INSTRUCTION MANUAL

TYPE 324 OSCILLOSCOPE

MANUFACTURERS OF CATHODE-RAY OSCILLOSCOPES

INSTRUCTION
MANUAL

Serial Number 302314

TYPE 324
OSCILLOSCOPE

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WARRANTY

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

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Specifications and price change privileges reserved.

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CHANGE INFORMATION

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.

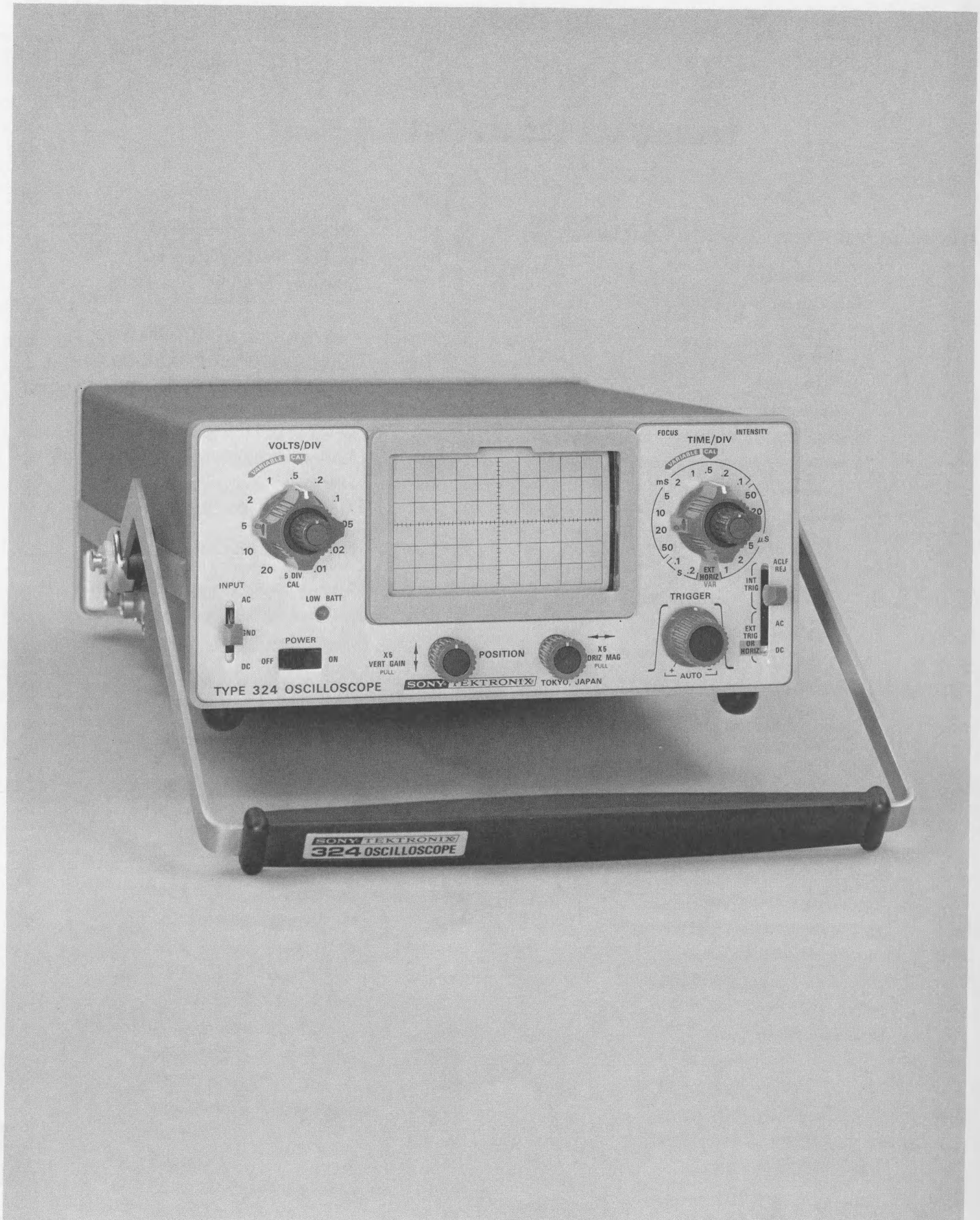

Fig. 1-1. Type 324 Oscilloscope.

SECTION 1
TYPE 324 SPECIFICATION

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

Introduction

The Sony/Tektronix Type 324 Oscilloscope is a solid-state portable instrument that combines small size and light weight with the ability to make precision waveform measurements. The instrument is mechanically constructed to withstand the shock, vibration and other extremes of environment associated with portability. A DC to 10 megahertz vertical system provides calibrated deflection factors from 0.01 volt to 20 volts/division (0.002 volt/division minimum with reduced frequency response). The trigger circuits provide stable triggering over the full vertical bandwidth. The horizontal deflection system provides calibrated sweep rates from 0.2 second to 1 microsecond/division. A X5 horizontal magnifier allows each sweep rate to be increased 5 times to provide a maximum sweep rate of 0.2 microsecond/division in the 1 μs position. X-Y measurements can be made by applying the vertical (Y) signal to the VERT INPUT connector and the horizontal (X) signal to the EXT TRIG OR HORIZ INPUT connector (TIME/DIV switch set to EXT HORIZ, Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ).

The Type 324 can be operated from any one of three power sources; AC line, external DC, or internal rechargeable batteries. A power regulator circuit assures that instrument performance is unaffected by variations in internal battery charge level, applied DC voltage, or AC line voltage and frequency. Operation from an AC line also provides full or trickle charging for the internal batteries.

The electrical characteristics which follow are divided into two categories. The instrument is checked in the Performance Check/Calibration Section against the characteristics listed under Performance Requirement. The following electrical characteristics apply over a calibration interval of 500 hours at an ambient temperature range of −15°C to +55°C, except as otherwise indicated. Warmup time for given accuracy is 10 seconds.

ELECTRICAL CHARACTERISTICS

VERTICAL DEFLECTION SYSTEM

Characteristic	Performance Requirement	
Deflection Factor		
Calibrated Range		
X1 Gain	0.01 volt to 20 volts/division in 11 steps in 1-2-5 sequence.	
X5 Gain	0.002 volt to 4 volts/division in 11 steps in 1-2-4 sequence.	
Accuracy	Within 3% of indicated deflection with VERT X1 GAIN correctly adjusted.	
Uncalibrated (variable) range	Provides continuously variable deflection factors between the calibrated steps. Extends maximum uncalibrated deflection factor to at least 50 volts/division.	
Bandwidth with four division reference	Without Probe	With P6049 Probe
X1 Gain	10 megahertz or higher.	8 megahertz or higher.
X5 Gain	8 megahertz or higher	8 megahertz or higher.
AC Low-Frequency Response (lower −3 dB point)		
Without probe	Two hertz or less.	
With P6049 probe	0.2 hertz or less.	
Step Response		
Risetime with four-division reference		
X1 Gain	36 nanoseconds or less.	
X5 Gain	45 nanoseconds or less.	
Overload Recovery 0°C to +40°C	0.2 microsecond, or less, to stabilize after a signal change at the VERT INPUT connector equivalent to +30 or −30 divisions of deflection.	

Characteristic	Performance Requirement	
−15°C to +55°C	0.4 microseconds, or less, to stabilize after a signal change at the VERT INPUT connector equivalent to +30 or −30 divisions of deflection.	
Displayed Noise at 0.002 Volt/Division		
Driven from 50-ohm termination or P6049 Probe	0.1 division, or less.	
Input Coupling Mode	AC (capacitive) coupled, DC (direct) coupled and internally grounded.	
Maximum Input Voltage (AC or DC input coupling)		
With or without probe	500 volts DC + Peak AC.	
Input RC Characteristics	Without probe	With P6049 probe
Input Resistance	1 MΩ, ±2%.	10 MΩ, ±2%
Input Capacitance	≈47 picofarads	≈13.5 picofarads

TRIGGERING

Characteristic	Performance Requirement
Trigger Source	Internal or external
Trigger Coupling	
Internal	AC (capacitive) coupled. AC (capacitive) coupled, low-frequency reject.
External	AC (capacitive) coupled. DC (direct) coupled.
Trigger Mode	Manual triggering adjustable for desired level. Automative triggering at average level of triggering waveform; free-running baseline in absence of adequate trigger signal.
Trigger Polarity	Sweep can be triggered from positive-going or negative-going portion of trigger signal.
Trigger Sensitivity (manual and automatic)	
Internal	See Fig. 1-2.
External	See Fig. 1-2.

Characteristic	Performance Requirement
External Trigger Input	
RC Characteristics	One megohm ±2% paralleled by 62 picofarads ±4 pF.
Maximum input voltage	300 volts DC + peak AC.
TRIGGER control range	
EXT TRIG OR HORIZ ATTEN at X1	+0.8 volt to −0.8 volt.
EXT TRIG OR HORIZ ATTEN at X10	+8 volts to −8 volts.

HORIZONTAL DEFLECTION SYSTEM

Characteristic	Performance Requirement
Calibrated Sweep Rates	One microsecond to 0.2 second/division in 17 steps in 1-2-5 sequence. Each sweep rate can be increased 5 times with X5 magnifier. Extends fastest sweep rate to 0.2 microsecond/division.
Unmagnified Time Measurement Accuracy (over center eight divisions of graticule)	
0.2 s/DIV, 1 μs/DIV, 2 μs/DIV	Within 4% over the center 8 divisions. Within 5% over any 2 division interval within the center 8 divisions.
0.1 s to 5 μs/DIV	Within 3% over the center 8 divisions. Within 4% over any 2 division interval within the center 8 divisions.
Magnified Time Measurement Accuracy (over center eight divisions of graticule, equivalent magnified sweep rates given)	
40 ms/DIV	Within 5% over the center 8 divisions. Within 6% over any 2 division interval within the center 8 divisions.
20 ms to 1 μs/DIV	Within 4% over the center 8 divisions. Within 5% over any 2 division interval within the center 8 divisions.

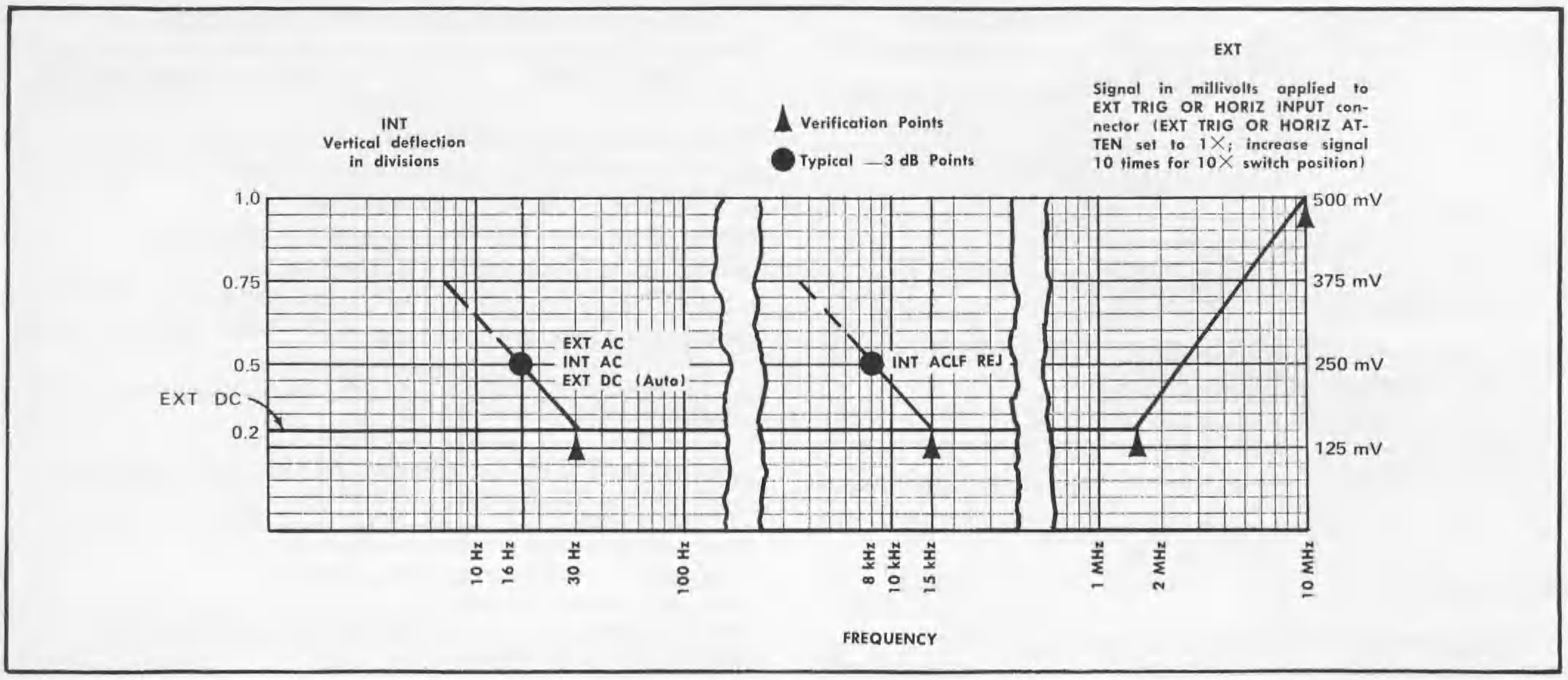

Fig. 1-2. Trigger sensitivity specification limit curve.

Characteristic	Performance Requirement
0.2 μs and 0.4 μs/DIV	Within 5% over the center 8 divisions. Within 6% over any 2 division interval within the center 8 divisions, excluding the first 2 divisions and last 2 divisions of magnified sweep.
Uncalibrated (variable) Sweep Rates	Provides continuously variable sweep rates between the calibrated steps. Extends the slowest uncalibrated sweep rate to at least 0.5 second/division.
Sweep Length	At least 10 divisions.
External Horizontal Input	
Deflection Factor	
EXT TRIG OR HORIZ ATTEN set to X1	20 to 30 millivolts/division.
EXT TRIG OR HORIZ ATTEN set to X10	200 to 700 millivolts/division.
Variable Deflection Factor Range	10:1 or greater.
Bandwidth with 5 divisions reference	DC to 200 kilohertz or greater.
Dynamic Range	At least 20 divisions (+2.5 to −2.5 volts) with EXT HORIZ VARIABLE fully CW.

CALIBRATOR

Characteristic	Performance Requirement
Wave shape	Square wave.
Output Voltage	Zero to +0.5 volt peak to peak.
Repetition Rate	≈800 hertz.
Output Resistance	Approximately 10 kilohms.

EXTERNAL BLANKING

Characteristic	Performance Requirement
Sensitivity	+5 to +20 volts.
Input Coupling	DC (direct) coupled.
Usable Frequency Range	DC to 100 kilohertz.
Maximum Input Voltage	150 volts DC + peak AC.

POWER SUPPLY

Characteristic	Performance Requirement
AC Operation	
Line Voltage	100 volts and 200 volts nominal for domestic Power Pack or 115 volts and 230 volts nominal for export Power Pack.
Operating Range (AC, RMS)	
100 volts nominal	90 to 110 volts.

Characteristic	Performance Requirement
115 volts nominal	104 to 126 volts.
200 volts nominal	180 to 220 volts.
230 volts nominal	208 to 252 volts.
Line Frequency	48 to 440 hertz.
Maximum Power Consumption	20 watts at 126 volts AC with a six-division ten megahertz signal displayed at full intensity and full charge rate.
DC Operation	
Voltage Range (DC)	6.5 volts to 16 volts.
Maximum power consumption	8.5 watts; six-division ten megahertz signal displayed, full intensity.
Battery Operation	
Batteries	Six 1.8 ampere-hour size C nickel-cadmium cells.
Charge time (Power Pack switch set to FULL CHG with the instrument turned off)	At least 16 hours.
Operating Time (batteries charged at +20°C to +25°C)	At maximum intensity, 4.5 hours or more with 5 divisions of calibrator displayed or 2.0 hours or more with 6 divisions of 10 MHz displayed. At minimum usable intensity, 4.7 hours or more with 5 divisions of calibrator displayed or 2.2 hours or more with 6 divisions of 10 MHz displayed.
Typical charge capacity (+20°C to +30°C charge-discharge reference)	

Charge temperature	Discharge Temperature		
	−15°C	+20°C to +25°C	+55°C
0°C	40%	60%	50%
+20°C to +25°C	65%	100%	85%
+40°C	40%	65%	55%

CATHODE-RAY TUBE (CRT)

Characteristic	Performance Requirement
Accelerating Potential	Approximately two kilovolts.
Graticule	
Type	Non-illuminated internal.
Area	Six divisions vertical by 10 divisions horizontal. Each division equals 0.25 inch.
Resolution	
Vertical	At least 15 lines in one division.
Horizontal	At least 15 lines in one division.
Geometry	Within 0.1 division.
Unblanking	Deflection-type, DC coupled.

ENVIRONMENTAL CHARACTERISTICS

The following environmental test limits apply when tested in accordance with the recommended test procedure. This instrument will meet the electrical performance requirements given in this section following environmental test. Complete details on environmental test procedures, including failure criteria, etc., may be obtained from Tektronix, Inc. Contact you local Tektronix Field office or representative.

Characteristic	Performance Requirement
Temperature	
Operating	−15°C to +55°C
Charging	0°C to +40°C.
Non-operating	
With batteries	−40°C to +60°C
Without batteries	−55°C to +75°C
Altitude	
Operating	15,000 feet maximum.
Non-operating (storage)	Tested to 50,000 feet.
Humidity	
Non-operating	Five cycles (120 hours) of Mil-Std-202C, Method 106B. Exclude freezing and vibration. Post-test drying period at +25°C ±5°C at 20% to 80% relative humidity.

Characteristic	Performance Requirement
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 (4 g 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 one each axis. All major resonances must be above 55 c/s.
Shock	
Operating and non-operating	Two shocks of 30 g, one-half sine, 11-millisecond duration each direction along each major axis. Guillotine-type shocks. Total of 12 shocks.
Electromagnetic Interference (EMI)	Test procedures and limits described in Mil-I-6181D and Mil-I-16910C.
Radiated interference	Interference radiated from the instrument within the given test limits from 14 kilohertz to 1000 megahertz.
Transportation	Meets National Safe Transit type of test when packaged as shipped by factory.
Package vibration	One hour vibration slightly in excess of 1 g.
Package drop	30-inch drop on any corner, edge or flat surface.

MECHANICAL CHARACTERISTICS

Characteristic	Description
Construction	
Chassis	Aluminum alloy.
Panel	Aluminum alloy with anodized finish.
Cabinet	Blue vinyl-coated aluminum.

Characteristic	Description
Overall Dimensions (measurement at maximum points)	
Height	4 1/5 inches (10.67 centimeters)
Width	8 1/2 inches (21.59 centimeters). 9 inches (22.86 centimeters) with AC power cord installed.
Length	
Handle extended	13 inches (33.02 centimeters).
Handle not extended	10 5/8 inches (27.05 centimeters).
Net Weight	Approximately 6 3/4 pounds (3.06 kilograms) without accessories.
Connectors	
VERT INPUT and EXT TRIG OR HORIZ INPUT	BNC
CAL OUT, EXT BLANK and EXT DC POWER	Banana jack
AC POWER	Special three-pin connector compatible with the AC power cord.

STANDARD ACCESSORIES

Standard accessories supplied with the Type 324 are listed on the last pull-out page of the Mechanical Parts List illustrations. For optional accessories available for use with this instrument, see the current Tektronix, Inc. catalog.

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SECTION 2
OPERATING INSTRUCTIONS

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

General

To effectively use the Type 324, the operation and capabilities of the instrument must be known. This section describes the operation of the instrument controls and connectors and gives first time and general operating information.

POWER PACK OPERATING PROCEDURE

General

The Power Pack contains internal batteries, a battery charger and a control switch. The switch determines the source of power for oscilloscope operation, and selects one of two battery charging rates. Charge current is applied to the batteries whenever AC power is applied, whether the oscilloscope is on or off. It should be noted that the battery cannot take charge when it is at a temperature below 0°C (32°F); nor should it be subjected to a charge when its temperature is above +40°C (104°F).

When fully charged, the battery pack can supply the 2.8 watts required by the oscilloscope during average operating conditions for approximately 5 hours. Actual operating time varies inversely with sweep rate, the display signal frequency and amplitude, the display intensity, and the ambient temperature during cell charging.

The Nickel-Cadmium (NiCd) cells have been selected to give the best high temperature performance available. Each cell has been rigidly inspected, received an ampere-hour test, and has met or exceeded the minimum ampere-hour storage time requirements. Maximum operating life can be obtained by adhering to the following recommendations regarding NiCd cells in general, and their use in the Type 324 Oscilloscope.

Operation

The oscilloscope can be operated from the internal batteries, from an external DC source of between 6.5 and 16 volts, or from an external AC power source. Nominal line voltages are dependent upon the specific Power Pack installed in the instrument. Refer to the Power Supply portion of the Specifications section in this manual or to the instrument rear panel. Battery charging takes place whenever AC is applied. The rate of charge is determined by the Power Pack switch which is accessible at the rear of the oscilloscope.

Internal Battery-Powered Operation

Setting the Power Pack switch to either TRICKLE CHG or FULL CHG connects the internal battery to the front-panel POWER switch, permitting internal battery-powered operation. Internal battery-powered operation is not possible with the Power Pack switch at EXT DC.

Internal battery-powered operation should not be continued after the LOW BATT lamp starts flashing. The battery should be immediately put on charge at FULL CHG rate to avoid the possibility of individual cells becoming reverse-charged. Operation can continue during recharge.

If internal battery-powered operation is continued after the LOW BATT lamp starts flashing, eventually the trace will disappear and the light will stop flashing; damage to the NiCd battery cells may result.

External DC-Powered Operation

The oscilloscope can be powered by an external DC source of between 6.5 and 16 volts. The external DC power source must be connected to the EXT DC POWER connectors on the right side of the oscilloscope and the Power Pack switch placed at EXT DC. The external DC source will not charge the internal battery.

CAUTION

Applying external DC power with the polarity reversed will cause the Power Regulator protection fuse F501 to blow.

AC-Powered Operation

An AC source can be used to power the oscilloscope when the Power Pack switch is at either TRICKLE CHG or FULL CHG. In addition, the battery charges at the indicated rate whenever AC is applied, regardless of the status of the oscilloscope POWER switch. It may be noted that if the Power Pack switch is left in EXT DC when AC is applied, the internal battery will charge at the full charge rate, even though AC or internal battery-powered oscilloscope operation is interrupted.

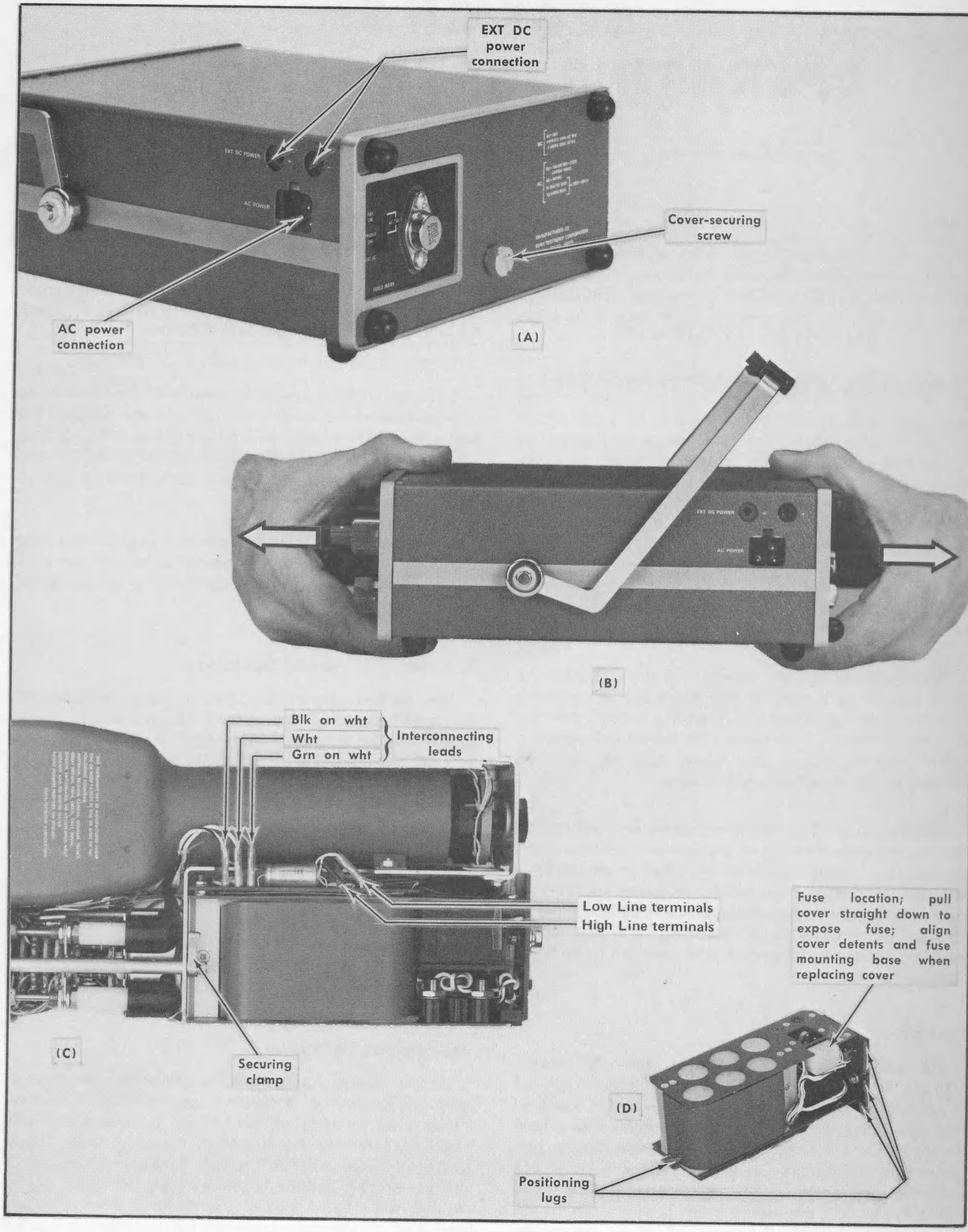


Fig. 2-1. Power Pack removal.

Slip-on connectors in the Power Pack must be connected in accordance with the line voltage to be used. The internal fuse must also be changed when the AC line voltage is changed. Spare fuses are contained inside the oscilloscope adjacent to the side panel. The following procedure explains the Power Pack removal, connection changes, and Power Pack replacement.

Power Pack Removal. Disconnect all cables from the oscilloscope and set the oscilloscope Power Pack switch at EXT DC.

Remove the cover-securing screw from the back of the case. See Fig. 2-1A.

Grip the front edge of the oscilloscope with one hand, and the cover assembly with the other hand as shown in Fig. 2-1B. Pull the cover assembly off the chassis, maintaining a firm grip on the front of the chassis.

Set the oscilloscope chassis down on a flat surface. Disconnect the three interconnecting leads and release the Power Pack securing clamp. See Fig. 2-1C.

Move the Power Pack approximately one-quarter inch toward the rear of the chassis to release the positioning lugs. Then remove the Pack sideways from its mounting area. Use caution to avoid striking transformer wires or the circuit board against the oscilloscope chassis.

WARNING

The batteries used in the Power Pack are capable of delivering a large amount of energy in a short time. Rings, watch bands, or other metallic items which short-circuit the battery can rapidly become hot enough to cause severe burns. Keeping the Power Pack switch at EXT DC minimizes the number of points in the circuitry to which the battery voltage is applied.

Line Voltage Conversion. Fig. 2-1C illustrates the location of the jumper wires and Fig. 2-1D illustrates the details of the Power Pack. The two possible circuit arrangements, accompanying fuse sizes and the locations of spare fuses are indicated in Fig. 2-2. Re-install the insulated tubing over the unused AC terminals.

Power Pack Replacement. Replace the Power Pack by reversing the removal procedure, insuring that the wire color code agrees with that written on the terminal mounting. See Fig. 2-1C. Be careful to avoid pinching your fingers at the front panel when the oscilloscope cover is replaced.

IMPORTANT

The oscilloscope will not operate from the internal batteries or from an AC source if the Power Pack switch is left in the EXT DC position. However, if the switch is left in this position and AC is applied, the batteries will charge at a full-charge rate.

Charging

Although the batteries contained in the Type 324 Oscilloscope are charged before packaging, they should recharge for 16 hours at a FULL CHG rate when put into service.

The charging characteristics of NiCd cells vary with the temperature existing during charge time. A cell which obtained a full charge in a given thermal environment will deliver more energy than an identical cell which was fully charged under higher temperature conditions. Cells can be expected to become warmer as the fully charged point is approached, despite ambient conditions. This is a natural phenomenon which has little effect upon the energy which the cell can retain, since the amount of total charge is dependent principally upon the cell temperature during the first three-quarters to seven-eighths of a full-charge cycle.

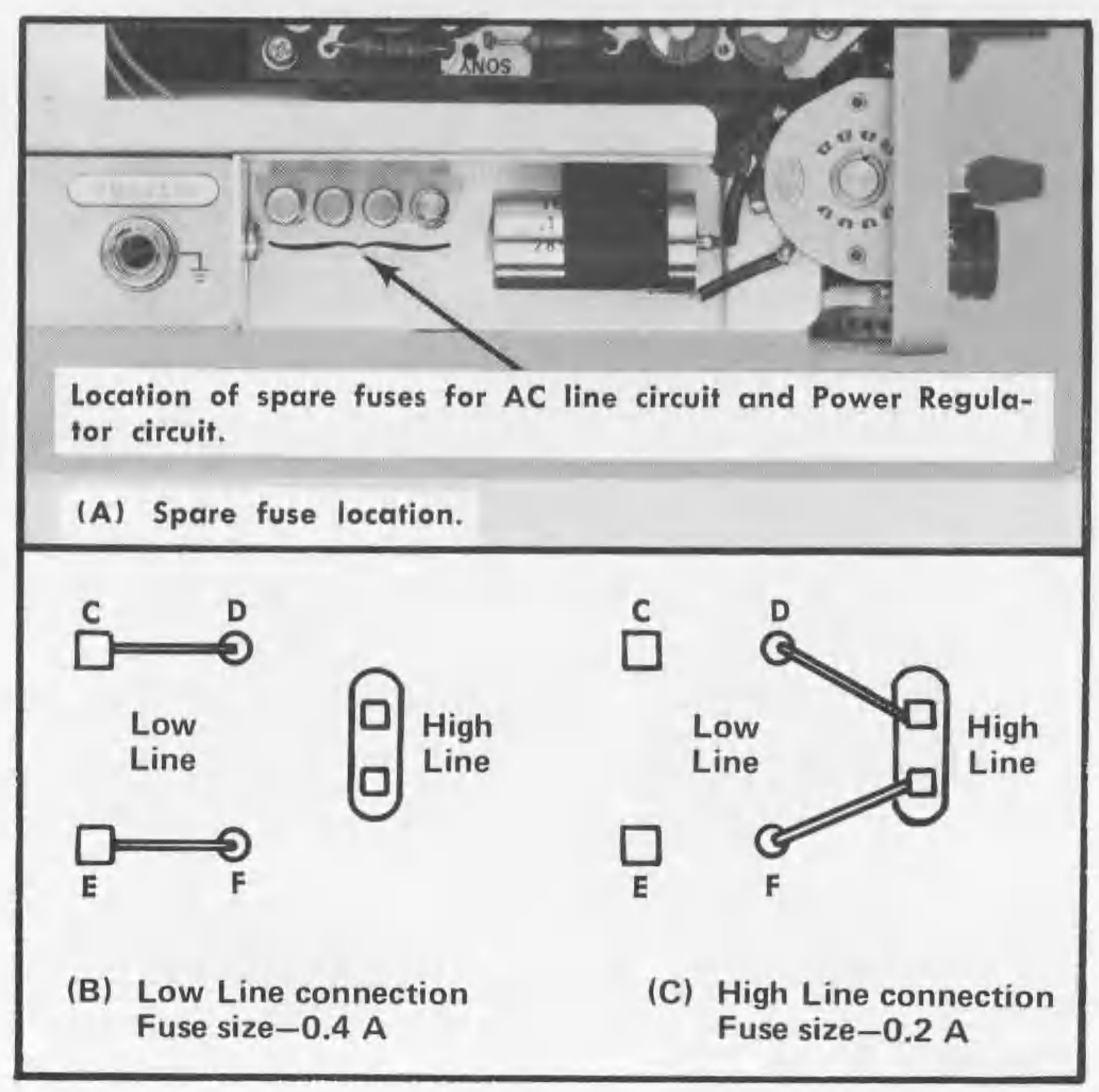


Fig. 2-2. (A) Location of spare fuses. (B) Connection changes for nominal AC line voltages.

The Power Pack is normally put on charge without removing it from the oscilloscope. However, it can be charged while it is outside of the oscilloscope. This permits better air circulation around the pack, thus maintaining a cooler battery temperature. Slightly more energy will be stored in the cells, providing a little longer battery-operated cycle. In addition, the ability to be charged independent of the oscilloscope permits continuous internal battery-powered use if a second Power Pack is obtained. Less than one minute is required for exchanging Power Packs.

If NiCd cells become reverse charged, their capacity for re-charging can be impaired or destroyed. The battery charger is designed to prevent accidental application of reverse charging current. However, an unbalance between cells in a battery can develop during operation or during partial charging. It is possible for the unbalance to become so great that during discharge the weakest cells completely lose their charge and then become reverse-charged by the current from the strong cells.

Considering that the battery initially consists of equal-quality cells, the way to avoid reverse-charging an individual cell is to keep the cells equally charged. This can be done by completing a full-charge cycle, which consists of applying FULL CHG current for 16 hours. The full charge cycle should be completed in preference to a partial charge cycle whenever possible. In addition, approximately once a month or every 15 charge-discharge cycles (whichever occurs first) the battery should be charged at a FULL CHG rate for approximately 24 hours.

Once the battery has been fully charged, the Power Pack switch should be placed in TRICKLE CHG and the AC power cord should be left connected. This will keep the battery in a fully charged condition.

Although partial recharging of NiCd batteries is not recommended as a common practice, occasional partial recharges can be tolerated. About 30 to 45 minutes of operating time can be expected as a result of a one hour charge period.

The energy-storing capability of the NiCd cells decreases gradually with age and the number of charge-discharge cycles. However, the battery should provide a useful operating life well in excess of several hundred charge-discharge cycles.

Storage

NiCd cells can be stored either fully or partially charged. Storage temperature may be between −40°C and +75°C, but the self-discharge rate increases with temperature. At +20°C, a fully charged cell can be expected to self-discharge down to about 50% in three months. Cells and Power Packs which are not in use should therefore be given a full re-charge at least every three months to avoid their becoming reverse-charged.

Maintenance and Repair

Additional data regarding maintenance and repair of the Power Pack and the NiCd cells can be found in the Maintenance section.

EXPLANATION OF EXTERIOR CONTROLS, CONNECTORS AND INDICATORS

General

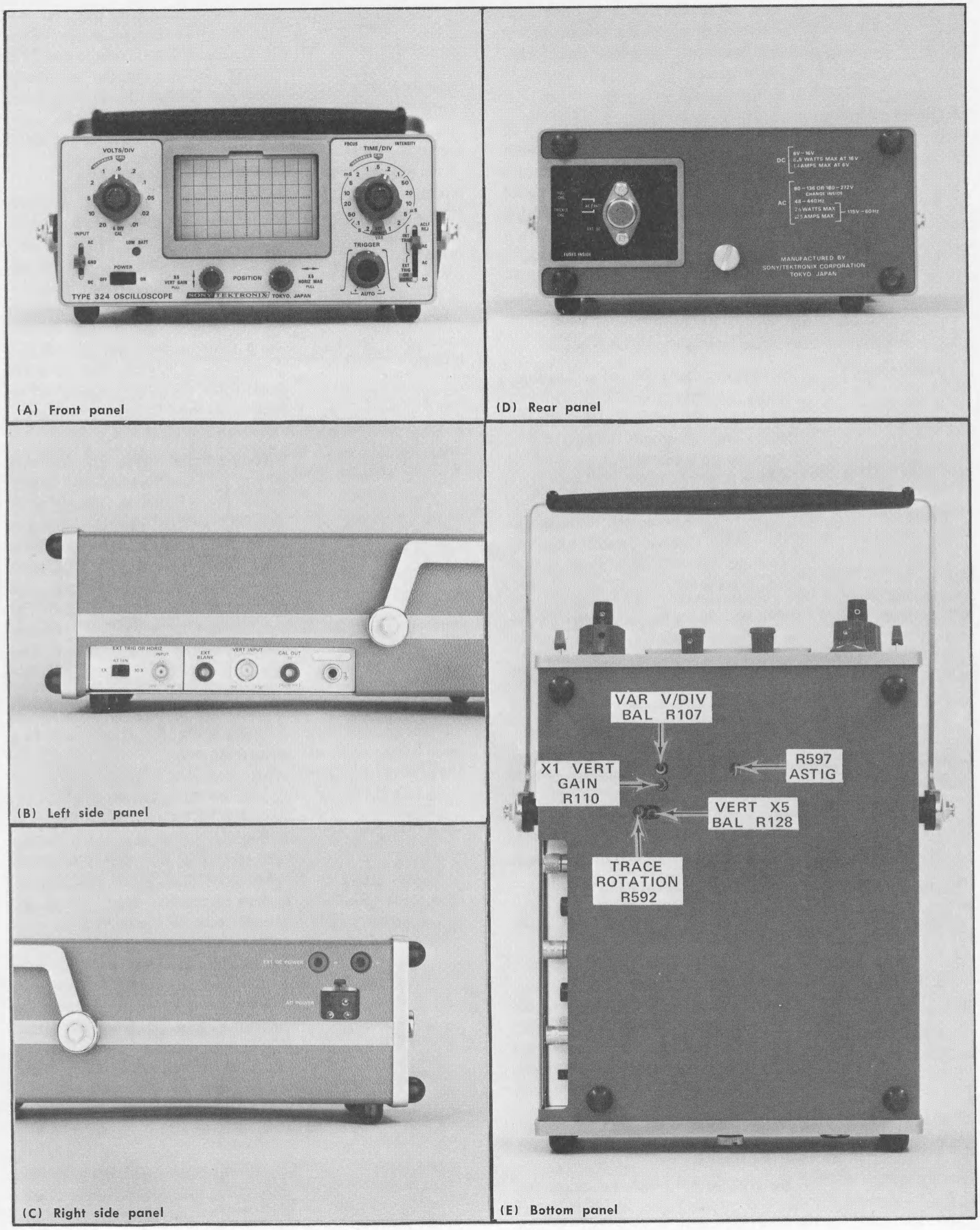
The following controls, connectors and indicators are contained on, or are accessible through the exterior surfaces of the Type 324 Oscilloscope, and are used during routine oscilloscope operation. All other controls are inside the covers. These controls should be moved only during instrument calibration. The names of all Type 324 controls, connectors and indicators are written in capital letters wherever they appear in the manual. Specifications regarding the controls can be found in Section 1.

Handle — 320° rotation. Detents hold the handle in any one of the numerous positions throughout travel arc. Detents automatically unlock in response to rotary pressure on handle.

Front Panel

POWER — Two position slide switch. Interrupts or completes power circuit between Power Pack and remaining oscilloscope circuitry. Does not affect battery charging circuitry.

LOW BATT — Indicator lamp. During "battery only" operation, flashes to indicate that batteries must be recharged before operation is continued. If the batteries become sufficiently low, the oscilloscope will stop operating and the lamp will stop flashing. Leaving the POWER switch ON after the batteries have reached this low state may damage the rechargeable cells. To distinguish this condition from equipment failure, apply AC power for a few minutes with the Power Pack switch at FULL CHG. Then disconnect the AC power and check for oscilloscope



(A) Front panel

(D) Rear panel

(B) Left side panel

(C) Right side panel

(E) Bottom panel

Fig. 2-3. External controls, connectors and indicators.

and LOW BATT lamp operation. Flashing during EXT DC operation indicates that the power input is below 6.5 V.

Vertical Controls

VOLTS/DIV — Rotary Switch. Selects calibrated vertical deflection factors from .01 to 20 VOLTS/DIV. Value indicated applies only when VARIABLE (VOLTS/DIV) is at CAL position and X5 VERT GAIN is pushed in. When set to the 5 DIV CAL position, it selects a 5 division reference square wave signal for calibration purposes.

VARIABLE — Potentiometer. Provides continuously variable deflection factors to at least 2.5 times the calibrated setting. The maximum deflection factor can be extended to at least 50 VOLTS/DIV.

INPUT — 3-position lever switch. Selects the vertical signal input coupling method desired. The three switch positions are:

AC—Capacitively coupled. Lower −3 dB point is 2 Hz.

GND—Grounds the amplifier input.

DC—Direct coupled. Extends the lower −3 dB point to DC.

In addition, the INPUT control provides a precharged-discharge circuit for the coupling capacitor. The input coupling capacitor charges to the DC level of the input signal in the GND position, and discharges in the DC position.

POSITION — Potentiometer. Sets the trace vertical position.

X5 VERT GAIN — A slide switch attached to the Vertical POSITION shaft. It increases vertical gain by a factor of 5 when pulled out. A yellow band around the switch shaft becomes visible to indicate that X5 VERT GAIN is in effect.

Horizontal Controls

TIME/DIV — Rotary switch. Selects calibrated sweep rates from .2 S/DIV to 1 µS/DIV. Value indicated applies only when VARIABLE (TIME/DIV) is set to CAL and the X5 HORIZ MAG is pushed in. When the TIME/DIV switch is in the EXT HORIZ position and the Trig/Horiz Coupling Switch is in the EXT TRIG OR HORIZ position, horizontal deflection must be provided by externally applied signals.

VARIABLE (TIME/DIV) — Potentiometer. Provides continuously variable sweep rates to at least 2.5 times the calibrated setting. Extends the slowest sweep rate to at least .5 S/DIV.

VARIABLE (EXT HORIZ) — Potentiometer connected to the same control knob as VARIABLE (TIME/DIV). Varies the external horizontal deflection factor by a ratio of at least 5:1.

POSITION — Potentiometer. Sets the starting point of the horizontal sweep. When the TIME/DIV switch is at the EXT HORIZ position, it determines the horizontal position of the CRT beam by setting the DC voltage applied to the CRT horizontal deflection plates. Coarse and fine control potentiometers are connected to the POSITION shaft. The fine control has 30° of rotation independent of the coarse control. This arrangement permits the use of a single knob for coarse and fine adjustments.

X5 HORIZ MAG — A slide switch attached to the Horizontal POSITION shaft. When it is pulled out, the horizontal sweep rate selected by the TIME/DIV switch is divided by 5. The two divisions of trace that previously straddled the graticule vertical center are thus expanded to cover the full length of the graticule. Any 2 divisions of sweep can be displayed as a 10 division trace by combined use of the Horizontal POSITION control and the X5 HORIZ MAG. A yellow band around the switch shaft becomes visible to indicate the X5 HORIZ MAG is in effect.

TRIGGER — A combination of rotary switch wafers and a center tapped potentiometer. Selects positive (+) slope triggering level when the knob's indicator spot is to the left of vertical center; selects negative (−) slope triggering level when the knob's indicator spot is to the right of vertical center. The indicator spot and the plus and minus waveform slopes (which appear alongside the TRIGGER knob) indicate the approximate point on the waveform at which triggering occurs. When the control is at the counterclockwise (+ AUTO) or clockwise (− AUTO) limit, a baseline is automatically provided during the absence of triggering signals. Input signals whose frequencies are higher than that of the automatic base line generator provide a stable triggered display.

Trig/Horiz Coupling Switch — Four position level switch. Selects the source and type of triggering. Also selects EXT HORIZ INPUT coupling mode.

INT TRIG ACLF REJ — Selects Internal AC triggering signal; the triggering circuit is desensitized to signals below about 15 kHz.

AC — Selects Internal AC triggering signal.

EXT TRIG OR HORIZ — Refers to External Horizontal input coupling when TIME/DIV is in EXT HORIZ position; refers to External Trigger coupling mode in all other positions of TIME/DIV switch.

AC — Selects external AC triggering signal.

DC — Provides direct coupling of an external triggering signal. Automatically reverts to AC coupling during AUTO trigger operation.

NOTE

The Trig/Horiz Coupling switch must be in an EXT TRIG OR HORIZ position when EXT HORIZ operation is selected by the TIME/DIV switch. Leaving it in either of the INT TRIG positions when EXT HORIZ operation is selected applies the vertical signal to both the vertical and horizontal axis.

Top Panel

FOCUS — Thumbwheel accessible through top panel. Adjusts CRT electron beam for optimum display sharpness.

INTENSITY — Thumbwheel accessible through top panel. Controls the brightness of the CRT display.

IMPORTANT

Battery operating time varies inversely with CRT trace intensity. Use the minimum brightness necessary for good viewing.

Left Side Panel

EXT TRIG OR HORIZ

ATTEN — Two position slide switch. When in 10X position it attenuates the EXT TRIG OR HORIZ INPUT signal by a factor of 10.

INPUT — BNC connector with 62 pF input capacitance. Has 1 MΩ input resistance whenever the Trig/Horiz coupling switch is at DC or when the EXT TRIG OR HORIZ ATTEN switch is at 10X. Maximum allowable input is 500 V DC + peak AC.

EXT BLANK — Banana jack; input is DC coupled to the unblanking circuits. Positive signals between 5 and 20 volts cause blanking of CRT trace. 150 V DC + peak AC maximum allowable input signal.

VERT INPUT — BNC connector with 1 MΩ and 47 pF input impedance. 500 V DC + peak AC maximum allowable input.

IMPORTANT

Battery operating time varies inversely with input signal frequency and the display amplitude.

CAL OUT — Banana jack which makes the vertical amplifier 0.5 volt square wave signal available for monitoring or external use, such as probe calibration. Has approximately 10 kΩ source impedance. External load will decrease its output in proportion to the load.

Ground	Banana jack type binding post connected to chassis ground.

Right Side Panel

EXT DC POWER	Banana jack type input connectors (red +, black −). Accepts external DC power source from 6.5 to 16 V for oscilloscope operation. Does not charge battery pack. Negative input jack is connected to chassis ground.

CAUTION

Applying external DC power with the polarity reversed will cause Power Regulator protection fuse F501 to blow.

AC POWER	A three terminal line plug connector. Accepts AC line voltages (ranges determined by specific Power Pack installed) for oscilloscope operation and battery charging. Batteries are on charge whenever AC power is applied, regardless of oscilloscope switch positions.

Rear Panel

Power Pack Switch	3 position slide switch which allows selection of the power source and the battery charge rate, as follows:
FULL CHG	AC power applied to the line connector charges the batteries at the maximum rate (full charge in 16 hours), and supplies power for oscilloscope operation. If no AC is present, internal battery power is applied to the POWER switch for oscilloscope operation.
TRICKLE CHG	Same conditions exist as for FULL CHG, except that the charging rate is reduced. Counteracts self-discharge, thus keeping batteries fully charged.
EXT DC	Permits operation from a DC source of between 6.5 and 16 volts. DC input does not recharge the internal battery pack.

IMPORTANT

The oscilloscope will not operate in any power mode if the switch is in the EXT DC position and no external DC power is applied.

Cover Securing Screw	Located near bottom-middle of rear panel. Counterclockwise rotation disconnects cover from oscilloscope chassis, allowing chassis to be removed through front of cover assembly.

Bottom Panel

The following screwdriver adjustments are accessible through holes in the bottom panel. The procedure for adjusting them is given under Operator's Adjustment Procedure and in the Performance Check/Calibration section.

TRACE ROTATION	Adjust the horizontal sweep path to parallel the graticule horizontal lines.
ASTIG	Astigmatism. Adjusts for optimum sharpness of vertical and horizontal lines with the FOCUS control properly set.
VERT X1 GAIN	Adjusts to provide calibrated gain factors with X5 VERT GAIN pushed in.
VERT X5 BAL	Adjust for no trace shift accompanying switching between X1 and X5 positions of X5 VERT GAIN control, under no-signal conditions.
VAR V/DIV BAL	Adjusts for no trace shift during rotation of VARIABLE (VOLTS/DIV) knob, under no-signal conditions.

ACCESSORIES

Standard accessories included with the Type 324 Oscilloscope are listed near the rear of this manual. Although most items require no explanation, the following information should be helpful in their use:

CRT Face Shield, Clear. This is not listed as a standard accessory, but is installed in the bezel plate recess prior to shipment from the factory. It provides protection for the CRT face, and also acts as protection against the possibility of implosion. It should always be kept installed except when the CRT light filter is in use. To install, insert the lower edge into the groove at the bottom of the bezel. Push it down against its spring until the top can be slid past at the top of the bezel.

CRT Light Filter. The filter performs the same function as the clear shield, and improves CRT viewing in brightly lighted locations.

Viewing Hood. To install, attach the top first, inserting the key into the groove at the top of the bezel.

P6049 Probe. This probe includes a right angle adapter which contains a compensation adjustment. See the explanation later in this section, or in the P6049 Probe manual.

Patch Cord. This cord can be used to connect a banana jack to a BNC-female connector; for example, connecting the Type 324 Oscilloscope CAL OUT jack to the TRIG OR HORIZ INPUT or the VERT INPUT connectors.

3 to 2-Wire Adapter (domestic orders only). Grounding is not provided through the AC power source when the adapter is in use. A separate grounding connection must be used.

Panel Cover. A friction fit keeps this cover over the front panel during storage or transporting. The cover can be placed over the rear of the oscilloscope for storage when the oscilloscope is in use. The recess in the cover accommodates the accessory pouch strap and should not be used as a finger grip for cover removal.

Accessory Pouch. This unit grips on the handle pivots and on the cover securing screw at the rear panel. It has sufficient capacity to hold the standard accessories, with the exception of the manuals and the Panel Cover.

Strap Assembly. The strap is designed to be snapped into place for transporting the oscilloscope. It can be used to suspend the oscilloscope in front of or alongside the operator during use. The handle can be extended between the operator and the oscilloscope to obtain optimum viewing positions.

FIRST TIME OPERATION

General

This first time operation is designed to obtain a trace and provide familiarization with the oscilloscope controls and responses. A control setup chart is provided in Fig. 2-4. It can be duplicated as a convenient method of recording specific setups in conjunction with oscilloscope familiarization and use.

CAUTION

1. Internal battery-powered operation should not be continued for long periods after the LOW BATT lamp starts flashing. Damage to the NiCd batteries may result. If the batteries become sufficiently discharged, the trace will disappear and the light will cease flashing. The battery should then be recharged to avoid the possibility of individual cells becoming reverse-charged. Operation can continue during recharging.

2. Always operate within the oscilloscope's allowable input values, which are as follows:

Power Source—AC	*Determined by specific Power Pack installed. Refer to the instrument rear panel or the Power Supply portion of the Specifications section of this manual.*
Power Source—DC	*6.5 to 16 volts.*
VERT INPUT	*500 V DC + peak AC*
EXT TRIG OR HORIZ INPUT	*300 V DC + peak AC*
EXT BLANK	*150 V DC + peak AC*

WARNING

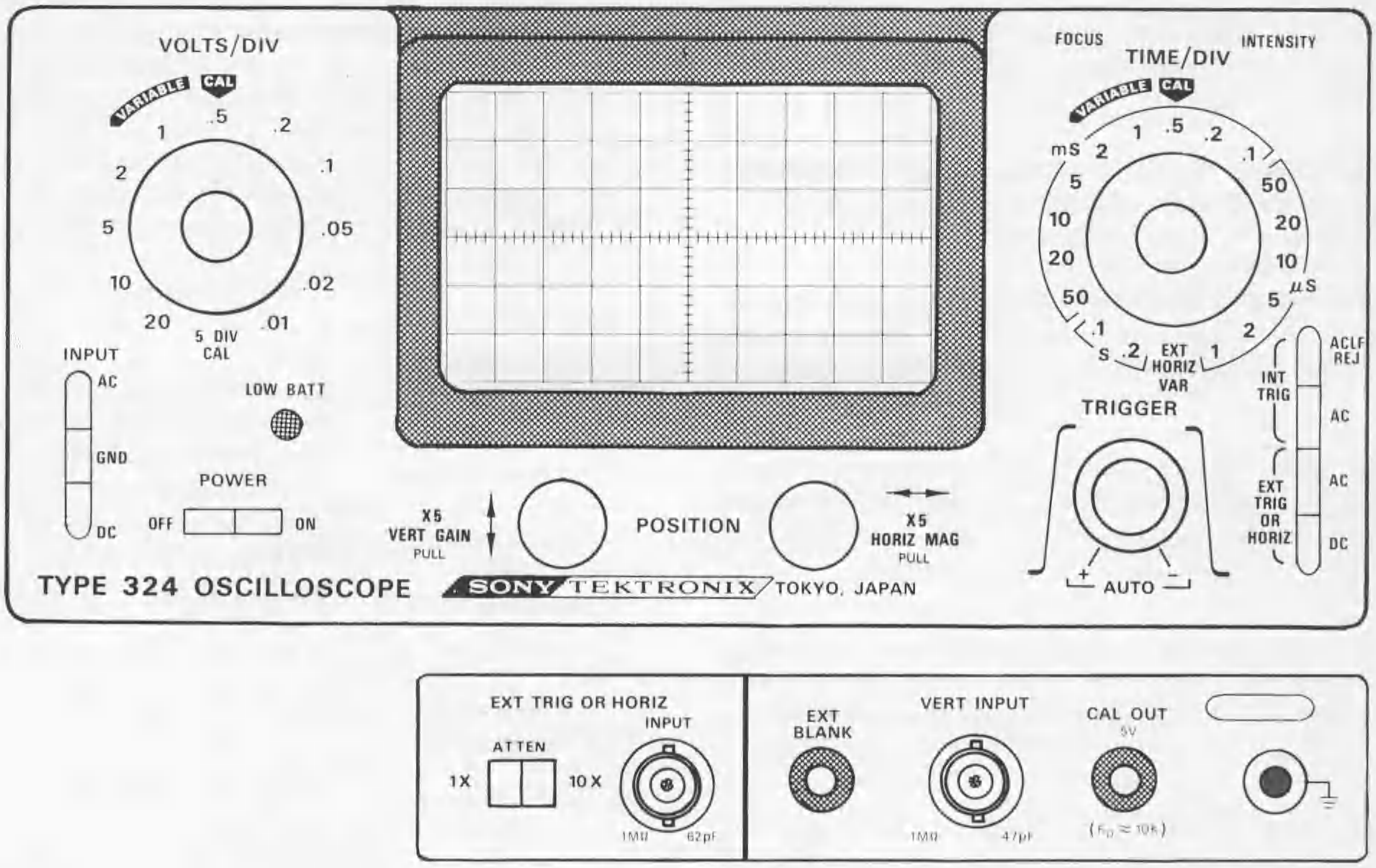
Unless the Type 324 Oscilloscope is connected to a common ground, its metallic parts will be elevated to the signal potential to which it is connected. To insure personnel safety and dependable equipment operation, connect a lead between oscilloscope ground and equipment ground before connecting the oscilloscope inputs to equipment test points. Do not remove the ground lead until all other connections are removed.

1. Preset the controls as follows:

VOLTS/DIV	5 DIV CAL
VARIABLE (VOLTS/DIV)	CAL
INPUT	GND
X5 VERT GAIN	In
POSITION (Vertical)	Midrange
X5 HORIZ MAG	In
POSITION (Horizontal)	Midrange
TIME/DIV	0.5 ms
VARIABLE (TIME/DIV)	CAL
TRIGGER	+AUTO
Trigger Coupling	INT TRIG AC
FOCUS	Midrange
INTENSITY	Midrange
Power Pack Switch	TRICKLE CHG

2. Connect the AC power cord (standard accessory) between the oscilloscope and an appropriate AC source, if

TYPE 324 TEST SETUP CHART



DATA:

Fig. 2-4. Control setup chart.

Ⓐ

available. Turn the POWER switch ON. Check that the LOW BATT indicator does not flash.

3. Observe that a square wave appears on the face of the cathode ray tube (CRT). Readjust INTENSITY and FOCUS for optimum presentation. Use the minimum CRT intensity necessary for good viewing to conserve battery power.

Operating the Vertical Controls

4. Adjust the vertical POSITION control to center the square wave; observe 5 divisions (±0.15 division) display amplitude.

5. Adjust the horizontal POSITION control to start the trace at the left (0-div) vertical graticule line.

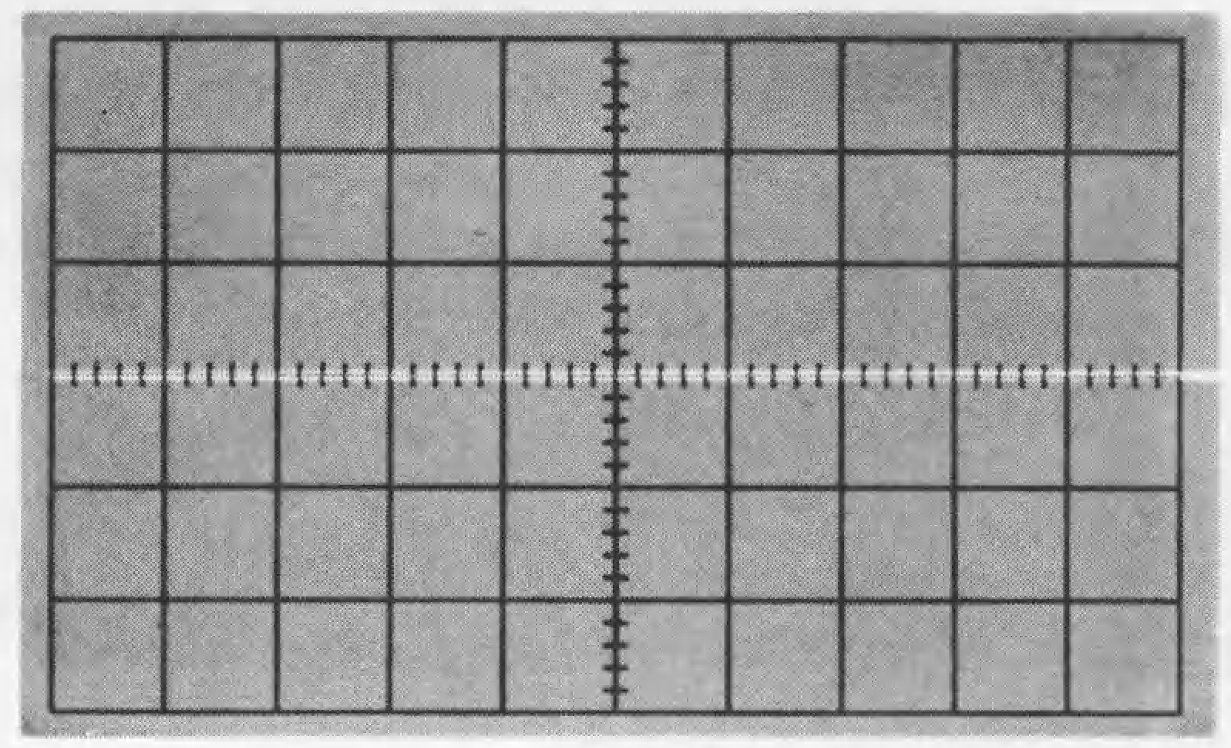
6. Gradually rotate the VARIABLE (VOLTS/DIV) knob counterclockwise from its CAL position. Observe that the square wave presentation simultaneously decreases to an amplitude of 2 divisions or less at the counterclockwise limit. Return the control to the CAL position.

7. Pull the X5 VERT GAIN out. Note that there is no change in the calibration signal display amplitude. The cal signal is reduced by a factor of five to compensate for the increase in gain when the X5 VERT GAIN control is out. Push in the X5 VERT GAIN control.

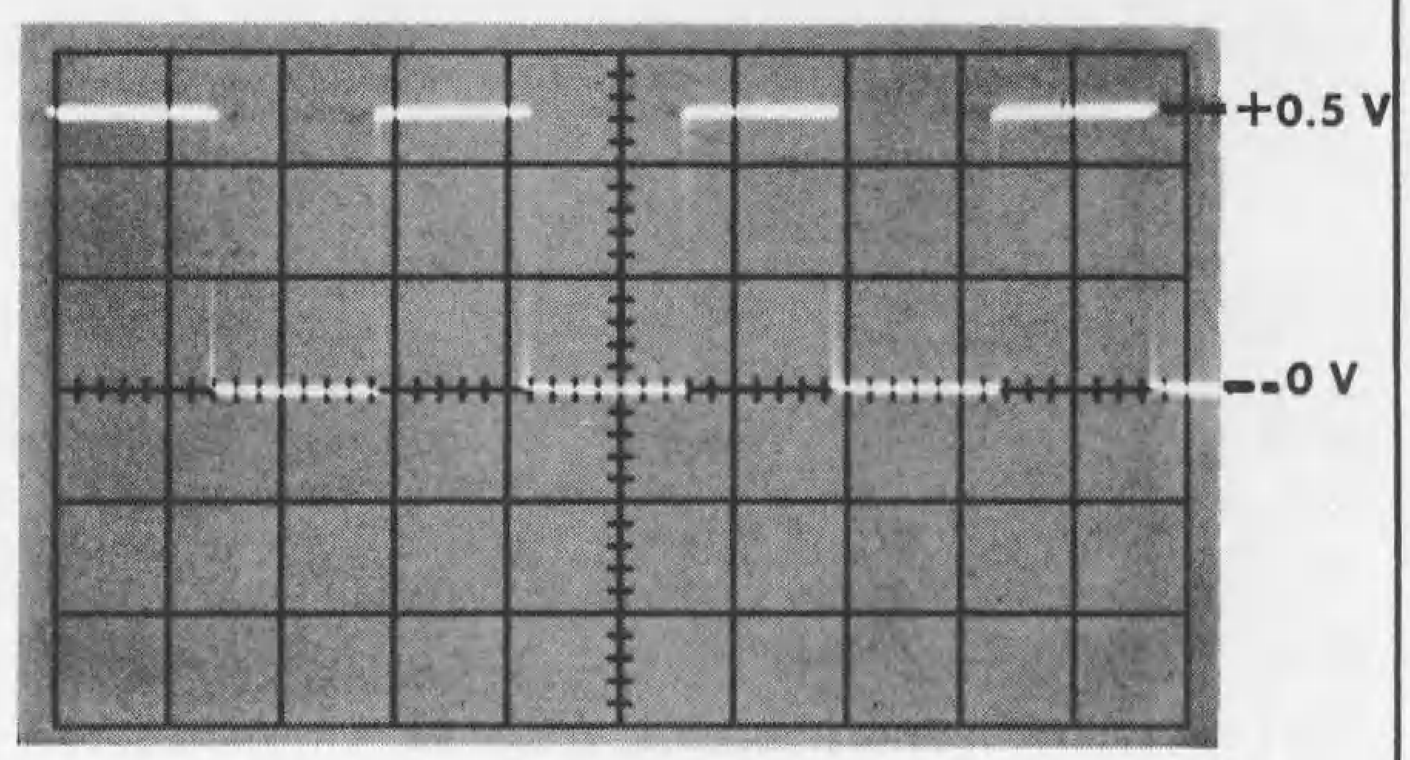
8. Set the VOLTS/DIV switch to .02. Observe that the 5 DIV CAL square wave is replaced by a horizontal trace which appears approximately 2 1/2 divisions below graticule center. Reset the trace to graticule center. This will be used as the DC reference position. (The DC reference position can be arbitrarily established anywhere on the CRT by adjusting the vertical POSITION control while the probe tip is grounded or the INPUT switch is at GND position.)

9. At the side panel, connect the Type P6049 probe cable to the VERT INPUT connector. Connect the probe tip to the 0.5 V square-wave signal at the CAL OUT jack.

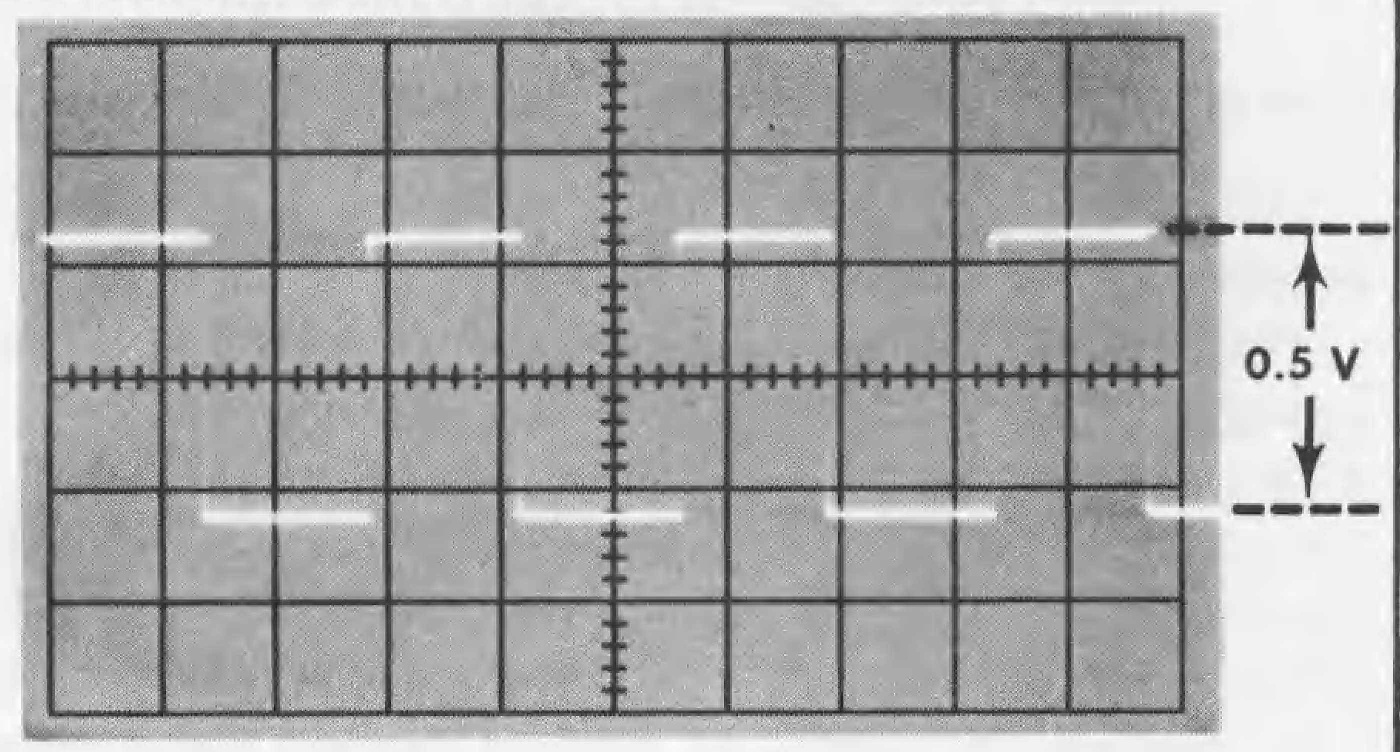
10. Switch the INPUT control to DC. Observe that a square wave 2 1/2 divisons in amplitude appears on the CRT. The instantaneous voltage at the top and bottom of the square wave can be measured as follows:



(A) DC reference position set at graticule vertical center.



(B) 0.5 V square wave signal DC-coupled into vertical circuit. DC operating level and signal amplitude can be determined. Deflection Factor .2 VOLTS/DIV.



(C) Same signal, AC-coupled into vertical circuit. Note that signal DC operating level cannot be determined.

Fig. 2-5. DC versus AC input coupling.

Determine that the number of divisions of separation between the previously established DC reference and the top of the square wave. Multiply by the value of the VOLTS/DIV knob setting and the probe attenuation factor. The position of the top of the trace is above the DC reference, indicating a positive voltage. The bottom of the trace appears at the DC reference point. The trace is operating between 0 and +0.5 V DC. See Fig. 2-5(A) and (B).

11. Switch the INPUT control to AC. Note that removal of the DC component causes the trace to shift downward, centering around the previously established trace DC reference position. See Fig. 2-5(C).

12. Compute the signal amplitude. .02 VOLTS/DIV deflection factor multiplied by the 10 X probe attenuation factor and by the 2 1/2 divisions of deflection equal 0.5 V signal amplitude. Note that this equal the difference between the waveform's DC voltage limits found during DC measurement in step 10, although the waveform's DC operating level does not appear.

13. Set the VOLTS/DIV control to 0.1. Note that the display amplitude reduces to 1/2 division. Again calculate the input signal amplitude (0.5 V).

14. Pull the X5 VERT GAIN control out. Note that the display amplitude increases to 2.5 divisions. Compute the display amplitude by using the following procedure:

Divide the VOLTS/DIV setting by 5 to determine the vertical deflection factor with the X5 VERT GAIN out.

Multiply this deflection factor by the number of divisions of deflection and the 10X probe factor to determine the input signal amplitude (0.5 V)

Operating the Horizontal Controls

15. Calculate the square wave period. Multiply the number of divisions per one cycle of square wave by the TIME/DIV setting. Reset the horizontal POSITION knob as necessary for convenient measurement. (Approximately 1.25 ms per cycle.) See Fig. 2-6.

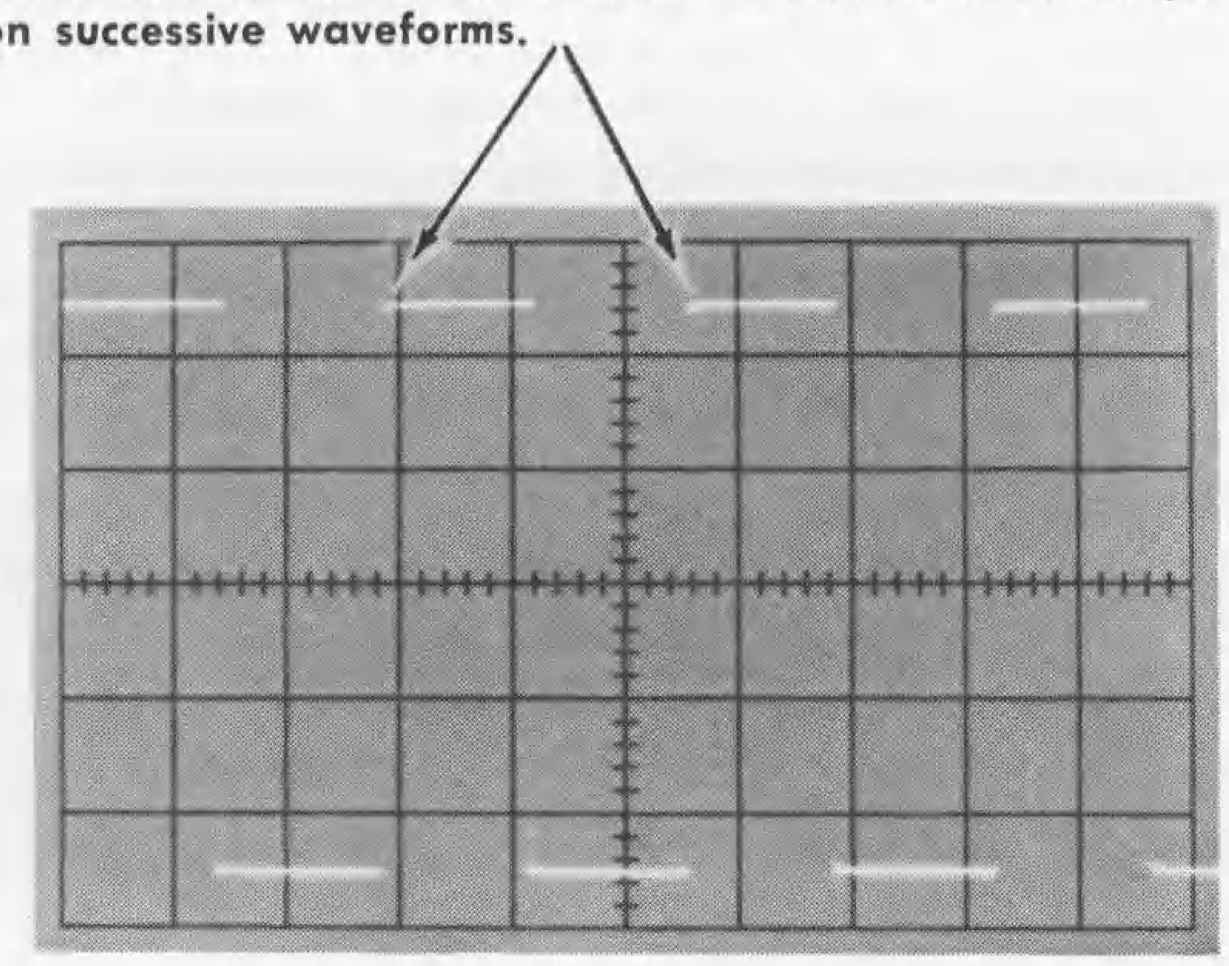


Fig. 2-6. Determining frequency.

16. Calculate the square-wave frequency by determining the reciprocal of the period. (Approximately 800 Hz).

17. Switch the TIME/DIV control to 2 ms. Observe that approximately 1 1/2 square waves per division are now being displayed. Calculate period (approximately 1.25 ms) and frequency (approximately 800 Hz).

18. Using the Horizontal POSITION control, set the left edge of the display to graticule center. Pull out the X5 HORIZ MAG. Observe that the start of the display remains near graticule center, but that now the display is only one square wave cycle per 3.2 divisions. Calculating the period and frequency, you will find it to still be about 1.25 ms and 800 Hz respectively.

19. Slowly rotate the Horizontal POSITION control. Note that any 20 per cent of the unmagnified display from step 17 can be selected in this way for viewing as a magnified display.

20. Rotate the VARIABLE (TIME/DIV) slowly counterclockwise. Note that the resultant decrease in sweep speed causes more square wave cycles to appear in the display. With VARIABLE fully ccw, approximately 8 square wave cycles appear. Return the VARIABLE control to CAL and the X5 HORIZ MAG to in.

Operating the Trigger Controls

21. Note that the positive portion of the square wave is being displayed at the beginning of the trace. Switch the TRIGGER control to −AUTO and observe that the negative portion of the square wave is being displayed at the beginning of the trace. The + or − selection determines whether the horizontal sweep is triggered by a positive-going (+) or a negative-going (−) signal. In the absence of a signal, AUTO provides a free-running time base of relatively constant brightness, regardless of the sweep rate.

22. Push in the X5 VERT GAIN control and set the VOLTS/DIV knob to .05. Connect the P6049 Probe to the VERT INPUT connector. Then connect the probe tip and ground lead across the output of a low-frequency sine wave generator. Set the generator for a 2-V peak-to-peak, 60 Hz output. Observe a sine wave which is 4 divisions peak-to-peak. Note that the beginning of the waveform has a negative (falling) slope. See Fig. 2-7(A).

23. Rotate the TRIGGER control slowly counterclockwise from the −AUTO position. Note that as the control is turned from the AUTO position, the trace disappears. As the control is moved further counterclockwise, a point is reached where the sweep is again triggered by the negative

change in signal level. Continue the counterclockwise movement of the TRIGGER control and note that triggering occurs at progressively more positive points of the waveform. See Fig. 2-7(B). Continue the rotation through the control center position. The trace will disappear or become unstable, then reappear, being triggered by the positive change in signal level. See Fig. 2-7(C). Leave it in this position. Either AUTO or manual trigger selection may be used in normal operation, as determined by the application and the operator's preference. It is suggested that AUTO be used in most applications, switching to manual when necessary to improve stability, increase the low-frequency triggering range, or to change the triggering point.

24. Switch the Trig/Horiz Coupling lever to EXT TRIG OR HORIZ-AC. Note that the trace disappears. At the side panel, connect the 2 volt peak-to-peak sine wave signal to the EXT TRIG OR HORIZ INPUT connector. (Keep the P6049 Probe connected to the 2 volt peak-to-peak sine wave.) Note that a stabilized trace appears. Decrease the generator frequency until the trace disappears and then note the frequency. (The triggering circuit half-power point occurs at approximately 16 Hz during AC-coupled operation.)

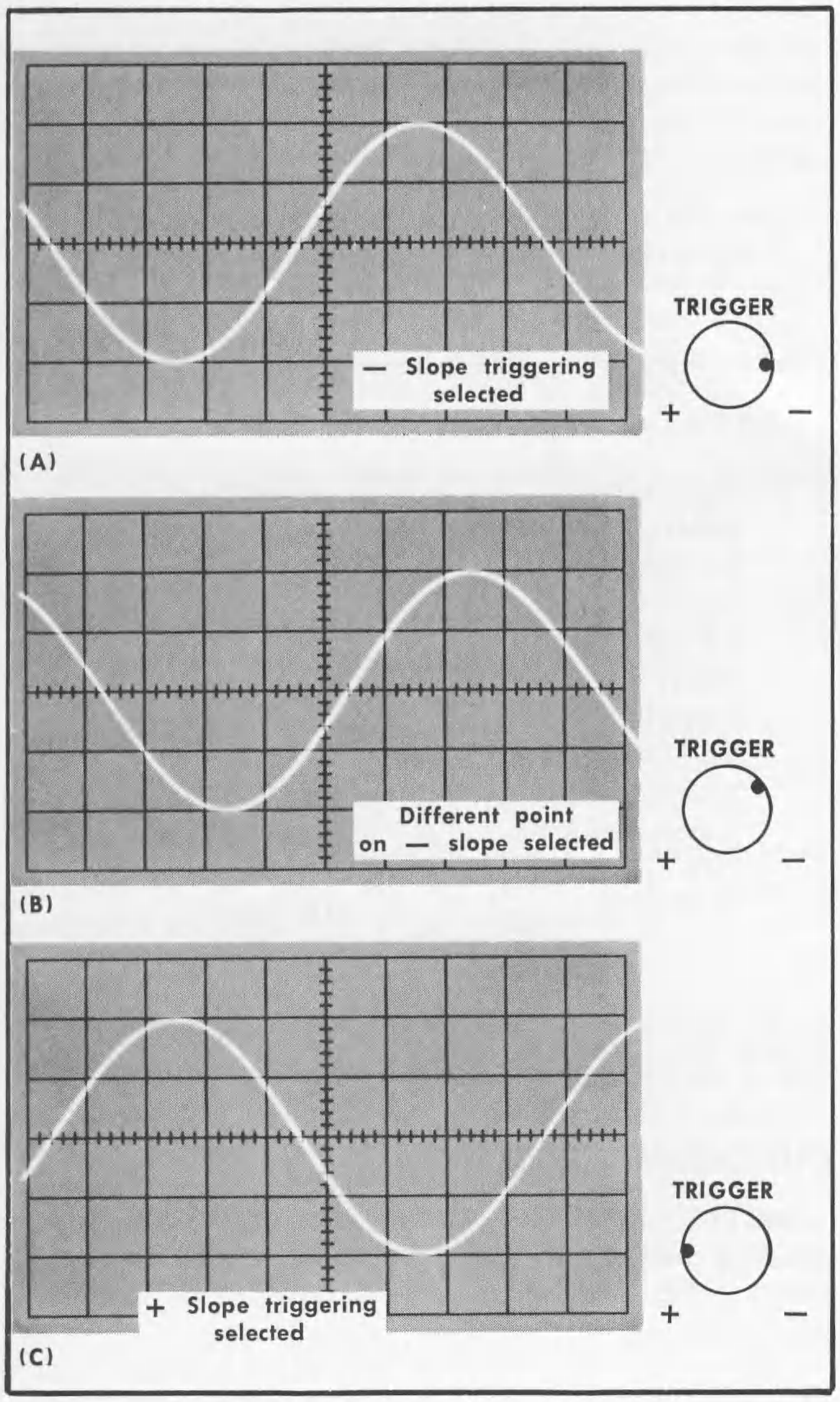


Fig. 2-7. Selection of triggering point.

25. Switch the Trig/Horiz Coupling control to DC, and the TIME/DIV control to 2 mS. Note that the trace reappears. Decrease the signal generator frequency to 2 Hz. Note that a stable trace remains. (Readjust the TRIGGER Level if necessary.) When DC coupling is selected and the TRIGGER control is not at AUTO, a trigger can be generated whenever the EXT TRIG OR HORIZ INPUT voltage passes through the DC value selected by the TRIGGER Level control, even though the transistion is made very slowly. If the signal has a DC bias, the trigger point will be influenced by that bias.

26. Switch the TRIGGER control to +AUTO. Note that the trace becomes unstable. The trigger input becomes AC-coupled whenever the TRIGGER control is at AUTO, regardless of the setting of the Trig/Horiz Coupling lever. The 2 Hz signal frequency is too low to cause AC-coupled triggering to occur. Increase the generator frequency to 60 Hz and note that the display becomes stable, indicating that the sweep is again being triggered by the input signal.

27. Disconnect the signal from the EXT TRIG OR HORIZ INPUT connector. Switch the Trigger Coupling lever to INT TRIG A CLF REJ. Note that the trace is again unstable. Change the generator frequency to 10 kHz and note that the trace stabilizes. A CLF REJ greatly reduces circuit sensitivity to internal trigger signals of approximately 10 kHz and lower, to prevent low-frequency signals from randomly triggering the sweep while high frequency signals are being observed.

XY Operation

NOTE

Whenever the Type 324 Oscilloscope is operated in EXT HORIZ mode, the CRT is unblanked and no internal sweep is available. If no input signal is present at the vertical or horizontal input connector, a bright stationary dot will appear. It is recommended that the brightness be reduced to provide an intensity which is consistent with good viewing. Decreasing beam intensity will also increase battery-operating time.

28. Reconnect the signal generator output to the EXT TRIG OR HORIZ INPUT jack. Switch the TIME/DIV control to EXT HORIZ and the Trig/Horiz Coupling lever to EXT TRIG OR HORIZ-AC. The straight diagonal line rising

as it progresses from left to right is indicative of in-phase conditions existing between the signals at the vertical and horizontal input connectors. The deflection along the vertical and horizontal coordinates is dependent upon the amplitude of the respective input signals and the deflection factors involved.

29. Rotate the EXT HORIZ VAR counterclockwise from CAL and note that as the horizontal gain decreases, the slope becomes greater. Return the EXT HORIZ VAR to CAL.

30. Switch the EXT TRIG OR HORIZ ATTEN to X10. Observe that the horizontal deflection is reduced to 1/10 of its previous amount.

31. Reset controls as follows:

EXT TRIG OR HORIZ	X1 ATTEN
VOLTS/DIV	5 DIV CAL
INPUT	GND
X5 VERT GAIN	In
X5 HORIZ MAG	In
TIME/DIV	.2 ms
TRIGGER	+ AUTO
Trigger Coupling	INT TRIG AC

Adjust the POSITION controls until the square wave again appears on the CRT.

32. Disconnect the cables from the VERT INPUT and EXT TRIG OR HORIZ INPUT connectors.

Power Supply Operation

33. Switch the Power Pack switch to FULL CHG. Note that no change occurs in the presentation.

34. Disconnect the AC source from the oscilloscope. Again note that no change occurs in the presentation.

35. Connect the oscilloscope to an external DC voltage of between 6.5 and 16 V, using two leads equipped with banana plugs. Make the proper polarity connections. Reverse connections will cause Power Regulator protection fuse F501 to blow. Switch the Power Pack switch to EXT DC. Again, note that there is no apparent change.

36. Switch the POWER control off and the Power Pack switch to FULL CHG. Disconnect the oscilloscope from the DC power source and reconnect the AC power input to an appropriate AC voltage supply. Retain this condition for 16 hours to obtain a full battery charge.

After 16 hours, switch the Power Pack switch to TRICKLE CHG to maintain the fully charged battery condition.

OPERATOR'S CHECK AND ADJUSTMENT PROCEDURE

General

The following characteristics of the Type 324 Oscilloscope should be checked prior to each period of operation. Access to screwdriver adjustments is provided through the bottom panel to permit the operator to optimize the instrument's performance. Perform the checks and adjustments in the sequence provided to avoid interaction.

CAUTION

To make adjustments, use a screwdriver with a tip that fits loosely into the screw head slots. Do not apply excessive force.

Preliminary

Set the Type 324 Oscilloscope controls as follows:

VOLTS/DIV	5 DIV CAL
INPUT	GND
X5 VERT GAIN	In
POSITION (Vertical)	Midrange
X5 HORIZ MAG	In
POSITION (Horizontal)	Midrange
TIME/DIV	1 mS
VARIABLE (TIME/DIV)	CAL
TRIGGER	+AUTO
Trigger Coupling	INT TRIG AC
POWER	ON
INTENSITY	Optimum

Set the oscilloscope on its left side to allow access to the bottom adjustments.

CHECKS/ADJUSTMENTS

ASTIG. Adjust the VARIABLE (VOLTS/DIV) to obtain 3 divisions of vertical amplitude. Center the trace as shown in Fig. 2-8.

CHECK—The horizontal and vertical lines of the square wave should both provide optimum sharpness at any setting of the FOCUS control.

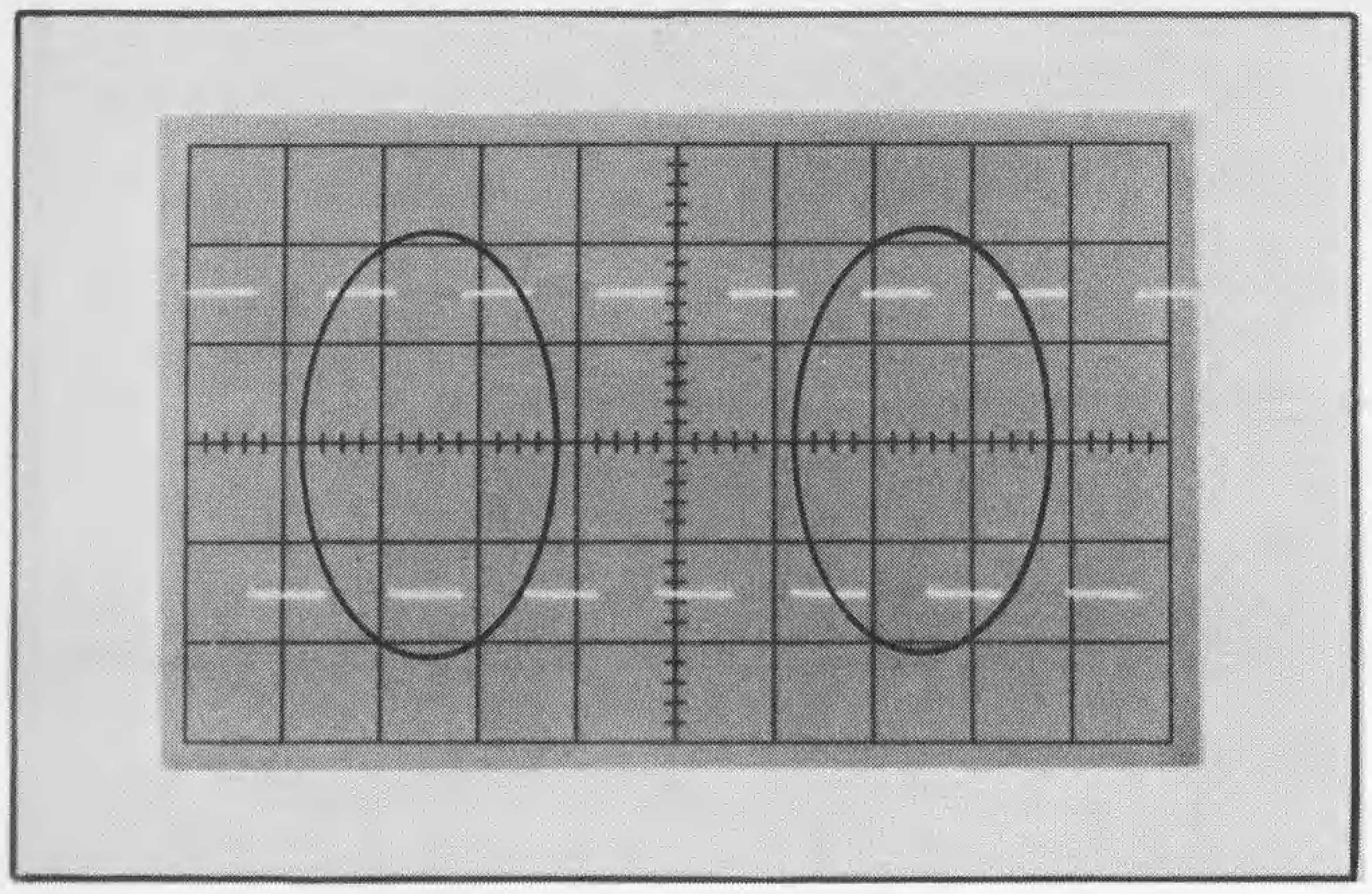


Fig. 2-8. Focus and Astigmatism adjustment waveform.

ADJUST—ASTIG and FOCUS controls until the corners of the square wave display are sharply and clearly defined. Concentrate on sharpening trace definition in the display areas circled in Fig. 2-8 to obtain best overall focusing. Once FOCUS and ASTIG have been set, changes in intensity should only require adjustment of the FOCUS control.

TRACE ROTATION. Set the VOLTS/DIV switch to 20 and position the trace to the graticule center line.

CHECK—The trace should be parallel to the graticule center horizontal line.

ADJUST—TRACE ROTATION as necessary to set the trace parallel to the graticule's center horizontal line.

VERT X5 BAL. CHECK—No vertical position shift of the trace occurs when the X5 VERT GAIN control is switched in and out.

ADJUST—VERT X5 BAL until minimum trace shift occurs when the X5 VERT GAIN control is switched in and out. Return the X5 VERT GAIN control to its in position.

VAR V/DIV BAL. CHECK—No trace shift occurs as the VARIABLE V/DIV BAL control is rotated from limit to limit.

ADJUST—VAR V/DIV BAL control until no trace shift occurs as the VARIABLE (VOLTS/DIV) control is rotated from limit to limit.

Return the VARIABLE (VOLTS/DIV) control to CAL.

Repeat the VERT X5 BAL and the VAR V/DIV BAL adjustments until interaction is no longer noticeable.

VERT X1 GAIN. Switch the VOLTS/DIV control to the 5 DIV CAL position. Using the Vertical POSITION control, center the square wave.

CHECK—The square-wave presentation has 5 divisions ±0.15 division vertical amplitude. The measurement should be made from trace center to trace center to avoid the effect of trace width.

ADJUST—VERT X1 GAIN to provide a 5 division square-wave presentation.

SIGNAL TRANSPORTING METHODS

General

Voltage and waveform observations normally require that the oscilloscope be placed in parallel with the load across which the observation is being made. Numerous methods of connecting signal sources (signal pick-off points) to the oscilloscope are available. The method to be used is basically determined by signal amplitude and/or signal frequency or risetime compared to the combination of signal source impedance and oscilloscope input impedance.

Signal Amplitude

Signals in excess of the display range of the oscilloscope (120 V peak to peak calibrated, 300 V peak to peak uncalibrated) can be reduced to an observable value by means of an attenuator placed in the signal-to-oscilloscope path. The P6049 Probe provided with the Type 324 Oscilloscope makes 1/10 of the source voltage available to the oscilloscope vertical input connector.

The peak-to-peak measurement which can be made with the P6049 Probe-Type 324 Oscilloscope combination is 500 V DC + peak AC. Other Tektronix probes which allow measurement of voltages as high as 40 kV are available for use with the Type 324 Oscilloscope.

CAUTION

Never apply voltage in excess of 500 V to the VERT INPUT connector or to the P6049 Probe. Use a high-voltage probe to reduce higher voltages to an acceptable level.

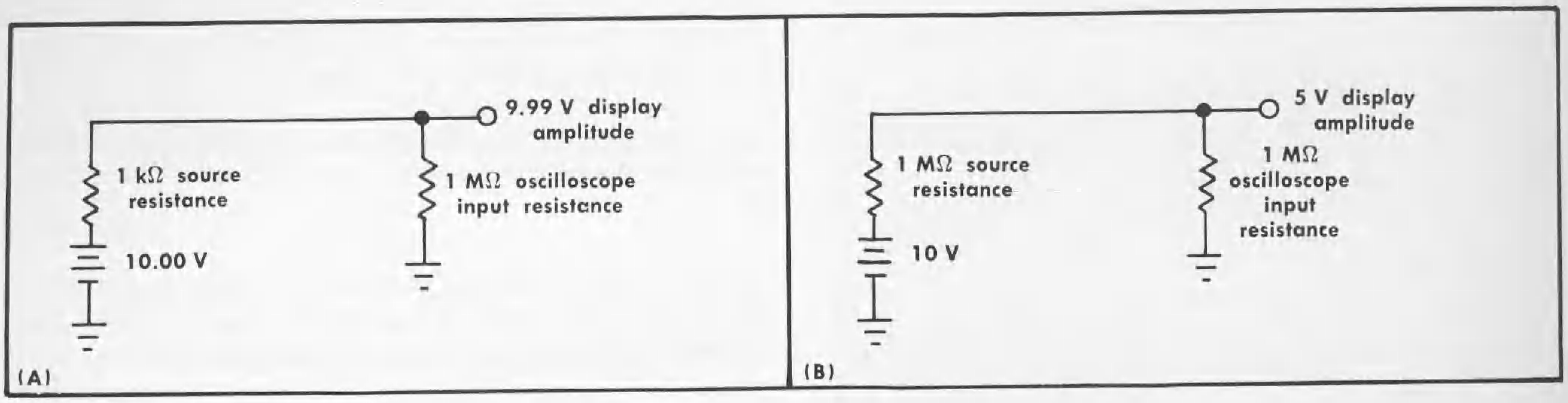


Fig. 2-9. Source resistance versus oscilloscope input resistance.

Signal Source Resistance and Oscilloscope Input Resistance

The oscilloscope input resistance (1 MΩ) and the signal source resistance form a voltage divider. When the input resistance is high with respect to the source resistance, display amplitude for DC and low-frequency AC signals is a relatively accurate evaluation of the signal at the source. See Fig. 2-9(A).

As the size of the oscilloscope input resistance decreases as compared to the signal source resistance, the display amplitude decreases. See Fig. 2-9(B). In addition to providing an incorrect display, such a situation loads a circuit to the point where an evaluation is being made of a false circuit performance.

The source-to-oscilloscope resistance ratio must be kept high. The 1 MΩ oscilloscope resistance is sufficient for most applications. However, when the signal source impedance is as high as 0.11 MΩ, approximately 10% error is introduced. This error can be computed in DC and low-frequency applications, and the display evaluation can be corrected accordingly.

An easier method is to use a X10 probe and a 10 times more sensitive volts/div setting. The P6049 Probe and Type 324 Oscilloscope combination have a resistance of approximately 10 MΩ. When used to evaluate the above-mentioned 0.11 MΩ circuit, the ratio of oscilloscope resistance to signal source resistance is increased to approximately 91:1 and display amplitude error is reduced to approximately 1%. Another important consideration is that the loading effect on the circuit becomes negligible and circuit performance is not affected.

Signal Frequency Versus Signal Source Capacitance and Oscilloscope Input Capacitance

The 47 pF oscilloscope input capacitance is of little concern when measuring DC or low-frequency signals. However, as frequency increases, the oscilloscope input capacitance in parallel with the signal source lowers the effective load impedance. Parallel capacitance inserted by signal transporting leads adds to the oscilloscope input capacitance and further lowers effective load impedance, decreasing AC and transient waveform display amplitudes. Signal transporting lead capacitance must therefore be kept as low as possible for AC or transient measurements.

When the signal source capacitance is high with respect to the oscilloscope input capacitance, AC display amplitudes are relatively accurate. The signal source capacitance to oscilloscope capacitance ratio can be improved by insertion of an attenuator probe in the signal path. Its effect upon AC and transients will be essentially the same as was its effect upon DC, both in increasing the effective range of the oscilloscope and in reducing loading effects.

Circuit current can be monitored with the Type 324 Oscilloscope and a current probe. One type of probe uses a device which can be clamped around or removed from the current-carrying wire in a few seconds. It is especially useful in working with current-driven transistor circuitry.

A summary of signal transporting information is provided in Table 2-1. Additional information concerning all Tektronix probes is contained in the Tektronix catalog.

PROBE ADJUSTMENT

Variations of total input capacitance and resistance occur with different combinations of oscilloscopes and probes. Therefore, many attenuator probes are equipped with adjustments to insure optimum performance. Explanations for performing Tektronix Probe adjustments are contained in the applicable probe manuals.

Because the P6049 Probe is a standard accessory for the Type 324 Oscilloscope, that particular adjustment procedure is repeated here.

P6049 Probe Adjustment Procedure:

(a) Preset the Type 324 Oscilloscope controls as follows:

TABLE 2-1

Signal Transporting Methods, Passive

Method	Advantages	Limitations	Equipment Required	Source Loading	Precautions
Unshielded Test Leads	Availability	Limited frequency response; subject to stray pickup and oscillation	BNC-to-Binding Post Adapter; two test leads	Oscilloscope input impedance	Insert 47 Ω resistor in series with signal lead to suppress oscillations. Place leads strategically to reduce shunt capacitance and stray pickup
Unterminated coaxial cable or 1× probe	Convenience	Limited frequency response; high capacitance of cable	Coaxial cable with BNC connectors; or 1× probe	Oscilloscope input impedance plus cable capacitance	High capacitive loading
Coaxial cable terminated in characteristic impedance at oscilloscope	Full oscilloscope bandwidth. Provides uniform response while using long cables	Loading effect due to termination (typically 50 Ω); power limit of termination	Coaxial cable with BNC connectors and BNC termination (typically 50 Ω)	Termination value (Typically 50 Ω) in parallel with oscilloscope input impedance	Loading on test point; power limit of termination; Use DC-blocking capacitor between source and termination; reflections from oscilloscope input impedance
Terminated coaxial cable with coaxial attenuator between source and termination	Less reflection from oscilloscope input impedance; increased voltage range	Reduces oscilloscope sensitivity	Coaxial cable with BNC connectors; BNC coaxial attenuator; BNC termination	Termination value (typically 50 Ω) in parallel with oscilloscope input impedance	Loading on test point; power limit of attenuator and termination; use DC-blocking capacitor between source and termination
Tap into terminated coaxial system with a BNC T at oscilloscope input	Optimum signal transfer; no termination required at oscilloscope		BNC T; 2 signal cables with BNC connectors	Oscilloscope input impedance	Signal size may require use of attenuators
Attenuator probes	Reduces oscilloscope loading; increases voltage range; protects oscilloscope	Oscilloscope sensitivity reduced by attenuation factor	10×, 100× or 1000× probe	10× ≈ 10 MΩ and 10 pF 100× ≈ 10 MΩ and 2.5 pF 1000× ≈ 100 MΩ and 3 pF	
Current probe	Permits current evaluation without interrupting circuit		Current Probe; Amplifier (optional) increases range	R <0.03 Ω L <3 μH	

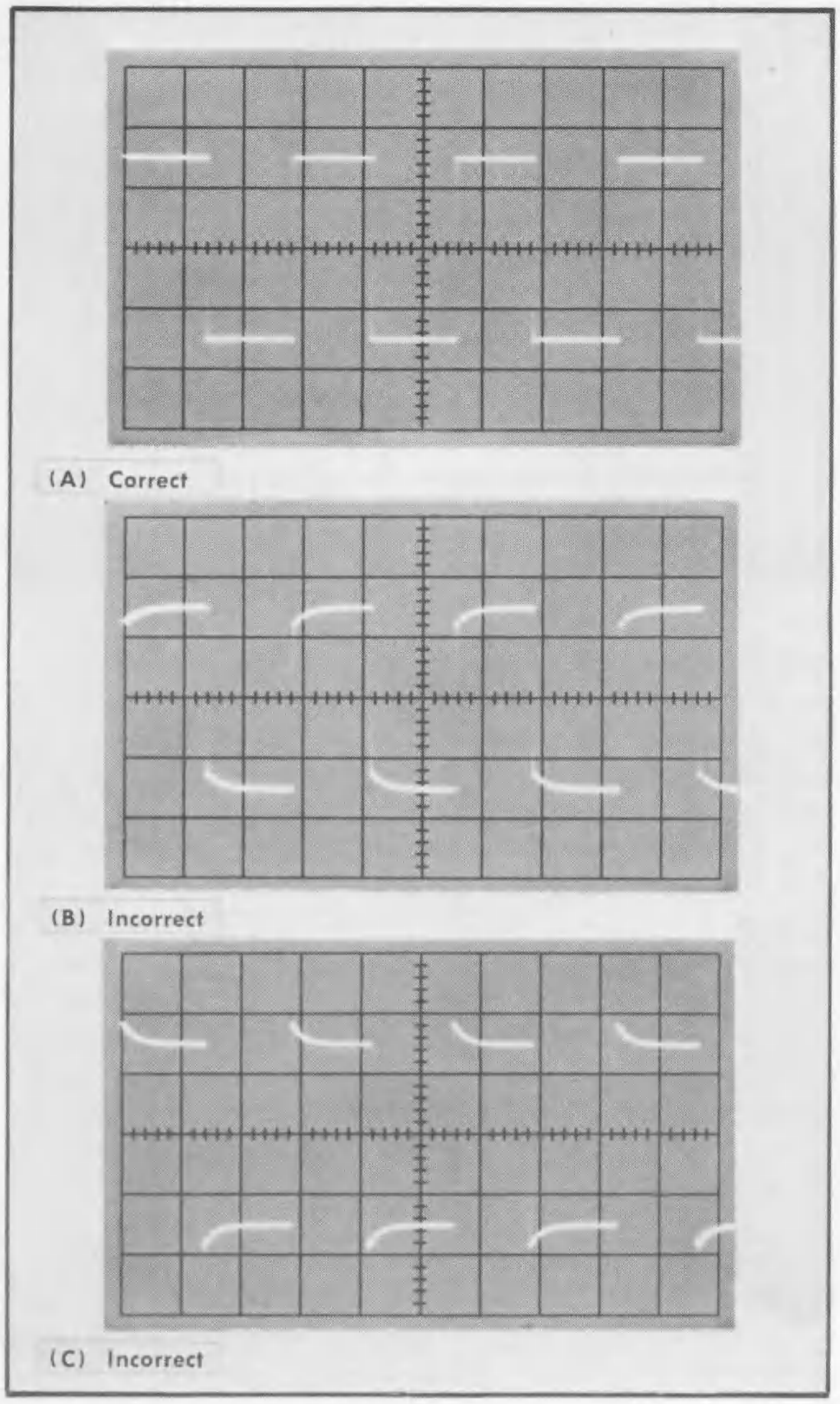


Fig. 2-10. Probe compensation.

INPUT	DC
VOLTS/DIV	.01
VARIABLE (VOLTS/DIV)	Adjust for 3 divisions of signal amplitude
TIME/DIV	.5 ms
X5 VERT GAIN	In
X5 HORIZ MAG	In
TRIGGER	+AUTO
Trig/Horiz Coupling	INT TRIG-AC

(b) Connect the P6049 Probe BNC connector to the VERT INPUT connector.

(c) Connect the P6049 Probe tip to the .5 V CAL OUT jack (left side of oscilloscope).

(d) Check the waveform presentation against Fig. 2-10(A). Waveform presentations resulting from incorrect adjustments are shown in Fig. 2-10(B) and (C).

(e) The probe adjustment is contained in the compensation housing which connects the oscilloscope INPUT connector.

Using a screwdriver, adjust it as necessary to obtain optimum square leading corners on the square wave presentation. Rounding or overshoot should be minimized.

MISCELLANEOUS OPERATING HINTS

WARNING

Failure to complete the ground circuit of the Type 324 will cause the entire unit to be elevated to the voltage of the applied signal, and may produce dangerous voltage levels on the instrument case.

Reference or ground lead. Reliable signal observations cannot be made unless both the oscilloscope and the unit under test are connected by a reference (ground) lead in addition to the signal lead. See Fig. 2-11. Most AC-operated equipment has a common ground supplied by the AC power source circuitry. This is true of the Type 324 Oscilloscope whenever the 3-wire AC line cord is connected to the oscilloscope and a grounded AC source. During internal battery or external DC operation, a reference (ground) lead must be externally connected between the oscilloscope and the equipment under test.

Ringing. It is not uncommon to have ringing accompany a waveform presentation. It usually results from inductance associated with the reference or signal leads. If the AC supply common (ground) is used as the reference lead, the length of wire involved introduces considerable inductance. To reduce inductance and the resultant ringing, use the shortest possible probe ground lead and connect it to a ground point as near the signal source as possible. See Fig. 2-12. If ringing persists, connect the oscilloscope ground jack to the equipment under test, using the shortest possible lead. Then disconnect the external power leads and operate the oscilloscope on its internal battery power.

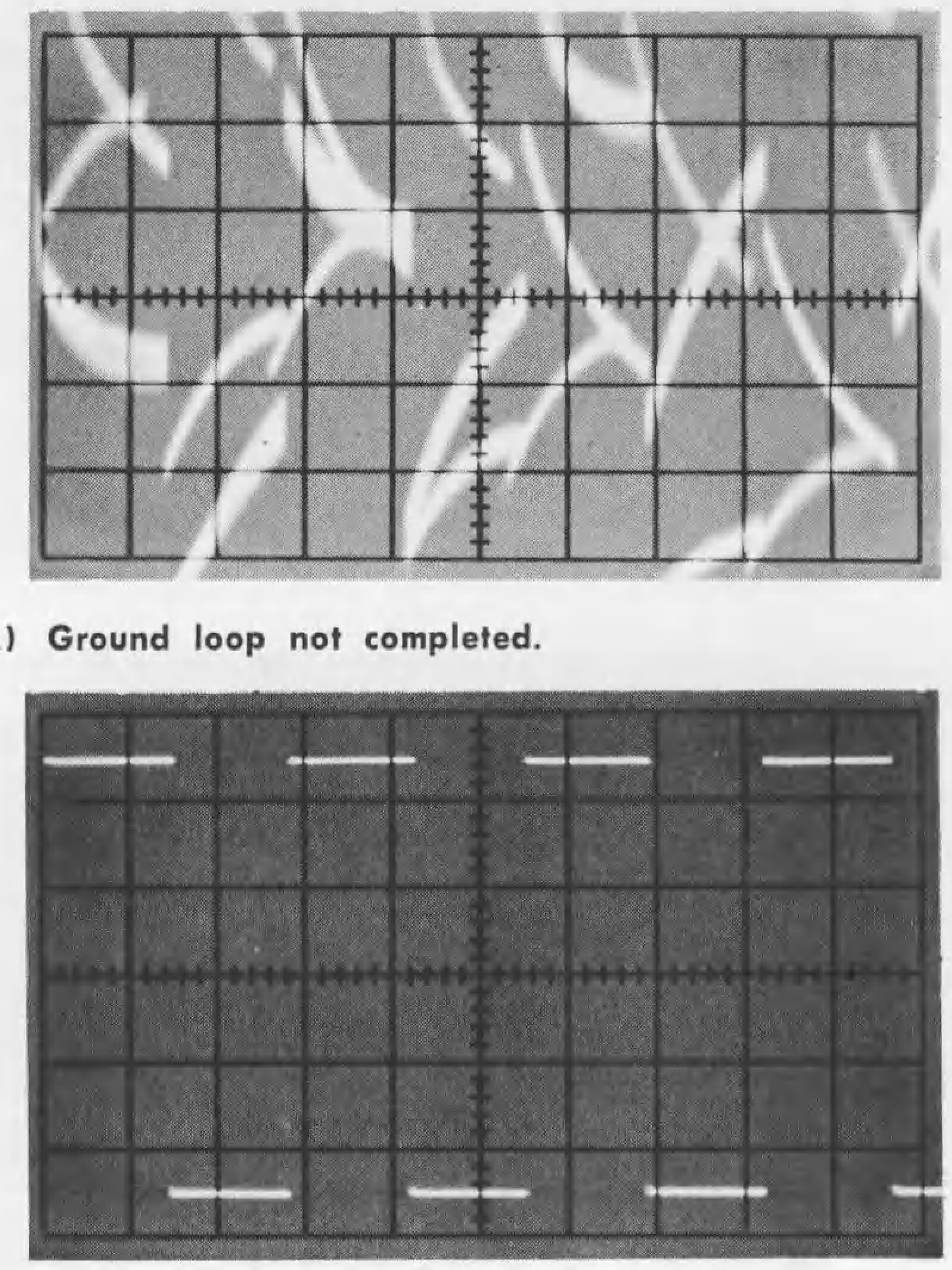
Loading. Use a 10X probe whenever possible. It provides more accurate waveform observation by reducing the loading effect on the signal source. Deflection factors indicated by the VOLTS/DIV switch must be multiplied by 10 when a 10X probe is in use.

Phase and Polarity Relationships. When internal triggering is used, the signal slope displayed at the beginning of the sweep is dependent upon the trigger slope selected by the operator. If a comparison of phase or polarity is required, use external triggering and the same trigger source for the entire sequence of phase or polarity comparisons. The examples in Fig. 2-13(B) use + internal triggering and show the positive spike coincident with the rising portion of the square wave. The examples given in Fig. 2-13(A) both use the same + external trigger source and show that the square wave actually goes negative at the time the positive spike occurs.

External triggering is extremely useful in measuring phase difference between signals. The circuit in Fig. 2-14(A) is used to demonstrate this feature.

Connect the reference waveform to the external triggering and the vertical input connectors. Select negative slope external triggering and adjust the triggering and horizontal controls so that one cycle of the reference signal covers 9 divisions of horizontal trace, passing through 0° at the intersection of the graticule center lines as in Fig. 2-14(B). This causes each division of horizontal base line to display 40° of the waveform being applied.

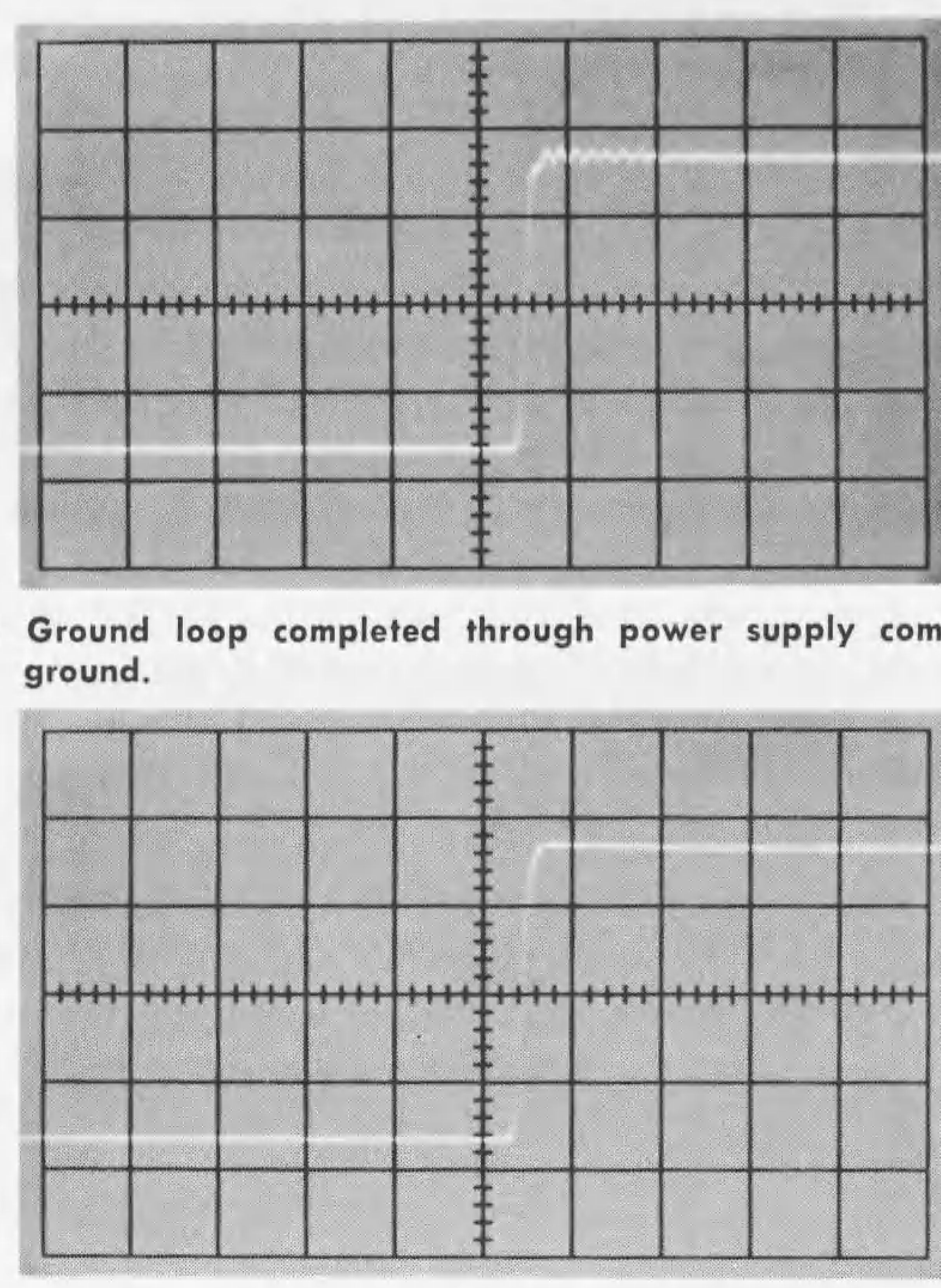
Disconnect the reference waveform from the vertical input. Connect the shifted waveform to the vertical input connector and measure the amount of separation between the graticule center vertical line and the waveform 0° point as in Fig. 2-14(C). Convert the amount of separation to degrees, using the 40°/div value which was established previously. If the 0° point has moved to the left, the waveform leads the reference. If it has moved to the right, the waveform lags the reference.



(A) Ground loop not completed.

(B) Ground loop completed.

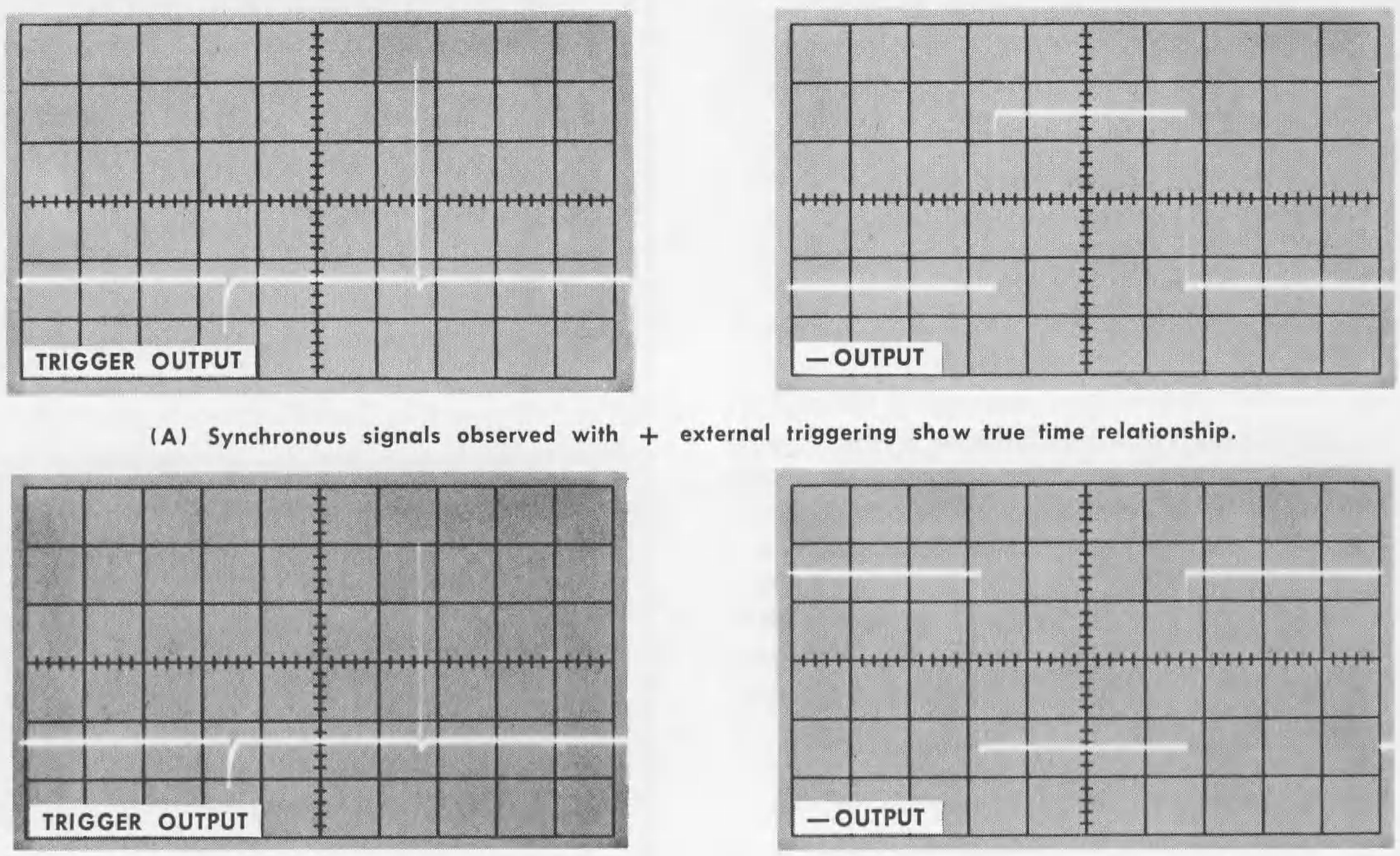
Fig. 2-11. Ground loop effect.



(A) Ground loop completed through power supply common ground.

(B) Probe ground lead connected to equipment ground.

Fig. 2-12. Reducing ringing caused by ground loop.



(A) Synchronous signals observed with + external triggering show true time relationship.

(B) Synchronous signals observed with + internal triggering show incorrect time relationship.

Fig. 2-13. Importance of external triggering for phase or polarity comparison. (Signals supplied by Tektronix Type 106 Square-Wave Generator.)

Leading and Trailing Edges of Waveforms. The sweep in the Type 324 Oscilloscope is normally triggered by either the rising (+) slope or the falling (–) slope of the applied signal. Thus, each sweep starts at a specific point on the waveform. If the beginning of the + or – slope is used to trigger the sweep, the slightest delay before the sweep begins will prevent the triggering point from being seen. If the sweep rate selected is slow enough, the next pulse or cycle will be displayed before the sweep ends. However, if the pulse frequency is quite low, the sweep will not "stretch out" the area of interest enough to get a good look at it. Three methods are suggested to improve viewing of the beginning of a + or – slope.

(a) If the viewed signal is dependent upon another signal which occurs earlier, use the earlier signal to externally trigger the sweep. Use the horizontal sweep rate, position and magnifier controls as necessary to view the slope.

(b) Use the opposite slope to trigger the sweep; select the sweep rate which displays the point to be observed as near the right of the sweep as possible (use the Horizontal VARIABLE control if calibrated measurement is not required). Using the Horizontal POSITION control, set the point of interest to the center of the graticule; then expand the sweep, using the X5 HORIZ MAG control.

(c) Select a sweep rate which causes the trigger point to be repeated once near the right side of the sweep; using the horizontal position controls, set the repeated trigger point to the center of the graticule. Using the horizontal magnifier, expand the sweep.

Amplitude Measurements. The Type 324 Oscilloscope can measure AC and DC signal amplitudes simultaneously or separately. However, best results will generally be ob-

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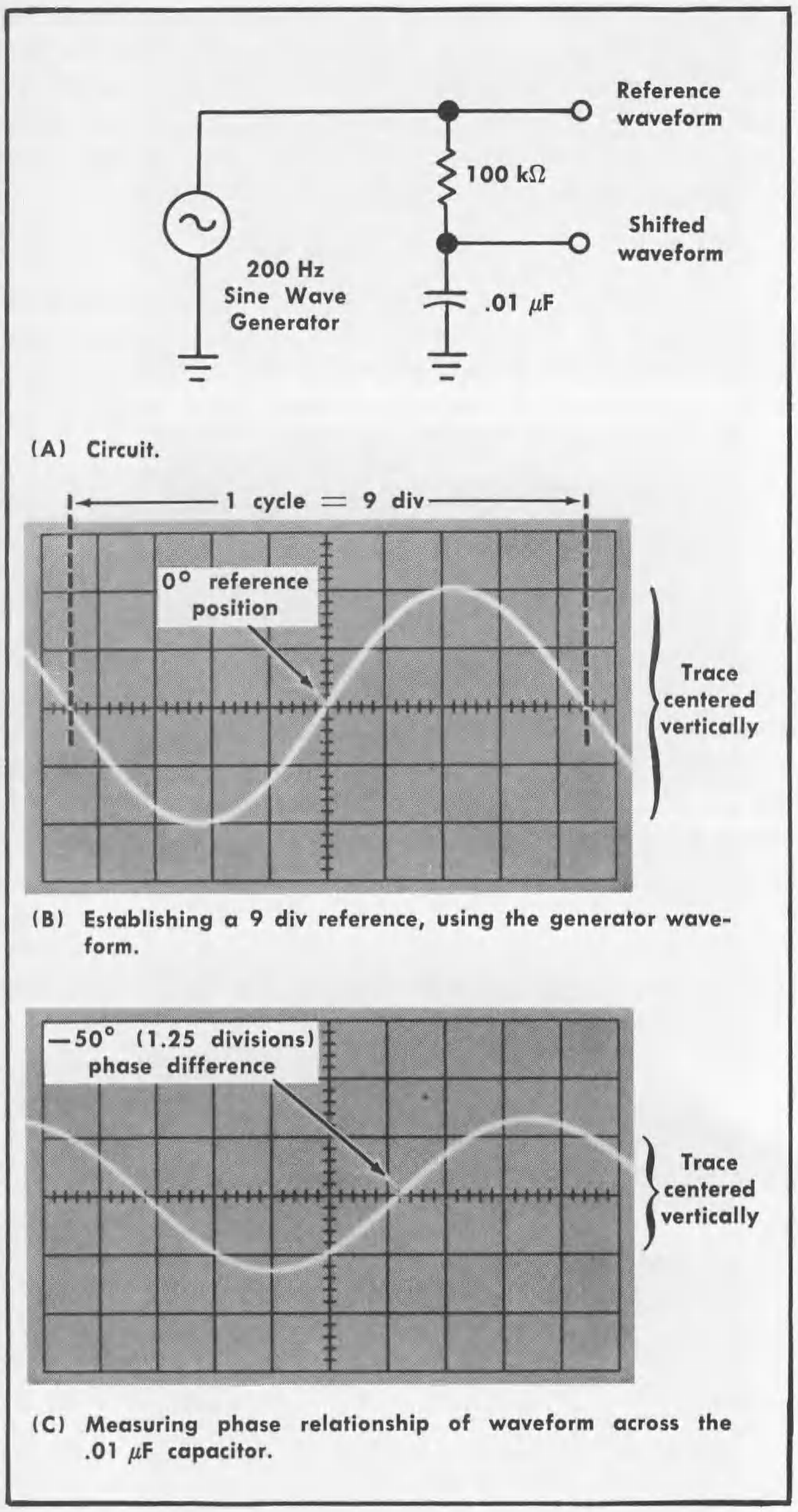


(A) Circuit.

(B) Establishing a 9 div reference, using the generator waveform.

(C) Measuring phase relationship of waveform across the .01 μF capacitor.

Fig. 2-14. Measuring phase relationships.

tained if they are measured separately, allowing selection of the best deflection factor for the component being measured. Example: Measuring the AC and DC components of a 0.02 V ripple riding on a 75 V power supply output. Establish a DC reference. Using DC coupling and a deflection factor of 20 V/division, the DC component causes 3.75 divisions of trace displacement, but the 0.02 V ripple component amounts to 1/1000 of a division and is not discernible. AC coupling and a deflection factor of 0.01 V/division displays two divisions of AC ripple without interference from the DC component.

Time Measurements. Although relatively accurate measurements are provided across the entire 10 horizontal divisions of CRT, critical waveform time measurements should be made in the center 8 divisions.

Frequency Measurements. To determine the frequency of a recurring event, find the reciprocal of the time (in seconds) it takes to complete one event. Example: With a sweep rate of 10 ms/div, a sine wave completes one cycle in 2.5 divisions (25 ms) of travel across the face of the CRT. $1/(25 \times 10^{-3})$ results in a frequency of 40 cycles per second, normally expressed as 40 Hertz (abbreviated Hz).

Comparison Measurements. In some applications it may be desirable to establish arbitrary units of measurement other than those indicated by the VOLTS/DIV switch or TIME/DIV switch. This is particularly useful when comparing unknown signals to a reference amplitude or repetition rate. One use for the comparison-measurement technique is to facilitate calibration of equipment (e.g., on an assembly line test) where the desired amplitude or repetition rate does not produce an exact number of divisions of deflection. The adjustment will be easier and more accurate if arbitrary units of measurement are established so that correct adjustment is indicated by an exact number of divisions of deflection. Arbitrary sweep rates can be useful for comparing harmonic signals to a fundamental frequency, or for comparing the repetition rate of the input and output pulses in a digital count-down circuit. The following procedure describes how to establish arbitrary units of measure for comparison measurements. 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 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 (division) 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 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 adjusted for 4 divisions of vertical deflection.

Substituting these values in the vertical conversion factor formula (step 4):

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

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 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 period of an unknown signal can be measured accurately at any setting of the TIME/DIV switch, the period 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 period 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

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

5. To measure the period of an unknown signal, disconnect the reference signal and connect the unknown signal to the 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 period of the unknown signal using the following formula:

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

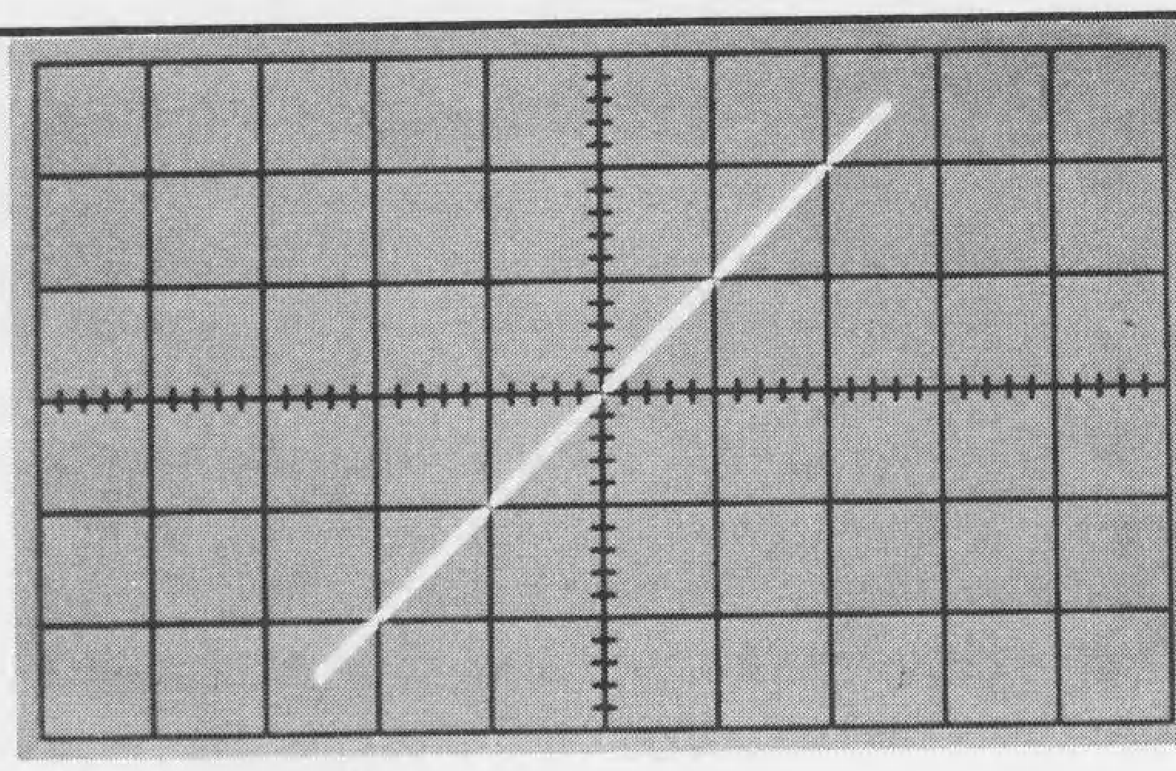
NOTE

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

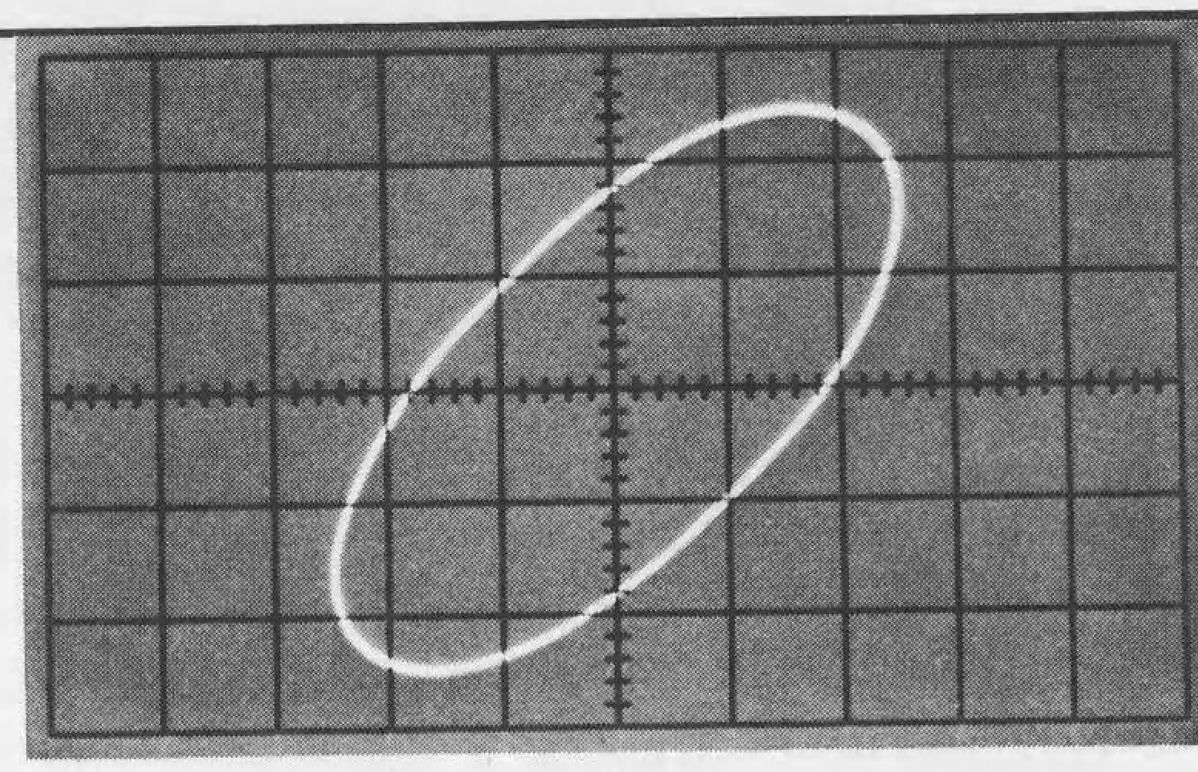
EXAMPLE. Assume a reference signal frequency of 455 (hertz period 2.19 milliseconds) and a TIME/DIV switch setting of 2 ms, with the VARIABLE TIME/DIV control adjusted to provide a horizontal deflection of eight divisions. Substituting these values in the horizontal conversion factor formula (step 4):

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

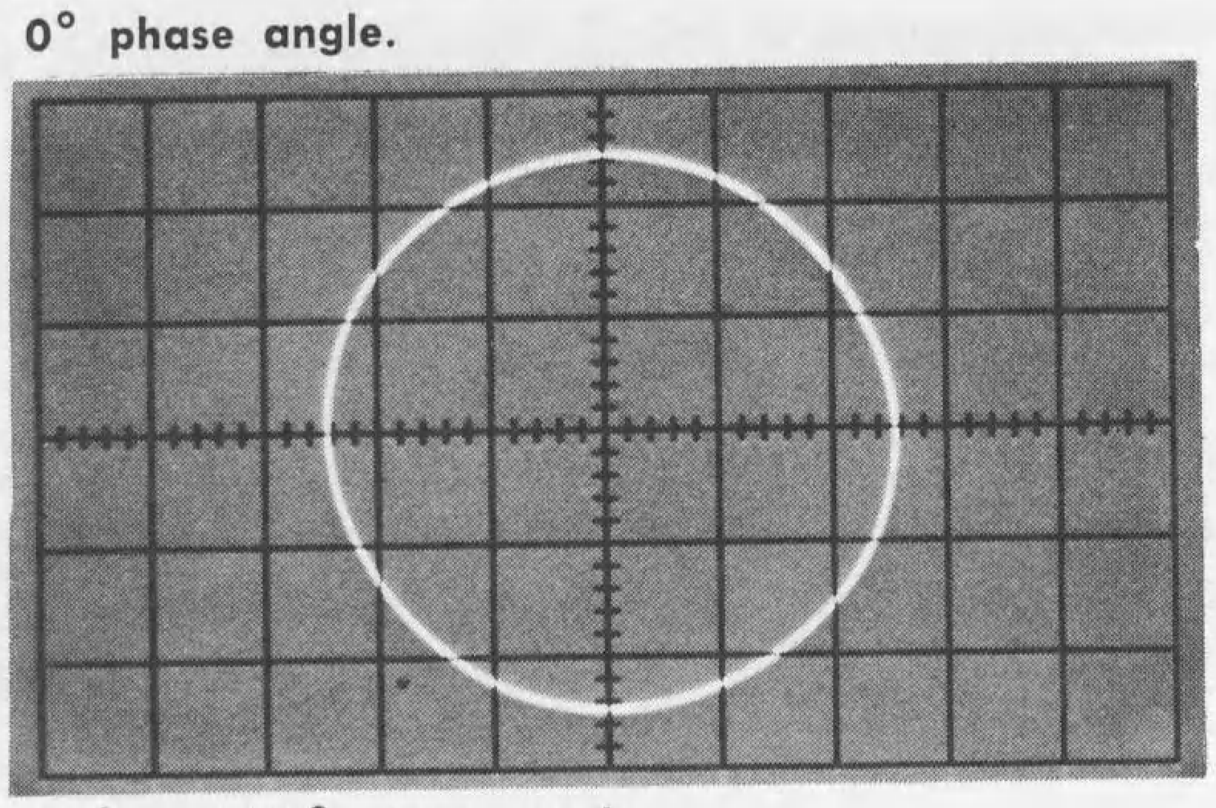
Then, with a TIME/DIV switch setting of 50 µs the repetition rate of an unknown signal which completes one cycle in seven horizontal divisions can be determined by using the period formula (step 6):



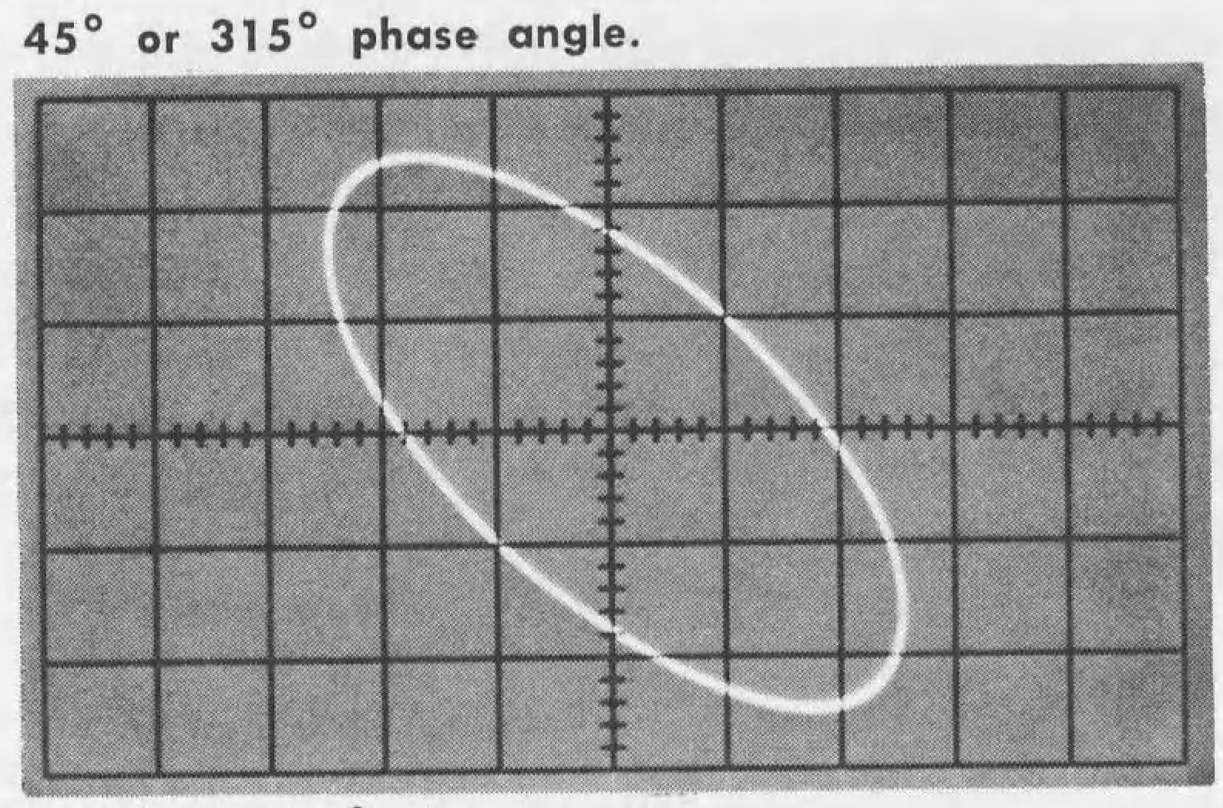
(A) 0° phase angle.



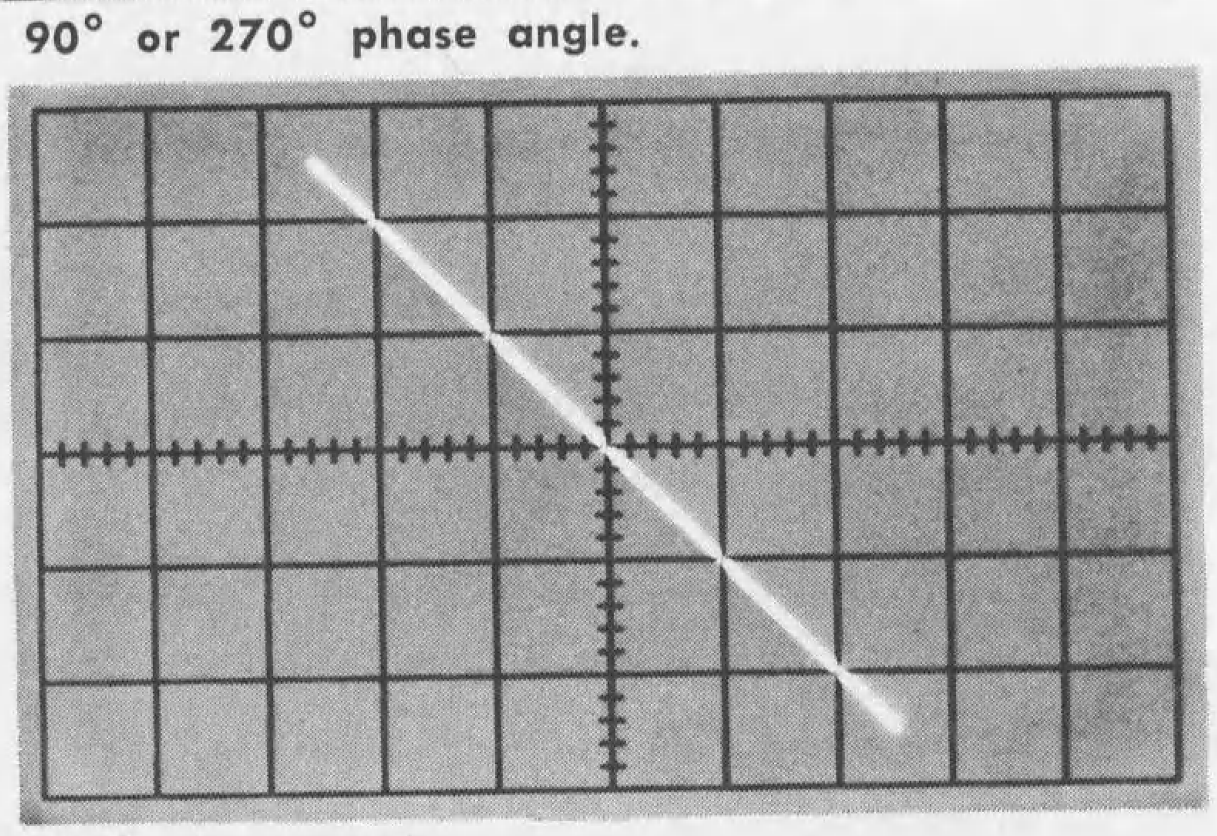
(B) 45° or 315° phase angle.



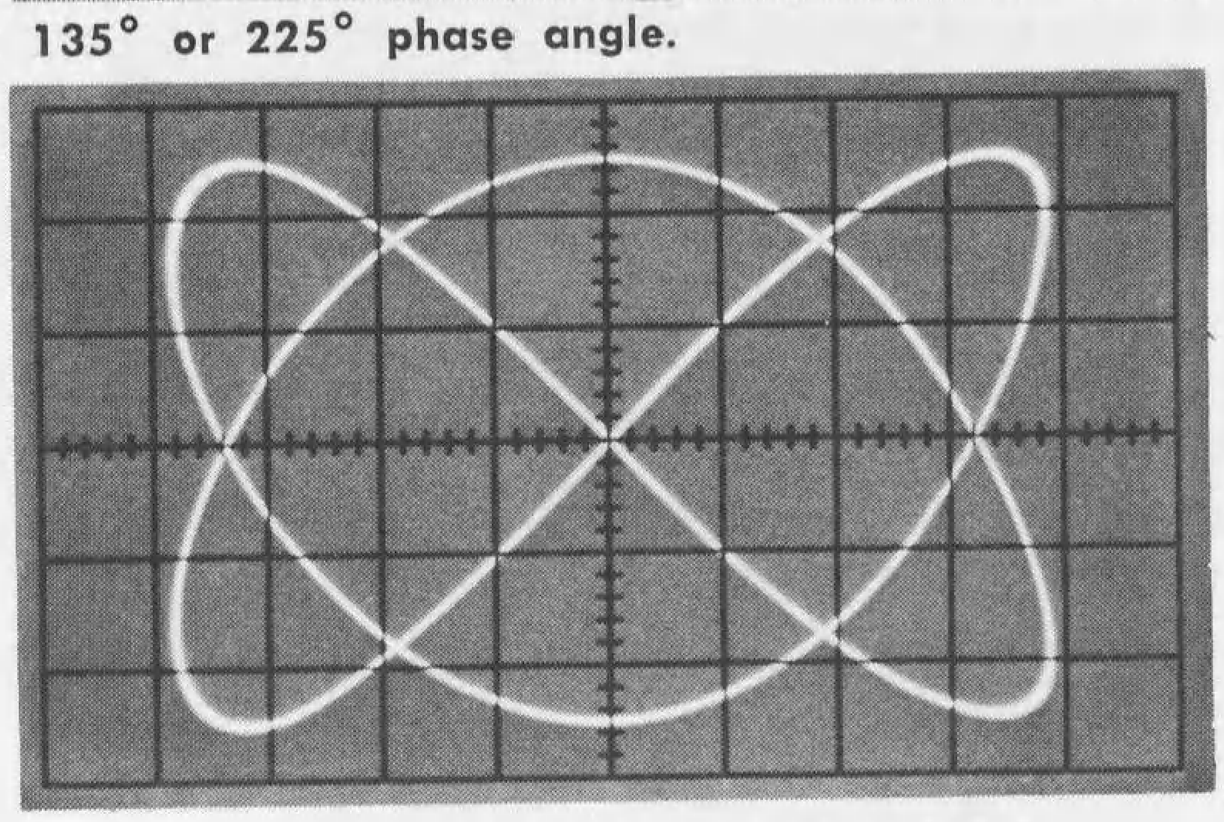
(C) 90° or 270° phase angle.



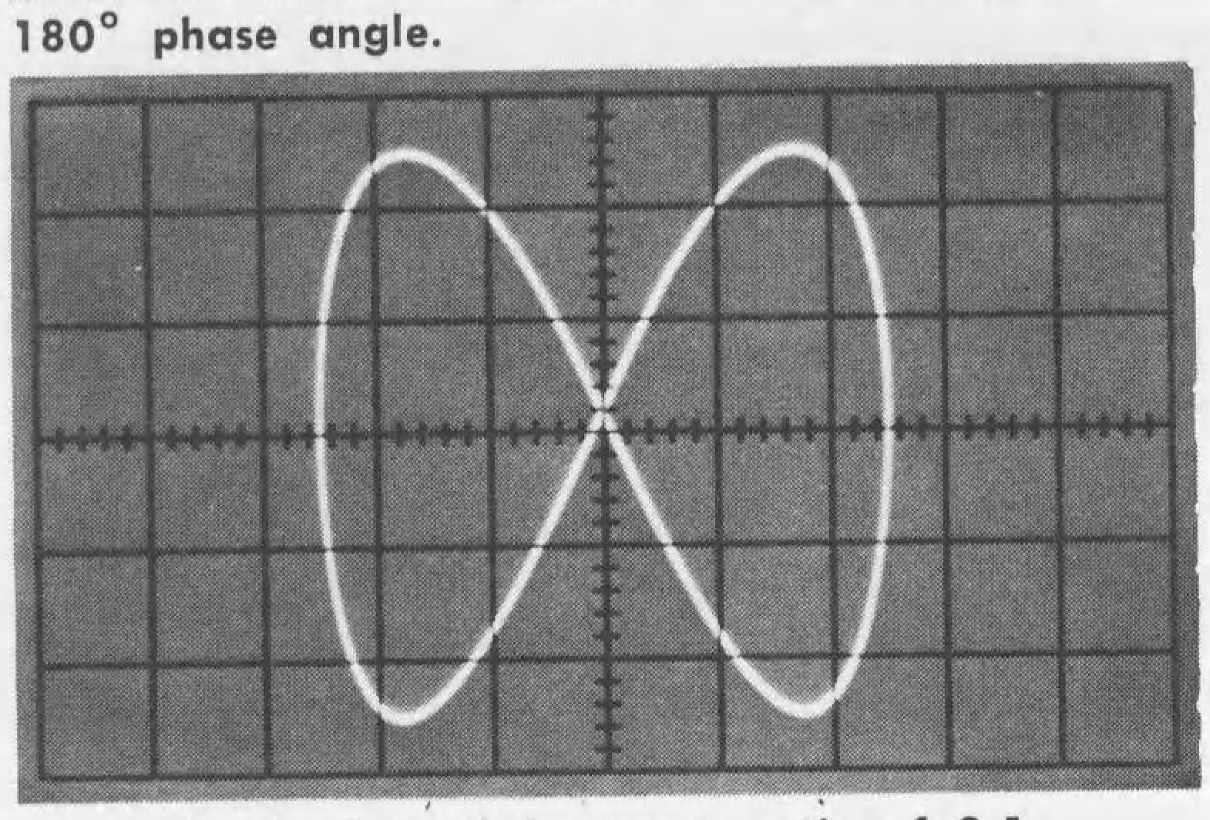
(D) 135° or 225° phase angle.



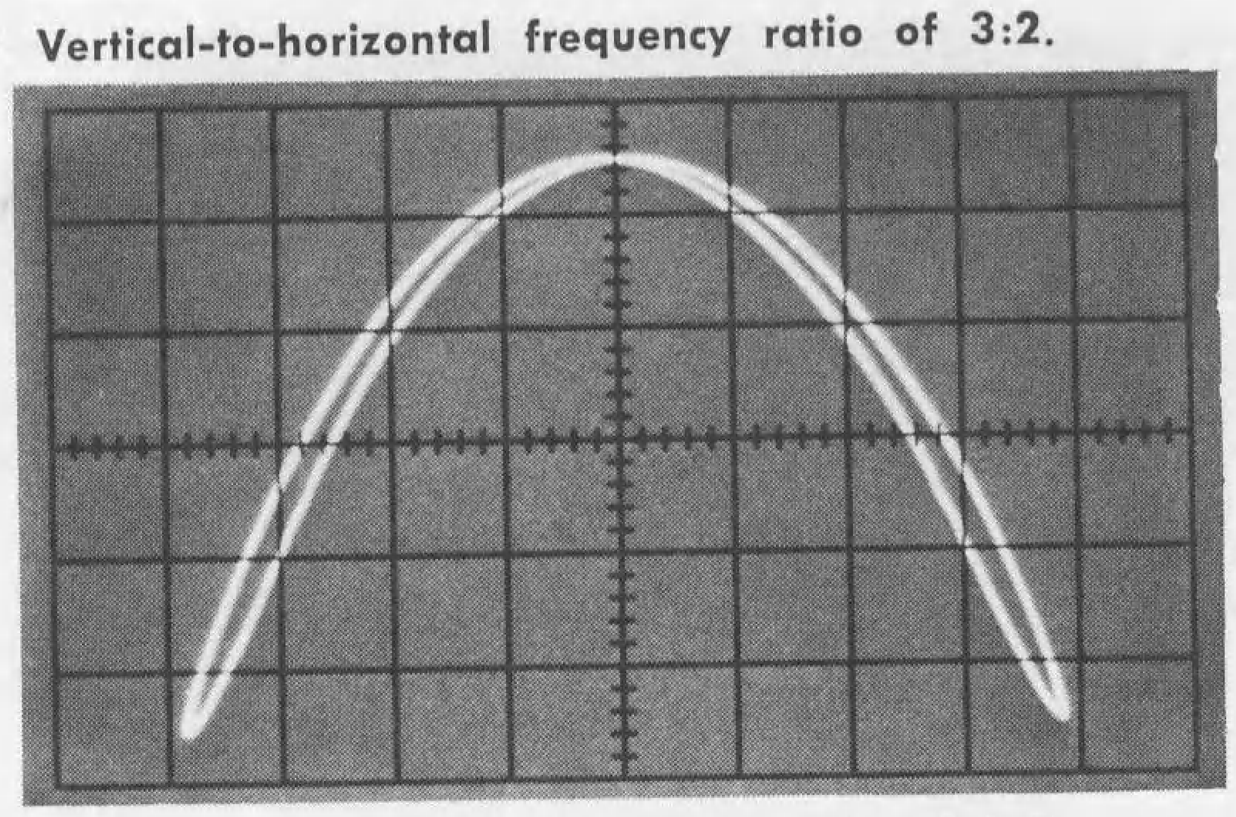
(E) 180° phase angle.



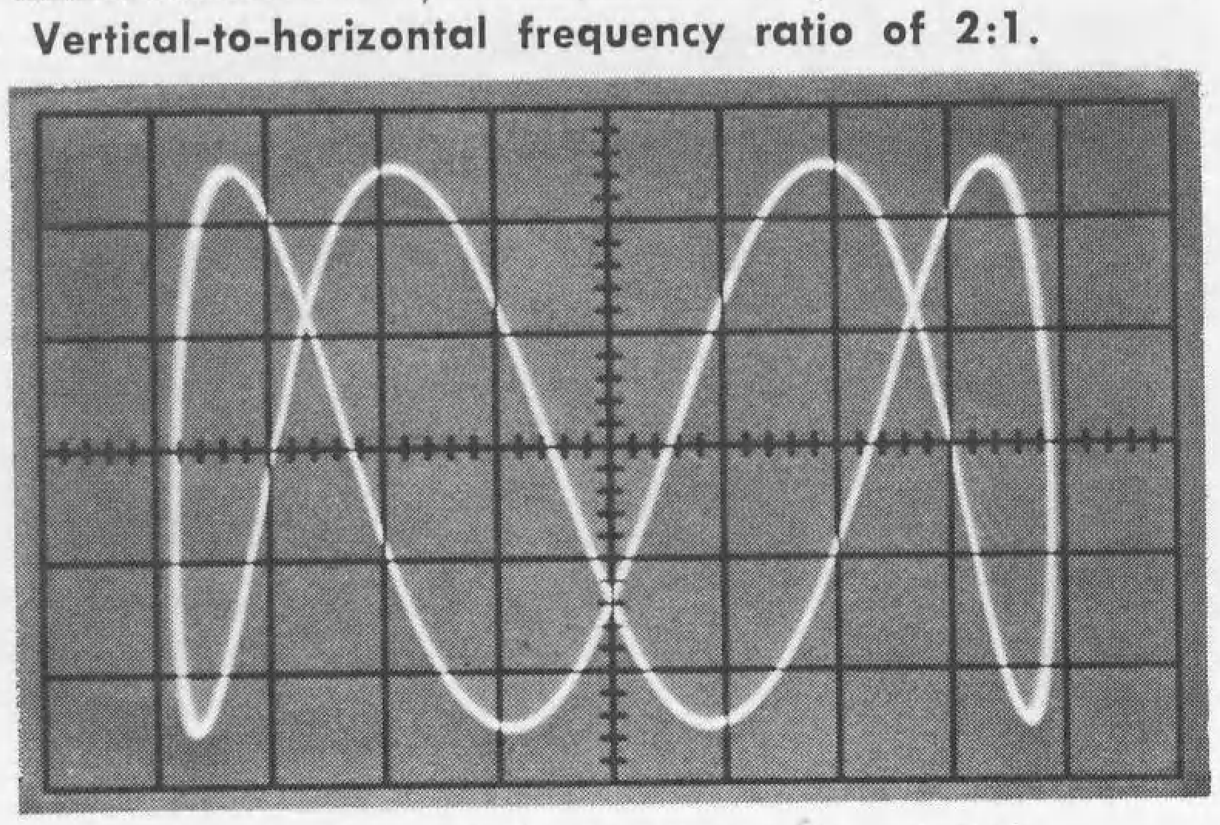
(F) Vertical-to-horizontal frequency ratio of 3:2.



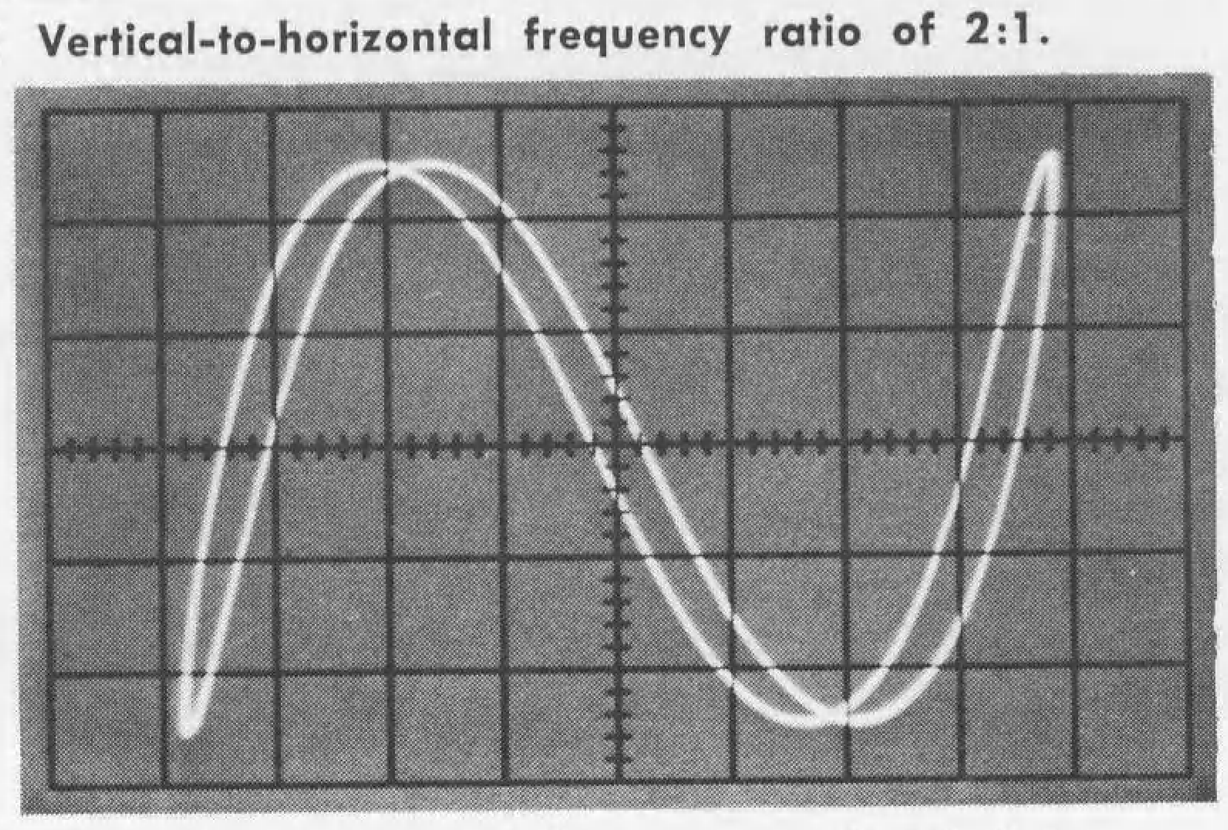
(G) Vertical-to-horizontal frequency ratio of 2:1.



(H) Vertical-to-horizontal frequency ratio of 2:1.



(I) Vertical-to-horizontal frequency ratio of 4:1.



(J) Vertical-to-horizontal frequency ratio of 3:1.

Fig. 2-15. Lissajous figures: (A) through (E) X and Y inputs having same frequency but different phase angles; (F) through (J) X and Y inputs having different frequencies which have a common divisor. Vertical to horizontal ratio is determined by the ratio 1_h to 1_v, where 1_h is the number of times the trace intercepts a specific horizontal graticule line, and 1_v is the number of times the trace intercepts a specific vertical line.

Period = 50 μs X 1.37 X 7 = 480 μs

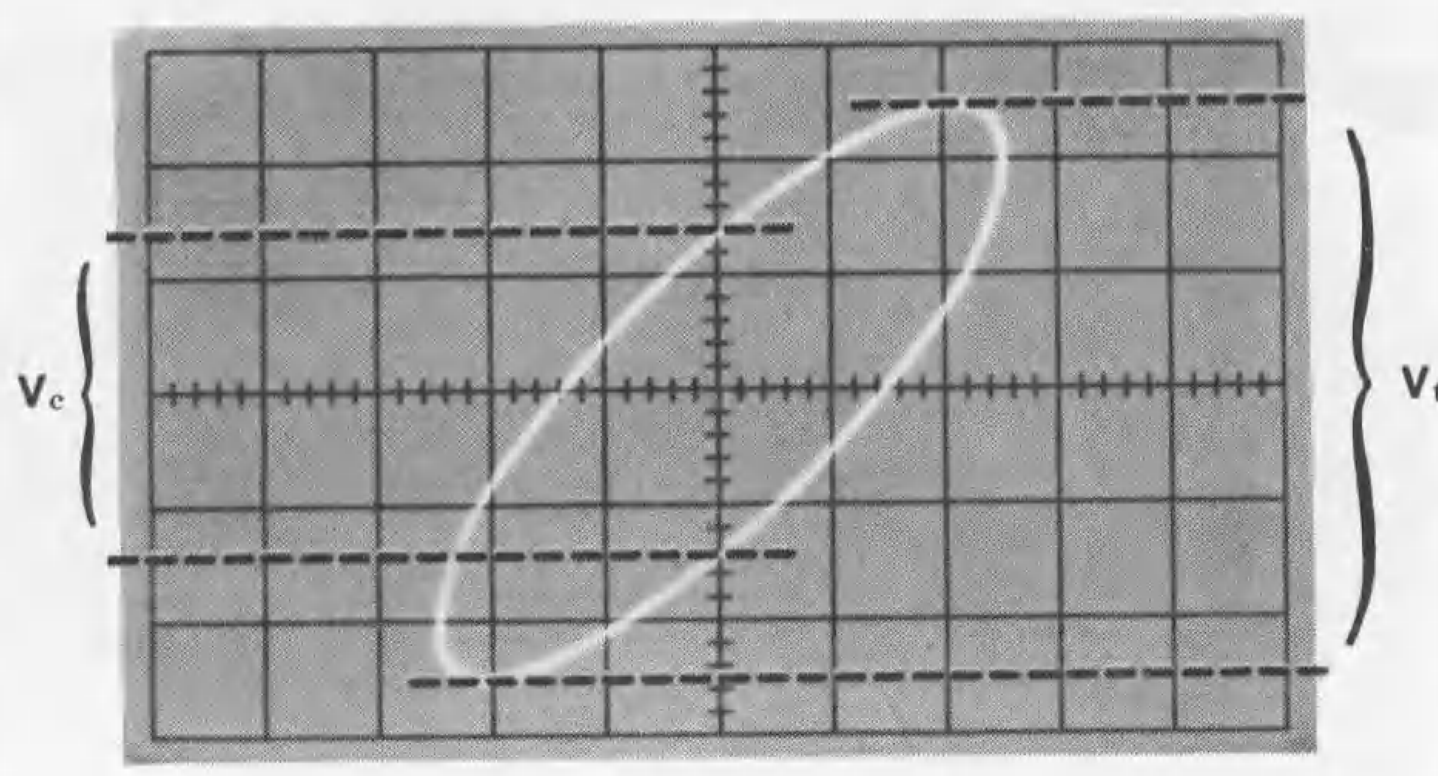
This answer can be converted to frequency by taking the reciprocal of the period (see applications on Frequency Measurements).

Lissajous Figures. An unlimited number of trace patterns (Lissajous figures) can be obtained by simultaneously applying signals of different frequencies or phase angles to the two input connectors. If the frequencies are different and do not have a common divisor, the pattern will change continuously. If the frequencies are the same, or have a common divisor, the pattern will be stationary, permitting phase, amplitude and frequency comparison. (The ease of comparison varies inversely with the ratio of frequency to common divisor.) One of the most practical uses of these patterns is in making extremely accurate adjustments of one frequency in respect to another.

An analysis of these patterns is a science in itself, and beyond the scope of this manual. However, a few patterns and their interpretations are contained in Fig. 2-15 and 2-16.

The characteristics of the oscilloscope's vertical and horizontal amplifier circuits must be considered in XY operation. Their bandwidth capabilities determine how much phase shift each one will introduce. For example, the horizontal circuit will introduce less than 5° phase shift at 200 kHz (its high-frequency half-power point).

The amount of difference in phase shift between the vertical and horizontal circuits will increase as frequency increases. This amount can be determined at any specific frequency. Couple the same signal into both the vertical and horizontal input connectors and calculate the difference in phase which appears in the presentation, using the method explained in Fig. 2-16.



1. Center the display horizontally.
2. Measure total vertical amplitude (V_t).
3. Measure amount of center vertical line which is enclosed by ellipse (V_c).
4. Divide V_c by V_t to obtain sine of phase angle.
5. Determine phase angle from table of trigonometric values.
6. Angle is > 270° and < 090° if ellipse rises from left to right.
7. Angle is > 090° and < 270° if ellipse falls from left to right.

Fig. 2-16. Determining phase angle.

GLOSSARY OF TERMS

The terms and definitions contained herein are limited to information required to understand the material in this manual. If a term is synonymous with a preferred term, its definition is restricted to the name of the preferred term.

−3 dB Point—Half-Power Point

AC Coupling—The condition existing when a capacitor is inserted between the signal pickoff point and the circuit to which the signal is applied.

Accelerating Voltage—A voltage applied to components within a cathode-ray tube to accelerate beam electrons during their passage from cathode to phosphor screen.

Astigmatism—Any deviation from a circular appearance of the electron beam spot. Also the control which corrects for the deviation.

Attenuator—Normally, any device used to intentionally decrease the amplitude of a signal prior to its application to the oscilloscope's amplifier circuitry. Any device which decreases a signal's amplitude.

Automatic Triggering—Applies to the trigger circuit. A triggering mode in which triggers to the Type 324 sweep circuit will initiate triggered sweeps in response to a broad range of internal or external signals without adjustment of the triggering level control. It will also provide a free-running sweep for reference in the absence of triggers.

Balanced Circuit—Two symmetrical (electrically identical) branches or nodes of a circuit which carry equal but opposite polarity signals. Also called Push-Pull circuit.

Bandwidth—The frequency range through which a circuit will provide an output which is at least 0.707 times the voltage output provided at a reference frequency within said range. The limits are referred to a "Half Power", or "–3 dB Points." The lower frequency limit is understood to be DC if only one value is given.

Beam—The electron beam emitted by the cathode of a CRT. Its impinging on the phosphor creates the light on the face of the cathode-ray tube.

Bezel—The flange or cover which holds the external graticule, light filter, viewing hood, etc. in front of the cathode-ray tube face.

Blanked—Condition under which the electron beam is prevented from striking the cathode-ray tube face.

Blanking—The process of creating the blanked condition.

Blooming—An increase in display size accompanying an increase in CRT INTENSITY setting.

Calibration—Process whereby an instrument is adjusted to perform within specified limits.

Characteristic Impedance—An ohmic value which expresses an electrical quality of a transmission line or cable. It is the impedance the line would present if it were of infinite length.

Circuit Board—Any of various boards on which are mounted circuit components and interconnections. The circuit board is usually fastened to a chassis with screws or clips.

Compression (Display)—An increase in the deflection factor, usually as the limits of the quality area are exceeded.

DC Balance—The condition existing in the Type 324 Oscilloscope when, with the vertical input grounded, no trace shift occurs as a result of any change in vertical deflection factor.

DC Coupling—The condition existing when no capacitor interrupts the path between the signal take-off point and the oscilloscope circuit to which the signal is applied.

DC Reference Position—The position on the oscilloscope graticule which is occupied by the trace when the input is grounded. Normally refers to the vertical circuit, but also pertains to the horizontal circuit during EXT HORIZ operation.

Decoupling—The process of removing AC signals or transients from the power supply voltages applied to a circuit. Usually refers to shunting AC and transient signals to ground by connecting a capacitor from the decoupling point to AC ground, and an impedance between the power supply and the decoupled point.

Deflection Blanking—Blanking by means of a deflection structure in the cathode-ray tube electron gun which traps the electron beam inside the gun to extinguish the spot, permitting blanking during retrace and between sweeps, regardless of intensity setting.

Deflection Factor—The ratio of the input signal amplitude to the resultant displacement of the indicating spot (volts/div).

Deflection Plates—Metal plates contained within a cathode-ray tube. Application of voltage to these plates creates an electrostatic field which controls horizontal, vertical or blanking deflection of the electron beam.

Deflection Polarity—The relation between signal polarity and spot displacement direction. The Type 324 Oscilloscope has a positive deflection polarity, indicating upward and right deflection in response to + vertical and horizontal input signals, respectively.

Deflection Sensitivity—The div/volt ratio which describes the amount of deflection resulting from a unit of applied signal.

Differential Amplifier—An amplifier whose output signal is proportional to the algebraic difference between 2 input signals.

Differential Signal—The instantaneous algebraic difference between two signals.

Display—The visual presentation created by the electron beam on the face of a cathode-ray tube.

External Horizontal Signal—Any signal applied to the Type 324 Oscilloscope TRIG OR HORIZ INPUT connector for purposes of EXT TRIG oscilloscope operation.

External Trigger—Any signal applied to the Type 324 Oscilloscope TRIG OR HORIZ INPUT connector for purposes of EXT TRIG oscilloscope operation. Also the trigger generated in response to this signal.

External Triggering—Introducing the triggering signal directly into the trigger circuit from an external source.

Field Effect Transistor (FET)—A semi-conductor device whose operation is analogous to a triode vacuum tube.

Free-Running Sweep—Continuously repetitive sweep occurring independent of triggers or input signals.

Geometry—The degree to which a rectilinear display on a CRT screen is accurately reproduced. Also the name of the control which adjusts this quality.

Graticule—A scale associated with the cathode-ray tube face.

Half-Power Point—The frequency at which the oscilloscope response limits the display amplitude to 70.7% of the actual voltage of the applied signal.

Holdoff—Sweep Holdoff.

Horizontal Amplifier—An amplifier for signals intended to produce horizontal deflection.

Horizontal Deflection—Horizontal movement of the cathode-ray tube electron beam away from its quiescent or no signal position.

Horizontal Displacement—The amount of horizontal space between electron beam quiescent position and instantaneous position.

Horizontal Gain—The voltage ratio of output to input signals associated with the Horizontal Amplifier.

Horizontal Sweep—The movement of the electron beam from left to right across the cathode-ray tube face in response to a changing horizontal amplifier voltage.

Input Coupling—Associated with the method of connecting a signal into a device or circuit. Usually refers to AC or DC coupling and signal attenuation.

Input Impedance—The combination of R, C and L which a signal must supply with energy when the signal is applied to the input of a circuit.

Input RC Characteristics—The value of capacitance and DC resistance present at the input of the oscilloscope. Also referred to as input impedance.

Internal Triggering—Using a sample of the signal present in the vertical amplifier as a triggering signal source.

Jitter—An aberration of a repetitive display indicating instability of the signal or of the oscilloscope. May be random or periodic, and is usually associated with the time axis.

Lissajous Figure—A special case of an X-Y display, produced by simultaneous application of sine waves to the vertical and horizontal deflection plates. Useful for determining phase and frequency relationships.

Load—The impedance offered by a circuit or device. The lower the impedance, the greater the loading effect.

Loading—Requiring a circuit to supply energy to another circuit. The term is often associated with the effect caused by attaching test equipment to a circuit.

Magnified Sweep—Enlarged portion of a sweep (usually horizontal). In the Type 324 Oscilloscope the sweep can be magnified so that 2 divisions of display are viewed over 10 divisions through use of the X5 HORIZ MAG control.

Noise—Any extraneous electrical disturbance tending to interfere with the normal display.

Open Circuit—A discontinuous circuit.

Overshoot—In the display of a step function (usually of time), that portion of the waveform which, immediately following the step, exceeds its nominal or final amplitude.

Period—The time elapsing between occurrence of identical points in an AC or recurring transient event. It usually refers to repetitive waveforms and is the reciprocal of their frequency.

Phase Shift—The change in the phase angle (of a sinusdoidal waveform) which is introduced when the waveform passes through a network.

Phosphor—The substance coating the inner face of a cathode-ray tube. It emits light when bombarded by electrons.

Plate—In a cathode-ray tube, any one of the deflection plates.

Preventive Maintenance—Cleaning, inspecting and lubricating equipment to insure continued reliable operation.

Probe—A pointed metal tip within an insulating handle. Used for temporary connecting to a signal source. It can include attenuation capability. Generally includes the associated cable and connector.

Probe Tip—That part of a probe which makes contact with the signal pickoff point.

Pulse Width—The time between specified equal amplitude points on both slopes of an electrical pulse. Usually measured at the 50% amplitude points.

Push-Pull—Currents or voltages which are equal in amplitude but opposite in polarity. Also defines a circuit which has that type of response.

Reflection—A signal caused by reflected signal energy. Usually thought of as energy returned by a transmission line which is not terminated in its characteristic impedance, or which has impedance discontinuities within it.

Response Characteristics—A quantitatitive description of the input-output characteristics of a device or circuit. Usually amplitude versus frequency response.

Retrace—Return of the spot to the left of the cathode-ray tube face upon completion of a horizontal sweep. Also that portion of the sweep waveform which causes the spot to return.

Retrace Blanking—The process of creating a CRT blanked condition during retrace.

Return Trace—A path created by the spot during retrace. Should not be seen during normal sweep operation.

Ringing—A damped oscillatory transient occurring in a system as a result of a sudden change of input.

Ripple—AC superimposed on a DC level. Commonly associated with filtered DC power supplies.

Risetime—The interval between the instants at which the instantaneous amplitude first reaches specified lower and upper limits. In the display of a step function of time, these limits are 10% and 90% of the nominal or final amplitude of the step.

Rounding—In the display of a step function (usually of time), the loss of the corner following the step.

Sawtooth Waveform—A waveform containing a linear sloped rise and return to its initial value, the two portions usually of unequal duration. Commonly describes the waveform created by the oscilloscope horizontal sweep generator.

Semi-Conductor Device—Any one of several devices made of semi-conductor material; usually diodes or transistors.

Sensitivity—See deflection sensitivity.

Short Circuit—A low impedance connection across circuit branches or power sources.

Signal Pickoff Point—A point at which a circuit is tapped into to provide a signal for any of various purposes, such as oscilloscope display.

Signal Source—The point of origin of a signal. Also used to describe Signal Pickoff Point.

Slope—In oscilloscope waveform presentations, the term describes the direction and ratio of change of vertical deflection related to a change of horizontal deflection $\frac{\Delta E}{\Delta t}$.

Source—The point of derivation of power or of a specific type of power (line, +300 V, −150 V, battery). Also the element in a Field Effect Transistor which operationally corresponds with the cathode of triode vacuum tube.

Sweep—An independent variable of a display; unless otherwise specified, this variable is a linear function of time, but may be any quantity that varies in a definable manner.

Sweep Generator—A unit that generates a signal used as an independent variable; the signal is usually a ramp, changing amplitude at a constant rate.

Sweep Holdoff—An interval immediately following a horizontal sweep, during which time the sweep is prevented for recurring while the circuits stabilize to their quiescent condition.

Sweep Linearity—Maximum displacement error of the independent variable between specified points on the display area.

Sweep Rate—The time required per division of trace movement (TIME/DIV).

Termination—The load present at the output of a circuit, device, or transmission line. Commonly identifies a device which terminates a transmission line with a specific impedance.

Tilt—Deviation of the upper and/or lower flat surfaces of a square wave or pulse from the horizontal.

TIME/DIV—The time required for the spot created by the electron beam to move 1 division. Commonly used in reference to horizontal sweep.

Time Base—The sweep generator in an oscilloscope.

Trace—The cathode-ray tube display produced by a moving spot.

Trace Width—The distance between two points on opposite sides of a trace at which the luminance is 50% of maximum.

Transient Response—The name of a number of characteristic time-domain reactions to abruptly-applied inputs.

Transient—A damped oscillation or pulse occurring in a circuit in response to a change in input.

Transition—A voltage shift; commonly refers to the step function of a square wave.

Trigger—A pulse used to initiate some function. In oscilloscopes, commonly refers to the signal which initiates the horizontal sweep.

Triggered Sweep—A sweep that can be initiated only in response to a trigger, as opposed to a free-running sweep.

Triggering Level—The instantaneous value of voltage of an input signal required to generate a trigger.

Triggering Signal—The signal from which a trigger is derived.

Triggering Slope—The direction of change (+ or –) of triggering signal voltage from which a trigger is to be derived.

Unblanked—The condition existing when the electron beam is permitted to strike the face of the cathode-ray tube.

Vertical Amplifier—An amplifier for signals intended to produce vertical deflection.

Vertical Deflection—Vertical movement of the electron beam.

Vertical Displacement—The amount of space between the vertical reference and actual trace positions.

Vertical Gain—The ratio of the amplitude of the output signal from the vertical amplifier to the amplitude of the vertical input signal.

Vertical Input Signal—The signal applied to the oscilloscope vertical input connector.

VOLTS/DIV—The ratio expressing the deflection factor of the oscilloscope. In front panel control nomenclature, it is the number of volts required to cause one division of vertical deflection.

X-Y Display—A rectilinear coordinate plot of two variables.

Z Axis—The third dimension of a display. Commonly implemented in oscilloscopes as beam intensity (display brightness) variations.

SECTION 3
CIRCUIT DESCRIPTION

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

Introduction

Block diagram descriptions and detailed descriptions of the Type 324 Oscilloscope circuitry are contained in this section. The block diagrams and schematics in the back of this manual are used in conjunction with the descriptions. Schematic numbers are used extensively for cross-referencing, and are therefore contained in a diamond-shaped outline for quick recognition.

Simplified drawings are provided where necessary for effective circuit explanations. No attempt is made to explain basic operations of components, except for those that are not considered generally known. Additional information regarding components is included in the Maintenance section.

BLOCK DIAGRAM DESCRIPTION

Refer to the block diagram in the Diagrams section. Operation with an internal sweep will be discussed first.

Internal battery, external DC, or AC powered operation can be selected at the Power Pack. During AC operation, the AC power input is full-wave rectified and applied to battery charger circuits which supply power to the external batteries and the oscilloscope circuits. During EXT DC operation, the battery and battery charging circuit are by-passed and the applied voltage goes directly to the POWER switch.

In all modes of operation, a DC voltage is received by the Power Regulator, which employs a blocking oscillator and a flyback-type transformer to develop voltages which are used throughout the oscilloscope. This includes CRT filament supply and high voltage.

When internal sweep operation is selected, the Trigger Generator develops triggers in response to any of three sources selected by the operator: trigger multivibrator, vertical signal, or externally applied triggering signal. When the vertical signal or the EXT TRIG input is selected, the Comparator Amplifier causes the Trigger Multivibrator to generator a trigger each time the input signal passes through a specific voltage determined by the Comparator Amplifier. When AUTO triggering is selected, the Trigger Multivibrator free-runs, providing a continuous succession of triggers. Whenever either a vertical signal or external triggering signal is present and has a higher frequency than the multivibrator's free-running rate, the multivibrator no longer free-runs but becomes slaved to the triggering signal.

The Trigger Multivibrator output enables a Sweep Gate circuit. This causes the Sweep Generator circuit to develop a linear sawtooth voltage, which drives the Horizontal Amplifier. The Horizontal Amplifier increases the amplitude of the sawtooth voltage as necessary to provide slightly more than ten divisions of horizontal deflection when the voltage reaches its peak.

When the sawtooth voltage out of the Sweep Generator rises sufficiently positive to provide full trace deflection, it disables the Sweep Gate and sweep voltage returns to its reference value. The Holdoff Circuit prevents triggers from reaching the Sweep Gate during sweep time, and continues to block them until enough time has elapsed after sweep time for the circuits to return to their quiescent values. This ensures that each sweep will start from the same point on the display as the preceding sweep.

Deflection blanking is used in the CRT to prevent the electron beam from striking the CRT face during retrace and holdoff time. The Sweep Gate output causes the Unblanking Amplifier to apply +100 V to an unblanking deflection plate during sweep time. This cancels the effect of the +100 V which continuously exists on an opposing deflection blanking plate, permitting the horizontal (and vertical) deflection plates to control beam position on the face of the CRT. The CRT beam can be blanked at any time by application of an external blanking signal of at least +5 V to EXT BLANK jack J350.

When a signal is applied to the VERT INPUT, it passes through an attenuator which is controlled by the VOLTS/DIV switch. The signal (or a portion of it determined by the switch setting) is applied to the Vertical Preamp where it is amplified and converted to a push-pull signal. It is then amplified by the Vertical Output Amplifier which applies the signal to the CRT vertical deflection plates. The vertical signal applied to the upper deflection plate is also applied to the Trigger Generator circuit. This slaves the trigger and sweep generator to the input signal frequency, thereby permitting a stable display.

Alternate Modes of Operation

5 DIV CAL. The gain and overall operation of the oscilloscope can be checked by switching the VOLTS/DIV switch to 5 DIV CAL position. At that time a square wave is accepted from an internal Calibrator. The appearance of a 5 division square wave on the CRT is indicative of proper operation. Its amplitude is sufficiently accurate to permit gain calibration. A 0.5 V square wave signal from the Calibrator is always available at the CAL OUT jack for purposes such as calibrating an attenuator probe.

EXT HORIZ. The horizontal beam deflection can be controlled by an externally applied signal when the TIME/DIV switch is placed in the EXT HORIZ position and the Trig/Horiz Coupling switch is in an EXT TRIG OR HORIZ position. At that time the Sweep Generator is disabled. The CRT is unblanked and the electron beam moves to center screen. Signals applied to the EXT TRIG OR HORIZ INPUT jack pass through the Trigger Input circuit to the Horizontal Amplifier, where they are amplified, converted to push-pull, and applied to the CRT horizontal deflection plates. Vertical deflection operation remains the same as previously described.

VERTICAL PREAMPLIFIER ⟨1⟩

Block Diagram Description

The principal sections and controls are shown on the block diagram which is on the Vertical Preamplifier schematic diagram page. Signals applied to the VERT INPUT connector can be AC or DC coupled into the attenuator section by the INPUT coupling switch. The position of the VOLTS/DIV switch determines the amount of attenuation the signal receives to provided the deflection factor indicated by the switch. One position of the switch allows selection of a square wave signal from a built-in calibrator unit to allow checking and calibrating of the oscilloscope circuitry. Two different calibrator amplitudes are available. The proper amplitude is automatically selected to present a 5 division calibration display in both positions of the X5 VERT GAIN switch.

The input signal is applied to one half of a dual field effect transistor (FET) in the Source Follower circuit. The FET provides an extremely high input impedance, and nearly unit gain output. The second half of the FET provides an offset signal which cancels any thermal or power supply change effects upon the input FET.

The signal from the Source Follower is applied to the First Amplifier circuit where equal but opposite polarity signals are developed to provide a differential signal.

With the variable control in CAL position and the X5 VERT GAIN pushed in, the gain (push-pull output ÷ single-ended input of the First Amplifier section is approximately 5. Stage gain decreases to approximately 2 when the VARIABLE control is fully inserted into the circuit.

The Second Amplifier provides a gain of about 8. The gain increases to about 40 when the X5 VERT GAIN switch is closed. (The deflection factor indicated by the VOLTS/DIV switch must be divided by 5 to determine the actual deflection factor whenever X5 VERT GAIN is in effect.) The POSITION control injects a push-pull current to change the quiescent (reference) vertical position of the trace.

Vertical Input Circuitry

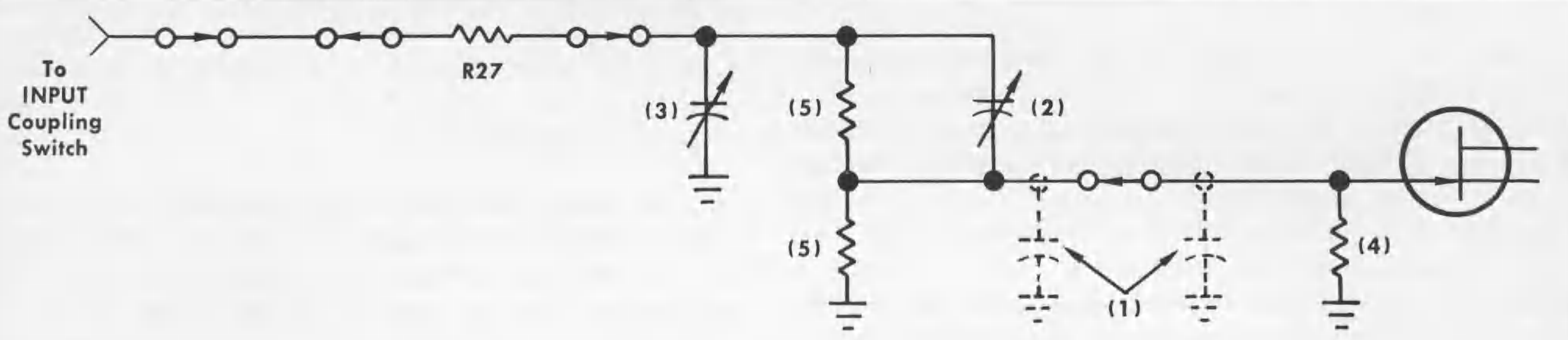
Refer to the Vertical Preamplifier schematic. The Vertical Input Circuitry consists of the VERT INPUT connector (J20), the INPUT Coupling Switch (S21), coupling capacitor C20, resistor R21, the input attenuators and the calibrator.

Input Coupling. With INPUT switch S21 in AC position, C20 blocks the DC component of the signal while permitting the AC component to pass to the attenuator and preamplifier circuitry. In GND position, the switch connects the attenuator circuitry to ground to provide a DC reference for adjusting the vertical DC reference position of the trace. When switched to DC, the INPUT switch bypasses C20 and R21, allowing both the AC and DC signal components to be applied to the attenuator and preamplifier circuitry.

Vertical Input Attenuators. Eleven deflection factors (VOLTS/DIV) are made available through various combinations of five attenuator circuits and a "straight-through" circuit. The combinations can be arrived at by connecting the attenuators as indicated at each switching position of S25 (VOLTS/DIV).

In the .01 (straight-through) position, 1 MΩ and 47 pF oscilloscope input impedance is provided by R101 and the Preamplifier input cabling and stray capacitance. Attenuators are designed to maintain this same value of impedance at the VERT INPUT connector, regardless of the attenuator in use. Since each attenuator has the same input impedance as the Preamplifier, attenuators can be connected in series and still maintain the 1 MΩ and 47 pF impedance at the VERT INPUT connector. The total attenuation affecting the signal is then equal to the product of the attenuation factors in use.

The attenuators are voltage dividers. DC voltage division is done soley by the resistors, while low-frequency AC signals are attenuated by resistors, capacitors and stray capacitance. At high frequencies the attenuation becomes largely a function of the capacitors and stray capacitance.



(1) Attenuator output capacitance and Preamplifier circuit input capacitance.

(2) In combination with (1), provides the AC voltage division indicated by the selected attenuation factor.

(3) In parallel with the (1) and (2) series combination, provides 47 pF input capacitance.

(4) 1 MΩ input resistance.

(5) In combination with (4), provides a 1 MΩ input resistance. Also provides voltage division as determined by the VOLTS/DIV switch position.

R27 limits current caused by over-driving signals in .01 mV position.

Fig. 3-1. Simplified input circuit configuration for .01, .02 or .05 VOLTS/DIV switch positions.

Fig. 3-1 shows a simplified input circuit configuration for .01, .02, or .05 VOLTS/DIV switch settings. Brief descriptions of component functions are included.

Calibrator. Refer back to the Vertical Preamplifier schematic. Assume that Q1 is conducting and Q9 is cut off. In this condition Q1 is saturated and its emitter is at approximately +4.4 V. C5 is being charged through R9 by the 9.4 V difference existing between the −5 V power supply and the Q1 emitter voltage. Initially, the current through R9 is sufficient to keep the Q9 emitter more positive than −0.6 V, preventing Q9 from conducting. When C5 charges to approximately 5 volts, the current through R9 is decreased sufficiently to lower the Q9 emitter voltage to approximately −0.6 V. Q9 goes into saturation. The Q9 collector and the base of Q1 fall to about −0.6 V, causing Q1 to cut off. C5 discharges through R4 until the Q1 emitter reaches about −1.2 V and Q1 again conducts. C5 stops discharging and Q9 cuts off. The voltage at the collector of Q9 goes positive, causing Q1 base and emitter voltage to follow. C5 again charges through R9, and the cycle repeats itself at an approximate 800 Hz rate.

The multivibrator square-wave output is taken from the collector of Q9 and applied to the D11-D12 switching circuit. When Q9 is cut off, D11 is back biased by the positive potential at the Q9 collector. Current flows through R12, D12 and R15 to provide 0.5 V, .05 V and .005 V at the tops of R17, R18 and R19 respectively. When Q9 conducts, D11 also goes into conduction and the voltage at the bottom of R12 drops below +0.6 V. D12 stops conducting and the output voltages drop to 0.

R3, R6, C3 and C6 are decoupling components. R13 and D13 counteract temperature effects on D12 to maintain an accurate calibration signal over the oscilloscope's operating temperature range.

Source Followers

Input signals are developed across R101 and applied through C101 and R102 to the gate of Field Effect Transistor (FET) Q11A. No signal current flows through the gate of Q11A, and therefore no signal loss occurs across R102. The operation of N-channel FET's such as Q11 is comparable to that of a triode vacuum tube, with the source, gate and drain comparing to the cathode, control grid and plate respectively. In typical cathode-follower fashion, most of the signal at the gate of Q11A is developed across R105 and applied to the base of Q21A. R104 and R107 permit adjustment for offset differences between Q11A and B, and between Q21A and B.

Q11A and Q11B are electrically and thermally paired, and therefore provide identical input conditions for both halves of the amplifier. This provides high common-mode rejection characteristics for the two halves, which results in cancellation of effects from + and − 5 V power supply variations and FET thermal variations.

R103 and C103 are decoupling components. D14, D15, D16 and D17 provide protection to Q11A by limiting Q11A gate signals to approximately ±1.2 V. R102 limits the overload current to a safe value during conduction of the diodes. C101 permits high frequency components of signals to bypass R102 to provide optimum transient response.

First Amplifier

The First Amplifier consists of paraphase amplifier Q21A-Q21B and operational amplifiers Q31 and Q32. Under quiescent conditions, equivalent points in the upper and lower halves of the amplifier are at approximately equal potential. Signals arriving at the base of Q21A are referenced to the fixed potential at the base of Q21B. The signal voltage unbalances the voltage at the emitter of Q21A with respect to that at the emitter of Q21B. The resistance between these two points then determines the amount of signal current which flows through the collector circuit of Q21A.

The emitters of Q31 and Q32 form a virtual signal ground which prevents the collectors of Q21A and Q21B from changing their voltages by an appreciable amount. Assume that a positive voltage is applied at the base of Q21A, causing an increase of current through the Q21A collector circuit. This increase of current through R113 tends to cause a negative signal voltage to develop at the base of Q31. This decreases the Q31 conduction and causes a positive voltage to appear at the Q31 collector. The voltage at the Q31 collector rises to a value sufficient to cause the Q21A signal current to flow through R118, and the circuit stabilizes with only a minimum change of voltage at the Q31 base.

Since the R118 signal current is essentially the same signal current that flows in the resistance between the emitters of Q21A and Q21B, the signal gain at the Q31 collector is essentially equal to the value of R118 divided by the resistance between the emitters of Q21A and Q21B. The size of the R108 and R112 compared to that of R110 and R111 causes most of this signal to be shunted through R110 and R111. When the VARIABLE control resistance is added to the Q21A-Q21B emitter circuit, it increases the resistance between the emitters, thereby reducing the stage gain.

Since the signal applied to Q21A has caused very little change of current in R108 and R112, most of the signal current flowing in the collector of Q21A must have been obtained from that previously flowing in the Q21B collector circuit. This decrease of Q21B collector current causes the Q21B collector voltage to attempt to rise. This increases the drive to Q32, causing an increase of current in its collector circuit. A negative voltage is thus developed at the Q32 collector, with its amplitude approximately equal to the positive voltage developed in the Q31 collector circuit. The push-pull gain of the First Amplifier stage is therefore, equal to twice the value expressed for the upper half. This gain can be approximated by the quotient of R118 plus R120, divided by the effective resistance between the emitters of Q21A and Q21B.

The large resistor which supplies Q31 and Q32 with emitter current acts as a constant current source to aid the First Amplifier stage in creating equal and opposite push-pull output signals.

Second Amplifier

The Second Amplifier stage consists of Q41, Q42 and Q51 in the upper half and Q44, Q43 and Q61 in the lower half. It should be noticed that the Q41-Q51 section of the upper half form an amplifier circuit similar to that in the upper half of the First Amplifier. Significant differences are that the Q41 emitter current is supplied by transistor Q42 and that the Q41 emitter current is supplied by transistor Q42 and that the Q41 collector and Q51 base are separated by a diode circuit. Except for these components, operation of the Second Amplifier stage is essentially the same as that of the First Amplifier stage.

Q42 and Q44 are high-impedance current sources for the Second Amplifier stage. In addition, push-pull voltages from the POSITION control can be applied to the Q42 and Q44 bases to permit positioning the display vertically on CRT. A small amount of feedback current is supplied through R115 and R116 to offset any positioning effect upon signal amplification.

The diode network consisting of D41 through D46 forms a signal clamping circuit to limit the maximum signal which can be applied to D51 and D53. A +0.6 V limit is imposed by D41 and D42 while D43, D44, D45, D46 and R137 combine to impose a −1.8 V limitation.

D51, D52, R138, D53, D54 and R139 form a limiting circuit to prevent overdriving of Q51, Q61 and the output amplifier circuit. Under balanced no-signal conditions, R138 current is supplied equally by D51 and D52. When a positive-going signal from the Q31 collector causes the Q41 collector current to decrease, the Q41 collector voltage goes slightly more negative, causing a decrease in D51 forward conduction. The current which had been flowing in D51 is now shunted through D52, providing additional drive to Q51. The increased Q51 collector current causes the Q51 collector voltage to go in a positive direction until most of the D52 signal current flows through R144 and the circuit stabilizes. If the signal voltage at the Q41 collector becomes excessively negative, D51 stops conducting and all of the R138 current flows through D52. If the Q41 collector continues to go negative, it will have no further effect upon the Q51 circuit.

During the time a positive signal is applied to Q41 base, an equal but opposite signal is being applied to the Q43 base. If the signal voltage at the Q43 collector becomes excessively positive, D53 demands all of the R139 current, causing the D54 cathode voltage to drop below that required for conduction. If the Q43 collector voltage continues in a positive direction, it will have no further effect upon Q51. Excessive amplitude signals of a polarity opposite to that just described will cause D52 and D53 to stop conducting, again protecting Q51 and Q61 from being overdriven.

It is possible for the vertical amplifier to be balanced and the trace to be at graticule vertical center through a wide range of equal voltages at the upper and lower deflection plates. R141 and R142 permit individual adjustment and balancing of the deflection plate voltages independent of the inputs from the limiter circuit. This enables the CRT vertical deflection plate voltages to be centered within their dynamic operating range.

VERTICAL OUTPUT AMPLIFIER ⟨2⟩

Block Diagram Description

Refer to the Vertical Output Amplifier block diagram. The Vertical Output Amplifier consists of two isolation amplifiers and a pair of multi-stage operational amplifiers quiescently supplying approximately 50 V DC to each of the vertical deflection plates of the cathode-ray tube. Signals at the VERT INPUT connector cause equal and opposite deviations from this value at the two plates, resulting in approximately 1 division of deflection for each 18 volts of differential signal output. Overall gain of the circuit is approximately 50, determined principally by the quotient of R163 (R_f) divided by R151 (R_i). Gain for one side is the same as push-pull gain.

Signals into the amplifier pass through R151 and an isolation amplifier in each half of the circuit. The output of each isolation amplifier goes through an emitter follower and then to the output amplifier, which supplies the signal to a deflection plate.

The two halves of the amplifier operate in push-pull. Current in one side descreases as current increases in the other side. During high frequency operation, rapid signal changes required at the CRT require additional current in the output stage. The high frequency boost circuit supplies this extra current.

Detailed Description

Quiescent Conditions. Refer to the Vertical Output Amplifier schematic diagram. When the trace is positioned at graticule center and no signal is applied, the voltage applied by Q51 and Q61 to the inputs of the amplifier causes the collectors of Q132 and Q133 to be at +50 V. Feedback current from the collector of Q132 passes through R163 to the collector of Q101 where it is joined by the R158 current to supply the current demand from Q101 by the input voltage. (The feedback follows a similar path through R174 in the lower half of the amplifier circuit.) The base voltages of Q111 and Q112 are thus controlled principally by the R151 current. These base voltages determine the Q111 and Q112 emitter voltages, controlling the current through R160 and R161. The majority of the R160 current divides between Q111 and Q121, with the Q121 current setting the base voltage of Q131. The R161 current similarly determines the Q134 base voltage.

The emitter voltage of Q111 and Q112 also sets the base voltages of Q132 and Q133, respectively. The resulting voltage at the emitter of Q132 (and the voltage at Q133 in the lower half) then determines the amount of current through R168, which establishes the standing current of the entire Q131-Q132-Q133-Q134 output stage.

The high frequency boost circuit is inoperative during quiescent conditions since Q142 has both its base and emitter referenced to ground. With Q142 cut off, no drive current can flow in the Q143 emitter-base circuit; thus, Q143 is held cut off. Q141 is self-biased in conduction, but has no effect on the circuit during quiescent or low frequency conditions, due to coupling capacitor C130.

Assume that the voltage at the input of R151 becomes less negative, decreasing the current demand through R151. Initially this change will be felt at the base of Q111, increasing the Q111 collector current. The change will be felt through the Q111 emitter circuit at the Q132 base, causing the impedance of Q132 to decrease. The increase of current through Q111 collector reduces the current flowing through Q121, causing the Q121 collector to go positive. This positive voltage is felt at the Q131 base, increasing the Q131 impedance. The combined effect of decreasing Q132 impedance and increasing Q131 impedance causes their collectors to become less positive. The collector voltage changes until the R163 feedback current has been reduced by an amount almost equal to the reduction in R151 current which was caused by the voltage change at the input.

When a positive-going change is being processed by the upper half of the circuit, a negative going change is received and processed by the lower half of the circuit. This causes an equal but opposite output. The collector voltages of the output transistors thereby modify the deflection plate voltages to cause vertical deflection.

During high frequency operation, signals arriving at the base of Q132 are also coupled through C128 and developed across R175. They then are applied to the base of Q141. The positive going pulses cause Q141 to increase conduction, causing a negative voltage to develop at the Q141 collector. This negative voltage is coupled through C130 to the base circuit of Q142, momentarily putting Q142 into conduction. This provides a drive current path for Q143, causing it to supply additional current for the output transistors through R167 and R169, thereby increasing their ability to handle rapid voltage changes at the CRT deflection plates. C132, in the base circuit of Q143, filters the Q142 pulses to provide Q143 with an average drive current proportional to the frequency and amplitude of the incoming signal.

Filtering capacitors include C129, C131, C122, C133 and C126. The remaining capacitors improve high frequency response of the circuit. Several of them are adjustable to permit optimum circuit compensation.

The voltage which is applied to the upper vertical deflection plate is also applied to voltage divider R170, R171, C127 to provide a portion of the output signal to the trigger generator circuit.

TRIGGER GENERATOR ⟨3⟩

General

The function of the Trigger Generator is to develop triggers to initiate horizontal sweeps. In EXT HORIZ mode, part of the Trigger Generator circuit processes external horizontal signals for application to the Horizontal Amplifier.

Block Diagram Description

Refer to the block diagram contained on the Trigger Generator schematic diagram page. Signals from the Vertical Output Amplifier or the EXT TRIG OR HORIZ INPUT are applied to a protection circuit and then to an FET Source Follower circuit. Trigger signals pass through the TIME/DIV switch to a Comparator Amplifier. When the input signal reaches the voltage level determined by the (TRIGGER) Level control, the voltage out of the Comparator Amplifier causes the Trigger Multivibrator to generate a trigger. The TRIGGER control can be used to select the direction of voltage change (+ or − Slope) which actually causes triggers to occur.

When AUTO operation is selected by the TRIGGER control, the Trigger Multivibrator free-runs at one of 3 frequencies (approximately 30 Hz, 200 Hz, 2 kHz) as determined by the TIME/DIV control. Triggers occur more often at higher sweep rates to maintain a relatively constant trace brightness regardless of sweep rate. A triggering signal whose frequency is higher than that of the multivibrator will override the automatic operation and synchronize the multivibrator (and therefore the sweep) to the signal frequency.

In EXT HORIZ mode, external horizontal signals pass through the Source Follower circuit and are routed to the Horizontal Amplifier by contacts of the TIME/DIV switch.

Protection and Source Follower Circuits

Refer to the Trigger Generator schematic (and to the Timing Switch schematic as necessary). Circuit operation during non-automatic internal triggering will be discussed first. The output signal from the upper half of the Vertical Amplifier is connected to a contact of the Trig/Horiz Coupling switch. With the switch in either internal position, the signal is applied to C209. The AC component is developed across R210 and applied through R212-C212 to the junction of D213, D214 and Q215. Under normal conditions, only leakage current flows in the Q215 gate circuit, so no signal loss occurs across R212. D213, D214, C212 and R212 provide overload protection for Q215 during EXT TRIG OR HORIZ operation and have no effect upon the internal vertical signal applied to Q215. Source-follower action (comparable to cathode-follower action) provides the signal to a contact of the TIME/DIV switch. In all except EXT HORIZ position, the output of the source-follower is sent through or around C221 and C223 to the base of Q231. With the Trig/Horiz Coupling switch in INT TRIG AC LF REJ, signals below approximately 15 kHz are attenuated, to avoid interfering with higher frequency triggering operation. During INT TRIG AC operation, C223 is bypassed and triggers are generated in response to signal frequencies as low as 30 Hz.

External triggering can be selected by placing the Trig/Horiz Coupling switch to either the EXT TRIG OR HORIZ AC or DC position. DC triggering is possible only when the switch is at DC and the TRIGGER control is not at AUTO. At that time, C209, C221 and C223 are bypassed to permit the EXT DC potential to reach Q231.

The 10X position of the (EXT TRIG OR HORIZ) ATTEN switch provides a frequency-compensated voltage divider which increases the EXT TRIG OR HORIZ INPUT operating range by a factor of 10, without appreciably changing circuit input impedance.

When the TIME/DIV switch is set at the EXT HORIZ position, the output of the Source Follower Q215 is disconnected from the trigger generating circuitry and is routed through switch contacts to the Horizontal Amplifier. Horizontal deflection of the beam then occurs in response to external horizontal input signals (Trig/Horiz Coupling switch in either EXT TRIG OR HORIZ position), and the horizontal POSITION control. R218 permits a setting of the voltage at the source of Q215 so that no beam position shift occurs when rotating the (EXT HORIZ) VAR control.

Comparator Amplifier

The Comparator Amplifier (Q231, Q239 and associated resistors) quiescently has the Q231 base referenced to ground through R230. The Q239 base is set to some voltage level determined by R246 (TRIGGER LEVEL), R242 and

R244. If R246 is set to a point midway between the center tap and either side, 0 V will be applied and the two transistors will be conducting equal current. The collector voltages will be approximately equal under those circumstances. A signal input to the Comparator Amplifier will generate an in-phase signal at the Q239 collector and an inverted signal at the Q231 collector. Both outputs are made available to contacts of the (TRIGGER SLOPE) switch.

Triggering action occurs when the selected collector varies approximately 0.1 V from a balanced output condition. If the TRIGGER LEVEL potentiometer is offset from 0 V, signals at the Q231 base must compensate for the offset before causing trigger action. Through the use of the TRIGGER control, both TRIGGER LEVEL and TRIGGER SLOPE can be manipulated to select any point along the rising or falling slope of a signal to cause trigger action. If two separate signals of different amplitudes are presented simultaneously to the comparator, R246 (TRIGGER LEVEL) can be set to a point where only the larger of the two signals can cause triggering action, thereby causing the sweep to be triggered at the frequency of the larger signal.

Trigger Multivibrator

Non-Automatic Operation. The Trigger Multivibrator is a Schmitt Trigger circuit when operated in the non-automatic mode. When Q253 is conducting, the current through R260 and that through the voltage divider connected to the base of Q263 create a combination of voltages which prevent Q263 from conducting. When the output voltage from the comparator decreases, the Q253 emitter voltage decreases and the collector voltage increases. Q263 is thereby permitted to go into conduction. Q263 emitter voltage rises and Q253 cuts off. The sudden increase of Q253 collector voltage is coupled through R256 and C256, aiding Q263 conduction. The current increase through R262 creates a negative step which is differentiated and applied to the Sweep Generator circuit. This develops a negative trigger which initiates a horizontal sweep. When the Q253 base voltage returns sufficiently positive, Q253 goes back into conduction, cutting Q263 off. The circuit is then ready for another cycle.

Automatic Operation. When the TRIGGER control is switched to either the + or — AUTO position, the following circuit changes are made: switch wafer IF inserts C250 in the Comparator Amplifier output signal path, causing the Q253 DC base voltage to be determined by R251, R252 and R253; wafer 2F inserts C221 in the triggering signal path, placing the Q231 base at ground potential; wafer 2R connects the base of Q239 to ground, simultaneously inserting one of the Trig Auto Caps into the base and collector circuits of Q263. The Trig Auto Cap value is dependent upon the position of the TIME/DIV switch.

In AUTO TRIGGER mode, the Schmitt trigger circuit becomes a free-running multivibrator which will synchronize to a triggering signal having a frequency greater than the multivibrator repetition rate. In the absence of triggering signals from Q231, operation occurs as follows: Assume that Q253 is conducting, Q263 is cut off, and that C270 has no charge on it. Circuit design causes the junction of R257 and R258 to go slightly positive, charging C270. The voltage at the base of Q263 increases in proportion to the voltage "ramp" at the C270-R257-R258 junction, until the Q263 is turned on. This increases the voltage at the emitter, turning Q253 off. The rise of Q253 collector voltage is coupled through C253 and R256, aiding Q263 conduction. The resulting current lowers the voltage at the collector of Q263, sending a negative gate to C301 in the Sweep Generator. The negative gate voltage is also coupled through R264, causing C270 to discharge. As C270 discharges, its negative-going voltage ramp is coupled through R257, decreasing the Q263 base voltage. The Q263 emitter voltage follows the base, carrying the Q253 emitter with it. Q253 conducts when its emitter becomes sufficiently negative. The resulting change of Q253 collector voltage is coupled through R256, cutting Q263 off. The cycle then repeats itself.

If a signal is coupled in through C250 during AUTO operation, it will either combine with the voltage ramp to cause switching action, or it will override the ramp and cause switching action by itself.

Consider the AUTO condition existing when Q263 is cut off. A positive-going ramp occurs at the base of Q263. If a negative signal simultaneously appears at the base of Q253, it will be coupled to the emitter, lowering the Q263 emitter voltage. The positive ramp at the base and the negative signal at the emitter combine their effects to increase the emitter-base forward bias, placing Q263 in conduction. In similar fashion when Q253 is turned off, a positive signal at its base will work in conjunction with the negative ramp at its emitter to turn Q253 on. It should be noted that if both the ramp and the input signal are required to produce switching action, the switching rate will not be much greater than the AUTO frequency, although it will be synchronized to the signal frequency or a sub-multiple of it. This situation occurs when trigger inputs are less than those specified under Trigger Sensitivity at the beginning of this manual.

If the signal in from the comparator has a higher frequency than the AUTO multivibrator, and has sufficient amplitude to override the ramp voltage, its effect alone will cause the previously explained switching action, creating negative gates at the frequency of the input signal.

Smaller Trig Auto Caps are substantiated when the TIME/DIV switch is changed from the .5 to .2 mS positions and from the 5 to 2 µS positions, thus increasing the AUTO repetition rate of the multivibrator. Changing the AUTO repetition rate keeps the sweep intensity relatively constant despite changes in sweep rate.

SWEEP GENERATOR ⟨4⟩

General

The Sweep Generator provides a linear sawtooth voltage to the Horizontal Amplifier. It also controls the minimum time between sweeps and provides unblanking to the cathode-ray tube electron beam during sweep time. When EXT HORIZ operation is selected, the Sweep Generator stops generating sweep voltages and provides continuous unblanking to the cathode-ray tube. The unblanked state can be interrupted by application of an external blanking signal.

Block Diagram Description

Refer to the block diagram on the Sweep Generator schematic diagram page. Triggers from the Trigger Generator are received through C301 and applied to the Sweep Gate circuit, which then develops a negative gate. As a result, the Disconnect Diode stops conducting. This allows the Miller Circuit to create a linear sawtooth voltage which is sent to the Horizontal Amplifier. When the sawtooth has sufficient amplitude to provide full horizontal trace deflection, feedback current through the SWEEP LENGTH potentiometer is sufficient to reset the Sweep Gate circuit. The disconnect diode then conducts and the sweep voltage rapidly decreases to its initial value, causing retrace to occur.

The sweep must start at the same quiescent DC voltage level for each sweep, or horizontal jitter will appear. The same signal that causes retrace is therefore sent to the Holdoff Circuit to block triggers from the Sweep Gate until the sweep circuitry has stabilized. The holdoff time is controlled by capacitors which are selected by the various positions of the TIME/DIV switch.

The electron beam is only allowed to strike the face of the cathode-ray tube during sweep time. This is accomplished by connecting the Sweep Gate output to the Unblanking Amplifier. The cathode-ray tube is thereby unblanked when the sawtooth starts rising, and is turned off at the instant retrace is initiated. Unblanking can be disabled by injection of a positive signal through the EXT BLANK connector.

Sweep Generator

A knowledge of N-channel Field Effect Transistor (FET) operation and Tunnel Diode switching action is necessary for understanding the Sweep Generator circuit. The FET operation can be understood by simply comparing a triode vacuum tube to it, with the cathode, grid, and plate comparing to the source, gate, and drain respectively. Like the vacuum tube, the FET has high input impedance and only leakage current flows in the gate circuit.

Refer to the tunnel diode voltage-current graph in Fig. 3-2. A tunnel diode switching circuit is designed to take advantage of the fact that a tunnel diode has two stable states. A tunnel diode operating in its low voltage state to the left of point B will stabilize to a point on the curve which satisfies circuit voltage and current requirements. If a signal input causes the voltage or current to exceed the value at point B, the tunnel diode will switch (pass through the unstable negative resistance region) and stabilize to the right of C at a point which will again satisfy circuit requirements. It is then operating in its high voltage state, and will remain there as long as its voltage and current remain greater than indicated by point C. If the current or voltage falls below that value, the diode will again switch through the negative resistance region and return to its low state. The difference between low and high state operating voltages is commonly in the vicinity of one half volt.

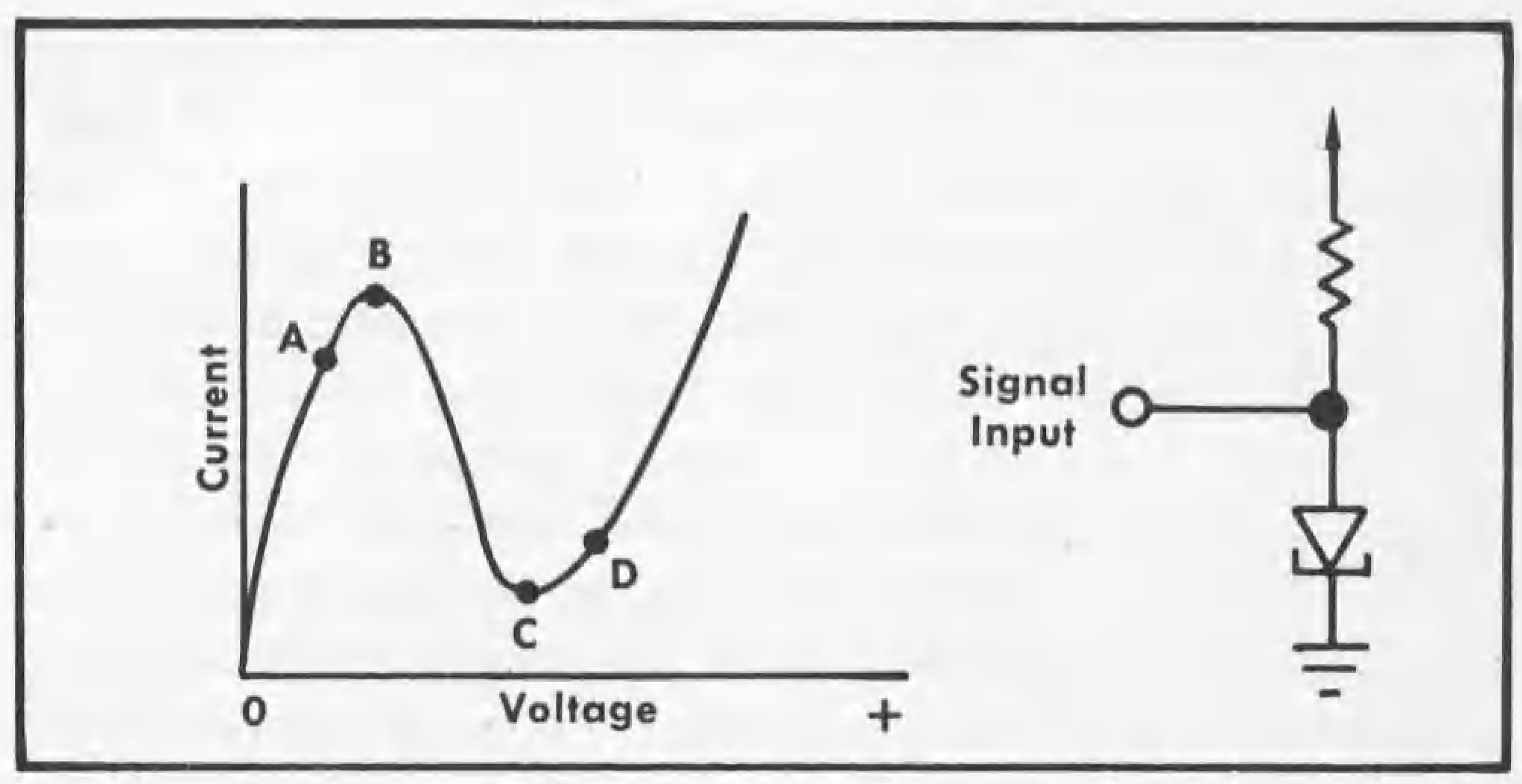


Fig. 3-2. Tunnel diode current-voltage graph and simplified circuit.

Circuits are designed to permit quiescent operation in either the high or low state at points such as A and D. Transients can then be used to cause switching action to occur, leaving the tunnel diode in the switched state after the transient has expired.

Refer to the schematic diagram of the Sweep Generator (and to the Timing Switch schematic as necessary). A summary of the purpose of components, and their status during a complete sweep cycle, is contained in Table 3-1.

TABLE 3-1

Operating Status of Sweep Generator Components

Component	Purpose	Status[1]			
		Quiescent	Sweep Rising	Retrace	Holdoff
D301	Holdoff Diode	On	Off	Off	Off
D303	Tunnel Diode	Low state	High State	Low state	Low State
D305	Gate Diode	On	Off	On	On
D309	Disconnect Diode	On	Off	On	On
D342/D343	Trigger Disabling Diodes	Off	On	On	Off
D350	Blanking Diode	On	Off	On	On
D353	Unblanking Diode	Off	On	Off	Off
Q305	Sweep Start/ Stop Switch	Off	Saturated	Off	Off
Q311, Q317 Q326, Q329	Sweep Amplifiers	On	On	On	On
Q343	Quiescent Position Switch	Saturated	Off	Off	Saturated
Q356	Unblanking Switch	Off	On	Off	Off
Q363	Unblanking Amplifier	Off	On	Off	Off
Q370	Plate Charging Switch	Off	Saturated	Off	Off
Q373	Plate Discharging Switch	Saturated	Off	Saturated	Saturated

[1]**Shaded areas indicate deviation from quiescent condition.**

Interaction requires that the circuit be explained as one unit, rather than as individual sections. The explanation starts with a trigger being received during quiescent circuit conditions, and goes through a complete cycle of operation.

Sweep Generation. The negative gate from the Trigger Generator is differentiated by C301 and the Sweep Generator input circuitry. A negative trigger thus developed causes increased conduction through D301 and D303. This current increase switches D303 to its high state, where it remains because of the R303 holding current. See Fig. 3-3 (A), (B) and (C). The resulting negative gate causes D305 to cut off, allowing the emitter of Q305 to go sufficiently negative for Q305 to saturate. R305 current (which has been flowing through D305) now flows through Q305 and R304. The collector voltage of Q305 goes negative and stops D309, Q343 and D350 from conducting. See Fig. 3-3(D). (Q343 has been in saturation with its base-emitter junction acting as a diode, connecting the emitter of Q329 to the gate of Q311 via D309). When Q343 cuts off, its positive-going collector voltage causes D342 and D343 to conduct, charging C340 and C342. The resulting positive voltage is coupled through R301, back biasing D301 so that triggers cannot pass through it until the sweep cycle has been completed. See Fig. 3-3(G), (H) and (B).

When Q305 causes D309 to stop conducting, the Miller Circuit goes into operation as follows: R330 (timing resistor) current, which had been flowing through D309, now charges C330, attempting to make the lower plate of the capacitor and the gate of Q311 go more negative. See Fig. 3-3(E). The resultant positive-going sawtooth signal at the Q311 drain increases the current drive to Q317. This causes a positive-going sawtooth voltage to be developed at the Q326 collector, and to be repeated at the Q329 emitter. See Fig. 3-3(F).

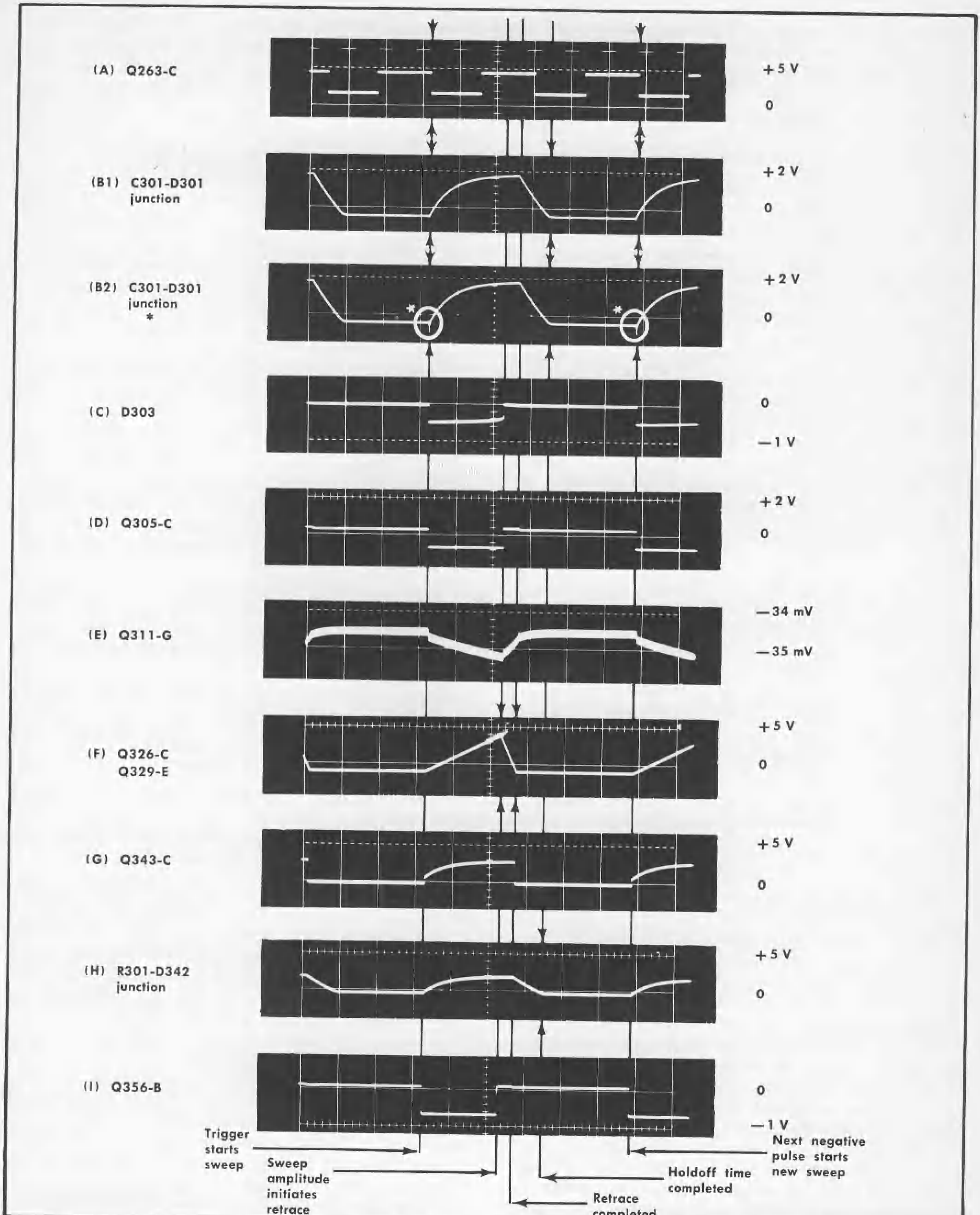


Fig. 3-3. Sweep Generator waveform analysis. Type 324 Oscilloscope sweep rate .1 ms/DIV. VOLTS/DIV switch set at 5 DIV CAL. Waveforms obtained with Type 547 Oscilloscope and C12 camera system; deflection factor 0.5 ms/div. *(B2) is the same as (B1) except that "B intens by 'A' " was used to show the triggers which initiate the sweep. 'A' Time/cm was set at 0.1 μs/div and a double exposure was taken, intensifying one of the trigger pulses each exposure.

The Q329 emitter voltage is applied to the upper plate of the Timing capacitor, C330. The upper plate of C330 goes positive at almost the same rate as the negative charge accumulates on the lower plate, keeping the lower plate at a relatively constant voltage with respect to ground. This results in an extremely small change across R330 during sweep time, keeping the R330 current constant. The constant current charges C330 at a constant rate, creating an extremely linear sweep voltage.

During generation of calibrated sweeps, the selected timing resistor (R330) is connected directly to −5 V. When the VARIABLE control (R334A) is moved from the CAL position, the voltage applied to R330 is decreased. The resulting increased time required to charge C330 causes a decrease in sweep rate (larger time/div value) from that indicated by the TIME/DIV switch.

Sweep Retrace. The positive-going Q329 emitter voltage causes an increasing amount of current to flow through R346 and SWEEP LENGTH potentiometer R347. This causes the current through D303 to decrease, because R303 current is relatively constant. D303 switches back to its low state as soon as its current drops below the amount required to hold it in the high state. See Fig. 3-3(C). The setting of R347 determines the output voltage (and therefore the sweep length) required to cause D303 to switch to its low state. D305 then goes into conduction, turning Q305 off. The positive signal at the Q305 collector enables D309 and D350. The positive potential coupled through D309 to the gate of Q311 causes the output at the Q329 emitter to drop until the voltage at the emitter of Q343 is low enough to permit Q343 to go back into saturation. See Fig. 3-3(D), (E), (F), (G). The output voltage feedback through the base-emitter junction of Q343 and through D309 causes the output voltage to stabilize at its quiescent value.

Holdoff Time. When Q305 cuts off and retrace is completed, the current from R343 again passes through Q343, saturating it. D342 and D343 stop conducting and the C342-R342-C340 junction discharges sufficiently for D301 to conduct and hold D303 in its low voltage state. The RC time of R342, C342 and C340 determines the time required before D301 can again conduct triggers. This delay is referred to as holdoff time. It allows the circuit to stabilize between sweeps, thereby minimizing sweep horizontal jitter. See Fig. 3-3(G), (H) and (B).

Oscillation of the Sweep Generator circuit is prevented by the addition of the C313, C316, R316 and C321.

Unblanking. The CRT is blanked during quiescence by the following conditions: Current from R355 flows through the Q373 base-emitter junction, saturating Q373. The voltage at the bottom of R355 sets the emitter of Q356 at about +0.6 V. The cathode of D353 is held at about 0 V by the potential on the base of Q343. The 0.6 V across D353 and Q356 base-emitter junction is not sufficient to cause forward conduction, and Q356 remains cut off. The voltage at the emitter of Q363 is also set by the Q373 emitter-base junction and is not sufficiently negative to cause Q363 to conduct. This causes both the base and the emitter of Q370 to be at +100 V, so that Q370 is also cut off. With Q370 cut off and Q373 saturated, the voltage at the Q370 collector is very near 0 V. This is connected to one of two opposing unblanking plates, the other of which is at +100 V whenever the oscilloscope is on. The electrostatic effect of the plates during the unbalanced condition prevents the beam from striking the face of the cathode-ray tube.

When a trigger signal causes Q301 to conduct, the negative gate which is coupled through D350 causes D353 and Q356 to go into conduction. The emitter voltage of Q356 decreases, turning Q373 off and D363 on. Current through R363 lowers the Q363 collector voltage by about 0.6 V, saturating Q370. This effectively connects the cathode-ray tube unblanking plate to +100 V, permitting the beam to strike the face of the CRT.

Application of a positive signal of 5 V or more at the EXT BLANK connector J350 will turn off Q356, again causing blanking to occur. Protection from large external blanking signals is provided by R351 and D351. Signals at the EXT BLANK connector in excess of approximately +8 V will cause D351 to go into conduction, limiting the signal at D353 to +5.6 V.

When the end of the sweep initiates retrace, Q305 turns off and D350 goes into conduction. This turns D353 and Q356 off and the circuit returns to its quiescent condition. C361, C362 and C364 improve circuit response sufficiently to cause the electron beam to be blanked before an appreciable amount of retrace occurs.

Residual voltage exists in the high voltage power supply for a brief period after the oscilloscope is turned off. As long as some voltage remains in the +100 V power supply, it appears on the non-driven unblanking deflection plate. Residual voltage in the +11 V supply is applied to the base of Q373 through contacts of the POWER switch and R369. This keeps Q373 in conduction, grounding the driven unblanking deflection plate, thereby keeping the CRT blanked while the high voltage power supply discharges and the CRT filament cools.

EXT HORIZ Operation. When EXT HORIZ operation is selected by the TIME/DIV switch, R340A is connected in parallel with R342. R330 and C330 (the timing components) become disconnected from the circuit. The parallel combination of R340 and R342 switches D303 to its high voltage state, turning Q305 on. Unblanking occurs, but disconnecting the timing resistor and the timing capacitor prevents a sweep from being generated. The intensity should be turned down under this condition to provide optimum viewing and to conserve operating power, thereby lengthening the operating cycle during internal battery powered operation.

HORIZONTAL AMPLIFIER ⟨6⟩

General

The Horizontal Amplifier accepts a horizontal sweep voltage from the Sweep Generator, amplifies it and applies the resulting push-pull signal to the horizontal deflection plates of the cathode-ray tube. During EXT HORIZ operation, the input from the Sweep Generator is disconnected, allowing EXT HORIZ input signals to be amplified and applied to the horizontal deflection plates. The overall gain of the amplifier is normally about 60 (Push-pull out —single-ended input) and increases by a factor of 5 during X5 HORIZ MAG operation.

Block Diagram Description

Refer to the block diagram on the Horizontal Amplifier schematic page. The horizontal sweep signal received from the Sweep Generator passes through a horizontal gain calibrating resistor, is processed by the Isolation Amplifier and is amplified by the Output Amplifier. The amplified signal is then applied to the left deflection plate of the cathode-ray tube. The Output Amplifier is an operational amplifier which uses R403-R404 as R_{in} during X1 gain operation, and R401-R402 during X5 operation. The Isolation Amplifier is a common base amplifier, isolating the input circuit from the Output Amplifier.

The signal from the Output Amplifier also drives the Output Inverter, which supplies the signal to the right deflection plate. The Output Inverter is also an operational amplifier and has a gain of one under all operating conditions.

The Output Amplifier and Output Inverter circuits both have current control circuits associated with them to provide the additional current required during retrace time and fast sweep operation.

The quiescent beam position (and therefore the horizontal area through which the beam moves) can be selected by the POSITION control, and it is normally set to start the sweep at the first vertical mark at the left of the graticule. During X5 HORIZ MAG operation, the POSITION control range permits any 20% of the normal sweep to be presented as a 10 division sweep.

When EXT HORIZ operation is selected by the TIME/DIV switch, the Horizontal Amplifier circuit operates exactly as previously explained, except that the sweep signal from the Sweep Generator circuit has been replaced by an externally applied signal. When the EXT HORIZ VAR control is fully clockwise, R334B is bypassed. The external horizontal gain will decrease to 1/10 of its previous value when the control is rotated fully counterclockwise.

Output Amplifier and Output Inverter

Refer to the schematic, and assume that a positive-going sweep signal is arriving at the input of the amplifier. The positive-going signal is felt at the emitter of Q440, increasing the Q440 collector current. The positive-going collector voltage is felt at the base of Q451. Q451 and Q453 form a non-inverting amplifier circuit, and a positive signal is developed at the Q453 collector. This signal is amplified and inverted by Q457, providing a negative-going signal for the left deflection plate. The collector voltage of Q457 is also applied to feedback circuit R452-C452. The changing collector voltage of Q457 causes most of the signal current required by the input signal to flow through the R452-C452 network. Therefore, only a very small part of the input signal is felt at the base of Q451 and at the emitter of Q440.

The gain of the Output Amplifier is determined principally by the ratio of feedback resistor R452 to the input resistance of R403-R404. This is equal to approximately 30 during X1 gain conditions. When X5 gain has been selected, the input resistance is decreased to approximately 1/5 of its previous value, resulting in a circuit gain of approximately 150.

The voltage at the collector of Q457 is also applied through R470 to the Q470-Q473 Output Inverter circuit. This circuit is also an operational amplifier, with the feedback resistor (R471) equal to the input resistor (R470). Gain of the circuit is therefore equal to one, providing an equal but opposite polarity signal to the right deflection plate.

It is desirable that the center two divisions of X1 display be presented as a 10 division display during X5 GAIN operation. Potentiometers R438 and R432 permit the circuit current to be adjusted as necessary to permit this situation to occur.

The current flowing through the summing node at the emitter of Q440 determines the circuit output voltages, and therefore, the beam position. The POSITION control modifies this summing node current by using a dual potentiometer arrangement for coarse and fine positioning. The fine potentiometer (R421) has its pickoff voltage connected through a large resistor and through Power Amplifier Q420 to the summing node. The POSITION control can move the fine potentiometer wiper 30° independent of the coarse potentiometer, moving the trace one division in X1 mode, and five division in X5 mode. Continued movement of the POSITION control causes both of the wipers to move. Combined movement of the coarse and fine wipers permits an approximate 14 division total horizontal movement range in X1 mode. R444 is also capable of modifying the position traversed by the sweep. When R444 is properly adjusted, either end of a 10 division sweep can be displayed at graticule center by adjustment of the POSITION control.

Current Control Circuits

Standing current for Q457 is provided by Q464 and its associated emitter circuit, which consists of Q460 and resistors R460, R461, R462 and R463. The base voltage of Q464 is established by Zener diode D442. This dictates the voltage at the Q464 emitter and therefore at the base Q460. Q460 and R463 provide the principal current paths for Q464. When slow sweep rates are selected, this current is relatively unchanged by the sweep signal. The Q473 standing current circuit is constructed in a similar manner.

When fast sweep rates are selected, the positive-going signal at the Q453 collector is felt through C462 at the base of Q460. This decreases the drive to Q460 and therefore to Q464, aiding in the generation of the negative-going signal the left deflection plate. During this same time, the negative-going signal at the Q470 emitter is coupled through C480 to the base of Q480. This increases the Q480 drive current and therefore the Q484 current, aiding in the generation of the positive-going signal for the right deflection plate. During retrace, the signal changes in a direction opposite to that just described, and the Q460 and Q480 circuits reverse their functions.

EXT HORIZ Operation

When EXT HORIZ operation is selected by the TIME/DIV switch, the Sweep Generator is disconnected from the Horizontal Amplifier, and the EXT HORIZ Amplifier circuit is connected in its place. External horizontal signals from Q215 are then processed by grounded base amplifier Q411. R334B and R410 then act as R_{in} for the operational amplifier. R334B can vary the gain at the Q457 collector between approximately 50 and 250.

POWER REGULATOR AND CRT CIRCUIT ⟨7⟩

General

The Power Regulator converts DC voltage (from the Power Pack) into the various operating voltages required by the oscilloscope. Employing a blocking oscillator, a flyback-type transformer, rectifiers and filters, it develops the following voltages: + and −5, +8.5, +11, + and −100, +175, and −1900 V DC, and 0.6 V AC. The −100 V supply is used only within the regulator circuitry, and the 0.6 V AC supplies the CRT filament power.

Block Diagram Description

Refer to the block diagram contained on the Power Regulator and CRT Circuit schematic page. When the POWER switch is closed, the Blocking Oscillator goes into operation, alternately causing the Energy Storage Switch to turn on and off. When the Energy Storage switch conducts, current flows through T538 primary, storing energy in the transformer. When Q529 stops conducting, the energy stored in T538 is delivered to the secondary windings, proving power to the previously mentioned supplies.

A Feedback Circuit, an Error Amplifier (Q515) and a Blocking Oscillator circuit (Q518) combine to determine the frequency at which the Q525/Q529 circuit operates. Initially, input power is applied through the Zener Reference line to the Start and Reference Circuit and then through a summing network to the Error Amplifier. Current flows through Q518, starting the oscillator. The Zener Reference voltage then develops in the secondary circuit and feeds back through the Start and Reference Circuit to the Error Amplifier. When the −100 V supply builds up, its feedback current flows through the summing network to offset the current from the Start and Reference circuit. A slight difference between the two feedback currents provides a drive current to the Error Amplifier, holding the Blocking Oscillator at its required frequency.

When CRT intensity is at a minimum, practically no cathode current flows, and a minimum amount of power is required by the high-voltage circuit. As CRT intensity is increased, cathode current increases. The CRT cathode voltage start to diminish, due to the increased drop across the high-voltage multiplier components. A CRT Cathode Current Sense circuit is designed to counteract this voltage loss by sending proportional changes of feedback current to the summing point. The Error Amplifier and Blocking Oscillator Control circuits cause the Blocking Oscillator to decrease its frequency. The Energy Storage switch then conducts longer, delivering more energy to the T538 primary. The additional high voltage power required by the increased cathode current is thus made available.

Blocking Oscillator Operation

Refer to the schematic diagram. When power is applied, a positive voltage appears at the collectors of Q515 and Q529, at the emitter of Q518, and at the base of Q515. Q515 conducts and supplies Q518 with base-emitter current, forward biasing Q518.

The forward-biased Q518 pulls the anode of D523 positive and forward-biases the base-emitter circuit of Q529, causing collector current to flow through the T538 N1 winding. The voltage induced into the N2 winding is regenerative to the base of Q529, turning it on fully. When the maximum Q529 base and collector current permitted by Q518 is flowing, current stops changing in the N1 winding. The N2 voltage decreases, decreasing the drive to Q529. Q529 collector current then decreases, and the field built up by N1 starts to collapse.

The voltage induced into the N2 and N3 windings is of opposite polarity with respect to the previous half cycle. It now simultaneously back biases D523 and causes Q525 to conduct. This rapidly cuts off Q529 and induces power into the secondary windings.

At the end of turn-off time, the N2 field collapses, Q518 again pulls the D523 anode positive, Q529 starts to conduct, and the cycle repeats itself.

The oscillator frequency varies indirectly with oscilloscope power requirements, since the power induced into the secondary varies directly with Q529 "on" time.

The collapsing magnetic field that occurs when Q529 turns off causes a large positive voltage at the Q529 collector. This charges C531 through D531. When Q529 again saturates, C531 attempts to discharge through D533 keeping C533 charged up to approximately −100 V.

Q518 current (Q529 drive current) is controlled by Q515 collector current, which is established as a function of reference voltage (from D547 through R513 and R514) in combination with the −100 V (through R535) and cathode current sensing feedback (through R515). As CRT cathode current increases, the voltage developed across R572 increases, causing an increase in Q515 and Q518 current. The resulting increase in Q518 drive keeps Q529 conducting longer, stores more energy in T538, and delivers more power to the secondary of T538.

The longer Q529 "on" time causes the charge on C533 to become more negative. The resulting increase in feedback current through R535 offsets most of the cathode current feedback (from R572), stabilizing the circuit. This action prevents an appreciable change of high voltage from occurring as a result of increased CRT current.

D516 temperature-compensates Q515 and sets its emitter at −0.6 volt. D517 bypasses R516 during turn on. D523 protects the base circuit of Q529 from large negative spikes which develop in the N2 winding when Q529 turns off. D525 bypasses Q518 during Q529 turn-off time, clamping one side of the N2 winding at the value of the Power Pack voltage.

C521 bypasses R521 to speed up on the Q529 switching action. C529 and L501 perform the dual function of filtering input pulses during AC operation, and minimizing radiation out of the power supply line. C587 provides decoupling on the reference voltage line.

+100 V Power Supply

When Q529 is conducting, energy is being stored in the magnetic circuit of T538. When Q529 turns off, the voltage generated at the Q529 collector causes current to flow through D543, charging C543 to approximately +100 V.

+175 V Power Supply

The N4 secondary winding of T538 has one side referenced to the +100 V pickoff point and the other side connected to D541. During the time the primary field is collapsing, voltage is induced into this secondary, adding its value to that at the +100 V pickoff point. Current flows through D541 and L541, developing +175 V across C540.

+5 V Power Supply

The +5 V Power Supply is directly powered by voltage from the Power Pack. However, regulation is dependent upon the +8.6 V reference provided by Zener diode D547, and series regulator Q557.

Error sensor Q555 constantly compares the voltage at the wiper of R552 against the +5 V output at the Q555 emitter. This comparison determines the drive current to Q558, which then controls the total Q557 emitter current. For example, if the +5 V supply tends to increase, Q555 decreases conduction, which decreases Q558 current drive. This decreases the current drive to Q557. Q557 decreases conduction and holds the +5 V supply within its specified limits. The +5 V output is filtered by C559 and L559 before being applied to external circuits.

−5 V Power Supply

The output of the +5 V Power Supply is used as the reference for the −5 V supply. The −5 V supply is derived from the output of the N7 winding of T538 and is rectified by D560 and D561. This voltage determines the voltage at the emitters of Q567 and Q569. Current through R565, R566 and R567 determines the drive to Q562. Q562 provides drive current to Q567, which then controls Q569. A comparison between the −5 V output at the collector of Q569 is made against the +5 V supply, and a voltage near −0.6 V is applied to the base of Q562. If the −5 V supply tends to go positive, current through Q562 decreases. This decreases the Q567 emitter-base current, which decreases its collector current. The Q567 collector voltage tries to rise, thereby increasing the Q569 emitter-base current. This causes an increase in Q569 collector current. The increase of collector current increases the current through the load, keeping the −5 V supply within design limits.

+11 V and +8.5 V Power Supplies

One side of the N6 secondary winding is referenced to the +5 V Power Supply line. Positive pulses from the upper side of the winding add to the 5 V reference and are applied through D549 and R549 to generate the +11 V power supply. The N6 winding also supplies current through D545 and R547 to develop the +8.6 V reference across D547. This is filtered by L551, providing an 8.5 V decoupled output.

Since the +8.6 V is not present during turn-on, current from the Power Pack flows through R550, R572 and D551 to provide starting power to the oscillator control circuit. D550 limits this starting voltage to +7.2 V at the R550-R572 junction. After the oscillator has started, the voltage across D547 increases to its prescribed +8.6 V, and D551 becomes back-biased, isolating the +8.6 V reference from the Power Pack input voltage.

High Voltage Power Supply

The N5 secondary winding drives the High Voltage Multiplier which consists of D575 and C573-C579. The multiplier has three negative high-voltage taps: one at −1900 V to supply the CRT cathode; one at −2250 V supplying the INTENSITY control circuit; and one at −1200 V for the FOCUS circuit. The −1900 V tap is connected into the CRT directly-heated cathode circuit in a manner that keeps the AC filament voltage from changing the cathode potential with respect to the grid, thus eliminating CRT intensity changes. The INTENSITY LIMIT control, R538, is an internal adjustment which sets the minimum voltage difference which can exist between the control grid and cathode. This avoids cathode damage caused by excessive cathode current.

The least negative voltage taken from the High Voltage Power Supply appears at CRT pin 13, the focus anode. The setting of the FOCUS potentiometer, R581, in combination with ASTIG potentiometer R597, determines the sharpness of the trace presentation. Only the FOCUS control is used during routine operation, and it is capable of focusing the trace at any intensity setting once the ASTIG control has been properly set.

CRT Circuit

+100 V appears at pin 5 whenever the oscillocope is energized. Pin 9 has 0 V applied except during sweep time or external horizontal operation, during which time +100 V is applied. When the voltages at pins 5 and 9 are unbalanced, the CRT beam is deflected into the pin 9 plate and cannot strike the CRT phosphor. When +100 V is applied to both plates, the deflection effect is nulled, and position control is exercised by the horizontal and vertical deflection plates.

The GEOMETRY control adjusts for a minimum amount of bowing of vertical and horizontal lines, regardless of the area to which they are positioned.

The TRACE ROTATION potentiometer (R592) controls the current through the trace rotation coil, thus creating a magnetic field through which the CRT electron beam passes. When TRACE ROTATION is properly adjusted, horizontal sweep voltages will cause the trace to follow the paths which are parallel to the horizontal graticule lines.

Explanations regarding the remaining CRT elements appear in conjunction with the High Voltage Power Supply description.

Low Battery Sensing Circuit

The Low Battery Sensing Circuit employs a relaxation oscillator (R506, C507 and DS509) operating at a frequency of approximately 1 Hz. When the input power exceeds 6.5 V, Q571 is saturated and the voltage at its collector is not sufficient to fire the neon LOW BATT indicator, DS509. When the input falls below 6.5 V, Q571 turns off and C507 charges toward +100 V until DS509 fires and partially discharges C507. The cycle then repeats.

Although DS509 will blink in any power mode when the supply is less than 6.5 V, it is of primary concern during internal battery operation. If the oscilloscope is left energized in the internal battery mode for a considerable period of time after the battery output falls below 6.5 V, the cells may be damaged to the point where they can no longer be charged.

POWER PACK ⟨8⟩

General

The Power Pack contains the battery which supplies the internal power, connectors for applying external AC or DC power, a transformer and rectifiers for AC operation, and a battery charging circuit for recharging the internal battery from an external AC source. The switching circuitry which selects the power source is also contained in the Power Pack.

Block Diagram Description

Refer to the block diagram contained on the Power Pack schematic diagram page.

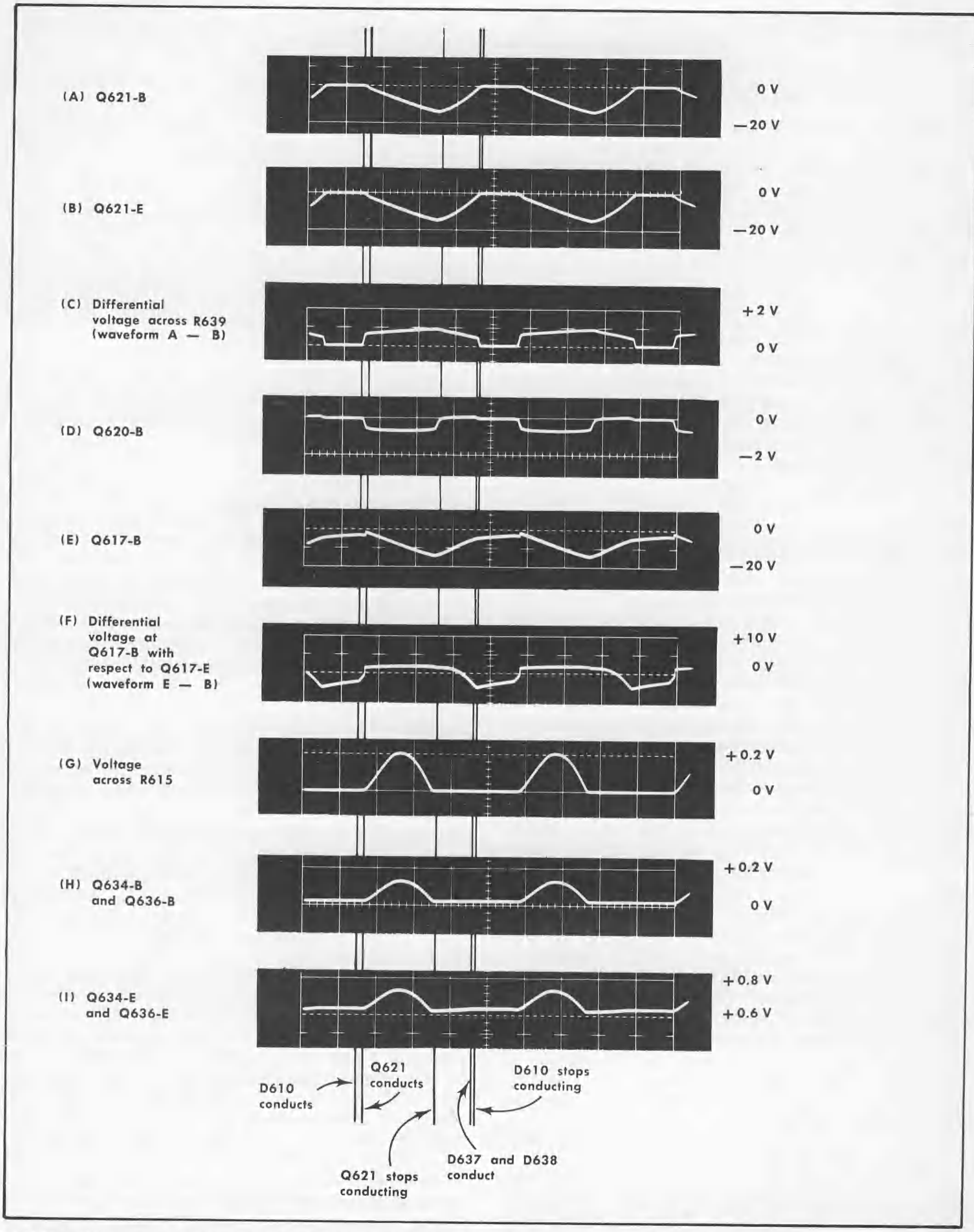


Fig. 3-4. Battery charger waveform analysis during full charge operation with oscilloscope OFF. Ground is used as reference except for (C) and (F). Waveforms are indicative of fully charged batteries. Amplitudes change with battery charge rate and ON/OFF status of the oscilloscope.

S612 is a multiple contact switch which has three positions—EXT DC, TRICKLE CHG and FULL CHG. In EXT DC position, power is routed from the DC input jacks to the oscilloscope POWER switch, S501. The internal battery and the battery charging circuit are disconnected from the rest of the oscilloscope in this mode of operation.

With S612 in FULL CHG or TRICKLE CHG position, either AC or internal battery operation is possible. With no AC applied, the battery supplies the power. When AC is applied, the transformer supplies operating power, and provides battery charging power during part of each input half cycle. When the output of the transformer secondary falls below a certain level, diodes disconnect the tranformer from the charging circuit and the battery supplies the operating power until the power supply diodes again conduct. In effect, the battery acts as a large filter capacitor for oscillope operation when AC is applied. In the AC mode of operation, a reference voltage is developed across D649. The Comparator Amplifier compares a portion of this reference to the voltage generated by the battery charging current flows through R615. The Comparator Amplifier output controls the Driver Amplifier, which controls the conduction of the Series Regulator Q617, thereby determining the battery charging current. The battery charging circuit is independent of the POWER switch, operating whenever AC power is applied (S612 in FULL CHG or TRICKLE CHG position).

Battery Charger

Refer to the Power Pack schematic. When AC power is applied, the output of the upper secondary winding of T601 is rectified by D605 and filtered by C605. The bottom of C605 is connected to the positive side of the battery. The charge on C605 is in series with the battery, and their combined voltage is applied to the R605-D649 combination. D649 provides a 6.2 V reference for battery charger operation.

This 6.2 V reference voltage is applied to R643-R644, setting the Q636 base voltage. This voltage is compared to the Q634 base voltage (average voltage across R615) to determine the division of R635 current between Q634 and Q636.

The lower secondary winding of T601 delivers charging and operating current through full-wave rectifier D610. The positive side of the rectifier is connected to the positive side of the battery, and the negative side is connected through the series regulator circuit to the battery negative side. There is a time interval between pulse peaks during which time D610 does not conduct. See Fig. 3-4(B). The current from Q634 and Q636 is then shunted to ground through D637 and D638, keeping Q634 and Q636 from saturating.

When the half-cycle output voltage of T601 secondary becomes large enough to overcome the battery voltage, D610 goes into conduction, delivering a negative-going voltage pulse to the battery charging network. R635 current starts to flow through R639, R637 and R638. See Fig. 3-4(A) and (C). The combination of a negative-going voltage at the emitter of Q621 and the voltage developed across R639 causes Q621 to conduct, supplying current drive to Q620, which supplies current drive to Q617. See Fig. 3-4(D), (E), and (F).

Q617 goes into conduction once each half-cycle and the resulting current develops a positive pulse across R615. See Fig. 3-4(G). Voltage-divider action causes a portion of each pulse to be developed at the base of Q634. C636 charges up to the average voltage, thus developing the Q634 base voltage. The comparison of this average voltage to that set on the base of Q636 (by CHARGE RATE potentiometer R644) determines how much drive current is provided to Q621. If an increase of line voltage attempts to increase the charging rate, C636 charges to a higher average value, decreasing the drive current to Q634 and Q621. This decreases the drive current to Q617, keeping the R615 charging pulses (and therefore the battery charging rate) within design limits.

It should be noted that even though C636 is charged to the average of the input pulses, almost identical pulses are present at the bases of Q634 and Q636, so that the current division between the two transistors is not upset during the presence of a charging pulse. See Fig. 3-4(H) and (I).

During TRICKLE CHARGE operation, R633 provides current to R630. This increases the voltage at the base of Q634 and decreases the current through R639. With less drive, Q621 provides less drive current to Q620, which decreases the drive current to Q617. The current that Q617 delivers to the battery is thereby reduced to a trickle charge rate. See Fig. 3-5(A).

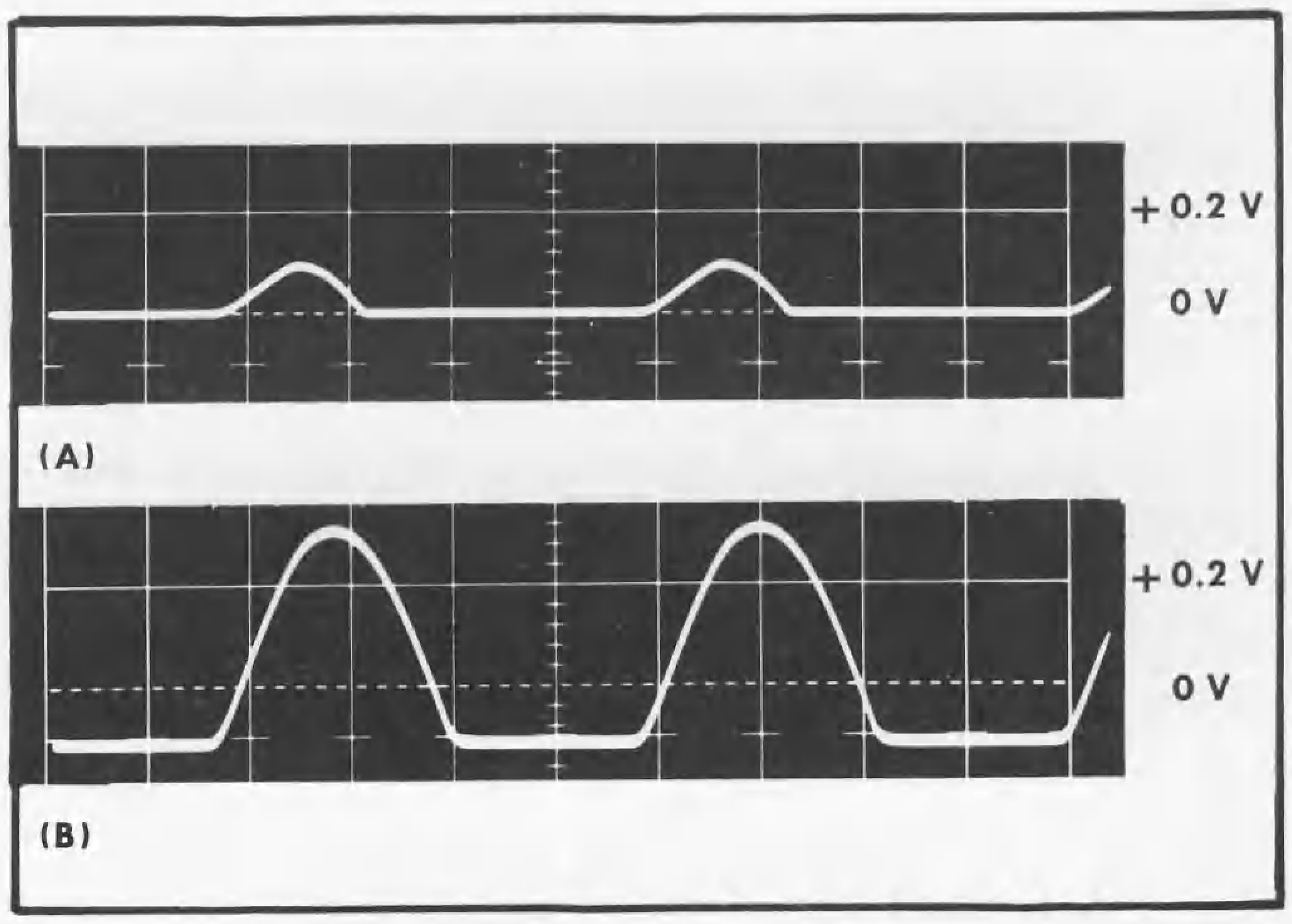


Fig. 3-5. Voltage across R615 during (A) TRICKLE CHG operation with the oscilloscope OFF, and (B) FULL CHG operation with the oscilloscope ON and INTENSITY at maximum brightness setting.

When the Power Pack is being charged and the oscilloscope POWER switch is turned on, the base of Q634 is driven negative between charging current pulses. This occurs because the battery reverses current flow through R615 while it supplies the oscilloscope with power. The net result is that the average charge on C636 tends to decrease, providing more drive to Q634. This permits more current to flow through Q617, keeping the average charge on C636 at its previous value by supplying the battery with additional current to make up for that being drained between half cycles. See Fig. 3-5(B).

SECTION 4
MAINTENANCE

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

Introduction

This section of the manual contains maintenance information for use in preventive maintenance, corrective maintenance or troubleshooting of the Type 324.

Cabinet Removal

Cabinet removal and replacement information appears in the Power Pack Operating Procedure in Section 2, Operating Instructions. The precautions outlined there should be observed to avoid personal injury or equipment damage during cabinet removal or replacement.

PREVENTIVE MAINTENANCE

General Information

The Type 324 Oscilloscope should be cleaned, lubricated, inspected and recalibrated at regular intervals. A recommended schedule for average operating conditions is every 6 months or every 500 hours of operation, whichever occurs first. Additional information regarding maintenance of the Power Pack is contained under the Disassembly and Assembly part of this section.

Cleaning

Cleaning the Type 324 Oscilloscope, in addition to improving its appearance, aids its operation and lengthens its operating life. Dirt on components can result in short circuits. A dry, soft cloth and soft-bristled brush are recommended for removing loose dirt from the outside of the instrument. Dirt on the inside should be loosened with a soft-bristled brush and removed by using a vacuum cleaner or a stream of low-pressure air. High-pressure air can damage the equipment and should not be used.

WARNING

Use an eye-shield when cleaning with pressurized air.

Hardened dirt should be removed by using a mild detergent and water solution on a cotton-tipped swab or a soft cloth. Remove the Power Pack before using the solution on the oscilloscope. Avoid excessive use of water. Do not allow water to penetrate any parts. Dry the instrument thoroughly before energizing it. Avoid the use of abrasives and chemical cleaning agents. Protect the oscilloscope from dirt and damage by keeping it covered when not in use.

Soap and water should not be used on the Power Pack unless one lead from the battery pack is unsoldered and taped up. The unit must be allowed to dry thoroughly before reconnecting the lead. The battery compartment should be checked for dirt and corrosion during the maintenance period. Corroded areas should be cleaned with a neutralizing solution of 2% borax and water to prevent further corrosion. Disassembly and Assembly instructions appear later in this section, and should be referred to before opening the battery compartment.

Visual Inspection

After cleaning, the instrument should be carefully inspected for defects such as poor connections, damaged parts and improperly seated transistors. Damaged parts require that the cause of the damage be eliminated before operation is resumed.

Lubrication

Keep all moving parts properly lubricated using a cleaning-type lubricant on shaft bushings and switch contacts. Lubricate switch detents and screw threads with a slight amount of grease. Do not overlubricate. Proper lubricants and lubricating instructions are contained in Tektronix lubrication kit, Part No. 003-0342-00. Contact the Tektronix Field Representative if additional information regarding lubricants or lubrication is required.

Transistor Checks

Checking transistors as a preventive maintenance function is not recommended. Circuit performance is thoroughly checked during calibration; unacceptable transistors will be detected at that time.

Recalibration

The calibration status of an instrument should be determined as a part of preventive maintenance for several reasons: 1) The calibration of an instrument changes slightly with age, use and operating conditions; 2) calibration may be affected during the cleaning process; and 3) checking the calibration status may reveal troubles which are not obvious during regular operation.

TROUBLESHOOTING

Test Equipment

The test equipment listed here should suffice for most troubleshooting jobs on the Type 324 Oscilloscope.

High Impedance Voltmeter (10,000 Ω/V DC or greater)

Ohmmeter; 1 1/2-V source supplying less than 2 mA of current on the X 1 k scale.

Test oscilloscope (2 MHz bandwidth; 25 MHz bandwidth for troubleshooting Vertical Amplifier high frequency problems)

Transistor Curve Tracer or Transistor Tester

General Techniques

Proper troubleshooting logic is the most important tool in equipment repair. The following guide provides a logical sequence for analyzing equipment failures:

1. Check all external control settings.

2. Determine that operating procedure is correct.

3. Determine all of the trouble symptoms.

4. Perform a visual inspection.

5. Troubleshoot the circuitry; repair as necessary.

6. Check the calibration status; recalibrate as necessary.

Control Settings and Operating Procedures. Refer to the Operating Instructions section to verify external control settings and operating procedure.

Trouble Symptoms. After it is confirmed that trouble exists, the response to all exterior controls should be observed. The first-time operation listed in Section 2 can be used for this purpose. All trouble symptoms should be evaluated and compared against each other. A good example of this is power supply trouble, which will usually cause problems in otherwise unrelated circuits.

Visual Inspection. In visually examining the Type 324 Oscilloscope, take special note of the area indicated by evaluation of symptoms. Look for loose or broken connections, improperly seated transistors, and burned or otherwise damage components. Repair all obviously defective parts. Investigate the cause of heat damage to components.

Detailed Troubleshooting. If the trouble has not been disclosed and corrected through the procedure outlined, a detailed troubleshooting analysis must be performed. The Circuit Description section, the Schematic Diagrams, the Calibration Procedure, and the Troubleshooting aids contained in this section are designed to expedite troubleshooting.

The Circuit Description Section provides a fundamental understanding of circuit operation and is referenced to the Schematic Diagrams. The Schematic Diagrams contain voltage and resistance values and signal waveforms. All specified operating conditions should be duplicated before making voltage or waveform comparisons. In cases where the black numbers and blue numbers on the schematics give conflicting voltage values, the blue numbers should be used.

NOTE

Voltages and waveforms may vary slightly between individual Type 324 Oscilloscopes and are also dependent upon the characteristics of the test equipment used to obtain them. Voltages and waveforms given in the schematics should be checked against each instrument while it is operating properly. Deviations should be noted on the schematics for later reference.

Calibration. Although the calibration procedure is intended primarily for instrument calibration, it can serve as an efficient troubleshooting aid. Since each step is based upon satisfactory performance of the preceding steps, the problem circuit will be encountered before circuits which are dependent upon it.

Troubleshooting Basic Components

Transistors and Diodes. The quantity of semi-conductor devices in the Type 324 Oscilloscope requires that anyone working on it have a general knowledge of semi-conductor operation. Some basic information is presented here to aid in this respect.

Direct Replacement. Once a casualty has been isolated to a specific circuit, the ease of replacing transistors often makes substitution the fastest means of repair. Use the following instructions if the replacement method is used:

Determine that the circuit is safe for the substitute component.

Use only known-good substitutes.

Have only one transistor out of the instrument at a time to avoid mixing them up.

Insert transistors properly, using Fig. 4-13 as a guide.

Check operation after each component is replaced, and be sure to return good components to their original sockets.

If the trouble is not corrected by this procedure, recheck the semi-conductors under operating conditions.

Check calibration after a bad component has been replaced.

WARNING

Voltage, either positive or negative, is often present on the cases of metal-cased transistors when the oscilloscope is energized.

Transistor Troubleshooting. Transistor defects usually take the form of the transistor opening, shorting, or developing excessive leakage. The best means of checking a transistor for these and other defects is by using a transistor curve display instrument such as a Tektronix Type 576. If a transistor checker is not readily available, a defective transistor can be found by signal tracing, by making in-circuit voltage checks, by measuring the transistor resistances, or by the substitution method previously described.

When troubleshooting with a voltmeter, measure the emitter-to-base and emitter-to-collector voltages to determine if the voltages are consistent with normal circuit voltages. Voltages across a transistor vary with the type of device and its circuit function. Some of these voltages are predictable. The base-emitter voltage of a conducting germanium transistor will normally be 0.3 V and that of a silicon transistor will normally be 0.6 to 0.7 V. The collector-emitter voltage of saturated transistors will vary between 30 mV and 0.2 V, approximately. Because these values are small, the best way to check them is by connecting the voltmeter across the junction and using a sensitive voltmeter setting, rather than by comparing two voltages taken with respect to ground.

If values less than these are obtained, either the device is shorted or no current is flowing in the circuit. If values are in excess of the base-emitter values given, the junction is back-biased or the device is defective (open). Values in excess of those given for emitter-collector could indicate either a non-saturated device operating normally, or a defective (open) transistor. If the device is conducting, voltage will be developed across resistances in series with it; whereas if it is open, no voltage will be developed across resistances in series with it unless current is being supplied by a parallel path.

An ohmmeter can be used to check a transistor if the ohmmeter's voltage source and current are kept within safe limits. 1-1/2 volts and 2 mA are generally acceptable. Selecting the X1 k scale on most ohmmeters will automatically provide safe voltages and currents. If the voltage and maximum output current of a specific ohmmeter is in doubt, it should be checked before using it on transistors by connecting the test leads to another multimeter.

CAUTION

A transistor's specifications should be checked to determine maximum allowable ratings before subjecting it or associated circuits to voltage or current higher than that recommended.

Table 4-1 contains the normal values of resistance to expect when making an ohmmeter check on an otherwise unconnected transistor. Fig. 4-13 illustrates transistors and sockets for pin location purposes.

TABLE 4-1

Transistor Resistance Checks

Ohmmeter Connections[1]	Resistance Readings That Can Be Expected When Using the R X 1 k Range (1.5 V ohmmeter operating voltage)
Emitter-Collector	High readings both ways (100 Ω to 500 kΩ, approximately)
Emitter-Base	High reading one way (200 kΩ or more). Low reading the other way (400 Ω to 3.5 kΩ, approximately)
Base-Collector	High reading one way (200 kΩ or more). Low reading the other way (400 Ω to 3.5 kΩ, approximately)

[1] Reverse the test lead connections to make the second reading. Reversal of the applied voltage polarity causes the junction to shift between being reverse and forward biased, as indicated by the difference in resistance.

Field Effect Transistor Checks. The voltage and resistance of field effect transistors can be checked in the same manner as transistors. However, it should be remembered that normal operation in the Type 324 Oscilloscope has the gate-to-source junction reverse biased, in a manner similar to control grid to cathode bias in vacuum tubes. 1-1/2 V and less than 2 mA should be used for ohmmeter checks. Resistance readings should be:

drain-to-source	Less than 500 Ω
gate-to-source and gate-to-drain	400 Ω to 10 kΩ (approximately) in one direction; more than 200 kΩ with leads reversed

Diode Troubleshooting. Checks on diodes (other than Zeners) can be performed in much the same manner as on transistor base-emitter junctions. Germanium diodes should have approximately 0.3 V and silicon diodes should have about 0.6 V across the junction when conducting. Higher readings indicate that they are either back biased or defective, depending on polarity. The ohmmeter precautions pertaining to transistors should also be observed when checking diodes.

Some diodes used in the Type 324 Oscilloscope are color coded to identify the diode type. A blue or pink first band indicates that the next three colors translate to the last three digits of its part number. Diode polarity can be determined by color code position. See Fig. 4-1.

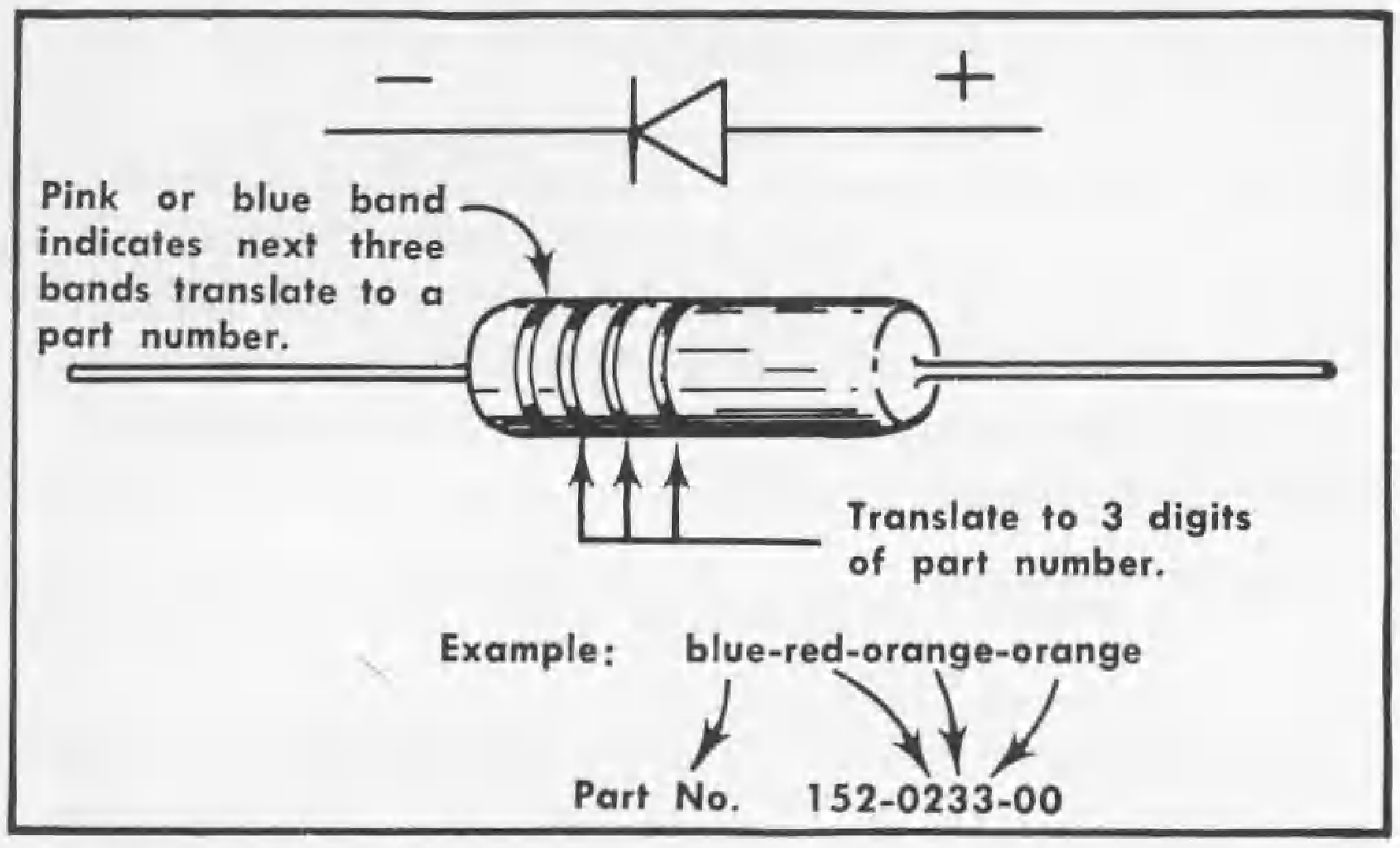


Fig. 4-1. Diode color code related to part number and conducting polarity.

NOTE

The positive side of an ohmmeter voltage source is often connected to the meter common test lead.

Resistors. The same ohmmeter voltage and current precautions observed in transistor troubleshooting also apply when making in-circuit resistance checks. Because semiconductor devices are present, most resistors in the Type 324 must be disconnected before reliable resistor checks can be made.

The types of resistors found in this instrument vary in accordance with the circuit needs. Composition, metal film and wire-wound resistors are used. Replacement resistors should be of the same type and must be at least as accurate as those originally in the circuit to maintain performance standards. The size, location and lead length are often critical because of frequency considerations.

Resistor values are indicated by one of three methods in the Type 324 Oscilloscope:

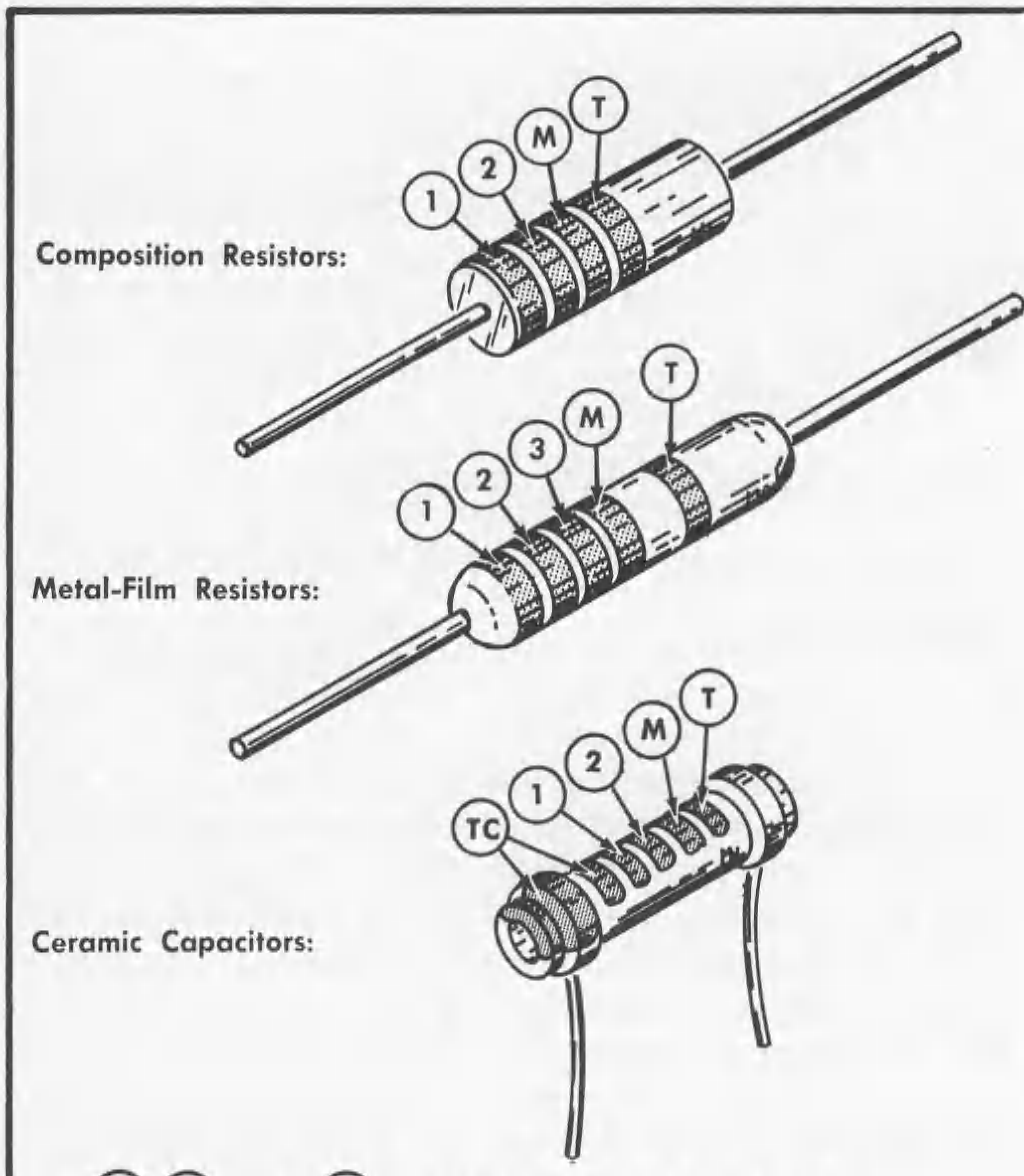
3 color bands (digit, digit, multiplier—tolerance)

4 color bands (digit, digit, digit, multiplier—tolerance)

Numbers printed on wire wound and metal film resistors

The first two methods translate to the IEEE color-code equivalent and are illustrated in Fig. 4-2.

Wiring Information. Insulated wires in the Type 324 Oscilloscope are color coded to make wire tracing easier. When it is necessary to disconnect several wires from components, record the wire color coding. In case of doubt in reconnecting wires, use an ohmmeter to insure selection of the proper lead.



(1) (2) and (3) —1st, 2nd and 3rd significant figures;
(M) —multiplier; (T) —tolerance;
(TC) —temperature coefficient.

Resistor and Capacitor Color Code

Color	Significant Figures	Multiplier		Tolerance	
		Resistors	Capacitors	Resistors	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. 4-2. Color-code for resistors and ceramic capacitors.

Switches. Rotary switch wafers are coded with a number and a letter on the schematic diagrams. The number indicates the wafer position in the switch assembly, counting from the front (mounting end). The letters "F" and "R" indicate whether the front or rear of the wafer performs the switching action. For example, a switch section designated 2R is contained on the rear of the second wafer as viewed from the front of the switch.

Individual switch wafers or mechanical parts of rotary switches are normally not replaced. If a switch is defective, replace the entire assembly. Wired or unwired replacement switches are available; refer to the Parts List for part numbers. When a switch is removed, make careful notation of the lead connections for installation reference.

Troubleshooting Charts

General. The troubleshooting charts contained here are designed to permit finding the malfunctioning circuit with a minimum of steps. The Master Troubleshooting Chart can be used without removing the cover from the oscilloscope, and will indicate the circuit or circuits most likely to contain the casualty.

The individual circuit troubleshooting charts isolate probable casualty areas within the circuits themselves. The power supply voltages should always be checked before troubleshooting an individual circuit, to avoid false indications.

To use the charts, start at the top, working down and to the right. If a check provides a "yes" answer, proceed down along the solid line. If the check provides a "no" answer, proceed to the right, following the broken line. Exceptions to the direction of flow are indicated by arrows where they occur.

Rectangles contain the checks to be performed; the hexagons indicate the probable casualty area. When checking the probable casualty area, associated leads, switches and other components should not be ignored. A transistor might be inoperative because of a resistor in series with it.

The charts are designed on the basis of single casualties. Multiple casualties may disrupt the logic, but it should still be effective in determining the casualties, one at a time.

CORRECTIVE MAINTENANCE

General

Many electrical components are mounted in a particular way to reduce or control stray capacitance and inductance. Part orientation and lead dress should duplicate the original installation.

WARNING

Disconnect the oscilloscope from power sources and remove the Power Pack before removing or replacing components. If the Power Pack is being worked on, unsolder and tape up one of the leads which connect the battery to terminals M and I of the Power Pack circuit board.

A thorough cleaning should accompany any repairs, and a satisfactory Performance Check or a Calibration Procedure should be performed after the repairs have been completed.

Parts Procurement

All parts used in this oscilloscope can be purchased through Sony/Tektronix Field Offices or representatives. However, replacements for standard electronic items can readily be obtained from local electronic parts stores.

When selecting replacement parts, it is important to remember that the physical size and shape of a component may affect its performance at high frequencies. All replacement parts should be direct replacements unless it is known that a different component will not adversely affect instrument performance. Before purchasing, consult the Electrical Parts List in Section 6 to determine the required specifications.

Special Parts. Some electrical parts are specially reworked, quality checked, or manufactured to fullfil a specific requirement. Most mechanical parts are common to the Type 324 Oscilloscope. All electrical parts whose stock numbers are preceded by an asterisk in Section 6 and most mechanical parts, are manufactured by or for Sony/Tektronix and can therefore be obtained only through the Type 324 Oscilloscope sales facilities. Ordering information precedes the Electrical Parts List in Section 6.

Soldering Equipment and Techniques

Soldering Equipment. Ordinary electrical solder should be used for all circuit repairs. The soldering iron should be selected in accordance with the work being done, as follows:

Soldering on circuit boards—15 to 40 watt iron with a 1/16 or 1/8 inch tip.

Soldering to metal terminals such as on switches and potentiometers—40 to 75 watt iron with 1/8 inch tip.

Soldering to heavy metal such as the chassis or binding posts—40 to 75 watt iron with 1/4 inch tip.

Component size and density demands the use of needle-nose pliers and needle-nose end nipper pliers when replacing

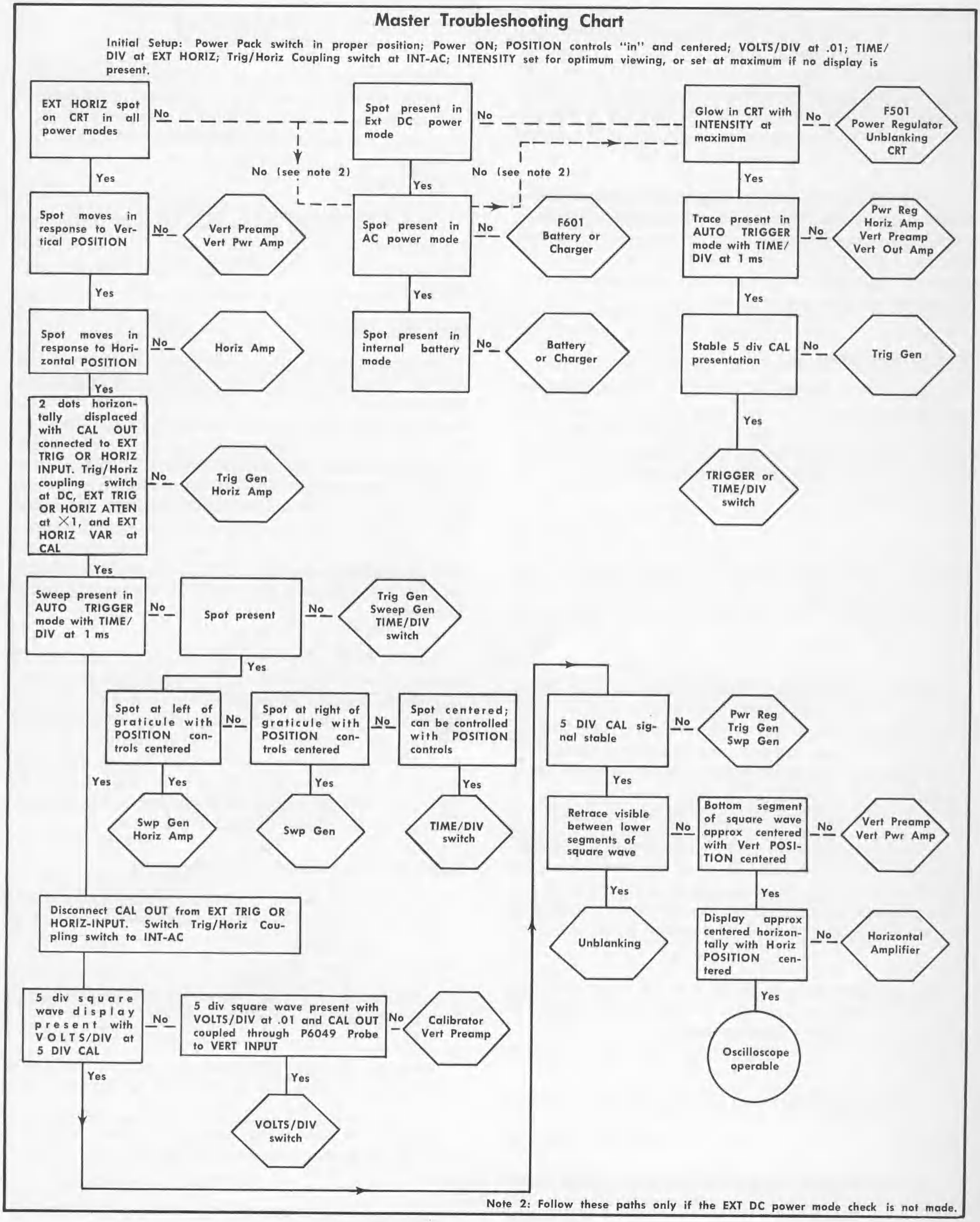


Fig. 4-3. Master troubleshooting chart.

POWER REGULATOR TROUBLESHOOTING CHART

The following observations were made with the indicated transistor removed from the circuit to simulate its being open circuited. The chart need not be restricted to the transistors themselves, but can be used as a basis for tracing symptoms to areas of the Power Regulator circuit which are associated with indicated transistors. Circuit response may vary slightly between instruments.

Initial setup: VOLTS/DIV at 5 DIV CAL; POSITION controls "in" and centered; TRIGGER at + AUTO; TIME/DIV at 1 mS; Trig/Horiz Coupling switch at INT TRIG—AC; 8.5 volts DC power applied; POWER—ON; INTENSITY control changed from minimum to maximum brightness setting during each check.

Transistor Removed	Power Supply Reaction				Comments
	At or near normal	High	Low	0 or near 0	
Q515 Q518			All	−1900	No CRT display
Q525	All				CRT display appears normal
Q529			All	−5, −1900	No CRT display
Q555			All	−5, +5	Defocused spot with INTENSITY fully CW
Q557	+8.5, +11, +100 +175, −1900		−5, +5		No display
Q558			All		No display
Q562 Q567	+5, +8.5, +100 +175, −1900	−5	+11		Bright dot appears as INTENSITY is advanced
Q569				All	Opens F501
Q571	All				CRT display appears normal. LO BATT light blinks

Fig. 4-4. Power Supply troubleshooting chart.

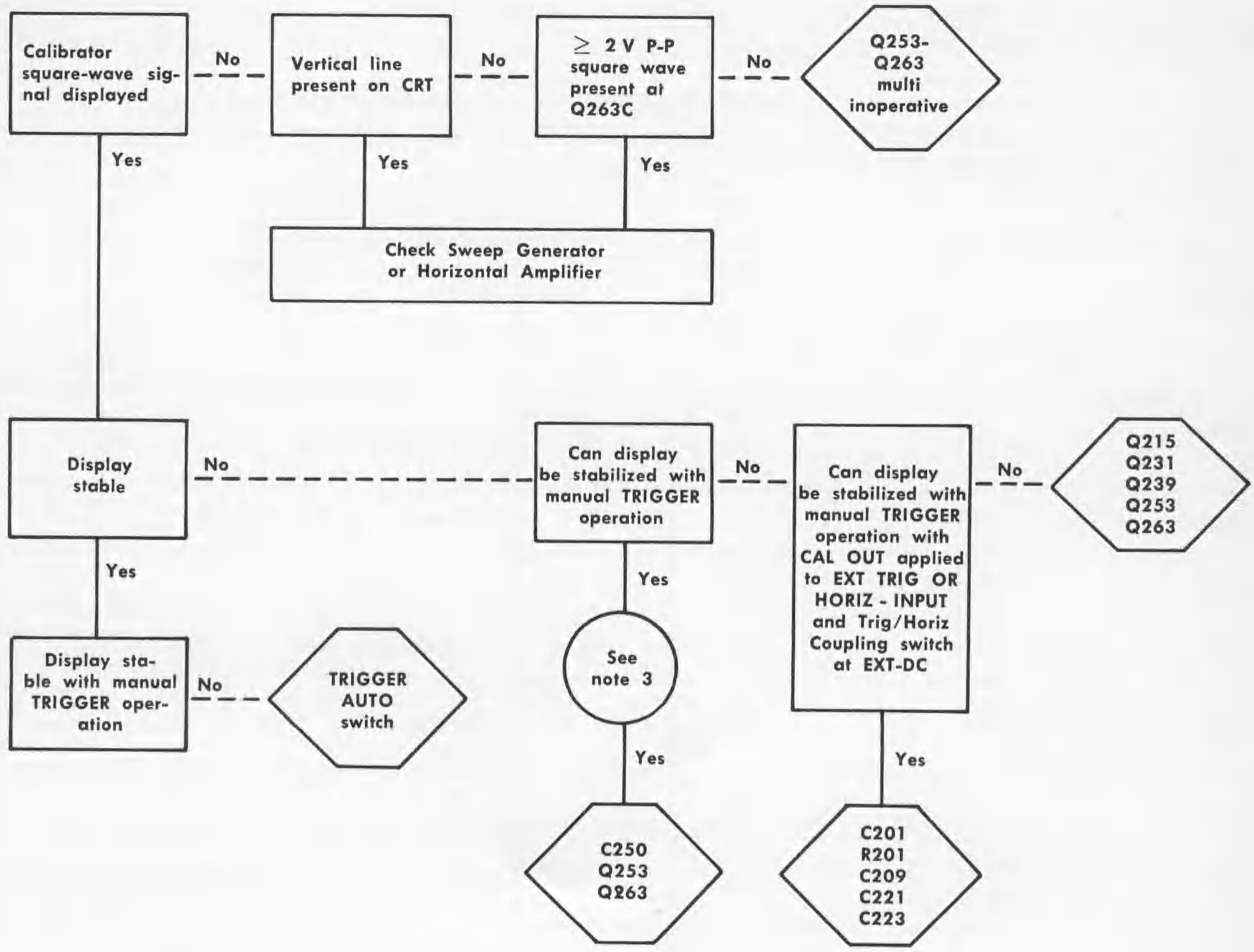
components. Tweezers are also helpful. Heat sinks (such as small alligator clips) are invaluable for protecting components from heat damage, leaving both hands free for soldering. A hold-down aid can be made from a wooden dowel, 6 to 8 inches long and 1/4 to 3/8 inch in diameter. Shape one end like a pencil tip and the other end similar to a screwdriver tip. The wood will absorb only a minimim amount of heat from the iron, but it will not guard against heat transfer to the parts being soldered. Flux remover solvent and cotton-tipped swabs are needed to remove flux from soldered connections.

A solder removing device such as an EDSYN SOLDAPULLT® Tektronix Part No. 003-0428-00, is extremely useful in removing solder from circuit boards, expediting component removal and replacement.

Other soldering aids should be made or purchased to suit specific needs.

General Soldering Techniques. Keep the soldering iron well tinned and wiped clean. To avoid excessive heating of the general area around the connection, the iron should be completely heated before being applied. When removing components, apply heat only long enough to allow the part to be removed easily. (Applying a small amount of solder between the tip and the joint will usually aid in heat transfer on difficult connections. This will decrease heating of the general area.) Use the extreme tip of needle-nose pliers to avoid drawing off too much heat. When connecting components, heat the solder sufficiently to allow free flow. Apply the solder to the wire being joined, not to the soldering iron. This will insure proper bonding. (Applying a small

Trigger Generator Troubleshooting Chart. Initial setup: TRIGGER at + AUTO; VOLTS/DIV at 5 DIV CAL; TIME/DIV at 1 mS; POSITION controls "in" and display centered; POWER — ON; Trig/Horiz Coupling switch at INT — AC.



Note 3: Certain waveforms might not provide stable triggering in AUTO; use AUTO until display is present, then stabilize the display with manual trigger operation, if necessary.

Fig. 4-5. Trigger Generator troubleshooting chart.

amount of solder between the iron and the wire will again aid in initial heat transfer. Once solder flows between the tip and the wire, the solder should be applied to the opposite side of the wire to complete the process.) Do not use more solder than is necessary to make a neat and effective bond.

Use heat sinks between the body of components and the joint being soldered whenever small components and/or short leads are involved. After soldering has been completed, clip off excess wire, deflecting wire ends with a gloved finger or other device to avoid damage to fingers, eyes, or circuit components. Remove clipped leads from the chassis. Clean the newly soldered area with a cotton-tipped swab and flux remover solvent.

CAUTION

Use extreme care when soldering wafer-type switch terminals. Excessive heat or solder flowing around and beyond the rivet will destroy the contact's spring tension. Excessive heat will damage plastic switches.

Circuit Board Soldering Techniques. Use a 15 to 40 watt iron with a 1/8 inch tip. Keep the tip well tinned and

Sweep Generator Troubleshooting Chart. Initial setup: Display is obtainable in EXT HORIZ mode; VOLTS/DIV set at 5 DIV CAL; TIME/DIV at .5 mS; POSITION controls "in" and centered; POWER — ON; VARIABLE controls at CAL; TRIGGER at + AUTO; Trig/Horiz Coupling switch at INT — AC.

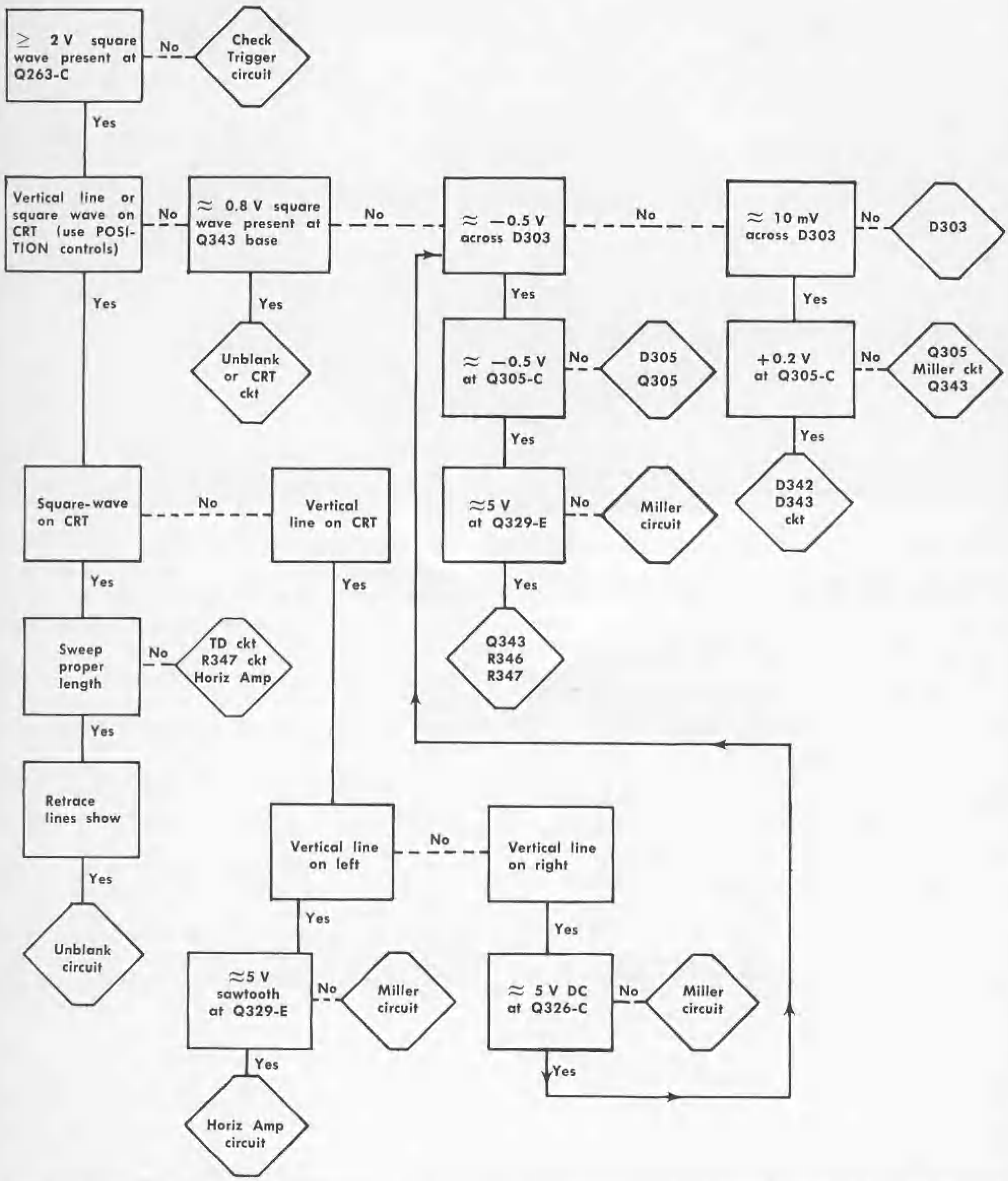


Fig. 4-6. Sweep Generator troubleshooting chart.

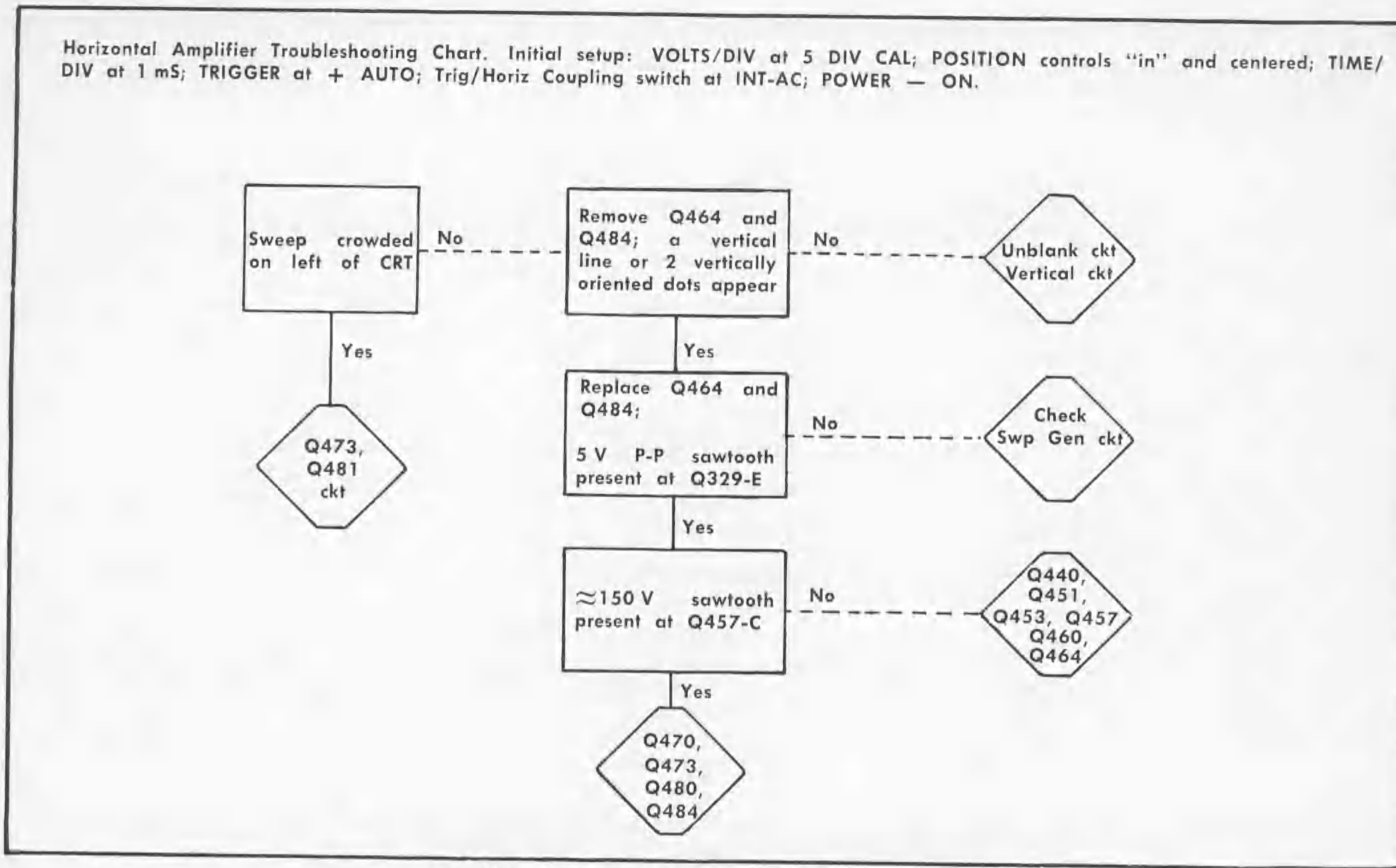


Fig. 4-7. Horizontal Amplifier troubleshooting chart.

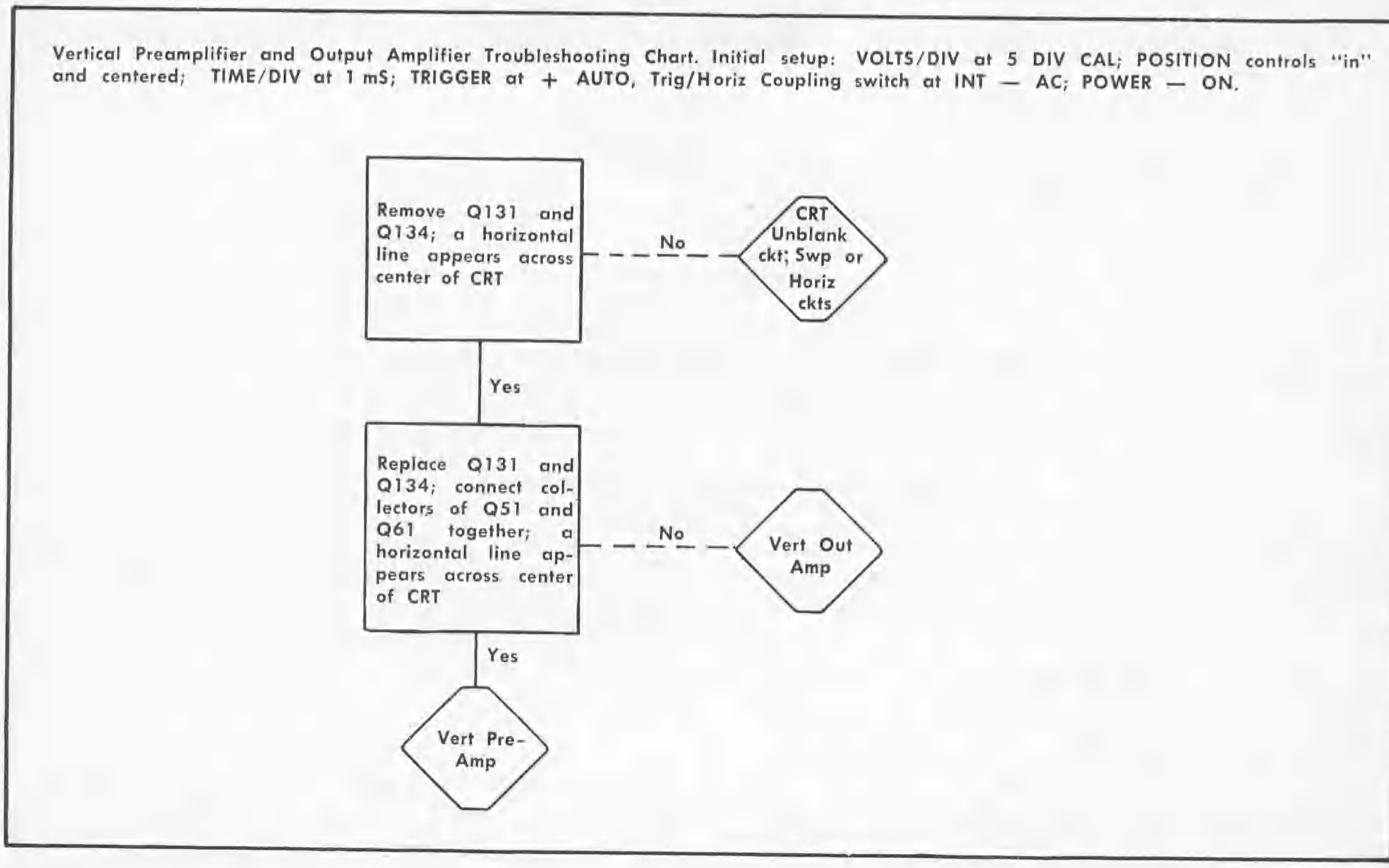


Fig. 4-8. Vertical circuit troubleshooting chart.

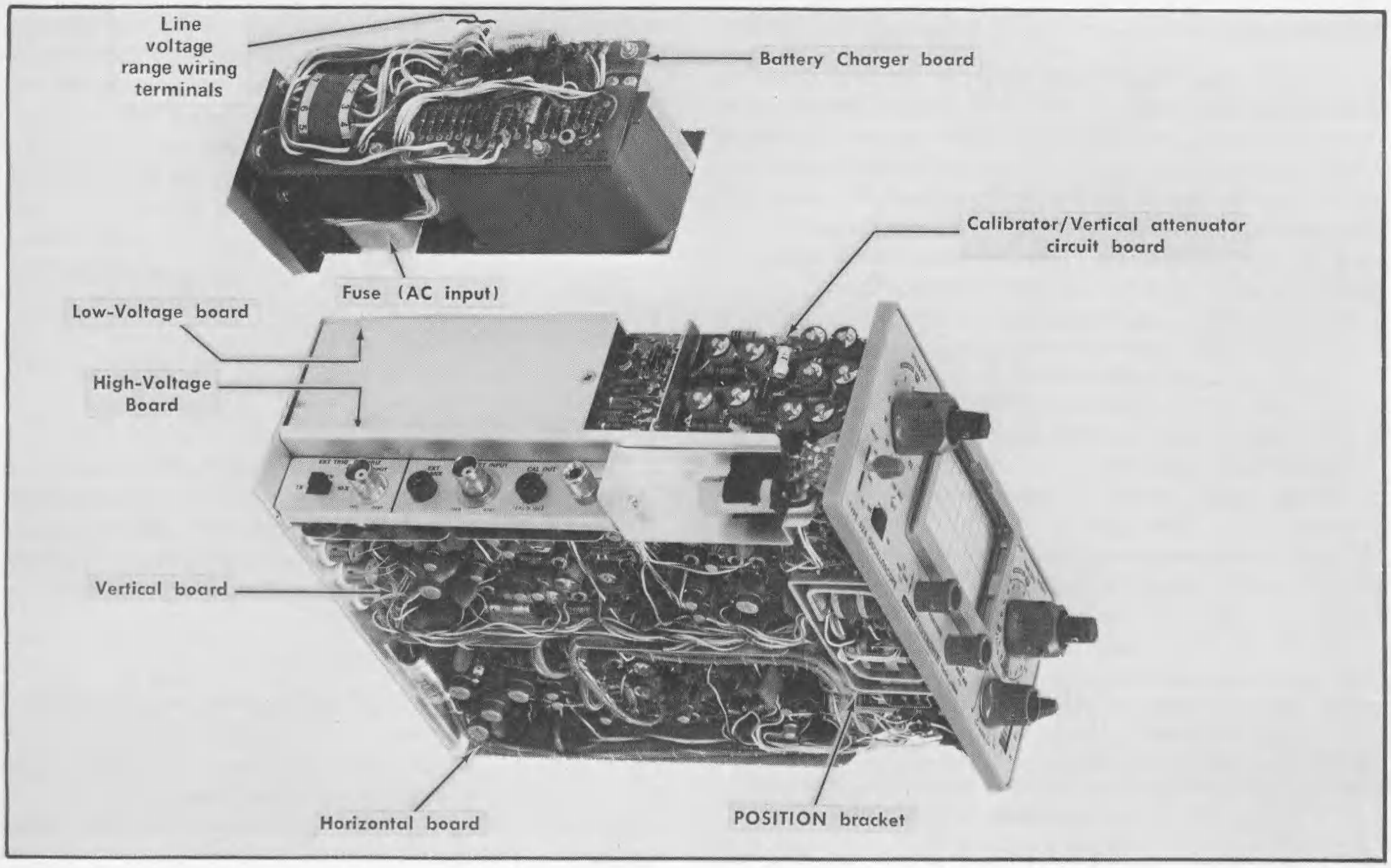


Fig. 4-9. Location view; bottom of oscilloscope and Power Pack.

clean. Do not overheat components or circuit board. Do not put excessive pressure on the board.

To remove a component, grip a lead with the tip of a pair of needle-nose pliers. Touch the tip of the soldering iron to the connection. When the solder melts, gently pull the lead from the board. If a clean hole is not left in the board, reheat it and remove the solder with a solder removing device, or bore it out gently with a toothpick or similar non-abrasive device.

Defective multiple-lead components that cannot be removed by the above process should first be removed by cutting the leads. Then remove the leads one at a time and clean the holes as necessary. If the leads are not accessible, remove the solder from each contact point with a solder removing device, then work the component out, applying heat alternately to the connections involved.

To replace components, first bend the leads to the proper shape. Cut the leads to proper size if the extra lead length interferes with installation or cannot be reached for cutting after installation. Insert the leads in holes and set the component to the position of the original part. Reheat holes if necessary for proper insertion of the part. Apply heat sinks to component leads as necessary. The tips of needle-nosed pliers serve as excellent heat sinks if only the component being installed needs protection. Apply the iron and a small amount of solder to the connection. Do not remove the iron until the solder flows freely. After removing the iron, hold the component steady until the solder is firm. Clip any excess lead wire. Clean the soldered area with a cotton-tipped swab and flux remover.

CAUTION

Ink used for circuit-board lettering will dissolve when contacted by certain types of solvents.

DISASSEMBLY AND ASSEMBLY

General

These instructions outline the most expeditious methods for removing components, or for exposing their surfaces so that they may be inspected or worked on. Undue force should not be used during disassembly or assembly. Soldering should be done in accordance with the information given earlier in this section under Soldering Instructions. Instructions for removing the oscilloscope case and replacing the Power Pack are contained in the Operating Instructions and are not repeated here. The locations of specific parts of the oscilloscope are shown in Fig. 4-9. Transistor installation information is contained in Fig. 4-13. The circuit boards are shown in Fig. 4-14 through 4-21, and indicate component locations and wire connecting points.

Power Pack

General. The Power Pack can be removed from the oscilloscope by disclosing three square-pin connectors at the circuit board, and releasing a toggle clamp at the front of the Power Pack. It is recommended that the Power Pack switch (at the rear of the Power Pack) be kept in the EXT DC position during removal and while the Power Pack is out of the oscilloscope. This minimizes the number of points to which the internal battery is connected.

WARNING

The battery used in the Power Pack is capable of delivering a large amount of energy in a short time. Rings, watch bands, or other metallic items which short-circuit the battery can rapidly become hot enough to cause severe burns.

Circuit Boards. Components on the Battery Charger circuit board can be replaced without removing the board. To reach the underside of the board, remove the three nuts which hold the board in place. Turn the Power Pack over to permit the washers to fall free of the board.

CAUTION

Do not allow components to become short circuited while the battery pack is connected to the circuitry. If a resistance check or disassembly is to be performed, it is recommended that the battery lead connected to terminal M of the circuit board be unsoldered and taped to avoid damage.

After the nuts and washers have been removed, the outer end of the board can be lifted up, pivoting it on the wiring cable. Be careful that the screw near the transformer does not bind on the corner of the board. If the board must be completely removed, the wire color code should be recorded before any wires are unsoldered.

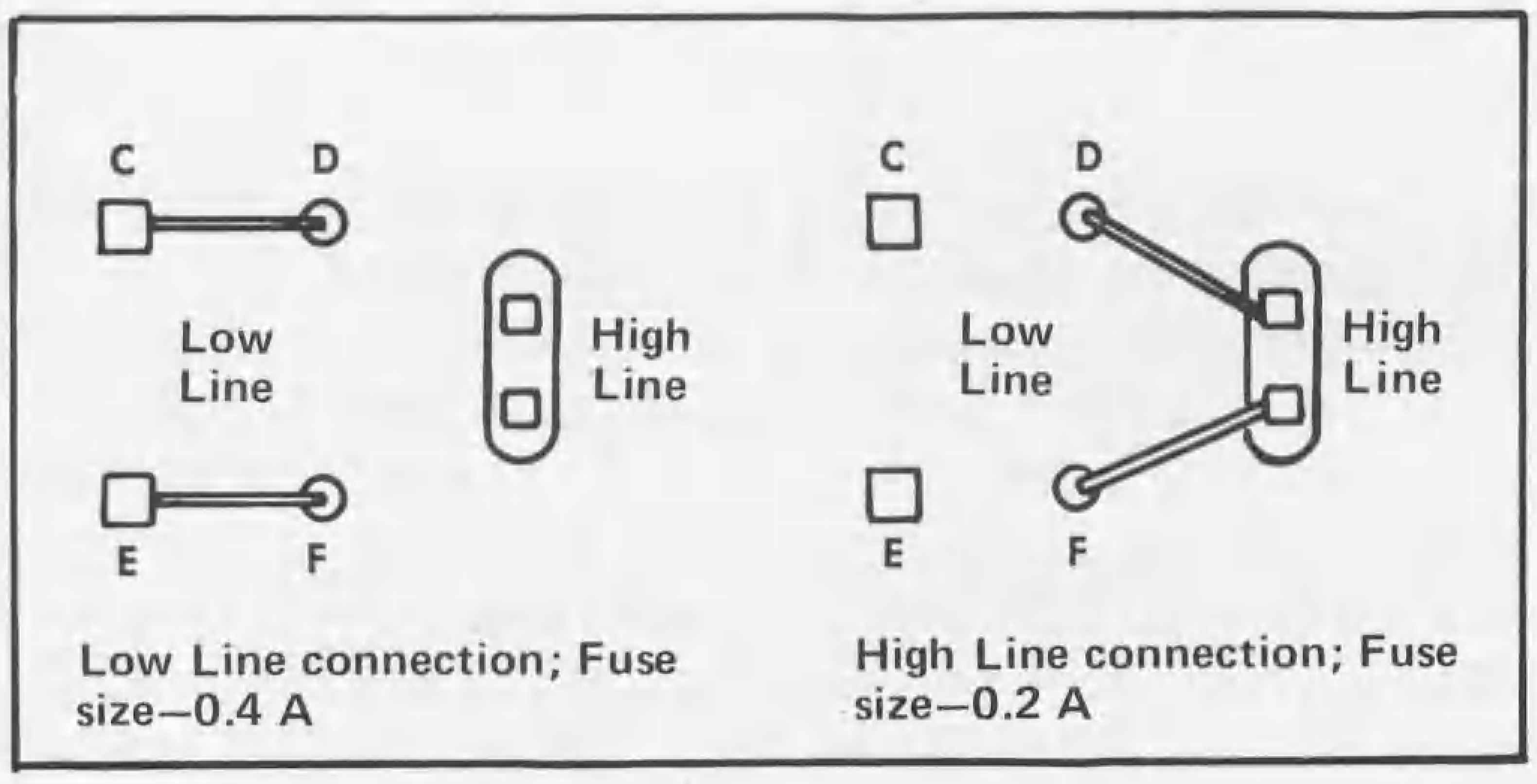


Fig. 4-10. Connections for 100 V and 200 V AC operation. Place insulated sleeves on unused square pins after changing the connections.

Transformers. To remove the transformer, unsolder its eight leads from the circuit board. Remove the Power Pack cover plate from the opposite side by removing the six screws from it. Then remove the two transformer mounting bolts; the transformer can then be lifted out through the hole in the side plate. See Fig. 4-10 for low line—high line wiring information.

Fuses. Access to the fuse can be obtained by pulling the plastic cap off toward the bottom. When replacing it, be sure that the grooves in the cap align with the fuse mounting board. See Fig. 4-10 for low line—high line fusing information.

Battery. The battery in the Power Pack is made up of six 1.25 V Nicket-Cadmium (NiCd) cells strapped together, series-aiding. See Fig. 4-11. Background information regarding these cells is given in the Operating Instructions section and should be read before any servicing is performed on the battery.

Battery Pack Removal. Unsolder the two leads which connect the battery pack to terminals I and M on the circuit board. Free the one lead from the cable clamp. Tape up one lead end (creating minimum bulk) so that the two leads cannot come in contact with each other. Remove the nine screws and the cover plate from the power connector side of the Power Pack. Remove the three battery pack screws through the access holes in the circuit board, freeing the pack. Separate the pack from the rest of the unit, pulling the pack leads through the hole in the circuit board. The battery holding bracket now can be removed by remov-

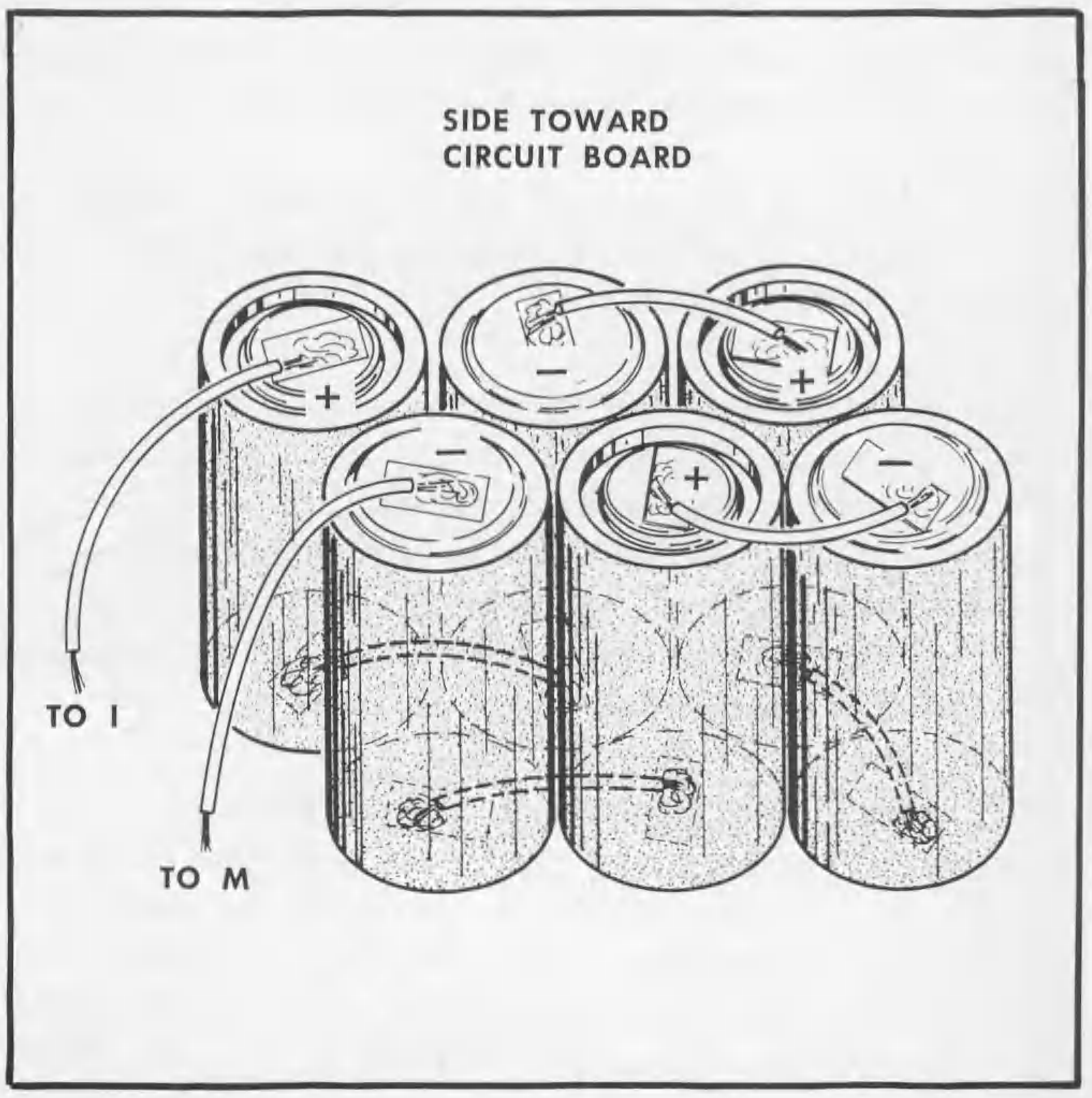


Fig. 4-11. Battery Wiring.

ing one screw from each end. The pack can be re-installed by reversing the procedure.

Servicing the Battery. The cells which make up the battery have been selected to meet specific performance requirements and can be expected to maintain relatively equal capabilities throughout the battery operating life. Upsetting this balance of equality by introducing a strong cell into a weak battery, or a weak cell into a strong battery, will precipitate reverse charging of the weakest cells, as explained in the Operating Instructions.

If one cell is defective and fails while the rest of the battery is still quite new, that cell may be replaced without undue concern. The Sony/Tektronix Field Representative or Office should be consulted before individual cells are replaced, especially if the warranty is in effect.

Gas evolution and recombination takes place during battery charging. This creates a pressure within the cells which they can normally withstand. If a cell becomes defective, or a circuit failure causes the recommended charge rate to be exceeded, excessive pressure builds up. The pressure may rupture a relief vent, exhausting the gas. This action may shorten the life of the cell, and will coat the surrounding areas with a corrosive substance.

The battery should be inspected every six months or every 500 operating hours, whichever occurs first. Individual cells on the entire battery should be replaced if venting or excessive corrosion has occurred. The cover plate on the power connector side must be removed to expose one side of the battery. Sight between the cells to check for obvious corrosion or venting on the circuit board side. If a more thorough check of the circuit board side is desired, remove the battery in accordance with the Battery Pack Removal instructions.

Individual Cell Replacement. When necessary, individual cells can be removed and replaced by cutting the straps which connect the two ends of the cell to the pack, and soldering in a new cell. See Fig. 4-11. The cell type specified in the parts list must be used. Other types may not function properly, despite operating claims. They may prove to be a hazard to the instrument and to personnel. Operating time and/or temperature performance may be degraded. If an emergency substitution must be made, the cell must be able to withstand a 180 mA charge rate. The cells should then only be used as long as is necessary to obtain the prescribed replacements. The battery should be charged for 24 hours at a FULL CHG rate after individual cells are replaced.

Cathode Ray Tube (CRT) and Trace Rotation Coil

WARNING

High-vacuum cathode ray tubes are dangerous to handle. To prevent personal injury from flying glass in case of tube breakage, wear a face mask or safety goggles, and gloves.

Handle the CRT with extreme care. Do not strike or scratch it. Never subject it to more than moderate force or pressure when removing or installing. Always store spare CRT's in original protective cartons. Save cartons to dispose of used CRT's.

After the oscilloscope cover has been removed, the CRT and CRT shield can be removed through the following procedure: Unsolder the trace rotation coil leads from pins P and Q of the Vertical circuit board.

Unscrew the black nylon screw from directly behind the CRT. Then extract the black plastic spacer from between the CRT base and the chassis.

Remove the nut and bolt from the shield mounting bracket located near the rear of the shield.

Slide back the CRT and shield by pushing gently on the face of the CRT.

Raise up on the CRT and shield until the slack is taken up on the front and rear cables, and then remove the base socket from the CRT. Do not put too much strain on the cables while removing the base socket. Avoid bending the CRT base pins. The CRT is free to slide out of the front of the shield once the base socket is removed, so be careful not to drop it.

Slide the CRT out of the front of the shield. The trace rotation coil in the shield now is accessible.

Replacement. Reverse the proceudre to replace the CRT, observing the following precautions:

The rotation coil must be installed with its narrower opening toward the back of the shield.

CRT pin location and orientation in the oscilloscope is shown in Fig. 4-12.

Do not strike the flanges (near the face of the CRT) against the shield when inserting the CRT in the shield.

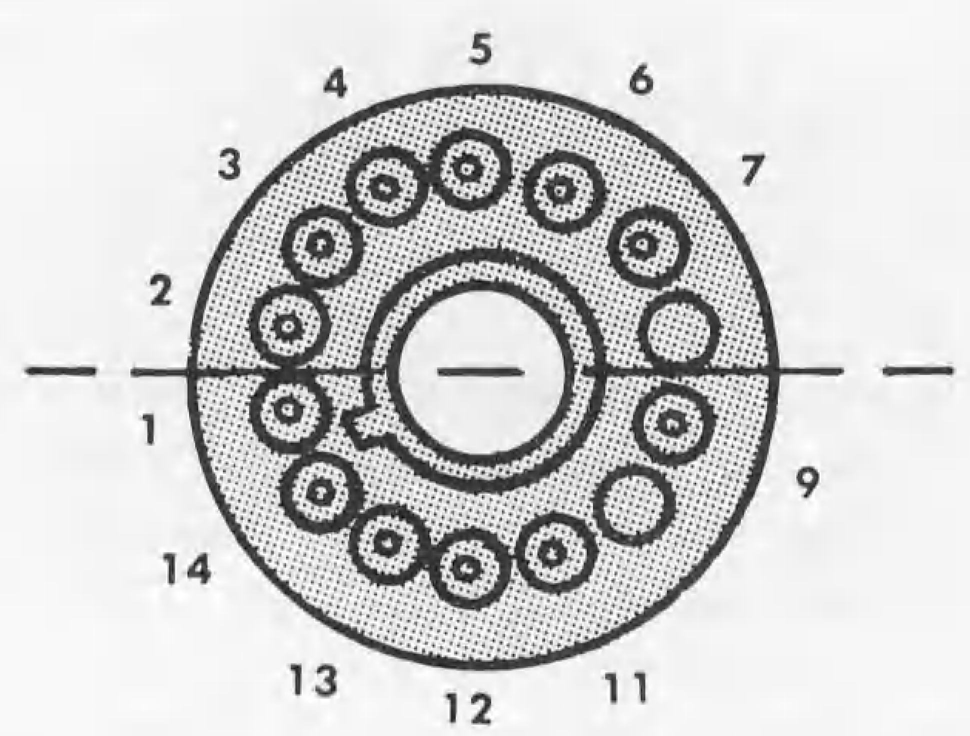


Fig. 4-12. Sketch of CRT base as viewed from rear when installed in oscilloscope.

When putting the CRT and shield in place, install the CRT shield inside the flanges on the right and left sides of the front panel CRT opening. The top of the shield must fit below the double flange at the top of the front casting. (The oscilloscope case fits between the flanges.)

Replace the shield-bracket nut and bolt before the nylon screw, but do not tighten them until the plastic spacer and the nylon screw have been installed and tightened. The flanged side of the plastic spacer should face the front of the assembly, and the nylon screw must fit in the depression at the center of the spacer.) Use moderate torque to fasten the nylon screw, and then tighten the shield-bracket nut and bolt.

It is recommended that the Type 324 be recalibrated whenever a replacement CRT is installed.

Vertical Circuit Board

Most of the circuit components can be replaced without removing the circuit board. However, if access to the underside of the board is necessary or the board needs to be removed from the instrument, proceed as follows:

Before unsoldering the wires connected to the vertical circuit board, record their color codes to facilitate installation.

The four transistors mounted in heat sinks on the instrument rear panel can be slipped out of the heat sinks. It is not necessary to unsolder the transistor leads from the circuit board.

Remove the three screws that hold the circuit board to the chassis and lift the board away from the chassis.

Horizontal Circuit Board

Most of the circuit components on the horizontal circuit board can also be replaced without removing the circuit board. However, removal of the board can be easily accomplished by proceeding as follows:

Before unsoldering the wires connected to the horizontal circuit board, record their color codes to facilitate re-installation.

Remove the three screws that hold the circuit board to the chassis and lift the board away from the chassis.

Position Bracket

Remove both POSITION knobs. Remove one securing nut and lock washer from each end of the POSITION bracket. Move the rear of the bracket away from the chassis, as far as the cables will allow. Then move the bracket back and out, hinging it on the cables at the rear of the bracket.

TRIGGER Control Assembly

Remove the TRIGGER knob; then remove the nut and flat washer from the exposed bushing. Lift the back of the assembly away from the chassis and pull it back until the shaft clears the front panel. Note that the internal lock washer is in place between the TRIGGER assembly and the front panel during re-installation.

INPUT and Trig/Horiz Coupling Switches

These can be removed after two nuts have been removed from the back, and the pressure-fit knob has been pulled from the lever arm. To avoid damage to switch contacts, unsolder the coupling capacitor (C20) before removing the INPUT Coupling switch.

POWER Switch

The face plate must be removed from the oscilloscope to expose the two screws holding this switch in place. The black-and-green plastic indicator plate should be removed and set aside until re-assembly.

Power Regulator Enclosure

To gain access to the enclosure, remove two nuts and screws from the front and one screw from the back of the enclosure cover.

WARNING

Dangerous potentials are present in the enclosure when the oscilloscope is energized.

Fuse. The fuse (operating power) is located at the rear of the compartment on the component side of the Low Voltage board. The circuit board must be removed to replace the fuse. Only 1.6 A 250 V fast blow fuses should be used as replacements. A spare fuse is provided with the oscilloscope and is contained in the spare-fuse holder located near the Attenuator Circuit Board.

Low Voltage Circuit Board. To remove the Low Voltage board, remove the three screws from the upper surface and lift the board up and out, pivoting it on the wiring harness at the side of the board.

High Voltage Circuit Board. For access to the bottom of this board, do the following:

Remove the Low Voltage board. Then unscrew the three nylon mounting posts and lift the board up and off the three mounting screws.

Transformer and Toroids. Leads should be tagged, or a written record should be made of the connections whenever these components are removed. The windings can be recognized by the point at which they leave the assembly; the ends can be distinguished either by lead length or by color code. Do not untwist any of the paired leads.

VOLTS/DIV, TIME/DIV, FOCUS and INTENSITY Control Assemblies

The front castings must be loosened and swung down and forward in order to remove these controls. Proceed as follows:

Remove the CRT and shield, following the previously given directions. Using a 1/16 inch allen wrench, loosen two set screws in the VOLTS/DIV knob and two in the TIME/DIV knob. Loosen one set screw in each of the variable knobs and in the POSITION knobs and the TRIGGER knob. Pull all of the knobs (except for the POWER switch) off their shafts. Remove the front panel from the instrument.

Remove the four machine screws which fasten the front casting of the instrument to the chassis frame posts.

Remove the screw which holds the frame post and Power Pack toggle clamp to the chassis, and remove the frame post.

Open the Power Regulator Enclosure and remove the Low Voltage circuit board. Remove the machine screw from the top frame post, moving the foil shield as necessary. Remove the frame post from the assembly.

The front casting can now be swung down and forward sufficiently to permit access to, or removal of the controls under consideration.

LOW BATT Indicator

The indicator lamp is soldered to the base cap which is snapped in place over the indicator holder. To remove it, force the cap off the holder.

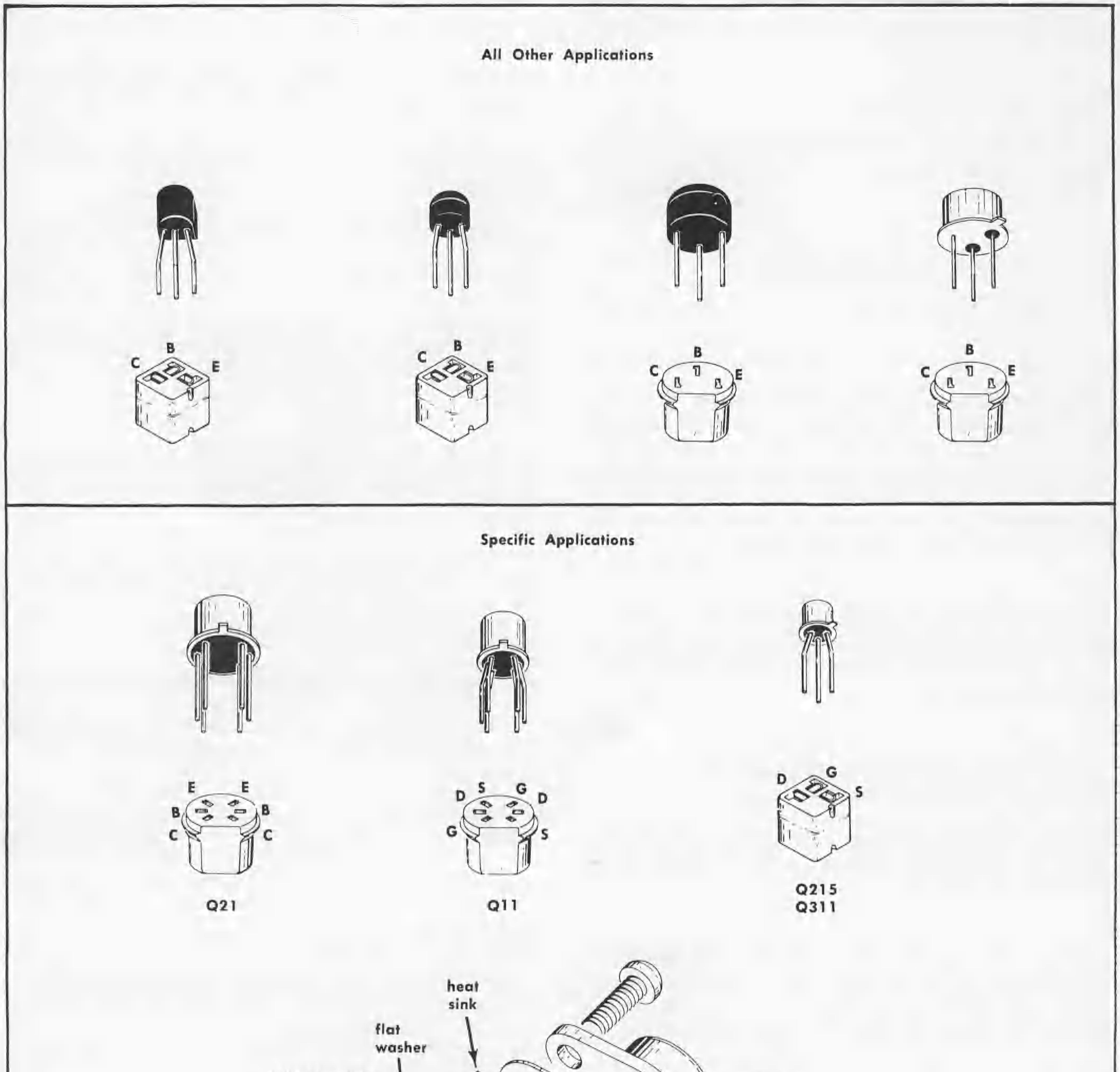


Fig. 4-13. Transistor data.

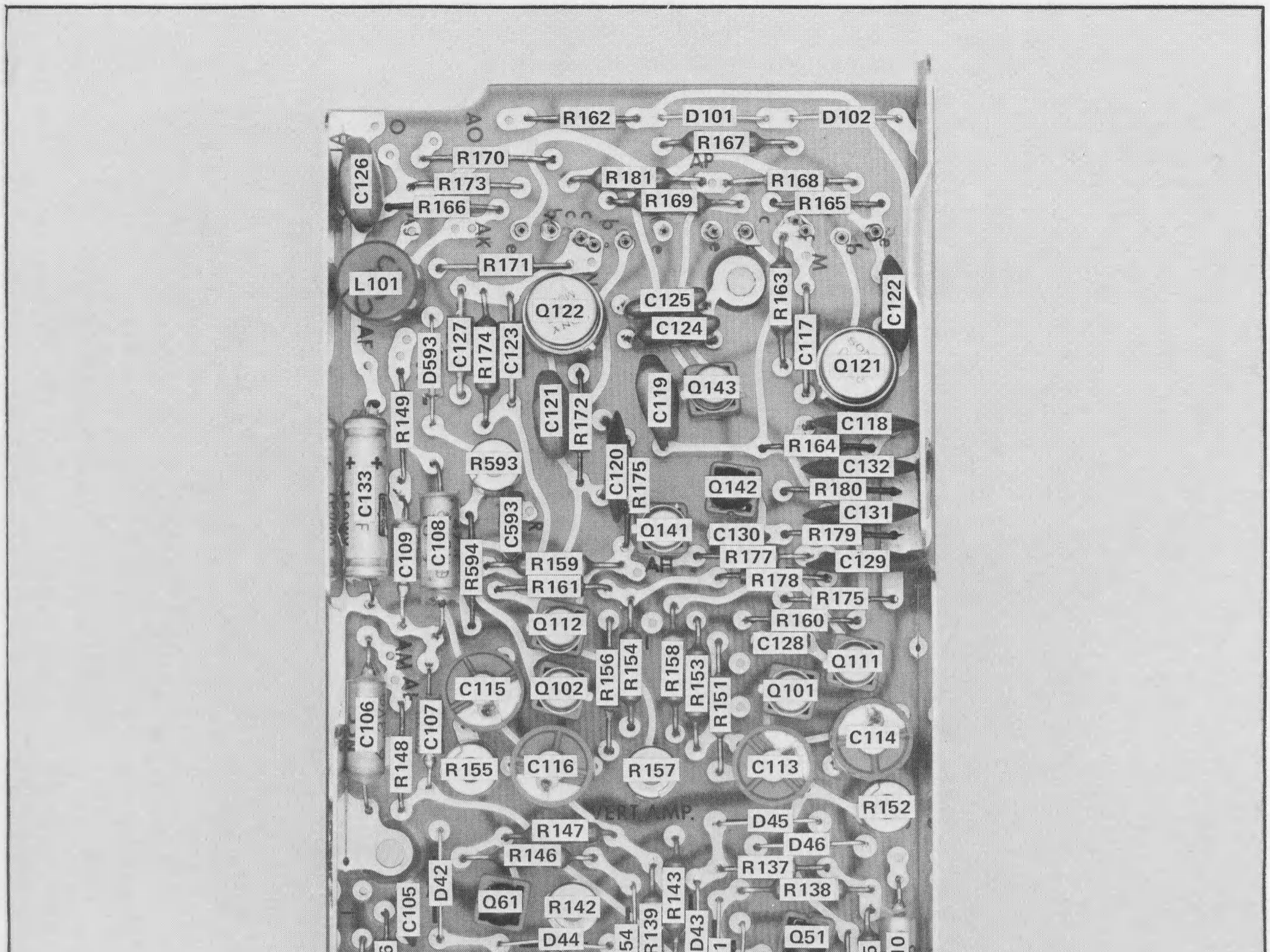


Fig. 4-14. Vertical circuit board circuit components.

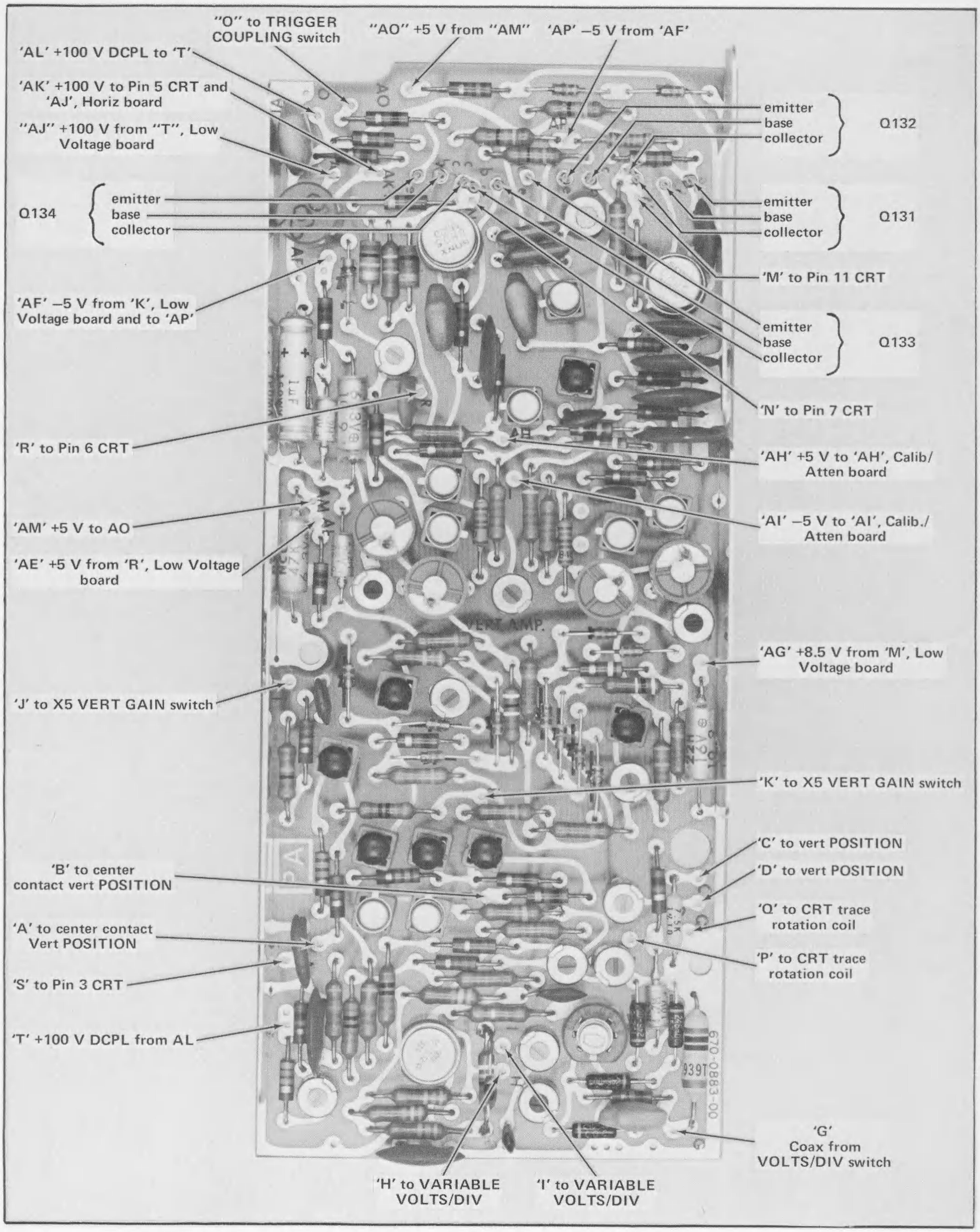


Fig. 4-15. Vertical circuit board wire connections.

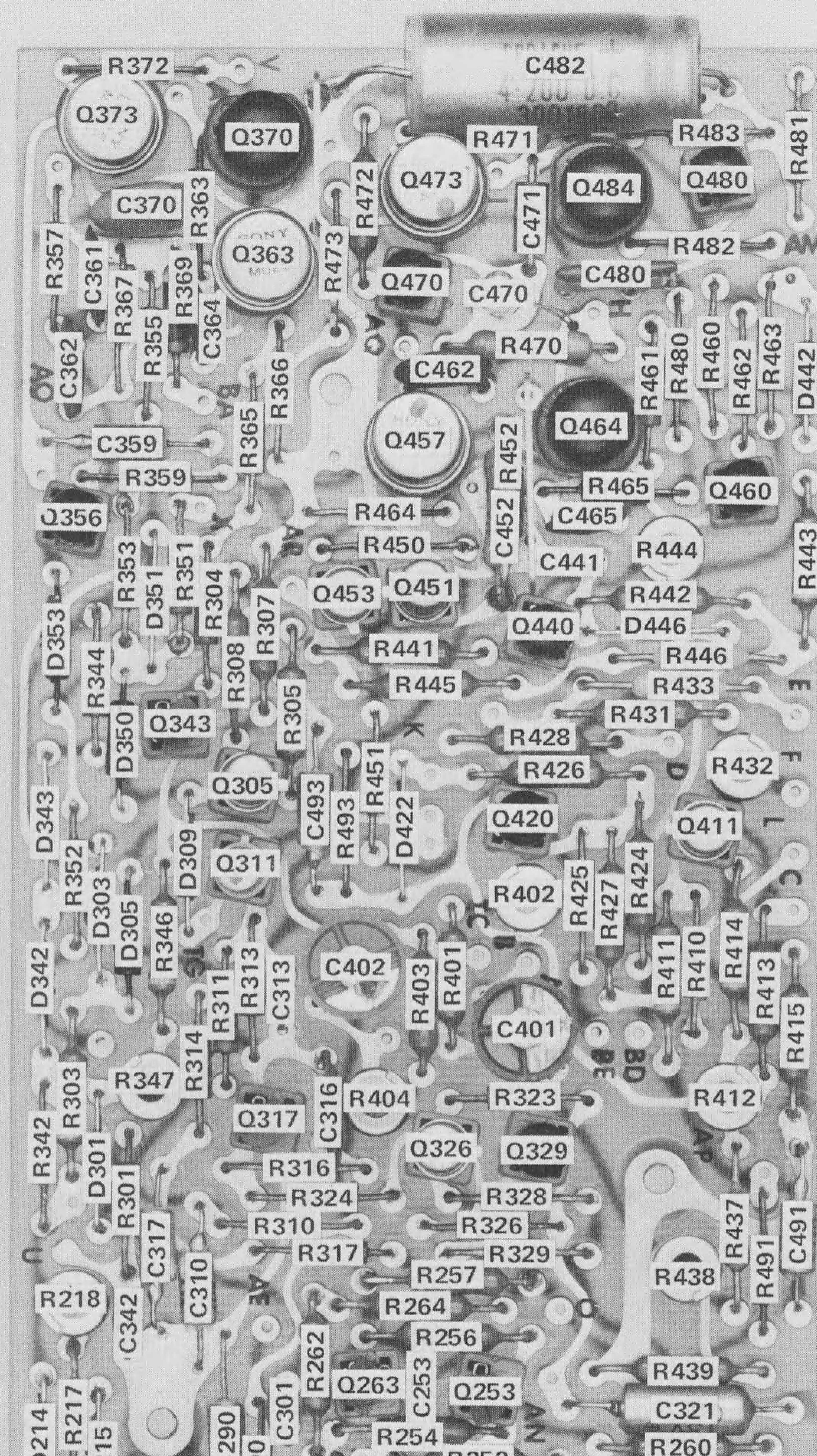


Fig. 4-16. Horizontal circuit board circuit components.

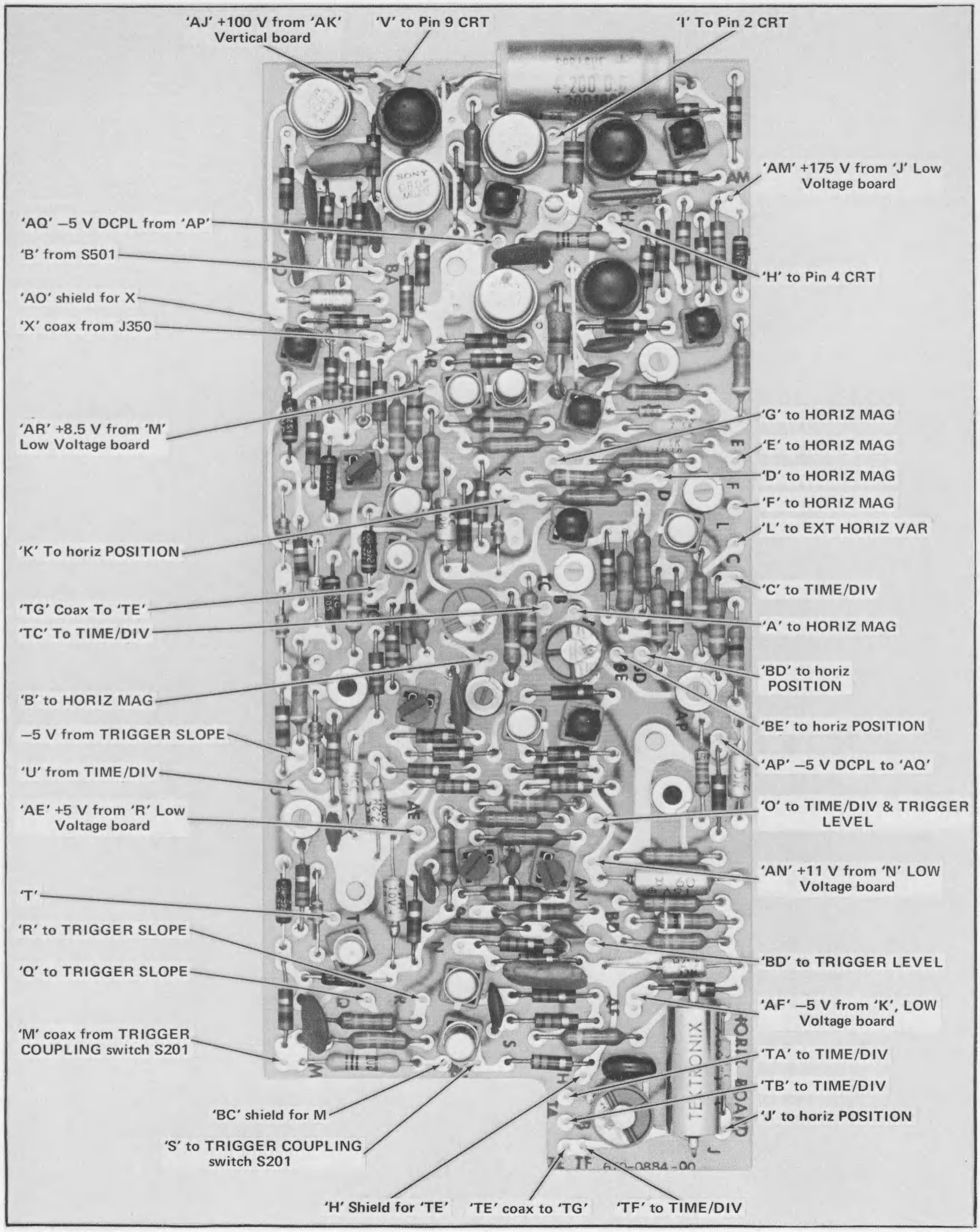


Fig. 4-17. Horizontal circuit board wire connections.

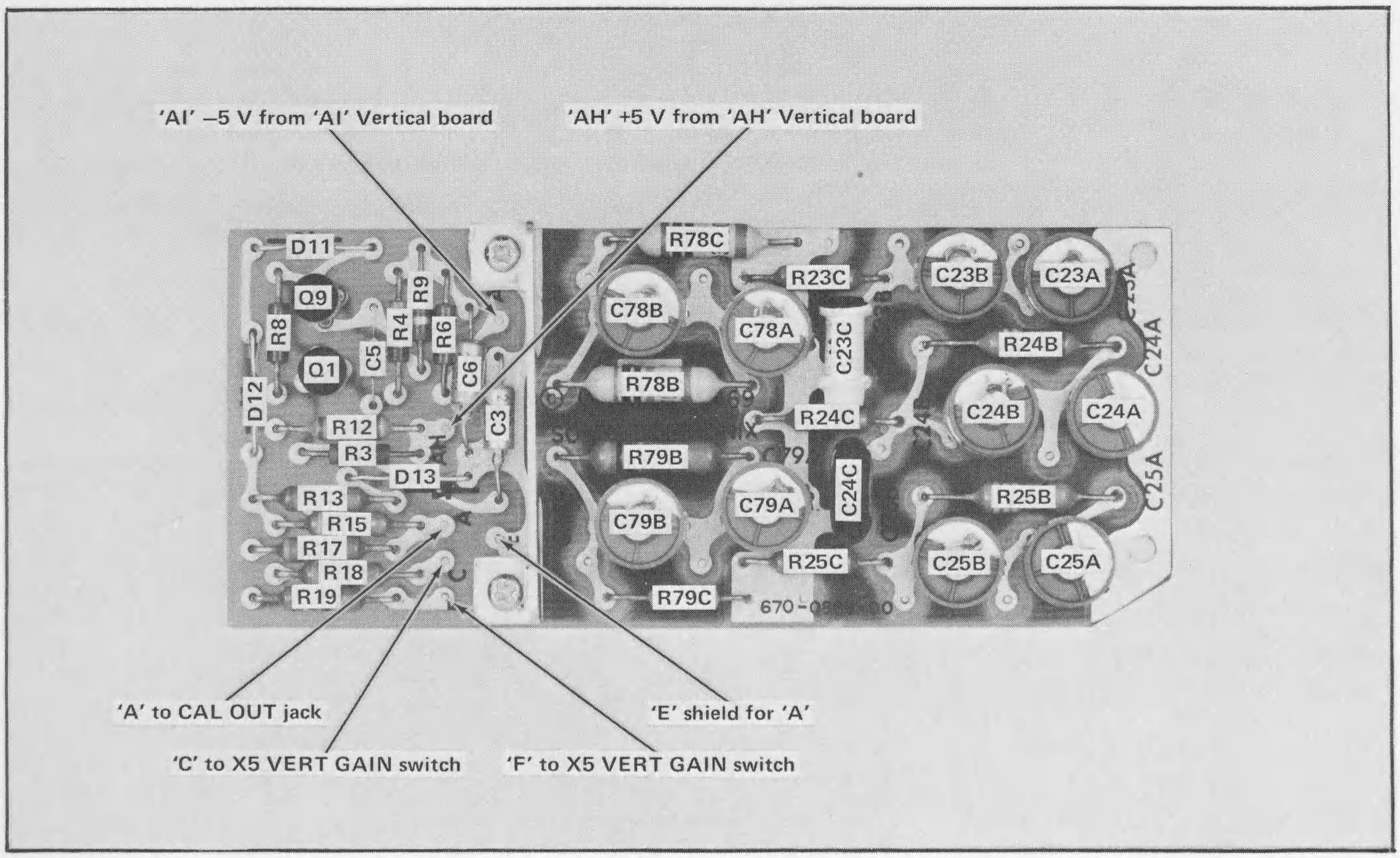


Fig. 4-18. Vertical Attenuator and Calibrator circuit board.

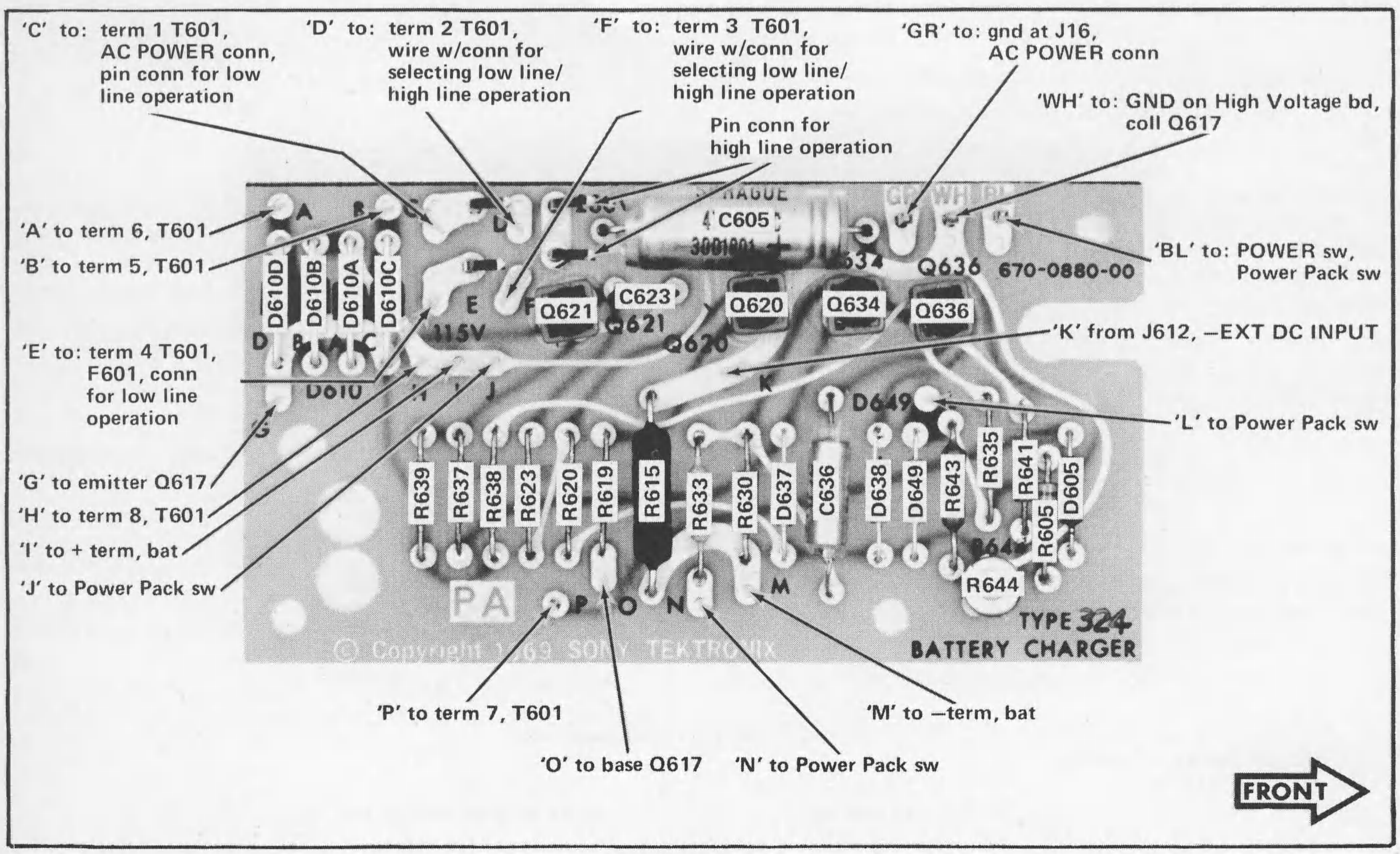


Fig. 4-19. Battery Charger circuit board.

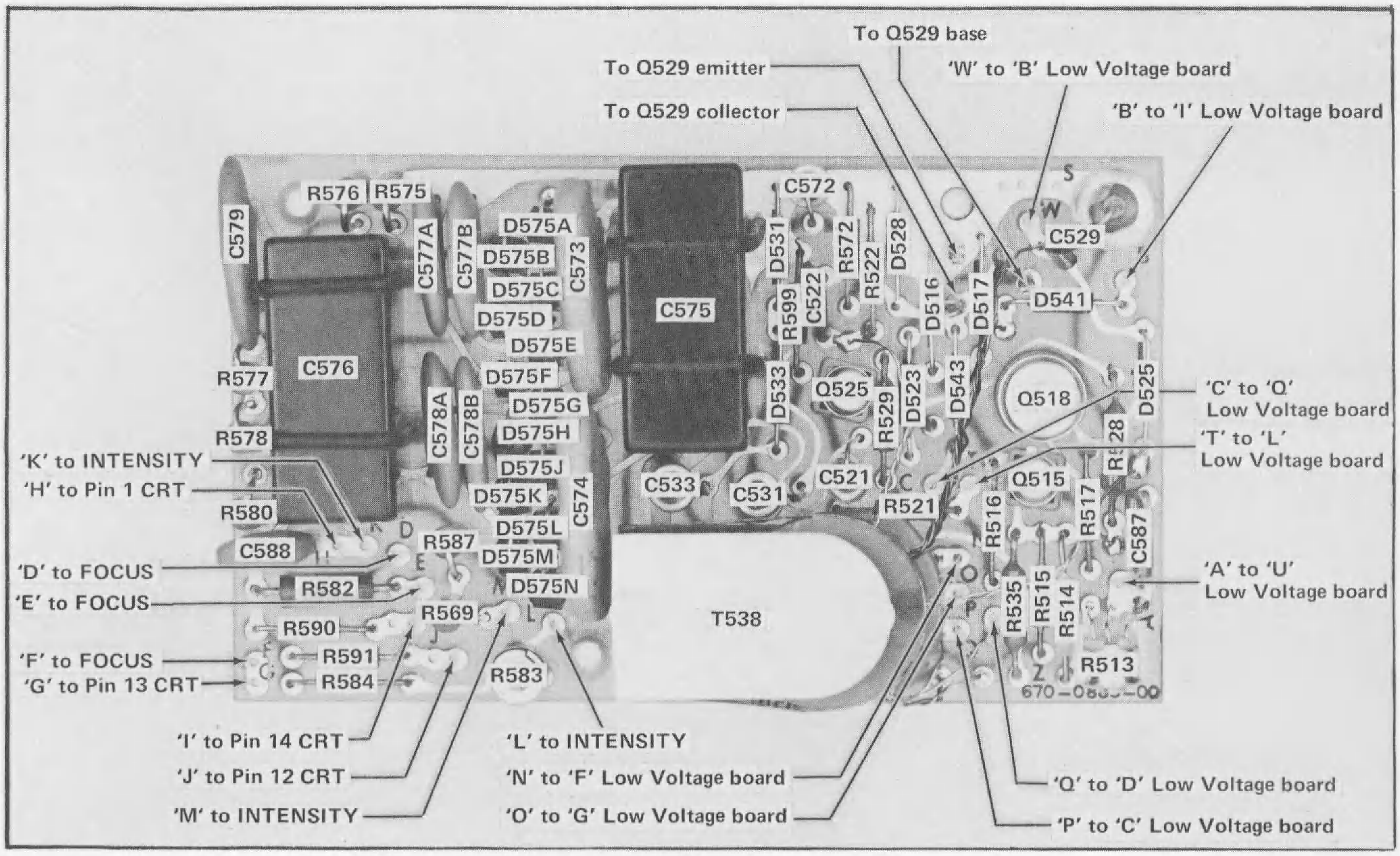


Fig. 4-20. High Voltage circuit board.

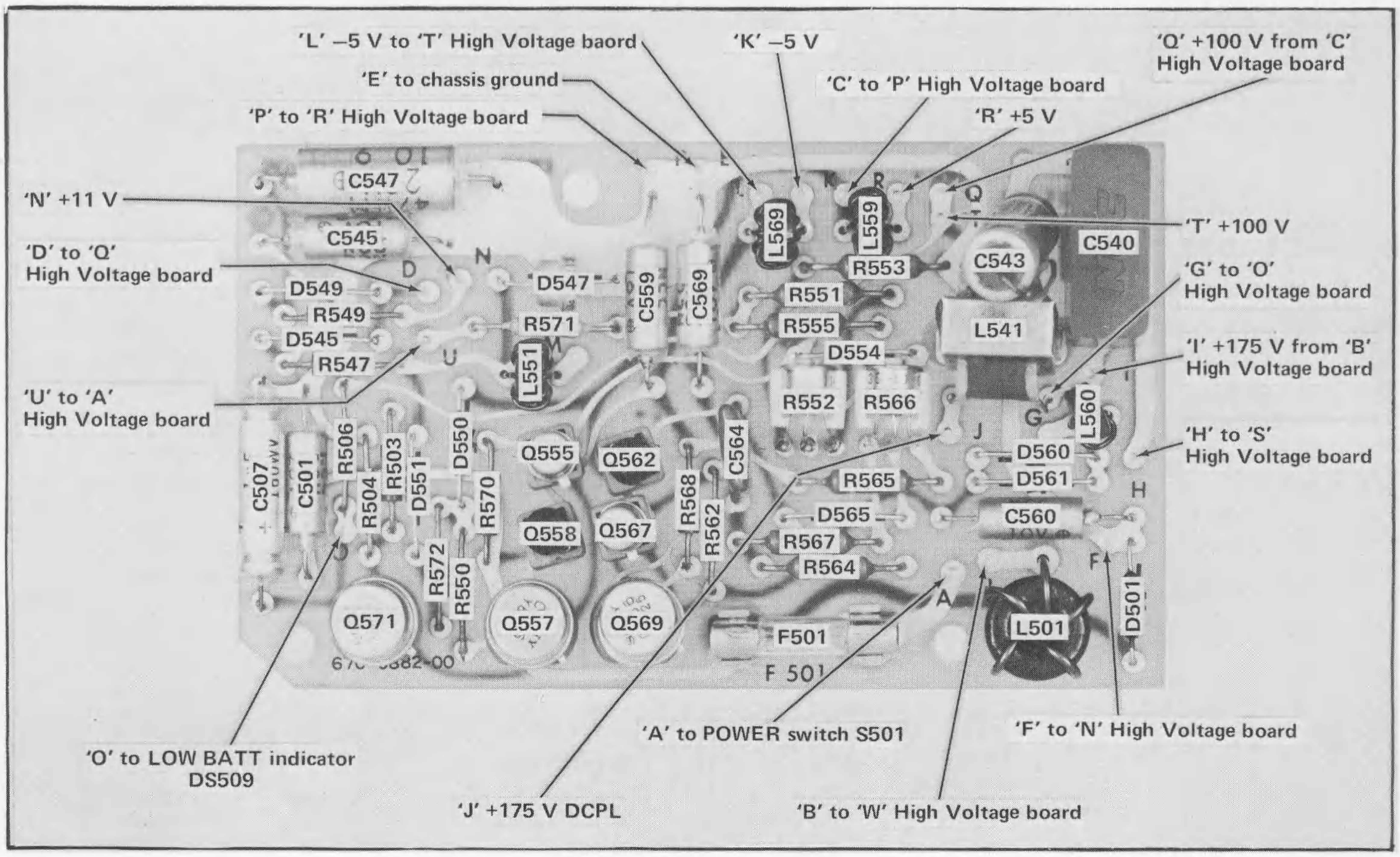


Fig. 4-21. Low Voltage circuit board.

SECTION 5
PERFORMANCE CHECK/CALIBRATION

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

Introduction

To assure instrument accuracy, check the calibration of the Type 324 every 500 hours of operation, or every six months if it is used infrequently. Before complete calibration, thoroughly clean and inspect this instrument as outlined in the Maintenance section.

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

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

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

A partial calibration is often desirable after replacing components or to touch up the adjustment of a portion of the instrument between major recalibrations. To check or adjust only part of the instrument, set the controls as given under Preliminary Control Settings and start with the nearest test equipment picture preceding the desired portion. If any controls need to be changed from the preliminary settings for this portion of the calibration procedure, they are listed under the heading Partial Procedure following the equipment required picture. To prevent unnecessary recalibration of other parts of the instrument, readjust only if the tolerance given in the CHECK— part of the step is not met. If readjustment is necessary, also check the calibration of any steps listed in the INTERACTION— part of the step.

NOTE

All waveforms shown in this procedure are actual photographs taken directly from the graticule. Limits, tolerances and waveforms are given as calibration guides and should not be interpreted as instrument specifications except as specified in Section 1.

TEST EQUIPMENT REQUIRED

General

The following test equipment and accessories, or its equivalent, is required for complete calibration of the Type 324. Specifications given are the minimum necessary for accurate calibration. Therefore, some of the recommended equipment may have specifications which exceed those given. All test equipment is assumed to be correctly calibrated and operating within the given specifications. If equipment is substituted, it must meet or exceed the specifications of the recommended equipment.

Special Sony/Tektronix calibration fixtures are used in this procedure only where they facilitate calibration. These special calibration fixtures are available from Sony/Tektronix. Order by part number through your local Sony/Tektronix Field Office or representative.

Test Equipment

1. Precision DC voltmeter. Accuracy, within ±0.1%; range, zero to 200 volts. For example, Fluke Model 825A Differential DC Voltmeter.

2. DC voltmeter (VOM)[1]. Minimum sensitivity, 10,000 ohms/volt; accuracy, checked to within 1% at −1900 volts. For example, Triplett Model 630-NA.

3. Variable DC power supply. Voltage range, at least +6 to +16 volts; current capability, at least 1.0 ampere; output voltage, measured within 3% except where noted. For example, Trygon Model HR40-750.

4. Test oscilloscope. Bandwidth, DC to four megahertz; minimum deflection factor, 10 millivolts/division; accuracy, within 3%. Sony/Tektronix Type 323 Oscilloscope recommended.

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

6. Standard amplitude calibrator. Amplitude accuracy, within 0.25%; signal amplitude, five millivolts to 100 volts; output signal, square wave. Tektronix calibration fixture 067-0502-01 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 one microsecond risetime; 500 millivolts into 50 ohms at one kilohertz and one megahertz repetition rates with a 50 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 10 megahertz; reference frequency, 50 kilohertz; output amplitude, variable from five millivolts to 0.5 volt into 50 ohms; amplitude accuracy, constant within 3% at 50 kilohertz and from 350 kilohertz to above 10 megahertz. Tektronix Type 191 Constant Amplitude Signal Generator recommended.

9. Low-Frequency constant-amplitude sine-wave generator. Frequency, two hertz to 100 kilohertz; output amplitude, variable from 50 millivolts to 16 volts peak to peak; amplitude accuracy, constant within 3% from two hertz to 100 kilohertz. For example, General Radio 1310-A Oscillator (use a General Radio Type 274QBJ Adaptor to provide BNC output).

[1] **If a precision voltage divider is available for use with the precision DC voltmeter (such as Fluke 80E-2 Voltage Divider), it is recommended for more accurate adjustment of the high-voltage supply.**

Accessories

10. AC power cord. Fits AC POWER jack of Type 324. Tektronix Part No. 161-0043-00 (supplied accessory).

11. Patch cord (two). Length, 18 inches; connectors, banana plug-jack on both ends. Tektronix Part No. 012-0031-00.

12. 1X Probe with BNC connector. Tektronix P6011 Probe recommended.

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

14. Calibration shield. Sony/Tektronix calibration fixture 067-0622-00.

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

16. Termination. Impedance, 50 ohms; accuracy, ±2%; connectors, BNC. Tektronix Part No. 011-0049-01.

17. 10X attenuator. Impedance, 50 ohms; accuracy, ±2%, connectors, BNC. Tektronix Part No. 011-0059-01.

18. Input RC normalizer. Time constant, 1 megohm X 47 pF; attenuation, 2X; connectors, BNC. Tektronix calibration fixture 067-0541-00.

19. 10X probe for Type 324 (and Type 323 test oscilloscope). Tektronix P6049 Probe recommended (supplied accessory).

20. BNC post jack. Tektronix Part No. 012-0092-00.

21. BNC T connector. Tektronix Part No. 103-0030-00.

22. Patch cord. Length, six inches; connectors, banana plug-jack and BNC male. Tektronix Part No. 012-0089-00 (supplied accessory).

23. Cable. Impedance, 50 ohms; type, RG-58/U; length, 18 inches; connectors, BNC. Tektronix Part No. 012-0076-00.

Adjustment Tools

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

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

SHORT-FORM PROCEDURE AND INDEX

Type 324, Serial No.____________________

Calibration Date____________________

Calibrated By____________________

1. Adjust Charging Current (R644) page 5-9

REQUIREMENT: 54 millivolts, ±3 millivolts, across R615 at FULL CHG.

PERFORMANCE:____ millivolts.

REQUIREMENT: Approximately 20 millivolts across R615 at TRICKLE CHG.

PERFORMANCE: ____ millivolts.

2. Adjust High-Voltage Supply and Check Regulation (R513) page 5-10

REQUIREMENT: −1900 volts, ±38 volts.

PERFORMANCE: ____ volts.

REQUIREMENT: Must remain within ±40 volts of the measured output over the DC power input range.

PERFORMANCE: Within ____ volts.

3. Adjust Intensity Limit (R583) page 5-10

REQUIREMENT: 0.6 volt, ±0.03 volt, at point K on the H.V. Power Supply board.

PERFORMANCE: ____ volt.

4. Adjust +5-Volt Power Supply (CAL OUT Voltage) (R552) page 5-11

REQUIREMENT: +0.500 volt, ±2.5 millivolts, at CAL OUT jack with Q9 removed.

PERFORMANCE: ____ volt.

REQUIREMENT: +5 volts ±0.1 volt, output from +5-Volt Supply.

PERFORMANCE: ____ volts.

5. Adjust −5-Volt Power Supply (R566) page 5-11

REQUIREMENT: −5 volts, ±0.1 volt.

PERFORMANCE: ____ volts.

6. Check Remaining Power Supplies page 5-11

See Table A.

TABLE A

Supply	REQUIREMENT:	PERFORMANCE:
+8.5-Volt	Within ±0.5 volt	____ volts
+11-Volt	Within ±2.2 volts	____ volts
+100-Volt	Within ±5 volts	____ volts
+175-Volt	Within +14 to −7 volts	____ volts

7. Check Low-Voltage Power Supply Ripple page 5-12

See Table B.

TABLE B

Supply	Maximum Ripple		Regulation	
	REQUIREMENT:	PERFORMANCE:	REQUIREMENT:	PERFORMANCE:
−5-Volt	10 millivolts	____ millivolts	Within ±0.1 volt	Within ____ volts
+5-Volt	10 millivolts	____ millivolts	Within ±0.1 volt	Within ____ volts
+8.5-Volt	20 millivolts	____ millivolts	Within ±0.75 volt	Within ____ volts
+11-Volt	200 millivolts	____ millivolts	Within ±2.2 volt	Within ____ volts
+100-Volt	200 millivolts	____ millivolts	Within ±5.0 volts	Within ____ volts
+175-Volt	750 millivolts	____ millivolts	Within ±14 volts	Within ____ volts

8. Check Low Batteries Indicator page 5-12

REQUIREMENT: LOW BATT light flashes with DC input voltage of +6.5 volts within +0.33 to −0 volts.

PERFORMANCE: LOW BATT light flashes at ____ volts.

9. Check/Adjust Variable Volts/Division Balance (R107) page 5-13

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

PERFORMANCE: ____ division shift.

10. Check/Adjust Vertical X5 Balance (R128) page 5-13

REQUIREMENT: Less than 1.5 division vertical trace shift as the X5 VERT GAIN switch is pulled out.

PERFORMANCE: ____ division shift.

11. Adjust Deflection Plate DC Level (R141, R142) page 5-13

REQUIREMENT: Voltage range at the collectors of Q132 and Q133 centered about +50 volts as the vertical POSITION control is rotated throughout its range.

PERFORMANCE: Correct ____; incorrect ____.

12. Check/Adjust Astigmatism (R597) page 5-14

REQUIREMENT: Best definition of marker display.

PERFORMANCE: Correct ____; incorrect ____.

13. Check/Adjust Trace Alignment (R592) page 5-14

REQUIREMENT: Trace parallel to horizontal graticule lines.

PERFORMANCE: Correct ____; incorrect ____.

14. Check/Adjust CRT Geometry (R593) page 5-15

REQUIREMENT: 0.1 division, or less, curvature of markers at left and right edges of graticule. Trace parallel to top and bottom horizontal lines of the graticule within 0.1 division.

PERFORMANCE: Left and right edges within ____ division; top and bottom within ____ division.

15. Check/Adjust Limit Centering (R123) page 5-15

REQUIREMENT: Minimum compression of a center screen two-division signal when positioned to the top and bottom of the graticule area. Compression or expansion should not exceed 0.1 division.

PERFORMANCE: ____ division.

16. Check/Adjust X1 Vertical Gain (R110) page 5-15

REQUIREMENT: Five divisions ±0.15 division of deflection.

PERFORMANCE: ____ divisions deflection.

17. Check Vertical X5 Gain page 5-16

REQUIREMENT: Five divisions ±0.15 division of deflection.

PERFORMANCE: ____ divisions of deflection.

18. Check Vertical Deflection Accuracy page 5-16

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

PERFORMANCE: All correct ____; incorrect (list exceptions) ______________________.

19. Check Variable Volts/Division Control Range page 5-16

REQUIREMENT: Continuously variable deflection factor between the calibrated VOLTS/DIV steps.

PERFORMANCE: Correct ____; incorrect ____.

20. Check Input Coupling Switch Operation page 5-16

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

PERFORMANCE: Correct ____; incorrect ____.

21. Check Trace Shift Due to Input Current page 5-17

REQUIREMENT: Negligible (0.085 division maximum).

PERFORMANCE: Correct ____; incorrect ____.

22. Check/Adjust High-Frequency Compensation (C113, C114, C115, C116, R152, R155, R157) page 5-17

REQUIREMENT: Optimum square-wave response with aberrations not to exceed +0.08 or −0.08 division with total peak-to-peak aberrations not to exceed ±0.12 division.

PERFORMANCE: ____ division maximum aberrations.

23. Check Input Capacitance page 5-18

REQUIREMENT: 0.2 division or less overshoot or rounding on a five-division display.

PERFORMANCE: ____ division.

24. Check/Adjust Volts/Division Switch Compensation (C24A, C24B, C25A, C25B, C78A, C78B, C79A, C79B) page 5-18

REQUIREMENT: Square corner and flat top within +3% or −3% with total peak-to-peak aberrations not to exceed 3%.

PERFORMANCE: All correct ____; incorrect (list exceptions)______________________.

25. Check Vertical −3 dB Point page 5-19

REQUIREMENT: Not more than −3 dB at 10 megahertz.

PERFORMANCE: −3 dB point ____ megahertz.

26. Check X5 Vertical Gain Upper −3 dB Point page 5-20

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

PERFORMANCE: −3 dB point _____ megahertz.

27. Check Vertical AC-Coupled Lower −3 dB Point page 5-20

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

PERFORMANCE: Correct ____; incorrect ____.

28. Check/Adjust Magnified Registration (R432, R438) page 5-20

REQUIREMENT: Less than one-division shift of marker at center vertical line when X5 HORIZ MAG switch is pulled out.

PERFORMANCE: ____ division shift.

29. Check/Adjust Normal Timing (R404) page 5-21

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

PERFORMANCE: Within ____ division.

REQUIREMENT: Within 0.08 division over any two-division interval within center eight divisions.

PERFORMANCE: Within ____ division.

30. Check Variable Time/Division Control Range page 5-22

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

PERFORMANCE: Correct ____; incorrect ____.

31. Check/Adjust Sweep Length and Centering (R347, R444) page 5-22

REQUIREMENT: 10.5 to 11 divisions sweep length.

PERFORMANCE: ____ divisions.

REQUIREMENT: Range of horizontal POSITION control centered.

PERFORMANCE: Correct ____; incorrect ____.

32. Check/Adjust Magnified Timing (R402) page 5-23

REQUIREMENT: Correct magnified timing within 0.32 division over center eight divisions of total sweep length.

PERFORMANCE: Within ____ division.

REQUIREMENT: Within 0.1 division over any two-division interval within center eight divisions of total sweep length.

PERFORMANCE: Within ____ division.

33. Adjust High-Speed Timing (C330F, C401, C402, C470) page 5-23

REQUIREMENT: Optimum timing and linearity at 1 µs/DIV.

PERFORMANCE: Correct ____; incorrect ____.

34. Check Normal Timing Accuracy page 5-24

REQUIREMENT: Correct timing at each TIME/DIV switch setting within limits given in Table 5-4 over center eight divisions of sweep.

PERFORMANCE: All correct ____; incorrect (list exceptions)________________________.

35. Check Magnified Sweep Timing Accuracy page 5-24

REQUIREMENT: Correct magnified timing at each TIME/DIV switch setting within limits given in Table 5-5 over center eight divisions of total sweep length.

PERFORMANCE: All correct ____; incorrect (list exceptions)________________________.

36. Check/Adjust External Horizontal Position Range (R412) page 5-24

REQUIREMENT: Less than 0.5 division horizontal shift as the EXT HORIZ VAR control is rotated throughout its range.

PERFORMANCE: ____ division shift.

37. Check/Adjust External Horizontal 10X Compensation (C206) page 5-25

REQUIREMENT: Optimum square-wave response.

PERFORMANCE: Correct ____; incorrect ____.

38. Check External Horizontal Operation page 5-25

REQUIREMENT: Deflection of 6.7 to 10 divisions with .2-volt input signal and 1X external horizontal attenuation.

PERFORMANCE: ____ division deflection.

REQUIREMENT: Deflection of 6.7 to 10 divisions with .2-volt input signal and 1X external horizontal attenuation.

PERFORMANCE: ____ divisions deflection.

REQUIREMENT: EXT HORIZ VAR control range 10:1 or greater.

PERFORMANCE: Correct ____; incorrect ____.

REQUIREMENT: Correct signal coupling in AC and DC positions of Trig/Horiz Coupling switch.

PERFORMANCE: Correct ____; incorrect ____.

39. Check External Horizontal Bandwidth page 5-26

REQUIREMENT: Not more than −3 dB at 200 kilohertz.

PERFORMANCE: −3 dB point ____megahertz.

40. Check External Blanking page 5-26

REQUIREMENT: Five-volt positive signal blanks trace.

PERFORMANCE: Correct ____; incorrect ____.

41. Check High-Frequency Triggering Operation page 5-26

REQUIREMENT: Stable display in INT TRIG AC and ACLF REJ positions of the Trig/Horiz Coupling switch with the TRIGGER control set to +AUTO, variable positive-slope area, variable negative-slope area, and −AUTO; check with a 0.3-division display at 1.5 megahertz and a one-division display at 10 megahertz.

PERFORMANCE: All correct ____; incorrect (list exceptions)________________________.

REQUIREMENT: Stable display in EXT TRIG AC and DC positions of the Trig/Horiz Coupling switch with the TRIGGER control set to +AUTO, variable positive-slope area, variable negative-slope area, and −AUTO; check with a 150-millivolt signal at 1.5 megahertz and a 500-millivolt signal at 10 megahertz.

PERFORMANCE: All correct ____; incorrect (list exceptions)________________________.

42. Check Low-Frequency Triggering Operation page 5-28

REQUIREMENT: Stable display in EXT TRIG AC and DC positions of the Trig/Horiz Coupling switch with the TRIGGER control set to +AUTO, variable positive-slope area, variable negative-slope area, and −AUTO; check with a 90-millivolt signal at 30 hertz.

PERFORMANCE: All correct ____; incorrect (list exceptions)________________________.

REQUIREMENT: Stable display in INT TRIG AC position of the Trig/Horiz Coupling switch with the TRIGGER control set to +AUTO, variable positive-slope area, variable negative-slope area, and −AUTO; check with a 0.3-division display at 30 hertz.

PERFORMANCE: All correct ____; incorrect (list exceptions)________________________.

43. Check Low-Frequency Reject Operation page 5-28

REQUIREMENT: Stable display with 0.3-division display at 15 kilohertz with the TRIGGER control set to +AUTO, variable positive-slope area, variable negative-slope area, and −AUTO. Check that stable display cannot be obtained at 30 hertz with any setting of the TRIGGER control.

PERFORMANCE: Correct ____; incorrect ____.

44. Check Trigger Slope Operation page 5-29

REQUIREMENT: Stable triggering on correct slope of trigger signal in +AUTO, variable positive-slope area, variable negative-slope area, and −AUTO positions of the TRIGGER control.

PERFORMANCE: All correct ____; incorrect (list exceptions)________________________.

45. Check Trigger Control Range page 5-29

REQUIREMENT: At least + and −0.8 volts with EXT TRIG ATTEN switch set to 1X. Check in variable positive-slope area and variable negative-slope area.

PERFORMANCE: Correct ____; incorrect ____.

REQUIREMENT: At least + and −8 volts with EXT TRIG ATTEN switch set to 10X. Check in variable positive-slope area and variable negative-slope area.

PERFORMANCE: Correct____; incorrect ____.

46. Check Calibrator Operation page 5-30

REQUIREMENT: Two microseconds or less risetime.

PERFORMANCE: ____ microseconds.

REQUIREMENT: Duration of one cycle between 5 and 8.3 divisons at .2 ms/DIV.

PERFORMANCE: ____ divisions.

REQUIREMENT: Length of positive segment of square wave between 4.0 and 6.0 divisions with one complete cycle/10 divisions.

PERFORMANCE: ____ divisions.

REQUIREMENT: Correct amplitude at CAL OUT jack and in the 5 DIV CAL position of the VOLTS/DIV switch.

PERFORMANCE: Correct ____; incorrect ____.

COMPLETE PERFORMANCE CHECK/CALIBRATION PROCEDURE

General

The following procedure is arranged so the Type 324 can be calibrated with the least interaction of adjustments and reconnection of equipment. A picture of the test equipment required for each group of steps is given to aid in identification of the necessary equipment. The control settings and test equipment setup throughout this procedure continue from the preceding step(s) unless noted otherwise. The control settings can be checked at any test equipment required picture by setting the controls as given at the start of the procedure under the heading Preliminary Control Settings. Then make any changes listed beneath the test equipment required picture under the heading Partial Procedure (also applies to partial calibration procedure).

NOTE

Control titles which are printed on the outside of the Type 324 are capitalized in this procedure (e.g., VOLTS/DIV). Internal adjustments are initial capitalized only (e.g., Limit Centering).

The following procedure uses the equipment listed under Test Equipment Required. If other equipment is substituted, control settings or calibration setup may need to be altered to meet the requirements of the equipment used. Detailed operating instructions for the test equipment are not given in this procedure. Refer to the instruction manual for the test equipment if more information is required.

NOTE

This instrument should be calibrated at an ambient temperature of +25°C ±5°C for best overall accuracy. 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 applicable tolerances.

Preliminary Procedure for Performance Check Only

1. Connect the Type 324 to the output of the variable DC power supply (set for +8 volts) with the two patch cords. If step 8 is deleted, the instrument can be connected directly to an AC power source which meets the voltage and frequency requirements of this instrument.

NOTE

Battery operation can be used for this procedure if the internal batteries are fully charged before proceeding.

2. Set the controls as given under Preliminary Control Settings. Allow at least five minutes warmup before proceeding.

3. Begin the performance check with step 8.

Preliminary Procedure for Complete Calibration

1. Remove the cabinet from the Type 324 (see Section 2).

2. Remove the high-voltage cover and power pack from the Type 324. Removal instructions are given in the Maintenance section.

3. Using the AC power cord, connect the power pack of the Type 324 to an AC line voltage source which is within the voltage and frequency requirements of this instrument.

4. Set the controls as given under Preliminary Control Settings. Allow at least five minutes warmup before proceeding.

Preliminary Control Settings

Set the Type 324 controls as follows:

Vertical Controls

VOLTS/DIV	.01
VARIABLE	CAL
INPUT	GND
Vertical POSITION	Midrange
X5 VERT GAIN	Pushed in

Triggering Controls

TRIGGER	+AUTO
Trig/Horiz Coupling	INT TRIG AC
EXT TRIG OR HORIZ ATTEN (side panel)	1X

Horizontal Controls

TIME/DIV	1 ms
VARIABLE	CAL
Horizontal POSITION	Midrange
X5 HORIZ MAG	Pushed in

CRT Controls

FOCUS	Adjust for well defined display
INTENSITY	Midrange

Power Controls

POWER	ON
Power Pack (rear panel)	FULL CHG

NOTES

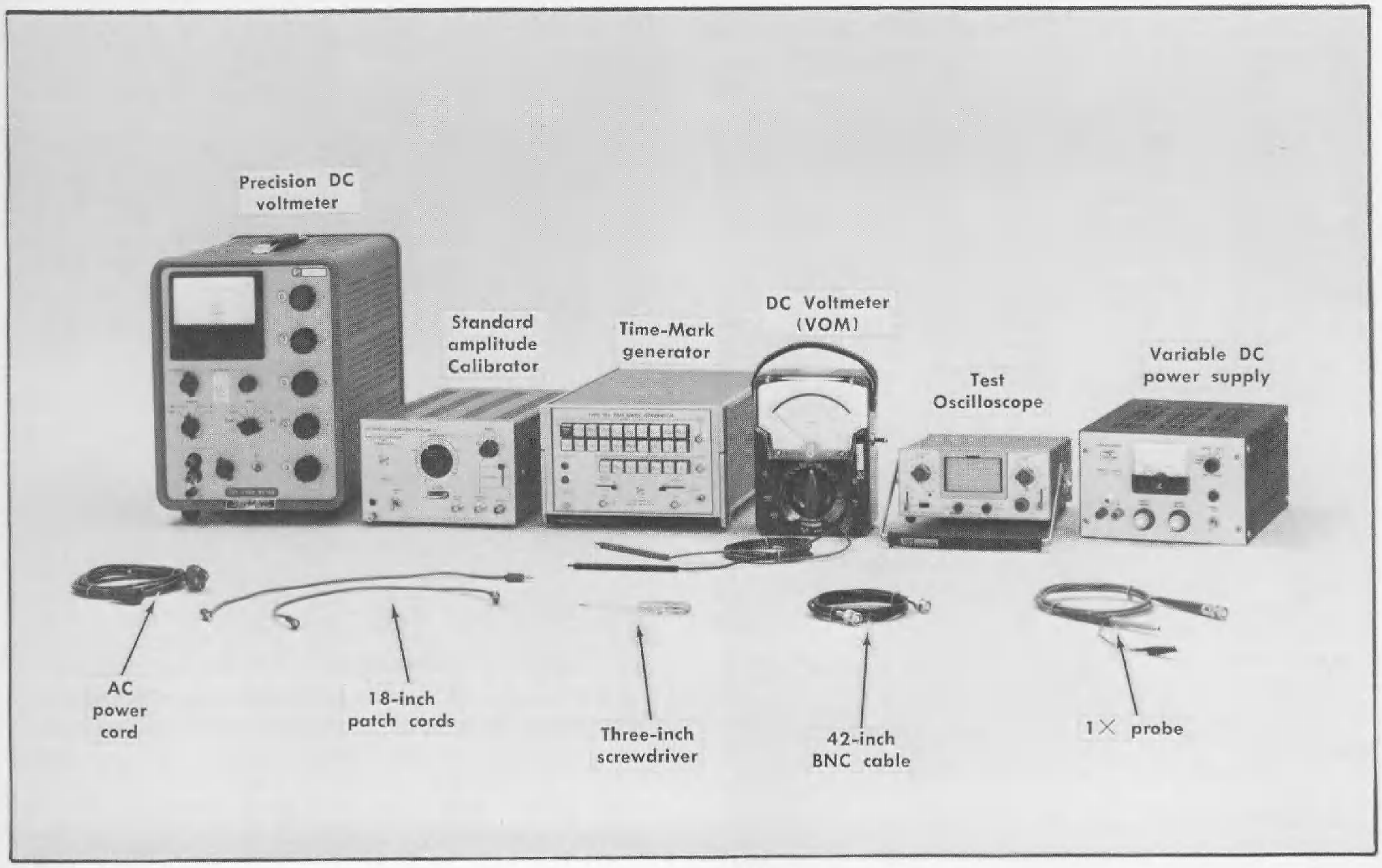


Fig. 5-1. Test equipment required for steps 1 through 20.

1. Adjust Charging Current

PERFORMANCE CHECK ONLY

Steps 1 through 7 are not applicable to a performance check. Set controls as given under Preliminary Control Settings and begin with step 8.

a. Test equipment required for steps 1 through 20 is shown in Fig. 5-1.

b. Change the following control settings:

INTENSITY	Fully counterclockwise
POWER	OFF

c. Connect the precision DC voltmeter across R615 (see Fig. 5-2). The positive lead of the voltmeter should be connected to the bottom of R615. Be sure the negative lead of the voltmeter is isolated from ground.

NOTE

Power supply voltage and ripple tolerances given in steps 1 through 8 are typical values provided as guides to correct instrument operation and are not instrument specifications. Actual values may exceed those listed without loss of measurement accuracy, if the instrument meets the specifications given in Section 1 when tested in accordance with this procedure.

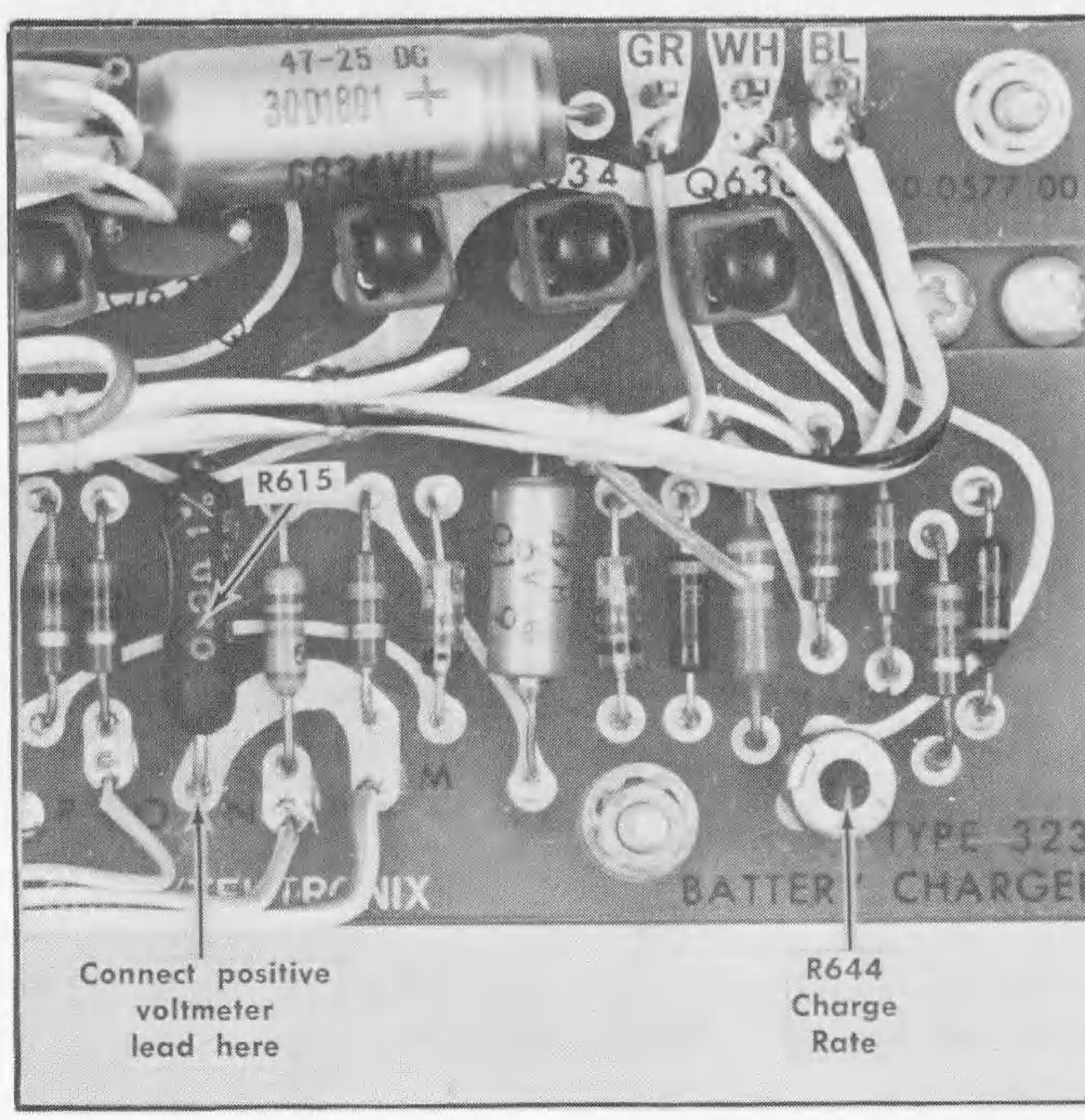


Fig. 5-2. Location of R615 and Charge Rate adjustment (Power Pack board).

d. CHECK—Meter reading; 54 millivolts, ±3 millivolts, (180 milliamperes, ±10 milliamperes, charge current).

e. ADJUST—Charge Rate adjustment, R644 (see Fig. 5-2), for a meter reading of 54 millivolts.

f. Set the Power Pack switch (rear panel of power pack) to TRICKLE CHG.

g. CHECK—Meter reading; approximately 20 millivolts.

h. Disconnect the precision DC voltmeter and the AC power cord.

2. Adjust High-Voltage Supply and Check Regulation

a. Set the Power Pack switch to EXT DC.

b. Install the power pack in the Type 324.

c. Connect the variable DC power supply to the EXT DC POWER input jacks with the banana-plug patch cords (be sure to observe correct polarity; red positive, black negative).

d. Set the variable DC power supply for a +8-volt output.

e. Set the POWER switch to ON.

f. Connect the DC voltmeter (VOM)[2] from point J on the H.V. Power Supply board (see Fig. 5-3) to chassis ground.

g. CHECK—Meter readings; −1900 volts, ±38 volts.

h. ADJUST—High Voltage adjustment, R513 (H.V. Power Supply board; see Fig. 5-3), for a meter reading of −1900 volts.

i. Change the variable DC power supply output voltage between +6 volts and +16 volts. Also, set the INTENSITY control fully clockwise at +6 volts and fully counterclockwise at +16 volts.

[2]If the precision 2 kV voltage divider is available for use with the precision DC voltmeter, it should be used for this step.

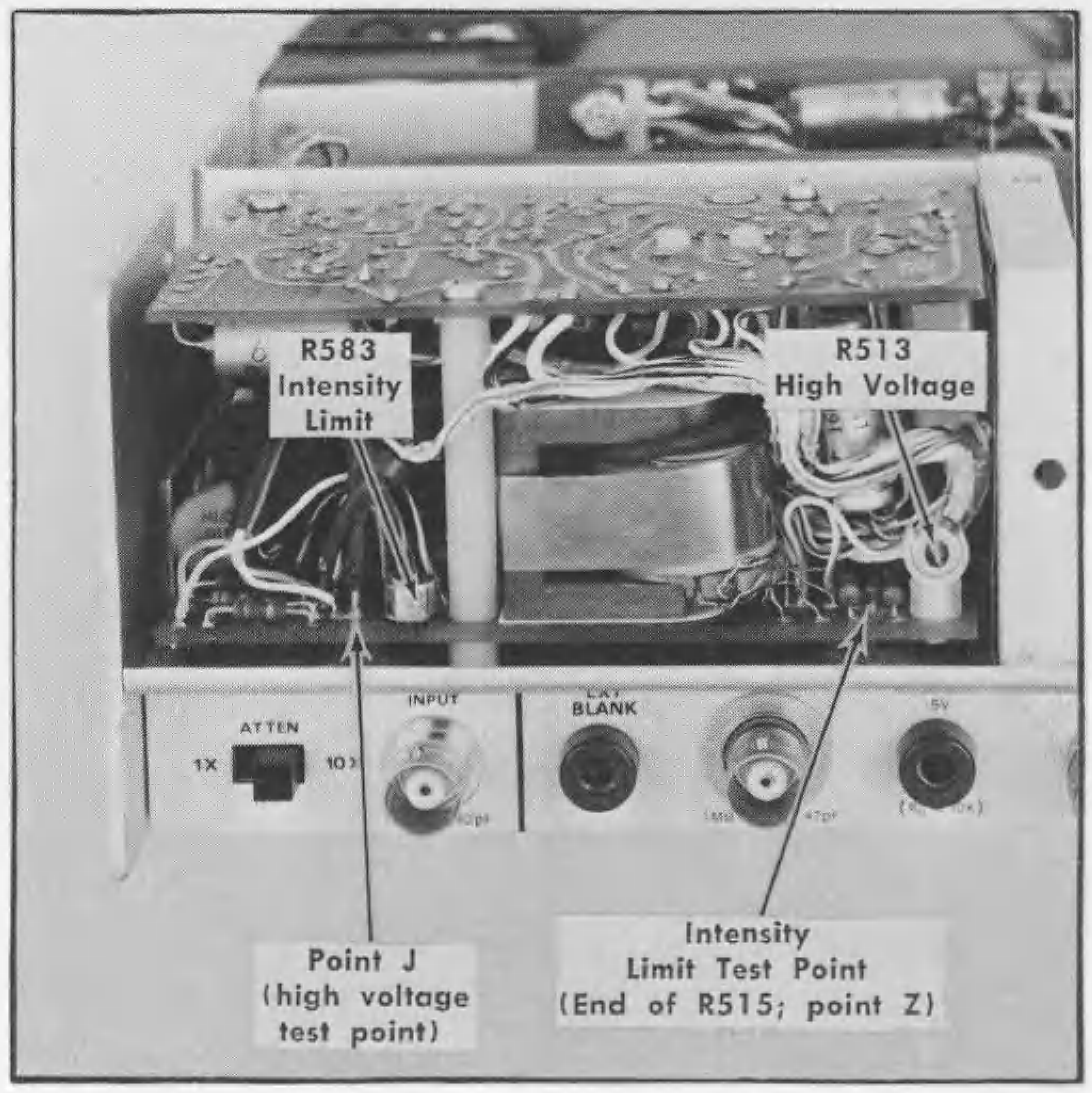


Fig. 5-3. Location of high-voltage test points and adjustments (H.V. Power Supply board).

j. CHECK—Less than ±40 volts change in the high-voltage output level.

NOTE

If the high-voltage supply is out of regulation, check the regulation of the low-voltage supplies (step 7) before troubleshooting in the high-voltage supply.

k. Return the variable DC power supply to +8 volts.

l. INTERACTION—May affect operation of all circuits within the Type 324.

3. Adjust Intensity Limit

a. Connect DC voltmeter (VOM) from the Intensity Limit Test Point on the H.V. Power Supply board (outside end of R515, point Z; see Fig. 5-3) to chassis ground.

b. Set the INTENSITY control fully clockwise (maximum).

c. CHECK—Meter reading, 0.6 volt, ±0.03 volt (140 microamperes, ±17 microamperes). Take into account any meter loading of R572 if the recommended voltmeter is not used.

Ⓐ

d. ADJUST—Intensity Limit adjustment, R583 (H.V. Power Supply board; see Fig. 5-3) for a meter reading of 0.6 volt. If R583 cannot be adjusted to obtain 0.6 volt, R584 may have to be re-selected. If the measured voltage is too low, replace R584 with a smaller value resistor (not less than 1.8 MΩ); if the voltage is too high, replace R584 with a larger value resistor (not more than 3.3 MΩ). Ideally, a value should be selected (within the prescribed range) which permits a near mid-range setting of R583. If a resistor larger than 3.3 MΩ is necessary, the CRT should be replaced.

4. Adjust +5-Volt Power Supply (CAL OUT Voltage)

a. Connect the precision DC voltmeter from the CAL OUT jack to chassis ground.

b. Remove Q9 from its socket on the Attenuator board (see Fig. 5-4A).

c. CHECK—Meter reading; +0.500 volt, ±2.5 millivolts.

d. ADJUST—+5 Volts adjustment, R552 (see Fig. 5-4A), for a meter reading of +0.500 volts.

e. Disconnect the precision DC voltmeter and replace Q9.

f. Connect the precision DC voltmeter from the +5-volt test point (point AE, Horizontal board; see Fig. 5-4B) to chassis ground.

g. CHECK—Meter reading; +5.0 volts, ±0.1 volt.

h. INTERACTION—May affect operation of all circuits within the Type 324.

5. Adjust −5-Volt Power Supply

a. Connect the precision DC voltmeter from the −5-volt test point (point AF, Horizontal board; see Fig. 5-4B) to chassis ground.

b. CHECK—Meter reading; −5 volts, ±0.1 volt.

e. ADJUST— −5 Volts adjustment, R566 (see Fig. 5-4A), for a meter reading of −5 volts.

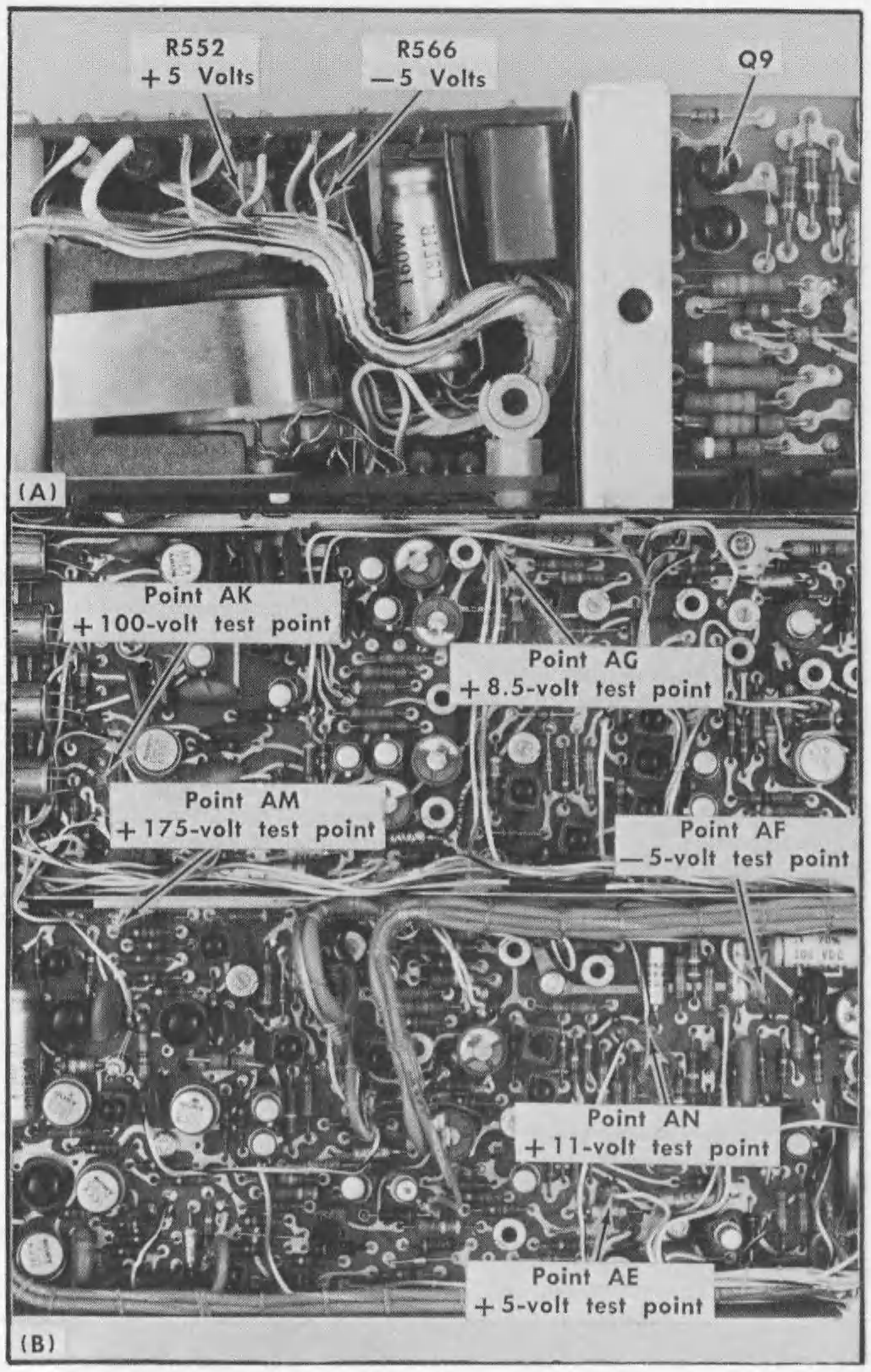


Fig. 5-4. (A) Location of Q9 (Attenuator board) and low-voltage power-supply adjustments (L.V. board), (B) Location of low-voltage power-supply test points (Vertical and Horizontal boards).

d. INTERACTION—May affect operation of all circuits within the Type 324.

6. Check Remaining Power Supplies

a. Connect the precision DC voltmeter from the +8.5-volt test point (point AG, Vertical board; see Fig. 5-4B) to chassis ground.

b. CHECK—Meter reading; +8.5 volts, ±0.5 volt.

c. Connect the precision DC voltmeter from the +11-volt test point (point AN, Horizontal board; see Fig. 5-4B) to chassis ground.

d. CHECK—Meter reading; +11 volts, ±2.2 volts.

e. Connect the precision DC voltmeter from the +100-volt test point (point AK, Vertical board, see Fig. 5-4B) to chassis ground.

f. CHECK—Meter reading; +100 volts, ±5 volts.

g. Connect the precision DC voltmeter from the +175-volt test point (point AM, Horizontal board; see Fig. 5-4B) to chassis ground.

h. CHECK—Meter reading; +175 volts, within +14 to −7 volts.

i. Disconnect the precision DC voltmeter.

j. Turn off the POWER switch temporarily and replace the high-voltage cover. Replacement instructions are given in the Maintenance section.

7. Check Low-Voltage Power Supply Ripple and Regulation

a. Change the following control settings:

TIME/DIV	EXT HORIZ
Vertical POSITION	Position spot off screen
POWER	ON

b. Connect the 1X probe to the test oscilloscope input.

c. Set the test oscilloscope for a vertical deflection factor of 0.01 volt/division, AC coupled, at a sweep rate of 20 microseconds/division.

d. CHECK—Test oscilloscope display for maximum ripple of each supply while varying the DC power supply output voltage between +6.5 volts and +16 volts. Table 5-1 lists the maximum ripple for each supply; Fig. 5-4B shows the power-supply test points. Change the vertical deflection factor of the test oscilloscope as necessary to make each measurement.

e. Disconnect the test oscilloscope.

TABLE 5-1

Power-Supply Ripple and Regulation

Supply	Maximum Ripple	Output voltage tolerance (regulation)
−5-Volt	10 millivolts	±0.1 volt
+5-Volt	10 millivolts	±0.1 volt
+8.5-Volt	20 millivolts	±0.75 volt
+11-Volt	200 millivolts	±2.2 volt
+100-Volt	200 millivolts	±5.0 volt
+175-Volt	750 millivolts	±14 volt

f. Change the variable DC power supply output voltage between +6.5 volts and +16 volts. Also set the INTENSITY control fully clockwise at +6.5 volts and fully counterclockwise at +16 volts.

g. CHECK—Each supply with the precision DC voltmeter for output change within the limits given in Table 5-1 while varying the DC power source as given above. Power-supply test points are shown in Fig. 5-4B.

8. Check Low Batteries Indicator

a. Change the following control settings:

Vertical POSITION	Midrange
TIME/DIV	1 ms
INTENSITY	Normal intensity

b. Connect the precision DC voltmeter across the applied DC voltage at the EXT DC POWER jacks.

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

d. CHECK—LOW BATT light begins to flash when variable DC power supply output voltage is +6.5 volts within +0.33 to −0 volts.

e. Return variable DC power supply output voltage to +8 volts.

NOTE

If the internal batteries of the Type 324 are fully charged, the remainder of this procedure can be performed with battery-powered operation.

9. Check/Adjust Variable Volts/Division Balance

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

b. CHECK—Rotate the VARIABLE VOLTS/DIV control throughout its range. Trace should not move more than one division vertically (if the trace is not visible at all, preset the VAR V/DIV BAL adjustment to bring the trace on screen).

PERFORMANCE CHECK ONLY

Adjustment accessible through cutout in bottom of cabinet; can be adjusted as part of performance check.

c. ADJUST—VAR V/DIV BAL adjustment, R107 (see Fig. 5-5), for no trace shift as the VARIABLE VOLTS/DIV control is rotated. If necessary, use the vertical POSITION control to keep the trace on screen during this adjustment.

10. Check/Adjust Vertical X5 Balance

a. Return the VARIABLE VOLTS/DIV control to CAL.

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

c. Pull the X5 VERT GAIN switch out (to prevent changing knob position, the X5 VERT GAIN switch can be actuated using the vertical POSITION control bracket behind the front panel).

d. CHECK—Trace shift less than 1.5 division vertically.

PERFORMANCE CHECK ONLY

Adjustment accessible through cutout in bottom of cabinet; can be adjusted as part of performance check.

e. ADJUST—VERT X5 BAL adjustment, R128 (see Fig. 5-5), to return the trace to the center horizontal line. Repeat parts b through e for minimum trace shift as the X5 VERT GAIN switch is pulled out.

f. Push the X5 VERT GAIN switch in.

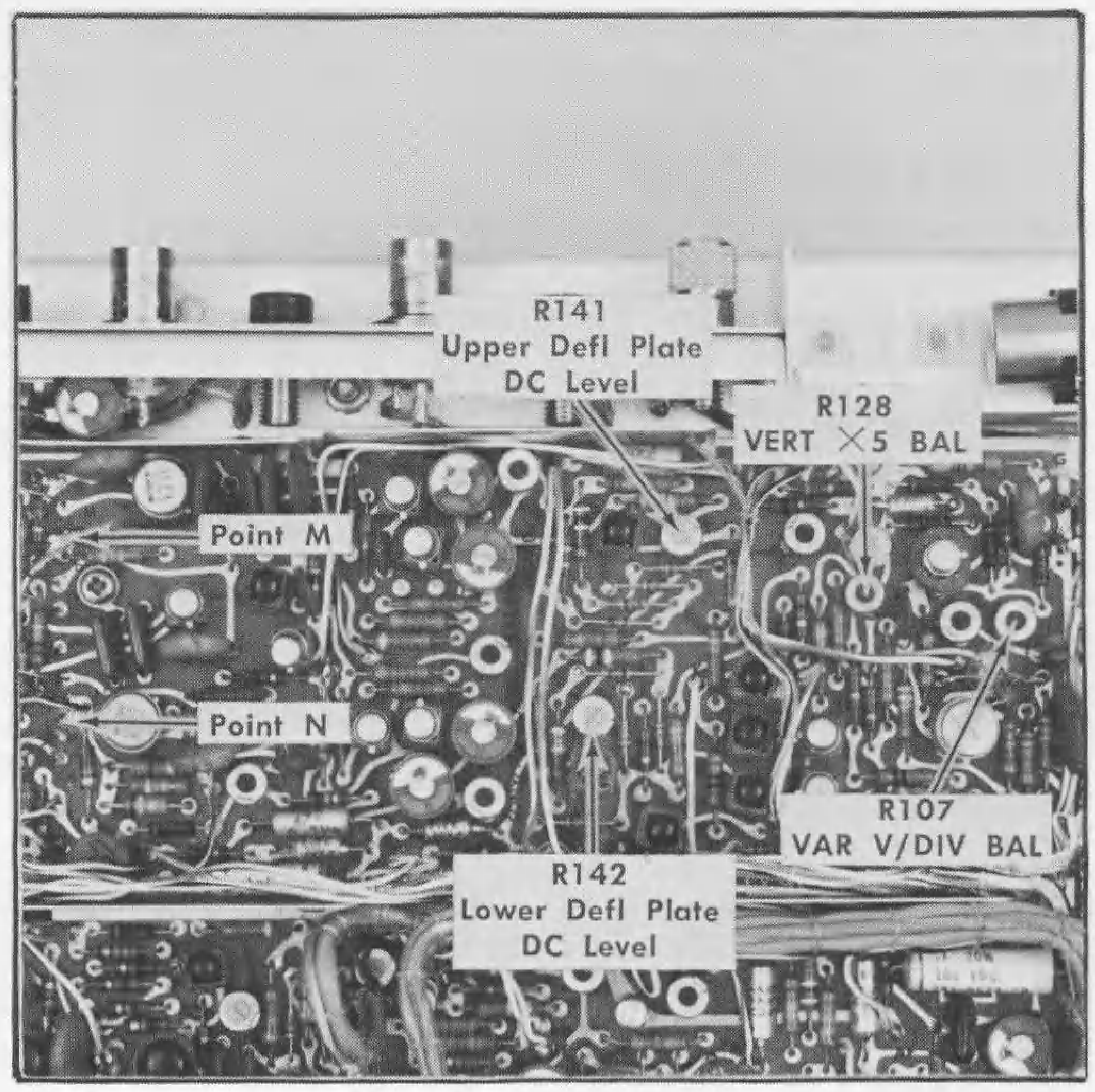


Fig. 5-5. Location of vertical adjustments (Vertical board).

g. Recheck step 9. If readjustment is necessary, recheck this step also.

11. Adjust Deflection Plate DC Level

PERFORMANCE CHECK ONLY

This step is not applicable to a performance check; proceed with step 12.

a. Connect the DC voltmeter from point M of the Vertical board (see Fig. 5-5) to chassis ground.

b. Rotate the vertical POSITION control fully clockwise and note the meter reading. Then rotate the vertical POSITION control fully counterclockwise and again note the meter reading.

c. CHECK—Voltage range measured in part b centered around +50 volts.

d. ADJUST—Upper Defl Plate DC Level adjustment, R141 (see Fig. 5-5), to center the measured voltage range around +50 volts.

e. Connect the DC voltmeter from point N of the Vertical board (see Fig. 5-5) to chassis ground.

f. Rotate the vertical POSITION control fully clockwise and note the meter reading. Then rotate the vertical POSITION control fully counterclockwise and again note the meter reading.

g. CHECK—Voltage range measured in part f centered around +50 volts.

h. ADJUST—Lower Defl Plate DC Level adjustment, R142 (see Fig. 5-5) to center the measured voltage range around +50 volts.

i. Position the trace to the center horizontal line with the vertical POSITION control.

j. With the DC voltmeter connected to point N, adjust the Limit Centering adjustment, R123 (see Fig. 5-6), for a meter reading of +50 volts (perform this adjustment only if proceeding to next step).

12. Check/Adjust Astigmatism

a. Change the following control settings:

VOLTS/DIV	.5
INPUT	DC

b. Set the INTENSITY control midway between a barely visible trace and fully clockwise.

c. Connect the time-mark generator (Type 184) to the VERT INPUT connector with the 42-inch BNC cable.

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

e. If necessary, set the TRIGGER control for a stable display.

f. CHECK—Markers should be well defined within the areas indicated in Fig. 5-6A with optimum setting of focus control.

PERFORMANCE CHECK ONLY

Adjustment accessible through cutouts in bottom of cabinet; can be adjusted as part of performance check.

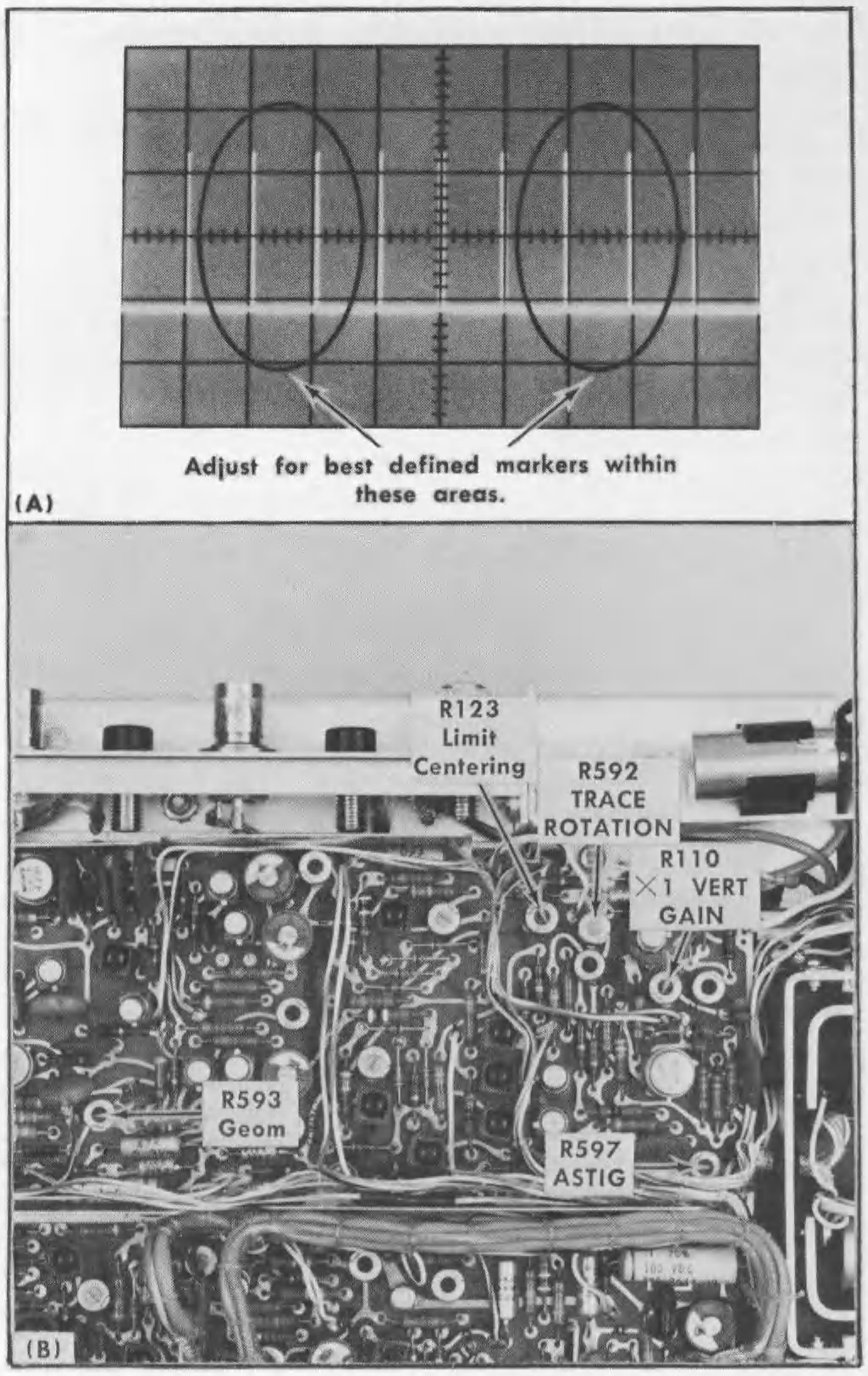


Fig. 5-6. (A) Area of CRT display to check for correct astigmatism adjustment, (B) Location of CRT and vertical adjustments (Vertical board).

g. ADJUST—FOCUS control and ASTIG adjustment, R597 (see Fig. 5-6B), for the best definition of the markers within the areas indicated in Fig. 5-6A.

13. Check/Adjust Trace Alignment

a. Position the baseline of the marker display to the center horizontal line with the vertical POSITION control.

b. CHECK—Baseline of marker display should be parallel to the center horizontal line.

PERFORMANCE CHECK ONLY

Adjustment accessible through cutout in bottom of cabinet; can be adjusted as part of performance check.

c. ADJUST—TRACE ROTATION adjustment, R592 (see Fig. 5-6B), so the baseline of the marker display is parallel to the center horizontal line.

14. Check/Adjust CRT Geometry ⓘ

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

b. Position the baseline of the marker display below the bottom of the graticule with the vertical POSITION control.

c. CHECK—CRT display for curvature of vertical lines (markers) within maximum deviation of 0.1 division from straight line. Curvature can be most easily checked by positioning the markers to the vertical graticule lines with the horizontal POSITION control.

d. ADJUST—Geom adjustment, R593 (see Fig. 5-6B), for minimum curvature of vertical lines.

e. Disconnect the time-mark generator.

f. Set the TRIGGER control to +AUTO.

g. Position the trace to the top line of the graticule with the vertical POSITION control.

h. CHECK—Deviation from straight line should not exceed 0.1 division.

i. Position the trace to the bottom line of the graticule with the vertical POSITION control.

j. CHECK—Deviation from straight line should not exceed 0.1 division.

NOTE

It may be necessary to compromise the setting of R593 to provide acceptable displays both in part c and parts g and i.

15. Check/Adjust Limit Centering ⓘ

a. Set the VOLTS/DIV switch to 5 DIV CAL.

b. Position the bottom of the display to the first graticule line below the center horizontal line.

c. Reduce the display to exactly two divisions with the VARIABLE VOLTS/DIV control.

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

e. CHECK—Compression (reduction in amplitude) not to exceed 0.1 division.

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

g. CHECK—Compression (reduction in amplitude) not to exceed 0.1 division.

h. Return the display to the position which produces the most compression of the display.

i. ADJUST—Limit Centering adjustment R123 (see Fig. 5-6B), for maximum display amplitude (least compression). Compression or expansion should not exceed 0.1 division.

16. Check/Adjust X1 Vertical Gain ⓘ

a. Change the following control settings:

VOLTS/DIV	.01
VARIABLE VOLTS/DIV	CAL

b. Connect the standard amplitude calibrator (067-0502-01) output connector to the VERT 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

Adjustment accessible through cutout in bottom of cabinet; can be adjusted as part of performance check.

f. ADJUST—X1 VERT GAIN adjustment, R110 (see Fig. 5-6B), for exactly five divisions of deflection.

17. Check Vertical X5 Gain

a. Set the standard amplitude calibrator for a 10-millivolt square-wave output.

b. Pull the X5 VERT GAIN switch.

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

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

NOTE

If X5 gain is incorrect, R135 can be re-selected. If display is greater than 5.15 divisions, increase the value of R135 (not more than 119 Ω). If less than 4.85 divisions, reduce the value of R135 (not less than 114 Ω).

18. Check Vertical Deflection Accuracy

a. Push the X5 VERT GAIN switch in.

b. CHECK—Using the VOLTS/DIV switch and standard amplitude calibrator settings given in Table 5-2, check vertical deflection within 3% at each position of the VOLTS/DIV switch.

TABLE 5-2

Vertical Deflection Accuracy

VOLTS/DIV switch setting	Standard amplitude calibrator output	Vertical deflection in divisions	Maximum error for ±3% accuracy (divisions)
.01	50 millivolts	5	Checked and adjusted in step 16
.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

19. Check Variable Volts/Division Control Range

a. Set the standard amplitude calibrator for a 50-millivolt square-wave output.

b. Change the following control settings:

VOLTS/DIV	.01
INPUT	AC

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

d. CHECK—Rotate the VARIABLE VOLTS/DIV control fully counterclockwise. Display must be reduced to two divisions or less (indicates adequate range for continuously variable deflection factors between the calibrated steps).

20. Check Input Coupling Switch Operation

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

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 switch to GND.

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

f. Set the INPUT switch to DC.

g. CHECK—CRT display for square wave with the bottom near the center horizontal line.

h. Disconnect all test equipment.

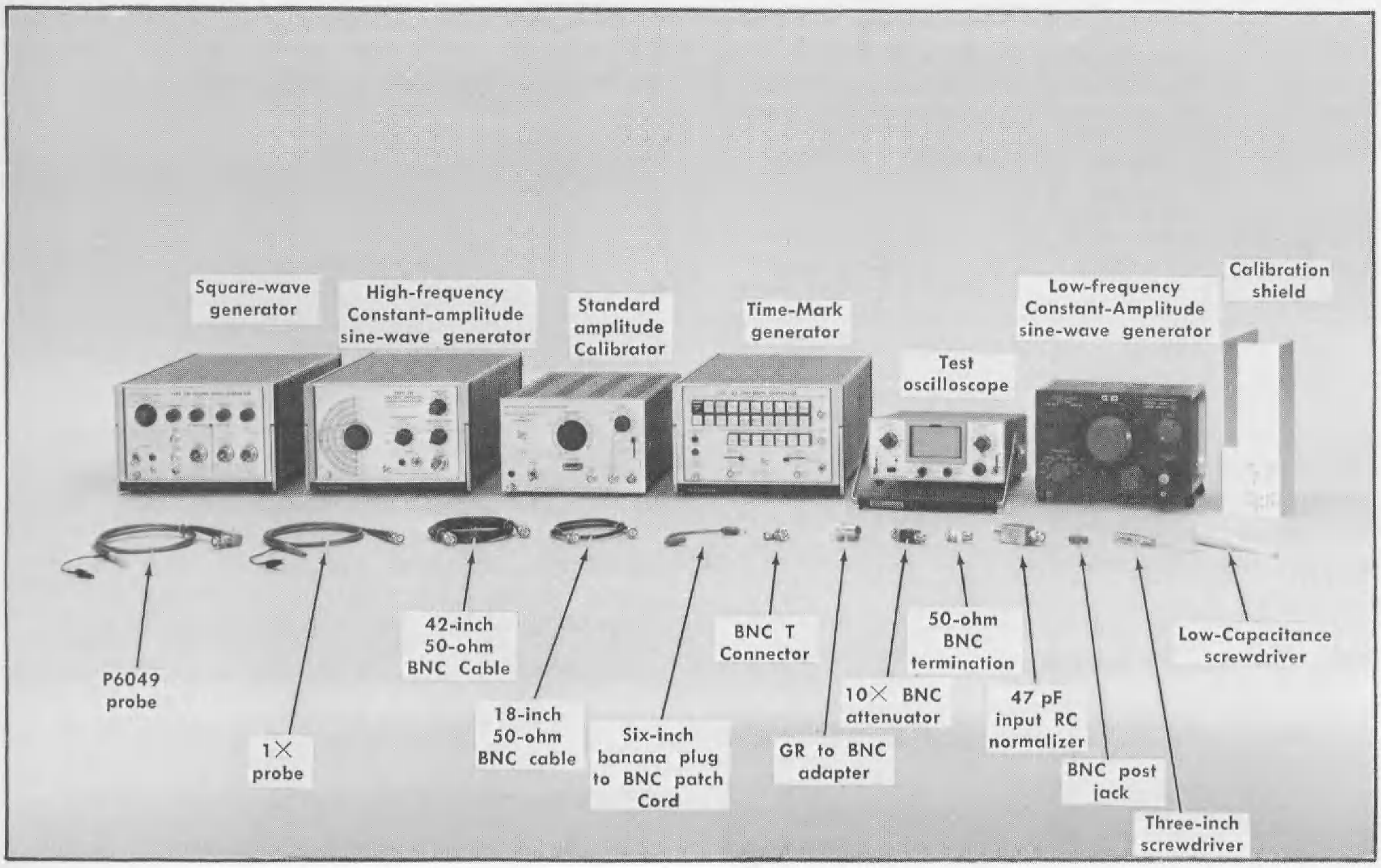


Fig. 5-7. Test equipment required for steps 21 through 46.

Partial Procedure

If beginning a partial procedure with this step, set the controls as given under Preliminary Control Settings.

21. Check Trace Shift Due to Input Current

a. Test equipment required for steps 21 through 46 is shown in Fig. 5-7.

b. Change the following control settings:

INPUT	GND
X5 VERT GAIN	Pulled out

c. Install the calibration shield (067-0622-00) on the Type 324.

d. Position the trace to the center horizontal line with the vertical POSITION control.

e. CHECK—Set the INPUT switch to DC. Trace shift should be negligible (0.085 division maximum).

f. Remove the calibration shield.

22. Check/Adjust High-Frequency Compensation ⓿

a. Change the following control settings:

X5 VERT GAIN	Pushed in
TIME/DIV	1 µs
X5 HORIZ MAG	Pulled out

b. Connect the square-wave generator (Type 106) fast-rise + output connector to the VERT INPUT connector through the GR to BNC adapter, 42-inch 50-ohm BNC cable, 10X BNC attenuator and the 50-ohm BNC termination.

c. Set the square-wave generator for a four-division display at 100 kilohertz.

d. Move the leading edge of the square wave onto the viewing area with the horizontal POSITION control.

e. Set the test oscilloscope for a vertical deflection factor of one volt/division (10 volts/division at 10X probe tip) at a sweep rate of five microseconds/division. Adjust the triggering controls when necessary to provide a stable display.

f. Connect the 10X probe tip to point M on the Vertical board (see Fig. 5-8A). Be sure the probe is compensated.

g. CHECK—Test oscilloscope display for flat top on square wave.

h. ADJUST—C113, C114, and R152 (see Fig. 5-8A) for optimum flat top on square wave (use low-capacitance screwdriver).

i. Connect the 10X probe tip to point N on the Vertical board (see Fig. 5-8A).

j. CHECK—Test oscilloscope display for flat bottom on square wave.

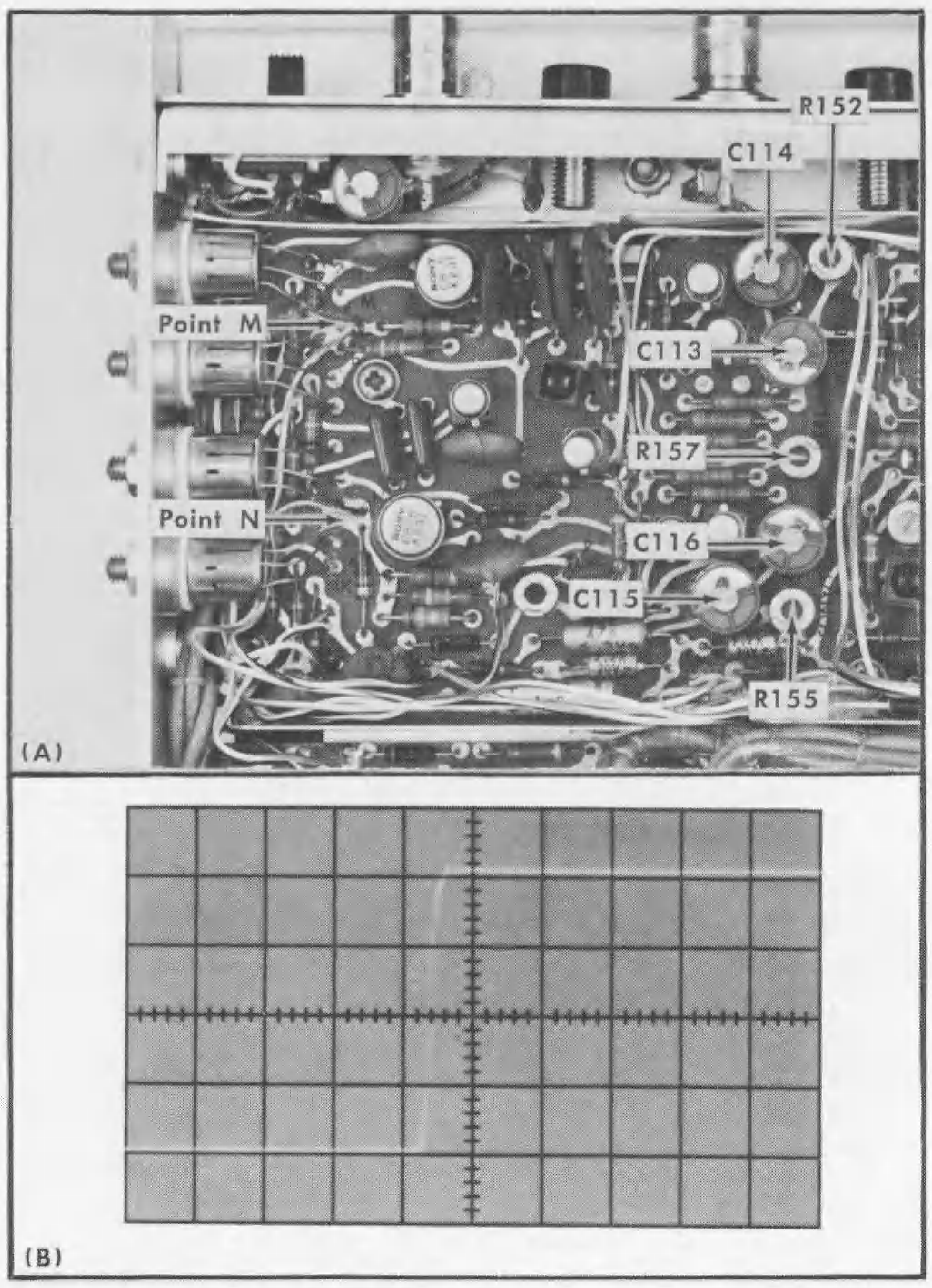


Fig. 5-8. (A) Location of high-frequency compensation test points and adjustments (Vertical board), (B) Typical CRT display showing correct high-frequency compensation.

k. ADJUST—C115, C116, and R155 (see Fig. 5-8A) for optimum flat bottom on square wave (use low-capacitance screwdriver).

l. Disconnect the probe tip.

m. CHECK—Type 324 CRT display for optimum square corner within +0.08 or −0.08 division with total peak-to-peak aberrations not the exceed ±0.12 division (within +2% or −2% with total peak-to-peak aberrations within 3%; see Fig. 5-8B).

n. ADJUST—R157 (see Fig. 5-8A) for optimum square corner on the CRT display. If necessary, readjust C113-C114-R152 and C115-C116-R155 about the same amount in the same direction for optimum square corner on the CRT display (if major readjustment of these capacitors is necessary, repeat the entire step).

o. Disconnect all test equipment.

23. Check Input Capacitance

a. Change the following control settings:

TIME/DIV	.5 ms
X5 HORIZ MAG	Pushed in

b. Install the calibration shield on the Type 324.

c. Connect the square-wave generator high-amplitude output connector to the VERT INPUT connector through the GR to BNC adapter, 10X BNC attenuator, 42-inch 50-ohm BNC cable, 50-ohm termination and 47 pF input RC normalizer, in given order.

d. Set the square-wave generator for a five-division display at one kilohertz.

e. CHECK—CRT display for 0.2 division, or less, overshoot or rounding (47 pF, ±4 pF; see Fig. 5-9).

f. Disconnect all test equipment (leave calibration shield on).

24. Check/Adjust Volts/Division Switch Compensation

a. Connect the P6049 Probe to the VERT INPUT connector of the Type 324.

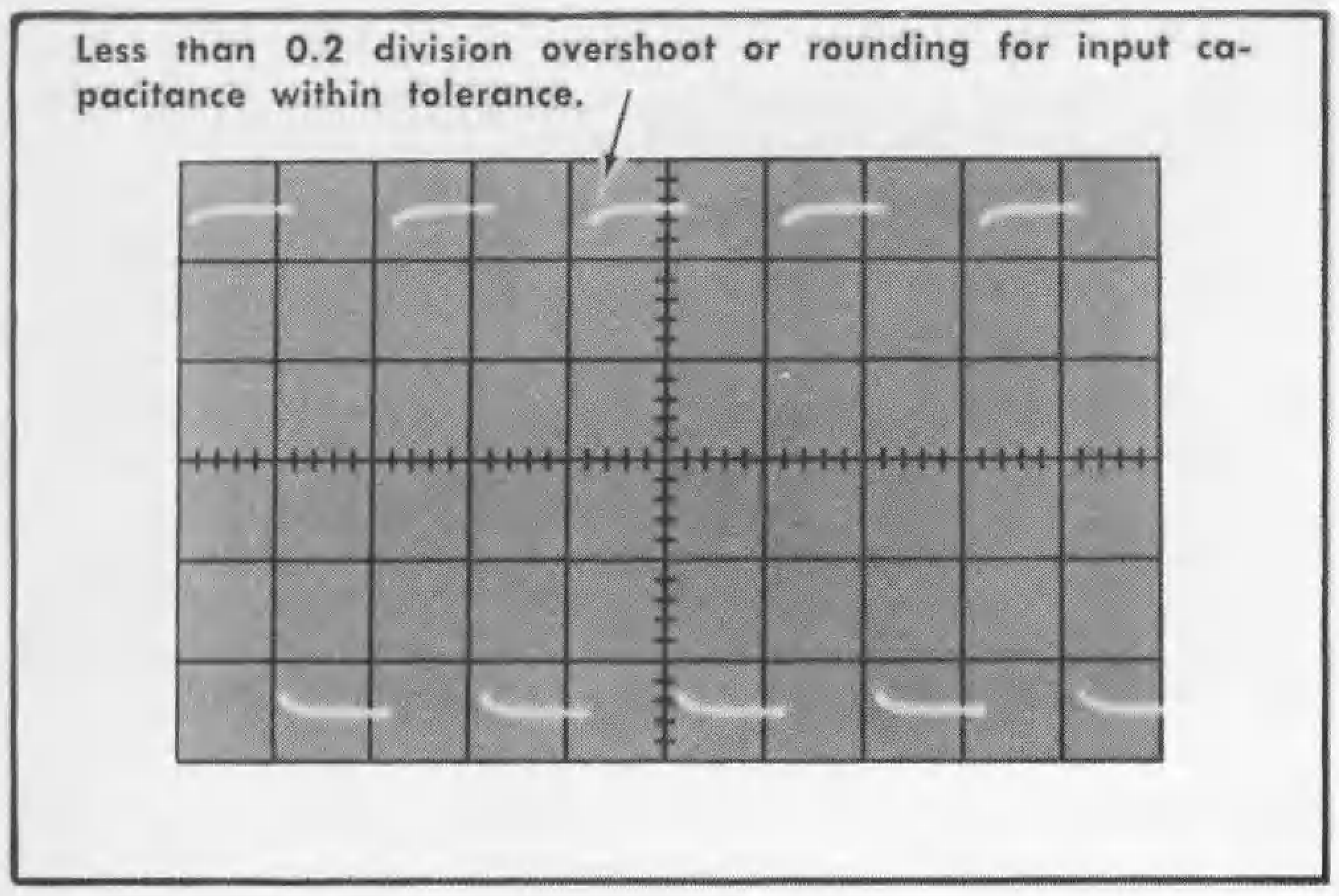


Fig. 5-9. Typical CRT display when checking input capacitance.

b. Install the GR to BNC adapter, 10X BNC attenuator and BNC post jack on the square-wave generator high-amplitude output connector in given order.

c. Connect the probe tip to the BNC post jack.

d. Set the square-wave generator for a five-division display at one kilohertz.

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

f. CHECK—CRT display at each VOLTS/DIV switch setting as given in Table 5-3 for optimum square corner and flat top within +3% or −3%, with total peak-to-peak aberrations not to exceed 3% (see Fig. 5-10A). Remove the attenuator and pull the X5 VERT GAIN switch as given in Table 5-3; readjust the generator at each setting to maintain a five-division display (maximum display is about three divisions in 20 position).

g. ADJUST—VOLTS/DIV switch compensation as given in Table 5-3 (use low-capacitance screwdriver). First adjust for optimum square corner and then for optimum flat top. Remove the attenuator and pull the X5 VERT GAIN switch as given in Table 5-3; readjust the generator at each setting to maintain a five-division display (maximum display is about three divisions in 20 position). Fig. 5-10B shows the location of the variable capacitors.

h. Disconnect all test equipment and remove the calibration shield.

TABLE 5-3

VOLTS/DIV Compensation

VOLTS/DIV switch setting	Attenuator compensated	Adjust for optimum Square Corner	Flat Top
.01	÷1	Compensate P6049 Probe	
.02	÷2	C78B	C78A
.05	÷5	C79B	C79A
Remove external 10X attenuator from generator			
.1	÷10	C23B	C23A
.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	÷100	C24B	C24A
2	Check	If out of tolerance, compromise setting at 1 and 2 for best overall response	
Pull X5 VERT GAIN switch			
5	Check	If out of tolerance, compromise setting at 1, 2 and 5 for best overall response	
10	÷1000	C25B	C25A
20	Check	If out of tolerance, compromise setting at 10 and 20 for best overall response	

25. Check Vertical −3 dB Point

a. Change the following control settings:

VOLTS/DIV	.01
X5 VERT GAIN	Pushed in
TIME/DIV	1 ms

b. Connect the high-frequency constant-amplitude sine-wave generator (Type 191) to the VERT INPUT connector through the GR to BNC adapter, 42-inch 50-ohm BNC cable, 10X BNC attenuator 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).

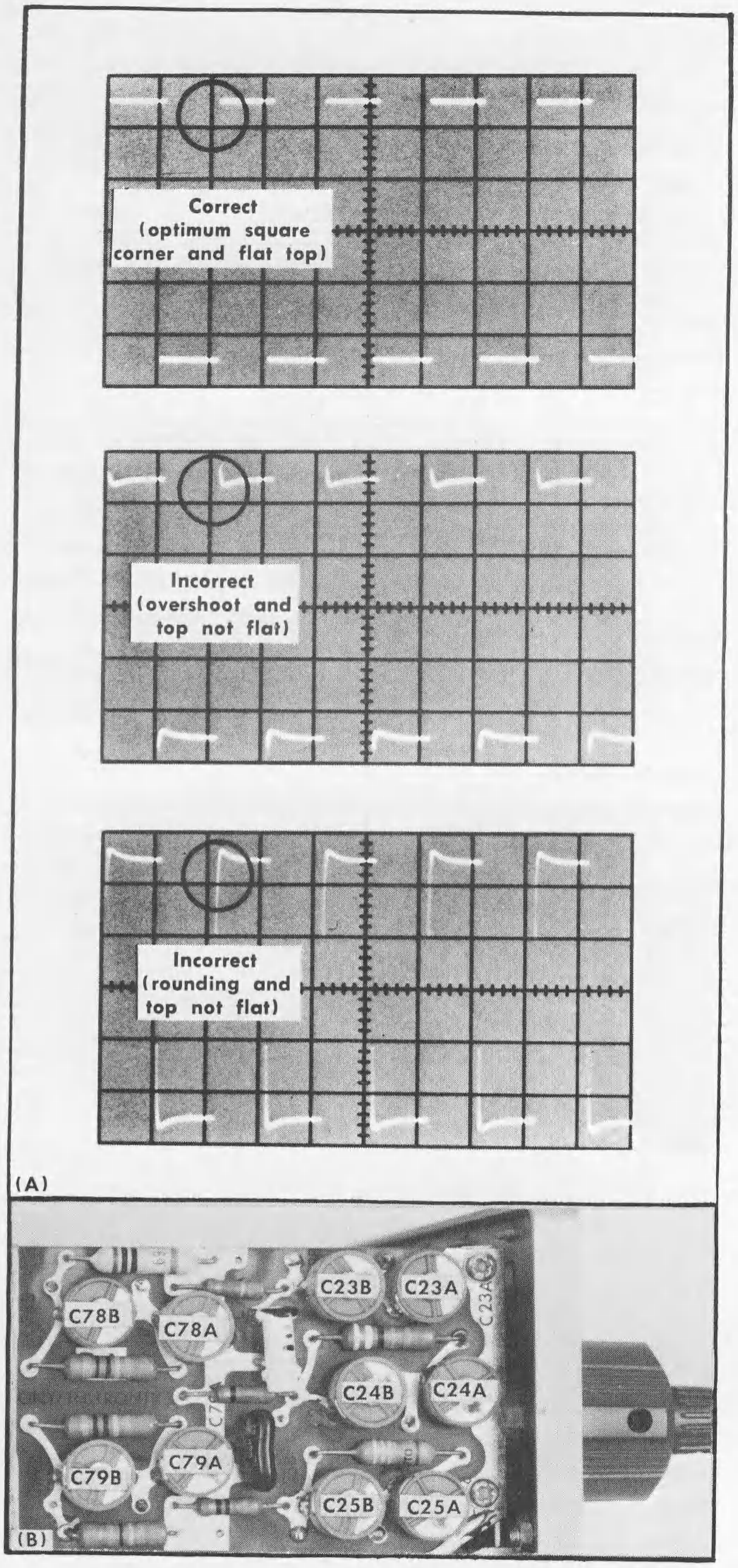


Fig. 5-10. (A) Typical CRT display showing correct and incorrect compensation, (B) Location of compensation adjustments (Attenuator board).

e. CHECK—Output frequency of generator must be 10 megahertz or higher.

26. Check X5 Vertical Gain Upper −3 dB Point

a. Pull the X5 VERT GAIN switch out.

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

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

d. CHECK—Output frequency of generator must be eight megahertz or higher.

e. Disconnect all test equipment.

27. Check Vertical AC-Coupled Lower −3 dB Point

a. Connect the low-frequency constant-amplitude generator to the VERT INPUT connector through the 42-inch 50-ohm BNC cable and the 50-ohm BNC termination.

b. Change the following control settings:

INPUT	AC
X5 VERT GAIN	Pushed in
TIME/DIV	.2 s

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

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

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

f. Disconnect all test equipment.

28. Check/Adjust Magnified Registration

a. Change the following control settings:

VOLTS/DIV	.5
INPUT	DC
TIME/DIV	1 ms

b. Connect the time-mark generator to the VERT INPUT connector through a 42-inch 50-ohm BNC cable and a 50-ohm BNC termination.

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

d. Set the TRIGGER control for a stable display in the variable positive-slope area.

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

f. Pull the X5 HORIZ MAG switch out (to prevent changing knob position, the X5 HORIZ MAG switch can be actuated using the horizontal POSITION control bracket behind the front panel).

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

NOTE

Tolerances given in this step are provided as a guide to correct instrument operation and are not an instrument specification.

h. ADJUST—Swp Mag Regis-1 adjustment, R438 (see Fig. 5-11), to position the middle marker to the center vertical line.

i. Push in the X5 HORIZ MAG switch.

j. Position the first marker to the center vertical line.

k. Pull the X5 HORIZ MAG switch out (use bracket behind panel).

l. CHECK—First marker should be within one division of center vertical line.

m. ADJUST—Swp Mag Regis-2, R432 (see Fig. 5-11) to position the first marker to the center vertical line.

n. Push in the X5 HORIZ MAG switch and repeat parts e through m.

29. Check/Adjust Normal Timing ⓿

a. Push in the X5 HORIZ MAG switch.

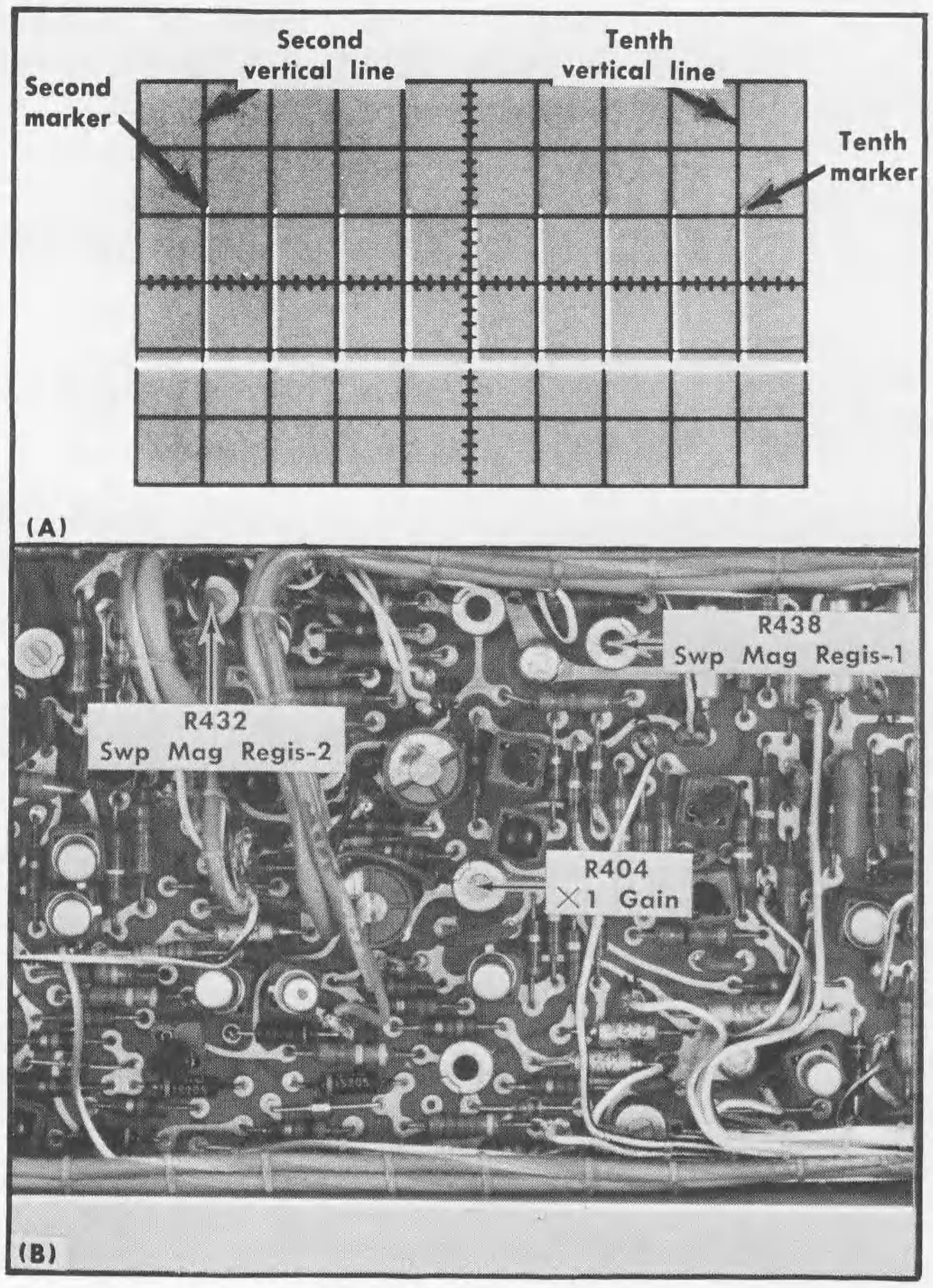


Fig. 5-11. (A) Typical CRT display showing correct normal timing, (B) Location of magnifier registration and normal sweep timing adjustments (Horizontal board).

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

c. Set the TRIGGER control for a stable display in the variable positive-slope area.

d. CHECK—CRT display for one marker each division between the second and tenth vertical lines of the graticule (see Fig. 5-11A). 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—X1 Gain, R404 (see Fig. 5-11B), 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).

f. Position the second marker to the second vertical line.

g. CHECK—Fourth marker within 0.08 division (within 4%) of the fourth vertical line.

h. Position the third marker to the third vertical line.

i. CHECK—Fifth marker within 0.08 division (within 4%) of the fifth vertical line.

j. Continue this check for each two-division portion of the sweep within the center eight divisions of the graticule.

k. INTERACTION—Check steps 30 through 35.

30. Check Variable Time/Division Control Range

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

b. Set the TRIGGER control for a stable display in the variable positive-slope area.

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

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

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

31. Check/Adjust Sweep Length and Centering

a. Return the VARIABLE TIME/DIV control to CAL.

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

c. Adjust the TRIGGER control for a stable display in the variable positive-slope area.

d. Move the eleventh marker (only part of first marker may be visible) to the tenth vertical line with the horizontal POSITION control (see Fig. 5-12A).

e. CHECK—Sweep length between 10.5 and 11 divisions as shown by 0.5 to 1.0 division of display to the right of the tenth vertical line (see Fig. 5-12A).

f. ADJUST—Sweep Length adjustment, R347 (see Fig. 5-12B), for a sweep length of 10.7 divisions (0.7 division of display to the right of the tenth vertical line).

g. Rotate the horizontal POSITION control fully clockwise.

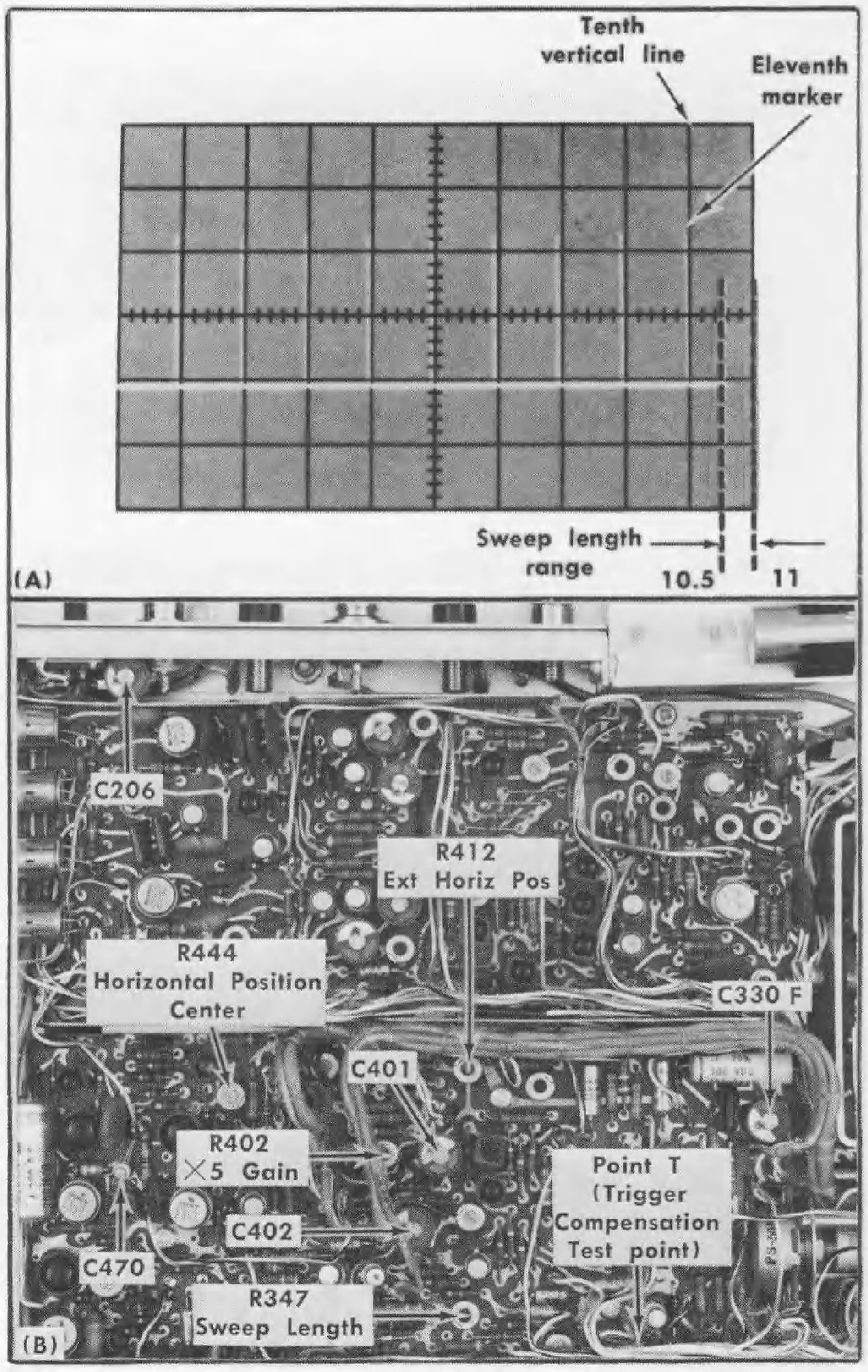


Fig. 5-12. (A) Typical CRT display when checking sweep length, (B) Location of horizontal adjustments (Horizontal board).

h. CHECK—First marker of display to the right of the center vertical line.

i. ADJUST—Horizontal Position Center adjustment, R444 (see Fig. 5-12B) to move the first marker to the right of the center vertical line.

j. Rotate the horizontal POSITION control fully counterclockwise.

k. CHECK—End of trace to the left of the center vertical line.

l. ADJUST—Horizontal Position Center adjustment, R444 (see Fig. 5-12B), to move the end of the trace to the left of the vertical center line. If necessary, compromise the adjustment of R444 for best display in parts h and k.

32. Check/Adjust Magnified Timing

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

b. Change the following control settings:

Horizontal POSITION	Midrange
X5 HORIZ MAG	Pulled out

c. Set the TRIGGER control for a stable display in the variable positive-slope area.

d. CHECK—CRT display for two markers each division between the second and tenth vertical lines. Marker at the tenth vertical line must be within 0.32 division (within 4%) of the graticule line when the marker at the second vertical line is positioned exactly.

e. ADJUST—X5 Gain adjustment, R402 (see Fig. 5-12B), 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).

f. Position a marker to the second vertical line.

g. CHECK—Marker within 0.1 division (within 5%) of the fourth vertical line.

h. Position the marker nearest the third vertical line exactly to that line.

i. CHECK—Marker within 0.1 division (within 5%) of the fifth vertical line.

j. Continue this check for each two-division portion of the displayed sweep within the center eight divisions of the graticule.

k. INTERACTION—Check steps 33 and 35.

PERFORMANCE CHECK ONLY

Complete normal and magnified timing accuracy is checked in Tables 5-4 and 5-5. Therefore, delete step 33 for a performance check only and proceed to step 34.

33. Adjust High-Speed Timing

a. Install the calibration shield on the Type 324.

b. Change the following control settings:

TIME/DIV	1 μs
X5 HORIZ MAG	Pushed in

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

d. Set the TRIGGER control for a stable display in the variable positive-slope area.

e. CHECK—CRT display for optimum linearity and timing between the sixth and tenth vertical lines.

f. ADJUST—C330F (see Fig. 5-12B) for optimum linearity and timing between the sixth and tenth vertical lines (use low-capacitance screwdriver).

g. CHECK—CRT display for optimum linearity and timing between the first and sixth vertical lines.

h. ADJUST—C470 (see Fig. 5-12B) for optimum linearity and timing between the first (left) and sixth vertical lines (preliminary adjustment).

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

j. Set the TRIGGER control for a stable display in the variable positive-slope area.

k. CHECK—CRT display for optimum linearity and timing between the first and second vertical lines.

l. ADJUST—C402 (see Fig. 5-12B) for optimum linearity and timing between the first and second vertical lines (use low-capacitance screwdriver).

m. Change the following control settings:

TIME/DIV	1 µs
X5 HORIZ MAG	Pulled out

n. Set the horizontal POSITION control so the last marker of the magnified display is positioned to the tenth vertical line.

o. Set the TRIGGER control for a stable display in the variable positive-slope area.

p. CHECK—CRT display for optimum linearity and timing between the second and tenth vertical lines.

q. ADJUST—C470 (see Fig. 5-12B) for optimum linearity and timing between second and tenth vertical lines (use low-capacitance screwdriver).

r. Position the third marker of the magnified display to the first vertical line of the graticule.

s. ADJUST—C401 (see Fig. 5-12B) for optimum linearity and timing between the second and tenth vertical lines (use low-capacitance screwdriver).

t. Repeat parts b through s of this step until optimum timing and linearity is obtained.

34. Check Normal Sweep Timing Accuracy

a. Push in the X5 HORIZ MAG switch.

b. CHECK—Using the TIME/DIV switch and time-mark generator settings given in Table 5-4, check normal sweep timing within the given tolerances over the middle eight divisions of the display. Set the TRIGGER control as necessary for a stable display in the variable positive-slope area.

TABLE 5-4

Normal Sweep Timing Accuracy

TIME/DIV switch setting	Time-mark generator output	CRT display (markers/division)	Allowable error for given accuracy
1 µs	1 µs	1	0.32 division (within 4%)
2 µs	1 µs	2	
5 µs	5 µs	1	0.24 division (within 3%)
10 µs	10 µs	1	
20 µs	10 µs	2	
50 µs	50 µs	1	
.1 ms	0.1 ms	1	
.2 ms	0.1 ms	2	
.5 ms	0.5 ms	1	
1 ms	1 ms	1	
2 ms	1 ms	2	
5 ms	5 ms	1	
10 ms	10 ms	1	
20 ms	10 ms	2	
50 ms	50 ms	1	
.1 s	0.1 s	1	
.2 s	0.1 s	2	0.32 division (within 4%)

35. Check Magnified Sweep Timing Accuracy

a. Pull out the X5 HORIZ MAG switch.

b. CHECK—Using the TIME/DIV switch and time-mark generator settings given in Table 5-5, check magnified timing within the given tolerances over the middle eight-division portion of the total magnified sweep length. Set the TRIGGER control as necessary for a stable display in the variable positive-slope area.

c. Disconnect all test equipment and remove the calibration shield.

36. Check/Adjust External Horizontal Position Range

a. Change the following control settings:

Trig/Horiz Coupling	EXT TRIG OR HORIZ DC
TIME/DIV	EXT HORIZ
X5 HORIZ MAG	Pushed in

TABLE 5-5

Magnified Sweep Timing Accuracy

TIME/DIV switch setting	Time-mark generator output	CRT display (markers/ division)	Allowable error for given accuracy
1 µs	0.1 µs	2	0.4 division (within 5%)
2 µs	0.1 µs	4	
5 µs	1 µs	1	0.32 division (within 4%)
10 µs	1 µs	2	
20 µs	1 µs	4	
50 µs	10 µs	1	
1 ms	10 µs	2	
.2 ms	10 µs	4	
.5 ms	0.1 ms	1	
1 ms	0.1 ms	2	
2 ms	0.1 ms	4	
5 ms	1 ms	1	
10 ms	1 ms	2	
20 ms	1 ms	4	
50 ms	10 ms	1	
.1 s	10 ms	2	
.2 s	10 ms	4	0.4 division (within 4%)

b. Set the horizontal POSITION control to the center of its range. Reduce the INTENSITY control setting to the minimum level that allows the dot to be viewed.

c. CHECK—CRT display for dot within 0.5 division of the center vertical line.

NOTE

This tolerance is provided as a guide to correct instrument operation and is not an instrument specification.

d. ADJUST—Ext Horiz Pos adjustment, R412 (see Fig. 5-12B), to position the dot to the center of the graticule.

37. Check/Adjust External Horizontal 10X Compensation

a. Set the EXT TRIG OR HORIZ ATTEN switch (side panel) to 10X.

b. Connect the standard amplitude calibrator to the EXT TRIG OR HORIZ INPUT connector with the 42-inch BNC cable.

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

d. Connect the 10X probe to the input connector of the test oscilloscope.

e. Set the test oscilloscope for a vertical deflection factor of 0.05 volt/division (0.5 volt/division at 10X probe tip) at a sweep rate of 0.5 millisecond/division. Adjust the triggering controls when necessary to provide a stable display.

f. Connect the 10X probe tip to the trigger compensation test point (point T, Horizontal board; see Fig. 5-12B). Be sure the probe is compensated.

g. CHECK—Test oscilloscope display for optimum square-wave response (optimum square corner and flat top).

h. ADJUST—C206 (see Fig. 5-12B) for optimum square-wave response (use low-capacitance screwdriver).

i. Disconnect the test oscilloscope.

38. Check External Horizontal Operation

a. CHECK—CRT display for horizontal deflection of 6.7 to 10 divisions between dots (0.2 to 0.3 volt/division).

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

c. Set the EXT TRIG OR HORIZ ATTEN switch to 1X.

d. CHECK—CRT display for horizontal deflection of 6.7 to 10 divisions between dots (20 to 30 millivolts/division).

e. Rotate the EXT HORIZ VAR control fully counterclockwise.

f. CHECK—CRT display not more than one-tenth of the deflection measured in previous step (indicates 10:1 range or greater).

g. Position the left dot of the display to the center vertical line with the horizontal POSITION control.

h. Set the Trig/Horiz Coupling switch to EXT TRIG OR HORIZ AC.

i. CHECK—CRT display for horizontal deflection centered about the center vertical line.

j. Disconnect all test equipment.

39. Check External Horizontal Bandwidth

a. Return the EXT HORIZ VAR control to CAL (fully clockwise).

b. Connect the low-frequency sine-wave generator to the EXT TRIG OR HORIZ INPUT connector through the 42-inch 50-ohm BNC cable and 50-ohm BNC termination.

c. Set the low-frequency generator for five-division horizontal deflection, centered about the center vertical line, at one kilohertz.

d. Without changing the output amplitude, increase the output frequency of the generator to 200 kilohertz.

e. CHECK—CRT display 3.5 divisions, or greater, horizontal deflection (not more than −3 dB).

f. Disconnect all test equipment.

40. Check External Blanking

a. Change the following control settings:

VOLTS/DIV	2
Trig/Horiz Coupling	INT TRIG AC
TIME/DIV	5 μs

b. Connect the low-frequency generator to the VERT INPUT connector through the 42-inch cable and the BNC T connector.

c. Set the low-frequency generator for a five-division display (five volt positive peaks) at 100 kilohertz.

d. Connect the output of the BNC T connector to the EXT BLANK jack with the six-inch BNC to banana plug patch cord.

e. CHECK—CRT display for blanking of a portion of each cycle of the waveform (see Fig. 5-13). The INTENSITY control setting may need to be changed to show blanking.

f. Disconnect all test equipment.

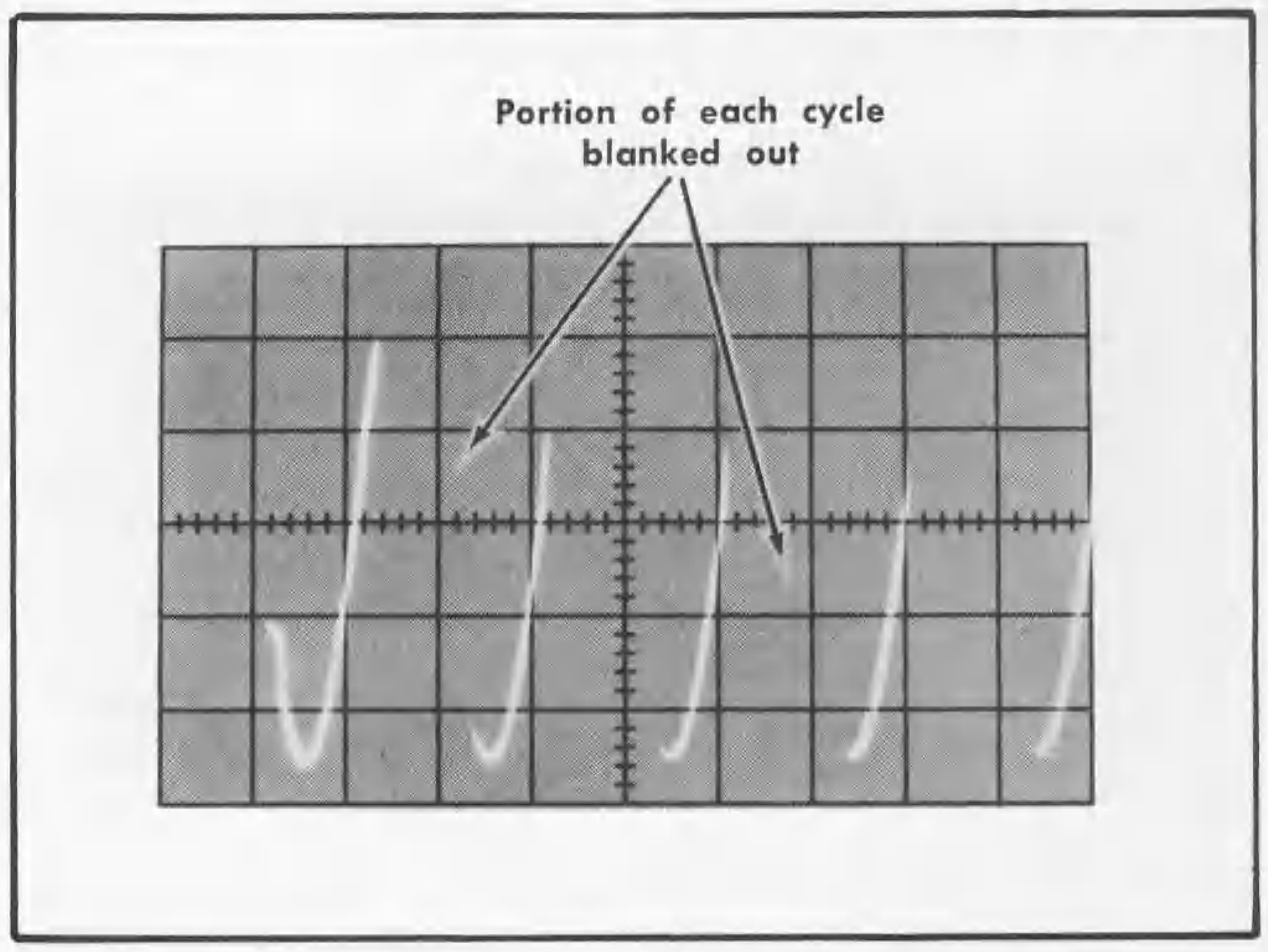


Fig. 5-13. Typical CRT display when checking external blanking.

41. Check High-Frequency Triggering Operation

a. Change the following control settings:

VOLTS/DIV	.1
TRIGGER	+AUTO
TIME/DIV	1 μs

b. Connect the high-frequency constant-amplitude sine-wave generator to the VERT INPUT connector through the GR to BNC adapter, 42-inch 50-ohm BNC cable, 50-ohm BNC termination and the BNC T connector. Connect the output of the BNC T connector to the EXT TRIG OR HORIZ INPUT connector with an 18-inch 50-ohm BNC cable.

c. Set the constant-amplitude generator for a 0.3-division display at 1.5 megahertz.

d. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ.

e. Turn the TRIGGER control clockwise to the variable positive-slope area.

f. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ (TRIGGER control may be adjusted as necessary to obtain a stable display).

g. Turn the TRIGGER control clockwise to the variable negative-slope area.

h. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ (TRIGGER control may be adjusted as necessary to obtain a stable display).

i. Set the TRIGGER control to −AUTO.

j. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ.

k. Set the constant-amplitude generator for a one-division display at 10 megahertz.

l. Pull the X5 HORIZ MAG switch out.

m. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ.

n. Turn the TRIGGER control counterclockwise to the variable negative-slope area.

o. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ (TRIGGER control may be adjusted as necessary to obtain a stable display).

p. Turn the TRIGGER control counterclockwise to the variable positive-slope area.

q. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ (TRIGGER control may be adjusted as necessary to obtain a stable display).

r. Set the TRIGGER control to +AUTO.

s. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ.

t. Change the following control settings:

Trig/Horiz Coupling	EXT TRIG OR HORIZ AC
X5 HORIZ MAG	Pushed in

u. Set the constant-amplitude generator for a 1.5-division display (150 millivolts) at 1.5 megahertz.

v. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to EXT TRIG AC and DC.

w. Turn the TRIGGER control clockwise to the variable positive-slope area.

x. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG AC and DC (TRIGGER control may be adjusted as necessary to obtain a stable display).

y. Turn the TRIGGER control clockwise to the variable negative-slope area.

z. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG AC and DC (TRIGGER control may be adjusted as necessary to obtain a stable display).

aa. Set the TRIGGER control to −AUTO.

ab. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to EXT TRIG AC and DC.

ac. Set the constant-amplitude generator for a five-division display (500 millivolts) at 1.5 megahertz.

ad. Without changing the output amplitude, set the generator to 10 megahertz.

ae. Pull the X5 HORIZ MAG switch out.

af. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to EXT TRIG AC and DC.

ag. Turn the TRIGGER control counterclockwise to the variable negative-slope area.

ah. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG AC and DC (TRIGGER control may be adjusted as necessary to obtain a stable display).

ai. Turn the TRIGGER control counterclockwise to the variable positive-slope area.

aj. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG AC and DC (TRIGGER control may be adjusted as necessary to obtain a stable display).

ak. Set the TRIGGER control to +AUTO.

al. CHECK—Stable CRT display is presented.

am. Disconnect the high-frequency generator.

42. Check Low-Frequency Triggering Operation

a. Connect the low-frequency constant-amplitude sine-wave generator to the VERT INPUT connector through the 42-inch 50-ohm BNC cable, 50-ohm BNC termination and the BNC T connector. Connect the output of the BNC T connector to the EXT TRIG OR HORIZ INPUT connector with an 18-inch 50-ohm BNC cable.

b. Change the following control settings:

TIME/DIV	10 ms
X5 HORIZ MAG	Pushed in

c. Set the low-frequency generator for a 0.9-division display (90 millivolts) at 30 hertz.

d. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to EXT TRIG AC and DC.

e. Turn the TRIGGER control clockwise to the variable positive-slope area.

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

g. Turn the TRIGGER control clockwise to the variable negative-slope area.

h. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG AC and DC (TRIGGER Control may be adjusted as necessary to obtain a stable display).

i. Set the TRIGGER control to —AUTO.

j. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling Switch set to EXT TRIG AC and DC.

k. Set the Trig/Horiz Coupling switch to INT TRIG AC.

l. Set the low-frequency generator for a 0.3-division display at 30 hertz.

m. CHECK—Stable CRT display is presented.

n. Turn the TRIGGER control counterclockwise to the variable negative-slope area.

o. CHECK—Stable CRT display can be obtained with the TRIGGER control.

p. Turn the TRIGGER control counterclockwise to the variable positive-slope area.

q. CHECK—Stable CRT display can be obtained with the TRIGGER control.

r. Set the TRIGGER control to +AUTO.

s. CHECK—Stable CRT display is presented.

43. Check Low-Frequency Reject Operation

a. Change the following control settings:

Trig/Horiz Coupling	INT TRIG ACLF REJ
TIME/DIV	.1 ms

b. Set the low-frequency generator for a 0.3-division display at 15 kilohertz.

c. CHECK—Stable CRT display can be obtained with the TRIGGER control set to + and − AUTO and in the variable positive- and negative-slope areas (adjust TRIGGER control as necessary).

d. Without changing the output amplitude, set the low-frequency generator to 30 hertz.

e. Set the TIME/DIV switch to 10 ms.

f. CHECK—Stable CRT display cannot be obtained at any setting of the TRIGGER control (notice that displays presented in the AUTO positions do not remain stable).

44. Check Trigger Slope Operation

a. Change the following control settings:

TRIGGER	+ AUTO
Trig/Horiz Coupling	INT TRIG AC
TIME/DIV	.5 ms

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. 5-14A).

d. Turn the TRIGGER control clockwise until a stable display is obtained in the positive-slope area.

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

f. Turn the TRIGGER control clockwise until a stable display is obtained in the negative-slope area.

g. CHECK—CRT display starts on the negative slope of the waveform (see Fig. 5-14B).

h. Set the TRIGGER control to −AUTO.

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

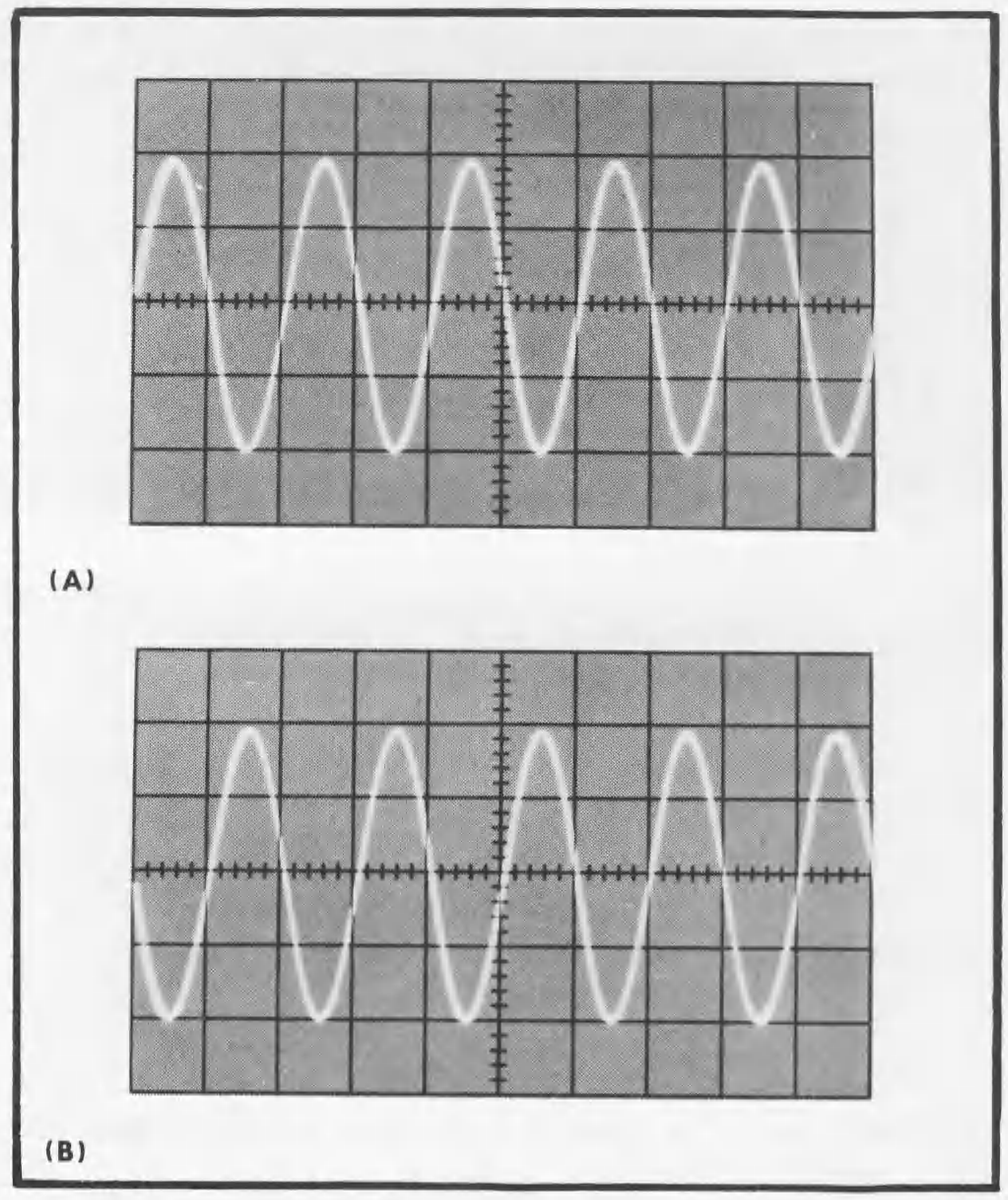


Fig. 5-14. (A) Typical CRT display when checking positive-slope triggering, (B) Typical CRT display when checking negative-slope triggering.

45. Check Trigger Control Range

a. Remove the 50-ohm termination and reconnect the low-frequency sine-wave generator to the BNC T connector through the 42-inch BNC cable.

b. Change the following control settings:

VOLTS/DIV	.5
TRIGGER	+AUTO
Trig/Horiz Coupling	EXT TRIG AC

c. Set the low-frequency generator for a 3.2-division display (1.6 volts peak to peak) at one kilohertz.

d. CHECK—Rotate the TRIGGER control throughout the positive-slope area and check that the display can be triggered (stable display) at any point along the positive slope of the waveform (indicates TRIGGER control range of at least + and − 0.8 volts). Display is not triggered at either extreme of the positive-slope area except in +AUTO detent.

e. CHECK—Rotate the TRIGGER control throughout the negative-slope area and check that the display can be triggered at any point along the negative slope of the waveform. Display is not triggered at either extreme of the negative-slope area except in —AUTO detent.

f. Change the following control settings:

VOLTS/DIV	5
TRIGGER	+AUTO
EXT TRIG OR HORIZ ATTEN	10X

g. Set the low-frequency generator for a 3.2-division display (16 volts peak to peak) at one kilohertz.

h. CHECK—Rotate the TRIGGER control throughout the positive-slope area and check that the display can be triggered at any point along the positive slope of the waveform. Display is not triggered at either extreme of the positive-slope area except in + AUTO detent.

i. CHECK—Rotate the TRIGGER control throughout the negative-slope area and check that the display can be triggered at any point along the negative slope of the waveform. Display is not triggered at either extreme of the negative-slope area except in —AUTO detent.

j. Disconnect all test equipment.

46. Check Calibrator Operation

a. Change the following control settings:

VOLTS/DIV	5 DIV CAL
INPUT	GND
TRIGGER	— AUTO
Trig/Horiz Coupling	INT TRIG AC
TIME/DIV	.1 ms
X5 HORIZ MAG	Pulled out

b. Position the rising portion of the waveform onto the viewing area with the horizontal POSITION control and center the display with the vertical POSITION control.

c. CHECK—CRT display for 0.1 division or less horizontal distance between the 10% and 90% points on the leading edge of the calibrator waveform (two microseconds or less risetime).

d. Change the following control settings:

TRIGGER	+ AUTO
TIME/DIV	.2 ms
X5 HORIZ MAG	Pushed in

e. Position the start of the trace to the left (first) vertical line of the graticule.

f. CHECK—CRT display for duration of one cycle between 5 and 8.3 divisions (repetition rate 800 hertz, ±200 hertz).

g. Set the TIME/DIV switch to .1 ms.

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

i. CHECK—CRT display for length of positive segment of the square wave between four and six divisions (duty cycle 40% to 60%).

j. Change the following control settings:

VOLTS/DIV	.1
INPUT	DC
TIME/DIV	.5 ms
VARIABLE	CAL

k. Connect the 1X probe to the INPUT connector.

l. Position the probe tip so it is in contact with the CAL OUT jack.

m. CHECK—CRT display five divisions in amplitude.

NOTE

Parts m and o check that the Calibrator circuit is functioning correctly. Accuracy of Calibrator output voltage was set in step 4 of this procedure.

n. Set the VOLTS/DIV switch to 5 DIV CAL.

o. CHECK—CRT display five divisions in amplitude.

This completes the calibration/checkout procedure for the Type 324. Disconnect all test equipment and replace the cabinet. If the instrument has been completely checked and adjusted to the tolerances given in this procedure, it will meet or exceed the electrical characteristics given in Section 1.

PARTS LIST ABBREVIATIONS

BHB	binding head brass
BHS	binding head steel
cap.	capacitor
cer	ceramic
comp	composition
conn	connector
CRT	cathode-ray tube
csk	countersunk
DE	double end
dia	diameter
div	division
elect.	electrolytic
EMC	electrolytic, metal cased
EMT	electrolytic, metal tubular
ext	external
F & I	focus and intensity
FHB	flat head brass
FHS	flat head steel
Fil HB	fillister head brass
Fil HS	fillister head steel
h	height or high
hex.	hexagonal
HHB	hex head brass
HHS	hex head steel
HSB	hex socket brass
HSS	hex socket steel
ID	inside diameter
inc	incandescent
int	internal
lg	length or long
met.	metal
mtg hdw	mounting hardware
OD	outside diameter
OHB	oval head brass
OHS	oval head steel
P/O	part of
PHB	pan head brass
PHS	pan head steel
plstc	plastic
PMC	paper, metal cased
poly	polystyrene
prec	precision
PT	paper, tubular
PTM	paper or plastic, tubular, molded
RHB	round head brass
RHS	round head steel
SE	single end
SN or S/N	serial number
S or SW	switch
TC	temperature compensated
THB	truss head brass
thk	thick
THS	truss head steel
tub.	tubular
var	variable
w	wide or width
WW	wire-wound

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.

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SECTION 6
ELECTRICAL PARTS LIST

Values are fixed unless marked Variable.

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				CHASSIS			
				Bulb			
DS509	150-0084-00			Neon, GE 2AA			
				Capacitors			
Tolerance ±20% unless otherwise indicated.							
C20	*285-0610-00			0.1 μF	MT	600 V	10%
C25C	283-0617-01			4700 pF	Mica	300 V	10%
C78C	281-0592-00			4.7 pF	Cer		±0.5 pF
C206	281-0060-01			2-8 pF, Var	Cer		
C208	283-0602-00			53 pF	Mica	300 V	5%
C209	283-0068-00			0.01 μF	Cer	500 V	
C221	290-0136-01			2.2 μF	Elect.	20 V	
C223	283-0067-00			0.001 μF	Cer	200 V	10%
C250	290-0136-01			2.2 μF	Elect.	20 V	
C270A	290-0459-00			10 μF			
C270B	290-0183-01			1 μF	Elect.	35 V	10%
C270C	290-0450-00			0.1 μF	Elect.	35 V	
C330A[1]				1 μF			
C330C[1]	*295-0134-00			0.01 μF	Timing capacitor assembly		
C330D[1]				0.001 μF			
C340A	290-0183-01			1 μF	Elect.	35 V	10%
C340B	283-0003-00			0.01 μF	Cer	150 V	
C369	283-0003-00			0.01 μF	Cer	150 V	

[1] Furnished as a unit with C330B.

CHASSIS (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Inductor			
L592	*108-0465-00			Trace rotation			
				Transistor			
Q529	151-0231-00			Silicon	NPN TO-5 2SC756-3		
				Resistors			
Resistors are fixed, composition, ±10% unless otherwise indicated.							
R21	315-0104-02			100 kΩ	1/4 W		5%
R23B	322-0621-31			900 kΩ	1/4 W	Prec	1/2%
R27	315-0470-02			47 Ω	1/4 W		5%
R109	311-1023-00			1 kΩ, Var			
R124	311-1024-00			5 kΩ x 5 kΩ, Var			
R205	315-0471-02			470 Ω	1/4 W		5%
R206	322-0621-30			900 kΩ	1/4 W	Prec	1%
R208	321-0617-30			111 kΩ	1/8 W	Prec	1%
R246	311-0687-00			50 kΩ, Var			
R330A	322-0481-01			1 MΩ	1/4 W	Prec	1/2%
R330B	322-0481-01			1 MΩ	1/4 W	Prec	1/2%
R330C	322-0610-01			500 kΩ	1/4 W	Prec	1/2%
R330D	321-0414-31			200 kΩ	1/8 W	Prec	1/2%
R330E	321-0385-31			100 kΩ	1/8 W	Prec	1/2%
R330F	321-0756-31			50 kΩ	1/8 W	Prec	1/2%
R333	315-0123-01			12 kΩ	1/4 W		5%
R334A,B	311-1026-00			20 kΩ x 20 kΩ, Var			
R340	315-0822-01			8.2 kΩ	1/4 W		5%
R373	315-0202-01			2 kΩ	1/4 W		5%
R374	315-0202-01			2 kΩ	1/4 W		5%
R420 R421	311-1025-00			10 kΩ 10 kΩ Var			
R458	315-0202-01			2 kΩ	1/4 W		5%
R459	315-0202-01			2 kΩ	1/4 W		5%
R581	311-1021-00			5 MΩ, Var			
R585	311-1021-00			5 MΩ, Var			

CHASSIS (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Switches			
	Wired or Unwired						
S21	260-0621-01			Lever	INPUT		
S25Wired	*262-0897-00			Rotary	VOLTS/DIV		
S25	260-1129-00			Rotary	VOLTS/DIV		
S45	260-0904-00			Slide	X5 VERT GAIN		
S201	260-0888-01			Lever	TRIG/HORIZ COUPLING		
S205	260-0905-00			Slide	ATTEN		
S246Wired	*262-0895-00			Rotary	TRIGGER		
S246	260-1128-00			Rotary	TRIGGER		
S335Wired	*262-0896-00			Rotary	TIME/DIV		
S335	260-1114-00			Rotary	TIME/DIV		
S435	260-0904-00			Slide	X5 HORIZ MAG		
S501	260-0903-00			Slide	POWER		
				Electron Tube			
V590	*154-0519-00			CRT Standard Phosphor			

LOW VOLTAGE POWER SUPPLY Circuit Board Assembly

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
	*670-0882-00			Complete Board			
				Capacitors			
Tolerance ±20% unless otherwise indicated.							
C501	290-0460-00			10 μF	Elect.		
C507	290-0453-00			1 μF	Elect.		
C540	283-0679-00			0.02 μF	Mica		
C543	290-0454-00			4.7 μF	Elect.		
C545	290-0134-01			22 μF	Elect.	15 V	
C547	290-0463-00			47 μF	Elect.		
C559	290-0134-01			22 μF	Elect.	15 V	
C560	290-0462-00			33 μF	Elect.		
C564	283-0059-00			1 μF	Cer	25 V	+80%-20%
C569	290-0134-01			22 μF	Elect.	15 V	

LOW VOLTAGE POWER SUPPLY Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description
				Semiconductor Device, Diodes
D501	*152-0107-00			Silicon Replaceable by 1N647
D545	*152-0185-00			Silicon Replaceable by 1N4152
D547	152-0448-00			
D549	*152-0185-00			Silicon Replaceable by 1N4152
D550	152-0127-00			Zener 1N755A 400 mW, 7.5 V, 5%
D551	*152-0185-00			Silicon Replaceable by 1N4152
D554	*152-0185-00			Silicon Replaceable by 1N4152
D560	*152-0185-00			Silicon Replaceable by 1N4152
D561	*152-0185-00			Silicon Replaceable by 1N4152
D565	*152-0185-00			Silicon Replaceable by 1N4152
				Fuse
F501	159-0098-00			1.6 A 250 V Fast-Blo
				Inductors
L501	108-0590-00			40 μH
L541	108-0591-00			10 μH
L551	108-0588-00			110 μH
L559	108-0588-00			110 μH
L560	108-0589-00			7 μH
L569	108-0588-00			110 μH
				Transistors
Q555	151-0304-00			2SC318A
Q557	151-0306-00			2SC756, checked
Q558	*151-0219-00			Silicon PNP TO-18 Replaceable by 2N4250
Q562	*151-0219-00			Silicon PNP TO-18 Replaceable by 2N4250
Q567	151-0304-00			2SC318A
Q569	151-0306-00			2SC756, checked
Q571	151-0234-00			Silicon NPN TO-5 2SC805

LOW VOLTAGE POWER SUPPLY Circuit Board Assembly (cont)

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

Resistors

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

Ckt. No.	Tektronix Part No.	Eff	Disc	Description			
R503	321-0318-30			20 kΩ	1/8 W	Prec	1%
R504	321-0385-30			100 kΩ	1/8 W	Prec	1%
R506	315-0105-01			1 MΩ	1/4 W		5%
R547	315-0241-01			240 Ω	1/4 W		5%
R549	315-0241-01			240 Ω	1/4 W		5%
R550	315-0102-01			1 kΩ	1/4 W		5%
R551	321-0305-30			14.7 kΩ	1/8 W	Prec	1%
R552	311-0633-00			5 kΩ, Var			
R553	321-0289-30			10 kΩ	1/8 W	Prec	1%
R555	321-0305-30			14.7 kΩ	1/8 W	Prec	1%
R562	315-0472-01			4.7 kΩ	1/4 W		5%
R564	321-0337-30			31.6 kΩ	1/8 W	Prec	1%
R565	321-0304-00			14.3 kΩ	1/8 W	Prec	1%
R566	311-0635-00			1 kΩ, Var			
R567	321-0325-30			23.7 kΩ	1/8 W	Prec	1%
R568	315-0912-02			9.1 kΩ	1/4 W		5%
R570	315-0102-01			1 kΩ	1/4 W		5%
R571	321-0273-00			6.81 kΩ	1/8 W	Prec	1%
R572	315-0431-01			430 Ω	1/4 W		5%

VERTICAL Circuit Board Assembly

Ckt. No.	Tektronix Part No.	Eff	Disc	Description
	*670-0883-00			Complete Board

Capacitors

Tolerance ±20% unless otherwise indicated.

Ckt. No.	Tektronix Part No.	Eff	Disc	Description			
C101	283-0068-00			0.01 μF	Cer	500 V	
C102	283-0232-00			0.005 μF	Cer	Selected	(nominal value)
C103	290-0457-00			4.7 μF	Elect.		
C104	283-0250-00			8 pF	Cer	50 V	10%
C105	283-0230-00			470 pF	Cer	500 V	

VERTICAL Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Capacitors (cont)			
C106	290-0114-02			47 µF	Elect.	6 V	10%
C107	290-0136-01			2.2 µF	Elect.	20 V	
C108	290-0114-02			47 µF	Elect.	6 V	10%
C109	290-0136-01			2.2 µF	Elect.	20 V	
C110	290-0134-01			22 µF	Elect.	15 V	
C113	281-0091-01			2-8 pF, Var	Cer		
C114	281-0093-01			5.5-18 pF, Var	Cer		
C115	281-0093-01			5.5-18 pF, Var	Cer		
C116	281-0091-01			2-8 pF, Var	Cer		
C117	281-0724-00			0.3 pF			
C118	283-0235-00			0.05 µF	Cer	50 V	+100%-0%
C119	283-0068-00			0.01 µF	Cer	500 V	
C120	283-0235-00			0.05 µF	Cer	50 V	+100%-0%
C121	283-0068-00			0.01 µF	Cer	500 V	
C122	283-0068-00			0.01 µF	Cer	500 V	
C123	281-0724-00			0.3 pF			
C124	283-0059-00			1 µF	Cer	25 V	+80%-20%
C125	283-0059-00			1 µF	Cer	25 V	+80%-20%
C126	283-0004-00			0.02 µF	Cer	150 V	
C127	283-0243-00			1 pF	Cer	500 V	10%
C128	283-0230-00			470 pF	Cer	500 V	
C129	283-0237-00			0.1 µF	Cer	25 V	+80%-20%
C130	283-0230-00			470 pF	Cer	500 V	
C131	283-0237-00			0.1 µF	Cer	25 V	+80%-20%
C132	283-0237-00			0.1 µF	Cer	25 V	+80%-20%
C133	290-0453-00			1 µF	Elect.	160 V	+75%-15%
C134	283-0237-00			0.1 µF	Cer	25 V	+80%-20%
C135	283-0237-00			0.1 µF	Cer	25 V	+80%-20%
C136	283-0250-00			8 pF	Cer	50 V	10%
C157	283-0224-00			5 pF	Cer	50 V	±0.5 pF
C589	283-0004-00			0.02 µF	Cer	150 V	±80%-20%
C593	283-0067-00			0.001 µF	Cer	200 V	10%

VERTICAL Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description		
				Semiconductor Device, Diodes		
D14	152-0246-00			Silicon	250 mW, 40 V, low leakage	
D15	152-0246-00			Silicon	200 mW, 40 V, low leakage	
D16	152-0246-00			Silicon	200 mW, 40 V, low leakage	
D17	152-0246-00			Silicon	250 mW, 40 V, low leakage	
D41	152-0062-00			Silicon	1N914	
D42	152-0062-00			Silicon	1N914	
D43	152-0062-00			Silicon	1N914	
D44	152-0062-00			Silicon	1N914	
D45	*152-0185-00			Silicon	Replaceable by 1N4152	
D46	*152-0185-00			Silicon	Replaceable by 1N4152	
D51	152-0062-00			Silicon	1N914	
D52	152-0062-00			Silicon	1N914	
D53	152-0062-00			Silicon	1N914	
D54	152-0062-00			Silicon	1N914	
D101	*152-0185-00			Silicon	Replaceable by 1N4152	
D102	*152-0185-00			Silicon	Replaceable by 1N4152	
D593	152-0281-00			Zener	1N969B 400 mW, 22 V, 5%	
				Inductor		
L101	108-0587-00			5.6 mH		
				Transistors		
Q11	151-1010-00			Silicon	FET, N channel, junction, Dual	
Q21	151-0232-00			Silicon	NPN	TO-78 Dual
Q31	151-0304-00					2SC318A
Q32	151-0304-00					2SC318A
Q41	151-0221-00			Silicon	PNP	TO-18 2N4258
Q42	*151-0216-00			Silicon	PNP	TO-92 Replaceable by MPS 6523
Q43	151-0221-00			Silicon	PNP	TO-18 2N4258
Q44	*151-0216-00			Silicon	PNP	TO-92 Replaceable by MPS 6523
Q51	151-0221-00			Silicon	PNP	TO-18 2N4258
Q61	151-0221-00			Silicon	PNP	TO-18 2N4258

VERTICAL Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Transistors (cont)			
Q101	151-0304-00					2SC318A	
Q102	151-0304-00					2SC318A	
Q111	151-0304-00					2SC318A	
Q112	151-0304-00					2SC318A	
Q121	151-0234-00			Silicon	NPN	TO-5 2SC805	
Q122	151-0234-00			Silicon	NPN	TO-5 2SC805	
Q131	151-0214-00			Silicon	PNP	TO-5 2N3495	
Q132	151-0234-00			Silicon	NPN	TO-5 2SC805	
Q133	151-0234-00			Silicon	NPN	TO-5 2SC805	
Q134	151-0214-00			Silicon	PNP	TO-5 2N3495	
Q141	151-0304-00					2SC318A	
Q142	*151-0219-00			Silicon	PNP	TO-18 Replaceable by 2N4250	
Q143	151-0304-01					2SC318A, checked	
				Resistors			
Resistors are fixed, composition, ±10% unless otherwise indicated.							
R101	322-0481-01			1 MΩ	1/4 W	Prec	1/2%
R102	315-0104-02			100 kΩ	1/4 W		5%
R103	315-0101-01			100 Ω	1/4 W		5%
R104	321-0069-30			51.1 Ω	1/8 W	Prec	1%
R105	321-0245-30			3.48 kΩ	1/8 W	Prec	1%
R106	321-0245-30			3.48 kΩ	1/8 W	Prec	1%
R107	311-0622-00			100 Ω, Var			
R108	321-0249-30			3.83 kΩ	1/8 W	Prec	1%
R110	311-0605-00			200 Ω, Var			
R111	321-0142-30			294 Ω	1/8 W	Prec	1%
R112	321-0294-30			3.83 kΩ	1/8 W	Prec	1%
R113	321-0241-30			3.16 kΩ	1/8 W	Prec	1%
R114	321-0241-30			3.16 kΩ	1/8 W	Prec	1%
R115	315-0683-01			68 kΩ	1/4 W		5%
R116	315-0683-01			68 kΩ	1/4 W		5%

VERTICAL Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors (cont)			
R117	321-0229-30			2.37 kΩ	1/8 W	Prec	1%
R118	321-0193-30			1 kΩ	1/8 W	Prec	1%
R119	321-0201-30			1.21 kΩ	1/8 W	Prec	1%
R120	321-0193-00			1 kΩ	1/8 W	Prec	1%
R121	321-0201-30			1.21 kΩ	1/8 W	Prec	1%
R122	315-0101-01			100 Ω	1/4 W		5%
R123	311-0633-00			5 kΩ, Var			
R125	321-0277-30			7.5 kΩ	1/8 W	Prec	1%
R126	315-0101-01			100 Ω	1/4 W		5%
R127	315-0512-01			5.1 kΩ	1/4 W		5%
R128	311-1022-00			50 kΩ, Var			
R129	315-0512-01			5.1 kΩ	1/4 W		5%
R130	315-0202-01			2 kΩ	1/4 W		5%
R131	321-0263-30			5.36 kΩ	1/8 W	Prec	1%
R132	321-0263-30			5.36 kΩ	1/8 W	Prec	1%
R133	315-0202-01			2 kΩ	1/4 W		5%
R134	321-0181-30			750 Ω	1/8 W	Prec	1%
R135	321-0103-30			115 Ω	1/8 W	Selected	(nominal value)
R136	315-0123-01			12 kΩ	1/4 W		5%
R137	315-0392-01			3.9 kΩ	1/4 W		5%
R138	321-0285-30			9.09 kΩ	1/8 W	Prec	1%
R139	321-0285-30			9.09 kΩ	1/8 W	Prec	1%
R140	321-0309-00			16.2 kΩ	1/8 W	Prec	1%
R141	311-0607-00			10 kΩ, Var			
R142	311-0607-00			10 kΩ, Var			
R143	321-0309-30			16.2 kΩ	1/8 W	Prec	1%
R144	321-0257-30			4.64 kΩ	1/8 W	Prec	1%
R145	321-0213-30			1.62 kΩ	1/8 W	Prec	1%
R146	321-0257-30			4.64 kΩ	1/8 W	Prec	1%
R147	321-0213-30			1.62 kΩ	1/8 W	Prec	1%
R148	315-0100-01			10 Ω	1/4 W		5%
R149	315-0100-01			10 Ω	1/4 W		5%
R151	321-0233-30			2.61 kΩ	1/8 W	Prec	1%
R152	311-0609-00			2 kΩ, Var			
R153	321-0261-30			5.11 kΩ	1/8 W	Prec	1%

VERTICAL Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R154	321-0261-30			5.11 kΩ	1/8 W	Prec	1%
R155	311-0609-00			2 kΩ, Var			
R156	321-0233-30			2.61 kΩ	1/8 W	Prec	1%
R157	311-0607-00			10 kΩ, Var			
R158	321-0253-30			4.22 kΩ	1/8 W	Prec	1%
R159	321-0253-30			4.22 kΩ	1/8 W	Prec	1%
R160	315-0561-02			560 Ω	1/4 W		5%
R161	315-0561-02			560 Ω	1/4 W		5%
R162	315-0272-02			2.7 kΩ	1/4 W		5%
R163	321-0401-30			147 kΩ	1/8 W	Prec	1%
R164	315-0621-01			620 Ω	1/4 W		5%
R165	315-0562-01			5.6 kΩ	1/4 W		5%
R166	315-0101-01			100 Ω	1/4 W		5%
R167	321-0113-30			147 Ω	1/8 W	Prec	1%
R168	321-0233-30			2.61 kΩ	1/8 W	Prec	1%
R169	321-0113-30			147 Ω	1/8 W	Prec	1%
R170	315-0105-01			1 MΩ	1/4 W		5%
R171	316-0156-00			15 MΩ	1/4 W		
R172	315-0621-01			620 Ω	1/4 W		5%
R173	315-0562-01			5.6 kΩ	1/4 W		5%
R174	321-0401-30			147 kΩ	1/8 W	Prec	1%
R175	315-0113-01			11 kΩ	1/4 W		5%
R176	315-0202-01			2 kΩ	1/4 W		5%
R177	315-0390-02			39 Ω	1/4 W		5%
R178	315-0392-01			3.9 kΩ	1/4 W		5%
R179	315-0822-01			8.2 kΩ	1/4 W		5%
R180	315-0302-01			3 kΩ	1/4 W		5%
R181	321-0113-30			147 Ω	1/8 W	Prec	1%
R592	311-0607-00			10 kΩ, Var			
R593	311-0660-00			200 kΩ, Var			
R594	315-0204-01			200 kΩ	1/4 W		5%
R596	315-0474-01			470 kΩ	1/4 W		5%
R597	311-0606-00			500 kΩ, Var			
R598	315-0104-02			100 kΩ	1/4 W		5%

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				HORIZONTAL Circuit Board Assembly			
	*670-0884-00			Complete Board			
				Capacitors			
Tolerance ±20% unless otherwise indicated.							
C212	283-0233-00			0.0022 μF	Cer	500 V	
C241	283-0024-00			0.1 μF	Cer	30 V	
C242	283-0247-00			680 pF			
C252	283-0228-00			51 pF	Cer	50 V	10%
C253	283-0228-00			51 pF	Cer	50 V	10%
C290	290-0457-00			4.7 μF	Elect.	10 V	
C293	290-0457-00			4.7 μF	Elect.	10 V	
C301	283-0226-00			12 pF	Cer	500 V	10%
C310	290-0455-00			2.2 μF	Elect.	20 V	10%
C313	283-0223-00			3 pF	Cer	50 V	±0.5 pF
C316	283-0229-00			220 pF	Cer	50 V	10%
C317	290-0136-01			2.2 μF	Elect.	20 V	
C321	290-0134-02			22 μF	Elect.	15 V	+20%+0%
C322	283-0237-00			0.1 μF	Cer	25 V	+80%-20%
C330B[2]	*295-0134-00			0.1 μF	Timing capacitor assembly		
C330E	283-0675-00			82 pF	Mica	300 V	1%
C330F	281-0093-01			5.5-18 pF, Var	Cer		
C342	283-0234-00			0.001 μF	Cer	50 V	
C359	290-0136-01			2.2 μF	Elect.	20 V	
C361	283-0236-00			0.01 μF	Cer	50 V	
C362	283-0233-00			0.0022 μF	Cer	500 V	
C364	283-0231-00			470 pF	Cer	500 V	10%
C370	283-0068-00			0.01 μF	Cer	500 V	
C401	281-0092-01			9-35 pF, Var	Cer		
C402	281-0091-01			2-8 pF, Var	Cer		
C441	283-0234-00			0.001 μF	Cer	500 V	
C452	283-0241-00			0.2 pF	Cer	500 V	
C462	283-0233-00			0.0022 μF	Cer	500 V	
C465	283-0231-00			470 pF	Cer	500 V	10%
C470	281-0064-00			0.25-1.5 pF, Var	Tub.		
C471	283-0240-00			1 pF	Cer	500 V	

HCRIZONTAL Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description		
				Capacitors (cont)		
C480	283-0079-00			0.01 μF	Cer	250 V
C482	290-0449-00			2 μF	Elect.	250 V
C491	290-0136-01			2.2 μF	Elect.	20 V
C493	290-0136-01			2.2 μF	Elect.	20 V
				Semiconductor Device, Diodes		
D213	152-0246-00			Silicon	250 mW, 40 V, low leakage	
D214	152-0246-00			Silicon	250 mW, 40 V, low leakage	
D215	*152-0185-00			Silicon	Replaceable by 1N4152	
D301	152-0062-00			Silicon	1N914	
D303	152-0330-00			Tunnel	2.2 mA, 10 pF	
D305	152-0449-00					
D309	152-0246-00			Silicon	200 mW, 40 V, low leakage	
D342	*152-0185-00			Silicon	Replaceable by 1N4152	
D343	*152-0185-00			Silicon	Replaceable by 1N4152	
D350	152-0449-00					
D351	*152-0185-00			Silicon	Replaceable by 1N4152	
D353	152-0449-00					
D422	*152-0185-00			Silicon	Replaceable by 1N4152	
D442	152-0127-00			Zener	1N755A 400 mW, 7.5 V, 5%	
D446	*152-0185-00			Silicon	Replaceable by 1N4152	
				Transistors		
Q215	151-1038-00				FET, 2SK-12-0	
Q231	151-0304-01				2SC318A, checked	
Q239	151-0304-01				2SC318A, checked	
Q253	151-0190-02			Silicon	NPN	TO-92 2N3904
Q263	151-0190-02			Silicon	NPN	TO-92 2N3904
Q305	151-0304-01				2SC318A, checked	
Q311	151-1018-00			Silicon	FET, N channel, junction, TO-72	
Q317	151-0304-01				2SC318A, checked	
Q326	151-0220-00			Silicon	PNP	TO-18 2N4122
Q329	151-0190-02			Silicon	NPN	TO-92 2N3904

HORIZONTAL Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description		
				Transistors (cont)		
Q343	151-0190-02			Silicon	NPN	TO-92 2N3904
Q356	151-0220-00			Silicon	PNP	TO-18 2N4122
Q363	151-0234-00			Silicon	NPN	TO-5 2SC805
Q370	*151-0228-00			Silicon	PNP	TO-5 Tek Spec
Q373	151-0234-00			Silicon	NPN	TO-5 2SC805
Q411	*151-0192-00			Silicon	NPN	TO-92 Replaceable by MPS 6521
Q420	151-0220-00			Silicon	PNP	TO-18 2N4122
Q440	151-0220-00			Silicon	PNP	TO-18 2N4122
Q451	151-0304-01					2SC318A, checked
Q453	151-0304-01					2SC318A, checked
Q457	151-0233-00			Silicon	NPN	TO-5 2SC805
Q460	151-0220-00			Silicon	PNP	TO-18 2N4122
Q464	*151-0228-00			Silicon	PNP	TO-5 Tek Spec
Q470	151-0220-00			Silicon	PNP	TO-18 2N4122
Q473	151-0233-00			Silicon	NPN	TO-5 2SC805
Q480	151-0220-00			Silicon	PNP	TO-18 2N4122
Q484	*151-0228-00			Silicon	PNP	TO-5 Tek Spec

Resistors

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

Ckt. No.	Tektronix Part No.	Eff	Disc	Description			
R210	322-0481-00			1 MΩ	1/4 W	Prec	1%
R212	315-0104-02			100 kΩ	1/4 W		5%
R217	315-0332-02			3.3 kΩ	1/4 W		5%
R218	311-0644-00			20 kΩ, Var			
R230	315-0472-01			4.7 kΩ	1/4 W		5%
R232	321-0237-30			2.87 kΩ	1/8 W	Prec	1%
R234	315-0161-01			160 Ω	1/4 W		5%
R236	321-0229-30			2.37 kΩ	1/8 W	Prec	1%
R238	321-0237-30			2.87 kΩ	1/8 W	Prec	1%
R239	315-0161-01			160 Ω	1/4 W		5%

HORIZONTAL Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors (cont)			
R242	315-0472-01			4.7 kΩ	1/4 W		5%
R244	315-0133-01			13 kΩ	1/4 W		5%
R251	321-0297-30			12.1 kΩ	1/8 W	Prec	1%
R252	321-0269-30			6.19 kΩ	1/8 W	Prec	1%
R253	321-0333-30			28.7 kΩ	1/8 W	Prec	1%
R254	321-0173-30			619 Ω	1/8 W	Prec	1%
R256	321-0297-30			12.1 kΩ	1/8 W	Prec	1%
R257	321-0257-30			4.64 kΩ	1/8 W	Prec	1%
R258	321-0285-30			9.09 kΩ	1/8 W	Prec	1%
R260	321-0217-30			1.78 kΩ	1/8 W	Prec	1%
R262	321-0185-30			825 Ω	1/8 W	Prec	1%
R264	321-0297-30			12.1 kΩ	1/8 W	Prec	1%
R290	315-0100-01			10 Ω	1/4 W		5%
R293	315-0100-01			10 Ω	1/4 W		5%
R301	315-0751-03			750 Ω	1/4 W		
R303	321-0253-30			4.22 kΩ	1/8 W	Prec	1%
R304	315-0153-02			15 kΩ	1/4 W		5%
R305	321-0273-30			6.81 kΩ	1/8 W	Prec	1%
R307	321-0113-30			147 Ω	1/8 W	Prec	1%
R308	321-0257-30			4.64 kΩ	1/8 W	Prec	1%
R310	315-0221-01			220 Ω	1/4 W		5%
R311	315-0682-01			6.8 kΩ	1/4 W		5%
R313	315-0153-02			15 kΩ	1/4 W		5%
R314	315-0563-02			56 kΩ	1/4 W		5%
R316	315-0751-03			750 Ω	1/4 W		5%
R317	315-0511-01			510 Ω	1/4 W		5%
R323	315-0222-02			2.2 kΩ	1/4 W		5%
R324	315-0222-02			2.2 kΩ	1/4 W		5%
R326	315-0101-01			100 Ω	1/4 W		5%
R328	315-0103-02			10 kΩ	1/4 W		5%
R329	315-0332-02			3.3 kΩ	1/4 W		5%
R342	315-0104-02			100 kΩ	1/4 W		5%
R344	315-0203-01			20 kΩ	1/4 W		5%
R346	321-0257-30			4.64 kΩ	1/8 W	Prec	1%

HORIZONTAL Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors (cont)			
R347	311-0609-00			2 kΩ, Var			
R351	315-0104-02			100 kΩ	1/4 W		5%
R352	315-0303-02			30 kΩ	1/4 W		5%
R353	315-0134-02			130 kΩ	1/4 W		5%
R355	315-0272-02			2.7 kΩ	1/4 W		5%
R357	315-0201-01			200 Ω	1/4 W		5%
R359	315-0102-01			1 kΩ	1/4 W		5%
R363	315-0473-01			47 kΩ	1/4 W		5%
R365	315-0752-01			7.5 kΩ	1/4 W		5%
R366	315-0202-01			2 kΩ	1/4 W		5%
R367	315-0103-02			10 kΩ	1/4 W		5%
R369	315-0623-00			62 kΩ	1/4 W		5%
R372	315-0102-01			1 kΩ	1/4 W		5%
R401	321-0268-30			6.04 kΩ	1/8 W	Prec	1%
R402	311-0635-00			1 kΩ, Var			
R403	321-0331-30			27.4 kΩ	1/8 W	Prec	1%
R404	311-0607-00			10 kΩ, Var			
R410	315-0561-02			560 Ω	1/4 W		5%
R411	321-0257-30			4.64 kΩ	1/8 W	Prec	1%
R412	311-0635-00			1 kΩ, Var			
R413	321-0223-00			2.05 kΩ	1/8 W	Prec	1%
R414	321-0257-30			4.64 kΩ	1/8 W	Prec	1%
R415	321-0177-30			681 Ω	1/8 W	Prec	1%
R423	321-0277-30			7.5 kΩ	1/8 W	Prec	1%
R424	321-0297-30			12.1 kΩ	1/8 W	Prec	1%
R425	315-0513-01			51 kΩ	1/4 W		5%
R426	321-0297-30			12.1 kΩ	1/8 W	Prec	1%
R427	321-0313-30			17.8 kΩ	1/8 W	Prec	1%
R428	321-0209-30			1.47 kΩ	1/8 W	Prec	1%
R431	321-0201-30			1.21 kΩ	1/8 W	Prec	1%
R432	311-0634-00			500 Ω, Var			
R433	321-0277-30			7.5 kΩ	1/8 W	Prec	1%
R437	321-0233-30			2.61 kΩ	1/8 W	Prec	1%
R438	311-0609-00			2 kΩ, Var			

HORIZONTAL Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors (cont)			
R439	321-0225-30			2.15 kΩ	1/8 W	Prec	1%
R441	321-0269-30			6.19 kΩ	1/8 W	Prec	1%
R442	321-0337-00			31.6 kΩ	1/8 W	Prec	1%
R443	321-0253-30			4.22 kΩ	1/8 W	Prec	1%
R444	311-0634-00			500 Ω, Var			
R445	321-0265-30			5.62 kΩ	1/8 W	Prec	1%
R446	321-0277-30			7.5 kΩ	1/8 W	Prec	1%
R450	315-0332-02			3.3 kΩ	1/4 W		5%
R451	315-0242-02			2.4 kΩ	1/4 W		5%
R452	322-0481-00			1 MΩ	1/4 W	Prec	1%
R460	315-0303-02			30 kΩ	1/4 W		5%
R461	315-0304-01			300 kΩ	1/4 W		5%
R462	315-0201-01			200 Ω	1/4 W		5%
R463	315-0133-01			13 kΩ	1/4 W		5%
R464	315-0105-01			1 MΩ	1/4 W		5%
R465	315-0102-01			1 kΩ	1/4 W		5%
R470	322-0481-00			1 MΩ	1/4 W	Prec	1%
R471	322-0481-00			1 MΩ	1/4 W	Prec	1%
R472	321-0331-30			27.4 kΩ	1/8 W	Prec	1%
R473	315-0153-02			15 kΩ	1/4 W		
R480	315-0203-01			20 kΩ	1/4 W		5%
R481	315-0303-02			30 kΩ	1/4 W		5%
R482	315-0244-01			240 kΩ	1/4 W		5%
R483	315-0303-02			30 kΩ	1/4 W		5%
R491	315-0100-01			10 Ω	1/4 W		5%
R493	315-0100-01			10 Ω	1/4 W		5%

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

HIGH VOLTAGE POWER SUPPLY Circuit Board Assembly

	*670-0885-00			Complete Board			

Capacitors

Tolerance ±20% unless otherwise indicated.

C521	290-0456-00			4.7 μF	Elect.		
C522	283-0231-00			470 pF	Cer	500 V	10%
C529	290-0464-00			150 μF	Elect.		
C531	290-0451-00			0.15 μF	Elect.		
C533	290-0453-00			1 μF	Elect.		
C572	290-0458-00			10 μF			
C573	283-0022-00			0.02 μF	Cer	1400 V DC	
C574	283-0022-00			0.02 μF	Cer	1400 V DC	
C575	283-0151-00			0.01 μF	7 section assembly		
C576	283-0151-00			0.01 μF	7 section assembly		
C577A	283-0013-00			0.01 μF	Cer	1000 V	
C577B	283-0013-00			0.01 μF	Cer	1000 V	
C578A	283-0013-00			0.01 μF	Cer	1000 V	
C578B	283-0013-00			0.01 μF	Cer	1000 V	
C579	283-0105-00			0.01 μF	Cer	2000 V	+80%-20%
C587	283-0059-00			1 μF	Cer	25 V	+80%2-0%
C588	283-0068-00			0.01 μF	Cer	500 V	

Semiconductor Device, Diodes

D516	*152-0185-00			Silicon	Replaceable by 1N4152
D517	*152-0185-00			Silicon	Replaceable by 1N4152
D523	*152-0242-00			Silicon	Selected from 1N486A
D525	*152-0185-00			Silicon	Replaceable by 1N4152
D528	*152-0061-00			Silicon	Tek Spec
D531	*152-0061-00			Silicon	Tek Spec
D533	*152-0061-00			Silicon	Tek Spec
D541	*152-0242-00			Silicon	Replaceable by 1N486A
D543	*152-0061-00			Silicon	Tek Spec
D575A-N	152-0331-00			Silicon	25 mA fast recovery

HIGH VOLTAGE POWER SUPPLY Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Inductors			
L580A	275-0525-00			Core, ferrite			
L590B	276-0606-00			Core, ferrite			
				Transistors			
Q515	151-0304-01			2SC318A, checked			
Q518	151-0305-00			2SA527			
Q525	151-0304-01			2SC318A, checked			
				Resistors			

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

Ckt. No.	Tektronix Part No.	Eff	Disc	Value	Watts	Type	Tolerance
R513	311-0633-00			5 kΩ, Var			
R514	321-0277-30			7.5 kΩ	1/8 W	Prec	1%
R515	315-0114-01			110 kΩ	1/4 W		5%
R516	315-0332-02			3.3 kΩ	1/4 W		5%
R517	315-0432-01			4.3 kΩ	1/4 W		5%
R521	315-0272-02			2.7 kΩ	1/4 W		5%
R522	315-0103-02			10 kΩ	1/4 W		5%
R528	321-0066-30			47.5 kΩ	1/8 W	Prec	1%
R529	315-0113-01			11 kΩ	1/4 W		5%
R535	321-0410-30			182 kΩ	1/8 W	Prec	1%
R569	301-0156-00			15 MΩ	1/2 W		5%
R572	315-0432-01			4.3 kΩ	1/4 W		5%
R575	301-0186-00			18 MΩ	1/2 W		5%
R576	301-0186-00			18 MΩ	1/2 W		5%
R577	301-0186-00			18 MΩ	1/2 W		5%
R578	301-0186-00			18 MΩ	1/2 W		5%
R580	301-0685-00			6.8 MΩ	1/2 W		5%
R582	301-0106-00			10 MΩ	1/2 W		5%
R583	311-0698-00			1 MΩ, Var			
R584	315-0275-01			2.7 MΩ	1/4 W	Selected	(nominal value)
R587	301-0186-00			18 MΩ	1/2 W		5%
R590	315-0470-02			47 Ω	1/4 W		5%
R591	315-0470-02			47 Ω	1/4 W		5%
R599	315-0304-01			300 kΩ	1/4 W		5%

HIGH VOLTAGE POWER SUPPLY Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Transformer			
T538	*120-0504-01			H. V. Power			
				VOLTS/DIV SWITCH Circuit Board Assembly			
	*670-0886-00			Complete Board			
				Capacitors			
Tolerance ±20% unless otherwise indicated.							
C3	290-0136-01			2.2 μF	Elect.	20 V	
C5	290-0450-00			0.1 μF	Elect.		
C6	290-0136-01			2.2 μF	Elect.	20 V	
C23A	281-0093-01			5.5-18 pF, Var	Cer		
C23B	281-0091-01			2-8 pF, Var	Cer		
C23C	281-0600-00			35 pF	Cer		10%
C24A	281-0093-01			5.5-18 pF, Var	Cer		
C24B	281-0091-01			2-8 pF, Var	Cer		
C24C	283-0597-01			470 pF	Mica	300 V	10%
C25A	281-0093-01			5.5-18 pF, Var	Cer		
C25B	281-0091-01			2-8 pF, Var	Cer		
C78A	281-0091-01			2-8 pF, Var	Cer		
C78B	281-0093-01			5.5-18 pF, Var	Cer		
C79A	281-0093-01			5.5-18 pF, Var	Cer		
C79B	281-0091-01			2-8 pF, Var	Cer		
				Semiconductor Device, Diodes			
D11	*152-0185-00			Silicon	Replaceable by 1N4152		
D12	*152-0185-00			Silicon	Replaceable by 1N4152		
D13	*152-0185-00			Silicon	Replaceable by 1N4152		

VOLTS/DIV SWITCH Circuit Board Assembly (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Transistors			
Q1	151-0224-00			Silicon	NPN	TO-18	2N3692
Q9	151-0224-00			Silicon	NPN	TO-18	2N3692
				Resistors			
Resistors are fixed, composition, ±10% unless otherwise indicated.							
R3	315-0102-01			1 kΩ	1/4 W		5%
R4	315-0752-01			7.5 kΩ	1/4 W		5%
R6	315-0511-01			510 Ω	1/4 W		5%
R8	315-0103-02			10 kΩ	1/4 W		5%
R9	315-0822-01			8.2 kΩ	1/4 W		5%
R12	321-0313-30			17.8 kΩ	1/8 W	Prec	1%
R13	321-0317-30			19.6 kΩ	1/8 W	Prec	1%
R15	321-0337-30			31.6 kΩ	1/8 W	Prec	1%
R17	321-0284-30			8.87 kΩ	1/8 W	Prec	1%
R18	321-0183-30			787 Ω	1/8 W	Prec	1%
R19	321-0125-30			196 Ω	1/8 W	Prec	1%
R23C	321-1389-31			111 kΩ	1/8 W	Prec	1/2%
R24B	322-0624-01			990 kΩ	1/4 W	Prec	1/2%
R24C	321-1289-31			10.1 kΩ	1/8 W	Prec	1/2%
R25B	322-0629-01			999 kΩ	1/4 W	Prec	1/2%
R25C	321-0193-31			1 kΩ	1/8 W	Prec	1/2%
R78B	322-0610-31			500 kΩ	1/4 W	Prec	1/2%
R78C	322-0481-01			1 MΩ	1/4 W	Prec	1/2%
R79B	322-0620-31			800 kΩ	1/4 W	Prec	1/2%
R79C	321-0618-01			250 kΩ	1/8 W	Prec	1/2%

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description		
				BATTERY PACK		
	*016-0160-00			Complete Battery Pack		
				Capacitors		
Tolerance ±20% unless otherwise indicated.						
C605	290-0287-00			47 μF	Elect.	25 V
C623	283-0003-00			0.01 μF	Cer	150 V
C636	290-0114-01			47 μF	Elect.	6 V
				Semiconductor Device, Diodes		
D605	*152-0107-00			Silicon	Replaceable by 1N647	
D610A,B,C,D	152-0447-00					
D637	152-0008-00			Germanium		
D638	152-0008-00			Germanium		
D649	152-0166-00			Zener	1N753A 400 mW, 6.2 V, 5%	
				Fuses		
F601	159-0097-00			0.4 A	Fast-Blo	100 V operation
F601	159-0100-00			0.2 A	Fast-Blo	200 V operation
				Connectors		
P601	131-0552-00			Motor base		
J611	136-0139-00			Socket, banana jack assembly		
J612	136-0140-00			Socket, banana jack assembly		
				Inductor		
L611A,B	*108-0488-00			150 μH		

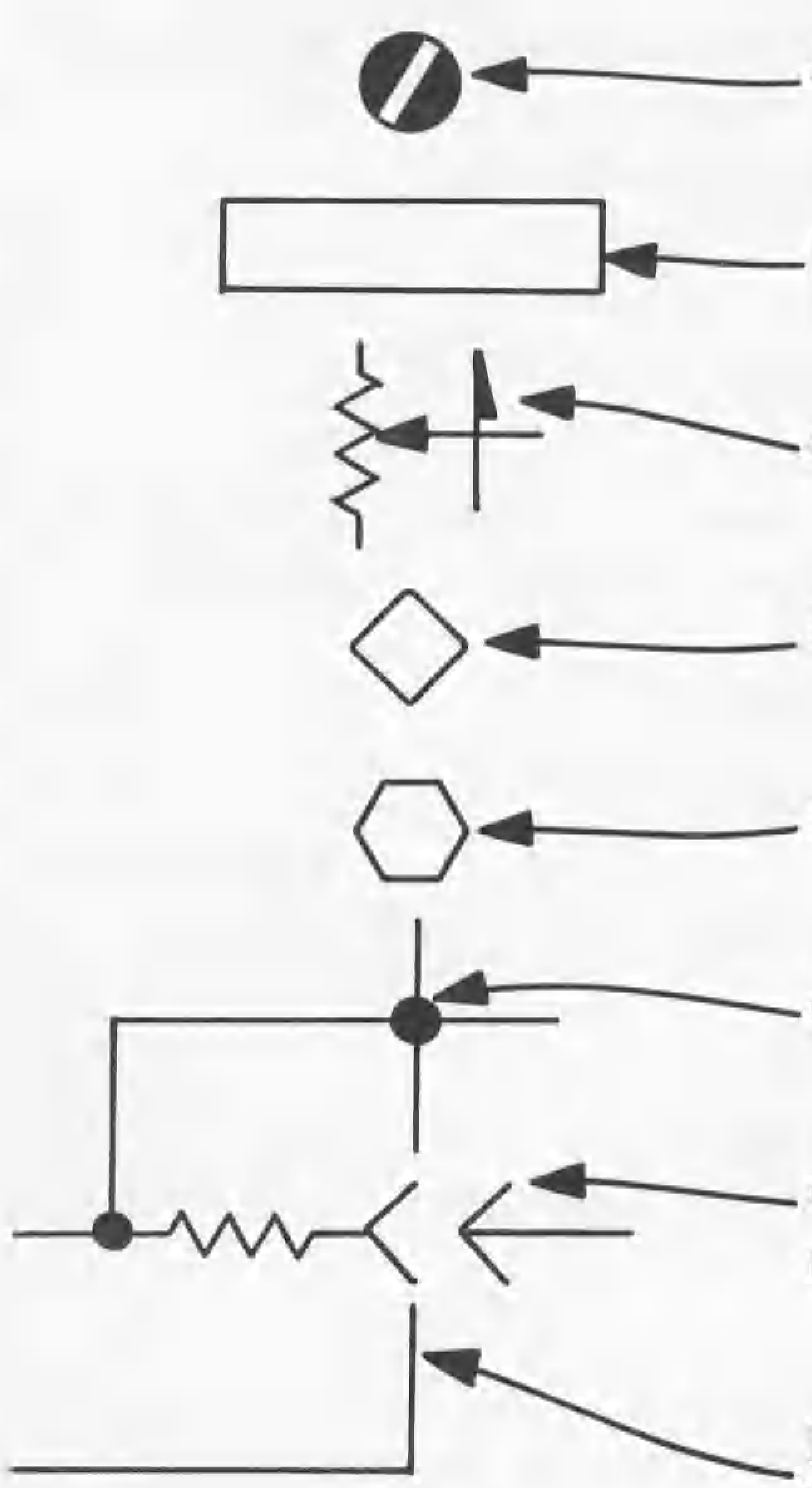
BATTERY PACK (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Transistors			
Q617	151-0229-00			Silicon	NPN	TO-66 2SD28	
Q620	*151-0219-00			Silicon	PNP	TO-18 Replaceable by 2N4250	
Q621	151-0224-00			Silicon	NPN	TO-18 2N3692	
Q634	*151-0219-00			Silicon	PNP	TO-18 Replaceable by 2N4250	
Q636	*151-0219-00			Silicon	PNP	TO-18 Replaceable by 2N4250	
				Resistors			
Resistors are fixed, composition, ±10% unless otherwise indicated.							
R605	315-0472-01			4.7 kΩ	1/4 W		5%
R615	308-0463-00			0.3 Ω	3 W	WW	1%
R619	315-0100-01			10 Ω	1/4 W		5%
R620	315-0102-01			1 kΩ	1/4 W		5%
R623	315-0471-02			470 Ω	1/4 W		5%
R630	315-0272-02			2.7 kΩ	1/4 W		5%
R633	321-0445-00			422 kΩ	1/8 W	Prec	1%
R635	315-0752-01			7.5 kΩ	1/4 W		5%
R637	315-0102-01			1 kΩ	1/4 W		5%
R638	315-0102-01			1 kΩ	1/4 W		5%
R639	315-0152-01			1.5 kΩ	1/4 W		5%
R641	315-0272-02			2.7 kΩ	1/4 W		5%
R643	321-0341-30			34.8 kΩ	1/8 W	Prec	1%
R644	311-0635-00			1 kΩ, Var			
				Switch			
	Wired or Unwired						
S612	260-0902-00			Slide			
				Transformer			
T601	120-0654-00			L. V. Power			

SECTION 7
ELECTRICAL DIAGRAMS
and
ILLUSTRATIONS

Symbols used on the diagrams are based on or taken directly from IEEE Standard 260 "Standard Symbols for Units", MIL-STD-12B, and other standards of the electronics industry.

The following special symbols are used on the diagrams:



Screwdriver adjustment.

Front- or rear-panel control or connector.

Clockwise control rotation in direction of arrow.

Refer to diagram number indicated in diamond.

Refer to waveform number indicated in hexagon.

Connection soldered to circuit board.

Connection made to circuit board with interconnecting pin.

Blue line encloses components located on circuit board.

BT	Battery	Q	Transistor or silicon-controlled rectifier
C	Capacitor, fixed or variable	P	Connector, movable, portion
D	Diode, signal or rectifier	R	Resistor, fixed or variable
DS	Indicating device (lamp)	S	Switch
F	Fuse	RT	Thermistor
J	Connector, stationary portion	T	Transformer
L	Indicator, fixed or variable	TP	Test Point
LR	Resistor inductor	V	Electron Tube

VOLTAGE AND WAVEFORM TEST CONDITIONS

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

Test Oscilloscope (with 10X Probe)

Frequency response	DC to 10 MHz
Deflection factor (with probe)	50 millivolts to 50 volts/division
Input impedance	10 megohm, 13 picofarads
Probe ground	324 chassis ground
Trigger source	As indicated on individual diagrams to indicate true time relationship between signals.
Recommended type (as used for waveforms on diagrams)	Tektronix 7504 with 7A16 and 7B50 plug-in units.

Voltmeter

Type	Non-loading digital multimeter
Input impedance	0 to 1.5 volts; ⩾ 1 kMΩ 15 to 1000 volts; 10 MΩ
Range	0 to 1000 volts
Reference voltage	324 chassis ground
Recommended type (as used for voltages on diagrams)	Fairchild Model 7050

324 Conditions

Applied voltage	8.5 volts DC
Signal applied	No signal applied for voltage measurements. As indicated on individual diagrams for waveforms only.
Connectors	No connections
Trace position	Centered
Control settings	As follows except as noted otherwise on individual diagrams.

Vertical Controls

VOLTS/DIV	.01
VARIABLE	CAL
INPUT	GND
Vertical POSITION	Midrange
X5 VERT GAIN	Pushed in

Triggering Controls

TRIGGER	+AUTO
Trig/Horiz Coupling	INT TRIG AC
EXT TRIG OR HORIZ ATTEN (side panel)	1X

Horizontal Controls

TIME/DIV	1 ms
VARIABLE	CAL
Horizontal POSITION	Midrange
X5 HORIZ MAG	Pushed in

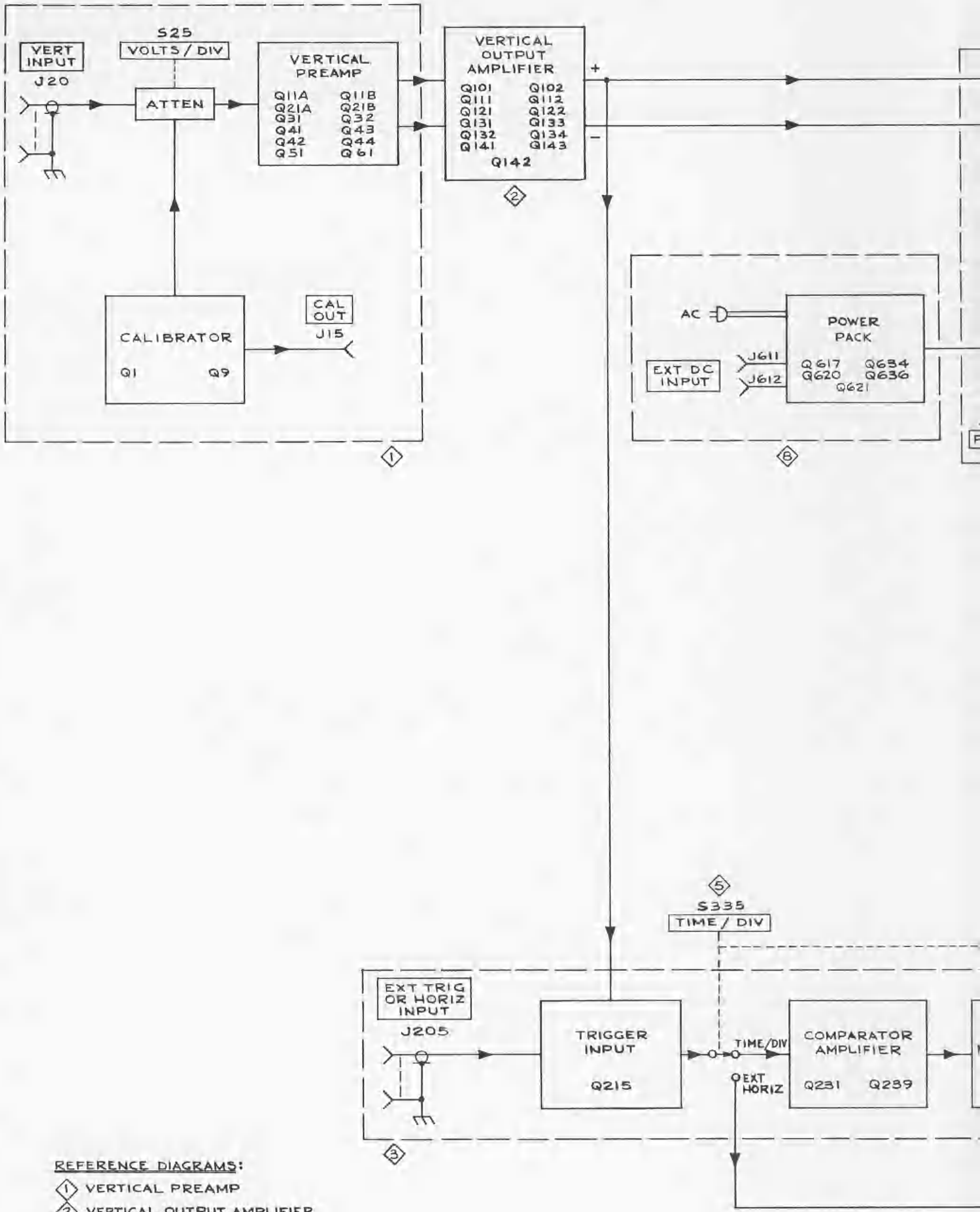
CRT Controls

FOCUS	Adjust for well defined display
INTENSITY	Midrange

Power Controls

POWER	ON
Power Pack (rear panel)	EXT DC

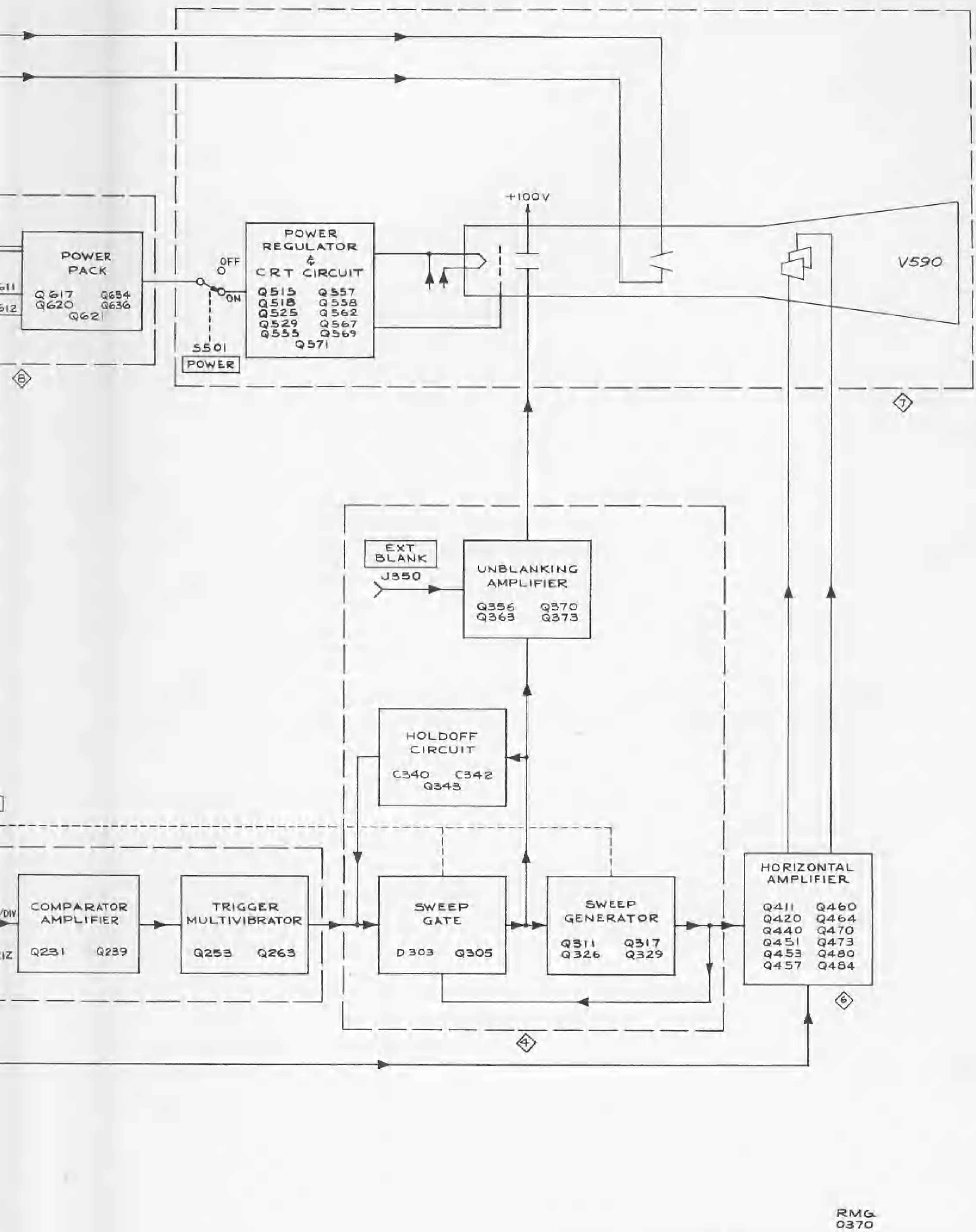
All voltages given on the diagrams are in volts. Waveforms shown are actual waveform photographs taken with a Tektronix Oscilloscope Camera System and Projected Graticule. Voltages and waveforms on the diagrams (shown in blue) are not absolute and may vary between instruments because of differing component tolerances, internal calibration or front-panel control settings.



REFERENCE DIAGRAMS:

1. VERTICAL PREAMP
2. VERTICAL OUTPUT AMPLIFIER
3. TRIGGER GENERATOR
4. SWEEP GENERATOR
5. TIMING SWITCH
6. HORIZONTAL AMPLIFIER
7. POWER REGULATOR & CRT CIRCUIT
8. POWER PACK

A



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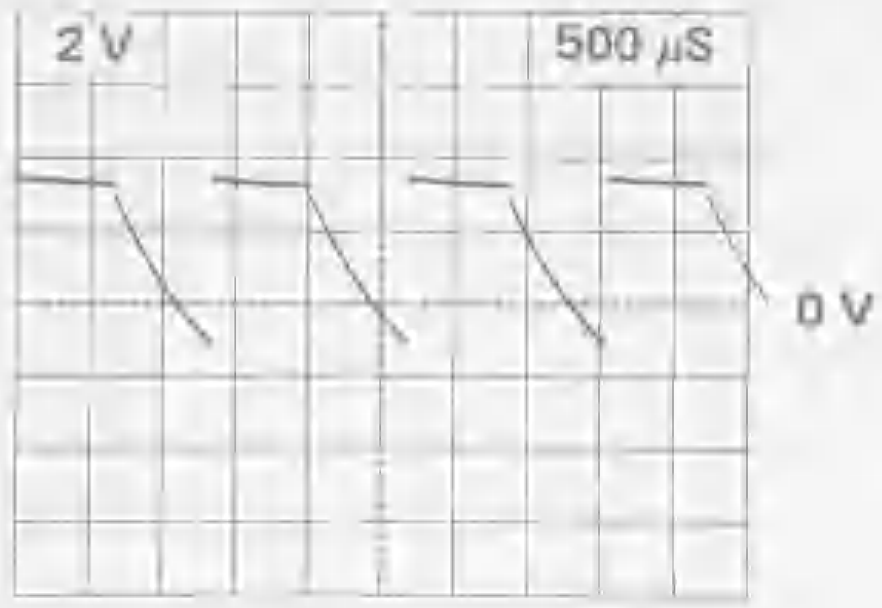
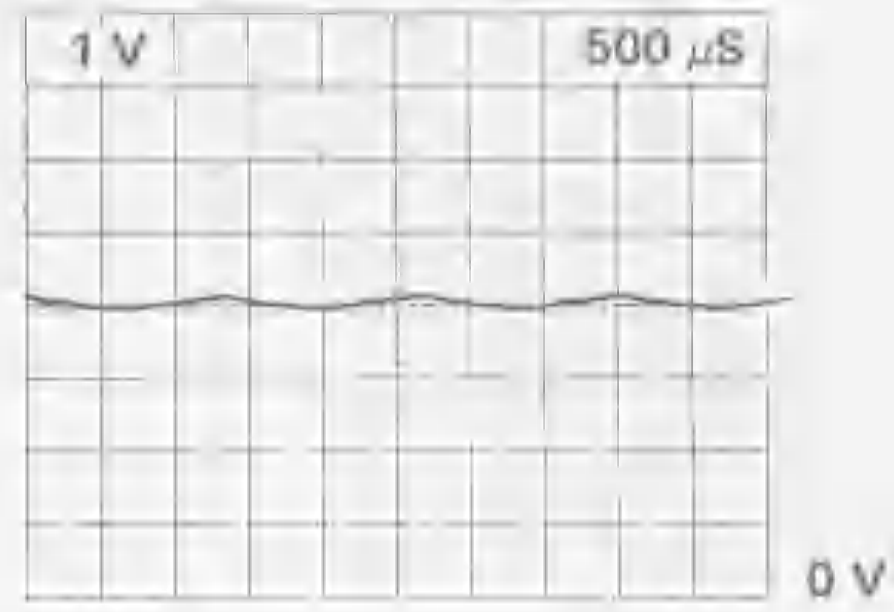
BLOCK DIAGRAM

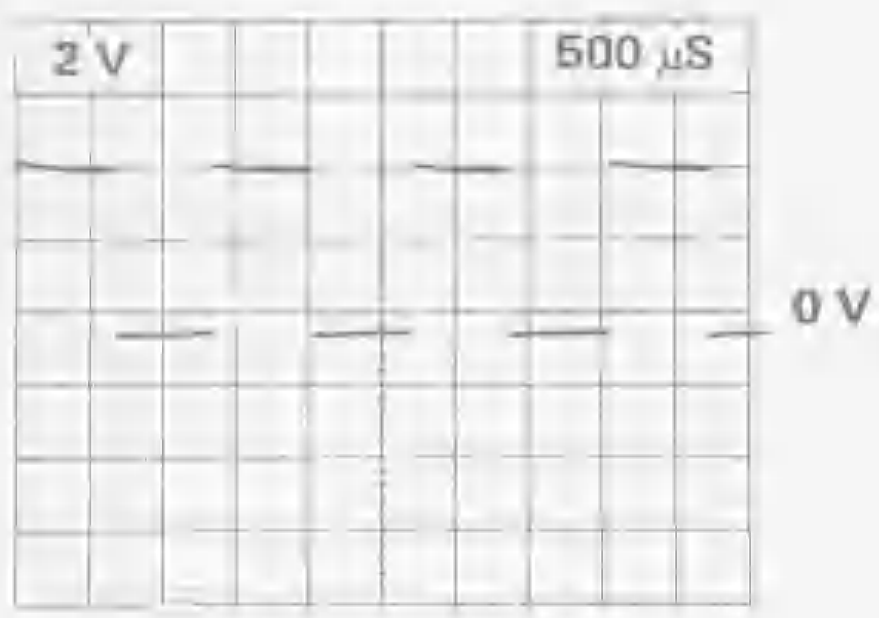
23


2 V
500 µS
0 V

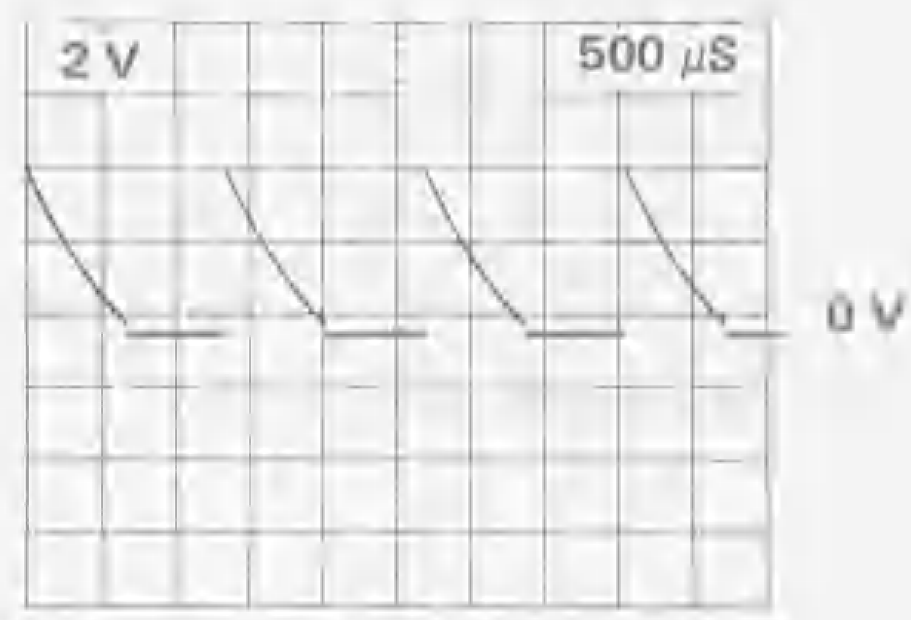
24


1 V
500 µS
0 V

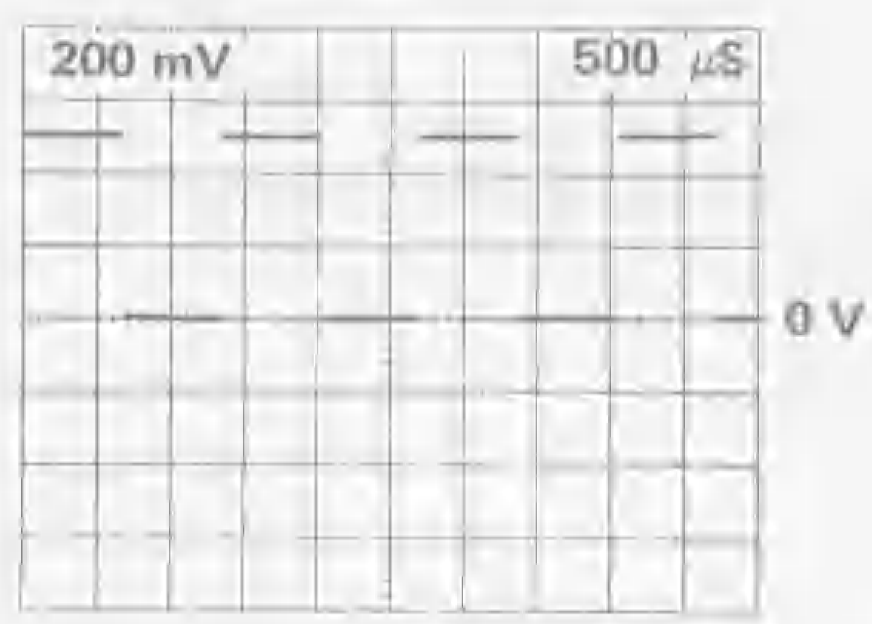
25

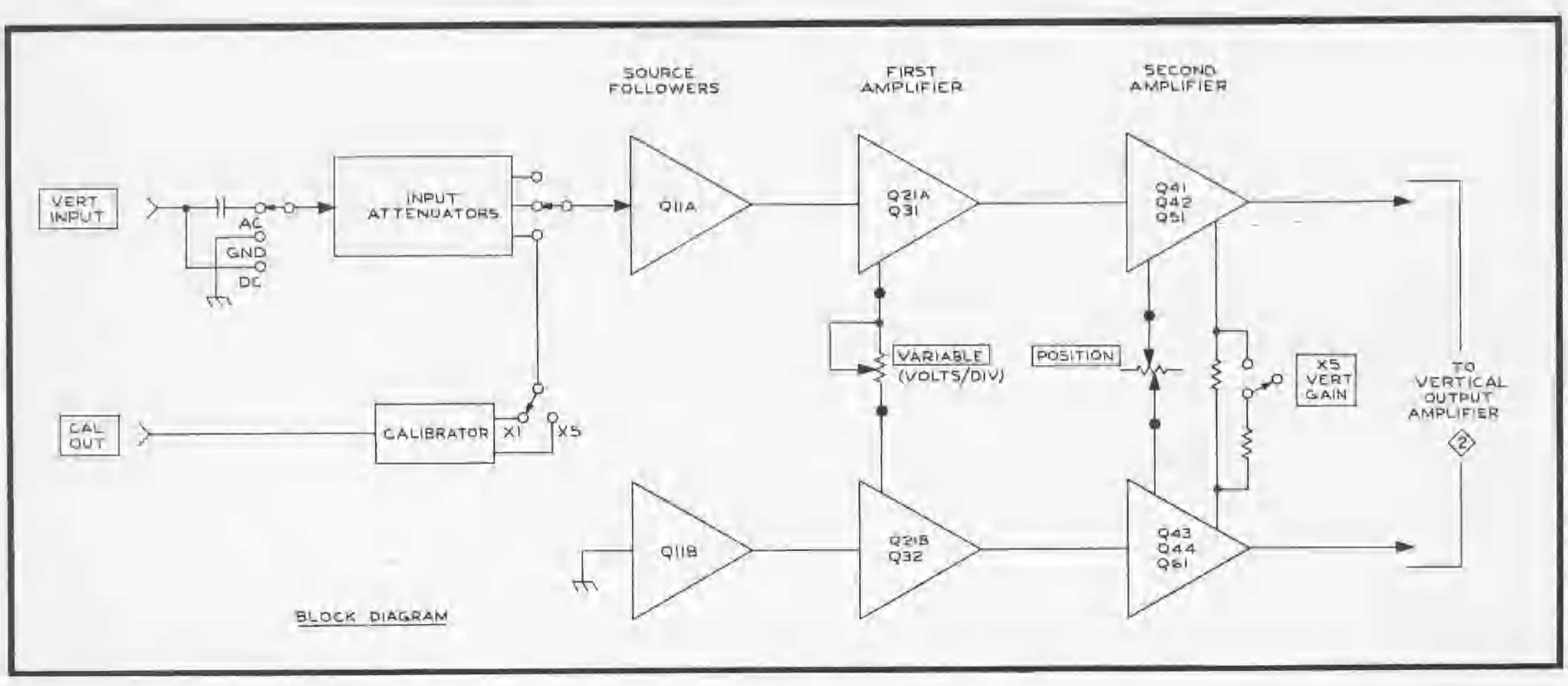

2 V
500 µS
0 V

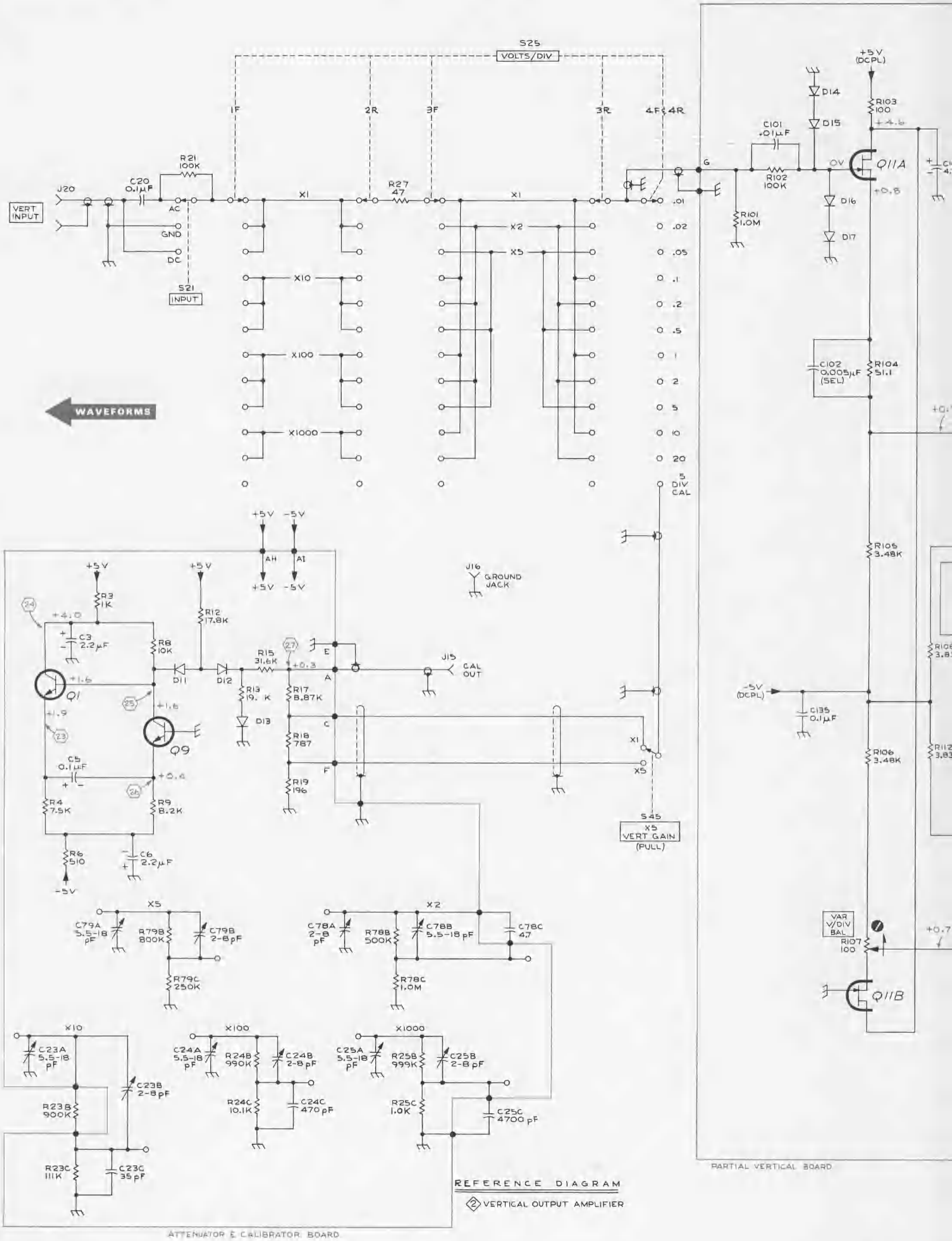
26


2 V
500 µS
0 V

27

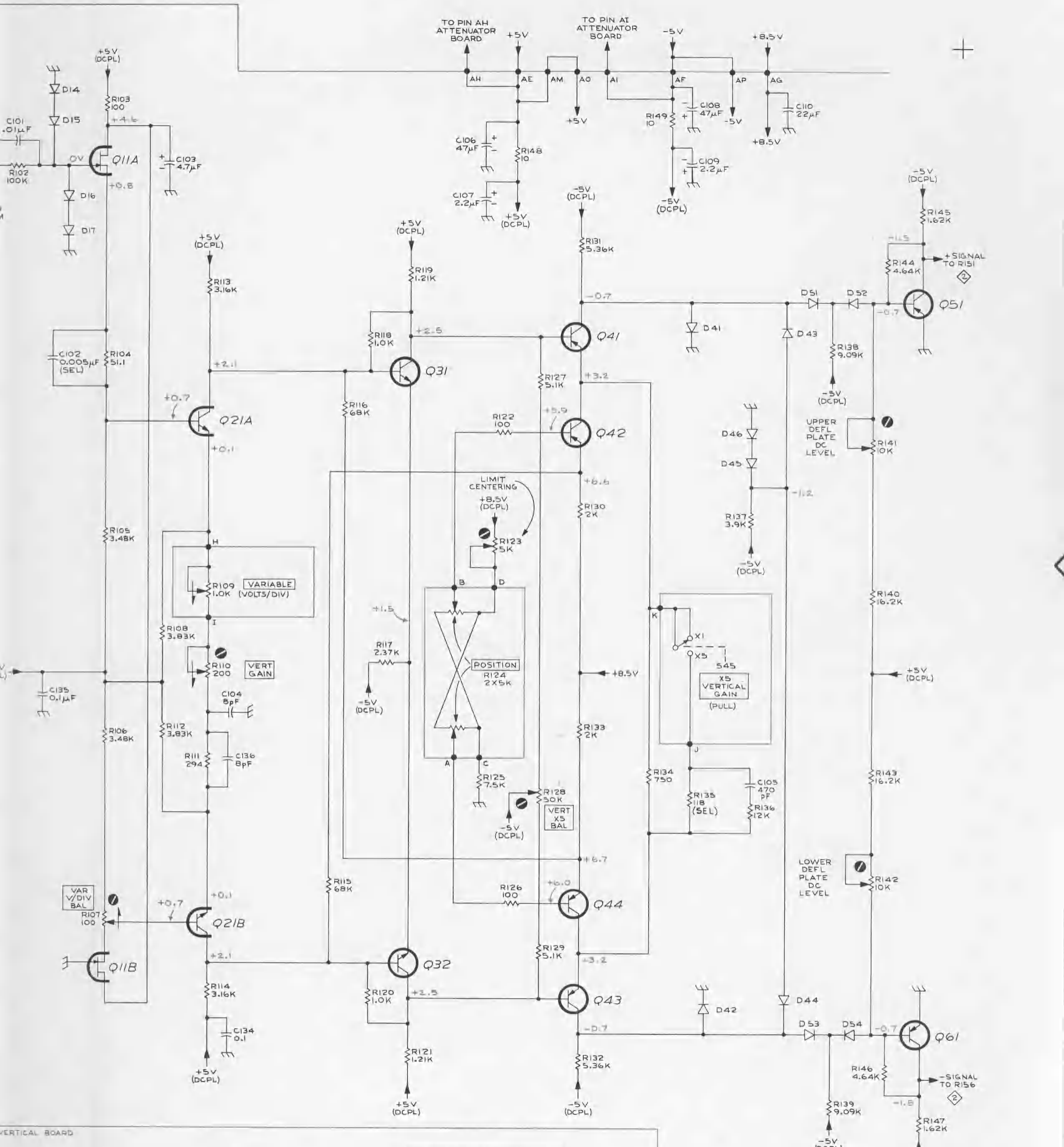

200 mV
500 µS
0 V


SOURCE FOLLOWERS
FIRST AMPLIFIER
SECOND AMPLIFIER
VERT INPUT
AC
GND
DC
INPUT ATTENUATORS
Q11A
Q21A Q31
Q41 Q42 Q51
VARIABLE (VOLTS/DIV)
POSITION
X5 VERT GAIN
TO VERTICAL OUTPUT AMPLIFIER
2
CAL OUT
CALIBRATOR
X1
X5
Q11B
Q21B Q32
Q43 Q44 Q61
BLOCK DIAGRAM



REFERENCE DIAGRAM

2 VERTICAL OUTPUT AMPLIFIER



NOTE:
SEE PARTS LIST FOR SEMICONDUCTOR TYPES

VOLTAGES and WAVEFORMS obtained under conditions given at the front of this section except as follows:

WAVEFORMS ONLY:

Test oscilloscope externally triggered from CAL OUT connector.

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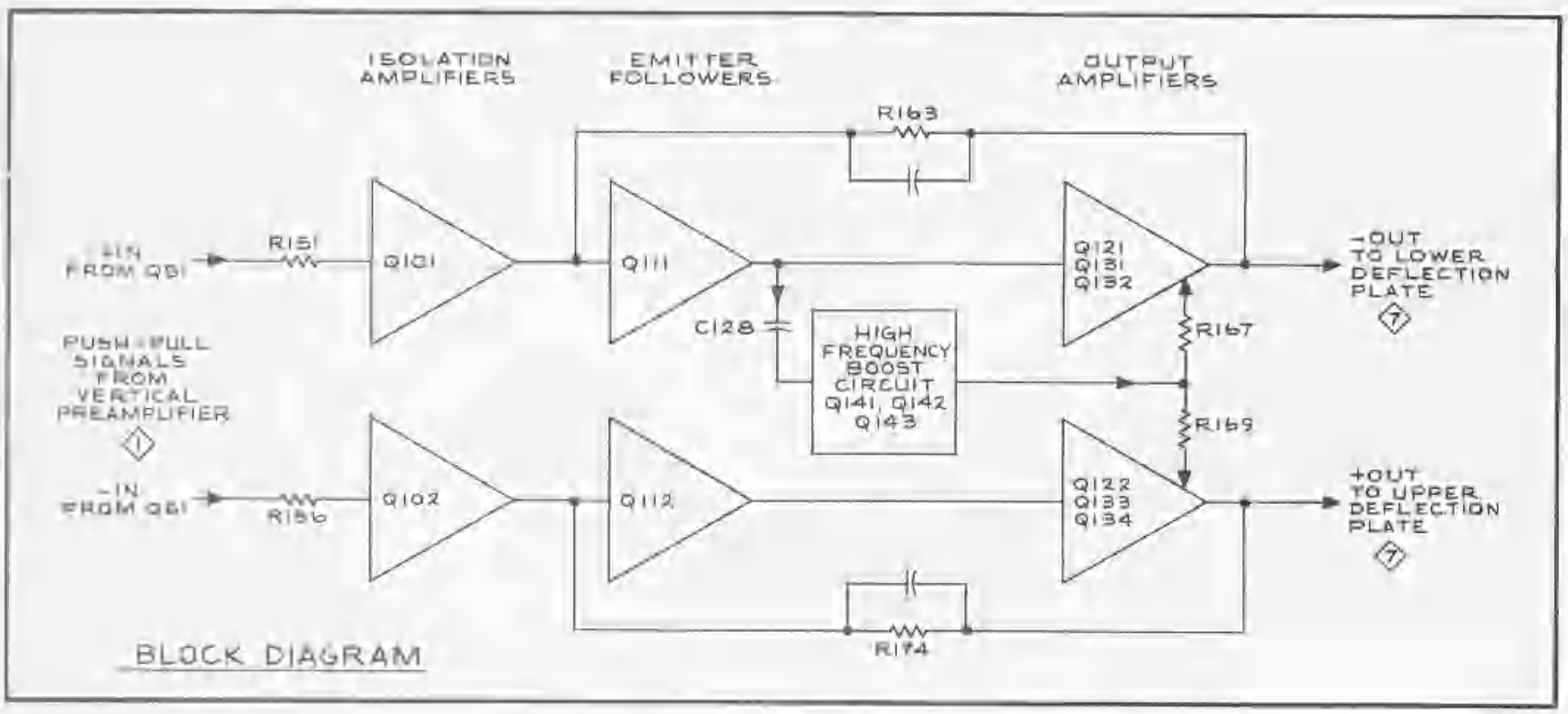
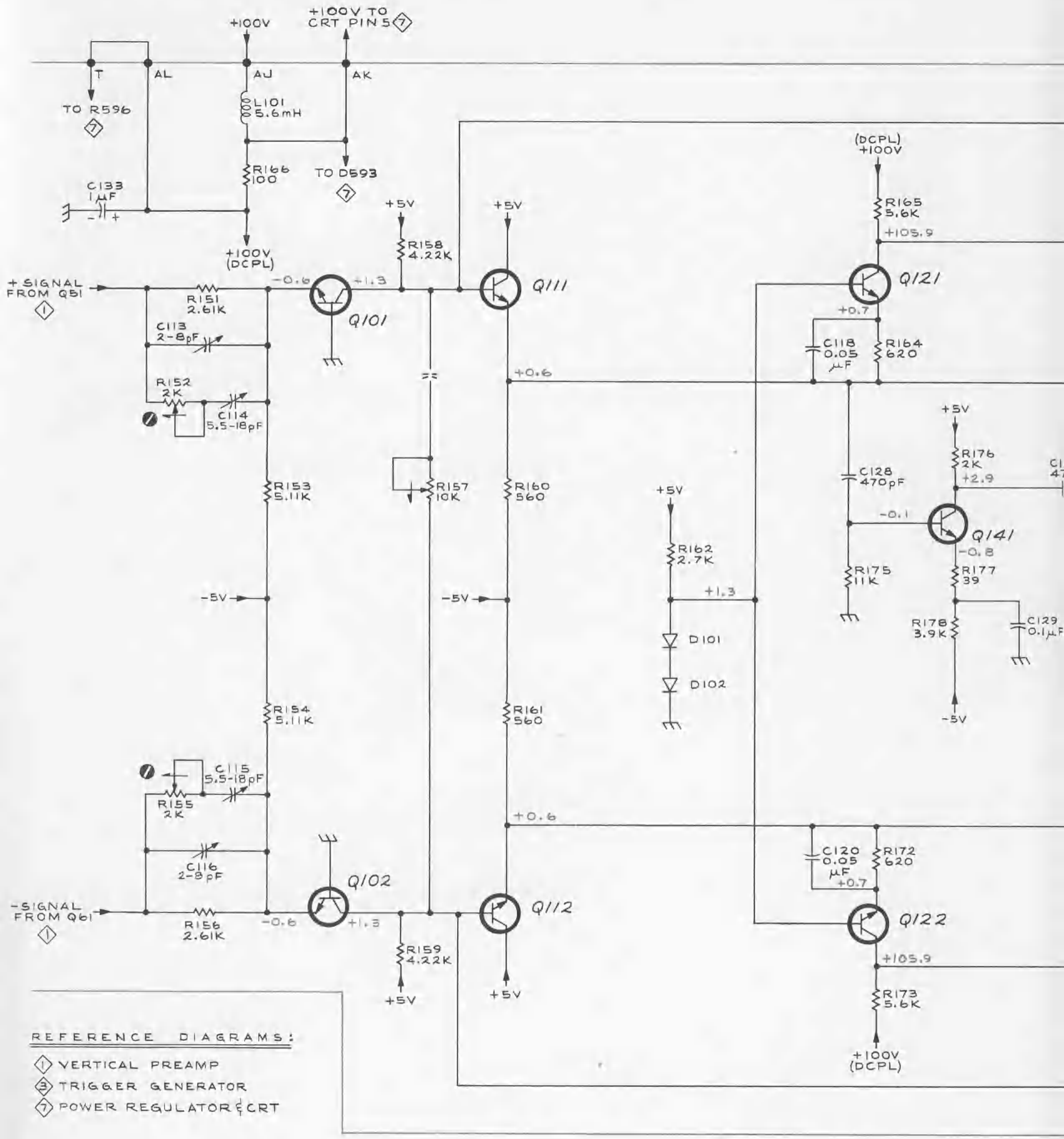
VERTICAL PREAMP ①


ISOLATION AMPLIFIERS
EMITTER FOLLOWERS
OUTPUT AMPLIFIERS
R163
+IN FROM Q81
R151
Q101
Q111
Q121
Q131
Q132
-OUT TO LOWER DEFLECTION PLATE
7
C128
HIGH FREQUENCY BOOST CIRCUIT Q141, Q142 Q143
R167
PUSH-PULL SIGNALS FROM VERTICAL PREAMPLIFIER
1
R169
-IN FROM Q81
R156
Q102
Q112
Q122
Q133
Q134
+OUT TO UPPER DEFLECTION PLATE
7
R174
BLOCK DIAGRAM

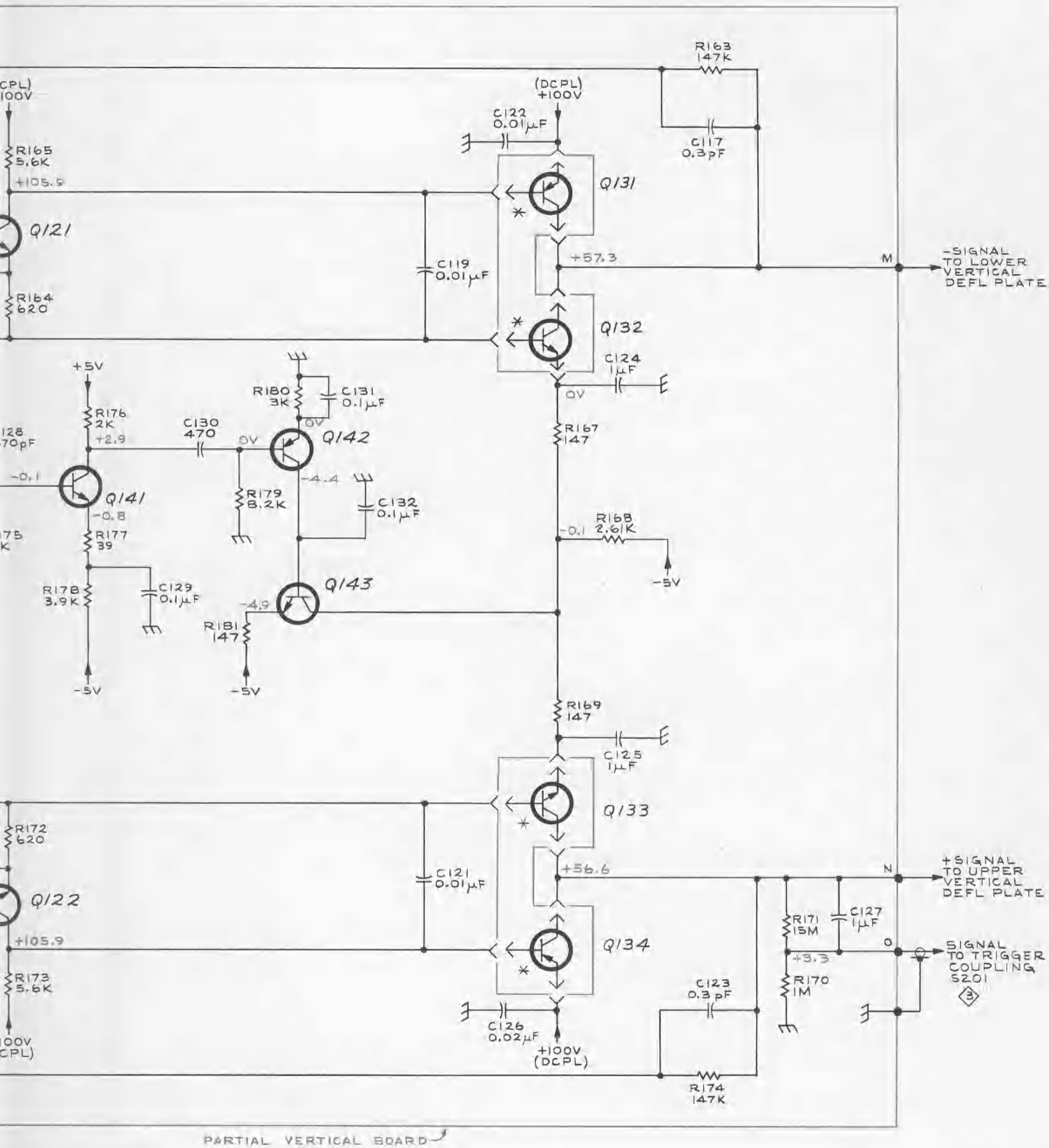


VOLTAGES obtained under conditions given at the front of this section.

NOTES:

1. SEE PARTS LIST FOR SEMICONDUCTOR TYPES.
2. ✱ HEAT SINK

Ⓐ



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0570

Ⓐ

VERTICAL OUTPUT AMPLIFIER ②

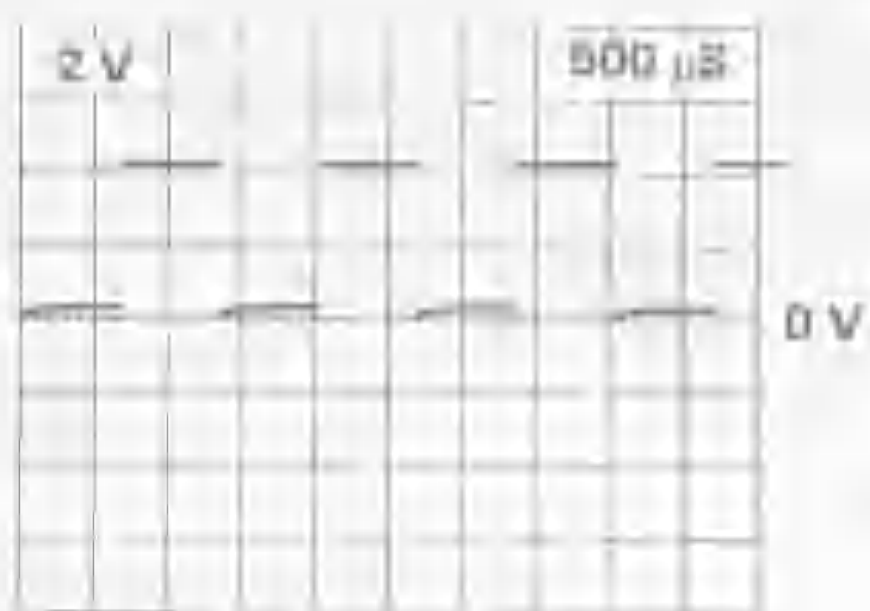
1


1 V
500 µS
0 V

2


1 V
500 µS
0 V

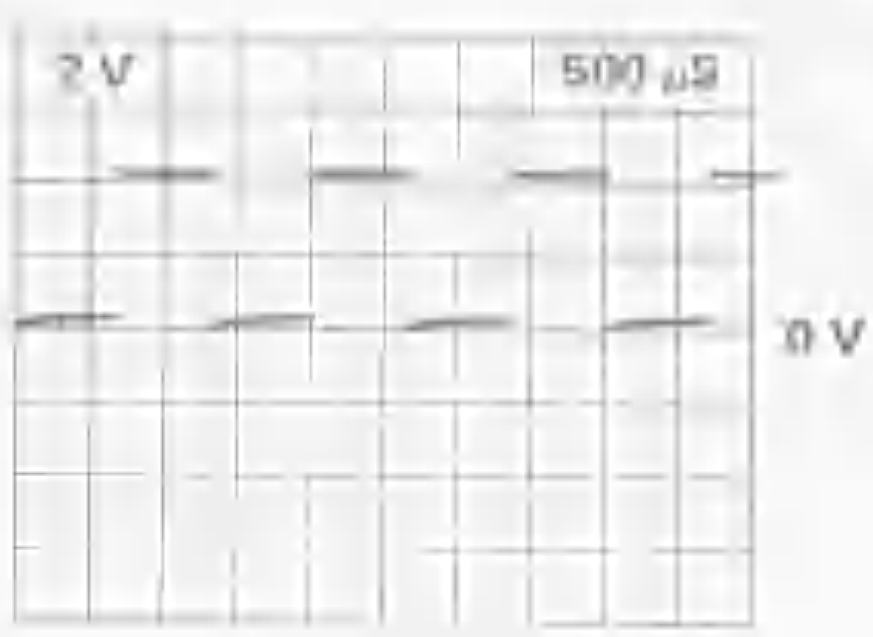
3


2 V
500 µS
0 V

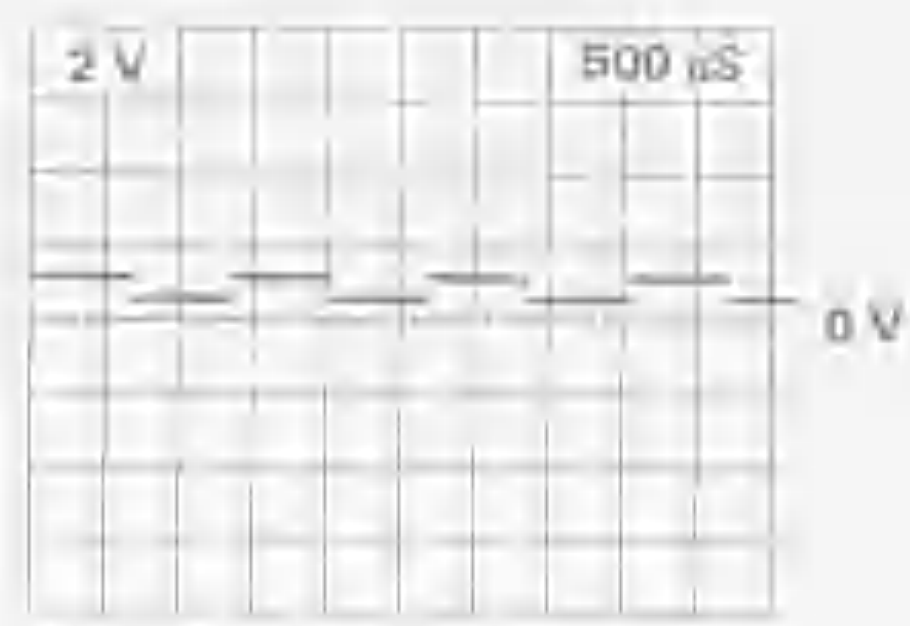
4


2 V
500 µS
0 V

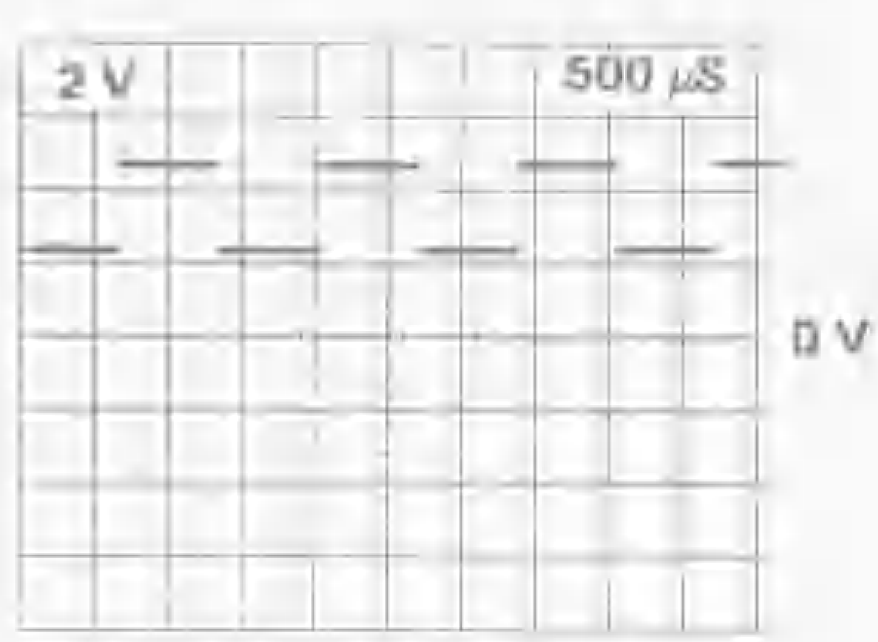
5

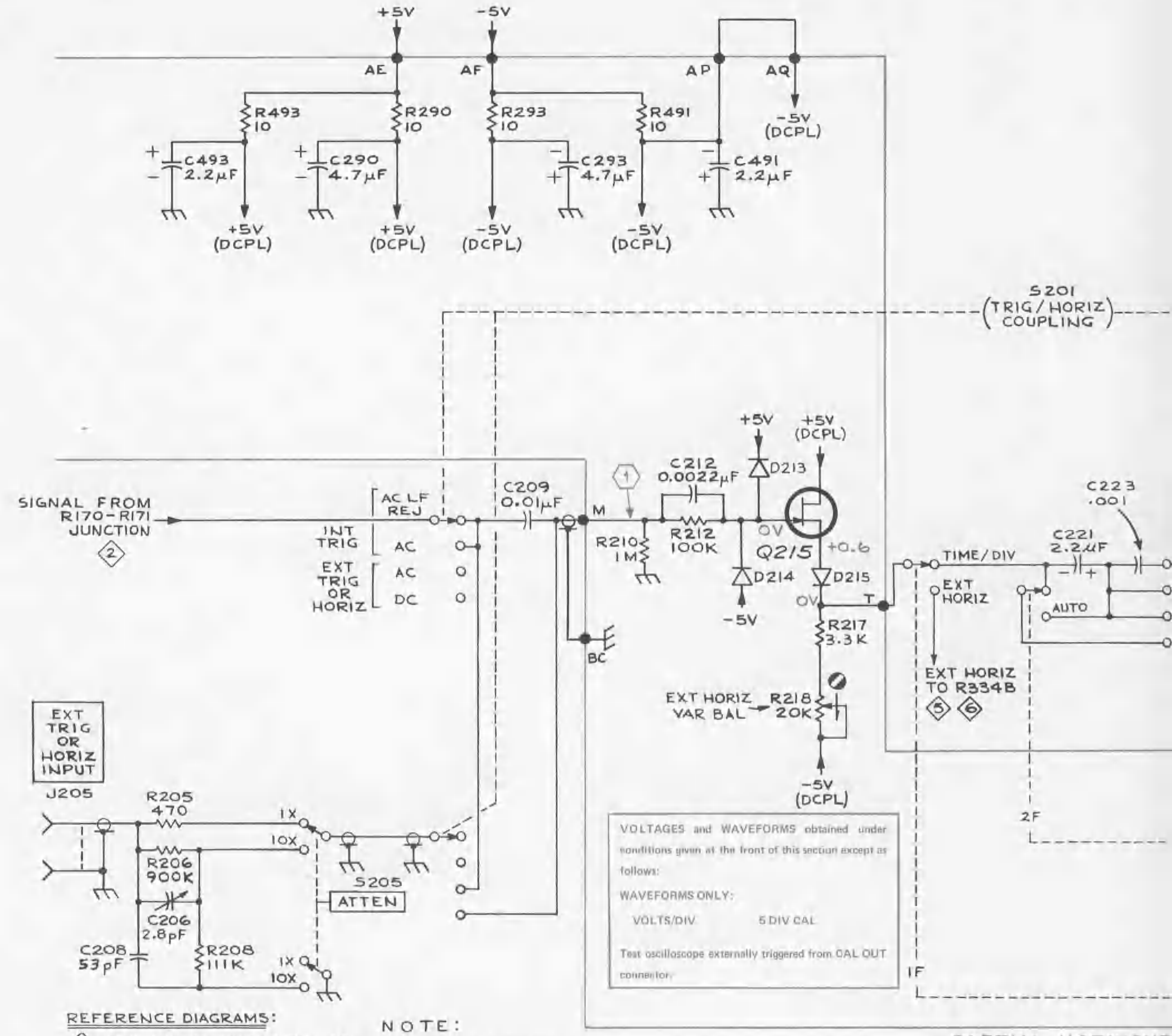

2 V
500 µS
0 V

6


2 V
500 µS
0 V

7


2 V
500 µS
0 V

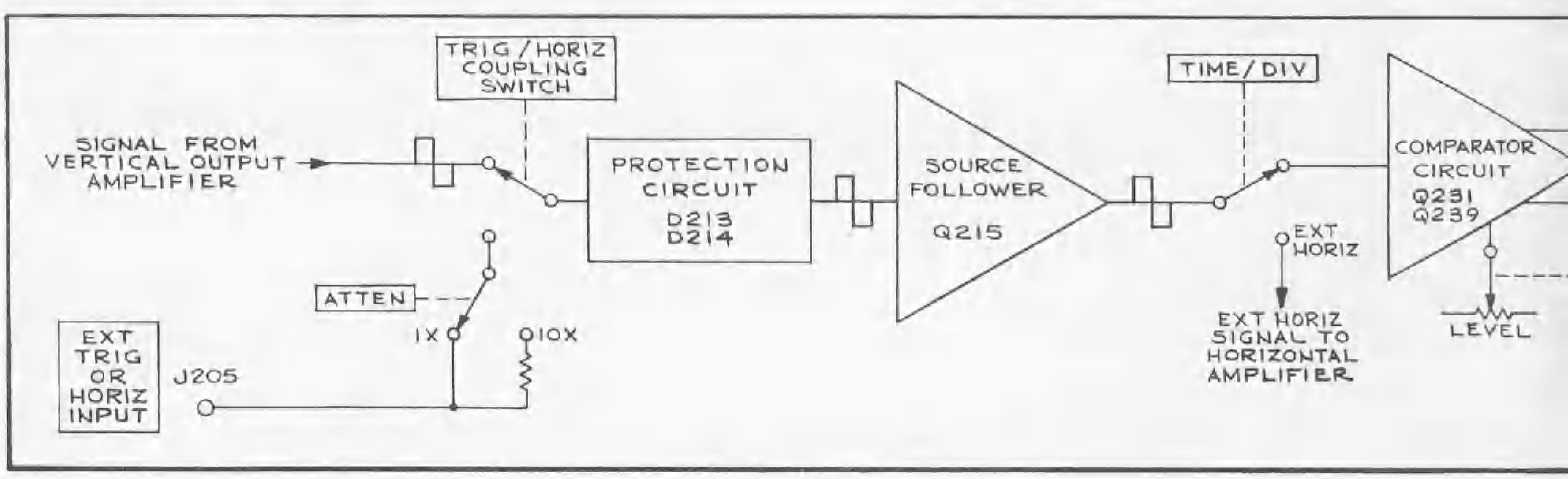


PARTIAL HORIZONT

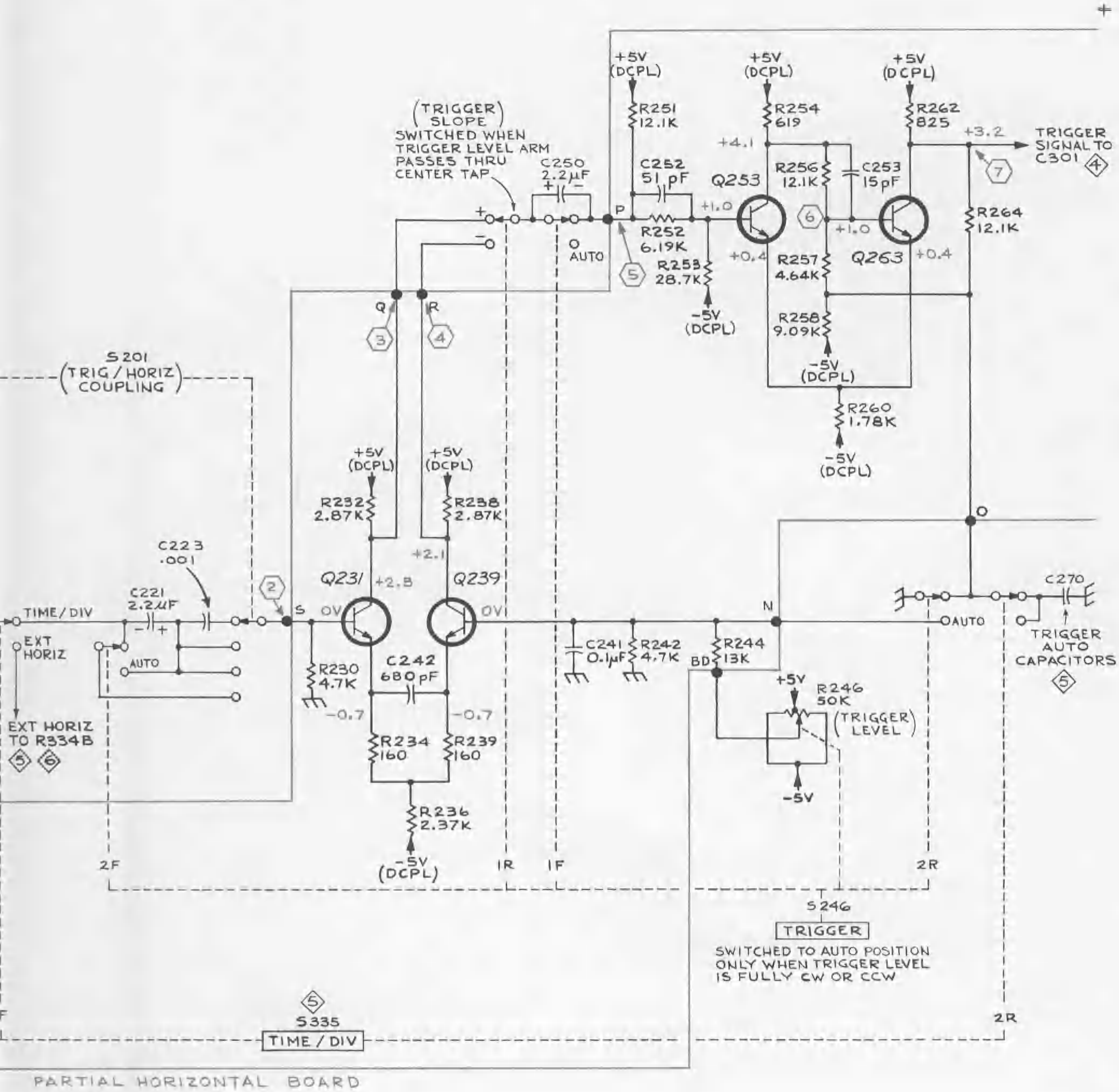
REFERENCE DIAGRAMS:

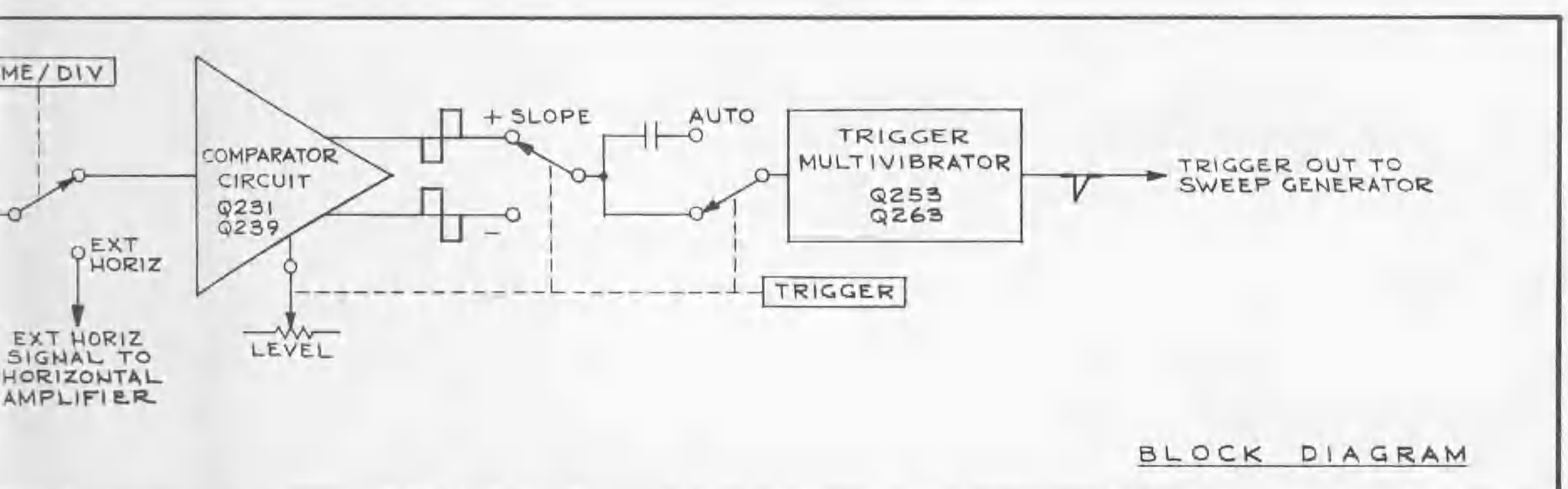
- 2 VERTICAL OUTPUT AMPLIFIER
- 4 SWEEP GENERATOR
- 5 TIMING SWITCH
- 6 HORIZONTAL AMPLIFIER

NOTE:
SEE PARTS LIST FOR SEMICONDUCTOR TYPES.



A1





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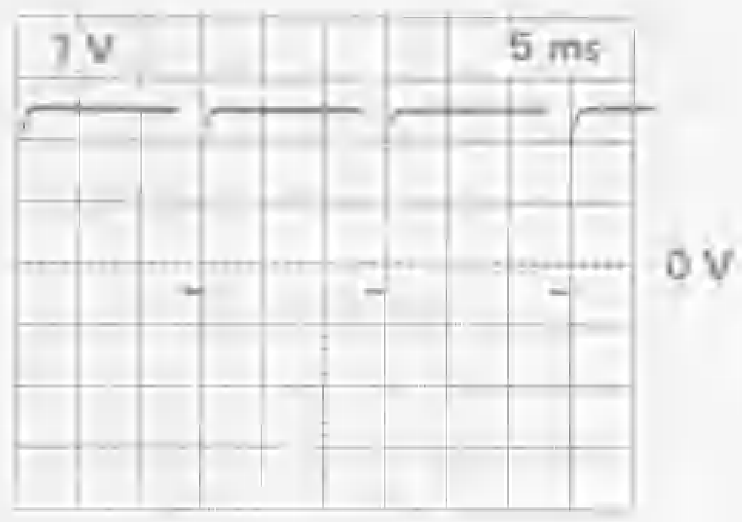
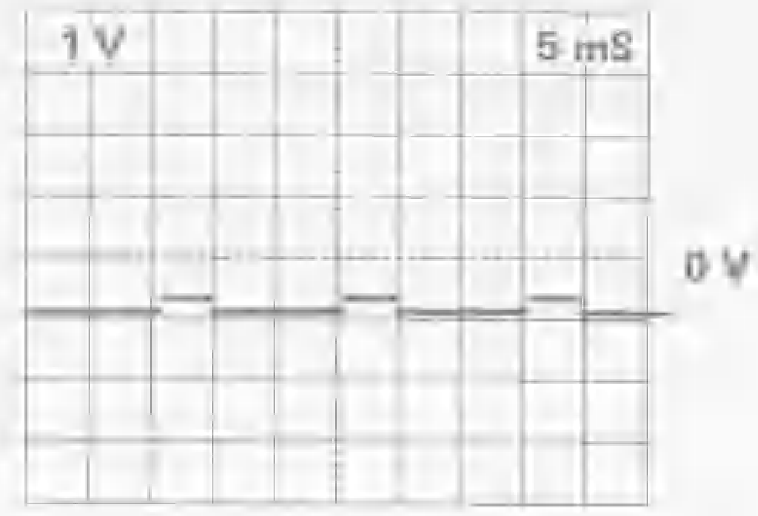
TRIGGER GENERATOR ③

Ⓐ1

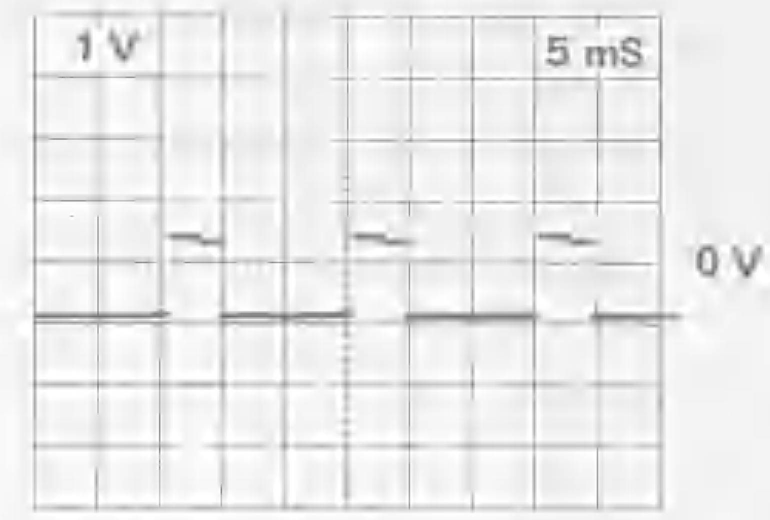
⟨8⟩



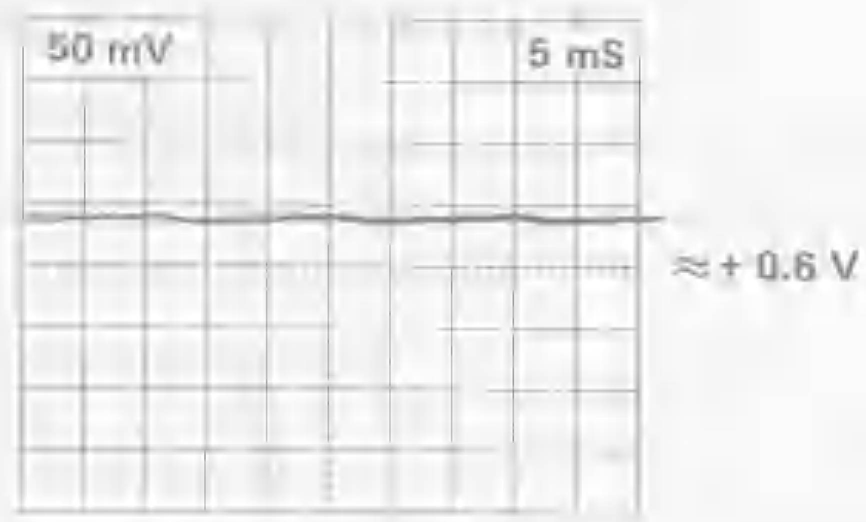
⟨9⟩



⟨10⟩

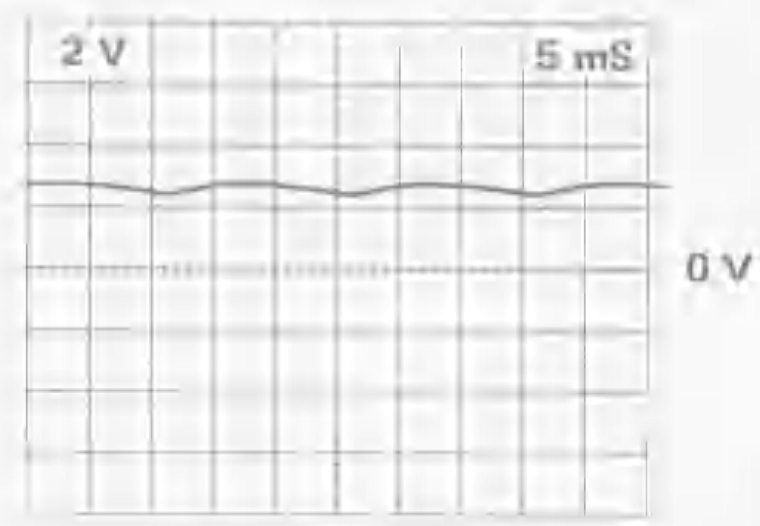


⟨11⟩

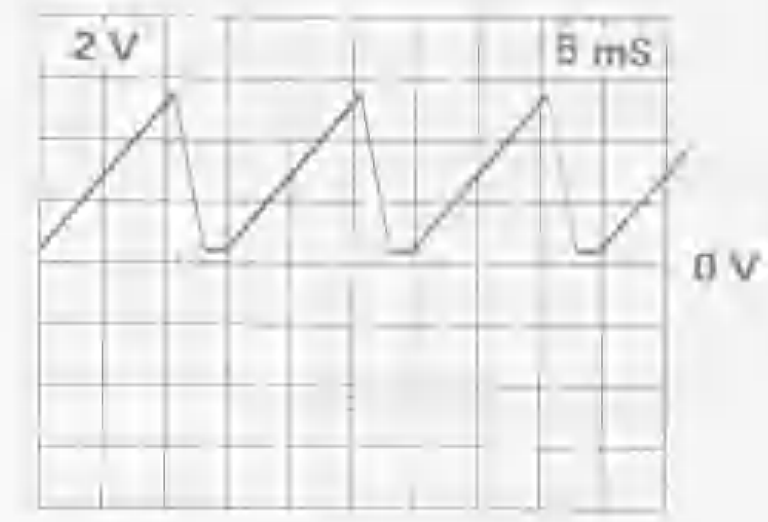


(AC COUPLED)

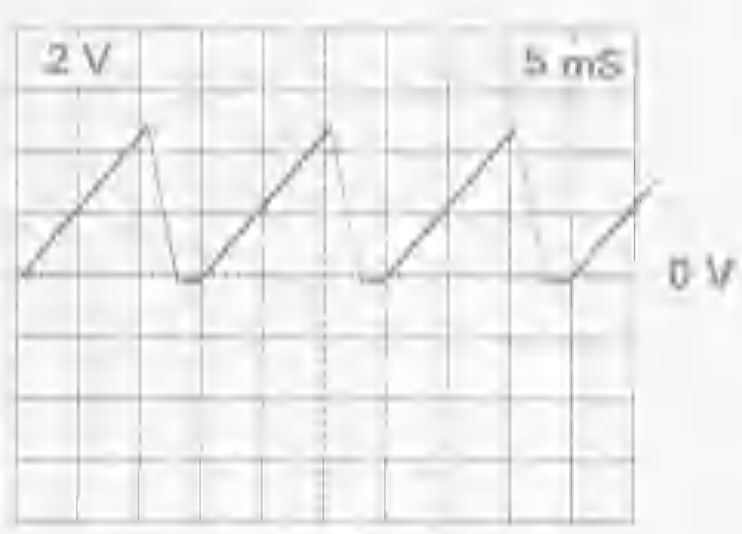
⟨12⟩



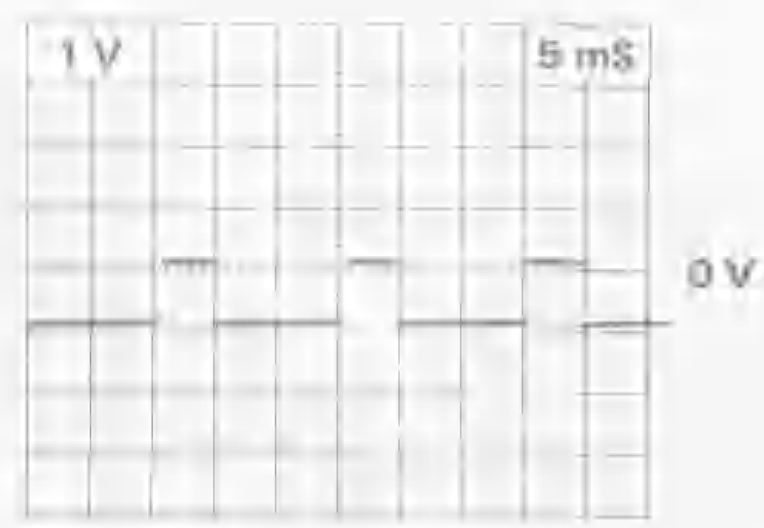
⟨13⟩



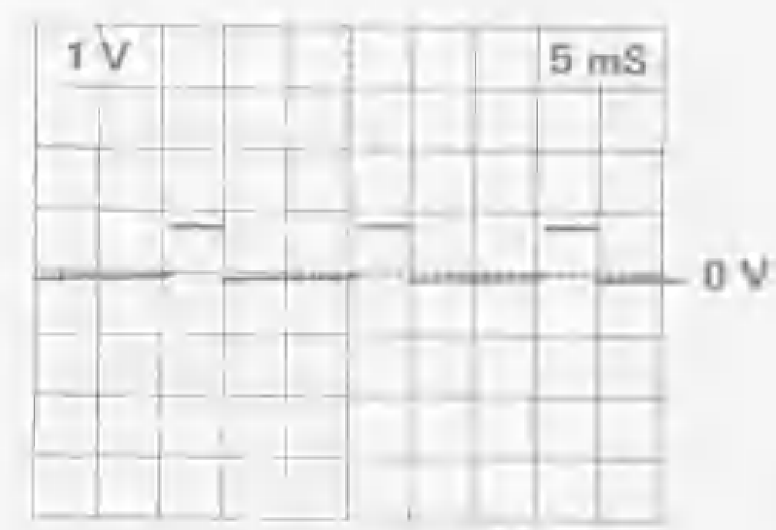
⟨14⟩



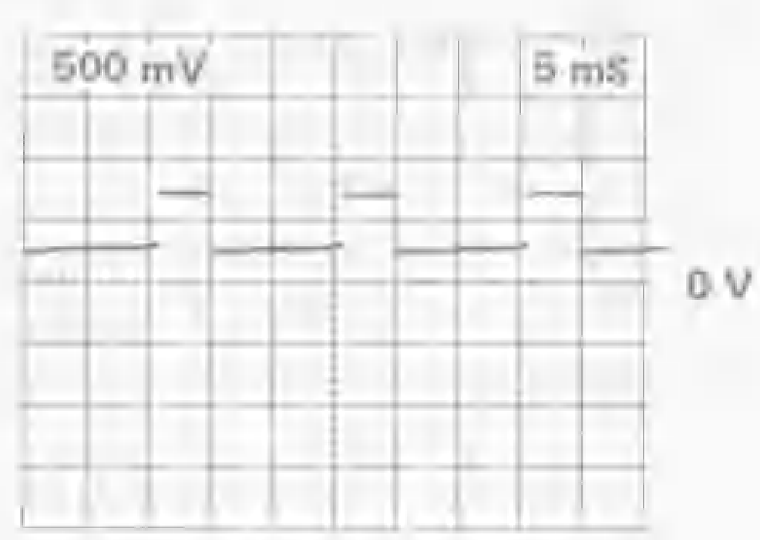
⟨15⟩



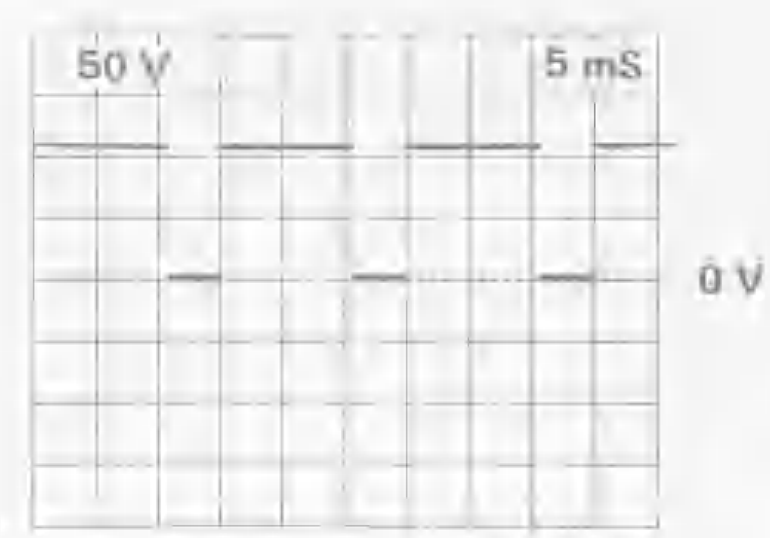
⟨16⟩

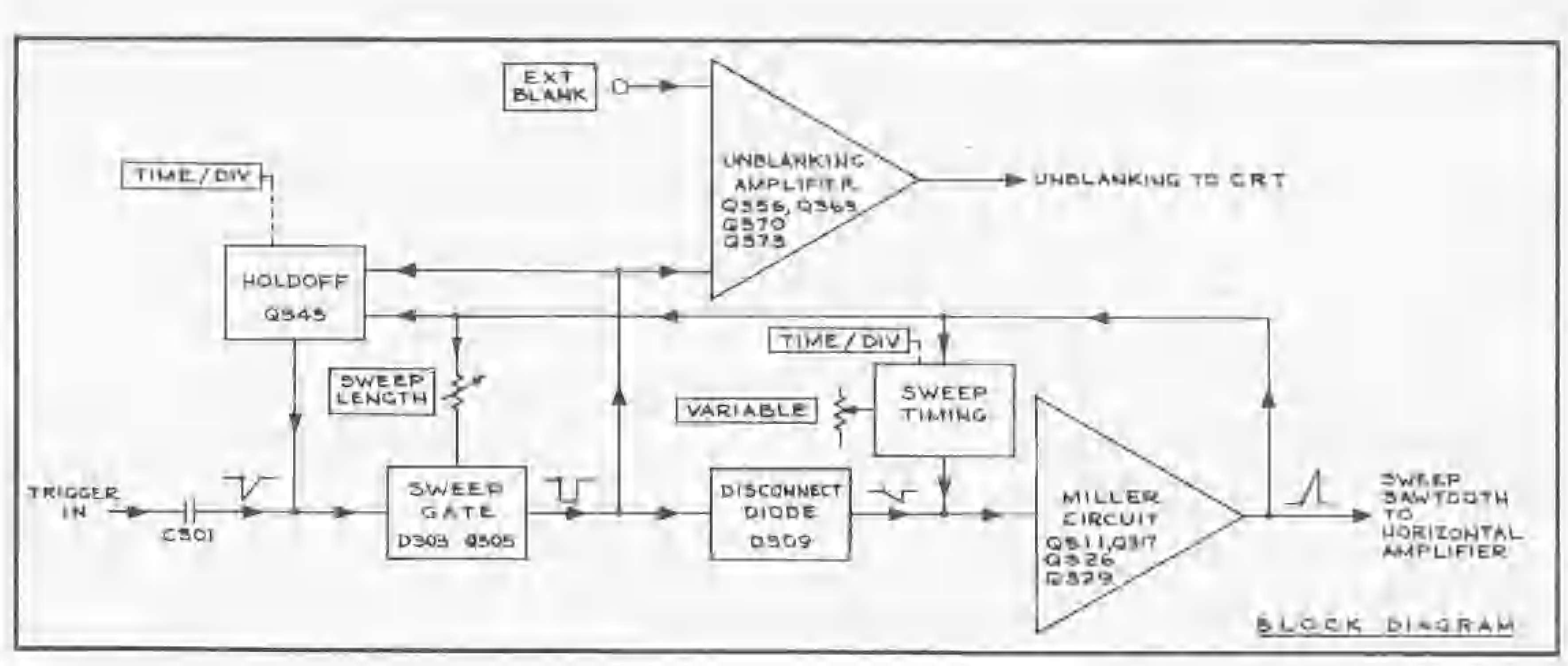


⟨17⟩

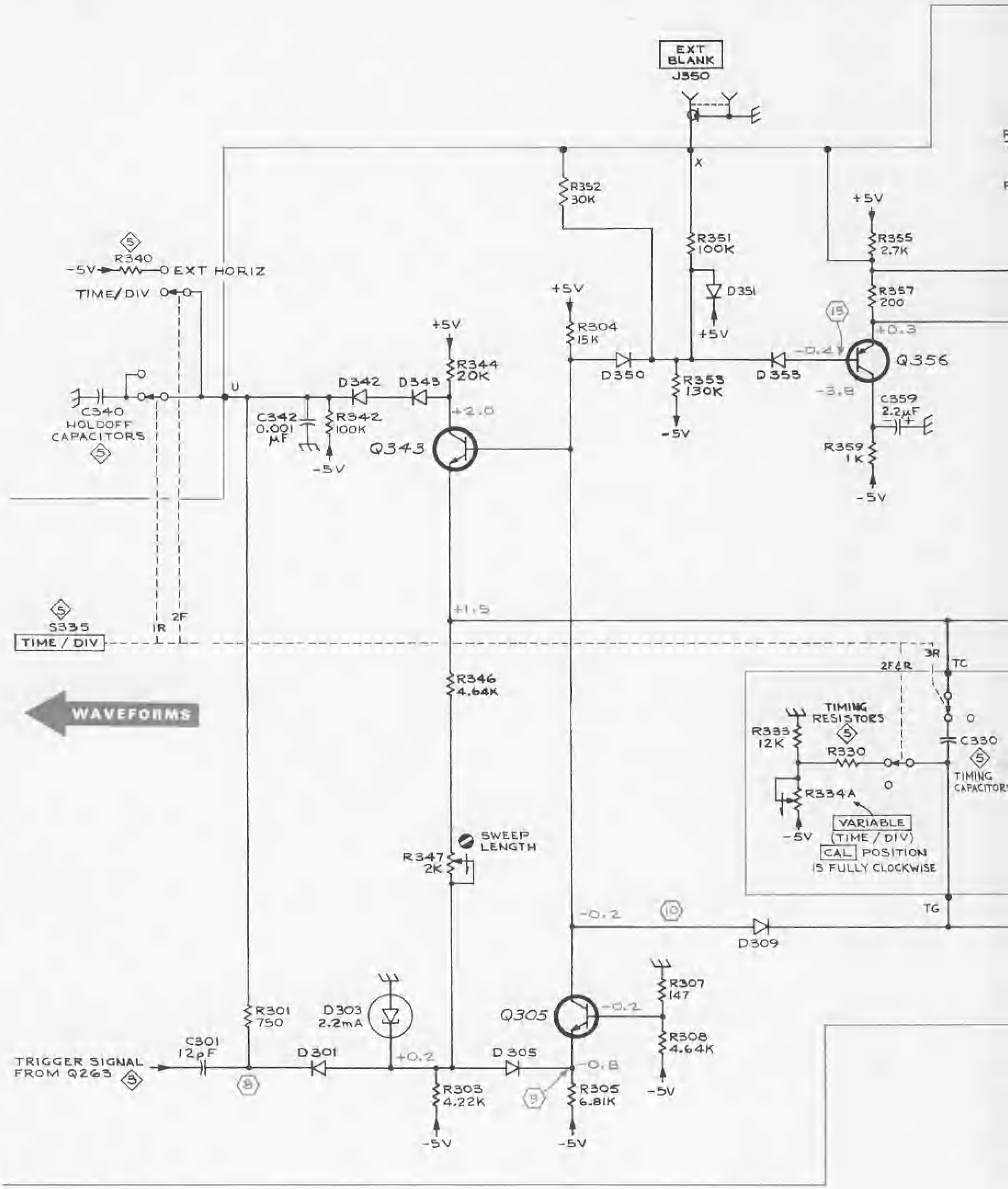


⟨18⟩

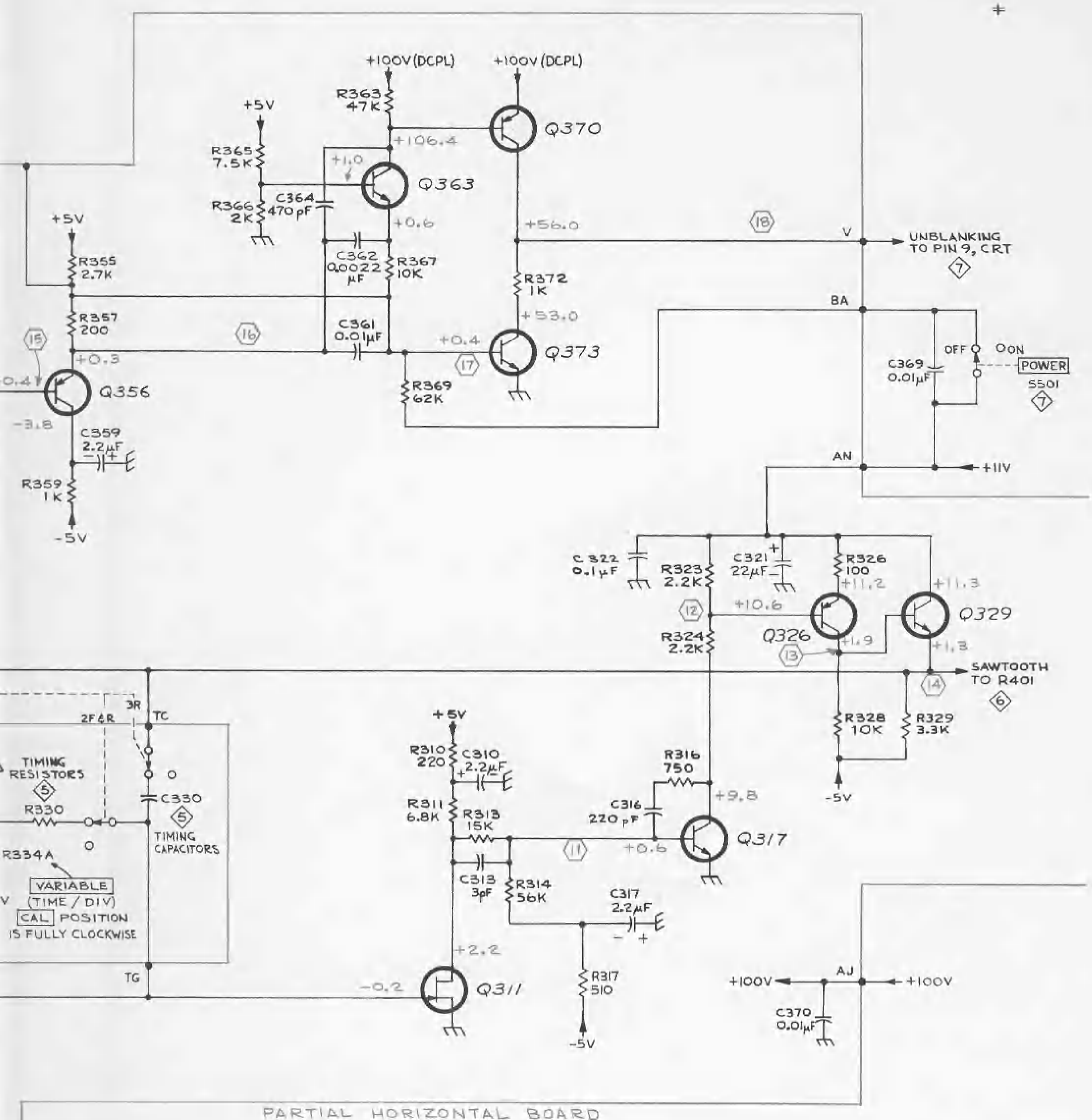




BLOCK DIAGRAM


EXT BLANK
J350
X
R352 30K
R351 100K
D351
+5V
R355 2.7K
R357 200
+0.3
-0.4
Q356
-3.8
C359 2.2µF
R359 1K
-5V
R340
-5V
EXT HORIZ
TIME/DIV
C340 HOLDOFF CAPACITORS
U
D342
D343
R344 20K
C342 0.001 µF
R342 100K
+2.0
Q343
R304 15K
D350
R353 130K
D353
+1.5
S335
TIME / DIV
IR
2F
3R
2F&R
TC
TIMING RESISTORS
R333 12K
R330
C330
TIMING CAPACITORS
R334A
VARIABLE (TIME / DIV) CAL POSITION IS FULLY CLOCKWISE
TG
WAVEFORMS
R346 4.64K
SWEEP LENGTH
R347 2K
-0.2
D309
R307 147
Q305
R308 4.64K
R301 750
D303 2.2mA
C301 12pF
TRIGGER SIGNAL FROM Q263
D301
+0.2
D305
-0.8
R303 4.22K
R305 6.81K

A1



NOTE:

SEE PARTS LIST FOR SEMICONDUCTOR TYPES.

REFERENCE DIAGRAMS:

- ② VERTICAL OUTPUT AMPLIFIER
- ③ TRIGGER GENERATOR
- ⑤ TIMING SWITCH
- ⑥ HORIZONTAL AMPLIFIER
- ⑦ POWER REGULATOR & CRT

VOLTAGES and WAVEFORMS obtained under conditions given at the front of this section except as follows:

WAVEFORMS ONLY:

VOLTS/DIV 5 DIV CAL

Test oscilloscope externally triggered from point V on Horizontal board.

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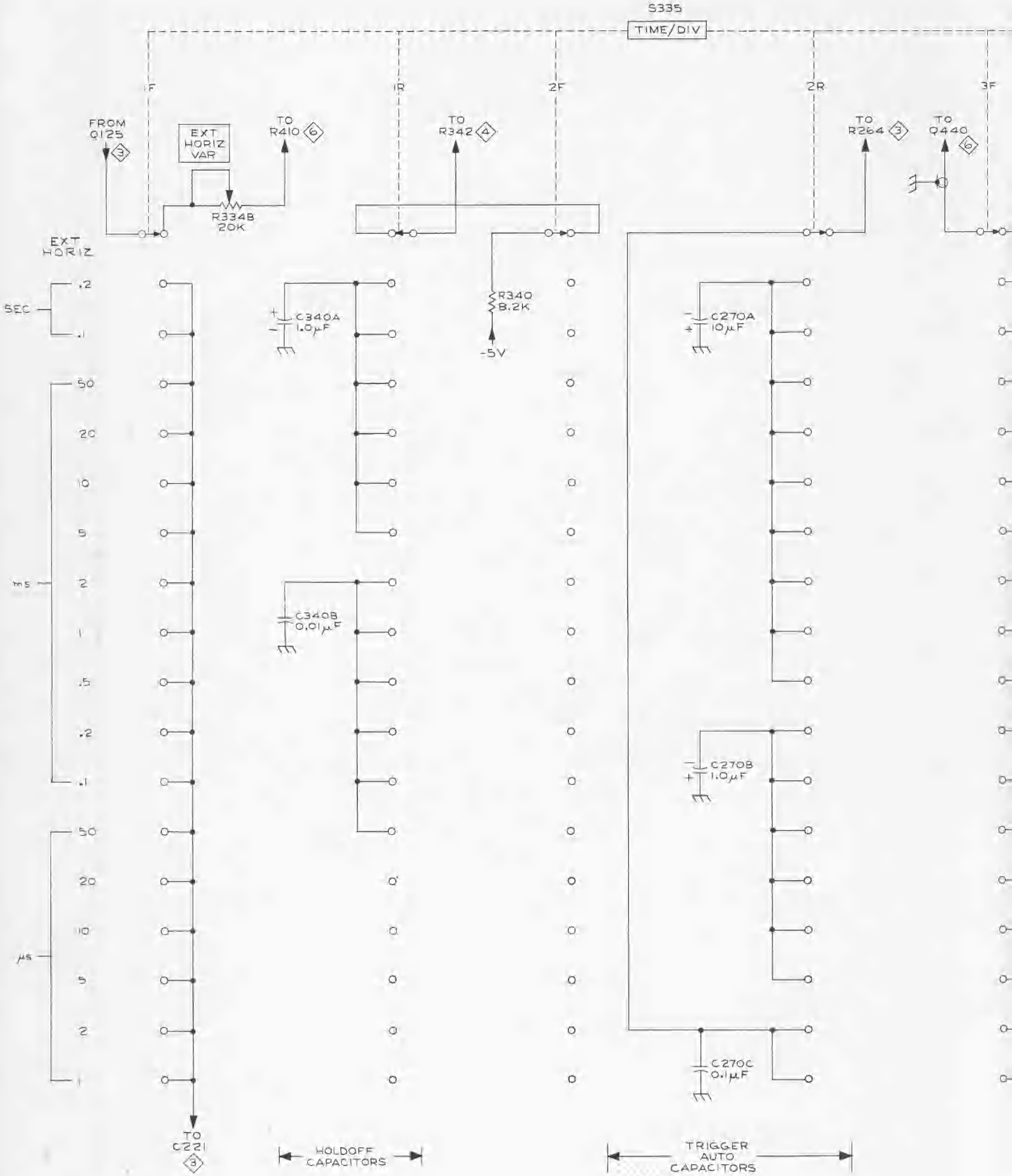
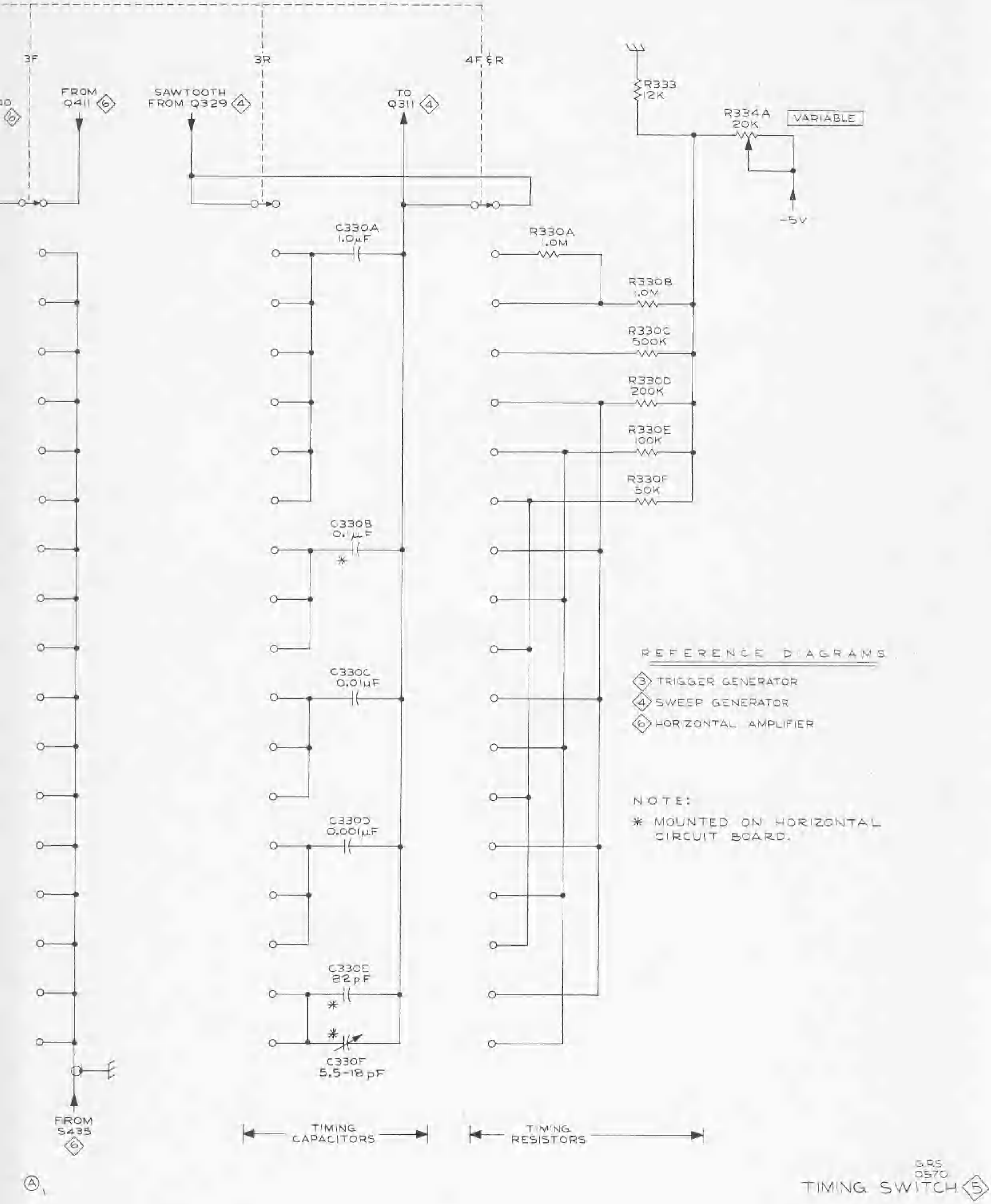
Ⓐ1

SWEEP GENERATOR ④

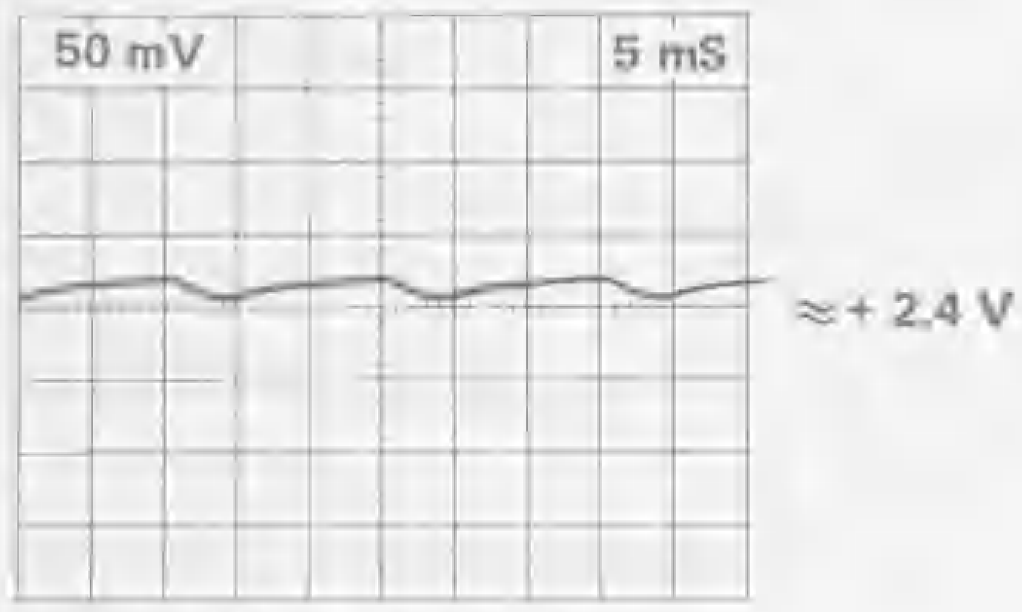

S335
TIME/DIV
1F
1R
2F
2R
3F
FROM Q125 3
EXT HORIZ VAR
R334B 20K
TO R410 6
TO R342 4
TO R264 3
TO Q440 6
R340 8.2K
-5V
EXT HORIZ
SEC
.2
.1
ms
50
20
10
5
2
1
.5
.2
.1
μs
50
20
10
5
2
1
C340A 1.0μF
C340B 0.01μF
C270A 10μF
C270B 1.0μF
C270C 0.1μF
TO C221 3
HOLDOFF CAPACITORS
TRIGGER AUTO CAPACITORS

TYPE 324



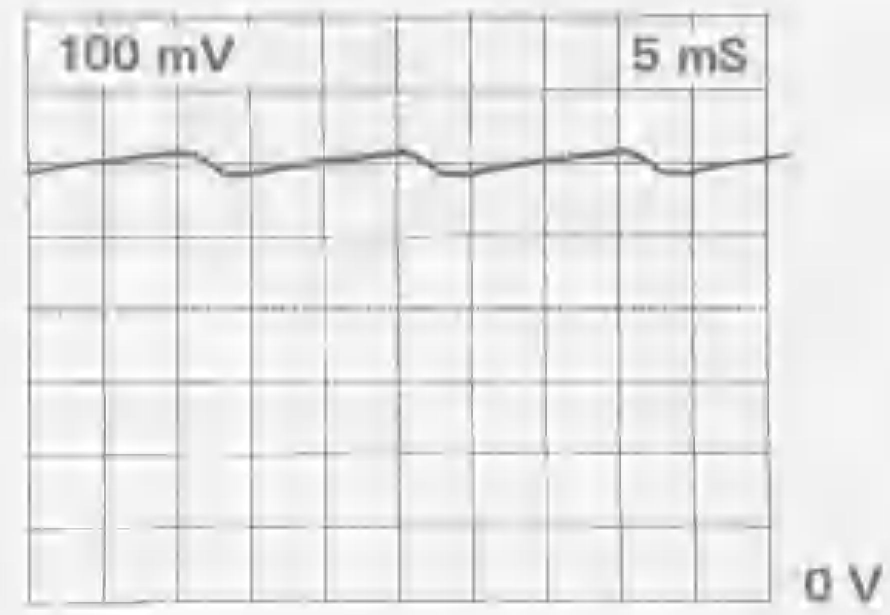
TIMING SWITCH 5

(19)

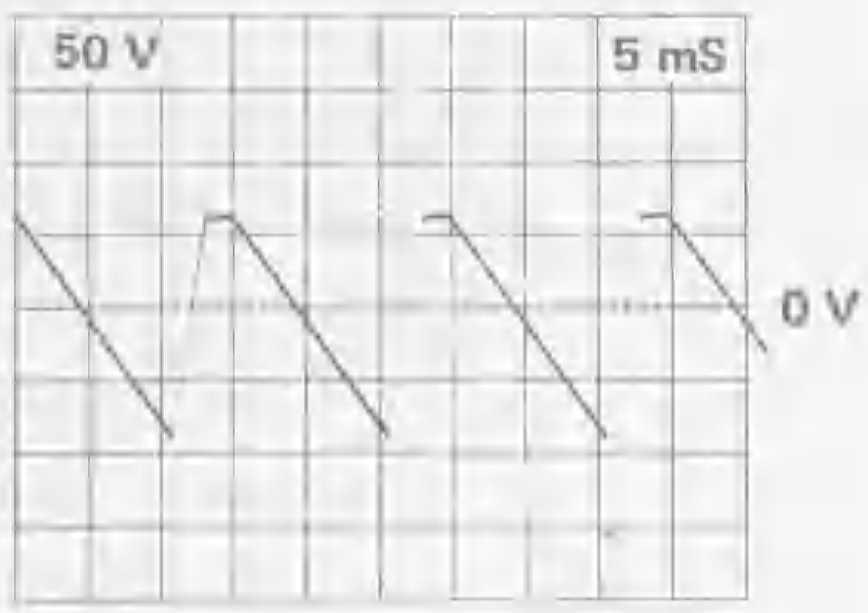


(AC COUPLED)

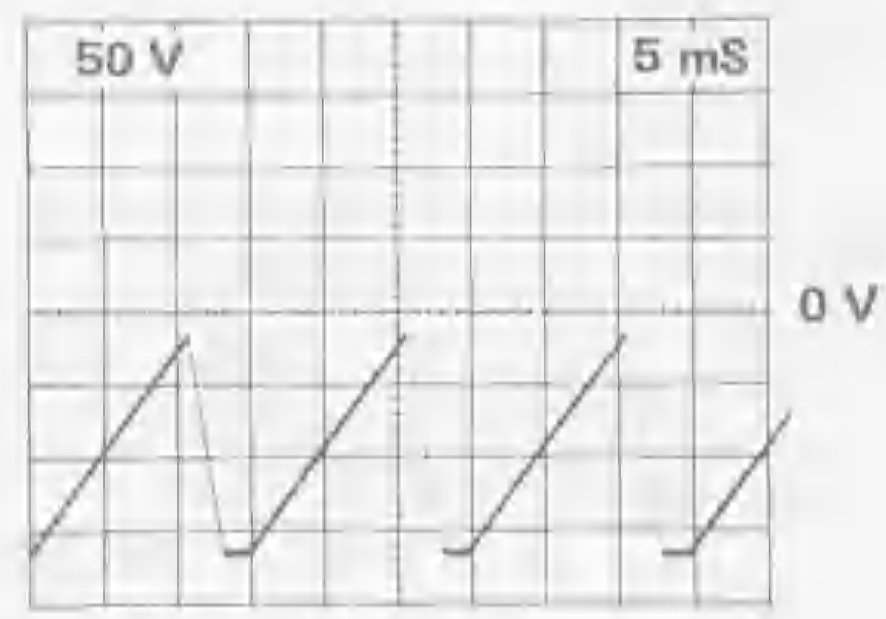
(20)

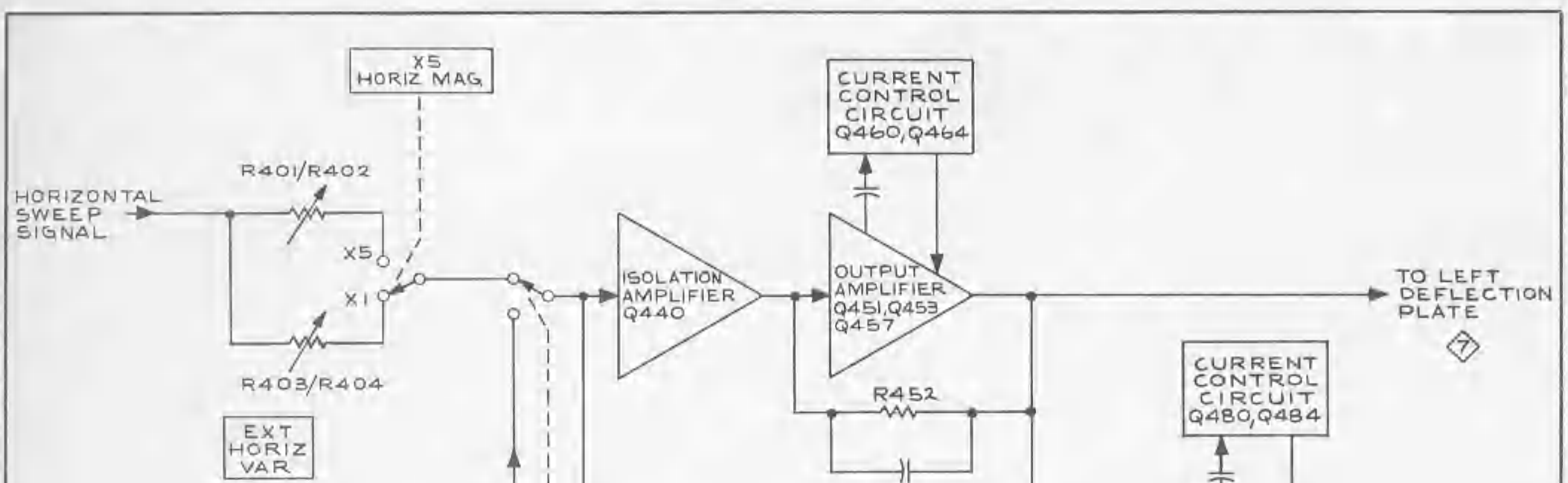


(21)

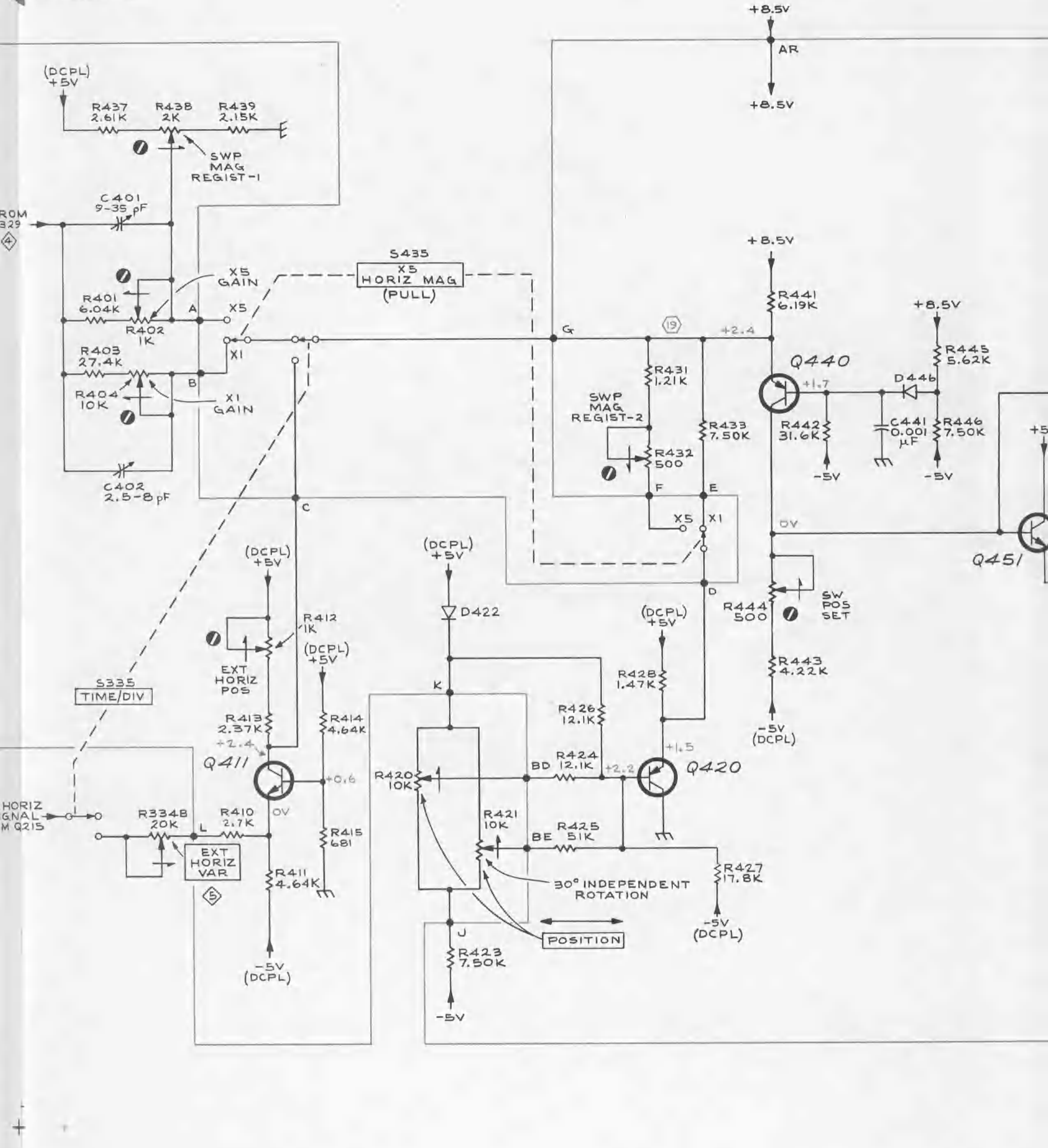


(22)

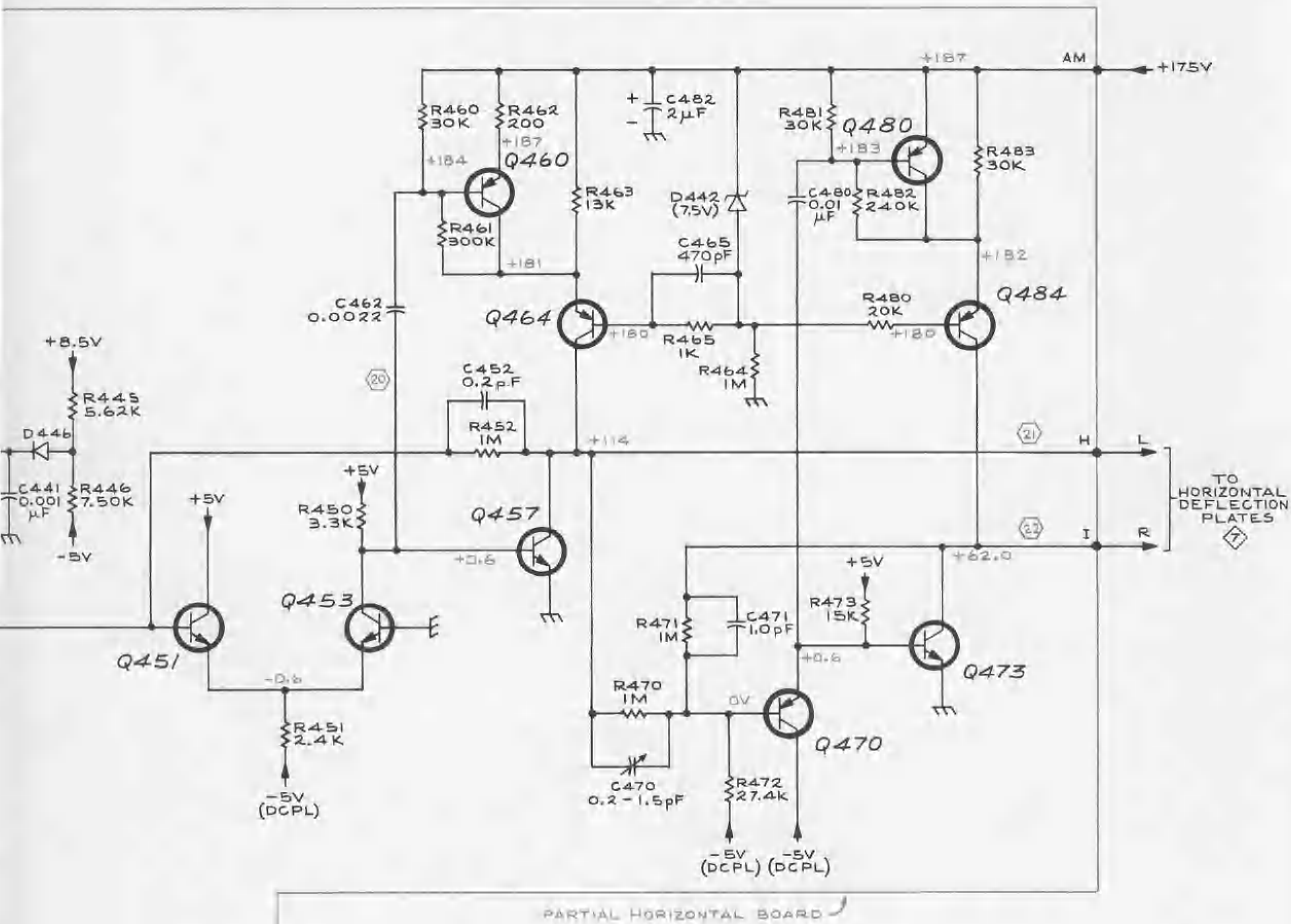




BLOCK DIAGRAM



+8.5V
AR
+8.5V
(DCPL) +5V
R437 2.61K
R438 2K
R439 2.15K
SWP MAG REGIST-1
C401 9-35 pF
ROM 329
S435 X5 HORIZ MAG (PULL)
X5 GAIN
R401 6.04K
R402 1K
A
X5
R403 27.4K
X1
B
R404 10K
X1 GAIN
C402 2.5-8 pF
C
G
+2.4
+8.5V
R441 6.19K
+8.5V
R445 5.62K
Q440
+1.7
D446
R431 1.21K
SWP MAG REGIST-2
R433 7.50K
R442 31.6K
C441 0.001 μF
R446 7.50K
R432 500
-5V
-5V
F
E
X5
X1
0V
Q451
D
(DCPL) +5V
(DCPL) +5V
D422
(DCPL) +5V
R412 1K
EXT HORIZ POS
(DCPL) +5V
R444 500
SW POS SET
R443 4.22K
R428 1.47K
K
R426 12.1K
S335 TIME/DIV
R413 2.37K
R414 4.64K
-5V (DCPL)
Q411
+0.6
R420 10K
BD
R424 12.1K
+2.2
+1.5
Q420
HORIZ SIGNAL FROM Q215
R334B 20K
R410 2.7K
L
0V
R415 681
R421 10K
BE
R425 51K
EXT HORIZ VAR
R411 4.64K
30° INDEPENDENT ROTATION
R427 17.8K
-5V (DCPL)
J
POSITION
R423 7.50K
-5V (DCPL)
-5V



REFERENCE DIAGRAMS

4 TRIGGER GENERATOR

5 SWEEP GENERATOR

7 HIGH VOLTAGE POWER SUPPLY

NOTE:

SEE PARTS LIST FOR SEMICONDUCTOR TYPES.

VOLTAGES and WAVEFORMS obtained under [illegible] as follows:

WAVEFORMS ONLY:

VOLTS/DIV [illegible]

Test oscilloscope externally triggered from point V on Horizontal board.

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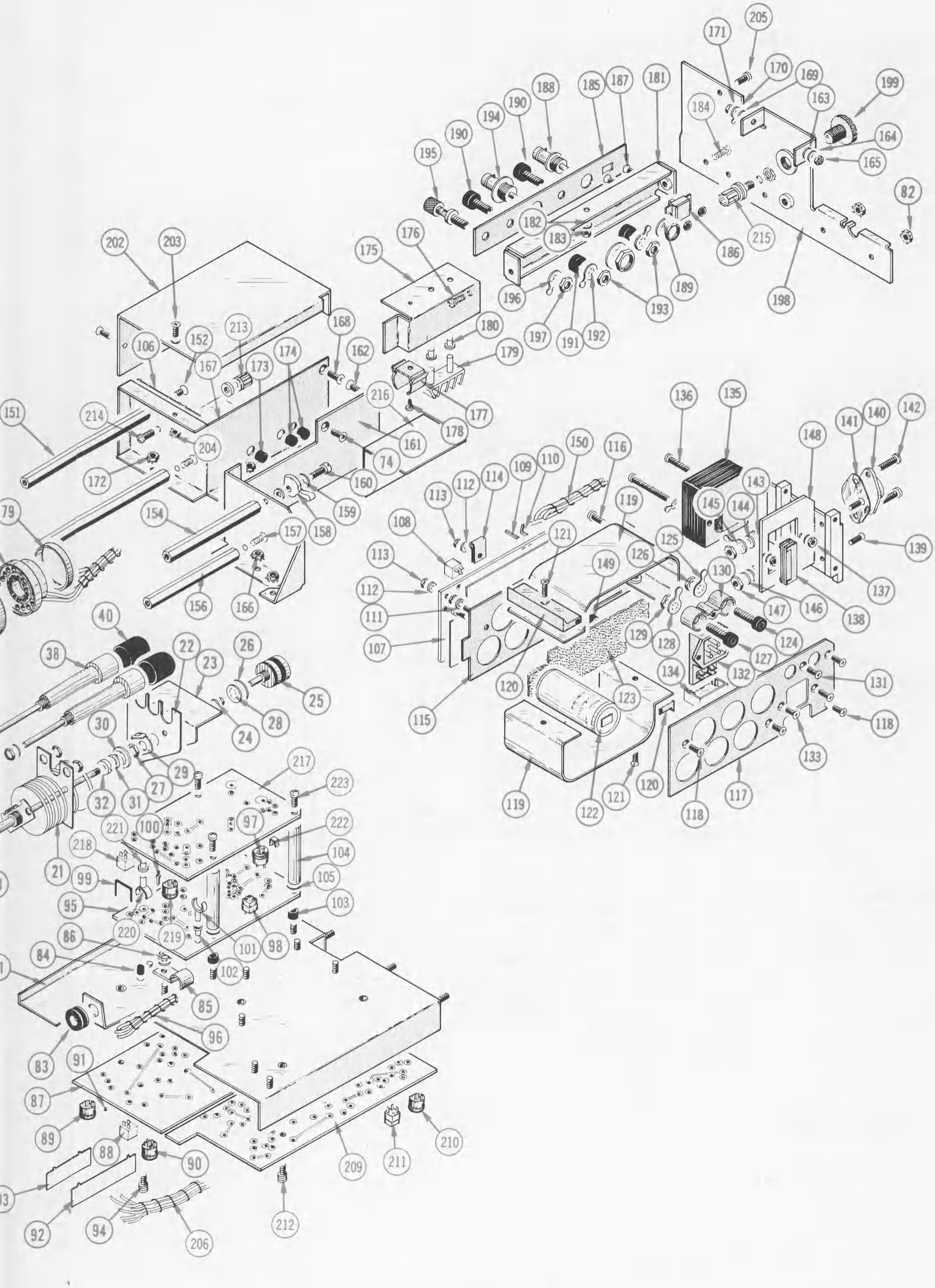
HORIZONTAL AMPLIFIER 6



205
171
170
169
199
163
164
165
82
188
185
187
181
184
190
194
190
195
215
186
198
182
183
189
193
196
197
191
192
202
203
176
175
180
179
213
168
162
174
106
152
167
173
177
178
216
161
151
214
204
74
172
160
159
158
154
157
166
156
79
136
135
148
141
140
142
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137
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128
124
107
134
132
127
131
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123
115
118
133
119
122
121
120
118
117
40
38
22
23
26
25
28
24
30
27
29
32
31
217
223
21
218
221
100
97
222
104
99
105
95
103
86
220
219
101
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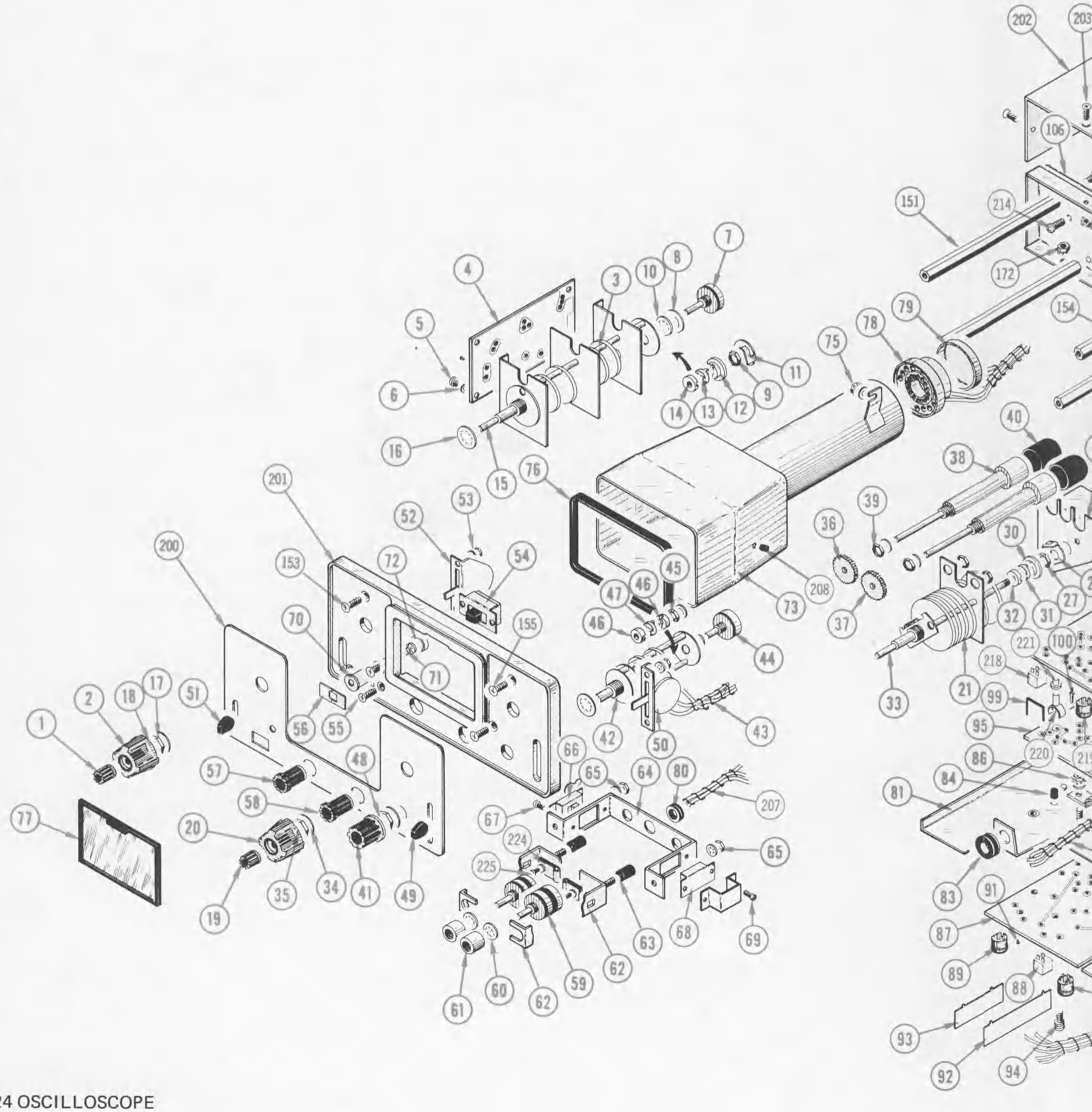
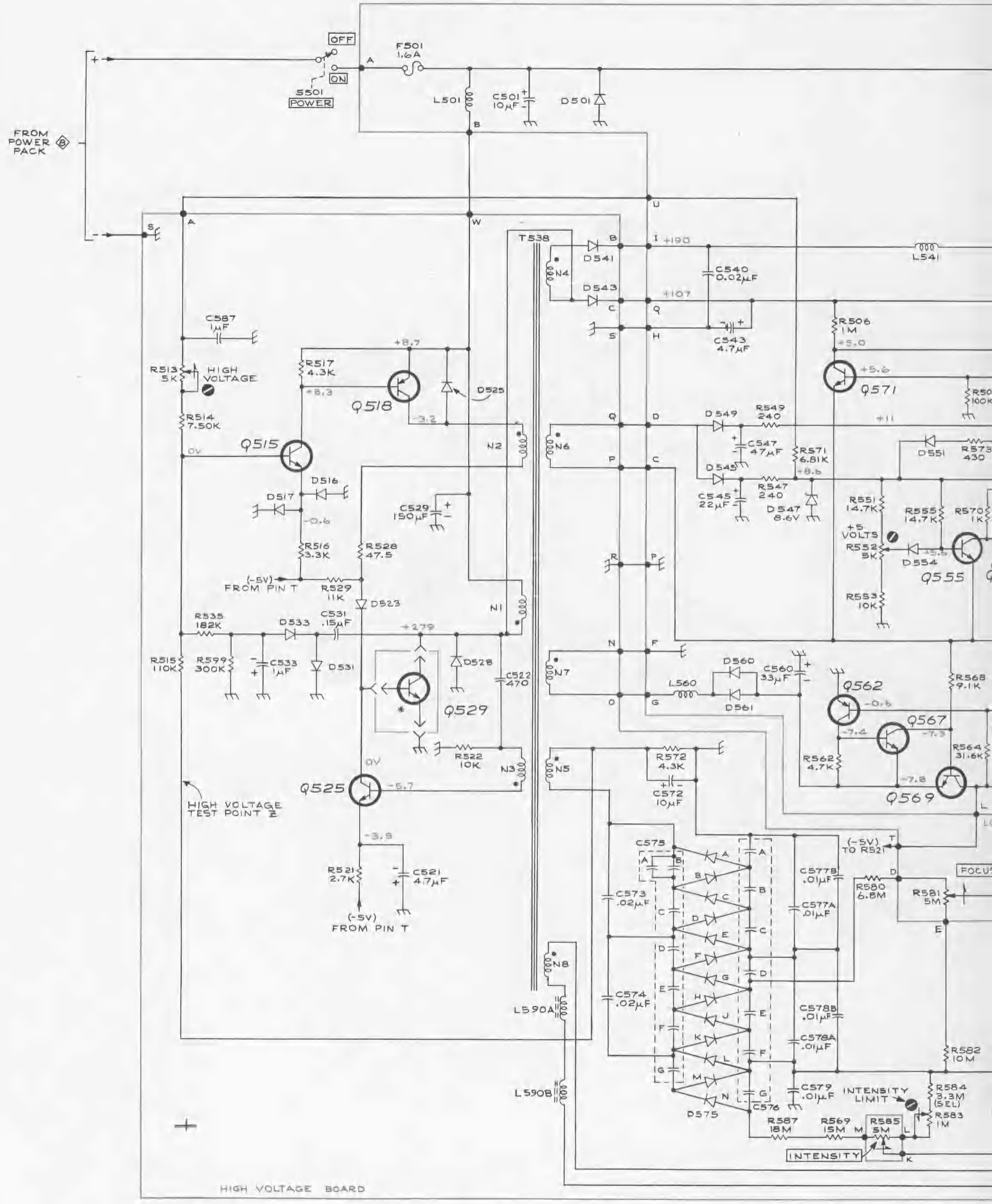
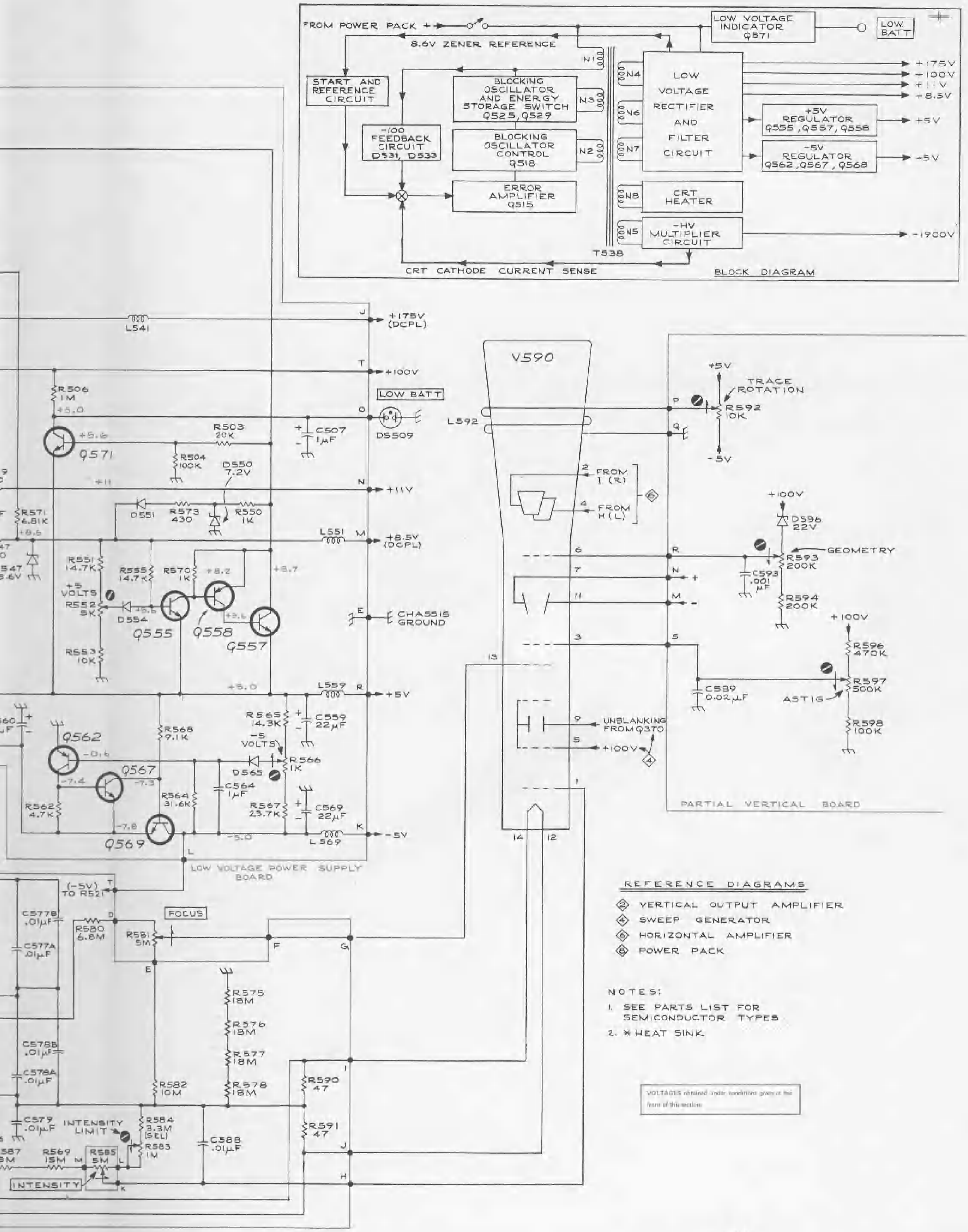
102
85
83
96
91
87
89
88
90
209
211
210
92
94
206
212


202
203
106
151
214
172
154
7
8
10
3
4
5
6
79
78
75
11
9
12
13
14
16
15
40
38
76
201
53
52
54
39
36
30
27
31
32
200
153
72
45
46
47
208
73
37
70
155
46
44
71
42
50
43
221
100
218
21
99
33
95
86
220
84
81
17
18
2
1
51
56
55
66
65
64
80
207
57
48
58
67
224
225
65
77
20
34
41
49
35
19
68
69
63
62
59
60
61
62
83
91
87
89
88
93
92
94


FROM POWER PACK ⑧
OFF
ON
S501 POWER
F501 1.6A
L501
C501 10μF
D501
T538
D541
D543
C540 0.02μF
C543 4.7μF
L541
+190
+107
R506 1M
Q571
C587 1μF
R513 5K
HIGH VOLTAGE
R514 7.50K
R517 4.3K
Q518
D525
Q515
D516
D517
R516 3.3K
R528 47.5
C529 150μF
(-5V) FROM PIN T
R529 11K
D523
R535 182K
D533
C531 .15μF
+279
R515 110K
R599 300K
C533 1μF
D531
D528
C522 470
Q529
R522 10K
Q525
HIGH VOLTAGE TEST POINT
R521 2.7K
C521 4.7μF
(-5V) FROM PIN T
D549
R549 240
C547 47μF
R571 6.81K
D545
C545 22μF
R547 240
D547 8.6V
D551
R573 430
R551 14.7K
R555 14.7K
R570 1K
+5 VOLTS
R552 5K
D554
Q555
R553 10K
D560
C560 33μF
L560
D561
Q562
Q567
R568 9.1K
R562 4.7K
R564 31.6K
Q569
R572 4.3K
C572 10μF
C575
C573 .02μF
C574 .02μF
D575
C576
C577B .01μF
C577A .01μF
C578B .01μF
C578A .01μF
C579 .01μF
(-5V) TO R521
R580 6.8M
R581 5M
FOCUS
R582 10M
R584 3.3M (SEL)
R583 1M
INTENSITY LIMIT
R587 18M
R569 15M
R585 5M
INTENSITY
L590A
L590B
HIGH VOLTAGE BOARD

TYPE 324

Ⓐ



REFERENCE DIAGRAMS

2 VERTICAL OUTPUT AMPLIFIER
4 SWEEP GENERATOR
6 HORIZONTAL AMPLIFIER
8 POWER PACK

NOTES:

1. SEE PARTS LIST FOR SEMICONDUCTOR TYPES
2. * HEAT SINK

VOLTAGES obtained under conditions given at the front of this section.

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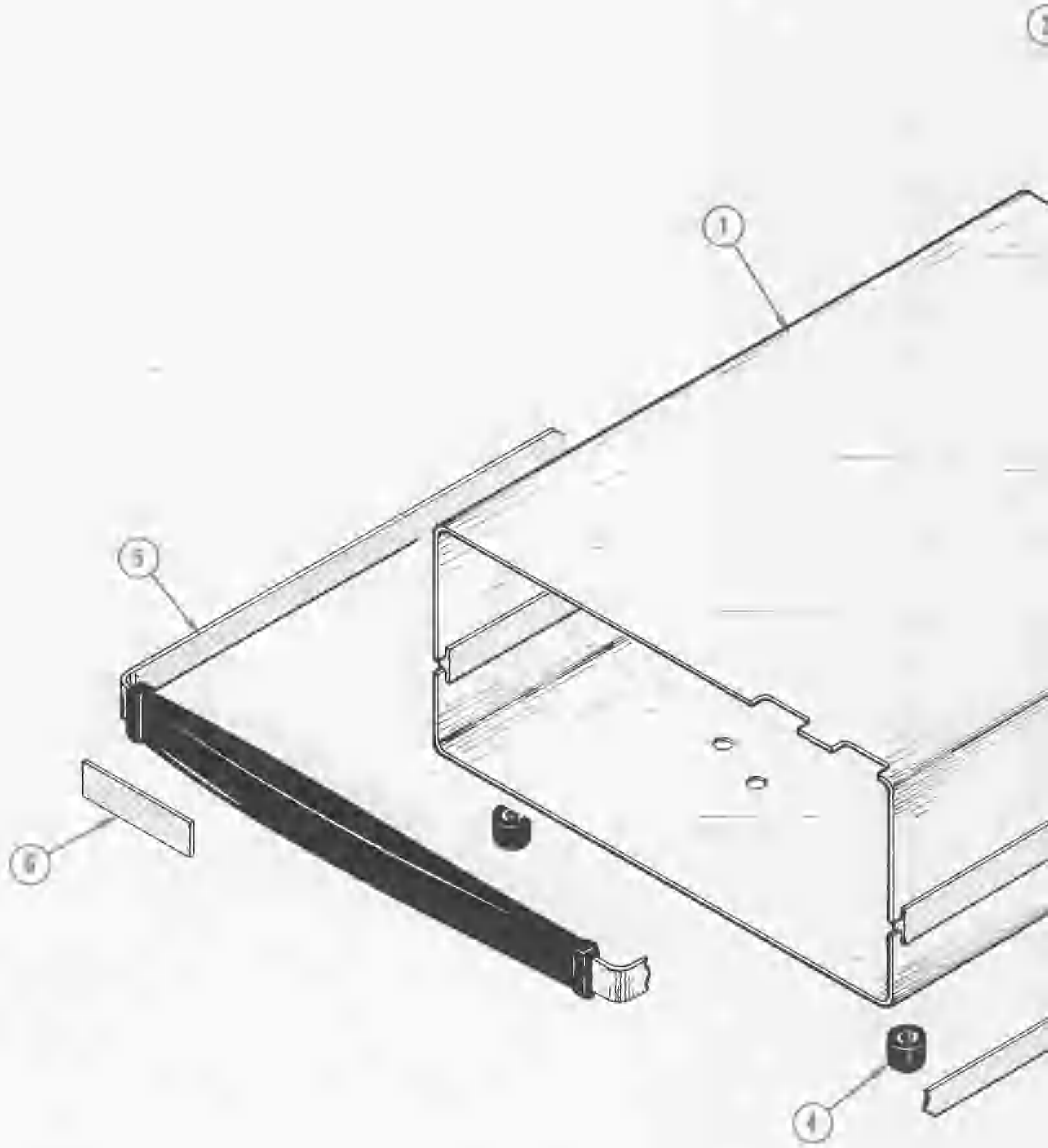
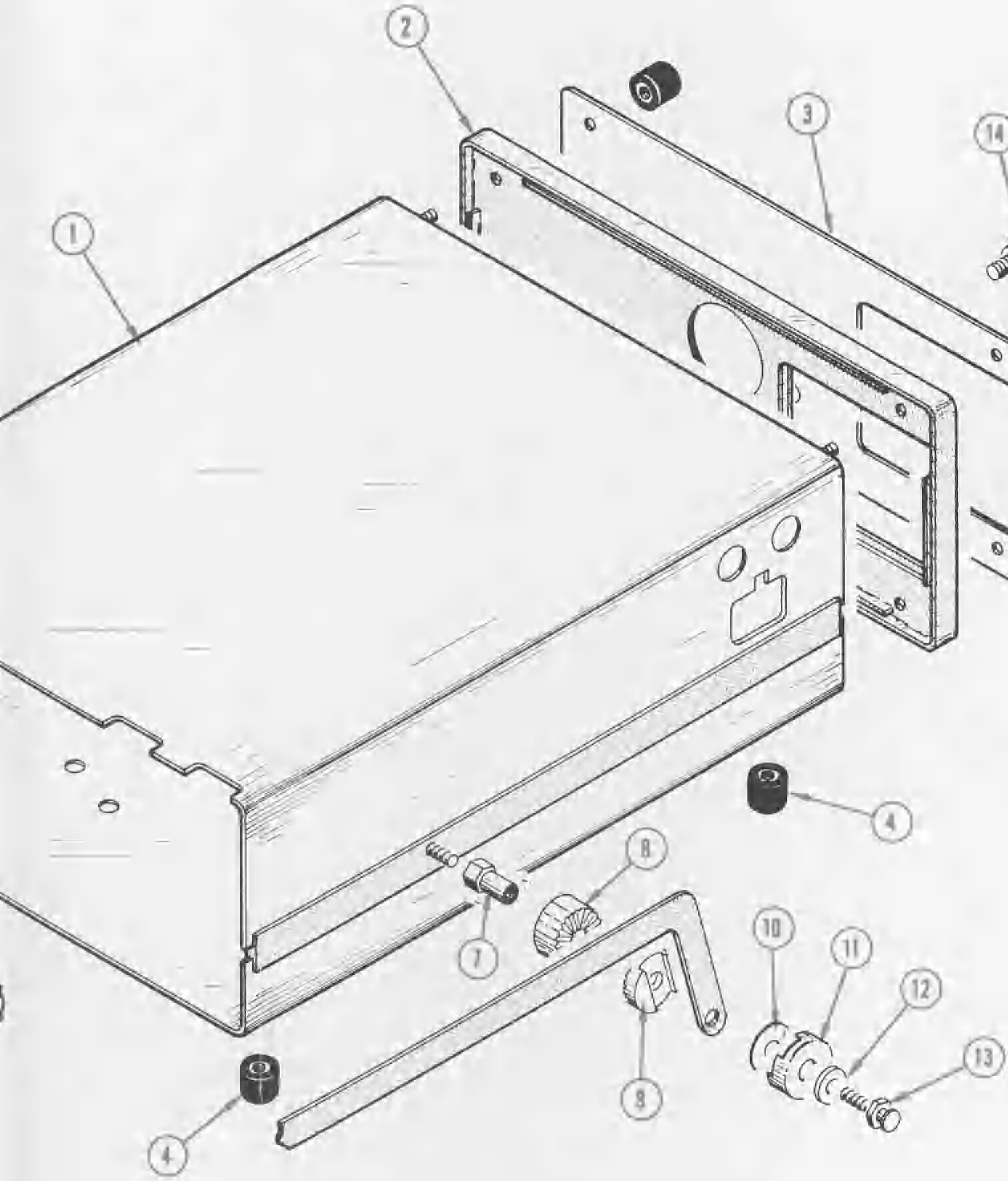
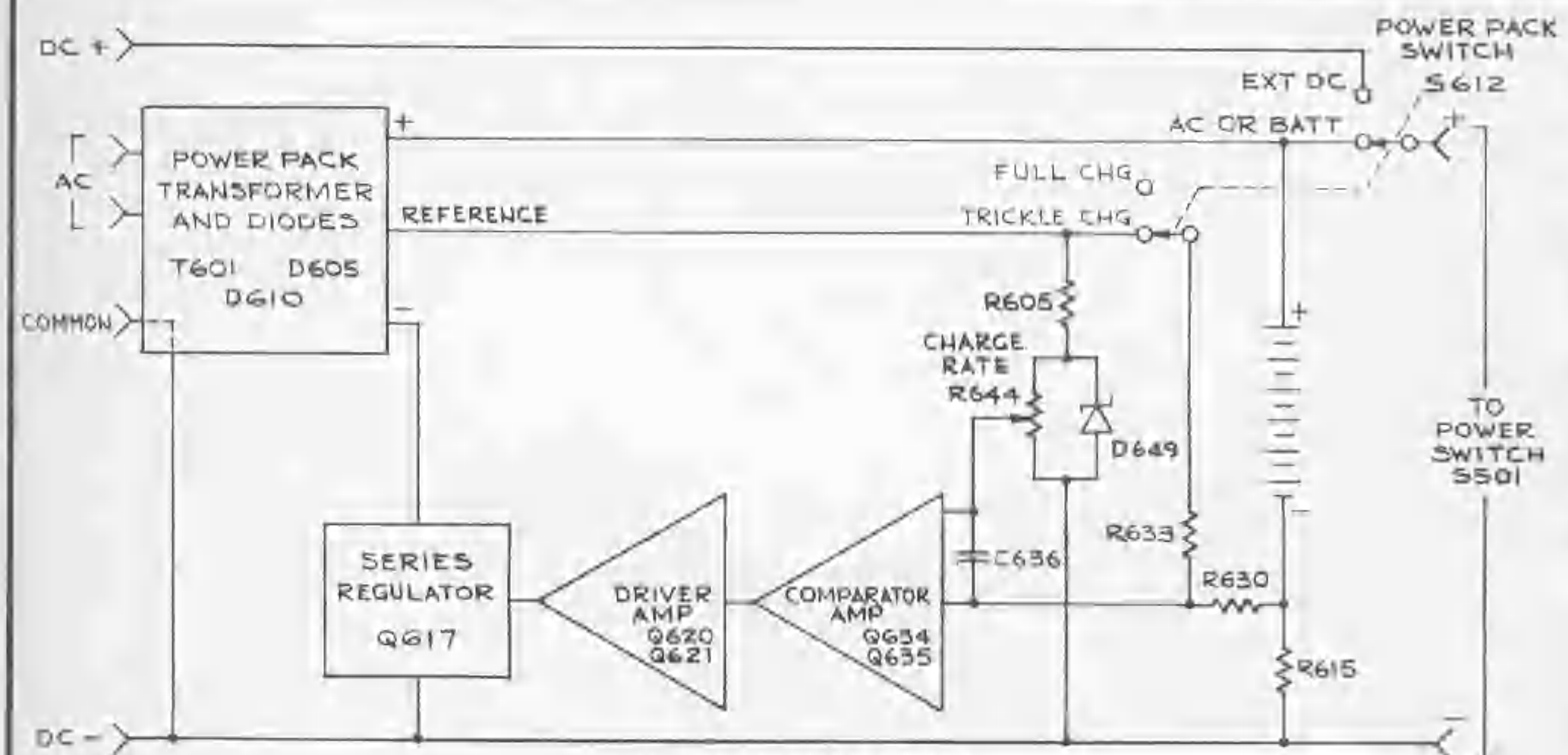
POWER REGULATOR & CRT CIRCUIT 7

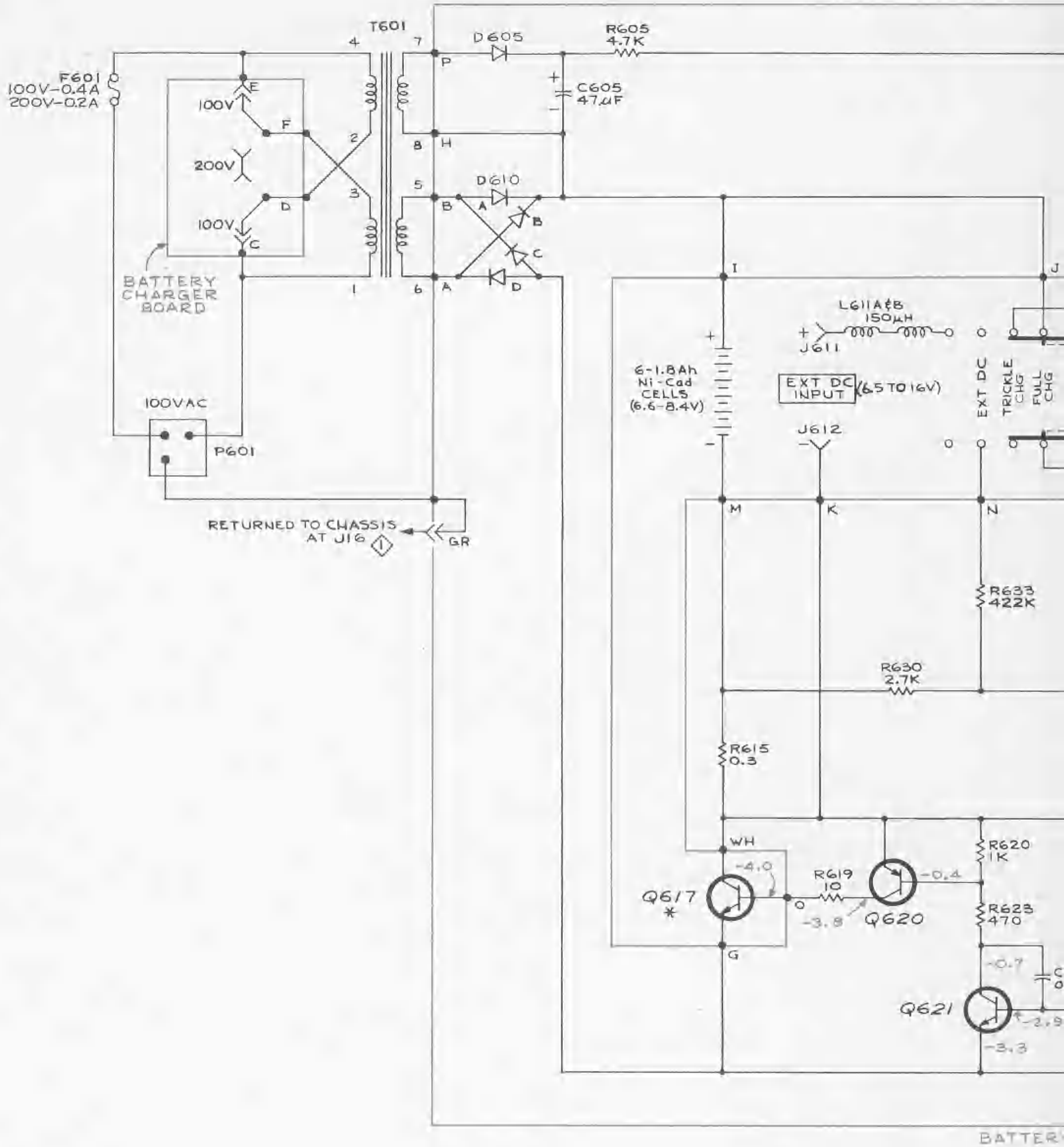


1
2
4
5
6


1
2
3
14
4
4
4
7
8
8
10
11
12
13



BLOCK DIAGRAM



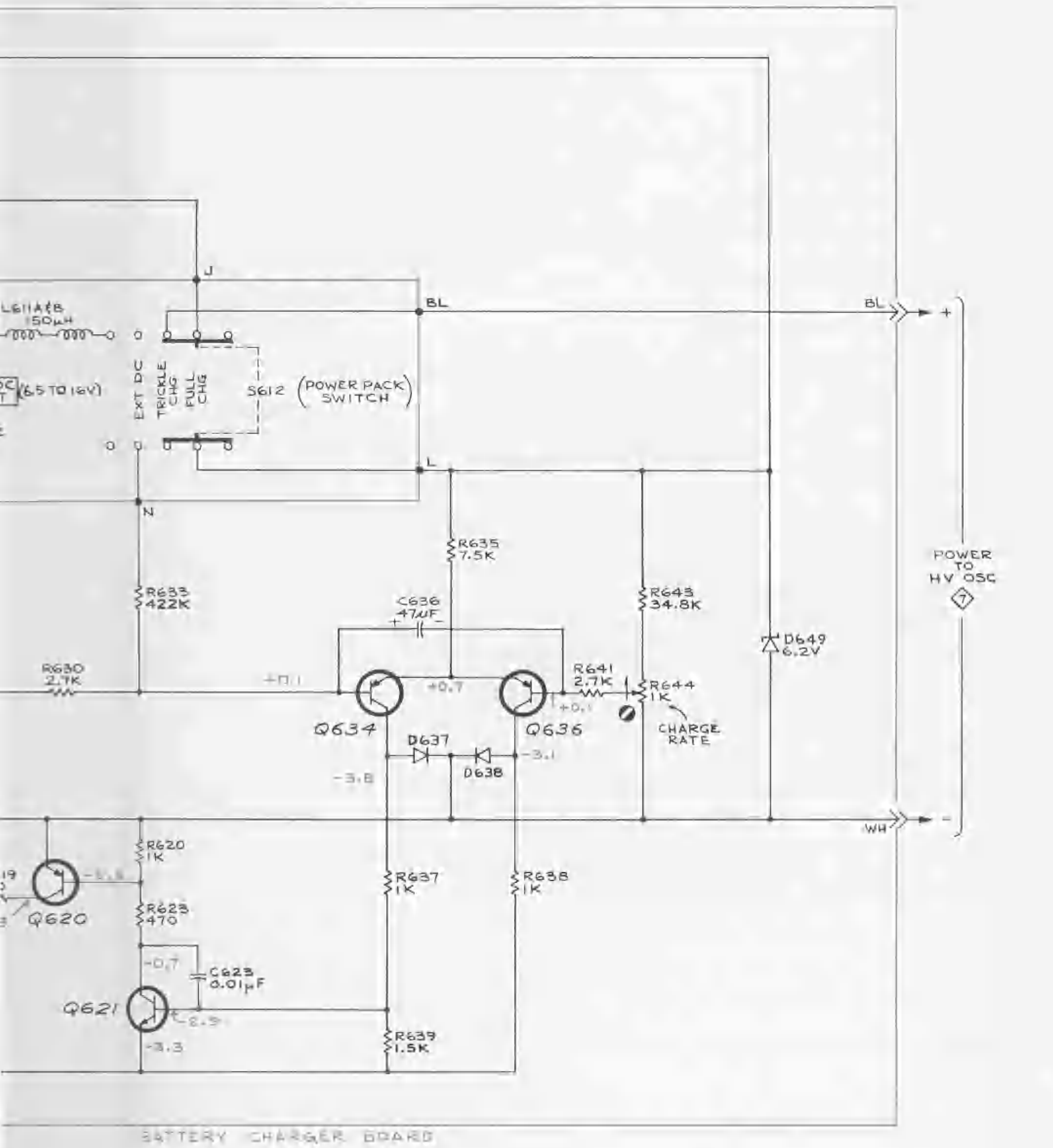
NOTES:

1. SEE PARTS LIST FOR SEMICONDUCTOR TYPES
2. * TRANSISTOR IS HEAT SINKED

REFERENCE DIAGRAMS:

⟨1⟩ VERTICAL PREAMP

⟨7⟩ POWER REGULATOR & CRT



VOLTAGES [illegible]

Ⓐ

POWER PACK ⑧ MRH/grs 0570

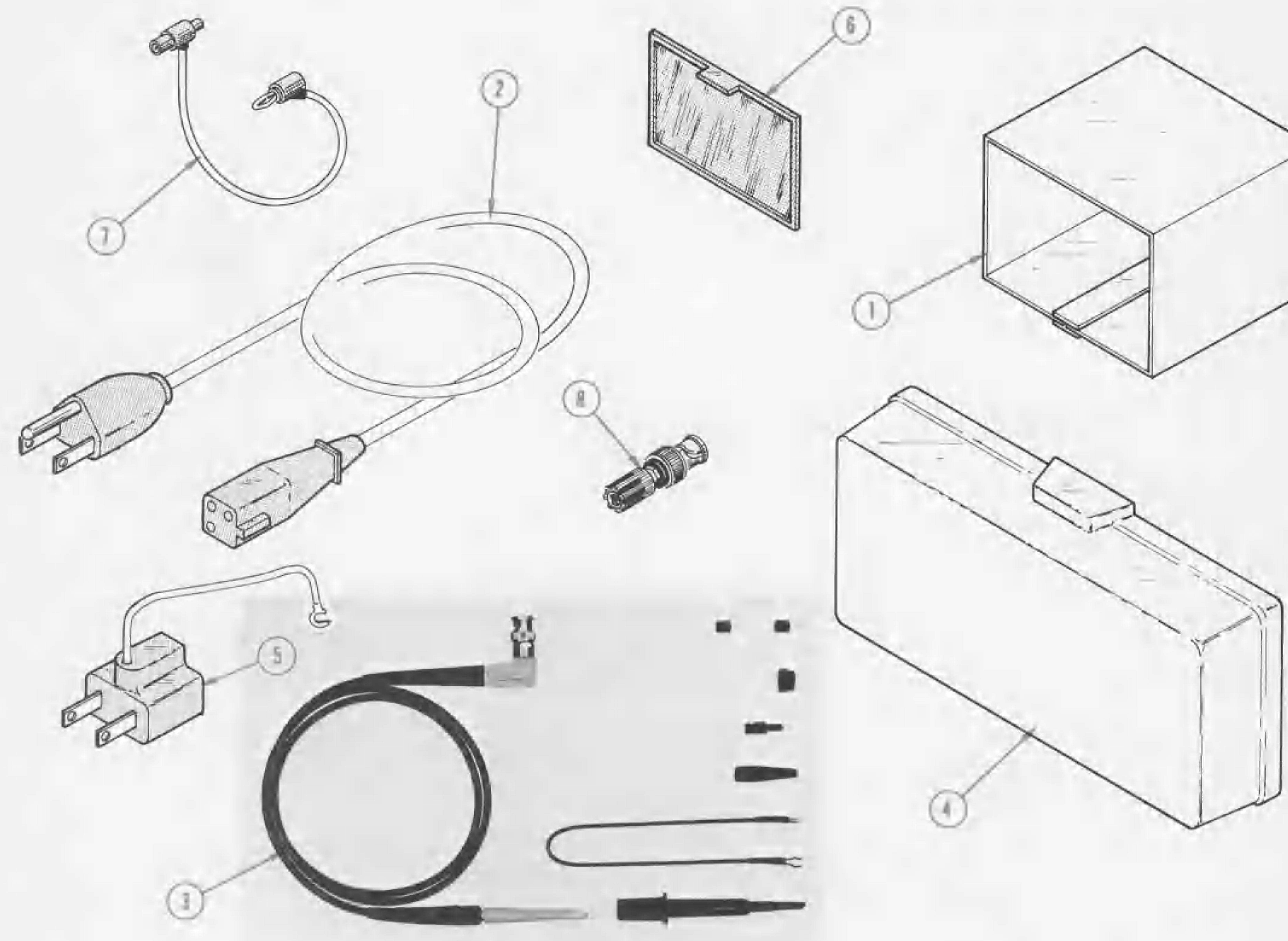


Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
3-1	016-0247-01			1	VIEWING HOOD
-2	161-0043-00			1	CABLE ASSEMBLY, power, 6 foot
-3	010-0223-00			1	PROBE PACKAGE, P6049
-4	200-0812-00			1	COVER, panel
~~-5~~	~~103-0013-00~~			~~1~~	~~ADAPTER, 3 to 2 wire~~
-6	426-0403-00			1	FILTER, light, smoke gray
-7	012-0089-00			1	CORD, patch, BNC to banana, 6 inch, red
~~-8~~	~~103-0033-00~~			~~1~~	~~ADAPTER, BNC to binding post~~
	346-0051-00			1	STRAP ASSEMBLY (not shown)
	016-0113-00			1	ACCESSORY PACK (not shown)
	070-1032-00			2	MANUAL, instruction (not shown)

Ⓐ

OPTIONAL ACCESSORIES

016-0160-00	1	POWER PACK
016-0117-00	1	COVER, protective, [illegible]

FIGURE AND INDEX NUMBERS

Items in this section are referenced by figure and index numbers to the illustrations which appear either on the back of the diagrams or on pullout pages immediately following the diagrams of the 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 ILLUSTRATIONS

TITLE	Location (reverse side of)
Figure 1 Mechanical Parts	Horizontal Amplifier Diagram
Figure 2 Cabinet	Power Modulator & CRT Circuit Diagram
Figure 3 Accessories	Power Pack Diagram

SECTION 8
MECHANICAL PARTS LIST

FIGURE 1 MECHANICAL PARTS

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-1	366-1031-00			1	KNOB, red--VARIABLE CAL
	- - - - - -			-	knob includes:
	213-0153-00			1	SETSCREW, 5-40 x 0.125 inch, HSS
-2	366-1037-00			1	KNOB, gray--VOLTS/DIV
	- - - - - -			-	knob includes:
	213-0153-00			2	SETSCREW, 5-40 x 0.125 inch, HSS
-3	262-0897-00			1	SWITCH, rotary--VOLTS/DIV, wired
	- - - - - -			-	switch includes:
	260-1129-00			1	SWITCH, rotary, unwired
	670-0886-00			1	CIRCUIT BOARD ASSEMBLY--ATTENUATOR
	- - - - - -			-	circuit board assembly includes:
-4	388-1545-00			1	CIRCUIT BOARD
	136-0252-00			6	SOCKET, pin, connector
	- - - - - -			-	mounting hardware: (not included w/circuit board
	- - - - - -			-	assembly)
-5	211-0070-00			4	SCREW, 2-56 x 0.25 inch, PHS
	210-0001-00			4	WASHER, lock, internal, #2
-6	337-1272-00			1	SHIELD, electrical
-7	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	resistor includes:
-8	- - - - - -			1	WASHER, flat
-9	- - - - - -			1	NUT (metric)
	- - - - - -			-	mounting hardware: (not included w/resistor)
-10	210-0046-00			1	WASHER, lock, internal, 0.261 ID x 0.40 inch OD
-11	214-1001-00			1	SPRING, detent
	376-0069-00			1	COUPLING, shaft extension, 0.125 to 0.80 inch
	- - - - - -			-	coupling includes:
-12	354-0319-00			1	RING, coupling (w/detent notch)
-13	376-0046-00			1	COUPLING, plastic
-14	354-0251-00			1	RING, coupling
	213-0048-00			4	SETSCREW, 4-40 x 0.125 inch, HSS
-15	384-0683-00			1	SHAFT, extension
	- - - - - -			-	mounting hardware: (not included w/switch)
-16	210-0012-00			1	WASHER, lock, internal, 0.375 ID x 0.50 inch OD
-17	210-0840-00			1	WASHER, flat, 0.39 ID x 0.562 inch OD
-18	210-0590-00			1	NUT, hex., 0.375-32 x 0.437 inch
-19	366-1031-00			1	KNOB, red--VARIABLE CAL
	- - - - - -			-	knob includes:
	213-0153-00			1	SETSCREW, 5-40 x 0.125 inch, HSS
-20	366-1037-00			1	KNOB, gray--TIME/DIV
	- - - - - -			-	knob includes:
	213-0153-00			2	SETSCREW, 5-40 x 0.125 inch, HSS

FIGURE 1 MECHANICAL PARTS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-21	262-0896-00			1	SWITCH, rotary--TIME/DIV, wired
	- - - - - -			-	switch includes:
	260-1114-00			1	SWITCH, rotary, unwired
-22	337-0989-00			1	SHIELD, switch, flat
-23	337-1277-00			1	SHIELD, switch, angle
	- - - - - -			-	mounting hardware: (not included w/shield)
	210-0054-00			2	WASHER, lock, #4 split
-24	210-0406-00			2	NUT, hex., 4-40 x 0.188 inch
-25	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	resistor includes:
-26	- - - - - -			1	WASHER, flat
-27	- - - - - -			1	NUT (metric)
	- - - - - -			-	mounting hardware: (not included w/resistor)
-28	210-0046-00			1	WASHER, lock, internal, 0.261 ID x 0.40 inch OD
-29	214-1001-00			1	SPRING, detent
	376-0070-00			1	COUPLING, shaft extension, 0.125 to 0.125 inch
	- - - - - -			-	coupling includes:
-30	354-0319-00			1	RING, coupling (w/detent notch)
-31	376-0049-00			1	COUPLING, plastic
-32	354-0251-00			1	RING, coupling
	213-0048-00			4	SETSCREW, 4-40 x 0.125 inch, HSS
-33	384-0682-00			1	SHAFT, extension
	- - - - - -			-	mounting hardware: (not included w/switch)
-34	210-0840-00			1	WASHER, flat, 0.39 ID x 0.562 inch OD
-35	210-0590-00			1	NUT, hex., 0.375-32 x 0.438 inch
-36	366-0456-00			1	KNOB, thumbwheel--FOCUS
	- - - - - -			-	knob includes:
	213-0048-00			2	SETSCREW, 4-40 x 0.125 inch, HSS
-37	366-0456-00			1	KNOB, thumbwheel--INTENSITY
	- - - - - -			-	knob includes:
	213-0048-00			2	SETSCREW, 4-40 x 0.125 inch, HSS
-38	- - - - - -			2	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
	210-0046-00			2	WASHER, lock, internal, 0.261 ID x 0.40 inch OD
-39	210-0583-00			2	NUT, hex., 0.25-32 x 0.312 inch
-40	200-0799-00			2	COVER, variable resistor
-41	366-1039-00			1	KNOB, charcoal--TRIGGER
	- - - - - -			-	knob includes:
	213-0153-00			2	SETSCREW, 5-40 x 0.125 inch, HSS

FIGURE 1 MECHANICAL PARTS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-42	262-0895-00			1	SWITCH, rotary--TRIGGER, wired
	- - - - - -			-	switch includes:
	260-1128-00			1	SWITCH, rotary, unwired
-43	179-1473-00			1	WIRING HARNESS, trigger
	179-1474-00			1	WIRING HARNESS, external trigger
-44	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	resistor includes:
	- - - - - -			1	WASHER, flat
-45	- - - - - -			1	NUT (metric)
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0046-00			1	WASHER, lock, internal, 0.261 ID x 0.40 inch OD
	376-0051-00			1	COUPLING, shaft extension, 0.125 to 0.125 inch
	- - - - - -			-	coupling includes:
-46	354-0251-00			2	RING, coupling
-47	376-0049-00			1	COUPLING, plastic
	213-0048-00			4	SETSCREW, 4-40 x 0.125 inch, HSS
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0012-00			1	WASHER, lock, internal, 0.375 ID x 0.50 inch OD
	210-0840-00			1	WASHER, flat, 0.39 ID x 0.562 inch OD
-48	210-0495-00			1	NUT, hex., 0.375-32 x 0.437 inch x 0.062 inch thick
-49	366-0215-02			1	KNOB, lever, gray--INT TRIG-EXT TRIG
-50	260-0888-01			1	SWITCH, lever--INT TRIG-EXT TRIG
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0004-00			2	WASHER, lock, internal, #4
	210-0406-00			2	NUT, hex., 4-40 x 0.188 inch
-51	366-0215-02			1	KNOB, lever, gray--INPUT
-52	260-0621-01			1	SWITCH, lever--INPUT
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0004-00			2	WASHER, lock, internal, #4
-53	210-0406-00			2	NUT, hex., 4-40 x 0.188 inch
-54	260-0903-00			1	SWITCH, slide--POWER
	- - - - - -			-	mounting hardware: (not included w/switch)
-55	211-0038-00			2	SCREW, 4-40 x 0.312 inch, 100° csk, FHS
-56	214-0992-00			1	INDICATOR, switch position
-57	366-1038-00			1	KNOB, gray w/yellow band--POSITION-10 X VERT GAIN
	- - - - - -			-	knob includes:
	213-0153-00			1	SETSCREW, 5-40 x 0.125 inch, HSS

FIGURE 1 MECHANICAL PARTS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-58	366-1038-00			1	KNOB, gray w/yellow band--POSITION-10 X HORIZ MAG
	------			-	knob includes:
	213-0153-00			1	SETSCREW, 5-40 x 0.125 inch, HSS
-59	------			2	RESISTOR, variable
	------			-	mounting hardware for each: (not included w/resistor)
-60	210-0046-00			1	WASHER, lock, internal, 0.261 ID x 0.40 inch OD
-61	358-0331-00			1	BUSHING, 0.418 inch OD, w/5.8mm x 0.75mm threads
-62	407-0413-01			1	BRACKET
-63	129-0141-00			1	POST, non metallic, 0.25 OD x 0.30 inches long
-64	407-0408-00			1	BRACKET, slide switch
	------			-	mounting hardware: (not included w/bracket)
	210-0004-00			2	WASHER, lock, internal, #4
-65	210-0406-00			2	NUT, hex., 4-40 x 0.188 inch
-66	260-0904-00			1	SWITCH, slide--5 X VERT MAG
	------			-	mounting hardware: (not included w/switch)
-67	211-0079-00			2	SCREW, 2-56 x 0.188 inch, PHS
-68	260-0904-00			1	SWITCH, slide--5 X HORIZ GAIN
	------			-	mounting hardware: (not included w/switch)
-69	211-0079-00			2	SCREW, 2-56 x 0.187 inch, PHS
	337-0997-00			1	SHIELD, slide switch (not shown)
-70	352-0084-01			1	HOLDER, neon
-71	378-0541-00			1	LENS, indicator light
-72	200-0609-00			1	COVER, cap, neon holder
-73	337-0983-01			1	SHIELD, CRT
	------			-	mounting hardware: (not included w/shield)
-74	211-0038-00			1	SCREW, 4-40 x 0.25 inch, 100° csk, FHS
-75	210-0586-00			1	NUT, keps, 4-40 x 0.25 inch
-76	331-0193-00			1	MASK, CRT
-77	426-0402-00			1	FRAME-FILTER ASSEMBLY, light
	------			-	mounting hardware: (not included w/frame-filter
	------			-	assembly)
	214-0986-00			1	SPRING, flat, pre-bent (not shown)
-78	136-0266-01			1	SOCKET, CRT, 12 pin, w/wiring harness

FIGURE 1 MECHANICAL PARTS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-79	386-1316-00			1	SUPPORT, CRT
-80	348-0003-00			1	GROMMET, rubber, 0.312 inch diameter
-81	441-0762-01			1	CHASSIS, main
	- - - - - -			-	mounting hardware: (not included w/chassis)
-82	210-0586-00			4	NUT, keps, 4-40 x 0.25 inch
-83	348-0004-00			1	GROMMET, rubber, 0.375 inch diameter
-84	348-0031-00			1	GROMMET, plastic, 0.156 inch diameter
-85	343-0042-00			1	CLAMP, cable, half, 0.312 inch diameter
	- - - - - -			-	mounting hardware: (not included w/clamp)
	210-0801-00			1	WASHER, flat, 0.14 ID x 0.281 inch OD
-86	210-0586-00			1	NUT, keps, 4-40 x 0.25 inch
-87	670-0883-00			1	CIRCUIT BOARD ASSEMBLY--VERTICAL
	- - - - - -			-	circuit board assembly includes:
	388-1547-00			1	CIRCUIT BOARD
-88	136-0220-00			15	SOCKET, transistor, 3 pin, square
-89	136-0183-00			2	SOCKET, transistor, 3 pin
-90	136-0235-00			2	SOCKET, transistor, dual
-91	136-0252-00			12	SOCKET, pin connector
-93	337-1005-00			1	SHIELD, electrical
-93	337-0975-00			2	SHIELD, electrical
	- - - - - -			-	mounting hardware: (not included w/circuit board
	- - - - - -			-	assembly)
-94	211-0116-00			3	SCREW, sems, 4-40 x 0.312 inch, PHB
-95	670-0885-00			1	CIRCUIT BOARD ASSEMBLY--H. V. POWER SUPPLY
	- - - - - -			-	circuit board assembly includes:
	388-1546-00			1	CIRCUIT BOARD
-96	179-1470-00			1	WIRING HARNESS, high voltage
-97	136-0183-00			1	SOCKET, transistor, 3 pin
-98	136-0220-00			2	SOCKET, transistor, 3 pin, square
-99	346-0032-00			4	STRAP, mousetail (not shown)
-100	344-0119-00			3	CLIP
-101	352-0100-00			1	HOLDER, toroid
	- - - - - -			-	mounting hardware: (not included w/holder)
-102	361-0008-00			1	SPACER, plastic, 0.188 inch long
	- - - - - -			-	mounting hardware: (not included w/circuit board
	- - - - - -			-	assembly)
-103	361-0173-00			3	SPACER, sleeve
-104	129-0142-00			3	POST, non metallic, 1.50 inches long
-105	210-0004-00			2	WASHER, lock, internal, #4
-106	337-1278-00			1	SHIELD, electrical, angle

FIGURE 1 MECHANICAL PARTS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-	016-0160-00			1	POWER PACK ASSEMBLY
	- - - - - -			-	power pack assembly includes:
-107	670-0880-00			1	CIRCUIT BOARD ASSEMBLY--BATTERY CHARGER
	- - - - - -			-	circuit board assembly includes:
	388-0911-01			1	CIRCUIT BOARD
-108	136-0220-00			4	SOCKET, transistor, 3 pin, square
-109	214-0506-00			3	CONNECTOR, square pin
-110	214-0507-00			4	CONNECTOR, square pin (angled)
	670-0881-00			1	BATTERY BOX ASSEMBLY
	- - - - - -			-	battery box assembly includes:
-111	210-0994-00			3	WASHER, flat, 0.125 ID x 0.25 inch OD
-112	210-0004-00			3	WASHER, lock, internal, #4
	210-0201-00			1	LUG, solder, SE #4
-113	210-0406-00			6	NUT, hex., 4-40 x 0.188 inch
-114	343-0119-00			1	CLAMP, cable, 0.093 inch
-115	386-1328-01			1	PLATE, battery box, inside
	214-1059-00			1	INSULATOR
	- - - - - -			-	mounting hardware: (not included w/insulator)
-116	211-0008-00			5	SCREW, 4-40 x 0.25 inch, PHS
-117	386-1327-00			1	PLATE, battery box, outside
	- - - - - -			-	mounting hardware: (not included w/plate)
-118	211-0101-00			6	SCREW, 4-40 x 0.25 inch, 100° csk, FHS
-119	343-0148-00			1	CLAMP, battery retaining (lower)
	343-0148-02			1	CLAMP, battery retaining (upper)
-120	105-0063-00			2	STRIKE, post
-121	211-0025-00			2	SCREW, 4-40 x 0.375 inch, 100° csk, FHS
-122	146-0012-01			1	BATTERY SET, spot-welded together and taped
	- - - - - -			-	battery set includes:
	- - - - - -			6	BATTERY, Ni-cd cell, 1.25 volts
-123	214-1013-01			2	INSULATOR, plate
-124	136-0140-00			1	SOCKET, banana jack, charcoal
	- - - - - -			-	mounting hardware: (not included w/socket)
-125	210-0223-00			1	LUG, solder, 0.25 ID x 0.437 inch OD, SE
-126	210-0465-00			1	NUT, hex., 0.25-32 x 0.375 inch
-127	136-0139-00			1	SOCKET, banana jack, red
	- - - - - -			-	mounting hardware: (not included w/socket)
-128	210-0223-00			1	LUG, solder, 0.25 ID x 0.437 inch OD, SE
-129	210-0465-00			1	NUT, hex., 0.25-32 x 0.375 inch
-130	352-0132-00			1	HOLDER, tip jack
	- - - - - -			-	mounting hardware: (not included w/holder)
-131	213-0107-00			1	SCREW, thread forming, 4-40 x 0.25 inch, 100°
	- - - - - -			-	csk, FHS

FIGURE 1 MECHANICAL PARTS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-132	131-0552-00			1	CONNECTOR, with fuse holder
	- - - - - -			-	mounting hardware: (not included w/connector)
-133	211-0101-00			2	SCREW, 4-40 x 0.25 inch, 100° csk, FHS
-134	200-0813-00			1	COVER, fuse
-135	- - - - - -			1	TRANSFORMER
	- - - - - -			-	mounting hardware: (not included w/transformer)
-136	211-0153-00			2	SCREW, 4-40 x 1.281 inches, RHS
	210-0906-00			3	WASHER, fiber, 0.125 ID x 0.203 inch OD
	210-0201-00			1	LUG, solder, SE #4
-137	210-0406-00			2	NUT, hex., 4-40 x 0.188 inch
-138	260-0902-00			1	SWITCH, slide--EXT DC TRICKLE CHG FULL CHG
	- - - - - -			-	mounting hardware: (not included w/switch)
-139	211-0119-00			2	SCREW, 4-40 x 0.25 inch, 100° csk, FHS
-140	- - - - - -			1	TRANSISTOR
	- - - - - -			-	mounting hardware: (not included w/transistor)
-141	214-1025-00			1	INSULATOR, mica
-142	211-0510-00			2	SCREW, 6-32 x 0.375 inch, PHS
-143	210-0811-00			2	WASHER, fiber, shouldered, #6
-144	210-0802-00			2	WASHER, flat, 0.15 ID x 0.312 inch OD
-145	210-0202-00			1	LUG, solder, SE #6
-146	210-0006-00			1	WASHER, lock, internal, #6
-147	210-0407-00			2	NUT, hex., 6-32 x 0.25 inch
-148	214-1390-00			1	HEAT SINK, transistor
-149	348-0055-00			1	GROMMET, plastic, 0.25 inch diameter
	348-0031-00			1	GROMMET, plastic, 0.156 inch diameter (not shown)
-150	179-1475-00			1	WIRING HARNESS, battery
-151	129-0135-00			2	POST, metallic, 4.31 inches long
	- - - - - -			-	mounting hardware for each: (not included w/post)
-152	211-0101-00			1	SCREW, 4-40 x 0.25 inch, 100° csk, FHS
-153	211-0038-00			1	SCREW, 4-40 x 0.312 inch, 100° csk, FHS
-154	129-0136-01			1	POST, metallic, 3.12 inches long
	- - - - - -			-	mounting hardware: (not included w/post)
-155	211-0038-00			1	SCREW, 4-40 x 0.312 inch, 100° csk, FHS
-156	129-0136-01			1	POST, metallic, 3.12 inches long
	- - - - - -			-	mounting hardware: (not included w/post)
-157	211-0101-00			1	SCREW, 4-40 x 0.25 inch, 100° csk, FHS
	211-0038-00			1	SCREW, 4-40 x 0.312 inch, 100° csk, FHS

FIGURE 1 MECHANICAL PARTS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-158	105-0062-00			1	CATCH, friction
	- - - - - -			-	mounting hardware: (not included w/catch)
-159	210-0948-00			1	WASHER, flat, 0.166 ID x 0.215 inch OD
	210-0802-00			1	WASHER, flat, 0.15 ID x 0.312 inch OD
	210-0994-00			1	WASHER, flat, 0.125 ID x 0.25 inch OD
-160	211-0140-00			1	SCREW, shouldered, 4-40 x 0.775 inch
-161	441-0763-00			1	CHASSIS, support, shield
	- - - - - -			-	mounting hardware: (not included w/chassis)
-162	211-0101-00			1	SCREW, 4-40 x 0.25 inch, 100° csk, FHS
-163	210-0801-00			1	WASHER, flat, 0.125 ID x 0.25 inch OD
-164	210-0004-00			1	WASHER, lock, internal, #4
-165	210-0406-00			1	NUT, hex., 4-40 x 0.188 inch
-166	210-0486-00			4	NUT, keps, 4-40 x 0.25 inch
-167	337-1274-00			1	SHIELD, electrical, high voltage box
	- - - - - -			-	mounting hardware: (not included w/shield)
-168	211-0101-00			1	SCREW, 4-40 x 0.25 inch, 100° csk, FHS
-169	210-0801-00			1	WASHER, flat, 0.125 ID x 0.25 inch OD
-170	210-0201-00			1	LUG, solder, SE #4
-171	210-0406-00			1	NUT, hex., 4-40 x 0.188 inch
-172	210-0586-00			3	NUT, keps, 4-40 x 0.25 inch
-173	348-0067-00			1	GROMMET, plastic, 0.312 inch diameter
-174	348-0055-00			2	GROMMET, plastic, 0.25 inch diameter
-175	337-0984-00			1	SHIELD, electrical attenuator
	- - - - - -			-	mounting hardware: (not included w/shield)
-176	211-0008-00			1	SCREW, 4-40 x 0.25 inch, PHS
-177	344-0124-00			1	CLIP, retainer, capacitor
	- - - - - -			-	mounting hardware: (not included w/clip)
-178	213-0120-00			1	SCREW, thread forming, 2-32 x 0.25 inch, PHS
-179	352-0135-00			1	HOLDER, spare fuses
	- - - - - -			-	mounting hardware: (not included w/holder)
-180	361-0007-00			2	SPACER, plastic, 0.188 inch long
-181	386-1314-01			1	PLATE, subpanel, side
	- - - - - -			-	mounting hardware: (not included w/plate)
-182	210-0004-00			1	WASHER, lock, internal, #4
-183	210-0406-00			1	NUT, hex., 4-40 x 0.188 inch
-184	211-0008-00			1	SCREW, 4-40 x 0.25 inch, PHS

FIGURE 1 MECHANICAL PARTS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-185	333-1028-01			1	PANEL, side
-186	260-0905-00			1	SWITCH, slide--ATTEN
	- - - - - -			-	mounting hardware: (not included w/switch)
-187	211-0073-00			2	SCREW, 2-56 x 0.218 inch, 82° csk, FHS
-188	131-0106-00			1	CONNECTOR, coaxial, 1 contact, BNC (with hardware)
	- - - - - -			-	mounting hardware: (not included w/connector)
-189	210-0255-00			1	LUG, solder, 0.375 inch
-190	136-0140-00			2	SOCKET, banana jack, charcoal
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-191	210-0895-00			1	WASHER, insulating
-192	210-0223-00			1	LUG, solder, 0.25 ID x 0.437 inch OD, SE
-193	210-0465-00			1	NUT, hex., 0.25-32 x 0.375 inch
-194	131-0274-00			1	CONNECTOR, coaxial, insulating, 1 contact, BNC (with hardware)
	- - - - - -			-	
-195	129-0103-00			1	BINDING POST ASSEMBLY
	- - - - - -			-	binding post assembly includes:
	129-0077-00			1	BINDING POST
	200-0103-00			1	CAP, binding post
	- - - - - -			-	mounting hardware: (not included w/binding post assembly)
	- - - - - -			-	
-196	210-0223-00			1	LUG, solder, 0.25 ID x 0.437 inch OD, SE
-197	210-0455-00			1	NUT, hex., 0.25-28 x 0.375 inch
-198	386-1317-01			1	PLATE, subpanel, rear (inner)
-199	213-0215-00			1	THUMBSCREW, plastic
-200	333-1252-00			1	PANEL, front
-201	386-1313-02			1	PLATE, front subpanel
-202	337-0973-00			1	SHIELD, voltage
	- - - - - -			-	mounting hardware: (not included w/shield)
-203	211-0101-00			2	SCREW, 4-40 x 0.25 inch, 100° csk, FHS
-204	210-0586-00			2	NUT, keps, 4-40 x 0.25 inch
-205	211-0008-00			1	SCREW, 4-40 x 0.25 inch, PHS
-206	179-1477-00			1	WIRING HARNESS, main
-207	179-1476-00			1	WIRING HARNESS, position
-208	348-0031-00			1	GROMMET, plastic, 0.093 inch diameter

FIGURE 1 MECHANICAL PARTS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-209	670-0884-00			1	CIRCUIT BOARD ASSEMBLY--HORIZONTAL
	- - - - - -			-	circuit board assembly includes:
	388-1549-00			1	CIRCUIT BOARD
-210	136-0183-00			7	SOCKET, transistor, 3 pin
-211	136-0200-00			20	SOCKET, transistor, 3 pin, square
	337-1275-00			1	SHIELD
	337-1276-00			1	SHIELD
	- - - - - -			-	mounting hardware: (not included w/circuit board
	- - - - - -			-	assembly)
-212	211-0116-00			3	SCREW, sems, 4-40 x 0.312 inch, PHB
-213	214-0757-00			1	HEAT SINK
	- - - - - -			-	mounting hardware: (not included w/heat sink)
-214	211-0040-00			1	SCREW, 4-40 x 0.25 inch, BH plastic
-215	214-1354-00			4	HEAT SINK, w/hardware
-216	337-1279-00			1	SHIELD, transformer
-217	670-0882-00			1	CIRCUIT BOARD ASSEMBLY--LOW VOLTAGE POWER SUPPLY
	- - - - - -			-	circuit board assembly includes:
	388-1548-00			1	CIRCUIT BOARD
-218	136-0220-00			8	SOCKET, transistor, 3 pin, square
-219	136-0183-00			3	SOCKET, transistor, 3 pin
-220	352-0100-00			3	HOLDER, variable resistor
	- - - - - -			-	mounting hardware for each: (not included w/holder)
-221	361-0008-00			1	SPACER, plastic, 0.281 inch long
-222	214-0283-00			2	SPRING
	- - - - - -			-	mounting hardware: (not included w/circuit board
	- - - - - -			-	assembly)
-223	211-0008-00			3	SCREW, 4-40 x 0.25 inch, PHS

FIGURE 2 CABINET

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
2-1	437-0109-00			1	CABINET
-2	386-1315-01			1	SUBPANEL, rear, outer
-3	386-1318-01			1	PANEL, rear
-4	348-0138-00			8	FOOT
-5	367-0084-00			1	HANDLE
-6	334-1431-00			1	TAG, identification
-7	129-0148-02			2	POST, metallic, 6-32 tap
-8	386-1339-00			2	PLATE, brake, friction, inner
-9	386-1331-00			2	PLATE, brake, friction, outer
-10	210-1053-00			4	WASHER, spring tension
-11	200-0819-00			2	COVER, handle, brake
-12	132-0084-00			2	SPACER, plastic, 0.45 dia x 0.05 inch long
-13	213-0179-02			2	SCREW, cap, 6-32 threads
-14	213-0170-00			1	THUMBSCREW, cabinet
	- - - - - -			-	mounting hardware: (not included w/thumbscrew)
	354-0324-00			1	RING, retaining (not shown)

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Sections of the manual are often printed at different times, so some of the information on the change pages may already be in your manual. Since the change information sheets are carried in the manual until ALL changes are permanently entered, some duplication may occur. If no such change pages appear in this section, your manual is correct as printed.

STANDARD ACCESSORIES CORRECTION

FIG. 4 ACCESSORIES

CHANGE last line to read:

070-1032-01	1	MANUAL, instruction (not shown)
070-1182-00	1	HANDBOOK, operators

ELECTRICAL PARTS LIST CORRECTION

VERTICAL Circuit Board Assembly

CHANGE TO:

C102	283-0675-01	82 pF	Mica	300 V	1%
C107	283-0675-01	82 pF	Mica	300 V	1%

HORIZONTAL Circuit Board Assembly

CHANGE TO:

C330E	283-0675-01	82 pF	Mica	300 V	1%

ELECTRICAL PARTS LIST CORRECTION

	HIGH VOLTAGE POWER SUPPLY	Circuit Board Assembly		
CHANGE TO:				
C531	290-0451-01	0.15 µF	Elect.	
C533	290-0453-01	1 µF	Elect.	
	LOW VOLTAGE POWER SUPPLY	Circuit Board Assembly		
CHANGE TO:				
C543	290-0454-01	4.7 µF		160 V

M14,563/371

ELECTRICAL PARTS LIST CORRECTION

[illegible]

C288	283-0602-01	53 pF	Mica	300 V	5%