

2237-72

465M with front cover.

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OPERATORS SAFETY SUMMARY

The general safety information in this part of the summary is for both operating and servicing personnel. Specific warnings and cautions will be found throughout the manual where they apply, but may not appear in this summary.

Terms In This Manual

CAUTION statements identify conditions or practices that could result in damage to the equipment or other property.

WARNING statements identify conditions or practices that could result in personal injury or loss of life.

Terms As Marked on Equipment

CAUTION indicates a personal injury hazard not immediately accessible as one reads the marking, or a hazard to property including the equipment itself.

DANGER indicates a personal injury hazard immediately accessible as one reads the marking.

Symbols As Marked on Equipment



DANGER — High voltage.



Protective ground (earth) terminal.



ATTENTION — refer to manual.

Power Source

This product is intended to operate from a power source that will not apply more than 264 volts rms between the supply conductors or between either supply conductor and ground. A protective ground connection by way of the grounding conductor in the power cord is essential for safe operation.

Grounding the Product

This product is grounded through the grounding conductor of the power cord. To avoid electrical shock, plug the power cord into a properly wired receptacle before connecting to

the product input or output terminals. A protective ground connection by way of the grounding conductor in the power cord is essential for safe operation.

Danger Arising From Loss of Ground

Upon loss of the protective-ground connection, all accessible conductive parts (including knobs and controls that may appear to be insulating) can render an electric shock.

Use the Proper Power Cord

Use only the power cord and connector specified for your product.

Use only a power cord that is in good condition.

Refer cord and connector changes to qualified service personnel.

Use the Proper Fuse

To avoid fire hazard, use only the fuse of correct type, voltage rating and current rating as specified in the parts list for your product.

Refer fuse replacement to qualified service personnel.

Do Not Operate in Explosive Atmospheres

To avoid explosion, do not operate this product in an explosive atmosphere unless it has been specifically certified for such operation.

Do Not Remove Covers or Panels

To avoid personal injury, do not remove the product covers or panels. Do not operate the product without the covers and panels properly installed.

SECTION I

INTRODUCTION AND GENERAL INFORMATION

1-1. INTRODUCTION

a. Manual Purpose. This manual provides instructions for operation and maintenance of the 465M Oscilloscope and includes illustrated parts breakdown data. The 465M is also known as the military AN/USM-425(V)1.

b. Manual Scope. The instructions provided in this manual are intended to be performed at organizational or intermediate level maintenance activities using tools, test equipment, and spare parts authorized in their allowance lists and supply activities.

c. Manual Arrangement. This manual is separated into eleven sections as follows:

(1) Section I, Introduction and General Information. Contains the purpose, scope, and arrangement of the manual and a description of the instrument including its leading particulars and accessories.

(2) Section II, Special Tools and Test Equipment. Contains listing of tools, test equipment, and consumable materials needed to maintain the instrument.

(3) Section III, Preparation for Use and Shipment. Contains instructions for preparing the instrument for initial use and repackaging for shipment.

(4) Section IV, Operation Instructions. Contains instrument theory of operation; a description of controls, connectors, and indicators; special operating instructions; initial turn-on and adjustment procedures; normal operation familiarization procedures; and examples of instrument applications.

(5) Section V, Maintenance Instructions. Contains procedures to check out, perform routine maintenance, troubleshoot, repair, test, and adjust the instrument.

(6) Section VI, Diagrams. Contains schematic diagrams with associated data referenced in other sections of the manual.

(7) Section VII, Introduction to the Illustrated Parts Breakdown. Contains information on how to use the illustrated parts breakdown data in Sections VIII through X.

(8) Section VIII, Maintenance Parts List. Contains the illustrated parts breakdown illustrations and parts descriptions.

(9) Section IX, Numerical Index. Contains a part number to figure and index cross reference listing.

(10) Section X, Reference Designation Index. Contains a reference designator to figure and index, and part number cross reference listing.

(11) Section XI, Difference Data Sheets. Provides a section for inserting information about different models, custom modifications, other accessories, etc., that may not be provided as part of the manual.

1-2. USE OF WARNING, CAUTION, AND NOTE SYMBOLS. Symbols are used throughout the manual text to highlight personnel safety warnings, precautions to prevent damage to the instrument, and special notes. These symbols are as follows:

WARNING

Personnel Safety Warnings

CAUTION

Equipment Damage Precautions

NOTE

Special Notes

1-3. GENERAL INFORMATION

a. Equipment Description. The 465M is a solid state, dual channel, 100 megahertz bandwidth, delayed sweep, general purpose oscilloscope. Each vertical channel has ten calibrated deflection factors from 5 millivolts/division to 5 volts/division selected in a 1-2-5 sequence. The horizontal deflection system has calibrated sweep rates of 0.5 seconds/division to 0.05 microseconds/division in 22 steps. It also has delayed sweep rates of 50 milliseconds/division to 0.05 microseconds/division in 19 steps. A ten times magnifier expands each horizontal sweep rate to a maximum of 5 nanoseconds/division. An X-Y display mode is provided through vertical mode and horizontal sweep speed selection.

b. Accessories Supplied. Figure 8-2 illustrates and lists the accessories that are shipped with the instrument.

c. Performance Conditions. Tables 1-1 through 1-3 list the electrical, environmental, and physical characteristics of the 465M. The electrical characteristics are valid under these conditions: (1) the instrument has been calibrated (adjusted) as described in Section V at an ambient temperature between +20°C and +30°C (+68° to +86°F), (2) the instrument is operating in an ambient temperature

between -15°C and +55°C (+5°F to +131°F) and (3) the instrument has warmed-up for 20 minutes below 0°C, or 5 minutes if above 0°C (+32°F).

d. Electrical Characteristics. Electrical characteristics are divided into two categories: Characteristics shown in the performance requirement column are instrument specifications and can be verified by the Operational Checkout (Performance Check) in Section V. Information in the Supplemental Information column is provided for reference or clarification.

Table 1-1. Electrical Characteristics

Characteristics	Performance Requirements	Supplemental Information
POWER SOURCE		
Line Voltage Range (ac, rms) 116 V 232 V	100 V to 132 V 200 V to 264 V	
Line Frequency		48 Hz to 440 Hz.
Maximum Power Consumption		60 watts at 115 V, 60 Hz.
CALIBRATOR		
Output Voltage into 1 M Ω and 22 pF -15°C to +55°C	1.0 V within 1%.	
Repetition Rate	1 kHz within 10%.	
Symmetry	Within $\pm 25\%$.	
Risetime	<1 microsecond.	
Output Resistance		Typically 190 Ω .
CRT DISPLAY		
CRT Graticule Display Area	8 div vertical by 10 div horizontal. Each div equals 1 cm.	
Vertical Resolution		At least 15 lines in 1 div.
Horizontal Resolution		At least 15 lines in 1 div.
Geometry		0.1 div or less.
Trace Rotation Range		Adequate to align trace with horizontal center line.
CRT Phosphor		P31
Raster Distortion		0.1 div or less.
Accelerating Potential		Nominally 12,000 volts.

Table 1-1. Electrical Characteristics—Continued

Characteristics	Performance Requirements	Supplemental Information
VERTICAL DEFLECTION SYSTEM		
Deflection Factor		
Calibrated Range	5 mV/div to 5 V/div in 10 steps in a 1-2-5 sequence.	
Variable Range	Continuously variable between calibrated steps and at least 2.5 to 1 range.	Extends deflection factor to at least 12.5 V/div.
DC Accuracy		
0°C to +40°C	±2%	With GAIN set at 5 mV/div.
-15°C to 0°C and +40°C to +55°C	±3%	
Low-frequency linearity		Typically 0.1 div or less of compression or expansion as a 2 div signal is positioned anywhere within the graticule limits.
Frequency Response		
DC Coupled Bandwidth	DC to at least 100 MHz (-3 dB)	5 division reference signal centered vertically from a 25 Ω source with VAR V/DIV in the calibrated position.
AC LF Response	10 Hz or less with ac coupling	1 Hz or less with X10 probe.
Step Response		5 div reference centered vertically, DC coupled at all deflection factors from a 25 Ω source with VAR V/DIV in calibrated position.
Risetime		
-15°C to +55°C	3.5 nanoseconds or less	Measured between 10% and 90% points indicated on the graticule.
Positive-going step (Excluding ADD mode)		
Aberrations		
+15°C to +35°C		Less than +3%, -3%, 3% peak-to-peak.
+35°C to +55°C and 0°C to +15°C		Less than +4%, -4%, 4% peak-to-peak. (AF 82-PD-332 Paragraph 3.8.3.2.2 does not specify aberrations below 0°C.)
Position Effect		Aberrations less than +6%, -6%, not to exceed 6% peak-to-peak.

Table 1-1. Electrical Characteristics—Continued

Characteristics	Performance Requirements	Supplemental Information
VERTICAL DEFLECTION SYSTEM—Cont.		
INVERT Trace Shift		Typically less than 2 div when switching from normal to inverted.
Input Gate Current		
−15°C to +30°C		Typically 0.5 nA or less (0.1 div at 5 mV/div).
+30°C to +55°C		Typically 4.0 nA or less (0.8 div at 5 mV/div).
Channel Isolation		
To 10 MHz	100:1	
10 to 20 MHz	50:1	
20 to 50 MHz	25:1	
50 to 100 MHz	15:1	
Position Range		Typically greater than +12 and −12 div from graticule center.
Chopped Mode Repetition Rate		Typically 250 kHz.
Common Mode Rejection Ratio (ADD Mode with CH 2 Inverted)		
To 10 MHz		Greater than 25:1
10 MHz to 50 MHz		Greater than 10:1
DC Stability		
Step Atten Balance		0.2 div or less.
DC Drift		
0°C to +55°C		Less than 0.1 div/hour.
−15°C to 0°C		Less than 0.5 div/hour.
CH 1 and CH 2 Input		
Impedance		1 M Ω \pm 2%, paralleled nominally by 20 pF.
Maximum Input Voltage		
At 20 kHz		\pm 250 V (dc + peak ac)
At 1 MHz		\pm 10 V (dc + peak ac)
At 100 MHz		\pm 5 V (dc + peak ac)
Channel 2 Signal Output (Through Main Module CH 2 OUT Connector)		
Bandwidth		DC to at least 40 MHz into 50 Ω .

Table 1-1. Electrical Characteristics—Continued

Characteristics	Performance Requirements	Supplemental Information
VERTICAL DEFLECTION SYSTEM—Cont.		
Output Voltage		50 mV/div $\pm 20\%$.
Into 1 M Ω		
Into 50 Ω		25 mV/div $\pm 20\%$.
Output Resistance		Approximately 50 Ω .
DC Level		Nominally 0 V.
Cascaded Operation (CH 2 OUT into CH 1)		CH 2 OUT into CH 1 input using a 42-inch 50 Ω coaxial cable terminated in 50 Ω at CH 1 input.
Bandwidth		DC to at least 40 MHz.
Sensitivity		Nominally 1 mV/div when terminated in 50 Ω at CH 1 input with both CH 1 and CH 2 sensitivity set to 5 mV/div.
Bandwidth Limit	20 MHz ± 5 MHz.	
HORIZONTAL DEFLECTION SYSTEM		
Sweep Rate		
Calibrated Range		
A Sweep	0.5 s/div to 0.05 μ s/div in 22 steps in a 1-2-5 sequence. X10 MAG extends maximum sweep rate to 5 ns/div.	
B Sweep	50 ms/div to 0.05 μ s/div in 19 steps in a 1-2-5 sequence. X10 MAG extends maximum sweep rate to 5 ns/div.	
Accuracy	Unmagnified X1	Magnified ¹ X10
+20°C to +30°C	$\pm 2\%$	$\pm 3\%$
-15°C to +55°C	$\pm 3\%$	$\pm 4\%$
Below -15°C	$\pm 6\%$	
Over any two division portion of full 10 divisions ^{1,2} .		
X1 Horizontal Linearity over full 10 divisions.	± 0.05 division.	
		Accuracy specification applies over the full 10 divisions.
		¹ Exclude the first and last 50 ns of the sweep on 5 ns, 10 ns, and 20 ns sweep rates.
		² $\pm 5\%$. Exclude first and last displayed division when checking 5 ns/div and 10 ns/div (X10 MAG on).

Table 1-1. Electrical Characteristics—Continued

Characteristics	Performance Requirements	Supplemental Information
HORIZONTAL DEFLECTION SYSTEM—Cont.		
Mixed Sweep		
Accuracy		
A Portion		Within 4%
B Portion		Within 2%
		B Sweep must be at least 1 sweep rate faster than A sweep. Exclude first div or $0.5 \mu\text{s}$ (whichever is greater) after sweep start. Also exclude first 0.2 div or $0.1 \mu\text{s}$ (whichever is greater) after the transition from A to B sweep.
Variable Range (A only)	At least 2.5:1	Continuously variable between calibrated settings. Extends slowest A sweep rate to at least 1.25 s/div.
Trigger Holdoff Variable	Increases A sweep holdoff time to at least 3X the time/div settings, except at .2 s/div and .5 s/div.	
Magnifier Registration		Within 0.25 division from graticule center (MAG on to MAG off).
Position Range	Start of sweep must position to right of graticule center. End of sweep must position to the left of graticule center (TIME/DIV at 1.0 ms/div).	
Position Drift at any given temperature		
0°C to $+55^{\circ}\text{C}$		≤ 0.1 div/hour.
-15°C to 0°C		≤ 0.5 div/hour.
Differential Time Measurement Accuracy for measurements of two or more major dial divisions (exclude delayed operation when knobs are locked at any sweep rate or when A TIME/DIV is at $0.5 \mu\text{s}/\text{div}$).		
$+15^{\circ}\text{C}$ to $+35^{\circ}\text{C}$	1% +0.1% of full scale.	
0°C to $+55^{\circ}\text{C}$	Additional 1% allowed.	
Below 0°C	Additional 4% allowed.	

Table 1-1. Electrical Characteristics—Continued

Characteristics	Performance Requirements	Supplemental Information
HORIZONTAL DEFLECTION SYSTEM—Cont.		
Delay Time Jitter	One part or less in 20,000 (0.005%) of ten times the A TIME/DIV setting.	
Calibrated Delay Time (VAR control in CAL)	Continuous from 0.1 μ s to at least 5 sec after the start of the delaying (A) sweep.	
X-Y Operation		TIME/DIV set to extreme ccw position. CH 2 or X-Y VERT MODE button must be pushed.
Sensitivity	Same as vertical system deflection factor calibrated range (with X10 MAG off).	
Variable Range	Same as vertical system variable range.	
X-Axis Bandwidth	DC to at least 4 MHz.	6 division reference signal.
Input Impedance	Same as for the vertical system.	
X-Axis Linearity		≤ 0.2 div compression or expansion when a 2 div X-Axis signal at center screen is positioned to right or left extreme of the graticule area.
Maximum Usable Input voltage	Same as for the vertical system.	
Phase Difference between X and Y Axes Amplifiers	Within 3° from dc to 50 kHz.	
X-Axis Deflection Accuracy		Within 4% with VAR control in the CAL position.
TRIGGERING		
Trigger Sensitivity		In EXT \div 10, multiply trigger voltage requirements by 10.
AC Coupled	0.3 div internal or 50 mV external from 30 Hz to 25 MHz increasing to 1.0 div internal or 150 mV external at 100 MHz.	
LF REJ Coupled	0.3 div internal or 50 mV external from 50 kHz to 25 MHz increasing to 1.0 div internal or 150 mV external at 100 MHz.	Attenuates signals below about 15 kHz.
HF REJ Coupled	0.3 div internal or 50 mV external from 60 Hz to 5 kHz.	Attenuates signals below about 30 Hz and above about 50 kHz.

Table 1-1. Electrical Characteristics—Continued

Characteristics	Performance Requirements	Supplemental Information
TRIGGERING—Cont.		
Trigger Sensitivity cont. DC Coupled	0.3 div internal or 50 mV external from dc to 25 MHz increasing to 1.0 div internal or 150 mV external at 100 MHz.	
Trigger Jitter (at 100 MHz and 5 ns/div) −15°C to +55°C	0.5 ns or less.	
Auto Free Run Freq.		Less than 40 Hz.
External Trigger Input Impedance		1 M Ω \pm 15% paralleled nominally by 20 pF.
Maximum Input Voltage		100 V (dc + peak ac); 100 V p-p ac at 1 kHz or less.
Trigger LEVEL range EXT EXT \div 10	At least + and −1 V, 2 V p-p.	At least + and −10 V, 20 V p-p.
Trigger View Deflection Factor EXT EXT \div 10		Typically 100 mV/div AC or DC trigger coupling only. Typically 1 V/div, AC or DC trigger coupling only.
Z AXIS INPUT		
Sensitivity	5 V p-p or more signal provides noticeable modulation at normal intensity.	
Polarity of Operation	Positive-going signal decreases trace intensity.	
Usable Frequency Range	DC to 15 MHz.	
Input Resistance at dc		Approximately 1.6 k Ω .
Maximum Input Voltage		50 V (dc + peak ac).
SIGNAL OUTPUTS		
A Gate Output Voltage (Positive-going pulse) Output resistance	5 V \pm 20%	Starts at approximately 0 V. Approximately 1.5 k Ω .

Table 1-1. Electrical Characteristics—Continued

Characteristics	Performance Requirements	Supplemental Information
SIGNAL OUTPUTS—Cont.		
B Gate		
Output Voltage (positive)	5 V \pm 20%	Starts at approximately 0 V.
Output Resistance		Approximately 500 Ω .

Table 1-2. Environmental Characteristics

Characteristics	Description
Temperature	
Non-operating	−62°C to +85°C
Operating	−15°C to +55°C
Humidity	5 cycles (120 hours) referred to MIL-T-28800B.
Altitude	
Non-operating	To 50,000 feet.
Operating	To 15,000 feet; maximum operating temperature decreased 1°C/1000 feet above 5000 feet.
Vibration	
Operating and Non-operating	With the instrument complete and operating, and vibration frequency swept from 10 to 55 to 10 Hz at 1 minute per sweep. Vibrate 15 minutes in each of the three major axes at 0.015-inch total displacement. Hold 10 minutes at any major resonance, or if none, at 55 Hz. Total time 75 minutes.
Shock	30 g's 1/2 sine, 11 ms duration, 3 shocks in each direction along 3 major axes, for a total of 18 shocks.
Transportation	Qualified under National Safe Transit Committee Test Procedure 1A-B-1 and 2.
Transit Drop (non-operating)	Drop unboxed instrument 8-inches on each corner and face, a total of 14 drops. Drop test performed on a rigid wooden surface. Per MIL-T-28800B as modified by US Government purchase description AF82-PD-332 configuration B.
Drip-proof (Front cover on, non-operating)	Spray from 3-feet above instrument with instrument tilted 15° away from horizontal plane in each of 4 directions and horizontal. Per MIL-T-28800B Style C.
Bench Handling (operating)	Edge lifts and drops on work bench on bottom and rear faces, total of 8 drops. Per MIL-T-28800B.

Table 1-3. Physical Characteristics

Characteristics	Description
Weight	
465M with Panel cover, modules, and accessories	27.0 lbs (12.2 kg).
Without Panel Cover and accessories	24.0 lbs (10.9 kg).
Domestic Shipping Weight	34.2 lbs (15.5 kg).
Height	
With Feet	7.05 inches (179.1 mm).
Width	
With Handle	13.65 inches (346.7 mm).
Without Handle	12.5 inches (317.5 mm).
Depth	
Including Panel Cover	21.45 inches (544.8 mm).
Handle Extended	24.1 inches (612.1 mm).
Construction	Plastic cabinet, aluminum alloy chassis and panel, with glass laminate etched wiring circuit boards.
Finish	Anodized front panel and textured cabinet.

SECTION II

SPECIAL TOOLS AND TEST EQUIPMENT

2-1. SPECIAL TOOLS. No special tools are required.

2-2. TEST EQUIPMENT. Test equipment required to maintain the instrument is listed in Table 2-1. Equivalent items may be used if the recommended items are not available.

2-3. CONSUMABLE MATERIALS. Table 2-2 lists the consumable materials recommended for maintaining the instrument. Equivalent materials may be used if those recommended are not available.

Table 2-1. Test Equipment List

Tool/Equipment Number	Nomenclature	Application	Description
Tektronix PG 506 ¹	Calibration Generator and Fast-rise Pulse Generator	Vertical deflection system checks and adjustments; trigger range check; trigger view check and adjustment; high and low frequency compensation adjustments.	Range, 1 kilohertz and 100 kilohertz square-wave; output amplitude, 20 millivolts to 20 volts; accuracy, within 0.4%; fast-rise output risetime, 1 nanosecond or less.
Tektronix TG 501 ¹	Time-Mark Generator	Sweep timing checks and adjustments; Y-axis adjustments; geometry adjustments.	Marker range, 10 nanoseconds to 0.5 seconds; accuracy, within 0.4%.
Tektronix SG 502 ¹	Sine-wave Generator Low Frequency	Trigger checks.	Range, 30 hertz to 50 kilohertz; output amplitude, 10 millivolts to 4 volts peak to peak.
Tektronix SG 503 ¹	Sine-wave Generator	Bandwidth checks; cascade sensitivity checks; trigger checks and adjustments.	Range, 4 megahertz to 100 megahertz with a 50 kilohertz reference; accuracy, within 3%; output amplitude, 5 millivolts to 4 volts peak to peak.
Tektronix DM 501A ¹	Digital Multimeter	Power supply checks and adjustments; calibrator adjustments; crt bias adjustments; troubleshooting.	Range, -10 volts dc to +50 volts dc; 300 volts ac, 2 kilohm to 20 megohm; accuracy, within 0.1%.
465M	Oscilloscope	Sweep gate output checks; calibrator output checks; Z-axis compensation adjustment and calibration checks; troubleshooting waveforms.	Bandwidth, at least 100 megahertz; vertical deflection factor, at least 5 millivolts/division; sweep rate, at least 2 microseconds/division.
Tektronix part 017-0061-00	CT-3 Signal Pickoff	Trigger checks.	Assembly, signal pickoff (CT-3).

See footnotes at the end of the table.

Table 2-1. Test Equipment—Continued

Tool/Equipment Number	Nomenclature	Application	Description
Tektronix part 011-0049-01 (2 required)	Feedthrough Termination	Test signal termination for performance checks and adjustments.	Termination, coaxial, 50 ohm, 2 watt, dc to 500 megahertz, BNC male to BNC female.
Tektronix part 067-0538-00	Input RC Normalizer	Vertical deflection system attenuator compensation adjustments.	Calibration fixture, 1 megohm with 20 picofarad input RC time constant, BNC male to BNC female.
Tektronix part 012-0057-01 (2 required)	Coaxial Cable with BNC Male Connectors	Test signal interconnections.	Cable assembly, RF, 50 ohm, 43 inches, BNC male to BNC male.
Tektronix part 067-0525-01 (2 required)	Dual Input Coupler	Matched dual test signal inputs.	Calibration fixture, BNC female input to dual BNC male output with RG-58C/U cable matched within 0.1 inch.
Tektronix part 103-0030-00	T Connector	Test signal interconnections	Adapter, connector, BNC, Tee, BNC male to two BNC female, type UG-274B/U.
Tektronix part 017-0063-00 Manufacturers part 0874-9700.	Adapter, GR874 to BNC female	Test signal interconnections.	Adapter, connector, BNC female to GR.
Tektronix part 017-0064-00. Manufacturers part 874QBPA	Adapter, GR874 to BNC male	Test signal interconnections.	Adapter, connector, BNC male to GR.
Tektronix part 011-0059-02	Attenuator, 10X, 50 ohm	Test signal interconnections.	Attenuator, 50 ohm, 2 watt, dc to 2 gigahertz, BNC female to BNC male.
Tektronix part 010-0277-00	Probe, high voltage	Used with DM 501A for power supply checks and troubleshooting.	Voltage range, 1 kilovolt to at least 4 kilovolts.
General Radio W8MT3VM	Metered variable autotransformer	Vary the power input source for regulation check over the 100 V to 132 V range.	Input voltage, 116 V; Output voltage, 100 V to 132 V. Metered output.

¹ Requires a TM 500 series mainframe/power module.

Table 2-2. Consumable Materials List

Nomenclature	Material	Specification Number	Part Number
Grease, insulation	Silicone compound	MIL-S-8660B	NSN6850-00-880-7616
Lubricant	Silicone compound	MIL-S-8660B	NSN6850-00-880-7616
Mild detergent			NSN6850-00-570-9360-or part GC8666 (vender code 80112)
Contact cleaner	Isopropyl alcohol	MIL-C-81302	NSN6850-00-105-3084

2-4. RACKMOUNTING ACCESSORY. Some instruments may be used in applications where rack mounting is useful. A 465M/USM-425(V)1 Rack Adapter

(Cradle Mount) kit is available as Tektronix part 040-0825-00. Installation instructions are provided with the kit.

SECTION III

PREPARATION FOR USE AND SHIPMENT

3.1 PREPARATION FOR USE

WARNING

Read the Safety Summary page in the front part of this manual before using the instrument.

a. Unpacking the Instrument. No special unpacking procedures are required.

b. Initial Inspection. This instrument was inspected and adjusted before shipment. Upon receipt, inspect for physical damage and missing accessories. The accessories, which are shown in Figure 8-2 are stored in the front cover.

c. Faceplate Filter Installation. The instrument was shipped with either a clear filter (faceplate protector) or blue filter installed. The blue filter is used to reduce light reflections and increase display contrast under high ambient light conditions. To exchange the filters refer to Figure 3-1.

d. Carrying Handle Positioning. The instrument handle can be positioned for carrying or as a tilt stand. There are several detent positions provided for convenient carrying or viewing. The instrument may also be set on its rear-panel feet for operation or storage. To position the handle (see CAUTION below), press in at both pivot points (see Figure 3-2) and position the handle to the desired position, then release the pivot points.

CAUTION

When positioning the handle as a tilt stand, be sure it is locked into a detent before letting the handle support the instrument. Otherwise, the tilt stand may collapse causing instrument damage.

e. Operating Voltage Selection. The instrument will operate from either a 116 volt ac or 232 volt ac nominal line voltage source with ranges as indicated on the rear

panel. Source selection is made with the LINE RANGE Selector on the rear panel (see Figure 3-3).

CAUTION

This instrument may be damaged if operated with the LINE RANGE Selector set to the incorrect position.

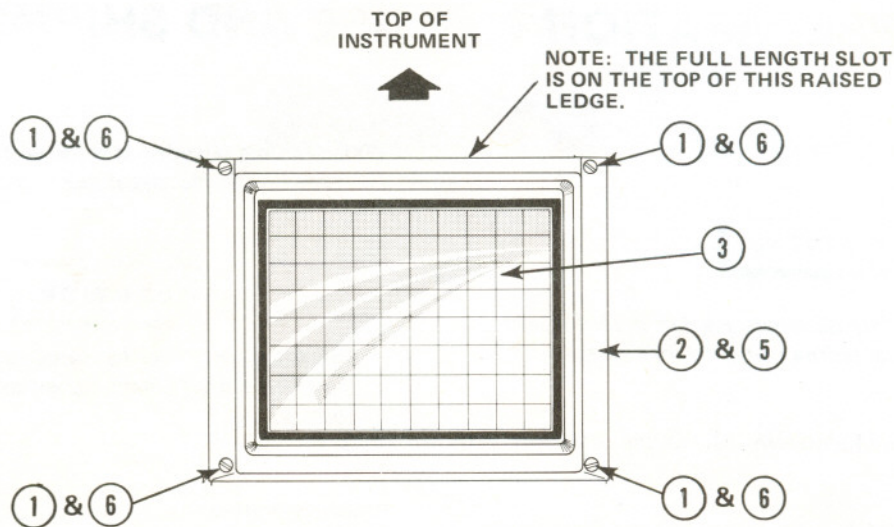
Before operating the instrument, perform the following line range selection and fuse verification procedures:

WARNING

To prevent electrical shock hazards when changing line voltage ranges or checking fuses, disconnect the power cord from the power source.

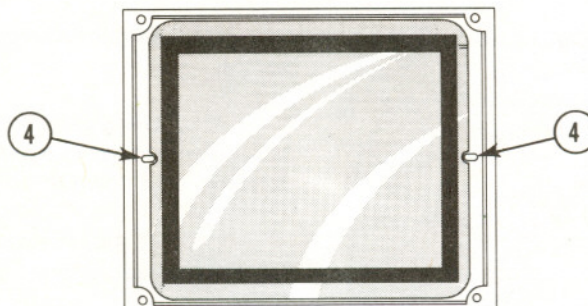
- (1). Disconnect the instrument from the power source.
- (2). Using a small blade screwdriver or other small blunt item (similar to a dull pencil), slide the LINE RANGE Selector up or down to the desired position (see Figure 3-3.)
- (3). Change the line cord plug to match the power source receptacle or use a 116 to 232 volt adapter.
- (4). Change the line fuse to the correct value. The correct fuse value for 116 volt operation is 1 A/250 volt, and for 232 volt operation is 0.5 A/250 volt.

f. Power Cord Information. This instrument has a detachable three wire power cord with a polarized plug for connection to the power source. The grounding terminal is directly connected to the instrument chassis. When not being used, the power cord may be removed and placed in the front cover.



REMOVAL INSTRUCTIONS

- ① UNSCREW FOUR CORNER THUMBSCREWS (DO NOT UNSCREW COMPLETELY OUT OF PLASTIC IMPLOSION RETAINER).
- ② PULL IMPLOSION RETAINER WITH FILTER FORWARD AWAY FROM CRT FACEPLATE.
- ③ REMOVE FILTER BY LIFTING IT OUT OF THE IMPLOSION RETAINER.



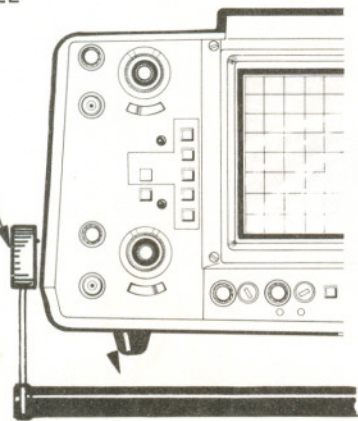
INSTALLATION INSTRUCTIONS

- ④ INSTALL FILTER IN NOTCHES ON IMPLOSION RETAINER WITH THE BLACK MASK AWAY FROM THE CRT.
- ⑤ POSITION IMPLOSION RETAINER ON CRT FACEPLATE SO FULL LENGTH SLOT IS TOWARD THE TOP OF THE INSTRUMENT.
- ⑥ SCREW IN THE FOUR CORNER THUMBSCREWS.

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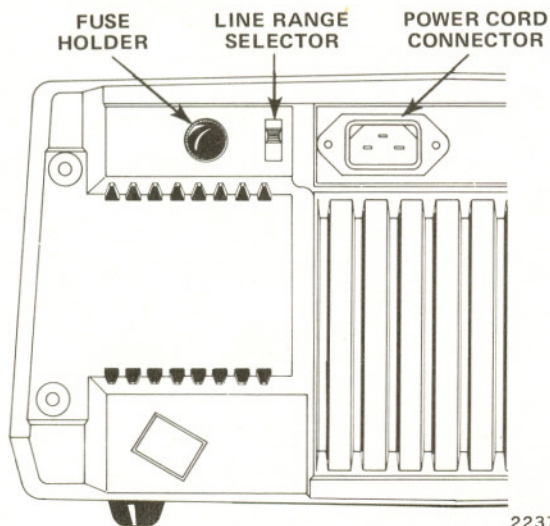
Figure 3-1. Removal and installation of faceplate filters.

PRESS IN ON PIVOT POINTS
BOTH SIDES TO POSITION
CARRYING HANDLE



2237-3

Figure 3-2. Carrying handle positioning.



2237-4

Figure 3-3. Power section of rear panel.

WARNING

This instrument is intended to be operated from a single phase power source. Operation from other power sources such as phase-to-phase on a three wire system is not recommended.

3-2. OPERATING TEMPERATURE. This instrument is cooled by natural convection; therefore, adequate clearance (at least one inch) should be maintained around the case. The clearance provided by the feet on the rear panel must be maintained to prevent power supply overheating. A thermal cutout inside the instrument provides overheating protection and disconnects power if the internal temperature exceeds a safe operating level. Power is automatically restored when the internal temperature returns to a safe operating level.

CAUTION

To prevent damage to the instrument when it continually shuts down due to overheating, it should be turned-off and referred to maintenance personnel.

3-3. PREPARATION FOR SHIPMENT. For shipment of the instrument, refer to the current edition of MIL-P-116 and MIL-STD-794 for preservation and packaging instructions and methods.

SECTION IV

OPERATION INSTRUCTIONS

4-1. THEORY OF OPERATION. The following discussion describes the operation of the oscilloscope circuitry. First a general description of the overall relationship between the basic circuits is given. Then each circuit is described in detail.

4-2. BASIC CIRCUIT FUNCTIONS. The overall relationship between the basic circuits is described below. Refer to the basic block diagram shown in Figure 4-1 to aid in understanding the discussion.

a. Vertical Module. The Vertical Module contains the CH 1 and CH 2 Input, CH 1 and CH 2 Preamplifier and Vertical Switching Hybrid Integrated Circuit, Vertical Switching Control Circuit, Delay Line Driver and Delay Line, and the Vertical Amplifier (see Figure 4-1).

(1) CH 1 and CH 2 Input. The Input circuits provide input coupling and attenuation for the signals connected to the CH 1 and CH 2 input connectors. AC, DC, and GND coupling modes are provided. Two attenuators in each channel provides attenuation factors of 10:1, 100:1, or when switched in series 1000:1.

(2) CH 1 and CH 2 Preamplifier and Vertical Switching. U4160 is a hybrid integrated circuit which contains the Vertical Switching circuitry and both the CH 1 and CH 2 Preamplifiers.

(a) The signal from the vertical input attenuators is applied to U4160, amplified, and supplied to the Delay Line Driver. In conjunction with the input attenuators, the gain of the preamplifiers is changed to provide the deflection factors indicated by the VOLTS/DIV switches. A sample of the signals present in the amplifiers is supplied to the Trigger Switching and Trigger Input Amplifiers in the Horizontal Module.

(b) The Vertical Switching circuitry selects which preamplifier will supply the signal to the Delay Line Driver.

(3). Vertical Switching Control. Inputs to this circuit are from the VERT MODE switch and from the Sweep Control circuit (alternate sync pulse). The output is supplied to U4160 to control Vertical Switching.

(4) Delay Line Driver and Delay Line. The vertical signal from the CH 1 and CH 2 Preamplifiers is amplified by the Delay Line Driver and supplied to the Delay Line. The Delay Line delays the vertical signal enough so the portion of the vertical signal initiating the sweep can be viewed.

(5) Vertical Amplifier. This circuit amplifies the signal from the Delay Line. The amplified signal is used to drive the vertical deflection plates of the crt.

b. Horizontal Module. The Horizontal Module contains Trigger Input Amplifiers and Trigger Switching, A Trigger Generator, B Trigger Generator, A Sweep Generator, B Sweep Generator, Horizontal Preamplifier, +A GATE OUT Amplifier, +B GATE Buffer, and Sweep Control (see Figure 4-1).

(1) Trigger Input Amplifiers and Trigger Switching. The Trigger Input Amplifiers are buffer amplifiers between the Trigger Generators and the source of the trigger signal. Trigger Switching selects the source of the signal used to trigger the Sweep Generator(s) and selects the method of coupling this signal to the Trigger Generator(s).

(2) A Trigger Generator. Using a signal selected by the A Trigger SOURCE switch, the A Trigger Generator produces a pulse which causes the A Sweep Generator to produce an A sweep ramp.

(3) B Trigger Generator. Using a signal selected by the B Trigger SOURCE switch, the B Trigger Generator produces a pulse which causes the B Sweep Generator to produce a B sweep ramp.

(4) A Sweep Generator. The A Sweep Generator, when initiated by the A Trigger Generator, produces a linear sawtooth output signal. The slope of the sawtooth is controlled by the A TIME/DIV switch.

(5) B Sweep Generator. The B Sweep Generator is basically the same as the A Sweep Generator. However, it produces a sawtooth output signal only after a delay time selected by the A TIME/DIV switch and the DELAY TIME POS control. When the B Trigger SOURCE switch is in the STARTS AFTER DELAY position, the B Sweep Generator begins to produce a sawtooth immediately following the selected delay time. In the other positions of the B Trigger SOURCE switch, the B Sweep Generator does not produce a sawtooth until it receives a trigger pulse occurring after the selected delay time.

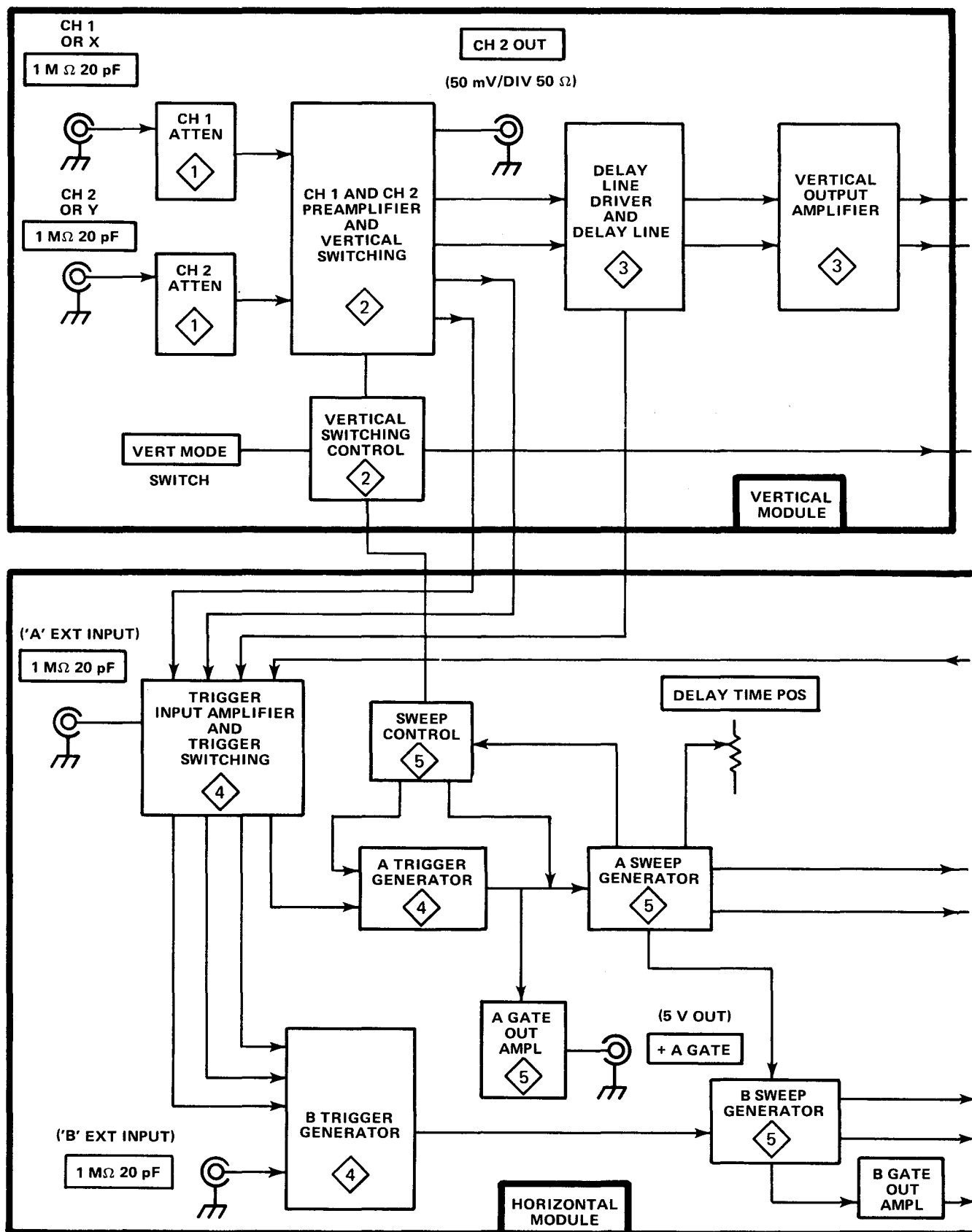


Figure 4-1. Overall block diagram (sheet 1 of 2).

2237-41

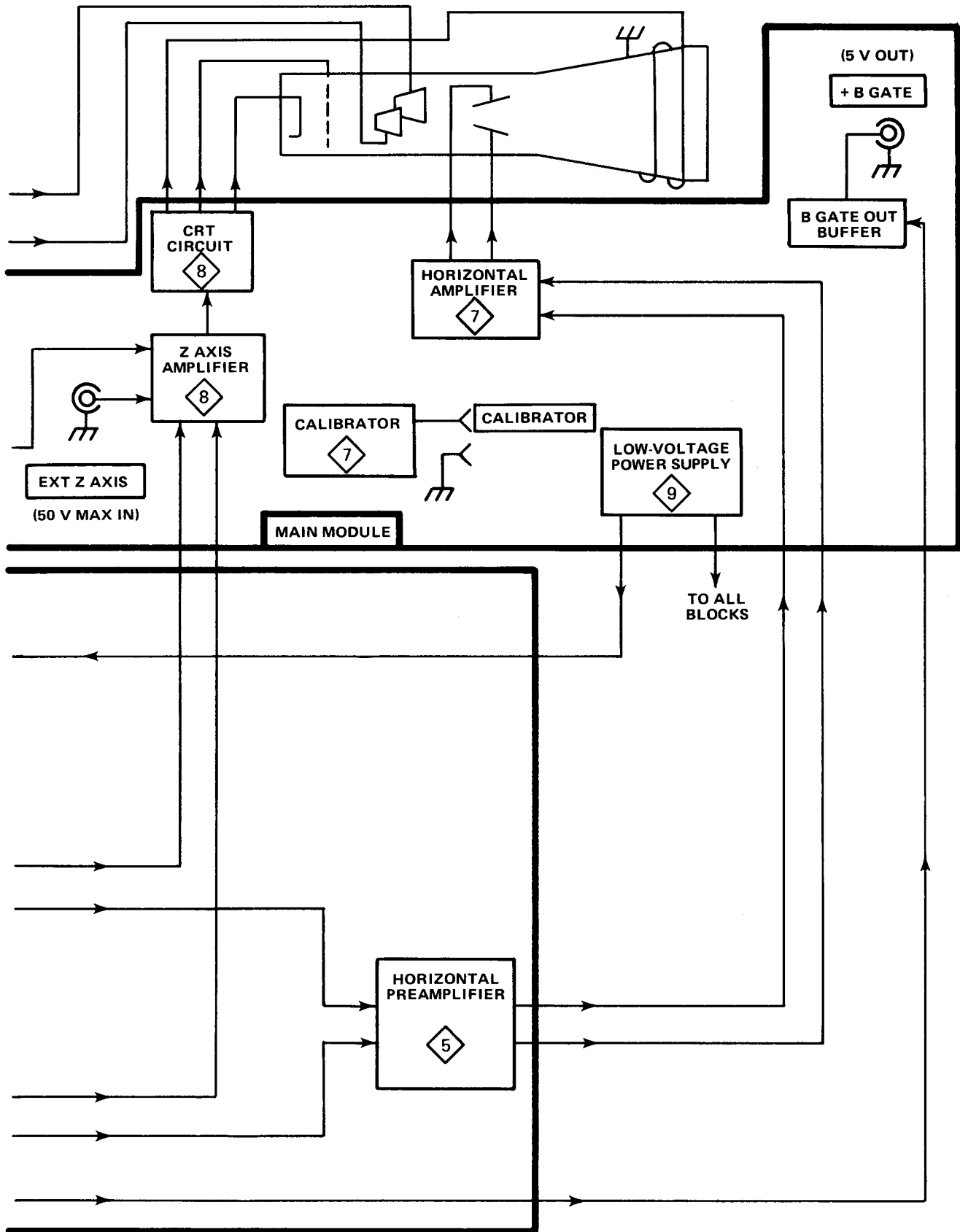


Figure 4-1. Overall block diagram (sheet 2 of 2).

(6) Horizontal Preamplifier. This circuit amplifies the output of the A or B Sweep Generator. The amplified sweep ramp is supplied to the Horizontal Amplifier in the Horizontal Module. In the X10 position of the X10 MAG switch, the gain of the Horizontal Preamplifier is increased by a factor of ten which increases the displayed sweep rate by a factor of ten. In the X-Y position of the TIME/DIV switches, the signal from the CH 1 Preamplifier is connected to the Horizontal Preamplifier and provides horizontal deflection.

(7) +A GATE OUT Amplifier. This circuit samples the A sweep start gate and produces a positive-going rectangular pulse coincident with A sweep time.

(8) +B GATE OUT Buffer. This circuit sums the B sweep holdoff signal from U2690, the delayed gate, and the B sweep gate, and produces an output signal coincident with B sweep time. This output is supplied to the +B GATE OUT Amplifier in the Main Module.

(9) Sweep Control. The Sweep Control circuitry is contained in an integrated circuit. This circuitry controls A Sweep holdoff time and A Trigger mode, and supplies the alternate sync pulse to the Vertical Switching Control circuit.

c. Main Module. The Main Module contains the Z Axis Amplifier, Crt Circuit, Horizontal Amplifier, Calibrator, and Low Voltage Power Supply.

(1) Z-Axis Amplifier. This circuit amplifies the unblanking signals supplied by the Vertical Switching Control circuit, the A Sweep Generator, and the B Sweep Generator. The output controls the brightness of the display through the Crt Circuit.

(2) Crt Circuit. This circuit provides the high voltages needed for operation of the crt.

(3) Horizontal Amplifier. This circuit amplifies the sweep ramp signal supplied by the Horizontal Preamplifier in the Horizontal Module. The output of the Horizontal Amplifier drives the horizontal deflection plates of the crt.

(4) +B GATE OUT Amplifier. This circuit amplifies the signal from the +B GATE OUT Buffer in the Horizontal Module. The amplified signal is supplied to an externally accessible BNC connector. The output signal is a positive-going rectangular pulse coincident with B Sweep time.

(5) Calibrator. The Calibrator provides an externally accessible square-wave output with an accurate voltage amplitude. This signal is used for checking vertical deflection accuracy and probe compensation.

(6) Low Voltage Power Supply. The Low Voltage Power Supply provides the low voltages needed to operate the oscilloscope. The high voltages are supplied by the Crt Circuit.

4-3. DETAILED CIRCUIT OPERATION. The following detailed circuit description is subdivided according to the overall block diagram shown in Figure 4-1. Simplified diagrams are used, where needed, for clarity. Complete schematic diagrams are located in Section VI.

a. Vertical Module.

(1) CH 1 and CH 2 Input. The CH 1 and CH 2 Input circuits are shown in Diagram 1 (FO-3). These circuits contain the input coupling switches, the vertical attenuators, and input source followers. Both circuits are the same so only the CH 1 circuit will be discussed.

(a) Input Coupling Switches. S4100A selects the method of coupling the input signal to the attenuators.

1 In the DC position of S4100A, the input signal is connected directly to the attenuators.

2 In the AC position of S4100A, the input signal passes through C4102 and then to the attenuators. This blocks the dc component of the input signal.

3 In the GND position of S4100A, the gate of the input source follower (Q4124A) is connected to ground through R4103. Since the resistance of R4103 is so small compared to that of R4102, the percentage of the input signal passed to the gate of Q4124A is negligible. This essentially disconnects the input signal from Q4124A and provides a 0 volt reference display. Also, in the GND position of S4100A, C4102 charges to the average dc level of the input signal through R4102 and R4103. This prevents coupling a high-amplitude transient to Q4124A when S4100A is switched from GND to AC.

(b) Vertical Attenuators. To obtain the vertical deflection factors indicated by the VOLTS/DIV control, the input signal is attenuated and the gain of the Vertical Preamplifier is reduced (see 4-3. a. (2) (a) 1). The attenuators are frequency-compensated voltage dividers. The attenuators provided are a divide by ten and a divide by one hundred. To obtain divide by 1000, the two attenuators are connected in series. Table 4-1 shows the VOLTS/DIV settings and the attenuation and gain switching required to obtain them.

Table 4-1. Attenuation and Gain Switching Sequence

VOLTS/DIV SETTING	ATTENUATION	GAIN REDUCTION
5 mV	1X	1X
10 mV	1X	2X
20 mV	1X	4X
50 mV	10X	1X
100 mV	10X	2X
200 mV	10X	4X
500 mV	100X	1X
1 V	100X	2X
2 V	100X	4X
5 V	1000X	1X

(c) **Input Source Followers.** The signal from the CH 1 attenuator is connected to the gate of Q4124A. The one megohm input impedance seen at J4100 is determined by R4122. To prevent damage to Q4124A in the presence of high-amplitude positive-going input signals, R4123 limits gate current. In the presence of high-amplitude negative-going input signals, CR4124 clamps the gate of Q4124A to about -5.7 volts and R4123 limits the current through CR4124. FET Q4124B provides a relatively constant current source for Q4124A.

(2) **CH 1 and CH 2 Preamplifier and Vertical Switching.** A schematic diagram of this circuit is shown in Diagram 2 (FO-4). The preamplifier and switching circuits are both contained in one hybrid integrated circuit (U4160). The preamplifier circuits provide the initial stages of amplification for the vertical input signals. The switching circuit determines which of the vertical input signals will be displayed on the crt.

(a) **CH 1 and CH 2 Preamplifier.** The single-ended signals from the input source followers are connected to terminals 1 and 32, respectively of U4160. The single-ended input signals are converted to paraphase signals and internally connected to the Vertical Switching circuit.

1 **Gain Switching.** To provide the vertical deflection factors indicated by the VOLTS/DIV control, the gains of the preamplifiers are reduced and attenuators are switched into the signal path, see 4-3. a. (1) (b). The CH 1 gain setting resistors are connected from terminals 4 and 6 to terminals 7 and 8 of U4160. The CH 2 gain setting resistors are connected from terminals 29 and 31 to terminals 26 and 27 of U4160. The VOLTS/DIV switches determine which gain setting resistors are used. Table 4-1 shows the VOLTS/DIV settings and the attenuation and gain switching needed to obtain them.

2 **CH 2 INVERT.** The CH 2 signal can be inverted as displayed on the crt. This is done by inverting the

signal in the CH 2 Preamplifier. The polarity of the CH 2 signal is determined by the dc voltage on terminals 34 and 36 of U4160. With 0.8 volts on terminal 34 and 0.0 volts on terminal 36, the CH 2 signal is not inverted. To invert the signal, the INVERT switch (S4240) is pushed, which sets terminal 34 to 0.0 volts and terminal 36 to 0.8 volts.

(b) **Vertical Switching.** Transistor gates within U4160 allow either the CH 1 or CH 2 signal to be connected to the output of U4160 (terminals 17 and 18). The transistor gates are controlled by the Vertical Switching Control circuit. Figure 4-2 shows a simplified diagram of the transistor gates and the Vertical Switching Control circuit. Figure 4-2 shows the signal path with the VERT MODE switch set to CH 1.

(c) **CH 1 and CH 2 Trigger Pickoff.** U4160 supplies samples of the signals present in the CH 1 and CH 2 Preamplifiers to the trigger circuits. The CH 1 trigger signal output is at terminal 13 of U4160 and the CH 2 trigger signal output is at terminal 22 of U4160.

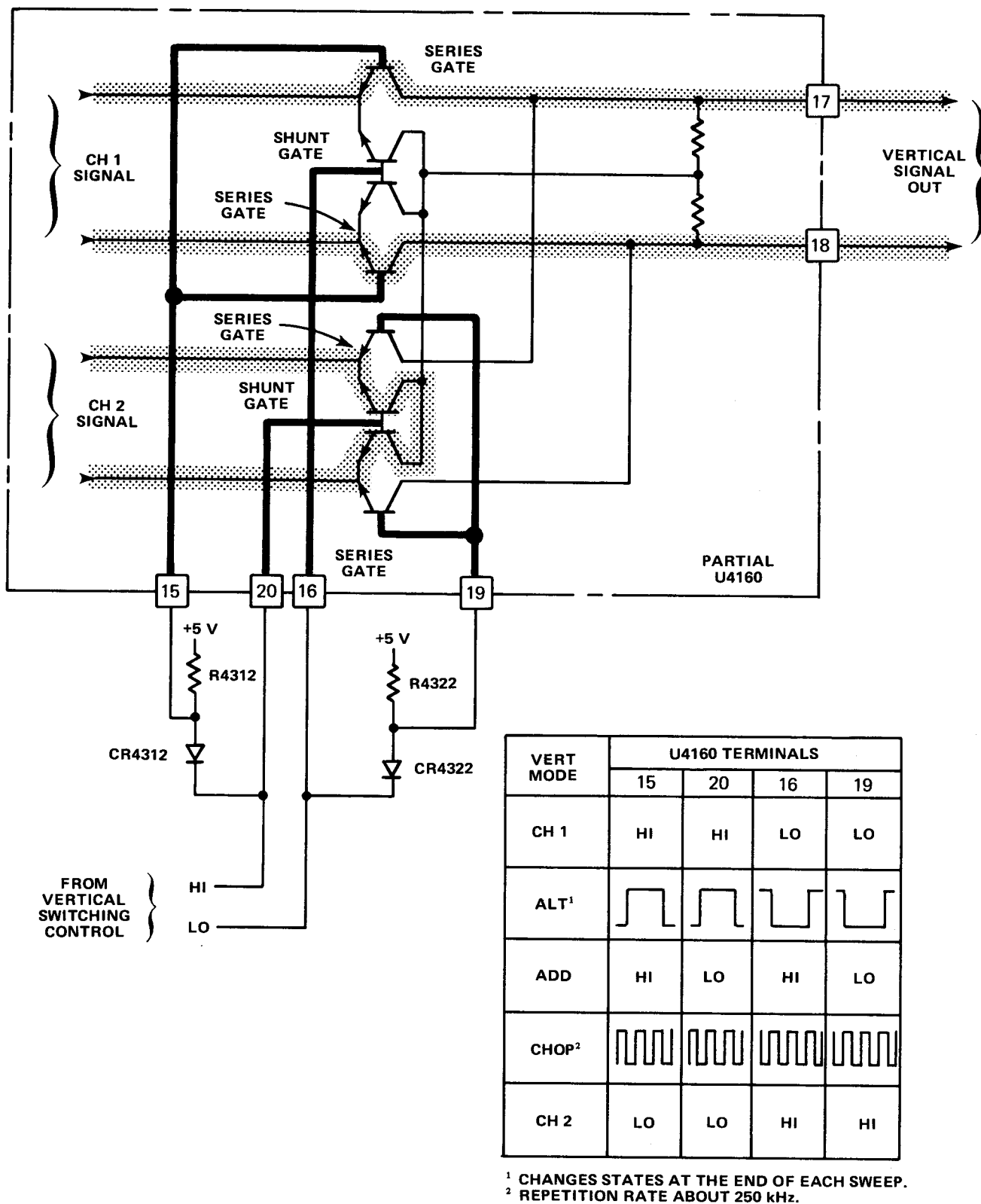
(d) **CH 2 OUT Signal Pickoff.** Terminal 21 of U4160 supplies a sample of the signal present in the CH 2 Preamplifier to the base of Q4282. This signal is amplified through Q4282 and Q4288, then connected to the CH 2 OUT connector (J4289).

(e) **X-Axis Signal Pickoff.** A sample of the signal present in the CH 1 Preamplifier is supplied to terminal 14 of U4160. In the X-Y horizontal mode, this signal is connected to the Horizontal Preamplifier in the Horizontal Module and provides horizontal deflection for the crt.

(3) **Vertical Switching Control.** Diagram 2 (FO-4) shows the Vertical Switching Control circuitry. Transistor gates within U4160 determine which of the signals in the CH 1 and CH 2 Preamplifiers is supplied to the output of U4160 (terminals 17 and 18). The CH 1 gate is controlled by the voltages on terminals 15 and 16 of U4160. The CH 2 gates are controlled by the voltages on terminals 19 and 20 of U4160. These voltages are controlled by the channel switching multivibrator and the VERT MODE switch.

(a) **Channel Switching Multivibrator.** The channel switching multivibrator consists of Q4316 and Q4326. The multivibrator operates in the CHOP and ALT settings of the VERT MODE switch. In the CHOP mode, the multivibrator is free running at about 250 kilohertz. In the ALT mode it switches states when triggered by the alternate trace sync pulse through Q4334.

(b) **CH 1 Vertical Mode.** When the VERT MODE switch is set to CH 1, -5 volts is connected to R4323 through the VERT MODE switch S4330. Resistors R4323 and R4322 form a divider which sets terminals 16 and 19



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Figure 4-2. Channel switching gates.

of U4160 LO. Terminals 15 and 20 of R4160 are pulled HI through R4312. This turns off the CH 2 series gate and turns on the CH 1 series gate. The CH 1 signal passes to terminals 17 and 18 of U4160.

(c) CH 2 Vertical Mode. This mode works the same as the CH 1 mode except —5 volts is connected to R4313 setting terminals 15 and 20 LO and terminals 16 and 19 are pulled HI through R4322. This turns on the CH 2 series gate and allows the CH 2 signal to pass to terminals 17 and 18 of U4160.

(d) Add Vertical Mode.

1 In the ADD mode the algebraic sum of the output signals from the CH 1 and CH 2 Preamplifiers is supplied to terminals 17 and 18 of U4160.

2 When the VERT MODE switch (S4330) is set to ADD, neither R4313 nor R4323 are connected to —5 volts. This allows terminals 15 and 19 to be pulled HI through R4312 and R4322 respectively. Terminal 20 is also pulled positive through R4312 but, because of CR4312, terminal 20 is LO with respect to terminal 15. In the same way, terminal 16 is LO with respect to terminal 19 due to CR4322. This turns on both the CH 1 and CH 2 series gates and turns off both shunt gates (see Figure 4-2). Both signals pass to terminals 17 and 18 of U4160.

(e) ALT Vertical Mode. In the ALT mode the channel switching multivibrator operates as a bistable multivibrator. The state of the multivibrator is switched at the end of each sweep. The CH 1 and CH 2 signals are individually displayed on alternate sweeps.

1 When the VERT MODE switch is set to ALT, —5 volts is connected to the emitter of Q4334 through R4333. The base of Q4334 is pulled positive with respect to its emitter through R4334. This turns on Q4334 and provides the negative supply voltage for the multivibrator.

2 When Q4334 turns on, either Q4316 or Q4326 will turn on. Assume Q4316 turns on. This pulls terminals 15 and 20 of U4160 LO. Terminals 16 and 19 are pulled HI through R4322. This blocks the CH 1 signal and passes the CH 2 signal to terminals 17 and 18 of U4160.

3 While Q4316 is on, the end of C4316 connected to the emitter of Q4316 charges positive with respect to the end connected to the emitter of Q4326.

4 At the end of each sweep, the Sweep Control circuit in the Horizontal Module supplies a negative-going pulse to the base of Q4334. This momentarily turns off Q4334 removing the negative supply voltage from the multivibrator. Neither Q4316 nor Q4326 can conduct.

5 We previously assumed Q4316 was on and had charged the end of C4316 connected to the emitter of Q4316 positive with respect to its other end. When Q4334 again turns on, the emitter of Q4326 will be more negative than the emitter of Q4316. Therefore Q4326 will turn on, reversing the previously assumed condition. Terminals 16 and 19 of U4160 will be pulled LO through Q4326 and terminals 15 and 20 will be pulled HI through R4312. The CH 2 signal will be blocked and the CH 1 signal will pass to terminals 17 and 18 of U4160.

(f) CHOP Vertical Mode. In the CHOP mode the channel switching multivibrator operates as an astable multivibrator. The CH 1 and CH 2 signals are alternately displayed during the same sweep. The switching transients are blanked and cannot be seen.

1 When the VERT MODE switch is set to CHOP, —5 volts is connected to the emitters of Q4316 and Q4326 through R4318 and R4328, respectively. This provides the negative supply voltage for the channel switching multivibrator. The multivibrator operates as an astable multivibrator with a repetition rate of about 250 kilohertz. Transistors Q4316 and Q4326 conduct alternately to switch the CH 1 and CH 2 transistor gates in the same manner as for the ALT setting of the VERT MODE switch.

2 The frequency determining components are C4316, R4318, and R4328.

3 The chop blanking amplifier (Q4338) provides an output pulse to the Z Axis Amplifier to blank the switching transients. During the time the multivibrator is switching, the current change in the primary of T4335 induces a voltage in the secondary. This induced voltage drives the base of Q4338 negative which turns it off. The resulting positive-going pulse on the collector of Q4338 is supplied to the Z Axis Amplifier in the Main Module. The length of this pulse is determined by R4335 and C4335.

(4) Delay Line Driver and Delay Line. Diagram 3 (FO-5) shows the Delay Line Driver and Delay Line circuitry. The Delay Line Driver buffers the vertical signal from terminals 17 and 18 of U4160 and supplies it to the Delay Line. The Delay Line delays the vertical signal about 120 nanoseconds. The Delay Line Driver and Delay Line circuitry also contains the NORM trigger signal pickoff, the BW LIMIT 20 MHz switch, and the TRIG VIEW switch.

(a) Delay Line Driver. The output from the channel switching gates, at terminals 17 and 18 of U4160, is applied to the Delay Line Driver (Q4342, Q4352, Q4362, and Q4372). Transistors Q4342 and Q4352 buffer the output of U4160 to provide optimum frequency response. Transistors Q4362 and Q4372 are connected as feedback

amplifiers with R4362 and R4372 providing feedback. Resistors R4365 and R4375 provide reverse termination for the Delay Line.

(b) NORM Trigger Signal Pickoff. A sample of the signal present in the Delay Line Driver is supplied to the base of emitter follower Q4384. The signal on the emitter of Q4384 is supplied to the Trigger Switching circuit in the Horizontal Module. This signal is used to trigger the sweep on the signal providing vertical deflection regardless of the setting of the VERT MODE switch.

(c) BW LIMIT 20 MHz Switch. When the BW LIMIT 20 MHz switch (S4380) is pulled, a low-pass filter is placed in the vertical path between the Delay Line Driver and the Delay Line. The filter components are C4388, C4389, L4378, and L4388. The inductors are in series with the signal path blocking high frequencies and the capacitors are in parallel with the signal path shunting high frequencies. This limits the upper -3 dB point of the vertical system to 20 megahertz.

(d) TRIG VIEW Switch. When the TRIG VIEW switch (S4380) is pushed in and held, the vertical signal is disconnected from the Delay Line input and a sample of the signal being applied to A Trigger Generator is applied in its place. This allows viewing the signal being applied to the A Trigger Generator at the time the sweep is triggered. This is useful when using an external source for triggering (in the EXT and EXT ÷ 10 positions of the A SOURCE switch).

(e) Delay Line. The Delay Line (DL4400) provides about 120 nanoseconds of signal delay. The delay allows the Trigger Generator to initiate sweep generation before the vertical signal reaches the crt. This allows viewing the portion of the vertical input signal at which the sweep is triggered.

(5) Vertical Amplifier. The Vertical Amplifier amplifies the signal from the output of the Delay Line to a level sufficient to drive the vertical deflection plates of the crt.

(a) The Vertical Amplifier is a two-stage cascode amplifier. The first stage consists of Q4421, Q4429, Q4431, and Q4439. The second stage consists of Q4447, Q4463, Q4457, and Q4473. A cascode amplifier consists of a common-emitter amplifier driving a common-base amplifier.

(b) The series RC networks between the emitters of Q4421 and Q4431 in the first stage provide high-frequency compensation. Thermistor RT4419 and varactors CR4416 and CR4417 correct for changes in high-frequency compensation as temperature changes.

(c) As temperature increases the gain of an amplifier of this type decreases. To compensate for this, the resistance of thermistor RT4416 decreases as temperature increases. This reduces the emitter resistance of Q4421 and Q4431. The decreased emitter resistance decreases the negative feedback due to the emitter resistance and holds the gain constant as temperature increases.

(d) Overall gain of the Vertical Amplifier is adjusted by R4443. Adjusting R4443 changes the collector load resistance on Q4429 and Q4439.

(e) Part of the BEAMFINDER switch (S500) is located in the Vertical Amplifier.

1 When S500 is not pushed, the junction of R4427 and R4437 is directly connected to +5 volts through S500. Resistors R4427 and R4437 supply current to Q4429 and Q4439.

2 When S500 is pushed, it removes +5 volts from the junction of R4427 and R4437. Now +5 volts is supplied to the junction of R4427 and R4437 through R4425. The increased resistance reduces the current supplied to Q4429 and R4439 reducing their dynamic range. The reduced dynamic range prevents Q4429 and Q4439 from passing any vertical signals which would cause an off-screen display. The resulting vertical display is compressed and always appears on the crt regardless of the amplitude of the input signal or the setting of the vertical POSITION control.

b. Horizontal Module.

(1) Trigger Input Amplifiers and Trigger Switching. Diagram 4 (FO-6) shows a schematic diagram of this circuit. The Trigger Input Amplifier buffers the trigger signal. The Trigger Switching circuit selects the source of the trigger signal and the method of coupling the trigger signal to the Trigger Generator.

(a) CH 1 and CH 2 Trigger Input Amplifiers. The CH 1 and CH 2 trigger signals are supplied by U4160 in the Vertical Module. The signals pass through emitter followers Q4142 and Q4122. The outputs of the emitter followers are supplied to the SOURCE switches.

(b) NORM Trigger Input Amplifier. The NORM trigger signal is picked off the Delay Line Driver circuit. Emitter follower Q4384, in the Delay Line Driver circuit, buffers the signal and supplies it to the SOURCE switches.

(c) EXT Trigger Input Amplifier.

1 The A EXT Trigger Input Amplifier consists of Q2212, Q2214, and Q2216. The B EXT Trigger Input Amplifier consists of Q2112, Q2114, and Q2116. Both amplifiers are the same so only the A EXT Trigger Input Amplifier will be discussed.

2 The A EXT trigger signal is applied to J2205. The signal passes through one of two voltage dividers. The A SOURCE switch (S2200) determines which divider is selected. In the EXT position, the A SOURCE switch selects the divider composed of R2205-C2205 and R2206-C2206. In the EXT position the selected divider attenuates the input signal by a factor of about 4. In the EXT \div 10 position, the A SOURCE selects the divider composed of R2203-C2203 and R2204-C2204. In the EXT \div 10 position the selected divider attenuates the input signal by a factor of about 40. The capacitors in parallel with the divider resistors provide correct voltage divider action at high frequencies.

3 In the AC, LF REJ, and HF REJ positions of the A COUPLING switch (S2220), the signal from the output of the selected voltage divider is coupled to the gate of Q2212 through a capacitor (C2212). In the DC position, the signal is directly connected to the gate of Q2212.

4 The EXT signal is applied to the gate of source-follower Q2212. FET Q2214 provides a relatively-constant current source for Q2212. Diode CR2214 compensates for current changes as temperature changes by slightly adjusting the bias on Q2214. The signal on the source of Q2212 is applied to the base of emitter follower Q2216. The signal on the emitter of Q2216 is supplied to the A SOURCE switch.

5 To protect Q2212 in the presence of high-amplitude positive-going input signals, R2203 or R2205 (depending on the A SOURCE setting) limits the gate current that can be drawn by Q2212. In the presence of high-amplitude negative-going signals, CR2213 becomes forward biased. The path for current flow is from -5 volts through R2229, CR2213, and R2204 or R2205. Resistor R2203 or R2205 limits the current through R2229 and CR2213 preventing the anode of CR2213 from going more negative than about -6 volts.

(d) Trigger Switching. Trigger SOURCE Switching selects the source of the signal applied to the Trigger Generators. Trigger COUPLING Switching determines the band of frequencies supplied to the Trigger Generators. The A and B Trigger Switching circuits are the same except A SOURCE has a LINE position and B SOURCE has a STARTS AFTER DELAY position. The LINE position supplies a sample of the power line voltage from the Low-Voltage Power Supply to the A Trigger Generator. The STARTS AFTER DELAY position will be discussed in the B Trigger Generator description. Since both circuits are so similar, only the A Trigger Switching circuit will be discussed.

1 Two paths exist for the triggering signal. The high-frequency signal components connect directly to input pins of U2260. The low-frequency signal components connect to pin 19 of U2260 through the A SOURCE switch.

Figure 4-3A shows a simplified diagram of the low-frequency signal path. Figure 4-3B shows a simplified diagram of the high-frequency signal path.

2 Figure 4-4 shows a simplified diagram of signal flow with A SOURCE set to NORM and A COUPLING set to AC. Other SOURCE settings operate in a similar manner. Each of the high-frequency signal inputs to U2260 is internally connected to the base of an emitter follower. Normally these emitter followers are prevented from conducting by connecting the base to -2 volts through a pair of resistors (see Figure 4-4). To select a high-frequency input, the junction of these resistors is connected to ground through the SOURCE switch which allows the emitter in U2260 to conduct. For instance, to select the NORM trigger source, the junction of R2233 and R2238 is grounded through the A SOURCE switch (see Figure 4-4).

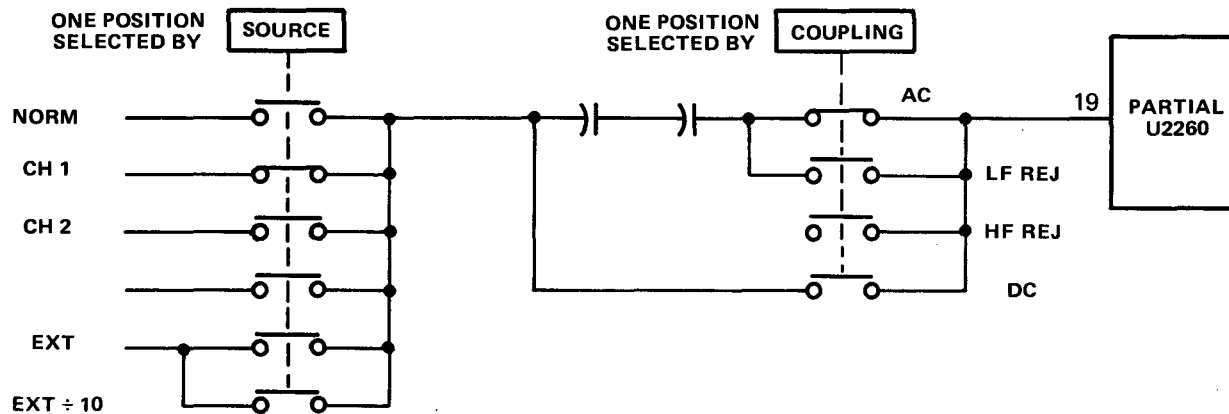
3 For all A COUPLING settings except HF REJ, the resistor junction selected is connected to ground through the A COUPLING switch (see Figure 4-3B and Figure 4-4). In the HF REJ position, the selected resistor junction is disconnected from ground and pin 4 of U2260 is selected by grounding the junction of R2243 and R2242. Pin 4 must be selected even though no signal is connected to it because one of the emitter followers within U2260 must be selected for proper operation of U2260. Since the high-frequency signal path is opened the only signal supplied to the A Trigger Generator is through the low-frequency path.

4 For the AC and HF REJ positions of the A COUPLING switch, the low-frequency signal is ac coupled through C2226 and C2227 to pin 19 of U2260. In the dc position, the low-frequency signal is dc coupled (C2226 and C2227 are bypassed). In the LF REJ position, the low-frequency signal is interrupted and only the high-frequency signal is connected to the A Trigger Generator.

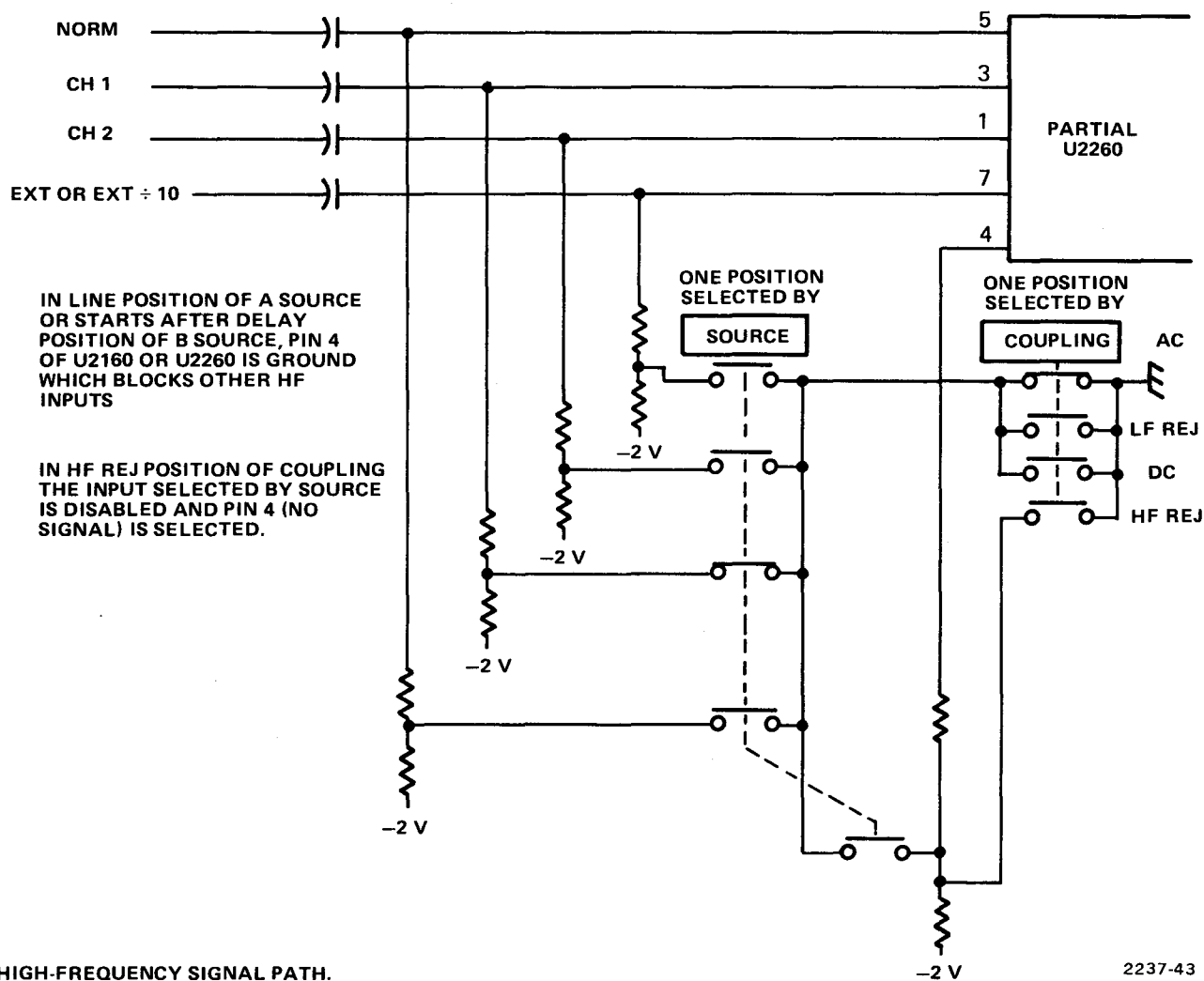
(2) A Trigger Generator. The A Trigger Generator consists of U2260 and associated circuitry. Figure 4-5 shows a simplified diagram of the A Trigger Generator.

(a) Sequence of Events During Trigger Generation. The following discussion will follow the sequence of events in the A Trigger Generator. Refer to Figure 4-5 throughout the discussion.

1 **During Holdoff.** Point E is held HI by the holdoff gate at pin 17 of U2260. Point I is held HI by the complement sweep gate output at point L causing point J to be LO. Both of the arm latch inputs are LO. The output of the arm latch (point K) has previously been reset to HI (at the beginning of holdoff by the holdoff signal applied to pin 17 of U2260). When point K is HI, pin 14 will be held LO regardless of the trigger signal input. The sweep gate latch is held off.



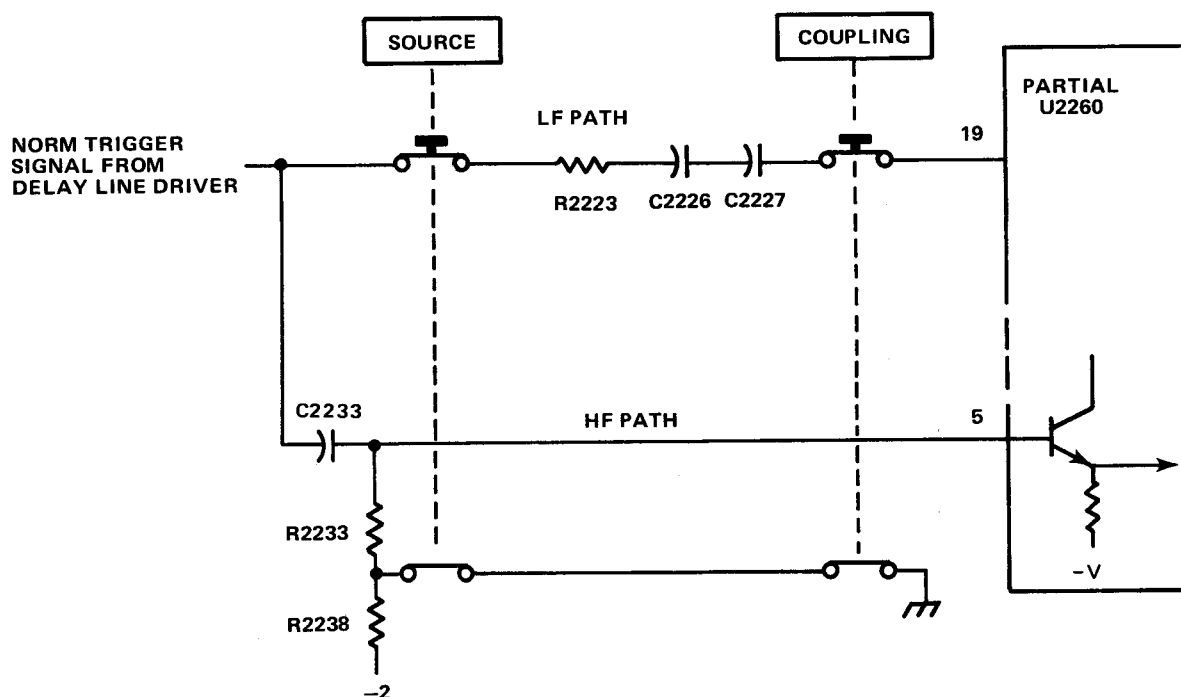
A. LOW-FREQUENCY TRIGGER SIGNAL PATH.



B. HIGH-FREQUENCY SIGNAL PATH.

Figure 4-3. Trigger switching.

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CONNECTING THE RESISTOR JUNCTION TO GROUND TURNS ON THE EMITTER FOLLOWER WITHIN U2260. DISCONNECTING THE GROUND CONNECTS THE BASE TO -2 V, THRU R2233 AND R2238, AND TURNS OFF THE EMITTER FOLLOWER.

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Figure 4-4. Trigger signal paths with SOURCE set to NORM and COUPLING set to AC.

2 At the End of Holdoff. At the end of hold-off, pin 17 of U2260 steps LO causing point H to step HI. There are now two possibilities depending on the state of the signal at point A. If the trigger input signal at point A is above the 3.55 volt threshold at the end of holdoff, no further changes will occur at this time. The HI at point K will continue to hold pin 14 LO. If the trigger input signal at point A is below the 3.55 volt threshold at the end of holdoff (or the first time after the end of holdoff the trigger input signal falls below the 3.55 volt threshold), point D goes LO setting point F HI. This sets the arm latch causing point K to go LO. With point K LO, the sweep gate latch will be allowed to change states.

3 After the Arm Latch Sets. After the arm latch sets, the first voltage at point A that is more positive than the 3.65 volt threshold, causes point B to go HI. This causes the output of the sweep gate latch (pin 14 of U2260) to go HI. The HI on pin 14 causes the A Sweep Generator to begin generating a sweep ramp.

4 Beginning of Holdoff. At the end of A Sweep time, the holdoff gate at pin 17 of U2260 steps HI. This causes point H to step LO. Point I is set to LO whenever the sweep gate (at pin 14) is HI. With points H and I both LO, point J momentarily steps HI. This resets the arm latch causing point K to go HI. When point K goes HI, the sweep gate goes LO and point I goes HI setting point J LO. The holdoff condition described in paragraph 4-3. b. (2) (a) 1 is restored.

(b) Slope Selection. The slope of the trigger input signal, on which a sweep gate is generated, is determined by the voltage connected to pin 8 of U2260. When the voltage is negative, the signal at point A is inverted (see Figure 4-5).

(c) LEVEL Control. The LEVEL control (R2253) shifts the dc level of the signal appearing at point A. This changes the position on the signal where the signal passes through the threshold voltage.

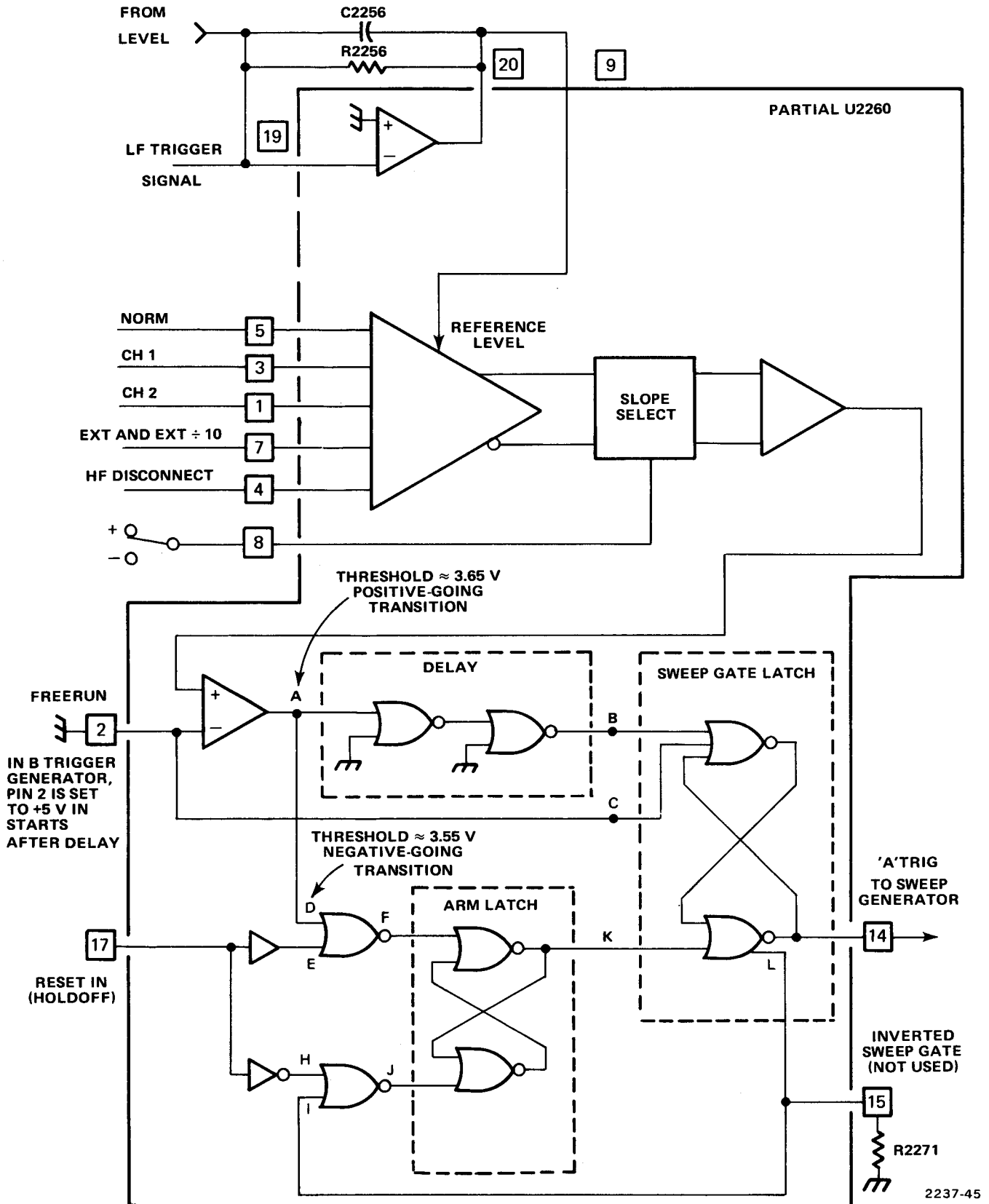


Figure 4-5. A trigger generator.

(d) Hysteresis Adjustment. The hysteresis adjustment (R2245) sets the difference in the trigger threshold and the arm threshold. The closer the levels are to each other, the more susceptible the circuit will be to triggering on noise. If the levels are too far apart, the circuit will require excessive input signal amplitude to generate a sweep gate.

(e) Trigger View Pickoff. A sample of the trigger input signal is supplied to pins 10 and 11 of U2260. This paraphase signal passes through emitter followers Q2350 and Q2356 to the TRIG VIEW switch (S4380). When the TRIG VIEW switch is pushed, the signal from the Delay Line Driver is disconnected from the Delay Line and the trigger view signal is connected in its place.

(3) B Trigger Generator. The B Trigger Generator operates in the same manner as the A Trigger Generator except in the STARTS AFTER DELAY position of the HORIZ DISPLAY switch. In the STARTS AFTER DELAY mode, +5 volts is connected to pin 2 of U2160 through S2100 and S2650 (see Figure 4-5). This disconnects the trigger signal from point B, sets point D LO, and sets point C HI. At the end of holdoff, point E goes LO causing point F to go HI. This sets point K LO and, because of the HI always present on point C, causes a sweep gate to be generated.

(4) A Sweep Generator. A sweep generator consists of U2790 and associated circuitry. Diagram 5 (FO-7) shows a complete schematic diagram of the circuit. Figure 4-6 shows a simplified diagram of the circuit. Figure 4-7 shows the waveforms produced during A sweep generation.

(a) Sweep Generator Integrated Circuits. Both the A and B Sweep Generator integrated circuits (U2790 and U2690 respectively) are the same. However, the functions of some of the pins are different. The following lists the pin numbers and their functions:

1 Pin 1 is the input for the DELAY TIME POS control. This pin is only used in the A Sweep Generator. When the A ramp on pin 2 is equal to the voltage on pin 1, a delayed gate is produced at pin 16.

2 Pin 2 is the input for the ramp voltage from the output Miller circuit. This voltage is internally connected to pin 5 when pin 7 is LO.

3 Pin 3 sets internal current levels.

4 Pin 4 sets the Miller null and retrace currents for the A Sweep Generator only. This function is performed by another circuit in the B Sweep Generator.

5 Pin 5 is the sweep ramp output. The ramp at pin 5 is connected to the Horizontal Preamplifier. Pin 5 is switched on or off by the voltage on pin 7.

6 Pin 6 sets the internal current levels which, along with R2682 or R2782, determine the sweep start voltage.

7 Pin 7 controls the sweep ramp output at pin 5. When pin 7 is LO the sweep ramp at pin 2 is internally connected to pin 5. When pin 7 is HI, the sweep ramp at pin 2 is disconnected from pin 5 and pin 5 is set to -5 volts.

8 Pin 8 is the connection for the -5 volt supply.

9 Pin 9 is the ground connection.

10 In the A sweep Generator, pin 10 produces an output which initiates holdoff. In the B Sweep Generator, pin 10 produces an output which is supplied to the +B GATE OUT Amplifier in the Main Module.

11 The voltage connected to pin 11 sets the amplitude of the unblanking signal at pin 12.

12 The signal at pin 12 is supplied to the Z Axis Amplifier in the Main Module to unblank the crt. The amplitude of this signal, and therefore the brightness of the crt display, is controlled by the voltage on pin 11.

13 Pins 13 and 14 work together. A HI on either pin prevents sweep generation. Both must be LO to start sweep generation. In the A Sweep Generator, pin 13 is held LO through a resistor to ground and only pin 14 controls sweep generation. In the B Sweep Generator pin 14 goes LO when the A Sweep Generator starts but pin 13 doesn't go LO until the B Trigger Generator produces a sweep gate. In the STARTS AFTER DELAY position of the B SOURCE switch, a B sweep gate is produced as soon as pin 16 of U2790 produces a delayed gate. In other settings, a B sweep gate is produced when the first adequate trigger signal occurs after a delayed gate is produced at pin 16 of U2790.

14 Pin 14 works with pin 13. See the pin 13 discussion.

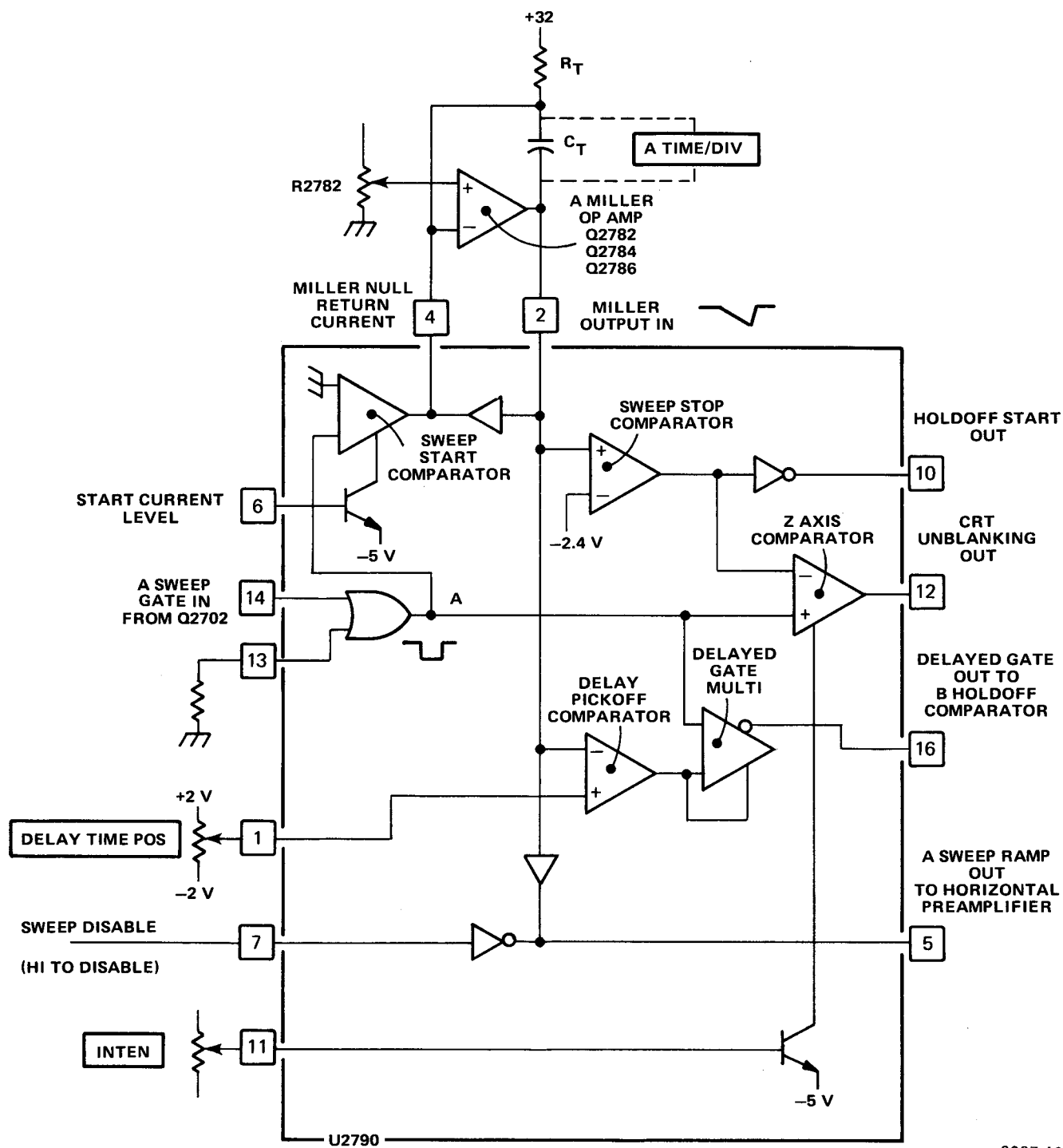
15 Pin 15 is the connection for the +5 volt supply.

16 Pin 16 of the A Sweep Generator produces a delayed gate to remove the holdoff condition from the B Trigger Generator. This output is produced when the A ramp voltage on pin 2 reaches the dc level on pin 1.

(b) Sequence of Events During A Sweep Generation.

1 Quiescent Condition. The quiescent condition exists during holdoff and after holdoff but before the A Trigger Generator produces a sweep start gate. Pin 14 of

U2790 is HI. This sets point A (see Figure 4-6) HI. This causes the output of the sweep start comparator to appear as a low-impedance point. The output of the sweep start comparator supplies current through pin 4 of U2790, and through R_t , to set the inverting input of the Miller op amp to the same voltage as the non-inverting input (the sweep



2237-46

Figure 4-6. Simplified diagram of the A sweep generator.

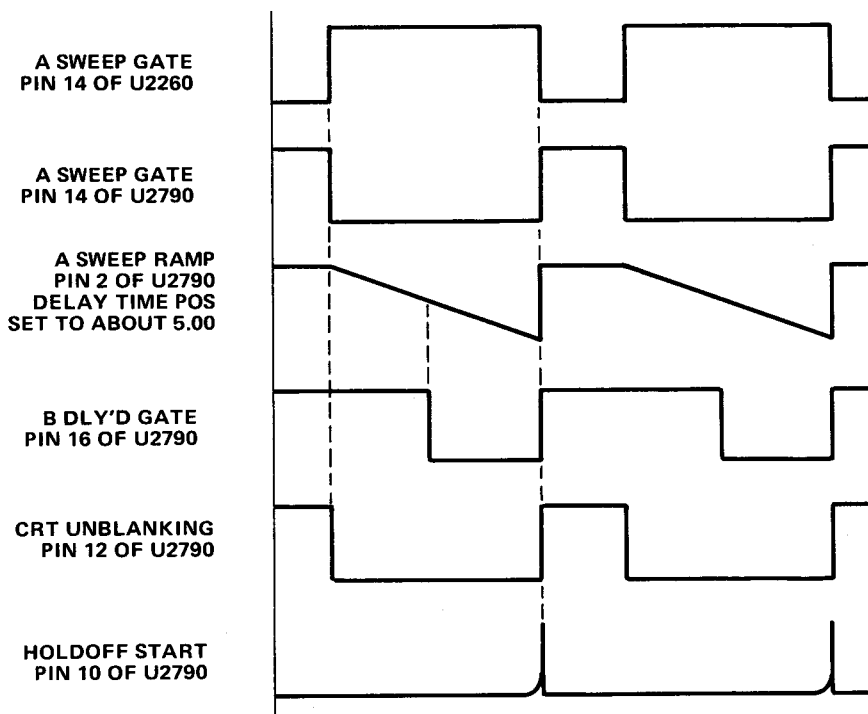
start voltage which is set by R2782). The output of the Miller op amp sets pin 2 of U2790 to the sweep start voltage also.

2 At Triggering. Pin 13 is always LO, except in the X-Y mode. When pin 13 is HI, point A (see Figure 4-6) is HI regardless of the state of pin 14. When the sweep gate causes pin 14 to go LO, point A steps LO (see Figure 4-6). This causes the output of the sweep start comparator to become a high-impedance point. The timing capacitor (C_t) starts charging through the timing resistor (R_t).

3 During Ramp Generation. As C_t starts charging through R_t , the inverting input of the Miller op amp tries to go more positive. This causes the output of the Miller op amp to go less positive which supplies current through C_t and R_t to hold the voltage on the inverting input constant. Since the resulting voltage across R_t is constant, the current through R_t and C_t must also be constant. Charging C_t with this constant current produces a linear negative-going voltage ramp at pin 2 of U2790. The slope of the ramp is determined by the values of R_t and C_t which are selected by the A TIME/DIV switch (S3100). The ramp at pin 2 is internally connected to pin 5 of U2790 whenever pin 7 is LO. Pin 7 is HI in the MIXED and B DLY'D positions of the HORIZ DISPLAY switch and LO in the A and A INTEN positions of the HORIZ DISPLAY switch and in the X-Y mode.

4 At Delayed Gate Generation. The negative-going ramp at pin 2 of U2790 is internally connected to a comparator. The ramp is compared to the dc voltage on pin 1 of U2790 (set by the DELAY TIME POS control). When the ramp voltage is the same as the voltage on pin 1, the comparator triggers the delayed gate multivibrator supplying a negative-going gate pulse to pin 16 of U2790. This gate is connected to the B holdoff comparator (Q2672 and Q2674) and terminates B holdoff. The negative-going gate from pin 16 of U2790 is also connected to the base of Q2622 through CR2608, CR2617, CR2618, and CR2622. This allows the B sweep gate, from the B trigger amplifier (Q2602 and Q2604), to start B sweep generation. Both signals must be LO at the same time to start B sweep.

5 Sweep End. The ramp on pin 2 of U2790 is internally connected to the sweep stop comparator. When the ramp reaches -2.4 volts, the comparator switches supplying a positive-going pulse to pin 10 of U2790. This pulse is supplied to the Sweep Control circuit and initiates A holdoff. At the beginning of holdoff, the sweep gate causes pin 14 of U2790 to step HI causing pin 4 to again appear as a low-impedance point. The current through R_t is now supplied by pin 4 of U2790. Also, when pin 14 of U2790 steps HI, it causes pin 12 to step HI and initiate B holdoff.



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Figure 4-7. Waveforms produced during A sweep operation.

6 Retrace. At the beginning of holdoff, the output of the Miller op amp and pin 2 of U2790 are at about -2.4 volts. This voltage is supplied to the input of a non-inverting amplifier within U2790. This amplifier tries to pull pin 4 of U2780, and the inverting input of the Miller op amp, less positive. To compensate, the output of the Miller op amp rapidly goes positive discharging C_t . The resulting positive-going ramp provides retrace.

(5) B Sweep Generator. The B Sweep Generator consists of U2690 and associated circuitry. The B Sweep Generator integrated circuit (U2690) is the same as the A Sweep Generator integrated circuit (U2790). Both are discussed in paragraph 4-3. b. (4) (a). Figure 4-8 shows a simplified diagram of the B Sweep Generator. Figure 4-9 shows the waveforms produced during B sweep generation. Figure FO-6 shows a complete schematic diagram of the B Sweep Generator.

(a) Sequence of Events During B Sweep Generation in B DLY'D or A INTEN Mode. Refer to Figure 4-8 and Figure 4-9 during the following discussion. Diagram 5 (FO-7) shows a complete schematic diagram of the B Sweep Generator.

1 Before B Delayed Gate Generation. In the B DLY'D or A INTEN modes, the base of Q6236 is set to about +2 volts through the HORIZ DISPLAY switch (S2650). The following conditions exist before the generation of a B delayed gate at pin 16 of U2790. The B trigger amplifier (Q2602 and Q2604) supplies a HI to the base of Q2622 which biases off Q2622. The B sweep start voltage (about +2 volts from pin 2 of U2690) is applied to the base of Q2632. Bias resistors set the base of Q2636 to about +2 volts also. Ideally Q2632 and Q2636 will conduct equally. The emitter of Q2624 is connected to the collector of Q2636 which forward biases Q2624. The collector of Q2624 pulls the emitter of Q2620 negative enough (through CR2621) to turn on Q2620. Transistor Q2620 supplies current through R_t to hold the inverting input of the B Miller op amp at the same voltage as its non-inverting input (set by R2682).

2 At B Delayed Gate Generation. When the A Sweep Generator generates a B delayed gate (at pin 16 of U2790), the resulting negative step on the base of Q2672, causes the B holdoff comparator (Q2672 and Q2674) to switch states and remove B holdoff from the B Trigger generator.

3 At B Sweep Gate Generation. When a B sweep gate is generated by the B Trigger Generator, the B trigger amplifier (Q2602 and Q2604) switches, which pulls the base of Q2622 negative. Transistor Q2622 turns on, pulling the emitter of Q2620 less negative. This turns off Q2620. This begins generation of a B ramp. When the B

ramp (at pin 2 of U2690) begins going less positive, it turns off Q2636. The emitter of Q2624 is now connected to -5 volts through R2638. Transistor Q2624 remains on, supplying the collector current for Q2622.

4 During B Ramp Generation. When Q2620 turns off, C_t begins charging through R_t . As C_t charges, the inverting input of the B Miller op amp tries to go more positive. To compensate, the output of the B Miller op amp supplies current through C_t and R_t to hold the inverting input at the same voltage as the non-inverting input (set by R2682). Since the resulting voltage across R_t is constant, the current through R_t and C_t is constant. Charging C_t with this constant current produces a linear negative-going ramp at pin 2 of U2690. The slope of the ramp is determined by the values of R_t and C_t which are selected by the B TIME/DIV switch (S3200). The ramp at pin 2 of U2690 is internally connected to pin 5 whenever pin 7 is LO. Pin 7 is LO in the B DLY'D mode and HI in the A INTEN mode. The B Sweep Generator does not provide horizontal deflection in the A INTEN mode, it only supplies additional unblanking current to intensify the display during the time a B sweep ramp is being generated.

5 Sweep Stop. When the ramp at pin 2 of U2690 reaches about -2.4 volts, the emitter of Q2629 becomes sufficiently negative to forward bias Q2629. When Q2629 turns on its collector becomes sufficiently negative to turn on Q2620. The resulting current through Q2620 flows through R_t and holds the inverting input of the B Miller op amp at the same voltage as the non-inverting input. The B Miller op amp no longer supplies current to C_t and the voltage on pin 2 of U2690 remains at about -2.4 volts. The B Sweep Generator does not reset at this time. If it did reset, it might be possible to trigger and generate another B sweep ramp before A sweep ends. This would produce an erroneous display. The gate at pin 10 of U2690 does not initiate B holdoff, it only supplies a signal to the +B GATE OUT Amplifier in the Main Module.

6 Retrace. At the end of a sweep, the holdoff gate from the Sweep Control circuit resets both the A and B Trigger Generators. When the B Trigger Generator resets, the B trigger amplifier (Q2602 and Q2604) switches and pulls the base of Q2622 HI. This turns off Q2622. When Q2622 turns off, it allows the collector of Q2629 to pull the emitter of Q2620 more negative which increases the forward bias on Q2620. The increased forward bias on Q2620 tries to increase the current through R_t and force the inverting input of the B Miller op amp less positive. To compensate, the output of the B Miller op amp rapidly goes positive, discharging C_t . The resulting positive-going ramp on pin 2 of U2690 provides retrace.

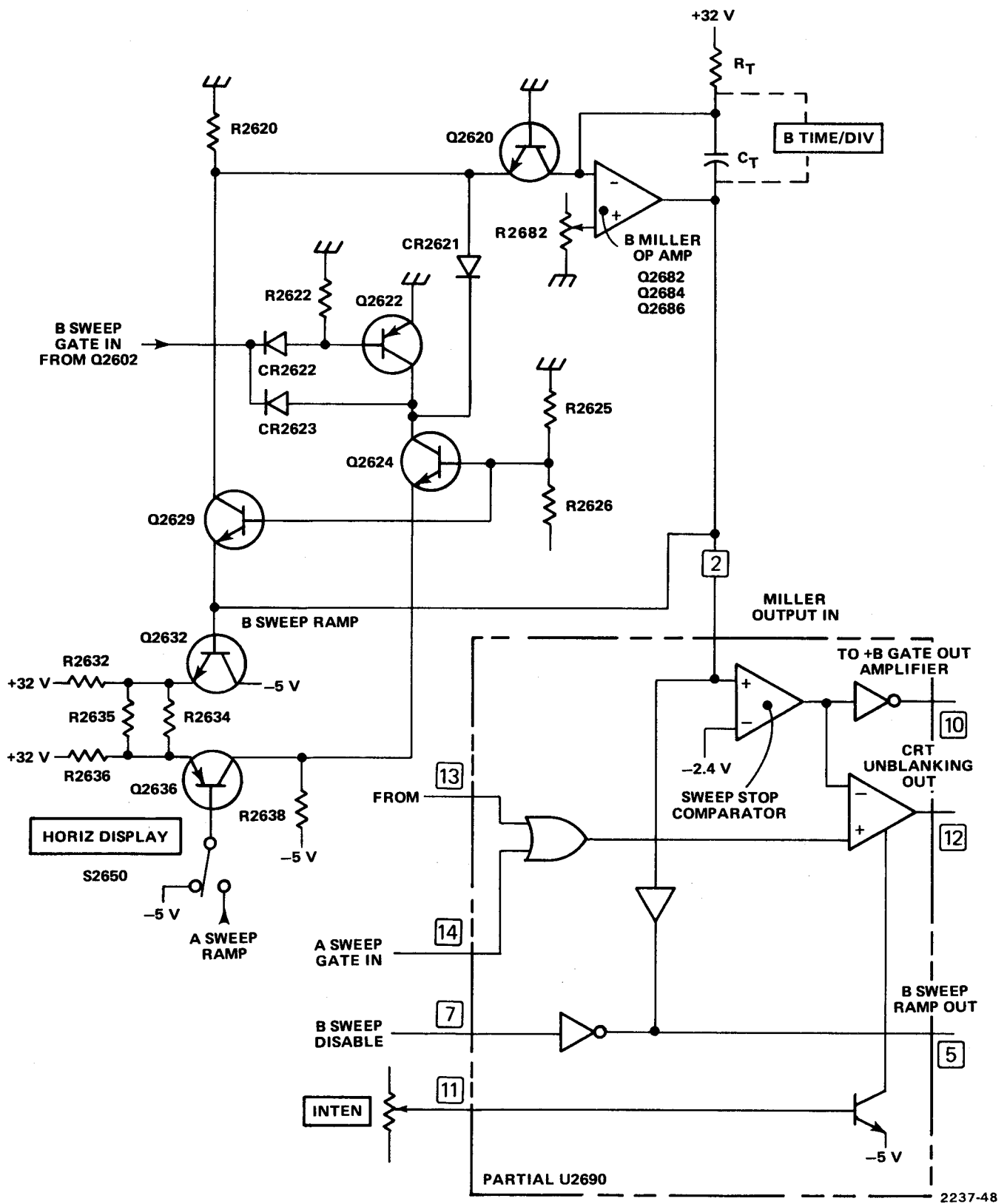
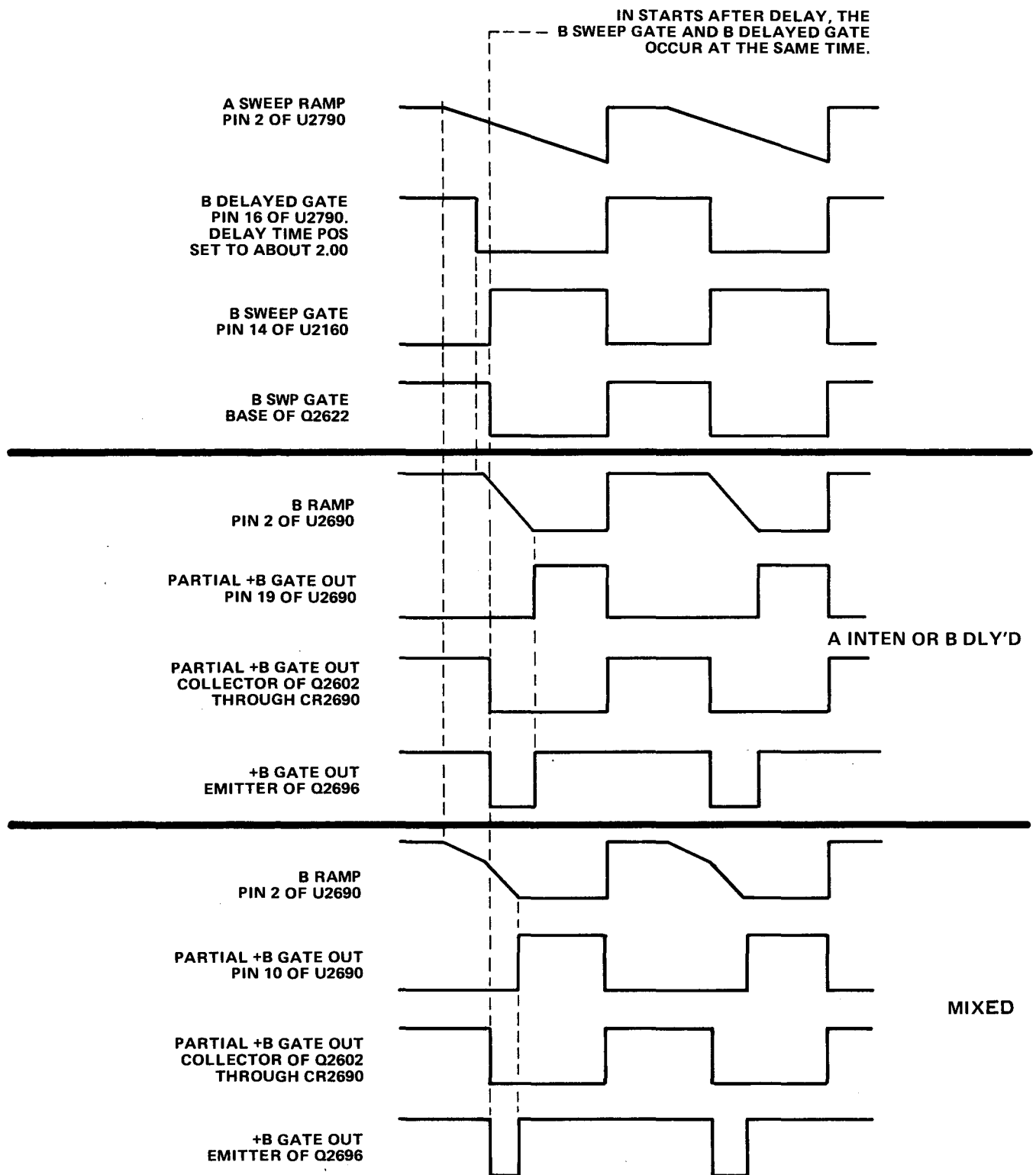


Figure 4-8. Simplified diagram of the B sweep generator.



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Figure 4-9. Waveforms produced during B sweep generation

7 End of Retrace. When the retrace ramp on pin 2 of U2690 reaches about +2 volts, the emitter of Q2636 (through the emitter of Q2632) is pulled sufficiently positive to forward bias Q2636. At the same time, the emitter of Q2629 becomes sufficiently positive to turn off Q2629. The initial condition (before B delayed gate generation) is restored. The collector of Q2636 goes less negative, decreasing the forward bias on Q2624. Now Q2624 supplies just enough current through Q2620 and R_t to hold the inverting and non-inverting inputs of the B Miller op amp at the same voltage.

(b) Sequence of Events During B Sweep Generation in MIXED Mode. In the MIXED mode, B sweep generation is similar to that in the A INTEN or B DLY'D modes. The main difference is that the voltage level on pin 2 of U2690 is controlled by the A sweep ramp before a B sweep gate is generated. Also, a HI is placed on pin 7 of U2790 causing pin 5 of U2790 to go LO and disconnect the A ramp from the Horizontal Preamplifier.

1 Before A Sweep Starts. When the MIXED button is pushed, the A sweep ramp is connected to the base of Q2636 through R2637 and R2781. Ideally the A and B sweep start voltages will be about the same, causing both Q2636 and Q2632 to conduct. The collector of Q2636 is connected to the emitter of Q2624, forward biasing Q2624. The collector of Q2624 pulls the emitter of Q2620 negative enough to forward bias Q2620. Transistor Q2620 supplies current through R_t to hold both inputs of the B Miller op amp at the same voltage. Also, a HI from the B trigger amplifier (Q2602 and Q2604) holds off Q2622.

2 After A Sweep Starts. When the A Sweep Generator is triggered, the negative-going A sweep ramp begins to appear at pin 2 of U2790 which is connected to the base of Q2636. As the base of Q2636 goes less positive, Q2636 turns on harder causing its collector to go less negative. The collector of Q2636 is connected to the emitter of Q2624. As the collector of Q2636 goes less negative, the forward bias on Q2624 is decreased, which decreases its collector current. Since Q2624 supplies the current through Q2620, the current through Q2620 also decreases. This causes the inverting input of the B Miller op amp to try to go more positive. To compensate, the output of the B Miller op amp supplies current through C_t and R_t to hold both inputs at the same voltage. C_t charges at a rate determined by the A sweep ramp. The resulting ramp at pin 2 of U2690 has the same slope as the A sweep ramp and is internally connected to pin 5 of U2690. This signal is connected to the Horizontal Preamplifier and provides horizontal deflection for both the A and B portions of the display.

3 When B Sweep Gate is Generated. When a B sweep gate is generated by the B Trigger Generator, the base of Q2622 steps negative, turning on Q2622 which

turns off Q2620. B sweep generation continues as in the A INTEN or B DLY'D modes. See 4-3. b. (5) (a) 3 through 7.

(6) Horizontal Preamplifier.

(a) The Horizontal Preamplifier is contained within a single integrated circuit (U2900). The Horizontal Preamplifier amplifies the sweep ramp outputs from the A and B Sweep Generators and supplies the amplified signal to the Horizontal Amplifier in the Main Module. In the X-Y mode, the CH 1 Preamplifier output is supplied to the Horizontal Preamplifier to provide horizontal (X axis) deflection.

(b) The following lists the pin numbers of U2900 and their functions.

1 Pin 1, Magnifier Registration. Used in conjunction with pin 8 to adjust magnifier registration. Adjustment is correct when display does not shift horizontally when switching between normal and magnified displays.

2 Pin 2, Sweep. Output for the negative-going signal which is supplied to the Horizontal Amplifier in the Main Module.

3 Pin 3, Gain. Used in conjunction with pin 6. The resistance between pins 3 and 6 determines the amplitude of the signal at pins 2 and 7. Decreasing this resistance increases gain. The X10 Magnifier switch, when pushed, decreases this resistance by a factor of ten and therefore increases the gain by a factor of ten.

4 Pin 4, -5 Volts. Connection for the -5 volt supply.

5 Pin 5, Current Source. Sets current levels within U2900.

6 Pin 6, Gain. See pin 3.

7 Pin 7, +Sweep. Output for positive-going signal which is supplied to the Horizontal Amplifier in the Main Module.

8 Pin 8, Magnifier Registration. See pin 1.

9 Pin 9, B Sweep Input. The output of the B Sweep Generator is connected here. The more positive of the levels connected to pins 9 and 10 is internally connected to the amplifier and provides the output at pins 2 and 7. The more negative level on pins 9 and 10 is ignored.

10 Pin 10, A Sweep Input. The output of the A Sweep Generator is connected here. See pin 9.

11 Pin 11, X Signal Input. A sample of the signal present in the CH 1 Preamplifier is connected here. When pin 12 is HI, the sweep inputs from pins 9 and 10 are internally disconnected and the signal from pin 11 is amplified and connected to the outputs on pins 2 and 7.

12 Pin 12, X-Y Control. This pin is set HI only in the X-Y mode. See pin 11.

13 Pin 13, Frequency Compensation. The frequency compensating capacitor is connected here.

14 Pin 14, Horizontal Position. The horizontal POSITION control is connected here. Changing the dc voltage on this pin shifts the dc level of the outputs at pins 2 and 7, except in the X-Y mode.

(7) +A GATE OUT Amplifier. The +A GATE OUT Amplifier consists of Q2712 and associated circuitry. The A sweep gate signal from the collector of Q2702 (part of the A trigger amplifier) is connected to the base of Q2712. At the beginning of A sweep the sweep gate turns off Q2712, causing its collector to go to +5 volts. At the end of A sweep the sweep gate steps positive, turning on Q2712. The collector of Q2712 goes to about 0 volts. The resultant +A GATE OUT signal is about +5 volts while an A sweep ramp is being generated and about 0 volts the rest of the time.

(8) +B GATE OUT Buffer. The +B GATE OUT Buffer consists of Q2696 and associated circuitry. The input to the buffer circuit is obtained from three sources; the partial B Gate signal from pin 10 of U2690, the B sweep gate from the collector of Q2602 which is part of the B trigger amplifier, and the delayed gate signal from pin 16 of U2790. Figure 4-9 shows the time relationship of the two signals. The output of the Buffer is LO only when both input signals are LO. All three input signals are LO at the same time only while a B ramp is being generated. The output of the Buffer is supplied to the +B GATE OUT Amplifier in the Main Module.

(9) Sweep Control. Sweep Control consists of U2750 and associated circuitry. The circuit controls holdoff duration, AUTO sweep, and single sweep operation. Figure 4-10 shows a functional block diagram of U2750 and associated circuitry.

(a) Holdoff Control. Holdoff control is provided by a Miller ramp generator which consists of three transistors within U2750, and an RC network. Resistors R2776 and R2777 are the timing resistors. Capacitor C2762 and a capacitor selected by the A TIME/DIV switch are the timing capacitors. Figure 4-10 shows a functional block diagram of U2750 and associated circuitry. Figure 4-11

shows the waveforms produced by the holdoff control circuitry.

1 At the beginning of A sweep generation, pin 6 of U2750 steps LO. This LO passes through an inverting amplifier and turns on transistor C and turns off transistors D and E (see Figure 4-10). When transistors D and E turn off, pin 11 of U2750 is pulled more positive through R2762. Pin 11 is clamped at about +5.7 volts by a diode within U2750. The current through the timing resistors (R2776 and R2777) is supplied by transistor C through pin 10 of U2750. This condition is maintained until the end of A sweep generation.

2 At the end of A sweep generation, pin 12 of U2750 momentarily steps HI which sets the holdoff latch within U2750. The Q output of the holdoff latch goes HI causing pin 9 of U2750 to go HI. The HI on pin 9 resets and holds off the A Trigger Generator.

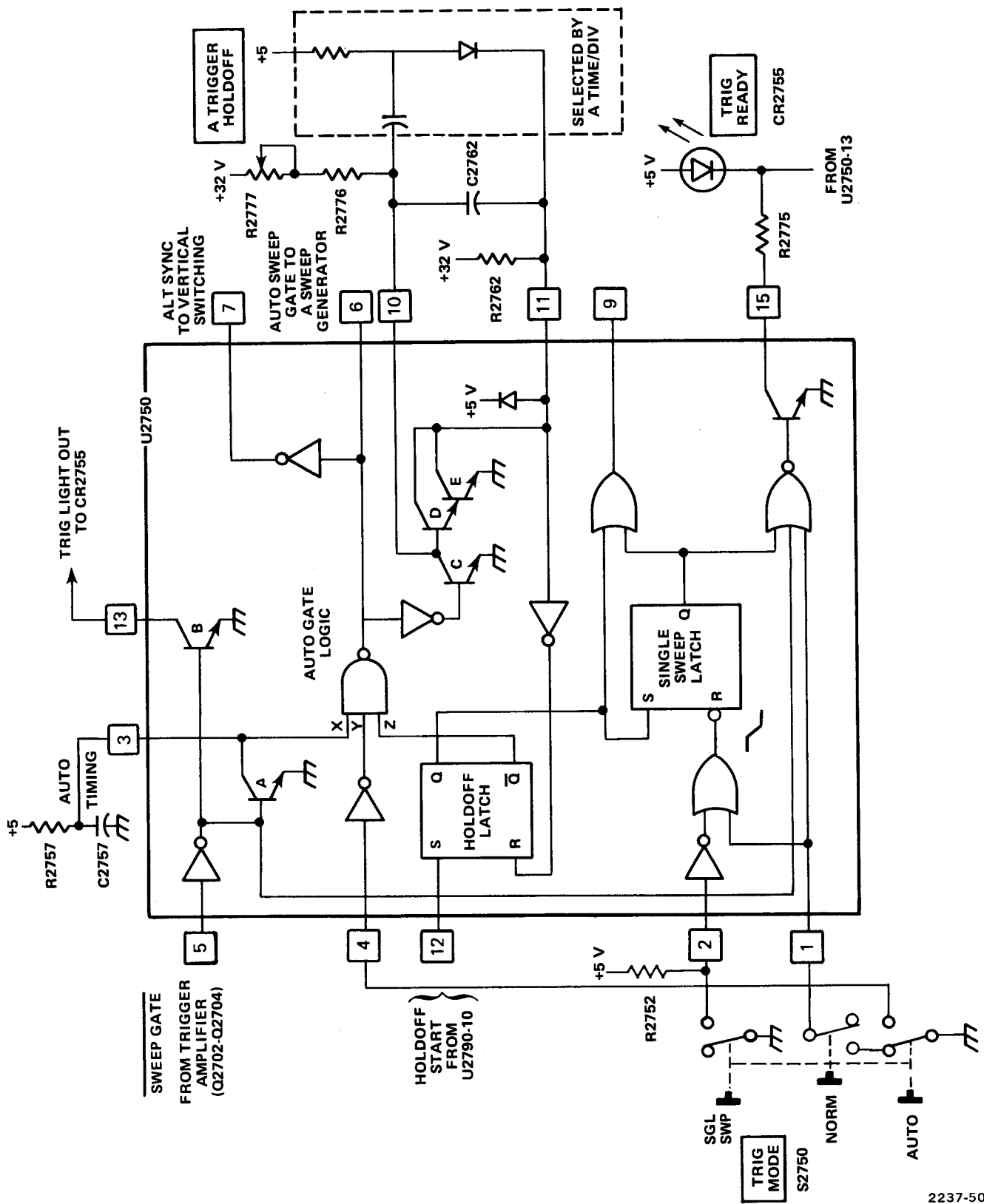
3 When the A Trigger Generator resets (or the AUTO sweep gate steps HI), pin 6 of U2750 steps HI. This turns off transistor C and turns on transistors D and E within U2750. Pin 10 is pulled positive to about +1.4 volts through R2776 and R2777.

4 After transistor C turns off, pin 10 tries to go more positive than +1.4 volts. This turns on transistor D harder and supplies current through C2762, R2776, and R2777. This current holds pin 10 at about +1.4 volts and begins charging C2762. As C2762 charges, pin 11 of U2750 begins going less positive.

5 As pin 11 of U2750 goes less positive, the diode selected by the A TIME/DIV becomes forward biased. Now the current to hold pin 10 at +1.4 volts is supplied through C2762 and a capacitor selected by the A TIME/DIV. Since the voltage across R2776 and R2777 doesn't change, the current doesn't change. Now this current must charge two capacitors, and the voltage ramp on pin 11 of U2750 will not be as steep. The ramp can also be made less steep by increasing the resistance of the A TRIGGER HOLDOFF control (R2777).

6 When the voltage on pin 11 falls to about 1 volt, the R input of the holdoff latch within U2750 is set HI through an inverting amplifier. The holdoff latch resets and its Q output goes LO. When the Q output goes LO, pin 9 of U2750 goes LO and terminates holdoff.

(b) AUTO Sweep Control. When pin 4 of U2750 is set LO by the TRIG MODE switch, Sweep Control provides a baseline trace in the absence of an adequate trigger signal. Figure 4-10 shows the Sweep Control integrated circuit and associated circuitry. Figure 4-12 shows the waveforms produced during AUTO sweep gate generation.



2237-50

Figure 4-10. Functional block diagram of the sweep control integrated circuit and associated circuitry.

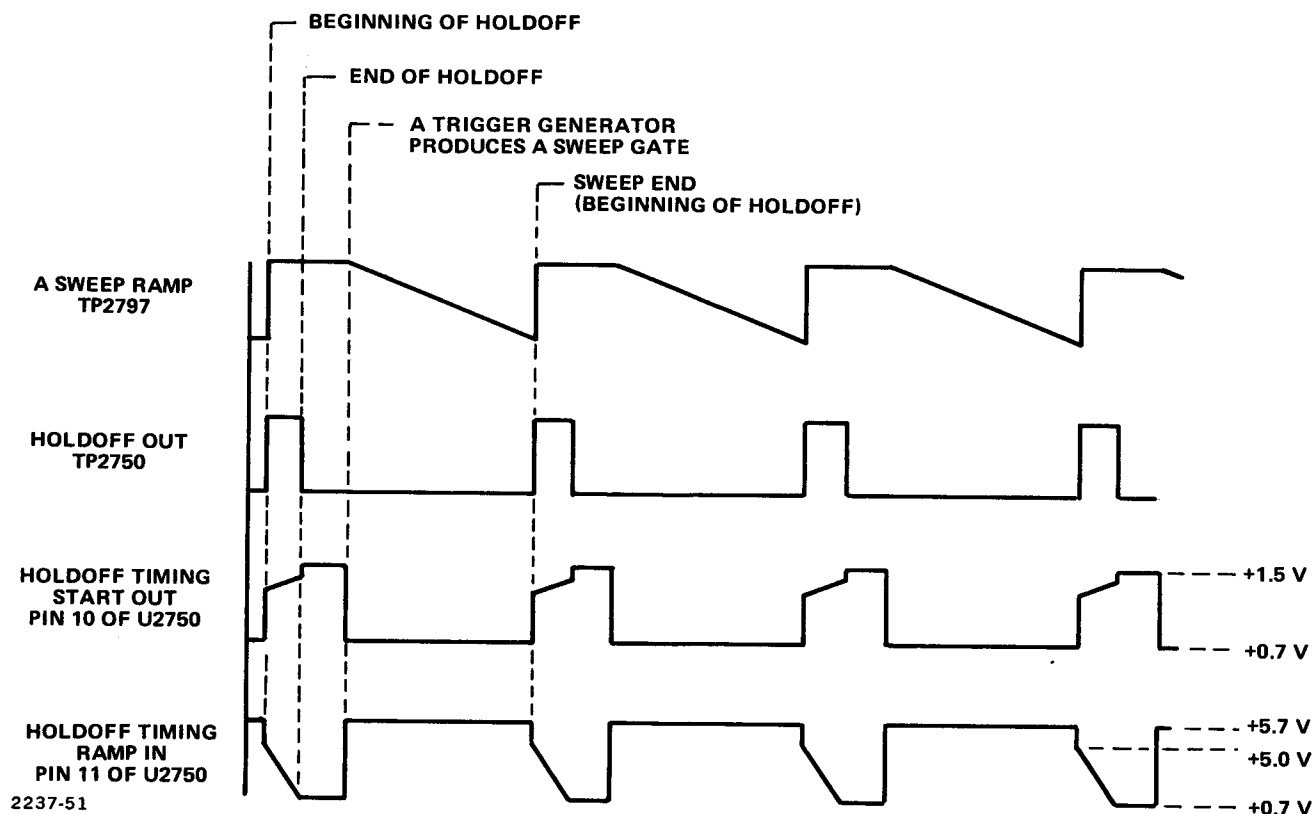


Figure 4-11. Waveforms produced by holdoff control circuitry.

1 When the TRIG MODE switch (S2750) is set to AUTO, pin 4 of U2750 is set LO. This sets input Y of the AUTO gate logic HI through an inverting amplifier within U2750 (see Figure 4-10).

2 If adequately triggered, pin 5 of U2750 steps LO at the beginning of A sweep generation. This turns on transistor A within U2750 and discharges C2757. Discharging C2757 prevents generation of an AUTO sweep gate by keeping input X of the AUTO gate logic LO.

3 Assume that the trigger signal becomes inadequate to cause the A Trigger Generator to generate an A sweep gate. At the end of the last triggered sweep, pin 12 of U2750 momentarily steps HI. This sets the holdoff latch within U2750. The \bar{Q} output of the holdoff latch sets input Z of the AUTO gate logic HI.

4 When the holdoff latch sets, pin 9 of U2750 resets the A Trigger Generator causing pin 5 of U2750 to step HI. The HI on pin 5 turns off transistor A within U2750. Now C2757 starts to charge through R2757.

5 When C2757 charges sufficiently, input X of U2750 is HI. Now all three inputs of the AUTO gate logic are HI which causes an AUTO sweep gate to be generated at pin 6 of U2750.

6 At the end of the first AUTO generated sweep ramp, pin 12 of U2750 momentarily steps HI, re-setting the holdoff latch. The \bar{Q} output of the holdoff latch goes LO, causing the output of the AUTO gate logic to step HI. At the same time, the Q output of the holdoff latch steps HI, causing holdoff to begin (pin 9 of U2750 steps HI).

7 When holdoff ends, the R input of the hold-off latch goes HI, resetting the holdoff latch. The \bar{Q} output goes HI, causing the AUTO gate at pin 6 of U2750 to step LO. This causes another AUTO sweep to be generated. As long as no adequate trigger signal is available, all subsequent sweeps will be initiated by the AUTO gate at pin 6 of U2750.

8 Assume an adequate trigger signal becomes available. When A Trigger Generator supplies an A sweep gate to pin 5 of U2750, transistor A within U2750 is turned

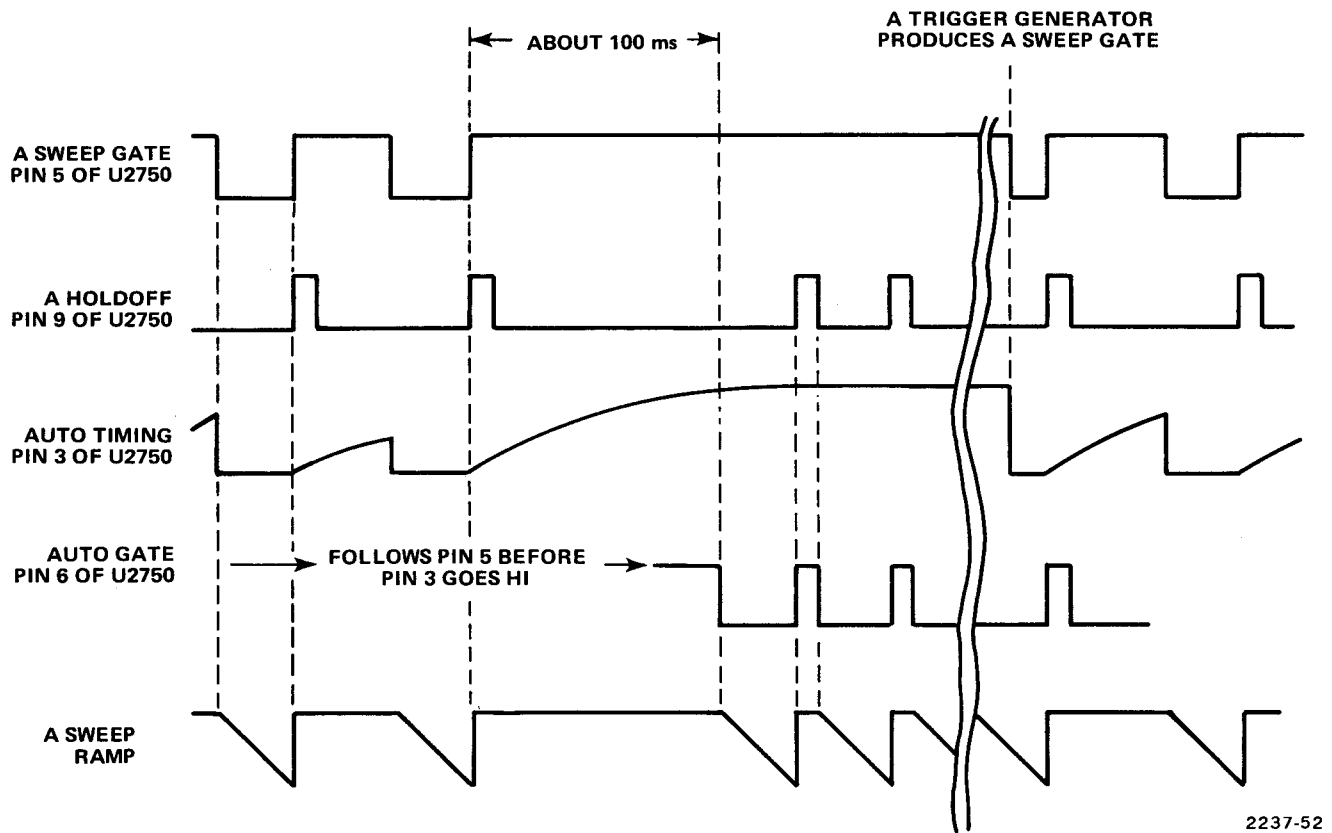


Figure 4-12 Waveforms produced during AUTO sweep gate generation.

2237-52

on, Capacitor C2757 discharges rapidly through transistor A. This sets input X of the AUTO gate logic LO which disables the logic. Now another AUTO gate can not be generated at pin 6 of U2750 until C2757 charges enough to set input X of the AUTO gate logic HI (about 100 milliseconds after the beginning of holdoff).

(c) Single Sweep Control. When the TRIG MODE switch (S2750) is set to SGL SWP, pin 1 of U2750 is connected to ground. Now, when adequately triggered, only one sweep ramp will be generated. After one sweep is displayed, another sweep can't be presented until after the SGL SWP button has been pushed. Figure 4-10 shows a functional block diagram of the Sweep Control integrated circuit and associated circuitry.

1 To operate in the single sweep mode, pin 1 of U2750 is grounded and pin 2 is pulled HI through R2752. This holds the R input of the single sweep latch within U2750 HI.

2 At the end of sweep ramp generation, the Q output of the holdoff latch steps HI. This HI is connected to the S input of the single sweep latch and sets the latch. The Q output of the single sweep latch holds pin 9 of

U2750 HI even after the holdoff latch has reset. This permanently holds off the A Trigger Generator.

3 To reset the single sweep latch, the SGL SWP button must be pushed and released. When the SGL SWP button is pushed, pin 2 of U2750 is set LO which sets the R input of the single sweep latch HI. When the SGL SWP button is released, pin 2 of U2750 steps HI causing a negative going transition on the R input of the single sweep latch. This transition resets the single sweep latch. The Q output of the single sweep latch goes LO which sets pin 9 of U2750 LO and terminates holdoff.

c. Main Module.

(1) Z-Axis Amplifier. Diagram 8 (FO-10) shows the Z-Axis Amplifier circuitry. The Z-Axis Amplifier consists of Q514, Q518, Q524, Q526 and associated circuitry.

(a) Normal Z-Axis Amplifier Operation. The Z-Axis Amplifier accepts signals from several sources, amplifies them, and supplies a control signal to the CRT Circuit to control display intensity. The sources of the signals used to control display intensity are: Vertical Switching Control circuit, A Sweep Generator, and the B Sweep Generator.

1 The Z Axis Amplifier input signals are applied to the emitter of common base amplifier Q514. Transistor Q514 provides isolation between the signal sources and the Z Axis Amplifier. The algebraic sum of the signals applied to the emitter of Q514 determines the current supplied to the base of Q518.

2 Transistor Q518 is an emitter follower. The signal on the emitter of Q518 drives Q524 and Q526.

3 Transistors Q524 and Q526 are connected as a complementary symmetry amplifier. The signal from the emitter of Q518 drives both bases and the output is taken from the junction of the two collectors. This output signal is supplied to the crt control grid through the dc restorer portion of the CRT Circuit.

(b) BEAMFINDER Z-Axis Amplifier Operation.

When the BEAMFINDER button is pushed and held, the Z Axis Amplifier ignores the input signals and provides a visible display.

1 With the BEAMFINDER button pushed and held, +32 volt is disconnected from R512 and +5 volts is connected to R504.

2 The +5 volts connected to R504 reverse biases CR506 and CR505. This disconnects the input signals from the emitter of Q514.

3 When +32 volts is removed from R512, the base of Q518 is pulled slightly more negative through R514. This sets conduction in Q518 at a level which provides a visible display regardless of the Z Axis Amplifier input signals.

(2) Crt Circuit. Diagram 8 (FO-10) shows the CRT Circuit. The CRT Circuit provides the high voltage levels needed to operate the crt. The CRT Circuit consists of the high voltage oscillator, high voltage regulator, high voltage rectifier, high voltage multiplier, and dc restorer.

(a) High Voltage Oscillator. The high voltage oscillator consists of Q552, Q556, T550 and associated circuitry. Figure 4-13 shows the waveforms produced in the high voltage oscillator.

1 To explain the high voltage oscillator, we must choose a given point in an oscillation and describe the sequence of events. Assume pin 3 of T550 is going more positive and pin 5 is going less positive.

2 As pin 3 of T550 goes more positive, the voltage across the feedback winding of T550 (between pins 3 and 6) adds to the voltage on C548. When the voltage on pin 3 becomes sufficiently positive, it pulls the base of Q552 positive enough to turn on Q552.

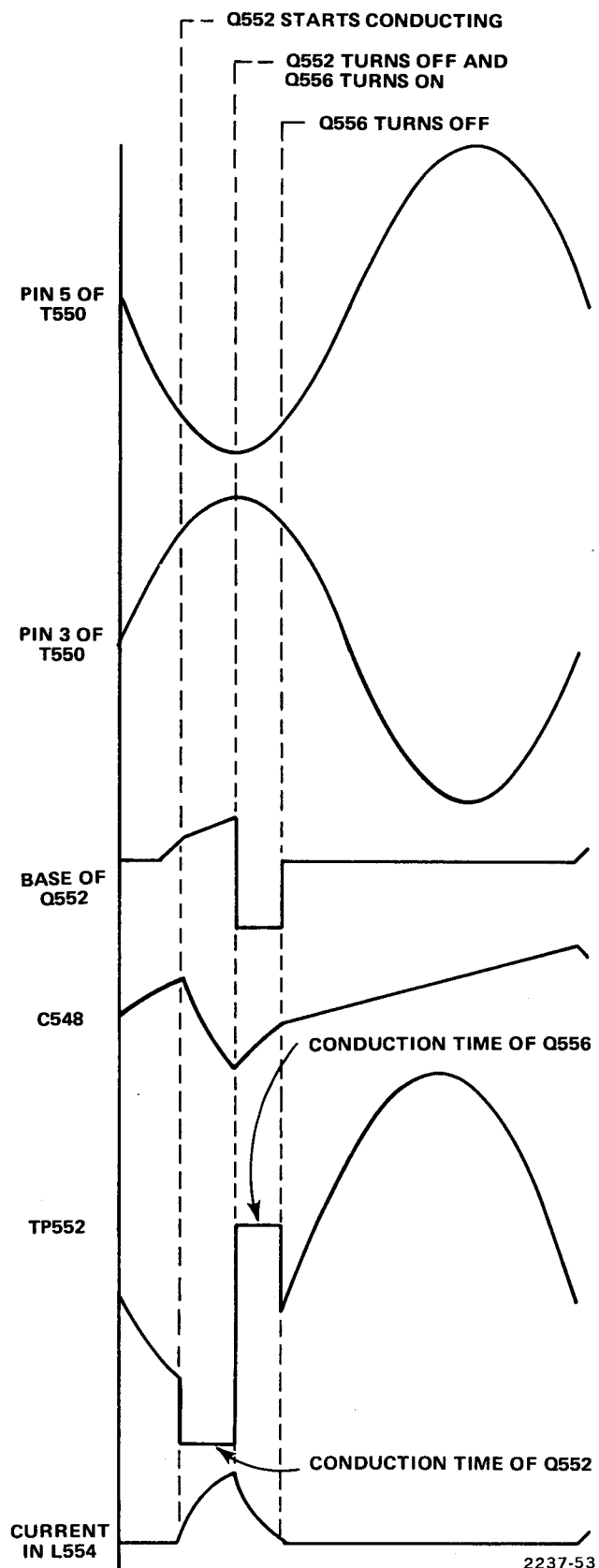


Figure 4-13. Waveforms produced in the high voltage oscillator

3 As Q552 turns on, current is drawn through T550 and L554. This current induces positive feedback into the feedback coil of L554 and turns on Q552 harder. The voltages induced into the feedback coils of T550 and L554 hold Q552 on.

4 As the magnitude of the current in T550 and L554 increases, the rate of change of the current decreases. When the rate of change of the current reaches about zero, the voltage induced in the feedback windings of T550 and L554 becomes insufficient to hold Q552 on. Q552 begins to turn off. Note that at this instant the voltage across the secondary of L554 is 0 volts.

5 As Q552 is turning off, the magnetic field around L554 starts collapsing. This induces a voltage in the feedback winding of L554 which speeds up the turnoff of Q552.

6 The collapsing magnetic field of L554 induces a voltage in L554 which forces the emitter of Q556 more positive. This voltage causes the emitter of Q556 to go more positive than pin 4 of T550. As a result, Q556 turns on and places L554 in parallel with the primary winding of T550.

7 The current produced by the collapsing magnetic field of L554 flows through Q556 and the primary winding of T550. This transfers the energy stored in L554 to T550 and increases the efficiency of the circuit. The amount of energy stored in L554 is controlled by the high voltage regulator.

8 As the oscillation cycle continues, the voltage across L554 decreases until it is not sufficient to hold Q556 on. Therefore Q556 turns off.

9 The cycle continues until pin 3 of T550 again becomes sufficiently positive to turn on Q552. Then the sequence just described repeats.

(b) High Voltage Regulator. The high voltage regulator consists of Q544, Q548, and associated circuitry. Diagram 8 (FO-10) shows the high voltage regulator circuitry. The high voltage regulator controls the output of the high voltage oscillator by controlling the energy in the primary circuit. To fully understand the high voltage regulator, read the previous High Voltage Oscillator discussion before continuing with this discussion.

1 The high voltage regulator controls the point during an oscillation cycle that Q552 is turned on. Assume the -2 kV supply starts to go more negative (too much energy is transferred to the secondary circuit of T550).

2 As the -2 kV supply goes more negative it pulls the base of Q554 less positive. The collector of Q544 goes more positive which decreases the collector current of Q548. Transistor Q548 supplies charge current to C548. Because the collector current of Q548 is decreased, C548 charges more slowly. As a result, the voltage on pin 3 of T550 will not become positive enough to turn on Q552 until later in the oscillation cycle (see Figure 4-13). Therefore less energy is stored in L554 and transferred to the primary of T550 when Q556 turns on. This decreases the amount of energy transferred to the secondary of T550 which causes the -2 kV supply to go less negative.

3 If the -2 kV supply goes less negative, Q544 and Q548 turn on harder charging C548 faster. The voltage on pin 3 of T550 becomes positive enough to turn on Q552 earlier in the oscillation cycle. Therefore more energy is stored in L554 and transferred to the primary of T550 when Q556 turns on. As a result, more energy is transferred to the secondary circuit of T550 and the -2 kV supply goes more negative.

4 In the event the high voltage regulator malfunctions, VR552, VR553, and CR552 provide over-voltage protection. If the peak voltage on pin 8 of T550 exceeds about +200 volts, VR552 conducts. When VR552 and VR553 conduct they turn on Q552 which draws enough current to open fuse F558.

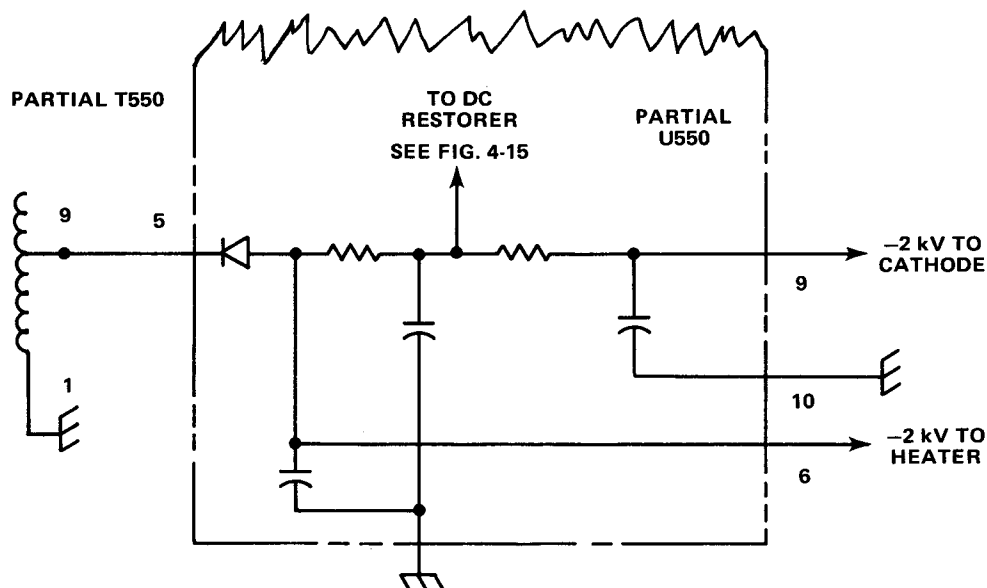
(c) High Voltage Rectifier. Figure 4-14 shows a simplified diagram of the high voltage rectifier. Diagram 8 (FO-10) shows the high voltage rectifier and associated circuitry.

1 The high voltage rectifier is contained within U550. The circuit half wave rectifies the -2 kV peak ac signal at pin 9 of T550. The rectified and filtered voltage is supplied to the crt cathode, dc restorer, FOCUS control, and the high voltage regulator.

2 The heater supply winding of T550 is referenced to the -2 kV supply. This prevents breakdown between the heater and the cathode due to a large voltage difference between them.

(d) High Voltage Multiplier. Diagram 8 (FO-10) shows the high voltage multiplier. The circuit is a standard voltage multiplier consisting of diodes and capacitors. The multiplication factor is 3. The multiplier is contained within module U550. The output of the multiplier supplies the positive anode voltage for the crt.

(e) DC Restorer. The dc restorer is contained within U550. Figure 4-15 shows a simplified diagram of the circuit.



2237-54

Figure 4-14. High voltage rectifier.

1 To control the crt beam current, and therefore display intensity, the voltage on the crt control grid is varied through the dc restorer. How negative the control grid is with respect to the cathode is determined by the difference in the voltages from the crt bias setting and the Z Axis Amplifier.

2 The voltages from the bias control and the Z Axis Amplifier will vary; however, to make this discussion easier to understand, assume the bias control sets pin 2 of U550 to +100 volts and the Z Axis Amplifier sets pin 1 of U550 to +20 volts.

3 On positive-going excursions of the voltage on pin 8 of T550, diode C clamps the voltage at point X to about the voltage on pin 2 of U550 (see Figure 4-15). We have assumed this voltage to be about 100 volts. Point Y is clamped at about -2 kV by diode G. Capacitor E charges to the difference between the -2 kV supply and pin 2 of U550 (about 2.1 kV). Note that diode F is reverse biased. When the voltage on pin 8 of T550 falls below the level on pin 1 of U550 (set by the Z Axis Amplifier), diode B clamps point X at about the voltage on pin 2 of U550 (+20 volts assumed). Since the voltage on capacitor E can't be changed instantaneously, point Y steps negative by an amount equal to the difference in the levels at which diodes B and C conduct (80 volts assumed). Point Y steps negative to -2080 volts. This is 2100 volts (the charge on capacitor A) more negative than the conduction level of diode B.

4 When point Y steps to -2080, diode G becomes reverse biased and diode F becomes forward biased.

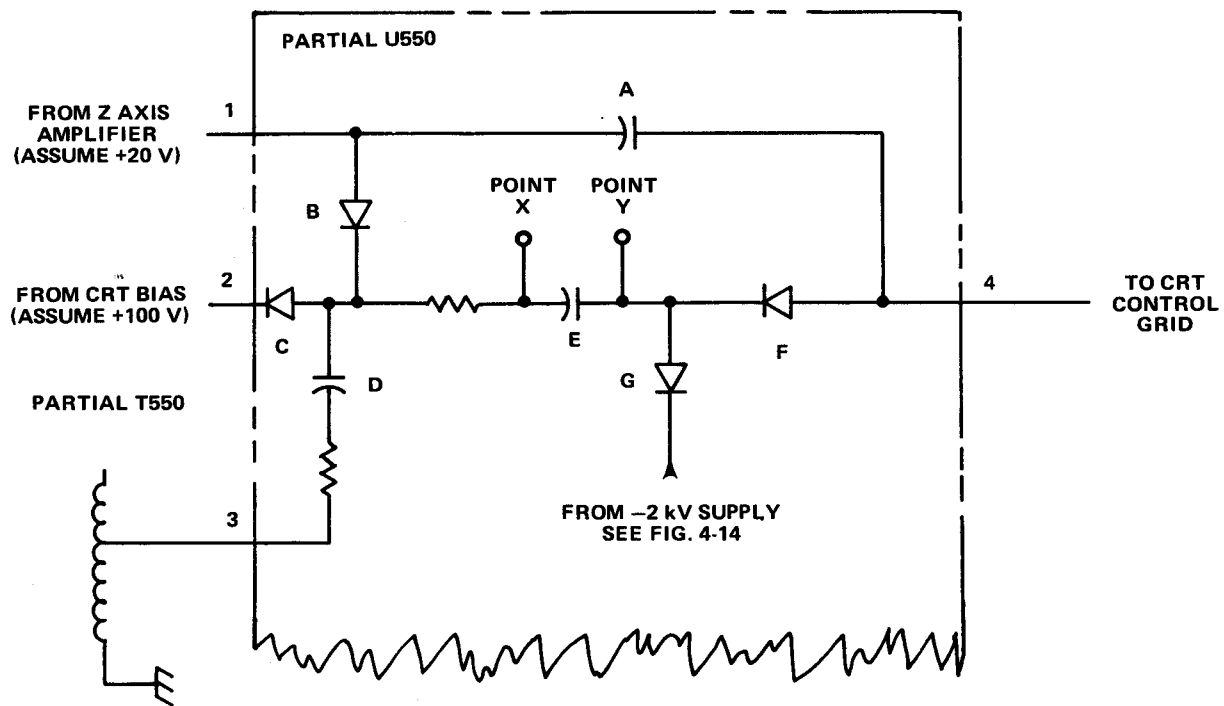
Point Y sets the crt grid to about -2080 volts or about 80 volts more negative than the cathode. While diode F is forward biased, capacitor E discharges slightly into capacitor A. This replaces the charge that leaks off capacitor A while diode F is reverse biased.

5 When the oscillation on pin 8 of T550 again becomes sufficiently positive, the original condition is restored. Diode C clamps point X at about 100 volts and diode F is reverse biased. While diode F is reverse biased, the charge on capacitor A holds the crt control grid at about -2080 volts.

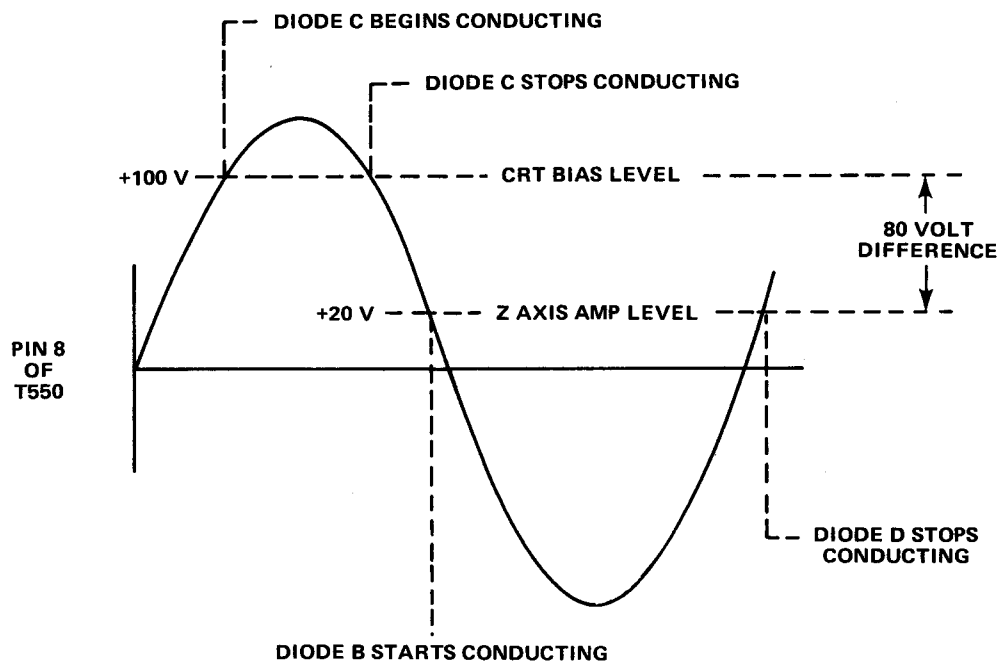
6 The action just described is fairly slow. To provide rapid intensity changes, the rapid voltage changes from the Z Axis Amplifier are supplied directly to the control grid through capacitor A.

(3) Horizontal Amplifier. Diagram 7 (FO-9) shows the Horizontal Amplifier circuitry. The Horizontal Amplifier provides the final signal amplification to drive the horizontal deflection plates of the crt. The circuit consists of two single ended feedback amplifiers. Transistor Q234 is a constant voltage source for the input stages of both amplifiers (Q232 and Q274). The collectors of Q232 and Q274 drive the bases of complementary symmetry amplifiers Q244-Q246 and Q284-Q286 respectively. The signals in the two amplifiers are 180 degrees out of phase with each other.

(4) +B GATE OUT Amplifier. Diagram 7 (FO-9) shows the +B GATE OUT Amplifier circuitry.



[A] DC RESTORER CIRCUITRY



[B] THEORETICAL DC RESTORER WAVEFORM (NOT MEASURABLE)

2237-55

Figure 4-15. Dc restorer.

(a) The +B GATE OUT Amplifier amplifies the signal from the +B GATE OUT buffer. The output of this circuit is connected to a rear panel mounted BNC connector. The output signal steps to about +5 volts during B sweep ramp generation and about 0 volts the rest of the time. The circuit consists of inverting amplifier Q356, emitter follower Q358, and associated circuitry.

(b) When the input of the circuitry goes more positive, Q356 turns on hard and its collector goes to about +0.7 volts. This causes the emitter of Q358 to go to about 0 volts.

(c) When the input steps less positive, Q356 turns off and the base of Q358 is pulled more positive through R354. The emitter of Q358 is prevented from going more positive than +5.1 volts by VR353.

(5) Calibrator. Diagram 7 (FO-9) shows the Calibrator circuitry. The Calibrator generates an accurate 1.0 volt square wave for use in probe compensation and checking vertical gain accuracy. The circuit consists of an astable multivibrator and an output amplifier.

(a) Multivibrator. Transistors Q376 and Q382 form an astable multivibrator. The multivibrator runs at approximately 1 kilohertz. The frequency is determined by the RC time constant of C376-R377-R375. Transistors Q376 and Q382 conduct alternately, producing a square wave output signal at the collector of Q382. Diodes CR372 and CR373 limit the charge on C376 to about 18 volts to prevent damage to Q376 or Q382 when either transistor is removed while the instrument is operating.

(b) Output Amplifier. The square wave output signal from the collector of Q382 drives the output amplifier (Q386). Transistor Q386 is alternately driven into saturation, then into cutoff. This results in a 0 to +5 volt square wave at the collector of Q386. Amplitude adjustment R386 sets the collector current in Q386 to produce a 1 volt square wave across R388. This 1 volt square wave is connected to J387 on the instrument front panel.

(6) Low Voltage Power Supplies. Diagram 9 (FO-11) shows the Low Voltage Power Supplies, except for the +95 volt supply. Diagram 8 (FO-10) shows the +95 volt supply.

(a) Primary Circuit. All the supplies except the +95 volt supply receive power from T700. To reduce electromagnetic interference, the ac supply voltage is filtered by a filter which is part of P700. There are two windings in the primary of T700. These windings can be placed in series or parallel by the line voltage selector switch (S701). The two windings are placed in series for operation from a 232 volt power source or in parallel for operation from a 116 volt power source.

(b) +32 Volt Supply. Diagram 9 (FO-11) shows the +32 volt supply. The +32 volt supply consists of U722A, Q732, Q734, Q736 and associated circuitry.

1 Operational amplifier U722A controls regulation of the +32 volt supply. The noninverting input of U722A is set to +9 volts by VR722. The output of the +32 volt supply sets the inverting input of U722A at +9 volts through voltage divider R735-R736-R737.

2 The output of U722A (about +9 volts) is level shifted by a zener diode (VR725). This level shifted voltage controls the base drive of Q732 and Q736 which are connected as a Darlington amplifier. Transistor Q734 provides overcurrent protection.

3 Regulation occurs as follows. Assume the +32 volt supply tries to go less positive. This is sensed on the wiper of R736 and causes the inverting input of U722A to try to go less positive. As a result, the output of U722A goes more positive which turns on Q732 and Q736 harder. When Q736 turns on harder, the +32 volt supply goes more positive which corrects for the original deviation.

(c) +5 Volt Supply. Diagram 9 (FO-11) shows the +5 volt supply. The +5 volt supply consists of U722B, Q742, Q744, Q746 and associated circuitry.

1 The reference voltage for the +5 volt supply is obtained from the +32 volt supply through R741 and R742. The reference voltage sets the noninverting input of U722B to +5 volts.

2 The inverting input of U722B senses changes in the +5 volt supply through R743.

3 The output of U722B controls conduction in Q744 and Q746 which are connected as a Darlington amplifier. The conduction level of Q746 controls the +5 volt supply output voltage. Transistor Q742 provides overcurrent protection for the +5 volt supply.

(d) -5 Volt Supply. Diagram 9 (FO-11) shows the -5 volt supply. The -5 volt supply consists of U762, Q764, Q766, Q768 and associated circuitry.

1 In the -5 volt supply, the noninverting input of the operational amplifier (U762) is not referenced to the +32 volt supply as in the +5 volt supply. Instead it is connected to ground (0 volts) through R764.

2 The inverting input of U762 does not directly sense the supply output voltage as in the +5 volt supply. Instead the inverting input senses both the +32 and -5 volt supplies through voltage divider R763-R762. This sets the inverting input to 0 volts. Since the +32 volt supply is constant, changes in the -5 volt supply are sensed at the inverting input.

3 The output of U762 is level shifted by several series connected diodes. The level shifted voltage controls the conduction of Q766. The collector of Q766 controls the conduction of Q768 which controls the -5 volt supply output voltage. Transistor Q764 provides overcurrent protection for the -5 volt supply.

4 Regulation of the -5 volt supply occurs as follows. Assume the -5 volt supply tries to go more negative. This tries to force the inverting input of U762 negative. The output of U762 drives the base of Q766 less negative. This causes Q768 to conduct less, causing its collector to go less negative and correct the original condition.

(e) Overcurrent Protection. The following describes overcurrent protection for the +32 volt supply. Overcurrent protection for the +5 volt and -5 volt supplies operates in a similar manner.

1 As the load on the +32 volt supply increases, the voltage dropped across R734 (the current sensing resistor) also increases. As the voltage across R734 increases it forces the emitter and the base of Q736 more positive.

2 When the load on the +32 volt supply becomes excessive, the voltage on the base of Q736 becomes sufficiently positive to forward bias Q734 through R732 and R733. As Q734 begins to conduct, it reduces the forward bias on Q732 and Q736 causing the +32 volt supply output to go less positive. The greater the load on the +32 volt supply the more Q734 conducts and the less positive the +32 volt supply goes.

3 The current sensing resistors for the +5 and -5 volt supplies are R748 and R768 respectively.

(f) +95 Volt Supply. Diagram 8 (FO-10) shows the +95 volt supply. The +95 volt supply consists of CR582 and associated circuitry. The +95 volt supply is powered by the high voltage oscillator through T550. The ac voltage on pin 2 of T550 is half wave rectified by CR582. The half wave rectified voltage is filtered by C582, L582, and C584. Regulation is provided by the high voltage regulator.

4.4 FUNCTIONS OF CONTROLS, CONNECTORS, AND INDICATORS.

The location of controls, connectors, and indicators is shown on Figure 6-2 (FO-1) in the foldout section at the rear of this manual. Detailed function descriptions are listed in Table 4-2.

Table 4-2. Functions of Controls, Connectors, and Indicators

Figure 6-2 Index No.	Control, connector, or indicator name	Function
1	LINE RANGE	Selects the line voltage range on which the instrument is to be operated. The ranges are indicated on the rear panel.
2	Fuse Holder	Contains the instrument line fuse.
3	Power Cord Connector	Connects the detachable power cord to the instrument.
4	POWER	Turns the instrument on and off. Pull to turn on; push to turn off.
5	ON Indicator	Indicates when power is applied to the instrument; flashes if the line voltage drops below allowable limits.
6	INTEN	Controls the brightness of the crt display.
7	ASTIG	Screwdriver adjustment used in conjunction with the FOCUS control to initially obtain a well defined display. Once set, usually requires little or no adjustment.
8	FOCUS	Adjusts for a well defined display during normal operation.
9	TRACE ROTATION	Screwdriver adjustment used to align the trace with horizontal graticule line.
10	CALIBRATOR	Provides a one volt, one kilohertz, square wave output for setting probe compensation and checking vertical gain.
11	Graticule	Internal graticule prevents parallax errors. Rise and fall time measurement points are indicated on the left edge, and near the top and bottom horizontal portions of the graticule.
12	BEAM FINDER	Locates an off screen display. When pushed, a compressed display is visible within the graticule area. This display is independent of position controls, intensity setting, or applied signals.
13	SCALE ILLUM	Controls graticule illumination.
14	VERT MODE	<p>Selects the operating mode for the vertical deflection system.</p> <p>CH 1: Displays only signals applied to the CH 1 input connector.</p> <p>ALT: Signals applied to CH 1 and CH 2 input connectors are alternately displayed. The alternation occurs during retrace at the end of each sweep. Useful at sweep rates of 0.5 milliseconds/division or faster. The display begins to flicker at rates slower than 0.5 milliseconds/division; therefore, the CHOP mode should be used at these rates.</p> <p>ADD: Displays the algebraic sum of the signals applied to the CH 1 and CH 2 input connectors.</p> <p>CHOP: Signals applied to CH 1 and CH 2 input connectors are alternately displayed at a fixed rate of about 250 kilohertz. Useful at sweep rates of 0.5 milliseconds/division or slower. At rates above 0.5 milliseconds/division the chopped segments become visible; therefore, the ALT mode should be used.</p>

Table 4-2. Functions of Controls, Connectors, and Indicators—Continued

Figure 6-2 Index No.	Control, connector, or indicator name	Function
14 (continued)		<p>CH 2 OR X-Y: Displays only signals applied to the CH 2 input connector. Must be selected for X-Y operation.</p> <p>TRIG VIEW or 20 MHz BW: Three position switch. When pulled out, the bandwidth of the vertical deflection system is limited to 20 megahertz; when pushed part way in the vertical bandwidth is normal; and when pushed completely in and held, the signal applied to the A Sweep trigger generator is displayed.</p>
15	VOLTS/DIV	Outer ring portion of the control selects the vertical deflection factor in a 1-2-5 sequence. Factors are calibrated when the VAR portion of the controls is in its fully clockwise detent position.
16	VAR	Inner knob portion of the VOLTS/DIV control. Provides continuously variable uncalibrated vertical deflection factors between calibrated settings. Extends the maximum vertical deflection factor to 125 volts/division when using a 10X probe. This control must be in its fully clockwise detent position for calibrated deflection factors.
17	Deflection Factor Indicator	A light colored area under the VOLTS/DIV control skirt, which indicates the vertical deflection factor associated with the probe being used. Check the attenuation factor of the probe and use the correspondingly marked light colored area.
18	UNCAL Indicator	Indicates when the VAR portion of the VOLTS/DIV control is out of its fully clockwise detent position and uncalibrated deflection factors are being used.
19	AC-GND-DC	<p>Selects the method of coupling the input signal to the vertical input amplifier.</p> <p>AC: Input signals are capacitively coupled, blocking any dc component. Low frequencies are attenuated about 3 dB at 10 hertz using a 1X probe and at 1 hertz using a 10X probe. Ac coupling may cause tilting of square wave signals below about 1 kilohertz.</p> <p>GND: Connects the vertical input amplifier to ground to provide a ground reference display (input signal is disconnected). Connects the input signal to ground through the ac input capacitor and a one megohm resistor to keep the input coupling capacitor precharged.</p> <p>DC: Input signals are directly coupled, thus passing all components of the signal to the input amplifier.</p>
20	Vertical Channel In- input Connectors	Connects the Channel 1 and Channel 2 vertical input probes to the instrument. In the X-Y mode of operation, the CH 1 OR X input provides horizontal deflection and the CH 2 OR Y input provides vertical deflection.
21	POSITION	Provides vertical positioning control of the display. In the X-Y mode of operation, the CH 1 OR X control positions the display horizontally and the CH 2 OR Y control positions the display vertically.
22	INVERT	Inverts the Channel 2 display only.

Table 4-2. Functions of Control, Connectors, and Indicators—Continued

Figure 6-2 Index No.	Control, connector, or indicator name	Function
23	HORIZ DISPLAY	<p>Selects the mode of operation for the horizontal deflection system.</p> <p>A: Horizontal deflection is provided by the A sweep generator at a rate set by A TIME/DIV. The B sweep generator (delayed sweep) is disabled.</p> <p>MIXED: The first part of the sweep is displayed at a rate set by A TIME/DIV and the last part of the sweep is displayed at a rate set by B TIME/DIV. The relative amount of display controlled by each setting is determined by the setting on the DELAY TIME POS dial.</p> <p>A INTEN: Horizontal deflection is provided by the A sweep generator at a rate set by A TIME/DIV. The B sweep generator produces an intensified zone on the display. The length of time the display is intensified is about ten times the B TIME/DIV setting except when A sweep ends before B sweep. The location of the intensified zone on the display is determined by the DELAY TIME POS dial setting.</p> <p>B DLY'D: Horizontal deflection is provided by the B sweep generator at a rate set by B TIME/DIV. The A sweep generator continues to operate. With the B sweep SOURCE set to STARTS AFTER DELAY, the start of B sweep is delayed from the start of A sweep by a time determined by the settings of A TIME/DIV and DELAY TIME POS. To calculate the delay, multiply the A TIME/DIV setting by the DELAY TIME POS dial setting.</p>
24	POSITION	Provides horizontal positioning control of the display, except in the X-Y mode of operation when the CH 1 OR X, POSITION control provides horizontal positioning.
25	A AND B TIME/DIV	<p>Selects the sweep rate for the A and B sweep. The A sweep rate is set by rotating the outer ring portion of the control. The rate is shown between the two black lines on the clear skirt of the control. This rate is multiplied by the DELAY TIME POS setting when using the A INTEN or B DLY'D display modes. For calibrated sweep rates, the VAR knob portion of the control must be in the fully clockwise detent position.</p> <p>The B sweep rate is set by pulling the outer ring out and rotating it to a setting shown by the white line scribed on the ring.</p> <p>The X-Y mode of operation is selected with the A sweep rate control is set fully counterclockwise.</p>
26	VAR	Inner knob portion of the A AND B TIME/DIV control. Provides continuously variable uncalibrated sweep rates between calibrated settings of the A TIME/DIV settings. Must be in its fully clockwise detent position for calibrated A sweep rates and delay times.
27	UNCAL Indicator	Indicates when the VAR portion of the A AND B TIME/DIV control is out of its fully clockwise detent position and the A sweep rates are not calibrated.

Table 4-2. Functions of Control, Connectors, and Indicators—Continued

Figure 6-2 Index No.	Control, connector, or indicator name	Function
28	X10 MAG	Increases the displayed sweep rate by a factor of 10. Extends the fastest sweep rate to 5 nanoseconds/division. The magnified sweep display is the center one division of the unmagnified display (0.5 division from either side of the center vertical graticule line).
29	X10 MAG Indicator	Indicates when the X10 MAG is selected.
30	DELAY TIME POS	Provides a variable B sweep delay from 0.000 to 10.000 times the setting of the A TIME/DIV control.
31	TRIG MODE	<p>Selects the mode of operation for the A sweep trigger.</p> <p>AUTO: With proper trigger LEVEL and COUPLING settings, A sweep can be initiated by signals above about 20 hertz. In the absence of a triggering signal or with control misadjustments, the A sweep generator free-runs to provide a reference display.</p> <p>NORM: With proper trigger LEVEL and COUPLING settings, A sweep can be initiated by an input signal. In the absence of a triggering signal or with control misadjustments, the A sweep generator does not run and there is no display.</p> <p>SGL SWP: A momentary contact push button, which cancels previous TRIG MODE selections and selects a single sweep mode of operation. This mode operates the same as NORM, except only one sweep is displayed on a trigger signal. Another single sweep cannot be displayed until the SGL SWP push button is pressed to reset the trigger circuit.</p>
32	TRIG READY Indicator	Indicates the A sweep is reset and ready for a single sweep display when a trigger signal occurs. If the indicator is out when in the SGL SWP mode, the SGL SWP push button must be pressed to reset the trigger circuit.
33	SOURCE	<p>Selects the source of trigger input signal.</p> <p>STARTS AFTER DELAY (B trigger only): B sweep runs immediately after the delay time selected by the A TIME/DIV setting multiplied by the DELAY TIME POS setting. No B trigger is required. In any other B trigger SOURCE setting a trigger is required after the delay time before B sweep will run.</p> <p>NORM: Provides a trigger from the vertical deflection system. The actual source is the displayed signal. In this mode, CH 1 and CH 2 time relationship measurements are not valid and should not be used. This mode is not recommended for use in the CHOP or ALT VERT MODE because the display triggers on the channel switching transients.</p> <p>CH 1: Provides a trigger from the CH 1 preamplifier. The CH 2 display may be unstable if it is not time related to CH 1.</p> <p>CH 2: Provides a trigger from the CH 2 preamplifier. The CH 1 display may be unstable if it is not time related to CH 2.</p> <p>LINE (A trigger only): Provides a trigger from a sample of the power-line frequency. This trigger is useful when channel inputs are time related (multiple or sub-multiple) to the power-line frequency. Also, it is useful for stabilizing a display that has a power-line frequency component on a complex waveform.</p>

Table 4-2. Functions of Control, Connectors, and Indicators—Continued

Figure 6-2 Index No.	Control, connector, or indicator name	Function
33 (continued)		<p>EXT: Provides a trigger from an external signal connected to the External Trigger Input connector. This trigger input must be time related to the input signals to provide a stable display.</p> <p>EXT (\div by 10): The same as EXT above, except the input signal is attenuated by a factor of 10.</p>
34	COUPLING	<p>Selects the method used to couple signals to the trigger generator.</p> <p>AC: Selects capacitive coupling, which blocks dc components on the signal. Signals below about 60 hertz are attenuated.</p> <p>LF REJ: Selects capacitive coupling, which blocks dc components on the signal. Signals below about 50 kilohertz are rejected. Useful for displaying high frequency components of complex waveforms.</p> <p>HF REJ: Signals are capacitively coupled, which blocks the dc component. Signals below about 60 hertz and above about 50 kilohertz are attenuated. Useful for displaying low frequency components of complex waveforms.</p> <p>DC: All components of the signal are coupled. Useful for displaying low-frequency or low repetition rate signals.</p>
35	LEVEL	Selects the amplitude point on the trigger signal at which the sweep is triggered. It is usually adjusted after the trigger SOURCE, COUPLING, and SLOPE have been selected.
36	SLOPE	<p>Selects the slope of the trigger signal on which the sweep is triggered.</p> <p>OUT +: Sweep is triggered on the positive going portion of the trigger signal.</p> <p>IN -: Sweep is triggered on the negative going portion of the trigger signal.</p>
37	External Trigger Input Connector	Connects external trigger input probe or cables to the instrument.
38	A TRIGGER HOLDOFF	<p>Provides control of holdoff time between sweeps. Variable up to ten times the setting of the A TIME/DIV setting, except in the .2 and .5 second ranges. Useful when triggering on low repetition pulses or aperiodic signals.</p> <p>Obtain the best possible display using the A sweep trigger controls before setting the hold off time.</p>
39	Ground Binding Post	External connector to chassis (earth) ground. The connector will accept cables or wires using open end solder lugs, banana plugs, or stripped wire for connection.
40	+A GATE	Provides a +5 volt positive pulse output during the A sweep time.
41	+B GATE	Provides a +5 volt positive pulse output during the B sweep time.
42	EXT Z AXIS	Connects external Z-axis inputs for crt intensity modulation. External inputs may also be used for crt blanking provided the crt intensity is properly set. Useful for adding time markers to a display, or when using the instrument as a peripheral display in a monitoring system.
43	CH 2 OUT	Provides an output signal from the CH 2 preamplifier. Useful for cascade operation (CH 2 into CH 1) to increase vertical deflection sensitivity. Also, may be used to trigger external equipment.

4-5. OPERATING CONSIDERATIONS. To ensure optimum measurement accuracy, the following information should be considered before operating the oscilloscope.

a. Signal Connections. In general, probes offer the most convenient means of connecting an input signal to the instrument. They are shielded to prevent pickup of electrostatic interference. The 10X probe offers a high input impedance, which allows the circuit under test to perform very close to normal operation conditions. However, it also attenuates the input signal ten times.

(1) In high frequency applications that require maximum overall bandwidth, use coaxial cables terminated at both ends in their characteristic impedance. For further information, refer to the paragraph on Coaxial Cables below.

(2) High level, low frequency signals may be directly connected to the input connectors with short, unshielded leads. This coupling method works best for signals below about one kilohertz and deflection factors above one volt/division. When this method is used, establish a common ground between the instrument and the equipment under test. To avoid errors in the display, keep the leads away from any source of interference. If interference is excessive with unshielded leads, use a coaxial cable or a probe.

b. Loading Effect of Input Connections. As nearly as possible, simulate actual operating conditions in the equipment under test. Otherwise, the equipment under test may not produce a normal signal. Because of their high input impedance, the supplied probes offer the least circuit loading. When the signal is directly coupled to the input of this instrument, the input impedance is about one megohm paralleled by about 20 picofarads. When the signal is coupled to the input through a coaxial cable, the effective input capacitance depends upon the type and length of cable used. For information on obtaining maximum frequency response with coaxial cables, refer to the paragraph on Coaxial Cables below.

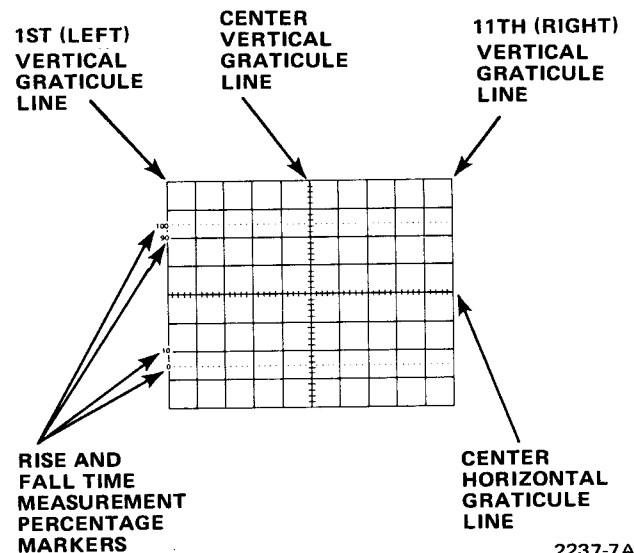
c. Coaxial Cables. Cables used to connect signals to the input connectors have a large effect on the accuracy of a displayed high frequency waveform.

(1) To maintain the high frequency characteristics of an applied signal, high quality, low loss coaxial cable should be used. Also, the cable should be terminated at both ends in its characteristic impedance. If it is necessary to use cables with differing characteristic impedances, use suitable impedance matching devices.

(2) To maintain fast rise time pulse characteristics; use the shortest length of coaxial cable possible. Also, observe the cable criteria for high frequency characteristics in (1) above.

d. Grounding. Reliable signal measurements cannot be made unless both the instrument and equipment under test are connected together by a common reference (ground) lead in addition to the signal lead or probe. Although the three-wire ac power cord provides a common connection when used with equipment with similar power cords, the ground loop produced may make accurate measurements impossible. The short ground lead connected to the probes provide the best signal ground. On coaxial cables, the shield provides a common ground when connected between two coaxial connectors (or with suitable adapters to provide a common ground). When using unshielded signal leads, a common ground lead should be connected from the chassis of the instrument (rear panel Ground Binding Post) to the chassis of the equipment under test.

e. Graticule. The internal 8 X 10 cm graticule provides parallax-free measurements. The graticule area is divided horizontally and vertically into 1 cm divisions. Vertical gain and horizontal timing are calibrated to the graticule, so accurate measurements can be made from the crt. Figure 4-17 shows the graticule with its various measurement markings. The terminology shown is used throughout this manual in discussions involving graticule measurements. Note the numeric scaling markings on the left side of the graticule. These are used when making rise or fall time measurements.



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Figure 4-17 Graticule measurement markings

f. Common Mode Rejection (Figure 4-18). Some signals may contain undesirable components, such as in the dotted portion of Figure 4-18A. Common mode rejection can eliminate or reduce these components from the measurement. Use the following procedure to reduce or eliminate an undesirable line frequency component:

- (1) Apply signal to CH 1 input connector.
- (2) Apply line frequency signal to CH 2 input connector.
- (3) Set VERT MODE to ALT.
- (4) Push in INVERT button to invert channel 2 display.

(5) Set CH 2 VAR control to make channel 2 display amplitude about equal to undesired component of channel 1 display.

(6) Set VERT MODE to ADD and slightly readjust CH 2 VAR control for maximum rejection of undesired signal component (see Figure 4-18B).

g. Cascaded Operation. Maximum vertical sensitivity can be increased to approximately 1 millivolt/division by cascading the CH 1 and CH 2 amplifiers as follows:

(1) Connect CH 2 OUT signal (on rear panel) to CH 1 input via a 50 ohm cable and a 50 ohm termination.

(2) Set VERT MODE to CH 1.

(3) Apply an input signal to CH 2 input connector.

NOTE

In this mode, bandwidth is limited to about 40 megahertz.

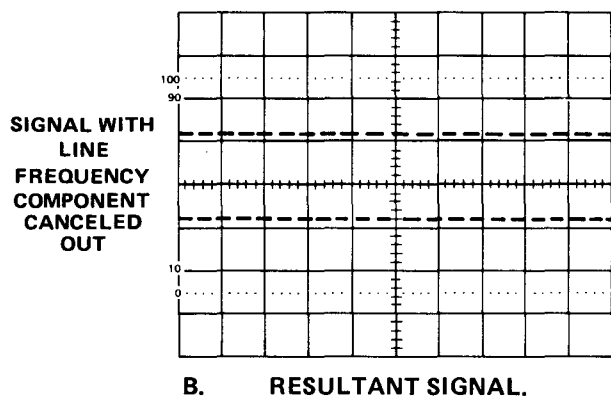
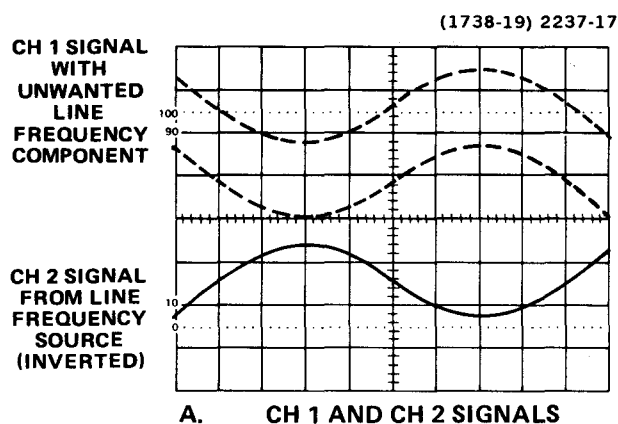


Figure 4-18. Common mode rejection of an undesired line-frequency.

h. Delayed Sweep Magnification. Following are two B Delayed modes, which may provide a higher apparent sweep rate magnification than provided by X10 MAG. First, try the Magnified Sweep Starts After Delay method. If this produces too much horizontal jitter, try the Magnified Triggered After Delay method.

(1) **Magnified Sweep Starts After Delay (Figure 4-19).** Use the following procedure to make delayed sweep magnification measurements.

(a) Set HORIZ DISPLAY to A INTEN and B SOURCE to STARTS AFTER DELAY.

(b) Use DELAY TIME POS to move the left edge of the intensified display to the left side of that portion of A sweep to be magnified.

(c) Set B TIME/DIV so just that portion of A sweep to be magnified is intensified (see Figure 4-19A).

(d) Set HORIZ DISPLAY to B DLY'D. The portion of A sweep that was intensified in (c) above is displayed in magnified form (see Figure 4-19B). The displayed sweep rate is determined by B TIME/DIV. To calculate the apparent magnification factor, use formula:

$$\text{Apparent Magnification} = \frac{\text{A TIME/DIV setting}}{\text{B TIME/DIV setting}}$$

(2) Magnified Sweep Triggered After Delay. If the Magnified Sweep Starts After Delay method above produces too much jitter, operate B sweep as follows:

(a) Perform steps (1) (a) through (1) (c) of Magnified Sweep Starts After Delay procedure above.

(b) Set B SOURCE to the same setting as A SOURCE. Set B LEVEL for a stable intensified zone.

NOTE

If the intensified zone cannot be stabilized, reset VOLTS/DIV for more display amplitude or use external triggering.

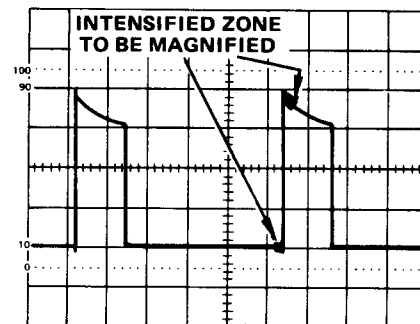
(c) Set HORIZ DISPLAY to B DLY'D. To obtain a stable display it may be necessary to slightly reset B LEVEL control.

4-6. INITIAL INSTRUMENT TURN-ON. Apply power to the instrument as follows:

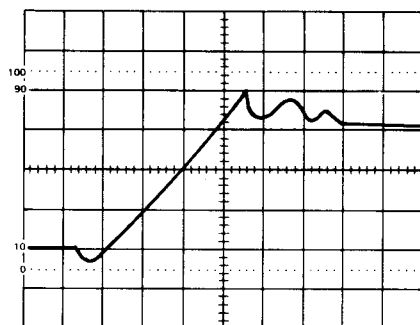
a. Verify that the instrument is configured for the correct power source (refer to the Operating Voltage Selection paragraphs in Section III, Preparation for Use and Shipment).

b. Remove the power cord from the front panel cover and plug it into the rear panel connector.

c. Connect the power cord to the power source receptacle.



A. A INTENSIFIED DISPLAY



B. B DLY'D DISPLAY

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Figure 4-19. Delayed sweep magnification.

d. Pull on the POWER switch. The ON indicator should light; if it blinks, the line voltage is too low.

e. Allow the instrument a few minutes to warm up (if actual measurements are to be taken, allow 5 minutes when the instrument has been stored in a temperature above 0°; 20 minutes for lower temperatures).

4-7. PRELIMINARY ADJUSTMENTS. Before using the instrument for the first time, make the following preliminary settings and adjustments, then perform a NORMAL OPERATION functional check.

a. Initial Control Settings. Set the controls as follows (both channels if applicable):

VOLTS/DIV	.2 in 10X probe window
VAR	Fully clockwise (calibrated detent)
POSITION	Midrange
AC-GND-DC	DC
VERT MODE	CH 1
INVERT	Out (normal)
20 MHz BW	In (off)
TRIG MODE	AUTO
LEVEL	Midpoint of + slope, then adjust as necessary
SLOPE	OUT +
COUPLING	AC
A SOURCE	CH 1
B SOURCE	STARTS AFTER DELAY
DELAY TIME POS	Fully counterclockwise
A and B TIME/DIV	.2 ms
A VAR	Fully clockwise (calibrated detent)
HORIZ DISPLAY	A
X10 MAG	OUT (off)
A TRIGGER HOLDOFF	NORM
SCALE ILLUM	Fully counterclockwise
POSITION, INTEN, and FOCUS	Midrange

NOTE

At this point there should be a trace displayed. If not, recheck control settings. Then press BEAM FINDER and adjust the POSITION controls so the trace is centered vertically and horizontally on the crt. If no trace appeared when BEAM FINDER was pressed, the instrument is malfunctioning. If the trace ap-

peared and could be centered, but disappeared when BEAM FINDER was released, increase the INTEN control.

b. Intensity Adjustment. Set the INTEN control for a comfortable viewing level. Later when FOCUS and ASTIG are adjusted, INTEN may need readjustment.

CAUTION

To protect the crt phosphor, do not turn the INTEN control higher than necessary to provide a satisfactory display. Since the blue faceplate filter reduces the display light output, avoid using too high an INTEN setting with this filter. When more intensity is desired, use the clear filter or reduce the ambient light level. The intensity may increase too high when changing the TIME/DIV settings from a fast to a slow sweep speed.

c. Focus and Astigmatism Adjustment. Adjust the FOCUS and ASTIG controls as follows:

- (1) Connect a probe to either vertical channel. Then connect the probe to the CALIBRATOR output. Set VERT MODE to the channel being used.
- (2) Adjust FOCUS so horizontal portion of display is focused.
- (3) Adjust INTEN so rising portion of the display can be seen (If display is unstable, A LEVEL may need adjustment).
- (4) Adjust ASTIG so horizontal and vertical portions of display are as equally focused as possible.
- (5) Adjust FOCUS so vertical portion of display is as thin as possible.
- (6) Repeat steps (4) and (5) for best overall display focus.
- (7) Disconnect the probe from the CALIBRATOR output.

d. Trace Rotation Adjustment. Adjust the TRACE ROTATION control as follows:

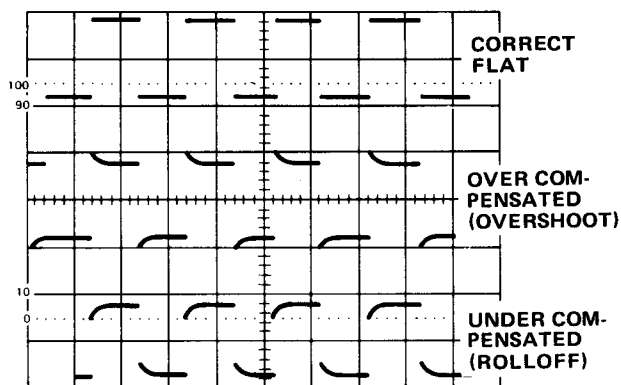
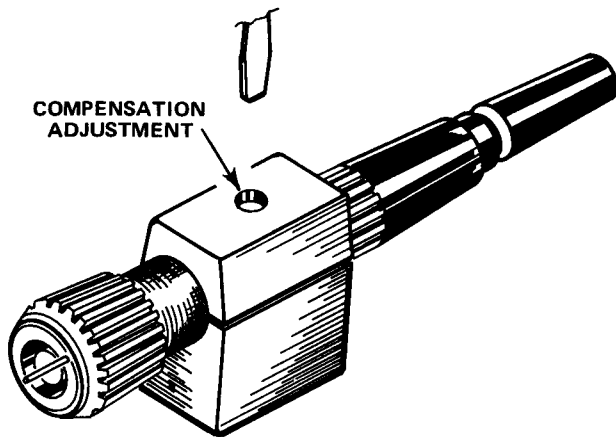
- (1) Set AC-GND-DC to GND.
- (2) Vertically position the trace to the center horizontal graticule line.

(3) Adjust TRACE ROTATION so the trace is parallel to the center horizontal graticule line.

e. Graticule Scale Illumination. To obtain scale illumination, rotate SCALE ILLUM clockwise until the desired amount of illumination is reached.

f. Probe Compensation (Figure 4-20). Each time the P6104 probes are used with the instrument, probe compensation should be checked and adjusted if necessary. A low capacitance screwdriver should be used. Use the following procedure for adjusting P6104 probe compensation:

(1) Connect P6104 probes to CH 1 and CH 2 vertical inputs.



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Figure 4-20. Probe compensation.

(2) Set the instrument controls as follows:

VOLTS/DIV	.2 (in 10X probe window)
A AND B TIME/DIV	.2 ms
AC-GND-DC	DC
VERT MODE	CH 1
A SOURCE	CH 1
A COUPLING	DC
HORIZ DISPLAY	A
SLOPE	OUT: +
LEVEL	Adjust as necessary for a stable display

(3) Connect the CH 1 and CH 2 probes to the CALIBRATOR. Adjust the POSITION controls so the top of at least one complete positive pulse is displayed.

(4) Adjust CH 1 probe compensation through hole in compensation box for the best flat top display.

(5) Set A SOURCE and VERT MODE to CH 2.

(6) Repeat step (4) above for CH 2.

4-8. NORMAL OPERATION. The following procedures demonstrate the operation of the controls, connectors, and indicators. These procedures may also be used for operator familiarization or as an instrument functional check. Before starting, preset the controls as listed in paragraph 4-7. a., connect probes to CH 1 and CH 2, and connect the probes to the CALIBRATOR. Where vertical channel and horizontal sweep or trigger controls are duplicated, only one set of controls is demonstrated. The procedures are intended to be preformed in the sequence listed.

a. Beam Finder. Demonstrate BEAM FINDER operation as follows:

(1) Position the CH 1 display off screen with the vertical POSITION control.

(2) Push in and hold BEAM FINDER. The display should return to on screen. Adjust POSITION to center the trace vertically and horizontally. Release BEAM FINDER. The trace should be on screen.

(3) Adjust INTEN until the display disappears.

(4) Push in and hold BEAM FINDER. The display should reappear. Release BEAM FINDER. Readjust INTEN for a visible display.

b. Intensity and Focus. Demonstrate INTEN and FOCUS operation as follows:

(1) Rotate INTEN between its maximum clockwise and counterclockwise positions. The display should vary from a blooming intensity to no display. Reset INTEN to a comfortable viewing level.

(2) Rotate FOCUS between its maximum clockwise and counterclockwise positions. The display should become blurred on either side of an optimum control setting. Reset the control for the best focused display.

c. Vertical Deflection System. Demonstrate the operation of the controls in the vertical deflection system as follows:

(1) Select CH 1 on VERT MODE. There should be one display.

(2) Rotate CH 1 POSITION between its maximum settings. The display should move off screen in both vertical directions. Reset POSITION for a visible display.

(3) Set VERT MODE to ALT. There should be two displays.

(4) Alternately rotate CH 1 and CH 2 POSITION between their maximum settings. Their respective displays should move off screen in both vertical directions. Reset POSITION for two visible displays.

(5) Set A AND B TIME/DIV to 20 ms. The CH 1 and CH 2 traces should be alternately displaying.

(6) Set VERT MODE to CHOP. The CH 1 and CH 2 traces should be simultaneously displayed. Reset A AND B TIME/DIV to 5 ms and VERT MODE to ALT.

(7) Set A SOURCE to LINE. Push in and hold TRIG VIEW. The display should be a sample of the power line trigger signal. Release TRIG VIEW and reset A SOURCE to CH 1.

(8) Set A AND B TIME/DIV to .5 ms and VOLTS/DIV to .5.

(9) Adjust vertical POSITION for one display on each side of the center horizontal graticule line. If the display is not stable, adjust A LEVEL. The display should be two vertical divisions in amplitude and each pulse width one division wide (corresponds to a one volt peak to peak, one kilohertz square wave CALIBRATOR output).

(10) Set AC-GND-DC to GND and note the position of the baseline trace. Set AC-GND-DC to AC. The display should be equally displayed on each side of the baseline trace position. Reset AC-GND-DC to DC.

(11) Adjust horizontal POSITION so the display starts at the left vertical graticule line.

(12) Push in INVERT and adjust CH 2 vertical POSITION for an on screen display. The CH 2 display should be inverted. Push in INVERT again (releases it) and readjust POSITION for separated dual displays.

(13) Rotate CH 2 VAR to its fully counterclockwise position. The UNCAL indicator should light and the display should decrease in vertical size to 0.8 divisions or less. Return VAR to its fully clockwise detent position.

(14) Set A AND B TIME/DIV to X-Y and VERT MODE to CH 2 (same as OR X-Y). The two dot display should form a 45 degree angle to the horizontal.

(15) Set CH 1 AC-GND-DC to GND. The display should be two dots in a vertical line. Reset control to DC.

(16) Set CH 2 AC-GND-DC to GND. The display should be two dots in a horizontal line. Reset control to DC.

(17) Set A AND B TIME/DIV to .5 ms and VERT MODE to ALT.

NOTE

At this point there should be a dual display with two divisions of vertical amplitude and one division pulse widths. The displays should be somewhat centered in the upper and lower halves of the screen. If not, reset the vertical deflection system controls and A AND B TIME/DIV until this display is obtained before proceeding to the horizontal deflection system procedures.

d. Horizontal Deflection System. Demonstrate the operation of the controls in the horizontal deflection system (sweep) as follows:

(1) Normal and Magnified Sweep.

(a) Set VERT MODE to CH 1.

(b) Rotate A AND B TIME/DIV one or two positions on either side of .5 ms. The display sweep rate should change. Reset A AND B TIME/DIV to .1 ms. The display pulse width should be five divisions.

(c) Rotate VAR to its fully counterclockwise position. The UNCAL indicator should light and the display pulse width should decrease to two divisions or less. Return VAR to its fully clockwise detent position.

(d) Set A AND B TIME/DIV to 1 ms and push in X10 MAG. The X10 MAG indicator should light and the display pulse width should expand to five divisions. The magnified display is the center one division (0.5 division on either side of the center vertical graticule line) of the normal display.

(e) Push in X10 MAG again (releases it).

(2) Mixed Sweep.

(a) Set A AND B TIME/DIV to .5 ms, HORIZ DISPLAY to MIXED, and DELAY TIME POS to 5.0.

(b) Pull out on the A AND B TIME/DIV outer ring, rotate B TIME/DIV to .2 ms, and release the outer ring. The display should show a sweep rate change at about the center of the display. The first five divisions of the display is at the A sweep rate and the last five divisions of the display is at the B sweep rate.

(c) Rotate DELAY TIME POS on each side of the 5.0 setting and observe the movement of the starting point of the B sweep rate portion of the display. Reset DELAY TIME POS to 5.0.

(3) A Intensified Sweep.

(a) Set HORIZ DISPLAY to A INTEN and B TIME/DIV to .1 ms. The intensified portion of the display is the B sweep time.

(b) Rotate DELAY TIME POS on either side of 5.0 and observe the movement of the intensified portion of the display.

(4) B Delayed Sweep.

(a) Set HORIZ DISPLAY to B DLY'D. The display is the intensified portion of the display seen in (3) (a) above.

(b) Rotate B TIME/DIV one position on either side of .1 ms. The display sweep rate should change. Reset B TIME/DIV to .1 ms.

(5) Normal Trigger.

(a) Set HORIZ DISPLAY to A and TRIG MODE to NORM. Rotate A LEVEL for a stable display. Adjust horizontal POSITION so display starts at the left vertical graticule line. Note that the display starts with a positive pulse.

(b) Push in A SLOPE (IN:—). Note that the display now starts with a negative pulse. Push in SLOPE again to reset it to the OUT: + position.

(6) Single Sweep Trigger.

(a) Adjust A LEVEL so display is just barely stabilized.

(b) Set A COUPLING to LF REJ.

(c) Push and release SGL SWP. The previously selected TRIG MODE should cancel.

(d) While watching the TRIG READY indicator and the display, push in and release SGL SWP. The indicator should have blinked and a display should have flashed across the screen. This indicates the trigger circuit was reset and then triggered.

(e) Disconnect the CH 1 probe tip from the CALIBRATOR and push in SGL SWP again. The TRIG READY indicator should be lit. While watching the TRIG READY indicator and the display, touch the CH 1 probe tip to the CALIBRATOR. The TRIG READY indicator should have gone out as the display flashed across the screen.

(f) Reset A COUPLING to AC and TRIG MODE to AUTO.

(g) Disconnect the probe tips from the CALIBRATOR.

(7) Low Frequency Rejection Trigger.

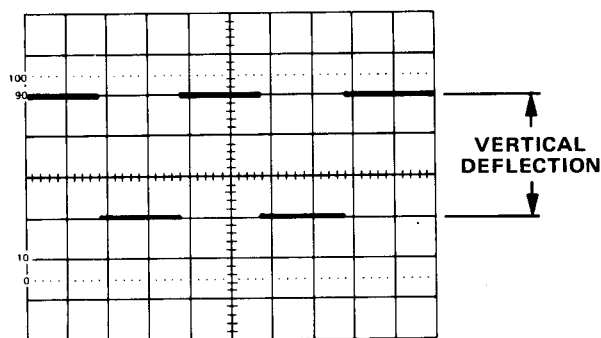
(a) Set A SOURCE to LINE and A AND B TIME/DIV to 10 ms.

(b) Push in and hold TRIG VIEW. The display should be a sample of the power line trigger input. Set A COUPLING to LF REJ. The display should disappear showing that the low frequency trigger rejection circuitry is working.

4-9. INSTRUMENT TURN OFF. The instrument is turned off by pushing in on the POWER push button. When turned off, the ON indicator should extinguish.

4-10. APPLICATIONS. The following information describes procedures and techniques for making specific measurements.

a. Peak to Peak Amplitude Measurement (Figure 4-21). Measure the peak to peak amplitude of a signal by multiplying the vertical deflection (in divisions) by the VOLTS/DIV setting.



EXAMPLE:

VERTICAL DEFLECTION X VOLTS/DIV = AMPLITUDE

3 DIVISIONS X .5 VOLTS/DIVISION = 1.5 VOLTS PEAK-TO-PEAK

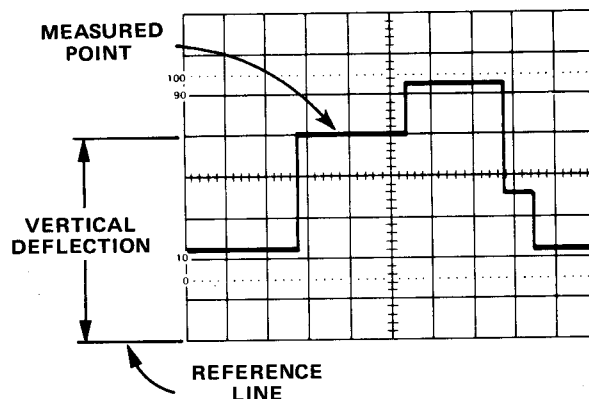
(1907-27) 2237-19

Figure 4-21. Example of peak to peak voltage measurement.

b. Instantaneous Amplitude Measurement (Figure 4-22).
Measure the amplitude of any point on a waveform with respect to ground as follows:

- (1) Set AC-GND-DC to DC.
- (2) Apply signal to be measured to either vertical input connector. Set VERT MODE to channel being used.
- (3) Obtain a stable display.
- (4) Set AC-GND-DC to GND. Position trace to a reference line.
- (5) Set AC-GND-DC to DC. If waveform appears above reference line, voltage is positive. If waveform appears below reference line, voltage is negative.
- (6) Measure vertical difference (in divisions) between reference line and desired point on waveform and multiply by VOLTS/DIV setting.

c. Dual Trace Phase Difference Measurement (Figure 4-23). Phase comparisons between two signals of the same frequency can be made using the dual trace feature. This method can be used up to the frequency limit of the vertical system and is usually more accurate and easier to use than the X-Y method. To make the comparison, use the following procedure:



EXAMPLE:

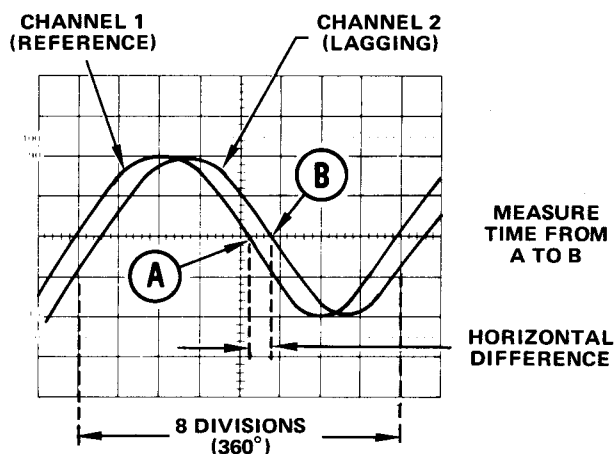
VERTICAL DEFLECTION FROM REFERENCE LINE TO MEASURED POINT X VOLTS/DIV = INSTANTANEOUS AMPLITUDE

5 DIVISIONS X 10 MILLIVOLTS/DIVISION = 50 MILLIVOLTS

(1907-28) 2237-20

Figure 4-22. Example of instantaneous voltage measurement.

- (1) Set both AC-GND-DC to AC.
- (2) Set VERT MODE to CHOP or ALT. (CHOP is more suitable for low frequency signals; ALT is more suitable for high frequency signals.) Position both traces to center horizontal graticule line.
- (3) Set A SOURCE to CH 1.
- (4) Connect reference signal to CH 1 input connector and comparison signal to CH 2 input connector using coaxial cables or probes which have equal time delay.
- (5) If signals are of opposite polarity, push INVERT button to invert CH 2 display. (Signals may be of opposite polarity due to 180° phase difference; if so, take this into account in final calculation.)
- (6) Set CH 1 and CH 2 VOLTS/DIV and their associated VAR controls so displays are equal and about five divisions in amplitude.
- (7) Set TIME/DIV to a sweep rate which displays about one cycle of reference waveform.
- (8) Set VAR TIME/DIV until one cycle of reference signal (CH 1) occupies exactly 8 divisions between the second and tenth graticule lines.

**EXAMPLE:**

$$\text{HORIZONTAL DIFFERENCE (A TO B)} \times \text{DEGREES/DIVISION} = \text{PHASE DIFFERENCE}$$

$$0.6 \text{ DIVISION} \times 45^\circ/\text{DIVISION} = 27^\circ$$

(465/DM-0-15) 2237-21

Figure 4-23. Example of dual trace phase difference measurement

NOTE

Each division of graticule represents 45° of cycle ($360^\circ \div 8 \text{ divisions} = 45^\circ/\text{division}$). Therefore; the sweep rate can be stated in terms of degrees as $45^\circ/\text{division}$.

(9) Measure horizontal difference (in divisions) between corresponding points on waveforms.

(10) Multiply difference (in divisions) by $45^\circ/\text{division}$ (sweep rate) to obtain exact amount of phase difference.

d. High Resolution Phase Difference Measurement (Figure 4-24). For phase differences less than 45° , measurement accuracy is increased by using X10 MAG as follows:

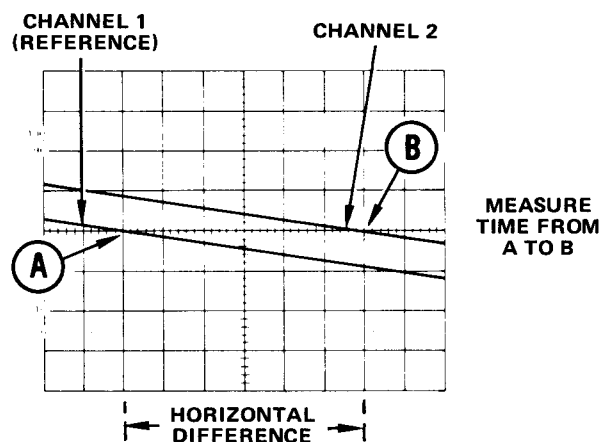
(1) Perform steps (1) through (8) of 4-10 c above.

(2) Center the measurement points on the vertical graticule line.

(3) Push in X10 MAG. Sweep rate is now $4.5^\circ/\text{division}$ ($45^\circ/\text{division} \div 10$).

(4) Slightly reset horizontal POSITION control to move measurement points within graticule area.

(5) Measure horizontal difference (in divisions) between corresponding points on waveforms.

**EXAMPLE:**

$$\text{HORIZONTAL DIFFERENCE (A TO B)} \times \text{DEGREES/DIVISION} = \text{PHASE DIFFERENCE}$$

$$6 \text{ DIVISIONS} \times 4.5^\circ/\text{DIVISION} = 27^\circ$$

(465/DM-0-16) 2237-22

Figure 4-24. Example of high resolution phase difference measurement.

(6) Multiply difference by magnified sweep rate ($4.5^\circ/\text{division}$).

e. Time Duration and Frequency Measurement (Figure 4-25). Measure the time duration between two points on a waveform by multiplying the horizontal distance (in divisions) between the points by the TIME/DIV setting. Frequency is the reciprocal of the time duration measurement of one cycle.

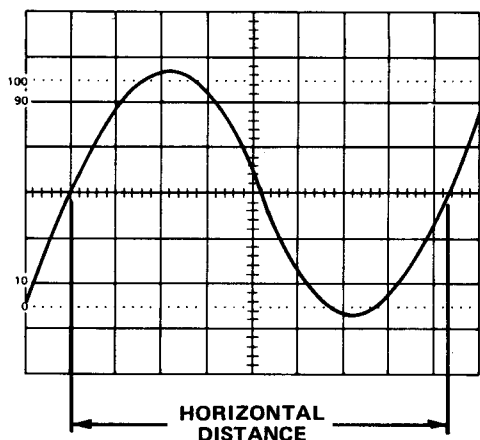
f. Rise Time Measurement (Figure 4-26). Rise time measurements are made in the same manner as time duration measurements, except the horizontal measurements are made between the 10% and 90% points of the waveform amplitude (see percentage markings on the left edge of the graticule) as follows:

(1) Set VOLTS/DIV and its associated VAR control for a 5 division display.

(2) Adjust vertical POSITION so display is between the 0% and 100% lines.

(3) Measure horizontal distance (divisions) between 10% and 90% points on waveform (points A and B).

g. Differential Time Measurement. Differential time measurements can be made using either the A INTENS, B DLY'D, or MIXED HORIZ DISPLAY modes.



EXAMPLE:

$$\text{HORIZONTAL DISTANCE} \times \text{TIME/DIV SETTING} = \text{TIME DURATION}$$

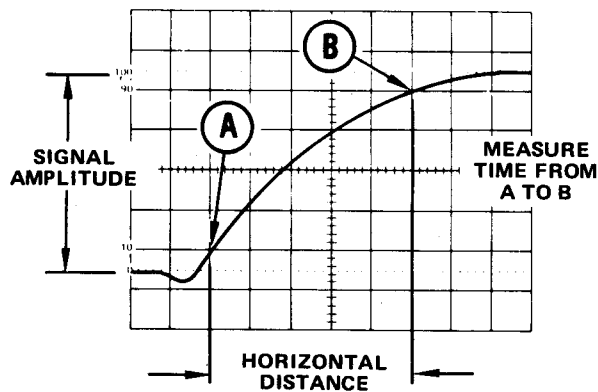
$$8.3 \text{ DIVISIONS} \times \frac{2 \text{ MILLISECONDS}}{\text{DIVISION}} = 16.6 \text{ MILLISECONDS}$$

$$\frac{1}{\text{TIME DURATION}} = \text{FREQUENCY}$$

$$\frac{1}{16.6 \text{ MILLISECONDS}} = 60 \text{ HERTZ}$$

(1738-20) 2237-23

Figure 4-25. Example of time duration and frequency measurement



EXAMPLE:

$$\text{HORIZONTAL DISTANCE (A TO B)} \times \text{TIME/DIV SETTING} = \text{RISE TIME}$$

$$5 \text{ DIVISIONS} \times \frac{1 \text{ MICROSECOND}}{\text{DIVISION}} = 5 \text{ MICROSECONDS}$$

(465/DM-0-13) 2237-24

Figure 4-26. Example of rise time measurement.

(1) **A Intensified Differential Time Measurement (Figure 4-27).** Use the following procedure to make differential time measurements using the A INTEN mode:

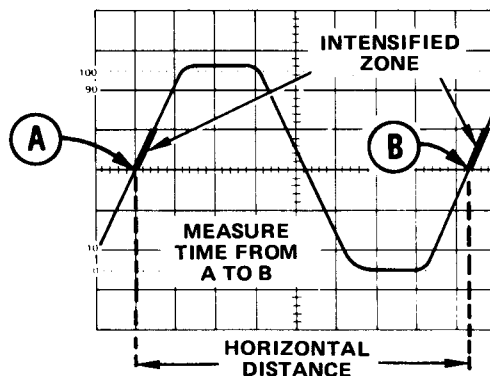
(a) Set A TIME/DIV and horizontal POSITION control to locate both time measurement points within graticule area.

(b) Set HORIZ DISPLAY to A INTEN and B SOURCE to STARTS AFTER DELAY.

(c) Pull out and set B TIME/DIV for the shortest useable intensified display zone.

(d) Use DELAY TIME POS control to move the left edge of intensified zone to just touch the first time measurement point (point A). Note DELAY TIME POS (1st DTP setting) setting.

(e) Use DELAY TIME POS control to move left edge of intensified zone to just touch the second time measurement point (point B). Note DELAY TIME POS (2nd DTP setting) setting.



EXAMPLE:

$$\text{2ND DTP SETTING} - \text{1ST DTP SETTING} \times \frac{\text{A TIME/DIV SETTING}}{\text{B TIME/DIV SETTING}} = \text{TIME DIFFERENCE}$$

$$9.56 - 1.23 \times \frac{2}{1} = 16.66 \text{ MILLISECONDS}$$

(465/DM-0-9) 2237-25

Figure 4-27. Example of time duration measurement using A INTEN mode.

(2) B Delayed Differential Time Measurement

(Figure 4-28). Use the following procedure to make differential time measurements using the B DLY'D mode:

(a) Set A TIME/DIV and horizontal POSITION control to locate both time measurement points within graticule area (see Figure 4-28A).

(b) Set HORIZ DISPLAY to A INTEN and B SOURCE to STARTS AFTER DELAY.

(c) Pull out and set B TIME/DIV for the shortest usable intensified display zone.

(d) Turn DELAY TIME POS so that first time measurement point (point A) is in center of intensified zone.

(e) Set HORIZ DISPLAY to B DLY'D.

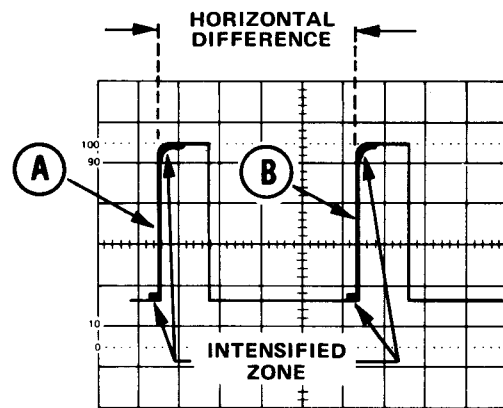
(f) Slightly reset DELAY TIME POS to move first time measurement point to the closest vertical graticule line (see Figure 4-28B). Note DELAY TIME POS (1st DTP setting) setting.

(g) Set HORIZ DISPLAY to A INTEN.

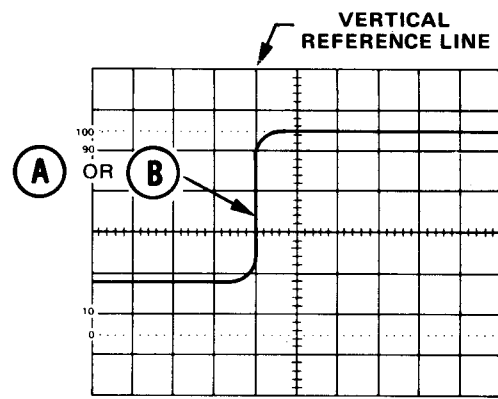
(h) Repeat step (d) for the second time measurement point (Point B).

(i) Set HORIZ DISPLAY to B DLY'D.

(j) Slightly reset DELAY TIME POS to move second time measurement point to the same vertical graticule line used in step (f). Note DELAY TIME POS (2nd DTP setting) setting.



A. A INTENSIFIED DISPLAY



B. B DELAYED DISPLAY

EXAMPLE:

$$\text{2ND DTP SETTING} - \text{1ST DTP SETTING} \times \text{A TIME/DIV SETTING} = \text{TIME DIFFERENCE}$$

$$5.57 - 0.88 \times .2 = 0.938$$

MICROSECONDS MILLISECONDS

(1907-29) 2237-26

Figure 4-28. Example of time duration measurement using B DLY'D mode.

SECTION V MAINTENANCE INSTRUCTIONS

5-1. OPERATIONAL CHECKOUT (PERFORMANCE CHECK). The operational checkout is a performance check of the 465M using test equipment listed in Table 2-1. Satisfactory completion of the checkout procedures indicates that the instrument should perform as listed in the Performance Requirement column in Table 1-1. The Operational Checkout procedure (Performance Check) is contained in Table 5-1 and is structured as follows:

a. The STEP column lists the sequential steps of the procedure.

b. The PROCEDURE column lists the instructions and illustrations necessary to setup and perform the procedure.

c. The PERFORMANCE REQUIREMENT column lists the desired result of the test.

d. The control settings listed in step 1 are used as initial settings for each numbered procedure step. Therefore, the numbered procedure steps may be performed individually or in any order by first performing step 1, then any other desired step. This feature is useful for testing the instrument after making repairs or replacing components in individual sections of the instrument.

CAUTION

Do not connect the instrument to a power source until instructed to do so in a procedural step. This will prevent instrument damage in the event the LINE RANGE Selector switch or other controls are not properly set.

Table 5-1. Operational Checkout Procedures (Performance Check)

Step	Procedure	Performance Requirement														
1.	<p>Preliminary Procedure</p> <p>a. To place the 465M into a basic operating mode:</p> <p>Check that the fuse value and Line Voltage Selector switch setting (on the rear panel) are set for the available power input voltage. Unless otherwise specified, the instrument is shipped from the factory with the switch set for 116 V and a fuse value of 1 A/250 V (to operate from a power input voltage source within a range of 100 to 132 volts). If the Line Selector switch setting is changed to the 232 V position (for operation from a power input voltage source within a range of 200 to 264 volts) the fuse value and type must be changed to 0.5 A, fast-blow.</p> <p>Then set the 465M controls as stated in the following list (set both vertical channels the same and both horizontal sweeps the same unless otherwise indicated).</p> <table><tr><td>POSITION (vertical)</td><td>Midrange</td></tr><tr><td>VOLTS/DIV</td><td>5 m (1X probe window)</td></tr><tr><td>VAR (VOLTS/DIV)</td><td>Fully clockwise (detent)</td></tr><tr><td>AC-GND-DC</td><td>DC</td></tr><tr><td>VERT MODE</td><td>CH 1</td></tr><tr><td>INVERT</td><td>Out (normal)</td></tr><tr><td>INTEN</td><td>Midrange</td></tr></table>	POSITION (vertical)	Midrange	VOLTS/DIV	5 m (1X probe window)	VAR (VOLTS/DIV)	Fully clockwise (detent)	AC-GND-DC	DC	VERT MODE	CH 1	INVERT	Out (normal)	INTEN	Midrange	
POSITION (vertical)	Midrange															
VOLTS/DIV	5 m (1X probe window)															
VAR (VOLTS/DIV)	Fully clockwise (detent)															
AC-GND-DC	DC															
VERT MODE	CH 1															
INVERT	Out (normal)															
INTEN	Midrange															

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement
1. (continued)	<p>SCALE ILLUM Fully counterclockwise</p> <p>HORIZ DISPLAY A</p> <p>A AND B TIME/DIV .1 ms</p> <p>VAR (A AND B TIME/DIV) Fully clockwise (detent)</p> <p>DELAY TIME POS 0.0</p> <p>X10 MAG Out (off)</p> <p>A TRIGGER HOLDOFF NORM (detent)</p> <p>LEVEL Midrange of + side of control (adjust as necessary throughout procedure)</p> <p>SLOPE Out +</p> <p>COUPLING AC</p> <p>SOURCE NORM</p> <p>TRIG MODE AUTO</p> <p>POSITION (horizontal) Midrange</p> <p>Next, remove the 465M top cover. Connect the 465M power cord plug to the desired power input voltage source. Pull the 465M POWER switch to ON.</p> <p style="text-align: center;">NOTE</p> <p><i>Allow approximately 5 minutes warmup time before starting any step of the Operational Checkout procedure.</i></p> <p>Set CH 1 AC-GND-DC to GND. Adjust INTEN and FOCUS for a low-intensity well-defined trace. Position the trace to the center horizontal graticule line, and if necessary adjust TRACE ROTATION so the trace is parallel with the graticule line. Return AC-GND-DC to DC.</p>	
2.	<p>Regulation</p> <p style="text-align: center;">NOTE</p> <p><i>Step 2 is optional and may be partially or totally omitted unless there is an individual reason to verify the 465M operation over all power input voltage ranges. To completely check the 465M for the power input voltage ranges of 100 to 132 volts and 200 to 264 volts requires variable power input voltage sources that will cover both ranges. An alternative method is to check that the individual 465M power supplies are within limits with the 465M powered from the available power input source voltage, and then proceed to step 3.</i></p> <p>a. Set the Digital Multimeter to read 50 volts dc.</p> <p>b. Connect the meter Low lead to ground and the Volts lead to the +32 V (regulated) test point.</p>	

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement				
2. (continued)						
c.	Check (using the following chart) the 465M power supplies regulation over the desired power input voltage ranges (vary the power input source voltage and alter meter settings and connections as required).					
	<table><tr><th>POWER INPUT VOLTAGE</th><th>POWER SUPPLY</th></tr><tr><td>100 V to 132 V or 200 V to 264 V</td><td>+32 V +5 V -5 V</td></tr></table> (Change Line Voltage Selector switch setting and fuse as appropriate)	POWER INPUT VOLTAGE	POWER SUPPLY	100 V to 132 V or 200 V to 264 V	+32 V +5 V -5 V	+31.9 V to +32.1 V +4.97 V to +5.03 V -4.97 V to -5.03 V
POWER INPUT VOLTAGE	POWER SUPPLY					
100 V to 132 V or 200 V to 264 V	+32 V +5 V -5 V					
d.	Set the 465M POWER switch to OFF, disconnect the meter leads from the 465M and the 465M line cord plug from the power input voltage source. Change the fuse value and Line Voltage Selector switch setting for the available source of power input voltage to be used for the rest of this procedure (116 V for a 100 V to 132 V range, or 232 V for a 200 to 264 V range). Refer to step 1, Preliminary Procedure before performing any other steps.					
3.	Calibrator Output					
a.	Preset the 465M per step 1, then set POWER to OFF.					
b.	Connect a Digital Multimeter (preset to read +1 V dc) to the CALIBRATOR output connector.					
c.	Connect a shorting jumper between TP376 and TP386 (a miniature alligator clip is suitable).					
d.	Turn the 465M on and allow at least 5 minutes warm-up.					
e.	Check the Digital Multimeter reading.	+0.99 V dc to +1.01 V dc				
f.	Disconnect the Digital Multimeter leads, turn the 465M power off, and disconnect the shorting jumper from TP376 and TP386.					
g.	Turn the 465M power on and use a 1X probe (465M standard accessory) to connect the 465M channel 1 input to the CALIBRATOR output terminal.					
h.	Preset the 465M controls as follows: Deflection Factor .2 V Vertical Input Coupling DC Sweep Speed .1 ms					
i.	Check the calibrator waveform characteristics.	Square wave of 5 divisions peak-to-peak at 1 kHz within 0.1 kHz; risetime, less than 1 μs; symmetry, within 25%.				

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

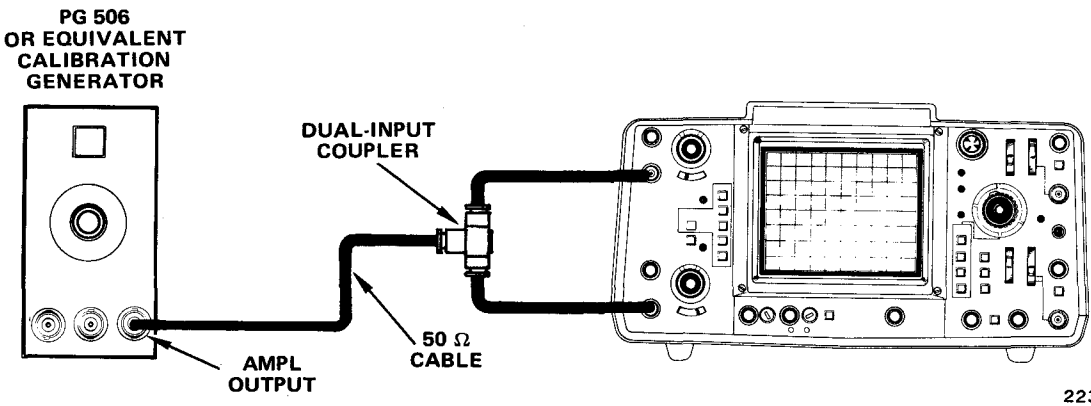
Step	Procedure	Performance Requirement																																	
4.	<p>Vertical Deflection Factor Accuracy.</p> <p>a. Connect the equipment as follows:</p>  <p>PG 506 OR EQUIVALENT CALIBRATION GENERATOR</p> <p>DUAL-INPUT COUPLER</p> <p>AMPL OUTPUT</p> <p>50 Ω CABLE</p> <p>2237-9</p> <p>b. Preset controls as listed in step 1.</p> <p>c. Check CH 1 and CH 2 vertical deflection factors at the following settings (VERT MODE must be set to channel being tested):</p> <table border="1"> <thead> <tr> <th>Calibration Generator Setting</th><th>VOLTS/DIV Setting (in X1 probe window)</th><th>Vertical Display (in divisions)</th></tr> </thead> <tbody> <tr><td>20 mV</td><td>5 mV</td><td>3.92 to 4.08</td></tr> <tr><td>50 mV</td><td>10 mV</td><td>4.90 to 5.10</td></tr> <tr><td>0.1 V</td><td>20 mV</td><td>4.90 to 5.10</td></tr> <tr><td>0.2 V</td><td>50 mV</td><td>3.92 to 4.08</td></tr> <tr><td>0.5 V</td><td>.1 V</td><td>4.90 to 5.10</td></tr> <tr><td>1.0 V</td><td>.2 V</td><td>4.90 to 5.10</td></tr> <tr><td>2.0 V</td><td>.5 V</td><td>3.92 to 4.08</td></tr> <tr><td>5.0 V</td><td>1 V</td><td>4.90 to 5.10</td></tr> <tr><td>10.0 V</td><td>2 V</td><td>4.90 to 5.10</td></tr> <tr><td>20.0 V</td><td>5 V</td><td>3.92 to 4.08</td></tr> </tbody> </table>	Calibration Generator Setting	VOLTS/DIV Setting (in X1 probe window)	Vertical Display (in divisions)	20 mV	5 mV	3.92 to 4.08	50 mV	10 mV	4.90 to 5.10	0.1 V	20 mV	4.90 to 5.10	0.2 V	50 mV	3.92 to 4.08	0.5 V	.1 V	4.90 to 5.10	1.0 V	.2 V	4.90 to 5.10	2.0 V	.5 V	3.92 to 4.08	5.0 V	1 V	4.90 to 5.10	10.0 V	2 V	4.90 to 5.10	20.0 V	5 V	3.92 to 4.08	
Calibration Generator Setting	VOLTS/DIV Setting (in X1 probe window)	Vertical Display (in divisions)																																	
20 mV	5 mV	3.92 to 4.08																																	
50 mV	10 mV	4.90 to 5.10																																	
0.1 V	20 mV	4.90 to 5.10																																	
0.2 V	50 mV	3.92 to 4.08																																	
0.5 V	.1 V	4.90 to 5.10																																	
1.0 V	.2 V	4.90 to 5.10																																	
2.0 V	.5 V	3.92 to 4.08																																	
5.0 V	1 V	4.90 to 5.10																																	
10.0 V	2 V	4.90 to 5.10																																	
20.0 V	5 V	3.92 to 4.08																																	
5.	<p>Variable Vertical Deflection Factor Range.</p> <p>a. Connect the equipment as shown in step 4, part a.</p> <p>b. Preset the 465M as listed in step 1; then reset CH 1 VOLTS/DIV to 10 m.</p> <p>c. Set the calibration generator to 50 mV.</p> <p>d. Rotate CH 1 VOLTS/DIV VAR fully counterclockwise.</p> <p>e. Set VERT MODE to CH 2 and CH 2 VOLTS/DIV to 10 m.</p> <p>f. Rotate CH 2 VOLTS/DIV VAR fully counterclockwise.</p> <p>g. Reset CH 1 and CH 2 VOLTS/DIV VAR fully clockwise (in detent position).</p>	<p>4.9 to 5.1 division vertical display.</p> <p>2 division or less vertical display.</p> <p>4.9 to 5.1 division vertical display.</p> <p>2 division or less vertical display.</p>																																	

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

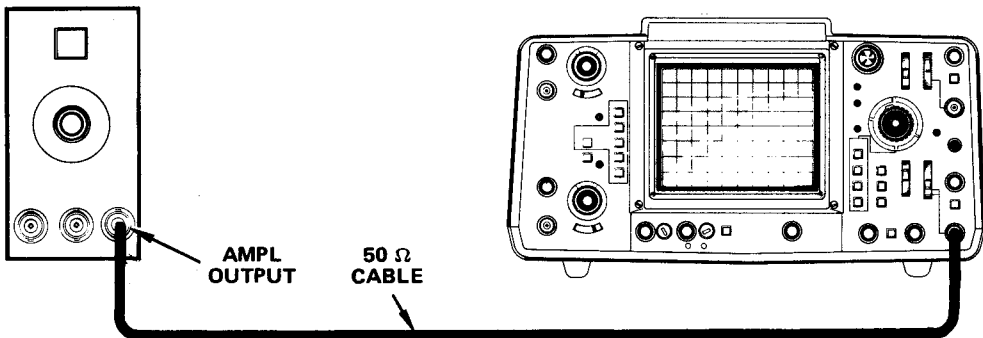
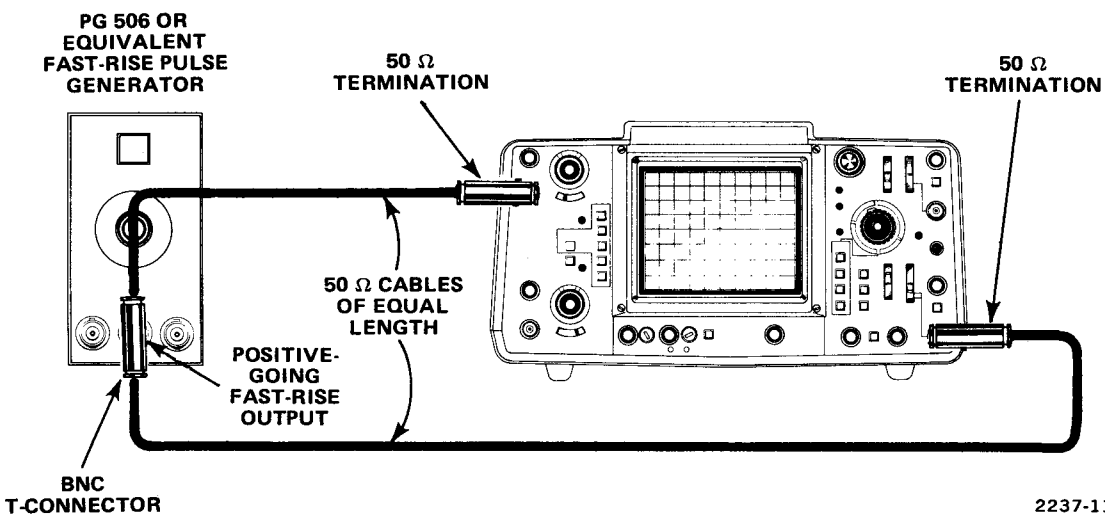
Step	Procedure	Performance Requirement												
6.	<p>X Gain.</p> <p>a. Connect the equipment as shown in step 4, part a.</p> <p>b. Preset the 465M as listed in step 1; then reset as follows:</p> <table><tr><td>CH 2 AC-GND-DC</td><td>GND</td></tr><tr><td>VERT MODE</td><td>CH 2</td></tr><tr><td>A AND B TIME/DIV</td><td>X-Y</td></tr></table> <p>c. Set the calibration generator for 20 mV (INTEN may need to be increased).</p> <p>d. Set CH 1 AC-GND-DC to AC.</p>	CH 2 AC-GND-DC	GND	VERT MODE	CH 2	A AND B TIME/DIV	X-Y	<p>3.88 to 4.12 division horizontal display.</p> <p>3.88 to 4.12 division horizontal display.</p>						
CH 2 AC-GND-DC	GND													
VERT MODE	CH 2													
A AND B TIME/DIV	X-Y													
7.	<p>Trigger View Gain.</p> <p>a. Connect the equipment as follows:</p> <div><p>PG 506 OR EQUIVALENT CALIBRATION GENERATOR</p><p>AMPL OUTPUT</p><p>50 Ω CABLE</p></div> <p>2237-10</p> <p>b. Preset the 465M as listed in 1; then reset as follows:</p> <table><tr><td>CH 1 VOLTS/DIV</td><td>.1</td></tr><tr><td>A SOURCE</td><td>EXT</td></tr><tr><td>A LEVEL</td><td>0</td></tr><tr><td>A AND B TIME/DIV</td><td>.2 ms</td></tr></table> <p>c. Set calibration generator for 0.2 V.</p> <p>d. Push in and hold TRIG VIEW, observe display, then release TRIG VIEW.</p> <p>e. Set instrument controls as follows:</p> <table><tr><td>VOLTS/DIV</td><td>1</td></tr><tr><td>A SOURCE</td><td>EXT \div 10</td></tr></table>	CH 1 VOLTS/DIV	.1	A SOURCE	EXT	A LEVEL	0	A AND B TIME/DIV	.2 ms	VOLTS/DIV	1	A SOURCE	EXT \div 10	<p>1.4 to 2.6 division vertical display.</p>
CH 1 VOLTS/DIV	.1													
A SOURCE	EXT													
A LEVEL	0													
A AND B TIME/DIV	.2 ms													
VOLTS/DIV	1													
A SOURCE	EXT \div 10													

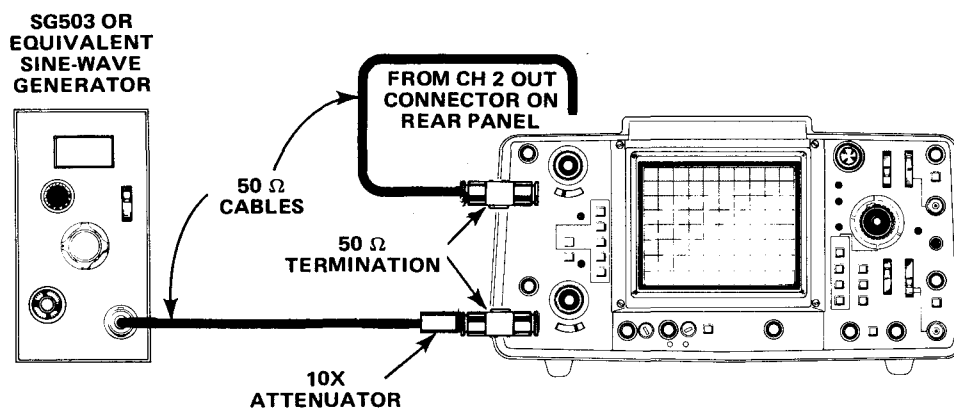
Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement
7. (continued)		
f.	Set calibration generator to 2 V.	
g.	Repeat step 7, part d.	
8.	Channel Position Effect.	
a.	Connect the equipment as follows:	
	 <p>PG 506 OR EQUIVALENT FAST-RISE PULSE GENERATOR</p> <p>50 Ω TERMINATION</p> <p>50 Ω CABLES OF EQUAL LENGTH</p> <p>POSITIVE-GOING FAST-RISE OUTPUT</p> <p>BNC T-CONNECTOR</p> <p>50 Ω TERMINATION</p> <p>2237-11</p>	
b.	Preset the 465M as listed in step 1; then, reset as follows:	
	CH 1 VOLTS/DIV 20 m A AND B TIME/DIV .05 μ s	
c.	Set calibration generator for a 5-division display at 100 kilohertz.	
d.	Rotate CH 1 vertical POSITION to observe the top of the waveform at the top horizontal graticule line then rotate POSITION and observe top of waveform at the bottom horizontal graticule line.	
e.	Set A SLOPE to – (IN).	
f.	Change the calibration generator output to the negative-going fast rise output.	
g.	Repeat step 8, parts c and d.	
h.	Change the calibration generator output cable from CH 1 to CH 2.	
i.	Set the instrument controls as follows:	
	CH 2 VOLTS/DIV 20 m VERT MODE CH 2	
j.	Repeat step 8, parts c and d using CH 2 vertical POSITION.	

The front corner of the waveform has no more than 0.3 division peak-to-peak aberrations.

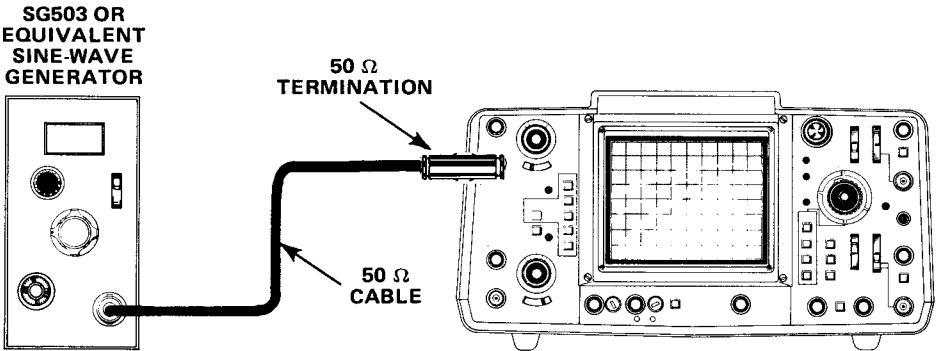
Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement
8. (continued)		
k.	Set A SLOPE to + (OUT).	
l.	Change the calibration generator output to the positive going fast rise output.	
m.	Repeat step 8, parts c and d using CH 2 vertical position.	
9.	Rise Time.	
a.	Connect the equipment as shown in step 8, part a.	
b.	Preset controls as listed in step 1, then reset as follows:	
	A AND B TIME/DIV .05 μ s	
	CH 1 VOLTS/DIV 20 m	
c.	Set calibration generator for a 5-division display at 1 megahertz.	
d.	Adjust vertical POSITION to place display between the 0 and 100% marks on the graticule.	
e.	Set X10 MAG to the In position (on).	
f.	Measure the time duration of the positive going portion of the display between 10 and 90% markers on the graticule.	3.5 nanoseconds (0.7 division) or less.
g.	Change the calibration generator output from CH 1 to CH 2.	
h.	Set controls as follows:	
	CH 2 VOLTS/DIV 20 m	
	VERT MODE CH 2	
	X10 MAG Out (off)	
i.	Repeat step 9, parts c through f.	
10.	Cascaded Sensitivity and Bandwidth.	
a.	Connect the equipment as follows:	



2237-12

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

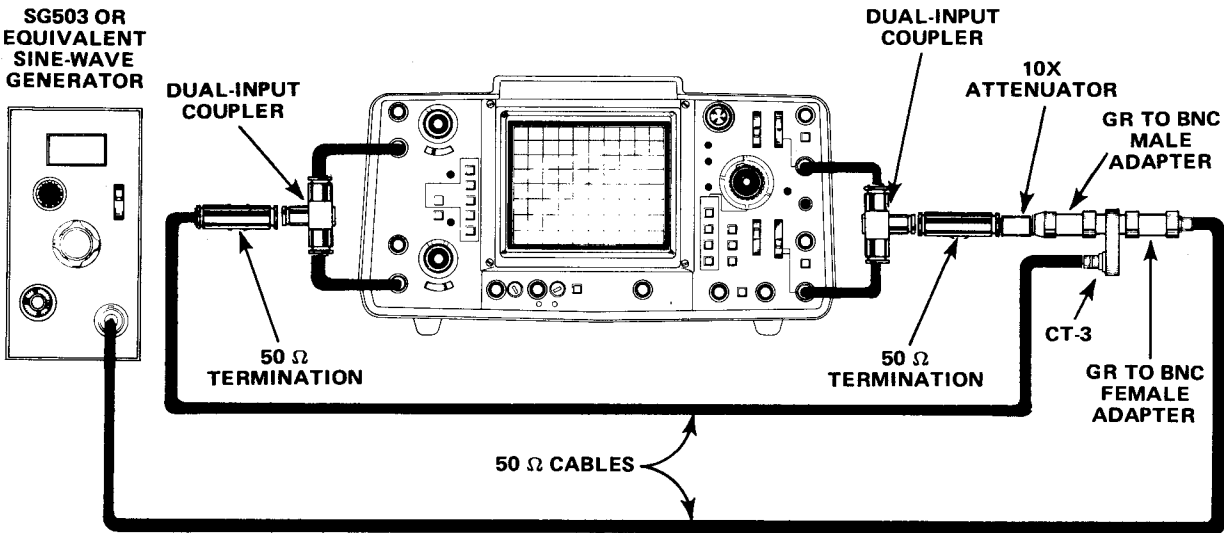
Step	Procedure	Performance Requirement
10. (continued)		
b.	Preset controls as listed in step 1, then reset as follows: <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div>VERT MODE A AND B TIME/DIV</div> <div>CH 2 .2 ms</div> </div>	
c.	Set sine-wave generator for a 1-division 50 kilohertz display.	
d.	Set VERT MODE to CH 1.	3.5 to 6.5 division vertical display.
e.	Set sine-wave generator for a 5-division display (may need to insert a 10X attenuator between 50 ohm BNC cable and 50 ohm termination).	
f.	Set sine-wave generator to 40 megahertz.	3.5 division or more vertical display.
11.	Channel 1, Channel 2, and X Bandwidth.	
a.	Connect equipment as follows: <div style="text-align: center; margin-top: 20px;">  <p>SG503 OR EQUIVALENT SINE-WAVE GENERATOR</p> <p>50 Ω CABLE</p> <p>50 Ω TERMINATION</p> </div>	
b.	Preset controls as listed in step 1, then reset A AND B TIME/DIV to 0.5 μ s.	
c.	Set sine-wave generator to 3 megahertz and adjust for a 6-division display.	
d.	Set sine-wave generator to 100 megahertz.	4.2 division or more vertical display.
e.	Change the sine-wave generator output from CH 1 to CH 2.	
f.	Set VERT MODE to CH 2.	
g.	Repeat step 11, parts c through d.	
h.	Change the generator output from CH 2 to CH 1.	

2237-13

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement
11. (continued)		
i.	Set controls as follows: <div style="display: flex; justify-content: space-between; margin-left: 40px;"> <div>A AND B TIME/DIV</div> <div>X-Y</div> </div> <div style="display: flex; justify-content: space-between; margin-left: 40px;"> <div>CH 1 POSITION</div> <div>May need adjustment for an on-screen display.</div> </div> <div style="display: flex; justify-content: space-between; margin-left: 40px;"> <div>INTEN</div> <div>May need to be increased.</div> </div>	
j.	Set sine-wave generator to 50 kilohertz and adjust for a 6-division horizontal display.	
k.	Set sine-wave generator to 4 megahertz.	4.2 division or more horizontal display.
12.	Trigger Jitter.	
a.	Connect the equipment as shown in step 11, part a.	
b.	Preset controls as listed in step 1; then reset as follows: <div style="display: flex; justify-content: space-between; margin-left: 40px;"> <div>A AND B TIME/DIV</div> <div>.05 μs</div> </div> <div style="display: flex; justify-content: space-between; margin-left: 40px;"> <div>X10 MAG</div> <div>In (on)</div> </div>	
c.	Set sine-wave generator to 100 megahertz and adjust for a 3-division display.	
d.	Adjust A LEVEL for a display with minimum horizontal displacement (jitter).	0.1 division or less, plus trace width, of horizontal displacement (jitter).
e.	Set controls as follows: <div style="display: flex; justify-content: space-between; margin-left: 40px;"> <div>VERT MODE</div> <div>CH 2</div> </div> <div style="display: flex; justify-content: space-between; margin-left: 40px;"> <div>HORIZ DISPLAY</div> <div>B DLY'D</div> </div>	
f.	Change sine-wave generator output from CH 1 to CH 2.	
g.	Repeat step 12, parts c and d using B LEVEL control.	
13.	Trigger Level Range.	
a.	Connect the equipment as shown in step 11, part a.	
b.	Preset controls as listed in step 1, part a; then reset as follows: <div style="display: flex; justify-content: space-between; margin-left: 40px;"> <div>VOLTS/DIV</div> <div>1</div> </div> <div style="display: flex; justify-content: space-between; margin-left: 40px;"> <div>TIME/DIV</div> <div>10 μs</div> </div>	
c.	Set sine-wave generator to 50 kilohertz and adjust for a 4-division display.	

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement
13. (continued)		
d.	Rotate A LEVEL between its limits.	The display is triggered on the positive going slope of the waveform and free runs at either extreme setting of A LEVEL.
e.	Set A SLOPE to – (IN).	
f.	Rotate A LEVEL between its limits.	The display is triggered on the negative going slope of the waveform and free runs at either extreme setting of A LEVEL.
g.	Set HORIZ DISPLAY to B DLY'D.	
h.	Repeat step 13, parts d through f using B LEVEL and B SLOPE.	The display disappears when not triggered, rather than free running.
14.	25 MHz Triggering.	
a.	Connect the equipment as follows:	
		
b.	Preset controls as listed in step 1; then reset as follows:	
	A AND B TIME/DIV	10 μ s
	COUPLING	DC
	SOURCE	EXT
	VOLTS/DIV	10 m

2237-14

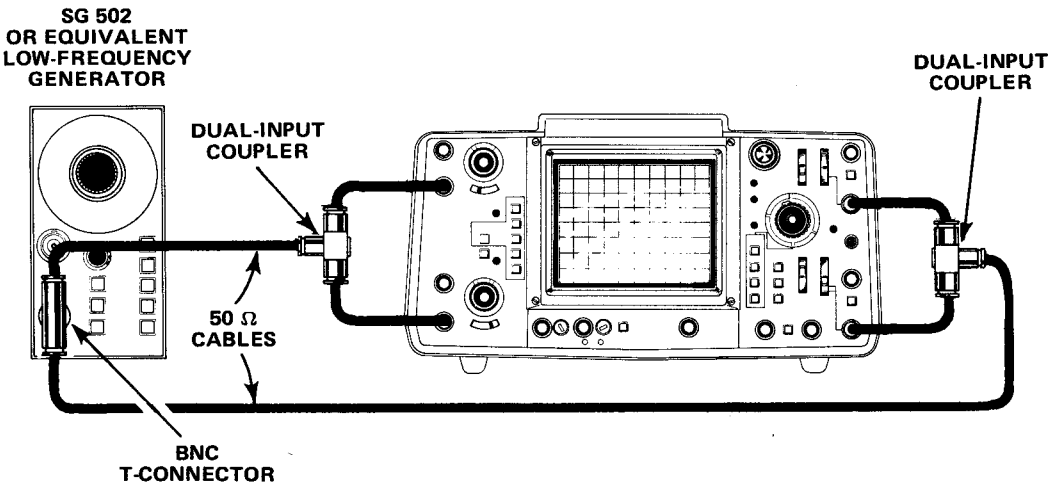
Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement												
14. (con- tinued)	<div><div><div>c. Set sine-wave generator to 50 kilohertz and adjust for a 5-division display; then set A AND B TIME/DIV to 0.5 μs and sine-wave generator to 25 megahertz.</div><div>d. Rotate A LEVEL for a stable display.</div><div>e. Set HORIZ DISPLAY to B DLY'D.</div><div>f. Rotate B LEVEL for a stable display.</div><div>g. Set controls as follows:<div><div>VOLTS/DIV5 m</div><div>SOURCENORM</div></div></div><div>h. Adjust sine-wave generator for a 3-division display.</div><div>i. Set VOLTS/DIV to 50 m.</div><div>j. Set each of the following conditions, then rotate B LEVEL to obtain a stable display:<div><div>NOTE</div><div><div>When checking B Sweep control, the A trigger must be stable. To restabilize A Trigger, set HORIZ DISPLAY to A and readjust A LEVEL for a stable display. Then, reset HORIZ DISPLAY to B DLY'D and continue check.</div></div></div></div></div></div>	<div><div>A stable display can be obtained.</div><div>A stable display can be obtained.</div></div>												
	<table><tr><th>B COUPLING</th><th>B SOURCE</th></tr><tr><td>DC</td><td>NORM</td></tr><tr><td>LF REJ</td><td>NORM</td></tr><tr><td>AC</td><td>NORM</td></tr><tr><td>DC</td><td>CH 1</td></tr><tr><td>DC</td><td>CH 2</td></tr></table>	B COUPLING	B SOURCE	DC	NORM	LF REJ	NORM	AC	NORM	DC	CH 1	DC	CH 2	
B COUPLING	B SOURCE													
DC	NORM													
LF REJ	NORM													
AC	NORM													
DC	CH 1													
DC	CH 2													
	<div><div>k. SET TRIG MODE to NORM.</div><div>l. Repeat step 14, part j.</div><div>m. Set B SLOPE to – (IN).</div><div>n. Repeat step 14, part j.</div><div>o. Set TRIG MODE to AUTO.</div><div>p. Repeat step 14, part j.</div><div>q. Set B COUPLING to HF REJ and rotate B LEVEL between its limits.</div></div>	<div><div>No stable display can be obtained.</div></div>												

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

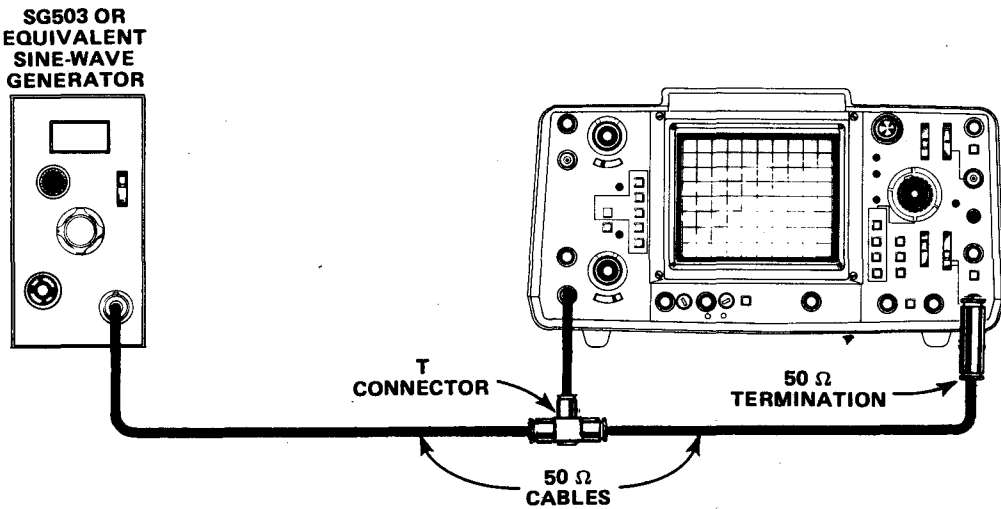
Step	Procedure	Performance Requirement												
14. (con- tinued)														
r.	Set HORIZ DISPLAY to A.													
s.	Repeat step 14, parts j through q. using A LEVEL, A COUPLING, and A SOURCE.													
15.	100 MHz Triggering.													
a.	Connect equipment as shown in step 14, part a.													
b.	Preset controls as listed in step 1; then reset as follows: VOLTS/DIV 50 m COUPLING DC SOURCE EXT													
c.	Set sine-wave generator to 50 kilohertz and adjust output for a 3-division display; then set generator to 100 megahertz.													
d.	Set controls as follows: A AND B TIME/DIV 0.5 μs X10 MAG In (on)													
e.	Rotate A LEVEL for a stable display.	A stable display can be obtained.												
f.	Set HORIZ DISPLAY to B DLY'D.													
g.	Rotate B LEVEL for a stable display.	A stable display can be obtained.												
h.	Set SOURCE to NORM.													
i.	Adjust sine-wave generator for a 1 division display.													
j.	Set each of the following conditions, then rotate B LEVEL to obtain a stable display.	A stable display can be obtained.												
	<table><tr><th>B COUPLING</th><th>B SOURCE</th></tr><tr><td>DC</td><td>NORM</td></tr><tr><td>LF REJ</td><td>NORM</td></tr><tr><td>AC</td><td>NORM</td></tr><tr><td>DC</td><td>CH 1</td></tr><tr><td>DC</td><td>CH 2</td></tr></table>	B COUPLING	B SOURCE	DC	NORM	LF REJ	NORM	AC	NORM	DC	CH 1	DC	CH 2	
B COUPLING	B SOURCE													
DC	NORM													
LF REJ	NORM													
AC	NORM													
DC	CH 1													
DC	CH 2													
k.	Set TRIG MODE to NORM.													
l.	Repeat step 15, part j.													
m.	Set B SLOPE to — (IN).													
n.	Repeat step 15, part j.													
o.	Set TRIG MODE to AUTO.													

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement
15. (continued)		
p.	Repeat step 15, part j.	
q.	Set HORIZ DISPLAY to A.	
r.	Repeat step 15, part j. using A LEVEL, A COUPLING, and A SOURCE.	
16.	Low Frequency Trigger.	
a.	Connect equipment as follows: 	
b.	Preset controls as listed in step 1; then reset as follows: A AND B TIME/DIV 10 m TRIG MODE NORM	
c.	Set low frequency sine-wave generator to 30 hertz and adjust for a 3-division display.	
d.	Set VOLTS/DIV to 50 m.	
e.	Rotate A LEVEL to obtain a stable display	A stable display can be obtained.
f.	Set A SLOPE to – (IN).	
g.	Repeat step 16, part e.	
h.	Set A COUPLING to LF REJ.	
i.	Rotate A LEVEL between its limits.	No stable display can be obtained.
j.	Set HORIZ DISPLAY to B DLY'D.	
k.	Repeat step 16, parts e through i. using B LEVEL, B SLOPE, and B COUPLING.	

2237-15

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement
17.	Z-Axis Input.	
a.	Connect equipment as follows: 	
b.	Preset controls as listed in step 1; then reset as follows: VERT MODE CH 2 CH 2 VOLTS/DIV 1 A AND B TIME/DIV .5 ms A SOURCE EXT	
c.	Set sine-wave generator to 50 kilohertz and adjust for a 5-division display.	
d.	Change the sine-wave generator output (T Connector) from CH 2 to Z-AXIS input on rear panel.	Trace modulation is noticeable at normal intensity.

2237-27

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

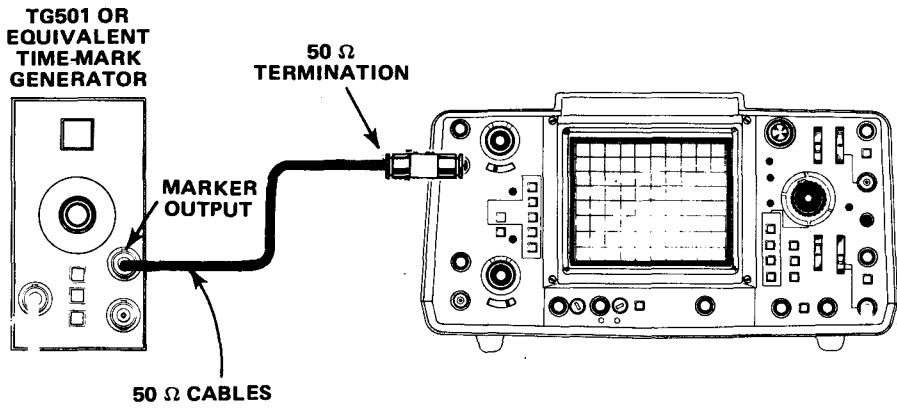
Step	Procedure	Performance Requirement																				
18.	<p>Sweep Rate Accuracy.</p> <p>a. Connect equipment as follows:</p> <div></div> <p style="text-align: right;">2237-16</p>																					
	<p>b. Preset controls as listed in step 1; then reset as follows:</p> <div><div>CH 1 VOLTS/DIV</div><div>B SOURCE</div><div>.5</div><div>STARTS AFTER DELAY</div></div> <p>c. Check A TIME/DIV accuracy at the following settings:</p> <table><tr><th>TIME/DIV Setting</th><th>Time-Mark Generator Output</th></tr><tr><td>.05 μs</td><td>50 ns</td></tr><tr><td>.1 μs</td><td>0.1 μs</td></tr><tr><td>.2 μs</td><td>0.2 μs</td></tr><tr><td>.5 μs</td><td>0.5 μs</td></tr><tr><td>1 μs</td><td>1 μs</td></tr><tr><td>2 μs</td><td>2 μs</td></tr><tr><td>5 μs</td><td>5 μs</td></tr><tr><td>10 μs</td><td>10 μs</td></tr><tr><td>20 μs</td><td>20 μs</td></tr></table>	TIME/DIV Setting	Time-Mark Generator Output	.05 μ s	50 ns	.1 μ s	0.1 μ s	.2 μ s	0.2 μ s	.5 μ s	0.5 μ s	1 μ s	1 μ s	2 μ s	2 μ s	5 μ s	5 μ s	10 μ s	10 μ s	20 μ s	20 μ s	<p>1 time mark per division within 0.2 division at the 11th vertical graticule line.</p>
TIME/DIV Setting	Time-Mark Generator Output																					
.05 μ s	50 ns																					
.1 μ s	0.1 μ s																					
.2 μ s	0.2 μ s																					
.5 μ s	0.5 μ s																					
1 μ s	1 μ s																					
2 μ s	2 μ s																					
5 μ s	5 μ s																					
10 μ s	10 μ s																					
20 μ s	20 μ s																					
		<p>1 time mark per division within 0.2 division at the 11th vertical graticule line.</p>																				

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure		Performance Requirement
18. (continued)	TIME/DIV Setting		1 time mark per division within 0.2 division at the 11th vertical graticule line.
	Time-Mark Generator Output		
	50 μ s		
	.1 ms		
	.2 ms		
	.5 ms		
	1 ms		
	2 ms		
	5 ms		
	*10 ms		
	*20 ms		
*50 ms			
*1 s		A	0.1 s
*2 s		SWEEP	0.2 s
*5 s		ONLY	0.5 s
*Set TRIG MODE switch to NORM.			
d.	Set HORIZ DISPLAY to B DLY'D.		
e.	Repeat Step 18, part c using B TIME/DIV.		
NOTE			
<i>If the 11th time marker is not visible, set A TIME/DIV one position counterclockwise from B TIME/DIV (e.g., A set to 1 ms and B to .05 ms).</i>			
19.	Variable Sweep Rate Range.		
a.	Connect equipment as shown in step 18, part a.		
b.	Preset controls as listed in step 1; then reset as follows:		
	CH 1 VOLTS/DIV	.5	
	A AND B TIME/DIV	2 ms	
	VAR TIME/DIV	Fully counterclockwise	
c.	Set time-mark generator for 5 millisecond time markers.		
1 division or less between markers.			
20.	Magnified Sweep Accuracy.		
a.	Connect equipment as shown in step 18, part a.		
b.	Preset controls as listed in step 1; then reset as follows:		
	CH 1 VOLTS/DIV	.5	
	A AND B TIME/DIV	.05 μ s	

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure			Performance Requirement																																																																					
20. (continued)	<div><div><div>c. Set time-mark generator for 10 nanosecond time markers.</div><div>d. Adjust horizontal POSITION to align first time marker with the left vertical graticule line.</div><div>e. Set X10 MAG to In (on).</div><div>f. Check magnified A TIME/DIV accuracy at the following settings:</div></div><div><div>NOTE</div><div>When aligning time markers with a graticule line after a new TIME/DIV selection, do not position the trace beyond alignment with the closest graticule line (see NOTE under Portion of total magnified sweep length to exclude from measurement column below).</div></div></div>			1 time marker per division within 0.3 division at the 11th vertical graticule line; except on .05 μ s setting, there is 1 time marker per two divisions.																																																																					
<table><tr><th colspan="2">TIME/DIV Setting</th><th>Time-Mark Generator Setting</th><th>Portion of total magnified sweep length to exclude from measurement</th></tr><tr><td colspan="2">0.5 μs</td><td>10 ns</td><td rowspan="5">First and last 50 nanoseconds</td></tr><tr><td colspan="2">.1 μs</td><td>10 ns</td></tr><tr><td colspan="2">.2 μs</td><td>20 ns</td></tr><tr><td colspan="2">.5 μs</td><td>50 ns</td></tr><tr><td colspan="2">1 μs</td><td>0.1 μs</td></tr><tr><td colspan="2">2 μs</td><td>0.2 μs</td><td rowspan="18"><div><div>NOTE</div><div>To determine the excluded portion of the sweep at .05, .1 and .2 μs, position the beginning (or end) of the sweep at the left (or right) vertical graticule line. Then horizontally POSITION the trace to the left (or right) the following number of time markers to exclude 50 ns of the sweep (be sure X10 MAG is selected): 10 time markers at 0.5 μs; 5 at .1 μs, or 2.5 at .2 μs.</div></div></td></tr><tr><td colspan="2">5 μs</td><td>0.5 μs</td></tr><tr><td colspan="2">10 μs</td><td>1 μs</td></tr><tr><td colspan="2">20 μs</td><td>2 μs</td></tr><tr><td colspan="2">50 μs</td><td>5 μs</td></tr><tr><td colspan="2">.1 ms</td><td>10 μs</td></tr><tr><td colspan="2">.2 ms</td><td>20 μs</td></tr><tr><td colspan="2">.5 ms</td><td>50 μs</td></tr><tr><td colspan="2">1 ms</td><td>0.1 ms</td></tr><tr><td colspan="2">2 ms</td><td>0.2 ms</td></tr><tr><td colspan="2">5 ms</td><td>0.5 ms</td></tr><tr><td colspan="2">10 ms</td><td>1 ms</td></tr><tr><td colspan="2">20 ms</td><td>2 ms</td></tr><tr><td colspan="2">50 ms</td><td>5 ms</td></tr><tr><td>*.1 s</td><td rowspan="3">A SWEEP ONLY</td><td>10 ms</td></tr><tr><td>*.2 s</td><td>20 ms</td></tr><tr><td>*.5 s</td><td>50 ms</td></tr></table>			TIME/DIV Setting		Time-Mark Generator Setting	Portion of total magnified sweep length to exclude from measurement	0.5 μ s		10 ns	First and last 50 nanoseconds	.1 μ s		10 ns	.2 μ s		20 ns	.5 μ s		50 ns	1 μ s		0.1 μ s	2 μ s		0.2 μ s	<div><div>NOTE</div><div>To determine the excluded portion of the sweep at .05, .1 and .2 μs, position the beginning (or end) of the sweep at the left (or right) vertical graticule line. Then horizontally POSITION the trace to the left (or right) the following number of time markers to exclude 50 ns of the sweep (be sure X10 MAG is selected): 10 time markers at 0.5 μs; 5 at .1 μs, or 2.5 at .2 μs.</div></div>	5 μ s		0.5 μ s	10 μ s		1 μ s	20 μ s		2 μ s	50 μ s		5 μ s	.1 ms		10 μ s	.2 ms		20 μ s	.5 ms		50 μ s	1 ms		0.1 ms	2 ms		0.2 ms	5 ms		0.5 ms	10 ms		1 ms	20 ms		2 ms	50 ms		5 ms	*.1 s	A SWEEP ONLY	10 ms	*.2 s	20 ms	*.5 s	50 ms	
TIME/DIV Setting		Time-Mark Generator Setting	Portion of total magnified sweep length to exclude from measurement																																																																						
0.5 μ s		10 ns	First and last 50 nanoseconds																																																																						
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50 ms		5 ms																																																																							
*.1 s	A SWEEP ONLY	10 ms																																																																							
*.2 s		20 ms																																																																							
*.5 s		50 ms																																																																							
*Change TRIG MODE switch to NORM.																																																																									
g.	Set HORIZ DISPLAY to B DLY'D.																																																																								

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement																																																			
20. (continued)																																																					
h.	Set A AND B TIME/DIV to 0.5 μ s.																																																				
i.	Repeat step 20, parts c through f.																																																				
21.	Differential Time Measurement Accuracy.																																																				
a.	Connect equipment as shown in step 18, part a.																																																				
b.	Preset controls as listed in step 1; then reset as follows: CH 1 VOLTS/DIV .5 HORIZ DISPLAY B DLY'D B SOURCE STARTS AFTER DELAY DELAY TIME POS 1.00																																																				
c.	Set time-mark generator for 0.1 microsecond time markers.																																																				
d.	Check each of the following conditions by using step 21, parts e through i.																																																				
	<table> <tr> <th>Time-Mark Generator Output</th><th>A TIME/DIV Setting</th><th>B TIME/DIV Setting</th></tr> <tr><td>.1 μs</td><td>.5 μs</td><td>.05 μs</td></tr> <tr><td>1 μs</td><td>1 μs</td><td>.1 μs</td></tr> <tr><td>2 μs</td><td>2 μs</td><td>.2 μs</td></tr> <tr><td>5 μs</td><td>5 μs</td><td>.5 μs</td></tr> <tr><td>10 μs</td><td>10 μs</td><td>1 μs</td></tr> <tr><td>20 μs</td><td>20 μs</td><td>2 μs</td></tr> <tr><td>50 μs</td><td>50 μs</td><td>5 μs</td></tr> <tr><td>0.1 ms</td><td>.1 ms</td><td>10 μs</td></tr> <tr><td>0.2 ms</td><td>.2 ms</td><td>20 μs</td></tr> <tr><td>0.5 ms</td><td>.5 ms</td><td>50 μs</td></tr> <tr><td>1 ms</td><td>1 ms</td><td>.1 ms</td></tr> <tr><td>2 ms</td><td>2 ms</td><td>.2 ms</td></tr> <tr><td>5 ms</td><td>5 ms</td><td>.5 ms</td></tr> <tr><td>10 ms</td><td>10 ms</td><td>1 ms</td></tr> <tr><td>20 ms</td><td>20 ms</td><td>*2 ms</td></tr> <tr><td>50 ms</td><td>50 ms</td><td>*5 ms</td></tr> </table>	Time-Mark Generator Output	A TIME/DIV Setting	B TIME/DIV Setting	.1 μ s	.5 μ s	.05 μ s	1 μ s	1 μ s	.1 μ s	2 μ s	2 μ s	.2 μ s	5 μ s	5 μ s	.5 μ s	10 μ s	10 μ s	1 μ s	20 μ s	20 μ s	2 μ s	50 μ s	50 μ s	5 μ s	0.1 ms	.1 ms	10 μ s	0.2 ms	.2 ms	20 μ s	0.5 ms	.5 ms	50 μ s	1 ms	1 ms	.1 ms	2 ms	2 ms	.2 ms	5 ms	5 ms	.5 ms	10 ms	10 ms	1 ms	20 ms	20 ms	*2 ms	50 ms	50 ms	*5 ms	
Time-Mark Generator Output	A TIME/DIV Setting	B TIME/DIV Setting																																																			
.1 μ s	.5 μ s	.05 μ s																																																			
1 μ s	1 μ s	.1 μ s																																																			
2 μ s	2 μ s	.2 μ s																																																			
5 μ s	5 μ s	.5 μ s																																																			
10 μ s	10 μ s	1 μ s																																																			
20 μ s	20 μ s	2 μ s																																																			
50 μ s	50 μ s	5 μ s																																																			
0.1 ms	.1 ms	10 μ s																																																			
0.2 ms	.2 ms	20 μ s																																																			
0.5 ms	.5 ms	50 μ s																																																			
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10 ms	10 ms	1 ms																																																			
20 ms	20 ms	*2 ms																																																			
50 ms	50 ms	*5 ms																																																			
	*Change TRIG MODE to NORM.																																																				
e.	Adjust horizontal POSITION to align 1st marker with the center vertical graticule line.																																																				
f.	Set DELAY TIME POS to 9.00, then adjust it to align the 1st marker with the center vertical graticule line.	8.91 to 9.09 DELAY TIME POS dial reading.																																																			
g.	Select new settings from step 21, part d.																																																				
h.	Set DELAY TIME POS to 9.00.																																																				

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement
21. (continued)		
i.	Adjust horizontal POSITION to align 1st marker with the center vertical graticule line.	0.91 to 1.09 DELAY TIME POS dial reading.
j.	Set DELAY TIME POS to 1.00, then adjust it to align the 1st marker with the center graticule line.	
k.	Select new settings from step 21, part d.	
l.	Set DELAY TIME POS to 1.00 and return to step 21, part e.	
22.	Delay Time Jitter.	
a.	Connect equipment as shown in step 17, part a.	1 division or less horizontal displacement (jitter) of waveform leading edge.
b.	Preset controls as listed in step 1; then reset as follows:	
	CH 1 VOLTS/DIV .5	
	A TIME/DIV 1 ms	
	B TIME/DIV .5 μ s	
	DELAY TIME POS 1.00	
	HORIZ DISPLAY B DLY'D	
	B SOURCE STARTS AFTER DELAY	
	INTEN Visible display	
c.	Set time-mark generator for 1 millisecond time markers.	
d.	Very slightly adjust DELAY TIME POS until leading edge of waveform is visible.	
e.	Set DELAY TIME POS to 9.00.	
f.	Repeat step 22, part d.	
23.	Mixed Sweep Accuracy.	
a.	Connect equipment as shown in step 18, part a.	
b.	Preset controls as listed in step 1; then reset as follows:	1 time marker per division within 0.36 division from the first to the tenth graticule line.
	B SOURCE STARTS AFTER DELAY	
	HORIZ DISPLAY MIXED	
	VOLTS/DIV .5	
	A TIME/DIV 1 ms	
	B TIME/DIV .1 ms	
	DELAY TIME POS Fully Clockwise	
c.	Set time-mark generator for 1 millisecond time markers.	
d.	Adjust horizontal POSITION to align 1st time marker with the left vertical graticule line.	

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement
23. (continued)		
e.	Set DELAY TIME POS fully counterclockwise.	
f.	Set time-mark generator for 0.1 millisecond time markers.	
g.	Adjust horizontal POSITION to align the first time marker with the left vertical graticule line.	1 time marker per division within 0.18 division from the second to the eleventh graticule line.
h.	Set controls as follows: A TIME/DIV .5 μ s B TIME/DIV .05 μ s	
i.	Set time-mark generator for 50 nanosecond time markers.	
j.	Adjust horizontal POSITION to align the first time marker with the left vertical graticule line.	1 time marker per division within 0.18 division from the second to the eleventh graticule line.
k.	Set DELAY TIME POS fully clockwise.	
l.	Set time-mark generator for 0.5 microsecond time markers.	
m.	Adjust horizontal POSITION to align the first time marker with the left vertical graticule line.	1 time marker per division within 0.36 division from the first to the tenth graticule line.
24.	+Gate Outputs and A Trigger Holdoff.	
a.	Preset controls as listed in step 1; then reset A AND B TIME/DIV to 2 μ s.	
b.	Connect a monitor oscilloscope to the +A GATE output on the rear panel with a 50 ohm BNC cable and set its TIME/DIV to 5 μ s.	5 volt positive pulse within 0.5 volt.
c.	Set oscilloscope under Test A AND B TIME/DIV to 5 μ s.	
d.	Set monitor oscilloscope TIME/DIV to 20 μ s.	
e.	Adjust monitor oscilloscope VAR TIME/DIV so the negative portion of the pulse is 1-division wide.	
f.	Rotate oscilloscope under test A TRIGGER HOLDOFF fully clockwise.	Negative portion of pulse width expands to 3 divisions or more.
g.	Rotate oscilloscope under test A TRIGGER HOLDOFF fully counterclockwise into the NORM detent.	
h.	Set monitor oscilloscope VAR TIME/DIV to its calibrated detent.	

Table 5-1. Operational Checkout Procedures (Performance Check)—Continued

Step	Procedure	Performance Requirement
24. (continued)		
i.	Set controls as follows: <div style="display: flex; justify-content: space-between;"> <div>HORIZ DISPLAY</div> <div>B DLY'D</div> </div> <div style="display: flex; justify-content: space-between;"> <div>B SOURCE</div> <div>STARTS AFTER DELAY</div> </div> <div style="display: flex; justify-content: space-between;"> <div>A AND B TIME/DIV</div> <div>2 μs</div> </div>	
j.	Change monitor oscilloscope input from +A GATE to +B GATE on oscilloscope under test.	5 volt positive pulse within 0.5 volt.
25.	Chopped Mode Repetition Rate.	
a.	Preset controls as listed in step 1; then reset as follows: <div style="display: flex; justify-content: space-between;"> <div>A AND B TIME/DIV</div> <div>1 μs</div> </div> <div style="display: flex; justify-content: space-between;"> <div>VERT MODE</div> <div>CHOP</div> </div> <div style="display: flex; justify-content: space-between;"> <div>A LEVEL</div> <div>Stable display</div> </div>	33.3 to 5 divisions between the start of each complete wave cycle of the display.

5-2. PREVENTIVE MAINTENANCE. Operator preventive maintenance consists of external inspection and cleaning. Instrument repair agency preventive maintenance consists of external and internal inspection, cleaning, and lubrication. When performed regularly, preventive maintenance can prevent instrument breakdown and improve reliability.

a. Preventive Maintenance Schedule. Preventive maintenance schedules are usually established by a combination of user policies, equipment uses, and equipment environmental conditions. Lacking this guidance, Table 5-2 is a recommended preventive maintenance schedule for instruments in continuous use.

Table 5-2. Preventive Maintenance Schedule

	As required	Monthly	Semiannual or 1000 instrument hours
External cleaning	X		
External inspection		X	
Internal cleaning			X
Internal inspection			X
Calibration			X

b. External Preventive Maintenance. The following instructions are intended for use by either operators or the instrument repair agency.

(1) External Inspection. Table 5-3 is a list of external items to be inspected for damage or wear. Coordinate with

the repair agency for repair of items that would cause serious or further damage to the instrument if not repaired immediately.

CAUTION

Instruments that appear to have been dropped, or otherwise abused, should be checked by qualified instrument repair technicians to verify correct operation and calibration.

(2) External Cleaning, Except Crt Faceplate and Filter. Dust the exterior surfaces with a dry, lint-free cloth or a soft bristle brush. If hard dirt remains, use a cloth or swab dampened with warm water and a mild detergent. A small swab is useful for cleaning in narrow spaces and around controls.

CAUTION

To prevent getting water inside the instrument during external cleaning use only enough water to dampen the cloth or swab.

Do not use chemical cleaning agents as they may damage the plastics used in the instrument. Use only approved cleaning agents.

(3) Cleaning the Crt Faceplate and Filter. To clean the crt faceplate and light filter, remove the filter as shown in Figure 3-1. Clean the faceplate and filter with a soft, lint-free cloth dampened with isopropyl alcohol.

Table 5-3. External Inspection Checklist

Item	Inspect for	Repair action (by repair agency unless otherwise noted)
Cabinet, front panel cover, front panel, and rear panel	Cracks, scratches deformations, and damaged hardware or gaskets.	Touch-up paint scratches (user). Replace cracked, deformed, or damaged parts.
Carrying handle	Correct operation.	Replace damaged parts.
Accessories	Missing items or parts of items, bent pins, broken or frayed cables, damaged connectors.	Repair frayed cables (user). Replace damaged or missing items (user). Repair damaged parts.
Front panel controls	Missing, damaged, or loose knobs or push buttons, Binding controls.	Tighten loose knobs (user). Repair or replace missing or damaged controls. Determine cause of binding controls, and repair.
Connectors	Broken shells, cracked insulation, and deformed contacts. Dirt in connector.	Replace damaged parts. Clean or wash out dirt (user).

c. Internal Preventive Maintenance. The following instructions are intended for use by instrument repair agencies only. When this maintenance is performed, the maintenance under External Preventive Maintenance above should also be performed.

WARNING

Electric shock hazards inside the instrument are exposed when the cabinet is removed. Disconnect the instrument from any power source before removing the covers.

(1) Cabinet Removal. Refer to Component Removal and Replacement for instructions on cabinet removal.

(2) Internal Cleaning. Internal cleaning should be done with a dry, low velocity stream of air. A soft bristle brush or swab is useful for cleaning in narrow spaces or around components. If these methods do not remove all the dust or dirt, the instrument may need to be disassembled and washed. Components may be spray washed using a 5% solution of water and mild detergent as follows:

CAUTION

Do not disassemble or wash the TIME/DIV switch and its associated circuit boards. Also, do not wash the vertical attenuators and their circuit boards. Washing may leave a residue on the switch contacts causing intermittent electrical problems.

When washing near unsealed electromechanical components, such as push-button switches use as little washing action as possible. This is to prevent washing all of the lubricant out of the part.

Do not use fluorocarbon base spray cleaners or silicone spray lubricants on cam switches or push-button switches. These sprays may damage the circuit board material or plastic parts and leave a dust collecting residue.

(a) Remove easily accessible shields and covers.

(b) Spray wash and thoroughly rinse the component.

(c) Blow-dry the component with low velocity air.

(d) Spray all switch contacts with isopropyl alcohol, wait for 60 seconds, and blow dry with low velocity air.

(e) Heat dry all components in an oven or compartment using low temperature (125° to 150°F) circulating air.

(3) TIME/DIV Switch Cleaning. This switch should not need cleaning unless it is intermittent. If so, rotate the switch between its limits a few times to see if it will self-clean. If this doesn't work, spray the contact area with

isopropyl alcohol, wait for 60 seconds, and blow dry with low velocity air. If these two methods do not solve the problem, remove the A AND B Timing Switch Board Assembly and disassemble it. Cleaning instructions are contained in the disassembly instructions.

(4) Attenuator Cleaning. The attenuator cam switches should be cleaned like the TIME/DIV switch above. If this doesn't work, disassemble the attenuator and clean the switch pads with an eraser (soft type on a pencil). See Component Removal, Replacement, and Disassembly instructions.

(5) Internal Inspection. Inspect the instrument for internal damage or wear using Table 5-4. Also, inspect externally using Table 5-3.

(6) Lubrication. Components are factory lubricated, which should be adequate for the life of the instrument. Occasionally, a replacement part in an assembly, such as a cam switch, may need lubricating. Where necessary, lubrication instructions are included in the Component Removal and Replacement instructions.

5-3. TROUBLESHOOTING. The following information is provided for troubleshooting the instrument. An understanding of the Theory of Operation in Section IV may be helpful in location of troubles.

Table 5-4. Internal Inspection Checklist

Item	Inspect for	Repair action
Circuit boards	Loose, broken, or corroded solder connections. Burned circuit boards. Burned, broken, or cracked circuit run plating.	Clean solder corrosion with an eraser and flush with isopropyl alcohol. Resolder connections. Determine cause of burned items, and repair. Repair damaged circuit runs.
Chassis	Detents, deformation, and damaged hardware.	Straighten, repair, or replace damaged hardware.
Resistors	Burned, cracked, broken, or blistered.	Replace damaged resistors.
Solder Connections	Cold solder or rosin joints.	Resolder and clean joint with isopropyl alcohol.
Wiring and Cables	Loose plugs or connectors. Burned, broken, or frayed.	Firmly seat connectors. Repair or replace damaged wire or cables.
Capacitors	Damaged or leaking cases. Corroded solder on terminals or leads.	Replace capacitors with damaged or leaking cases. Clean solder connections and flush with isopropyl alcohol.
Semiconductors	Loosely inserted in sockets. Bent pins.	Remove items with bent pins, carefully straighten the pins with long-nose pliers, and reinsert firmly (be sure that the straightening action hasn't cracked the pin such that it will break easily). Firmly seat all loose semiconductors.
Push-button controls	Binding controls. Missing push buttons.	Determine cause of binding control, and repair. Replace push buttons.

a. Troubleshooting Aids.

(1) Diagrams. Complete circuit diagrams are contained on foldout pages in Section VI, Diagrams. The portions of the circuit mounted on circuit boards are enclosed with heavy lines. The component number and electrical value of each component in this instrument are shown on the diagrams (see the Diagrams section for symbols used on diagrams). Each main circuit is assigned a series of component numbers to assist in identifying their circuit location. Important voltages and waveforms are also shown on the diagrams. The physical locations of the waveform test points are shown on the circuit board illustrations.

(2) Circuit Board Illustrations. An illustration showing the location of each circuit board precedes each applicable schematic diagram. Portions of a circuit board may apply to more than one schematic diagram. A circuit board illustration showing all of the components on a board

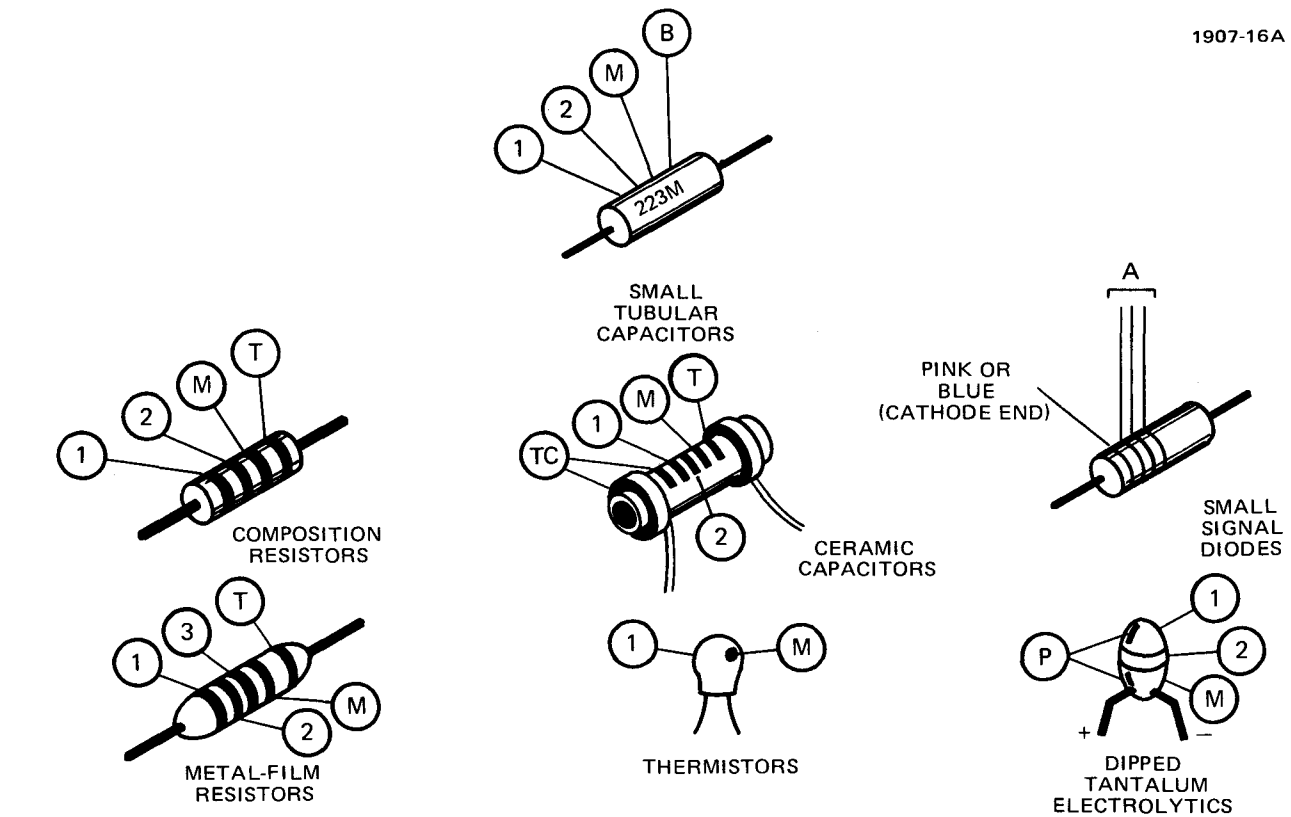
is located on the back of a foldout page preceding the first schematic diagram the board components apply to. Each circuit board illustration is provided with a grid and a grid index to facilitate rapid location of components contained on the circuit board.

(3) Component Value Identification. Values of capacitors, diodes and resistors used in this instrument are identified by direct numerical values or by a color code scheme. Figure 5-1 shows the color code and numerical value schemes used.

(4) Troubleshooting Chart. A troubleshooting chart Figure 5-2, is provided to aid in locating problem areas.

(5) Semiconductor Lead Configurations. Typical semiconductor lead configurations are shown in Figure 5-3.

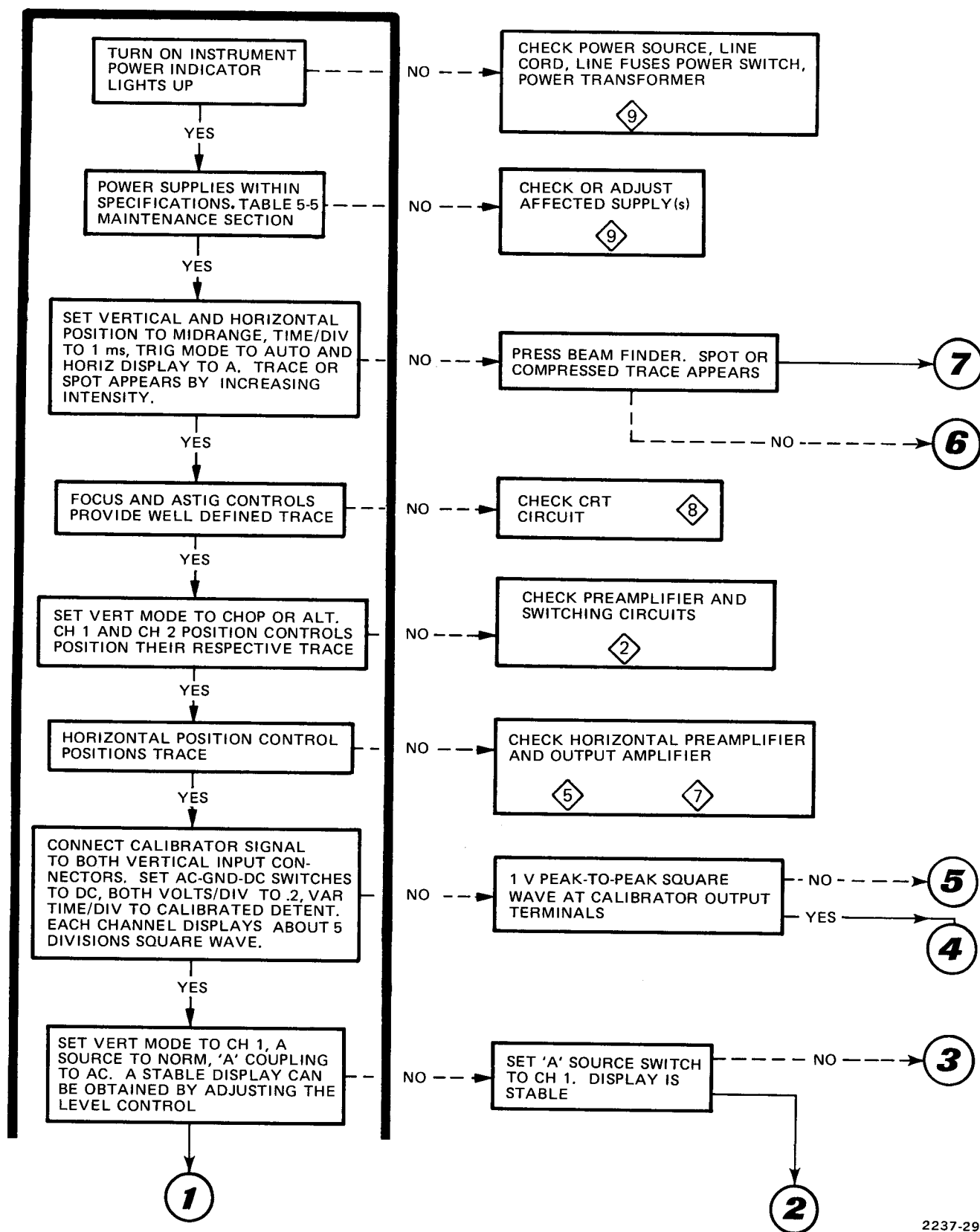
1907-16A



- (A) COLORS IDENTIFY SIGNIFICANT DIGITS IN TEKTRONIX PART NUMBER (E.G. BROWN, GRAY, GREEN STRIPES INDICATE PART NUMBER 152-0185-00)
- (B) TOLERANCE; F=±1%, J=5%, K=10%, M=20%
- (1) (2) and (3) 1ST, 2ND, AND 3RD SIGNIFICANT FIGS.
- (T) AND/OR (TC) COLOR CODE MAY NOT BE PRESENT ON SOME CAPACITORS;
- (M) MULTIPLIER (T) TOLERANCE;
- (P) POLARITY AND VOLTAGE RATING
- (TC) TEMPERATURE COEFFICIENT.

COLOR	SIGNIFICANT FIGURES	RESISTORS (Ω)		CAPACITORS (pF)			DIPPED TANTALUM VOLTAGE RATING
		MULTIPLIER	TOLERANCE	MULTIPLIER	TOLERANCE		
					over 10 pF	under 10 pF	
BLACK	0	1	----	1	±20%	±2 pF	4 VDC
BROWN	1	10	±1%	10	±1%	±0.1 pF	6 VDC
RED	2	10 ² or 100	±2%	10 ² or 100	±2%	----	10 VDC
ORANGE	3	10 ³ or 1 K	±3%	10 ³ or 1000	±3%	----	15 VDC
YELLOW	4	10 ⁴ or 10 K	±4%	10 ⁴ or 10,000	+100% –9%	----	20 VDC
GREEN	5	10 ⁵ or 100 K	±½%	10 ⁵ or 100,000	±5%	±0.5 pF	25 VDC
BLUE	6	10 ⁶ or 1 M	±¼%	10 ⁶ or 1,000,000	----	----	35 VDC
VIOLET	7	----	±1/10%	----	----	----	50 VDC
GRAY	8	----	----	10 ⁻² or 0.01	+80% –20%	±0.25 pF	----
WHITE	9	----	----	10 ⁻¹ or 0.1	±10%	±1 pF	3 VDC
GOLD	–	10 ⁻¹ or 0.1	±5%	----	----	----	----
SILVER	–	10 ⁻² or 0.01	±10%	----	----	----	----
NONE	–	----	±20%	----	±10%	±1 pF	----

Figure 5-1. Component value identification.



2237-29

Figure 5-2. Troubleshooting chart (sheet 1 of 5).



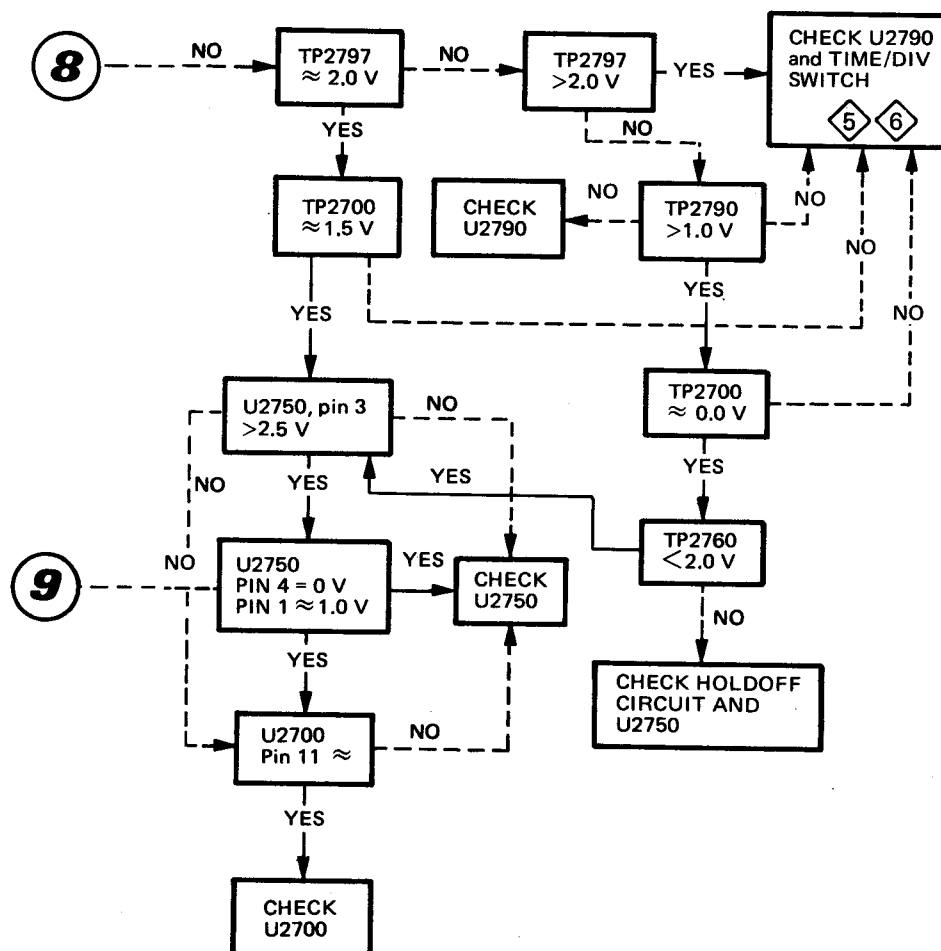


Figure 5-2. Troubleshooting chart (sheet 3 of 5).

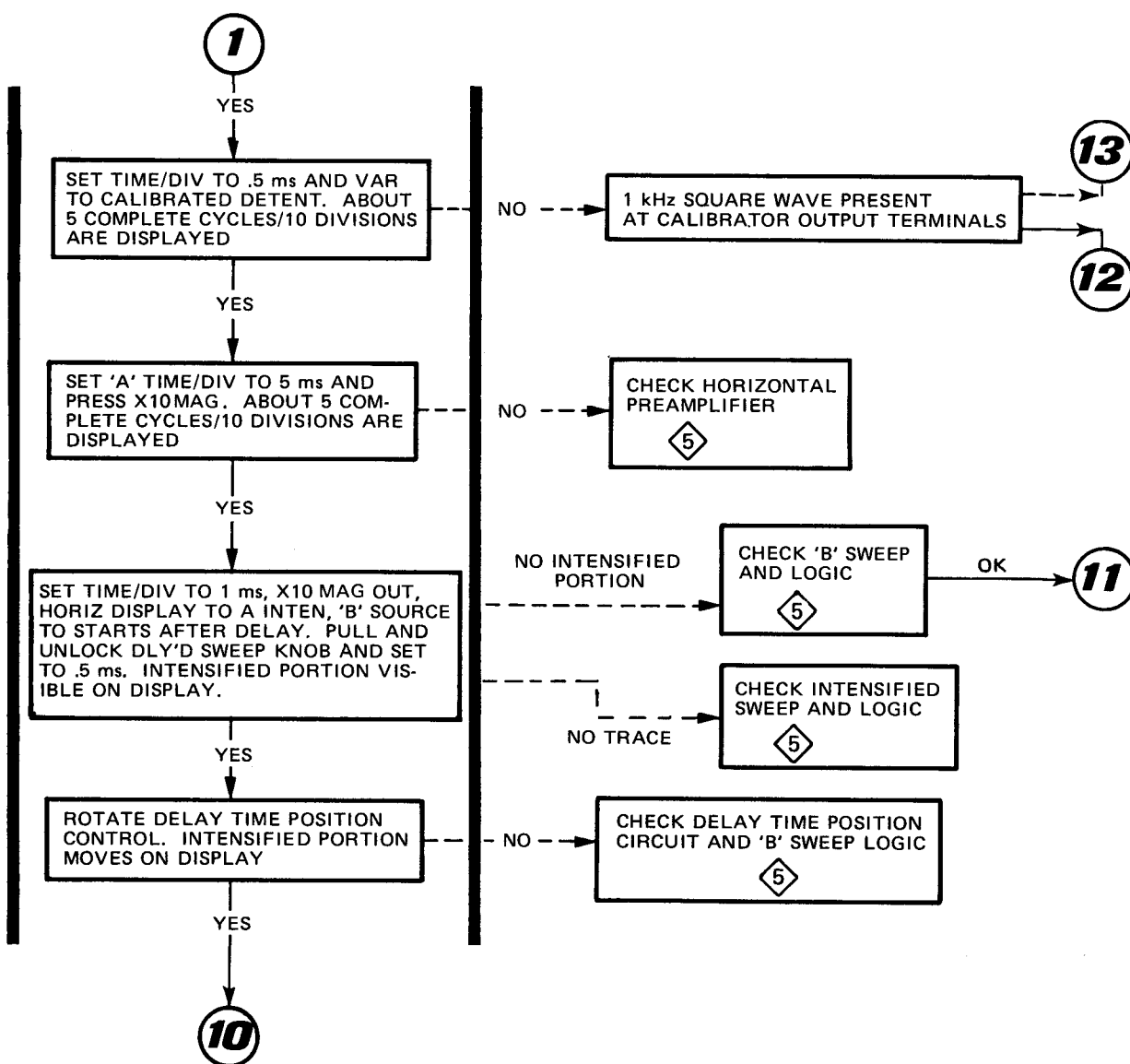
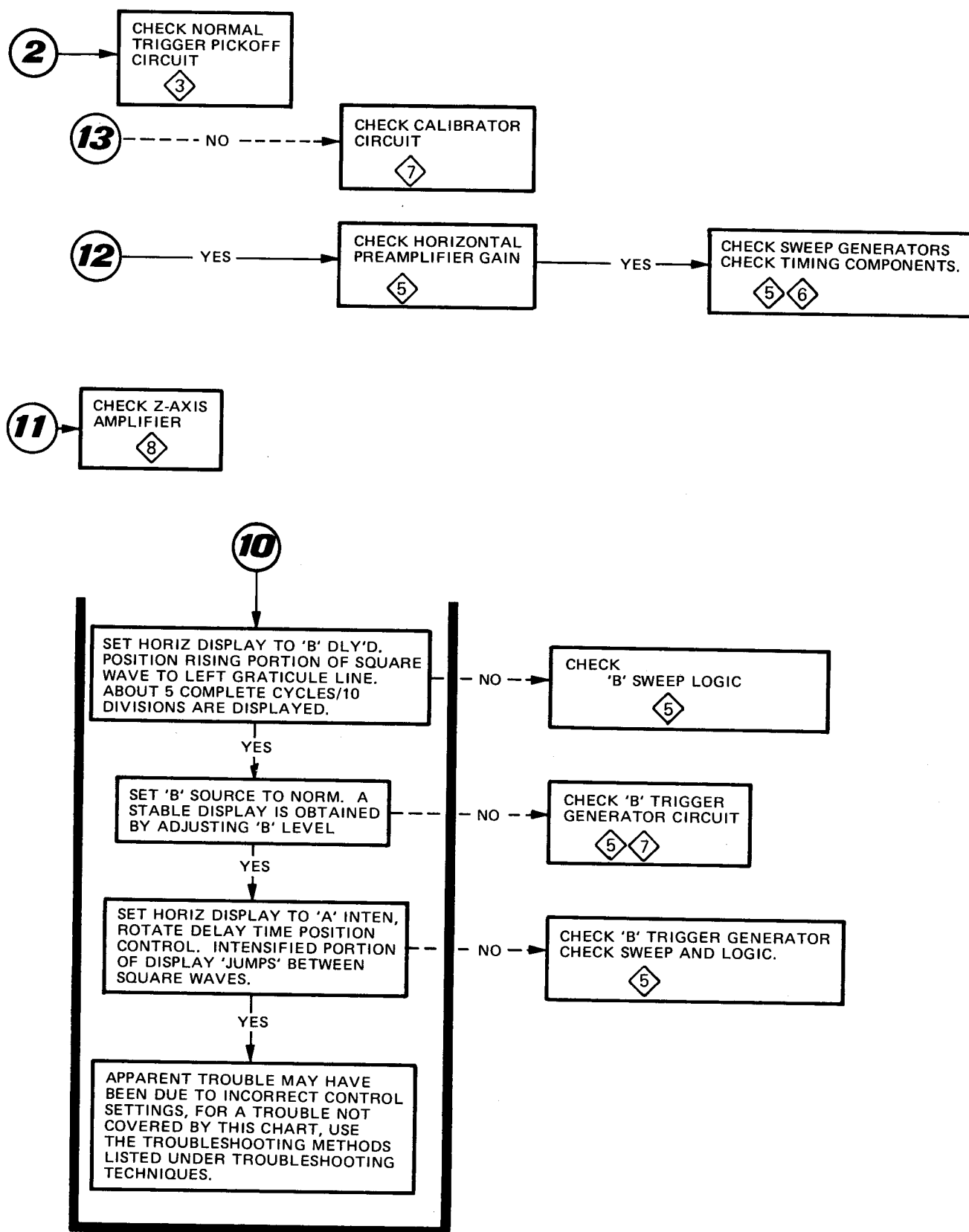


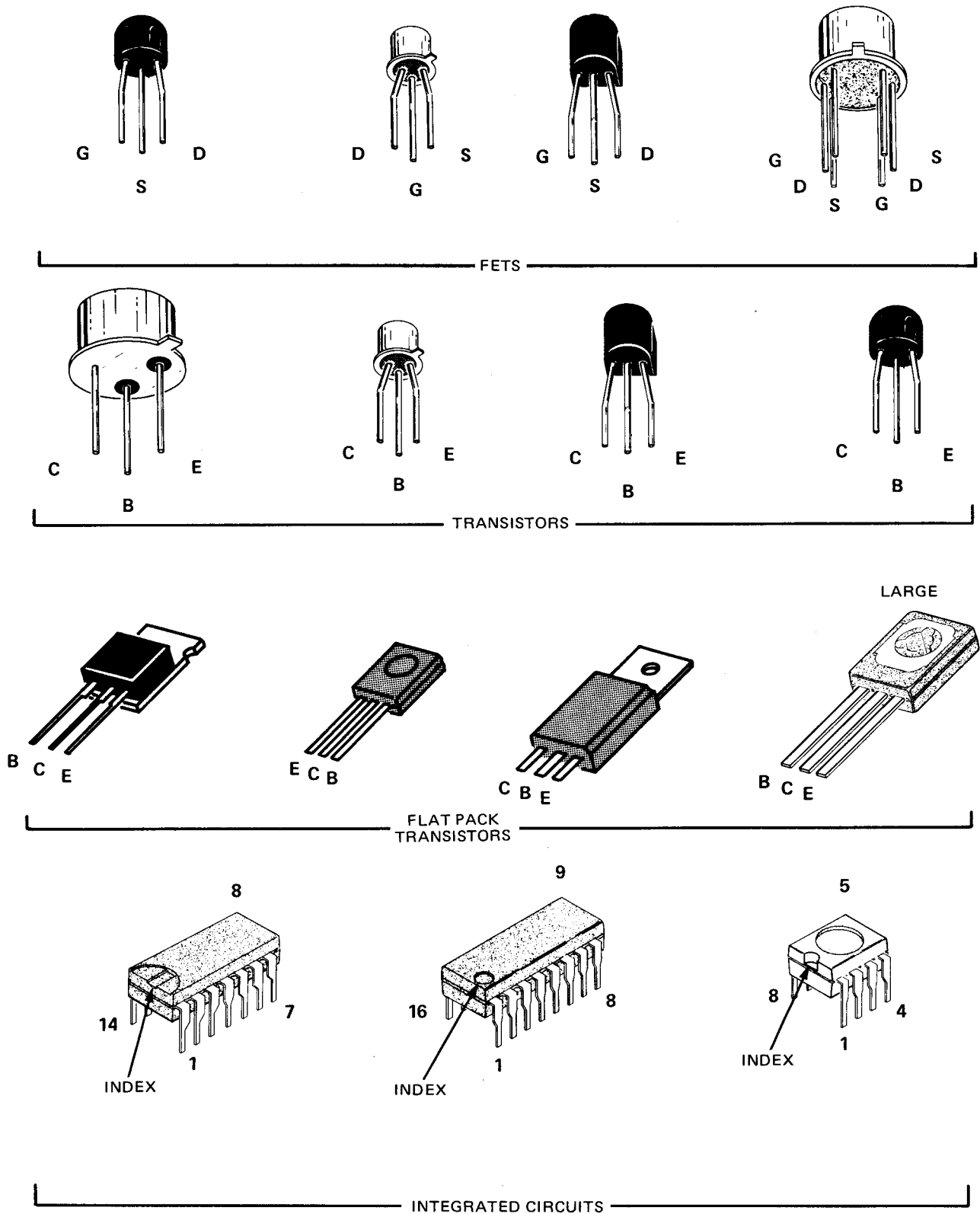
Figure 5-2. Troubleshooting chart (sheet 4 of 5).



2237-111

Figure 5-2. Troubleshooting chart (sheet 5 of 5).

NOTE
LEAD CONFIGURATIONS AND CASE STYLES ARE TYPICAL, BUT MAY
VARY DUE TO VENDOR CHANGES OR INSTRUMENT MODIFICATIONS.



1907-788

Figure 5-3. Semiconductor lead configurations.

b. Troubleshooting Techniques. The following procedures are arranged in an order that checks the simple trouble possibilities before proceeding with extensive troubleshooting. The first few checks ensure proper connection, operation, and calibration. If the trouble is not located by these checks, the remaining checks should aid in locating the defective component.

(1) Check Control Settings. Incorrect control settings can give a false indication of an instrument malfunction. If there is any question about the correct function or operation of any control, see the Operation Instructions section.

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

(3) Check Instrument Calibration. Check the calibration of this instrument, or the affected circuit if the trouble exists in one circuit. The apparent trouble may only be misadjustment that can be corrected by calibration.

(4) Visual Check. Visually check the portion of the instrument in which the trouble is located. Many troubles can be located by visible indications such as unsoldered connections, broken wires, damaged circuit boards, and damaged components.

(5) Isolate Trouble to a Circuit. Using the troubleshooting chart Figure 5-2, isolate trouble to a particular circuit. The symptom often identifies the defective circuit. Trouble appearing in more than one circuit can indicate possible power supply problems. Power supply tolerance and ripple limits can be checked using Table 5-5. Power supply disconnect jumpers are provided for each of the supplies. Refer to the schematics and circuit board illustrations for their location. These jumpers can be unsoldered to disconnect the circuit load from most of the supplies. Each unregulated supply contains a fuse for circuit protection.

(6) Check Circuit Board Interconnections. After the trouble has been isolated to a particular circuit, check for loose or broken connections, improperly seated transistors and heat damaged components.

(7) Check Voltages and Waveforms. Often the defective component can be located by checking for the correct voltage or waveform in the circuit. Typical voltages are given on the diagrams. Waveforms are shown on the circuit diagram apron.

NOTE

Voltages and waveforms given on the diagrams are not absolute and therefore may vary slightly between instruments. To obtain operating conditions similar to those used to take these readings, see the voltage and waveform set up procedures in the Diagrams section. Individual deviations should be noted on the schematics for future reference.

Table 5-5. Power Supply Tolerance and Ripple.

Supply	Tolerance	Maximum Ripple (peak-to-peak)
-5 V	$\pm 1.1\%$ (5.5 mV)	1 mV
+5 V	$\pm 1.1\%$ (5.5 mV)	1 mV
+32 V	$\pm 0.6\%$ (192 mV)	1 mV
+95 V	$\pm 2.0\%$	1 V
-2 kV	$\pm 1.25\%$ (25 V)	200 mV

(8) Check Individual Components. The following procedures described methods of checking individual components. Components which are soldered in place are best checked by disconnecting one end. This isolates the measurement from the effects of surrounding circuitry.

WARNING

The Power switch must be turned off before removing or replacing components to prevent electrical shock or circuit damage.

(a) Semiconductors. A good check of transistor operation is actual performance under operating conditions. A transistor can be most effectively checked by substituting a new component for it (or one which has been checked previously). However, be sure that circuit conditions are not such that a replacement transistor might also be damaged. If substitute transistors are not available, use a dynamic tester. Static type testers are not recommended, since they do not check operation under simulated operating conditions.

1 When troubleshooting transistors in the circuit 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 emitter to base voltage of a conducting silicon transistor will normally be 0.6 to 0.8 volts. The emitter to collector voltages of a saturated transistor is about 0.2 volts. 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 2 voltages taken with respect to ground (both leads of the voltmeter must be isolated from ground if this method is used). If values less than these are obtained, either the device is short-circuited 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. Values in excess of those given for emitter collector could indicate either a nonsaturated device operating normally, or a defective (open-circuited) transistor. If the device is conducting, voltage will be developed across resistances in series with it; if it is open, no voltage will be developed across resistances in series with it unless current is being supplied by a parallel path.

2 When troubleshooting a field effect transistor, the voltages across its elements can be checked in the same manner as for transistors. However, it should be remembered that normal depletion mode operation has the gate to source junction reverse biased, while the enhanced mode has the junction forward biased.

3 Integrated circuits (IC's) can be checked with a voltmeter, test oscilloscope, or by direct substitution. A good understanding of circuit operation is essential to troubleshooting circuits using IC's. Use care when checking voltages and waveforms around the IC's so that adjacent leads are not shorted together. A convenient means of clipping a test probe to the 14- and 16-pin IC's is with an IC test clip. This device also doubles as an extraction tool.

(b) Diodes. A diode can be checked for an open or for a short circuit by measuring the resistance between terminals with an ohmmeter set to the R X 1 kilohm scale. The diode resistance should be very high in one direction and very low when the meter leads are reversed.

CAUTION

Do not use an ohmmeter scale that has a high internal current. High currents can damage diodes. Check diodes in the same manner as transistor emitter to base junctions. Silicon diodes should have 0.6 to 0.8 volts across the junction when conducting. Higher readings indicate that they are either back biased or defective, depending on polarity.

(c) Resistors. Check the resistors with an ohmmeter. Check the parts list for tolerance of the resistors used in this instrument. Resistors normally do not need to be replaced unless the measured value varies considerably from the specified value.

(d) Inductors. Check for open inductors by checking continuity with an ohmmeter. Shorted or partially shorted inductors can usually be found by checking the waveform response when high-frequency signals are passed through the circuit.

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

(f) Attenuators. The thick film attenuators are best checked by substitution. If only one channel is not operating properly, and there is reason to believe an attenuator is defective, replace the suspected attenuator with the same attenuator from the other channel and check instrument operation. If proper operation results, replace or repair the defective attenuator.

5-4. CALIBRATION AND CHECKOUT AFTER REPAIR. Whenever repairs involve the power supplies or instrument disassembly, Calibration and an Operational Checkout should be performed.

5-5. COMPONENT REMOVAL, REPLACEMENT, AND DISASSEMBLY.

WARNING

To prevent electrical shock or damage to the instrument, always disconnect the instrument from the power source before removing or replacing components. Also, review the Safety Summary page in the front of this manual.

a. Cabinet Top and EMI Shield Removal and Replacement.

(1) Using a coin or large bladed screwdriver, rotate the three circular locks on each side of the cabinet (see Figure 5-5) counterclockwise until the slots are vertical.

(2) Lift the cabinet top straight up.

(3) Remove the nine screws holding the EMI Shield (6 on left side near the front, 2 on the top at the rear, and 1 on the top right at the front).

(4) Lift the EMI Shield straight up.

(5) Replace the EMI Shield and cabinet top in reverse order.

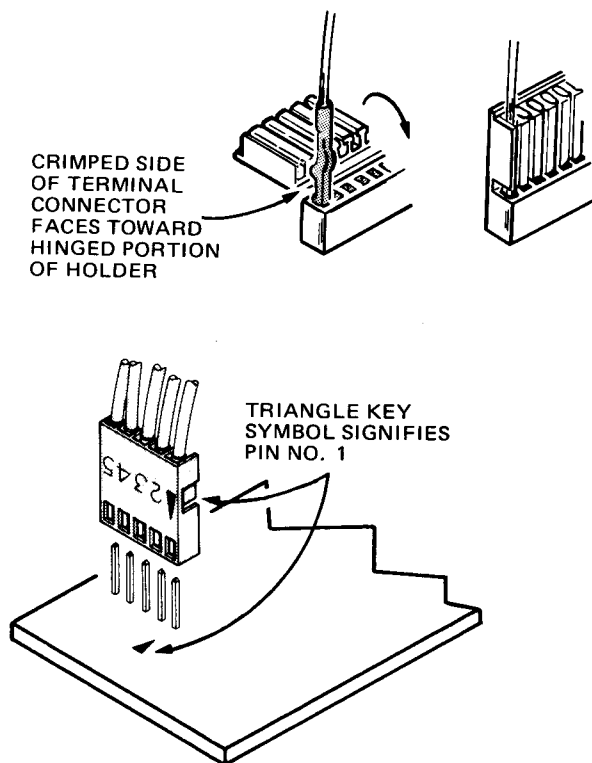
b. Interconnecting Cables and Connectors (Figure 5-4). The interconnecting cable assemblies are factory assembled. They consist of machine installed pin connectors mounted in plastic holders. The plastic holders are easily replaced as individual items, but if the connectors are faulty, the entire cable should be replaced. It is possible for the pin connectors to become dislodged from the plastic holders. If this happens, the connector can be reinstalled as follows:

(1) Bend grooved portion of holder away from cable as shown.

(2) Reinsert connector into its hole in the plug-in portion of holder. Wires are positioned in holder according to color code system (see note below).

NOTE

Holder positions are numbered (number one is identified with a triangle).



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Figure 5-4. Multiconductor connector identification.

(3) Bend grooved part of holder so that connector is inserted into groove.

(4) When plugging connector holders on to board pins, be sure to match triangle mark on holder with triangle mark on circuit board.

c. Rear Panel Assembly Removal and Replacement (Figure 5-5).

(1) Remove the cabinet top.

(2) Unplug the power cord.

(3) Unplug the coaxial connector end at the +A GATE OUT (white wire with yellow trace) and CH 2 OUT (white wire with brown trace) connectors located on the A8 Sweep and A5 Vertical boards, respectively.

(4) Remove the four screws on the inside corners of the rear subpanel.

CAUTION

When removing the rear panel in the next step, be careful not to break or damage the attached wiring or cables.

(5) While carefully pulling the top of the rear panel away from the mounting brackets lift the bottom up and out of the groove in the cabinet bottom. Then lay the rear panel on its back and disconnect the attached wires and cables.

(6) Replace the rear panel in the reverse order. Reconnect the wires and cables. Then hold the panel vertical and set it into the groove in the cabinet bottom. Align the screw holes and install the four corner screws. If the rear panel wires and cables were not tagged when removed, the following may be useful.

(a) The input power wires and power transformer leads are color coded as shown on the schematic diagrams. Also, the circuit board lead mounting holes for the rectifiers are color code numbered for the transformer leads (e.g., 2 is red, 6 is blue, etc).

(b) The clear plastic connectors for the transistors on the rear panel can be installed only with the mounting holes closest to the panel. These transistors are numbered Q736, Q746, and Q768 starting at the power transformer and moving away from it. They connect to number matching

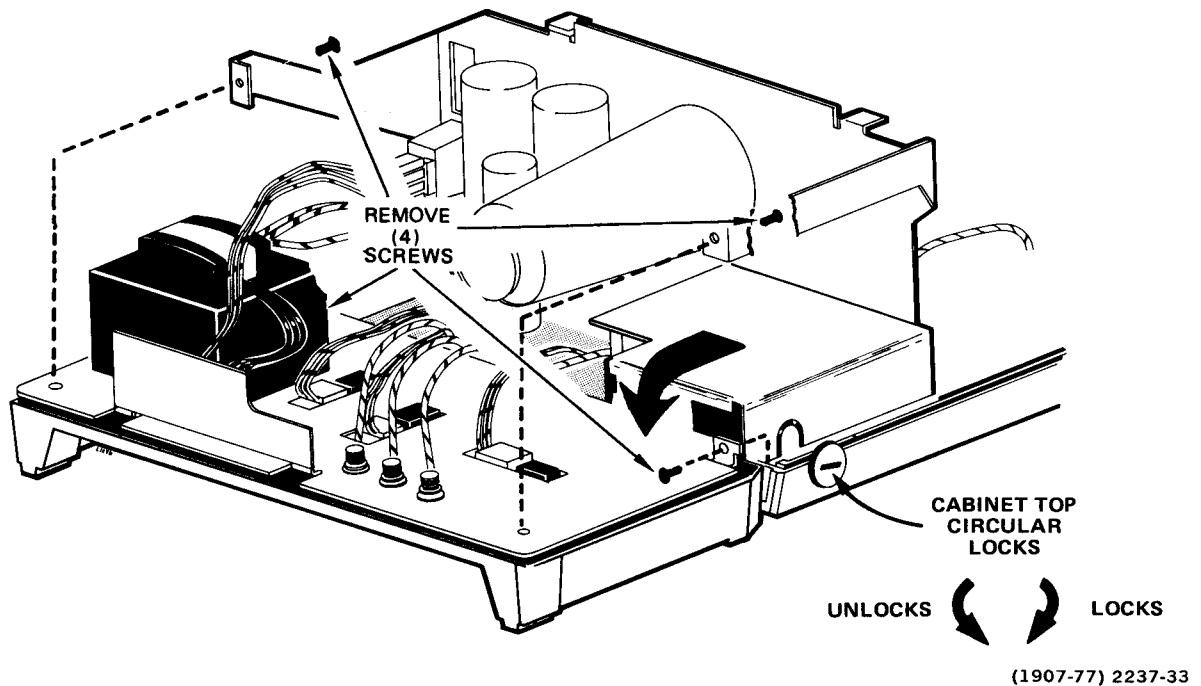


Figure 5-5. Rear panel removal.

plugs (e.g., Q736 to J736, etc.) on the A11 board. Be sure multiconductor holders are installed with proper triangle key orientation (see Figure 5-4).

d. Cabinet Bottom Removal and Replacement (Figure 5-6).

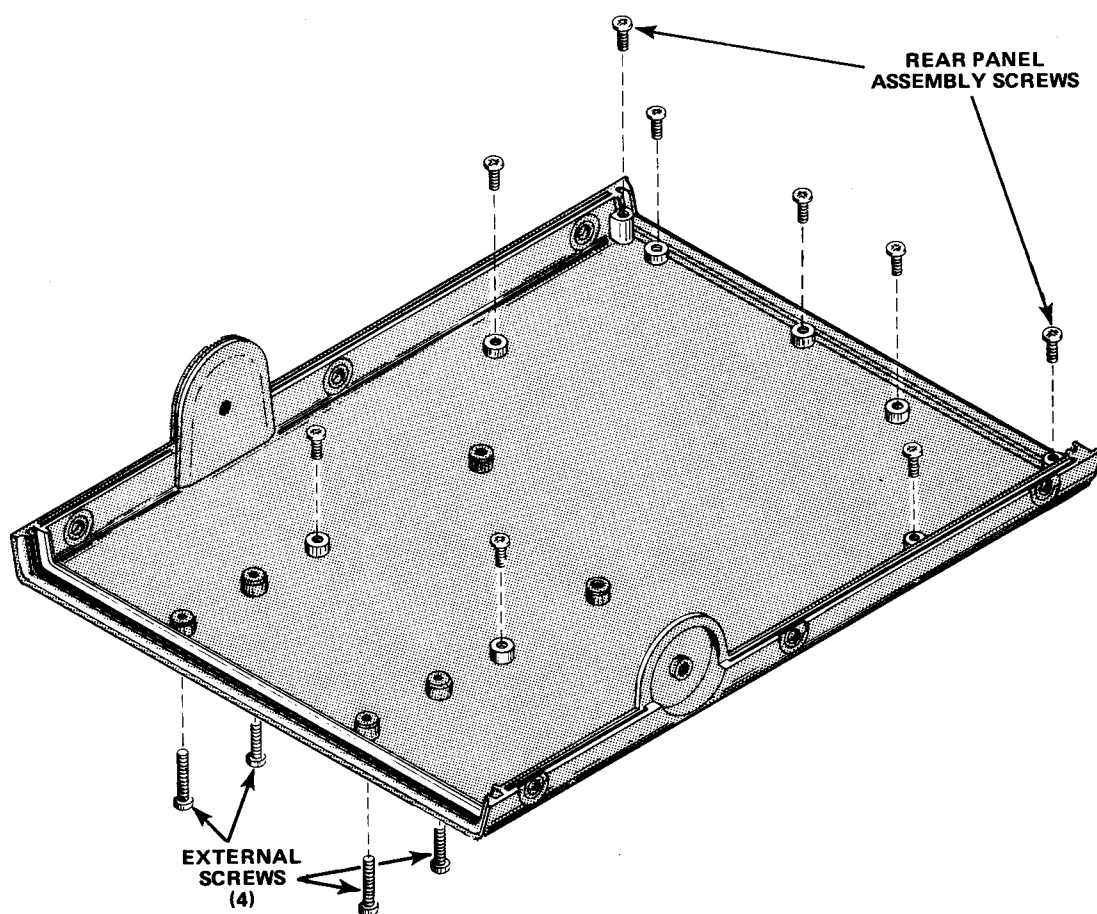
- (1) Remove the cabinet top.
- (2) Raise the front of the instrument and remove the four external screws from the cabinet bottom.
- (3) Remove the rear panel assembly.
- (4) Remove the remaining seven internal screws from the cabinet bottom.
- (5) Lift the instrument off the cabinet bottom.
- (6) Replace the bottom in the reverse order of removal. When installing the four external screws in the front part of the cabinet bottom, the floating nuts inside the instrument along side the front part of the crt, may need to be aligned.

e. Vertical Module Removal (Figure 5-7).

- (1) Remove the remaining screw holding the module.
- (2) Unplug CH 2 OUT cable, vertical deflection plate leads, and multiconductor connector to the horizontal module.
- (3) Pull plug in module straight up and away from interface connector.
- (4) Reinstall the module in reverse order. Be sure CH 2 OUT cable is routed through cutout at bottom of module.

f. Horizontal Module Removal (Figure 5-8).

- (1) Remove the remaining screw holding the module.
- (2) Unplug multiconductor connector to vertical module and +A GATE OUT cable.
- (3) Unsnap the POWER switch extension rod from yokes on POWER switch shaft.



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Figure 5-6. Cabinet bottom removal.

(4) Pull plug in module straight up and away from interface connector.

(5) Reinstall the module in reverse order. Be sure plastic yokes on POWER switch are aligned before reinstalling the extension rod.

g. Cathode Ray Tube (Crt) Removal.

WARNING

Handle crt carefully. Rought handling or scratching may cause crt to implode.

(1) Remove vertical module.

(2) Remove plastic bezel and filter on front of crt.

(3) Unplug crt anode lead and discharge to chassis.

(4) Unplug crt base socket.

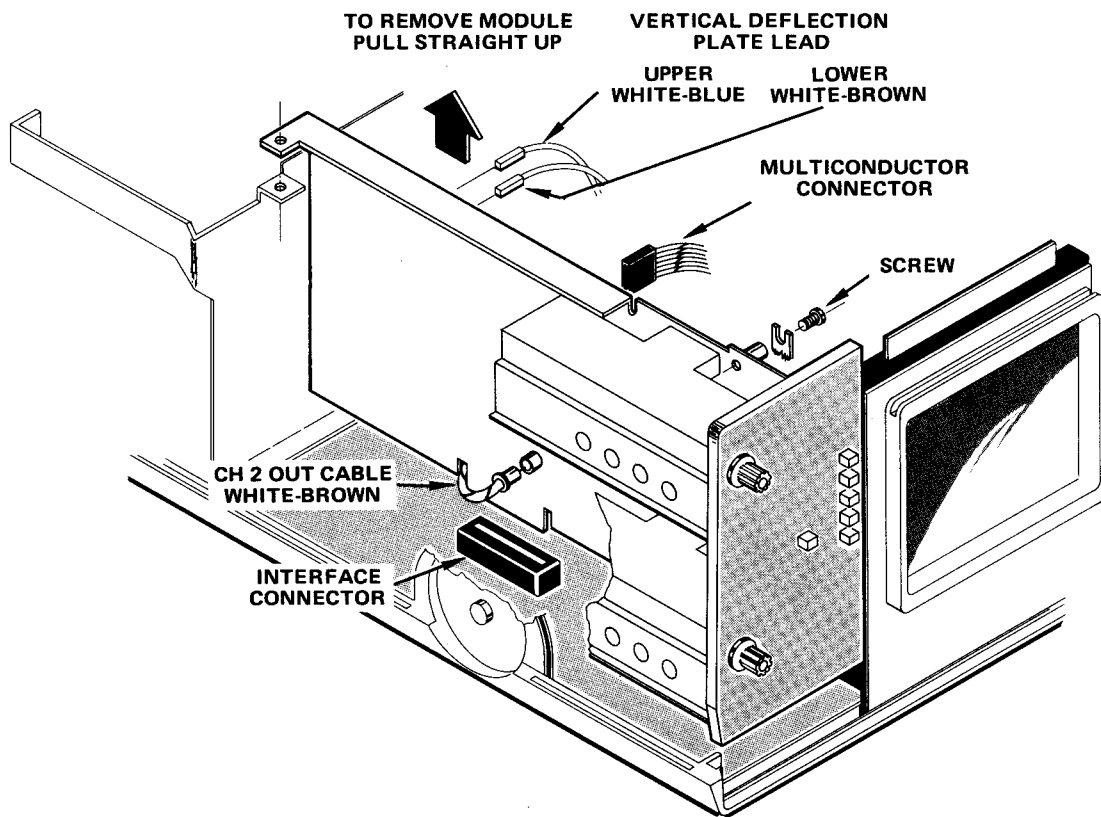
NOTE

When removing leads in the next two steps make a note of the lead color, or tag the leads.

(5) Disconnect two vertical deflection plate leads from left side of crt neck.

(6) Disconnect two horizontal deflection plate leads from the circuit board.

(7) Hold crt face in one hand and slowly push crt base with other hand.



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Figure 5-7. Vertical module removal.

(8) Carefully pull crt out of shield (watch horizontal deflection leads).

(9) Reinstall the crt in reverse order.

h. Shaft-Knob Removal (Figure 5-9).

(1) Grip knob end with one hand and shaft with other hand.

(2) Pull on knob, while pushing on shaft, to free recessed portion of shaft from retainer bushing. Some shaft-knobs may require considerable force to remove.

(3) Replace the shaft-knob in reverse order.

i. Interface Board Removal.

(1) Remove the vertical and horizontal modules.

(2) Lift up the front of the instrument and remove the four external cabinet bottom screws.

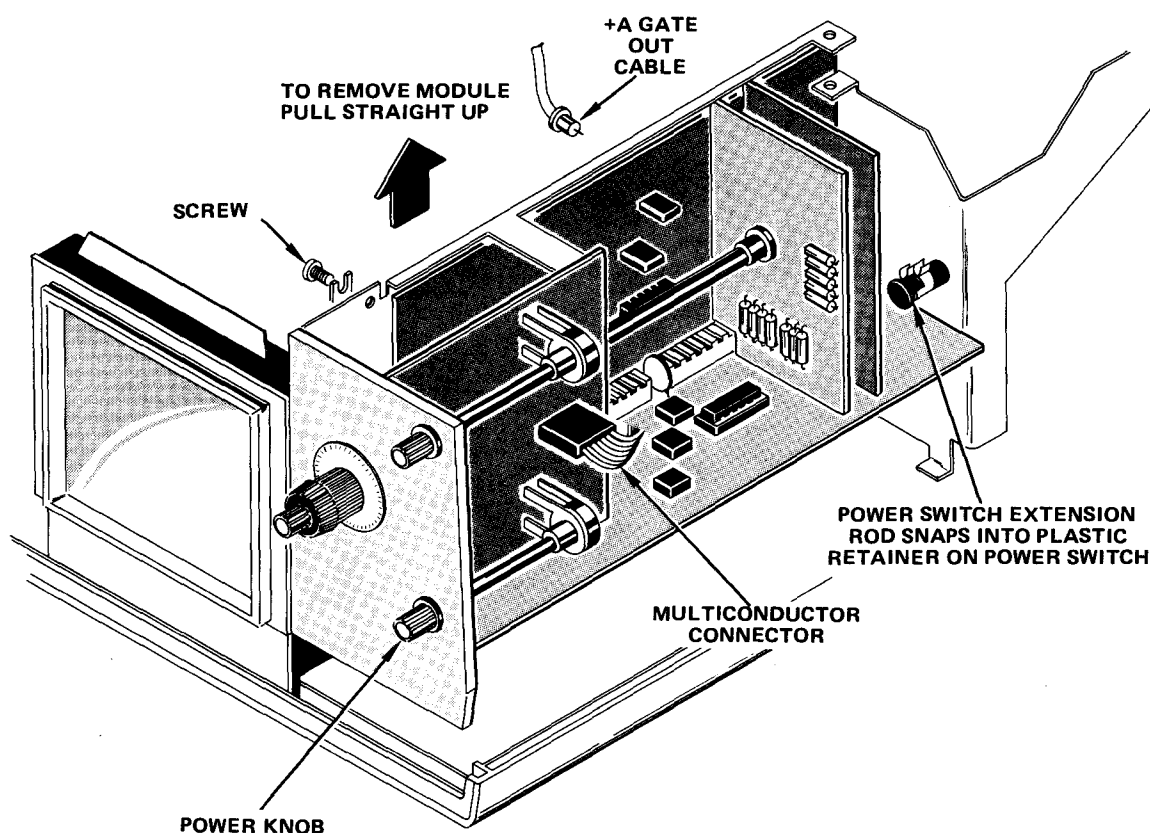
(3) Unplug the crt socket.

(4) Remove the high voltage shield.

(5) Remove the shaft-knob from INTEN, ASTIG, FOCUS, TRACE ROTATION, and SCALE ILLUM controls (see h. above).

(6) Unplug the crt anode lead and discharge it to the chassis.

(7) Unplug the crt vertical deflection plate leads from crt (left side) and horizontal deflection plate leads from the Interface circuit board.



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Figure 5-8. Horizontal module removal.

(8) Unplug the crt trace rotation and Y-Axis leads coming from the top of the crt.

(9) Remove the ground post and bracket at the top rear of the crt shield.

(10) Carefully lift the crt assembly (crt, shield, and center front section) forward and up away from the chassis.

The BEAM FINDER push button should slip out of the assembly.

(11) Remove the two screws and two nuts holding the power supply chassis divider. Loosen the small screw in the front lower right corner of this chassis (there is a heat sink on the other side). Carefully remove the chassis.

(12) Remove the rear panel and disconnect the wires and cables to the Interface Board.

(13) Remove the remaining screws holding the Interface Board to the cabinet bottom.

(14) Reinstall the board in reverse order. Be sure to properly install the heat sink when replacing the divider chassis in step (11).

j. A and B Timing Switch Board Assembly Removal and Replacement (Figure 5-10).

(1) Remove the horizontal module.

(2) Remove the VAR (1 hex screw) and the TIME/DIV knobs by loosening their set screws with a 1/16 inch hex wrench.

(3) Remove the two screws and hex nuts holding the switch board assembly.

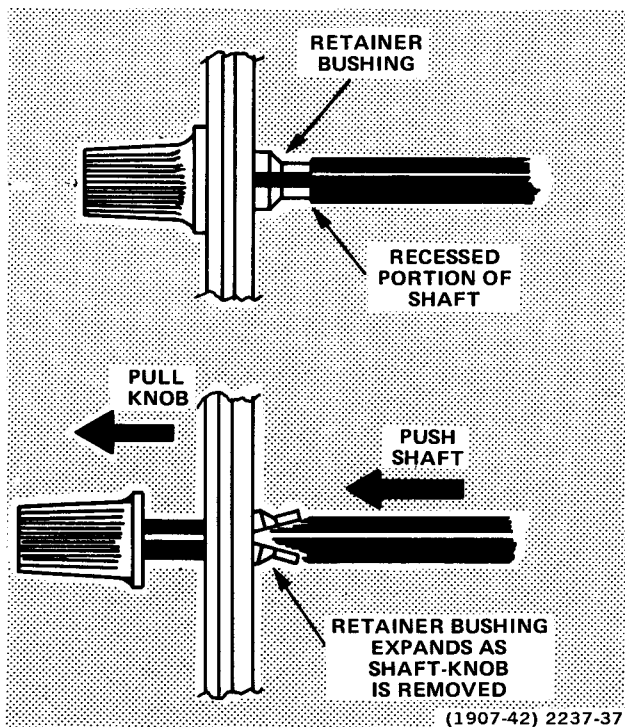


Figure 5-9. Shaft-knob removal.

(4) Remove the TIME/DIV knob skirt by loosening its set screw with a 5/64 inch hex wrench.

CAUTION

When removing the assembly in the next step, be careful not to bend the connector pins on the A8 Sweep Board.

(5) Carefully pull the board assembly away from the Sweep Board until it just unplugs. Then pull the board assembly toward the rear of the module until the switch shaft exits the front panel.

(6) Reinstall the assembly as follows:

(a) Guide the switch shaft through the front panel opening and carefully plug the board into the Sweep board.

(b) Grip the bushing at the switch end of the A TIME/DIV shaft and rotate the shaft fully counterclockwise, then two positions clockwise (.2 ms). Install the plastic knob skirt so the window in the skirt aligns with the .2 ms panel marking and tighten the knob skirt set screw.

(c) Grip the bushing at the switch and rotate the A TIME/DIV shaft fully counterclockwise. Temporarily install the B TIME/DIV knob, pull to unlock and rotate the B TIME/DIV shaft fully counterclockwise.

(d) Loosen set screw and install the B TIME/DIV knob so that the white line points to the same setting as the black bordered window on the knob skirt (pointing at X-Y). Tighten the set screws.

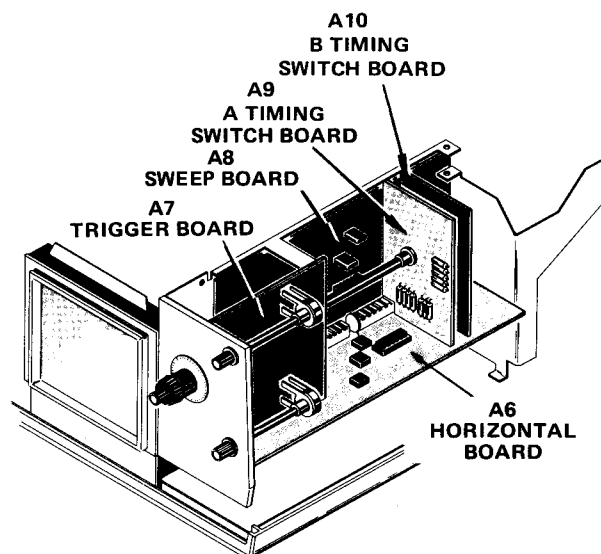
(e) Grip the VAR potentiometer shaft coupling and rotate the VAR shaft fully clockwise into the detent. Install the VAR knob with the word VAR horizontal and tighten the set screw.

(f) Set TIME/DIV to X-Y. Pull the B TIME/DIV knob to unlock and rotate fully clockwise. When properly installed, B TIME/DIV should set to 0.5 μ s and cause A TIME/DIV to set to .2 s.

k. A and B Timing Switch Disassembly (Figures 5-10 and 5-11).

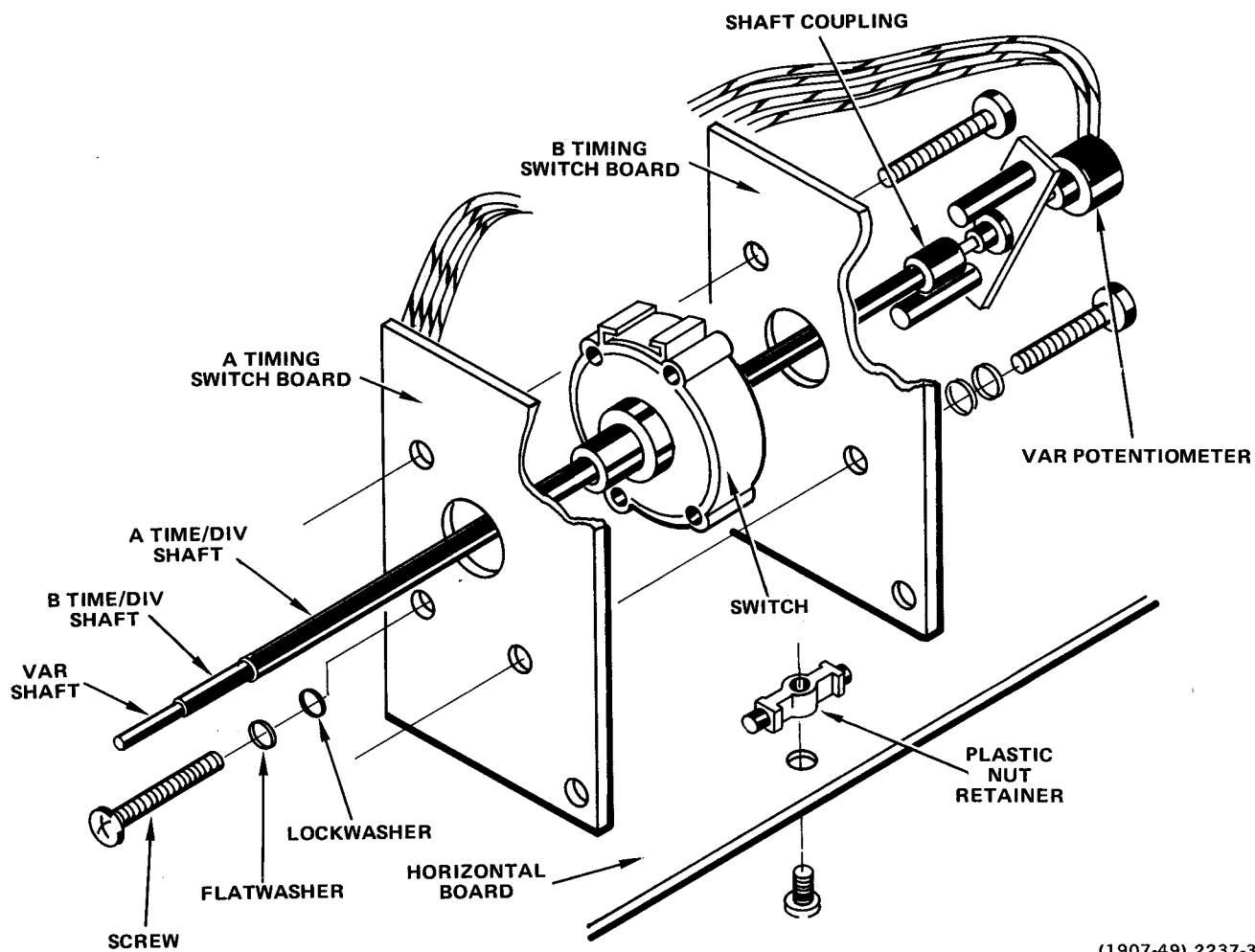
(1) Remove the VAR shaft by loosening its set screw at the VAR potentiometer coupling with a 0.05 inch hex wrench.

(2) Remove the four screws holding the switch and boards together. Separate the boards, being careful that the switch doesn't fall out. Also, do not lose the two plastic nut retainers.



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Figure 5-10. Horizontal module board locator.



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Figure 5-11. TIME/DIV switch disassembly.

CAUTION

Do not touch the switch contact wipers as they are easily damaged or contaminated. Do not use a brush or swab to clean the wipers. Whenever the switch is separated from the boards, it should be placed in some type of container for protection from damage or contamination.

(3) Clean the switch contact pads with a soft eraser (pencil type).

(4) Clean the boards with isopropyl alcohol.

(5) Reassemble the switch as follows:

(a) Insert the switch shaft through the A Timing Switch Board from the control side of the board and position the switch on the board.

NOTE

There are two small tabs on the switch—one round and one oval. These fit into properly sized holes for switch positioning.

(b) Set the remaining switch board on the switch. Be sure the two plastic nut retainers are in place. Install the

two screws and nuts that hold the boards together (insert from the B Timing Switch board side in the unplated holes), but do not tighten them.

(c) Install the VAR potentiometer using the remaining two screws, but do not tighten them.

(d) Install the VAR shaft (untapered end) in the VAR potentiometer and tighten the set screw with a 0.050 inch hex wrench.

(e) Tighten the four screws holding the assembly together.

l. Trigger Board Removal and Replacement (Figure 5-10).

(1) Remove the horizontal module.

(2) Unplug the three multiconductor connectors.

(3) Unsolder the B Trigger external input and its ground at the rear of the BNC connector.

(4) Remove one screw at top rear of board.

(5) Carefully pull the bottom of the board toward the right until it just unplugs. Then pull the board out away from the module.

(6) Replace the board in reverse order.

m. Source and Coupling Switch Disassembly. These switches are disassembled by removing the one screw holding each set to the board. Once disassembled, the switch contact pads can be cleaned with an eraser (pencil type) and isopropyl alcohol. Reassemble the switches in reverse order.

CAUTION

Do not touch or clean the switch contact wipers as they are easily damaged or contaminated. Whenever the switches are disassembled, place the switches in a container to protect the wipers.

n. Horizontal Board Removal and Replacement (Figure 5-10).

(1) Remove the horizontal module.

(2) Remove the Trigger Board.

(3) Remove both screws holding the A and B Timing Switch Board Assembly. Unplug the assembly and move it far enough toward the top of the module to uncover the Horizontal Board plugs to the Sweep Board.

(4) Remove the horizontal POSITION and A TRIGGER HOLDOFF shaft knobs (see h. above).

(5) Remove the two screws holding the board (left rear corner and right front corner).

(6) Unsolder the A Trigger external input at the BNC connector and remove the board.

(7) Replace the board in reverse order.

o. Sweep Board Removal and Replacement (Figure 5-10).

(1) Remove the horizontal module.

(2) Remove the A and B Timing Switch Board Assembly.

(3) Remove the Trigger Board.

(4) Remove the Horizontal Board.

(5) Unplug the three multiconductor connectors going to front panel controls.

(6) Remove the four screws holding the board to the chassis and remove the board.

(7) Replace the board in reverse order.

p. Graticule Illumination Board Removal and Replacement.

(1) Remove the horizontal module.

(2) Remove the crt.

(3) Unplug the Graticule Illumination Board connector (beside the Graticule illumination potentiometer), and remove the board.

(4) Reinstall the board in reverse order.

q. Hybrid IC Removal and Replacement (Figure 5-12).

CAUTION

When removing the hybrid IC, handle it with care as the ceramic material may break or crack if dropped or hit sharply.

(1) Remove the vertical module.

(2) Release the TRIG VIEW/20 MHz BW switch shaft from the switch using a 0.050 inch hex wrench. Move it away from the hybrid IC.

(3) Release the INVERT switch shaft by holding the shaft and pulling off the gray push button. Rotate the shaft away from the hybrid IC.

(4) Insert a narrow blade screwdriver between the socket (near the lip) and the mounting clip. Carefully twist the screwdriver until the mounting clamp unlatches from the lip. While holding a finger on the mounting clamp to keep it from springing into the air, unlatch the other lip on the same side. Remove the mounting clamp.

(5) Lift out the hybrid IC.

(6) Replace the hybrid IC as follows:

(a) Note the index key on the hybrid IC and the socket, then set the IC into the socket.

(b) Hook one end of the mounting clamp over two of the lips on one end of the socket; hold this end of the clamp so it doesn't spring off the socket. Push the other end of the clamp down until it hooks over the other two lips.

(c) Return to step (3) above and continue the replacement in reverse order of removal.

r. VOLTS/DIV Attenuator Disassembly (Figure 5-13).

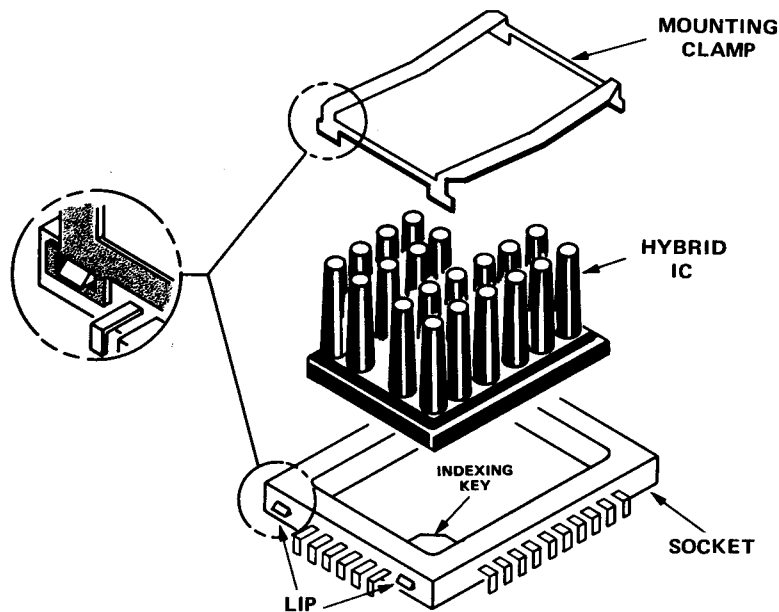
(1) Remove the vertical module.

(2) Remove the VAR knob and shaft by loosening the shaft coupling set screw at the VAR potentiometer with a 0.050 inch hex wrench.

(3) Remove the VOLTS/DIV knob with skirt and shaft by pulling it away from the module.

(4) Remove the vertical POSITION knob with shaft (see h. above).

(5) Remove the attenuator shield by removing its four holding screws and the ground braid screw from the module chassis (on channel 2, unsolder the ground braid from the lug on the shield).



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Figure 5-12. Hybrid IC removal.

(6) Remove the small grounding bracket at the front right part of the attenuator assembly by removing the nut just above the BNC connector and the screw under the front right corner of the assembly.

(7) Unsolder the resistor and adjustable capacitor tab from the BNC center conductor.

(8) Remove the BNC connector by unscrewing the large nut and pulling the connector out through the front panel.

NOTE

On some early instruments, the vertical input BNC connector lock washers are secured with Loctite. Later instruments use Loctite without lock washers. Once the Loctite seal on a lock washer is broken, it is recommended that the washer be removed and the nut secured with a drop of Loctite. Hardened Loctite can be softened with low temperature heat between 80° — 100°F.

(9) Unplug the multiconductor connector from the Vertical Board (located near the rear of the attenuator).

(9.1) Remove large shield on soldered side of board (be careful not to lose the two washers under the shield in the holes near the front of the module. They must be installed under the shield in the holes).

(10) Remove the long, narrow shield on the soldered side of the Vertical Board.

(11) Unsolder the one pin connection under the shield removed in (10) above.

(12) Remove the remaining three screws holding the attenuator assembly to the chassis (one located on the soldered side of the Vertical Board near the top front corner; the other two are located on the chassis under the attenuator).

(13) Carefully remove the attenuator assembly. Ensure that the 4 pins near the pin unsoldered in (11) above are disconnected without damage and note their orientation for reassembly reference.

(14) Pull off the AC-GND-DC lever (may need to be very carefully pried away from the cam assembly with a small, thin blade screwdriver).

(15) Remove the three screws holding the cam bearing sections to the circuit board. Then lift the cam out of the assembly.

(16) Remove the three screws holding the contact retainer to the circuit board. Being careful that the two switch contact assemblies (wipers) do not fall out, or otherwise get damaged, lift the retainer out of the assembly. If the contact assemblies stay in the switch, lift them out. If they stick to the retainer, carefully pull them off.

CAUTION

If the contact assemblies are not to be immediately reinstalled, put them in a protective container to prevent damage or contamination.

(17) The switch contact pads on the circuit board can be cleaned with an eraser (pencil type) and isopropyl alcohol.

(18) The cam can be removed from the end bearing section by pulling the cam rotor out of the end bearing section with a twisting motion.

(19) Reassemble the switch as follows:

(a) Install the contact assemblies on the contact retainer as shown in Figure 5-13B. Install these parts in the attenuator assembly. Be sure the plastic alignment posts on the contact retainer are properly inserted in the circuit board. Install the three contact retainer screws, but don't fully tighten them. Very carefully push the end contact assembly down to its pad and check the alignment. Move the contact retainer to align the contact assembly and pad, then tighten the three contact retainer screws.

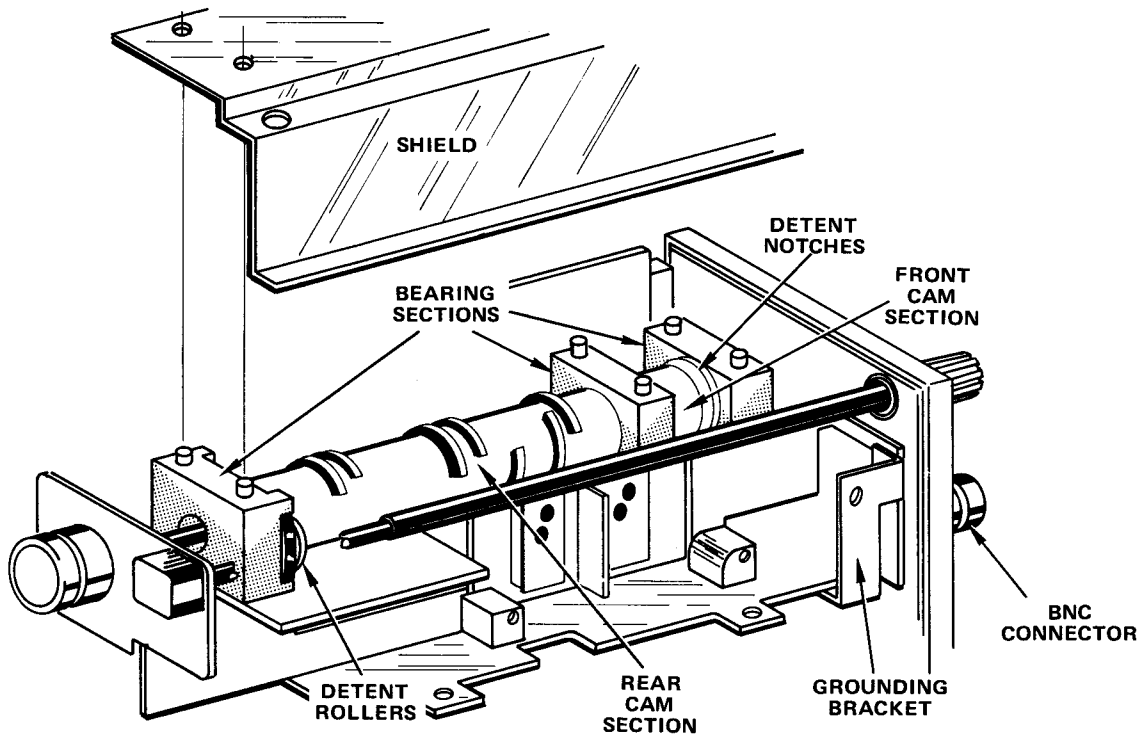
(b) Install each of the two cams in an end bearing section. Set the notched detent end of the cam on the section, then push it into the bearing until it seats (the cam may need to be rotated to get the detent notches past the detent rollers).

NOTE

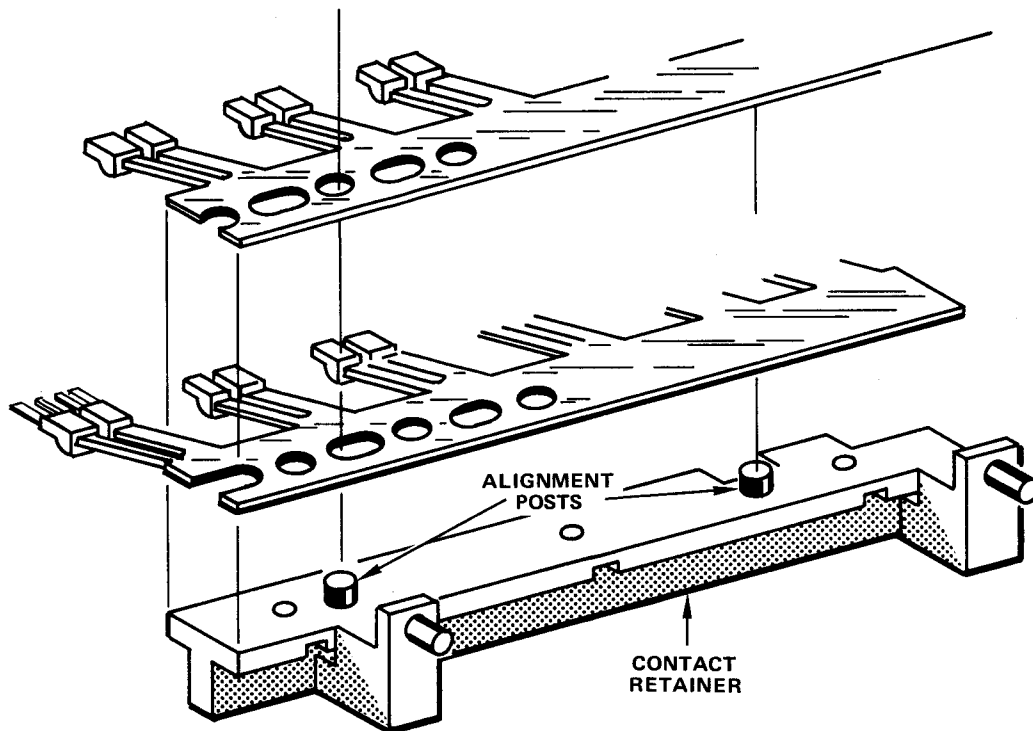
If new cam parts are being installed or the cam has been washed, very lightly lubricate the detent notches and cam ends with silicone grease.

WARNING

Handle silicone grease with care as it can cause skin or eye irritation. Wash hands thoroughly after use.



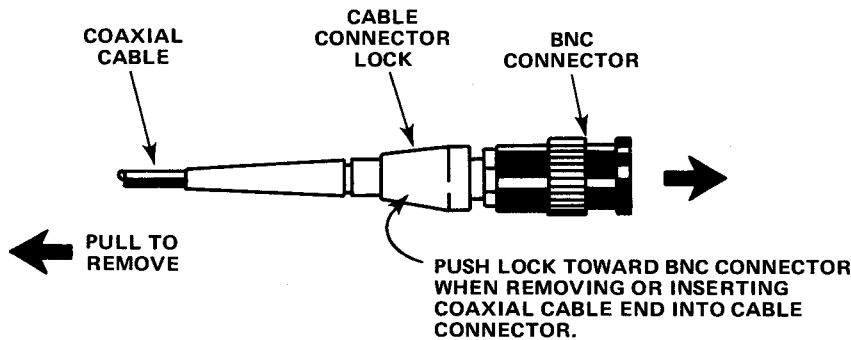
A. ATTENUATOR CAM AND BEARING SECTIONS



B. ATTENUATOR CONTACT ASSEMBLIES

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Figure 5-13. VOLTS/DIV attenuator disassembly.



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Figure 5-14. Probe BNC connector removal and replacement.

(c) Assemble the cam and three bearing sections so the attaching nuts are facing downward. Hold these parts together and set them into the attenuator assembly with the attaching nuts toward the circuit board. Install the three cam bearing section screws.

(d) Return to step (14) above and continue the reassembly in reverse order of disassembly.

s. Probe Disassembly and Repair.

(1) **BNC Connector.** The BNC connector on the P6101 probe is removed and replaced as shown in Figure 5-14.

(2) **Compensation Box.** To remove the compensation box and BNC connector section of the P6104 probe, grasp the retainer cover next to the compensation box with one hand. Then grasp the probe connector adjacent to the retainer cover with the other hand and pull the pieces apart. To reinstall the two parts, just push them together.

(3) **Probe Head.** The probe head on either the P6101 or P6104 probes can be removed by holding the probe head and the cable connector and pulling them apart.

(4) **Probe Cable.** By performing step(3) and either (1) or (2) above, the probe cable can be separated into one piece.

t. Light-Emitting Diode (LED) Replacement (Figure 5-15).

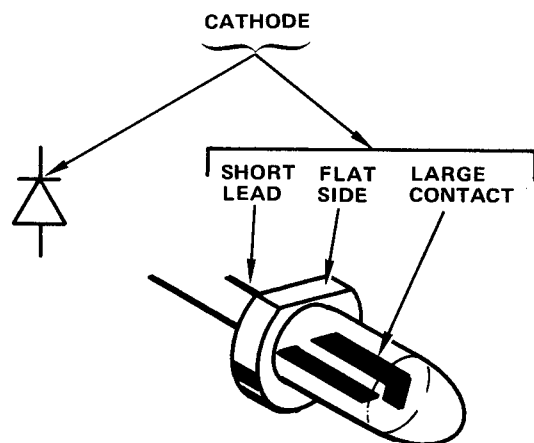
NOTE

When unplugging the LED connectors, note which wire color is connected to the LED cathode. The LED shouldn't be damaged if reverse connected, but it won't light.

(1) Remove the LED from the front panel by pushing it out of the panel from the front.

(2) Unplug the LED connector.

(3) Reinstall the LED in reverse order.



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Figure 5-15. Light-emitting diode (LED) lead identification.

u. Push Button, Shaft Extension, and Shaft Extension Adapter Removal and Replacement.

(1) To remove the small gray buttons on push button switches, hold the switch shaft and pull the button off. To replace them, hold the shaft and push the button on.

(2) To remove a shaft extension or its adapter, very carefully pry the connecting joint apart and pull the extension or adapters away from its connecting part.

5-6. CALIBRATION. The following instructions contain complete adjustment procedures for the instrument. When completed, the instrument should meet its original performance characteristics. The procedures are intended to be done in the sequence listed. Test equipment needed for the procedures is listed in Table 2-1. Whenever one procedural step interacts with another, an Interaction Note is provided.

a. Preliminary Calibration Set-Up Procedure:

(1) Remove the top cabinet.

WARNING

To prevent electrical shock with the cabinet removed, do not touch exposed connections or components when the instrument is turned on, or connected to a power source.

(2) Turn on the instrument and allow at least five minutes warm-up.

NOTE

Instrument must be calibrated in an ambient temperature between +20° and +30°C (+68° to +86°F) to meet performance characteristics.

(3) Preset front panel controls as follows (set both vertical channels and horizontal sweeps the same unless otherwise indicated):

VOLTS/DIV	.5 (1X window)
VAR	Fully clockwise (in detent)
AC-GND-DC	DC
POSITION (Vertical)	Midrange
VERT MODE	CH 1
20 MHz BW	In (off)
INVERT	Out (off)
SCALE ILLUM	Fully counterclockwise

HORIZ DISPLAY
TRIG MODE
COUPLING
SOURCE
SLOPE
A AND B TIME/DIV
VAR
DELAY TIME POS
POSITION (Horizontal)
A TRIGGER HOLDOFF
X10 MAG

A
AUTO
AC
NORM
+ (out)
.5 μ s
Fully clockwise (in detent)
0.0
Midrange
NORM (in detent)
Out (off)

(4) Do not preset ASTIG and TRACE ROTATION. They will be adjusted later.

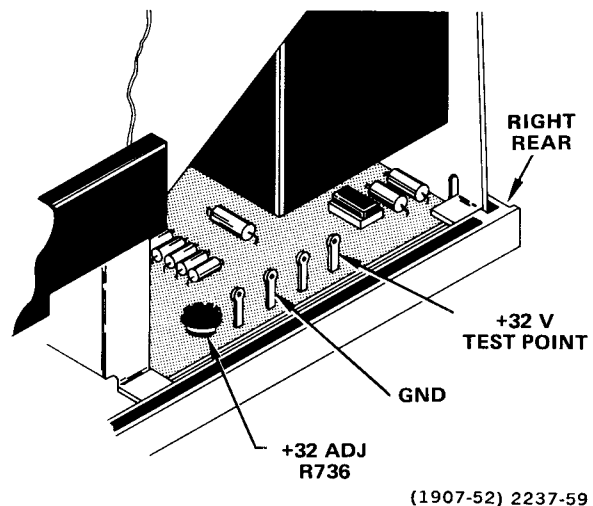
(5) Throughout the procedure INTEN, FOCUS, and LEVEL may be adjusted as necessary to obtain a visible, well defined, and stable display. Occasionally, these controls may be set by a procedural step.

b. +32 Volt Power Supply (Figure 5-16).

(1) Connect a digital voltmeter between +32 Volt test point and GND.

(2) Adjust +32 V ADJ, R736 for a +32.0 voltage reading.

(3) Disconnect the voltmeter.



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Figure 5-16. +32 volt test point and adjustment location.

c. Crt Bias (Figures 5-17 and 5-18).

- (1) Set A AND B TIME/DIV to X-Y.
- (2) Connect a digital voltmeter between TP526 and GND.
- (3) Set INTEN for about +20 volts (within 0.5 volt) voltage reading.
- (4) Disconnect the voltmeter.
- (5) Adjust FOCUS and ASTIG for a well defined spot (if spot is not visible, adjust CRT BIAS, R532 until it is; then adjust FOCUS and ASTIG).
- (6) Adjust CRT BIAS, R532 until the spot is just visible.

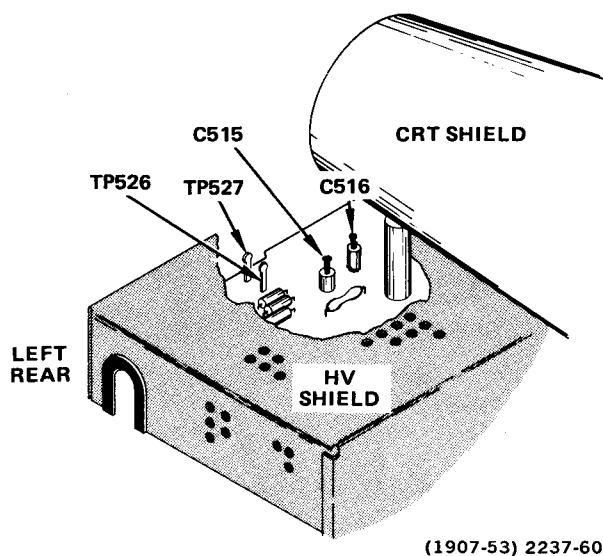
d. Z-Axis Compensation (Figure 5-17).

Figure 5-17. Crt and Z-Axis test point and adjustment locations.

- (1) Set A TIME/DIV to .5 μ s.
- (2) Set INTEN for a low intensity display.
- (3) Connect a test oscilloscope between TP527 and GND with a 10X probe. Set test oscilloscope TIME/DIV for 2 μ s, adjust for a four division, positive going pulse display, and reset test oscilloscope TIME/DIV to 1 μ s.

NOTE

A high voltage oscillator signal will be visible, but should be ignored when making the adjustment in the next step.

- (4) Adjust C515 and C516 for the squarest front corner on the displayed pulse.
- (5) Disconnect the test oscilloscope.

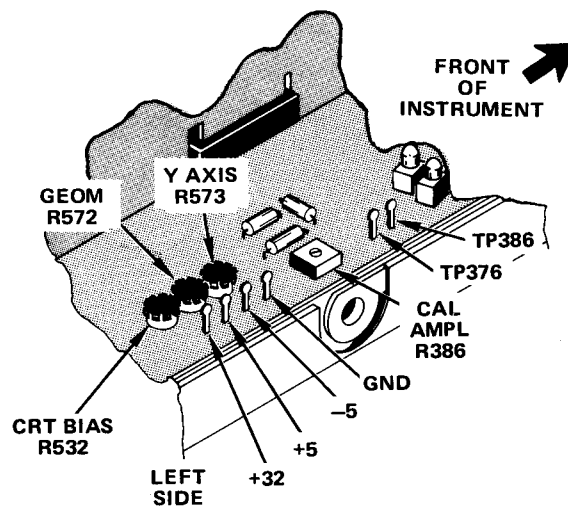
e. Y-Axis Alignment (Figure 5-18).

Figure 5-18. Crt and Calibration test point and adjustment locations.

- (1) Set A AND B TIME/DIV to 1 ms and CH 1 AC-GND-DC to GND.
- (2) Vertically position the display to the center horizontal graticule line.
- (3) Adjust TRACE ROTATION to align the trace with the center horizontal graticule line.
- (4) Set CH 1 AC-GND-DC to DC.
- (5) Connect a time mark generator to CH 1 input through a 50 ohm BNC cable and 50 ohm termination. Set the generator for one millisecond time marks.
- (6) Set CH 1 VOLTS/DIV for a display of greater than 8 divisions. Adjust vertical POSITION to place baseline of display below the bottom graticule line.

(7) Set A AND B TIME/DIV, its associated VAR control, and horizontal POSITION for exactly one time marker per division.

(8) Adjust Y AXIS, R573 to align the center time marker with the center vertical graticule line.

INTERACTION NOTE

This adjustment may affect the TRACE ROTATION adjustment. Position the display baseline to the center horizontal graticule line and recheck display alignment. If TRACE ROTATION needs readjustment, alternate between it and the Y-AXIS adjustment until no further adjustment is needed.

(9) Continue to the next procedure.

f. Geometry (Figure 5-18).

(1) Readjust TIME/DIV VAR and horizontal POSITION for one time marker per division.

(2) Adjust GEOM, R572 for minimum bowing of time markers.

INTERACTION NOTE

This adjustment may affect Y-Axis Alignment and TRACE ROTATION. Repeat Y-Axis Alignment, TRACE ROTATION, and Geometry adjustments for optimum overall alignment.

(3) Reset TIME/DIV VAR fully clockwise in its detent.

(4) Disconnect the time mark generator.

g. Calibrator (Figure 5-18).

(1) Connect a digital voltmeter to the CALIBRATOR output.

(2) Connect a shorting jumper between TP376 and TP386 (a small alligator clip works nicely).

(3) Adjust CAL AMPL, R386 for a 1.00 volt dc reading.

(4) Disconnect the voltmeter.

(5) Remove the shorting jumper from TP376 and TP386.

h. Dc Balance (Figure 5-19).

(1) Set CH 1 and CH 2 VOLTS/DIV to 5 m (1X window) and A AND B TIME/DIV to .2 ms.

(2) Adjust CH 1 vertical POSITION to vertically center the trace.

(3) Adjust R4134 for no trace shift when switching CH 1 VOLTS/DIV between 5 m and 10 m.

(4) Set VERT MODE to CH 2.

(5) Adjust CH 2 vertical POSITION to vertically center the trace.

(6) Adjust R4234 for no trace shift when switching CH 2 VOLTS/DIV between 5 m and 10 m.

i. Vertical Gain (Figure 5-19).

(1) Set CH 1 and CH 2 VOLTS/DIV to 5 m (1X window) and VERT MODE to CH 1.

(2) Connect a calibration generator (select STD OUTPUT) to CH 1 input through an unterminated 50 ohm BNC cable. Set the generator for a 20 millivolt output.

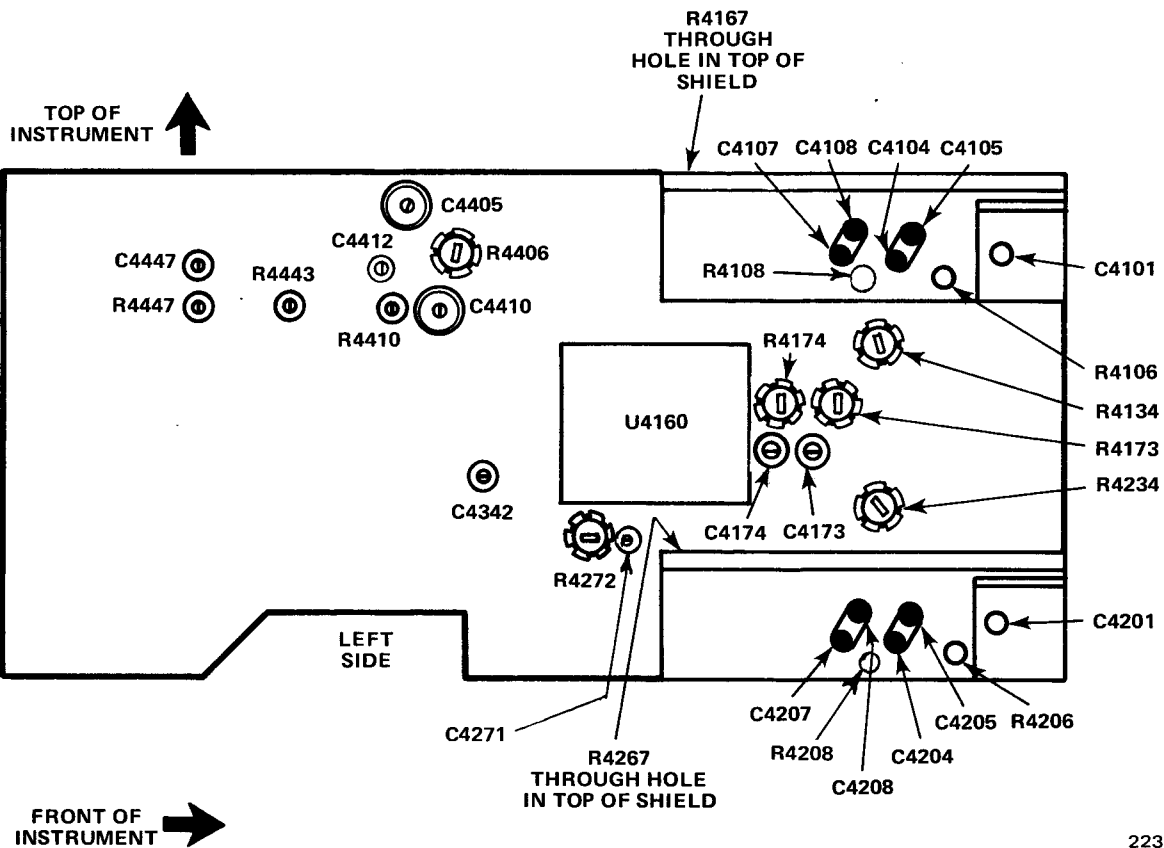
(3) Adjust R4443 for a 4-division display.

(4) Set VERT MODE to CH 2.

(5) Move the calibration generator output from CH 1 input to CH 2 input.

(6) Adjust R4272 for a 4-division display.

(7) Continue to the next procedure.



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Figure 5-19. Vertical adjustment locations.

j. Channel 2 Low Frequency Compensation (Figure 5-19).

(1) Set square wave generator (same as calibration generator, if using PG 506) for a 1 kilohertz, HIGH AMPL OUTPUT.

(2) Disconnect the square wave generator output from CH 2 and reconnect it to CH 2 through a 10X attenuator, 50 ohm termination, and an input RC normalizer. Set the generator for a 5-division display. During adjustment, set the generator output as necessary to maintain a 5-division display.

NOTE

Use a low capacitance tuning tool when making compensation adjustments.

(3) Adjust C4201 for the best flat top waveform.

(4) Set CH 2 VOLTS/DIV to 50 m and reset the generator output level for a 5-division display.

(5) Adjust C4208 for the best flat top, and C4207 for the best front corner on the waveform. Alternately readjust both capacitors for the best overall waveform response.

(6) Set CH 2 VOLTS/DIV to .5, remove the 10X attenuator, and reset the generator output level for a 5-division display.

(7) Adjust C4205 for the best flat top, and C4204 for the best front corner on the waveform. Alternately readjust both capacitors for the best overall waveform response.

(8) Continue to the next procedure.

k. Channel 1 Low Frequency Compensation (Figure 5-19).

(1) Set VERT MODE to CH 1.

(2) Remove the square wave generator output from CH 2 input and reconnect it to CH 1 through a 50 ohm BNC cable, 10X attenuator, 50 ohm termination, and an input RC normalizer.

(3) Set the generator output level for a 5-division display. During adjustments, reset the generator output as necessary to maintain a 5-division display.

NOTE

Use a low capacitance tuning tool when making compensation adjustments.

(4) Adjust C4101 for the best flat top waveform.

(5) Set CH 1 VOLTS/DIV to 50 m and readjust the generator for a 5-division display.

(6) Adjust C4108 for the best flat top, and C4107 for the best front corner on the waveform. Alternately readjust both capacitors for the best overall waveform response.

(7) Set CH 1 VOLTS/DIV to .5, remove the 10X attenuator, and readjust the generator for a 5-division display.

(8) Adjust C4105 for the best flat top, and C4104 for the best front corner on the waveform. Alternately readjust both capacitors for the best overall waveform response.

(9) Continue to the next procedure.

I. High-Frequency Compensation (Figure 5-19).

(1) Move the output of the square wave generator to its positive going, FAST RISE OUTPUT.

(2) Set CH 2 VOLTS/DIV to 5 m and VERT MODE to CH 2.

(3) Disconnect the square wave generator output from the CH 1 input, remove the input RC normalizer, install the 10X attenuator between the BNC cable and termination, and connect the generator output to CH 2. Set the generator output to 1 kilohertz and adjust for a 5-division display. During adjustments, maintain a 5-division display.

(4) Adjust R4406 for the best flat top on the waveform.

(5) Set TIME/DIV to 20 μ s.

(6) Set generator to 10 kilohertz and adjust for a 5-division display.

(7) Adjust C4405 for the best flat top on the waveform.

(8) Set TIME/DIV to .1 μ s.

(9) Set generator for 100 kilohertz and adjust for a 5-division display.

(10) Push in X10 MAG (on).

(11) Adjust CH 2 vertical POSITION so top of waveform is on the center horizontal graticule line.

(12) Adjust C4271, R4410, C4410, C4342, C4412, C4447, and R4447 for the best front corner of the waveform. Total aberrations should not exceed $\pm 3\%$ or 3% peak-to-peak (+0.15 division, -0.15 division, or 0.15 division peak-to-peak).

(13) Set CH 2 VOLTS/DIV to 20 m.

(14) Adjust generator for a 5-division display.

(15) Adjust R4267 for the best front corner of the waveform.

(15.1) Set CH 2 VOLTS/DIV to 50 m.

(15.2) Adjust generator for a 5-division display.

(15.3) Adjust R4208 for the best flat top on the front corner of the waveform.

(16) Set CH 2 VOLTS/DIV to .5.

(17) Remove the 10X attenuator from the generator input to CH 2.

(18) Adjust R4206 for the best front corner of the waveform.

(19) Reinstall the 10X attenuator in the CH 2 input. Set VOLTS/DIV to 5 m and TIME/DIV to 0.5 μ s. Adjust for a 5-division display. Check rise time. If it is greater than 3.5 nanoseconds repeat steps (2) through (18).

(20) Move the generator output from CH 2 input to CH 1 input.

(21) Set CH 1 VOLTS/DIV to 5 m and VERT MODE to CH 1.

(22) Adjust CH 1 vertical POSITION so top of waveform is on the center horizontal graticule line.

(23) Adjust C4173, R4173, C4174, and R4174 for the best transient response of the waveform. Total aberrations should not exceed $\pm 3\%$ or 3% peak-to-peak ($+0.15$ division, -0.15 division, or 0.15 division peak-to-peak).

INTERACTION NOTE

If CH 1 response cannot be adjusted within requirements, very slightly touch up the adjustment in step (12) above. Then recheck the CH 2 response and rise time of both channels.

(24) Set CH 1 VOLTS/DIV to 20 m and TIME/DIV to $.1 \mu\text{s}$.

(25) Adjust R4167 for the best front corner of the waveform.

(25.1) Set CH 1 VOLTS/DIV to 50 m.

(25.2) Adjust generator for a 5-division display.

(25.3) Adjust R4108 for the best flat top on the front corner of the waveform.

(26) Set CH 1 VOLTS/DIV to $.5$.

(27) Remove the 10X attenuator from the CH 1 input.

(28) Adjust R4106 for the best front corner of the waveform.

(29) Disconnect the generator.

m. Trigger Hysteresis and Slope Centering (Figure 5-20).

(1) Set controls as follows:

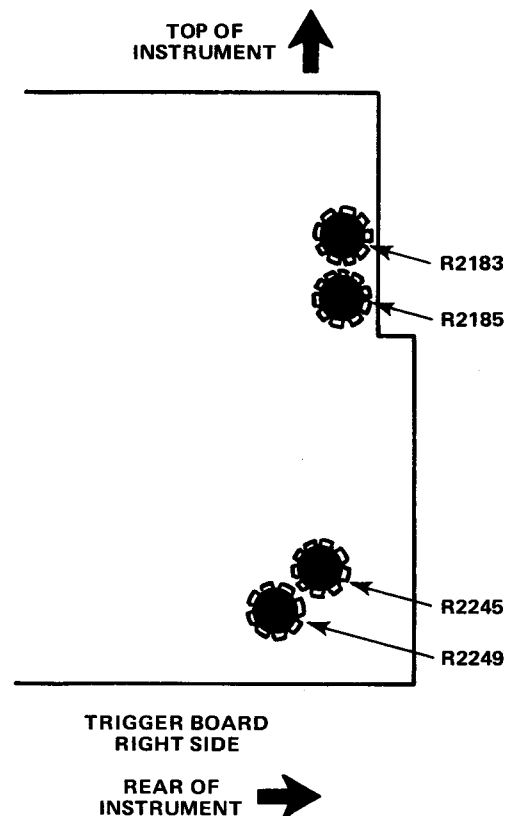
VOLTS/DIV	5 m
A AND B TIME/DIV	$5 \mu\text{s}$
X10 MAG	Out (off)
VERT MODE	CH 2
A LEVEL	0
A SOURCE	CH 2

(2) Connect a sine wave generator to CH 1 and CH 2 through a 50 ohm BNC cable, 50 ohm termination, and dual input coupler. Set the output for 50 kilohertz and adjust for a 4-division display.

(3) Set R2245 at midrange.

(4) Adjust R2249 so trace starts at the same point when switching A SLOPE between $-$ (in) and $+$ (out).

(5) Set CH 2 VOLTS/DIV to $.1$, A AND B TIME/DIV to $50 \mu\text{s}$, and A SLOPE to $+$ (out).



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Figure 5-20. Trigger hysteresis and slope centering adjustment locations.

NOTE

When making the next adjustment, set CH 2 VOLTS/DIV to .1 for a 0.2 division signal and .2 for a 0.1 division signal.

(6) Adjust R2245 and A LEVEL so a stable display is obtained with a 0.2-division display, but not with a 0.1-division display.

NOTE

If R2245 is set too sensitive, double triggering may occur at low frequencies. To desensitize R2245, adjust A LEVEL until the display just double triggers. Then slightly readjust R2245 until the double triggering disappears.

(7) Set CH 2 VOLTS/DIV to 5 m and A AND B TIME/DIV to 5 μ s.

(8) Repeat step (4) above.

(9) Set CH 2 VOLTS/DIV to 20 m and adjust A LEVEL for a stable display.

(10) Set controls as follows:

VERT MODE	CH 1
HORIZ MODE	B DLY'D
B SOURCE	CH 1
B LEVEL	0
A AND B TIME/DIV	5 μ s

(11) Set R2185 to midrange.

(12) Adjust R2183 so trace starts at the same point when switching B SLOPE between — (in) and + (out).

(13) Set CH 1 VOLTS/DIV to .1, A AND B TIME/DIV to 50 μ s, and B SLOPE to + (out).

NOTE

When making the next adjustment, set CH 1 VOLTS/DIV to .1 for a 0.2-division display and .2 for a 0.1-division display.

(14) Adjust R2185 and B LEVEL so a stable display is obtained with a 0.2-division display, but not with a 0.1-division display.

NOTE

If R2185 is set too sensitive, double triggering may occur at low frequencies. To desensitize R2185, adjust B LEVEL until the display just double triggers, then slightly readjust R2185 until the double triggering disappears.

(15) Set CH 1 VOLTS/DIV to 5 m and A AND B TIME/DIV to 5 μ s.

(16) Repeat step (12) above.

(17) Disconnect the generator.

n. External Trigger Centering (Figures 5-21 and 5-22).

(1) Set controls as follows:

CH 2 VOLTS/DIV	5 m
VERT MODE	CH 2
HORIZ DISPLAY	A
A AND B TIME/DIV	5 μ s
A SOURCE	EXT
B SOURCE	EXT

(2) Set A COUPLING to AC.

(3) Adjust A LEVEL for a stable display.

(4) Set A COUPLING to DC.

(5) Adjust A TRIGGER LEVEL CENTERING, R2715 for a stable display.

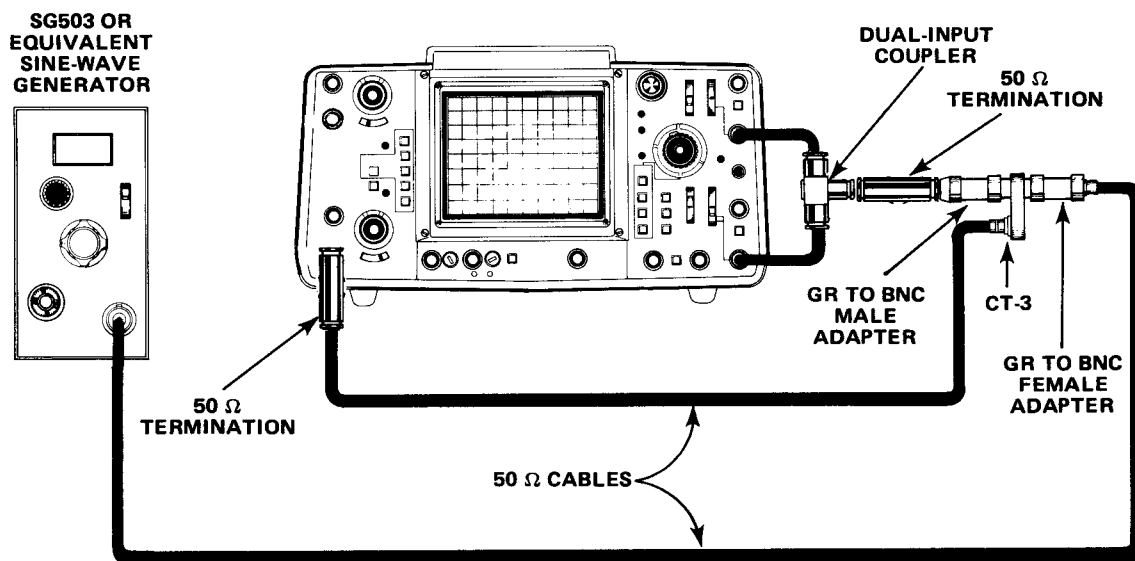
INTERACTION NOTE

A LEVEL and R2715 may interact with each other; therefore, repeat steps (2) through (5) until no further adjustment of R2715 is needed.

(6) Set HORIZ DISPLAY to B DLY'D

(7) Set B COUPLING to AC.

(8) Adjust B LEVEL for a stable display.



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Figure 5-21. External trigger centering setup.

(9) Set B COUPLING to DC.

(4) Adjust R2782 so the second time marker is intensified.

(10) Adjust B TRIGGER LEVEL CENTERING, R2615 for a stable display.

(5) Set DELAY TIME POS to 9.00.

INTERACTION NOTE

B LEVEL and R2615 may interact with each other; therefore, repeat steps (2) through (5) until no further adjustment of R2615 is needed.

(6) Adjust R2748 so the tenth time marker is intensified.

INTERACTION NOTE

R2782 and R2748 may interact with each other; therefore, repeat steps (3) through (6) until no further adjustment is needed.

(11) Disconnect the sine wave generator.

o. Sweep Start-Stop (Figure 5-23).

(1) Set controls as follows:

VERT MODE	CH 1
CH 1 VOLTS/DIV	.5
A TIME/DIV	1 ms
B TIME/DIV	5 μ s
HORIZ DISPLAY	A INTEN
A SOURCE	NORM
B SOURCE	STARTS AFTER
	DELAY
COUPLING	AC

(2) Connect a time mark generator to the CH 1 input through a 50 ohm BNC cable and 50 ohm termination. Set the generator for 1 millisecond time markers.

(3) Set DELAY TIME POS to 1.00.

(7) Set HORIZ DISPLAY to B DLY'D and horizontally position the start of sweep within the graticule area.

(8) Set DELAY TIME POS to 1.00.

(9) Very slightly adjust R2782 until the time marker starts at the beginning of the sweep.

(10) Set DELAY TIME POS to 9.00.

(11) Very slightly adjust R2748 until the time marker starts at the beginning of the sweep.

INTERACTION NOTE

R2782 and R2748 may interact with each other; therefore, repeat steps (8) through (11) until no further adjustment is needed.

(12) Set DELAY TIME POS to 0.0.

(13) Continue to the next procedure.

p. Horizontal Gain (Figure 5-22).

(1) Set HORIZ DISPLAY to A.

(2) Adjust X1 GAIN, R2923 until the 1st and 11th time markers are exactly aligned with a graticule line. There should be one time marker per division within 0.25 minor divisions.

(3) Set X10 Mag to In (on).

(4) Set time mark generator for .1 ms time markers.

(5) Adjust X10 GAIN, R2925 for one time marker per division.

(6) Continue to the next procedure.

q. Magnifier Registration (Figure 5-22).

(1) Set X10 MAG to In (on).

(2) Adjust horizontal POSITION until the sweep starts at the center vertical graticule line.

(3) Set X10 MAG to Out (off).

(4) Adjust MAG REG, R2932 until the sweep starts at the center vertical graticule line.

INTERACTION NOTE

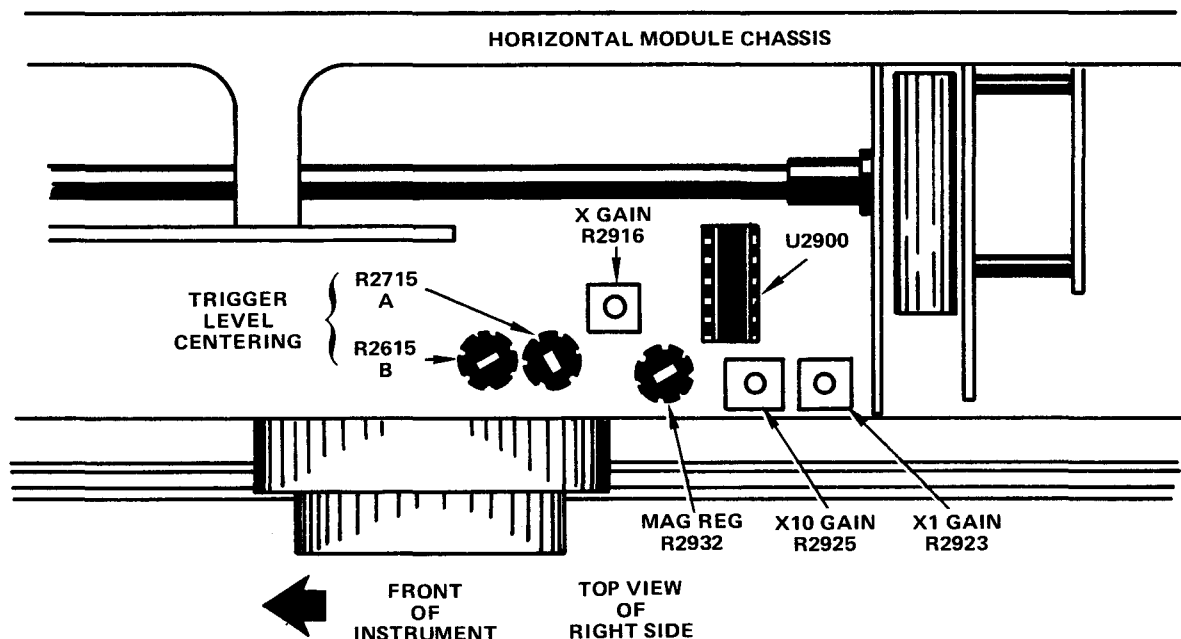
R2932 and horizontal POSITION may interact; therefore, repeat steps (1) through (4) until no further adjustment of R2932 is needed.

(5) Continue to the next procedure.

r. B Sweep Timing (Figure 5-23).

(1) Set controls as follows:

X10 MAG	Out (off)
A AND B TIME/DIV	1 ms
HORIZ DISPLAY	B DLY'D



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Figure 5-22. Trigger and horizontal adjustment locations.

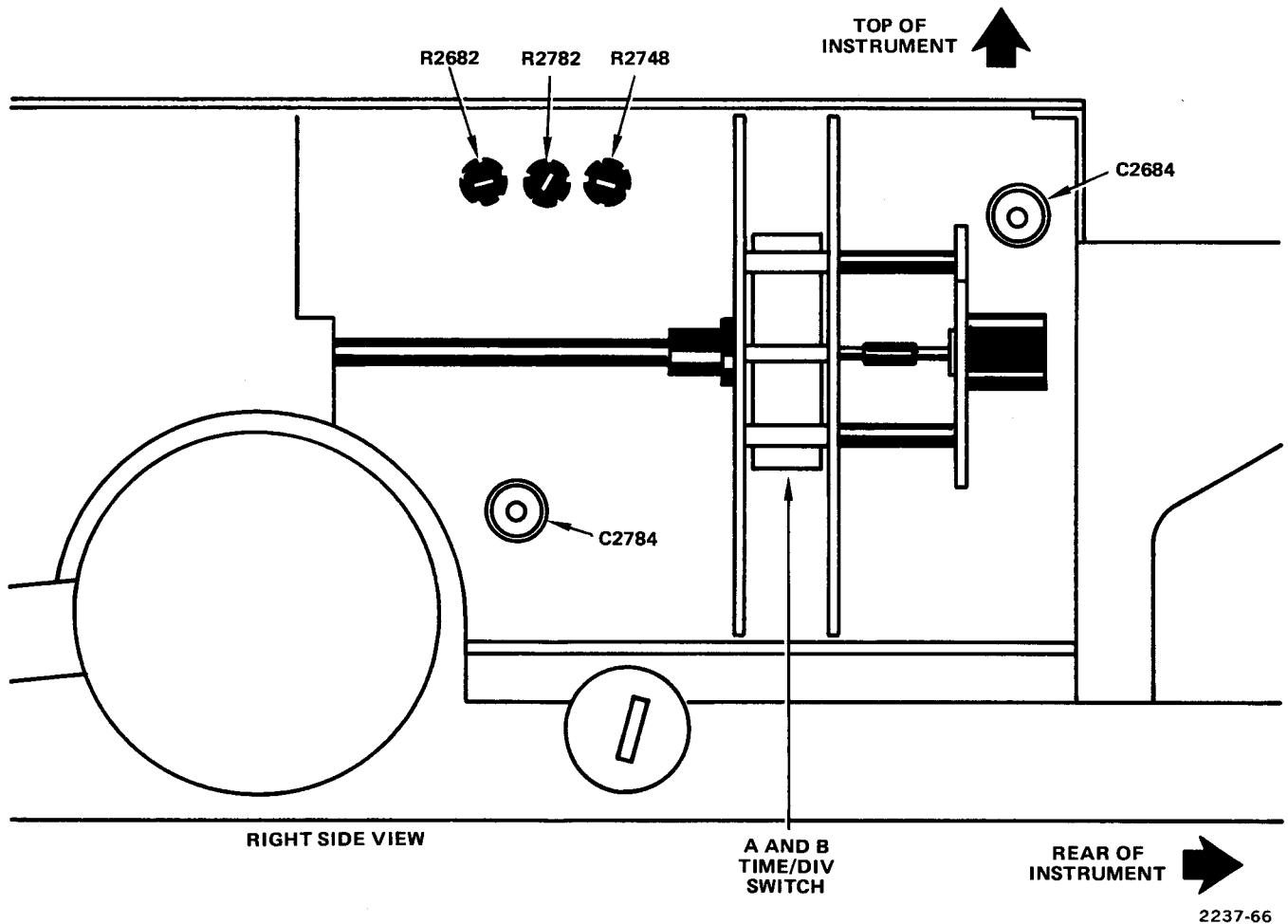


Figure 5-23. Sweep adjustment locations.

(2) Set time mark generator for one millisecond time markers.

(3) Set horizontal POSITION to align the first time marker with the left graticule line.

(4) Adjust R2782 for one time marker per division.

(5) Continue to the next procedure.

s. .5 μ s Timing (Figure 5-23).

(1) Set A TIME/DIV to .5 μ s and HORIZ DISPLAY to A.

(2) Set time mark generator for 0.5 microsecond time markers.

(3) Adjust C2784 for one time marker per division.

(4) Set HORIZ DISPLAY to B DLY'D.

(5) Set DELAY TIME POS to 1.00, then rotate it toward 0.0 until there is one time marker per division and a time marker is aligned with the left vertical graticule line.

(6) Adjust C2684 for one time marker per division.

(7) Set B TIME/DIV to .05 μ s and DELAY TIME POS to 1.00.

(8) Adjust horizontal POSITION and align the time marker with the center vertical graticule line.

(9) Set DELAY TIME POS to 9.00.

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(10) Very slightly adjust C2784 so the time marker aligns with the center vertical graticule line.

INTERACTION NOTE

C2784 and C2684 may interact; therefore, repeat this procedure until no further adjustment is needed.

(11) Set DELAY TIME POS to 0.0.

(12) Continue to the next procedure.

t. 5 ns Timing (Figure 5-24).

(1) Set controls as follows:

HORIZ DISPLAY	A
A AND B TIME/DIV	.05 μ s
X10 MAG	In (on)

(2) Set time mark generator for 10 nanosecond time markers.

(3) Adjust C232 and C272 for one time marker per two divisions.

INTERACTION NOTE

The adjustment screws for C232 and C272 should be adjusted to about the same height; otherwise horizontal linearity may be degraded.

(4) Check the beginning and end of the .05 microsecond sweep using step 19 in Table 5-1 and excluding the first and last 40 nanoseconds of the sweep. If necessary, slightly readjust C232 and C272 for one time marker per two divisions.

(5) Disconnect the generator.

u. X Gain (Figure 5-22).

(1) Set controls as follows:

CH 1 VOLTS/DIV	5 m
VERT MODE	CH 2
A AND B TIME/DIV	X-Y
X10 MAG	Out (off)

(2) Connect a calibration generator STD AMPL OUTPUT to the CH 1 input through a 50 ohm BNC cable. Set the generator for a 50 millivolt output.

(3) Adjust X GAIN, R2916 for a 10-division (horizontal) display.

(4) Disconnect the generator.

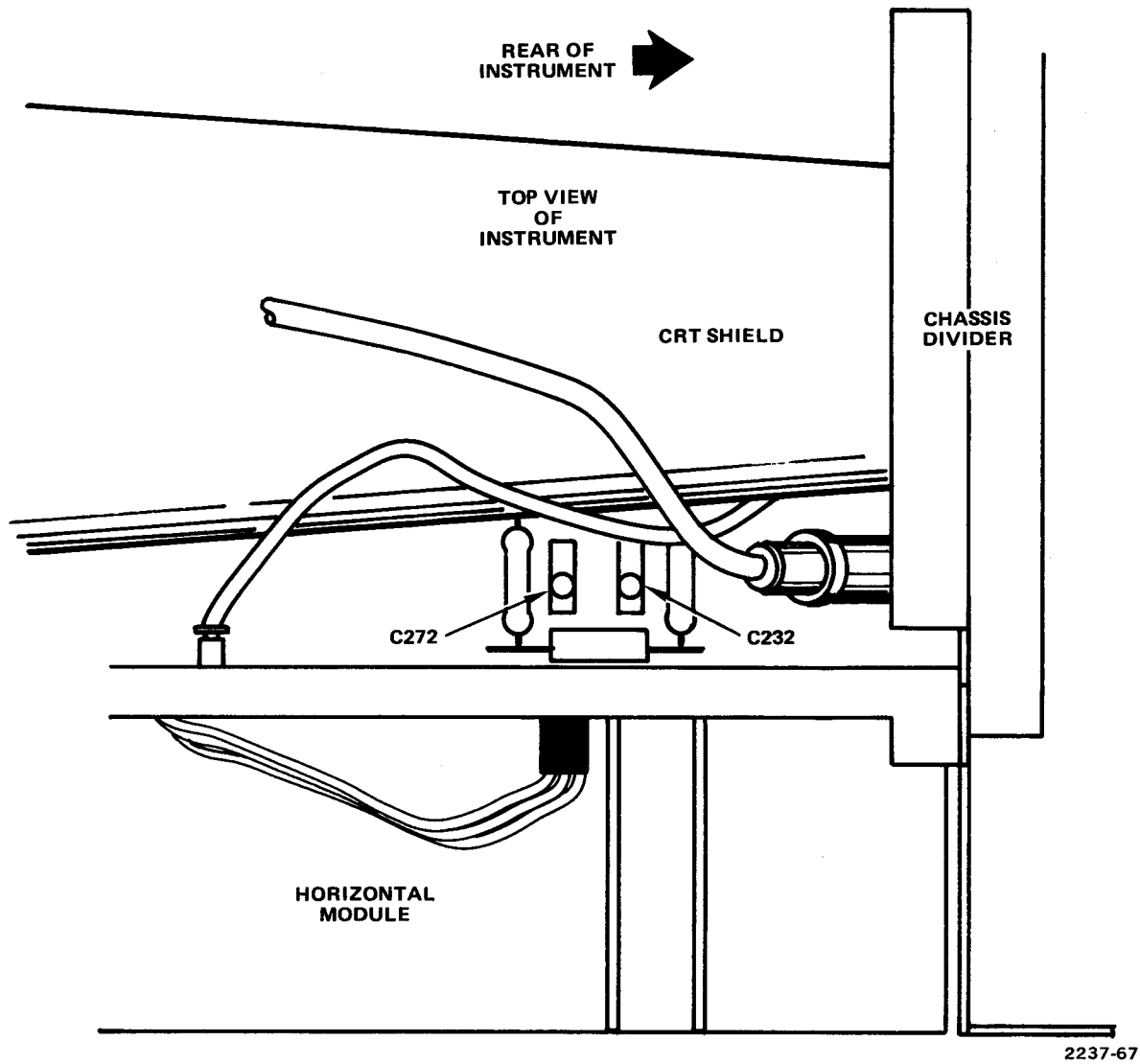


Figure 5-24. 5 nanosecond timing adjustment locations.

SECTION VI DIAGRAMS

6-1. INTRODUCTION. This section contains diagrams and associated data for maintaining the instrument. Included are front and rear panel control, connector, and indicator layouts; schematic diagrams with voltages and waveforms, and circuit board layouts with grid chart component locators.

6-2. ARRANGEMENT.

a. Schematic Diagrams. Schematic diagrams are drawn to group circuit functions; therefore, any one diagram may include portions of any number of circuit boards or assemblies. To aid in tracing circuits from one diagram to another, each diagram is identified with a name and a number in a diamond shaped box. Circuits going from one diagram to another identify the destination component and destination diagram number.

b. Symbols and Reference Designators.

(1) Electrical components shown on the diagrams are in the following units unless noted otherwise.

Capacitors	Values one or greater are in picofarads (pF). Values less than one are in microfarads (μ F).
Resistors	Ohms (Ω).

(2) Table 6-1 is a partial listing of prefix letters used as reference designators. These are used to identify components or assemblies on the diagrams. A complete listing is contained in MIL STD 16 and also in the ANSI standard.

Table 6-1. Reference Designators

REFERENCE DESIGNATOR	DESCRIPTION	REFERENCE DESIGNATOR	DESCRIPTION
A	Assembly, separable or repairable (circuit board, etc.)	LR	Inductor/resistor combination
AT	Attenuator, fixed or variable	M	Meter
B	Motor	P	Connector, movable portion
BT	Battery	Q	Transistor or silicone-controlled rectifier
C	Capacitor, fixed or variable	R	Resistor, fixed or variable
CB	Circuit breaker	RT	Thermistor
CR	Diode, signal or rectifier	S	Switch or contactor
DL	Delay line	T	Transformer
DS	indicating device (lamp)	TC	Thermocouple
E	Spark Gap, Ferrite bead	TP	Test point
F	Fuse	U	Assembly, inseparable or nonrepairable (integrated circuit, etc.)
FL	Filter	V	Electron tube
H	Heat dissipating device (heat sink, heat radiator, etc.)	VR	Voltage regulator (zener diode, etc.)
HR	Heater	W	Wirestrap or cable
HY	Hybrid circuit	Y	Crystal
J	Connector, stationary portion	Z	Phase shifter
K	Relay		
L	Inductor, fixed or variable		

(3) An explanation of the symbols used on the diagrams is shown in Figure 6-1.

6-3. WAVEFORMS AND VOLTAGE TEST CONDITIONS.

a. Waveform Conditions. The following test setup is used for all waveforms, except as noted. This uniform setup simplifies troubleshooting. The test oscilloscope trigger setup allows time comparison (horizontally) between the waveforms. Use an AN/USM-425(V)1, Tektronix 465M, or equivalent for waveforms.

(1) Instrument Setup.

(a) Connect a P6104 Probe (10X) to CH 1 input and the probe tip to the CALIBRATOR.

(b) Set the instrument controls as follows:

VOLTS/DIV (both)	.2
AC-GND-DC (both)	DC
VERT MODE	CH 1
HORIZ DISPLAY	MIXED
SOURCE (both)	CH 1
SLOPE (both)	OUT: +
A TIME/DIV	.2 ms
B TIME/DIV	50 μ s
LEVEL (both)	For a stable mixed display

(2) Test Oscilloscope Setup.

(a) Connect a 50 ohm unterminated BNC cable between the A EXT Trigger input of the test oscilloscope and the +A GATE of the oscilloscope under test.

(b) Set the test oscilloscope controls as follows:

A Coupling	Dc
A Slope	Out: +
A Source	Ext \div 10
Vert Mode	CH 1
CH1 ac-gnd-dc	Dc
A Level	Adjust so Trig Ready indicator is lit. Push Trig View to verify triggering on the positive slope.

b. Voltage Conditions. The voltages were taken between the indicated test point and chassis ground using a Tektronix DM 501A digital multimeter. Any change from the following setup may change some of the indicated voltages. Set controls as follows (where controls are duplicated, set both controls the same):

VOLTS/DIV	5 m
AC-GND-DC	GND
POSITION (Vertical)	Midrange
VERT MODE	CH 2
DELAY TIME POS	5.00
HORIZ DISPLAY	A
TIME/DIV	1 ms
POSITION (Horizontal)	Midrange
INTEN	Fully counterclockwise
FOCUS	Fully counterclockwise
SCALE ILLUM	Midrange
TRIG MODE	NORM
COUPLING	AC
SOURCE	CH 1
SLOPE	+
LEVEL	Midrange

NOTE

These settings place the instrument in a quiescent operating state for making dc voltage measurements.

DIAGRAMS AND CIRCUIT BOARD ILLUSTRATIONS

Symbols and Reference Designators

Electrical components shown on the diagrams are in the following units unless noted otherwise:

- Capacitors = Values one or greater are in picofarads (pF).
Values less than one are in microfarads (μ F).
Resistors = Ohms (Ω).

Graphic symbols and class designation letters are based on ANSI Standard Y32.2-1975.

Logic symbology is based on ANSI Y32.14-1973 in terms of positive logic. Logic symbols depict the logic function performed and may differ from the manufacturer's data.

The overline on a signal name indicates that the signal performs its intended function when it goes to the low state.

Abbreviations are based on ANSI Y1.1-1972.

Other ANSI standards that are used in the preparation of diagrams by Tektronix, Inc. are:

- | | |
|--------------|--|
| Y14.15, 1966 | Drafting Practices. |
| Y14.2, 1973 | Line Conventions and Lettering. |
| Y10.5, 1968 | Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering. |

The following special symbols may appear on the diagrams:

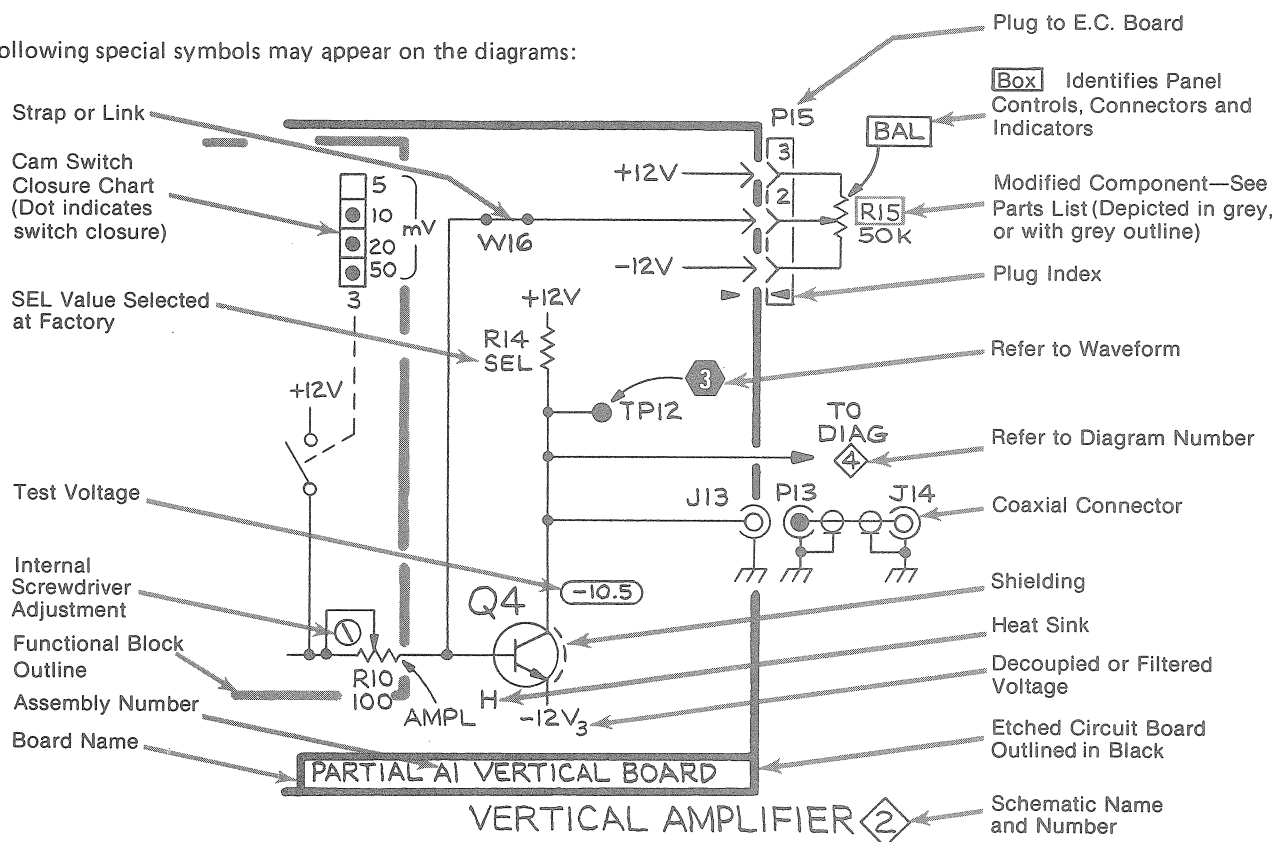
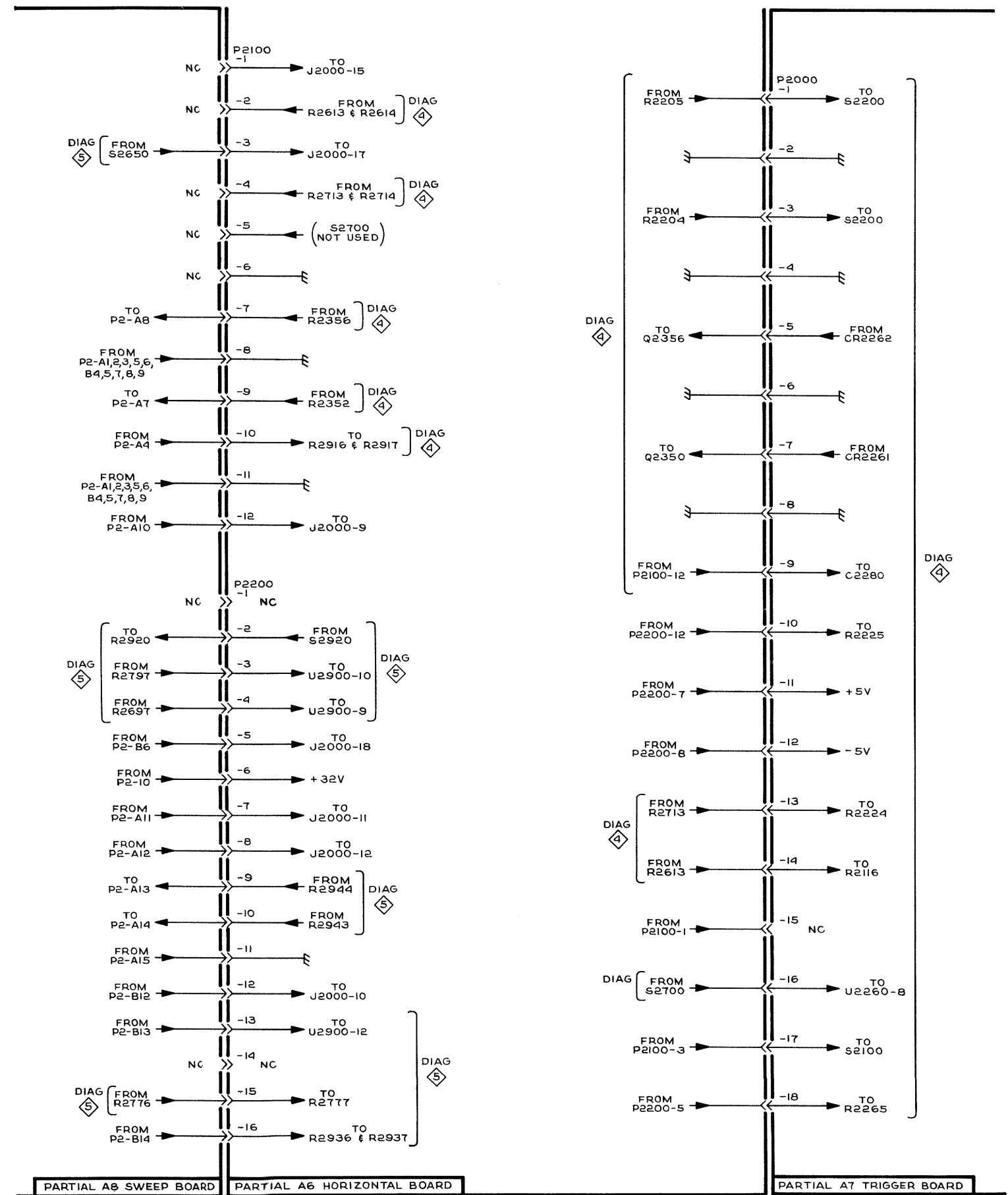
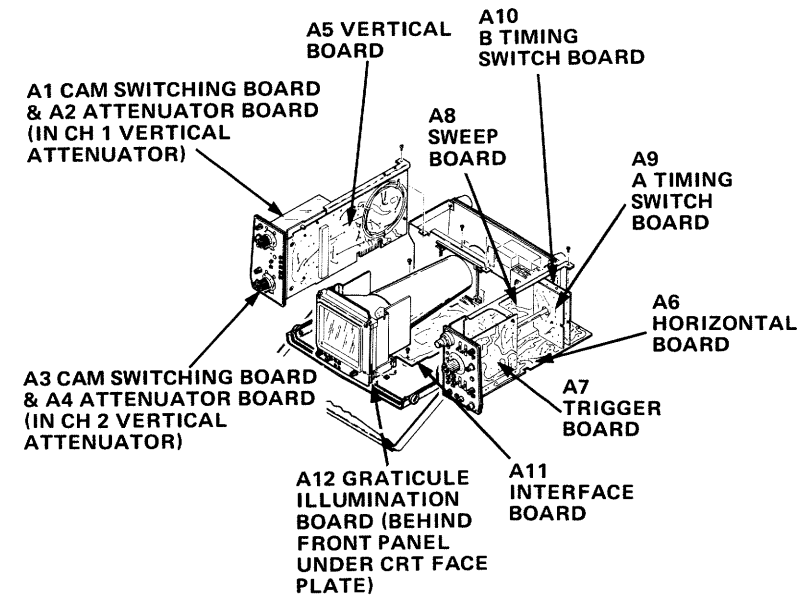


Figure 6-1. Schematic symbols.



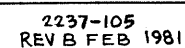




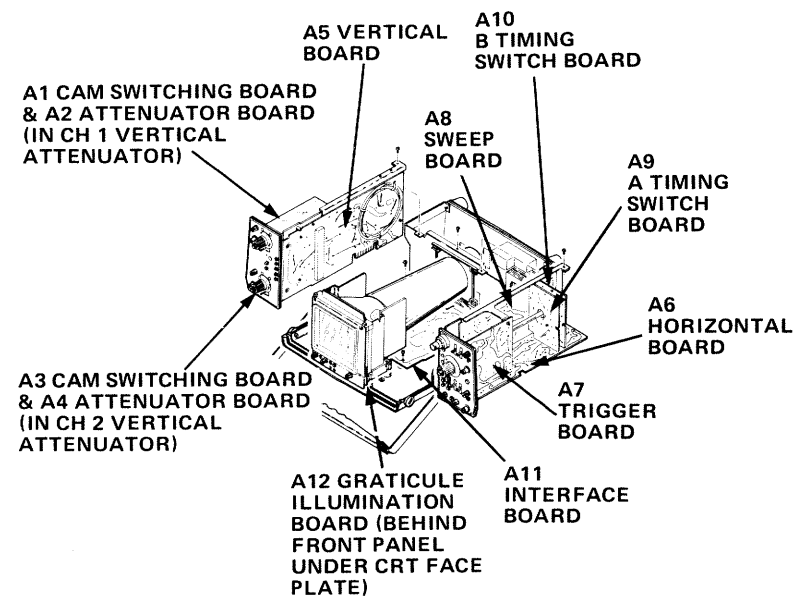
58



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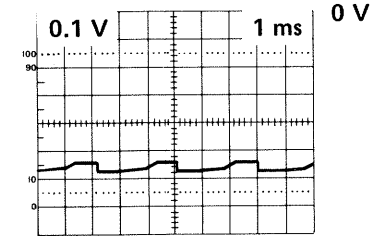


FO-10 (Front)
(FO-10 Rear Blank)

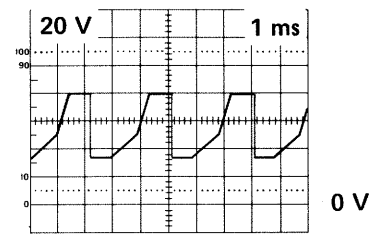


Refer to Waveform and Voltage Test Conditions.

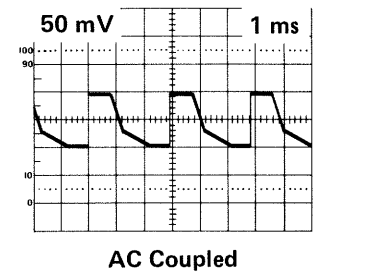
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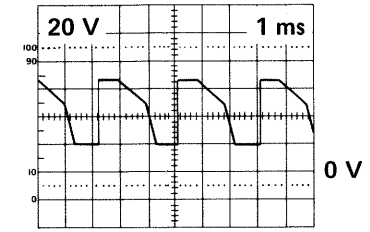
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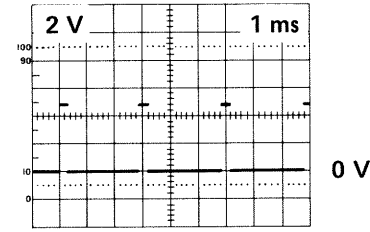
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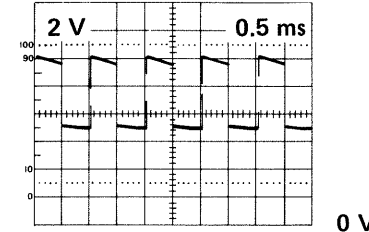
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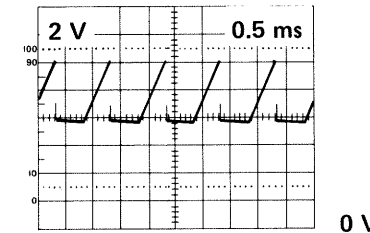
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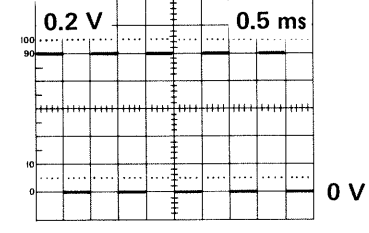
51



52



53



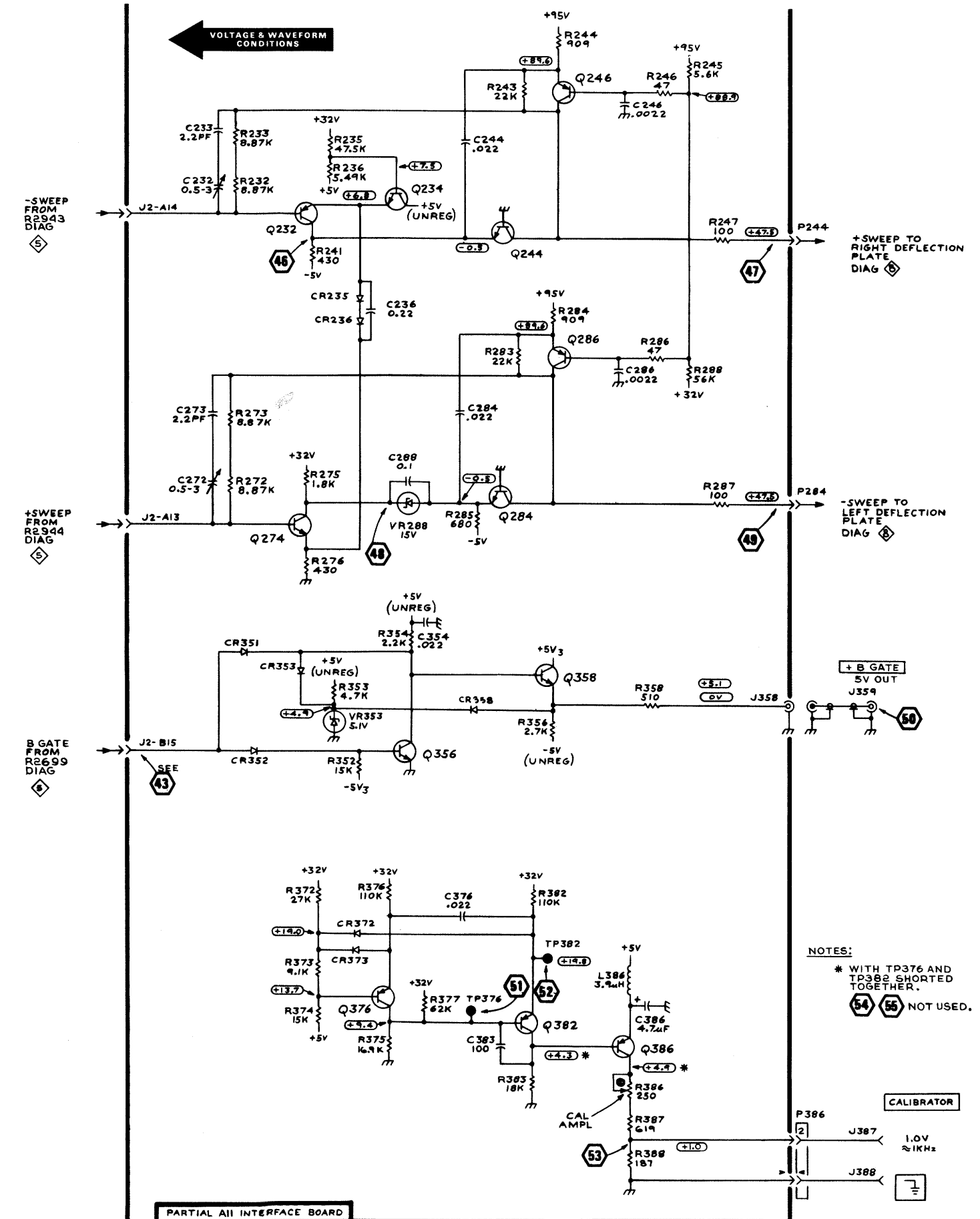
2237-119

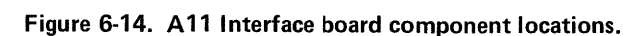
465M

2137-104
REV B FEB 1981

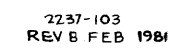
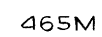
HORIZONTAL AMPLIFIER, +B GATE & CALIBRATOR

FO-9 (Front)
FO-9 Rear Blank





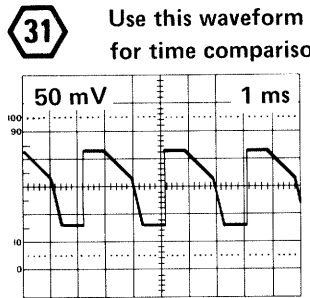
***See Parts List for serial number ranges.**



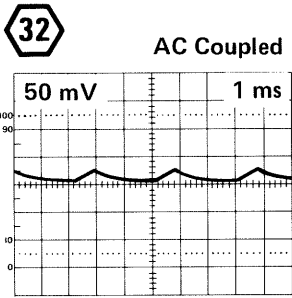
A & B TIMING SWITCH & INTERFACE CONNECTOR

FO-8 (Front)
(FO-8 Rear Blank)

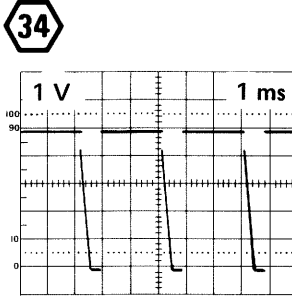
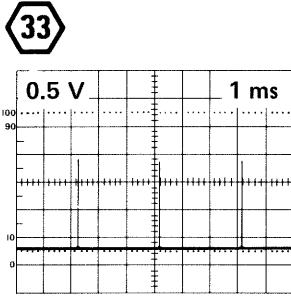
Refer to Waveform and Voltage Test Conditions.



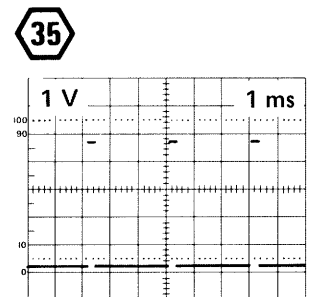
AC Coupled



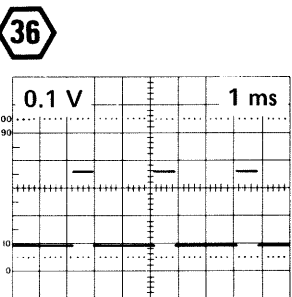
Amplitude of waveform increases as time between end of holdoff and triggering increases.



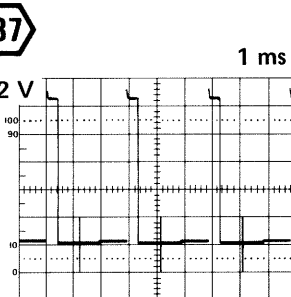
0 V



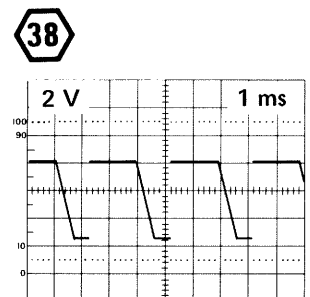
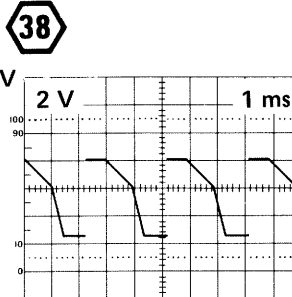
Instrument HORIZ MODE set to A or A INTEN. In B DLY'D or MIX, TP2797 is at -5 V dc.



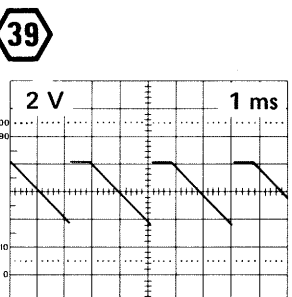
Slight positive step at -0.6 V only present in MIX. Positive spike at -0.6 V is higher in A INTEN and B DLY'D modes.



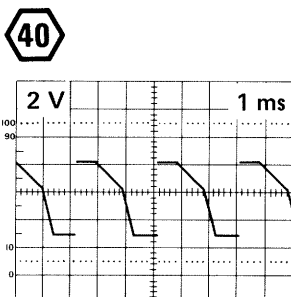
Position of transition between A and B sweep rates dependent on setting of instrument DELAY TIME POS control.



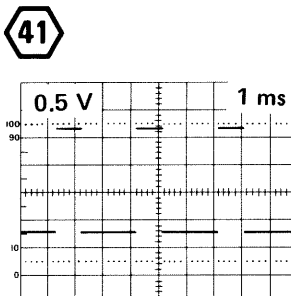
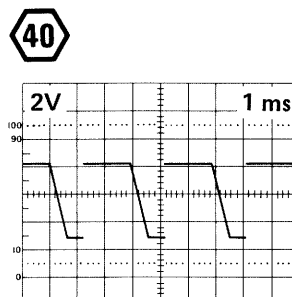
Instrument HORIZ MODE to B
DLY'D. Beginning of sweep ramp
dependent on setting of instrument
DLEAY TIME POS control.



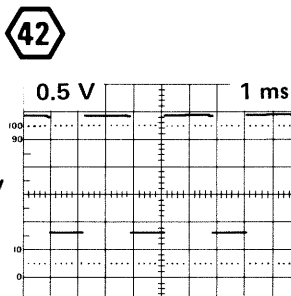
Instrument HORIZ MODE set to
B DLY'D.



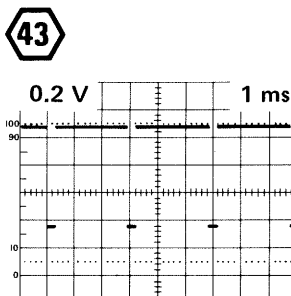
With instrument HORIZ MODE set to A or A INTEN, TP2697 goes to -5 V dc.



LO when

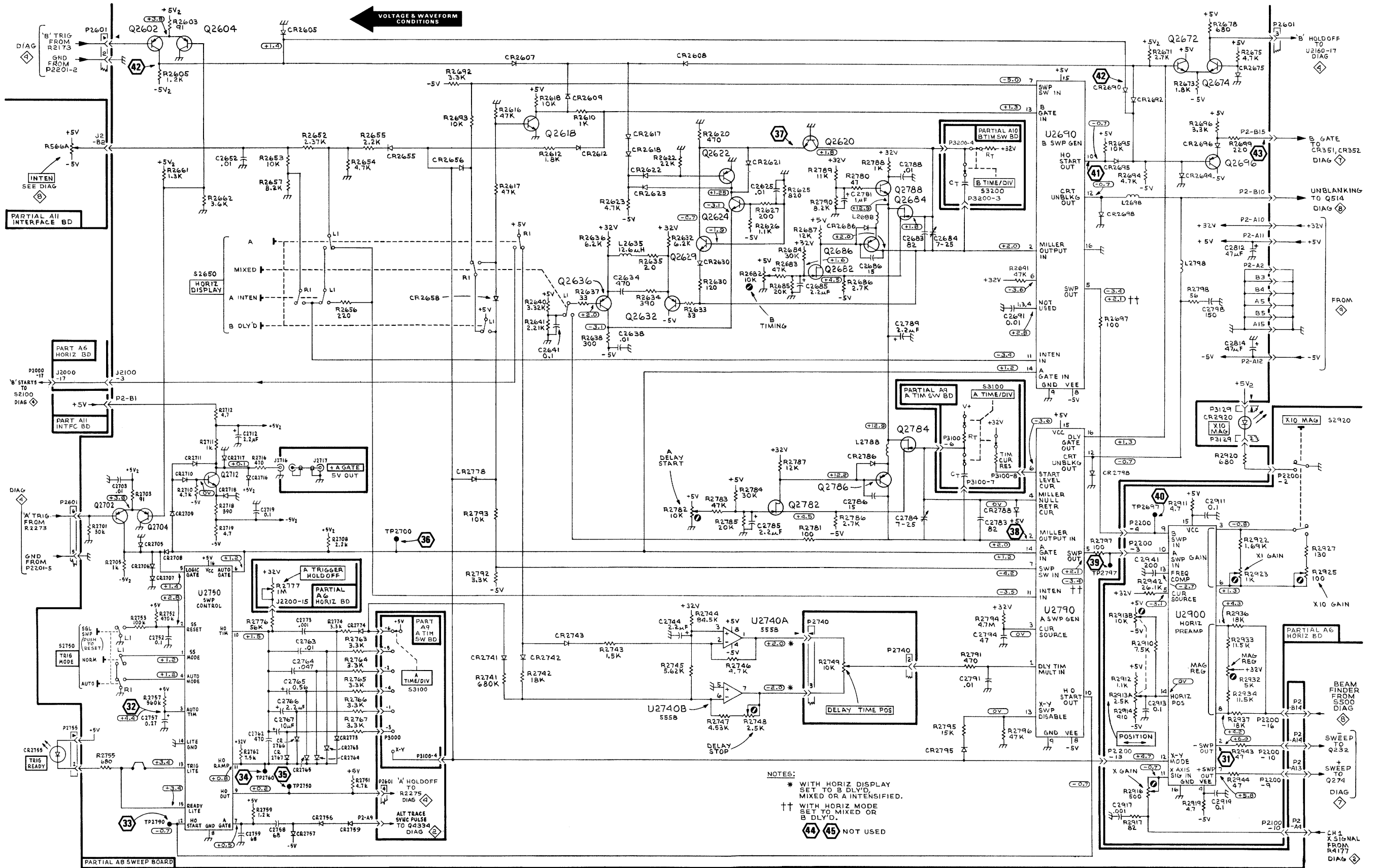


42 are both LO



0 V

2237-118



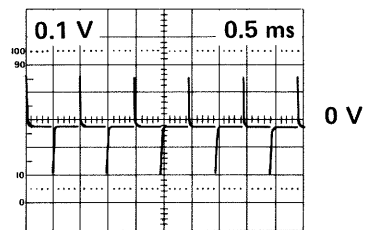
465M

2237-102
REYB FEB 1981

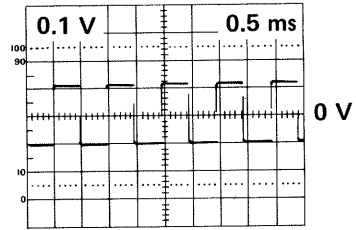
SWEEP & HORIZONTAL PREAMPLIFIER 5

FO-7 (Front)
(FO-7 Rear Blank)

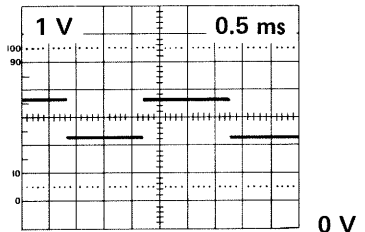
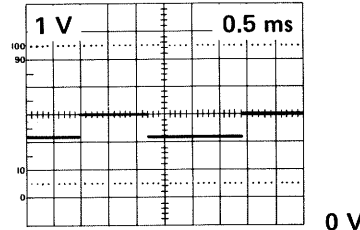
Refer to Waveform and Voltage Test Conditions.



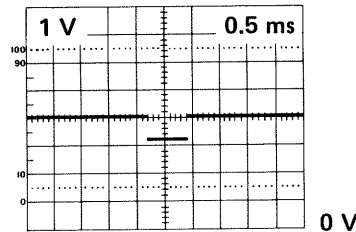
0 volt point depends on setting of instrument vertical POSITION control.



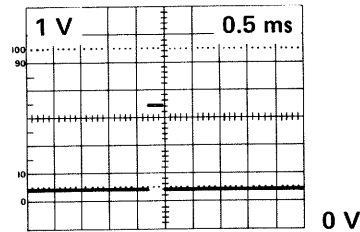
0 volt reference depends on setting of instrument LEVEL control.
No signal with instrument coupling to LF REJ.



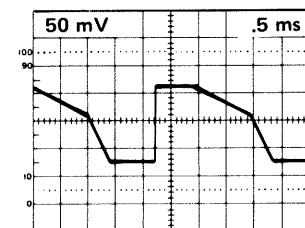
0 V



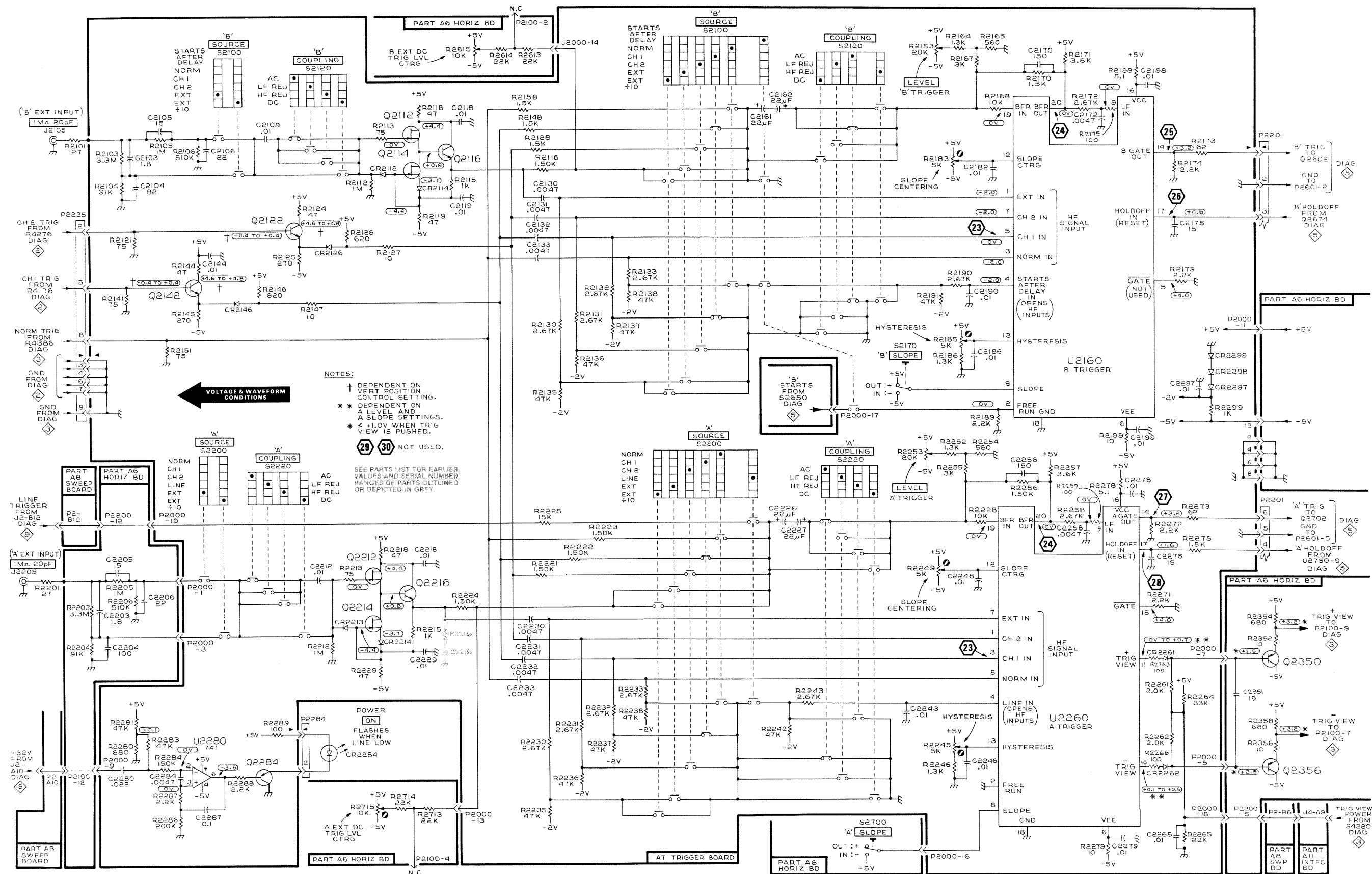
0 V



0 V



Sweep ramp from pin 2 of U2900 for time comparison.



2237-117

465 M

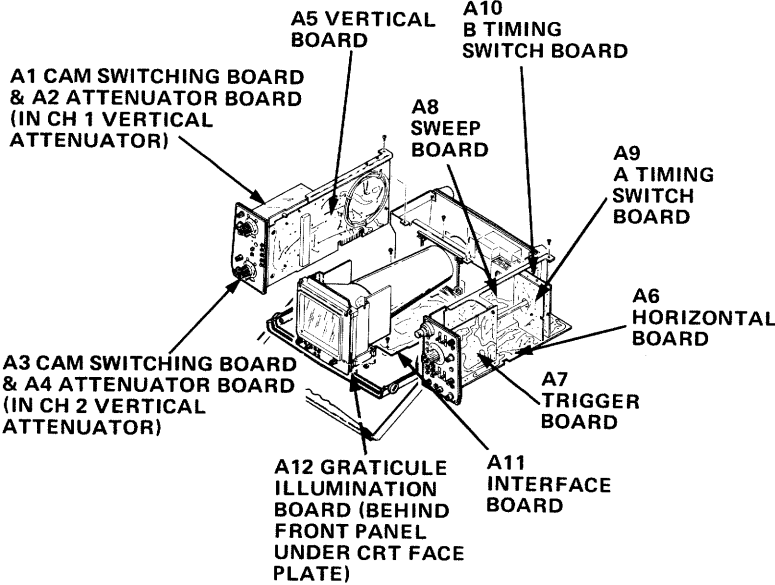
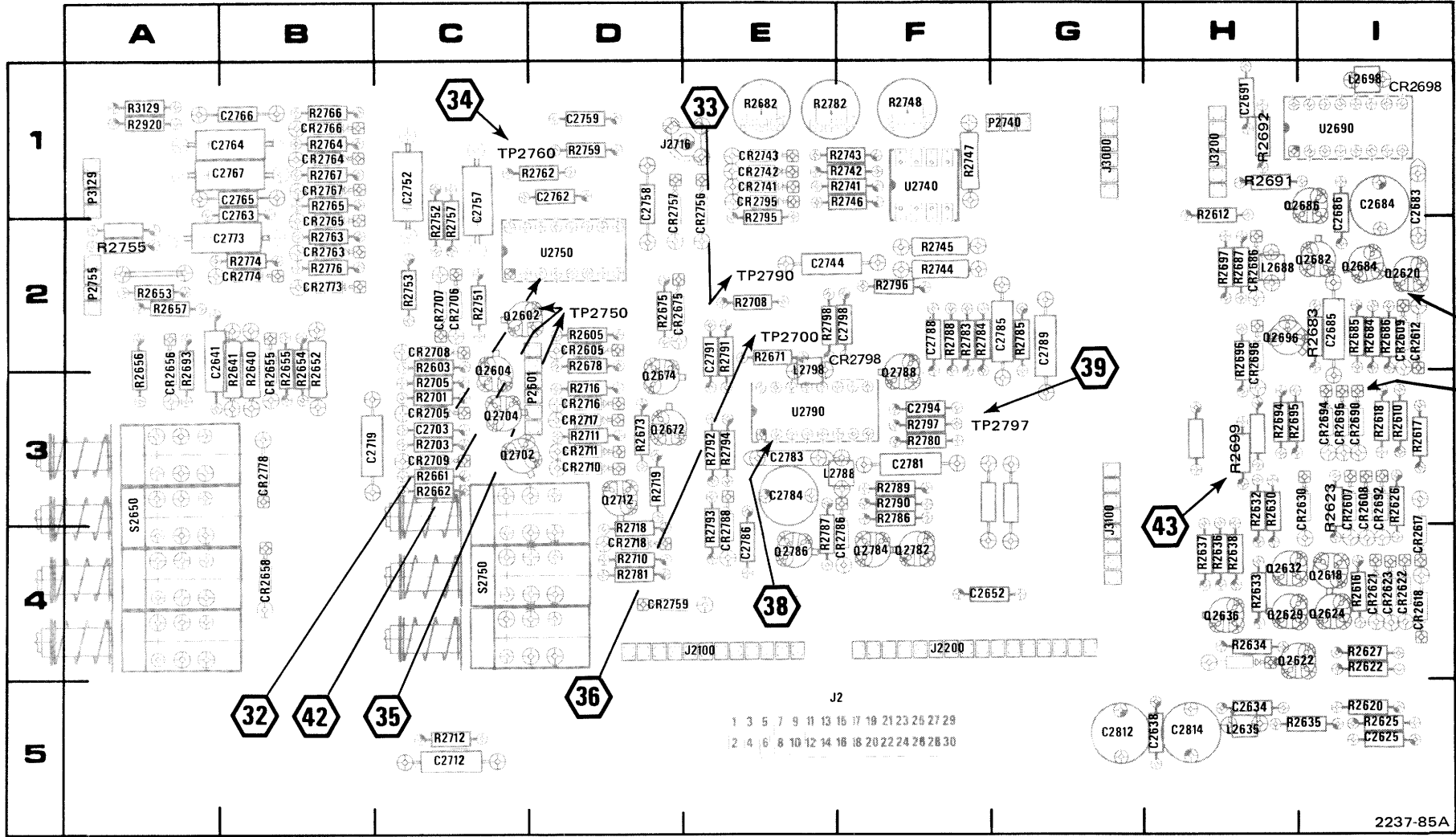
2237-101
REVA SEPT 1980

TRIGGER AMPLIFIER 4

TRIGGER AMPL (FO-6)

4

FO-6 (Front)

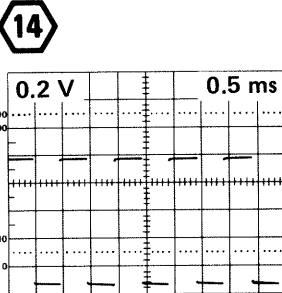


†On back of board.

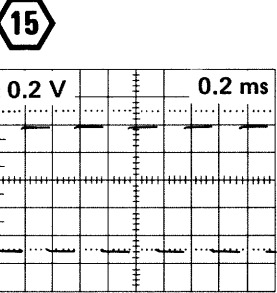
Figure 6-11. A8 Sweep board component locations.

CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC
C2625	5I	C2758	1D	C2791	2E	CR2655	2B	CR2710	3D	CR2773	2B	L2688	2H	Q2629	4H	R2603	2C	R2634	4H	R2673	3D	R2699	3H	R2746	1F	R2776	2B	R2795	2E	U2740	1F
C2634	5H	C2759	1D	C2794	3F	CR2656	2A	CR2711	3D	CR2774	2B	L2698	1I	Q2632	4H	R2605	2D	R2635	5I	R2675	2D	R2701	3C	R2747	1F	R2780	3F	R2796	2F	U2750	2D
C2638	5H	C2762	1D	C2798	2F	CR2658	3B	CR2716	3D	CR2778	3B	L2788	3F	Q2636	4H	R2610	3I	R2636	4H	R2678	2D	R2703	3C	R2748	1F	R2781	4D	R2797	3F	U2790	3E
C2641	2A	C2763	1B	C2812	5G	CR2675	2D	CR2717	3D	CR2786	4F	L2798	3E	Q2672	3D	R2612	1H	R2637	4H	R2682	1E	R2705	3C	R2751	2C	R2782	1E	R2798	1E		
C2652	4F	C2764	1B	C2814	5H	CR2686	2H	CR2718	4D	CR2788	4E			Q2674	3D	R2616	4I	R2638	4H	R2683	2I	R2708	2E	R2752	2C	R2783	2F	R2920	1A		
C2683	1I	C2765	1B	CR2605	2D	CR2690	3A	CR2741	1E	CR2795	1E	P2601	3D	Q2682	2I	R2617	3I	R2640	3B	R2684	2I	R2710	4D	R2753	2C	R2784	2F	R3129	1A		
C2684	1I	C2766	1B	CR2607	3I	CR2692	3I	CR2742	1E	CR2798†		P2740	1G	Q2684	2I	R2618	3I	R2641	3B	R2685	2I	R2711	3D	R2755	2A	R2785	2G				
C2685	2I	C2767	1B	CR2608	3I	CR2694	3I	CR2743	1E			P2755	2A	Q2686	1I	R2620	5I	R2652	2B	R2686	2I	R2712	5C	R2757	2C	R2786	3F	S2650	3A		
C2686	1I	C2773	2B	CR2609	2I	CR2695	3I	CR2756	1E	J2	5E	P3129	1A	Q2696	2H	R2622	4I	R2653	2A	R2687	2H	R2716	3D	R2759	1D	R2787	4E	S2750	4C		
C2691	1H	C2781	3F	CR2612	2I	CR2696	2H	CR2757	2D	J2100	4E	J2100	4E	Q2702	3C	R2623	3I	R2654	2B	R2691	1H	R2718	4D	R2762	1D	R2788	2F				
C2703	3C	C2783	3E	CR2698†		CR2759	4D	J2200	4F			J2200	4F	Q2602	2C	R2704	3C	R2625	5I	R2692	1H	R2719	3D	R2763	2B	R2789	3F	TP2700	2E		
C2712	5C	C2784	3E	CR2618	4I	CR2705	3C	CR2763	2B	J2716	1D			Q2604	3C	Q2712	3D	R2626	3I	R2655	2B	R2693	2A	R2741	1F	R2764	1B	R2790	3F	TP2750	2C
C2719	3B	C2785	2G	CR2621	4I	CR2706	2C	CR2764	1B	J3000	1G			Q2618	4I	Q2782	4F	R2627	4I	R2657	2A	R2694	3H	R2742	1F	R2765	1B	R2791	2E	TP2760	1C
C2744	1E	C2786	4E	CR2622	4I	CR2707	2C	CR2765	2B	J3100	3G			Q2620	2I	Q2784	4F	R2630	3H	R2661	3C	R2695	3H	R2743	1F	R2766	1B	R2792	3E	TP2790	2E
C2752	1C	C2788	2F	CR2623	4I	CR2708	2C	CR2766	1B	J3200	1H			Q2622	4H	Q2786	4E	R2632	3H	R2662	3C	R2696	2H	R2744	2F	R2767	1B	R2793	4E		
C2757	1C	C2789	2G	CR2630	3I	CR2709	3C	CR2767	1B	L2635	5H			Q2624	4I	Q2788	3F	R2633	4H	R2671	2E	R2697	2H	R2745	2F	R2774	2B	R2794	3E	U2690	1I

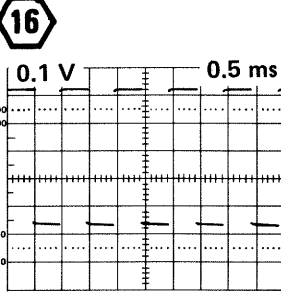
Refer to Waveform and Voltage Test Conditions.



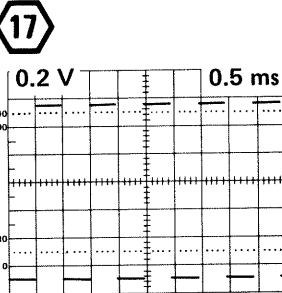
0 volt point depends on setting of instrument vertical POSITION control.



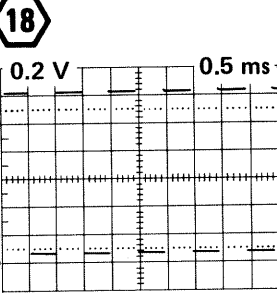
0 volt point depends on setting of instrument vertical POSITION control.



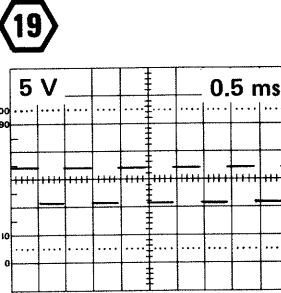
0 volt point depends on setting of instrument vertical POSITION control.



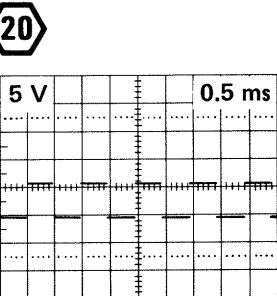
0 volt point depends on setting of instrument vertical POSITION control.



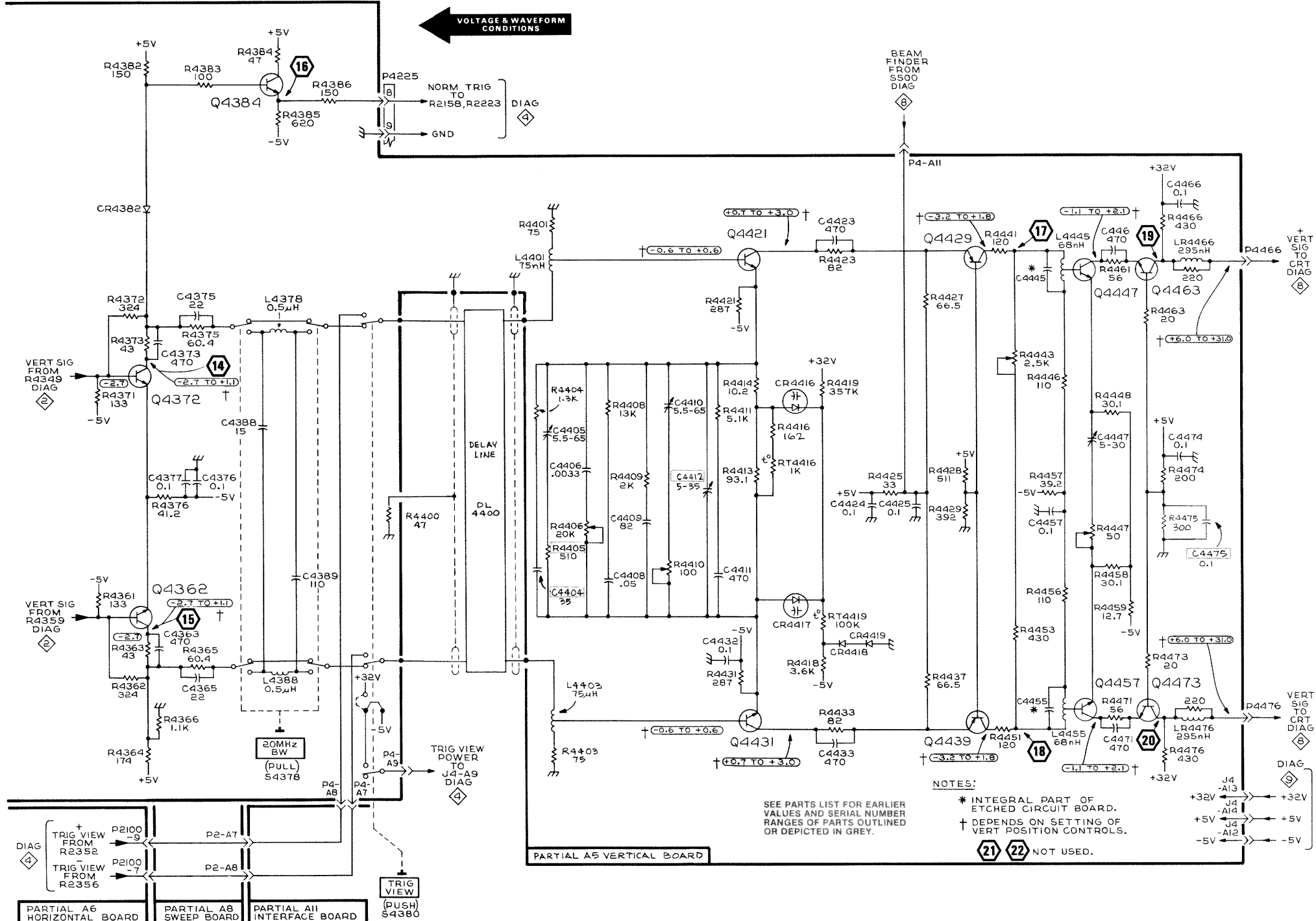
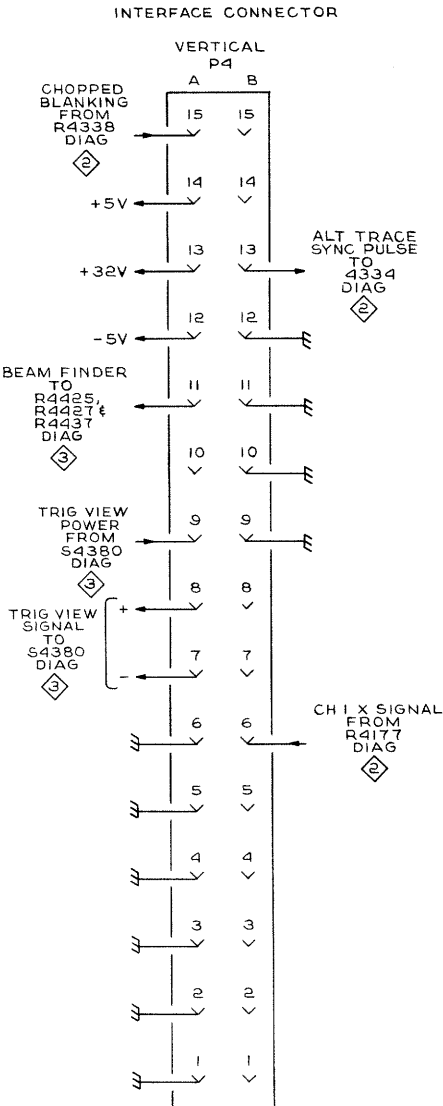
0 volt point depends on setting of instrument vertical POSITION control.



0 volt point depends on setting of instrument vertical POSITION control.



0 volt point depends on setting of instrument vertical POSITION control.



DELAY LINE DRIVER, VERTICAL AMPLIFIER
& INTERFACE CONNECTOR

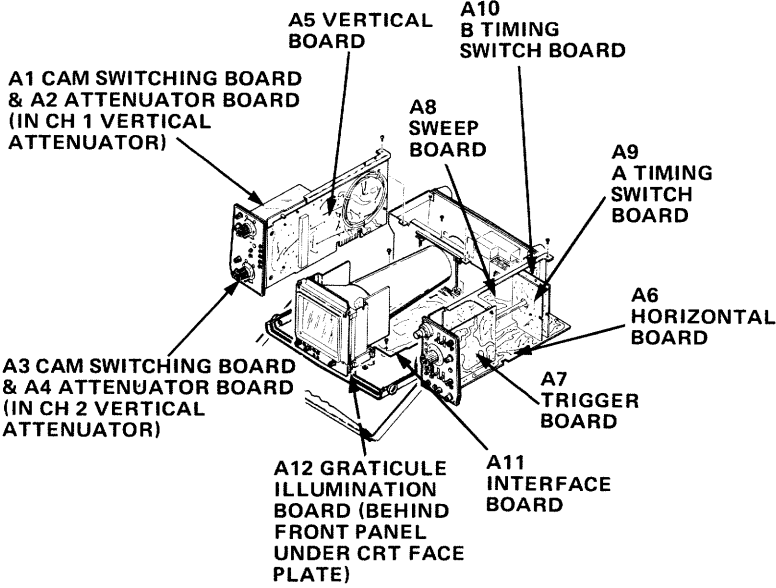
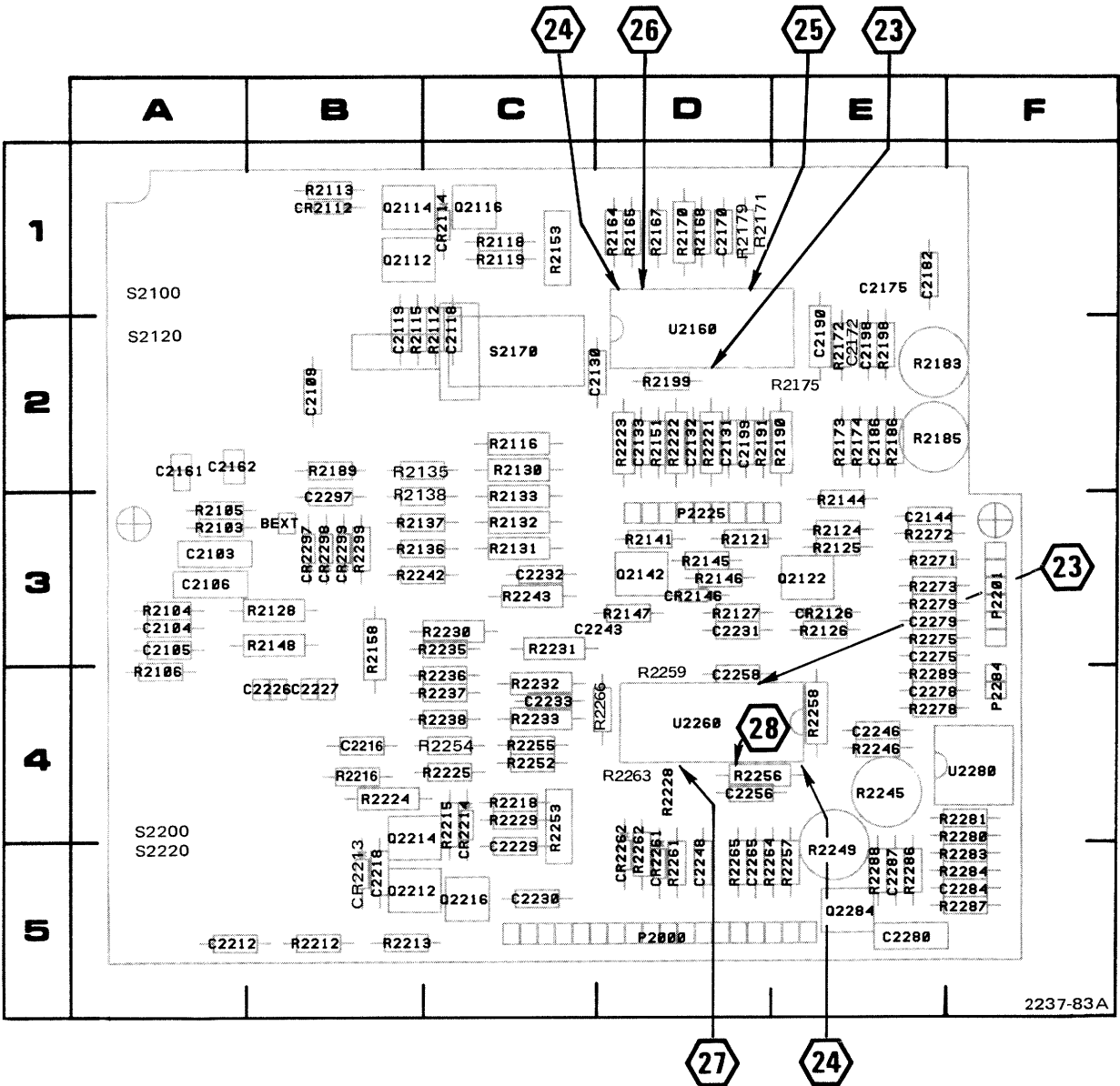


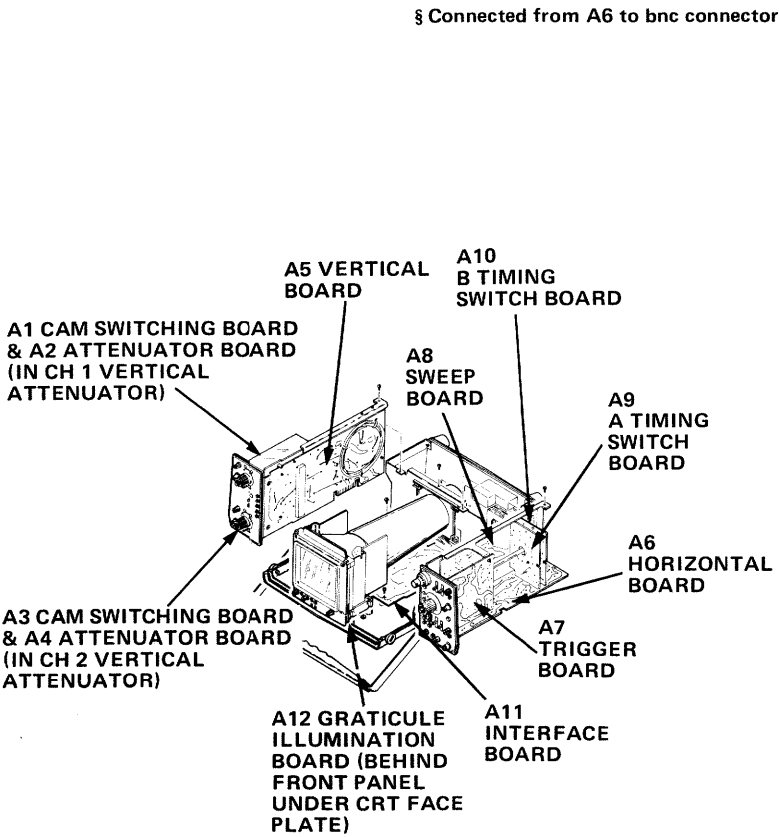
Figure 6-9. A7 Trigger board (SN B021600 & above) component locations.

Figure 6-10. A7 Trigger board (below SN B021600) component locations.

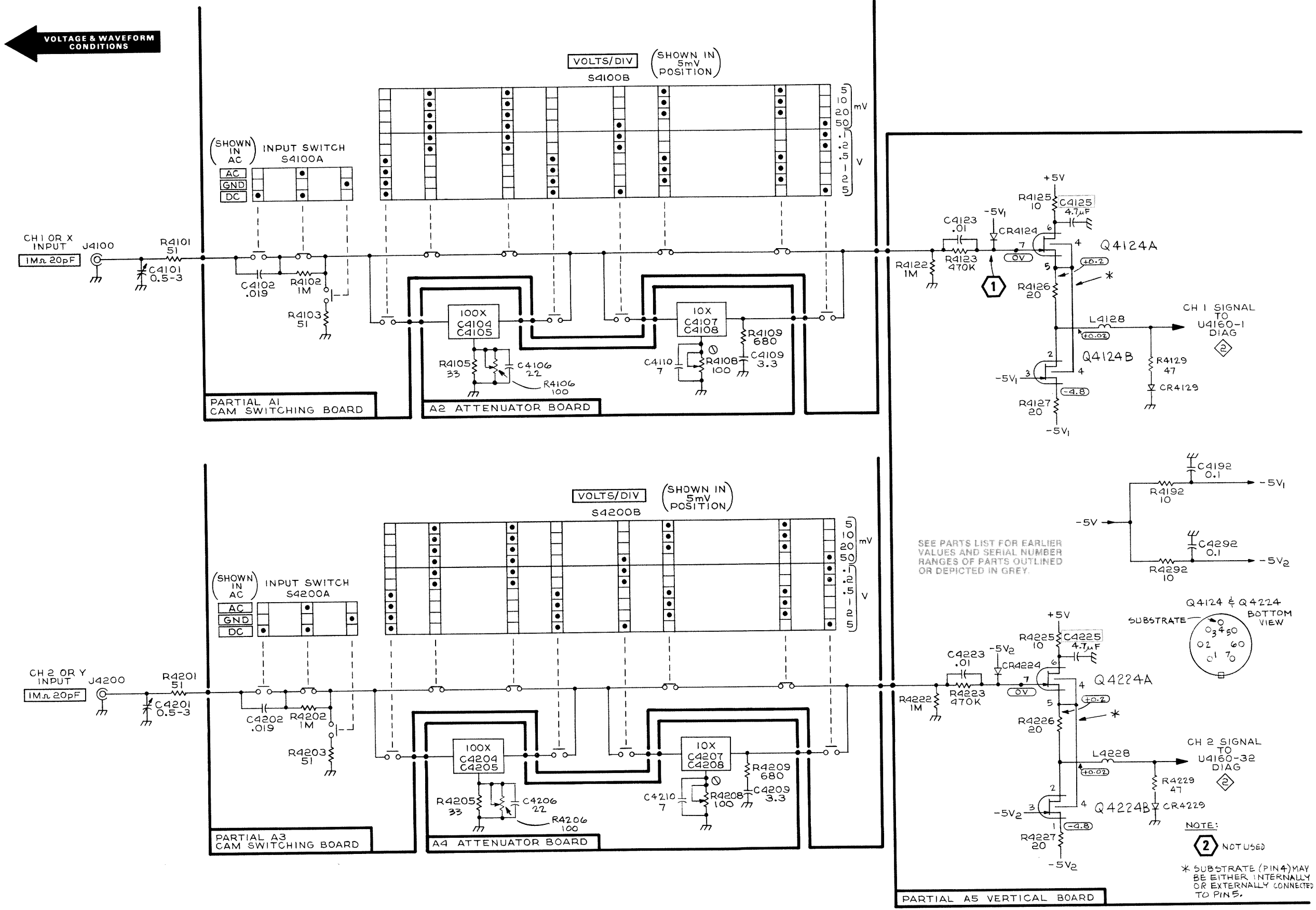
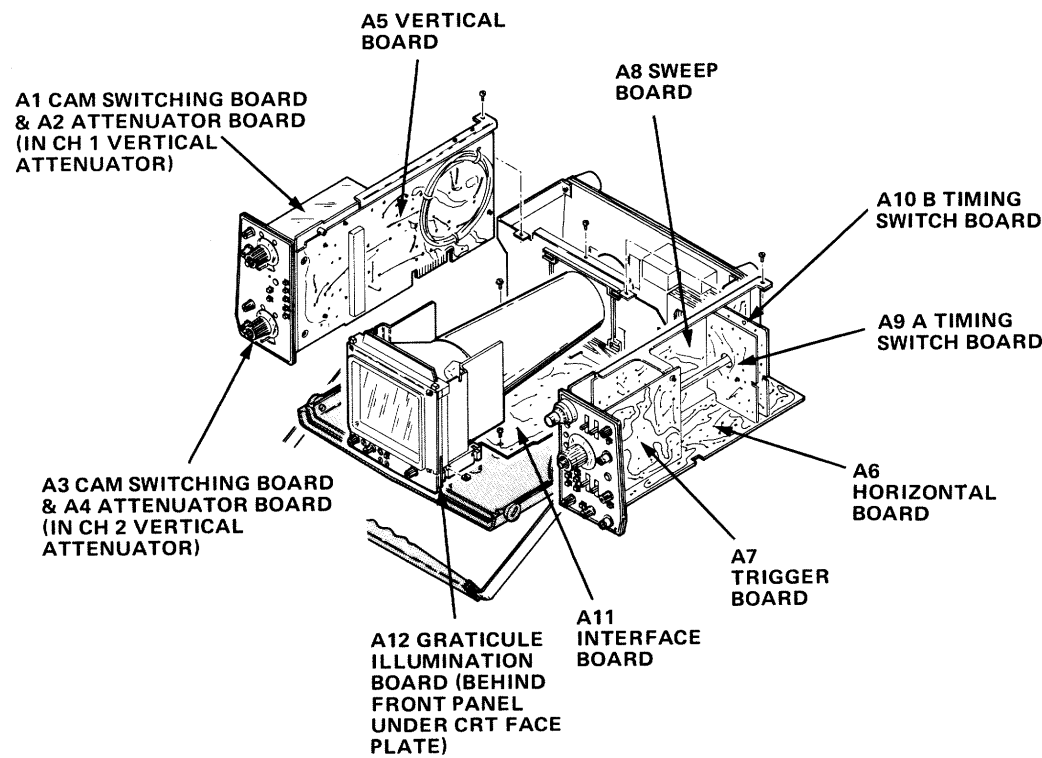
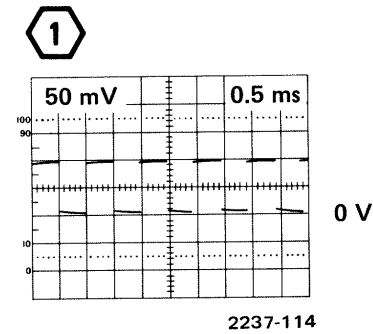
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	LOC	NO	LOC	NO	LOC	NO	LOC	NO	LOC	NO	LOC	NO	LOC	NO	LOC	NO	LOC	NO	LOC	NO	LOC	NO	LOC	NO	LOC	NO	
C2103	3A	C2172	2E	C2232	3C	CR2112	1B	P2284	4F	R2105	3A	R2131	3C	R2158	3B	R2189	2B	R2228	4D	R2252	4C	R2272	3E	S2100	1A		
C2104	3A	C2175	1E	C2233	4C	CR2114	1C			R2106	4A	R2132	3C	R2164	1D	R2190	2E	R2229	4C	R2253	4C	R2273	3E	S2120	2A		
C2105	3A	C2182	1E	C2243	3D	CR2126	3E	Q2112	1B	R2112	2C	R2133	3C	R2165	1D	R2191	2D	R2230	3C	R2254	4C	R2275	3C	S2200	4A		
C2106	3A	C2186	3E	C2246	4E	CR2146	3D	Q2114	1B	R2113	1B	R2135	2B	R2167	1D	R2198	2E	R2231	3C	R2255	4C	R2278	4E	S2220	5A		
C2109	2B	C2190	2E	C2248	5D	CR2213	5B	Q2116	1C	R2115	2B	R2136	3B	R2168	1D	R2199	2D	R2232	4C	R2256	4D	R2279	3E	S2170	2C		
C2118	2C	C2198	2E	C2256	4D	CR2214	4C	Q2122	3E	R2116	2C	R2137	3B	R2170	1D	R2212	5B	R2233	4C	R2257	5E	R2280	4F				
C2119	2B	C2199	2D	C2258	4D	CR2261	5D	Q2142	3D	R2118	1C	R2138	3B	R2171	1D	R2213	5B	R2235	3C	R2258	4E	R2281	4F	U2160	2D		
C2130	2C	C2212	5A	C2265	5D	CR2262	5D	Q2212	5B	R2119	1C	R2141	3D	R2172	2E	R2215	4C	R2236	4C	R2259	4D	R2283	5F	U2260	4D		
C2131	2D	C2216*	4B	C2275	3E	CR2297	3B	Q2214	4B	R2121	3D	R2144	3E	R2173	2E	R2216*	4B	R2237	4C	R2261	5D	R2284	5F	U2280	4F		
C2132	2D	C2218	5B	C2278	4E	CR2298	3B	Q2216	5C	R2124	3E	R2145	3D	R2174	2E	R2218	4C	R2238	4C	R2262	5D	R2286	5E				
C2133	2D	C2226	4B	C2279	3E	CR2299	3B	Q2284	5E	R2125	3E	R2146	3D	R2175	2E	R2221	2D	R2242	3B	R2263	4D	R2287	5F				
C2144	3E	C2227	4B	C2280	5E					R2126	3E	R2147	3D	R2179	1D	R2222	2D	R2243	3C	R2264	5D	R2288	5E				
C2161	2A	C2229	5C	C2284	5F	P2000	5D	R2101§		R2127	3D	R2148	3B	R2183	2E	R2223	2D	R2245	4E	R2265	5D	R2289	4E				
C2162	2A	C2230	5C	C2287	5E	P2201	3F	R2103	3A	R2128	3B	R2151	2D	R2185	2E	R2224	4B	R2246	4E	R2266	4D	R2299	3B				
C2170	1D	C2231	3D	C2297	3B	P2225	3D	R2104	3A	R2130	2C	R2153	1C	R2186	2E	R2225	4C	R2249	5E	R2271	3E						

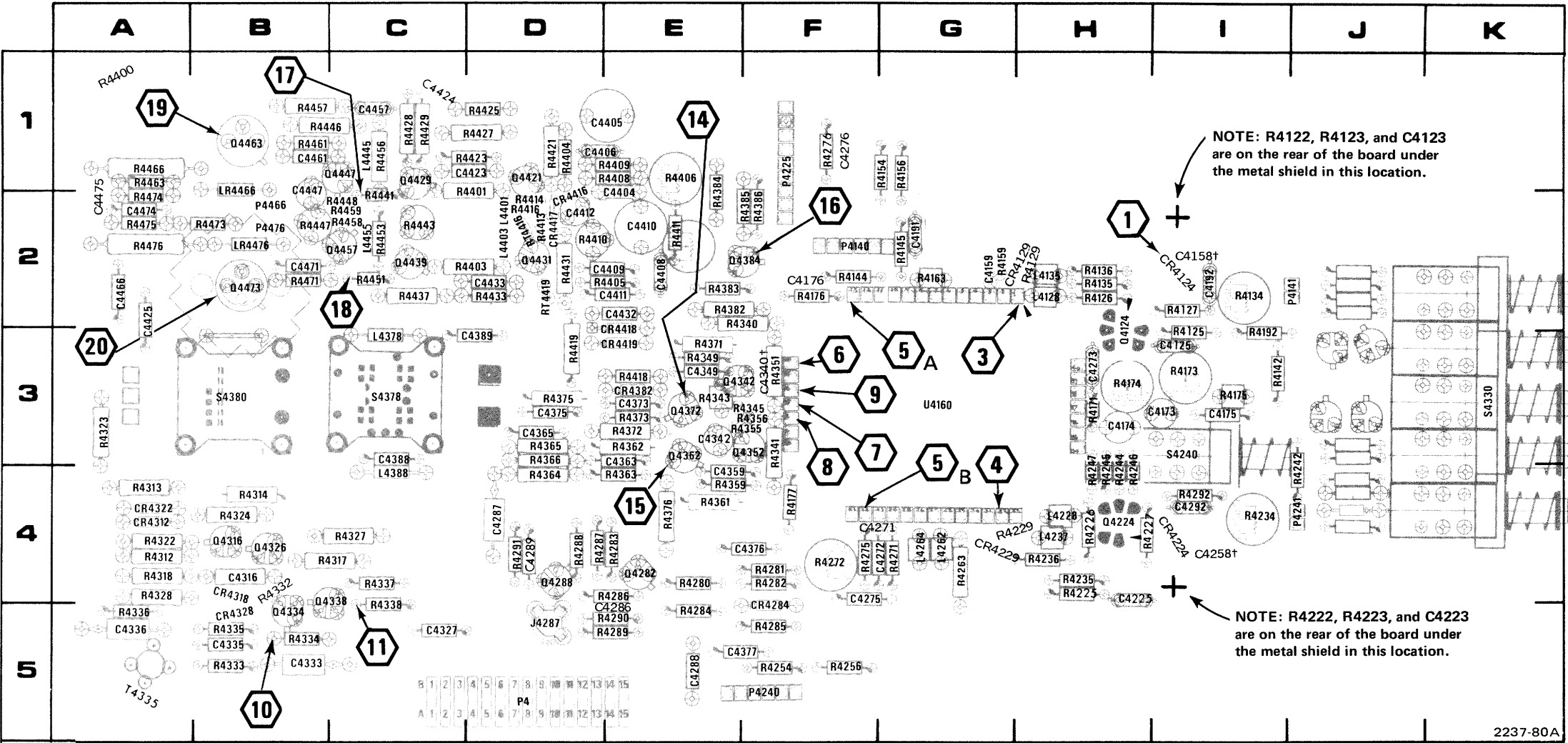
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C2103	3A	C2186	3E	C2258	4D	CR2297	3B	R2101	3A	R2131	3C	R2167	1D	R2213	5B	R2238	4C	R2265	5D	S2100	1A
C2104	3A	C2190	2E	C2265	5D	CR2298	3B	R2103	3A	R2132	3C	R2168	1D	R2215	4C	R2242	3B	R2266†	4C	S2120	2A
C2105	3A	C2198	2E	C2275	3E	CR2299	3B	R2104	3A	R2133	3C	R2170	1D	R2216	4B	R2243	3C	R2271	3E	S2200	4A
C2106	3A	C2199	2D	C2278	4E			R2105	3A	R2135	2B	R2171	1D	R2218	4C	R2245	4E	R2272	3E	S2220	5A
C2109	2B	C2212	5A	C2279	3E	P2000	5D	R2106	4A	R2136	3B	R2172	2E	R2221	2D	R2246	4E	R2273	3E	S2170	2C
C2118	2C	C2216	4B	C2280	5E	P2201	3F	R2112	2C	R2137	3B	R2173	2E	R2222	2D	R2249	5E	R2275	3E		
C2119	2B	C2218	5B	C2284	5F	P2225	3D	R2113	1B	R2138	3B	R2174	2E	R2223	2D	R2252	4C	R2278	4E	U2160	2D
C2130	2C	C2226	4B	C2287	5E	P2284	4F	R2115	2B	R2141	3D	R2175	2E	R2224	4B	R2253	4C	R2279	3E	U2260	4D
C2131	2D	C2227	4B	C2297	3B			R2116	2C	R2144	3E	R2179	2E	R2225	4C	R2254	4C	R2280	4F	U2280	4F
C2132	2D	C2229	5C			Q2112	1B	R2118	1C	R2145	3D	R2183	2E	R2228	4D	R2255	4C	R2281	4F		
C2133	2D	C2230	5C	CR2112	1B	Q2114	1B	R2119	1C	R2146	3D	R2185	2E	R2229	4C	R2256	4D	R2283	5F		
C2144	3E	C2231	3D	CR2114	1C	Q2116	1C	R2121	3D	R2147	3D	R2186	2E	R2230	3C	R2257	5E	R2284	5F		
C2161	2A	C2232	3C	CR2126	3E	Q2122	3E	R2124	3E	R2148	3B	R2189	2B	R2231	3C	R2258	4E	R2286	5E		
C2162	2A	C2233	4C	CR2146	3D	Q2142	3D	R2125	3E	R2151	2D	R2190	2E	R2232	4C	R2259†		R2287	5F		
C2170	1D	C2243	4D	CR2213	5B	Q2212	5B	R2126	3E	R2153	1C	R2191	2E	R2233	4C	R2261	5D	R2288	5E		
C2172	2E	C2246	4E	CR2214	4C	Q2214	4B	R2127	3D	R2158	3B	R2198	2E	R2235	3C	R2262	5D	R2289	4E		
C2175	1E	C2248	5D	CR2261	5D	Q2216	5C	R2128	3B	R2164	1D	R2199	2D	R2236	4C	R2263†		R2299	3B		
C2182	1E	C2256	4D	CR2262	5D	Q2284	5E	R2130	2C	R2165	1D	R2212	5B	R2237	4C	R2264	5D				

FO-4 (Front)

REV A SEP 1980

Refer to Waveform and Voltage Test Conditions.

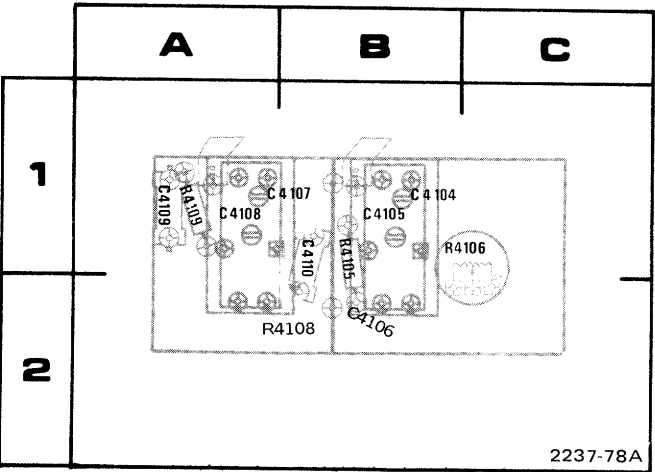




A5 VERTICAL BOARD.

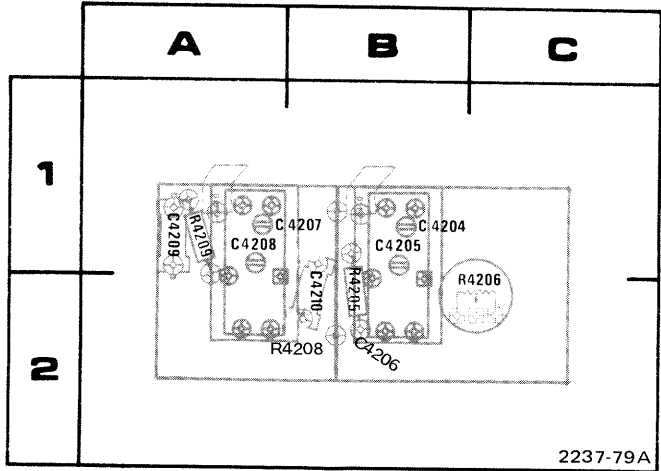
†On back of board
‡Selected; Added as necessary.
*See Parts List for serial number ranges.
§Integral part of etched circuit board.

CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC
C4123†		C4423 1D		P4 5D		R4173 3I		R4324 4B		R4416 2D	
C4125 3I		C4424 1C		P4140 2F		R4174 3H		R4327 4C		R4418 3E	
C4158†‡		C4425 2A		P4141 1J		R4175 3I		R4328 4A		R4419 3D	
C4159 2G		C4432 2E		P4225 1F		R4176 2F		R4332 5B		R4421 1D	
C4173 3I		C4433 2D		P4240 5F		R4177 4F		R4333 5B		R4423 1D	
C4174 3H		C4445§		P4466 2B		R4192 2I		R4334 5B		R4425 1D	
C4175 3I		C4447 1B		P4476 2B		R4222†		R4335 5B		R4427 1D	
C4176* 2F		C4449 3E				R4223†		R4336 5A		R4428 1C	
C4191 2G		C4455§		Q4124 2H		R4225 4H		R4337 4C		R4429 1C	
C4192 2I		C4457 1C		Q4224 4H		R4226 4I		R4338 5C		R4431 2D	
C4223†		C4461 1B		Q4282 4E		R4227 4H		R4340 2E		R4433 2D	
C4225 4H		C4466 2A		Q4288 4D		R4229 4H		R4341 3F		R4437 2C	
C4258†‡		C4471 2B		Q4316 4B		R4234 4I		R4343 3E		R4441 2C	
C4271* 4G		C4474 2A		Q4326 4B		R4235 4H		R4345 3F		R4443 2C	
C4272 5G		C4475 2A		Q4334 5B		R4236 4H		R4349 4E		R4446 1B	
C4273 3H				Q4338 5C		R4242 4J		R4351 3F		R4447 2B	
C4275 5F		CR4124 2I		Q4342 3F		R4244 4H		R4355 3F		R4448 2C	
C4276* 1F		CR4129 2H		Q4352 3F		R4245 4H		R4356 3F		R4451 2C	
C4286* 5E		CR4224 2I		Q4362 3E		R4246 4H		R4359 4E		R4453 2C	
C4287 4D		CR4229 4G		Q4372 3E		R4247 4H		R4361 4E		R4456 1C	
C4288 5E		CR4284 5F		Q4384 2F		R4254 4F		R4362 3E		R4457 1B	
C4289 5E		CR4312 4A		Q4421 1D		R4256 5F		R4363 4E		R4458 2C	
C4292 4I		CR4318 4B		Q4429 1C		R4263 4G		R4364 4D		R4459 2C	
C4316 4B		CR4322 4A		Q4431 2D		R4271 4G		R4365 3D		R4461 1B	
C4327 5C		CR4328 5B		Q4439 2C		R4272 4F		R4366 3D		R4463 1A	
C4333 5B		CR4382 3E		Q4447 1C		R4275 4F		R4371 3E		R4466 1A	
C4335 5B		CR4416 2D		Q4457 2C		R4276 1F		R4372 3E		R4471 2B	
C4336 5A		CR4417 2D		Q4463 1B		R4280 4E		R4373 3E		R4473 2B	
C4340†		CR4418 3E		Q4473 2B		R4281 4F		R4375 3D		R4474 2A	
C4342 3E		CR4419 3E				R4282 4F		R4376 4E		R4475 2A	
C4359 4E				R4122†		R4283 4E		R4382 2E		R4476 2A	
C4363 3E		J4287 5D		R4123†		R4284 5E		R4383 2E			
C4365 3D				R4125 2I		R4285 5F		R4384 2E		RT4119 2D	
C4373 3E		L4128 2H		R4126 2H		R4286 4E		R4385 2F		RT4116 2D	
C4375 3D		L4135 2H		R4127 2I		R4287 4D		R4386 2F			
C4376 4F		L4228 4H		R4129 2H		R4288 4D		R4400†		S4240 3I	
C4377 5F		L4237 4H		R4134 2I		R4289 5E		R4401 2D		S4330 3K	
C4388 3C		L4262 4G		R4135 2H		R4290 5E		R4403 2D		S4380 3B	
C4389 3D		L4264 4G		R4136 2H		R4291 4D		R4404 1D		S4378 3C	
C4404 2E		L4378 3C		R4142 3O		R4292 4I		R4405 2E			
C4405 1E		L4388 4C		R4144 2F		R4312 4A		R4406 1E		U4160 3G	
C4406 1D		L4401 2D		R4145 2G		R4313 4A		R4408 1E			
C4408 2E		L4403 2D		R4154 1G		R4314 4B		R4409 1E			
C4409 2E		L4445 1C		R4156 1G		R4317 4C		R4410 2D			
C4410 2E		L4456 1C		R4159 2G		R4318 4A		R4411 2E			
C4411 2E		L4466 1B		R4163 2G		R4322 4A		R4413 2D			
C4412 2D		L4476 2B		R4171 3H		R4323 3A		R4414 2D			



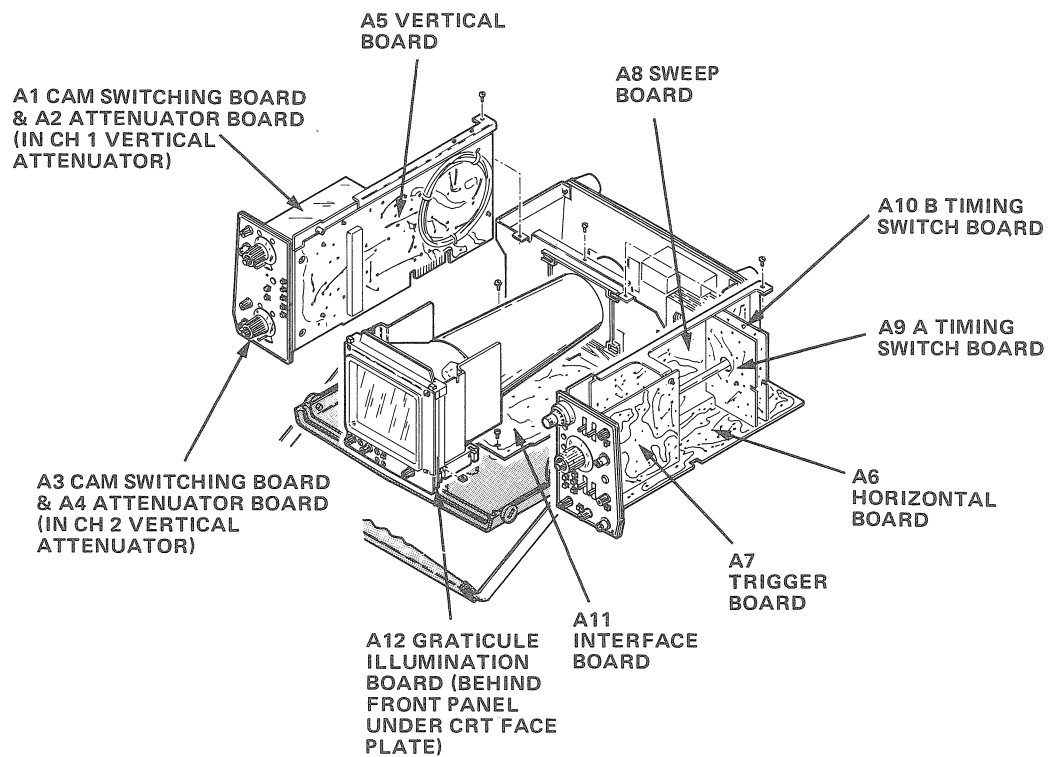
A2 ATTENUATOR BOARD.

CKT NO	GRID LOC	CKT NO	GRID LOC
C4104 1B		C4110 1B	
C4105 1B			
C4106 2B		R4105 1B	
C4107 1B		R4106 1B	
C4108 1A		R4108 2B	
C4109 1A		R4109 1A	



A4 ATTENUATOR BOARD

CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC
C4204 1B		C4207 1B		C4210 2B		R4206 1C	
C4205 1B		C4208 1A				R4208 2B	
C4206 2B		C4209 1A		R4205 2B		R4209 1A	



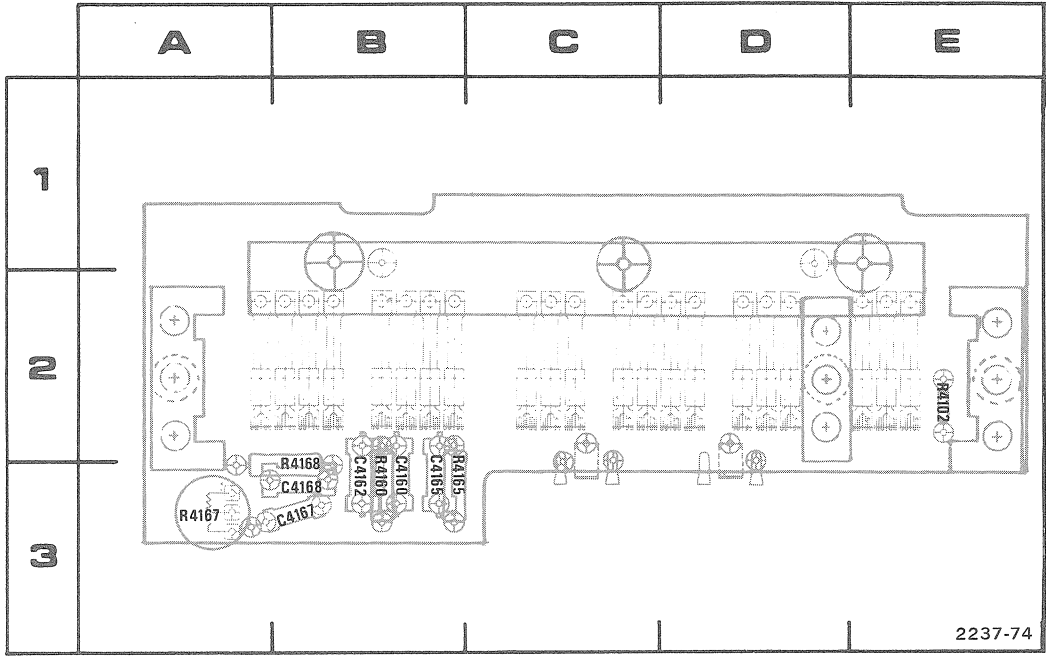


Figure 6-3. A1 Cam Switching board (top) component locations.

CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC
C4160	3B	C4165	3B	C4168	3B	R4160	3B	R4167	3A
C4162	3B	C4167	3B	R4102	2E	R4165	3B	R4168	3B

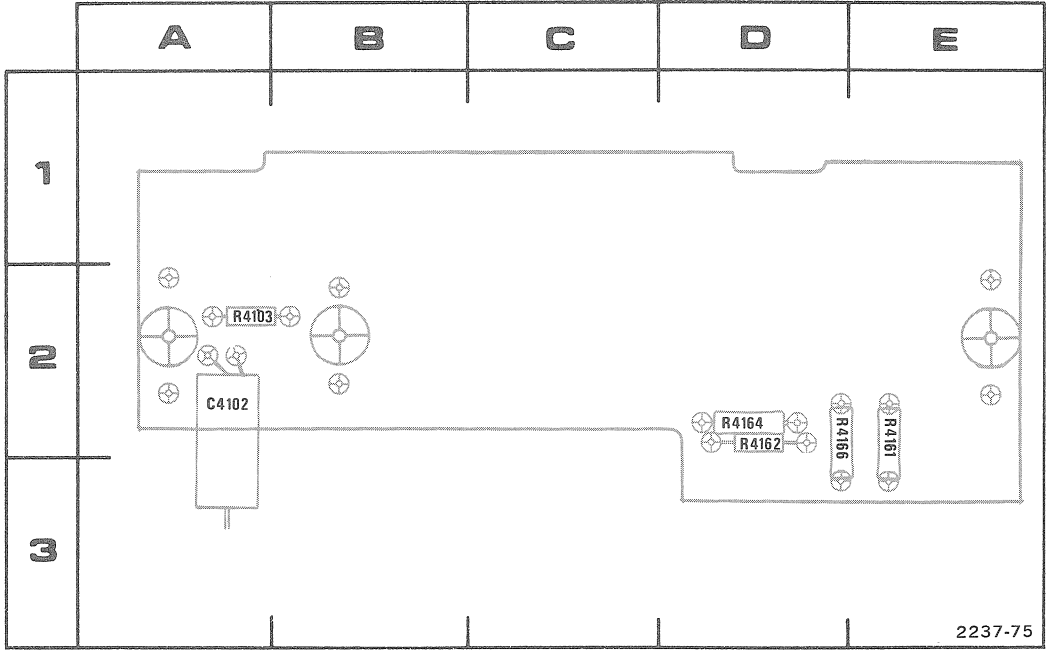


Figure 6-4. A1 Cam Switching board (bottom) component locations.

CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC
C4102	2A	R4161	2E	R4164	2D
R4103	2A	R4162	2D	R4166	2D

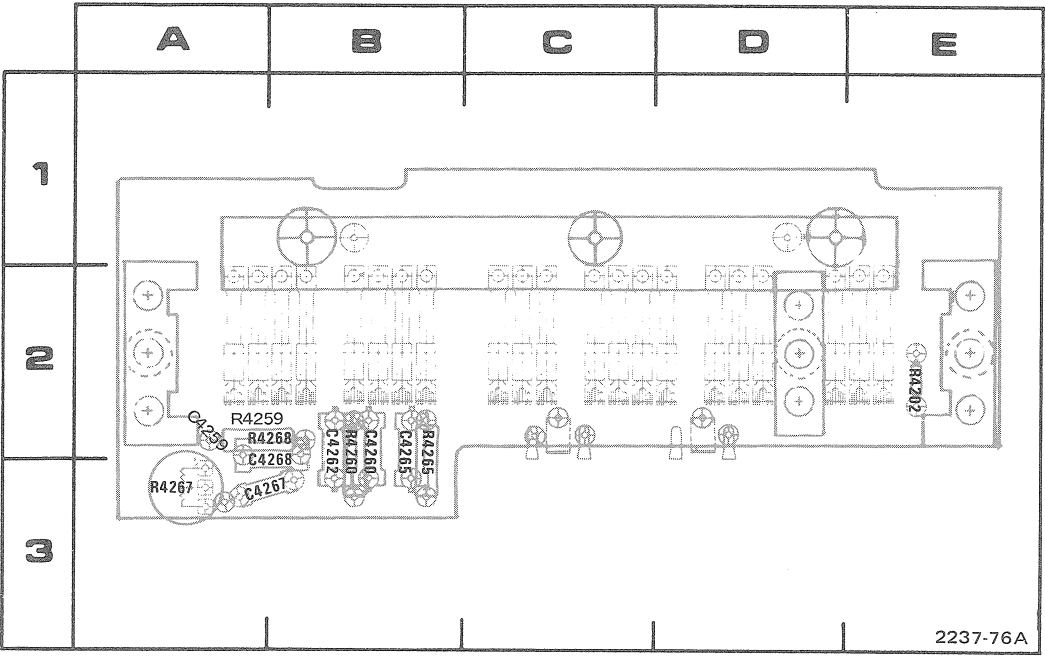


Figure 6-5. A3 Cam Switching board (top) component locations.

CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC
C4259	2A	C4265	2B	C4268	2A	R4260	2B	R4267	3A
C4260	2B	C4267	3A	R4202	2E	R4265	2B	R4268	2A
C4262	2B			R4259	2A				

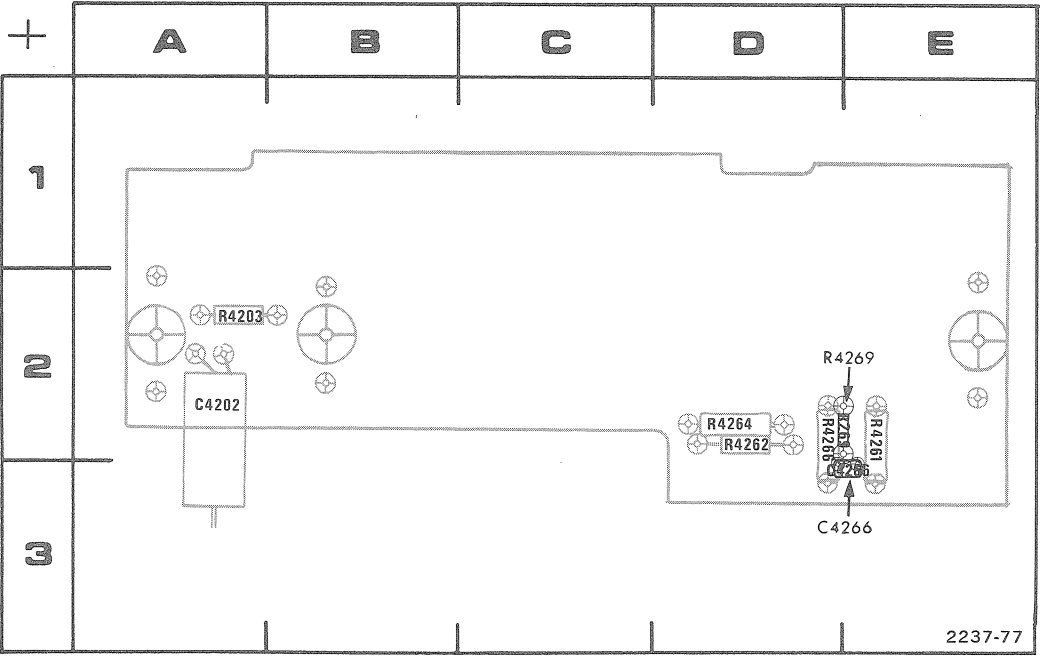


Figure 6-6. A3 Cam Switching board (bottom) component locations.

CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC
C4202	2A	R4203	2A	R4262	2D	R4266	2D
C4266	3E	R4261	2E	R4264	2D	R4269	2E