INSTRUCTION MANUAL

Serial Number 6515

TYPE 321A OSCILLOSCOPE SN6000 up

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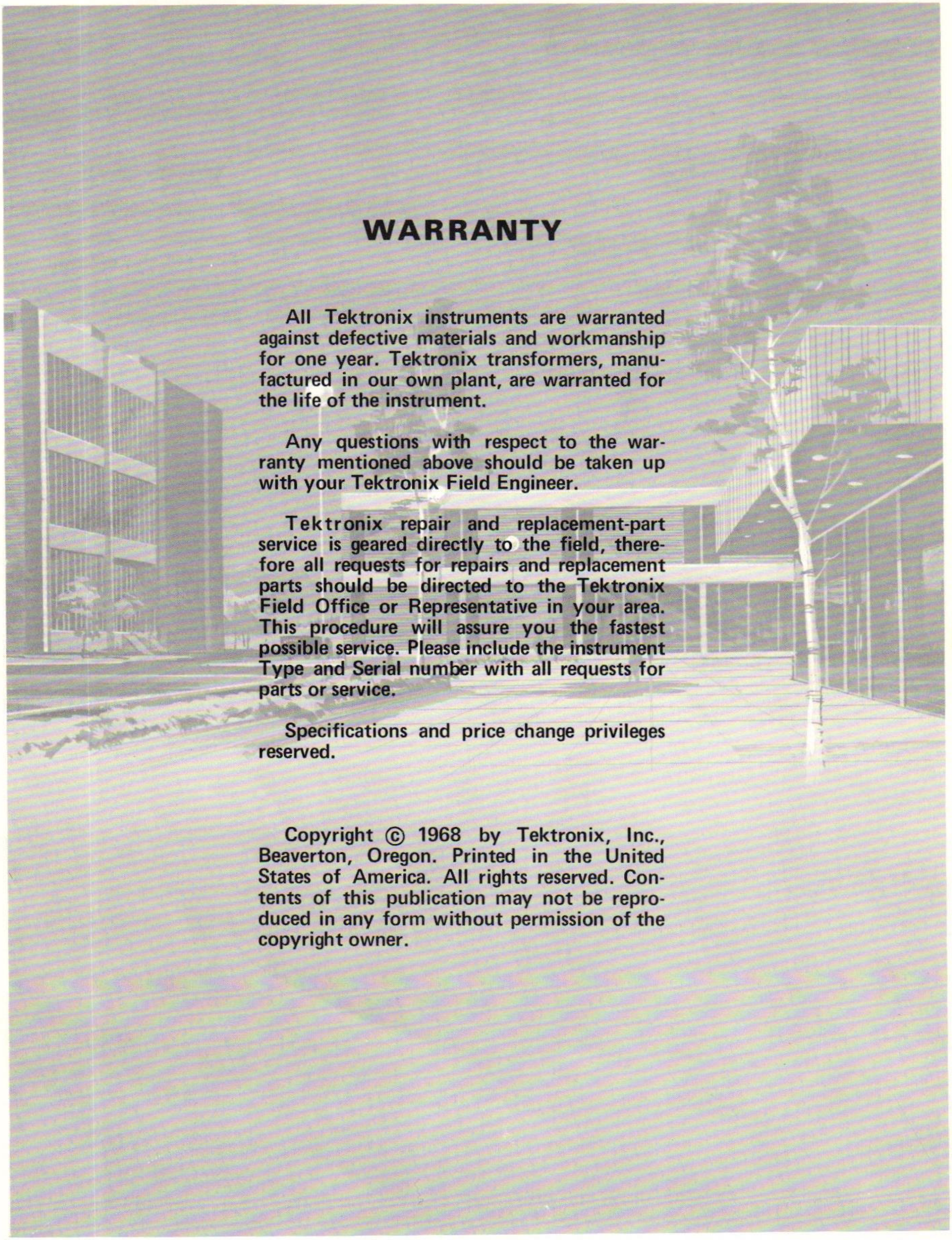


WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our own 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 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.

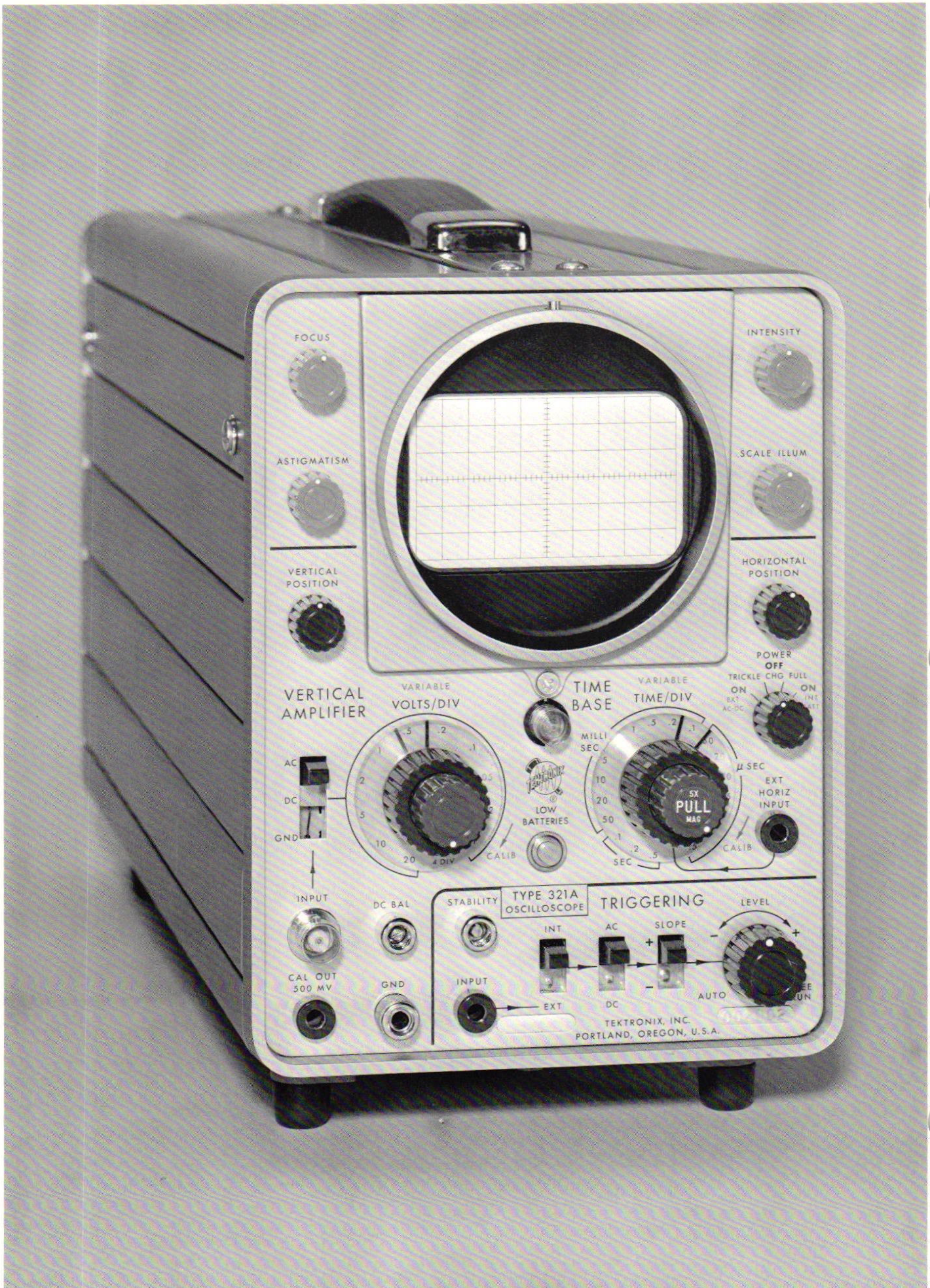


Fig. 1-1. The Type 321A Oscilloscope.

SECTION 1
TYPE 321A SPECIFICATION

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

Introduction

The Tektronix Type 321A is a portable instrument of solid-state design that combines small size and light weight with the ability to make precise waveform measurements. The instrument is mechanically constructed to withstand the shock, vibration and other environmental extremes associated with portability. A DC to six megahertz vertical system provides calibrated deflection factors from 0.01 to 20 volts/division.

The trigger circuits provide stable triggering over the full vertical bandwidth. The horizontal deflection system provides calibrated sweep rates from 0.5 second to 0.5 microsecond/division. A 5X magnifier allows each sweep rate to be increased five times (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 jack (TIME/DIV switch set to the External Horizontal position).

The Type 321A can be operated from any one of three power sources; AC line, external DC or internal batteries (optional). A power regulator circuit ensures that instrument performance is not affected by variations in internal battery charge level, applied DC voltage, or AC line voltage or frequency. Maximum total power consumption is 12 watts for external DC (11.5 to 20 volts DC source) or internal battery operation and 26 watts when operated from an AC line (with trickle charge to batteries). A built-in battery charger allows rechargeable batteries to be charged from an AC line voltage source.

This instrument will meet the electrical characteristcs 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 1000 hours and an ambient temperature range of –15° C to +55° C, except as otherwise indicated. Warm-up time for given accuracy is 20 minutes.

TABLE 1-1

ELECTRICAL

Characteristic	Performance
Vertical Deflection System	
Deflection Factor	
Calibrated range	
Without probe	0.01 volt/division to 20 volts/division in 11 steps. Steps in 1-2-5 sequence.
With P6012 Probe	0.1 volt/division to 200 volts/division in 11 steps. Steps in 1-2-5 sequence.
Accuracy (with or without probe)	Within 3% of indicated deflection throughout calibrated range.
Uncalibrated (variable) range	Continuously variable between calibrated deflection factor settings. Extends maximum deflection factor to at least 50 volts/division.
Low-frequency linearity	0.1 division or less compression or expansion of a center-screen two-division signal when positioned to the top and bottom of the graticule area.
Bandwidth with Four-Division Reference (VARIABLE VOLTS/DIV control at CALIB)	
DC input coupling	DC to at least six megahertz (–3 dB points).
AC input coupling	
Without probe	Two hertz or less to six megahertz or greater (–3 dB points).
With P6012 Probe	0.2 hertz or less to six megahertz or greater (–3 dB points).
Step Response	
Risetime	58 nanoseconds or less with positive four-division step input.
Aberrations	Peak aberrations not to exceed +2% or –2%; total peak-to-peak aberrations not to exceed 3% within 300 nanoseconds after leading edge of step.

ELECTRICAL (Cont)

Characteristic	Performance	
Input Coupling Modes	AC (capacitive) coupled, DC (direct) coupled and internally grounded. Selected by front-panel Input Coupling switch.	
Maximum Input Voltage		
DC and AC input coupling	500 volts (DC + peak AC). Peak-to-peak AC less than 500 volts.	
Input RC Characteristics	Without probe	With P6012 Probe
Resistance	One megohm ±2%.	10 megohms ±3%.
Capacitance	41 picofarads ±6 pF.	8.5 picofarads ±1.5 pF.
Time constant	Constant within 2% at all VOLTS/DIV switch setting.	
Input Current (25° C $\pm 5^{\circ}$ C)	500 picoamperes or less resulting in 0.05 division or less trace shift at 0.01 VOLTS/DIV	

Triggering

Characteristic	Performance
Trigger Source	Internal or external. Selected by front-panel Triggering Source switch.
Trigger Coupling	AC (capacitive) coupled or DC (direct) coupled. Selected by front-panel Triggering Coupling switch.
Trigger Polarity	Sweep can be triggered from positive-going or negative-going portion of trigger signal. Selected by front-panel SLOPE switch.
Trigger Mode	Manual triggering adjustable for desired level; automatic triggering at average level of triggering waveform with free-running sweep at 50 hertz ±12.5 hertz rate in absence of adequate trigger signal; free-running at the repetition rate of the Sweep Generator. Selected by front-panel LEVEL control.
Trigger Sensitivity	
Internal	
DC	0.2 division of deflection minimum, DC to one kilohertz; increasing to one division at six megahertz.
AC	0.2 division of deflection minimum at one kilohertz; increasing to one division at six megahertz.
External	
DC	One volt peak to peak minimum, DC to one kilohertz; increasing to three volts peak to peak at six megahertz.
AC	One volt peak to peak minimum, 30 hertz to one kilohertz; increasing to three volts peak to peak at six megahertz.
External Trigger Input RC Characteristics	100 kilohms ±20% paralleled by nine picofarads ±4 pF.

Time Base

Characteristic	Performance
Sweep Rate	
Calibrated range	0.5 microsecond to 0.5 second/division in 19 steps. Steps in 1-2-5 sequence. Each sweep rate can be increased five times with the 5X magnifier. Extends fastest sweep rate to 0.1 microsecond/division.
Uncalibrated (variable) range	Continuously variable between calibrated sweep rate settings. Extends slowest uncalibrated sweep rate to at least 1.25 seconds/division.
Sweep Accuracy	
Unmagnified time measurement accuracy, 5X MAG switch pushed in	Within 3% of indicated sweep rate over center eight divisions of graticule.
Magnified time measurement accuracy, 5X MAG switch pulled out	Within 5% of equivalent magnified sweep rate over center eight divisions of graticule.

ELECTRICAL (Cont)

Characteristic	Performance
External Horizontal Amplifier	
Deflection Factor	One volt/division with 5X magnifier on.
Deflection Accuracy	Within 10%.
Input RC Characteristics	100 kilohm ±5% paralleled by 25 picofarads ±5 pF.
X Bandwidth with Four-Division Reference	DC to at least one megahertz (−3 dB points).
Calibrator	
Waveshape	Square wave.
Output Voltage	
Internal	40 millivolts ±2%. Internally connected to vertical amplifier in CAL 4 DIV position of VOLTS/DIV switch.
CAL OUT jack	+500 millivolts ±3%.
Repetition Rate	Two kilohertz ±20%.
Risetime	One microsecond or less.
Duty Cycle	45% to 55%.
Z-Axis Input	
Sensitivity	Five volts peak-to-peak signal at one kilohertz provides visible trace modulation at normal intensity.
Coupling	AC (one megohm and 0.01 microfarad).
Input Resistance	One megohm ±20%.
Power Supply	
AC Operation	
Line voltage range	
115-volts nominal	103.5 to 126.5 volts.
230-volts nominal	207 to 253 volts.
Line Frequency	45 to 800 hertz.

Characteristic	Performance
Maximum power consumption	
Power switch set to ON EXT AC-DC, Charger switch set to Dry Cells	20 watts.
POWER switch set to ON EXT EXT AC-DC, Charger switch set to High	26 watts.
POWER switch set to OFF FULL CHG, Charger switch set to High	30 watts.
DC Operation	
Voltage range	11.5 to 35 volts.
Maximum current	600 milliamperes.
Maximum power consumption	
11.5 volts DC	6.9 watts.
20 volts DC	12 watts.
35 volts DC	21 watts.
Battery Operation	
Batteries	10 size D cells.
Operating time	Approximately eight hours with fully charged nickel-cadmium batteries (Tektronix Part No. 146-0010-00) within operating temperature range given in Table 1-2.
Cathode-Ray Tube (CRT)	
Graticule Type	External with variable edge lighting when operated from AC line.
Area	Six divisions vertical by 10 divisions horizontal. Each division equals 0.25 inch.
Geometry	0.1 division or less.
Horizontal Resolution	At least 120 markers in 10 divisions.

TABLE 1-2

ENVIRONMENTAL

Characteristic	Performance
NOTE This instrument will meet the electrical characteristics given in this section over the following environmental limits. Complete details on environmental test procedures, including failure criteria, etc., can be obtained from Tektronix, Inc. Contact your local Tektronix Field Office or representative.	
Temperature Without batteries Operating	−15°C to +55° C.
Non-operating	−55° C to +75° C.
With batteries Operating (discharge)	−15° C to +40° C. Operating time is reduced at −15° C.
Operating (charging)	0° C to +40° C.
Non-operating	−40° C to +60°C.
Altitude Operating	15,000 feet maximum
Non-operating	Test limit 50,000 feet.
Humidity Non-operating	Five cycles (120 hours) of Mil-Std-202C, Method 106B. Omit freezing and vibration. Allow 24-hour post-test drying period at +25° C ±5° C and 20% to 80% relative humidity.
Vibration Operating and non-operating	15 minutes along each of the three major axes at a total displacement of 0.025-inch peak to peak (4g at 55 c/s) with frequency varied from 10-55-10 c/s in one minute cycles. Hold at 55 c/s for three minutes on each axis.
Shock Operating	Two guillotine-type shocks of 20 g, one-half sine, 11 millisecond duration each direction along each major axis for a total of 12 shocks.
Non-operating	One guillotine-type shocks of 60 g, one-half sine, 11 millisecond duration each direction along each major axis for a total of 6 shocks.
Transportation	Qualifies under National Safe Transit Committee test procedure 1A.

TABLE 1-3

PHYSICAL

Dimensions (measured at maximum points) Height	8 1/2 inches (21.6 centimeters).
Width	5 3/4 inches (14.6 centimeters).
Length	16 inches (40.6 centimeters).
Weight Without batteries	Approximately 14 pounds (6.4 kilograms).
With batteries	Approximately 17 1/2 pounds (7.9 kilograms).
Finish	Anodized front panel with chrome-plated front and rear castings. Blue vinyl painted cabinet.

STANDARD ACCESSORIES

Standard accessories supplied with the Type 321A are listed on the last pullout page at the rear of this manual. For optional accessories available for use with this instrument, see the Tektronix, Inc. catalog.

SECTION 2
OPERATING INSTRUCTIONS

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

General

To effectively use the Type 321A, the operation and capabilities of the instrument must be known. This section describes selection of the power source, operation of the front- and rear-panel controls and connectors, gives first time and general operating information and lists some basic applications for this instrument.

OPERATING VOLTAGE

Power Requirement

The Type 321A can be operated from either a 115-volt or a 230-volt nominal AC line voltage source, from a 11.5 to 35 volt external DC source or from internal batteries. The following discussions provide the information necessary for operation in each mode as well as information on rechargeable nickel-cadmium batteries.

AC Operation

A tag on the bottom of the Type 321A indicates the voltage for which it was wired at the factory. When connected for 115-volt nominal operation, this instrument provides stable operation over a line voltage range of 103.5 to 126.5 volts. When connected for 230-volt nominal operation, stable operation is provided with line voltage variations between 207 and 253 volts. Stable operation is also provided for line frequencies between 50 and 800 hertz at the line voltage for which the instrument is wired.

To convert this instrument to a different nominal line voltage than the one for which it is wired, use the following procedure.

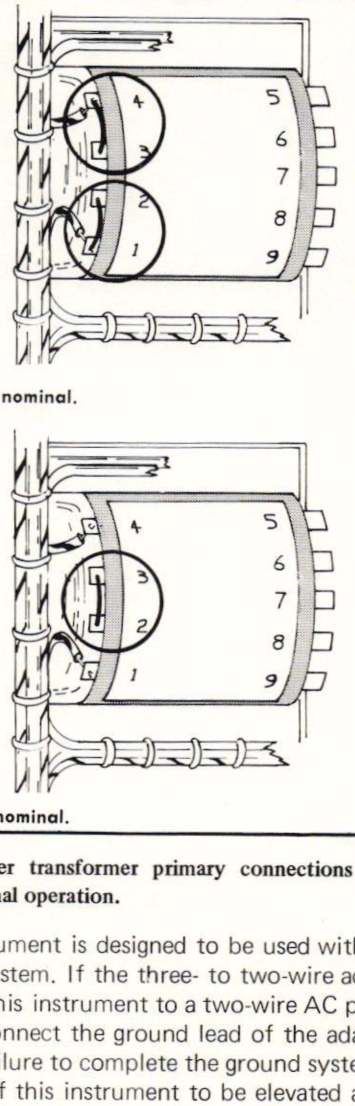
1. Disconnect the instrument from the power source.

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

3. Change the line-cord power plug to match the power-source receptacle or use a suitable adapter.

4. Change the voltage tag to indicate the correct nominal operating voltage. The Tektronix Part No. for the voltage tags are:

115-volt nominal, 50-800 hertz	334-0931-00
230-volt nominal, 50-800 hertz	334-0938-00



A. 115-volts nominal.

B. 230-volts nominal.

Fig. 2-1. Power transformer primary connections for 115- and 230-volt nominal operation.

This instrument is designed to be used with a three-wire AC power system. If the 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 earth (ground). Failure to complete the ground system may allow the chassis of this instrument to be elevated above ground potential and pose a shock hazard.

The AC power cord is connected to the AC portion of the power receptacle (see Fig. 2-2) for AC operation. Whenever the instrument is connected to an AC power source, power is applied to the primary of the power transformer. This provides power to the battery charger circuit and the graticule lights in all positions of the POWER switch except ON INT BATT. Applications of power to these circuits allows the batteries to be charged when the instrument is turned off. Also, the graticule lights are operative for AC operation only to provide longer operating time from the internal batteries.

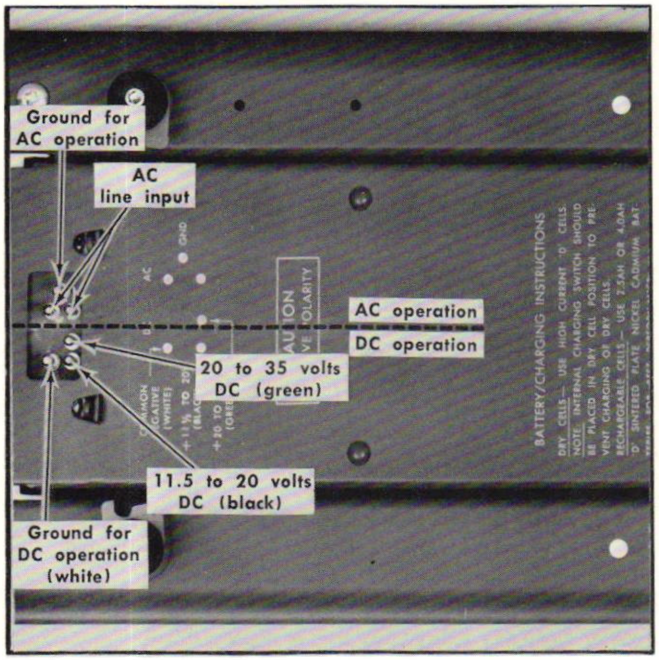


Fig. 2-2. Power cord connections to the power receptacle on bottom of instrument for external AC and DC operation.

For AC operation, the instrument is operative when the POWER switch is set to ON EXT AC-DC. A trickle charge is also available when using internal rechargeable batteries. This instrument is inoperative in the OFF TRICKLE CHG and OFF FULL CHG positions of the POWER switch. The OFF TRICKLE CHG position can be considered as the normal off position for AC operation. However, power is applied to the battery charger circuit in both OFF CHG positions to recharge internal batteries. For more information on charging the batteries, see Battery Operation in this section.

DC Operation

This instrument can be operated from an external DC source by connecting the DC power cord to the DC portion of the power receptacle (see Fig. 2-2). The DC power cord is supplied without an input connector. A suitable connector may be added to match the power source or the pigtail leads can be used as supplied. Connect the white lead (ground) and either the black or green lead as follows for DC operation:

White lead	Ground
Black lead	+11.5 to +20 volts DC
Green lead	+20 to +35 volts DC

WARNING

When this instrument is connected to a DC power source, the chassis is floating with respect to earth (ground). Connect the instrument to earth with a jumper lead from the front-panel GND post. Operation without this ground lead is not recommended due to the potential shock hazard produced if the chassis becomes elevated with respect to earth.

To turn the instrument on for DC operation, set the POWER switch to the ON EXT AC-DC position. The instrument is off in either the OFF TRICKLE CHG or OFF FULL CHG position. The internal battery charger is inoperative when connected for DC operation. Therefore, the internal batteries cannot be recharged from an external DC source.

CAUTION

The power receptacle of this instrument is designed so only one of the external power cords supplied can be connected at a time. To prevent damage to this instrument, do not use power cords which allow both external power sources to be connected to the instrument at the same time.

Battery Operation

Battery Selection. The Type 321A can be operated from 10 size D battery cells. Table 2-1 lists some common size D battery cells and the approximate continuous operating time provided by each type. Other types of size D batteries are available for use with this instrument. The operating time provided depends upon the individual characteristics of the batteries.

TABLE 2-1

Common Size D Battery Cells for Use in the Type 321A

Battery type	Continuous operating time (approximate)	Advantages and disadvantages
Standard flashlight cells	About 0.5 hour.	Most practical and convenient battery type where battery operation is to be used frequently.
Alkaline cells (such as Eveready E95, Burgess AL-2 or Mallory MN-1300)	About 2.5 hours.	Same as above except this battery type provides extended operating time.
Rechargeable nickel-cadmium cells (Tektronix Part No. 146-0010-00).	About eight hours (may vary with manufacturer or age of cells).	Provides economical battery operation if batteries are used infrequently; cost becomes excessive when battery operation is used repeatedly.

Battery Installation and Operation. Installation of the batteries is illustrated in Fig. 2-3. First remove the battery cover as shown in Fig. 2-3A. Then, following the instructions given in Fig. 2-3B, install the battery cells. Be sure to observe the battery polarity as printed inside the battery

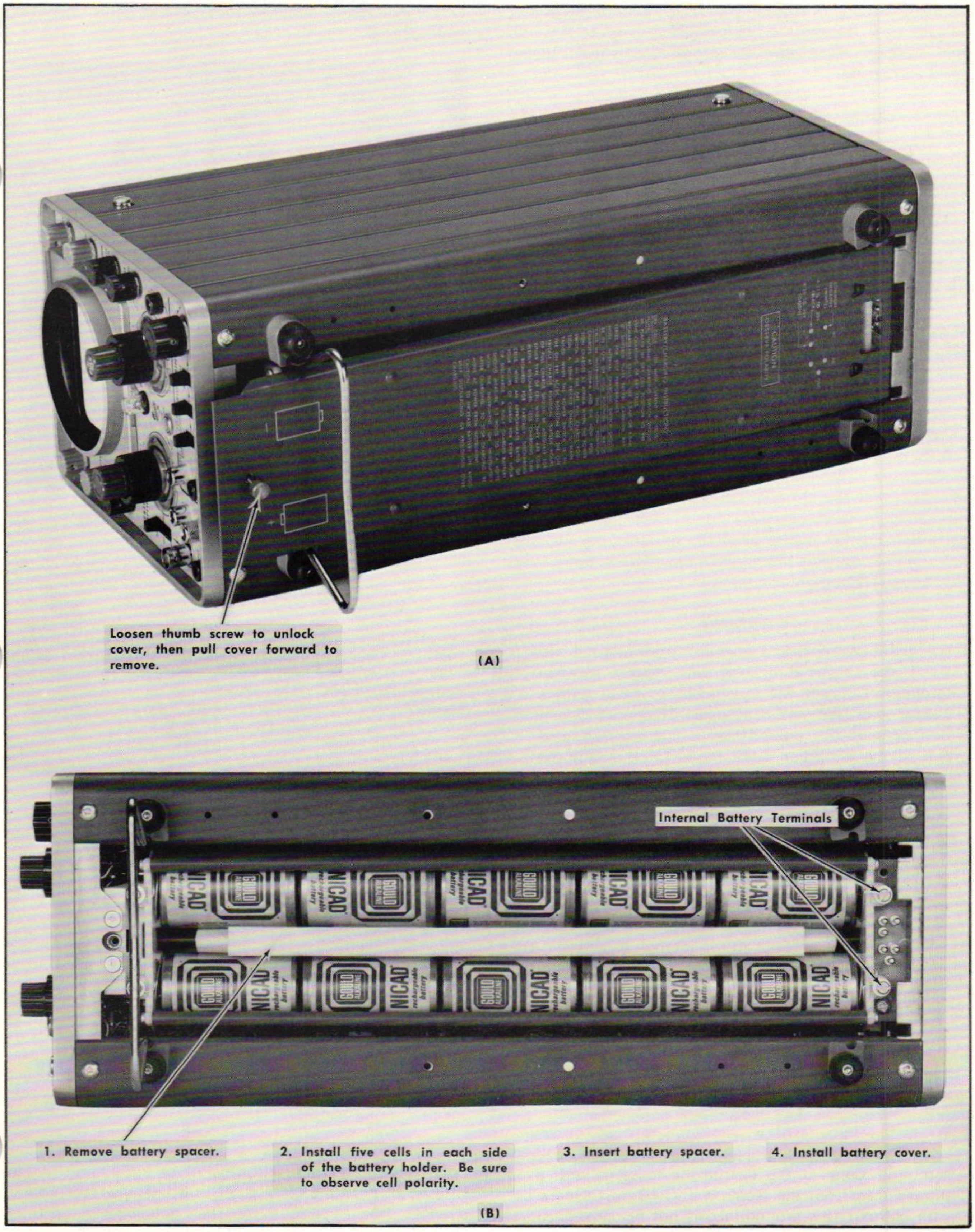


Fig. 2-3. (A) Removing the battery cover from the instrument, (B) installing the batteries.

compartment and on the battery cover. If non-rechargeable cells are used, be sure the Charger switch is set to the Dry Cells position. More complete information is given under Battery Charging.

Rechargeable cells obtained from Tektronix, Inc. (Tektronix Part No. 146-0010-00) have solder tabs on each end. These cells can be soldered together to reduce inter-cell contact resistance for improved battery operation.

This instrument can be operated on the internal batteries over an ambient temperature range of −15° C to +40° C. However, the maximum operating time and useful battery life when using rechargeable batteries is provided between +15° C and +25° C. For operation from the internal batteries, set the POWER switch to the ON INT BATT position. This instrument is off in either the OFF TRICKLE CHG or OFF FULL CHG position. When the instrument is connected to an AC line-voltage source, rechargeable batteries can be charged with the correct setting of the Charger switch (see Battery Charging). In the ON INT BATT position of the POWER switch, the battery charger circuit is disconnected. The LOW BATTERIES light provides an indication that the batteries have been discharged to near the minimum level necessary for correct power supply regulation. Further discharge of the batteries beyond this level not only provides inaccurate measurements but it may also damage rechargeable batteries.

WARNING

When this instrument is operated from internal batteries, the chassis is floating with respect to earth (ground). Connect the instrument to earth with a jumper lead from the front-panel GND post. Operation without this ground lead is not recommended due to the potential shock hazard produced if the chassis becomes elevated with respect to earth.

Battery Charging. When rechargeable battery cells are used in this instrument, the batteries can be recharged with the correct setting of the Charger switch. The Charger switch is located behind the left side panel (see Fig. 2-4). When the Charger switch is set to High or Low and the instrument is connected to an AC line-voltage source, a trickle charge is connected to the internal batteries in the ON EXT AC-DC and OFF TRICKLE CHG positions of the POWER switch. This trickle charge maintains a full charge on the batteries without over-charging them. In the OFF FULL CHG position of the POWER switch, the Charger switch determines the charge rate of the internal batteries. Table 2-2 lists the charge rate in each position of the POWER and Charger switches at various line voltages within the regulating range. The rechargeable batteries supplied by Tektronix, Inc. can be charged in the High position of the Charger switch at all line voltages. However, batteries obtained from other sources should be charged in the Low position of the Charger switch unless the manufacturer's specifications state that it will withstand the High position charge rate. If necessary, an autotransformer can be used to lower the line voltage and reduce the charge rate (necessary only for batteries obtained from sources other than Tektronix, Inc.).

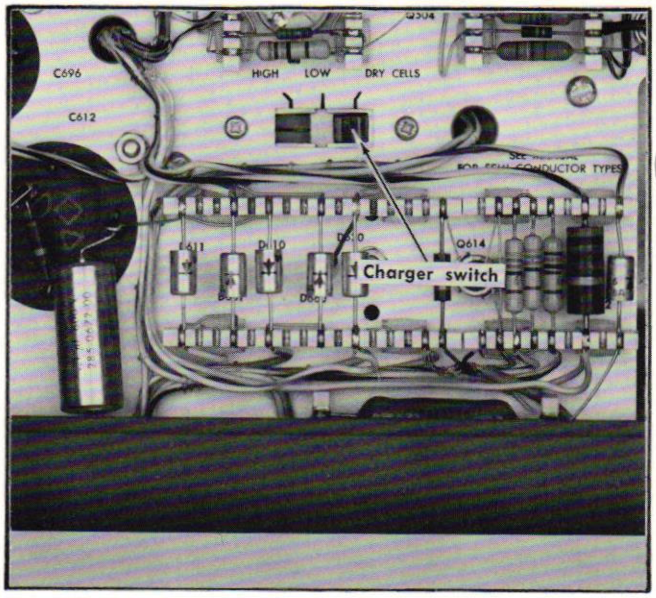


Fig. 2-4. Location of Charger switch (left side).

TABLE 2-2

Charging Current

AC line voltage applied	Charger switch positions	Approximate charging current (milliamperes) in each position of the POWER switch			
		ON EXT AC–DC	OFF TRICKLE CHG	OFF FULL CHG	ON INT BATT
103.5 or	Low	20	31	160	Battery charger circuit disconnected
207 volts	High	22	34	290	
109 or	Low	24	34	180	
218 volts	High	26	37	320	
115 or	Low	27	38	200	
230 volts	High	30	41	360	
121 or	Low	31	41	220	
242 volts	High	33	44	380	
126.5 or	Low	33	44	230	
253 volts	High	35	48	410	

A charge period of 14 to 16 hours should be sufficient to charge the battery cells to their full potential. Although the batteries may not be damaged immediately by longer charge periods, repeated overcharging will shorten the useful life of the batteries. If it is desired to maintain a full charge on the batteries, use the OFF TRICKLE CHG position of the POWER switch. A trickle charge is also applied to the batteries when operating from an external AC power source.

The batteries in this instrument can be charged over an ambient temperature range of 0° C to +40° C. However, maximum operating time and useful battery life is provided when the batteries are charged and discharged at about +25° C.

During normal usage or storage, the individual battery cells in this instrument attain slightly different charge characteristics. To provide the best overall operation and maximum operating life, the charge on the battery cells should be equalized periodically. This can be done without damage to the battery cells by charging the batteries at the full-charge rate for 24 hours. This should be done after every 15 charge-discharge cycles or every 30 days, whichever occurs first.

Nickel-Cadmium Battery Information

General. The nickel-cadmium battery cells available from Tektronix, Inc. for use with this instrument have been selected as a result of extensive evaluation. Each battery cell has received an ampere-hour test, has met or exceeded the minimum ampere-hour storage requirement and has been rigidly inspected. The battery cells used in this instrument should provide a useful operating life extending over several hundred charge-discharge cycles.

Precautions. To extend the useful operating life of the nickel-cadmium battery cells used in this instrument, observe the following precautions.

1. Do not exceed the recommended charge rate and period (see Battery Charging).

2. Be sure the battery charger is operated correctly as described previously in this section.

3. Be sure to observe the cell polarity when inserting the batteries (see Fig. 2-3B).

4. Excessive discharge of the batteries after the LOW BATTERIES light comes on may cause one or more of the cells to reverse polarity. Although the cells are protected against immediate damage, repeated polarity reversal will shorten the useful life of the batteries.

5. Observe the temperature limits given in this manual for battery charging, operation and storage.

Maintenance. When the battery cells are overcharged or when discharged to the point of polarity reversal, gas is formed within the nickel-cadmium cells. This gas produces pressure within the cells. The nickel-cadmium cells supplied by Tektronix, Inc. (Tektronix Part No. 146-0010-00) incorporate a vent so this internal pressure does not damage the battery. However, as the internal pressure is relieved, a small amount of the electrolyte may be expelled with the gas. Although the cell will probably not be damaged, this loss of electrolyte may result in shorter overall battery life. The batteries and battery compartment should be inspected occasionally for any electrolyte residue on the batteries themselves or in the battery compartment. Any residue which is found should be cleaned away with a 2% solution of boric acid in water. A 2% solution of boric acid can be obtained by dissolving 1 1/4 teaspoons of boric acid powder in one cup of water. After the residue has been cleaned from the batteries and the battery compartment, dry the wetted area thoroughly with a soft cloth.

If the total potential across the battery terminals (see Fig. 2-3B) does not reach 13-14 volts even after the recommended charge time, one or more of the battery cells is probably defective. To locate the defective cell, first be sure the batteries have been charged for the recommended charge period. Then, while operating the instrument on the internal batteries, measure the potential across each individual cell. Use a meter which has a long, thin probe tip to reach the contacts between the batteries. If an individual battery cell measures below about 1.15 volts, it is probably defective; above this voltage, the battery cell is probably operating correctly. If the total potential across the battery terminals is 13-14 volts after the recommended charge period, but the LOW BATTERIES light comes on too soon when operating on internal batteries, the charge retaining capacity of one or more of the battery cells has probably decreased below the acceptable limits. (NOTE: Batteries may not be reaching full charge due to a defective charger circuit.) This can be checked in a manner similar to that described above. First be sure that the batteries have been charged for the recommended charge period. Then, operate the instrument on the internal batteries until the LOW BATTERIES light comes on. Now measure the potential across each cell. If an individual cell measures below about 1.15 volts, it is probably defective; above this voltage, it is probably acceptable. If the voltage of all the cells is above 1.2 volts and the charger circuit is operating correctly, the LOW BATTERIES circuit may be at fault.

When replacing battery cells in this instrument, charge the entire set of batteries at the recommended charge rate and charge period before operating the instrument from the internal batteries. This equalizes the charge on all the battery cells and protects the new cells from polarity reversal damage. The batteries should be replaced only with cells which have the same charge rate and charge capacity as those in the instrument (see Battery Charging for more information).

Battery Storage. The battery cells used in this instrument may be stored in a charged or partially charged condition. For best shelf-life when storing individual cells, fully recharge the battery cells at three to six month intervals. Although replacement cells obtained from Tektronix, Inc. are fully charged before shipment, recharge the complete set of batteries before operating the instrument.

Charge retention characteristics of nickel-cadmium cells vary with the storage temperature. They may be stored at any temperature between −40° C and +60° C without damage, either in the instrument or as individual cells. However, the self-discharge rate increases with ambient temperature and humidity. For example, cells stored at +20° C will lose about 50% of their stored charge in three months but when stored at +50° C, they will be almost completely self-discharged in only one month. High humidity also increases the rate of self-discharge. If this instrument must be stored at either high ambient temperature or high humidity for an extended period of time, it is recommended that the batteries be continuously trickle charged using the OFF TRICKLE CHG position of the POWER switch (charge batteries completely at full-charge rate before extended trickle charge).

Low-Batteries Light

The LOW BATTERIES light indicates when the unregulated voltage connected to the Power Supply Series Regulator stage is too low for continued measurement accuracy. This is particularly useful when using rechargeable batteries as these battery cells may be damaged by excess discharge. Therefore, the instrument should not be operated from the internal batteries after the LOW BATTERIES light comes on since it not only may provide inaccurate measurements but it may also shorten the useful life of the rechargeable battery cells. For external operation, the LOW BATTERIES light comes on when the external voltage source is too low for correct operation.

OPERATING TEMPERATURE

General

The Type 321A depends upon radiant cooling from the side and rear panels to maintain a safe operating temperature. Adequate clearance on all sides must be provided to allow heat to be dissipated away from the instrument. The clearance provided by the feet at the bottom should be maintained. Provide at least two inches of clearance at the sides, top and rear (more if possible).

A thermal cutout in the instrument provides thermal protection and disconnects the power to the instrument if the internal temperature exceeds a safe operating level. Power is automatically restored when the temperature returns to a safe level. The Type 321A can be operated where the ambient air temperature is between −15° C and +55° C (+40° C maximum with batteries). After storage at temperatures beyond the operating limits, allow the chassis temperature to come within the operating limits before power is applied.

OPERATING POSITION

General

A bail-type stand is mounted on the bottom of this instrument. This stand permits the Type 321A to be tilted up for more convenient viewing (see Fig. 2-5).

CONTROLS AND CONNECTORS

General

A brief description of the function and operation of the front- and rear-panel controls and connectors follows. Fig. 2-6 shows the front and rear panels of this instrument. More detailed information is given in this section under General Operating Information.

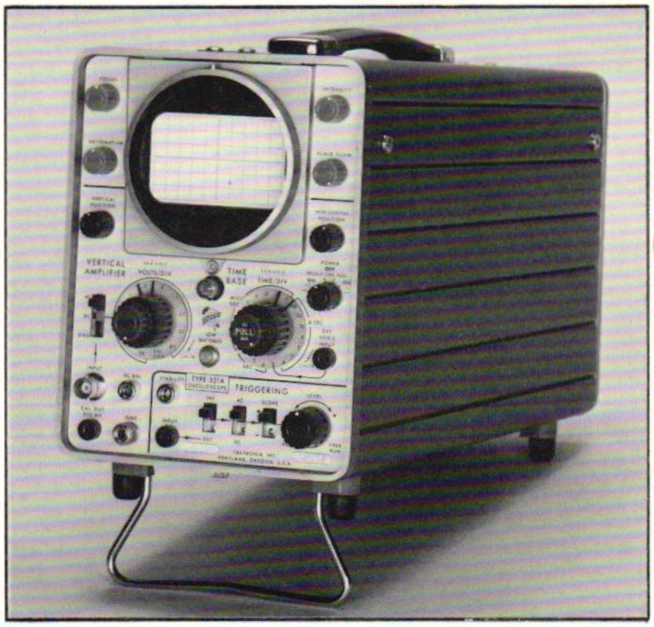


Fig. 2-5. Instrument positioned on bail stand.

CRT Controls

FOCUS	Provides adjustment for optimum display definition.
ASTIGMATISM	Used in conjunction with the FOCUS control to obtain a well-defined display.
INTENSITY	Controls brightness of the display.
SCALE ILLUM	Controls graticule illumination (only when operating from an AC line voltage source).

Vertical

VERTICAL POSITION	Controls vertical position of trace.
Input Coupling (AC DC GND)	Selects method of coupling input signal to vertical deflection system. AC: DC component of input signal is blocked. Low-frequency −3 dB point is about 1.6 hertz. DC: Provides equal coupling for all signals from DC to six megahertz or greater. GND: Input circuit is grounded (does not ground applied signal).
VOLTS/DIV	Selects vertical deflection factor in 1-2-5 sequence (VARIABLE control must be in CAL position for indicated deflection factor). Fully clockwise position of switch selects internal calibrator signal.

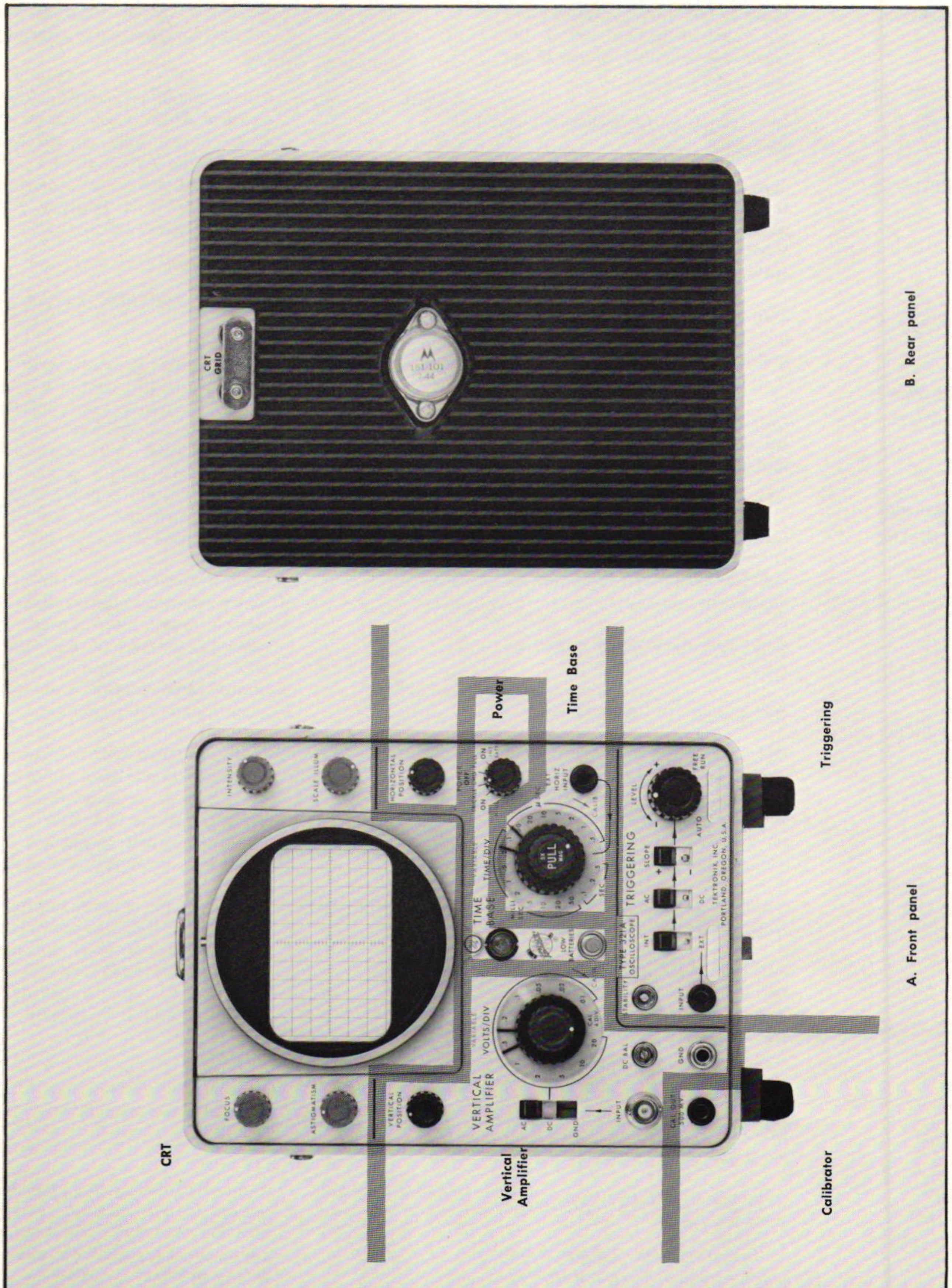


Fig. 2-6. Front- and rear-panel controls and connectors.

VARIABLE	Provides continuously variable uncalibrated deflection factors between the calibrated settings of the VOLTS/DIV switch.
INPUT	Input connector for vertical deflection signal.
DC BAL	Screwdriver adjustment to balance the Vertical Amplifier so there is no vertical shift of the trace as the VARIABLE control is rotated (with no signal applied).
GND	Terminal for establishing a common ground between the equipment under test and the Type 321A.

Calibrator

CAL OUT	Output jack providing 500-millivolt square-wave signal for compensating a probe.

Triggering

STABILITY	Screwdriver adjustment to provide correct operation of the trigger circuit (see Calibration Procedure for adjustment procedure).
INPUT	Input jack for external trigger signal.
Source (INT-EXT)	Selects source of trigger signal. INT: Trigger signal obtained from vertical deflection system. EXT: Trigger signal obtained from an external signal applied to the Triggering INPUT jack.
Coupling (AC-DC)	Determines method of coupling trigger signal to trigger circuit. AC: Rejects DC and attenuates signals below about 600 hertz in INT position of the Source switch or below about 30 hertz in EXT position. Accepts all signals above lower frequency limit to six megahertz or greater. DC: Accepts all trigger signals from DC to six megahertz or greater.
SLOPE	Selects slope of trigger signal which starts the sweep. +: Sweep can be triggered from positive-going portion of trigger signal. −: Sweep can be triggered from negative-going portion of trigger signal.
LEVEL	Selects amplitude point on trigger signal at which sweep is triggered. When turned fully counterclockwise to the AUTO position, the sweep is automatically triggered. In the FREE RUN position, fully clockwise, the sweep free runs.

Time Base

HORIZONTAL POSITION	Controls horizontal position of trace.
TIME/DIV	Selects sweep rate of the sweep circuit (VARIABLE control must be in CALIB position for indicated sweep rate). In the External Horizontal position (note arrow from EXT HORIZ INPUT jack), horizontal deflection is provided by a signal connected to the EXT HORIZ INPUT jack.
VARIABLE	Control concentric with TIME/DIV switch which provides continuously variable sweep rates between the calibrated settings of the TIME/DIV switch. Sweep rate is calibrated when control is set fully clockwise to CALIB position.
5X MAG	Switch actuated with VARIABLE TIME/DIV knob. When pulled out, sweep rate is increased five times the setting of the TIME/DIV switch by horizontally expanding the center two divisions of the display.
EXT HORIZ INPUT	Input jack for external horizontal signal when TIME/DIV switch is set for external horizontal operation (arrow connects EXT HORIZ INPUT jack to External Horizontal position of TIME/DIV switch).

Power

Power on Light (not labeled)	Indicates that POWER switch is in one of the ON positions and power is available.
LOW BATTERIES	Light which indicates that the input voltage to the Regulator circuit is too low for correct power supply regulation. Operable with all three modes of power; external AC, external DC and internal batteries.

POWER	Four-position switch which determines the operating power source and the battery charging voltage.
	ON EXT AC—DC: Instrument operable from an external AC or DC power source. External power source determined by connections to the power receptacle.
	OFF TRICKLE CHG: Instrument inoperable. Trickle charge is applied to internal batteries when connected to an external AC power source.
	OFF FULL CHG: Instrument inoperable. Internal batteries can be charged when the Charger switch is set to Low or High and the instrument is connected to an external AC power source.
	ON INT BATT: Instrument operable from internal batteries.

Rear Panel

CRT GRID	Input jacks for intensity modulation of the CRT display.

FIRST-TIME OPERATION

General

The following steps demonstrate the use of the controls and connectors of the Type 321A. It is recommended that this procedure be followed completely for general familiarization with this instrument.

Setup Information

1. Set the front-panel controls as follows:

CRT Controls	
FOCUS	Midrange
ASTIGMATISM	Midrange
INTENSITY	Counterclockwise
SCALE ILLUM	Counterclockwise
Vertical Amplifier	
VERTICAL POSITION	Midrange
Input Coupling	GND
VOLTS/DIV	CAL 4 DIV
VARIABLE	CALIB
Triggering	
Source	INT
Coupling	AC
SLOPE	+
LEVEL	FREE RUN
Time Bases	
HORIZONTAL POSITION	Midrange
TIME/DIV	.2 MILLISEC
VARIABLE	CALIB
5X MAG	Pushed in
Power	
POWER	OFF TRICKLE CHG

2. Connect the Type 321A to an external AC power source that meets the voltage and frequency requirements of this instrument. If external DC or the internal batteries must be used for this procedure, see Operating Voltage in this section for more information.

3. Set the POWER switch to ON EXT AC-DC. Allow about five minutes warmup so the instrument reaches a normal operating temperature before proceeding.

CRT Controls

4. Advance the INTENSITY control until the display is at the desired viewing level (near midrange).

5. Adjust the FOCUS and ASTIGMATISM control for a sharp, well-defined display over the entire trace length.

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

Vertical Controls

7. Turn the VERTICAL POSITION control to center the display. The display is a square wave, about four divisions in amplitude with about four cycles displayed on the screen.

8. Turn the VARIABLE VOLTS/DIV control throughout its range. The deflection should be reduced so 1.6 divisions or less in the fully counterclockwise position. Return the VARIABLE control to CALIB.

9. Set the VOLTS/DIV switch to .02 and position the display to the center horizontal line with the VERTICAL POSITION control. This provides a ground reference at the center horizontal line.

10. Rotate the VARIABLE VOLTS/DIV control throughout its range. If the vertical position of the trace changes, see DC Balance in this section for the balancing procedure. Return the VARIABLE control to CALIB.

11. Connect the 10X probe (supplied accessory) to the vertical INPUT connector. Position the probe tip so it is in contact with the CAL OUT jack for steps 12 through 19.

12. Set the Input Coupling switch to DC. Notice that the baseline of the waveform remains at the center horizontal line (ground reference).

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

Triggering Controls

14. Turn the LEVEL control clockwise to the FREE RUN position. The display appears as two lines 2.5 divisions apart (free running).

15. Rotate the LEVEL control counterclockwise until a stable display appears. This indicates that the sweep is triggered. Continue rotating the LEVEL control counterclockwise and notice that more of the leading edge of the display is shown as the LEVEL control is turned toward – (due to the fast rise of the calibrator waveform, it may be difficult to observe this effect). Turn the LEVEL control fully counterclockwise to the AUTO position. The trace is again stable.

16. Set the SLOPE switch to –. The trace starts on the negative part of the square wave. Return the switch to +; the trace starts with the positive part of the square wave.

17. Set the Coupling switch to DC and turn the LEVEL control clockwise until the display is triggered on the positive part of the square wave. Now turn the VERTICAL POSITION control clockwise until the display becomes unstable or disappears completely. Return the Coupling 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 screen.

18. Connect the CAL OUT connector to the Triggering INPUT jack with a dual banana-plug patch cord and reconnect the 10X probe tip to the CAL OUT jack. Set the Triggering Source switch to EXT. LEVEL, SLOPE and Coupling operation is the same as described in steps 14 through 17.

19. Disconnect the 10X probe and the patch cord from between the CAL OUT and Triggering INPUT jacks. Set the VOLTS/DIV switch to CAL 4 DIV and the Triggering Source switch to INT.

Normal and Magnified Sweep

20. Note the CRT display. Then, set the TIME/DIV switch to 1 MILLISEC and pull the 5X MAG switch. The display should be similar to that obtained with the TIME/DIV switch set to .2 MILLISEC and the 5X MAG switch pushed in.

21. Turn the HORIZONTAL POSITION control so the display starts at about the center of the graticule. Now turn the HORIZONTAL POSITION control slowly in the opposite direction. Notice that for about 60° of rotation the trace moves slowly to the left and the control turns easily. Then, the drag on the control increases slightly and the trace begins to move much faster to the left. This control provides a combination of coarse and fine adjustment in a single control. To use the control effectively, turn it slightly past the desired point of adjustment (course adjust). Then reverse the direction of rotation and use the fine adjustment to establish the precise position. Set the TIME/DIV switch to .2 MILLISEC, push the 5X MAG switch in and return the start of the trace to the left edge of the graticule.

22. Turn the VARIABLE TIME/DIV control throughout its range. The sweep rate is reduced as the VARIABLE control is turned counterclockwise as indicated by more cycles displayed on the CRT. Return the VARIABLE control to CALIB.

External Horizontal

23. Connect the CAL OUT jack to the EXT HORIZ INPUT jack with a banana plug patch cord. Reduce the INTENSITY control setting to protect the CRT phosphor.

24. Set the TIME/DIV switch to the External Horizontal position (position with arrow to EXT HORIZ INPUT jack) and pull the 5X MAG switch. Increase the INTENSITY control setting until a display is visible (two dots displayed diagonally). The display should be four divisions vertically and about 0.5 divisions horizontally.

25. Disconnect the jumper lead from between the CAL OUT and EXT HORIZ INPUT jacks. Set the TIME/DIV switch to .2 MILLISEC and push in the 5X MAG switch.

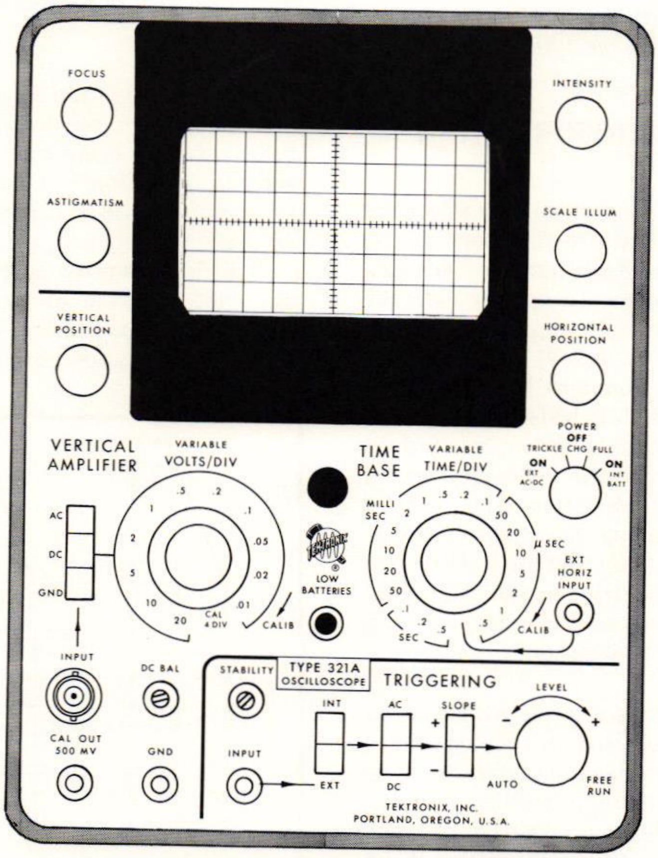
Z-Axis Input

26. If an external signal is available (10 volts peak to peak minimum) the function of the CRT GRID input (rear panel) can be demonstrated. Remove the ground bar from between the two jacks on the rear panel and connect the external signal to both the vertical INPUT connector and the CRT GRID jacks (connect the signal to the red jack and the generator ground to the black jack). Set the TIME/DIV switch to display about five cycles on the waveform (if necessary adjust the INTENSITY control to show blanking). The positive peaks of the waveform should be intensified and the negative peaks blanked, indicating intensity modulation.

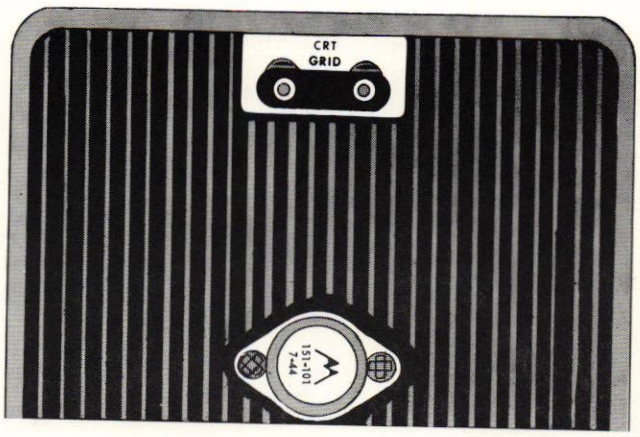
27. Disconnect the signal from the CRT GRID jack and replace the ground bar.

This completes the basic operating procedure for the Type 321A. Instrument operations not explained here, or operations which need further explanation are discussed under General Operating Information.

TYPE 321A TEST SETUP CHART



A. Front panel



B. Partial rear panel

Fig. 2-7.

TEST SETUP CHART

General

Fig. 2-7 shows the front and rear panels of the Type 321A. 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 and ASTIGMATISM controls 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 filters 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.

The Type 321A CRT uses deflection plate blanking to deflect the CRT beam off the viewing area during retrace time and when the sweep is not operating. With this type of blanking system, the CRT cathode is emitting electrons at the same rate whether a display is produced or not. The cathode current is determined entirely by the setting of the INTENSITY control. For this reason, the CRT may fail prematurely even though a display has not been presented if the INTENSITY control is left at a high setting for extended periods of time. Therefore to obtain maximum CRT life always set the INTENSITY control fully counterclockwise except when viewing the CRT.

Focus and Astigmatism Adjustment

The following procedure provides a convenient method of establishing optimum setting of the FOCUS and ASTIGMATISM controls.

1. Set the VOLTS/DIV switch to CAL 4 DIV.

2. Set the TIME/DIV switch to .2 MILLISEC and the LEVEL control to AUTO.

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

4. Set the ASTIGMATISM control so the vertical and horizontal 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 321A is scribed on the clear-plastic faceplate protector. The graticule is marked with six vertical and 10 horizontal l/4-inch divisions. In addition, each major division is divided into five major 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. Fig. 2-8 shows the graticule of the Type 321A and defines the various measurement lines. The terminology defined here is used in all discussions involving graticule measurements.

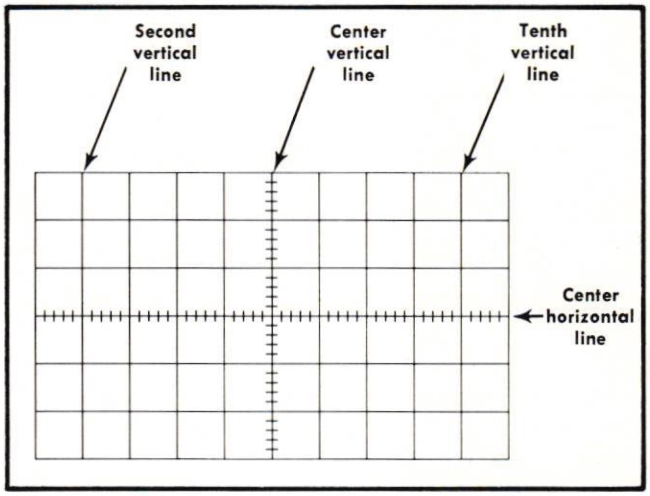


Fig. 2-8. Definition of measurement lines on Type 321A graticule.

When making waveform measurements using the graticule, be careful that errors are not introduced into the measurement due to parallax. Fig. 2-9 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 which is 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 mesh filter provided with the Type 321A provides shielding against radiated EMI (electro-magnetic interference) from the face of the CRT. It also serves as a light filter to make the trace more visible under high ambient light conditions. To remove or install the filter, take out the Phillips-head screw at the bottom of the graticule cover and remove the cover. Place the mesh filter so the

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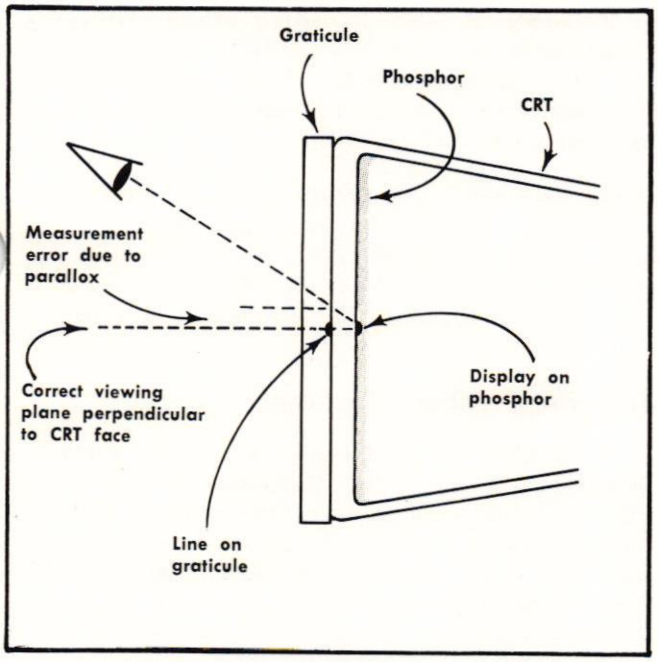

Fig. 2-9. Effect of parallax on measurement accuracy

spring clips are against the graticule and then replace the graticule cover. The graticule or a similar clear-plastic protector should always be on the instrument when the mesh filter is used to prevent scratching the face of the CRT.

The tinted light filter minimizes light reflections from the face of the CRT to improve contrast when viewing the display under high ambient light conditions. This filter mounts beneath the graticule cover in a manner similar to the mesh filter. It can be used with or without the graticule.

Scale Illumination

The illumination of the graticule lines can be varied with the SCALE ILLUM control when the instrument is connected to an AC power source. Due to the circuit-configuration necessary to provide an internal battery charger, the POWER switch does not shut off the power to the graticule lights when it is in either of the OFF positions. To turn off the graticule lights when the instrument is connected to an AC power source, turn the SCALE ILLUM control fully counterclockwise. To provide minimum power drain and maximum battery operating time, the graticule lights are inoperative when operating from either an external DC power source or the internal batteries.

Vertical Gain Check

To check the vertical gain, set the VOLTS/DIV switch to the CAL 4 DIV position and the VARIABLE VOLTS/DIV control to CALIB. The vertical deflection should be exactly four divisions. If not, see the Calibration section for adjustment procedure.

DC Balance Adjustment

To check the DC balance, set the VOLTS/DIV switch to any position except CAL 4 DIV, Input Coupling switch to GND and the LEVEL control to FREE RUN. Rotate the VARIABLE VOLTS/DIV control throughout its range. If the trace moves vertically, adjust the DC BAL adjustment as follows (allow at least 10 minutes warm up before performing this adjustment):

1. With the other controls set as for the check, set the variable control clockwise just past the CALIB detent.

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

3. Return the VARIABLE VOLTS/DIV control to the CALIB position.

4. Adjust the DC BAL adjustment to return the trace to the center horizontal line.

5. Repeat steps 1 through 4 until no trace shift occurs when the VARIABLE VOLTS/DIV control is rotated throughout its range.

Signal Connections

In general, probes offer the most convenient means of connecting a signal to the INPUT connector of the Type 321A. 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 compatability of probes for use with this system.

In applications requiring maximum overall bandwidth, use coaxial cables terminated in their characteristic impedance at the Type 321A INPUT connector. High-level, low-frequency signals can be connected directly to the Type 321A INPUT connector using short unshielded leads and the BNC to binding post adapter (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 321A 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 321A

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 INPUT connector of the Type 321A, the input impedance is about one megohm paralleled by about 41 picofarads. When the signal is coupled to the 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 both 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 accurate measurements impossible. The ground straps supplied with the probes provide an adequate ground. The shield of coaxial cables 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 321A chassis to the chassis of the equipment under test.

Input Coupling

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

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 which is much larger than the AC component.

The GND position provides a ground reference at the input of the Type 321A without the need to externally ground the INPUT connector. The signal applied to the INPUT connector is internally disconnected but not grounded and the input circuit is held at ground potential.

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 control is set to the CALIB position.

The VARIABLE VOLTS/DIV control provides variable (uncalibrated) vertical deflection factors between the calibrated settings of the VOLTS/DIV switch. The VARIABLE control extends the maximum vertical deflection factor of the Type 321A to at least 50 volts/division (20 volts position).

Triggering Stability Adjustment

The STABILITY adjustment is normally adjusted during instrument calibration (see Calibration Procedure) and should not need readjustment during normal use. However, the following procedure can be used to set the STABILITY adjustment if the Type 321A cannot be triggered correctly. Before readjusting the STABILITY adjustment, be sure the triggering controls are correctly set and the applied trigger signal is within the required limits.

1. Set the VOLTS/DIV switch to any position except CAL 4 DIV.

2. Set the TIME/DIV switch to .1 MILLISEC.

3. Set the LEVEL control to the AUTO detent.

4. Turn the STABILITY adjustment fully counterclockwise.

5. Slowly turn the STABILITY adjustment clockwise until the trace first appears. Note the position of the STABILITY adjustment.

6. Continue to slowly turn the STABILITY adjustment clockwise until the trace brightens. Again note the position of the STABILITY adjustment.

7. Set the Stability adjustment half way between the point where the trace first appeared in part 5 and where the trace brightened in part 6.

Trigger Source

INT. For most applications, the sweep can be triggered internally. In the INT position of the Triggering Source 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 Triggering INPUT jack can be used to trigger the sweep in the EXT position of the Triggering Source 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 triggered 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 Triggering INPUT jack. Then the sweep is triggered by the same signal at all times and allows amplitude, time relationship or waveshape changes of signals at various points in the circuit to be examined without resetting the trigger controls.

Trigger Coupling

AC. In the AC position of the Triggering Coupling switch, the DC component of the trigger signal is blocked. Signals with low-frequency components below about 600 hertz are attenuated in the INT position of the Source switch or below about 30 hertz in the EXT position. 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 Triggering Coupling 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 would 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 LEVEL control. When using the internal trigger source, the setting of the VERTICAL POSITION control affects the DC triggering point.

Trigger Slope

The Triggering SLOPE switch determines whether the trigger circuit responds on the positive-going or negative-going portion of the trigger signal. When the SLOPE switch is in the + (positive-going) position, the trigger circuits respond to the positive-going portion of the triggering waveform; in the – (negative-going) position, the trigger circuits respond to the negative-going portion of the triggering waveform (see Fig. 2-10). 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 setting of the SLOPE switch is often unimportant. However, if only a certain portion of a cycle is to be displayed, correct setting of the SLOPE switch is important to provide a display of the desired portion of the input signal.

Trigger Level

The Triggering LEVEL control determines the voltage level on the triggering waveform at which the sweep is triggered when set to the variable region between the AUTO and FREE RUN detents. When the 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. 2-10 illustrates this effect with different settings of the SLOPE switch.

To set the LEVEL control, first select the Triggering source, coupling and slope. Then rotate the LEVEL control fully counterclockwise to the AUTO position (operation in the AUTO position is discussed below). Now turn the LEVEL control 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. In the extreme clockwise position, the sweep free runs.

Trigger Mode

Automatic Triggering. Automatic triggering is obtained by rotating the Triggering LEVEL control fully counterclockwise to the AUTO position. 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 above 50 hertz.

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

Normal Triggering. When the LEVEL control is in the variable region between the AUTO and FREE RUN detents, the display can be triggered at the desired level by correct adjustment of the LEVEL control. When a trigger signal is not present, there is no display. Use the normal triggering mode to display signals with repetition rates below about 50 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.

Free Running. When the Triggering LEVEL control is turned fully clockwise, the sweep free runs independent of any trigger signal. One difference between the free running traces produced in the AUTO and FREE RUN positions is the repetition rate. The repetition rate in the FREE RUN position is dependent upon the setting of the TIME/DIV switch and the trace appears at essentially the same intensity at all sweep rates. The repetition rate in the AUTO position is fixed at about 50 hertz and will therefore produce a dim trace at the fastest sweep rate.

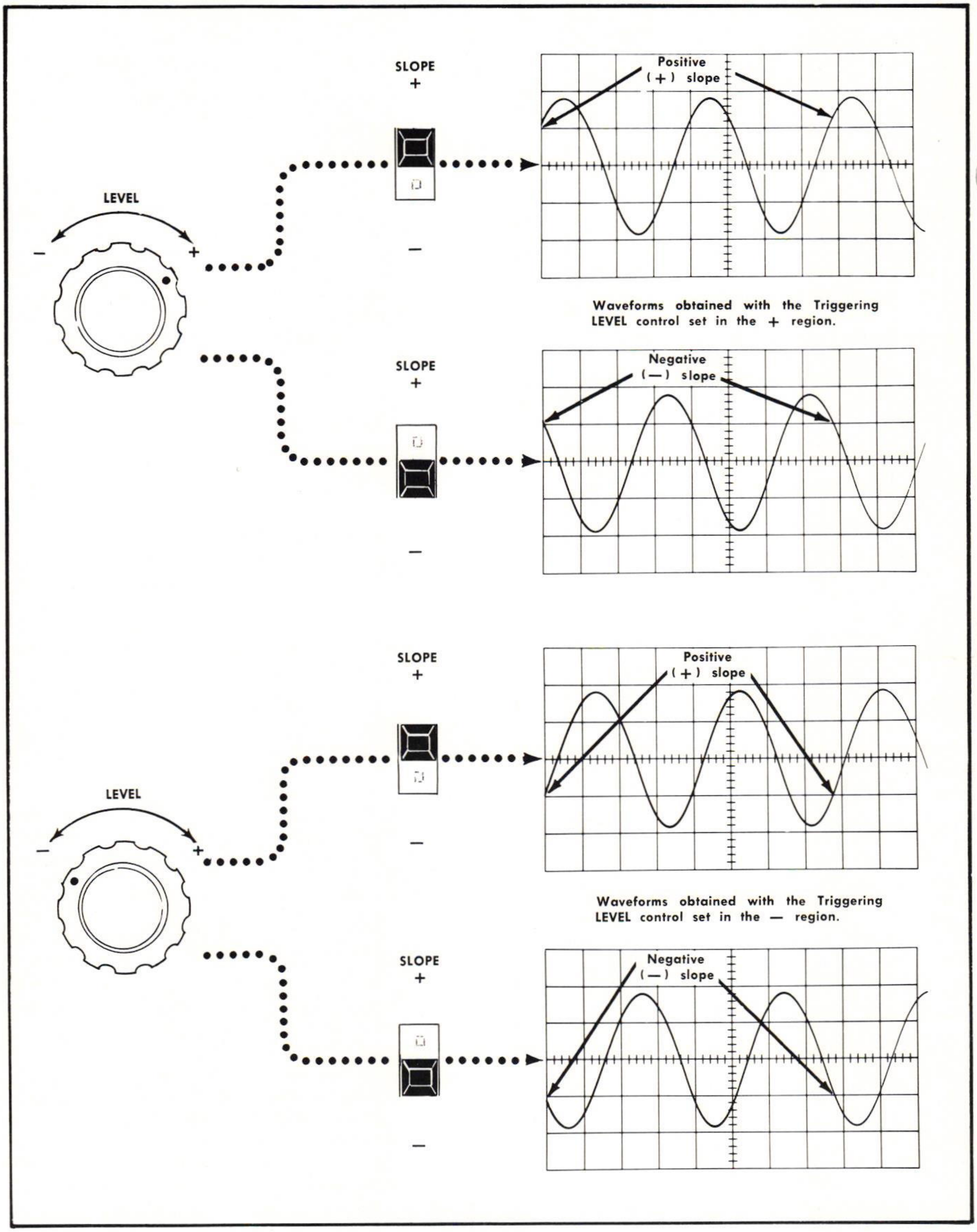

Fig. 2-10. Effect of the Triggering LEVEL control and SLOPE switch on the CRT display.

Horizontal Sweep Rate

The TIME/DIV switch provides 19 calibrated sweep rates ranging from 0.5 microsecond to 0.5 second/division. The VARIABLE TIME/DIV control provides continuously variable sweep rates between the settings of the TIME/DIV switch. The calibrated sweep rate selected by the TIME/DIV switch applies only when the VARIABLE TIME/DIV control is set fully clockwise to CALIB.

When making time measurements from the graticule, the area between the second- and tenth-vertical lines provides the most linear time measurement (see Fig. 2-11). Therefore, the first and last division of the display should not be used when making accurate time measurements.

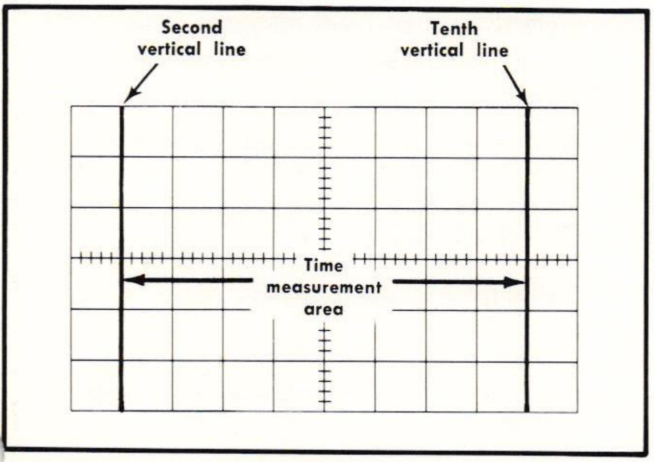

Fig. 2-11. Area of graticule used for accurate time measurements.

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. 2-12). 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 pull the 5X MAG switch. Now, adjust the dual-range HORIZONTAL POSITION control for precise positioning of the magnified portion (see Horizontal Position Control discussion which follows for operation of HORIZONTAL POSITION control). When the 5X MAG switch is pulled out, 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 5X MAG switch is pulled out. The magnified sweep rate is calibrated when the VARIABLE TIME/DIV control is set fully clockwise to the CALIB position.

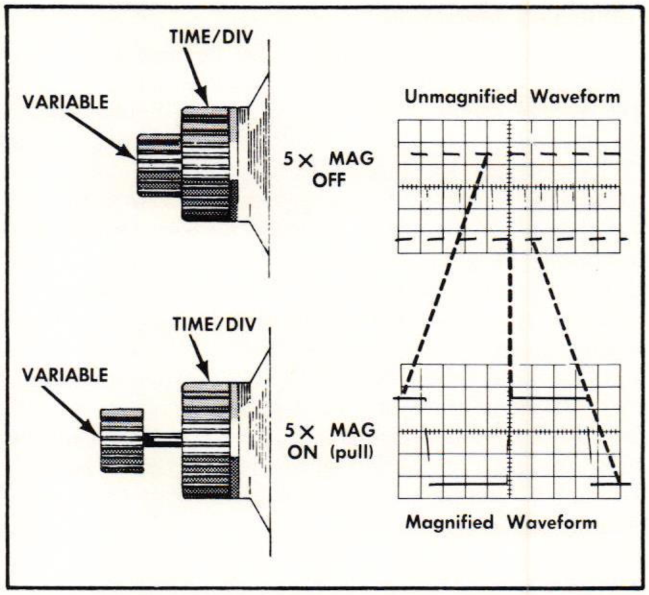

Fig. 2-12. Operation of the sweep magnifier.

Horizontal Position Controls

The dual-range HORIZONTAL POSITION control used in the Type 321A provides a combination of coarse and fine adjustment in a single control. When this control is rotated, fine positioning is provided for a range of about 60° and the trace can be positioned precisely. Then, after the fine range is exceeded, the coarse adjustment comes into effect to provide rapid positioning of the trace. To use this control effectively for precise positioning, first turn the control to move the trace slightly beyond the desired position (coarse range). Then reverse the direction of rotation to use the fine range to establish the precise trace position desired.

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 jack. Set the TIME/DIV switch to the External Horizontal position (position with arrow from EXT HORIZ INPUT jack). The external horizontal deflection factor is about one volt/division with the 5X MAG switch pulled out and about five volts/division with the 5X MAG switch pushed in. The signal applied to the EXT HORIZ INPUT jack is inverted when displayed on the CRT. Also, the X and Y channels of this instrument are not time matched and some inherent phase shift is apparent. 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 GRID jacks 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 negative-going signals completely blank portions of the display and positive-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 on the setting of the INTENSITY control. At normal intensity level, a five volt peak-to-peak signal provides intensity modulation. When the CRT GRID jacks are not in use, keep the ground bar in place to prevent changes in trace intensity due to extraneous noise.

Time markers applied to the CRT GRID jacks 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 unstable.

Calibrator

The square-wave calibrator of the Type 321A provides a convenient signal source for checking vertical gain. This signal is internally connected to the vertical amplifier when the VOLTS/DIV switch is set to the CAL 4 DIV position. The calibrator output signal available at the CAL OUT jack on the front panel is very useful for adjusting probe compensation as described in the probe instruction manuals. In addition, the calibrator provides 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 321A Oscilloscope. These applications are not described in detail since each application 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, Cleaver-Hume Press Ltd., London, 1960.

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, "Practical 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.

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. 2-13).

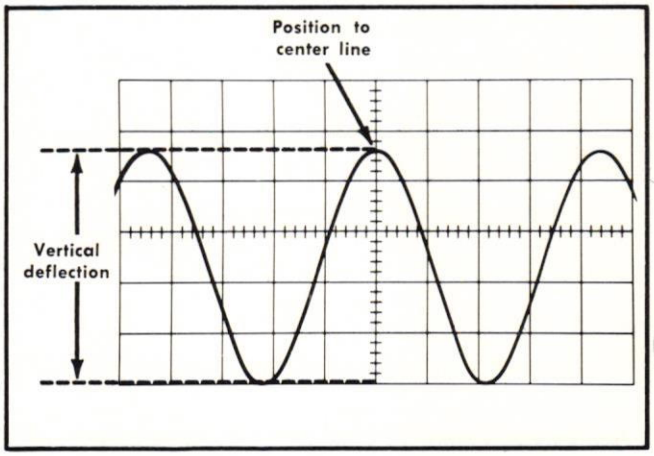

Fig. 2-13. Measuring peak-to-peak voltage of a waveform.

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6. Measure the divisions of vertical deflection from peak to peak. Make sure the VARIABLE VOLTS/DIV control is in the CALIB 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. 2-13) using a 10X attenuator probe and a VOLTS/DIV switch setting of .5.

Using the formula:

Volts Peak to Peak = vertical deflection (divisions) X VOLTS/DIV setting X 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. 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 GND.

4. Set the LEVEL control to AUTO.

5. 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 rather than ground, make the following changes in step 6: Set the Input Coupling switch to DC and apply the reference voltage to the INPUT connector, then position the trace to the reference line.

6. Set the Input Coupling switch to DC. The ground reference line can be checked at any time by switching to the GND position (except when using a DC reference voltage).

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

8. 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. 2-14 the measurement is made between the reference line and point A.

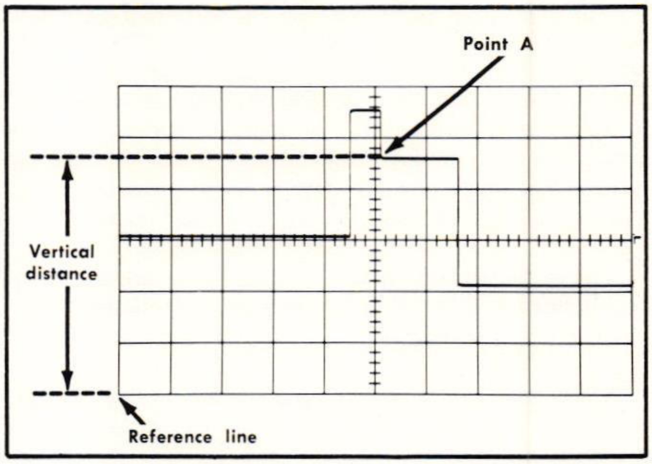

Fig. 2-14. Measuring instantaneous DC voltage with respect to a reference voltage.

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

10. Multiply the distance measured in step 8 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. 2-14), the waveform is above the reference line, using a 10X attenuator probe and a VOLTS/DIV switch setting of 2.

Using the formula:

Instantaneous Voltage = vertical distance (divisions) X polarity X VOLTS/DIV setting X probe attenuation factor

Substituting the given values:

Instantaneous Voltage = 4.6 X +1 X 2 V X 10

The instantaneous voltage is +92 volts.

Comparison Measurements

In some applications it may be desireable 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. Although 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, proceed 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:

Repetition Rate =

TIME/DIV switch setting X horizontal conversion factor X 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 mSEC 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 μSEC, 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 recipricol 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 controls 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. 2-15). (See the topic entitled Horizontal Sweep Rate in this section concerning non-linearity of first and last divisions of display.)

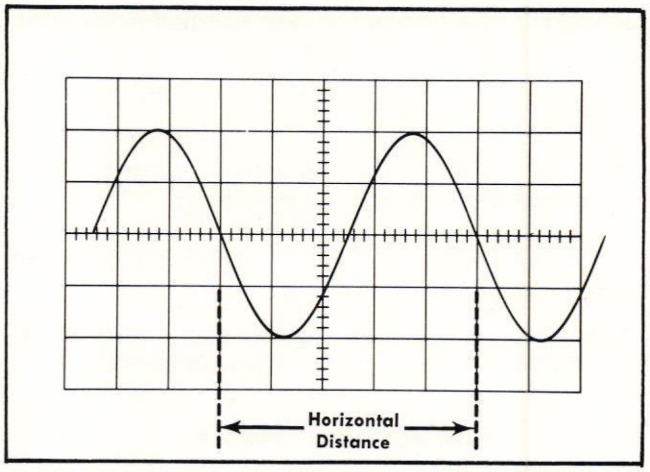

Fig. 2-15. Measuring the time duration between points on a waveform.

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 CALIB.

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. 2-15) and the TIME/DIV switch is set to .1 mSEC with the magnifier off.

Using the formula:

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

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 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. 2-15 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 basically 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 display 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 of the rising portion of the waveform. The figures given in Table 2-3 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 2-3

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

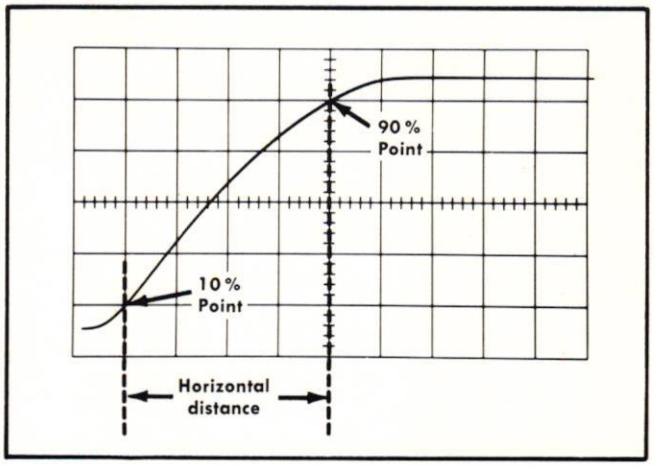

Fig. 2-16. Measuring risetime.

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. 2-16, 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 CALIB.

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. 2-16) and the TIME/DIV switch is set to .5 μSEC with the MAG switch pulled out.

Applying the time duration formula to risetime:

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

Substituting the given values:

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

The risetime is 0.4 microseconds.

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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 321A Oscilloscope. The description begins with a discussion of the instrument using a basic block diagram. Each circuit is then 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 rear of this manual. This block diagram shows the overall relationship between all of the circuits in this instrument. 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 DIAGRAMS

General

The following discussion is provided to aid in understanding the overall concept of the Type 321A before the individual circuits are discussed in detail. A basic block diagram of the Type 321A 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. The number of each block refers to the complete circuit diagram which is located at the rear of this manual.

Signals to be displayed on the CRT are applied to the vertical INPUT connector. The signal is amplified by the Vertical Amplifier circuit and converted to a push-pull signal to drive the vertical deflection plates of the CRT. This circuit contains vertical deflection factor, vertical position, input coupling, variable attenuation, gain and balance 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 Calibrator circuit produces a square-wave output with accurate amplitude which can be used to check the gain of the vertical system or to compensate attenuator probes. In the CAL 4 Div position of the VOLTS/DIV switch, the Calibrator signal is internally connected to the Vertical Amplifier circuit. If the internal Gain adjustment of the Vertical Amplifier is correctly set, a display exactly four divisions in amplitude is presented. The Calibrator output signal is also available at the CAL OUT 500 mV jack on the front panel.

The Time-Base Trigger circuit produces an output pulse which initiates the sweep signal produced by the Time-Base Generator circuit. The input signal to the Time-Base Trigger circuit can be selected from the internal trigger signal from the Vertical Amplifier circuit or an external signal connected to the Triggering INPUT jack. The Time-Base Trigger circuit contains level, slope, coupling, source and mode controls to select the desired triggering.

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

The sawtooth output signal from the Time-Base Generator circuit is connected to the Horizontal Amplifier circuit in all positions of the TIME/DIV switch except the External Horizontal position (position with arrow from EXT HORIZ INPUT jack). In the External Horizontal position, external signals 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 5X magnifier circuit. When the 5X MAG switch is pulled out the gain of the Horizontal Amplifier circuit is increased five times to produce a sweep which is five times faster than that indicated by the TIME/DIV switch or a five-times increase in external horizontal deflection sensitivity for external horizontal mode operation.

The CRT Circuit contains the controls necessary for operation of the cathode-ray tube. The CRT GRID jack allows signals to be connected to the control grid of the CRT to provide intensity modulation of the display.

The Regulator Circuit provides a regulated 10-volt output to the Converter circuit This regulated output voltage is produced from an external AC or DC voltage connected to this instrument or from internal batteries. The Regulator Circuit also contains a battery charging circuit for use when rechargeable internal batteries are used. The Converter circuit produces the power necessary for the operation of this instrument. This circuit produces the positive and negative accelerating potential for the CRT as well as the low-voltage power for all of the circuits.

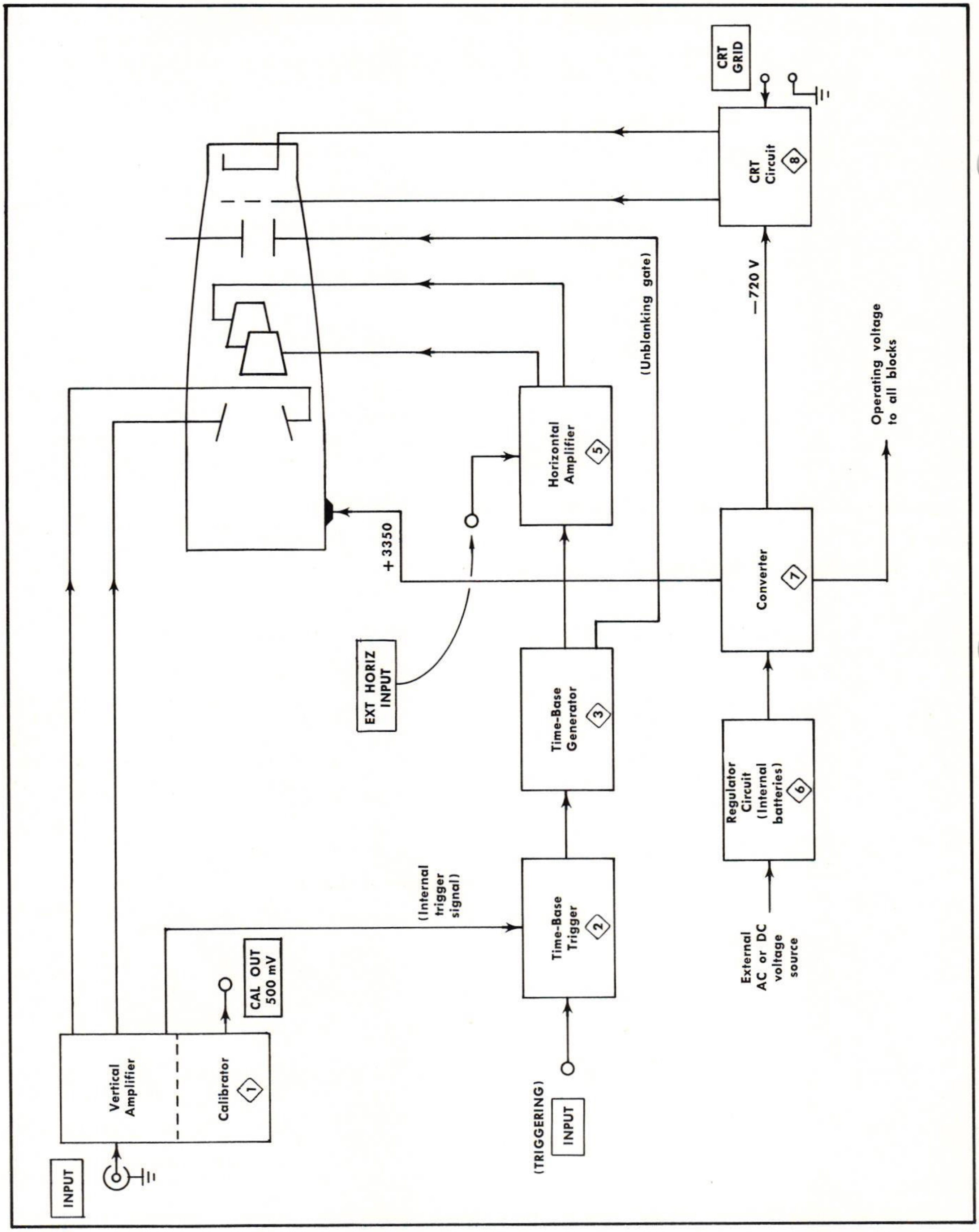


Fig. 3-1. Basic block diagram of the Type 321A Oscilloscope.

CIRCUIT OPERATION

General

This section describes the electrical operation and relationship of the circuits in the Type 321A. The theory of operation for circuits which are unique to this instrument are described in detail in this discussion. Circuits which are commonly used in the electronics industry are not described in detail. Instead, references are given to textbooks or other source material which describe the complete operation of these circuits.

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 of this manual.

VERTICAL AMPLIFIER and CALIBRATOR

General

Input signals for vertical deflection on the CRT can be connected to the Vertical Amplifier INPUT connector. This circuit provides control of input coupling, vertical deflection factor, DC balance, vertical position and vertical gain. The Trigger Pickoff stage provides a sample of the applied signal to the Time-Base Trigger circuit for internal triggering. This circuit also contains the Calibrator circuit. The Calibrator circuit produces a square-wave output with accurate amplitude. This output is available at the CAL OUT 500 mV jack on the front panel or it is internally connected to the Vertical Amplifier in the CAL 4 DIV position of the VOLTS/DIV switch. Fig. 3-2 shows a detailed block diagram of the Vertical Amplifier and Calibrator circuit. A schematic of this circuit is shown on diagram I at the rear of this manual.

Input Coupling

Input signals connected to the vertical INPUT connector can be AC coupled, DC coupled or internally disconnected. When Input Coupling switch SW401 is in the DC position, the input signal is coupled directly to the Input Attenuator stage. In the AC position, the input signal is connected to capacitor C401. This capacitor prevents the DC component of the input signal from passing to the Vertical Amplifier. The GND position opens the signal path and connects the input circuit of the amplifier to ground. This provides a ground reference without the need to disconnect the applied signal from the INPUT connector.

Input Attenuator

The effective overall vertical deflection factor of the Type 321A is determined by the VOLTS/DIV switch. In all positions of the VOLTS/DIV switch, the basic deflection factor of the Vertical Amplifier is 0.01 volt per division of CRT deflection. To increase this basic deflection factor to the values indicated on the front panel, precision attenuators are switched into the circuit by the VOLTS/DIV switch, SW410. These attenuators are switched into the circuit singly or in pairs to produce the vertical deflection factor indicated on the front panel. The 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 descreases 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 this instrument, the Input Attenuator is designed to maintain the same input RC characteristics (one megohm X about 35 pF) for each position of the VOLTS/DIV switch.

Input Stage

The signal from the Input Attenuator stage is connected to the Input Stage through the network C422-C423-R422-R423-R424. R422 establishes the input resistance of this stage and is a part of the attenuation network at all VOLTS/DIV switch positions. R423 limits the current drive to the Input Stage.

FET (field-effect transistor) Q423A is connected as a source follower to provide a high input impedance for the applied signal with a low-impedance drive to the following stage. Diodes D423 and D424 protect Q423A by limiting the peak-to-peak voltage swing at its gate to about 1.2 volts. FET Q423B is a constant current source for Q423A and also provides temperature compensation for Q423A. The signal at the source of Q423A is connected to the next stage through C426 and R426.

Paraphase Amplifier

The signal from the Input Stage is coupled to the base of paraphase amplifier Q464-Q474 through emitter follower Q443. This emitter follower provides a very low impedance drive to Q464 (about 20 ohms). Q464 and Q474 are connected as a common-emitter phase inverter (paraphase amplifier)[1] 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 base of Q464 is increasing. This produces a corresponding decrease in current through Q464 and its collector voltage goes negative toward the collector supply voltage. At the same time, the emitter of Q464 goes positive and this change is connected to the emitter of Q474 through R464, R466 and R468. As far as signal changes are concerned, Q474 is connected as a

[1] **Lloyd P. Hunter (ed.) "Handbook of Semiconductor Electronics", second edition, McGraw-Hill, New York, pp. 11-94.**

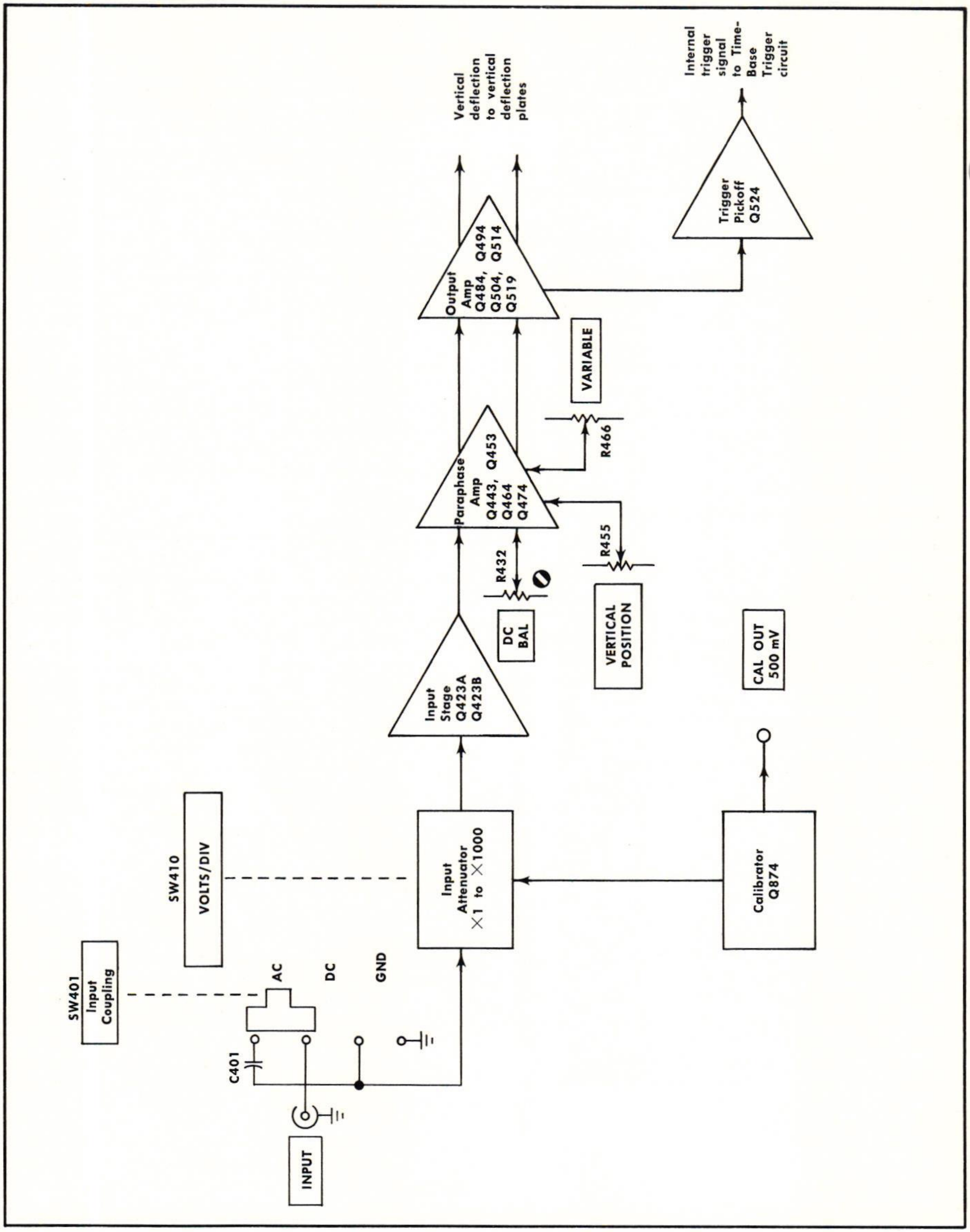


Fig. 3-2. Vertical Amplifier and Calibrator detailed block diagram.

grounded base stage so that it operates as the emitter-driven section of the paraphase amplifier. The positive-going signal connected to the emitter of Q474 forward biases Q474 and its collector voltage goes positive by about the same amount that the collector of Q464 went negative. Thus the single-ended signal at the base of Q464 has been amplified and is available as a push-pull signal at the collectors of Q464 and Q474. This output signal is connected to the Output Amplifier stage through C462-R462 and C472-R472.

Gain of this stage is determined by the emitter degeneration. As the resistance between the emitters of Q464 and Q474 increase, emitter degeneration increases to result in less gain through the stage. Vert Gain adjustment R468 varies the resistance between the emitters of Q464-Q474 to control the overall gain of the Vertical Amplifier. VARIABLE control R466 also varies the resistance between the emitters of Q464-Q474 to provide continuously variable deflection factors between the calibrated settings of the VOLTS/DIV switch.

The VERTICAL POSITION control R455 varies the DC emitter current of Q464 and Q474, although this produces only a small voltage change at the emitters of Q464 and Q474, it produces a voltage change at the collectors which establishes the position of the display of the CRT. DC BAL adjustment R432 sets the base level of Q474 through emitter follower Q453. This adjustment is set to establish the same DC voltage level at the emitter of Q474 as at the emitter of Q464. Since the emitters of Q464 and Q474 are at the same DC voltage level, there is no current flow through VARIABLE control R466. This configuration prevents the DC level of the display from shifting when the VARIABLE control is rotated.

Output Amplifier

The Output Amplifier stage consists of two individual push-pull amplifier stages. The first stage of amplification, Q484-Q494, has collector to base feedback provided by R482 and R492. This negative feedback provides linear amplification from this stage. The signal at the collectors of Q484 and Q494 is connected to the bases of Q504 and Q514. Q504-Q514 provide the final amplification to the vertical deflection signal before it is connected to the vertical deflection plates of the CRT. The network C504-C506-C507-C508-R504-R505-R506 provides high-frequency compensation for this stage. Capacitor C506 is adjustable to provide optimum high-frequency response of the displayed waveform. Transistor Q519 provides a constant emitter-current source for Q504-Q514. This constant current is connected to the junction of R509-R511. The output signal at the collector of Q504 is connected to the lower vertical deflection plate of the CRT and the signal at the collector of Q514 is connected to the upper vertical deflection plate.

Trigger Pickoff

The signal at the collector of Q514 in the Output Amplifier stage is connected to the Trigger Pickoff stage, Q524, through divider R520-R521. This sample of the vertical signal provides internal triggering from the signal displayed on the CRT. Q524 is connected as an emitter follower to provide isolation between the Vertical Amplifier circuit and the Time-Base Trigger circuit. It also provides a minimum load for the Output Amplifier stage while providing a low output impedance to the Time-Base Trigger circuit. Output from this stage is connected to the Time-Base Trigger circuit through Triggering Source switch SW2.

Calibrator

The Calibrator circuit produces a square-wave output voltage with accurate amplitude for setting the basic gain of the Vertical Amplifier or for compensation of attenuator probes. Frequency of the Calibrator output signal is about two kilohertz.

The Calibrator circuit consists of a grounded emitter amplifier which is overdriven by a signal from the Converter circuit. The drive signal for the Calibrator circuit is a 100-volt, two-kilohertz signal from terminal 10 of transformer T701 (see Converter circuit, diagram 7). This signal is applied to the base of Q874 through the networks C707-R707 (Converter circuit) and C871-R871. These networks shape the driving signal to provide a fast leading edge for the calibrator output signal. When the drive signal from T701 is more negative than about +0.5 volts, Q874 is reverse biased and its collector rises positive toward the +10-volt supply through R881. Zener diode D881 clamps the collector of Q874 at about +5.1 volts.

When the drive signal to Q874 goes positive above about +0.5 volts, Q874 is forward biased. Q874 is overdriven by the large signal at its base and it quickly goes into saturation. The collector of Q874 drops negative to about the emitter level (near zero volts). This produces the negative portion of the output square wave. Diode D882 is reverse biased by the collector level of Q874 to disconnect all voltage to the output. Therefore the negative portion of the output square wave drops to zero volts.

The output level is determined by voltage divider R882-R884-R886-R888 between the collector of Q874 and ground. The voltage level at the junction of R884-R886 is connected to the CAL OUT 500 mV jack on the front panel. The Cal Ampl adjustment R884 is set to provide an accurate 500 millivolt peak-to-peak square wave output level at this jack. The voltage level at the junction of R886-R888 is internally connected to the Vertical Amplifier in the CAL 4 DIV position of the VOLTS/DIV switch to provide a quick check of the basic Vertical Amplifier gain. The amplitude of this internal calibrator signal is 40-millivolts peak to peak.

TIME-BASE TRIGGER

General

The Time-Base Trigger circuit produces trigger pulses to start the Time-Base Generator circuit. These trigger pulses are derived either from the internal trigger signal from the

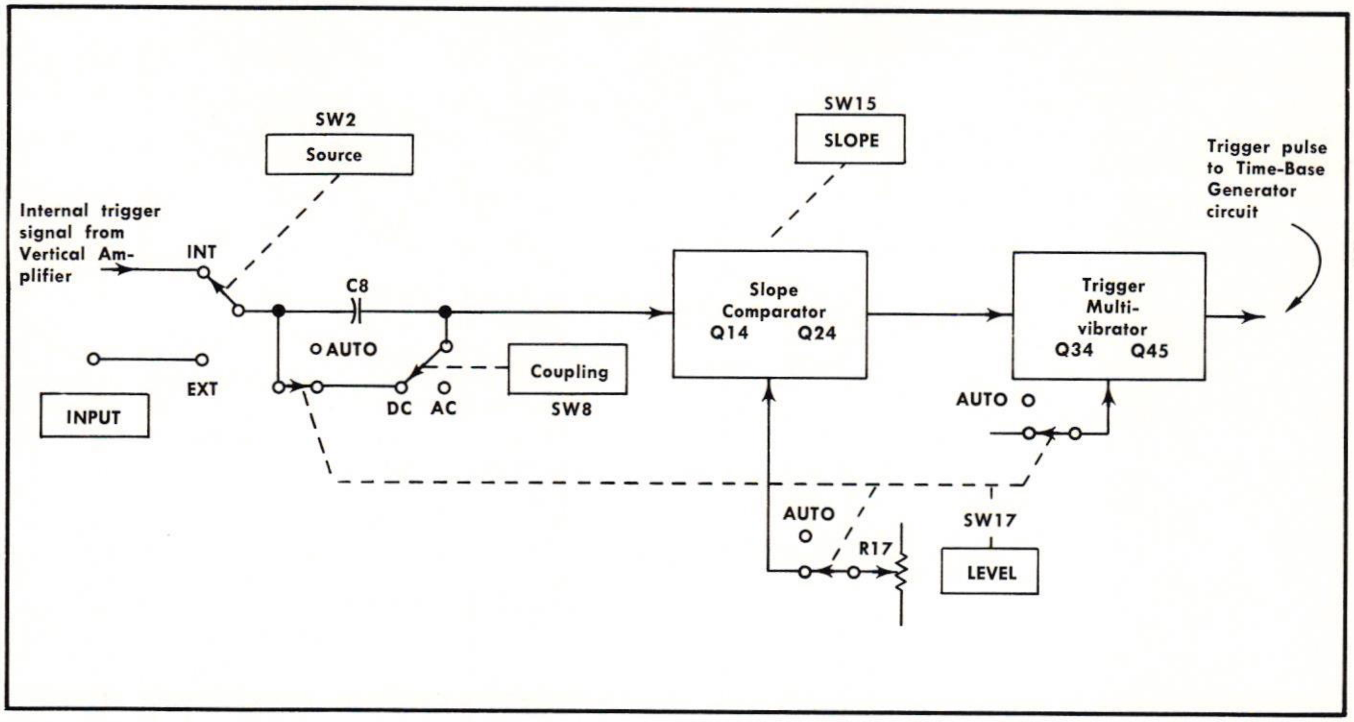


Fig. 3-3. Time Base Trigger detailed block diagram.

Vertical Amplifier circuit or an external signal connected to the Triggering INPUT jack. Controls are provided in this circuit to select trigger level, slope, coupling, source and mode. Fig. 3-3 shows a detailed block diagram of the Time-Base Trigger circuit. A schematic of this circuit is shown on diagram 2 at the rear of this manual.

Triggering Source switch SW2 selects the source of the trigger signal. Two trigger sources are available; internal and external. 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 Triggering INPUT jack can be used to produce a trigger in the EXT position of the source switch. Input resistance (DC) is about 90 kilohms as established by R2-R14-R15. C2 compensates for stray capacitance to provide good high-frequency response.

Trigger Coupling

The Triggering Coupling switch, SW8, allows selection of the portion of the trigger signal from which the trigger pulse is derived. In the DC position of the Coupling switch, SW8 bypasses capacitor C8 and the trigger signal is coupled directly to the Slope Comparator stage. This position provides equal coupling for all trigger signals from DC to six megahertz. When the Coupling switch is set to the AC position, SW8 is open and the trigger signal must pass through C8. This capacitor blocks the DC component of the trigger signal and attenuates AC signals below about 600 hertz in the INT Source switch position or 16 hertz in the EXT Source switch position.

When the Triggering LEVEL control is turned fully counterclockwise to the AUTO position, SW17 (ganged with the LEVEL control) opens the DC bypass around C8. All trigger signals must pass through this capacitor in the AUTO trigger mode so that only AC trigger coupling is provided in this mode.

Slope Comparator

Transistors Q14 and Q24 are connected as a difference amplifier (comparator)[2] 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 collector of Q24 and the sweep is started from the positive-going portion of the signal at this point. To provide selection of the trigger slope, SLOPE switch SW15 connects the trigger signal to the base of Q14 for positive-slope triggering or to the base of Q24 for negative-slope triggering. Circuit operation is as follows:

For positive-slope triggering, the trigger signal is applied to the base of Q14 and a reference voltage from LEVEL control R17, is connected to the base of Q24 through R19. R23 establishes the emitter current of Q14 and Q24. Capacitor C23, connected across R23, improves response of this circuit at high frequencies. In this configuration, the transistor with the most negative base controls conduction of the comparator. For example, with a positive-going trigger signal, Q14 conducts until its base is raised more positive than the base of Q24. Then Q14 is reverse biased and the decreased current flow through R23 produces a smaller volt-

[2]Phillip Cutler, "Semiconductor Circuit Analysis", McGraw-Hill, New York, pp. 365-372.

A

age drop and the emitter of both Q14 and Q24 go more positive. A more positive voltage at the emitter of Q24 forward biases this transistor, since its base is held at the voltage set by the LEVEL control. The collector current of Q24 increases to produce a positive-going output signal from this stage. Notice that the output signal from this stage is in phase with the input signal. Therefore, the sweep is started on the positive-going portion of the trigger input signal (waveform displayed 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).

LEVEL control R17 sets the base level of Q24 for positive slope triggering. This in turn determines the level on the trigger signal at which the comparator switches. With the LEVEL control set near midrange and a positive-going signal applied, Q14 conducts until the applied trigger signal raises the base of Q14 more positive than the base of Q24 (transistor with most negative base always controls conduction of the comparator). Q14 is then reverse biased to produce a positive-going output at the collector of Q24 as discussed previously. Q14 remains off and Q24 conducts until the applied trigger signal drops the voltage at the base of Q14 more negative than the base of Q24. Then the circuit returns to the original condition. Now, assume that the LEVEL control is turned clockwise to produce a display which starts at a more positive level. A more positive level is established at the base of Q24 by the LEVEL control. The trigger signal must now rise more positive before the base of Q14 is more positive than the base of Q24. Then Q14 is reverse biased to produce the positive-going output from this stage. The resultant CRT display starts at a more positive point on the displayed signal since the sweep is started later. When the 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, SLOPE switch SW15 reverses the connections to the bases of Q14 and Q24. Now the trigger signal is connected to the base of Q24 and the reference level from the LEVEL control is connected to the base of Q14. The LEVEL control establishes the point at which the comparator switches as discussed for positive-slope triggering. Assume that Q24 is conducting with a positive-going signal applied. As the base of Q24 goes more positive than the level established at the base of Q14 by the LEVEL control, Q24 is reverse biased. The collector current of Q24 decreases to produce a negative-going change at its collector. Note that this signal is 180° out of phase with the applied trigger signal. The sweep is always started on the positive-going portion of the signal at the output of this stage. Therefore, since there is 180° phase shift through the Slope Comparator stage for – slope triggering, the sweep is triggered on the negative-going slope of the trigger input signal.

In the AUTO (fully counterclockwise) position of the Triggering LEVEL control, SW17 (ganged with the LEVEL control) disconnects LEVEL control R17 from the circuit. In this triggering mode, the triggering level is set very near the zero-volt level by R20.

Trigger Multivibrator

LEVEL Control in Variable Range. The output from the Slope Comparator stage is connected to the Trigger Multivibrator stage, Q35 and Q45. These transistors are connected as a Schmitt bistable multivibrator[3] when the LEVEL control is in the variable range. To understand the operation of this circuit, assume that the LEVEL control is set near midrange, SLOPE switch set to + and the circuit is ready to receive a trigger signal. These conditions produce a negative output level from the Slope Comparator stage (see Slope Comparator discussion) which reverse biases Q35. When Q35 is off, its collector rises positive toward the collector supply voltage (ground level). The quiescent level on the collector is determined by voltage divider R35-R37-R38 between ground and –10 volts. This divider also sets the quiescent level at the base of Q45 positive enough so that Q45 is forward biased. The collector of Q45 goes negative to establish an output level of about +3 volts at the junction of C43-R32-R43.

When a trigger signal applied to the Time-Base Trigger circuit produces a positive-going output from the Slope Comparator stage, Q35 is forward biased. The collector of Q35 goes negative and the voltage at the base of Q45 is also pulled negative through divider R37-R38. At the same time, the emitters of both Q35 and Q45 rise positive, following the positive voltage at the base of Q35. The result is that Q45 is quickly cut off and its collector rises positive toward the supply voltage through C43-R32-R43. Capacitors C37 and C43 improve the response of this circuit to fast changes to produce an output signal with a fast rise. This positive-going transition at the junction of C43-R32-R43 is connected to the Time-Base Generator circuit through C131 to start the sweep. The circuit remains in the condition just described until the output from the Slope Comparator stage drops negative and Q35 is reverse biased. Then the base of Q45 rises positive and Q45 turns on. The output level from this stage drops negative to the quiescent level of about +3 volts.

LEVEL Control in AUTO Position. When the LEVEL control is in the AUTO position (fully counterclockwise), SW17 (ganged with LEVEL control) disconnects the –10 volt level from the divider R35-R37-R38. R34 is connected to this divider and the negative level for the divider is now –45 volts. The charge rate of C30 also affects the base level of Q45. In the AUTO triggering mode, the Trigger Multivibrator stage 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 50 hertz, the Trigger Multivibrator stage operates as an astable multivibrator[4] 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 Q35 has just turned off. When Q35 is off Q45 is

[3] Jacob Millman and Herbert Taub, "Pulse, Digital and Switching Waveforms", McGraw-Hill, New York, pp. 389-394.

[4] Millman and Taub, pp. 438-451.

on and its collector drops negative. This places less voltage across divider R33-R34 and the voltage at the junction of R33 and R34 starts to go negative at the charge rate of C30. This voltage is connected to the base of Q45 through R38 to produce a similar negative going change at the emitter of Q45. Since the emitters of Q35 and Q45 are connected together, the emitter of Q35 goes negative also at the rate determined by the charge rate of C30. The base level of Q35 is at about −10 volts since Q24 is off when there is no trigger signal applied in the AUTO mode. The emitter of Q35 continues to go negative with the charging of C30 until it drops negative enough to forward bias Q35 (charge time of C30 is about 10 milliseconds). Then Q35 comes on and its collector drops negative. The base of Q45 goes negative also as determined by divider R37-R38 between the collector of Q35 and the junction of C30-R33-R34. Q45 is reverse biased and its collector goes positive to produce a trigger pulse for the Time-Base Generator circuit. Now there is more voltage across divider R33-R34 and the voltage at the junction of R33 and R34 goes positive at the discharge rate of C30. As C30 discharges, the negative voltage to the divider R37-R38 slowly rises more positive and the base of Q45 rises positive also until Q45 is forward biased (discharge time of C30 is about 10 milliseconds). Then Q45 turns on and its emitter rises positive to reverse bias Q35 by way of the common-emitter connection. Now the cycle begins again as C30 starts to recharge. As long as the instrument is in the AUTO mode and there is no trigger signal applied or the trigger signal repetition rate is too low, the Trigger Multivibrator stage free runs at a 50 hertz rate to automatically retrigger the sweep and provide a reference trace (do not confuse this free running operation with the FREE RUN position of the LEVEL control which is described in the Time-Base Generator discussion).

Whenever a trigger signal with a repetition rate higher than about 50 hertz is applied to the base of Q35, the Trigger Multivibrator stage operates in much the same manner as described with the LEVEL control in the variable region. 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 50 hertz is such that C30 does not charge or discharge enough to affect the base level of Q45. The voltage drop across R34 under triggered conditions is such that divider R35-R37-R38 is connected between about the same voltages as when the LEVEL control is in the variable region.

TIME-BASE GENERATOR

General

The Time-Base 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 Time-Base Trigger circuit when the LEVEL control is in any position except FREE RUN. When the LEVEL control is set fully clockwise to FREE RUN, the sweep free-runs at the sweep rate selected by the TIME/DIV switch. The Time-Base Generator circuit also produces an unblanking gate to unblank the CRT during sweep time. Fig. 3-4 shows a detailed block diagram of the Time-Base Generator circuit. A schematic of this circuit is shown in diagram 3 at the rear of this manual.

Sweep Gate Multivibrator

The trigger pulse from the Time-Base Trigger circuit is applied to the Time-Base Generator circuit through C131. The trigger pulse applied to C131 is a fast-rise square wave with the repetition rate and duty cycle determined by the Trigger Multivibrator stage. C131 differentiates this square wave to produce positive and negative going pulses which are very fast (trigger pulses at base of Q135 are difficult to see at normal test oscilloscope intensity; it may be necessary to increase the test oscilloscope intensity when viewing this waveform). The negative-going pulses produced from the trigger square wave are shunted by D131 to prevent them from turning off Q135 during sweep time. Q135 and Q145 are connected as a Schmitt bistable multivibrator. Quiescently, Q135 is off and Q145 is conducting. This produces a negative level at the collector of Q145 which forward biases D149 and D150. The function of these diodes is discussed under Disconnect Circuit. The collector current of Q145 flows through divider R147-R148. Diode D148 clamps the junction of R147 and R148 at about −0.5 volt to limit the collector current of Q145. With Q135 off, its collector rises positive. This signal is connected to the Unblanking Circuit. The STABILITY adjustment, R111, sets the quiescent base level of Q135 so it is near the forward bias point.

The positive-going trigger pulse applied to the base of Q135 turns Q135 on and its collector goes negative. This produces a negative-going signal to the Unblanking Circuit through R134 and R135. It also applies less voltage across divider R141-R143 which results in a more negative voltage at the base of Q145. This reverse biases Q145 and its collector rises positive to reverse bias D149 and D150. Capacitor C141, connected between the collector of Q135 and the base of Q145, improves the response time of this circuit. Diodes D144 and D145 protect Q135 and Q145 from exceeding their base-emitter breakdown voltage when they are reverse biased. The circuit remains in this condition with Q135 on and Q145 off until it is reset by the Reset and Holdoff Circuit at the end of the sweep. This reset action is described under Reset and Holdoff Circuit.

Unblanking Circuit

The negative-going signal at the collector of Q135 when the instrument is triggered is connected to the base of Q194 through R134 and R135. This forward biases Q194 and due to the circuit configuration, Q194 attempts to go into saturation. However, D194 prevents Q194 from going into full saturation by clamping the collector of Q194 about 0.2 volt more negative than its base. With the collector of Q194 clamped in this manner, the unblanking gate has a fast falling edge as well as a fast leading edge. The level at the collector of Q194 when it is conducting is about +8.4 volts. This voltage is connected to the blanking deflection plate of the CRT to allow a display to be presented (more details on

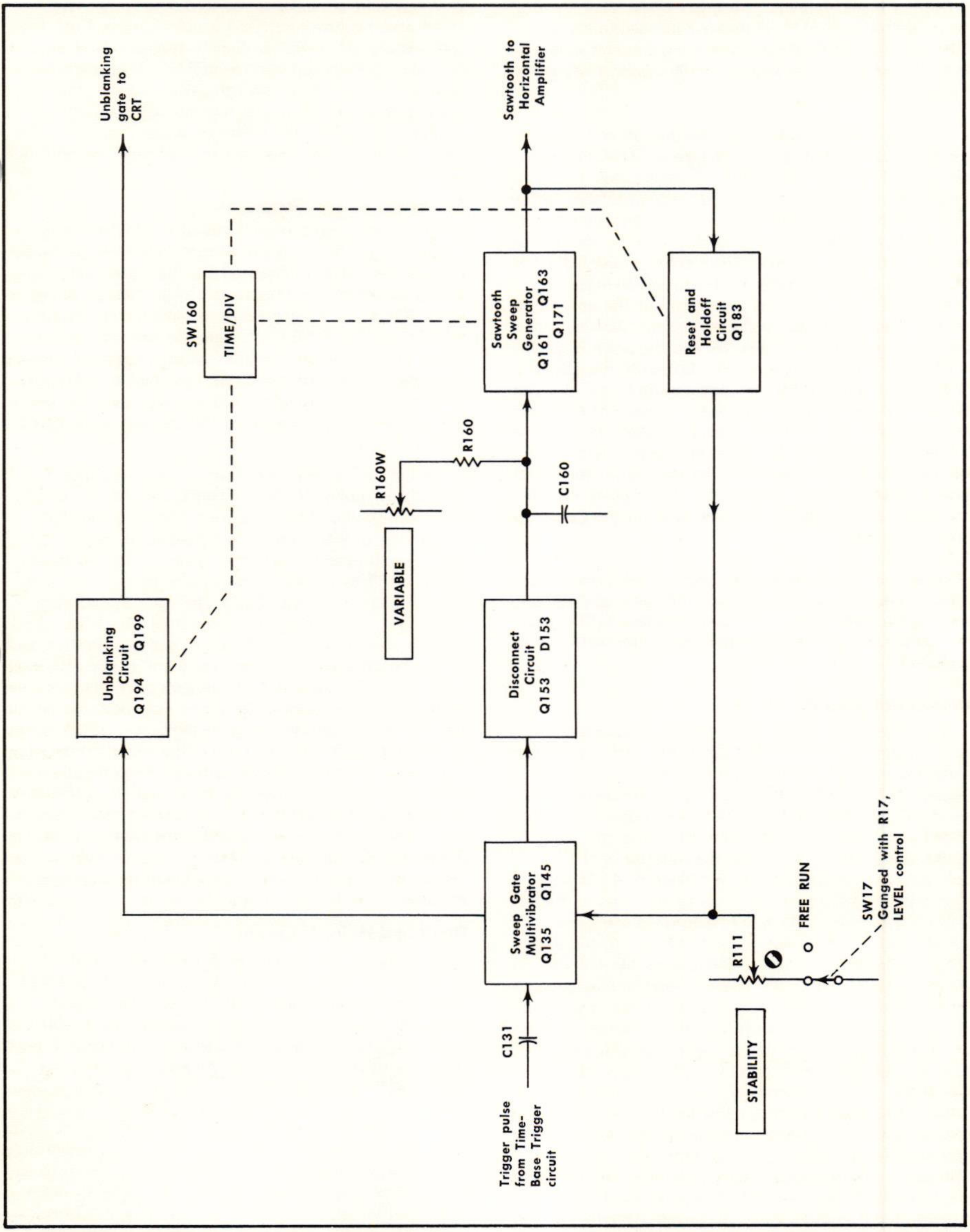


Fig. 3-4. Time-Base Generator detailed block diagram.

deflection blanking plates are given under CRT Circuit). The collector level of Q194 is also connected to the base of Q199 through R197. When Q194 is on, the positive level at its collector raises the base of Q199 positive enough to reverse bias it.

At the end of the sweep, Q135 is shut off and its collector rises positive. This allows the base of Q194 to go positive toward +10 volts and Q194 is reverse biased. Its collector drops negative to about −22 volts as established by divider R194-R196-R197. This voltage level is connected to the blanking deflection plate in the CRT to deflect the beam off the display area. Since D194 prevented Q194 from going into full saturation when it was on during sweep time, Q194 can be turned off rapidly at the end of the sweep. Then, the voltage connected to the blanking deflection plate quickly drops negative and the beam is quickly deflected off the display area. With Q194 off, the voltage at the base of Q199 is determined by divider R194-R196-R197. The voltage at the junction of R196 and R197 is such that Q199 is forward biased. Notice that Q199 is on when Q194 is off and vise versa. Q199 is in this circuit to prevent a change in the loading on the power supply when Q194 is turned off. Q199 serves no other purpose than to provide the same load on the Converter circuit at all times.

When the TIME/DIV switch is set for the external horizontal mode of operation, the base of Q194 is connected to ground through R190. This forward biases Q194 to unblank the CRT. Now the external horizontal signal can be displayed.

Disconnect Circuit

The Disconnect Circuit is comprised of transistor Q153 and disconnect diode D153. Quiescently, Q153 is forward biased by the negative level at the collector of Q145 in the Sweep Gate Multivibrator stage. Q153 conducts heavily when in this quiescent state before a trigger pulse is received and it goes into saturation. However, the action of diodes D149 and D150 prevent the collector of Q153 from reaching the full saturation level. Diode D149 is a silicon type with a forward voltage drop of 0.6 volts and diode D150 is a germanium type with a forward voltage drop of 0.4 volt. In the quiescent state of this circuit, the voltage drop of diodes D149 and D150 clamps the collector of Q153 about 0.2 volt more negative than its base and prevents it from reaching full saturation. Since a transistor requires more time to turn off from the saturated condition when it is not clamped, this configuration allows Q153 to turn off quickly when the instrument is triggered. Disconnect diode D153 is quiescently conducting current through Q153, R153, timing resistor R160 and VARIABLE control R160W (when VARIABLE control is not set to CALIB position). The emitter current of Q153 sets the level at the cathode of D153 which in turn determines the quiescent conduction of the Sawtooth Sweep Generator stage to establish the starting point of the sweep. Also, the conduction of D153 prevents timing capacitor C160 from charging in this quiescent condition.

When a trigger pulse is received, the output level from Q145 goes positive and Q153 is quickly turned off. When Q153 shuts off, D153 is quickly reverse biased since its cathode is pulled positive through R152. This interrupts the quiescent current flow through D153 and now the timing current through the timing resistor begins to charge the timing capacitor. 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[5] circuit. When the quiescent current flow through the Disconnect Circuit is interrupted by the sweep gate signal, timing capacitor C160 begins to charge through timing resistor R160. The timing capacitor and timing resistor are selected by the TIME/DIV switch to provide the various sweep rates listed on the front panel. Diagram 4 shows a complete diagram of the TIME/DIV switch. VARIABLE control R160W provides continuously variable, uncalibrated sweep rates by varying the charging current to the timing capacitor.

As the timing capacitor begins to charge positive toward the voltage applied to the timing resistor, the base of Q163 rises positive also. This produces a positive-going change at the emitter of Q163 which is coupled to the base of Q161. Q161 amplifies and inverts the voltage change at the emitter of Q163 to produce a negative-going sawtooth output through emitter follower Q173. The signal at the emitter of Q173 is connected to the Horizontal Amplifier circuit through the TIME/DIV switch and is also connected back to the negative side of timing capacitor C160. This feedback to the timing capacitor maintains a constant charging current for C160 to produce a linear sawtooth output signal. The actual voltage change at the base of Q163 is very small compared to the sawtooth output signal produced by this stage. The output signal continues to go negative until the circuit is reset through the Reset and Holdoff Circuit. The divider R174-R176-R177 in the emitter circuit of Q173 determines the level at which the sweep is reset. The Sweep Length adjustment R176 is set to provide the correct sweep length. Complete operation of this adjustment is discussed under Reset and Holdoff Circuit.

Reset and Holdoff Circuit

The negative-going sawtooth from the emitter of Q173 is connected to the base of Q183 through R177 and R176. The sweep Length adjustment, R176, determines the DC level and amplitude of the signal applied to the base of Q183 to set the length of the sweep. The negative-going sawtooth at the base of Q183 produces a similar negative-going change at the emitter of Q183 which charges holdoff capacitors C180 and C181 through D183. The level at the anode of D183 is also connected to the base of Q135 through R131. During sweep time, Q135 in the Sweep Gate multivibrator stage is on and Q145 is off. The negative-going signal from Q183 pulls the base of Q135 negative toward cutoff as the sawtooth produced by the Time-Base Generator circuit goes negative. D111 disconnects the

[5]Millman and Taub, pp. 540-548.

STABILITY control from the circuit as the negative-going voltage reverse biases it. As the base of Q135 is pulled negative, the emitter of Q135 goes negative also and this change is coupled to the emitter of Q145 through D144 and D145. This action continues until the emitter of Q145 drops negative enough to forward bias Q145 (voltage at base of Q145 is held constant by divider R141-R143 from the collector of Q135 to the −45-volt supply). Q145 then takes control of the emitter current and the negative-going sawtooth connected to the base of Q135 cuts Q135 off to reset the Sweep Gate Multivibrator stage. The level on the negative-going sawtooth at which this stage is reset can be varied with the Sweep Length adjustment, R176. When R176 is turned clockwise, the sawtooth must go more negative before the Sweep Gate Multivibrator is reset which produces a longer sweep. The action is the opposite when R176 is turned counterclockwise to produce a shorter sweep.

When Q145 comes into conduction as the Sweep Gate Multivibrator is reset, its collector drops negative to quickly forward bias Q153 and D153. Timing capacitor C160 discharges rapidly through D153, R153 and Q153. As C160 discharges the base of Q163 goes negative also to produce the retrace portion of the sweep. Since the resistance of the discharge path for C160 is less than the charging path (through the timing resistor), 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 produced by the Unblanking Circuit ended when the Sweep Gate Multivibrator stage was reset so this retrace is not visible on the display area. Now the Disconnect Circuit and the Sawtooth Sweep·Generator stages have returned to their quiescent condition 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 anode of D183 went negative along with the negative-going sawtooth applied to the base of Q183, the holdoff capacitor charged negative also. However, when the circuit is reset to produce the retrace portion of the sawtooth signal, the emitter of Q183 rises positive with the retrace but the anode of D183 is clamped by the charge level on the holdoff capacitor. D183 is reverse biased to disconnect the positive-going retrace from the holdoff capacitor and the base circuit of Q135. This action blocks incoming trigger pulses 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 through R181, the base of Q135 rises positive also through R131. When the holdoff capacitor has discharged to the level where D111 is forward biased, the voltage level at the base of Q135 is again determined by STABILITY control R111 as described for the Quiescent condition of the Sweep Gate Multivibrator. Now the circuit is ready to accept the next positive-going trigger pulse. Holdoff capacitor C180 is changed by the TIME/DIV switch to provide the correct holdoff time for the sweep rate selected (see Diagram 4). Holdoff capacitor C181 is connected in the circuit at all times. For sweep rates of five microseconds and faster, C180 is disconnected and C181 determines the holdoff time of the circuit.

When the Triggering LEVEL control is turned fully clockwise to the FREE RUN position, SW17 (ganged with R17) disconnects the negative voltage level from STABILITY control R111. Now, D111 and R111 have no control on the quiescent level at the emitter of Q135 as described previously. Instead, the base of Q135 continues to rise positive as the holdoff capacitor discharges until Q135 is forward biased. The result is that the Time-Base Generator 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 repetition rate in the AUTO triggering mode.

HORIZONTAL AMPLIFIER

General

The Horizontal Amplifier circuit provides the output signal to the CRT horizontal deflection plates. In all positions of the TIME/DIV switch except the external horizontal position (position with arrow to EXT HORIZ INPUT jack), the horizontal deflection signal is a sawtooth from the Time-Base Generator circuit. In the external horizontal position, the horizontal deflection signal is an external signal applied to the EXT HORIZ INPUT jack. In addition this circuit contains the horizontal magnifier circuit and the horizontal positioning network. Fig. 3-5 shows a detailed block diagram of the Horizontal Amplifier circuit. A schematic of this circuit is shown on diagram 5 at the rear of this manual.

Input Signal EF

The input signal for the Horizontal Amplifier circuit is selected by TIME/DIV switch SW160. In all positions of the TIME/DIV switch except external horizontal (note arrow to EXT HORIZ INPUT jack), the input signal is the sawtooth produced by the Time-Base Generator circuit. The sawtooth is applied to the base of Q313 through C311-R311. These components are part of the compensated divider network C311-C312-R311-R312-R316 which establishes the input resistance for the Horizontal Amplifier circuit as well as the correct DC voltage level at the base of Q313.

For external horizontal mode operation, an external signal from the EXT HORIZ INPUT jack provides the horizontal deflection. The network C300-R300-R30l-R302 is added to the divider network mentioned previously to provide the desired input impedance for external horizontal mode operation (approximately 100 kilohm X 30 pF). When the TIME/DIV switch is set to the external horizontal position, SW160 connects R316 to −10 volts rather than ground. This voltage applied to divider R312-R316 along with divider R301-R302 sets the base level of Q313 such that the display is near the center of the display area (hori-

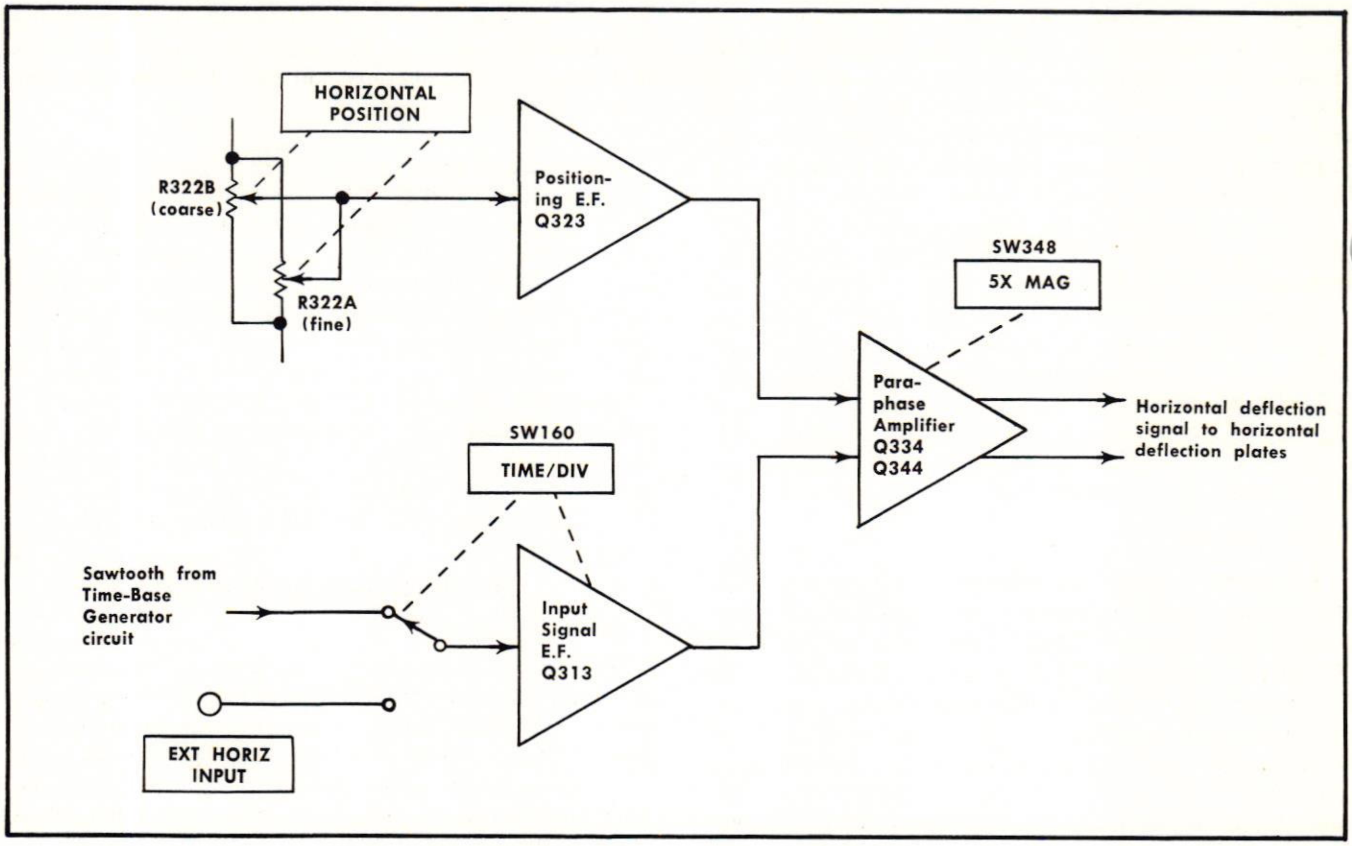


Fig. 3-5. Horizontal Amplifier detailed block diagram.

zontally) for external horizontal mode operation when the HORIZONTAL POSITION control is centered.

Positioning EF

The HORIZONTAL POSITION control, R322A and R322B, sets the DC voltage level at the base of Q323 which determines the horizontal position of the CRT display. Q323 is connected as an emitter follower (EF) and the voltage at its emitter is connected to the base of Q344 in the Paraphase Amplifier stage.

The HORIZONTAL POSITION control is a dual-range control to provide a combination of coarse and fine adjustment in a single control. When this control is rotated, fine control R322A provides positioning for a range of about 60° of rotation. Then, after the fine range is exceeded, coarse control R322B provides rapid positioning of the trace.

Paraphase Amplifier

Q334 and Q344 are connected as a paraphase amplifier to convert the single-ended input signal to a push-pull output signal. In addition, this stage provides a five times sweep magnifier and adjustments to set the normal and magnified gain. The input signal from Q313 is connected to the base of Q334 and it produces equal but opposite output signals at the collectors of Q334 and Q344. This occurs as follows: The negative-going sawtooth (or negative-going external horizontal signal) applied to the base of Q334 from Q313 forward biases Q334 and the current through Q334 increases. This increase in current produces a positive-going sawtooth output signal at the collector of Q334 which is connected to the right deflection plate of the CRT. At the same time the increase in current through Q334 produces a negative-going sawtooth at its emitter. The emitters of Q334 and Q344 are coupled together through two degeneration networks. For normal sweep (5X MAG switch pushed in), R328 and R338 control the emitter degeneration between Q334 and Q344 to set the gain of this stage. R338, Horiz Gain, is adjusted to provide calibrated horizontal sweep rates. When 5X MAG switch SW348 is pulled out, R347 and R348 are connected in parallel with R328 and R338. This additional resistance decreases the emitter degeneration of the stage and increases the gain five times. R348, Mag Gain, is adjusted to provide calibrated magnified sweep rates.

The negative-going sawtooth coupled to the emitter of Q344 through the degeneration network reverse biases Q344 and the current through it decreases. This decrease in current produces a negative-going sawtooth at the collector of Q344, which is connected to the left deflection plate of the CRT. The positioning level from the Positioning Emitter Follower stage sets the quiescent bias level at the base of Q344. Due to the emitter coupling between Q344 and Q334, the quiescent conduction of Q344 also establishes the quiescent conduction of Q334 to determine the starting point of the sweep or the quiescent position of an external horizontal display.

REGULATOR CIRCUIT

General

The Regulator Circuit provides a regulated +10-volt output to the Converter circuit from a variety of power sources. Electronic regulation[6] is used in this circuit to provide a stable, low-ripple output voltage. Fig. 3-6 shows a detailed block diagram of the Regulator Circuit. A schematic of this circuit is shown on diagram 6 at the rear of this manual.

Power Sources

AC Power Input and AC Rectifier. AC power is applied to the primary of transformer T601 through AC line fuse F601. The primary of T601 contains two windings which can be connected in parallel for 115-volt nominal operation or in series for 230-volt nominal operation.

The secondary of T601 provides three power outputs. Diodes D610 and D611 are connected to one secondary winding to form a full-wave rectifier which provides rectified voltage to the Power Selection stage through D620. C612 provides filtering for this voltage. Diodes D660 and D661 are also connected to this secondary winding to form a full-wave rectifier which is connected in series with the D610-D611 rectifier to provide an output of about +32 volts. This voltage is filtered by C660 and connected to the Battery Charger stage to charge rechargeable battery cells.

The other secondary winding of T601 is connected to the SCALE ILLUM control, R602. The current through the scale illumination lights, B601 and B602 is controlled by the SCALE ILLUM control to change the illumination of the graticule lines. Notice that the POWER switch is located after this stage. Therefore, power is applied to the secondary of T601 whenever the instrument is connected to an AC voltage source. To turn off the scale illumination lights when connected to an AC voltage source, rotate the SCALE ILLUM control fully counterclockwise. Also to provide maximum operating time for battery operation, these lights are located in the AC Power Input stage. They are not operative for external DC or battery operation.

DC Power Input. This instrument can be operated from a DC power source with the correct connections to the DC section of the power receptacle. For operation from a +11.5-volt to +20-volt DC source (positive voltage connected to black lead of pigtail connector), power is connected directly to the POWER switch SW621. D620 is reverse biased by the applied voltage to disconnect the secondary circuit of T601 and the Battery Charger stage for this mode of operation. A DC source between +20 volts and +35 volts (positive voltage connected to green lead) is connected to the Power Selection stage through R610. This resistor limits the voltage to the instrument to extend the useable range from external DC voltage sources.

Internal Batteries. When 10 size D battery cells are installed in the battery compartment of this instrument, voltage is applied to the Power Selection stage for battery operation. If the batteries installed in this instrument are of the rechargeable type, they can be recharged from the internal battery charger. See the description under Battery Charger for more details.

Power Selection

The power source is selected by the POWER switch SW621. In the fully counterclockwise ON EXT AC-DC position, the power source is an external AC or external DC voltage. The selection of AC or DC voltage is made at the power receptacle by connecting either the AC cord or the DC cord to the instrument. The cords and receptacle are designed so that only one cord can be connected to the instrument at a time. In the middle two positions of SW621, the instrument is off but the Battery Charger stage provides either a trickle or full charge to the internal batteries (see Battery Charger for complete details). In the fully clockwise ON INT BATT position, the external power sources are disconnected and power is supplied from the 10 internal size D battery cells.

Thermal cutout TK621 provides thermal protection for this instrument. If the internal temperature of the instrument exceeds a safe operating level, TK621 opens to interrupt the applied power. When the temperature returns to a safe level TK621 automatically closes to reapply the power. Fuse F621 provides protection for this instrument if it draws too much current.

Battery Charger

The rectified voltage produced by diodes D660-D661 provides a charging voltage for internal batteries as controlled by Charger switch SW692 and POWER switch SW621. When non-rechargeable batteries are installed in the Type 321A, the Charger switch must be set to the Dry Cells position to disconnect all charging current. In the Low position of SW692, charging current is applied to the POWER switch through R693 and D692. In the High position, R692 is connected in parallel with R693 to provide about twice the charging current as in the Low position.

The POWER switch determines whether the charging current selected by the Charger switch is applied to the batteries. In the ON EXT AC-DC and OFF TRICKLE CHG positions, the charging current is connected to the internal batteries through R694. This resistor limits the charging current applied to the batteries to provide a slow charge for the batteries or to maintain a full charge on the batteries when they are not being used. In the OFF FULL CHG position, the internal batteries are charged at the rate selected by the Charger switch. All charging current is disconnected in the ON INT BATT position.

[6]Tektronix Circuit Concepts booklet, "Power Supply Circuits", Tektronix Part No. 062-0888-00, pp. 21-40.

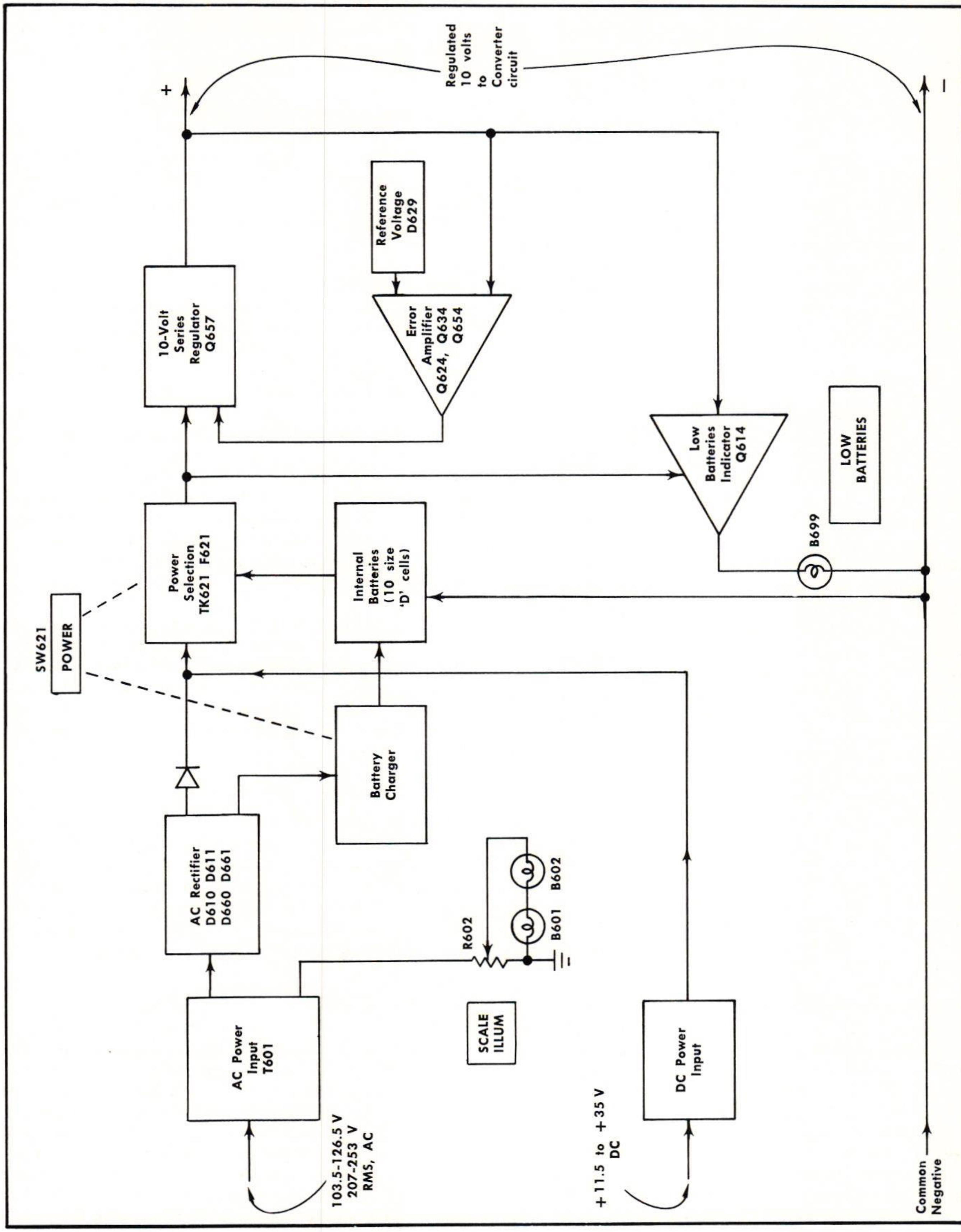


Fig. 3-6. Regulator Circuit detailed block diagram.

Voltage Regulation

The following discussion includes the description of the +10-Volt Series Regulator, Error Amplifier and Reference Voltage stages. Since these stages are closely related in the production of the 10-volt regulated output voltage, their operation is most easily understood when discussed as a unit.

The power source selected by the Power Selection stage is connected to the 10-Volt Series Regulator stage to provide a stable output voltage. 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.

The Error Amplifier stage, Q624 and Q634, is connected as a comparator. Reference voltage for the comparator is provided by zener diode D629 which sets the base of Q624 at about +5.1 volts. The base level of Q634 is determined by voltage divider R650-R651-R652 connected between the positive and negative output of this supply. R651 is adjustable to set the output voltage of this supply to 10 volts. R631 is the emitter resistor for both transistors in the comparator and the current through it divides between Q624 and Q634. The output current of the Error Amplifier controls the conduction of the Series Regulator stage (through Q654). This output current is changed to provide a constant, low-ripple 10-volt output level. This occurs as follows: The comparator action of Q624 and Q634 attempts to maintain equal voltages at the bases of both transistors. If 10 V Adj R651 is turned clockwise, the current through Q634 increases (Q634 base tends to go more positive than the base of Q624) and the current through Q624 decreases. Decreased current through Q624 produces less voltage drop across R624 and the base of Q654 goes positive. The emitter of Q654 pulls the base of Q657 positive to decrease the current through the load, thereby decreasing the output voltage of the supply. This places less voltage across divider R650-R651-R652 and the divider action returns the base of Q634 to about +5 volts. A similar, but opposite, action takes place when R651 is turned counterclockwise so the base of Q634 is more negative than the base of Q624. The 10 V Adj adjustment is set to provide a 10-volt level at the output of this supply.

The output voltage of this supply is regulated to provide a constant voltage to the load (Converter circuit) by feeding a sample of the output voltage back to the Series Regulator, Q657. For example, assume that the output voltage increases because of a change in load or an increase in input voltage. This produces a more positive voltage at the collector of Q657 which is connected across the voltage divider R650-R651-R652 to produce a more positive level at the base of Q634. The current flow through Q634 increases which allows Q624 to conduct less and its collector goes positive. When the collector of Q624 goes positive, the bias of Q654 increases, resulting in reduced current through Series Regulator Q657. Reduced current through Q657 also means that there is less current through the load and the output voltage decreases. In a similar manner, the Series Regulator and Error Amplifier stages compensate for output changes due to ripple.

Low-Batteries Indicator

Transistor Q614 with its associated circuitry constitutes a low-batteries warning system. The emitter of Q614 is connected to the output of the 10-Volt Series Regulator stage and is therefore held constant. The voltage at the base of Q614 is determined by voltage divider R695-R696-R697 between the unregulated input voltage and the common negative level of this supply. Quiescently when the batteries are charged, the voltage established at the base of Q614 is positive enough to reverse bias Q614. Therefore, there is no current flowing through B699, the LOW BATTERIES indicator light. Diode D614 is forward biased under these conditions to protect the base-emitter junction of Q614 from reverse-voltage breakdown.

As the unregulated voltage applied to the 10-Volt Series Regulator stage drops to about 11.5 volts, the level at the base of Q614 drops negative enough to forward bias it. The collector current of Q614 flows through B699 to indicate that the batteries are low. Operation of the instrument after the LOW BATTERIES light comes on may not only provide inaccurate operation but it may also result in damage to rechargeable battery cells.

Since the Low-Batteries Indicator stage is active with all power sources, this stage also provides an inidcation whenever the unregulated voltage to the Series Regulator stage drops below about 11.5 volts. Although continued operation from an external power source after this light comes on will probably not damage the instrument, it may provide inaccurate measurements.

CONVERTER

General

The Converter circuit produces the various output voltages necessary for the operation of this instrument. This circuit also produces the positive and negative accelerating potentials for the CRT. Fig. 3-7 shows a detailed block diagram of the Converter circuit. A schematic of this circuit is shown on diagram 7 at the rear of this manual.

Converter Oscillator

The regulated 10-volt output of the Regulator Circuit provides the power for the Converter Oscillator stage. Transistors Q700 and Q710 and transformer T701 comprise the oscillator. The emitter of both Q700 and Q710 are connected to the positive output of the 10-volt regulator and the bases of these transistors are connected to the common negative output through resistors R700 and R701 and the base winding of T701. When power is first applied to the instrument, both transistors are forward biased by the applied voltages. However, since the transistors will not have identical characteristics (even though they are of the same type), one transistor conducts more heavily than the

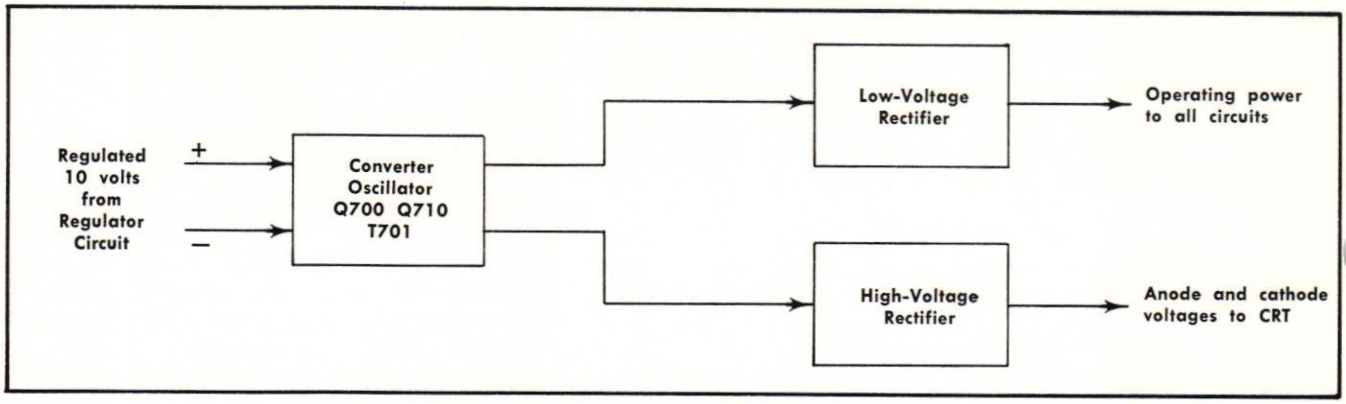


Fig. 3-7. Converter detailed block diagram.

other. For purposes of this explanation, assume that Q700 conducts heaviest. The collector current of Q700 flows through the primary winding of T701 (terminals 1 and 2) and induces a voltage into one half of the base winding (terminals 6 and 7) which causes Q700 to conduct even harder. At the same time, a voltage of the opposite polarity is induced into the other half of the base winding (terminals 5 and 6) which reverse biases Q710. Voltage is induced into the base winding of T701 holding Q700 in conduction and Q710 off until the transformer reaches saturation. When T701 saturates, Q710 is no longer held reverse biased since there is no voltage induced into the base winding. The collector current of Q710 flows through the primary of T701 (terminals 3 and 4) in the opposite direction to the current flowing through the other half of the primary winding. At the same time, the magnetic field of T701 starts to collapse. These actions result in a voltage being induced into the base winding of T701 which forward biases Q710 and reverse biases Q700. Conditions remain this way until T701 reaches saturation again. Then Q700 comes back into conduction to begin the cycle again. Frequency of oscillation is about two kilohertz. The output waveshape in the secondary of T701 is a square wave since T701 reaches saturation on both positive and negative half cycles of the driving signal.

Low-Voltage Rectifier

The voltage induced into the secondary of T701 is rectified by diodes D710-D711-D712-D713-D720-D721-D726. The rectified voltage is then filtered by capacitor-input "pi" filter networks to produce DC output voltages of +45 volts, +10 volts, −10 volts, −45 volts and −47.5 volts. Notice that the voltages in the secondary circuit of T701 are not regulated. The regulated 10 volt input to the Converter circuit provides regulated output voltages. Also, the circuits within this instrument are designed to provide minimum change in power-supply loading under normal operation.

The unregulated voltage at terminal 10 of T701 is connected to the Calibrator circuit through the network C707-R707. This network prevents signal changes in the Calibrator circuit from affecting the Converter circuit.

High Voltage Rectifier

The voltage at terminal 16 of T701 provides the high-voltage potentials necessary for the CRT. Diodes D714-D715-D717-D718-D719 and capacitors C714-C715-C716-C717-C720 form a voltage-pentupler multiplier[7] network to provide a positive accelerating potential of about +3350 volts at the CRT anode. Resistors R714 and R720 limit the current available from the supply to protect the rectifiers. Neon bulb B714 reduces the input voltage to the voltage-pentupler network by about 60 volts to provide the correct output level (+3350 volts) to the CRT anode.

Diode D716 provides rectified voltage for the CRT cathode. R719 and C719 provide filtering for this output. Output voltage level of this supply is about −720 volts. A separate winding (terminals 8 and 9) provides 6.3 volts AC for the CRT heater. R718 is connected between the −720 volt supply and this winding to elevate the DC output level to about −720 volts. This prevents arc-over between the CRT heater and CRT cathode.

CRT CIRCUIT

General

The CRT Circuit provides the control circuits necessary for operation of the cathode-ray tube (CRT). Fig. 3-8 shows a detailed block diagram of the CRT Circuit. A schematic of this circuit is shown on diagram 8 at the rear of this manual.

Operating Potentials

Positive accelerating voltage for the CRT anode (about +3350 volts) is provided by the Converter circuit. Ground return for this supply is through the resistive helix inside the CRT to pin 8 of the CRT and then to ground through the GEOM Adj R861. Negative accelerating potential is pro-

[7]**Tektronix Circuit Concepts booklet, "Power Supply Circuits", Tektronix Part No. 062-0888-00, pp. 14-16.**

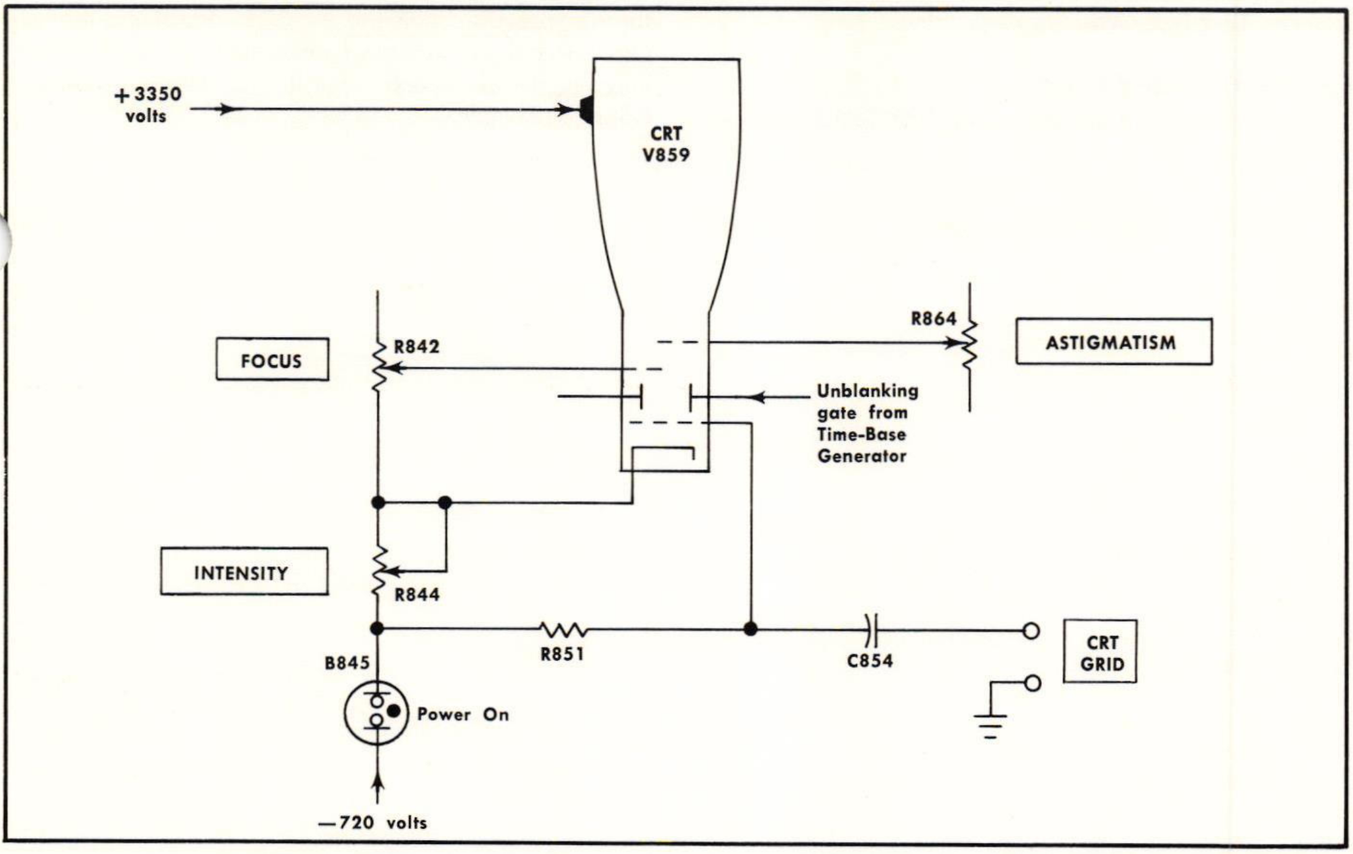


Fig. 3-8. CRT Circuit detailed block diagram.

vided by the —720-volt supply in the Converter circuit. This voltage is connected to the CRT cathode through B845 and INTENSITY control R844. It is also connected to the CRT control grid through R851. Neon bulb B845, Power On light, ignites when the —720 volts is applied to indicate that the power is on. Total CRT accelerating potential is about four kilovolts.

CRT Control Circuits

Focus of the CRT display is controlled by FOCUS control R842. Resistors R841 and R842 form a voltage divider between ground and the CRT cathode so that the voltage applied to the focus grid is more positive (less negative) than the voltage on either the control grid or the CRT cathode. The ASTIGMATISM control R864, which is used in conjunction with the FOCUS control to provide a well-defined display, varies the positive level on the astigmatism grid.

Geom Adj R861 varies the positive level on the deflection plate isolation shield to control the overall geometry of the display. Intensity of the display is determined by the setting of INTENSITY control R844. This control varies the level on the CRT cathode. Since the control grid voltage is fixed, varying the cathode voltage changes the bias on the cathode-ray tube.

Deflection Blanking Plates

The CRT in the Type 321A uses deflection blanking to deflect the CRT beam off the viewing area during retrace time and when the sweep is not operating. The deflection blanking plate connected to pin 10 is fixed at +10 volts and the level of the plate connected to pin 6 is determined by the unblanking gate from the Time-Base Generator circuit. When the voltage difference between the blanking plates is significant, the CRT is blanked and virtually no electrons strike the phosphor. However, if the voltage difference between the blanking plates is small, the CRT is unblanked and a trace can be displayed. Quiescently, before the sweep is triggered, the unblanking gate level is at about —22 volts to completely blank the CRT. When the instrument is triggered, the unblanking gate level rises positive to about +8.4 volts to allow the CRT beam to reach the phosphor and produce a display. After the sweep is completed, the unblanking gate level again drops to about —22 volts to blank the CRT during the retrace portion of the sawtooth. Provisions are also made in the Unblanking Circuit so the CRT can be unblanked for external horizontal mode operation (see Time-Base Generator discussion).

External CRT Grid Input

An external signal applied to the CRT GRID input on the rear panel is coupled to the CRT control grid through C854. This signal produces an increase or decrease in trace intensity, depending upon polarity, to provide Z-axis modulation of the display.

SECTION 4
MAINTENANCE

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

Introduction

This section of the manual contains preventive maintenance, corrective maintenance and troubleshooting procedures for the Type 321A.

Panel Removal

The side panels of the Type 321A are held in place by two slotted fasteners. To remove the panels, turn each fastener counterclockwise about two turns with a screwdriver. Then, pull the panel out at the top and lift away from the instrument. To remove the battery compartment to reach the bottom areas of the instrument, loosen the thumb screw and lift the front of the compartment out to clear the instrument. Then, slide the compartment forward to release the clips at the rear. The panels should be kept on the instrument except during maintenance since they protect the instrument from dust in the interior. They also reduce the EMI radiation from the instrument or EMI interference of the display due to other equipment.

WARNING

Dangerous potentials exist at several points throughout this instrument. When this instrument is operated with the covers removed, do not touch exposed connections or components. Some transistors may have elevated cases. Disconnect power before cleaning the instrument or replacing parts.

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 321A is subjected determines the frequency of maintenance. A convenient time to perform preventive maintenance is preceding recalibration of the instrument.

Cleaning

General. The Type 321A 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 which 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 accumulated on the outside of the Type 321A 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, faceplate protector and the CRT face with a soft, lint-free cloth dampened with denatured alcohol. The CRT mesh filter can be cleaned in the following manner.

1. Hold the filter in a vertical position and brush lightly with a soft No. 7 water-color brush to remove light coatings of dust or lint.

2. Greasy residues or dried-on dirt can be removed with a solution of warm water and a neutral-pH liquid detergent. Use the brush to lightly scrub the filter.

3. Rinse the filter thoroughly in clean water and allow to air dry.

4. If any lint or dirt remains, use clean low-pressure air to remove. Do not use tweezers or other hard cleaning tools on the filter as the special finish may be damaged.

5. When not is use, store the mesh filter in a lint-free, dust proof container such as a plastic bag.

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 circuits, particularly parts located in the high-voltage supply and the area surrounding the post-deflection anode connector, should receive special attention. Excessive dirt in these areas 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 321A should be inspected occasionally for such defects as broken connections, broken or damaged ceramic strips, improperly seated transistors 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.

Transistor Checks

Periodic checks of the transistors in the Type 321A are not recommended. The best check of transistor performance is its actual operation in the instrument. More details on checking transistor operation are given under Troubleshooting.

Recalibration

To ensure accurate measurements, check the calibration of this instrument after each 1000 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 321A, if trouble develops. 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 in this instrument 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 321A 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	Diagram Number	Circuit
1-99	2	Time-Base Trigger
100-199	3	Time-Base Generator
300-399	5	Horizontal Amplifier
400-599	1	Vertical Amplifier
600-699	6	Regulator Circuit
700-799	7	Converter
800-869	8	CRT Circuit
870-899	1	Calibrator

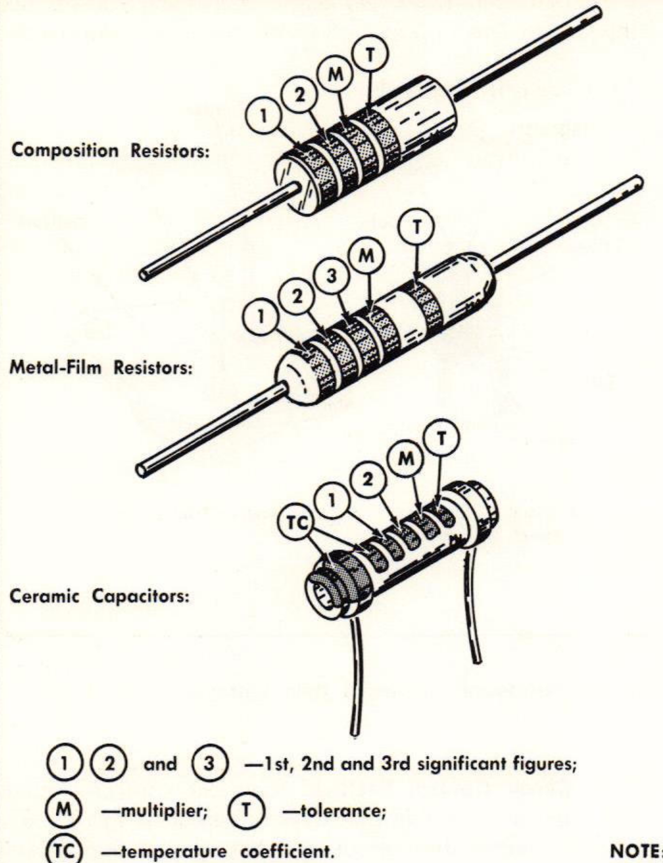
Switch Wafer Identification. Switch wafers shown on the diagrams are coded to indicate the position of the wafer in the complete switch assembly. The numbered portion of the code refers to the wafer number counting from the front, or mounting end of the switch, toward the rear. The letters F and R indicate whether the front or rear of the wafer performs the particular switching function. For example, a wafer designated 2R indicates that the rear of the second wafer (from the front) is used for this particular switching function.

Wire Color-Code. All insulated wire and cable used in the Type 321A 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 321A.

TABLE 4-2

Power Supply Wiring Color Code

Supply	Background Color Stripe	First Stripe	Second Stripe	Third Stripe
−720 volt	tan	violet	green	black
−45 volt	tan	yellow	green	black
−10 volt	tan	brown	black	black
+10 volt	white	brown	black	black
+45 volt	white	yellow	green	black



Resistor and Capacitor Color Code

Color	Significant Figures	Multiplier: Resistors	Multiplier: Capacitors	Tolerance: Resistors	Tolerance: Capacitors
Silver	---	10^{-2}	---	±10%	---
Gold	---	10^{-1}	---	±5%	---
Black	0	1	1	---	±20% or 2 pF*
Brown	1	10	10	±1%	±1% or 0.1 pF*
Red	2	10^{2}	10^{2}	±2%	±2%
Orange	3	10^{3}	10^{3}	±3%	±3%
Yellow	4	10^{4}	10^{4}	±4%	+100% −0%
Green	5	10^{5}	10^{5}	±0.5%	±5% or 0.5 pF*
Blue	6	10^{6}	10^{6}	---	---
Violet	7	---	---	---	---
Gray	8	---	10^{-2}	---	+80% −20% or 0.25 pF*
White	9	---	10^{-1}	---	±10% or 1 pF*
(none)	---	---	---	±20%	±10% or 1 pF*

***For capacitance of 10 pF or less.**

NOTE: T and/or TC color code for capacitors depends upon manufacturer and capacitor type. May not be present in some cases.

Fig. 4-1. Color-code for resistors and ceramic capacitors.

Resistor Color-Code. In addition to the brown composition resistors, some metal-film resistors and some wire-wound resistors are used in the Type 321A. The resistance values of wire-wound resistors are printed on the body of the component. The resistance values of composition resistors and metal-film resistors are color-coded on the components with EIA color-code (some metal-film resistors may have the value printed on the body). The color-code is read starting with the stripe nearest the end of the resistor. Composition resistors have four stripes which consist of two significant figures, a multiplier and a tolerance value (see Fig. 4-1). Metal-film resistors have five stripes consisting of three significant figures, a multiplier and a tolerance value (see Fig. 4-1). Metal-film resistors have five stripes consisting of three significant figures, a multiplier and a tolerance value.

Capacitor Marking. The capacitance values of common disc capacitors and small electrolytics are marked in microfarads on the side of the component body. The white ceramic capacitors used in the Type 321A are color-coded in picofarads using a modified EIA code (see Fig. 4-1).

Diode Color-Code. The cathode end of each glass-encased diode is indicated by a stripe, a series of stripes or a dot. For most silicon or germanium diodes with a series of stripes, the color-code identifies the three significant digits of the Tektronix Part Number using the resistor color-code system (e.g., a diode color-coded blue or pink-brown-gray-green indicates Tektronix Part Number 152-0**185**-00). The cathode and anode end of metal-encased diodes can be identified by the diode symbol marked on the body.

Transistor Lead Configuration. Fig. 4-2, shows the lead configurations of the transistors used in this instrument. This view is as seen from the bottom of the transistor.

Troubleshooting Equipment

The following equipment is useful for troubleshooting the Type 321A.

1. Transistor Tester

Description: Tektronix Type 575 Transistor-Curve Tracer or equivalent.

Purpose: To test the semiconductors used in this instrument.

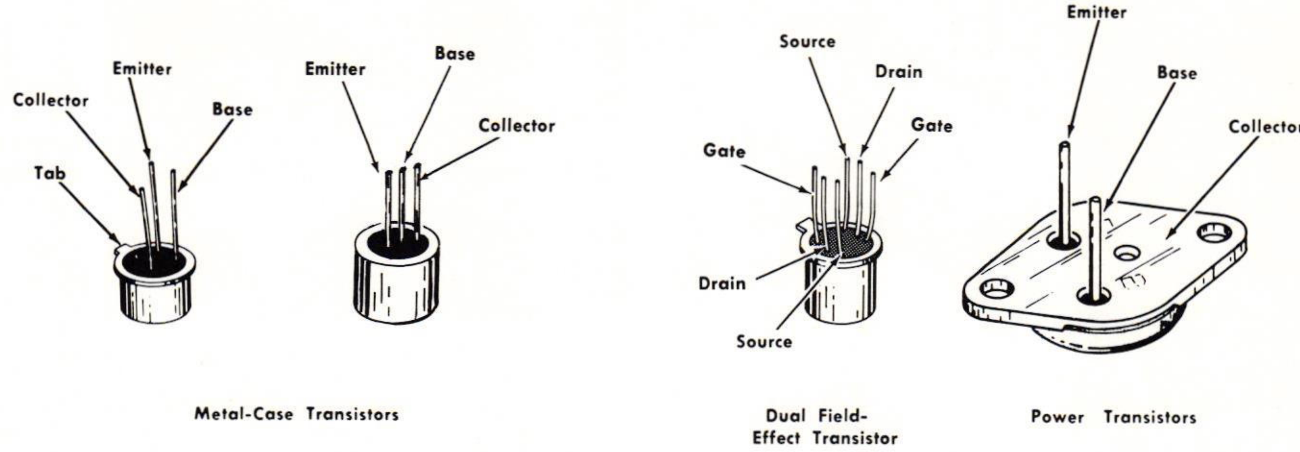


Fig. 4-2. Electrode configuration for transistors in this instrument (as viewed from bottom).

2. Multimeter

Description: VTVM, 10 megohm input impedance 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 in this instrument.

NOTE

A 20,000 ohms/volt VOM can be used to check the voltages in this instrument if allowances are made for the circuit loading of the VOM at high-impedance points.

3. 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 in this instrument.

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 controls, see the Operating Instructions section of this manual.

2. Check Associated Equipment. Before proceeding with troubleshooting of the Type 321A, 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 this instrument, or the affected circuit if the trouble appears in only 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 of this manual.

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 tolerance of the power supplies in this instrument. 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)
−720 volt	−715 to −745 volts	2 volts
−45 volt	−44.5 to −46.5 volts	20 millivolts
−10 volt	−10.8 to +11.2 volts	5 millivolts
+10 volt	+9.4 to +9.8 volts	25 millivolts
+45 volt	+45 to +47 volts	10 millivolts
10-volt regulated	9.9 to 10.1 volts	50 millivolts

Fig. 4-3 provides a guide to aid in locating a defective circuit. This chart may not include checks for all possible defects; use steps 6 and 7 in such cases. Start from the top of the chart and perform the given checks on the left side of the page until a step is found which does not produce the indicated results. Further checks and/or the circuit in which the trouble is probably located are listed to the right of this step.

After the defective circuit has been located, proceed with steps 6 and 7 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 321A. Components which are soldered in place are best checked by disconnecting them. This isolates the measurement from the effects of surrounding circuitry. Observe the soldering precautions given in this section when disconnecting components.

A. TRANSISTORS. The best check of transistor operation is actual performance under operating conditions. If a transistor 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 transistor might also be damaged. If substitute transistors are not available, use a dynamic tester (such as Tektronix Type 575). Static-type testers are not recommended, since they do not check operation under simulated operating conditions.

CAUTION

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

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.

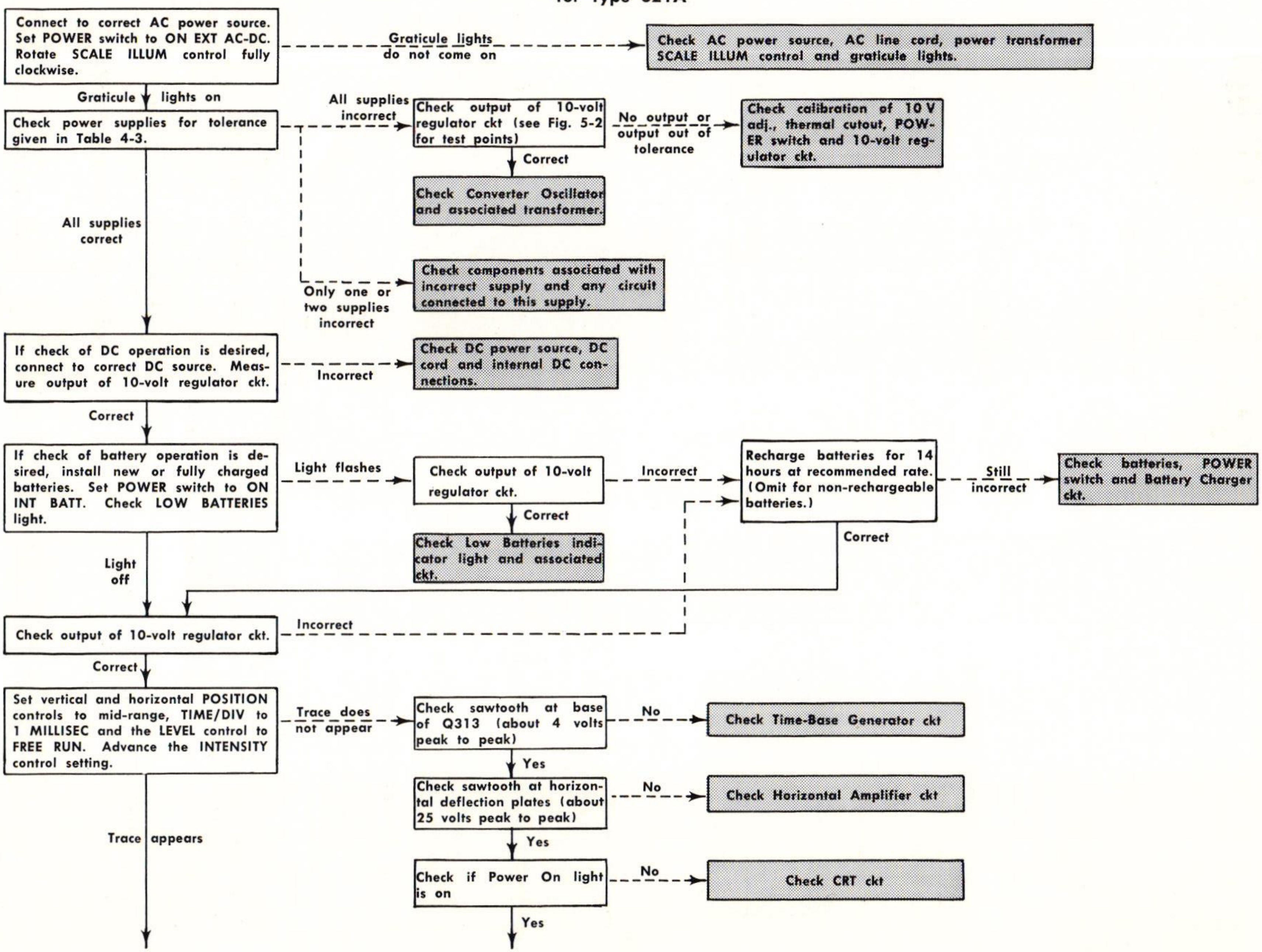
8. Repair and Readjust the Circuit. If any defective parts are located, follow the replacement procedures given in this section. Be sure to check the performance of any circuit that has been repaired or that has had any electrical components replaced.

CORRECTIVE MAINTENANCE

General

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

Troubleshooting Chart for Type 321A



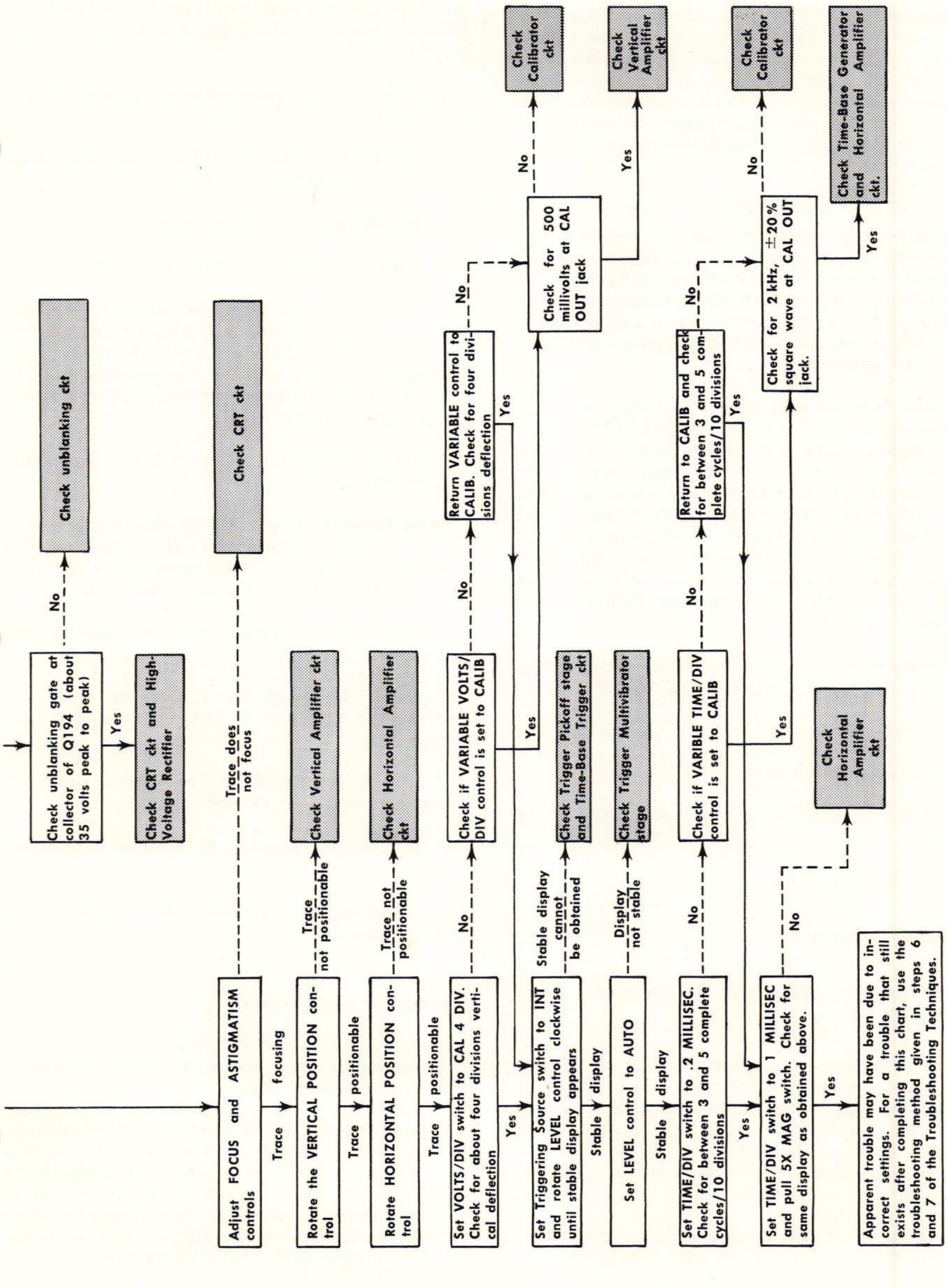

Adjust FOCUS and ASTIGMATISM controls
Trace focusing
Trace does not focus
Check CRT ckt
Check unblanking gate at collector of Q194 (about 35 volts peak to peak)
Yes
No
Check CRT ckt and High-Voltage Rectifier
Check unblanking ckt
Rotate the VERTICAL POSITION control
Trace positionable
Trace not positionable
Check Vertical Amplifier ckt
Rotate HORIZONTAL POSITION control
Trace positionable
Trace not positionable
Check Horizontal Amplifier ckt
Set VOLTS/DIV switch to CAL 4 DIV. Check for about four divisions vertical deflection
Yes
No
Check if VARIABLE VOLTS/DIV control is set to CALIB
Yes
No
Return VARIABLE control to CALIB. Check for four divisions deflection
Yes
No
Check for 500 millivolts at CAL OUT jack
No
Yes
Check Calibrator ckt
Check Vertical Amplifier ckt
Set Triggering Source switch to INT and rotate LEVEL control clockwise until stable display appears
Stable display
Stable display cannot be obtained
Check Trigger Pickoff stage and Time-Base Trigger ckt
Set LEVEL control to AUTO
Stable display
Display not stable
Check Trigger Multivibrator stage
Set TIME/DIV switch to .2 MILLISEC. Check for between 3 and 5 complete cycles/10 divisions
Yes
No
Check if VARIBLE TIME/DIV control is set to CALIB
Yes
No
Return to CALIB and check for between 3 and 5 complete cycles/10 divisions
Yes
No
Check for 2 kHz, ±20% square wave at CAL OUT jack.
No
Yes
Check Calibrator ckt
Check Time-Base Generator and Horizontal Amplifier ckt.
Set TIME/DIV switch to 1 MILLISEC and pull 5X MAG switch. Check for same display as obtained above.
Yes
No
Check Horizontal Amplifier ckt
Apparent trouble may have been due to incorrect settings. For a trouble that still exists after completing this chart, use the troubleshooting method given in steps 6 and 7 of the Troubleshooting Techniques.

Fig. 4-3.

Obtaining Replacement Parts

Standard Parts. All electrical and mechanical part replacements for the Type 321A 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 effect 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 321A. 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 bottom of this instrument beneath the battery compartment. 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.

2. Maintain a clean, properly tinned tip.

3. Avoid putting pressure on the ceramic terminal strip.

4. Touch the iron to the connection and apply a small amount of solder to make a firm solder joint; do not attempt to fill the notch with solder. To protect heat-sensitive components, hold the lead between the component body and the solder joint with a pair of long-nose pliers or other heat sink.

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.

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. 4-4. 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.

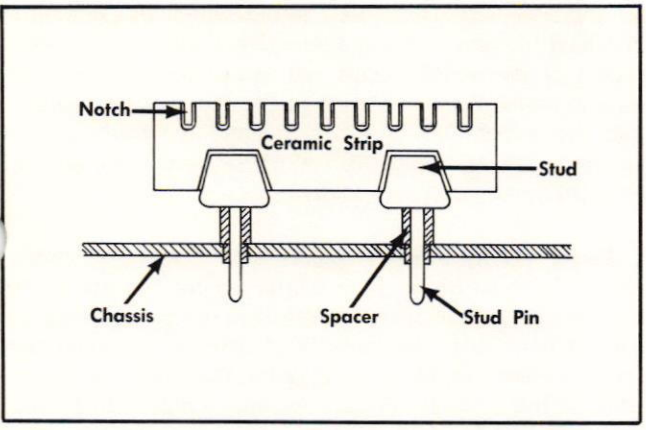


Fig. 4-4. Ceramic terminal strip assembly.

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 adviseable 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 durface 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 as described previously.

2. Remove the phillips-head screw at the bottom of the graticule cover and remove the graticule cover, light filter and graticule.

3. Disconnect the CRT anode connector. Ground this lead and the anode connection to discharge any stored charge.

4. Disconnect the deflection-plate pins.

5. Remove the CRT socket.

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

7. Hold the left hand on the CRT faceplate and push forward on the CRT base with the right hand. As the CRT starts out of the shield, grasp it firmly with the left hand. When the CRT is free of the clamp, slide the CRT completely out of the shield. Be careful not to bend the neck pins.

B. REPLACEMENT:

1. Insert the CRT into the shield. Be careful not to bend the neck pins.

2. Replace the CRT socket.

3. Reconnect the anode connector. Align the jack on the CRT and the plug in the connector and press firmly on the insulated cover to snap the plug into place.

4. Reconnect the deflection-plate connectors. Correct location is indicated on the CRT shield.

5. Replace the graticule, light filter and graticule cover.

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

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

Transistor Replacement. Transistors should not be replaced unless actually defective. Unnecessary replacement of transistors may affect the calibration of this instrument. When transistors are replaced, check the operation of that part of the instrument which may be affected.

CAUTION

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

Replacement transistors should be of the original type or a direct replacement. Fig. 4-2 shows the lead configuration of the transistors used in this instrument. Observe the soldering precautions given in this section when replacing transistors.

Fuse Replacement. Table 4-4 gives the rating, location and function of the fuses in this instrument.

TABLE 4-4
Fuse Ratings

Circuit Number	Rating	Location	Function
F601	0.25A, Fast	Left side below power transformer	AC line
F621	1.5A, Fast	Left side below power transformer	DC and battery

Rotary Switches. Individual wafers or mechanical parts of rotary switches are normally not replaceable. 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 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 given in Section 5 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 321A every 500 hours of operation, or every six months if used infrequently. Before complete calibration, thoroughly clean and inspect this instrument as outlined in the Maintenance section.

This section provides several features to aid in checking or calibrating this instrument. Some of these features are:

Index. The Short-Form Procedure lists the step numbers and titles of the Complete Calibration Procedure and gives the page on which each step begins. Therefore, the Short-Form Procedure can be used to locate a step in the complete procedure.

Calibration Record. The Short-Form Procedure can be reproduced and used as a permanent record of instrument calibration. Spaces are provided to record performance date for this instrument or to check off steps as they are completed.

Abridged Calibration Procedure. The Short-Form Procedure lists the adjustments necessary for each step and the applicable tolerance for correct calibration. The experienced calibrator who is familiar with the calibration of this instrument can use this procedure to facilitate checking or calibrating this instrument.

Performance Check. The Complete Calibration Procedure can be used as a checkout procedure by performing all portions except the ADJUST- part of a step. The performance check procedure checks the instrument to the original performance standards without removing the covers or making internal adjustments. Screwdriver adjustments which are accessible without removing the covers can be adjusted. Some steps are not applicable to a performance checkout procedure. These steps have a note titled PERFORMANCE CHECK ONLY which gives the next applicable step and any changes in control settings or equipment setup necessary for the next check.

Complete Calibration. Completion of each step in the Complete Calibration Procedure checks this instrument to the original performance standards and gives the procedure to return each adjustment to its optimum setting. Limits, tolerances and waveforms in this procedure are given as calibration guides and are not instrument specifications. Where possible, instrument performance is checked before an adjustment is made. For best overall instrument performance make each adjustment to the exact setting even if the CHECK- is within the allowable tolerance.

Partial Calibration. To check or adjust only part of this instrument, start with the nearest equipment required picture preceding the desired portion. To prevent recalibration of other parts of the instrument when performing a partial calibration, readjust only if the tolerance given in the CHECK- part of the step is not met. If an adjustment is made, any steps listed in the INTERACTION- part of the step should also be checked for correct tolerance.

TEST EQUIPMENT REQUIRED

General

The following test equipment and accessories, or its equivalent, is required for complete calibration of the Type 321A. 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.

For the quickest and most accurate calibration, special Tektronix calibration fixtures are used where necessary. These special calibration fixtures are available from Tektronix, Inc. Order by part number through your local Tektronix Field Office or representative.

Test Instruments

1. Variable autotransformer.[1] Must be capable of supplying about 75 volt-amperes over a range of 103.5 to 126.5 volts (207 to 253 volts for 230-volt nominal line). (If autotransformer does not have an AC voltmeter to indicate output voltage, monitor the output with an AC voltmeter with range of at least 126.5 or 253 volts, RMS.) For example, General Radio W10MT3W Metered Variac Autotransformer (note that the full current capabilities of this unit are not required).

2. Precision DC voltmeter.[1] Accuracy, within ±0.1%; range, zero to 50 volts. For example, Fluke Model 825A Differential DC Voltmeter.

3. DC volt-ammeter (VOM).[1] Minimum sensitivity, 20,000 ohms/volt; range, 0 to 750 volts and 0 to 400 milliamperes; accuracy, checked to within 1% at the voltages

[1] Not required for performance check only.

and currents to be measured. For example, Triplett Model 630-NA.

4. Test oscilloscope. 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 3B3 Time Base unit recommended.

5. Variable DC power supply.[1] Voltage range, at least +11 to +35 volts; current capabilities, at least 0.75 ampere: output voltage measured within 3%. For example, Trygon Model HR40-750.

6. 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.

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

8. High-frequency constant-amplitude sine-wave generator. Frequency, 350 kilohertz to above six 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.

9. Low-frequency constant-amplitude sine-wave generator. Frequency, two hertz to one megahertz; output amplitude, variable from 40 millivolts to five 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.

10. Time-mark generator. Marker outputs, 0.5 microsecond to 0.5 second; marker accuracy, within 0.1%. Tektronix Type 184 Time-Mark Generator recommended.

Accessories

11. AC power cord. Fits AC portion of Type 321A power receptacle. Tektronix Part No. 161-0015-01 (supplied accessory).

12. 1X probe for test oscilloscope.[1] Tektronix P6011 Probe recommended.

13. DC power cord.[1] Fits DC portion of Type 321A power receptacle. Tektronix Part No. 161-0016-01 (supplied accessory).

14. Battery cells (10).[1] Size D rechargeable. Tektronix Part No. 016-0077-01 (set of 10). Standard nonrechargeable battery cells can also be used.

15. Patch cord. Length, 18 inches; connectors, dual banana plug-jack: Tektronix Part No. 012-0031-00.

16. 10X probe for test oscilloscope.[1] Tektronix P6006 Probe recommended.

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

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

19. 10X attenuator. Impedance, 50 ohms; accuracy, ±3%; connectors, BNC. Tektronix Part No. 011-0059-00.

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

21. Adapter. BNC-to-post. Tektronix Part No. 012-0092-00.

22. 10X probe for Type 321A. Tektronix P6012 recommended (supplied accessory).

23. Adapter. Adapts BNC male connector to dual binding post. Tektronix Part No. 013-0094-00.

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

25. Patch cord. Length, six inches; connectors, banana plug-jack and BNC plug-jack. Tektronix Part No. 012-0089-00.

26. Patch cord. Length, 18 inches; connectors, banana plug-jack and BNC plug-jack Tektronix Part No. 012-0091-00 (supplied accessory).

Adjustment Tools

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

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

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

SHORT-FORM PROCEDURE

Type 321A, Serial No. ______________

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

Calibration date ____________________

Calibrated by ____________________

1. Adjust Regulated 10-Volt Supply and Check Regulation (R651) — Page 5-7

REQUIREMENT: 10 volts, ±20 millivolts at the regulated 10-volt test point over AC power input range.

PERFORMANCE: 10 volts, ±_____ millivolts.

2. Check Power Supply Output Voltage — Page 5-8

Power supply	REQUIREMENT: Voltage range	PERFORMANCE: Output voltage
+45 volt	+45 to +47 volts	________volts
+10 volt	+9.4 to +9.8 volts	________volts
−10 volt	−10.8 to −11.2 volts	________volts
−45 volt	−44.5 to −46.5 volts	________volts
−47.5 volt	−47 to −49 volts	________volts
−720 volt	−715 to −745 volts	________volts

3. Check Power Supply Ripple — Page 5-8

Power supply	REQUIREMENT: Maximum ripple	PERFORMANCE:
+45 volt	10 millivolts	______millivolts
+10 volt	25 millivolts	______millivolts
−10 volt	5 millivolts	______millivolts
−45 volt	20 millivolts	______millivolts
−47.5 volt	100 millivolts	______millivolts
−720 volt	2 volts	______volts

4. Check DC Operation — Page 5-8

REQUIREMENT: 10 volts ±50 millivolts at the regulated 10-volt test points over DC power input range.

PERFORMANCE: 10 volts ±_____ millivolts.

5. Check Low Batteries Indicator Light — Page 5-10

REQUIREMENT: LOW BATTERIES indicator light comes on with DC input voltage of 11.0 volts ±0.2 volt. Voltage at regulated 10-volt test points 10 volts ±50 millivolts.

PERFORMANCE: LOW BATTERIES indicator light flashes at_____volts. Regulated 10 volts; 10 volts, ±_____ millivolts.

6. Check Battery Operation — Page 5-10

REQUIREMENT: 10 volts, ±5.0 millivolts at the regulated 10-volt test point with fully charged rechargeable batteries or new non-rechargeable batteries.

PERFORMANCE: 10 volts ±_____volt. Battery type

7. Check Battery Charger Operation — Page 5-10

POWER switch	Charger switch	REQUIREMENT: Charge current range	PERFORMANCE: Charge current
ON EXT AC-DC (AC applied)	Dry Cells	0 mA	mA
	Low	30 mA, ±6 mA	30 mA, ± mA
	High	32 mA, ±6 mA	32 mA, ± mA
OFF TRICKLE CHG	Dry Cells	0 mA	mA
	Low	20 mA, ±5 mA	20 mA, ± mA
	High	40 mA, ±8 mA	40 mA, ± mA
OFF FULL CHG	Dry Cells	0 mA	mA
	Low	200 mA, ±40 mA	200 mA, ± mA
	High	360 mA, ±72 mA	360 mA, ± mA

8. Check/Adjust DC Balance (R432) — Page 5-11

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

PERFORMANCE: _____division shift.

9. Check/Adjust Trace Alignment (Reposition CRT) — Page 5-11

REQUIREMENT: Trace parallel to center horizontal line within 0.2 divisions/10 divisions.

PERFORMANCE: Within_____divisions.

10. Check/Adjust Geometry (R861) — Page 5-11

REQUIREMENT: Trace parallel to the top and bottom horizontal lines of the graticule within 0.1 division.

PERFORMANCE: Within_____division.

11. Check/Adjust Stability (R111) — Page 5-12

REQUIREMENT: Correct operation of trigger circuit; see procedure.

PERFORMANCE: Correct_____; incorrect_________

12. Check/Adjust Vertical Gain (R468) — Page 5-13

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

PERFORMANCE: Five divisions, ±_____ divisions.

13. Check Vertical Deflection Factor Accuracy Page 5-14

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

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

14. Check Variable Volts/Division Control Range Page 5-14

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

PERFORMANCE: Correct _____; incorrect _____.

15. Check Input Coupling Switch Operation Page 5-14

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

PERFORMANCE: Correct _____; not correct _____.

16. Check Low-Frequency Linearity Page 5-14

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

PERFORMANCE: _____ division.

17. Check/Adjust Calibrator Amplitude Page 5-15 (R884)

REQUIREMENT: CAL 4 DIV position of VOLTS/DIV switch, four divisions deflection ±0.08 division (with vertical gain set correctly). Amplitude at CAL OUT jack, 500 millivolts ±15 millivolts.

PERFORMANCE: CAL 4 DIV, four divisions ±_____ division. At CAL OUT jack, 500 millivolts ±_______ millivolts.

18. Check Calibrator Repetition Rate Page 5-15

REQUIREMENT: Duration of one cycle between 4.2 and 6.3 divisions at .1 MILLISEC/DIV.

PERFORMANCE: _____ divisions.

19. Check Calibrator Duty Cycle Page 5-15

REQUIREMENT: Length of positive segment of square wave between 4.5 and 5.5 divisions with one complete cycle/10 divisions.

PERFORMANCE: Positive segment _____ divisions.

20. Check Calibrator Risetime Page 5-16

REQUIREMENT: 0.1 microsecond or less.

PERFORMANCE: _____ microseconds.

21. Check Trace Shift Due to Input Current Page 5-16

REQUIREMENT: 0.05 division or less.

PERFORMANCE: _____ division.

22. Check/Adjust Volts/Div Switch Compensation (C410A, C410C, C412A, C412C, C414A, C414C, C416A, C416C, C418A, C418C) Page 5-17

REQUIREMENT: Optimum square corner and flat top within +2% or −2% with total peak to peak aberrations not to exceed 3% at each VOLTS/DIV switch position.

PERFORMANCE: Correct _____; incorrect (list exceptions)________________________________.

23. Check/Adjust High-Frequency Compensation (C506) Page 5-18

REQUIREMENT: Optimum 400 kilohertz square-wave response at 0.1 VOLTS/DIV within +0.08 or −0.08 division with total peak to peak aberrations not to exceed 0.12 division.

PERFORMANCE: Correct _____; incorrect _____.

24. Check Upper Vertical Bandwidth Limit Page 5-19

REQUIREMENT: Not more than −3 dB at six megahertz.

PERFORMANCE: −3 dB point _____ megahertz.

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

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

PERFORMANCE: Correct _____; incorrect _____.

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

REQUIREMENT: Internal, stable display in the AC and DC Coupling switch positions with the LEVEL control set to AUTO and the variable triggering area; check with one-division display at six megahertz. External, stable display in the AC and DC Coupling switch positions with the LEVEL control set to AUTO and the variable triggering area; check with a three-volt signal at six megahertz.

PERFORMANCE: Correct____; incorrect (list exceptions)________________________.

27. Check Low-Frequency Triggering Operation — Page 5-20

REQUIREMENT: Internal, stable display in the AC and DC Coupling switch positions with the LEVEL control set to AUTO and the variable triggering area; check with a 0.2-division display at one kilohertz. External, stable display in the AC and DC Coupling switch positions with the LEVEL control set to AUTO and the variable triggering area; check with a one-volt signal at one kilohertz and 30 hertz.

PERFORMANCE: Correct____; incorrect (list exceptions)________________________.

28. Check Triggering Slope Operation — Page 5-21

REQUIREMENT: Stable triggering on correct slope of trigger signal.

PERFORMANCE: Correct____; incorrect____.

29. Check/Adjust Normal Timing (R338) — Page 5-22

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

PERFORMANCE: Within____division over center eight divisions.

30. Check/Adjust Sweep Length (R176) — Page 5-23

REQUIREMENT: Between 10.2 and 11.2 divisions.

PERFORMANCE:____divisions.

31. Check/Adjust Magnified Timing (R348) — Page 5-23

REQUIREMENT: Correct timing within 0.32 division at 1 MILLISEC/DIV over center eight divisions of total magnified sweep length with 5X MAG switch pulled out. Timing over center eight divisions of each 10-division portion of total magnified sweep length within 0.32 division (exclude first five divisions of total magnified sweep length).

PERFORMANCE: Within____division over center eight division. Within____division (worst case) over each 10-division portion of total magnified sweep length.

32. Check Magnified Registration — Page 5-24

REQUIREMENT: Less than two-division shift of marker at center vertical line when 5X MAG switch is pulled out.

PERFORMANCE:____division shift.

33. Check Variable Time/Division Control Range — Page 5-24

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

PERFORMANCE: Correct____; incorrect____.

34. Adjust High-Frequency Timing (C160L) — Page 5-24

REQUIREMENT: Correct timing at .5 μSEC/DIV within 0.24 division.

PERFORMANCE: Within____division.

35. Check Normal Sweep Timing Accuracy — Page 5-24

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

PERFORMANCE: Correct____; incorrect (list exceptions)________________________.

36. Check Magnified Sweep Timing Accuracy — Page 5-24

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

PERFORMANCE: Correct____; incorrect (list exceptions)________________________.

37. Check External Horizontal Deflection Factor — Page 5-26

REQUIREMENT: Deflection of 4.5 to 5.5 divisions with five-volt square wave applied (5X MAG on).

PERFORMANCE:____divisions.

38. Check External Horizontal Bandwidth — Page 5-26

REQUIREMENT: Not more than −3 dB at one megahertz.

PERFORMANCE: Correct____; incorrect____.

39. Check External Blanking Page 5-27

REQUIREMENT: Five-volt positive, one-kilohertz signal blanks trace.

PERFORMANCE: Correct ; incorrect

COMPLETE CALIBRATION PROCEDURE

General

This calibration procedure is arranged so the Type 321A can be calibrated with the least interaction of adjustments and reconnection of equipment. The equipment required pictures identify the test equipment necessary for each group of checks and adjustments. Following this picture is a complete list of front-panel control settings for the Type 321A. To aid in performing a Complete Calibration Procedure, controls which must be changed for the next step are printed in bolt type. Each step following the equipment required picture continues from the equipment setup and control settings used in the preceding step(s) unless noted otherwise. External controls or adjustments of the Type 321A referred to in this procedure are capitalized (e.g., VOLTS/DIV). Internal adjustment names are initial capitalized only (e.g., Vert Gain). All waveforms shown in this procedure were taken with a Tektronix Oscilloscope Camera System.

The following procedure uses the equipment listed under Test Equipment Required. If equipment is substituted, control settings or equipment setup may need to be altered to meet the requirements of the equipment used. Detailed operating instructions for the test equipment is not given in this procedure. If in doubt as to the correct operation of any of the test equipment, refer to the instruction manual for that unit.

NOTE

This instrument should be calibrated at an ambient temperature of +25° C, ±5° C. The performance of this instrument 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 aplicable tolerances.

Preliminary Procedure for Performance Check Only

1. Connect the Type 321A to a power source which meets the voltage and frequency requirements of this instrument.

2. Set the POWER switch to ON. Allow at least 20 minutes warm up before proceeding.

3. Begin the performance check with step 8.

Preliminary Procedure for Complete Calibration

1. Remove the side panels from the Type 321A.

2. Connect the autotransformer to a suitable power source.

3. Connect the Type 321A to the autotransformer output.

4. Set the autotransformer output voltage to 115 (or 230) volts.

5. Set the POWER switch to ON. Allow at least 20 minutes warm up before proceeding.

NOTES

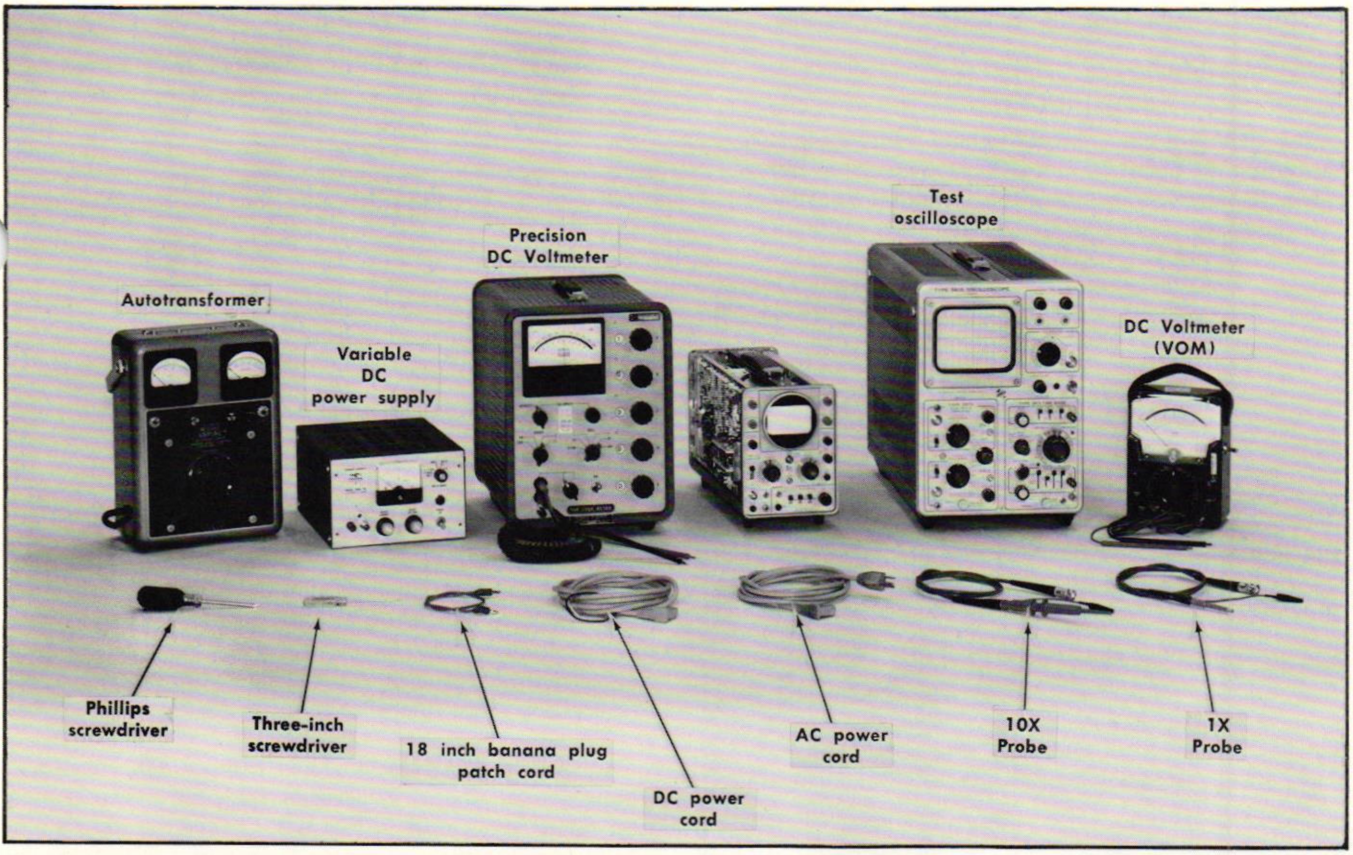


Fig. 5-1. Equipment required for steps 1 through 11.

CRT CONTROLS

FOCUS	Midrange
ASTIGMATISM	Midrange
INTENSITY	Counterclockwise
SCALE ILLUM	As desired

Vertical Amplifier

VERTICAL POSITION	Midrange
Input Coupling	DC
VOLTS/DIV	.01
VARIABLE	CALIB

Triggering

Source	INT
Coupling	AC
SLOPE	+
LEVEL	AUTO

Time Base

HORIZONTAL POSITION	Midrange
TIME/DIV	1 MILLISEC
VARIABLE	CALIB
5X MAG	Pushed in

Power

POWER	ON EXT AC-DC

1. Adjust Regulated 10-volt Supply and Check Regulation

PERFORMANCE CHECK ONLY

Steps 1 through 7 are not applicable to a performance check. Set controls as given beneath Fig. 5-1 and begin with step 8.

a. Equipment required for steps 1 through 11 is shown in Fig. 5-1.

b. Connect the precision DC voltmeter to the regulated 10-volt test points shown in Fig. 5-2. Observe the polarity shown.

NOTE

Power supply voltage and ripple tolerances given in steps 1 through 7 are typical values provided as guides to correct instrument operation and are not instrument specifications. The actual values may be greater than those listed without loss in measurement accuracy if the instrument meets the specifications given in Section 1 as tested in this procedure.

c. CHECK—Meter reading; 10 volts, ±20 millivolts.

NOTE

The 10 V Adj has a locknut to hold it in the adjusted position to maintain more stable calibration. Use a No. 10 nutdriver to loosen this locknut if adjustment is necessary. Retighten the locknut after calibration.

d. ADJUST—10 V Adj. R651 (see Fig. 5-2) for a meter reading of 10 volts.

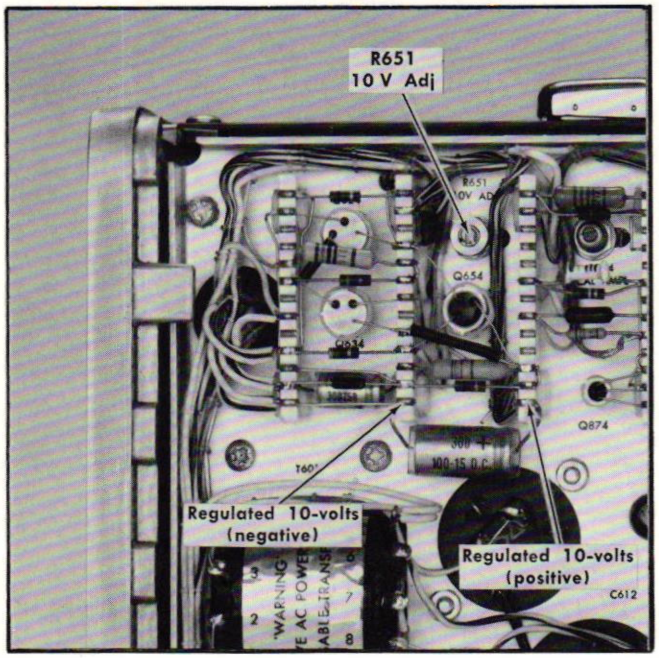


Fig. 5-2. Location of regulated 10 volts test points and adjustments (left side).

e. CHECK—Change the autotransformer output voltage between 103.5 and 126.5 (207 and 253 volts for 230-volt operation) and check for less than 50 millivolts change in the regulated 10 volt output level.

f. Return the autotransformer output voltage to 115 (or 230) volts.

g. INTERACTION—May affect operation of all circuits within the Type 321A.

2. Check Power Supply Output Voltage

a. CHECK—Table 5-1 lists the power supplies in this instrument. Check each supply with the DC voltmeter (VOM) for output voltage within the given range. Power supply test points are shown in Fig. 5-3.

b. Disconnect the DC voltmeter.

TABLE 5-1
Power Supply Output Voltage and Ripple

Power supply	Output voltage range[3]	Maximum ripple (peak to peak)
+45 volt	+45 to +47 volts	10 millivolts
+10 volt	+9.4 to +9.8 volts	25 millivolts
−10 volt	−10.8 to −11.2 volts	5 millivolts
−45 volt	−44.5 to −46.5 volts	20 millivolts
−47.5 volt	−47 to −49 volts	100 millivolts
−720 volt	−715 to −745 volts	2 volts

[3] **Measured with 20,000 ohms/volt meter.**

3. Check 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 (if operated from a power source with a frequency other than 60 cycles, set the test oscilloscope sweep rate to an applicable setting).

c. CHECK—Test oscilloscope display for maximum ripple of each supply as listed in Table 5-1. Power supply test points are shown in Fig. 5-3. Change the test oscilloscope vertical deflection factor as necessary to provide the correct display of the ripple.

d. Disconnect the 1X probe and the test oscilloscope.

4. Check DC Operation

NOTE

This step can be deleted if DC operation will not be used.

a. Disconnect the AC power cord and install the DC power cord.

b. Connect the white lead of the DC power cord to the ground terminal of the variable DC power supply. Then connect the green lead to the positive terminal.

c. Connect the front-panel GND post to earth ground.

d. Set the variable DC power supply to +35 volts output.

e. Connect the precision DC voltmeter to the regulated 10-volt test points shown in Fig. 5-2. Observe the polarity shown.

f. CHECK—Meter reading; 10 volts, ±50 millivolts.

g. Set the variable DC power supply for +20 volts output.

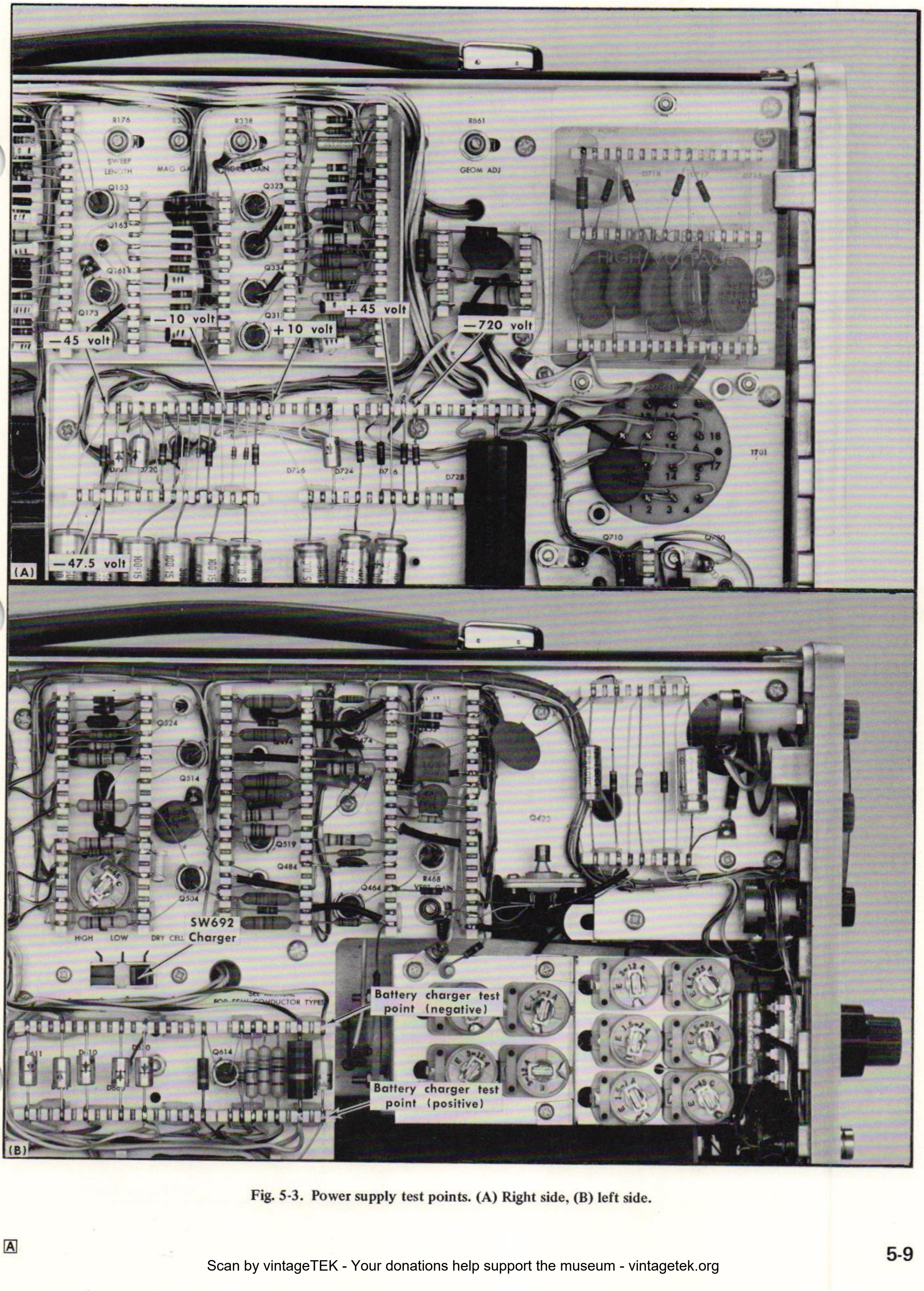


Fig. 5-3. Power supply test points. (A) Right side, (B) left side.

h. CHECK—Meter reading; 10 volts, ±50 millivolts.

i. Disconnect the green lead of the DC power cord and connect the black lead to the positive terminal of the variable DC power supply.

j. CHECK—Meter readings; 10 volts, ±50 millivolts.

k. Set the variable DC power supply for +11.5 volts output.

l. CHECK—Meter reading; 10 volts, ±50 millivolts.

5. Check Low Batteries Indicator Light

a. Connect the precision DC voltmeter to the battery terminals (see Fig. 5-4).

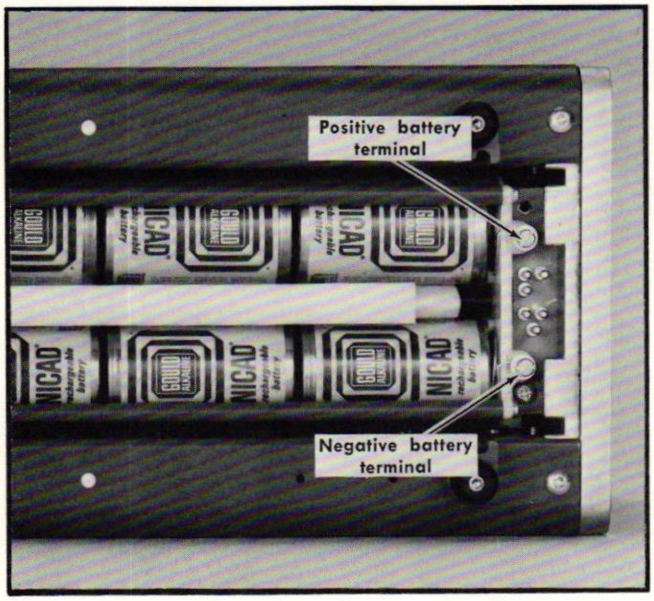


Fig. 5-4. Battery terminals (bottom).

b. Set the variable DC power supply for about +15 volts output.

c. CHECK—LOW BATTERIES indicator light is off.

d. Slowly decrease the output voltage of the variable DC power supply.

e. CHECK—LOW BATTERIES indicator light comes on when power supply output voltage is 11.0 volts, ±0.2 volt as indicated by precision DC voltmeter. Also check the voltage at the regulated 10-volt test points (see Fig. 5-2) with the precision DC voltmeter; 10 volts, ±50 millivolts.

f. Disconnect the DC power cord and variable DC power supply.

6. Check Battery Operation

NOTE

This step can be deleted if battery operation will not be used.

a. Install a set of fully charged rechargeable batteries or new nonrechargeable batteries into the battery compartment (see Section 2 for complete instructions on battery installation).

b. Set the POWER switch to ON INT BATT.

c. CHECK—Meter reading; 10 volts, ±50 millivolts.

d. Disconnect the precision DC voltmeter and ground connection.

7. Check Battery Charger Operation

NOTE

This step can be performed only if rechargeable battery cells are installed in the battery compartment.

a. Reconnect the AC power cord and check that the autotransformer is set for 115 (or 230) volts.

b. Connect the ammeter (VOM) to the battery charger test points shown in Fig. 5-3 (across D692). Observe the polarity shown.

c. CHECK—Using the POWER switch and Charger switch positions given in Table 5-2, check the battery charger current.

d. Set the VOM to measure at least 30 volts.

e. CHECK—Voltmeter reading; between 0.5 and 1.0 volts (indicates that D692 is not open and battery charger circuit is operative).

f. Disconnect all test equipment.

TABLE 5-2
Battery Charger Current

POWER switch	Charger switch	Charge current
ON EXT AC-DC (AC applied)	Dry Cells	0 milliamperes
	Low	30 milliamperes,±6 mA
	High	32 milliamperes,±6 mA
OFF TRICKLE CHG	Dry Cells	0 milliamperes
	Low	20 milliamperes,±5 mA
	High	40 milliamperes,±8 mA
OFF FULL CHG	Dry Cells	0 milliamperes
	Low	200 milliamperes,±40 mA
	High	360 milliamperes,±72 mA

8. Check/Adjust DC Balance

a. 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).

b. Adjust the FOCUS and ASTIGMATISM controls for a well defined trace.

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

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

PERFORMANCE CHECK ONLY

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

e. ADJUST—DC BAL adjustment R432 (see Fig. 5-5) for minimum trace shift as the VARIABLE VOLTS/DIV control is rotated.

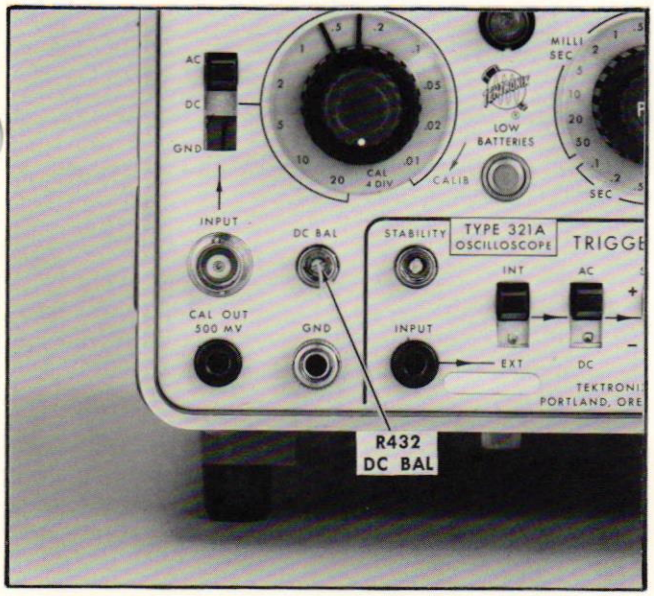


Fig. 5-5. Location of DC BAL adjustment (front panel).

f. Return the VARIABLE VOLTS/DIV control to CALIB.

9. Check/Adjust CRT Alignment

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

b. CHECK—The trace should be parallel to the center horizontal line within 0.2 division/10 divisions (i.e., with trace positioned to center horizontal line at the left vertical line of the graticule, the trace must be within 0.2 division of the center horizontal line at the right vertical line).

c. ADJUST—Loosen the CRT base clamp with the Phillips screwdriver. Use a plastic rod or similar tool as a lever behind the CRT socket to push the CRT face against the external graticule. Rotate the CRT until the trace is parallel to the center horizontal line and retighten the base clamp.

10. Check/Adjust Geometry

a. Position the trace to the top horizontal line of the graticule.

b. CHECK—CRT display for straight line coincident with the top horizontal line. Maximum deviation from straight line should not exceed 0.1 division.

c. ADJUST—Geom Adj R861 (see Fig. 5-6) for optimum line straightness.

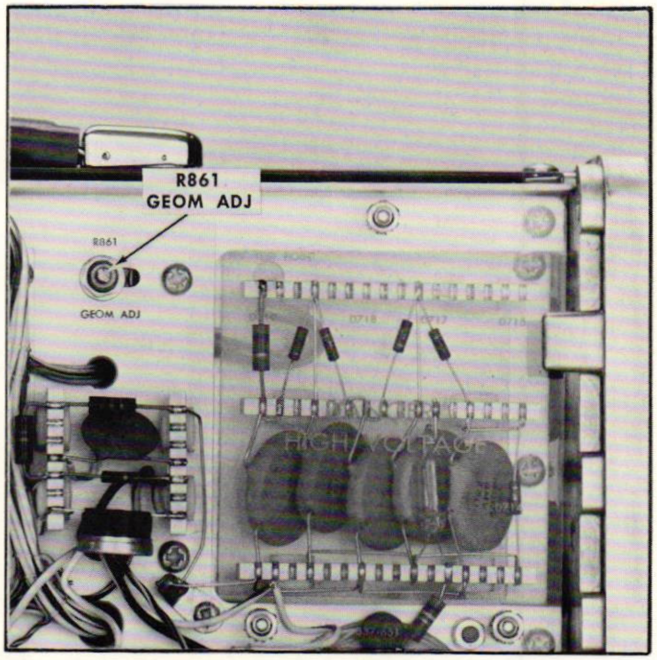


Fig. 5-6. Location of geometry adjustment (right side).

d. Position the trace to the bottom horizontal line of the graticule.

e. CHECK—CRT display for a straight line coincident with the bottom horizontal line. Maximum deviation from straight line should not exceed 0.1 division.

f. ADJUST—If necessary, compromise the adjustment of R861 for the straightest line at both the top and bottom of the graticule.

11. Check/Adjust Stability

a. Change the following control settings:

Source	EXT
LEVEL	AUTO
TIME/DIV	.1 MILLISEC

b. Connect the Triggering INPUT jack to the front-panel GND post with the 18-inch dual banana-plug patch cord.

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 STABILITY adjustment as follows (this procedure may not provide correct instrument performance under all operating conditions): (1) Rotate the STABILITY adjustment 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 STABILITY adjustment until the trace brightens; again note the rotation. (3) Set the STABILITY adjustment midway between the position noted in parts (1) and (2). (4) Disconnect the patch cord and proceed to the next equipment required picture.

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), DC coupled, at a sweep rate of two milliseconds/division.

e. Connect the 10X probe tip to the stability test point (base of Q135, see Fig. 5-7A). Connect the probe ground strap to the Type 321A chassis near the test point.

f. Rotate the STABILITY adjustment R111 (see Fig. 5-7B) fully counterclockwise. Then, slowly rotate it clockwise until the trace first appears on the Type 321A CRT. Adjust the test oscilloscope vertical position control to move the trace to a graticule below the center horizontal line.

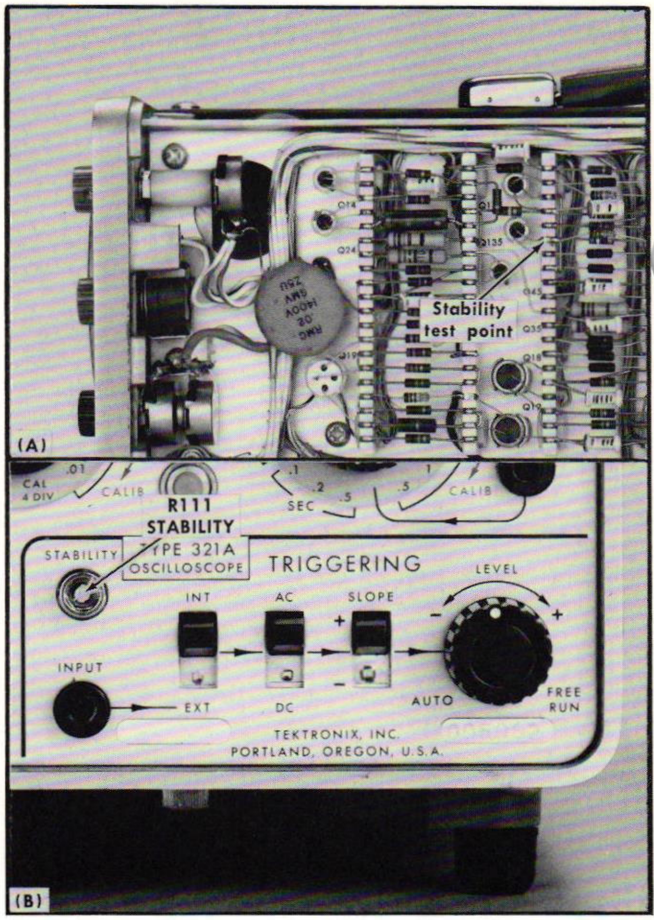


Fig. 5-7. (A) Stability test point (right side), (B) location of STABILITY adjustment (front panel).

g. Continue rotating the STABILITY adjustment clockwise until the trace on the Type 321A CRT brightens. Note the location of the trace on the test oscilloscope CRT.

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

i. Disconnect all test equipment.

NOTES

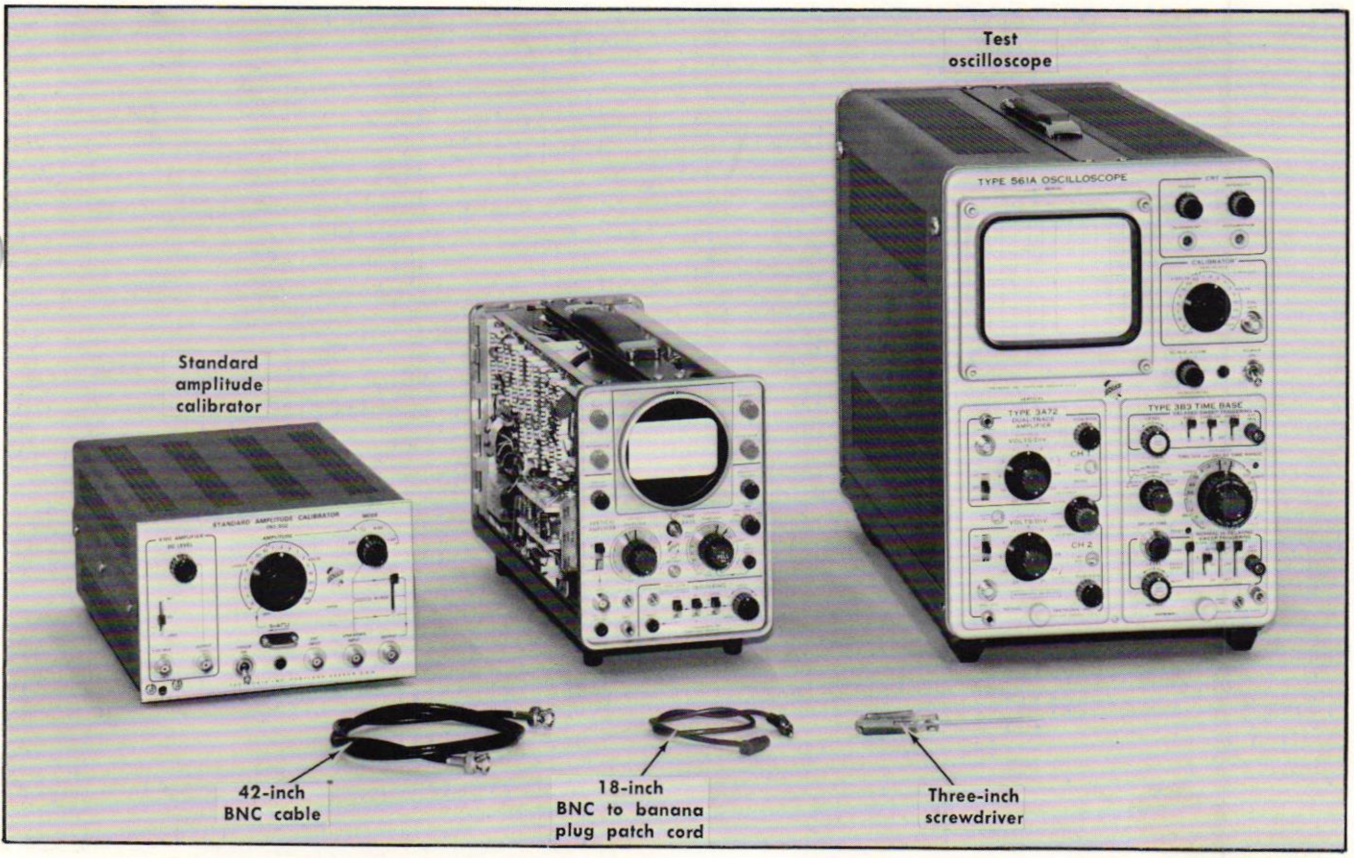


Fig. 5-8. Equipment required for steps 12 through 21.

CRT Controls

FOCUS	Adjust for well defined display
ASTIGMATISM	Adjust for well defined display
INTENSITY	Adjust for visible display
SCALE ILLUM	As desired

Vertical Amplifier

VERTICAL POSITION	Midrange
Input Coupling	DC
VOLTS/DIV	.01
VARIABLE	CALIB

Triggering

Source	**INT**
Coupling	AC
SLOPE	+
LEVEL	AUTO

Time Base

HORIZONTAL POSITION	Midrange
TIME/DIV	**1 MILLISEC**
VARIABLE	CALIB
5X MAG	Pushed in

Power

POWER	ON EXT AC-DC

12. Check/Adjust Vertical Gain

a. Equipment required for steps 12 through 17 is shown in Fig. 5-8.

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 50 millivolt square-wave output.

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

e. CHECK—CRT display for five divisions ±0.15 division of deflection (within 3%).

PERFORMANCE CHECK ONLY

If the vertical deflection is not exactly five divisions in step 12e, the error must be calculated for use in step 17. This can be calculated as follows: % error = divisions error (measured in 12e) ÷ 5. Also note the direction of error.

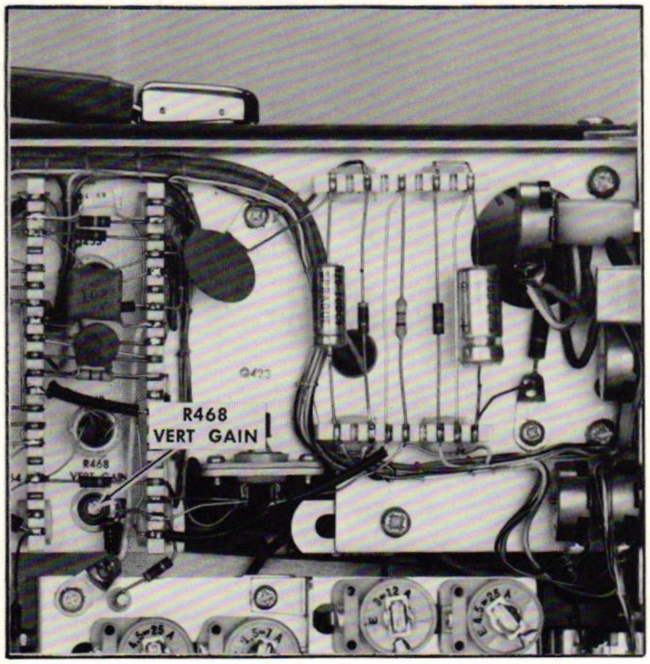


Fig. 5-9. Location of vertical gain adjustment (left side).

f. ADJUST—Vert Gain adjustment R348 (see Fig. 5-9) for exactly five divisions of deflection.

13. Check Vertical Deflection Factor Accuracy

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

TABLE 5-3
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 volt	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

14. Check Variable Volts/Division Control Range

a. Change the following control settings:

VOLTS/DIV	.01
Input Coupling	AC

b. Set the standard amplitude calibrator for a 50-millivolt 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 clockwise just past the CALIB detent. Display must be reduced to two divisions or less (indicates adequate range for continuously variable deflection factors between the calibrated steps).

15. Check Input Coupling Switch Operation

a. Set the VARIABLE VOLTS/DIV control to CALIB.

b. Set the standard amplitude calibrator for a 20-millivolt 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. Set the Input Coupling switch to GND.

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

16. Check Low-Frequency Linearity

a. Set the Input Coupling switch to DC.

b. Set the standard amplitude calibrator for a 50-millivolt 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 division with the VARIABLE VOLTS/DIV control (keep the display centered about the center horizontal line).

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

f. CHECK—Vertical compression or expansion not to exceed 0.1 division.

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

h. CHECK—Vertical compression or expansion not to exceed 0.1 division.

17. Check/Adjust Calibrator Amplitude

a. Change the following control settings:

VOLTS/DIV	CAL 4 DIV
VARIABLE VOLTS/DIV	CALIB
TIME/DIV	.5 MILLISEC

b. CHECK—CRT display for four divisions of deflection ±0.08 division (internal calibrator voltage correct within 2%).

PERFORMANCE CHECK ONLY

If the vertical deflection measured in step 12e was not exactly five divisions (indicating incorrect vertical gain), the tolerance for this step must be figured as follows: (1) Multiply four divisions by the error calculated in the note following step 12e. Take into account the direction of error. (2) Add this figure (or subtract depending upon direction of error) to four divisions. This is the deflection which the internal calibrator would produce with no error. (3) Multiply the number of divisions calculated in part 2 by ±2%. This provides the allowable tolerance for correct internal calibrator voltage.

c. ADJUST—Cal Amp adjustment, R884 (see Fig. 5-10A), for exactly four divisions of deflection.

NOTE

Accuracy of this adjustment depends upon the accuracy of the vertical gain. Step 12 must be performed before this adjustment can be made correctly.

d. Change the following control settings:

VOLTS/DIV	.01
TIME/DIV	.5 MILLISEC

e. Connect the CAL OUT jack to the unknown input connector of the standard amplitude calibrator with the 18-inch BNC to banana plug patch cord.

f. Set the standard amplitude calibrator for a positive 0.5-volt DC output in the mixed mode.

g. Connect the standard amplitude calibrator output connector to the vertical INPUT connector of the Type 321A with a 42-inch BNC cable.

h. Position the top of the waveform onto the display area with the VERTICAL POSITION control.

i. If necessary, set the LEVEL control for a stable display.

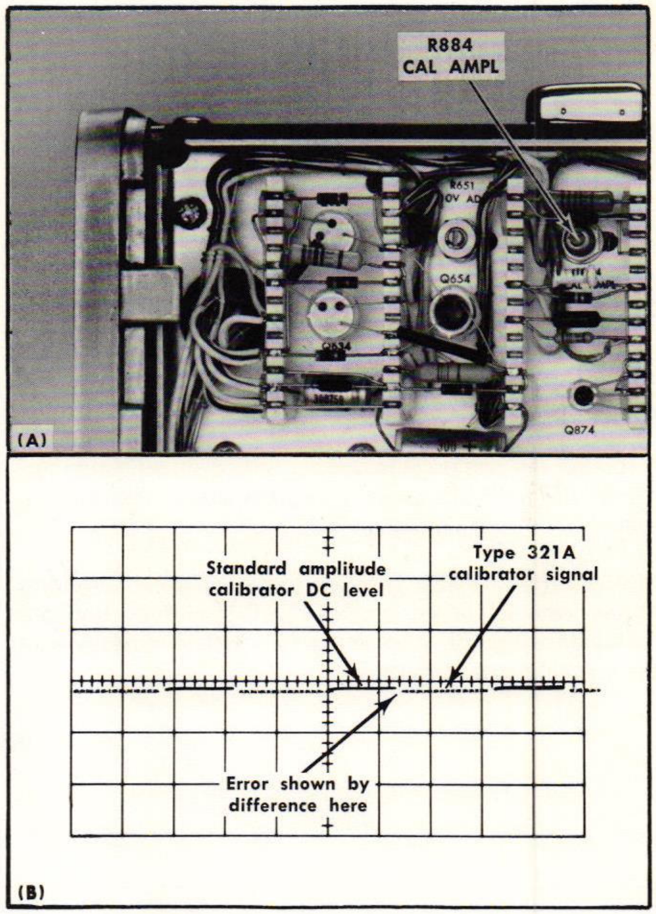


Fig. 5-10. (A) location of calibration amplitude adjustment (left side), (B) typical CRT display when checking voltage output at CAL OUT jack.

j. CHECK—Difference between the standard amplitude calibrator output level and the Type 321A calibrator output level is 0.15 division (15 millivolts) or less (calibrator output amplitude, 500 millivolts ±3%; see Fig. 5-10B).

k. Disconnect all test equipment.

18. Check Calibrator Repetition Rate

a. Change the following control settings:

VOLTS/DIV	CAL 4 DIV
LEVEL	AUTO
TIME/DIV	.1 MILLISEC

b. Position the start of the trace to the first vertical line of the graticule.

c. CHECK—CRT display for duration of one complete cycle between 4.2 and 6.3 divisions (repetition rate two kilohertz, ±20%).

19. Check Calibrator Duty Cycle

a. Set the TIME/DIV switch to 50 μSEC.

b. Set the VARIABLE TIME/DIV control for one complete cycle in 10 divisions.

c. CHECK—CRT display for length of positive segment of the square wave between 4.5 and 5.5 divisions (duty cycle 45% to 55%).

d. Return the VARIABLE TIME/DIV control to CALIB.

20. Check Calibrator Risetime

a. Connect the CAL OUT jack to the vertical input of the test oscilloscope with the 18-inch BNC to banana plug patch cord.

b. Set the test oscilloscope for a vertical deflection factor of 100 millivolts/division, negative-slope triggering at a sweep rate of 50 microseconds/division.

c. Position the rising portion of the calibrator waveform to the center of the test oscilloscope CRT with the horizontal position control. Also center the display vertically with the vertical position control.

d. Using the delayed sweep feature, set the test oscilloscope for a delayed sweep rate of one microsecond/division and adjust the delay time controls so that the rising portion of the calibrator waveform is displayed on the delayed sweep.

e. CHECK—Test oscilloscope display for one division or less horizontal distance between the 10% and 90% points on the leading edge of the calibrator waveform (one microsecond or less risetime).

f. Disconnect all test equipment.

21. Check Trace Shift Due to Input Current

a. Change the following control settings:

INPUT COUPLING	GND
VOLTS/DIV	.01

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

c. CHECK—Set the Input Coupling switch to DC and note the trace shift; must be 0.05 division or less.

NOTES

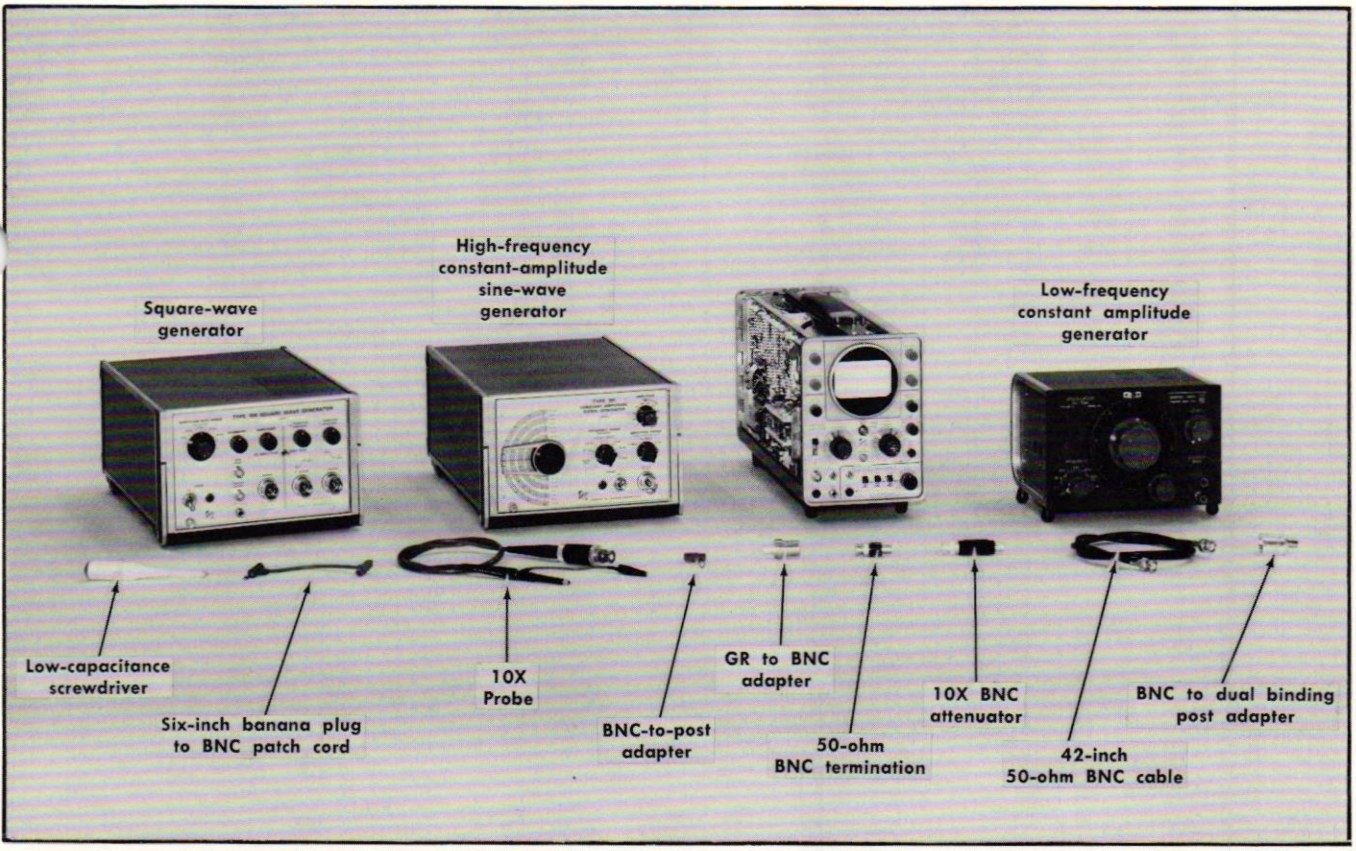


Fig. 5-11. Equipment required for steps 22 through 28.

CRT Controls

FOCUS	Adjust for well defined display
ASTIGMATISM	Adjust for well defined display
INTENSITY	Adjust for visible display
SCALE ILLUM	As desired

Vertical Amplifier

VERTICAL POSITION	Midrange
Input Coupling	DC
VOLTS/DIV	.01
VARIABLE	CALIB

Triggering

Source	INT
Coupling	AC
SLOPE	+
LEVEL	AUTO

Time Base

HORIZONTAL POSITION	Midrange
TIME/DIV	**.2 MILLISEC**
VARIABLE	CALIB
5X MAG	Pushed in

Power

POWER	ON EXT AC-DC

22. Check/Adjust Volts/Division Switch Compensation

a. Equipment required for steps 22 through 28 is shown in Fig. 5-11.

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

c. Install the GR to BNC adapter, 10X BNC attenuator and BNC-to-post adapter on the square-wave generator (Type 106) high-amplitude output connector, in given order.

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 for square corner and flat top within +2% or −2% with total peak-to-peak aberrations not to exceed 3% (see Fig. 5-12A). Remove the 10X attenuator as given in Table

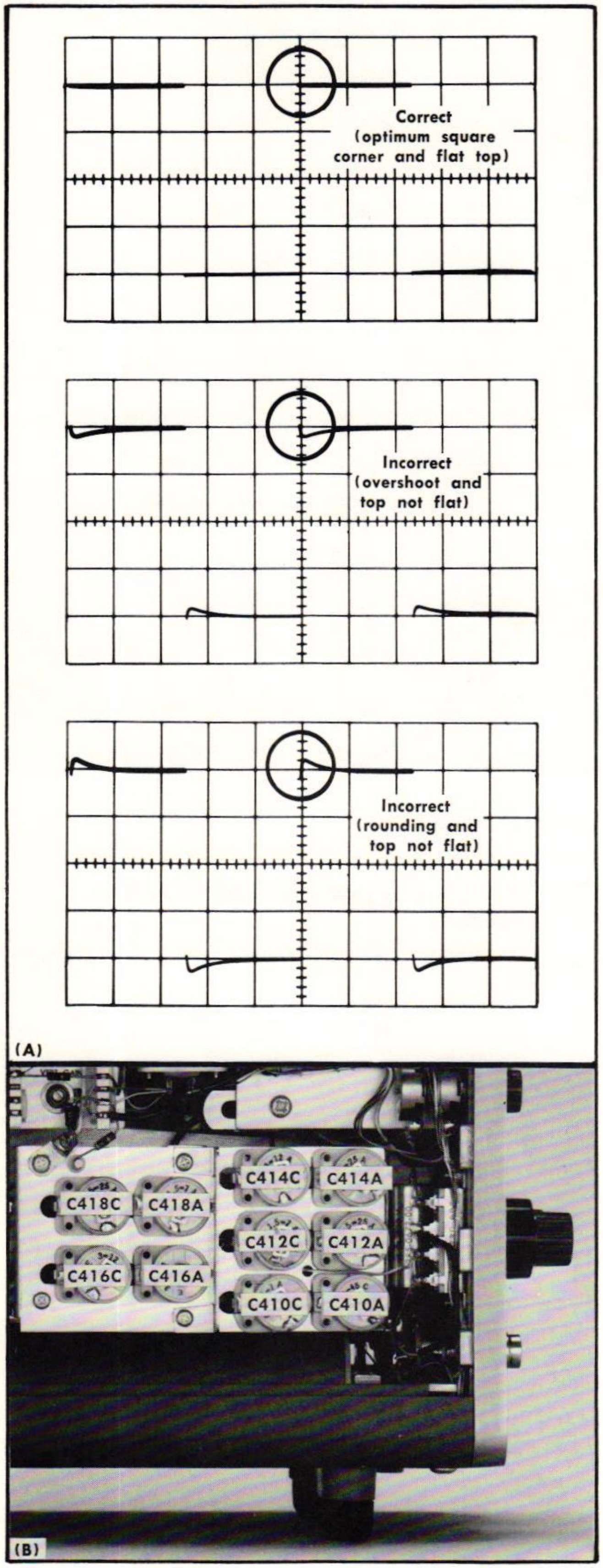


Fig. 5-12. (A) Typical CRT displays showing correct and incorrect compensation. (B) location of compensation adjustments (left side).

TABLE 5-4
VOLTS/DIV Switch Compensation

VOLTS/DIV switch setting	Attenuator compensated	Adjust for optimum Square corner	Flat top
.01	X1	Compensate probe	
.02	X2	C418C	C418A
.05	X5	C416C	C416A
Remove external 10X attenuator from generator			
.1	X10	C414C	C414A
.2	Check	If out of tolerance, compromise setting at .1 and .2 for best overall response.	
.5	Check	If out of tolerance, compromise setting at .1, .2 and .5 for best overall response.	
1	X100	C412C	C412A
2	Check	If out of tolerance, compromise setting at 1 and 2 for best overall response.	
5	Check	If out of tolerance, compromise setting at 1, 2, and 5 for best overall response.	
10	X1000	C410C	C410A
20	Check	If out of tolerance, compromise setting at 10 and 20 for best overall response.	

5-4 and readjust the generator output amplitude at each setting to maintain a four-division display, or to provide maximum vertical deflection in the 5, 10 and 20 position.

h. ADJUST—VOLTS/DIV switch compensation as given in Table 5-4 (use the low-capacitance screwdriver). First adjust for best square corner on the display and then for best flat top. Remove the 10X attenuator as given in Table 5-4 and readjust the generator output amplitude at each VOLTS/DIV switch setting to maintain a four-division display, or to provide maximum vertical deflection in the 5, 10 and 20 positions. Fig. 5-12B shows the location of the variable capacitors.

i. Disconnect all test equipment.

23. Check/Adjust High-Frequency Compensation

a. Change the following control settings:

VOLTS/DIV	.01
TIME/DIV	.5 μSEC
5X MAG	Pulled out

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, 10X BNC attenuator and the 50-ohm BNC termination, in given order.

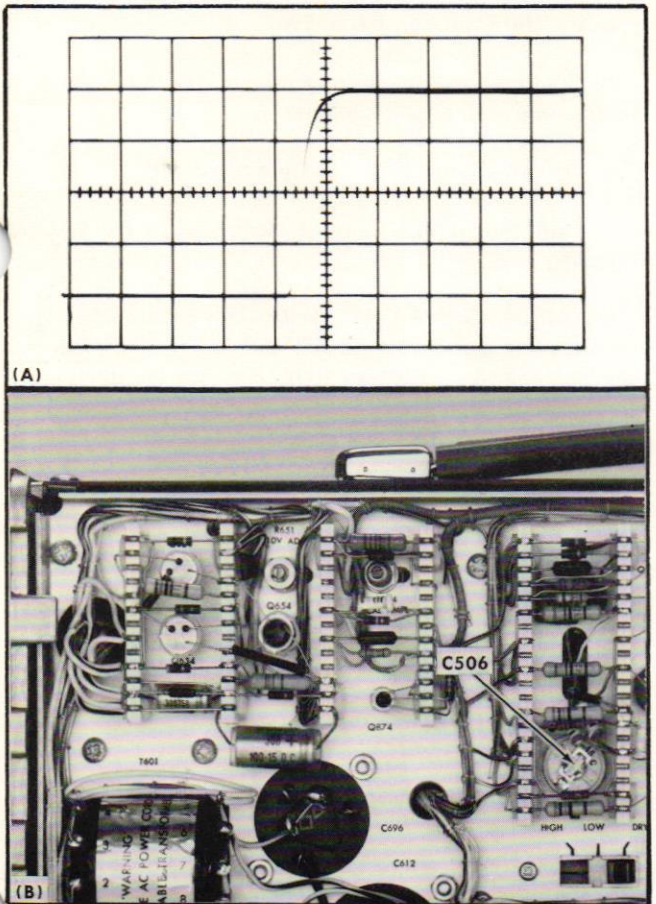


Fig. 5-13. (A) Typical CRT display showing correct high-frequency compensation (B) location of high-frequency compensation adjustment (left side).

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

d. Move the leading edge of the square wave onto the viewing area with the HORIZONTAL POSITION control and set the LEVEL control for a stable display.

e. CHECK—CRT display for square corner within +0.08 or −0.08 with total peak-to-peak aberrations not to exceed 0.12 division (see Fig. 5-13A).

f. ADJUST—C506 (see Fig. 5-13B) for best square corner on the CRT display.

g. Disconnect all test equipment.

24. Check Upper Vertical Bandwidth Limit

a. Change the following control settings:

LEVEL	AUTO
TIME/DIV	1 MILLISEC
5X MAG	Pushed in

b. Connect the high-frequency constant-amplitude sine-wave generator (Type 191) 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 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 six megahertz or higher.

f. Disconnect all test equipment.

25. Check AC-Coupled Lower Vertical Bandwidth Limit

a. Change the following control settings:

Input Coupling	AC
TIME/DIV	.5 SEC

b. Connect the low-frequency constant-amplitude 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 from reference frequency).

f. Disconnect all test equipment.

26. Check High-Frequency Triggering Operation

a. Change the following control settings:

VOLTS/DIV	1
Input Coupling	DC
TIME/DIV	.5 μSEC
5X MAG	Pulled out

b. Connect the high-frequency constant-amplitude 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 Triggering INPUT connector with the six-inch BNC to banana plug patch cord.

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

d. CHECK—Stable CRT display is presented.

e. Turn the LEVEL control clockwise to the variable triggering area.

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

g. Change the following control settings:

Source	EXT
LEVEL	AUTO
TIME/DIV	50 μSEC

h. Set the high frequency generator for a three-division display (three volts) at 50 kilohertz.

i. Without changing the output amplitude, set the constant-amplitude generator to six megahertz.

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

k. CHECK—Stable CRT display is presented.

l. Turn the LEVEL control clockwise to the variable triggering area.

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

n. Disconnect the high-frequency generator.

27. Check Low-Frequency Triggering Operation.

a. Change the following control settings:

Source	INT
LEVEL	AUTO
TIME/DIV	1 MILLISEC
5X MAG	Pushed in

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 BNC termination and the BNC T connector. Connect the output of the BNC T connector to the Triggering INPUT connector with the six-inch BNC to banana plug patch cord.

c. Set the low-frequency generator for a 0.2-division display at one kilohertz.

d. CHECK—Stable CRT display is presented.

e. Turn the LEVEL control clockwise to the variable triggering area.

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

g. Set the Source switch to EXT.

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

i. CHECK—Stable CRT display is presented.

j. Turn the LEVEL control clockwise to the variable triggering area.

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

l. Set the TIME/DIV switch to 10 MILLISEC.

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

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

o. Set the LEVEL control to AUTO.

p. CHECK—Stable CRT display is presented.

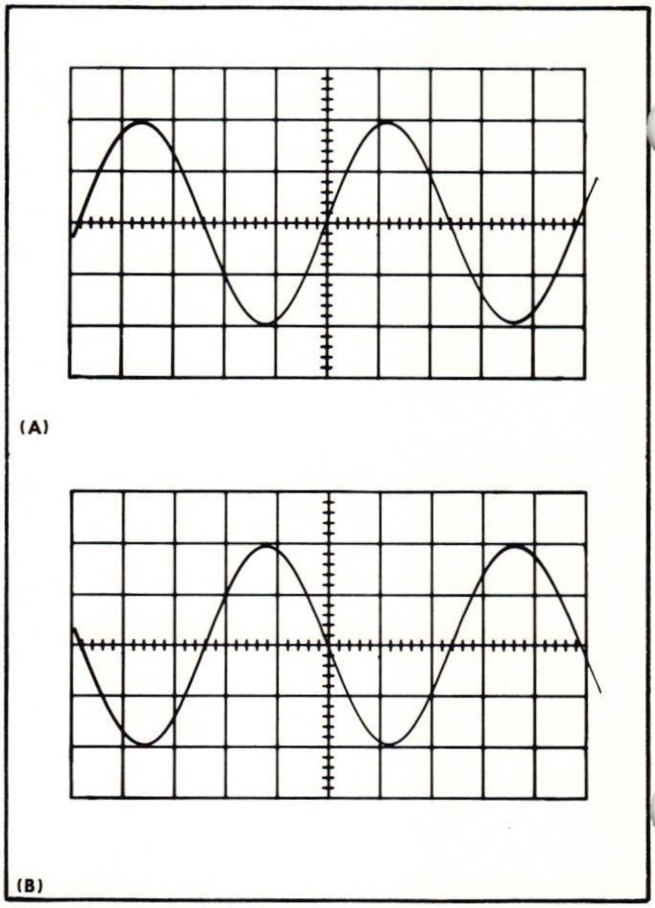


Fig. 5-14. (A) Typical CRT display when checking positive-slope triggering, (B) typical CRT display when checking negative-slope triggering.

28. Check Triggering Slope Operation

a. Change the following control settings:

Source	INT
Coupling	AC
TIME/DIV	.2 MILLISEC

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 (see Fig. 5-13A).

d. Set the SLOPE switch to −.

e. CHECK—CRT display starts on the negative slope of the waveform (see Fig. 5-13B).

NOTES

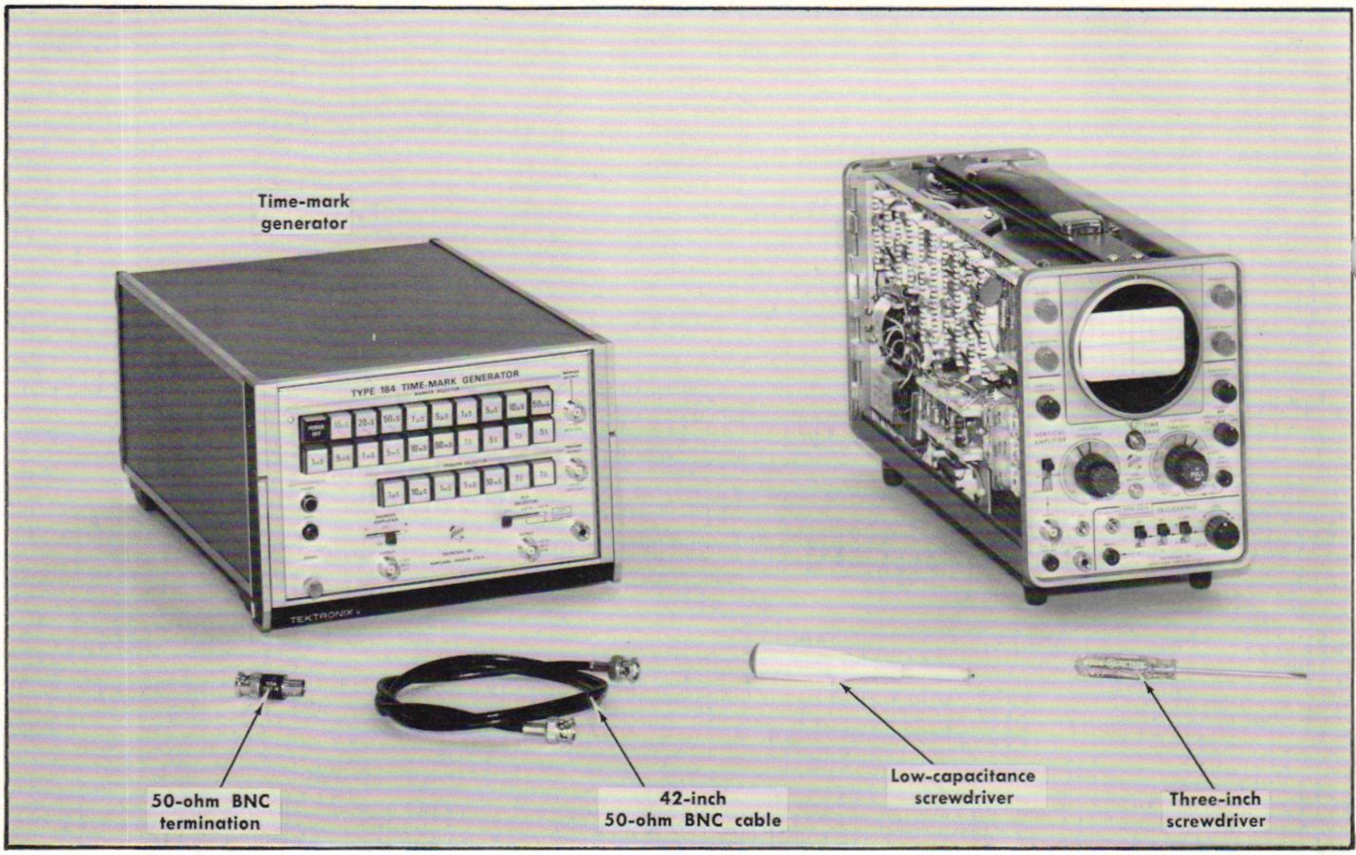


Fig. 5-15. Equipment required for steps 29 through 36.

CRT Controls

FOCUS	Adjust for well defined display
ASTIGMATISM	Adjust for well defined display
INTENSITY	Adjust for visible display
SCALE ILLUM	As desired

Vertical Amplifier

VERTICAL POSITION	Midrange
Input Coupling	DC
VOLTS/DIV	**.5**
VARIABLE	CALIB

Triggering

Source	**INT**
Coupling	AC
SLOPE	+
LEVEL	AUTO

Time Base

HORIZONTAL POSITION	Midrange
TIME/DIV	**1 MILLISEC**
VARIABLE	CALIB
5X MAG	Pushed in

Power

POWER	ON EXT AC-DC

29. Check/Adjust Normal Timing

a. Equipment required for steps 29 through 36 is shown in Fig. 5-15.

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.

d. CHECK—CRT display for one marker each division between the second and tenth vertical lines of the graticule (see Fig. 5-16A). 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.

NOTE

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

e. ADJUST—Horiz Gain adjustment R338 (see Fig. 5-16B) for one marker each division. The second and tenth markers must coincide exactly with their respective graticule lines (reposition the display slightly with the HORIZONTAL POSITION control if necessary).

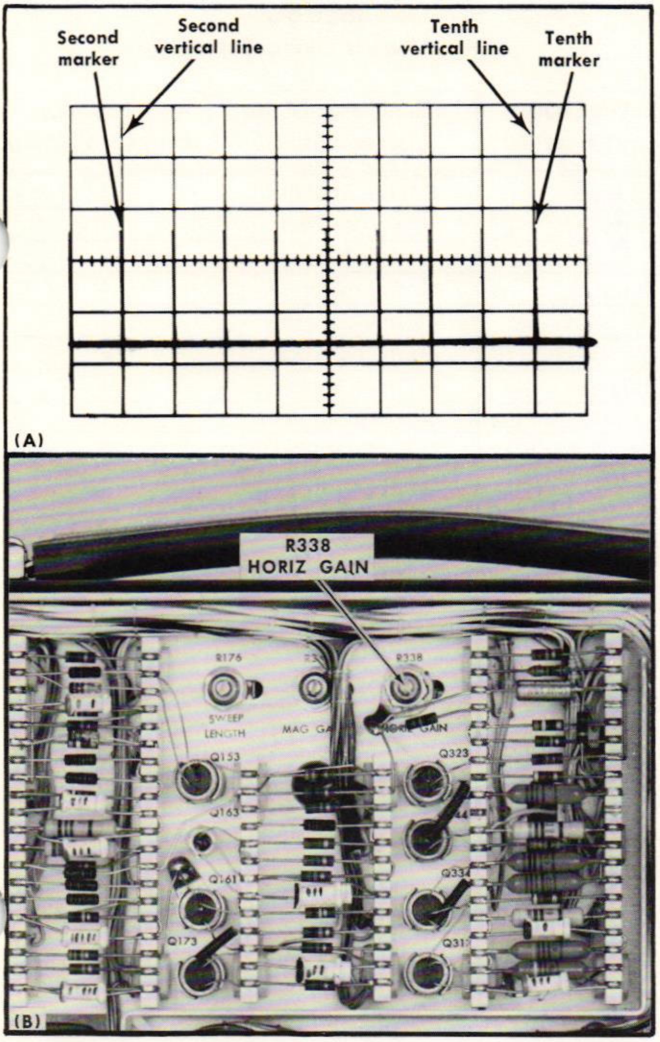


Fig. 5-16. (A) Typical CRT display showing correct normal timing, (B) location of normal timing adjustment (right side).

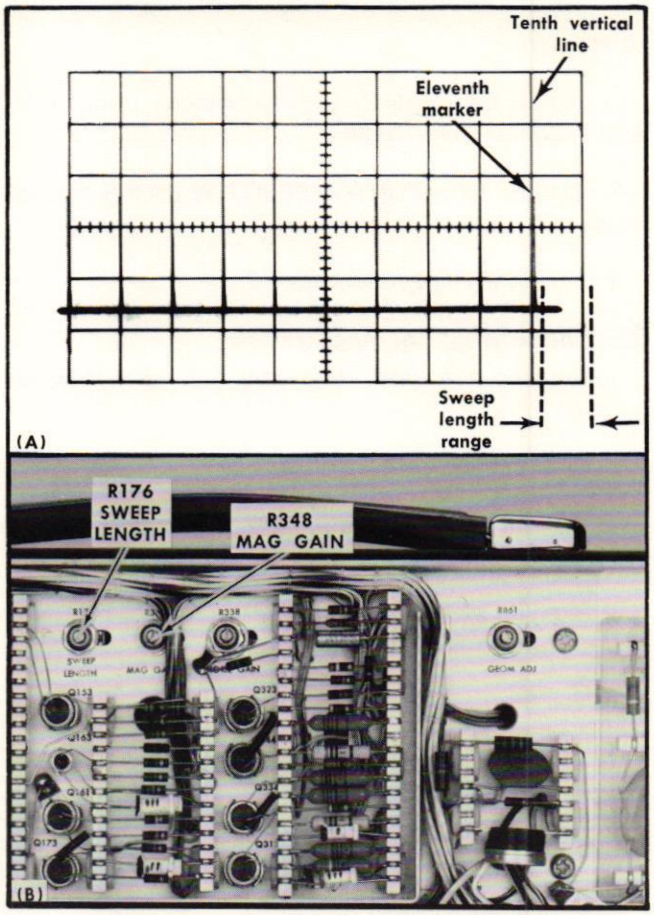


Fig. 5-17. (A) Typical CRT display when checking sweep length, (B) location of sweep length and magnified timing (right side).

f. INTERACTION—Check steps 30 through 36.

30. Check/Adjust Sweep Length

a. Move the eleventh marker to the tenth vertical line of the graticule with the HORIZONTAL POSITION control (see Fig. 5-17A).

b. CHECK—Sweep length between 10.2 and 11.2 divisions as shown by 0.2 to 1.2 division of horizontal deflection to the right of the tenth vertical line (see Fig. 5-17A).

c. ADJUST—Sweep Length adjustment R176 (see Fig. 5-16B) for a sweep length of 10.7 divisions (0.7 division of display to the right of the tenth vertical line).

31. Check/Adjust Magnified Timing

a. Change the following control settings:

HORIZONTAL POSITION	Midrange
5X MAG	Pulled out

b. Set the time-mark generator for 0.1-millisecond markers.

c. CHECK—CRT display for two markers each division between the second and tenth vertical lines. Marker at the tenth vertical line must be within 0.4 division (within 5%) of that graticule line when the marker at the second vertical line is positioned exactly.

d. ADJUST—Mag Gain adjustment R348 (see Fig. 5-17B) for two markers each division. The markers at the second and tenth vertical lines must coincide exactly with their respective graticule lines (reposition the display slightly with the HORIZONTAL POSITION control if necessary).

e. Position the fifth marker of the total magnified sweep length to the second vertical line of the graticule with the HORIZONTAL POSITION control.

f. CHECK—Two markers each division between the second and tenth vertical lines. Marker at tenth vertical line must be within 0.4 division (within 5%) of that graticule line when the marker at the second vertical line is positioned exactly.

g. Repeat this check for each 10-division portion of the total magnified sweep length.

h. Set the HORIZONTAL POSITION control to midrange.

i. INTERACTION—Check step 32.

32. Check Magnifier Registration

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

b. Push in the 5X MAG switch.

c. Set the LEVEL control for a stable display in the variable triggering area.

d. Position the middle marker (three markers on sweep) to the center vertical line.

e. Pull the 5X MAG switch out.

f. CHECK—Middle marker should be within two divisions of the center vertical line.

33. Check Variable Time/Division Control Range

a. Push in the 5X MAG switch.

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

c. Set the LEVEL control for a stable display in the variable triggering area.

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

e. Turn the VARIABLE TIME/DIV control fully counterclockwise.

f. CHECK—CRT display for four-division maximum spacing between markers (indicates adequate range for continuously variable sweep rate between the calibrated steps).

34. Adjust High-Speed Timing

PERFORMANCE CHECK ONLY

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

a. Change the following control settings:

TIME/DIV	.5 μSEC
VARIABLE TIME/DIV	CALIB

TABLE 5-5
Normal Sweep Timing Accuracy

TIME/DIV switch setting	Time-mark generator marker 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 MILLISEC	0.1 millisecond	1
.2 MILLISEC	0.1 millisecond	2
.5 MILLISEC	0.5 millisecond	1
1 MILLISEC	1 millisecond	1
2 MILLISEC	1 millisecond	2
5 MILLISEC	5 millisecond	1
10 MILLISEC	10 millisecond	1
20 MILLISEC	10 millisecond	2
50 MILLISEC	50 millisecond	1
.1 SEC	0.1 second	1
.2 SEC	0.1 second	2
.5 SEC	0.5 second	1

b. Set the time-mark generator for 0.5 microsecond markers.

c. Set the LEVEL control for a stable display.

d. CHECK—CRT display for one marker each division between the second and tenth vertical lines of the graticule (see Fig. 5-18A).

e. ADJUST—C160L (see Fig. 5-18B) for one marker each division.

35. 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. CHECK—Using the TIME/DIV switch and time-mark generator setting given in Table 5-5, check normal sweep timing within 0.24 division (within 3%) over the middle eight divisions of the display. Set the LEVEL control as necessary for a stable display.

36. Check Magnified Sweep Timing Accuracy

a. Pull the 5X MAG switch out.

b. CHECK—using the TIME/DIV switch and time-mark generator settings given in Table 5-6, check magnified

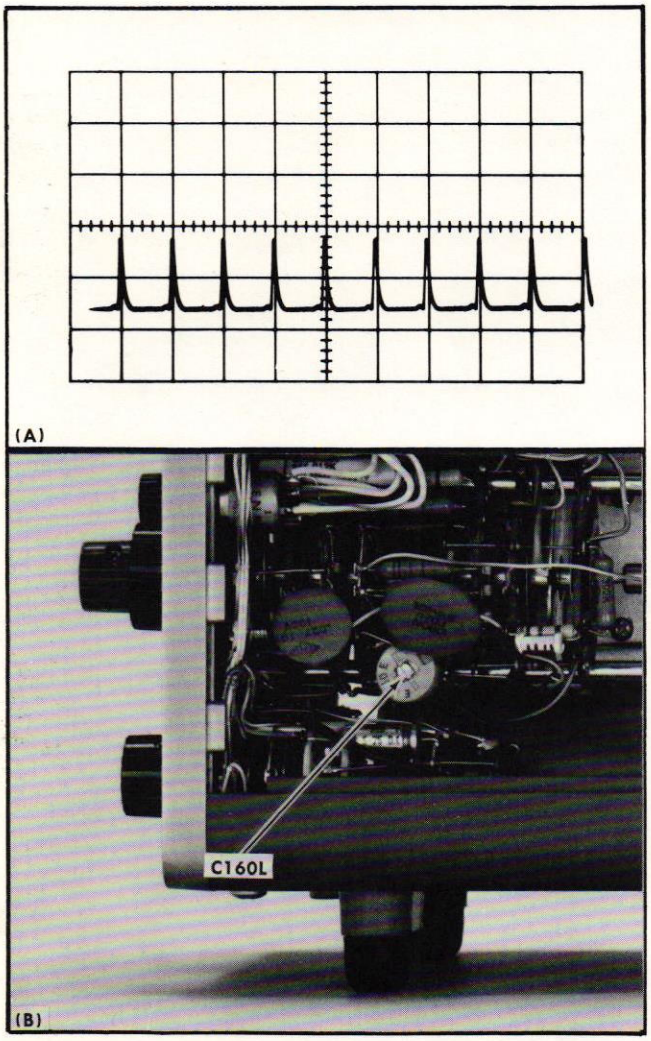


Fig. 5-18. (A) Typical CRT display showing correct high-speed timing (B) location of C160L (right side).

TABLE 5-6
Magnified Sweep Timing Accuracy

TIME/DIV switch setting	Time-mark generator marker output	CRT display (markers/division)
.5 μSEC	.1 microsecond	1
1 μSEC	.1 microsecond	2
2 μSEC	.1 microsecond	4
5 μSEC	1 microsecond	1
10 μSEC	1 microsecond	2
20 μSEC	1 microsecond	4
50 μSEC	10 microsecond	1
.1 MILLISEC	10 microsecond	2
.2 MILLISEC	10 microsecond	4
.5 MILLISEC	.1 millisecond	1
1 MILLISEC	.1 millisecond	2
2 MILLISEC	.1 millisecond	4
5 MILLISEC	1 millisecond	1
10 MILLISEC	1 millisecond	2
20 MILLISEC	1 millisecond	4
50 MILLISEC	10 millisecond	1
.1 SEC	10 millisecond	2
.2 SEC	10 millisecond	4
.5 SEC	.1 second	1

sweep timing within 0.4 division (within 5%) over the center eight divisions of the total magnified sweep length. Be sure that the indicated number of markers are displayed each division. Set the LEVEL control as necessary for a stable display.

c. Disconnect all test equipment.

NOTES

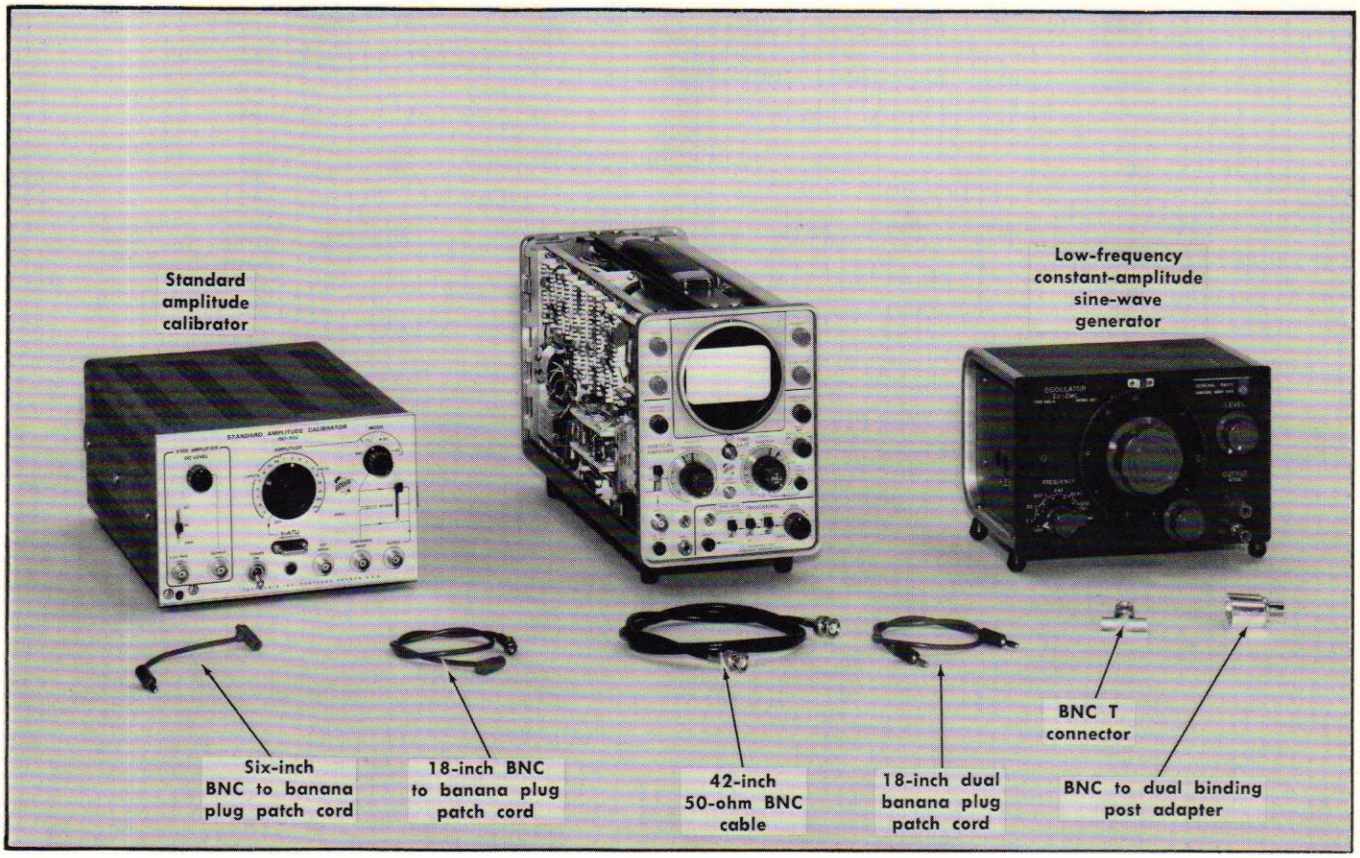


Fig. 5-19. Equipment required for steps 37 through 39.

CRT Controls	
FOCUS	Adjust for well defined display
ASTIGMATISM	Adjust for well defined display
INTENSITY	Adjust for visible display
SCALE ILLUM	As desired
Vertical Amplifier	
VERTICAL POSITION	Midrange
Input Coupling	**GND**
VOLTS/DIV	**2**
VARIABLE	CALIB
Triggering	
Source	INT
Coupling	AC
SLOPE	+
LEVEL	**AUTO**
Time Base	
HORIZONTAL POSITION	Midrange
TIME/DIV	**External Horizontal**
VARIABLE	CALIB
5X MAG	Pulled out
Power	
POWER	ON EXT AC-DC

37. Check External Horizontal Deflection Factor

a. Equipment required for steps 37 through 39 is shown in Fig. 5-19.

b. Connect the standard amplitude calibrator to the vertical INPUT connector through the 42-inch BNC cable and the BNC T connector. Connect the output of the BNC T connector to the EXT HORIZ INPUT jack with the six-inch BNC to banana plug patch cord.

c. Set the standard amplitude calibrator for a five-volt square-wave output.

d. CHECK—CRT display for horizontal deflection of 4.5 to 5.5 divisions between dots (one volt/division, ±10%).

e. Disconnect the standard amplitude calibrator.

38. Check External Horizontal Bandwidth

a. Connect the low-frequency constant-amplitude generator to the vertical INPUT connector through the BNC to dual binding post adapter, 42-inch BNC cable and the BNC T connector. Connect the output of the BNC T connector to the EXT HORIZ INPUT jack with the six-inch BNC to banana plug patch cord.

b. Set the low-frequency generator for four-divisions horizontal deflection at one kilohertz.

c. Without changing the output amplitude, increase the output frequency of the generator to one megahertz.

d. CHECK—CRT display for 2.8 divisions or greater horizontal deflection (not more than −3 dB from reference frequency).

e. Disconnect the six-inch BNC to banana plug patch cord.

39. Check External Blanking

a. Change the following control settings:

Input Coupling	DC
TIME/DIV	.2
5X MAG	Pushed in

b. Set the low-frequency generator for a five-division display (five volt positive peaks) at one kilohertz.

c. Remove the ground bar from between the two jacks on the rear panel.

d. Connect the output of the BNC T connector to the red CRT GRID jack on the rear panel with an 18-inch BNC to banana plug patch cord and an 18-inch banana plug patch cord.

e. CHECK—CRT display for blanking of a portion of each cycle of the waveform (see Fig. 5-20). The INTENSITY control setting may need to be changed to show blanking.

f. Replace the ground bar between the CRT GRID jacks.

This completes the Calibration Procedure for the Type 321A. 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 listed in Section 1 of this manual.

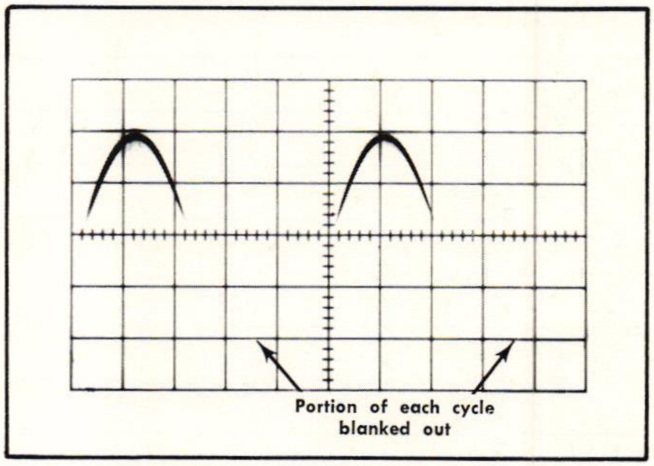


Fig. 5-20. Typical CRT display when checking external blanking.

NOTES

NOTES

ABBREVIATIONS AND SYMBOLS

A or amp	amperes
AC or ac	alternating current
AF	audio frequency
α	alpha—common-base current amplification factor
AM	amplitude modulation
$\approx$	approximately equal to
β	beta—common-emitter current amplification factor
BHB	binding head brass
BHS	binding head steel
BNC	baby series "N" connector
$\times$	by or times
C	carbon
C	capacitance
cap.	capacitor
cer	ceramic
cm	centimeter
comp	composition
conn	connector
$\sim$	cycle
c/s or cps	cycles per second
CRT	cathode-ray tube
csk	countersunk
Δ	increment
dB	decibel
dBm	decibel referred to one milliwatt
DC or dc	direct current
DE	double end
$^\circ$	degrees
$^\circ$C	degrees Celsius (degrees centigrade)
$^\circ$F	degrees Fahrenheit
$^\circ$K	degrees Kelvin
dia	diameter
$\div$	divide by
div	division
EHF	extremely high frequency
elect.	electrolytic
EMC	electrolytic, metal cased
EMI	electromagnetic interference (see RFI)
EMT	electrolytic, metal tubular
ε	epsilon—2.71828 or % of error
$\geq$	equal to or greater than
$\leq$	equal to or less than
ext	external
F or f	farad
F & I	focus and intensity
FHB	flat head brass
FHS	flat head steel
Fil HB	fillister head brass
Fil HS	fillister head steel
FM	frequency modulation
ft	feet or foot
G	giga or 10^9
g	acceleration due to gravity
Ge	germanium
GHz	gigahertz
GMV	guaranteed minimum value
GR	General Radio
$>$	greater than
H or h	henry
h	height or high
hex.	hexagonal
HF	high frequency
HHB	hex head brass
HHS	hex head steel
HSB	hex socket brass
HSS	hex socket steel
HV	high voltage
Hz	hertz (cycles per second)
ID	inside diameter
IF	intermediate frequency
in.	inch or inches
incd	incandescent
∞	infinity
int	internal
$\int$	integral
k	kilohms or kilo (10^3)
k Ω	kilohm
kc	kilocycle
kHz	kilohertz

L	inductance
λ	lambda—wavelength
$\gg$	large compared with
$<$	less than
LF	low frequency
lg	length or long
LV	low voltage
M	mega or 10^6
m	milli or 10^{-3}
MΩ or meg	megohm
μ	micro or 10^{-6}
mc	megacycle
met.	metal
MHz	megahertz
mm	millimeter
ms	millisecond
—	minus
mtg hdw	mounting hardware
n	nano or 10^{-9}
no. or #	number
ns	nanosecond
OD	outside diameter
OHB	oval head brass
OHS	oval head steel
Ω	omega—ohms
ω	omega—angular frequency
p	pico or 10^{-12}
/	per
%	percent
PHB	pan head brass
ϕ	phi—phase angle
π	pi—3.1416
PHS	pan head steel
$+$	plus
$\pm$	plus or minus
PIV	peak inverse voltage
plstc	plastic
PMC	paper, metal cased
poly	polystyrene
prec	precision
PT	paper, tubular
PTM	paper or plastic, tubular, molded
pwr	power
Q	figure of merit
RC	resistance capacitance
RF	radio frequency
RFI	radio frequency interference (see EMI)
RHB	round head brass
ρ	rho—resistivity
RHS	round head steel
r/min or rpm	revolutions per minute
RMS	root mean square
s or sec.	second
SE	single end
Si	silicon
SN or S/N	serial number
$\ll$	small compared with
T	tera or 10^{12}
TC	temperature compensated
TD	tunnel diode
THB	truss head brass
θ	theta—angular phase displacement
thk	thick
THS	truss head steel
tub.	tubular
UHF	ultra high frequency
V	volt
VAC	volts, alternating current
var	variable
VDC	volts, direct current
VHF	very high frequency
VSWR	voltage standing wave ratio
W	watt
w	wide or width
w/	with
w/o	without
WW	wire-wound
xmfr	transformer

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.
◐	Screwdriver adjustment.
▭	Control, adjustment or connector.

SECTION 6
ELECTRICAL PARTS LIST

Values are fixed unless marked Variable.

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			

Bulbs

Ckt. No.	Tektronix Part No.	Eff	Disc	Description
B601	150-0001-00			Incandescent #47
B602	150-0001-00			Incandescent #47
B699	150-0038-00			Assembly w/GE #680
B714	150-0027-00			Neon NE-23
B845	150-0020-00			Neon FML-1-AFC-000

Capacitors

Tolerance ±20% unless otherwise indicated.

Ckt. No.	Tektronix Part No.	Eff	Disc	Value	Type	Voltage	Tolerance
C2	281-0501-00			4.7 pF	Cer	500 V	±1 pF
C8	283-0008-00			0.1 μF	Cer	500 V	
C20	283-0003-00			0.01 μF	Cer	150 V	
C23	281-0518-00			47 pF	Cer	500 V	10%
C30	290-0026-00			5 μF	Elect.	25 V	+75%—10%
C37	281-0516-00			39 pF	Cer	500 V	10%
C43	281-0549-00			68 pF	Cer	500 V	10%
C131	281-0549-00			68 pF	Cer	500 V	10%
C141	281-0516-00			39 pF	Cer	500 V	10%
C147	281-0589-00			170 pF	Cer	500 V	5%
C160A	*295-0078-00			10 μF	Timing Series (matched within ±1%)		
C160C				1 μF			
C160E				0.1 μF			
C160G				0.01 μF			
C160J				0.001 μF			
C160L	281-0022-00			8-50 pF, Var	Cer		
C160M	283-0148-00			470 pF	Cer	1000 V	5%
C165	281-0512-00			27 pF	Cer	500 V	10%
C170	281-0512-00			27 pF	Cer	500 V	10%
C180A	290-0121-00			2 μF	Elect.	25 V	+150%—10%
C180C	285-0633-00			0.22 μF	PTM	100 V	10%
C180E	283-0058-00			0.027 μF	Cer	100 V	10%
C180G	283-0051-00			0.0033 μF	Cer	100 V	5%
C181	281-0524-00			150 pF	Cer	500 V	
C193	281-0525-00			470 pF	Cer	500 V	
C300	281-0513-00			27 pF	Cer	500 V	
C311	281-0501-00			4.7 pF	Cer	500 V	±1 pF
C312	281-0506-00			12 pF	Cer	500 V	10%
C401	*285-0672-00			0.1 pF	MT	600 V	+5%—15%
C410A	281-0012-00			7-45 pF, Var	Cer		

Capacitors *(Cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
C410C	281-0005-00			1.5-7 pF, Var	Cer		
C410E	283-0626-00			1800 pF	Mica	500 V	5%
C412A	281-0010-00			4.5-25 pF, Var	Cer		
C412C	281-0005-00			1.5-7 pF, Var	Cer		
C412E	283-0598-00			253 pF	Mica	300 V	5%
C414A	281-0010-00			4.5-25 pF, Var	Cer		
C414C	281-0007-00			3-12 pF, Var	Cer		
C414E	281-0518-00			47 pF	Cer	500 V	
C416A	281-0007-00			3-12 pF, Var	Cer		
C416C	281-0007-00			3-12 pF, Var	Cer		
C417	281-0512-00			27 pF	Cer	500 V	10%
C418A	281-0005-00			1.5-7 pF, Var	Cer		
C418C	281-0010-00			4.5-25 pF, Var	Cer		
C422	281-0534-00			3.3 pF	Cer	500 V	±0.25 pF
C423	283-0041-00			0.0033 μF	Cer	500 V	5%
C426	283-0080-00			0.022 μF	Cer	25 V	+80%—20%
C429	290-0140-00			120 μF	Elect.	10 V	
C435	281-0525-00			470 pF	Cer	500 V	
C436	283-0059-00			1 μF	Cer	25 V	+80%—20%
C462	283-0003-00			0.01 μF	Cer	150 V	
C472	283-0003-00			0.01 μF	Cer	150 V	
C479	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C483	283-0010-00			0.05 μF	Cer	50 V	
C484	283-0026-00			0.2 μF	Cer	25 V	
C504	281-0549-00			68 pF	Cer	500 V	10%
C506	281-0012-00			7-45 pF, Var	Cer		
C507	281-0549-00			68 pF	Cer	500 V	10%
C508	281-0549-00			68 pF	Cer	500 V	10%
C517	283-0059-00			1 μF	Cer	25 V	+80%—20%
C522	283-0059-00			1 μF	Cer	25 V	+80%—20%
C524	283-0003-00			0.01 μF	Cer	150 V	
C612	290-0086-00			2000 μF	Elect.	30 V	
C621	*285-0672-00			0.1 μF	MT	600 V	+5%—15%
C629	290-0106-00			10 μF	Elect.	15 V	
C654	283-0000-00			0.001 μF	Cer	500 V	
C657	290-0201-00			100 μF	Elect.	15 V	
C660	290-0218-00			500 μF	Elect.	30 V	
C696	290-0118-00			2 X 100 μF	Elect.	50 V	
C701	283-0001-00			0.005 μF	Cer	500 V	
C707	283-0000-00			0.001 μF	Cer	500 V	
C714	283-0034-00			0.005 μF	Cer	4000 V	
C715	283-0034-00			0.005 μF	Cer	4000 V	
C716	283-0022-00			0.02 μF	Cer	1400 V	
C717	283-0034-00			0.005 μF	Cer	4000 V	
C718	283-0013-00			0.01 μF	Cer	1000 V	

Capacitors *(Cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
C719	283-0575-00			0.1 μF	PTM	1000 V	
C720	283-0034-00			0.005 μF	Cer	4000 V	
C730	290-0117-00			50 μF	Elect.	50 V	
C731	290-0117-00			50 μF	Elect.	50 V	
C737	290-0167-00			10 μF	Elect.	15 V	
C738	290-0201-00			100 μF	Elect.	15 V	
C739	290-0201-00			100 μF	Elect.	15 V	
C750	290-0201-00			100 μF	Elect.	15 V	
C751	290-0201-00			100 μF	Elect.	15 V	
C753	290-0137-00			100 μF	Elect.	30 V	+75%—15%
C754	290-0201-00			100 μF	Elect.	15 V	
C756	290-0117-00			50 μF	Elect.	50 V	
C757	290-0117-00			50 μF	Elect.	50 V	
C758	290-0117-00			50 μF	Elect.	50 V	
C852	283-0022-00			0.02 μF	Cer	1400 V	
C854	283-0013-00			0.01 μF	Cer	1000 V	
C864	283-0003-00			0.01 μF	Cer	150 V	
C871	281-0525-00			470 pF	Cer	500 V	

Semiconductor Device, Diodes

Ckt. No.	Tektronix Part No.	Eff	Disc	Description	
D111	*152-0185-00			Silicon	Replaceable by 1N4152
D131	152-0008-00			Germanium	
D144	*152-0185-00			Silicon	Replaceable by 1N4152
D145	*152-0185-00			Silicon	Replaceable by 1N4152
D148	*152-0185-00			Silicon	Replaceable by 1N4152
D149	*152-0185-00			Silicon	Replaceable by 1N4152
D150	152-0008-00			Germanium	
D151	*152-0185-00			Silicon	Replaceable by 1N4152
D153	*152-0185-00			Silicon	Replaceable by 1N4152
D183	*152-0185-00			Silicon	Replaceable by 1N4152
D194	152-0008-00			Germanium	
D423	152-0246-00			Silicon	Low Leakage, 40 V
D424	152-0246-00			Silicon	Low Leakage, 40 V
D610	152-0066-00			Silicon	1N3194
D611	152-0066-00			Silicon	1N3194
D614	152-0008-00			Germanium	
D620	152-0066-00			Silicon	1N3194
D629	152-0226-00			Zener	1N851A 0.4 W, 5.1 V, 5%
D660	152-0066-00			Silicon	1N3194
D661	152-0066-00			Silicon	1N3194
D692	152-0066-00			Silicon	1N3194
D700	152-0001-00			Germanium	1N91
D710	152-0141-02			Silicon	1N4152
D711	152-0141-02			Silicon	1N4152
D712	152-0141-02			Silicon	1N4152

Semiconductor Device, Diodes *(Cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
D713	152-0141-02			Silicon	1N4152
D714	152-0002-00			Silicon	1N1329
D715	152-0002-00			Silicon	1N1329
D716	152-0002-00			Silicon	1N1329
D717	152-0002-00			Silicon	1N1329
D718	152-0002-00			Silicon	1N1329
D719	152-0002-00			Silicon	1N1329
D720	152-0066-00			Silicon	1N3194
D721	152-0066-00			Silicon	1N3194
D726	152-0066-00			Silicon	1N3194
D874	*152-0185-00			Silicon	Replaceable by 1N4152
D881	152-0226-00			Zener	1N751A 0.4 W, 5.1 V, 5%
D882	*152-0185-00			Silicon	Replaceable by 1N4152

Fuses

F601	159-0028-00			0.25 A 3AG Fast-Blo	
F621	159-0016-00			1.5 A 3AG Fast-Blo	

Inductor

L24	*108-0237-00			80 μH	

Transistors

Q14	*151-0133-00			Silicon	Tek Spec
Q24	*151-0133-00			Silicon	Tek Spec
Q35	*151-0108-00			Silicon	Replaceable by 2N2501
Q45	*151-0126-00			Silicon	Replaceable by 2N2484
Q135	*151-0108-00			Silicon	Replaceable by 2N2501
Q145	*151-0108-00			Silicon	Replaceable by 2N2501
Q153	151-0063-00			Germanium	2N2207
Q161	151-0063-00			Germanium	2N2207
Q163	*151-0126-00			Silicon	Replaceable by 2N2484
Q173	151-0063-00			Germanium	2N2207
Q183	151-0063-00			Germanium	2N2207
Q194	151-0063-00			Germanium	2N2207
Q199	151-0071-00			Germanium	2N1305
Q313	151-0063-00			Germanium	2N2207
Q323	151-0063-00			Germanium	2N2207
Q334	151-0063-00			Germanium	2N2207
Q344	151-0063-00			Germanium	2N2207
Q423 A, B	151-1011-00			Silicon	Dual, FET
Q443	*151-0134-00			Silicon	Replaceable by 2N2905
Q453	*151-0134-00			Silicon	Replaceable by 2N2905

Transistors *(Cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
Q464	151-0063-00			Germanium	2N2207
Q474	151-0063-00			Germanium	2N2207
Q484	*151-0108-00			Silicon	Replaceable by 2N2501
Q494	*151-0108-00			Silicon	Replaceable by 2N2501
Q504	151-0063-00			Germanium	2N2207
Q514	151-0063-00			Germanium	2N2207
Q519	151-0063-00			Germanium	2N2207
Q524	*151-0126-00			Silicon	Replaceable by 2N2484
Q614	151-0063-00			Germanium	2N2207
Q624	*151-0136-00			Silicon	Replaceable by 2N3053
Q634	*151-0136-00			Silicon	Replaceable by 2N3053
Q654	*151-0134-00			Silicon	Replaceable by 2N2905
Q657	151-0101-00			Germanium	2N2137
Q700	151-0101-00			Germanium	2N2137
Q710	151-0101-00			Germanium	2N2137
Q874	*151-0108-00			Silicon	Replaceable by 2N2501

Resistors

Resistors are fixed, composition, ±10% unless otherwise indicated.

Ckt. No.	Tektronix Part No.	Eff	Disc	Description			
R2	315-0913-00			91 kΩ	¼ W		5%
R14	316-0335-00			3.3 MΩ	¼ W		
R15	316-0103-00			10 kΩ	¼ W		
R17	311-0345-00			20 kΩ, Var			
R19	316-0472-00			4.7 kΩ	¼ W		
R20	315-0202-00			2 kΩ	¼ W		5%
R23	315-0473-00			47 kΩ	¼ W		5%
R24	315-0272-00			2.7 kΩ	¼ W		5%
R25	316-0681-00			680 Ω	¼ W		
R32	323-0232-00			2.55 kΩ	½ W	Prec	1%
R33	323-0276-00			7.32 kΩ	½ W	Prec	1%
R34	323-0333-00			28.7 kΩ	½ W	Prec	1%
R35	315-0332-00			3.3 kΩ	¼ W		5%
R37	315-0433-00			43 kΩ	¼ W		5%
R38	315-0103-00			10 kΩ	¼ W		5%
R43	323-0251-00			4.02 kΩ	½ W	Prec	1%
R46	315-0183-00			18 kΩ	¼ W		5%
R110	316-0682-00			6.8 kΩ	¼ W		
R111	311-0159-00			20 kΩ, Var			
R113	316-0562-00			5.6 kΩ	¼W		
R131	316-0392-00			3.9 kΩ	¼ W		
R133	302-0821-00			820 Ω	½ W		
R134	316-0102-00			1 kΩ	¼ W		
R135	315-0103-00			10 kΩ	¼ W		5%
R141	315-0393-00			39 kΩ	¼ W		5%

Resistors *(Cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R143	315-0184-00			180 kΩ	¼ W		5%
R144	315-0393-00			39 kΩ	¼ W		5%
R147	316-0153-00			15 kΩ	¼ W		
R148	315-0621-00			620 Ω	¼ W		5%
R151	315-0102-00			1 kΩ	¼ W		5%
R152	316-0273-00			7 kΩ	¼ W		
R153	315-0330-00			33 Ω	¼ W		5%
R160A	323-0486-00			1.13 MΩ	½ W	Prec	1%
R160C	323-0448-00			453 kΩ	½ W	Prec	1%
R160E	322-0419-00			226 kΩ	¼ W	Prec	1%
R160G	323-0390-00			113 kΩ	½ W	Prec	1%
R160J	323-0352-00			45.3 kΩ	½ W	Prec	1%
R160K	316-0186-00			18 MΩ	¼ W		
R160L	323-0323-00			22.6 kΩ	½ W	Prec	1%
R160R	316-0223-00			22 kΩ	¼ W		
R160S	316-0273-00			27 kΩ	¼ W		
R160T	316-0473-00			47 kΩ	¼ W		
R160U	316-0223-00			22 kΩ	¼ W		
R160V[1]	311-0166-01			20 kΩ, Var			
R160Z	316-0473-00			47 Ω	¼ W		
R161	316-0151-00			150 Ω	¼ W		
R162	316-0186-00			18 MΩ	¼ W		
R165	316-0563-00			56 kΩ	¼ W		
R167	316-0104-00			100 kΩ	¼ W		
R169	316-0273-00			27 kΩ	¼ W		
R174	316-0683-00			68 kΩ	¼ W		
R176	311-0153-00			10 kΩ, Var			
R177	316-0103-00			10 kΩ	¼ W		
R178	316-0272-00			2.7 kΩ	¼ W		
R181	316-0104-00			100 kΩ	¼ W		
R182	316-0153-00			15 kΩ	¼ W		
R183	316-0333-00			33 kΩ	¼ W		
R190	316-0103-00			10 kΩ	¼ W		
R193	316-0151-00			150 Ω	¼ W		
R194	316-0223-00			22 kΩ	¼ W		
R196	316-0331-00			330 kΩ	¼ W		
R197	316-0333-00			33 kΩ	¼ W		
R198	315-0243-00			24 kΩ	¼ W		5%
R199	316-0273-00			27 kΩ	¼ W		
R300	322-0365-00			61.9 kΩ	¼ W	Prec	1%
R301	323-0442-00			392 kΩ	½ W	Prec	1%
R302	315-0684-00			680 kΩ	¼ W		5%
R311	323-0348-00			41.2 kΩ	½ W	Prec	1%
R312	323-0286-00			9.31 kΩ	½ W	Prec	1%
R316	323-0346-00			39.2 kΩ	½ W	Prec	1%

[1]**Furnished as a unit with SW348.**

Resistors *(Cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R317	316-0472-00			4.7 kΩ	¼ W		
R322A } R322B }	311-0429-00			100 kΩ 10 kΩ Var			
R323	316-0392-00			3.9 kΩ	¼ W		
R324	316-0183-00			18 kΩ	¼ W		
R325	315-0103-00			10 kΩ	¼ W		5%
R326	315-0103-00			10 kΩ	¼ W		5%
R327	316-0472-00			4.7 kΩ	¼ W		
R328	321-0177-00			681 Ω	⅛ W	Prec	1%
R333	323-0289-00			10 kΩ	½ W	Prec	1%
R336	323-0308-00			15.8 kΩ	½ W	Prec	1%
R338	311-0328-00			1 kΩ, Var			
R343	323-0286-00			9.31 kΩ	½ W	Prec	1%
R346	323-0308-00			15.8 kΩ	½ W	Prec	1%
R347	321-0117-00			162 Ω	⅛ W	Prec	1%
R348	311-0461-00			250 Ω, Var			
R410C	323-0481-01			1 MΩ	½ W	Prec	½%
R410E	323-0193-01			1 kΩ	½ W	Prec	½%
R412C	323-0614-01			990 kΩ	½ W	Prec	½%
R412E	322-1289-01			10.1 kΩ	¼ W	Prec	½%
R414C	323-0611-01			900 kΩ	½ W	Prec	½%
R414E	323-1389-01			111 kΩ	½ W	Prec	½%
R416C	323-0620-01			800 kΩ	½ W	Prec	½%
R416E	322-0614-01			250 kΩ	¼ W	Prec	½%
R418C	322-0610-01			500 kΩ	¼ W	Prec	½%
R418E	323-0481-01			1 MΩ	½ W	Prec	½%
R420	316-0470-00			47 Ω	¼ W		
R422	323-0481-01			1 MΩ	½ W	Prec	½%
R423	316-0394-00			390 kΩ	¼ W		
R424	316-0470-00			47 Ω	¼ W		
R426	321-0164-00			499 Ω	⅛ W	Prec	1%
R427	321-0164-00			499 Ω	⅛ W	Prec	1%
R429	315-0470-00			47 Ω	¼ W		5%
R432	311-0579-00			20 kΩ, Var			
R434	315-0473-00			47 kΩ	¼ W		5%
R435	315-0154-00			150 kΩ	¼ W		5%
R436	321-0164-00			499 Ω	⅛ W	Prec	1%
R437	316-0220-00			22 Ω	¼ W		
R443	316-0682-00			6.8 kΩ	¼ W		
R453	316-0682-00			6.8 kΩ	¼ W		
R454	315-0223-00			22 kΩ	¼ W		5%
R455	311-0346-00			2 x 20 kΩ, Var			
R457	315-0223-00			22 kΩ	¼ W		5%
R462	321-0243-00			3.32 kΩ	⅛ W	Prec	1%
R464	321-0109-00			133 Ω	⅛ W	Prec	1%

Resistors *(Cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R466	*311-0477-00			780 Ω, Var			
R468	311-0258-00			100 Ω, Var			
R472	321-0243-00			3.32 kΩ	1/8 W	Prec	1%
R476	321-0291-00			10.5 kΩ	1/8 W	Prec	1%
R478	321-0291-00			10.5 kΩ	1/8 W	Prec	1%
R479	323-0221-00			1.96 kΩ	1/2 W	Prec	1%
R481	316-0101-00	X6039		100 Ω	1/4 W		
R482	323-0233-00			2.61 kΩ	1/2 W	Prec	1%
R483	323-0197-00			1.1 kΩ	1/2 W	Prec	1%
R484	323-0231-00			2.49 kΩ	1/2 W	Prec	1%
R489	323-0221-00			1.96 kΩ	1/2 W	Prec	1%
R492	323-0233-00			2.61 kΩ	1/2 W	Prec	1%
R494	323-0231-00			2.49 kΩ	1/2 W	Prec	1%
R502	323-0245-00			3.48 kΩ	1/2 W	Prec	1%
R504	321-0107-00			127 Ω	1/8 W	Prec	1%
R505	321-0081-00			68.1 Ω	1/8 W	Prec	1%
R506	315-0151-00			150 Ω	1/4 W		5%
R509	323-0146-00			324 Ω	1/2 W	Prec	1%
R511	323-0146-00			324 Ω	1/2 W	Prec	1%
R512	323-0245-00			3.48 kΩ	1/2 W	Prec	1%
R516	323-0160-00			453 Ω	1/2 W	Prec	1%
R517	323-0223-00			2.05 kΩ	1/2 W	Prec	1%
R519	323-0200-00			1.18 kΩ	1/2 W	Prec	1%
R520	321-0381-00			90.9 kΩ	1/8 W	Prec	1%
R521	321-0318-00			20 kΩ	1/8 W	Prec	1%
R522	321-0331-00			27.4 kΩ	1/8 W	Prec	1%
R523	321-0204-00			1.3 kΩ	1/8 W	Prec	1%
R524	316-0222-00			2.2 kΩ	1/4 W		
R525	316-0682-00			6.8 kΩ	1/4 W		
R602	311-0344-00			100 Ω, Var			
R610	308-0175-00			10 Ω	10 W	WW	5%
R612	302-0682-00			6.8 kΩ	1/2 W		
R622	315-0102-00			1 kΩ	1/4 W		5%
R624	316-0102-00			1 kΩ	1/4 W		
R631	315-0132-00			1.3 kΩ	1/4 W		5%
R635	308-0362-00			50 Ω	10 W	WW	5%
R644	316-0470-00			47 Ω	1/4 W		
R650	323-0202-00			1.24 kΩ	1/2 W	Prec	1%
R651	311-0380-00			500 Ω, Var			
R652	323-0204-00			1.3 kΩ	1/2 W	Prec	1%
R692	308-0110-00			100 Ω	8 W	WW	5%
R693	308-0174-00			117 Ω	8 W	WW	5%
R694	306-0681-00			680 Ω	2 W		
R695	323-0163-00			487 Ω	1/2 W	Prec	1%
R696	323-0163-00			487 Ω	1/2 W	Prec	1%

Resistors *(Cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R697	323-0218-00			1.82 kΩ	½ W	Prec	1%
R699	302-0101-00			100 Ω	½ W		
R700	316-0331-00			330 Ω	¼ W		
R701	302-0100-00			10 Ω	½ W		
R707	316-0223-00			100 kΩ	¼ W		
R714	302-0104-00			100 kΩ	½ W		
R718	316-0105-00			1 MΩ	¼ W		
R719	316-0472-00			4.7 kΩ	¼ W		
R720	302-0105-00			1 MΩ	½ W		
R731	315-0161-00			160 Ω	¼ W		5%
R737	316-0560-00			56 Ω	¼ W		5%
R739	315-0330-00			33 Ω	¼ W		5%
R751	315-0200-00			20 Ω	¼ W		5%
R753	315-0270-00			27 Ω	¼ W		5%
R754	315-0221-00			220 Ω	¼ W		5%
R757	315-0151-00			150 Ω	¼ W		5%
R758	316-0100-00			10 Ω	¼ W		
R841	301-0225-00			2.2 MΩ	½ W		5%
R842	311-0349-00			2 MΩ, Var			
R844	311-0589-00			250 kΩ, Var			
R848	301-0156-00			15 MΩ	½ W		5%
R849	301-0186-00			18 MΩ	½ W		5%
R851	316-0105-00			1 MΩ	¼ W		
R854	302-0105-00			1 MΩ	½ W		
R861	311-0157-00			100 kΩ, Var			
R864	311-0347-00			100 kΩ, Var			
R871	316-0104-00			100 kΩ	¼ W		
R881	316-0222-00			2.2 kΩ	¼ W		
R882	323-0253-00			4.22 kΩ	½ W	Prec	1%
R884	311-0323-00			1.5 kΩ, Var			
R886	321-0169-00			562 Ω	⅛ W	Prec	1%
R888	321-0067-00			48.7 Ω	⅛ W	Prec	1%

Switches

	Unwired or Wired			
SW2		260-0449-00	Slide	INT-EXT
SW8		260-0449-00	Slide	AC-DC
SW15		260-0449-00	Slide	SLOPE
SW17	Wired	*262-0662-00	Rotary	AUTO (Level)
SW17		260-0296-00	Rotary	AUTO (Level)

Switches Cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc		Description
SW160 Wired	*262-0660-00			Rotary	TIME/DIV
SW160	260-0376-00			Rotary	TIME/DIV
SW348[2]	311-0166-01				X5 MAG
SW401	260-0448-00			Slide	AC-DC-GND
SW410 Wired	*262-0661-00			Rotary	VOLTS/DIV
SW410	260-0625-00			Rotary	VOLTS/DIV
SW621	260-0617-00			Rotary	POWER
SW692	260-0450-00			Slide	CHARGER

Thermal Cutout

TK621	260-0611-00			135°F ±6°F	

Transformers

T601	*120-0152-00			Power	
T701	*120-0210-00			Converter	

Electron Tube

V859	*154-0433-00			T3211-31	CRT Standard Phosphor

[2]Furnished as a unit with R160V.

FIGURE AND INDEX NUMBERS

Items in this section are referenced by figure and index numbers to the illustrations which appear on the pullout pages immediately following the Diagrams section of this instruction manual.

INDENTATION SYSTEM

This mechanical parts list is indented to indicate item relationships. Following is an example of the indentation system used in the Description column.

Assembly and/or Component
  Detail Part of Assembly and/or Component
  mounting hardware for Detail Part
    Parts of Detail Part
    mounting hardware for Parts of Detail Part
mounting hardware for Assembly and/or Component

Mounting hardware always appears in the same indentation as the item it mounts, while the detail parts are indented to the right. Indented items are part of, and included with, the next higher indentation.

Mounting hardware must be purchased separately, unless otherwise specified.

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.

Change information, if any, is located at the rear of this manual.

ABBREVIATIONS AND SYMBOLS

For an explanation of the abbreviations and symbols used in this section, please refer to the page immediately preceding the Electrical Parts List in this instruction manual.

INDEX OF MECHANICAL PARTS LIST ILLUSTRATIONS

(Located behind diagrams)

SECTION 7
MECHANICAL PARTS LIST

FIG. 1 FRONT & REAR

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-1	366-0203-00			1	KNOB, gray—FOCUS
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $^3/_{16}$ inch, HSS
-2	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0940-00			1	WASHER, flat, $^1/_4$ ID x $^3/_8$ inch OD
-3	210-0583-00			1	NUT, hex., $^1/_4$-32 x $^5/_{16}$ inch
-4	366-0203-00			1	KNOB, gray—ASTIGMATISM
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $^3/_{16}$ inch, HSS
-5	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0940-00			1	WASHER, flat, $^1/_4$ ID x $^3/_8$ inch OD
-6	210-0583-00			1	NUT, hex., $^1/_4$-32 x $^5/_{16}$ inch
-7	366-0270-00			1	KNOB, charcoal—VERTICAL POSITION
	- - - - - -			-	knob includes:
	213-0075-00			1	SCREW, set, 4-40 x $^3/_{32}$ inch, HSS
-8	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0940-00			1	WASHER, flat, $^1/_4$ ID x $^3/_8$ inch OD
-9	210-0583-00			1	NUT, hex., $^1/_4$-32 x $^5/_{16}$ inch
-10	366-0203-00			1	KNOB, gray—INTENSITY
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $^3/_{16}$ inch, HSS
-11	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0940-00			1	WASHER, flat, $^1/_4$ ID x $^3/_8$ inch OD
-12	210-0583-00			1	NUT, hex., $^1/_4$-32 x $^5/_{16}$ inch
-13	366-0203-00			1	KNOB, gray—SCALE ILLUM
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $^3/_{16}$ inch, HSS
-14	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0940-00			1	WASHER, flat, $^1/_4$ ID x $^3/_8$ inch OD
-15	210-0583-00			1	NUT, hex., $^1/_4$-32 x $^5/_{16}$ inch

FIG. 1 FRONT & REAR *(Cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-16	366-0270-00			1	KNOB, charcoal—HORIZONTAL POSITION
	- - - - - -			-	knob includes:
	213-0075-00			1	SCREW, set, 4-40 x $^{3}/_{32}$ inch, HSS
-17	- - - - - -			-	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0223-00			1	LUG, solder, $^{1}/_{4}$ ID x $^{7}/_{16}$ inch OD, SE
	210-0940-00			1	WASHER, flat, $^{1}/_{4}$ ID x $^{3}/_{8}$ inch OD
-18	210-0583-00			1	NUT, hex., $^{1}/_{4}$-32 x $^{5}/_{16}$ inch
-19	366-0270-00			1	KNOB, charcoal—POWER
	- - - - - -			-	knob includes:
	213-0075-00			1	SCREW, set, 4-40 x $^{3}/_{32}$ inch, HSS
-20	260-0617-00			1	SWITCH, unwired—POWER
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0940-00			1	WASHER, flat, $^{1}/_{4}$ ID x $^{3}/_{8}$ inch OD
-21	210-0583-00			1	NUT, hex., $^{1}/_{4}$-32 x $^{5}/_{16}$ inch
-22	366-0148-00			1	KNOB, charcoal—LEVEL
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $^{3}/_{16}$ inch, HSS
-23	262-0662-00			1	SWITCH, wired—LEVEL
	- - - - - -			-	switch includes:
	260-0296-00			1	SWITCH, unwired
-24	376-0014-00			1	COUPLING
-25	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-26	210-0583-00			2	NUT, hex., $^{1}/_{4}$-32 x $^{5}/_{16}$ inch
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0012-00			1	LOCKWASHER, internal, $^{3}/_{8}$ ID x $^{1}/_{2}$ inch OD
	210-0840-00			1	WASHER, flat, 0.390 ID x $^{9}/_{16}$ inch OD
-27	210-0413-00			1	NUT, hex., $^{3}/_{8}$-32 x $^{1}/_{2}$ inch

FIG. 1 FRONT & REAR *(Cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-28	366-0276-00			1	KNOB, red—VARIABLE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $^3/_{16}$ inch, HSS
-29	366-0230-00			1	KNOB, charcoal—TIME/DIV
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $^3/_{16}$ inch, HSS
-30	262-0660-00			1	SWITCH, wired—TIME/DIV
	- - - - - -			-	switch includes:
	260-0376-00			1	SWITCH, unwired
-31	407-0024-00			1	BRACKET
	- - - - - -			-	mounting hardware: (not included w/bracket)
	210-0006-00			2	LOCKWASHER, internal, #6
-32	210-0449-00			2	NUT, hex., 5-40 x $^1/_4$ inch
-33	348-0055-00			1	GROMMET, plastic, $^1/_4$ inch diameter
-34	384-0197-00			1	ROD, extension
	- - - - - -			-	mounting hardware: (not included w/rod)
	213-0075-00			1	SCREW, set, 4-40 x $^3/_{32}$ inch, HSS
-35	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0012-00			1	LOCKWASHER, internal, $^3/_8$ ID x $^1/_2$ inch OD
-36	210-0413-00			2	NUT, hex., $^3/_8$-32 x $^1/_2$ inch
	- - - - - -			-	mounting hardware: (not included w/switch)
-37	211-0504-00			2	SCREW, 6-32 x $^1/_4$ inch, PHS
	210-0840-00			1	WASHER, flat, 0.390 ID x $^9/_{16}$ inch OD
-38	210-0413-00			1	NUT, hex., $^3/_8$-32 x $^1/_2$ inch
-39	366-0081-00			1	KNOB, red—VARIABLE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $^3/_{16}$ inch, HSS
-40	366-0230-00			1	KNOB, charcoal—VOLTS/DIV
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $^3/_{16}$ inch, HSS

FIG. 1 FRONT & REAR *(Cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-41	262-0661-00			1	SWITCH, wired—VOLTS/DIV
	- - - - - -			-	switch includes:
	260-0625-00			1	SWITCH, unwired
-42	- - - - - -			10	CAPACITOR
	- - - - - -			-	mounting hardware for each: (not included w/capacitor)
-43	214-0153-00			1	FASTENER, snap, plastic
-44	337-0332-00			1	SHIELD
	- - - - - -			-	mounting hardware: (not included w/shield)
	211-0008-00			2	SCREW, 4-40 x 1/4 inch, PHS
-45	407-0060-00			1	BRACKET
-46	406-0020-00			1	BRACKET
	131-0182-00			1	CONNECTOR, terminal (not shown)
	358-0135-00			1	BUSHING, plastic (not shown)
-47	441-0581-00			1	CHASSIS
	- - - - - -			-	mounting hardware: (not included w/chassis)
-48	211-0008-00			4	SCREW, 4-40 x 1/4 inch, PHS
	210-0201-00			1	LUG, solder, SE #4
	210-0004-00			2	LOCKWASHER, internal, #4
	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-49	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-50	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-51	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-52	260-0448-00			1	SWITCH, slide—AC DC GND
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-53	260-0449-00			1	SWITCH, slide—INT EXT
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-54	260-0449-00			1	SWITCH, slide—AC DC
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-55	260-0447-00			1	SWITCH, slide—SLOPE
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch

FIG. 1 FRONT & REAR *(Cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-56	131-0106-00			1	CONNECTOR, coaxial, 1 contact, BNC w/hardware
-57	136-0140-00			3	SOCKET, banana-jack
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-58	210-0895-00			1	WASHER, insulating
	210-0223-00			1	LUG, solder, $^1/_4$ ID x $^7/_{16}$ inch OD, SE
-59	210-0465-00			2	NUT, hex., $^1/_4$-32 x $^3/_8$ inch
-60	129-0053-00			1	ASSEMBLY, binding post
	- - - - - -			-	assembly includes:
	200-0103-00			1	CAP, binding post
	355-0507-00			1	STEM, binding post
	- - - - - -			-	mounting hardware: (not included w/assembly)
	210-0011-00			1	LOCKWASHER, internal, #4
	210-0223-00			1	LUG, solder, $^1/_4$ ID x $^7/_{16}$ inch OD, SE (not shown)
	210-0455-00			2	NUT, hex., $^1/_4$-28 x $^3/_8$ inch (not shown)
-61	- - - - - -			2	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
-62	358-0075-00			1	BUSHING
-63	- - - - - -			1	BULB ASSEMBLY, w/hardware
-64	- - - - - -			1	PILOT LIGHT
-65	200-0584-00			1	COVER, graticule
	- - - - - -			-	mounting hardware: (not included w/cover)
-66	211-0038-00			1	SCREW, 4-40 x $^5/_{16}$ inch, 100° csk, FHS
-67	331-0055-00			1	GRATICULE
-68	333-0830-00			1	PANEL, front
-69	387-0940-00			1	PLATE, front
-70	124-0109-00			1	STRIP, felt, $4^1/_{16}$ inches long
-71	124-0115-00			1	STRIP, felt, $2^3/_8$ inches long
-72	200-0197-00			1	COVER, CRT anode
-73	131-0084-00			1	ASSEMBLY, connector, anode
	- - - - - -			-	assembly includes:
	131-0073-00			1	CONNECTOR, CRT brush
	200-0110-00			1	COVER, CRT anode
-74	337-0336-00			1	SHIELD, CRT
	- - - - - -			-	mounting hardware: (not included w/shield)
	211-0007-00			2	SCREW, 4-40 x $^3/_{16}$ inch, PHS

FIG. 1 FRONT & REAR *(Cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-75	175-0582-00			1	LEAD, CRT, striped brown
	175-0583-00			1	LEAD, CRT, striped red
	175-0584-00			1	LEAD, CRT, striped green
	175-0596-00			1	LEAD, CRT, striped blue
	- - - - - -			-	each lead includes:
	131-0049-00			1	CONNECTOR, CRT lead
-76	337-0652-00			1	SHIELD, switch
	- - - - - -			-	mounting hardware: (not included w/shield)
	211-0504-00			3	SCREW, 6-32 x 1/4 inch, PHS
-77	337-0654-00			1	SHIELD, switch
	- - - - - -			-	mounting hardware: (not included w/switch)
	211-0007-00			1	SCREW, 4-40 x 3/16 inch, PHS
-78	387-0938-00			1	PLATE, bulkhead, front
	- - - - - -			-	mounting hardware: (not included w/plate)
	211-0504-00			4	SCREW, 6-32 x 1/4 inch, PHS
-79	348-0056-00			4	GROMMET, plastic, 3/8 inch diameter
-80	348-0055-00			9	GROMMET, plastic, 1/4 inch diameter
-81	- - - - - -			1	CAPACITOR
	- - - - - -			-	mounting hardware: (not included w/capacitor)
	210-0018-00			1	LOCKWASHER, internal, 5/16 inch ID
-82	210-0524-00			1	NUT, hex., 5/16-24 x 1/2 inch
-83	- - - - - -			1	CAPACITOR
	- - - - - -			-	mounting hardware: (not included w/capacitor)
-84	210-0457-00			2	NUT, keps, 6-32 x 5/16 inch
-85	387-0941-00			1	PLATE, bulkhead, rear
	- - - - - -			-	mounting hardware: (not included w/plate)
	211-0504-00			3	SCREW, 6-32 x 1/4 inch, PHS
-86	- - - - - -			2	RESISTOR
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
-87	211-0553-00			1	SCREW, 6-32 x 1 1/2 inches, RHS
	210-0601-00			1	EYELET
	210-0478-00			1	NUT, resistor mounting
-88	211-0507-00			1	SCREW, 6-32 x 5/16 inch, PHS
-89	348-0030-00			1	GROMMET, CRT shield, plastic
-90	343-0029-00			1	CLAMP, CRT socket
	- - - - - -			-	mounting hardware: (not included w/clamp)
-91	210-0457-00			4	NUT, keps, 6-32 x 5/16 inch
	210-0803-00			4	WASHER, flat, 0.150 ID x 3/8 inch OD
	211-0534-00			4	SCREW, sems, 6-32 x 5/16 inch, PHS
	210-0501-00			1	NUT, square, 10-32 x 3/8 inch
-92	212-0557-00			1	SCREW, 10-32 x 1/2 inch, RHS

FIG. 1 FRONT & REAR *(Cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-93	354-0095-00			1	RING, CRT rotating
-94	179-0887-00			1	CABLE HARNESS, CRT
	- - - - - -			-	cable harness includes:
	136-0081-00			1	SOCKET, CRT
-95	179-0885-00			1	CABLE HARNESS, power connector
-96	214-0210-00			1	ASSEMBLY, solder spool
	- - - - - -			-	assembly includes:
	214-0209-00			1	SPOOL, w/o solder
	- - - - - -			-	mounting hardware: (not included w/assembly)
	361-0007-00			1	SPACER, plastic, 0.188 inch long
-97	381-0227-00			1	BAR, handle assembly
	- - - - - -			-	bar includes:
-98	344-0098-00			2	CLIP
-99	367-0037-00			1	HANDLE
	210-0010-00			2	LOCKWASHER, internal, #10
-100	212-0507-00			2	SCREW, 10-32 x 3/8 inch, PHS
	- - - - - -			-	mounting hardware: (not included w/bar)
-101	211-0504-00			4	SCREW, 6-32 x 1/4 inch, PHS
-102	136-0140-00			1	SOCKET, banana jack, charcoal
	- - - - - -			-	mounting hardware: (not included w/socket)
	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch OD, SE
-103	210-0465-00			1	NUT, hex., 1/4-32 x 3/8 inch
-104	136-0139-00			1	SOCKET, banana jack, red
	- - - - - -			-	mounting hardware: (not included w/socket)
-105	210-0898-00			1	WASHER, insulating, red
-106	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch OD, SE
-107	210-0465-00			2	NUT, hex., 1/4-32 x 3/8 inch
-108	334-0715-00			1	TAG, CRT grid
-109	134-0012-00			1	PLUG, banana jack, male
-110	- - - - - -			1	TRANSISTOR
	- - - - - -			-	mounting hardware: (not included w/transistor)
-111	211-0511-00			2	SCREW, 6-32 x 1/2 inch, PHS
-112	200-0196-01			1	COVER, transistor, plastic
-113	387-0345-00			1	PLATE, insulating
-114	136-0135-00			1	SOCKET, transistor, 2 pin
	- - - - - -			-	mounting hardware: (not included w/socket)
-115	213-0113-00			2	SCREW, thread forming, 2-32 x 5/16 inch, PHS
-116	387-0948-00			1	PLATE, rear
-117	392-0164-00			1	BOARD, power connector
	- - - - - -			-	mounting hardware: (not included w/board)
-118	211-0504-00			2	SCREW, 6-32 x 1/4 inch, PHS

FIG. 2 CHASSIS

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
2-1	441-0557-01			1	CHASSIS, vertical amplifier & power
	- - - - - - -			-	mounting hardware: (not included w/chassis)
-2	211-0534-00			4	SCREW, sems, 6-32 x 5/16 inch, PHS
-3	386-1418-00			1	PLATE, transistor mounting
	- - - - - - -			-	mounting hardware: (not included w/plate)
	213-0055-00			2	SCREW, thread forming, 2-32 x 3/16 inch, PHS
-4	- - - - - - -			6	RESISTOR, variable
	- - - - - - -			-	mounting hardware for each: (not included w/resistor)
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
-5	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-6	- - - - - - -			1	RESISTOR, variable
	- - - - - - -			-	mounting hardware: (not included w/resistor)
	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch OD, SE
-7	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-8	352-0077-00			6	HOLDER, transistor, plastic, 0.135 inch diameter
-9	352-0078-00			11	HOLDER, transistor, plastic, 0.270 inch diameter
-10	343-0044 00			14	CLAMP, transistor mounting
	- - - - - - -			-	mounting hardware for each: (not included w/clamp)
	213-0044-00			1	SCREW, thread forming, 5-32 x 3/16 inch, PHS
-11	343-0044-00			1	CLAMP, transistor mounting
	- - - - - - -			-	mounting hardware: (not included w/clamp)
	210-0202-00			1	LUG, solder, SE #6
	213-0044-00			1	SCREW, thread forming, 5-32 x 3/16 inch, PHS
-12	343-0088-00			3	CLAMP, cable, plastic, small
-13	136-0235-00			1	SOCKET, transistor, 6 pin
	- - - - - - -			-	mounting hardware: (not included w/socket)
	354-0234-00			1	RING, socket mounting
-14	- - - - - - -			1	CAPACITOR
	- - - - - - -			-	mounting hardware: (not included w/capacitor)
-15	214-0153-00			1	FASTENER, snap

FIG. 2 CHASSIS *(Cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
2-16	352-0025-00			1	HOLDER, fuse, dual
	- - - - - -			-	mounting hardware: (not included w/holder)
	211-0510-00			2	SCREW, 6-32 x $^3/_8$ inch, PHS
-17	200-0412-00			1	COVER, fuse holder, plastic
-18	344-0016-00			1	CLIP, metal
	- - - - - -			-	mounting hardware: (not included w/clip)
	211-0504-00			1	SCREW, 6-32 x $^1/_4$ inch, PHS
	210-0006-00			1	LOCKWASHER, internal, #6
	210-0407-00			1	NUT, hex., 6-32 x $^1/_4$ inch
-19	260-0450-00			1	SWITCH, slide—HIGH LOW DRY CELLS
	- - - - - -			-	mounting hardware: (not included w/switch)
	211-0008-00			2	SCREW, 4-40 x $^1/_4$ inch, PHS
	210-0004-00			2	LOCKWASHER, internal, #4
-20	210-0406-00			2	NUT, hex., 4-40 x $^3/_{16}$ inch
-21	210-0201-00			10	LUG, solder, SE #4
	- - - - - -			-	mounting hardware for each: (not included w/lug)
	213-0044-00			1	SCREW, thread forming, 5-32 x $^3/_{16}$ inch, PHS
-22	210-0203-00			3	LUG, solder, SE #6, long
	- - - - - -			-	mounting hardware for each: (not included w/lug)
	213-0044-00			1	SCREW, thread forming, 5-32 x $^3/_{16}$ inch, PHS
-23	200-0256-00			1	COVER, capacitor, plastic, 1 ID x 2$^1/_{32}$ inches long
-24	200-0293-00			1	COVER, capacitor, plastic, 1.365 ID x 2$^9/_{16}$ inches long
-25	- - - - - -			1	CAPACITOR
	- - - - - -			-	mounting hardware: (not included w/capacitor)
	211-0534-00			2	SCREW, sems, 6-32 x $^5/_{16}$ inch
-26	386-0252-00			1	PLATE, fiber, small
	210-0006-00			2	LOCKWASHER, internal, #6
-27	210-0407-00			2	NUT, hex., 6-32 x $^1/_4$ inch
-28	- - - - - -			1	CAPACITOR
	- - - - - -			-	mounting hardware: (not included w/capacitor)
	211-0543-00			2	SCREW, 6-32 x $^5/_{16}$ inch, RHS
	386-0254-00			1	PLATE, fiber, large
	210-0006-00			2	LOCKWASHER, internal, #6
	210-0407-00			2	NUT, hex., 6-32 x $^1/_4$ inch

FIG. 2 CHASSIS *(Cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
2-29	- - - - - -			1	TRANSFORMER
	- - - - - -			-	mounting hardware: (not included w/transformer)
-30	211-0507-00			4	SCREW, 6-32 x $^5/_{16}$ inch, PHS
-31	406-0685-00			1	BRACKET, mounting
-32	441-0556-00			1	CHASSIS, sweep
	- - - - - -			-	mounting hardware: (not included w/chassis)
-33	211-0534-00			5	SCREW, sems, 6-32 x $^5/_{16}$ inch, PHS
-34	- - - - - -			1	TRANSFORMER
	- - - - - -			-	mounting hardware: (not included w/transformer)
	210-0006-00			2	LOCKWASHER, internal, #6
-35	210-0407-00			2	NUT, hex., 6-32 x $^1/_4$ inch
-36	- - - - - -			2	TRANSISTORS
	- - - - - -			-	mounting hardware for each: (not included w/transistor)
-37	211-0511-00			2	SCREW, 6-32 x $^1/_2$ inch, PHS
-38	210-0811-00			4	WASHER, fiber, shouldered, #6
-38	210-0812-00			2	WASHER, fiber, shouldered, #10
-39	210-0407-00			4	NUT, hex., 6-32 x $^1/_4$ inch
	210-0202-00			1	LUG, solder, SE #6
-40	210-0006-00			1	LOCKWASHER, internal, #6
-41	337-0655-00			1	SHIELD, sweep circuit
	- - - - - -			-	mounting hardware: (not included w/shield)
-42	211-0504-00			5	SCREW, 6-32 x $^1/_4$ inch,PHS
-43	441-0558-00			1	CHASSIS, high voltage
	- - - - - -			-	mounting hardware: (not included w/chassis)
-44	211-0507-00			2	SCREW, 6-32 x $^5/_{16}$ inch, PHS
-45	211-0534-00			2	SCREW, sems, 6-32 x $^5/_{16}$ inch, PHS
-46	337-0653-00			1	SHIELD, insulating, plastic
-47	337-0651-00			1	SHIELD, high voltage, plastic
	- - - - - -			-	mounting hardware: (not included w/shield)
-48	210-0586-00			3	NUT, keps, 4-40 x $^1/_4$ inch

FIG. 2 CHASSIS *(Cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
2-49	348-0031-00			6	GROMMET, plastic, $^3/_{32}$ inch diameter
-50	348-0056-00			3	GROMMET, plastic, $^3/_8$ inch diameter
-51	348-0055-00			2	GROMMET, plastic, $^5/_8$ inch diameter
-52	348-0012-00			1	GROMMET, rubber, $^5/_8$ inch diameter
-53	136-0035-00			2	SOCKET, graticule light
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-54	211-0510-00			1	SCREW, 6-32 x $^3/_8$ inch, PHS
	210-0803-00			1	WASHER, flat, 0.150 ID x $^3/_8$ inch OD
-55	210-0457-00			1	NUT, keps, 6-32 x $^5/_{16}$ inch
	352-0080-00			1	ASSEMBLY, battery holder
	- - - - - -			-	assembly includes:
-56	387-0967-00			2	PLATE, contact, plastic
-57	214-0501-00			2	SPRING, contact
-58	213-0045-00			6	SCREW, self-tapping, 4-40 x $^5/_{16}$ inch, PHS
-59	213-0133-00			4	SCREW, 6-32 x 0.750 inch, Fil HS
-60	210-0802-00			4	WASHER, flat, 0.150 ID x $^5/_{16}$ inch OD
-61	352-0079-00			1	HOLDER, battery
-62	391-0060-00			1	BLOCK, contact assembly
	- - - - - -			-	mounting hardware: (not included w/block)
	211-0538-00			2	SCREW, 6-32 x $^5/_{16}$ inch, 100° csk, FHS
-63	361-0078-00			1	SPACER, battery
-64	387-0966-00			1	PLATE, bottom
	- - - - - -			-	plate includes:
	213-0131-00			1	SCREW, thumb, 6-32 x 0.850 inch, Fil HS
-65	122-0123-00			2	ANGLE, rail bottom
	- - - - - -			-	mounting hardware for each: (not included w/angle)
	211-0565-00			3	SCREW, 6-32 x $^1/_4$ inch, THS
-66	211-0576-00			4	SCREW, 6-32 x $^7/_8$ inch, Socket HS
-67	348-0062-00			4	GROMMET, foot, plastic
-68	348-0027-00			2	FOOT, plastic, right front, left rear
-69	348-0026-00			2	FOOT, plastic, left front, right rear
	210-0457-00			4	NUT, keps, 6-32 x $^5/_{16}$ inch
-70	348-0024-00			1	FOOT, flip stand
-71	387-0969-00			2	PLATE, side
	- - - - - -			-	each plate includes:
-72	210-0470-00			2	NUT, cabinet fastener
	210-0870-00			2	WASHER, flat, $^9/_{64}$ ID x $^5/_{16}$ inch OD
	105-0009-00			2	STOP, $^5/_{32}$ ID x $^{11}/_{32}$ inch OD
-73	213-0040-00			2	SCREW, fastening, 6-32 x $^1/_2$ inch

FIG. 2 CHASSIS *(Cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
2-74	179-0886-01			1	CABLE HARNESS, transformer
-75	179-0882-01			1	CABLE HARNESS, vertical amplifier
-76	179-0883-02			1	CABLE HARNESS, sweep
-77	124-0092-00			2	STRIP, ceramic, $^{7}/_{16}$ inch h, w/3 notches
	- - - - - - -			-	each strip includes:
	355-0082-00			2	STUD, plastic
	- - - - - - -			-	mounting hardware for each: (not included w/strip)
	351-0007-00			2	SPACER, plastic, $^{5}/_{32}$ inch long
-78	124-0145-00			13	STRIP, ceramic, $^{7}/_{16}$ inch h, w/20 notches
	- - - - - - -			-	each strip includes:
	355-0082-00			2	STUD, plastic
	- - - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0007-00			2	SPACER, plastic, $^{5}/_{32}$ inch long
-79	124-0146-00			7	STRIP, ceramic, $^{7}/_{16}$ inch h, w/16 notches
	- - - - - - -			-	each strip includes:
	355-0082-00			2	STUD, plastic
	- - - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0007-00			2	SPACER, plastic, $^{5}/_{32}$ inch long
-80	124-0147-00			7	STRIP, ceramic, $^{7}/_{16}$ inch h, w/13 notches
	- - - - - - -			-	each strip includes:
	355-0082-00			2	STUD, plastic
	- - - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0007-00			2	SPACER, plastic, $^{5}/_{32}$ inch long
-81	124-0148-00			4	STRIP, ceramic, $^{7}/_{16}$ inch h, w/9 notches
	- - - - - - -			-	each strip includes:
	355-0082-00			2	STUD, plastic
	- - - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0007-00			2	SPACER, plastic, $^{5}/_{32}$ inch long
-82	124-0149-00			5	STRIP, ceramic, $^{7}/_{16}$ inch h, w/7 notches
	- - - - - - -			-	each strip includes:
	355-0082-00			2	STUD, plastic
	- - - - - - -			-	mounting hardware for each: (not include w/strip)
	361-0007-00			2	SPACER, plastic, $^{5}/_{32}$ inch long

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. If it does not, your manual is correct as printed.

TYPE 321A   TENT SN 6540

ELECTRICAL PARTS LIST CORRECTION

CHANGE TO:

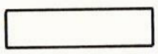
C418A	281-0007-00	3-12 pF, Var	Cer

M14,258/169

SECTION 8
DIAGRAMS

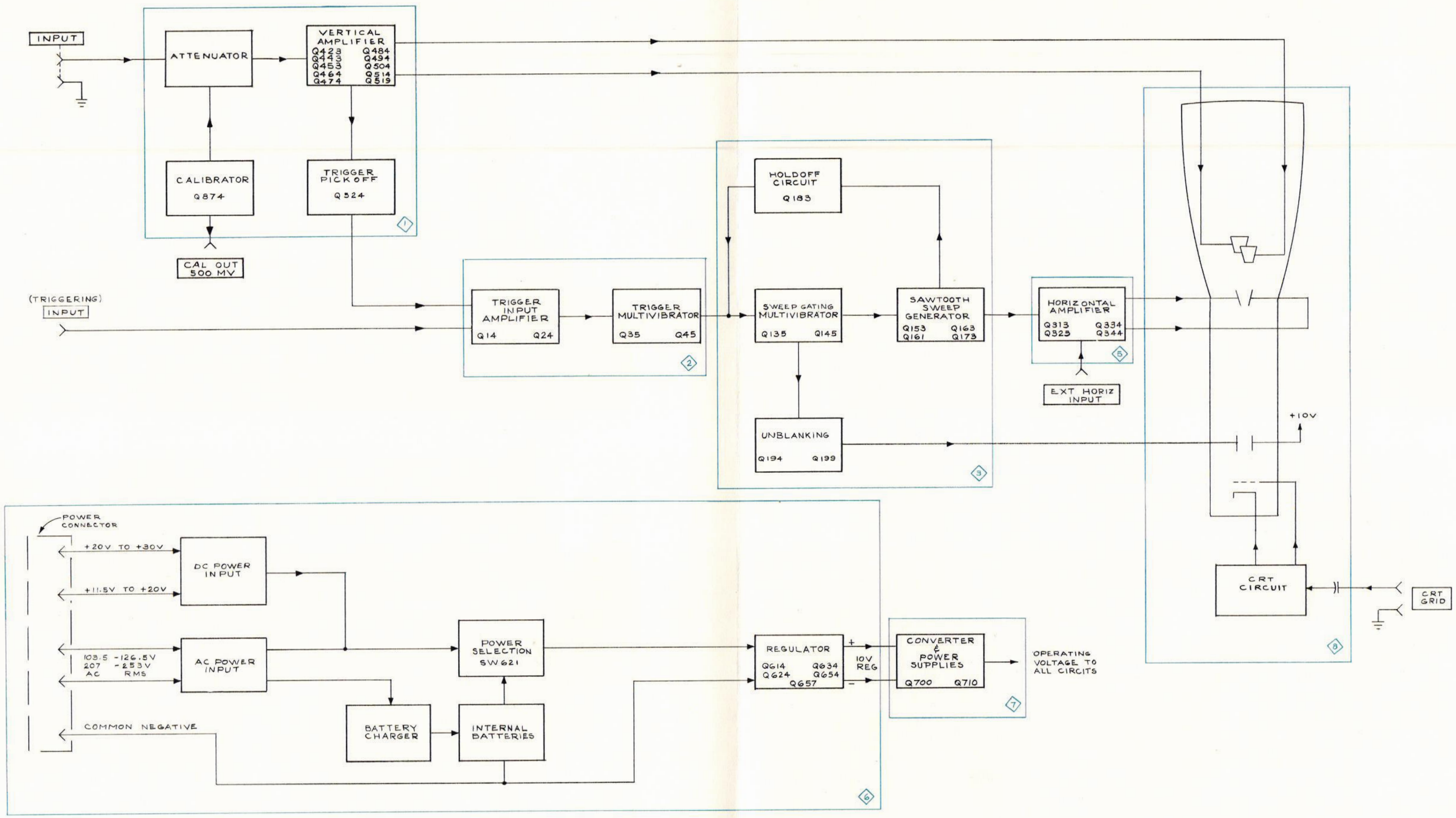
The following symbols are used on the diagrams:

 Screwdriver adjustment

 Front-, side- or rear-panel control or connector

 Clockwise control rotation indirection of arrow

Refer to indicated diagram



TYPE 321A

1068
BLOCK DIAGRAM
S/N 6000-UP

VOLTAGE AND WAVEFORM

TEST CONDITIONS

Typical voltage measurements and waveform photographs were obtained under the following conditions unless noted otherwise on the individual diagrams:

Test Oscilloscope (with 10X probe)

Frequency response	DC to 10 MHz
Deflection factor (with 10X probe)	0.5 volts to 50 volts/division
Input impedance (with 10X probe)	10 Megohms, 7.5 picofarads
Probe ground	Type 321A chassis ground
Trigger Source	External from unblanking gate to indicate true time relationship between signals
Recommended type (as used for waveforms on diagrams)	Type 543B with Type 1A2 plug-in unit

Voltmeter

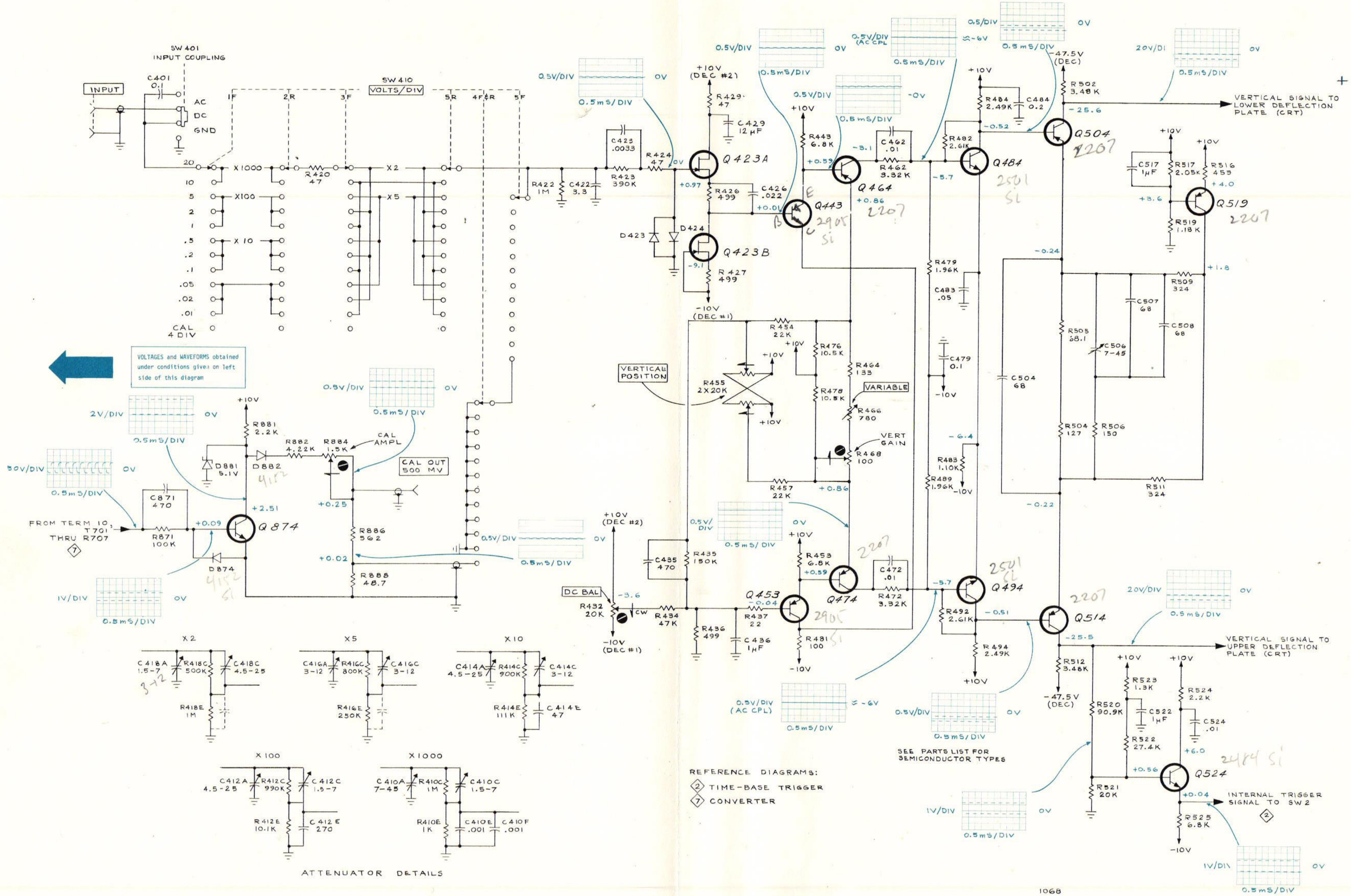
Type	Non-loading AC (RMS)-DC VTVM
Sensitivity	
Range	0 to 1000 volts
Reference voltage	Type 321A chassis ground

Type 321A Conditions

Line voltage	115 volts
Signal applied	
Voltages	None
Waveforms	internal calibrator signal
Connectors	No connections (except as given above)
Trace position	Centered
Control settings	As follows except as noted otherwise on individual diagrams:
CRT Controls	
FOCUS	Adjust for well defined display
ASTIGMATISM	Adjust for well defined display
INTENSITY	Midrange
SCALE ILLUM	As desired
Vertical Amplifier	
VERTICAL POSITION	Midrange
Input Coupling	GND
VOLTS/DIV	.01 (CAL 4 DIV for waveforms only)
VARIABLE	CALIB
Triggering	
Source	INT
Coupling	AC
SLOPE	+
LEVEL	AUTO
Time Base	
HORIZONTAL POSITION	Midrange
TIME/DIV	.2 MILLISEC
VARIABLE	CALIB
5X MAG	Pushed in
Power	
POWER	ON EXT AC-DC

All voltages given on the diagrams are in volts. Waveforms shown are actual waveform photographs taken with a Tektronix Oscilloscope Camera System and Projected Graticule.

Voltages and waveforms on the diagrams (shown in blue) are not absolute and may vary between instruments because of differing component tolerances, internal calibration, front-panel control settings or meter accuracy.



1068

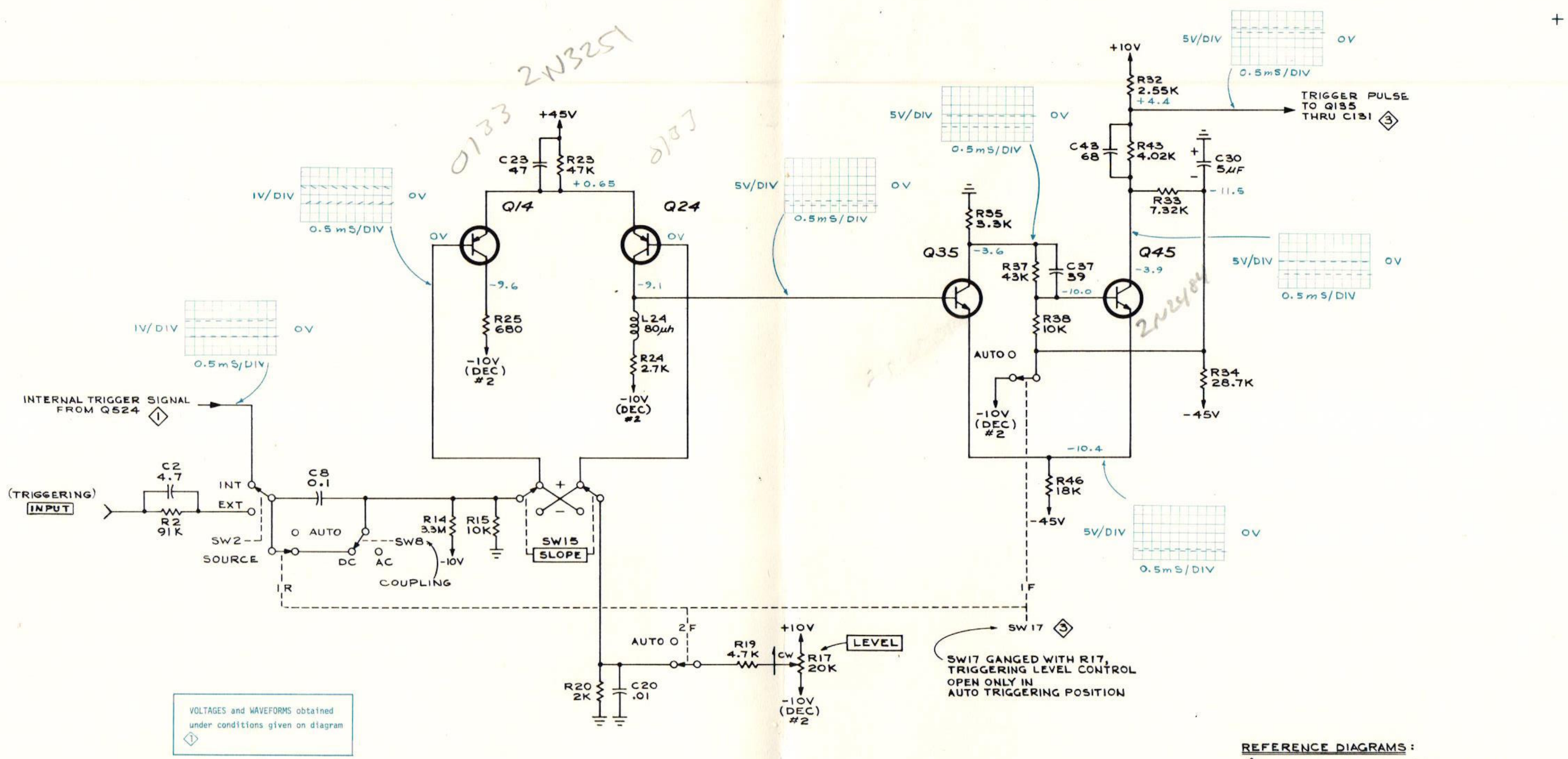
TYPE 321A OSCILLOSCOPE

A

VERTICAL AMPLIFIER & CALIBRATOR 1

SN 6000-UP

VERT AMP & CAL 1



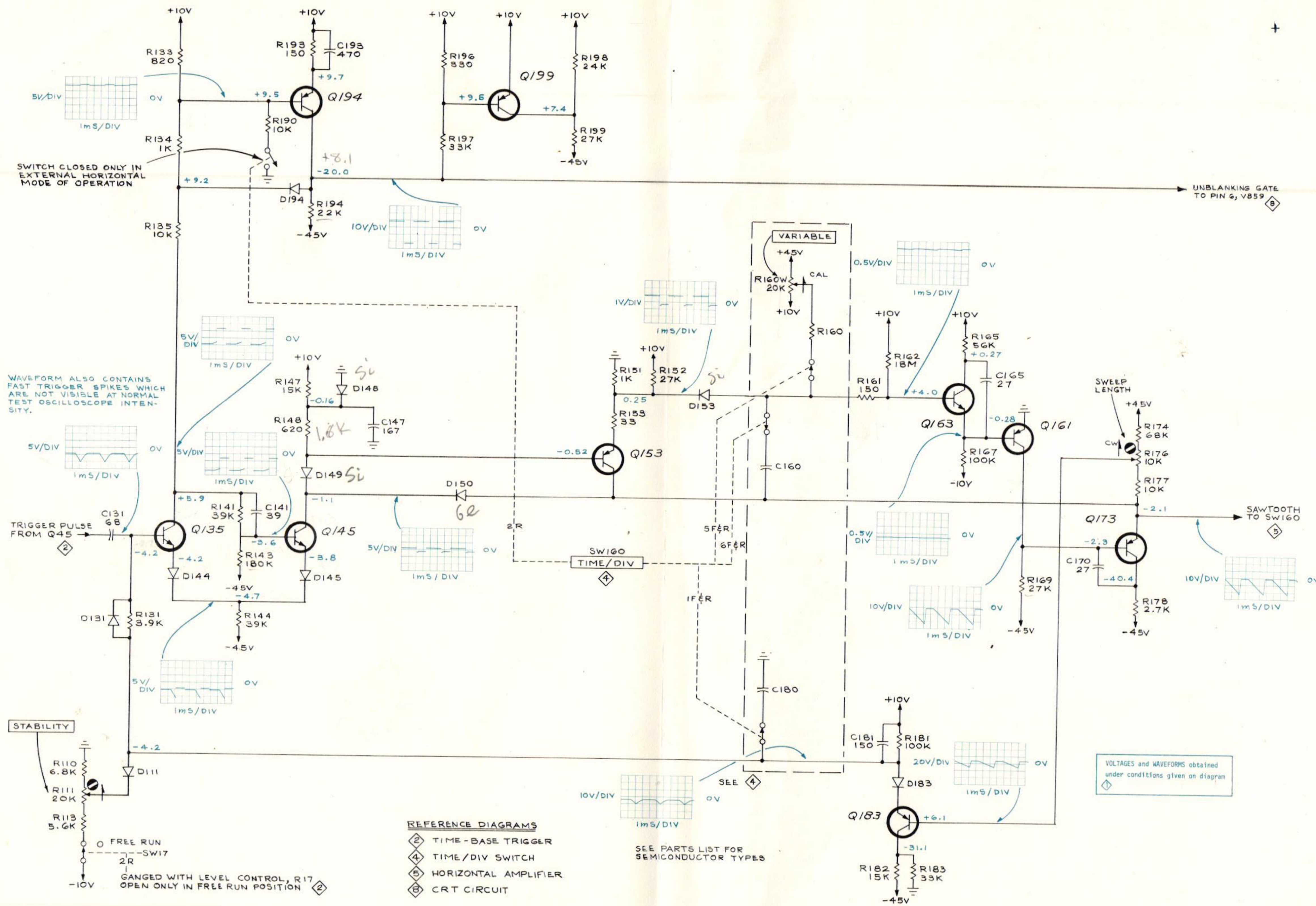
REFERENCE DIAGRAMS:
1 VERTICAL AMPLIFIER & CALIBRATOR
3 TIME-BASE GENERATOR

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

TYPE 321A OSCILLOSCOPE

1068

TIME-BASE TRIGGER 2
S/N 6000-UP



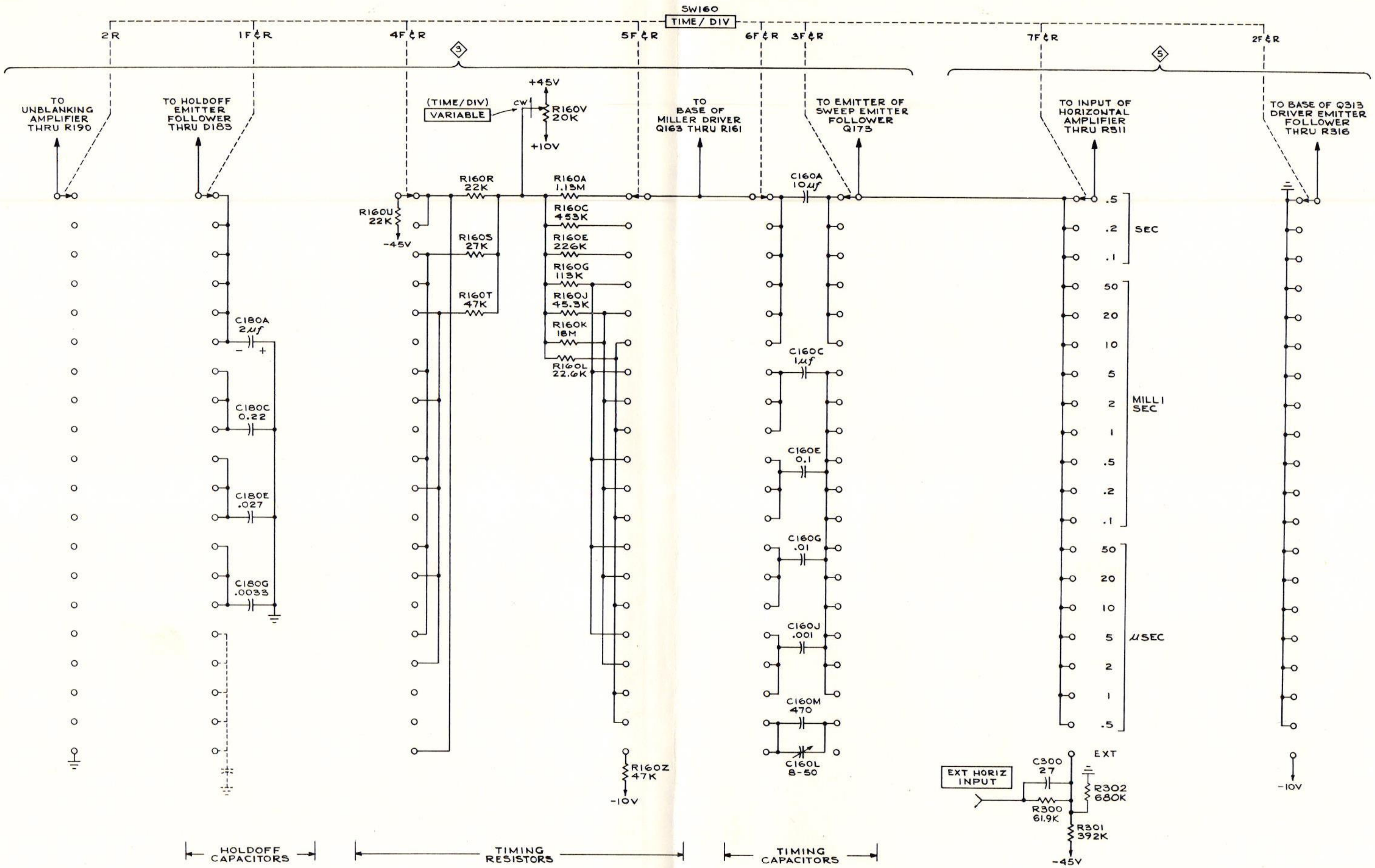
TYPE 321A OSCILLOSCOPE

A

1068

TIME-BASE GENERATOR 3
S/N 6000-UP

TIME BASE GEN 3



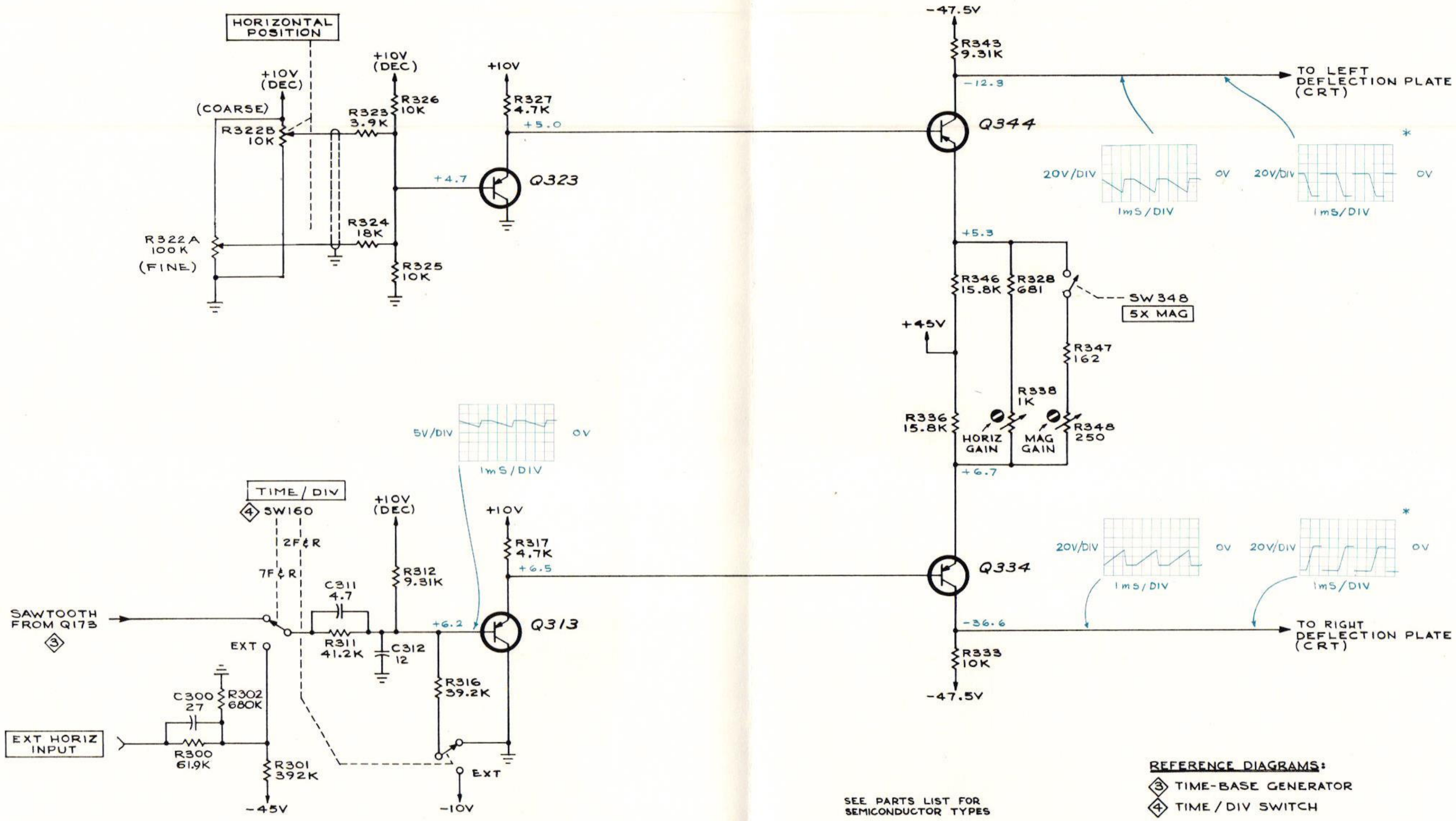
REFERENCE DIAGRAMS
3 TIME-BASE GENERATOR
5 HORIZONTAL AMPLIFIER

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

A

TYPE 321A OSCILLOSCOPE

1068
TIME/DIV SWITCH 4
SN 6000-UP



SEE PARTS LIST FOR SEMICONDUCTOR TYPES

REFERENCE DIAGRAMS:

3 TIME-BASE GENERATOR

4 TIME / DIV SWITCH

VOLTAGES and WAVEFORMS obtained under conditions given on diagram 1, except as follows: WAVEFORMS ONLY *5 X MAG Pullout

TYPE 321A OSCILLOSCOPE

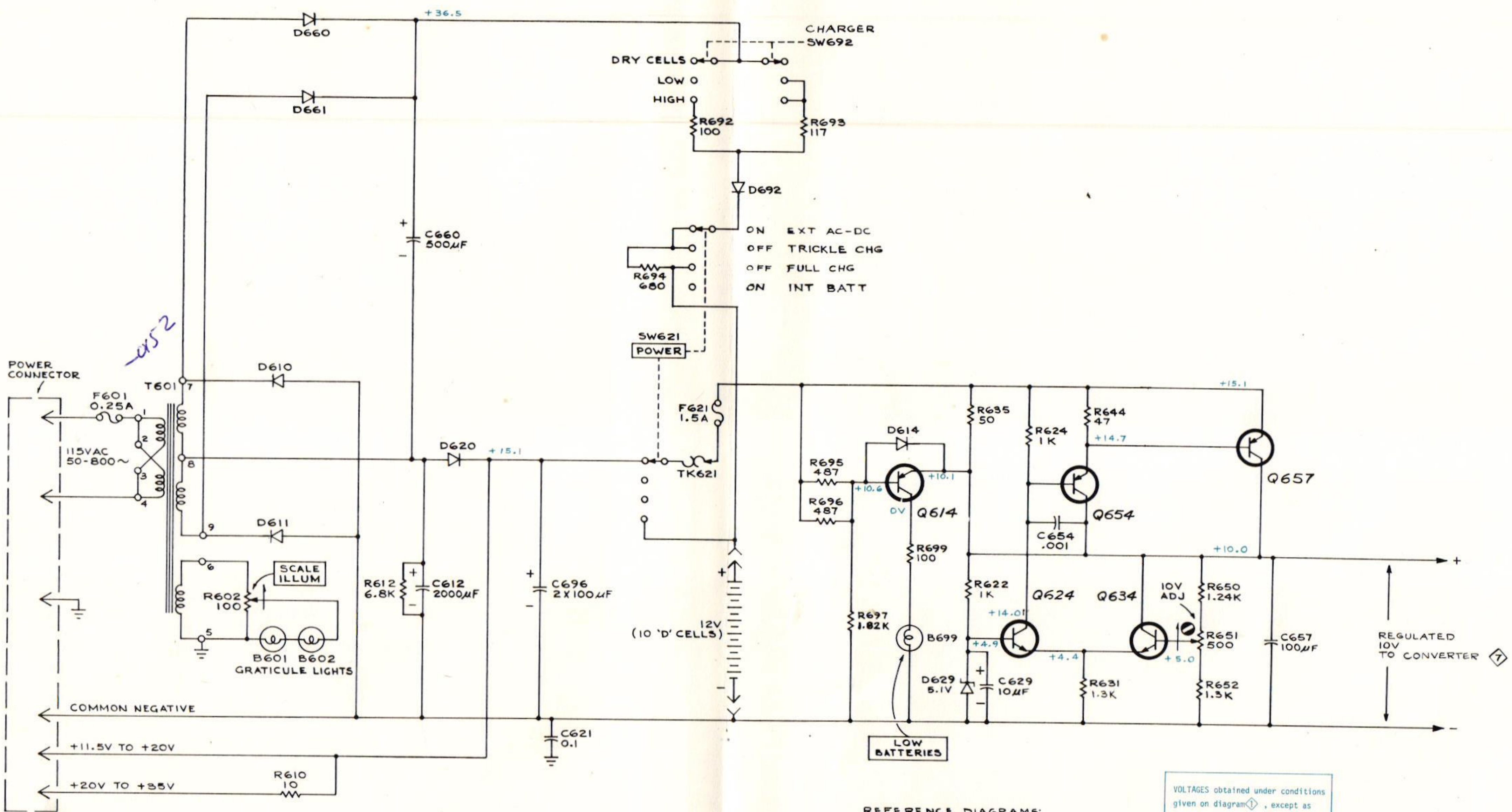
A

1068

HORIZONTAL AMPLIFIER 5

SN 6000-UP

HORIZ AMP 5



REFERENCE DIAGRAMS:
7 CONVERTER

VOLTAGES obtained under conditions given on diagram 1, except as follows:
Ground reference - common negative

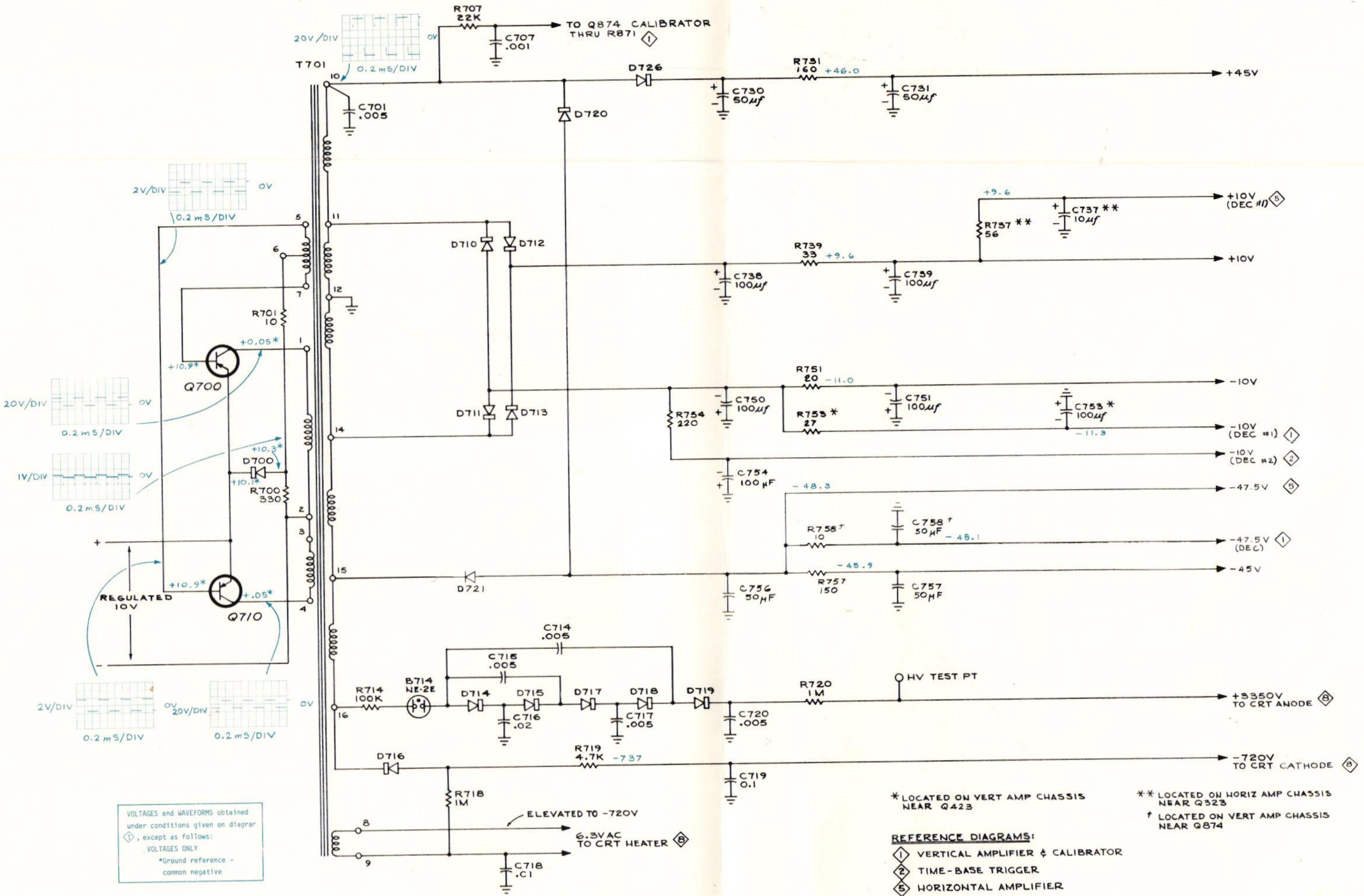
SEE PARTS LIST FOR SEMICONDUCTOR TYPES

TYPE 321A OSCILLOSCOPE

1068

REGULATOR CIRCUIT 6
SN 6000-UP

REGULATOR CKT 6



VOLTAGES and WAVEFORMS obtained under conditions given on diagram 1, except as follows:
VOLTAGES ONLY
*Ground reference - common negative

* LOCATED ON VERT AMP CHASSIS NEAR Q423

** LOCATED ON HORIZ AMP CHASSIS NEAR Q323

† LOCATED ON VERT AMP CHASSIS NEAR Q874

REFERENCE DIAGRAMS:

1. VERTICAL AMPLIFIER & CALIBRATOR
2. TIME-BASE TRIGGER
5. HORIZONTAL AMPLIFIER
8. CRT CIRCUIT

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

1068

TYPE 321A OSCILLOSCOPE

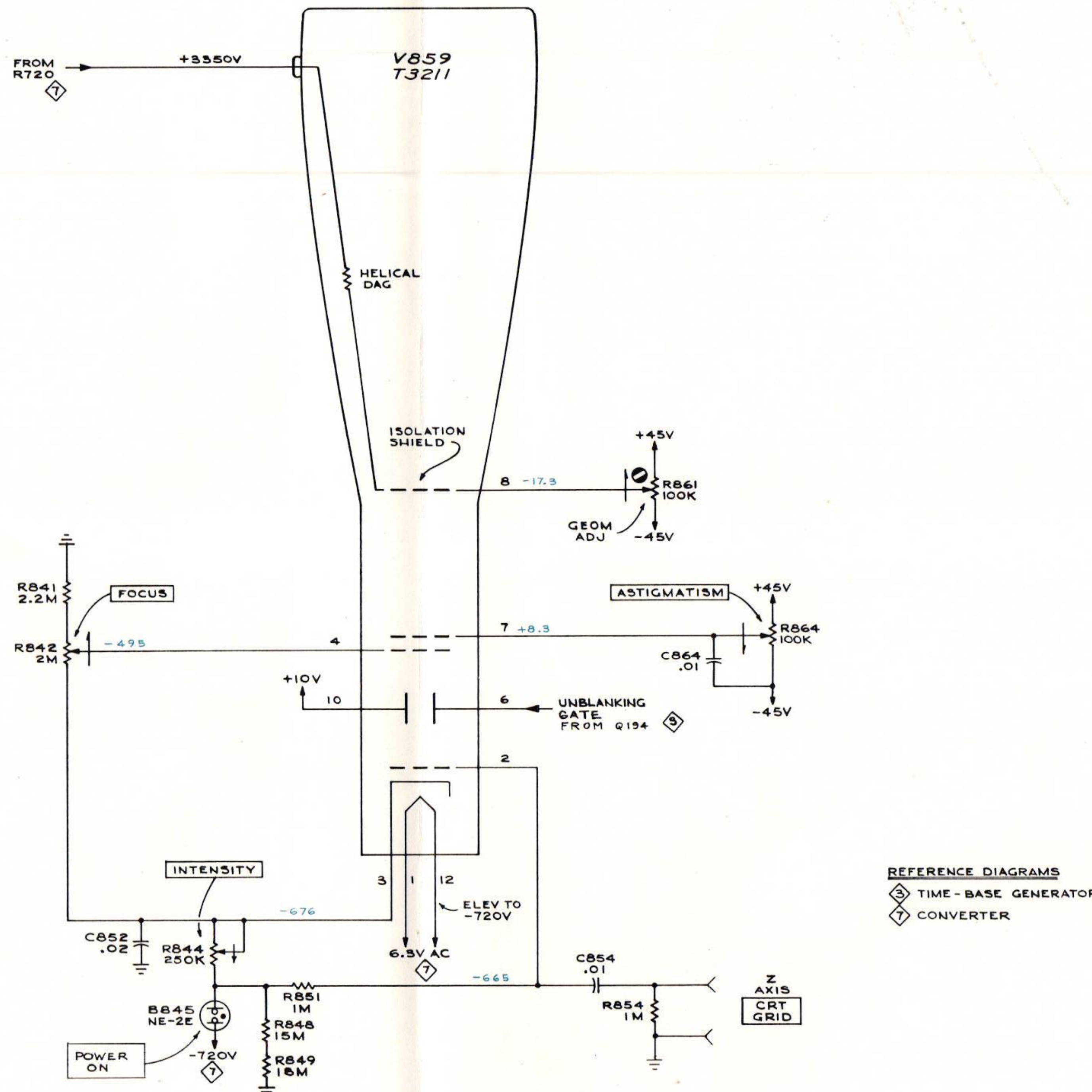
A

CONVERTER 7

SN 6000-UP

CONVERTER 7

CRT CKT 8



VOLTAGES obtained under conditions given on diagram 7

REFERENCE DIAGRAMS
3 TIME - BASE GENERATOR
7 CONVERTER

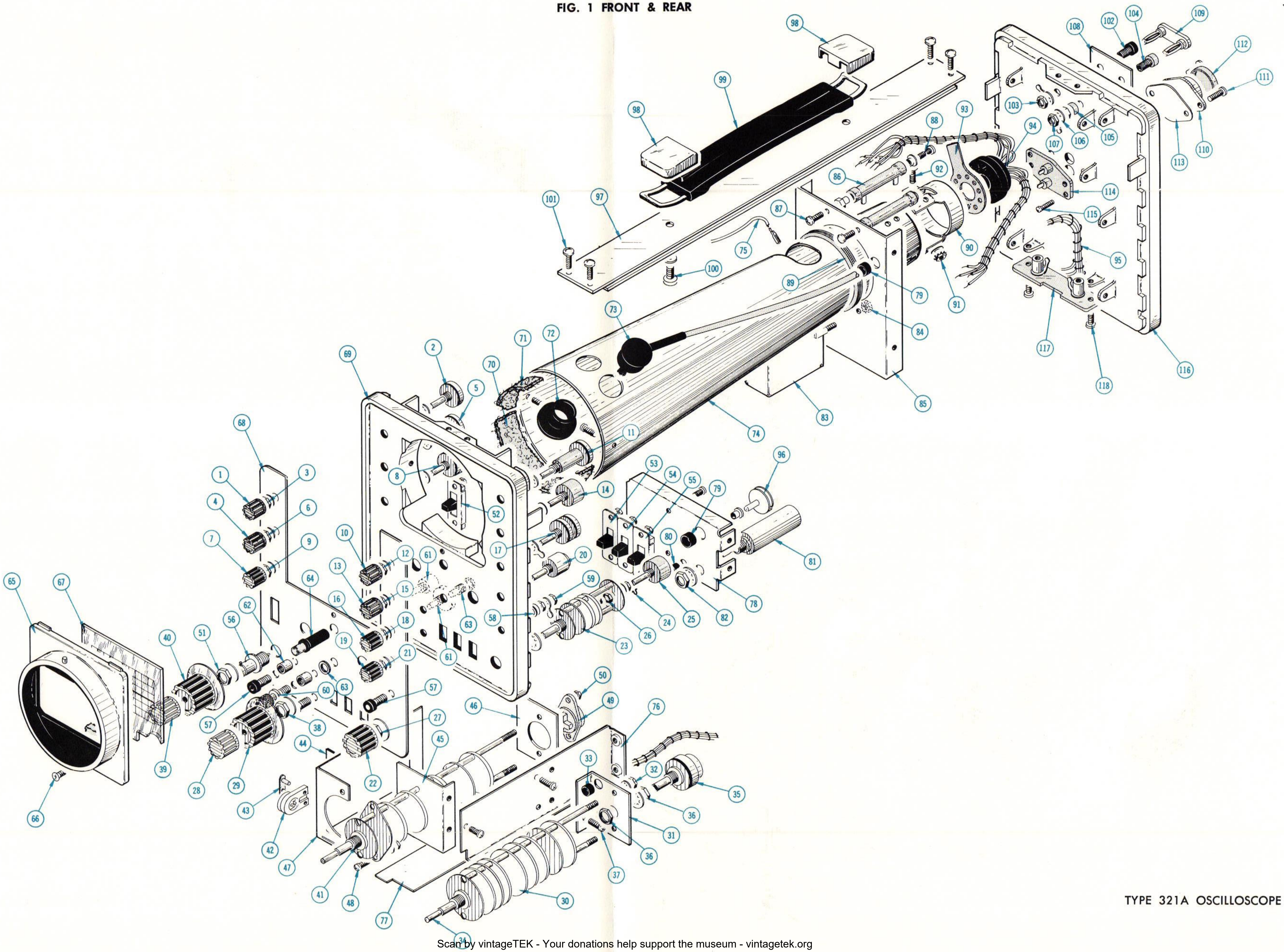
TYPE 321A OSCILLOSCOPE

A

1068

CRT CIRCUIT 8
SN 6000-UP

FIG. 1 FRONT & REAR

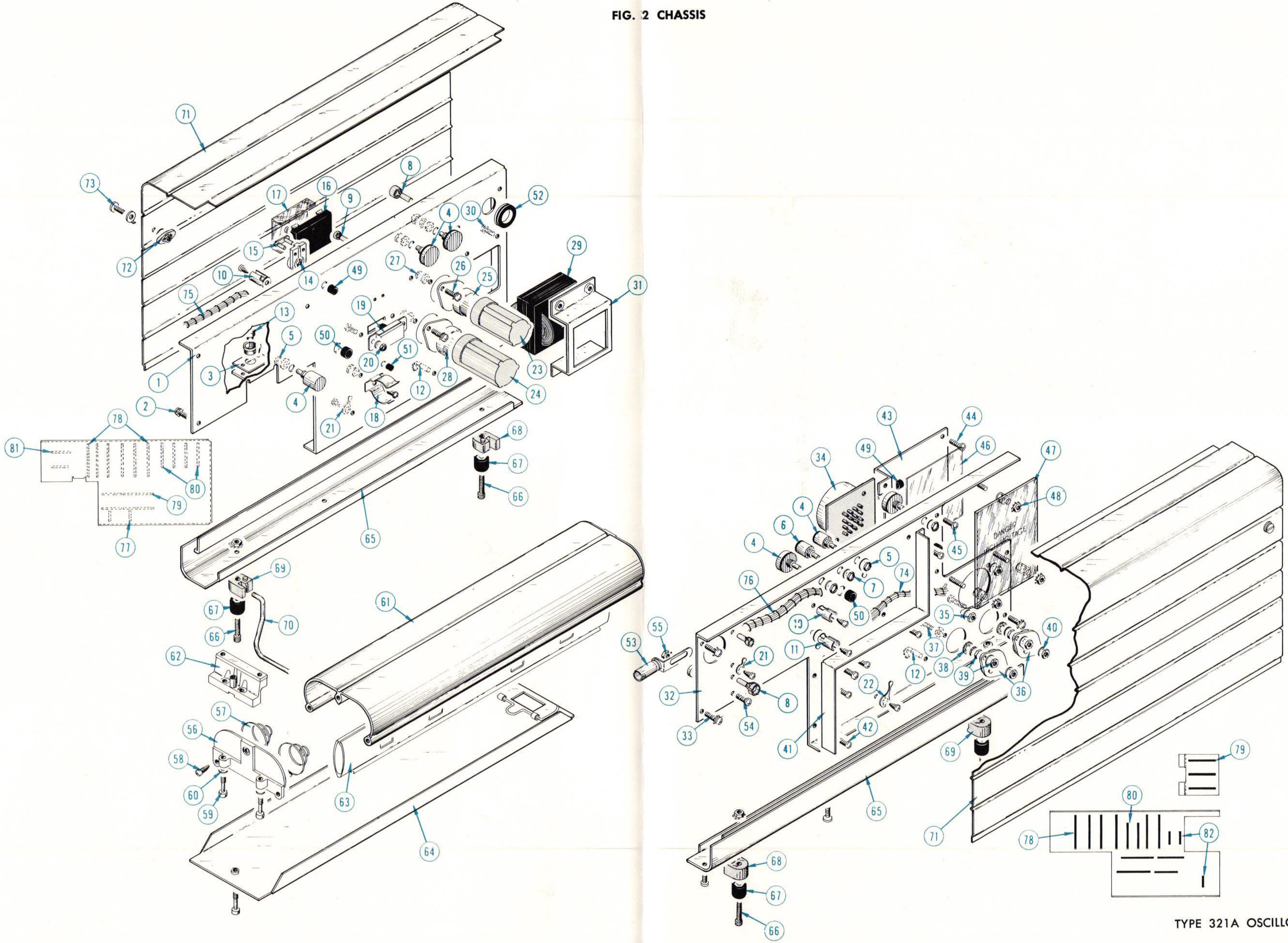


TYPE 321A OSCILLOSCOPE

FIG. 1

A

FIG. 2 CHASSIS



TYPE 321A OSCILLOSCOPE

FIG. 3 STANDARD ACCESSORIES

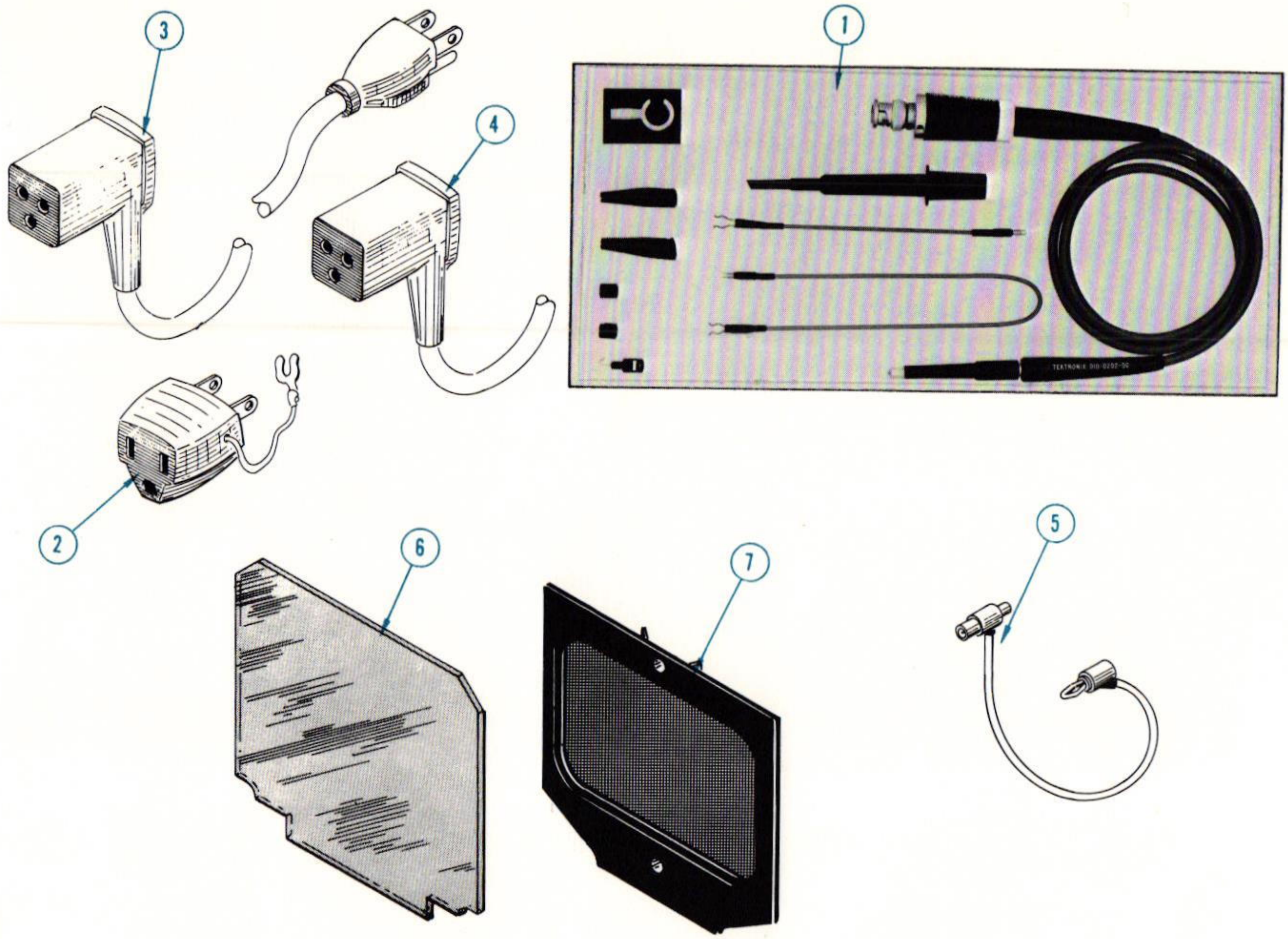


Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
3-1	010-0203-00			1	PROBE PACKAGE, P6012
-2	103-0013-00			1	ADAPTER, 3 to 2 wire
-3	161-0015-01			1	CORD, power, AC, 3 wire, 8 feet long
-4	161-0016-01			1	CORD, power, DC, 3 wire, 8 feet long
-5	012-0091-00			2	CORD, patch, BNC to banana plug, 18 inches long
-6	378-0547-00			1	FILTER, light, graticule
-7	378-0577-00			1	FILTER, mesh (installed)
	070-0891-00			2	MANUAL, instruction (not shown)