00			1	SCREW, 8-32 x 5/8 inch BHS
5	386-0954-00	10001	12578	1	PLATE, cabinet door, blue wrinkle
	387-0048-00	12579		1	PLATE, cabinet door, blue vinyl
6	386-0952-00	10001	12578	1	PLATE, cabinet bottom, power half, blue wrinkle
	387-0046-00	12579		1	PLATE, cabinet bottom, power half, blue vinyl

FRONT



REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	Q T Y.	DESCRIPTION
1	333-0452-00			1	PANEL, front
2	210-0434-00			4	NUT, knurled, 10-32 x 3/8 inch
	210-0844-00			4	WASHER, neoprene, 7/32 ID x 3/8 inch OD
3	200-0073-00			1	COVER, graticule
4	331-0027-00			1	GRATICULE
5	366-0033-00	10001	20759	1	KNOB, small black — INTENSITY
	366-0148-00	20760		1	KNOB, small charcoal — INTENSITY
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS
6	366-0033-00	10001	20759	1	KNOB, small black — FOCUS
	366-0148-00	20760		1	KNOB, small charcoal — FOCUS
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS

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FRONT *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	QTY.	DESCRIPTION
7	366-0029-00	10001	20759	1	KNOB, large black — TIME/DIV.
	366-0142-00	20760		1	KNOB, large charcoal — TIME/DIV.
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS
8	366-0031-00			1	KNOB, TIME/DIV., red
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW set, 6-32 x 3/16 inch HSS
	262-0199-00			1	SWITCH, TIME/DIV., wired
	- - - - - -			-	Includes:
	260-0093-00			1	SWITCH, TIME/DIV., unwired
	384-0095-00			1	ROD, extension, steel, 1/8 x 5 19/32 inch
	376-0014-00			1	COUPLING, pot, wire steel
	210-0413-00			2	NUT, hex, brass, 3/8-32 x 1/2 inch
	210-0012-00			1	LOCKWASHER, steel, internal 3/8 x 1/2 inch
	406-0139-00			1	BRACKET, aluminum, 1 1/2 x 2 1/8 inch
	- - - - - -			-	Mounting Hardware: (not included)
	210-0449-00			2	NUT, hex, brass, 5-40 x 3/16 inch
	210-0017-00			1	LOCKWASHER, spring, #5
	210-0202-00			1	LUG, solder, SE #6 with 2 wire holes
	- - - - - -			-	Mounting Hardware For Switch:
	210-0413-00			1	NUT, hex, brass, 3/8-32 x 1/2 inch
	210-0012-00			1	LOCKWASHER, steel, internal 3/8 x 1/2 inch
9	366-0028-00	10001	20759	1	KNOB, large black — TRIG. LEVEL
	366-0145-00	20760		1	KNOB, large charcoal — TRIG. LEVEL
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS
10	366-0032-00			1	KNOB, STABILITY, red
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS
11	366-0033-00	10001	20759	1	KNOB, small black — MAG.
	366-0148-00	20760		1	KNOB, small charcoal — MAG.
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS
	358-0029-00			1	BUSHING, brass, hex, 3/8-32 x 13/32 inch
	210-0413-00			1	NUT, hex, brass, 3/8-32 x 1/2 inch
	210-0840-00			1	WASHER, steel, .390 ID x 9/16 OD x .020 inch
12	129-0020-00			3	POST, binding, assembly
	- - - - - -			-	Each Consists Of:
	200-0072-00			1	CAP, plated brass, 3/8 x 5/8 inch
	355-0503-00			1	STEM, plated
	- - - - - -			-	Mounting Hardware For Each: (not included)
	210-0445-00			1	NUT, hex, steel, 10-32 x 3/8 x 1/8 inch
	210-0010-00			1	LOCKWASHER, steel, internal #10
13	366-0029-00	10001	20759	1	KNOB, large black — VOLTS/DIV.
	366-0142-00	20760		1	KNOB, large charcoal — VOLTS/DIV.
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS

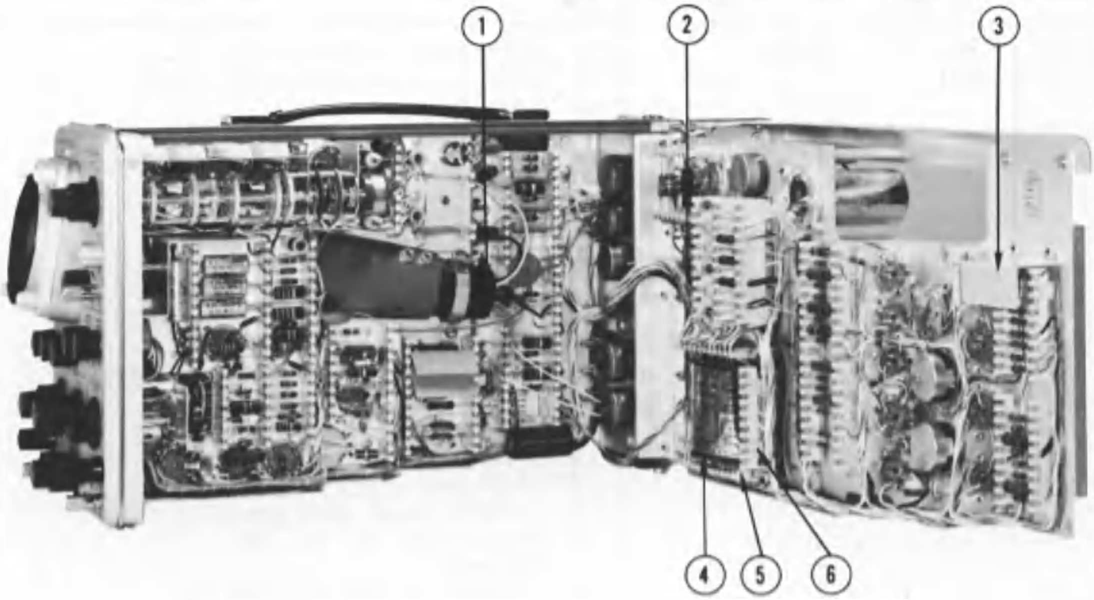
FRONT *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
14	366-0031-00			1	KNOB, VOLTS/DIV., red
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS
	262-0198-00			1	SWITCH, VOLTS/DIV., wired
	- - - - - -			-	Includes:
	260-0206-00			1	SWITCH, VOLTS/DIV., unwired
	384-0164-00			1	ROD, extension, aluminum, 1/8 x 6 7/16 inch
	406-0339-00			1	BRACKET, brass, 1 1/8 x 4 15/32 x 1 3/8 inch
	- - - - - -			-	Mounting Hardware: (not included)
	211-0007-00			2	SCREW, 4-40 x 3/16 inch BHS
	210-0004-00			2	LOCKWASHER, steel, internal #4
	210-0406-00			2	NUT, hex, brass, 4-40 x 3/16 inch
	210-0413-00			2	NUT, hex, brass, 3/8-32 x 1/2 inch
	210-0012-00			1	LOCKWASHER, steel, internal 3/8 x 1/2 inch
	376-0014-00			1	COUPLING, pot, wire steel
	406-0499-00			1	BRACKET, aluminum, 3 1/8 x 1 1/4 x 1/4 inch
	- - - - - -			-	Mounting Hardware For Switch:
	210-0413-00			1	NUT, hex, brass, 3/8-32 x 1/2 inch
	210-0012-00			1	LOCKWASHER, steel, internal 3/8 x 1/2 inch
15	131-0081-00	10001	19119	1	CONNECTOR, chassis mounted, coaxial, UHF
	131-0126-00	19120		1	CONNECTOR, chassis mounted, coaxial, BNC
16	366-0033-00	10001	20759	1	KNOB, small black—AC, DC
	366-0148-00	20760		1	KNOB, small charcoal—AC, DC
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS
	262-0217-00			1	SWITCH, AC, DC, wired
	- - - - - -			-	Includes:
	260-0097-00			1	SWITCH, AC, DC, unwired
	337-0278-00			1	SHIELD, aluminum 1 3/4 x 3 3/8 inch
	- - - - - -			-	Mounting Hardware: (not included)
	210-0406-00			2	NUT, hex, brass, 4-40 x 3/16 inch
	210-0004-00			2	LOCKWASHER, steel, internal #4
	343-0007-00			1	CLAMP, cable, 5/8 inch plastic
	- - - - - -			-	Mounting Hardware: (not included)
	211-0510-00			1	SCREW, 6-32 x 3/8 inch BHS
	210-0802-00			1	WASHER, steel, 6S x 5/16 inch
	210-0006-00			1	LOCKWASHER, steel, internal #6
	210-0407-00			1	NUT, hex, brass, 6-32 x 1/4 inch
	- - - - - -			-	Mounting Hardware For Switch:
	210-0413-00			1	NUT, hex, brass, 3/8-32 x 1/2 inch
	210-0012-00			1	LOCKWASHER, steel, internal 3/8 x 1/2 inch
17	366-0033-00	10001	20759	1	KNOB, small black—VERTICAL POSITION
	366-0148-00	20760		1	KNOB, small charcoal—VERTICAL POSITION
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS
18	366-0033-00	10001	20759	1	KNOB, small black—HORIZONTAL POSITION
	366-0148-00	20760		1	KNOB, small charcoal—HORIZONTAL POSITION
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS

FRONT *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	QTY.	DESCRIPTION
19	366-0033-00	10001	20759	1	KNOB, small black—SCALE ILLUM.
	366-0148-00	20760		1	KNOB, small charcoal—SCALE ILLUM.
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x $^{3}/_{16}$ inch HSS
20	366-0030-00	10001	20759	1	KNOB, large black—CALIBRATOR
	366-0146-00	20760		1	KNOB, large charcoal—CALIBRATOR
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x $^{3}/_{16}$ inch HSS
	262-0120-00			1	SWITCH, CALIBRATOR, wired
	- - - - - -			-	Includes:
	260-0098-00			1	SWITCH, CALIBRATOR, unwired
	337-0106-00			1	SHIELD, aluminum, 1 $^{9}/_{16}$ x 1 $^{1}/_{8}$ inch
	- - - - - -			-	Mounting Hardware: (not included)
	210-0406-00			2	NUT, hex, brass, 4-40 x $^{3}/_{16}$ inch
	210-0004-00			2	LOCKWASHER, steel, internal #4
	- - - - - -			-	Mounting Hardware For Switch:
	210-0413-00			1	NUT, hex, brass, $^{3}/_{8}$-32 x $^{1}/_{2}$ inch
	210-0012-00			1	LOCKWASHER, steel, internal $^{3}/_{8}$ x $^{1}/_{2}$ inch
21	366-0031-00			1	KNOB, AUTO, AC, DC, red
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x $^{3}/_{16}$ inch HSS
22	129-0036-00	10001	20759	2	POST, binding, black
	129-0063-00	20760		2	POST, binding, charcoal
	- - - - - -			-	Mounting Hardware For Each: (not included)
	358-0036-00	10001	20759	1	BUSHING, black
	358-0169-00	20760		1	BUSHING, charcoal
	210-0445-00	10001	19189	2	NUT, hex, 10-32 x $^{3}/_{8}$ inch
	220-0410-00	19190		1	NUT, keps, 10-32 x $^{3}/_{8}$ inch
	210-0010-00	10001	19189X	1	LOCKWASHER, internal #10
	210-0206-00	10001	19189X	1	LUG, solder, SE 10, long
23	366-0029-00	10001	20759	1	KNOB, large black—TRIGGER
	366-0142-00	20760		1	KNOB, large charcoal—TRIGGER
	- - - - - -			-	Includes
	213-0004-00			1	SCREW, set, 6-32 x $^{3}/_{16}$ inch HSS
	262-0200-00	10001	12419	1	SWITCH, wired—TRIGGER
	262-0361-00	12420		1	SWITCH, wired—TRIGGER
	- - - - - -			-	Includes:
	260-0252-00			1	SWITCH, TRIGGER, unwired
	- - - - - -			-	Mounting Hardware For Switch:
	210-0413-00			1	NUT, hex, brass, $^{3}/_{8}$-32 x $^{1}/_{2}$ inch
	210-0012-00			1	LOCKWASHER, steel, internal $^{3}/_{8}$ x $^{1}/_{2}$ inch
	210-0840-00			1	WASHER, steel, .390 ID x $^{9}/_{16}$ OD x .020 inch
24	352-0006-00	10001	21331	1	HOLDER, black nylon, double neon
	352-0064-00	21332		1	HOLDER, gray nylon, double neon
	378-0541-00	X21332		2	FILTER, lens, neon
	- - - - - -			-	Mounting Hardware: (not included)
	211-0031-00	10001	21331	1	SCREW, 4-40 x 1 inch FHS
	211-0109-00	21332		1	SCREW, 4-40 x $^{7}/_{8}$ inch, FHS
	210-0406-00			2	NUT, hex, brass, 4-40 x $^{3}/_{16}$ inch
	210-0004-00			1	LOCKWASHER, steel, internal #4
25	358-0054-00			1	BUSHING, banana jack, brass $^{1}/_{4}$-32 x $^{13}/_{32}$ inch
	- - - - - -			-	Mounting Hardware: (not included)
	210-0471-00			1	NUT, hex, aluminum, $^{1}/_{4}$-32 x $^{5}/_{16}$ x $^{19}/_{32}$ inch
	210-0011-00			2	LOCKWASHER, steel, internal, $^{1}/_{4}$ inch

RIGHT SIDE (Open)



REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	QTY.	DESCRIPTION
1	136-0063-00	10001	18969	1	SOCKET, 12 pin, CRT
	136-0143-00	18970		1	SOCKET, CRT assembly with 10 leads
2	343-0005-00			2	CLAMP, cable, $^7/_{16}$ inch, plastic
	- - - - - - -			-	Mounting Hardware For Each: (not included)
	211-0513-00			1	SCREW, 6-32 x $^5/_8$ inch, plastic
	210-0803-00			1	WASHER, steel, 6L x $^3/_8$ x .032 inch
	210-0457-00			1	NUT, keps, steel, 6-32 x $^5/_{16}$ inch
2	337-0116-00			1	SHIELD, aluminum, 1$^1/_4$ x 2$^3/_4$ inches
	- - - - - - -			-	Mounting Hardware: (not included)
	211-0507-00			2	SCREW, 6-32 x $^5/_{16}$ inch BHS
	210-0457-00			2	NUT, keps, steel, 6-32 x $^5/_{16}$ inch
4	386-0645-00			1	PLATE, aluminum transformer ring
	- - - - - - -			-	Mounting Hardware For Plate
	212-0517-00			4	SCREW, 10-32 x 1$^3/_4$ inches HHS
	210-0010-00			4	LOCKWASHER, steel, internal #10
	210-0812-00			4	WASHER, fiber, #10
	210-0564-00			8	NUT, hex, stainless steel, 10-32 x$^3/_8$ x $^1/_8$ inch
5	124-0091-00	10001	14453	2	STRIP, ceramic, $^3/_4$ inch x 11 notches
	124-0106-00	14454		2	STRIP, ceramic, $^7/_{16}$ inch x 11 notches
	- - - - - - -			-	Each Includes:
	355-0046-00			2	STUD, nylon
	- - - - - - -			-	Mounting Hardware For Each: (not included)
	361-0009-00	10001	14453	2	SPACER, nylon, $^9/_{32}$ inch
	361-0007-00	14454		2	SPACER, nylon, $^1/_{16}$ inch

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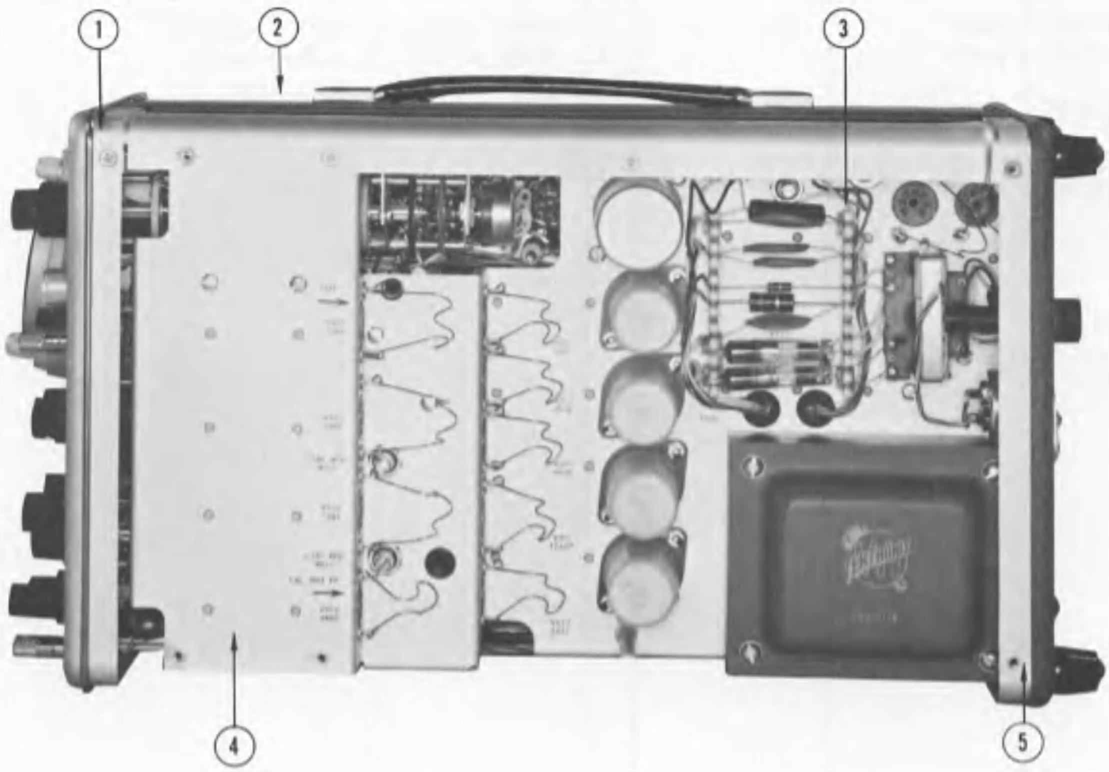
RIGHT SIDE (Open) *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	QTY.	DESCRIPTION
6	124-0090-00	10001	14453	1	STRIP, ceramic, $^3/_4$ inch x 9 notches
	124-0095-00	14454		1	STRIP, ceramic, $^7/_{16}$ inch x 9 notches
	- - - - - -			-	Each Includes:
	355-0046-00			2	STUD, nylon
	- - - - - -			-	Mounting Hardware For Each (not included)
	361-0009-00	10001	14453	2	SPACER, nylon, $^9/_{32}$ inch
	361-0007-00	14454		2	SPACER, nylon, $^1/_{16}$ inch

RIGHT SIDE (Closed)

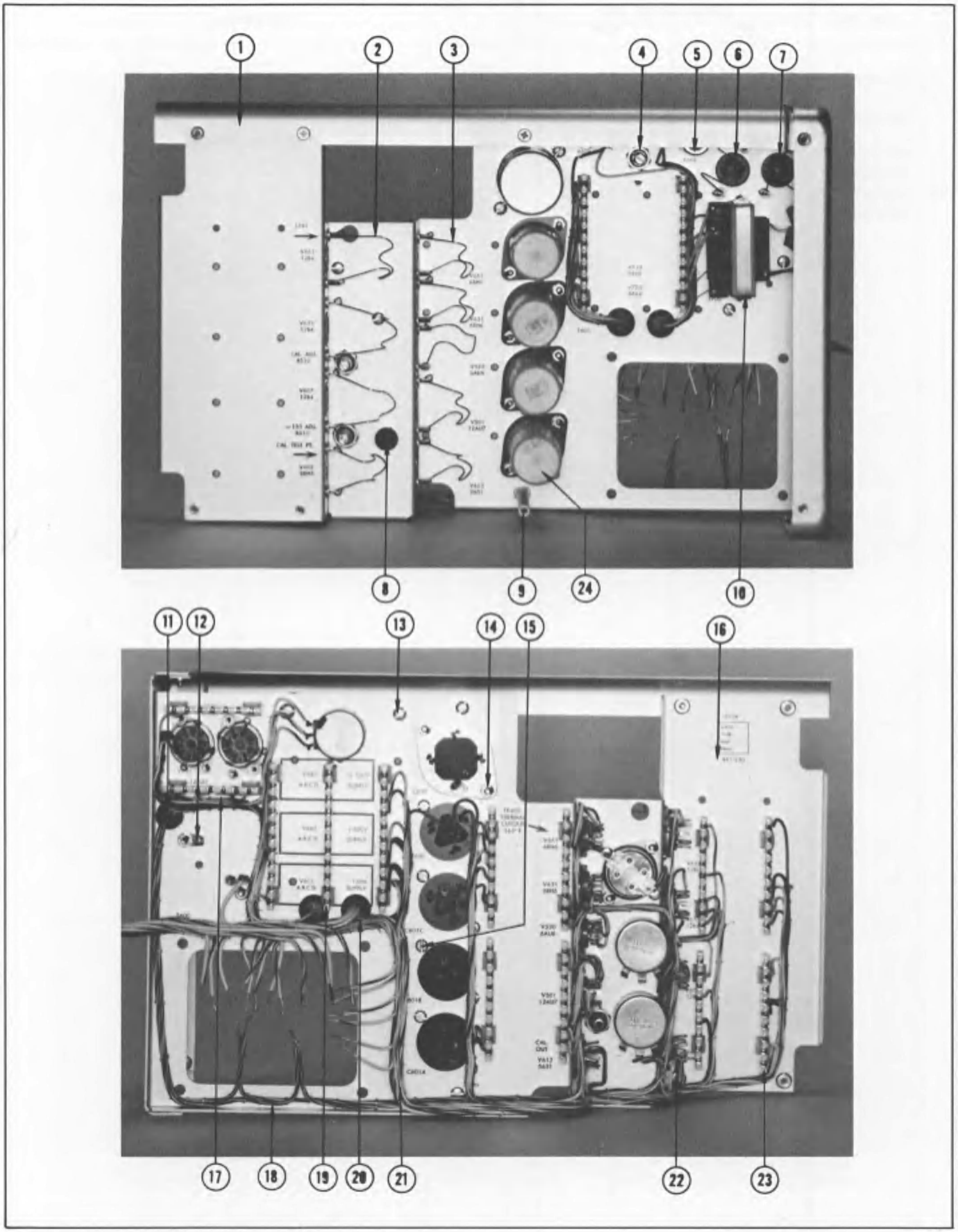


REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	QTY.	DESCRIPTION
1	386-0871-00			1	PLATE, sub-panel, front
	- - - - - -			-	Mounting Hardware: (not included)
	211-0538-00			4	SCREW, 6-32 x 5/16 inch FHS 100°
	210-0006-00			4	LOCKWASHER, steel, internal #6
	210-0407-00			4	NUT, hex, brass, 6-32 x 1/4 inch
2	381-0113-00	10001	12578	1	BAR, top support, w/handle
	381-0166-00	12579	19424	1	BAR, top support, w/handle
	381-0235-00	19425		1	BAR, top support, w/handle
	- - - - - -			-	Bar Includes:
	367-0039-00	10001	19424	1	HANDLE, assembly
	367-0043-00	19425		1	HANDLE, assembly
	- - - - - -			-	Assembly Includes:
	367-0001-00	10001	19424	1	HANDLE, black leather
	367-0037-00	19425		1	HANDLE, blue
	343-0052-00	10001	19424	2	CLAMP, handle
	344-0098-00	19425		2	CLIP, handle
	210-0903-00	10001	19424	2	WASHER, handle mounting
	212-0566-00	19425	21509	2	SCREW, 10-32 x 5/16 inch RHS
	212-0507-00	21510		2	SCREW, 10-32 x 3/8 inch PHS
	210-0010-00	X21510		2	LOCKWASHER, internal, #10
	- - - - - -			-	Mounting Hardware: (not included w/bar)
	211-0542-00			4	SCREW, 6-32 x 5/16 inch THS
	381-0084-00			2	BAR, retaining

RIGHT SIDE (Closed) *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
3	124-0091-00			2	STRIP, ceramic, 7/16 inch x 11 notches
	- - - - - -			-	Each Includes:
	355-0046-00			2	STUD, nylon
	- - - - - -			-	Mounting Hardware For Each (not included)
	361-0008-00			2	SPACER, nylon, 1/4 inch high
4	441-0230-00			1	CHASSIS, power
5	386-0881-00	10001	13416	1	PLATE, sub-panel, rear
	387-0324-00	13417		1	PLATE, sub-panel, rear

POWER CHASSIS



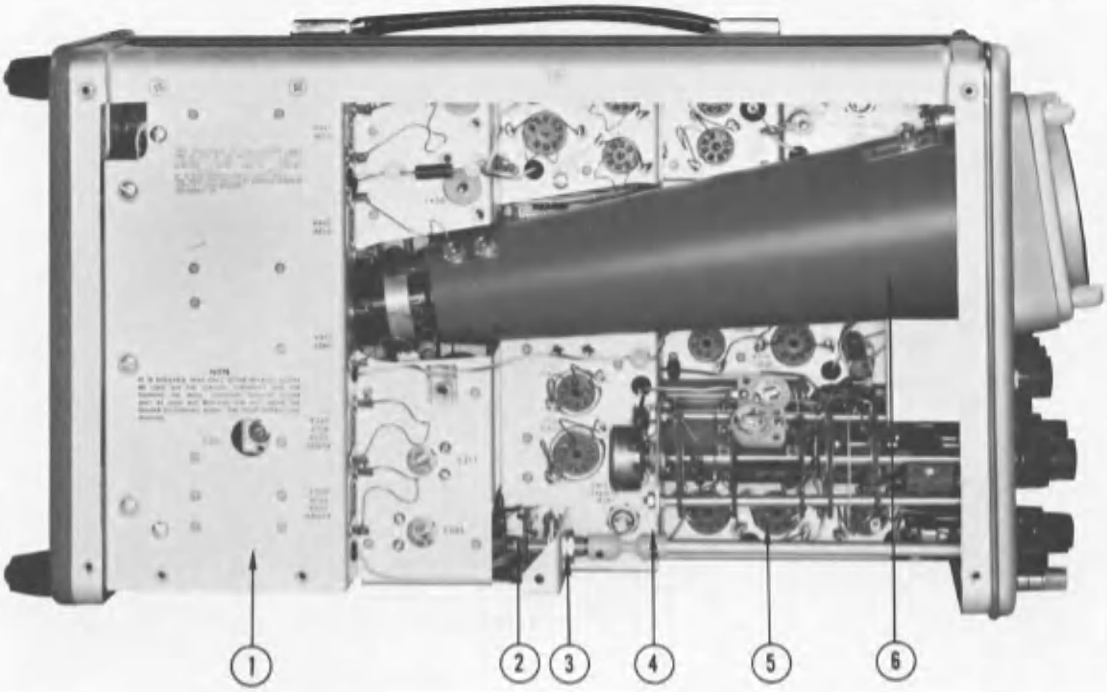
POWER CHASSIS

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
1	426-0066-00			1	FRAME, top right, $\frac{7}{8} \times 13\frac{15}{16}$ inches
	- - - - - -			-	Mounting Hardware: (not included)
	211-0538-00			6	SCREW, 6-32 x $\frac{5}{16}$ inch FHS 100°
2	344-0014-00			4	CLIP, spring, tube, large
3	344-0013-00			7	CLIP, spring, tube, medium
4	210-0413-00			1	NUT, hex, brass, $\frac{3}{8}$-32 x $\frac{1}{2}$ inch
	210-0840-00			1	WASHER, steel, .390 ID x $\frac{9}{16}$ OD x .020 inch
5	212-0037-00			1	SCREW, 8-32 x $1\frac{3}{4}$ inches Fil HS
	210-0808-00			1	WASHER, brass, centering
	210-0462-00			1	NUT, hex, aluminum, 25 w resistor mounting
	212-0004-00			1	SCREW, 8-32 x $\frac{5}{16}$ inch BHS
6	136-0044-00			1	SOCKET, 7 pin tube
	- - - - - -			-	Mounting Hardware: (not included)
	214-0034-00			2	BOLT, spade, steel, 4-40 x $\frac{3}{16}$ inch
	210-0004-00			4	LOCKWASHER, steel, internal #4
	210-0801-00			2	WASHER, steel, 5S x $\frac{9}{32}$ x .025 inch
	166-0029-00			2	TUBE, spacer, aluminum, $\frac{1}{4}$ OD x $\frac{1}{8}$ inch long
	210-0406-00			2	NUT, hex, brass, 4-40 x $\frac{3}{16}$ inch
7	136-0015-00			5	SOCKET, STM9G
	- - - - - -			-	Mounting Hardware For Each: (not included)
	214-0034-00			2	BOLT, spade, steel, 4-40 x $\frac{3}{16}$ inch
	210-0004-00			4	LOCKWASHER, steel, internal #4
	210-0801-00			2	WASHER, steel, 5S x $\frac{9}{32}$ x .025 inch
	210-0406-00			2	NUT, hex, brass, 4-40 x $\frac{3}{16}$ inch
8	136-0037-00			1	SOCKET, tip jack, black nylon
	- - - - - -			-	Mounting Hardware: (not included)
	210-0413-00			1	NUT, hex, brass, $\frac{3}{8}$-32 x $\frac{1}{2}$ inch
	210-0840-00			1	WASHER, steel, .390 ID x $\frac{9}{16}$ OD x .020 inch
9	385-0125-00			2	ROD, aluminum, $\frac{1}{4} \times 2\frac{11}{32}$ inches (support post)
	- - - - - -			-	Mounting Hardware For Each: (not included)
	211-0507-00			1	SCREW, 6-32 x $\frac{5}{16}$ inch BHS
	210-0803-00			1	WASHER, steel, 6L x $\frac{3}{8}$ x .032 inch
10	346-0001-00			1	STRAP, mounting $\frac{5}{16} \times 4\frac{1}{4}$ inches
	210-0406-00			2	NUT, hex, brass, 4-40 x $\frac{3}{16}$ inch
	210-0004-00			2	LOCKWASHER, steel, internal #4
11	348-0004-00			1	GROMMET, rubber, $\frac{3}{8}$ inch
12	210-0202-00			1	LUG, solder, SE #6 with 2 wire holes
	- - - - - -			-	Mounting Hardware: (not included)
	211-0507-00			1	SCREW, 6-32 x $\frac{5}{16}$ inch BHS
	210-0407-00			1	NUT, hex, brass, 6-32 x $\frac{1}{4}$ inch
13	211-0507-00			1	SCREW, 6-32 x $\frac{5}{16}$ inch BHS
	210-0478-00			1	NUT, hex, aluminum, 5-10 w resistor mounting
	210-0601-00			1	EYELET, brass, tapered barrel mounting
	211-0553-00			1	SCREW, 6-32 x $1\frac{1}{2}$ inches RHS

POWER CHASSIS *(Cont'd)*

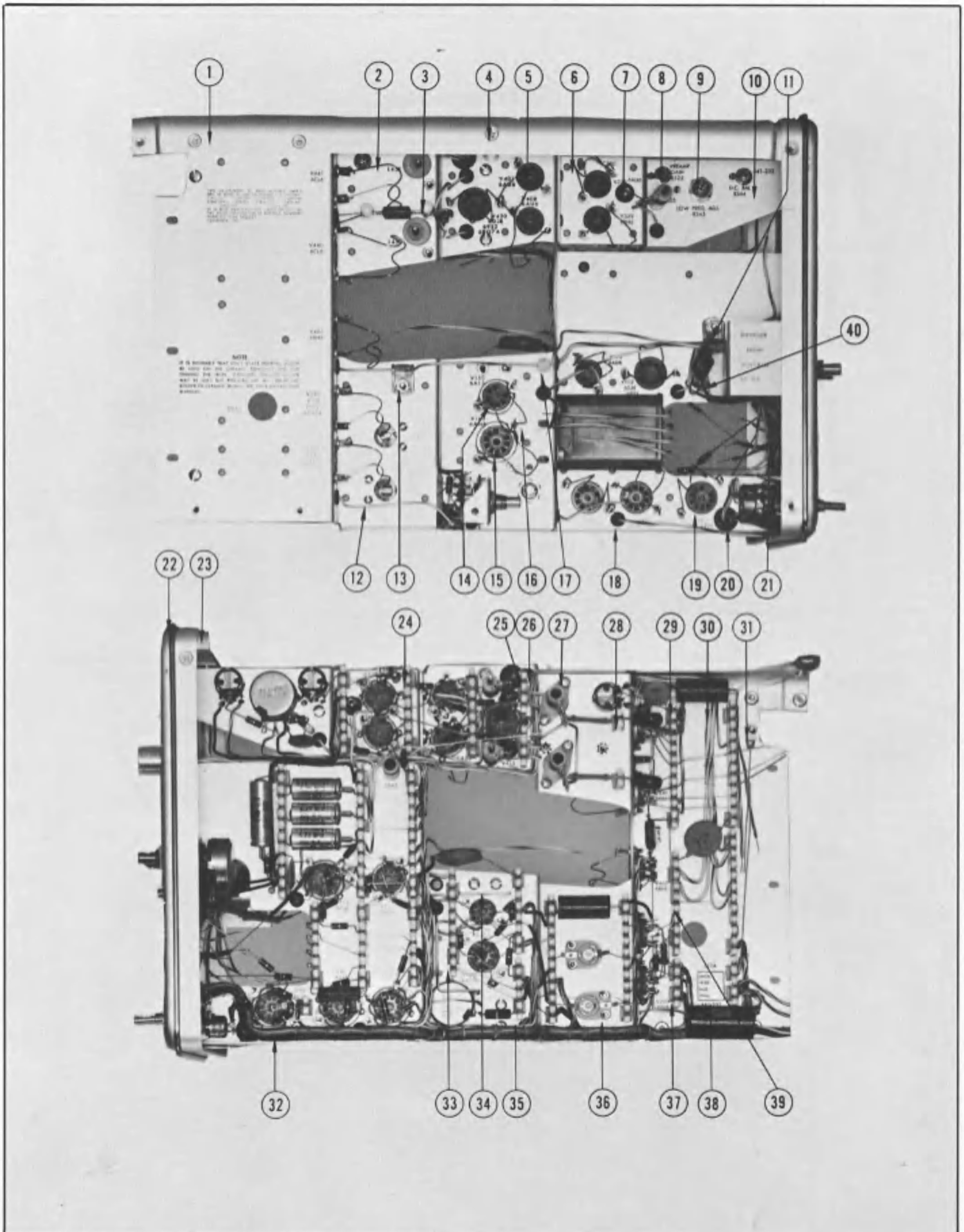
REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
14	211-0511-00			2	SCREW, 6-32 x 1/2 inch BHS
	166-0030-00			2	TUBE, spacer, aluminum, 1/4 OD x 3/16 inch long
	210-0006-00			2	LOCKWASHER, steel, internal #6
	210-0407-00			2	NUT, hex, brass, 6-32 x 1/4 inch
	210-0005-00			2	LOCKWASHER, steel, external #6
15	211-0534-00			8	SCREW, 6-32 x 5/16 inch PHS with lockwasher
	210-0006-00			8	LOCKWASHER, steel, internal #6
	210-0407-00			8	NUT, hex, brass, 6-32 x 1/4 inch
16	441-0230-00			1	CHASSIS, power
17	124-0089-00			2	STRIP, ceramic, 3/4 inch x 7 notches
	- - - - - -			-	Each Includes:
	355-0046-00			2	STUD, nylon
	- - - - - -			-	Mounting Hardware For Each: (not included)
	361-0008-00			2	SPACER, nylon, 1/4 inch high
18	179-0347-00			1	CABLE HARNESS, 110 V
19	124-0091-00			3	STRIP, ceramic, 3/4 inch x 11 notches
	- - - - - -			-	Each Includes:
	355-0046-00			2	STUD, nylon
	- - - - - -			-	Mounting Hardware For Each: (not included)
	361-0008-00			2	SPACER, nylon, 1/4 inch high
20	348-0005-00			2	GROMMET, rubber, 1/2 inch
21	179-0290-00			1	CABLE HARNESS
22	136-0008-00			5	SOCKET, STM7G
	- - - - - -			-	Mounting Hardware For Each: (not included)
	214-0034-00			2	BOLT, spade, steel, 4-40 x 3/16 inch
	210-0004-00			4	LOCKWASHER, steel, internal #4
	210-0801-00			2	WASHER, steel, 5S x 9/32 x .025 inch
	210-0406-00			2	NUT, hex, brass, 4-40 x 3/16 inch
23	124-0095-00			8	STRIP, ceramic 7/16 inch x 9 notches
	- - - - - -			-	Each Includes:
	355-0046-00			2	STUD, nylon
	- - - - - -			-	Mounting Hardware For Each: (not included)
	361-0007-00			2	SPACER, nylon, 063 inch high
24	200-0256-00			4	COVER, capacitor, plastic, 2 1/32 inch diameter

LEFT SIDE



REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	QTY.	DESCRIPTION
1	441-0231-00			1	CHASSIS, vertical amplifier
2	260-0096-00			1	SWITCH, MAG., rotary
	- - - - - - -			-	Mounting Hardware: (not included w/switch)
	210-0413-00			1	NUT, hex, brass, $^3/_8$-32 x $^1/_2$ inch
	210-0012-00			1	LOCKWASHER, steel, internal $^3/_8$ x $^1/_2$ inch
	210-0840-00			1	WASHER, steel, .390 ID x $^9/_{16}$ OD x .020 inch
3	406-0419-00			1	BRACKET, aluminum, 1 x 2$^1/_2$ x $^5/_8$ inch (switch support)
	- - - - - - -			-	Mounting Hardware: (not included)
	211-0510-00			2	SCREW, 6-32 x $^3/_8$ inch BHS
	211-0537-00			2	SCREW, 6-32 x $^3/_8$ inch, THS
	210-0803-00			1	WASHER, steel, 6L x $^3/_8$ x .032 inch
	210-0457-00			1	NUT, keps, steel, 6-32 x $^5/_{16}$ inch
4	376-0011-00			1	COUPLING, molded nylon, insulated
	- - - - - - -			-	Includes:
	213-0004-00			2	SCREW, set, 6-32 x $^3/_{16}$ inch HSS
5	384-0181-00			1	ROD, extension, aluminum, $^1/_4$ x 6$^1/_2$ inches
6	337-0121-00			1	CRT SHIELD
	- - - - - - -			-	Mounting Hardware: (not included)
	211-0531-00			1	SCREW, 6-32 x $^3/_8$ inch Fil HS
	211-0532-00			2	SCREW, 6-32 x $^3/_4$ inch Fil HS

VERTICAL AMPLIFIER CHASSIS



VERTICAL AMPLIFIER CHASSIS *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
1	426-0067-00			1	FRAME, top left, $\frac{7}{8} \times 14\frac{7}{16}$ inches
2	344-0014-00			2	CLIP, spring, tube, large
3	129-0029-00			2	POST, connecting 1 inch x 2 notches
	- - - - - -			-	Mounting Hardware For Each: (not included)
	210-0001-00			1	LOCKWASHER, steel, internal #2
	210-0002-00			1	LOCKWASHER, steel, external #2
	210-0405-00			2	NUT, hex, 2-56 x $\frac{3}{16}$ inch
4	211-0538-00			1	SCREW, 6-32 x $\frac{5}{16}$ inch FHS, 100°
	385-0126-00			1	ROD, aluminum $\frac{1}{4} \times 2\frac{21}{32}$ inches
	210-0803-00			1	WASHER, steel, 6L x $\frac{3}{8}$ inch
	211-0507-00			1	SCREW, 6-32 x $\frac{5}{16}$ inch PHS
5	136-0008-00			6	SOCKET, STM7G
	- - - - - -			-	Mounting Hardware For Each: (not included)
	214-0034-00			2	BOLT, spade, steel, 4-40 x $\frac{3}{16}$ inch
	210-0004-00			4	LOCKWASHER, steel, internal #4
	210-0801-00			2	WASHER, steel, 5S x $\frac{9}{32}$ x .025 inch
	210-0406-00			2	NUT, hex, brass, 4-40 x $\frac{3}{16}$ inch
6	344-0013-00			14	CLIP, spring, tube, medium
7	348-0003-00			1	GROMMET, rubber, $\frac{5}{16}$ inch
8	210-0465-00			1	NUT, hex, brass, $\frac{1}{4}$-32 x $\frac{3}{8}$ x $\frac{3}{32}$ inch
	210-0011-00			1	LOCKWASHER, steel, internal $\frac{1}{4}$ inch
9	210-0413-00			1	NUT, hex, brass, $\frac{3}{8}$-32 x $\frac{1}{2}$ inch
	210-0840-00			1	WASHER, steel, .390 ID x $\frac{9}{16}$ OD x .020 inch
10	441-0232-00			1	CHASSIS, preamp
	- - - - - -			-	Mounting Hardware: (not included)
	211-0504-00			2	SCREW, 6-32 x $\frac{1}{4}$ inch PHS
11	343-0003-00			1	CLAMP, cable, $\frac{1}{4}$ inch plastic
	- - - - - -			-	Mounting Hardware: (not included)
	210-0407-00			1	NUT, hex, brass, 6-32 x $\frac{1}{4}$ inch
	210-0006-00			1	LOCKWASHER, steel, internal #6
	210-0803-00			1	WASHER, steel, 6L x $\frac{3}{8}$ x .032 inch
	211-0511-00			1	SCREW, 6-32 x $\frac{1}{2}$ inch PHS
12	211-0016-00			4	SCREW, 4-40 x $\frac{5}{8}$ inch RHS
13	343-0001-00			1	CLAMP, cable, $\frac{1}{8}$ inch plastic
14	136-0007-00			1	SOCKET, STM7
15	136-0014-00			1	SOCKET, STM9
16	344-0012-00			1	CLIP, spring, tube, small
17	385-0074-00	10001	14329	1	ROD, nylon
	385-0135-00	14330		1	ROD, delrin, $\frac{5}{16}$ x $\frac{15}{16}$ inch
	- - - - - -			-	Mounting Hardware: (not included)
	211-0507-00	10001	14329	1	SCREW, 6-32 x $\frac{5}{16}$ inch PHS
	213-0041-00	14330		1	SCREW, thread cutting, 6-32 x $\frac{3}{8}$ inch THS
18	348-0002-00			13	GROMMET, rubber, $\frac{1}{4}$ inch
19	136-0015-00			9	SOCKET, STM9G
20	348-0004-00			2	GROMMET, rubber, $\frac{3}{8}$ inch
21	337-0271-00			1	SHIELD, aluminum $1\frac{7}{8} \times 1\frac{5}{8} \times 1$ inch
22	354-0067-00			1	RING, ornamental (feature strip)
23	426-0070-00			1	FRAME, aluminum $\frac{7}{8} \times \frac{7}{8}$ inch (stop)

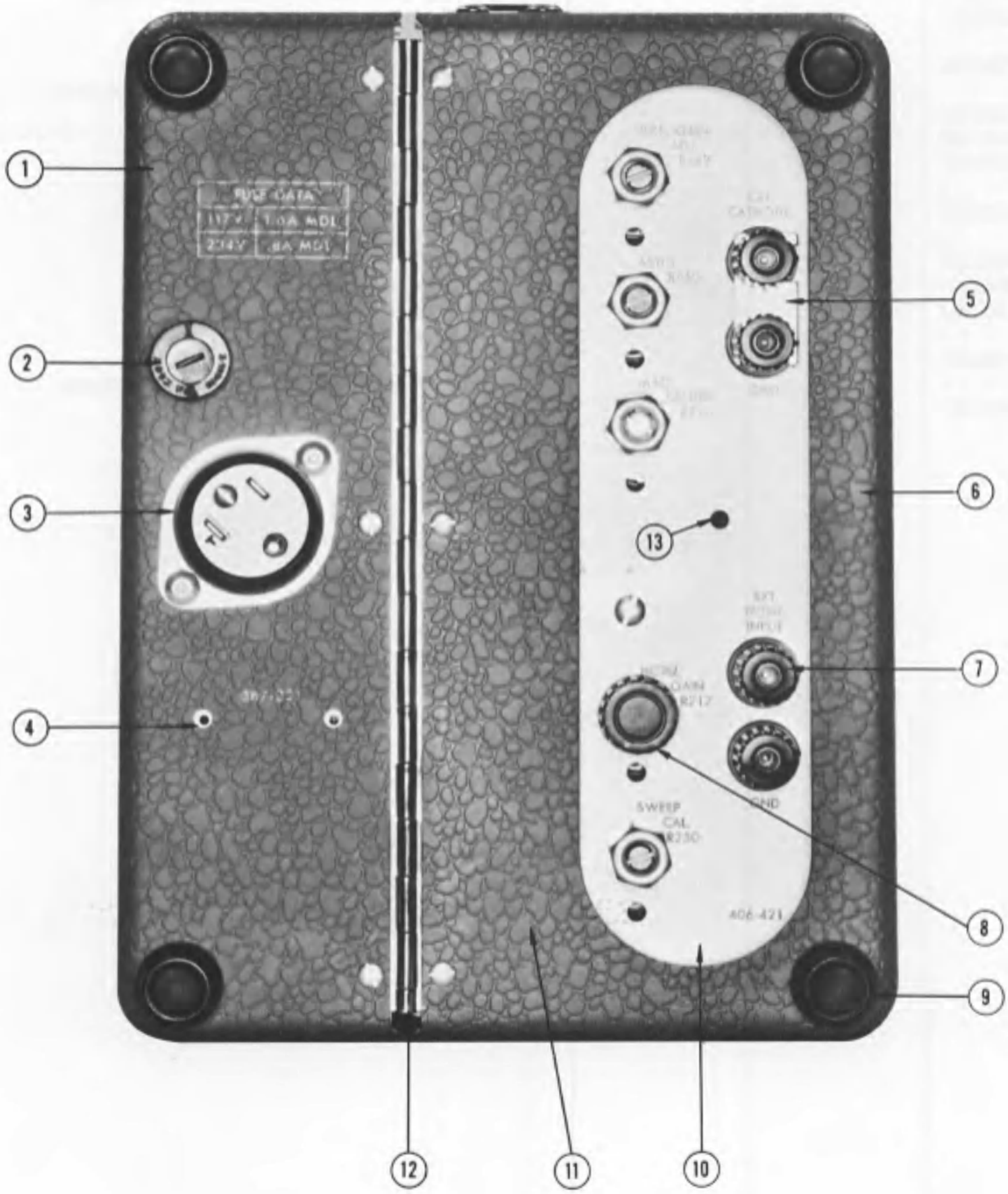
VERTICAL AMPLIFIER CHASSIS *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
24	124-0089-00			7	STRIP, ceramic, $^3/_4$ inch x 7 notches
	- - - - - -			-	Each Includes:
	355-0046-00			2	STUD, nylon
	- - - - - -			-	Mounting Hardware For Each: (not included)
	361-0007-00			2	SPACER, nylon .063 inch high
25	124-0087-00	10001	10533	2	STRIP, ceramic, $^3/_4$ inch x 3 notches
	124-0092-00	10534		2	STRIP, ceramic $^7/_{16}$ inch x 3 notches
	- - - - - -			-	Each Includes:
	355-0046-00			1	STUD, nylon
	- - - - - -			-	Mounting Hardware For Each: (not included)
	361-0008-00	10001	10533	1	SPACER, nylon, $^5/_{32}$ inch
	361-0007-00	10534		1	SPACER, nylon, $^1/_{16}$ inch
26	179-0292-00	10001	11039	1	CABLE HARNESS, preamp #2
	179-0402-00	11040		1	CABLE HARNESS, preamp #2
27	211-0011-00			4	SCREW, 4-40 x $^5/_{16}$ inch BHS
	210-0406-00			4	NUT, hex, brass, 4-40 x $^3/_{16}$ inch
	210-0004-00			4	LOCKWASHER, internal #4
28	124-0100-00			2	STRIP, ceramic, $^3/_4$ inch x 1 notch
	- - - - - -			-	Each Includes:
	355-0046-00			1	STUD, nylon
	- - - - - -			-	Mounting Hardware For Each: (not included)
	361-0008-00			1	SPACER, nylon, $^1/_4$ inch high
29	124-0091-00			8	STRIP, ceramic, $^3/_4$ inch x 11 notches
	- - - - - -			-	Each Includes
	355-0046-00			2	STUD, nylon
	- - - - - -			-	Mounting Hardware For Each: (not included)
	361-0007-00			2	SPACER, nylon, .063 inch high
30	179-0293-00			1	CABLE HARNESS, vertical amplifier #3
31	210-0202-00			1	LUG, solder, SE #6, with 2 wire holes
	- - - - - -			-	Mounting Hardware: (not included)
	211-0507-00			1	SCREW, 6-32 x $^5/_{16}$ inch BHS
	210-0407-00			1	NUT, hex, brass, 6-32 x $^1/_4$ inch
	210-0006-00			1	LOCKWASHER, steel, internal #6
32	179-0291-00	10001	21879	1	CABLE HARNESS, vertical amplifier #1
	179-0291-01	21880		1	CABLE HARNESS, vertical amplifier #1
33	124-0095-00			1	STRIP, ceramic, $^7/_{16}$ inch x 9 notches
	- - - - - -			-	Includes:
	355-0046-00			2	STUD, nylon
	- - - - - -			-	Mounting Hardware: (not included)
	361-0007-00			2	SPACER, nylon, .063 inch high
34	337-0267-00	10001	21879	1	SHIELD, 1$^7/_{16}$ x $^7/_8$ x $^7/_{16}$ inch
	337-0267-01	21880		1	SHIELD, 1$^7/_{16}$ x $^7/_8$ x $^7/_{16}$ inch
	- - - - - -			-	Mounting Hardware: (not included)
	211-0507-00			2	SCREW, 6-32 x $^5/_{16}$ inch BHS
	210-0006-00			2	LOCKWASHER, steel, internal #6
	210-0407-00			2	NUT, hex, brass, 6-32 x $^1/_4$ inch
35	124-0093-00			1	STRIP, ceramic, $^7/_{16}$ inch x 5 notches
	- - - - - -			-	Includes:
	355-0046-00			2	STUD, nylon
	- - - - - -			-	Mounting Hardware: (not included)
	361-0007-00			2	SPACER, nylon, .063 inch high

VERTICAL AMPLIFIER CHASSIS *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	QTY.	DESCRIPTION
36	210-0406-00			4	NUT, hex, brass, 4-40 x 3/16 inch
	210-0004-00			4	LOCKWASHER, steel, internal #4
	166-0025-00			4	SPACER, aluminum, 3/16 OD x 1/4 inch long
37	124-0088-00			2	STRIP, ceramic, 3/4 inch x 4 notches
	- - - - - -			-	Each Includes:
	355-0046-00			2	STUD, nylon
	- - - - - -			-	Mounting Hardware For Each: (not included)
	361-0007-00			2	SPACER, nylon, .063 inch high
38	441-0231-00			1	CHASSIS, vertical amplifier
39	124-0090-00			1	STRIP, ceramic, 3/4 inch x 9 notches
	- - - - - -			-	Includes:
	355-0046-00			2	STUD, nylon
	- - - - - -			-	Mounting Hardware: (not included)
	361-0008-00			2	SPACER, nylon, 1/4 inch high
40	124-0086-00	10001	17578	1	STRIP, ceramic, 3/4 inch x 2 notches
	124-0087-00	17579		1	STRIP, ceramic, 3/4 inch x 3 notches
	- - - - - -			-	Includes:
	355-0046-00			1	STUD, nylon
	- - - - - -			-	Mounting Hardware: (not included w/strip)
	361-0007-00			1	SPACER, nylon, 1/16 inch

REAR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FUSE DATA
117V 1.0A MDL
234V .8A MDL
SWEEP CAL R250
406-421
GND

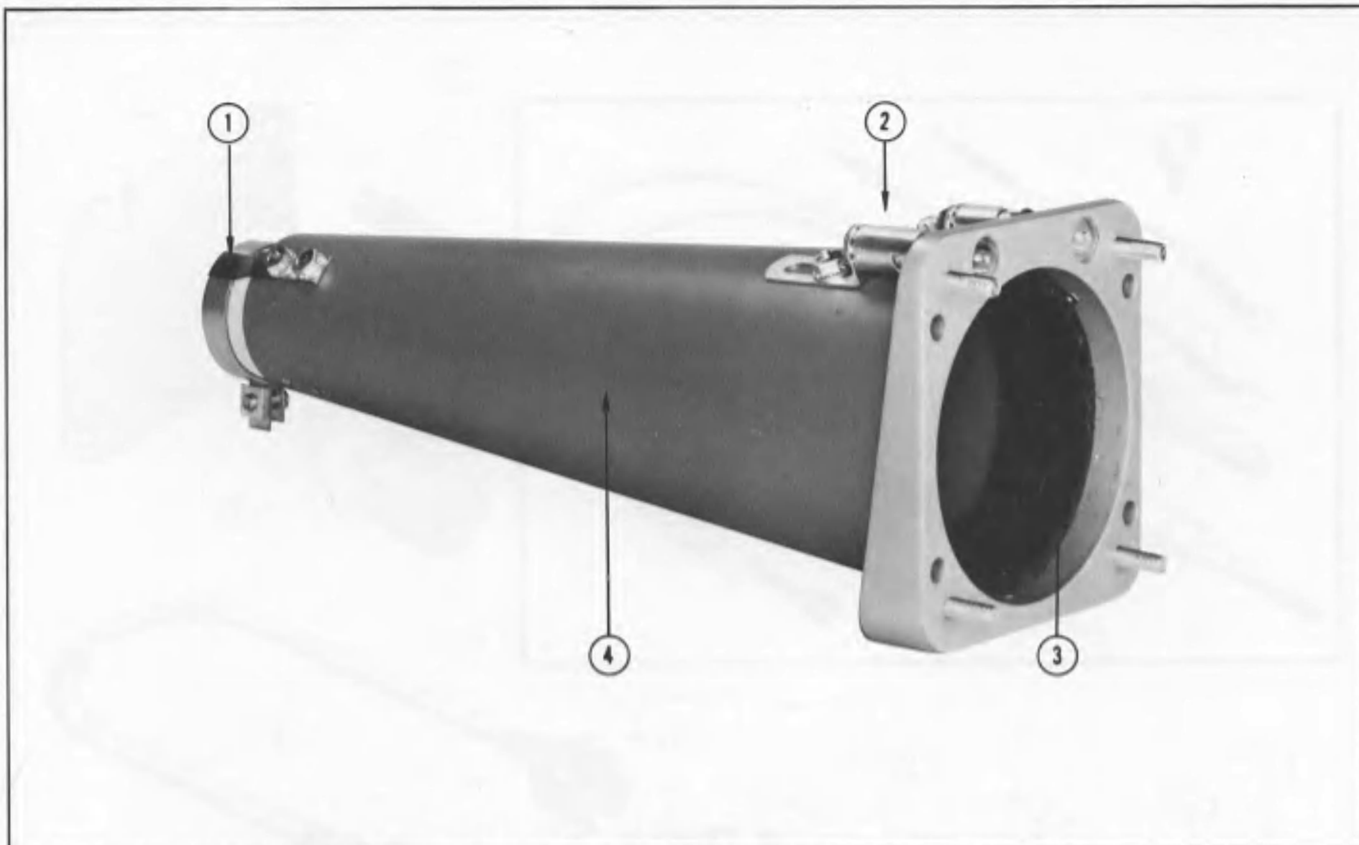
REAR *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
1	386-0879-00	10001	12578	1	PLATE, overlay, power half, blue wrinkle
	387-0049-00	12579	13416	1	PLATE, overlay, power half, blue vinyl
	387-0321-00	13417		1	PLATE, overlay, power half, blue vinyl
2	352-0007-00	10001	19559	1	HOLDER, fuse
	352-0014-00	19560		1	HOLDER, fuse
	210-0873-00			1	WASHER, rubber, $\frac{1}{2}$ ID x $\frac{11}{16}$ inch OD
3	131-0102-00	10001	13416	1	CONNECTOR, chassis mounted, 3 wire
	- - - - - -			-	Mounting Hardware: (not included)
	361-0012-00	10001	13416	1	SPACER, 1.130 ID x $\frac{13}{16}$ inch thick
	211-0529-00	10001	13416	2	SCREW, 6-32 x $1\frac{1}{4}$ inch BHS
	210-0457-00	10001	13416	2	NUT, keps, steel, 6-32 x $\frac{5}{16}$ inch
	131-0150-00	13417	22229	1	CONNECTOR, chassis mounted, 3 wire
	131-0150-01	22230	22319	1	CONNECTOR, chassis mounted, 3 wire
	131-0572-00	22320		1	CONNECTOR, chassis mounted, 3 wire
	- - - - - -			-	Mounting Hardware: (not included)
	213-0041-00	13417		2	SCREW, thread cutting, 6-32 x $\frac{3}{8}$ inch THS
4	334-0650-00			1	TAG, voltage rating, (not shown)
	- - - - - -			-	Mounting Hardware: (not included)
	213-0088-00			2	SCREW, thread forming, type B #4 x $\frac{1}{4}$ inch PHS
5	386-0427-00			1	PLATE, brass, $\frac{9}{16}$ x $1\frac{9}{32}$ inch, ground
6	386-0880-00	10001	12578	1	PLATE, overlay, VA half, blue wrinkle
	387-0050-00	12579		1	PLATE, overlay, VA half, blue vinyl
	386-0882-00			1	PLATE, sub-panel, rear, VA half (not shown)
7	129-0036-00	10001	20759	4	POST, binding, black
	129-0063-00	20760		4	POST, binding, charcoal
	- - - - - -			-	Mounting Hardware for each: (not included with post)
	358-0036-00	10001	20759	1	BUSHING, black
	358-0169-00	20760		1	BUSHING, charcoal
	210-0445-00	10001	19189	2	NUT, hex, 10-32 x $\frac{3}{8}$ inch
	220-0410-00	19190		1	NUT, keps, 10-32 x $\frac{3}{8}$ inch
	210-0010-00	10001	19189X	1	LOCKWASHER, internal, #10
	210-0206-00	10001	19189X	1	LUG, solder, SE 10, long
8	366-0033-00	10001	20759	1	KNOB, small black—HORIZ. GAIN
	366-0148-00	20760		1	KNOB, small charcoal—HORIZ GAIN
	- - - - - -			-	Includes:
	213-0004-00			1	SCREW, set, 6-32 x $\frac{3}{16}$ inch HSS
9	348-0015-00			4	CUSHION, rubber ball, $\frac{7}{16}$ inch, blue
	348-0014-00			4	FOOT, molded, black
	- - - - - -			-	*Mounting Hardware: (not included)*
	210-0010-00			4	SCREW, 8-32 x $\frac{5}{8}$ inch BHS
	210-0008-00			4	LOCKWASHER, steel, internal #8
	210-0458-00			4	NUT, keps, 8-32 x $\frac{11}{32}$ inch

REAR *(Cont'd)*

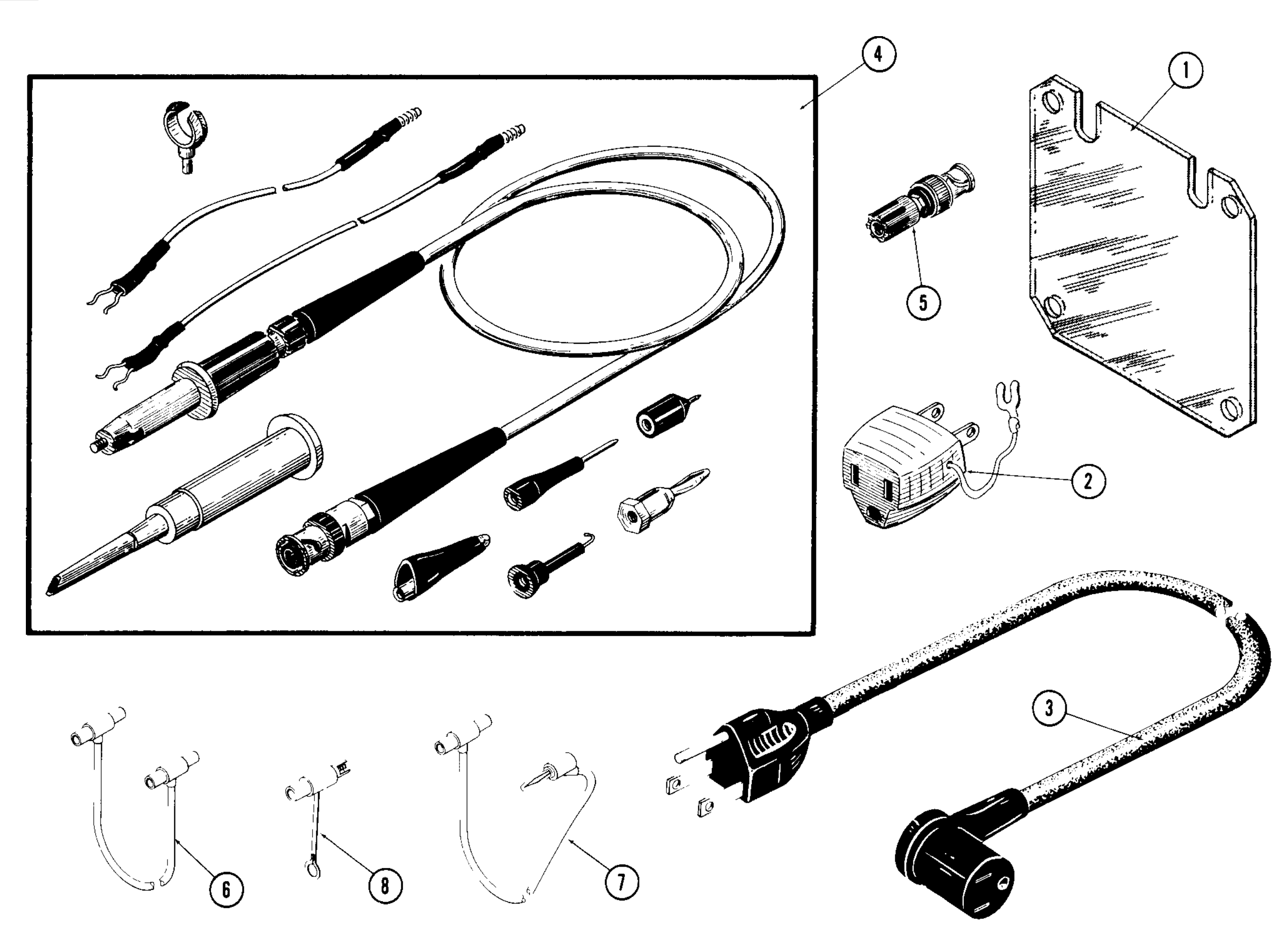
REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
10	406-0421-00			1	BRACKET, aluminum, $1\frac{7}{16} \times 3\frac{1}{8} \times 7\frac{7}{16}$ inches (rear pot)
	- - - - - -			-	Mounting Hardware: (not included)
	210-0407-00			3	NUT, hex, brass, 6-32 x $\frac{1}{4}$ inch
	210-0006-00			3	LOCKWASHER, steel, internal #6
	211-0538-00			3	SCREW, 6-32 x $\frac{5}{16}$ inch FHS
11	343-0002-00			1	CLAMP, cable, $\frac{3}{16}$ inch plastic (not shown)
	- - - - - -			-	Mounting Hardware: (not included)
	211-0510-00			1	SCREW, 6-32 x $\frac{3}{8}$ inch BHS
	210-0803-00			1	WASHER, steel, 6L x $\frac{3}{8}$ inch
	210-0006-00			1	LOCKWASHER, steel internal #6
	210-0407-00			1	NUT, hex, brass, 6-32 x $\frac{1}{4}$ inch
12	214-0003-00			1	HINGE, brass, with brass pin, $1\frac{1}{16} \times 8\frac{11}{16}$ inches
	- - - - - -			-	Mounting Hardware: (not included)
	211-0038-00			2	SCREW, 4-40 x $\frac{5}{16}$ inch FHS
	211-0012-00			3	SCREW, 4-40 x $\frac{3}{8}$ inch BHS
	210-0004-00			4	LOCKWASHER, steel, internal #4
	210-0406-00			5	NUT, hex, brass, 4-40 x $\frac{3}{16}$ inch
13	214-0210-00	X14449		1	ASSEMBLY, solder spool (not shown)
	- - - - - -			-	assembly includes:
	214-0209-00			1	SPOOL, solder
	- - - - - -			-	mounting hardware: (not included w/assembly)
	361-0007-00			1	SPACER, plastic

CRT SHIELD



REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	QTY.	DESCRIPTION
1	343-0029-00			1	CLAMP, CRT, $1\frac{7}{16}$ inches diameter
	- - - - - - -			-	Mounting Hardware: (not included)
	210-0457-00			4	NUT, keps, 6-32 x $\frac{5}{16}$ inch
	210-0803-00			4	WASHER, steel, 6L x $\frac{3}{8}$ inch
	211-0538-00			4	SCREW, 6-32 x $\frac{5}{16}$ inch FHS
	210-0501-00			1	NUT, square, steel, 10-32 x $\frac{3}{8}$ inch
	212-0557-00			1	SCREW, 10-32 x $\frac{1}{2}$ inch RHS
2	136-0001-00			2	SOCKET, graticule lamp
	- - - - - - -			-	Mounting Hardware For Each: (not included)
	211-0534-00			1	SCREW, 6-32 x $\frac{5}{16}$ inch PHS, with lockwasher
	210-0457-00			1	NUT, keps, 6-32 x $\frac{5}{16}$ inch
3	124-0050-00			1	STRIP, felt
4	337-0121-00			1	SHIELD, CRT, 3 inches
	- - - - - - -			-	Mounting Hardware: (not included w/shield)
	212-0509-00			4	SCREW, 10-32 x $\frac{5}{8}$ inch HHS

STANDARD ACCESSORIES



REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	QTY.	DESCRIPTION
1	378-0509-00	1001	21119	1	FILTER, light, plexi., green
	378-0550-00	21120	24179	1	FILTER, light, smoke gray
	378-0552-00	24180		1	FILTER, light, blue
2	103-0013-00	10001	24179X	1	ADAPTER, 3 to 2 wire
3	161-0013-00	10001	20219	1	CORD, power
	161-0022-00	20220	20939	1	CORD, power
	161-0024-00	20940	22079	1	CORD, power
	161-0024-01	22080	22969	1	CORD, power
	161-0024-03	22970		1	CORD, power
4	010-0038-00	10001	19119	1	PROBE, package, P6017
	010-0127-00	19120	21739	1	PROBE, package, P6006
	010-0203-00	21740	24179	1	PROBE, package, P6012
	010-0127-00	24180		1	PROBE, package, P6006
5	013-0004-00	10001	19119	1	ADAPTER, binding post
	103-0033-00	19120	20474X	1	ADAPTER, BNC to binding post
	012-0031-00	X19120	20474	1	CORD, patch (not shown)
6	012-0087-00	20475		1	CORD, patch
7	012-0091-00	X20475		1	CORD, patch
8	012-0092-00	X20475		1	JACK, BNC—post
--	070-0893-00			2	MANUAL, instruction (not shown)

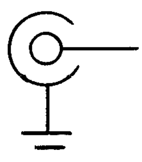
Ⓑ

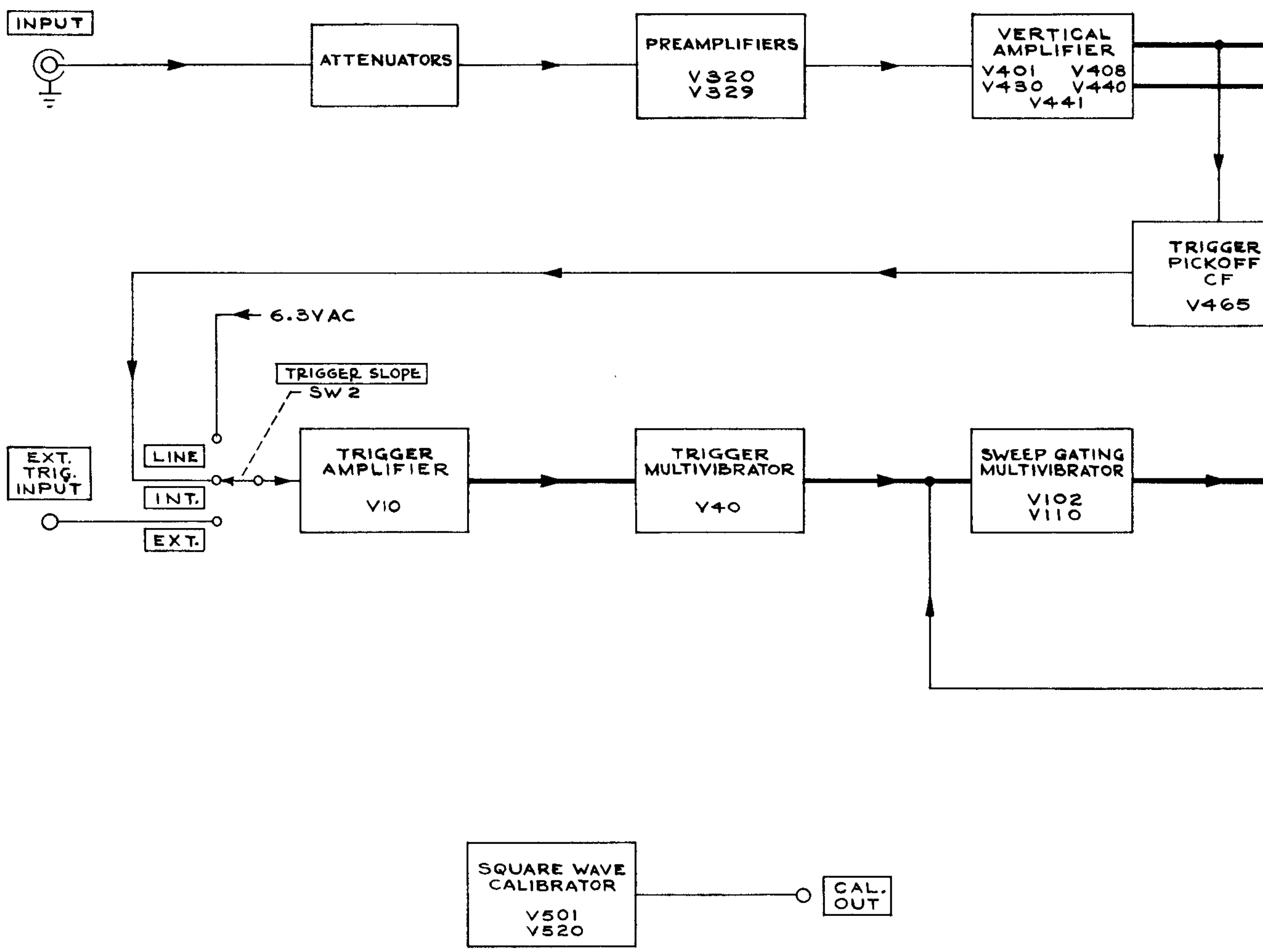
SECTION 8
DIAGRAMS

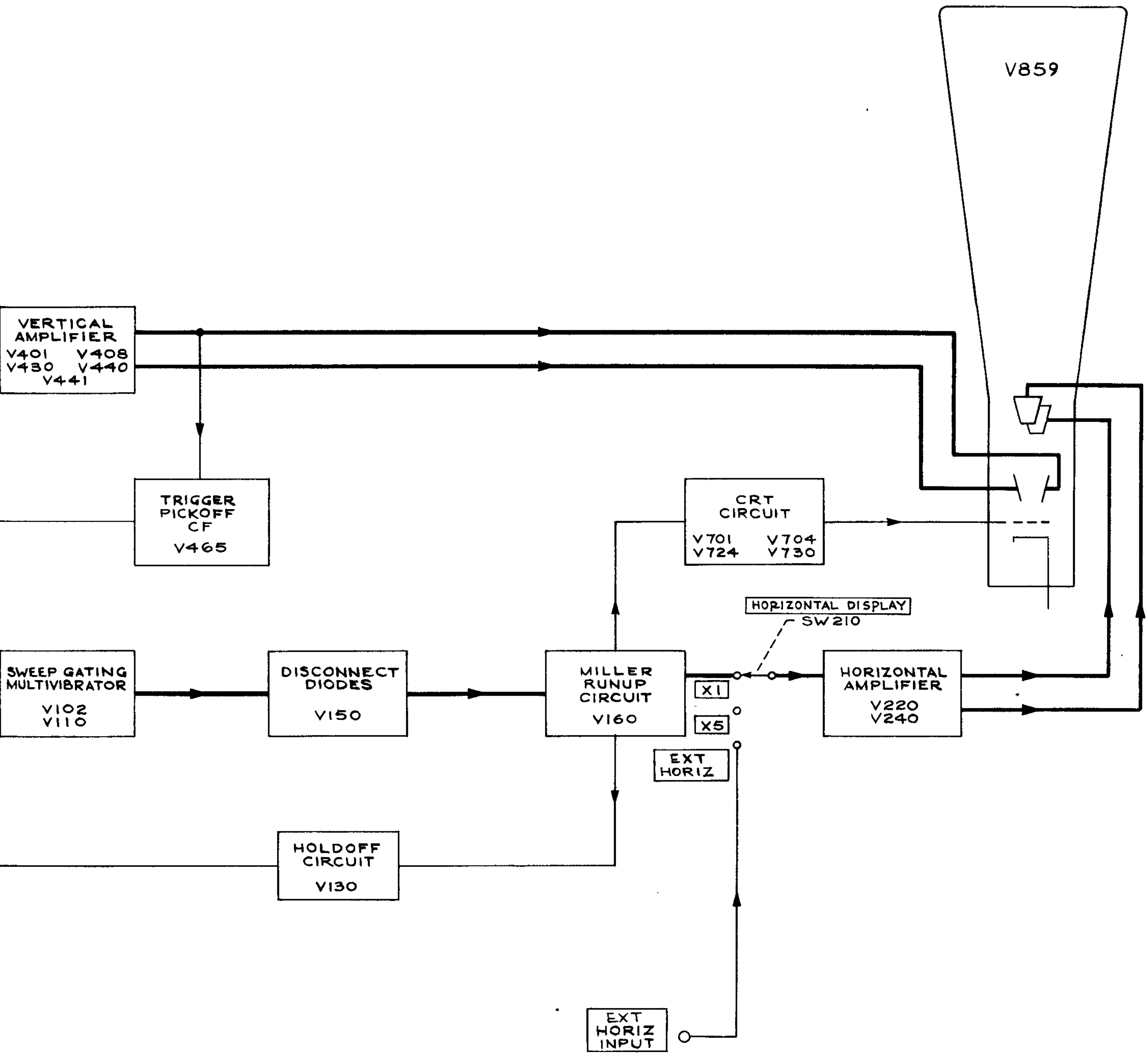
The following special symbols are used on the diagrams:


Screwdriver adjustment


Front- or rear-panel control or connector.


Indicates coaxial connector


INPUT
ATTENUATORS
PREAMPLIFIERS
V320
V329
VERTICAL AMPLIFIER
V401 V408
V430 V440
V441
TRIGGER PICKOFF CF
V465
6.3VAC
TRIGGER SLOPE
SW 2
LINE
INT.
EXT.
EXT. TRIG. INPUT
TRIGGER AMPLIFIER
V10
TRIGGER MULTIVIBRATOR
V40
SWEEP GATING MULTIVIBRATOR
V102
V110
SQUARE WAVE CALIBRATOR
V501
V520
CAL. OUT



669

BLOCK DIAGRAM

Ⓐ

CONDITIONS OF SCOPE UNDER TEST

VOLTAGE READINGS

UPPER READINGS - TRIG. LEVEL CONTROL CCW
LOWER READINGS - TRIG. LEVEL CONTROL CW

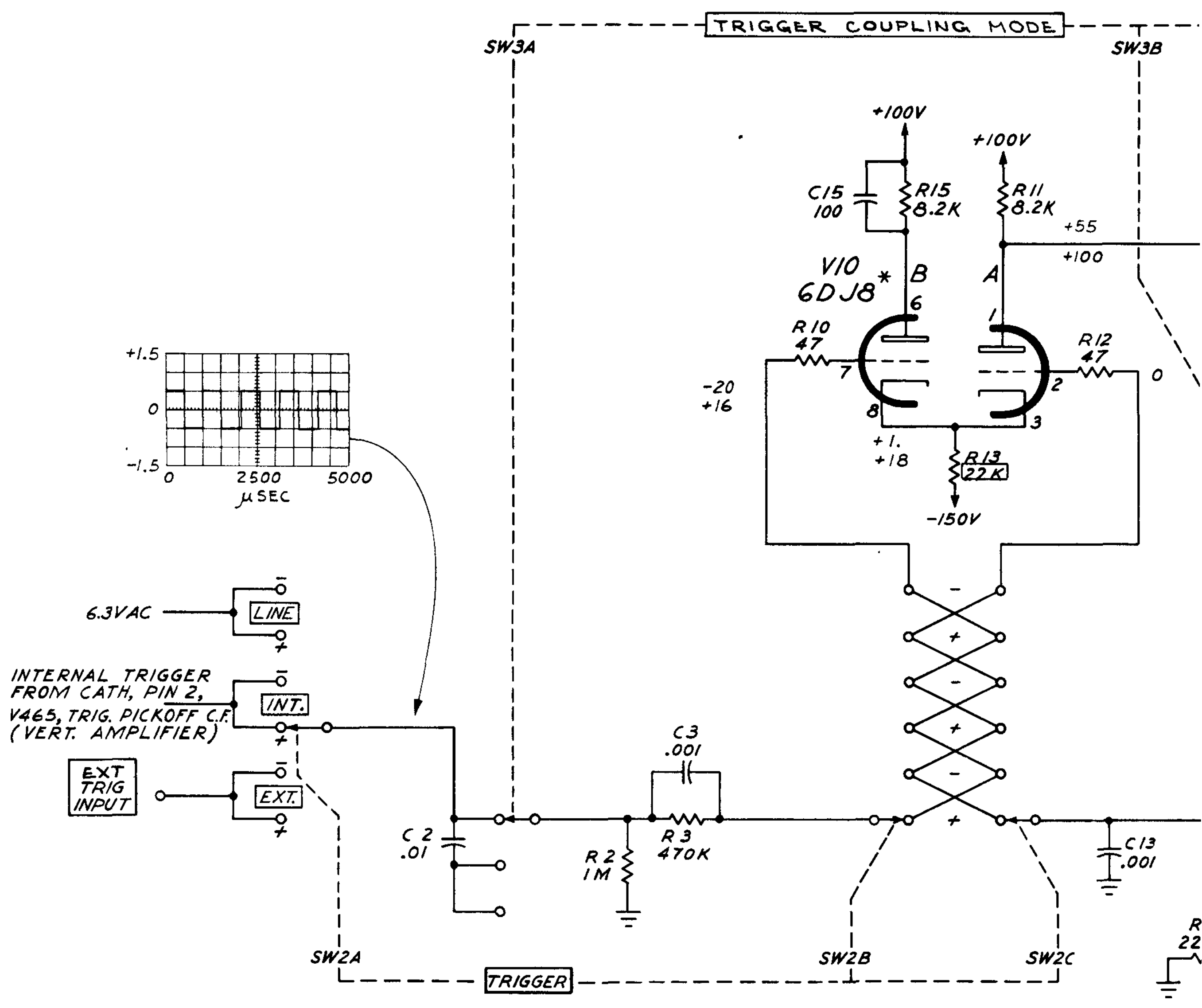
WAVEFORMS

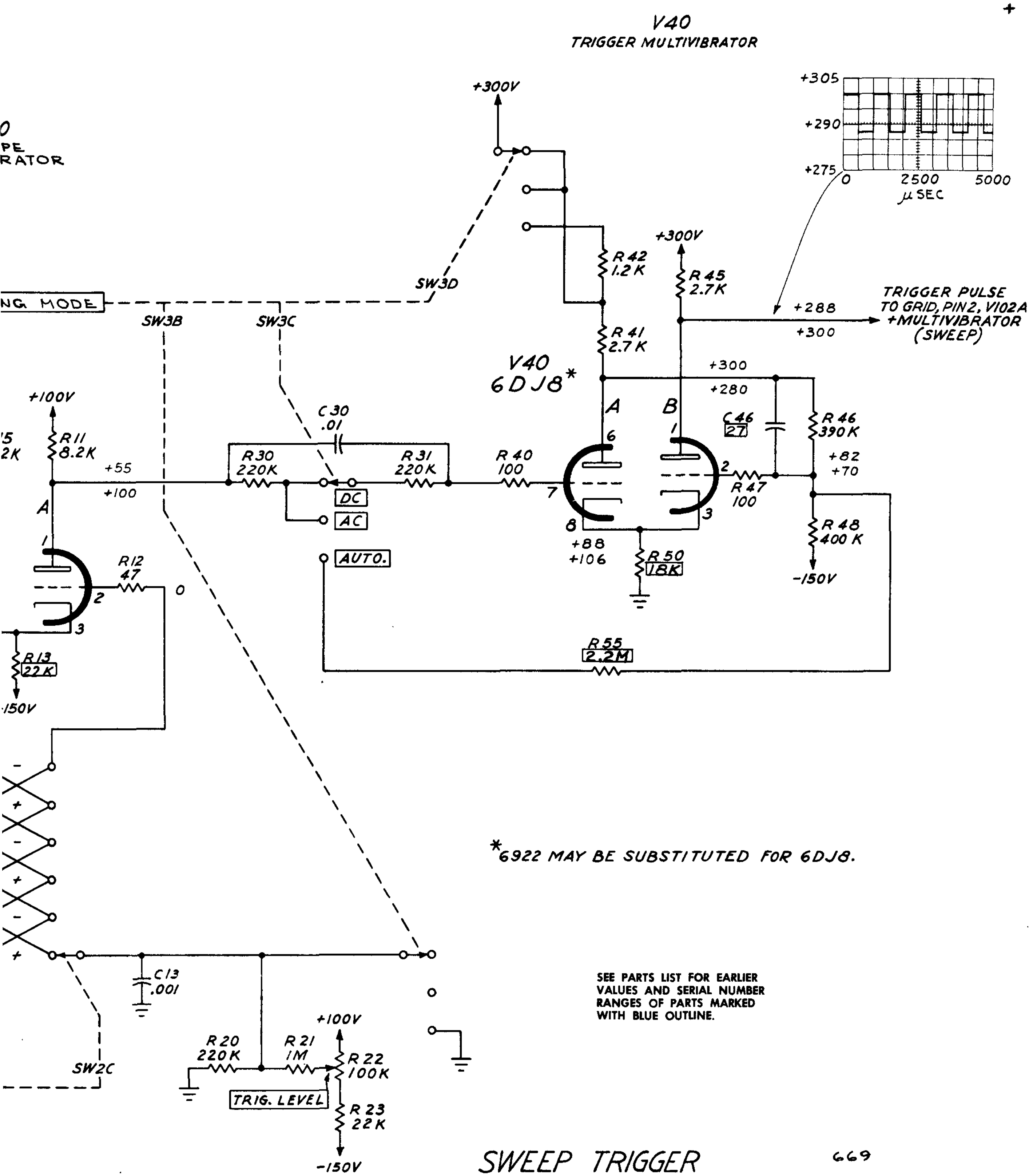
SWITCHES AS SHOWN
CALIBRATOR WAVEFORM BEING DISPLAYED

310A SWP. TRIG.

A

V10
SLOPE
COMPARATOR





*6922 MAY BE SUBSTITUTED FOR 6DJ8.

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

SWEEP TRIGGER

669

CIRCUIT NUMBERS
1 THRU 49

Ⓐ

CONDITIONS OF SCOPE UNDER TEST

VOLTAGE READINGS

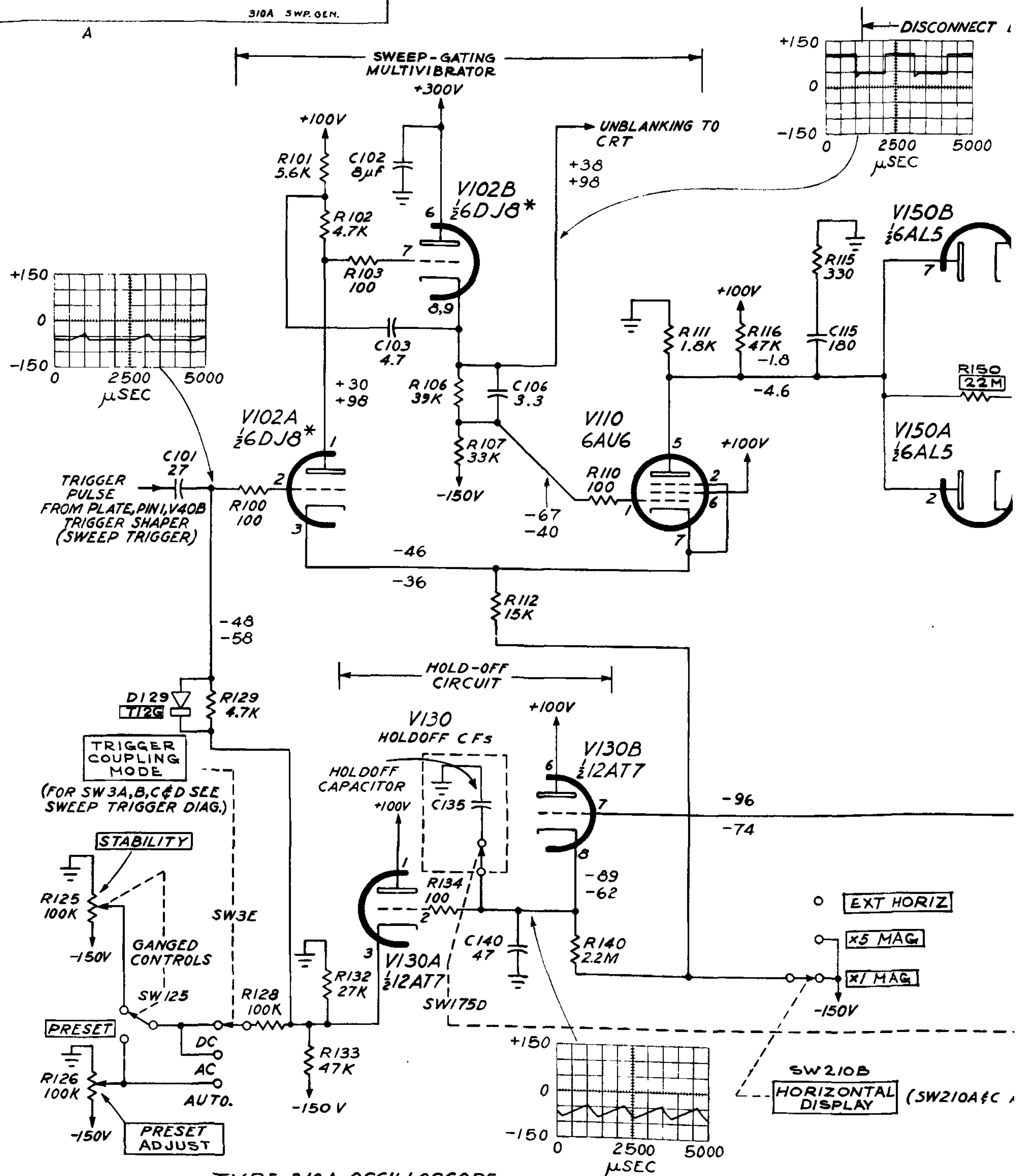
UPPER READINGS – STABILITY CONTROL CCW
LOWER READINGS – STABILITY CONTROL CW

WAVEFORMS

SWEEPTIME – 100 µSEC / CM
CALIBRATOR WAVEFORM BEING DISPLAYED

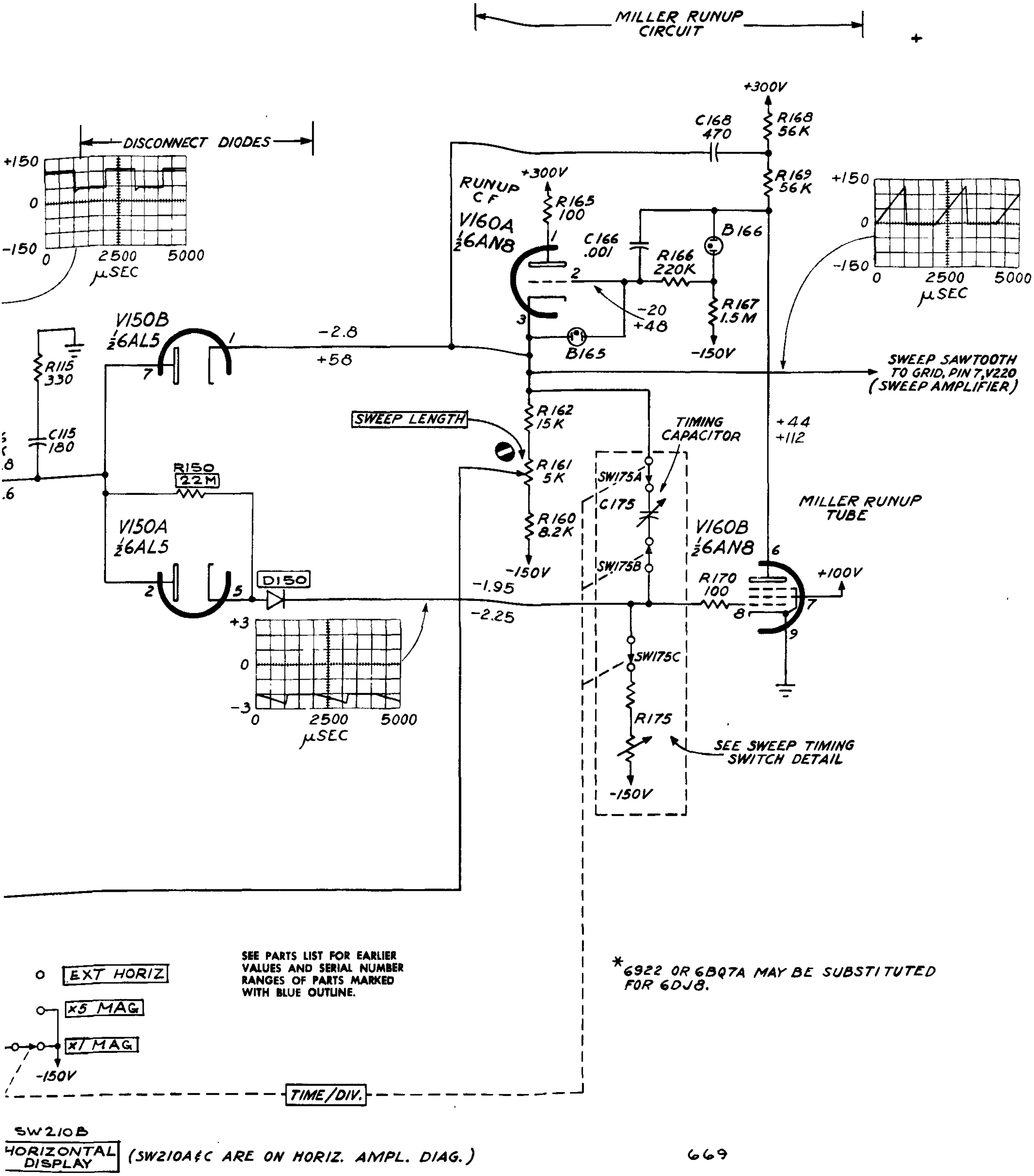
310A SWP. GEN.

A



TYPE 310A OSCILLOSCOPE

Ⓐ



(SW210A&C ARE ON HORIZ. AMPL. DIAG.)

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

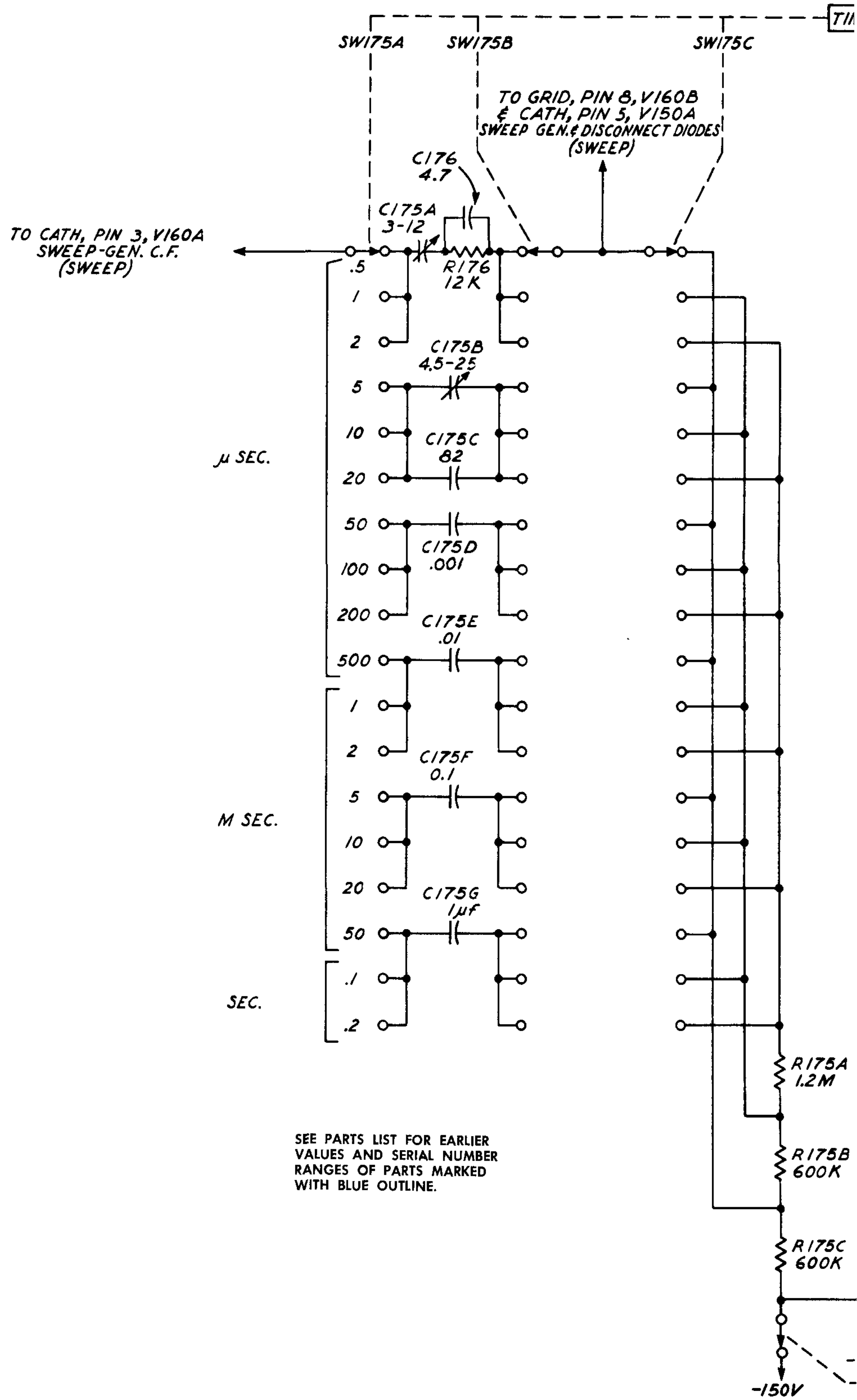
*6922 OR 6BQ7A MAY BE SUBSTITUTED FOR 6DJ8.

669

CIRCUIT NUMBERS 101 THRU 179

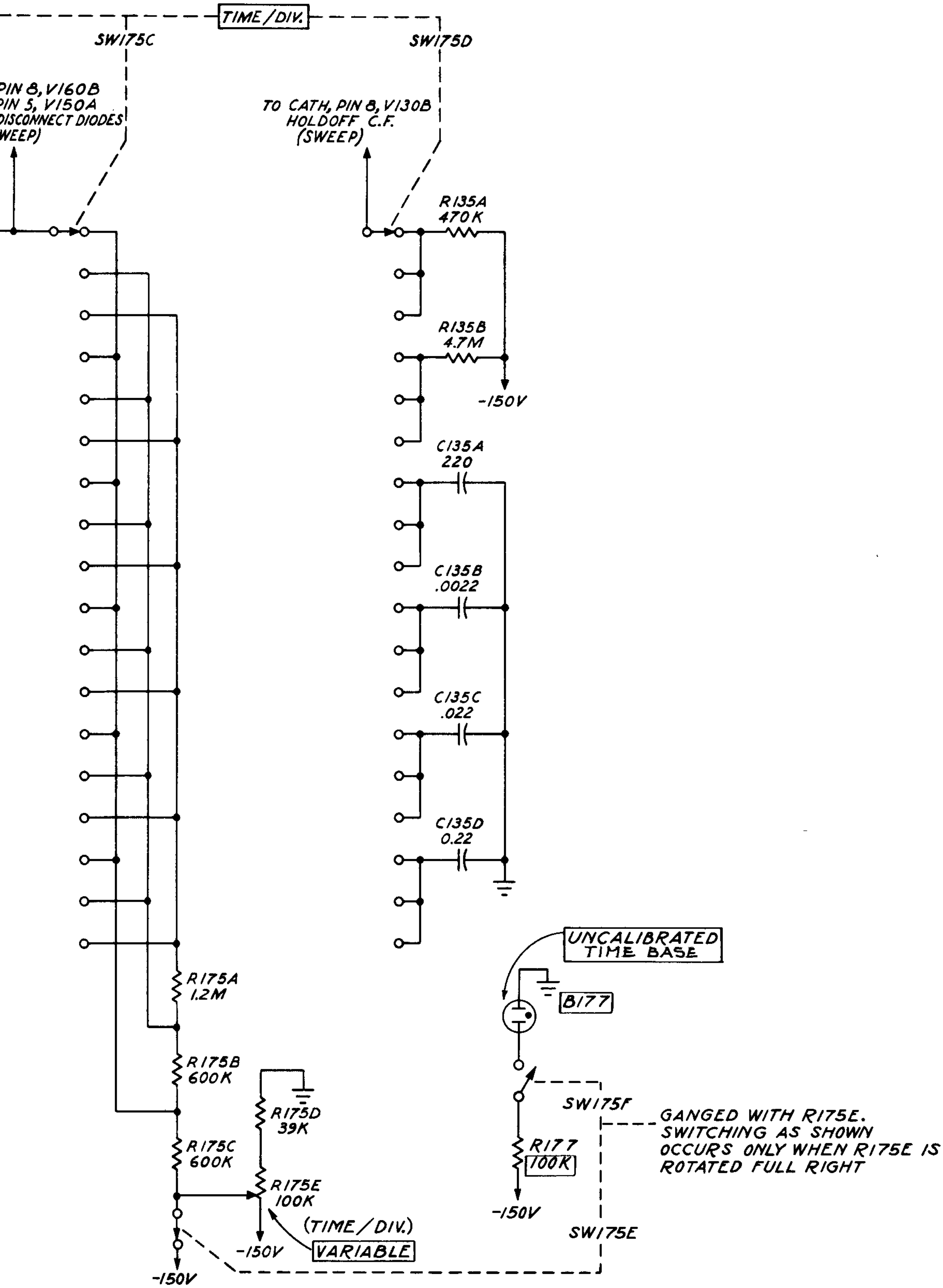
SWEEP GENERATOR

Ⓐ



SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

SW



SWEEP-TIMING SWITCH 669

CONDITIONS OF SCOPE UNDER TEST

VOLTAGE READINGS

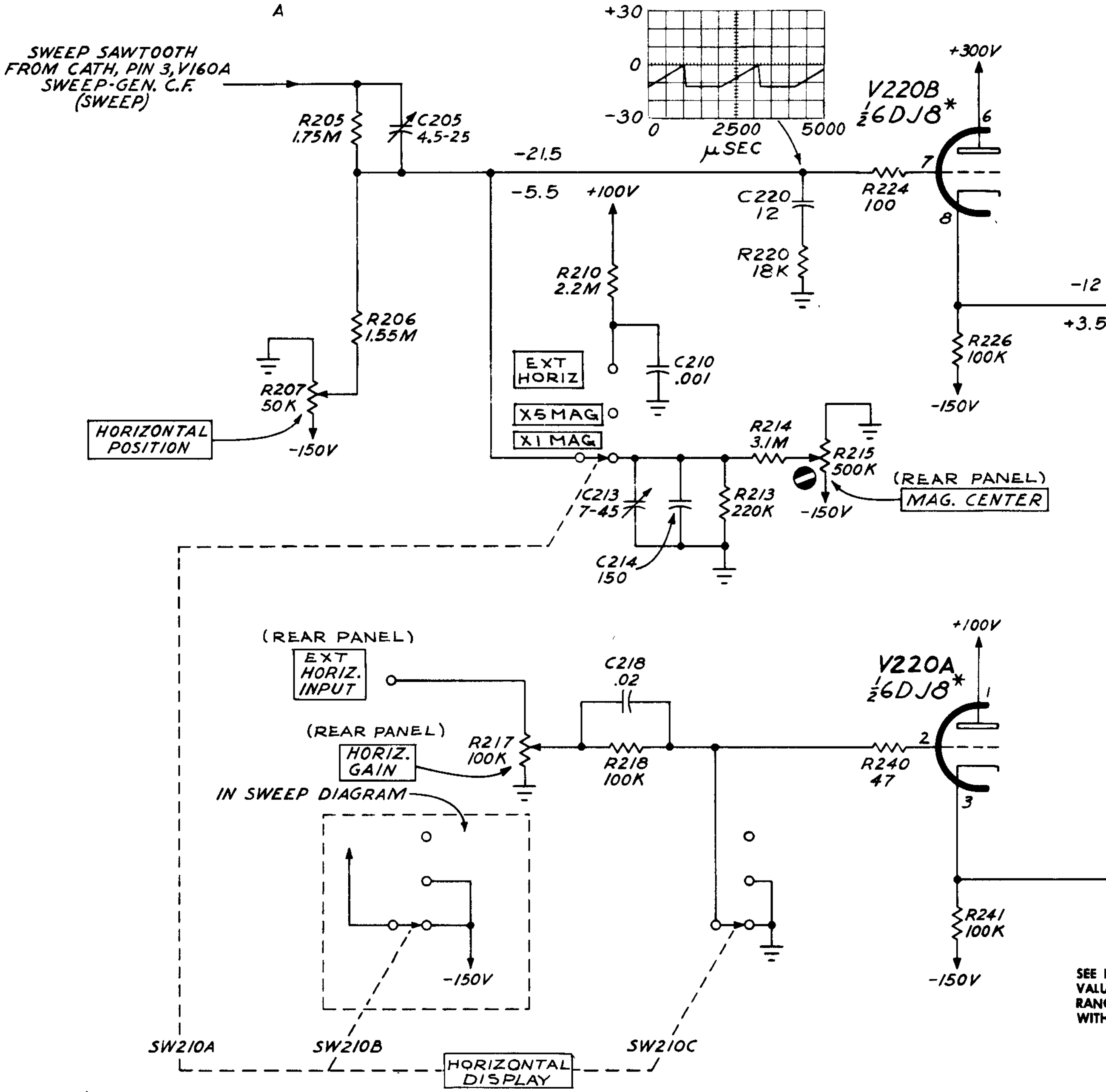
UPPER READINGS – HORIZONTAL POSITION CONTROL CCW
LOWER READINGS – HORIZONTAL POSITION CONTROL CW
SWEEP STABILITY CONTROL CCW

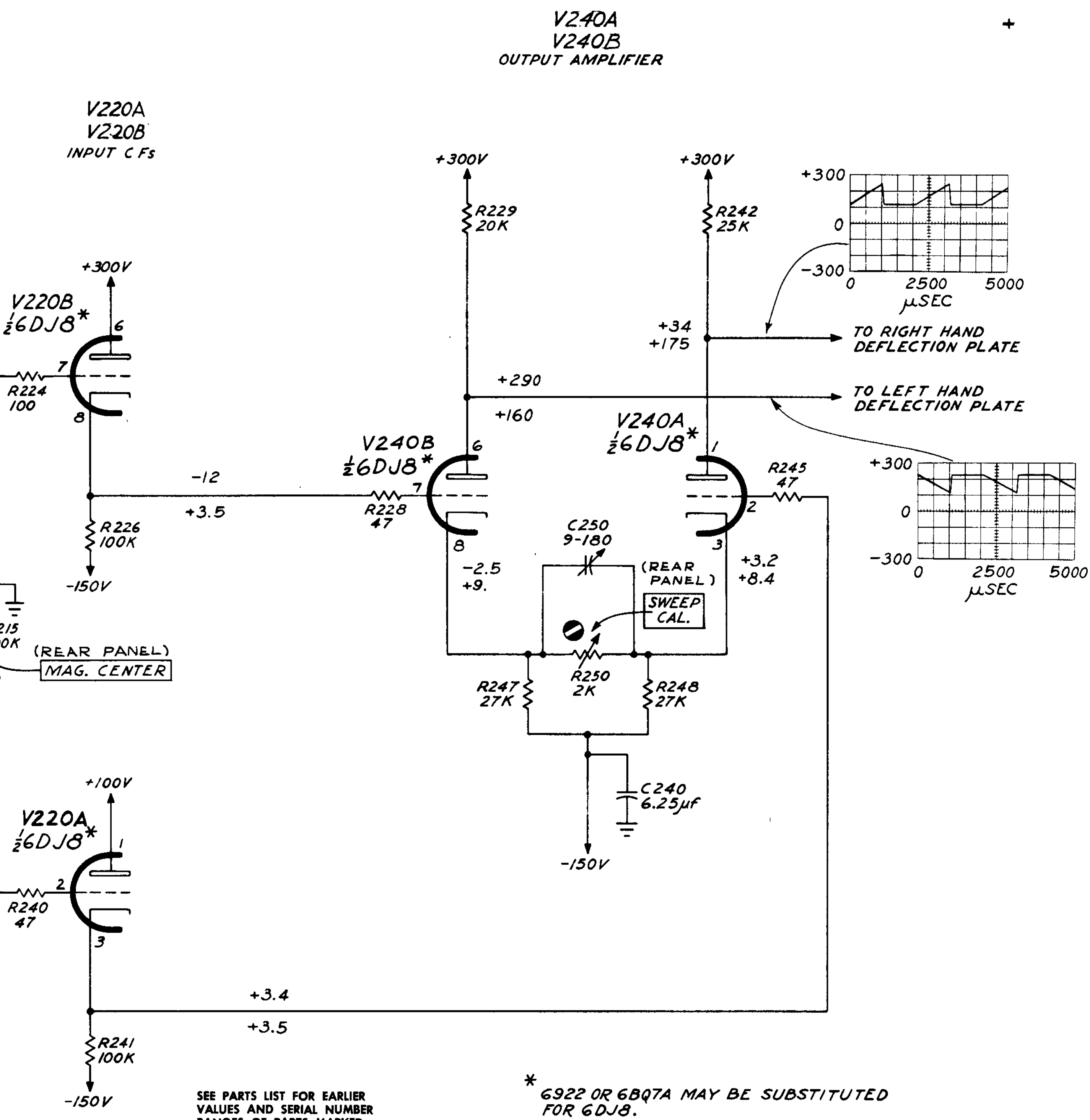
WAVEFORMS

SWEEPTIME – 100 μSEC / CM
SWITCHES AS SHOWN
CALIBRATOR WAVEFORM BEING DISPLAYED

310A HOR. AMP.

V220A
V220B
INPUT C Fs



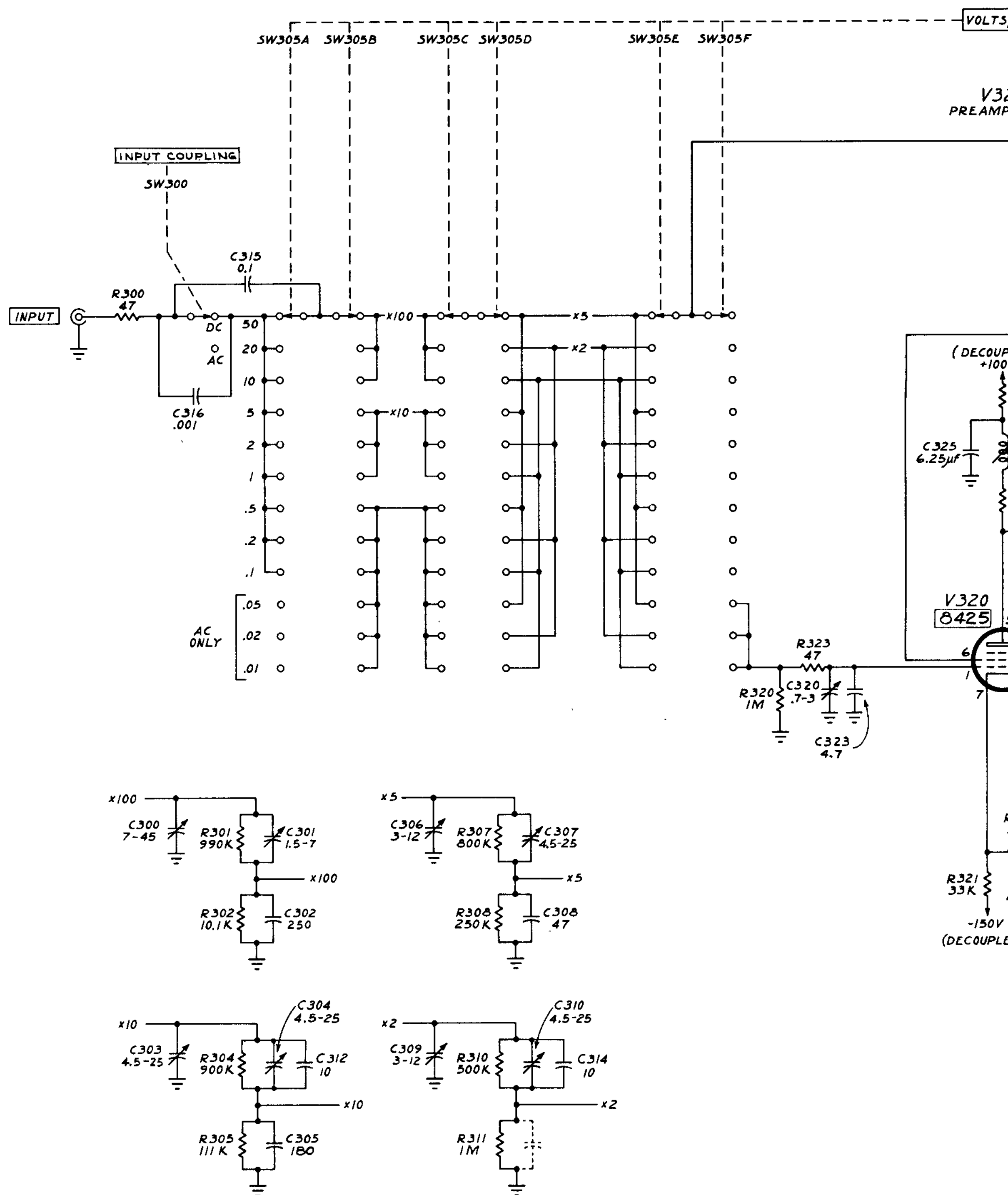


SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

* 6922 OR 6BQ7A MAY BE SUBSTITUTED FOR 6DJ8.

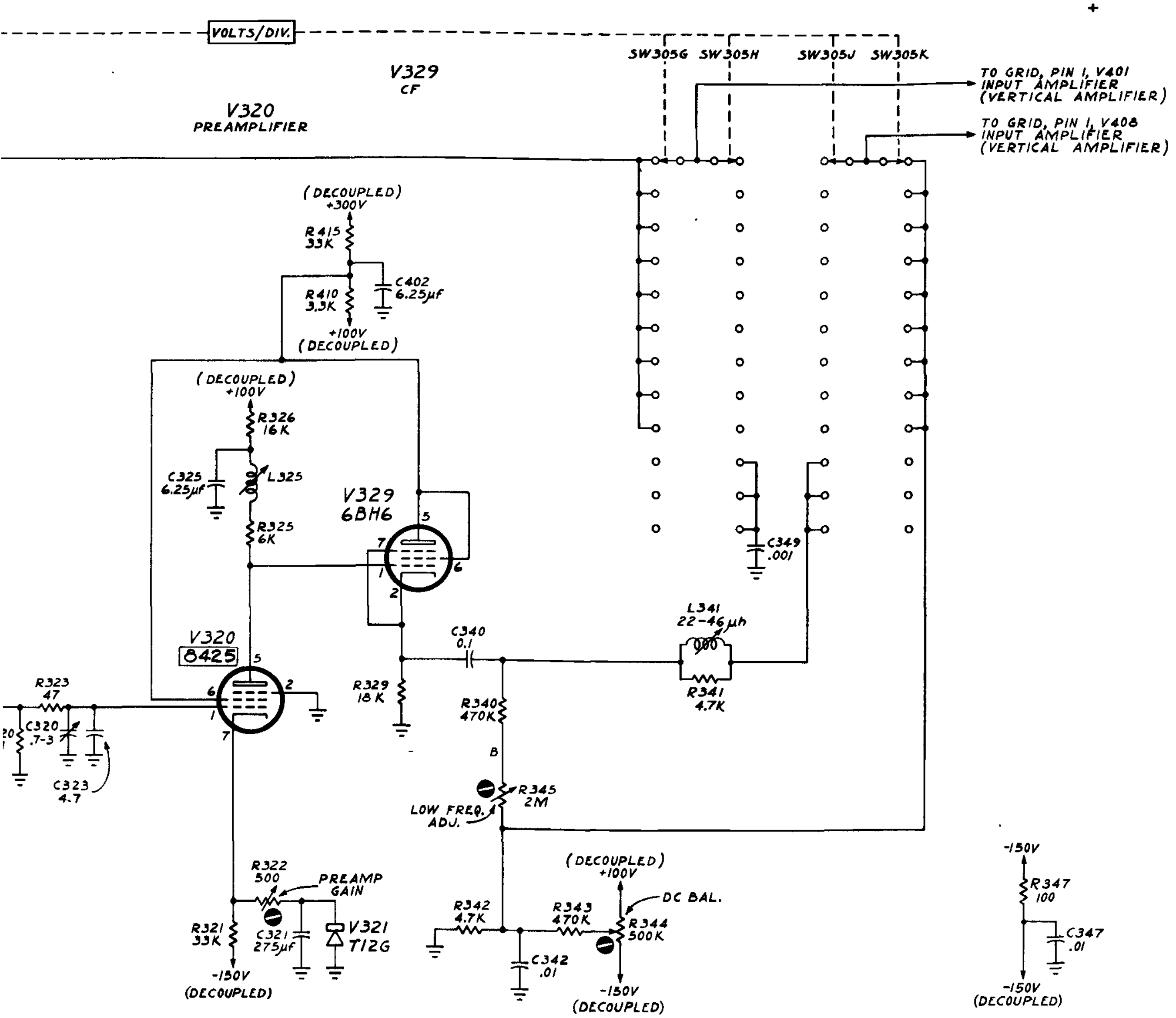
HORIZONTAL AMPLIFIER

CIRCUIT NUMBERS 250-UP



TYPE 310A OSCILLOSCOPE

Ⓐ



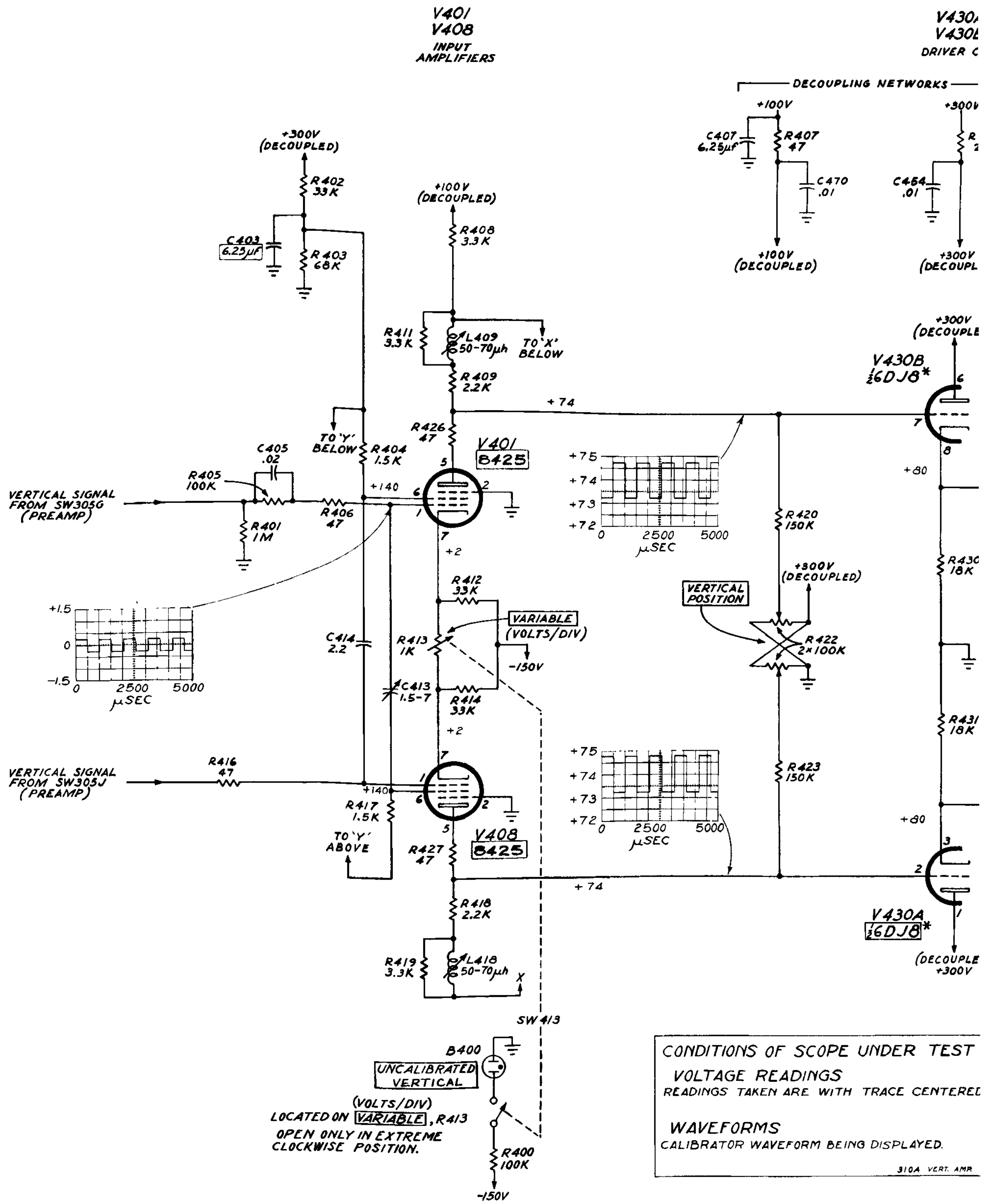
NOTE.-
FOR ADDITIONAL DECOUPLING NETWORKS SEE VERTICAL AMPLIFIER DIAG.

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

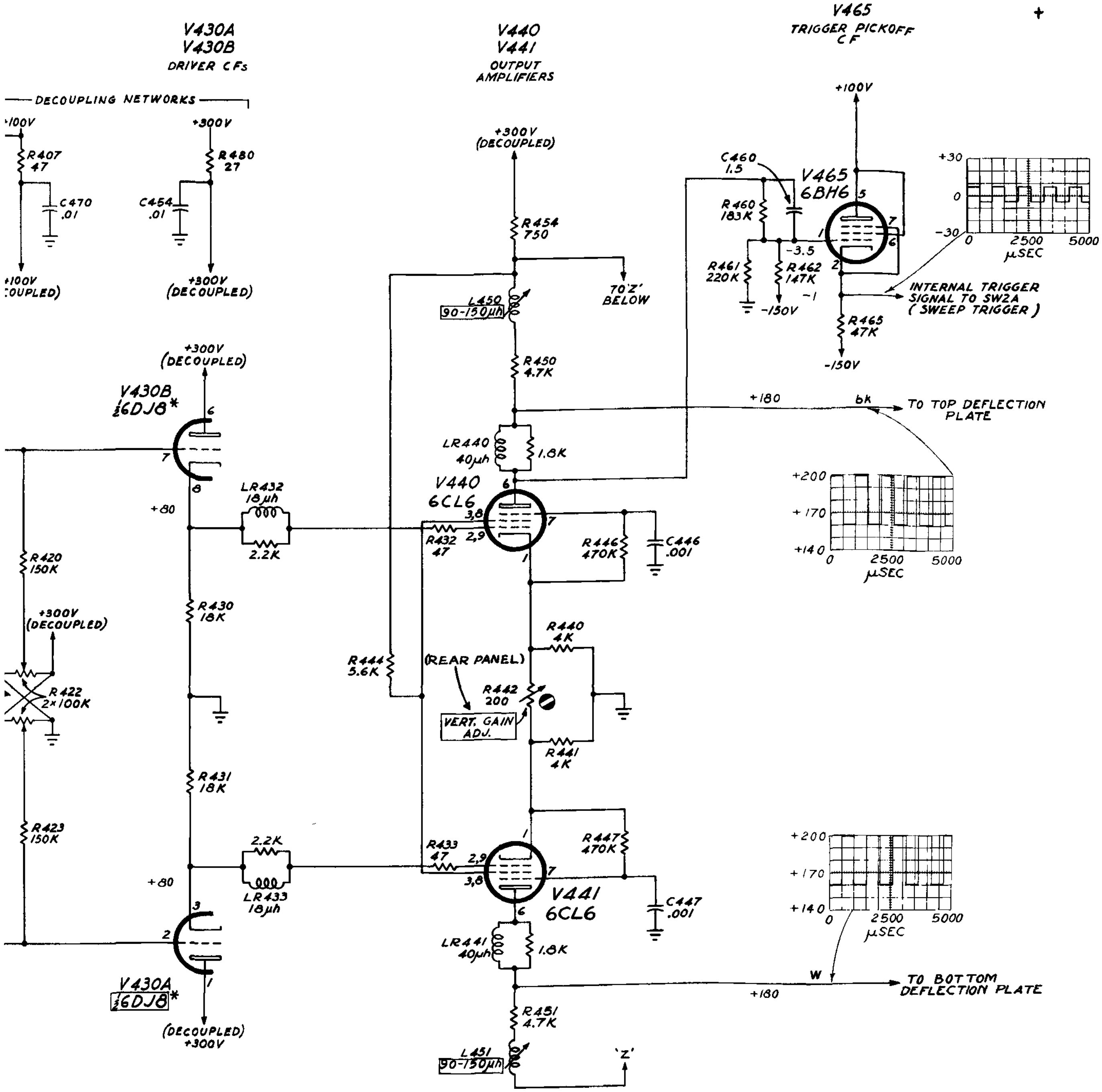
VERTICAL PREAMPLIFIER

669

CIRCUIT NUMBERS 300 THRU 399



TYPE 310A OSCILLOSCOPE



OF SCOPE UNDER TEST

READINGS

EN ARE WITH TRACE CENTERED.

MS

/AVEFORM BEING DISPLAYED.

310A VERT. AMP

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

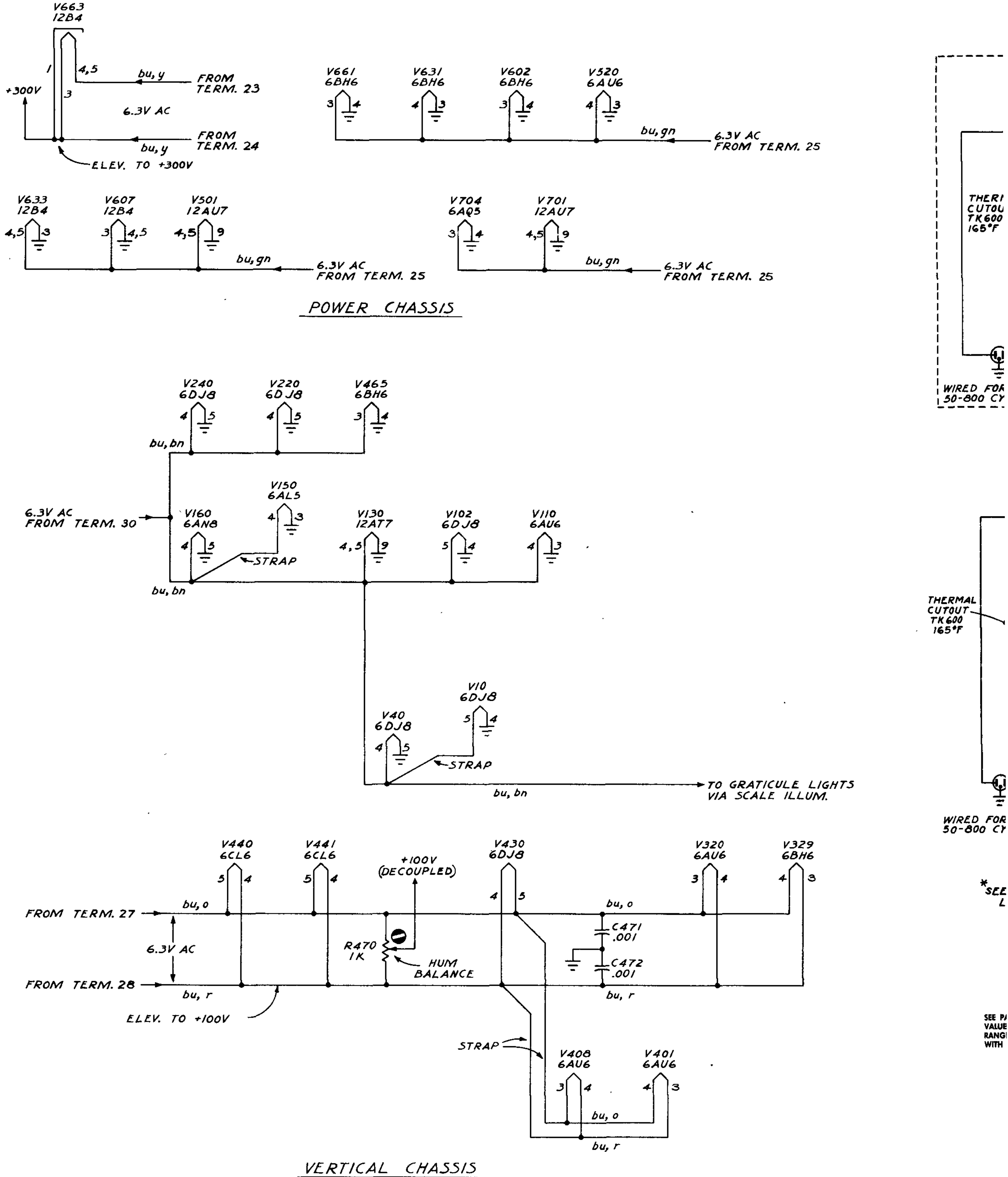
NOTE:
FOR HUM BALANCE CONTROL SEE HEATER WIRING DIAGRAM.

*6922 OR 6BQ7A MAY BE SUBSTITUTED FOR 6DJ8.

669

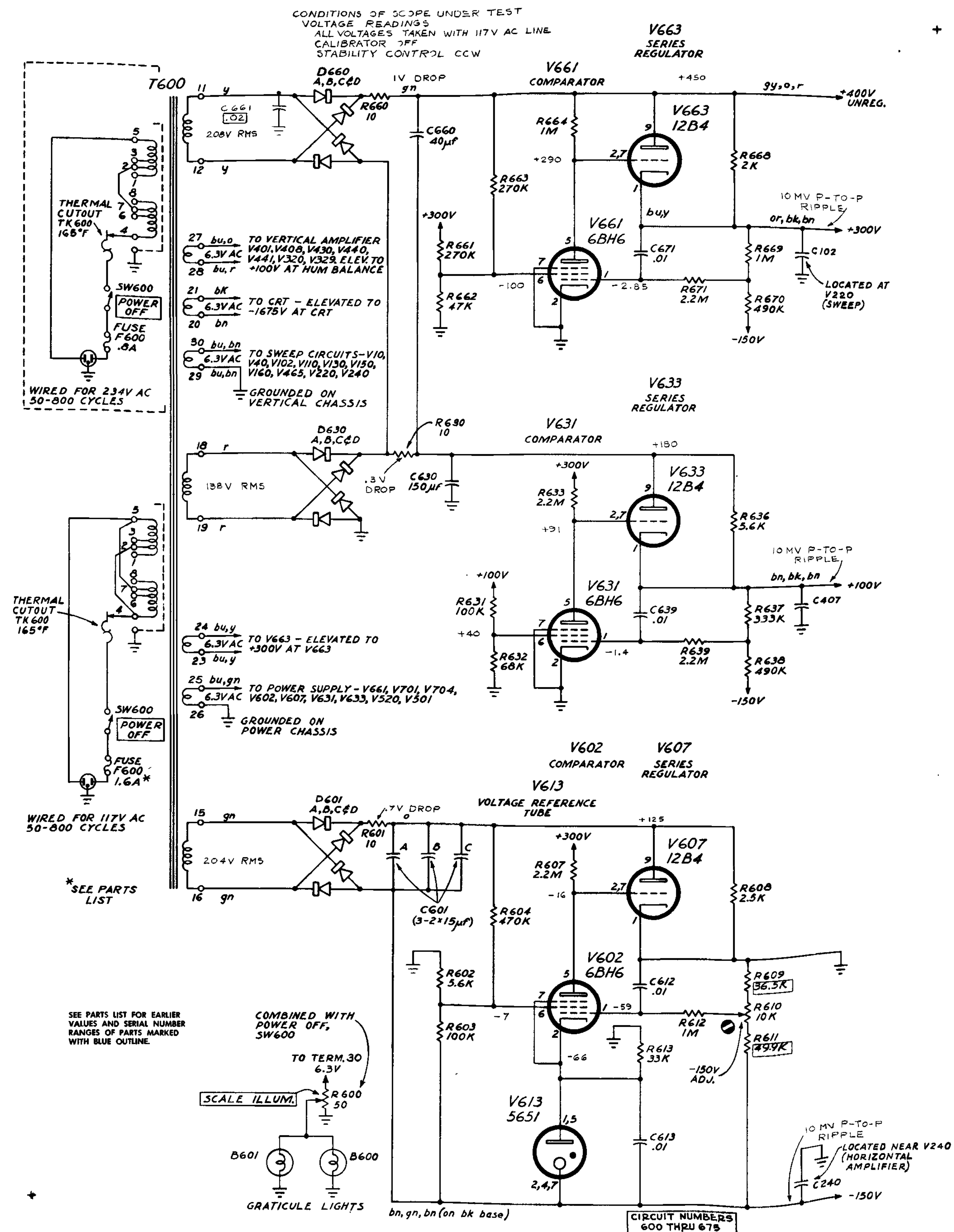
VERTICAL AMPLIFIER

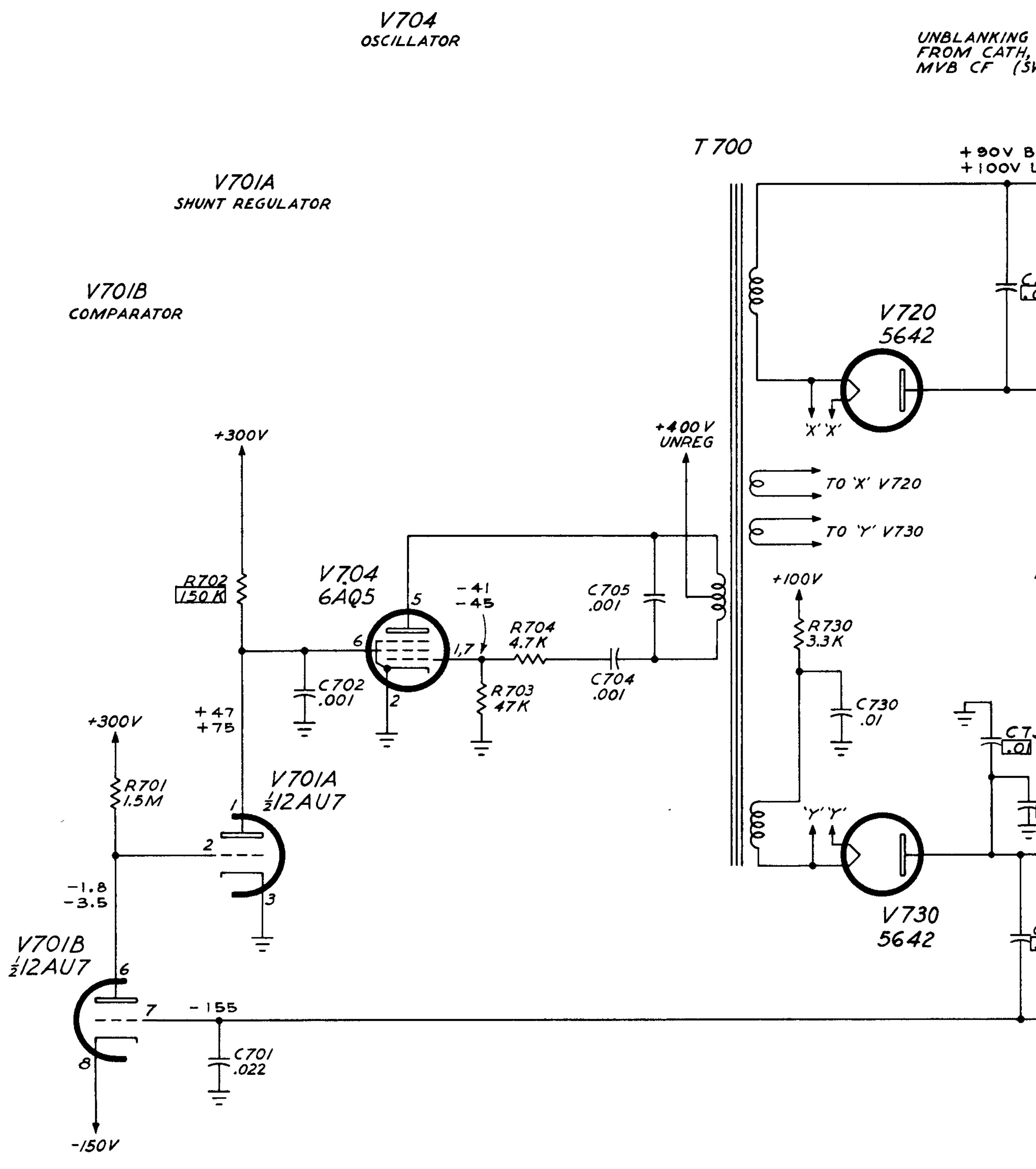
CIRCUIT NUMBERS 400 THRU 480



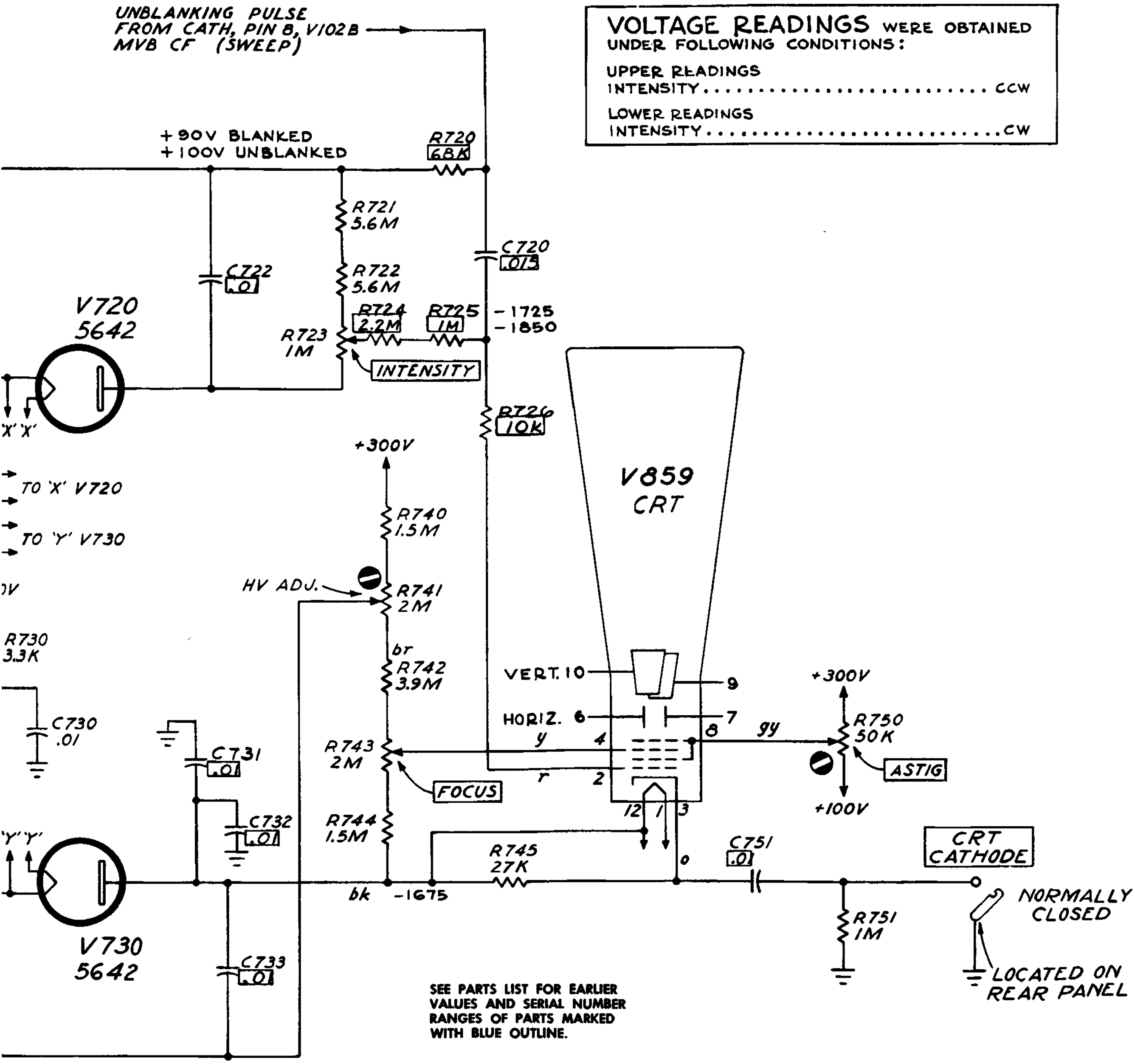
TYPE 310A OSCILLOSCOPE

HEATER WIRING DIAGRAM


CONDITIONS OF SCOPE UNDER TEST
VOLTAGE READINGS
ALL VOLTAGES TAKEN WITH 117V AC LINE
CALIBRATOR OFF
STABILITY CONTROL CCW
T600
D660 A,B,C&D
1V DROP
C661 .02
208V RMS
R660 10
C660 40µf
V661 COMPARATOR
V663 SERIES REGULATOR
+450
+400V UNREG.
R664 1M
V663 12B4
+290
R663 270K
R668 2K
V661 6BH6
10 MV P-TO-P RIPPLE
or, bk, bn
+300V
R661 270K
R662 47K
C671 .01
R671 2.2M
R669 1M
C102
R670 490K
LOCATED AT V220 (SWEEP)
-100
-2.85
-150V
THERMAL CUTOUT TK600 165°F
SW600
POWER OFF
FUSE F600 .8A
WIRED FOR 234V AC 50-800 CYCLES
TO VERTICAL AMPLIFIER V401, V408, V430, V440, V441, V320, V329. ELEV. TO +100V AT HUM BALANCE
TO CRT - ELEVATED TO -1675V AT CRT
TO SWEEP CIRCUITS - V10, V40, V102, V110, V130, V150, V160, V465, V220, V240
GROUNDED ON VERTICAL CHASSIS
6.3VAC
D630 A,B,C&D
R630 10
138V RMS
.3V DROP
C630 150µf
V631 COMPARATOR
V633 SERIES REGULATOR
+180
+300V
R633 2.2M
V633 12B4
R636 5.6K
+91
+100V
R631 100K
V631 6BH6
C639 .01
R637 333K
C407
+40
R632 68K
R639 2.2M
R638 490K
-1.4
10 MV P-TO-P RIPPLE
bn, bk, bn
TO V663 - ELEVATED TO +300V AT V663
TO POWER SUPPLY - V661, V701, V704, V602, V607, V631, V633, V520, V501
GROUNDED ON POWER CHASSIS
SW600
POWER OFF
FUSE F600 1.6A*
WIRED FOR 117V AC 50-800 CYCLES
*SEE PARTS LIST
V602 COMPARATOR
V607 SERIES REGULATOR
V613 VOLTAGE REFERENCE TUBE
D601 A,B,C&D
.7V DROP
R601 10
204V RMS
C601 (3-2×15µf)
+125
+300V
R607 2.2M
V607 12B4
-16
R604 470K
R608 2.5K
R602 5.6K
V602 6BH6
C612 .01
R609 36.5K
R610 10K
R603 100K
-7
-59
R612 1M
R611 49.9K
R613 33K
-66
-150V ADJ.
V613 5651
C613 .01
10 MV P-TO-P RIPPLE
LOCATED NEAR V240 (HORIZONTAL AMPLIFIER)
C240
-150V
SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.
COMBINED WITH POWER OFF, SW600
TO TERM. 30 6.3V
SCALE ILLUM.
R600 50
B601
B600
GRATICULE LIGHTS
bn, gn, bn (on bk base)
CIRCUIT NUMBERS 600 THRU 675


V704
OSCILLATOR
UNBLANKING
FROM CATH,
MVB CF
V701A
SHUNT REGULATOR
V701B
COMPARATOR
T700
+90V
+100V
V720
5642
'X' 'X'
+300V
+400V
UNREG
TO 'X' V720
TO 'Y' V730
+100V
R702
150K
V704
6AQ5
-41
-45
C705
.001
R704
4.7K
R730
3.3K
C702
.001
1,7
R703
47K
C704
.001
C730
.01
+47
+75
+300V
R701
1.5M
V701A
½12AU7
'Y' 'Y'
-1.8
-3.5
V730
5642
V701B
½12AU7
-155
C701
.022
-150V

Ⓐ



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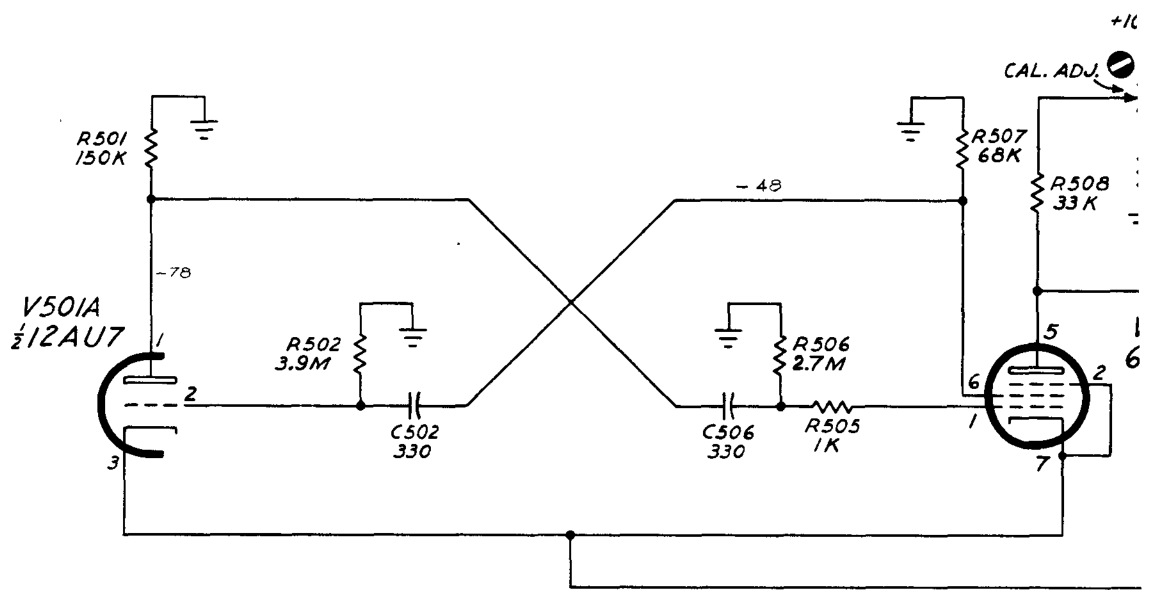
CRT CIRCUIT

669

CIRCUIT NUMBERS
700 THRU 760

CALIBRATOR MULTIVIBRATOR

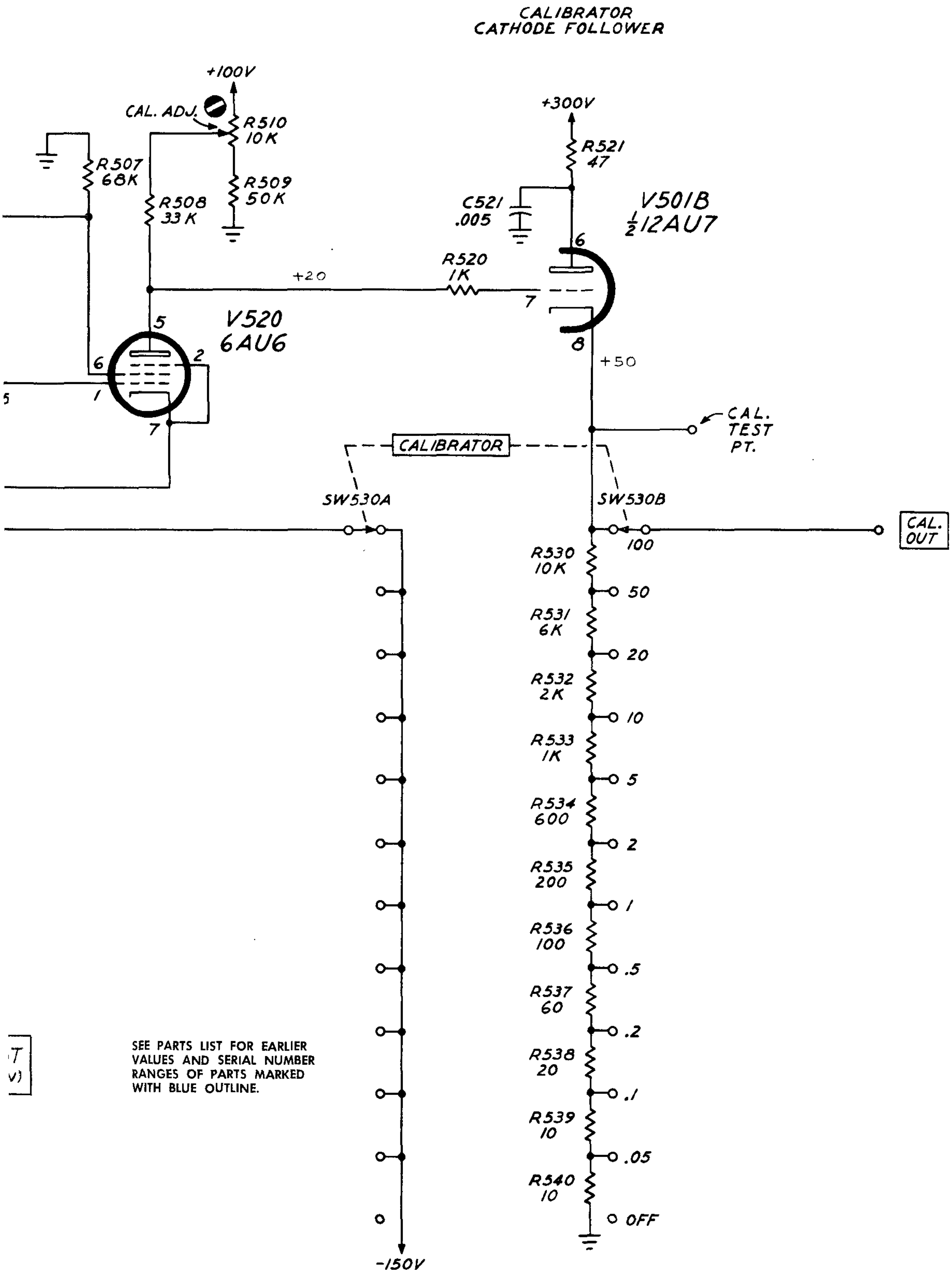


CONDITIONS OF SCOPE UNDER TEST	
CALIBRATOR	ON (100V)

SEE PARTS LIST F
VALUES AND SER
RANGES OF PART
WITH BLUE OUTLI

TYPE 310 A OSCILLOSCOPE

A



SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

CALIBRATOR

669

CIRCUIT NUMBERS
500 THRU 549

Ⓐ

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Sections of the manual are often printed at different times, so some of the information on the change pages may already be in your manual. Since the change information sheets are carried in the manual until ALL changes are permanently entered, some duplication may occur. If no such change pages appear in this section, your manual is correct as printed.