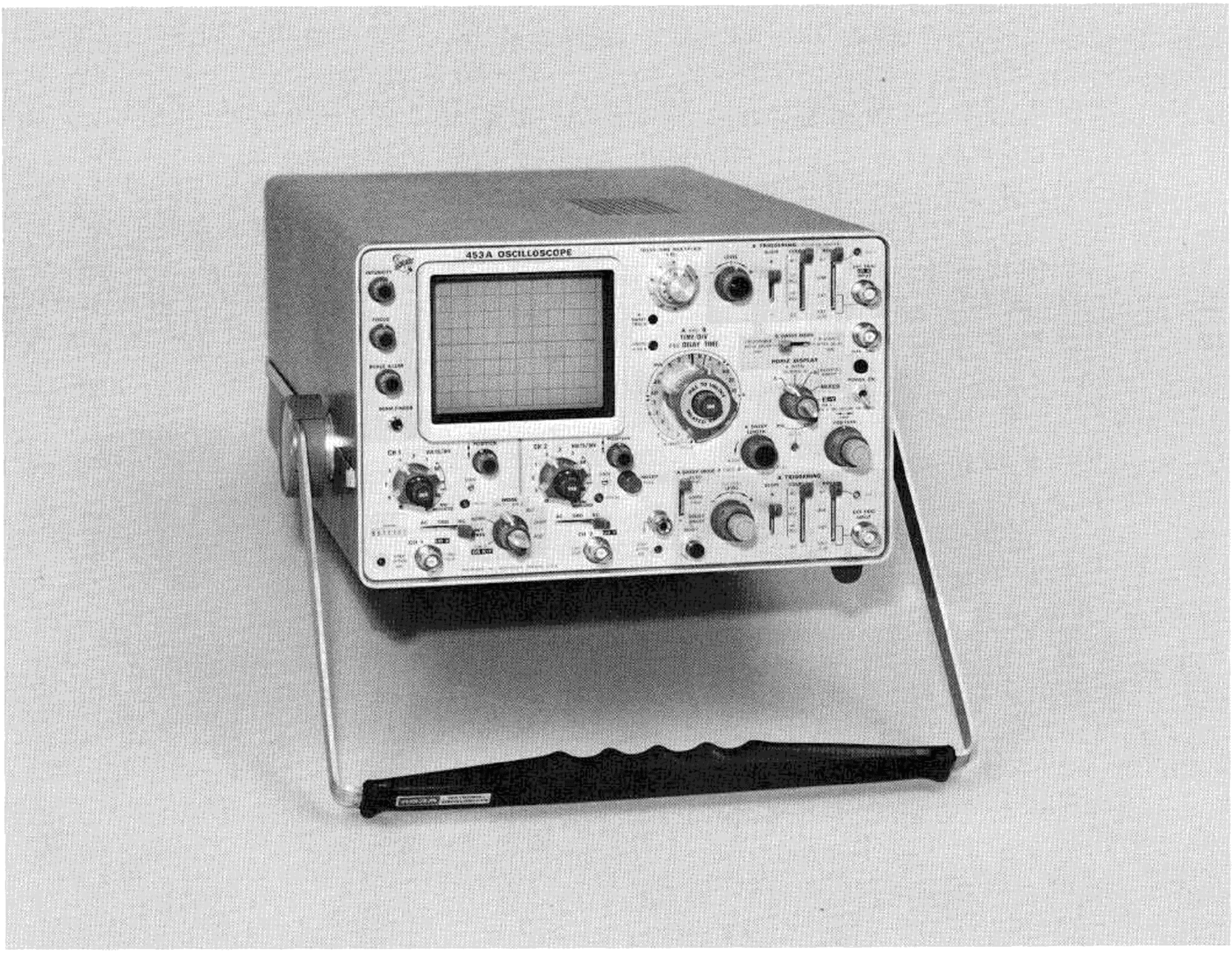
TEKTRONIX - 453 A



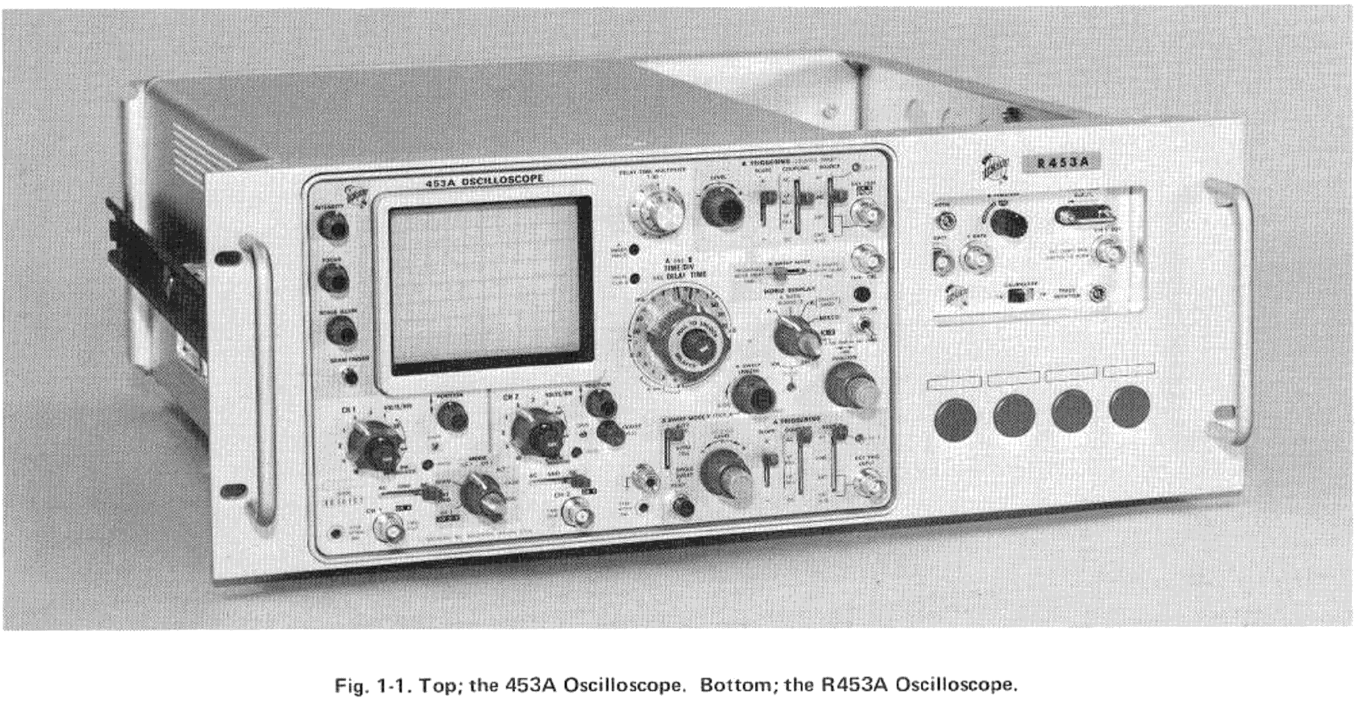


Fig. 1-1. Top; the 453A Oscilloscope. Bottom; the R453A Oscilloscope.

SECTION 1
453A/R453A SPECIFICATION

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

Introduction

The Tektronix 453A Oscilloscope is a transistorized portable oscilloscope designed to operate in a wide range of environmental conditions. The light weight of the 453A allows it to be easily transported, while providing the performance necessary for accurate high-frequency measurements. The dual-channel DC-to-60 MHz vertical system provides calibrated deflection factors from 5 millivolts to 10 volts/division. Channels 1 and 2 can be cascaded using an external cable to provide a one millivolt minimum deflection factor (both VOLTS/DIV switches set to 5 mV).

The trigger circuits provide stable triggering over the full range of vertical frequency response. Separate trigger controls are provided to select the desired triggering for the A and B sweeps. One of three sweep modes can be selected for the A sweep; automatic, normal, or single sweep. The horizontal sweep provides a maximum sweep rate of 0.1 microsecond/division (10 nanoseconds/division using 10X magnifier) along with a delayed sweep feature for accurate relative-time measurements. Accurate X-Y measurements can be made with Channel 2 providing the vertical deflection, and Channel 1 providing the horizontal deflection (INT TRIG switch set to CH 1 OR X-Y, HORIZ DISPLAY switch set to X-Y). The regulated DC power supplies maintain constant output over a wide variation of line voltages and frequencies. Total power consumption of the instrument is approximately 90 watts.

Information given in this instruction manual applies to the R453A also unless otherwise noted. The R453A is electrically identical to the 453A, but is mechanically adapted for mounting in a standard 19-inch rack. Rackmounting instructions and a dimensional drawing for the R453A are provided in Section 6 of this manual.

This instrument will meet the electrical characteristics listed in Table 1-1 following complete calibration as given in Section 5. The performance check procedure in Section 5 provides a convenient method of checking instrument performance without making internal checks or adjustments. The following electrical characteristics apply over a calibration interval of 1000 hours and an ambient temperature range of 0°C to +50°C, except as otherwise indicated. Warmup time for given accuracy is 20 minutes.

TABLE 1-1

ELECTRICAL

Characteristic	Performance Requirement	Supplemental Information
	VERTICAL DEFLECTION SYSTEM	
Deflection Factor	5 millivolts/division to 10 volts/division in 11 calibrated steps for each channel. Less than one millivolt/division when Channel 1 and 2 are cascaded.	Selected by VOLTS/DIV switch. Steps in 1-2-5 sequence.
Deflection Accuracy	Within 3% of indicated deflection. Cascaded deflection factor uncalibrated.	With GAIN correctly adjusted at 20 mV and VAR VOLTS/DIV control set to calibrated.
Variable Deflection Factor	Continuously variable between calibrated settings.	Extends maximum deflection factor to at least 25 volts/division.

TABLE 1-1 (cont)

Characteristic	Performance Requirement	Supplemental Information
Bandwidth at −3 dB points (with or without P6061 Probe)		Driven from 25-ohm source. VAR VOLTS/DIV control set to calibrated position.
20 mV to 10 VOLTS/DIV	DC to at least 60 megahertz	
10 mV/DIV	DC to at least 50 megahertz	
5 mV/DIV	DC to at least 40 megahertz	
Channels 1 and 2 cascaded	DC to at least 25 megahertz	
AC Low-Frequency Response (lower −3 dB point)		Input Coupling switch set to AC.
Without probe	1.6 hertz or less at all deflection factors.	
With P6061 Probe	0.16 hertz or less at all deflection factors.	
Input RC Characteristics		
Resistance		One megohm ±2%
Capacitance		Approximately 20 picofarads
Maximum Safe Input Voltage		600 volts DC + peak AC (one kilohertz or less).
Input Coupling Modes	AC or DC.	Selected by Input Coupling switch.
Vertical Display Modes	Channel 1 only. Channel 2 only. Dual-trace, alternate between channels. Dual-trace, chopped between channels. Added algebraically.	
Chopped Repetition Rate	Approximately 500 kilohertz.	
Amplifier Crosstalk	100:1 or greater, DC to 20 megahertz.	
Common Mode Rejection Ratio (all deflection factors)	At least 20:1 DC to one kilohertz for signals less than eight times the VOLTS/DIV switch setting.	
Polarity Inversion	Displayed signal from Channel 2 can be inverted.	
Signal Delay Line	Permits viewing of leading edge of triggering signal (internal triggering only).	

TABLE 1-1 (cont)

Characteristic	Performance Requirement	Supplemental Information
TRIGGERING (A AND B SWEEP)		
Source	Internal from displayed channel or from Channel 1 only. Internal from AC power source. External. External divide by 10.	Selected by SOURCE switch.
Coupling	AC AC low-frequency reject AC high-frequency reject DC	Selected by COUPLING switch.
Polarity	Sweep can be triggered from positive-going or negative-going portion of trigger signal.	Selected by SLOPE switch
Internal Trigger Sensitivity		
AC	0.3 division of deflection, minimum, 30 hertz to 10 megahertz; increasing to 1.5 division at 60 megahertz.	
LF REJ	0.3 division of deflection, minimum, 30 kilohertz to 10 megahertz; increasing to 1.5 division at 60 megahertz.	
HF REJ	0.3 division of deflection, minimum, 30 hertz to 50 kilohertz.	
DC	0.3 division of deflection, minimum, DC to 10 megahertz; increasing to 1.5 division at 60 megahertz.	
External Trigger Sensitivity		
AC	50 millivolts, minimum, 30 hertz to 10 megahertz; increasing to 200 millivolts at 60 megahertz.	SOURCE switch set to EXT. Triggering signal requirements increased 10 times for EXT ÷ 10 position.
LF REJ	50 millivolts, minimum, 30 kilohertz to 10 megahertz; increasing to 200 millivolts at 60 megahertz.	
HF REJ	50 millivolts, minimum, 30 hertz to 50 kilohertz.	
DC	50 millivolts, minimum, DC to 10 megahertz; increasing to 200 millivolts at 60 megahertz.	

TABLE 1-1 (cont)

Characteristic	Performance Requirement	Supplemental Information
Auto Triggering (A sweep only)	Stable display presented with signal amplitudes given under Internal and External Trigger Sensitivity above 20 hertz. Presents a free-running sweep for lower frequencies or in absence of trigger signal.	
Single Sweep (A Sweep only)	A Sweep Generator produces only one sweep when triggered. Further sweeps are locked out until RESET button is pressed. Trigger sensitivity same as given for internal and external sensitivity.	
Display Jitter	One nanosecond or less at 10 nanoseconds/division sweep rate (MAG switch set to X10).	
External Trigger Input RC Characteristics		One megohm paralleled by 20 picofarads (approximate).
LEVEL control range EXT		At least + and − 2 volts.
EXT ÷ 10		At least + and − 20 volts.
Maximum safe input voltage		600 volts DC + peak AC (one kilohertz or less)

HORIZONTAL DEFLECTION SYSTEM

A and B Sweep Generator

Characteristic	Performance Requirement	Supplemental Information
Sweep Rates A sweep (delaying sweep)	0.1 microsecond/division to 5 seconds/division in 24 calibrated steps.	Selected by A TIME/DIV switch. Steps in 1-2-5 sequence.
B sweep (delayed sweep)	0.1 microsecond/division to 0.5 second/division in 21 calibrated steps	Selected by B TIME/DIV switch. Steps in 1-2-5 sequence.

Sweep Accuracy	Performance Requirement			
	0°C to +40°C		−15°C to +55°C	
Over center eight divisions	Unmagnified	Magnified	Unmagnified	Magnified
5 s/DIV to 0.1 s/DIV	Within 3%	Within 4%	Within 5%	Within 6%
50 ms/DIV to 0.1 μs/DIV	Within 3%	Within 4%	Within 4%	Within 5%
Sweep Linearity Over any two division portion within center eight divisions (all sweep rates)	Within 5%	Within 5%	Within 5%	Within 10%

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TABLE 1-1 (cont)

Characteristic	Performance Requirement		Supplemental Information
Variable Sweep Rate	Continuously variable between calibrated sweep rates.		Extends maximum A sweep rate to at least 12.5 seconds/division and B sweep rate to at least 1.25 seconds/division.
A Sweep Length	Variable from four divisions or less to 10 divisions or greater.		Measured at 1 ms/DIV.
Mixed and Delayed Sweep			
Mixed Sweep Accuracy	Within 2% ± measured A sweep error when viewing the A portion only. B portion accuracy is same as stated under Sweep Accuracy.		Exclude first 0.5 division of displayed sweep and 0.2 division or 0.1 microsecond, whichever is greater, after transition from A to B sweep.
Calibrated Delay Range	Continuous from 50 seconds to 0.2 microseconds.		Selected by DELAY-TIME MULTIPLIER dial and A TIME/DIV switch.
Delay Accuracy Over Center Eight Divisions	0°C to +40°C	−15°C to +55°C	
5 s to 0.1 s/DIV	Within 1.5% of indicated delay	Within 3.5% of indicated delay	
50 ms to 1 µs/DIV	Within 1.5% of indicated delay	Within 2% of indicated delay	
Incremental Multiplier Linearity	Within 0.2%	Within 0.3%	
Delay Time Jitter	Less than 1 part in 20,000 of the maximum available delay time (10 times A TIME/DIV switch setting).		
External Horizontal Amplifier			
Input to CH 1 or X connector Deflection Factor	5 millivolts/division to 10 volts/division in 11 calibrated steps.		INT TRIG switch set to CH 1 OR X-Y. Steps in 1-2-5 sequence.
Accuracy	0°C to +40°C	−15°C to +55°C	External horizontal gain correctly adjusted at 20 mV.
	Within 5% of indicated deflection	Within 8% of indicated deflection	
X Bandwidth at Upper −3 dB Point	Five megahertz or greater		
Input RC Characteristics Resistance			1 megohm ±2%
Capacitance			Approximately 20 picofarads
Phase difference between X and Y amplifiers	3° or less at 50 kilohertz		

TABLE 1-1 (cont)

Characteristic	Performance Requirement		Supplemental Information
Input to EXT TRIG OR X INPUT Connector			
Deflection Factor	B SOURCE switch in EXT; 270 millivolts/division ±15%.		
	B SOURCE switch in EXT ÷ 10; 2.7 volts/division ±20%.		
X Bandwidth at Upper −3 dB point	Five megahertz or greater		
Input RC Characteristics			One megohm paralleled by 20 picofarads (approximate)
Phase difference between X and Y amplifiers	3° or less at 50 kilohertz		
Maximum Safe Input Voltage			600 volts DC + peak AC (one kilohertz or less).

CALIBRATOR

Waveshape	Square wave		
Polarity	Positive going.		Baseline at zero volts.
Output Voltage	0.1 volt or 1 volt, peak to peak		Selected by CALIBRATOR switch.
Output Current	Five milliamperes through PROBE LOOP on side panel		
Repetition Rate	One kilohertz.		
Accuracy	0°C to +40°C	−15°C to +55°C	
Voltage	±1%	±1.5%	
Current	±1%	±1.5%	
Repetition Rate	±0.5%	±1%	
Risetime	One microsecond or less		
Output Resistance			Approximately 200 ohms in 1 V position
			Approximately 20 ohms in 0.1 V position

TABLE 1-1 (cont)

Characteristic	Performance Requirement	Supplemental Information
Z AXIS INPUT		
Sensitivity	Five volt peak-to-peak signal produces noticeable modulation at normal intensity.	
Polarity of Operation	Positive-going input signal decreases trace intensity; negative-going input signal increases trace intensity.	
Usable Frequency Range	DC to 50 megahertz or greater.	
Input Resistance at DC		Approximately 47 kilohms
Input Coupling	DC coupled	
Maximum Input Voltage		200 volts DC + peak AC
OUTPUT SIGNALS		
A and B Gate Waveshape	Rectangular pulse	
Amplitude	Approximately 12 volts peak	
Polarity	Positive-going	Baseline at about −0.7 volt
Duration	Same duration as respective sweep.	
Output Resistance		Approximately 1.5 kilohms.
Vertical Signal Out (CH 1 only) Output Voltage	25 millivolts or greater, for each division of CRT display.	Into one megohm load. INT TRIG switch set to NORM.
Bandwidth	DC to 25 megahertz or greater when cascaded with Channel 2, or into 50-ohm load.	
Output coupling	DC coupled	
Output resistance		Approximately 50 ohms.

TABLE 1-1 (cont)

Characteristic	Performance Requirement	Supplemental Information
DISPLAY		
Graticule		
Type	Internal	
Area	Eight divisions vertical by 10 divisions horizontal. Each division equals 0.8 centimeter.	
Illumination	Variable edge lighting.	
Phosphor	P31 standard. Others available on special order.	
Beam Finder	Limits display within graticule area when pressed.	
POWER SUPPLY		
Line Voltage	115 volts nominal or 230 volts nominal.	Nominal line voltage and voltage range selected by Line Voltage Selector. Given voltages apply when line voltage contains 2% or less harmonic distortion.
Voltage Ranges (AC, RMS)		
115-volts nominal	90 to 110 volts 104 to 126 volts 112 to 136 volts	
230-volts nominal	180 to 220 volts 208 to 252 volts 224 to 272 volts	
Line Frequency		48 to 62 hertz
Maximum Power Consumption		92 watts, one ampere at 60 hertz, 115-volt line

TABLE 1-2

ENVIRONMENTAL CHARACTERISTICS

Characteristic	Performance

NOTE

This instrument will meet the electrical characteristics given in Table 1-1 over the following environmental limits. Complete details on environmental test procedures, including failure criteria, etc., can be obtained from Tektronix, Inc. Contact your local Tektronix Field Office or representative.

Characteristic	Performance
Temperature	
Operating	−15°C to +55°C
Storage	−55°C to +75°C
Altitude	
Operating	15,000 feet maximum. Maximum operating temperature decreases by 1 °C per 1000 feet increase in amplitude above 5000 feet.
Storage	Tested to 50,000 feet
Humidity Operating and storage	Five cycles (120 hours) to 95% relative humidity referenced to MIL-E-16400F.
Vibration Operating and non-operating	15 minutes along each of the three major axes at a total displacement of 0.025-inch peak to peak (4 g at 55 Hz) with frequency varied from 10-55-10 Hz in one-minute cycles. Hold at 55 Hz for three minutes on each axis.
Shock Operating and non-operating	Two shocks at 30 g, one-half sine, 11 millisecond duration each direction along each major axis. Guillotine-type shocks. Total of 12 shocks.
Electro-magnetic Interference (EMI) as tested in MIL-I-6181D (when equipped with MOD 163D only)	
Radiated interference	Interference radiated from the instrument under test within the given limits from 150 kilohertz to 1000 megahertz (mesh filter installed).
Conducted interference	Interference conducted out of the instrument under test through the power cord within the given limits from 150 kilohertz to 25 megahertz.
Transportation	Meets National Safe Transit type of test when packaged as shipped from Tektronix, Inc.

TABLE 1-3

PHYSICAL

Characteristic	Information
Cooling	Safe operating temperature maintained by forced-air cooling. Automatic resetting thermal cutout protects instrument from overheating.
Finish	Anodized aluminum panel and chassis. Blue vinyl-coated cabinet.
Overall Dimensions, 453A (measured at maximum points)	
Height	7.2 inches (18.3 centimeters)
Width	12.6 inches (32.0 centimeters)
Length	20.7 inches (52.6 centimeters) including front cover; 22.4 inches (56.9 centimeters) with handle positioned for carrying.
Overall Dimensions, R453A (measured at maximum points)	
Height	7.0 inches (17.8 centimeters)
Width	19 inches (48.3 centimeters)
Length	17.4 inches (44.2 centimeters) behind front panel; 19.2 inches (48.8 centimeters) overall.

Characteristic	Information
Net Weight	
453A (includes front cover without accessories)	Approximately 30 pounds (13.6 kilograms).
R453A (without accessories)	Approximately 33.5 pounds (15.2 kilograms).

STANDARD ACCESSORIES

Standard accessories supplied with the 453A and R453A are listed in the Mechanical Parts List illustrations. For optional accessories available for use with this instrument, see the current Tektronix, Inc. catalog.

SECTION 3
CIRCUIT DESCRIPTION

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

Introduction

This section of the manual contains a description of the circuitry used in the 453A Oscilloscope. The description begins with a discussion of the instrument using the basic block diagram shown in Fig. 3-1. Then, each circuit is described in detail, using a detailed block diagram to show the interconnections between the stages in each major circuit and the relationship of the front-panel controls to the individual stages.

A complete block diagram is located in the Diagrams section at the rear of this manual. This block diagram shows the overall relationship between all of the circuits. Complete schematics of each circuit are also given in the Diagrams section. Refer to these diagrams throughout the following circuit description for electrical values and relationship.

BLOCK DIAGRAM

General

The following discussion is provided to aid in understanding the overall concept of the 453A before the individual circuits are discussed in detail. A basic block diagram of the 453A is shown in Fig. 3-1. Only the basic interconnections between the individual blocks are shown on this diagram. Each block represents a major circuit within this instrument. The number on each block refers to the complete circuit diagram which is located at the rear of this manual.

Signals to be displayed on the CRT are applied to either the CH 1 OR X and/or the CH 2 OR Y connectors. The input signals are then amplified by the Channel 1 Vertical Preamp and/or the Channel 2 Vertical Preamp circuits. Each Vertical Preamp circuit includes separate vertical deflection factor, position, input coupling, gain, variable attenuation, and balance controls. A trigger-pickoff stage in the Channel 1 Vertical Preamp circuit supplies a sample of the Channel 1 signal to the Trigger Preamp circuit or the CH 1 OUT connector. The Channel 2 Vertical Preamp circuit contains an invert feature to invert the Channel 2 signal as displayed on the CRT. The output of both Vertical Preamp circuits is connected to the Vertical Switching circuit. This circuit selects the channel(s) to be displayed. An output signal from this circuit is connected to the Z Axis Amplifier circuit to blank out the between-channel switching transients when in the chopped mode of operation. A trigger-pickoff stage at the output of the Vertical Switching circuit provides a sample of the displayed signal(s) to the Trigger Preamp circuit.

The output of the Vertical Switching circuit is connected to the Vertical Output Amplifier through the Delay Line. The Vertical Output Amplifier circuit provides the final amplification for the signal before it is connected to the vertical deflection plates of the CRT. This circuit includes the BEAM FINDER switch which compresses the vertical and horizontal deflection within the viewing area to aid in locating an off-screen display.

The Trigger Preamp circuit provides amplification for the internal trigger signal selected by the INT TRIG switch. This internal trigger signal is selected from either the Channel 1 Vertical Preamp circuit or the Vertical Switching circuit. Output from this circuit is connected to the A Trigger Generator circuit and the B Trigger Generator circuit.

The A and B Trigger Generator circuits produce an output pulse which initiates the sweep signal produced by the A or B Sweep Generator circuits. The input signal to the A and B Trigger Generator circuits can be individually selected from the internal trigger signal from the Trigger Preamp circuit, an external signal applied to the EXT TRIG INPUT connector, or a sample of the line voltage applied to the instrument. Each trigger circuit contains level, slope, coupling, and source controls.

The A Sweep Generator circuit produces a linear sawtooth output signal when initiated by the A Trigger Generator circuit. The slope of the sawtooth produced by the A Sweep Generator circuit is controlled by the A TIME/DIV switch. The operating mode of the A Sweep Generator circuit is controlled by the A SWEEP MODE switch. In the AUTO TRIG position, the absence of an adequate trigger signal causes the sweep to free run. In the NORM TRIG position, a horizontal sweep is presented only when correctly triggered by an adequate trigger signal. The SINGLE SWEEP position allows one (and only one) sweep to be initiated after the circuit is reset with the RESET button. The A Sweep Generator circuit also produces an unblanking gate signal to unblank the CRT so the display can be pre-

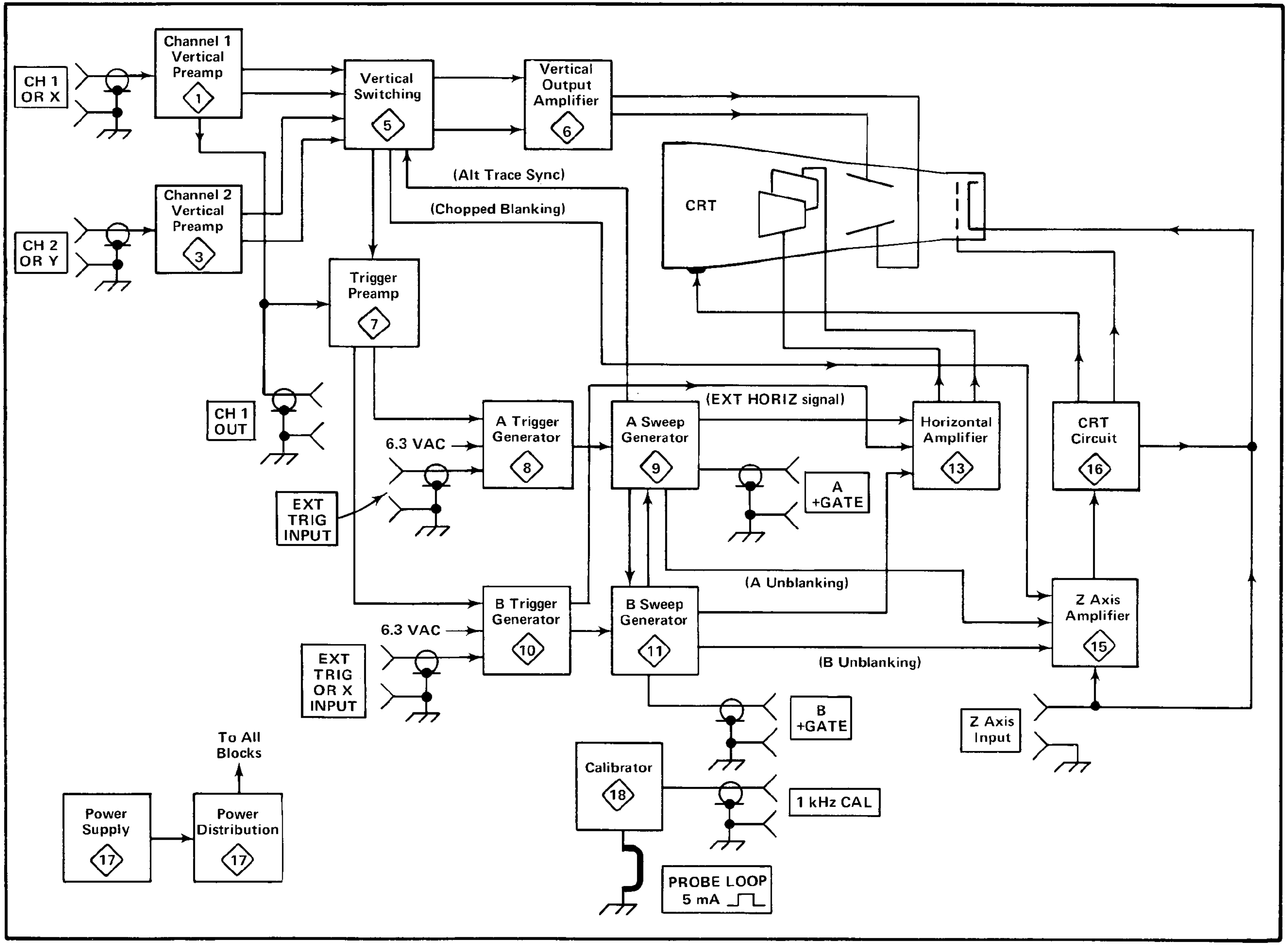

Fig. 3-1. Basic block diagram of 453A.

sented. This gate signal is coincident with the sawtooth produced by the A Sweep Generator circuit. A gate signal, which is also coincident with the sawtooth, is available at the A GATE connector on the side panel. The A Sweep Generator circuit also produces an alternate sync pulse, which is connected to the Vertical Switching circuit. This pulse switches the display between channels at the end of each sweep when the MODE switch is in the ALT position.

The B Sweep Generator circuit is basically the same as the A Sweep Generator circuit. However, this circuit only produces a sawtooth output signal after a delay time determined by the A TIME/DIV switch and the DELAY-TIME MULTIPLIER dial. If the B SWEEP MODE switch is set to the B STARTS AFTER DELAY TIME position, the B Sweep Generator begins to produce the sweep immediately following the selected delay time. If this switch is in the TRIGGERABLE AFTER DELAY TIME position, the B Sweep Generator circuit does not produce a sweep until it receives a trigger pulse from the B Trigger Generator circuit after the selected delay time.

The output of either the A or B Sweep Generator circuit is amplified by the Horizontal Amplifier circuit to produce horizontal deflection for the CRT in all positions of the HORIZ DISPLAY switch except X-Y. This circuit contains a 10 times magnifier to increase the sweep rate ten times in any A or B TIME/DIV switch position. Other horizontal deflection signals can be connected to the Horizontal Amplifier by using the X-Y mode of operation. When the B SOURCE switch is set to INT, the X signal is connected to the Horizontal Amplifier circuit through the CH 1 Vertical Preamp circuit, the Trigger Preamp circuit and the B Trigger Generator circuit (HORIZ DISPLAY switch set to X-Y, B SOURCE switch set to INT, and the INT TRIG switch set to CH 1 OR X-Y). In the EXT or EXT ÷ 10 position of the B SOURCE switch, the X signal is obtained from a signal connected to the B EXT TRIG OR X INPUT connector.

The Z Axis Amplifier circuit determines the CRT intensity and blanking. The Z Axis Amplifier circuit sums the current inputs from the INTENSITY control, Vertical Switching circuit (chopped blanking), A and B Sweep Generator circuits (unblanking), and the external Z AXIS INPUT binding post. The output level of the Z Axis Amplifier circuit controls the trace intensity through the CRT Circuit. The CRT Circuit provides the voltages and contains the controls necessary for operation of the cathode-ray tube.

The Power Supply circuit provides the low-voltage power necessary for operation of this instrument. This voltage is distributed to all of the circuits in this instrument as shown by the Power Distrubution diagram. The Calibrator circuit produces a square-wave output with accurate amplitude and frequency which can be used to check the calibration of the instrument and the compensation of probes. The PROBE LOOP provides an accurate current source for calibration of current-measuring probe systems.

CIRCUIT OPERATION

General

This section provides a detailed description of the electrical operation and relationship of the circuits in the 453A. The theory of operation for circuits unique to this instrument is described in detail in this discussion. Circuits which are commonly used in the electronics industry are not described in detail. If more information is desired on these commonly used circuits, refer to the following textbooks:

Tektronix Circuit Concepts Books (order from your local Tektronix Field Office or representative).

Cathode-Ray Tubes, Tektronix Part No. 062-0852-01.

Horizontal Amplifier Circuits, Tektronix Part No. 062-1144-00.

Oscilloscope Trigger Circuits, Tektronix Part No. 062-1056-00.

Power Supply Circuits, Tektronix Part No. 062-0888-01.

Sweep Generator Circuits, Tektronix Part No. 062-1098-01.

Vertical Amplifier Circuits, Tektronix Part No. 062-1145-00.

Phillip Cutler, "Semiconductor Circuit Analysis", McGraw-Hill, New York, 1964.

Lloyd P. Hunter (Ed.), "Handbook of Semiconductor Electronics", second edition, McGraw-Hill, New York, 1962.

Jacob Millman and Herbert Taub, "Pulse, Digital, and Switching Waveforms", McGraw-Hill, New York, 1965.

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

NOTE

All references to direction of current in this manual are in terms of conventional current; i.e., from plus to minus.

CHANNEL 1 VERTICAL PREAMP

General

Input signals for vertical deflection on the CRT can be connected to the CH 1 OR X connector. In the X-Y mode of operation, this input signal provides the horizontal (X-axis) deflection (HORIZ DISPLAY switch set to X-Y, B SOURCE switch set to INT, and INT TRIG switch set to CH 1 OR X). The Channel 1 Vertical Preamp circuit provides control of input coupling, vertical deflection factor, balance, vertical position, and vertical gain. It also contains a stage to provide a sample of the Channel 1 input signal to the Trigger Preamp circuit to provide internal triggering from the Channel 1 signal only. Fig. 3-2 shows a detailed block diagram of the Channel 1 Vertical Preamp circuit. A schematic of this circuit is shown on diagram 1 at the rear of this manual.

Input Coupling

Input signals applied to the CH 1 OR X connector can be AC-coupled, DC-coupled, or internally disconnected. When Input Coupling switch S1 is in the DC position, the input signal is coupled directly to the Input Attenuator stage. In the AC position, the input signal passes through capacitor C1. This capacitor prevents the DC component of the signal from passing to the amplifier. The GND position opens the signal path and the input to the amplifier is connected to ground. This provides a ground reference without the need to disconnect the applied signal from the CH 1 connector. Resistor R2, connected across the input coupling switch, allows C1 to be precharged in the GND position so the trace remains on screen when switched to the AC position with a high DC level applied.

Input Attenuator

The effective overall Channel 1 deflection factor of the 453A is determined by the CH 1 VOLTS/DIV switch. In all positions of the CH 1 VOLTS/DIV switch above 20 mV, the basic deflection factor of the Vertical Deflection System is 20 millivolts per division of CRT deflection. To increase this basic deflection factor to the values indicated on the front panel, precision attenuators are switched into the circuit. In the 5 and 10 mV positions, input attenuation is not used. Instead, the gain of the Feedback Amplifier is changed to decrease the deflection factor (see Feedback Amplifier discussion).

For the CH 1 VOLTS/DIV switch positions above 20 mV, the attenuators are switched into the circuit singly or in pairs to produce the vertical deflection factor indicated on the front panel. These attenuators are frequency-compensated voltage dividers. For DC and low-frequency signals, they are primarily resistance dividers and the voltage attenuation is determined by the resistance ratio in the circuit. The reactance of the capacitors in the circuit is so high at low frequencies that their effect is negligible. How-

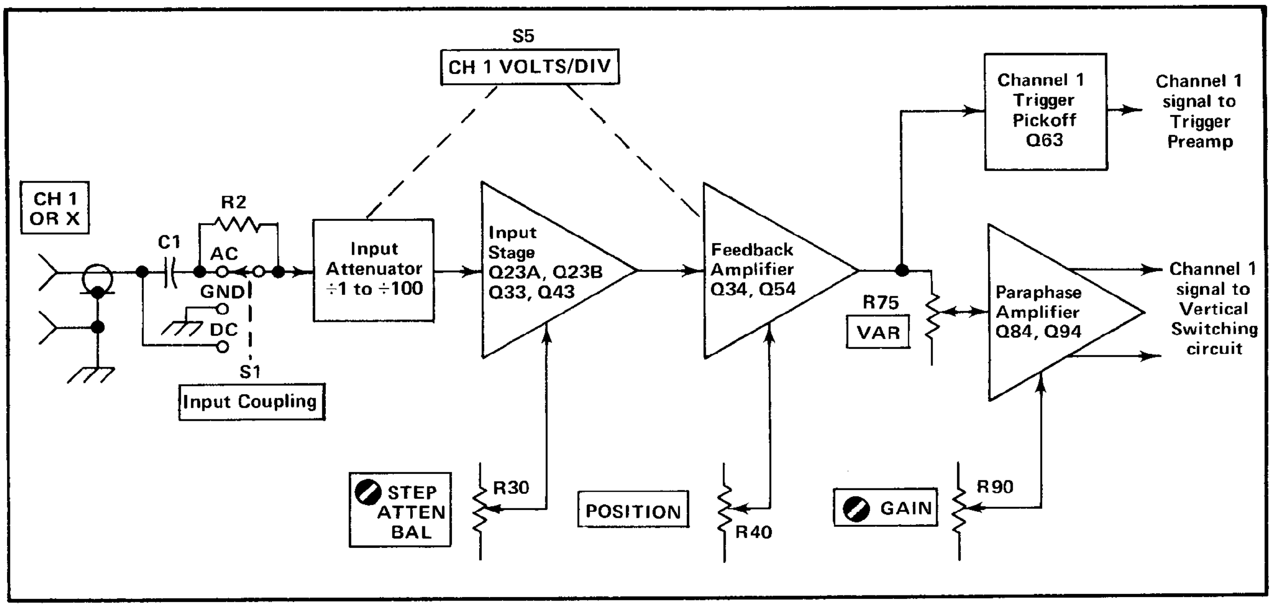

Fig. 3-2. Channel 1 Vertical Preamp detailed block diagram.

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ever, at higher frequencies, the reactance of the capacitors decreases and the attenuator becomes primarily a capacitance voltage divider.

In addition to providing constant attenuation at all frequencies within the bandwidth of the instrument, the Input Attenuators are designed to maintain the same input RC characteristics (one megohm X 20 pF) for each setting of the CH 1 VOLTS/DIV switch. Each attenuator contains an adjustable series capacitor to provide correct attenuation at high-frequencies and an adjustable shunt capacitor to provide correct input capacitance.

Input Stage

The Channel 1 signal from the Input Attenuator is connected to the Input Stage through the network C17-C18-C20-R16-R17-R18-R19-R20-R21. R16, R17, and R20 provide the input resistance for this stage. These resistors are part of the attenuation network at all CH 1 VOLTS/DIV switch positions. Variable capacitor C17 adjusts the basic input time constant for a nominal value of one megohm X 20 picofarads. The divider action of R16-R17-R20 allows about 98% of DC and low-frequency signals to pass to the gate of FET (field-effect transistor) Q23A. C18, with the stray capacitance in the circuit, forms an AC divider which maintains this same voltage division for high-frequency signals. R18 limits the current drive to the gate of Q23A. Diode CR18 protects the circuit by clamping the gate of Q23A at about −12.5 volts if a high-amplitude negative signal is applied to the CH 1 OR X connector. Over-voltage protection for high-amplitude positive signals is provided by forward conduction of Q23A. This current path is through R23, L23, CR36, and CR37.

FET Q23B is a constant current source for Q23A and also provides temperature compensation for Q23A. STEP ATTEN BAL adjustment R30 varies the gate level of Q23B to provide a zero-volt level at the emitter of Q34 with no signal applied. With a zero-volt level at the emitter of Q34, the trace position will not change when switching between the 5, 10, and 20 mV positions of the CH 1 VOLTS/DIV switch.

DC and low-frequency signals are connected from the source of Q23A to the Feedback Amplifier through R23, L23, Q33, and R39. L23 isolates the base of Q33 from the source of FET Q23A. Diodes CR34-CR35 and CR36-CR37 limit the dynamic range of the signal at the base of Q33 and prevent the following stages from being damaged by a large voltage swing at the source of Q23A. The signal path for high-frequency signals is through C23, Q43, and C39. High-frequency signals at the emitter of Q43 are connected to the base of Q33 through C38. This allows Q33 to be driven at high frequencies while preventing the base circuitry of Q33 from capacitively loading the input FET, Q23A. C38 is selected to provide the same amplitude AC and DC signal at the base of Q33. C24 couples high-frequency information to the junction of R25-R26, thereby reducing the loading at the base of Q43.

Feedback Amplifier

Feedback Amplifier Q34 and Q54 changes the overall gain of the Channel 1 Vertical Preamp to provide the correct deflection factor in the 5 and 10 mV positions of the CH 1 VOLTS/DIV switch. Gain of this stage is determined by the ratio of R46-R50 to R43, R44, or R45. In the 5 mV position of the CH 1 VOLTS/DIV switch, the network C43A-C43B-C43C-C43D-C43E-L43A-R43A-R43C-R43E is connected into the emitter circuit of Q34. The ratio between R46-R50 and R43 provides a gain of about 10. C43A, C43C, L43A, and R43C are adjustable to provide high-frequency peaking for the network. In the 10 mV position, conditions are the same except that the network C44A-C44B-C44C-L44A-R44A-R44B-R44C is connected into the circuit in place of the previous network. The ratio between R46-R50 and R44 provides a gain of about five times in this CH 1 VOLTS/DIV switch position. C44C and R44C provide high frequency peaking for this network. In the 20 mV and higher CH 1 VOLTS/DIV switch positions, the gain of the Feedback Amplifier is about 2.5 as established by the ratio between R46-R50 and R45. Adjustable capacitor C45A provides high-frequency peaking for the Feedback Amplifier stage. C49 and R49 provide high-frequency damping for the circuit. As mentioned previously, the STEP ATTEN BAL adjustment is set to provide zero volts at the emitter of Q34 when the input is at zero volts. Since there is no voltage difference across emitter resistor R43, R44, or R45, changing the value of the resistance does not change the current in the circuit. Therefore, the trace position will not change when switching between the 5 mV, 10 mV, and 20 mV positions of the CH 1 VOLTS/DIV switch if the STEP ATTEN BAL control is correctly adjusted.

Vertical position of the trace is determined by the setting of POSITION control R40. This control changes the current into the emitter of Q34, a low-impedance point, which results in negligible voltage change at this point. However, the change in current from the POSITION control produces a resultant DC voltage at the output of the Feedback Amplifier stage to change the vertical position of the trace. CH 1 Position Center adjustment R55 is adjusted to provide a centered display when the Channel 1 POSITION control is centered (with a zero-volt DC input level).

Zener diode VR53 provides a low-impedance current source for Q54. Variable capacitor C54 provides feedback from the collector to the base of Q54 for amplifier stabilization. The output signal from the Feedback Amplifier stage is connected to the Paraphase Amplifier stage and the Channel 1 Trigger Pickoff stage.

Channel 1 Trigger Pickoff

The signal at the collector of Q54 in the Feedback Amplifier stage is connected to the Channel 1 Trigger Pickoff stage through CR58 and R59. This sample of the Channel 1 input signal provides internal triggering from the Channel 1 signal or X-axis deflection for X-Y operation. Q63 is connected as an emitter follower to provide isolation between the Trigger Preamp circuit and the Feedback Amplifier stage. It also provides a minimum load for the Feedback Amplifier stage and a low output impedance to the Trigger Preamp circuit. CR58 provides thermal compensation for Q63. CH 1 Trigger DC Level adjustment R60 sets the DC level at the base of Q63 for a zero-volt DC output level from the Trigger Preamp circuit when the Channel 1 trace is centered vertically. Output from the Channel 1 Trigger Pickoff stage is connected to the Trigger Preamp circuit through INT TRIG switch S230B.

Paraphase Amplifier

The output signal from the Feedback Amplifier stage is connected to the Paraphase Amplifier stage through VAR (variable) control R75. When the VAR control is set to the calibrated position (fully clockwise), R75 is effectively by-passed and maximum signal current reaches the base of Q84. Switch S75, ganged with the VAR control, is open and the UNCAL neon bulb is disconnected. As the VAR control is rotated counterclockwise from the calibrated detent, S75 is closed and UNCAL light DS75 ignites to indicate that the vertical deflection factor is uncalibrated. The signal applied to the base of Q84 is continuously reduced as the VAR control is rotated counterclockwise.

Q84 and Q94 are connected as a common-emitter phase inverter (paraphase amplifier) to convert the single-ended input signal to a push-pull output signal. Gain of this stage is determined by the emitter degeneration. As the resistance between the emitters of Q84 and Q94 increases, emitter degeneration increases also to result in less gain through the stage. GAIN adjustment R90 varies the resistance between the emitters to control the overall gain of the Channel 1 Vertical Preamp.

CHANNEL 2 VERTICAL PREAMP

General

The Channel 2 Vertical Preamp circuit is basically the same as the Channel 1 Vertical Preamp circuit. Only the differences between the two circuits are described here. Portions of this circuit not described in the following description operate in the same manner as for the Channel 1 Vertical Preamp circuit (corresponding circuit numbers assigned in the 100-199 range). Fig. 3-3 shows a detailed block diagram of the Channel 2 Vertical Preamp circuit. A schematic of this circuit is shown on diagram 3 at the rear of this manual.

Feedback Amplifier

Basically, the Channel 2 Feedback Amplifier operates as described for Channel 1. However, the Channel 2 Vertical Preamp circuit does not have a trigger pickoff stage. To provide a load at the collector of Q154 similar to the load the Channel 1 Trigger Pickoff stage provides at the collector of Q54, C159 and R159 are connected into the circuit.

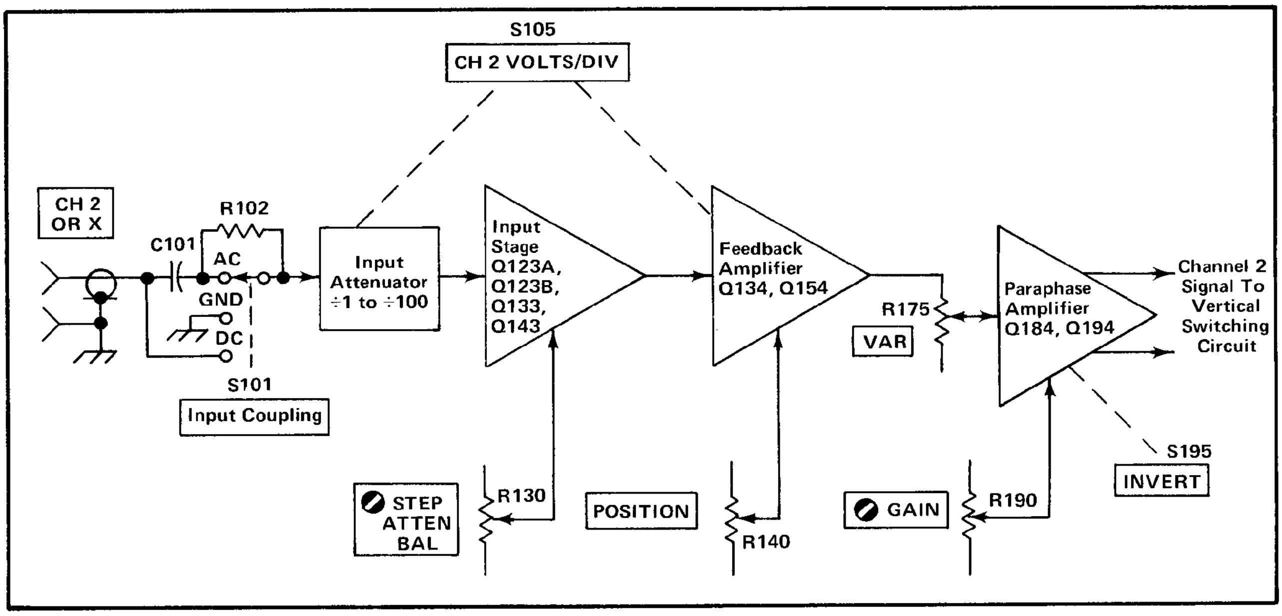

Fig. 3-3. Channel 2 Vertical Preamp detailed block diagram.

Paraphase Amplifier

The basic Channel 2 Paraphase Amplifier configuration and operation is the same as for Channel 1. However, INVERT switch S195 has been added in the Channel 2 circuit. This switch allows the displayed signal from Channel 2 to be inverted.

VERTICAL SWITCHING

General

The Vertical Switching circuit determines if the CH 1 and/or the CH 2 Vertical Preamp output signal is connected to the Vertical Output Amplifier circuit (through the Delay Line Driver and Delay Line stages). In the ALT and CHOP positions of the MODE switch, both channels are alternately displayed on a shared-time basis. Fig. 3-4 shows a detailed block diagram of the Vertical Switching circuit. A schematic of this circuit is shown on diagram 5 at the rear of this manual.

Diode Gates

The Diode Gates, consisting of four diodes each, can be thought of as switches which allow either of the Vertical Preamp output signals to be coupled to the Vertical Output Amplifier. CR201 through CR204 control the Channel 1 output and CR206 through CR209 control the Channel 2 output. These diodes are in turn controlled by the Switching Multivibrator for dual-trace displays, or by the MODE switch for single-trace displays.

CH 1. In the CH 1 position of the MODE switch, −12 volts is applied to the junction of CR207-CR208 in the Channel 2 Diode Gate through R227 (see simplified diagram in Fig. 3-5). This forward biases CR207-CR208 and reverse biases CR206-CR209, since the input to the Delay-Line Driver stage is at about −5.8 volts. CR206-CR209 block the Channel 2 signal so it cannot pass to the Delay-Line Driver stage. At the same time, in the Channel 1 Diode Gate, CR202-CR203 are connected to ground through R212. CR202-CR203 are held reverse biased while CR201-CR204 are forward biased. Therefore, the Channel 1 signal passes to the Delay-Line Driver stage.

CH 2. In the CH 2 position of the MODE switch, the above conditions are reversed. CR202-CR203 are connected to −12 volts through R217 and CR207-CR208 are connected to ground through R222. The Channel 1 Diode Gate blocks the signal and the Channel 2 Diode Gate allows it to pass.

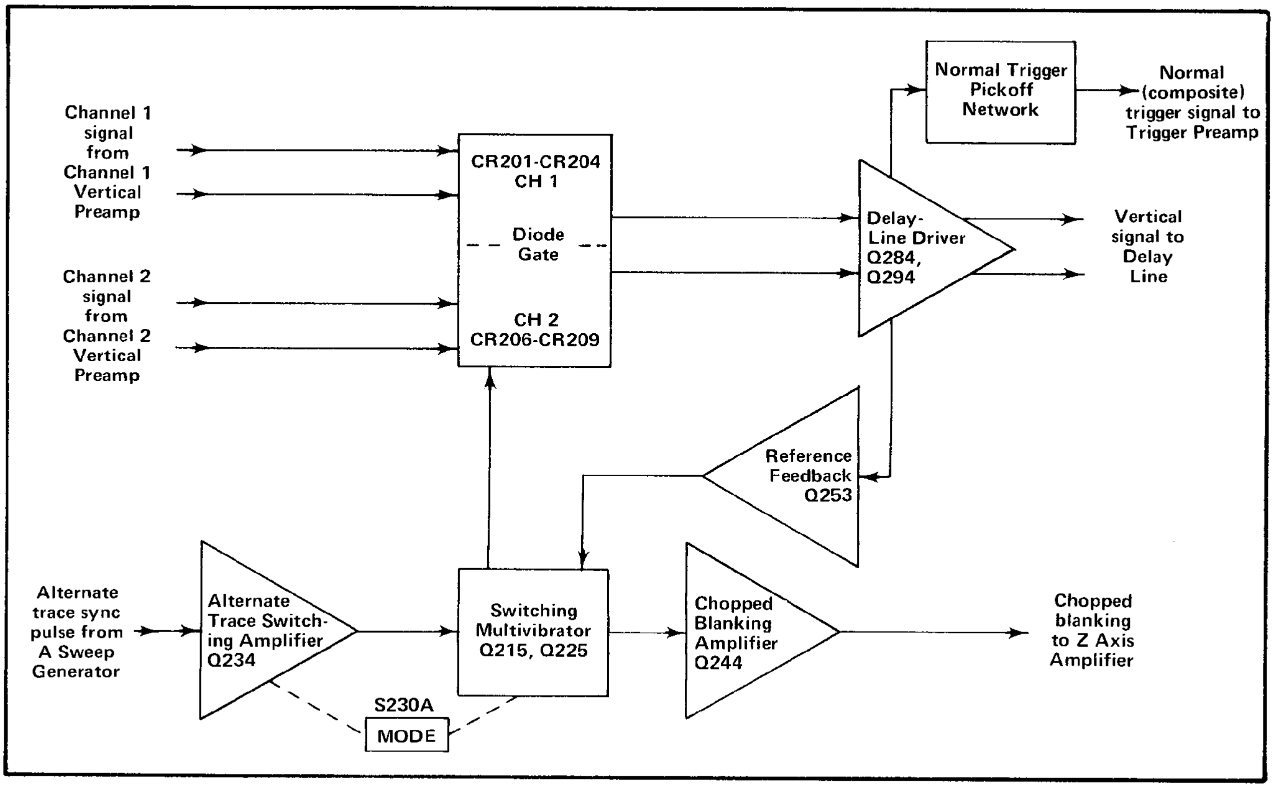

Fig. 3-4. Vertical Switching detailed block diagram.

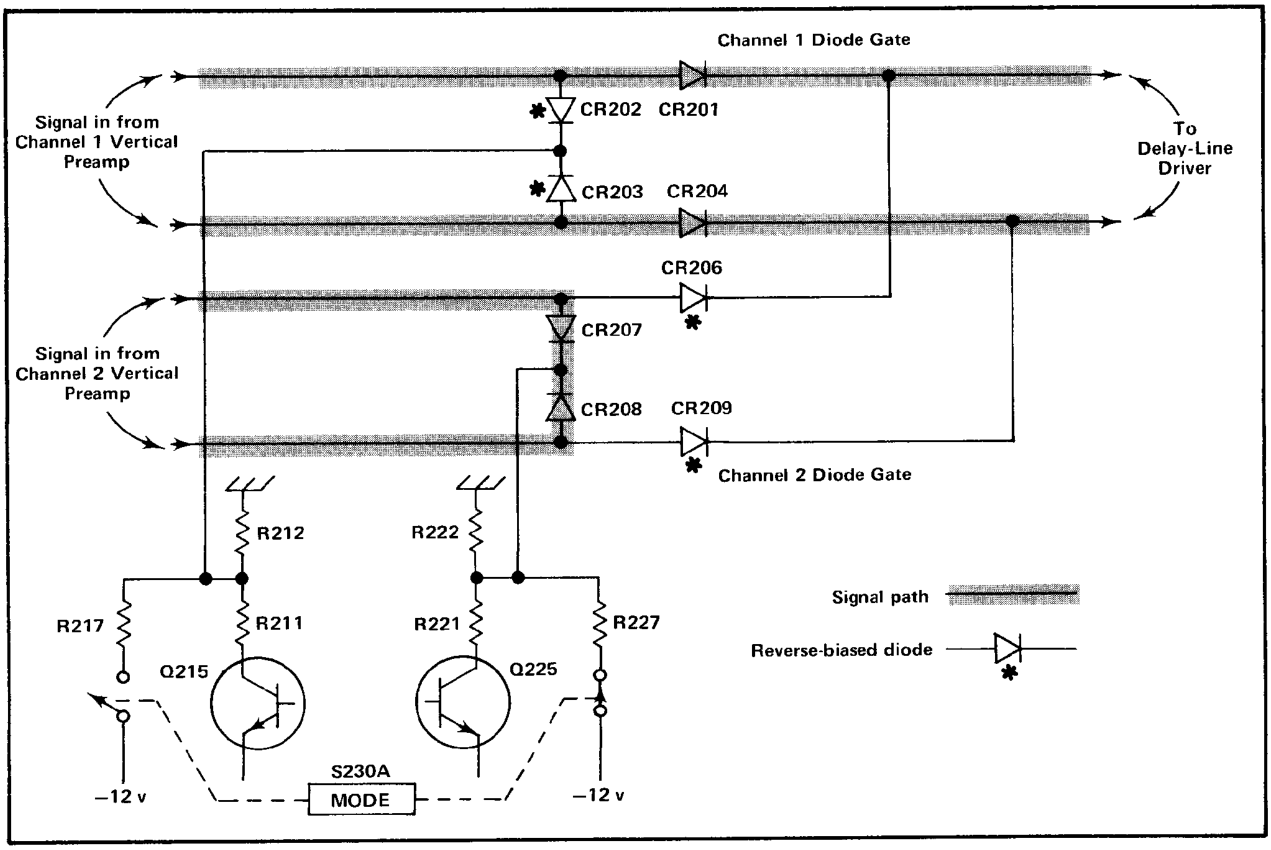

Fig. 3-5. Effect of Diode Gates on signal path (simplified Vertical Switching diagram). Conditions shown for CH 1 position of MODE switch.

Switching Multivibrator

ALT. In this mode of operation, the Switching Multivibrator operates as a bistable multivibrator. In the ALT position of the MODE switch, −12 volts is applied to the emitter of Alternate Trace Switching Amplifier stage Q234 by the MODE switch. Q234 is forward biased to supply current to the "on" Switching-Multivibrator transistor through R234, and CR218 or CR228. For example if Q225 is conducting, current is supplied to Q225 through R228. The current flow through collector resistors R221 and R222 drops the CR207-CR208 cathode level negative so the Channel 2 Diode Gate is blocked as for Channel 1 only operation. The signal passes through the Channel 1 Diode Gate to the Delay-Line Driver stage.

The alternate-trace sync pulse is applied to Q234 at the end of each sweep. This negative-going sync pulse momentarily interrupts the current through Q234 and both Q215 and Q225 are turned off. When Q234 turns on again after the alternate-trace sync pulse, the charge on C218 determines whether Q215 or Q225 conducts. For example, when Q225 was conducting, C218 was charged negatively on the CR218 side to the emitter level of Q215 and positively on the CR228 side. This charge is stored while Q234 is off and holds the emitter of Q215 more negative than the emitter of Q225. When both Q215 and Q225 were off the voltage at their bases became approximately equal. Now when Q234 comes back on, the transistor with the most negative emitter will start conducting first with the resulting negative movement at its collector holding the other transistor off. The conditions described previously are reversed; now the Channel 1 Diode Gate is reversed biased and the Channel 2 signal passes through the Channel 2 Diode Gate.

Reference Feedback stage Q253 provides common-mode voltage feedback from the Delay-Line Driver stage to allow the diode gates to be switched with a minimum amplitude switching signal. The emitter level of Q253 is connected to the junction of the Switching Multivibrator collector resistors, R211-R212 and R221-R222 through CR213 or CR223. The collector level of the "on" Switching Multivibrator transistor is negative and either CR213 or CR223 is forward biased. This clamps the cathode level of the forward-biased shunt diodes in the applicable Diode Gate about 0.5 volt more negative than the emitter level of Q253. The level at the emitter of Q253 follows the average voltage level at the emitters of the Delay-Line Driver stage. The shunt diodes are clamped near their switching level and therefore they can be switched very fast with a minimum amplitude switching signal. This maintains about the same current through the Diode Gate shunt diodes so they can be switched with a minimum amplitude switching signal, regardless of the deflection signal at the anodes of the shunt diodes.

CHOP. In the CHOP position of the MODE switch, the Switching Multivibrator free runs as an astable multivibrator at about a 500-kHz rate. The emitters of Q215 and Q225 are connected to −12 volts through R218 and R228. At the time of turn-on, one of the transistors begins to conduct; for example, Q225. Q225 conducts the Channel 2 current and prevents the Channel 2 signal from reaching the Delay-Line Driver stage. Meanwhile, the Channel 1 Diode Gate passes the Channel 1 signal to the Delay-Line Driver.

The frequency-determining components in the CHOP mode are C218-R218-R228. Switching action occurs as follows: When Q225 is on, C218 attempts to charge to −12 volts through R218. The emitter of Q215 slowly goes toward −12 volts as C218 charges. The base of Q215 is held at a negative point determined by voltage divider R215-R224 between −12 volts and the collector of Q225. When the emitter voltage of Q215 reaches a level slightly more negative than its base, Q215 conducts. The collector level of Q215 goes negative and pulls the base of Q225 negative also, through divider R214-R225, to cut Q225 off and allow Q215 to conduct. This action switches the Diode Gate stage to connect the opposite half to the Delay-Line Driver stage. Again C218 begins to charge towards −12 volts but this time through R228. The emitter of Q225 slowly goes negative as C218 charges, until Q225 turns on. Q215 shuts off and the cycle begins again.

Diodes CR218 and CR228 have no effect in the CHOP mode. Q253 operates the same in CHOP as in ALT, to allow the Diode Gates to be switched with a minimum signal level.

The Chopped Blanking Amplifier stage, Q244, provides an output pulse to the Z Axis Amplifier which blanks out the transition between the Channel 1 trace and the Channel 2 trace. When the Switching Multivibrator changes states, the current through T241 momentarily changes. A negative pulse is applied to the base of Q244, to turn it off. The width of the pulse at the base of Q244 is determined by R241 and C241. Q244 clips the signal applied to its base, and the positive-going output pulse, which is coincident with trace switching, is applied to the Z Axis Amplifier circuit through R245.

ADD. In the ADD position of the MODE switch, the Diode Gate stage allows both signals to pass to the Delay-Line Driver stage. The Diode Gates are both held on by −12 volts applied to their cathodes through R260 and R270. Since both signals are applied to the Delay-Line Driver stage, the output signal is the algebraic sum of the signals on both Channel 1 and 2.

Delay-Line Driver

Output of the Diode Gate stage is applied to Delay-Line Driver stage Q284 and Q294. Q284 and Q294 are connected as operational amplifiers with feedback provided by R268-R269 and R278-R279 and the delay-line compensation network. The delay-line compensation network, C261-C262-C263-C264-C265-C266-R261-R262-R264-R265, provides high-frequency compensation for the Delay Line. R289-C289 in the collector circuit of Q284-Q294 improve the high-frequency reverse termination of the Delay Line. Output of the Delay-Line Driver stage is connected to the Vertical Output Amplifier through the Delay Line.

Normal Trigger Pickoff Network

The trigger signal for NORM trigger operation is obtained from the collector of Q284. Normal Trigger DC Level adjustment R285 sets the DC level of the normal trigger output signal so the sweep is triggered at the zero-level of the displayed signal when the Triggering LEVEL control is set to 0. The normal trigger signal is connected to the Trigger Preamp through S230B. R294 and R295 provide the same DC load for Q294 as provided to Q284 by the Normal Trigger Pickoff Network.

VERTICAL OUTPUT AMPLIFIER

General

The Vertical Output Amplifier circuit provides the final amplification for the vertical deflection signal. This circuit includes the Delay Line and the BEAM FINDER switch. The BEAM FINDER switch compresses an overscanned display within the viewing area when pressed in. Fig. 3-6 shows a detailed block diagram of the Vertical Output Amplifier circuit. A schematic of this circuit is shown on diagram 6 at the rear of this manual.

Delay Line

Delay Line DL301 provides approximately 140 nanoseconds delay for the vertical signal to allow the Sweep Generator circuits time to initiate a sweep before the vertical signal reaches the vertical deflection plates. This allows the instrument to display the leading edge of the signal originating the trigger pulse when using internal triggering.

Phase Equalizer Network

The Phase Equalizer Network is comprised of L301-L302-L311-C301-C302-C311-C312. This network compen-

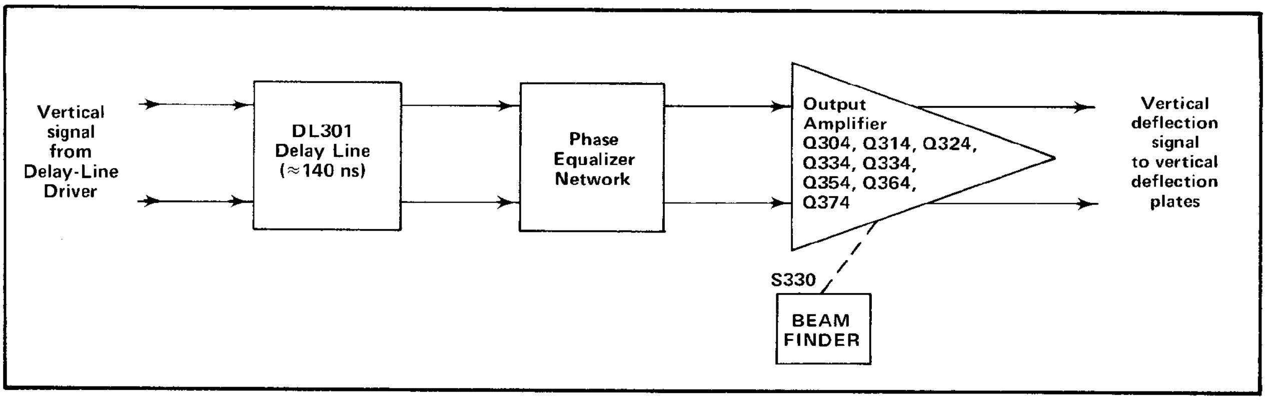

Fig. 3-6. Vertical Output Amplifier detailed block diagram.

sates for the phase distortion of the Delay Line. C303-R303 and C313-R313 in series with the base-emitter resistance of Q304 and Q314 provide the forward termination for the Delay Line.

Output Amplifier

Q304 and Q314 are connected as common-base amplifiers to provide a low input impedance to properly terminate the Delay Line (along with the Phase Equalizer Network). It also provides isolation between the Delay Line and the following stages.

The output of Q304 and Q314 is connected to the bases of Q324 and Q334. The network C326-C327-C328-C336-R328 provides high-frequency peaking to compensate for the capacitive loading of the deflection plates on the output stage. C328, C336, and R328 are adjustable to provide optimum response. BEAM FINDER switch S330 reduces the quiescent current of Q324 and Q334, when pressed, to compress an off-screen display within the graticule area. Normally, the collector current for Q324 and Q334 is supplied through R321, R322 and the parallel combination of R323 and R333. When S330 is pressed, −12-volts is connected to the collector circuit of Q324 and Q334 through R332. This reduces the collector potential of Q324 and Q334 to limit their dynamic range and compress the display vertically within the graticule area. Although this compressed display is nonlinear, it provides a method of locating a signal that is off screen vertically due to incorrect positioning or deflection factor.

Q344 and Q354 amplify the output of Q324 and Q334. The signal at the collectors of Q344 and Q354 is applied to the output transistors, Q364 and Q374, through C344-R344-VR344, C354-R354-VR354, and T357. VR344 and VR354 prevent saturation of Q344 and Q354 to improve the recovery of the Vertical Output Amplifier circuit when large signals deflect the display off screen. T357 provides high-frequency balance for the Output Amplifier stage. Q364 and Q374 provide the output signal voltage to drive the CRT vertical deflection plates. LR367 and LR377 provide damping for the leads connecting the output signal to the deflection plates.

TRIGGER PREAMP

General

The Trigger Preamp circuit amplifies the internal trigger signal to the level necessary to drive the A and B Trigger Generator circuits. Input signal for the Trigger Preamp circuit is either a sample of the signal applied to Channel 1 or a sample of the composite vertical signal from the Vertical Switching circuit. Fig. 3-7 shows a detailed block diagram of the Trigger Preamp circuit. A schematic of this circuit is shown on diagram 7 at the rear of this manual.

Input Circuitry

The internal trigger signal from the Vertical Deflection System is connected to the Trigger Preamp through INT TRIG switch S230B. When the INT TRIG switch is in the NORM position, the trigger signal is a sample of the composite vertical signal in the Vertical Switching circuit. This signal is obtained from the collector of Q284 and is a sample of the displayed channel (or channels for dual-trace operation). Since the signal source follows the dual-trace switching stage, the NORM trigger signal also includes the chopped switching transients when operating in the CHOP mode. When the INT TRIG switch is in the NORM position, the CH 1 lights DS400 and DS401 are disconnected. Also, the sample of the Channel 1 signal is connected to the CH 1 OUT connector. This output signal can be used to monitor Channel 1 or it can be used to cascade with Channel 2 to provide a one millivolt/division minimum deflection factor (with reduced bandwidth).

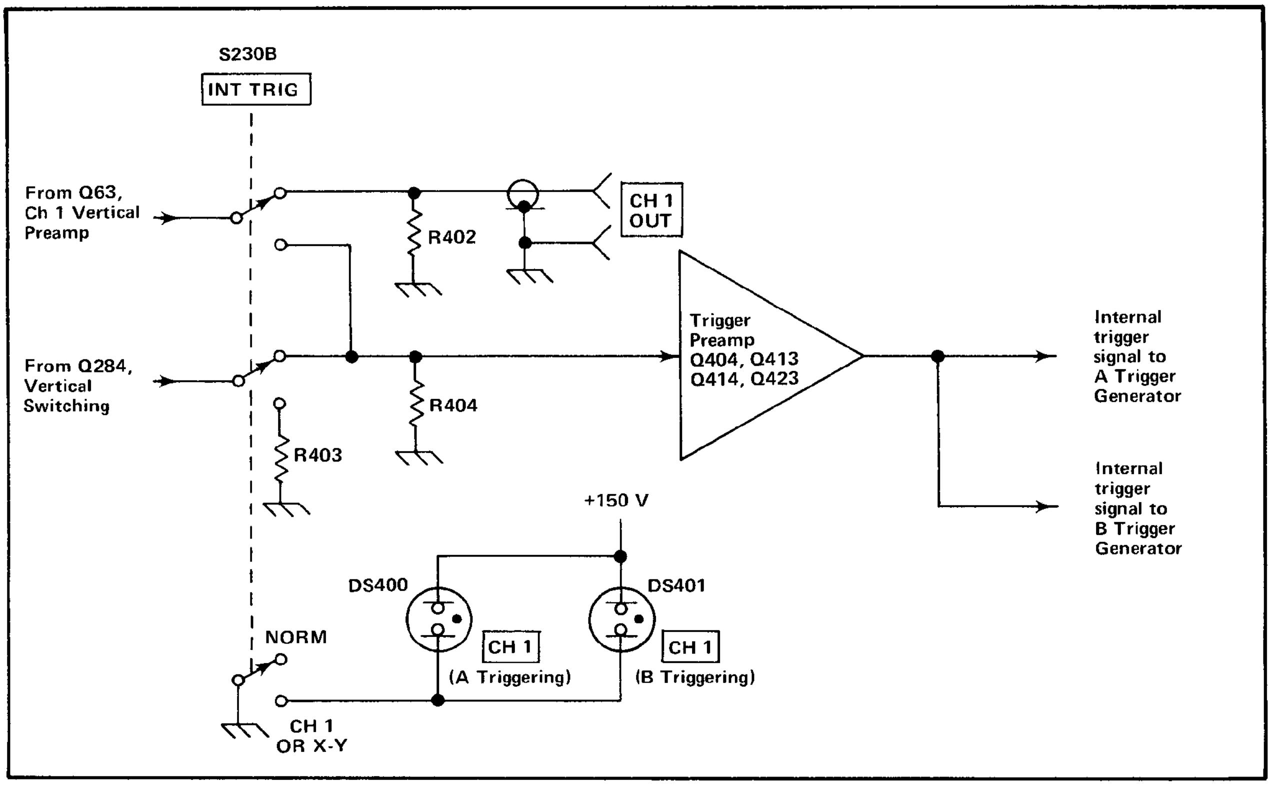

Fig. 3-7. Trigger Preamp detailed block diagram.

In the CH 1 OR X-Y position of the INT TRIG switch, the internal trigger signal is obtained from the emitter of Q63 in the CH 1 Vertical Preamp circuit. Now, the internal trigger signal is a sample of only the signal applied to the CH 1 OR X connector. The CH 1 lights are turned on to indicate that the INT TRIG switch is in the CH 1 OR X-Y position and the CH 1 OUT connector is disconnected from the circuit.

R402, R403, and R404 terminate the coaxial cables from the trigger pickoff stages to provide a constant load for these stages. In the NORM position of the INT TRIG switch, the NORM trigger signal from the Vertical Switching circuit is terminated at the input to the amplifier by R404. The CH 1 OR X-Y trigger signal from the CH 1 Vertical Preamp circuit is terminated at the CH 1 OUT connector by R402. In the CH 1 OR X-Y position, the CH 1 OR X-Y trigger signal is terminated at the input to the amplifier by R404, and the NORM trigger signal is terminated by R403.

Amplifier Circuitry

The internal trigger signal selected by the INT TRIG switch is connected to the base of Q404. Transistor Q404 converts the trigger voltage signal at its base to a current drive for the remainder of the Trigger Preamp. CR408 in the emitter circuit of Q404 provides thermal compensation for the amplifier.

The signal current at the collector of Q404 is connected to the base of Q414. Q413, Q414, and Q423 are connected as a current-driven, voltage-output operational amplifier. The amplified signal at the collector of Q414 is connected directly to the base of Q413, and to the base of Q423 through zener diode VR421. This zener diode provides a DC voltage drop while the signal is connected to the base of Q423 with minimum attenuation. Q413 and Q423 are connected as emitter followers in the complementary symmetry amplifier configuration. This configuration overcomes the basic limitation of emitter followers; inability to provide equal response to both positive- and negative-going portions of a signal. This is remedied in this configuration by using an NPN transistor for one emitter follower, Q413, and a PNP transistor for the other emitter follower, Q423. Since Q413 is an NPN transistor, it responds best to positive-going signals and Q423, being a PNP transistor responds best to negative-going signals. The result is a circuit which has equally fast response to both positive- and negative-going trigger signals while maintaining a low output impedance. Feedback from the output of the Trigger Preamp circuit is connected to the base of Q414 through R419. This feedback provides more linear operation. Total overall gain of the Trigger Preamp is about 10. The amplified internal trigger signal is connected to the A and B SOURCE switches through R427 and R429.

A TRIGGER GENERATOR

General

The A Trigger Generator circuit produces trigger pulses to start the A Sweep Generator circuit. These trigger pulses are derived either from the internal trigger signal from the Vertical Deflection System, an external signal connected to the EXT TRIG INPUT connector, or a sample of the line voltage applied to the instrument. Controls are provided in this circuit to select trigger level, slope, coupling, and source. Fig. 3-8 shows a detailed block diagram of the A Trigger Generator circuit. A schematic of this circuit is shown on diagram 8 at the rear of this manual.

Trigger Source

The A SOURCE switch, S430, selects the source of the A trigger signal. Three trigger sources are available; internal, line, and external. A fourth position of the A SOURCE switch provides 10 times attenuation for the external trigger signal.

The internal trigger signal is obtained from the Vertical Deflection System through the Trigger Preamp circuit. This signal is a sample of the signal(s) applied to the CH 1 OR X and/or CH 2 OR Y connectors. Further selection of the internal trigger source is provided by the INT TRIG switch to provide the internal trigger signal from both channels or from Channel 1 only (see Trigger Preamp discussion for details).

The line trigger is obtained from voltage divider R1104-R1105 in the Power Supply circuit. This sample of the line frequency, about 1.5 volts RMS, is coupled to the A Trigger Generator in the LINE position of the A SOURCE switch. The A COUPLING switch should not be in the LF REJ position when using this trigger source.

External trigger signals applied to the A EXT TRIG INPUT connector can be used to produce a trigger in the EXT and EXT ÷ 10 positions of the A SOURCE switch. Input resistance (DC) is about one megohm in both exter-

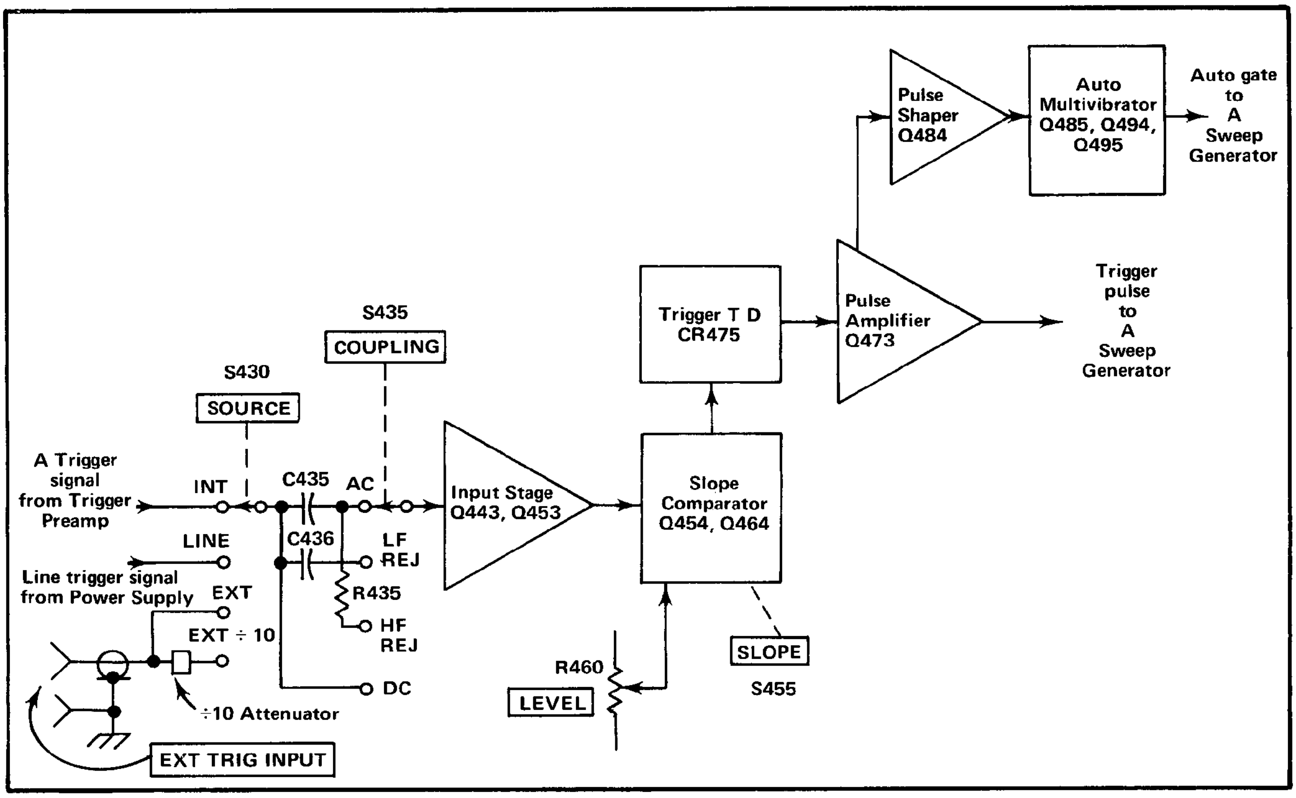

Fig. 3-8. A Trigger Generator detailed block diagram.

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nal positions. However, in the LF REJ position of the A COUPLING switch, the medium and high-frequency resistance drops to about 90 kilohms due to the addition of C436-R436 in the circuit. In the EXT ÷ 10 position, a 10 times frequency compensated attenuator is connected into the input circuit. This attenuator reduces the input signal amplitude 10 times to provide more A LEVEL control range while maintaining the one-megohm X20 pF input RC characteristics.

Trigger Coupling

The A COUPLING switch offers a means of accepting or rejecting certain frequency components of the trigger signal. In the AC and LF REJ positions, the DC component of the trigger signal is blocked by coupling capacitors C435 or C436. In the AC position, frequency components below about 30 hertz are attenuated. In the LF REJ position, frequency components below about 30 kilohertz are attenuated.

The HF REJ position attenuates high-frequency components of the triggering signal. The trigger signal is AC coupled to the input, attenuating signals below about 30 hertz and above about 50 kilohertz. The DC position provides equal coupling for all signals from DC to 60 megahertz.

Input Stage

The trigger signal from the A COUPLING switch is connected to the Input Stage through the network C440-R438-R439-R440-R441. R438-R439 provide the input resistance for this stage. The voltage-divider action of R438-R439 allows about 98% of DC or low frequency signals applied to R438 to be available at the junction of R438 and R439. C440 along with the stray capacitance in the circuit forms an AC divider which maintains about this same voltage division for high-frequency signals. R440 limits the current drive to the gate of FET Q443. Diode CR441 protects the circuit by clamping the gate of Q443 at about −12.5 volts if a high-amplitude negative signal is applied to the EXT TRIG INPUT connector. Over-voltage protection for high-amplitude positive signals is provided by the forward conduction of FET Q443.

Q443 is connected as a source follower to provide a high input impedance and a low output impedance. As a result, this stage provides isolation between the A Trigger Generator circuit and the trigger signal source. The output signal from Q443 is connected to the Slope Comparator stage through emitter follower Q453. Diode CR449, CR459, and VR460 provide protection for the Slope Comparator stage transistors, Q454 and Q464.

Slope Comparator

Q454 and Q464 are connected as a difference amplifier (comparator) to provide selection of the slope and level at which the sweep is triggered. The reference voltage for the comparator is provided by A LEVEL control R460 and A Trigger Level Center adjustment R462. The A Trigger Level Center adjustment sets the level at the base of Q464 so the display is triggered at the zero-volt DC level of the incoming trigger signal when the A LEVEL control is centered. The A LEVEL control varies the base level of Q464 to select the point on the trigger signal where triggering occurs.

R458 establishes the emitter current of Q454 and Q464. The transistor with the most positive base controls conduction of the comparator. For example, assume that the trigger signal from the Input Stage is positive going and Q454 is forward biased. The increased current flow through R458 produces a larger voltage drop, and the emitters of both Q454 and Q464 go more positive. A more positive voltage at the emitter of Q464 reverse biases this transistor, since its base is held at the voltage set by the A LEVEL control, and its collector current decreases. At the same time, Q454 is forward biased and its collector current increases. Notice that the signal currents at the collectors of Q454 and Q464 are opposite in phase. The sweep can be triggered from either the negative-going or positive-going slope of the input trigger signal by producing the trigger pulse from either the signal at the collector of Q464 for − slope operation or the signal at the collector of Q454 for + slope operation. This selection is made by SLOPE switch S455.

When the A LEVEL control is set to 0 (midrange), the base of Q464 is at about one volt positive, which corresponds to a zero-volt level at the input to this circuit (with correct calibration). The base-emitter drop of Q464 sets the common emitter level of Q454-Q464 to about +0.3 volt. Since the base of Q454 must be about 0.65 volt more positive than the emitter before it can conduct, the comparator switches around the zero-volt level of the trigger signal (zero-volt level on the trigger signal corresponds to about one volt positive at this point). As the A LEVEL control is turned clockwise toward +, the voltage at the base of Q464 becomes more positive. This increases the current flow through R458 to produce a more positive voltage on the emitters of both Q454 and Q464. Now the trigger signal must rise more positive before Q454 is biased on. The resultant CRT display starts at a more positive point on the displayed signal. When the A LEVEL control is in the − region, the effect is the opposite, to produce a resultant CRT display which starts at a more negative point on the trigger signal.

The slope of the input signal which triggers the A sweep is determined by A SLOPE switch S455. When the A SLOPE switch is set to the − position, the collector of Q454 is connected to the +12-volt supply through CR456 and R467. The anode of CR466 is grounded and it is reverse biased. Now the collector current of Q464 must flow through CR465, R459, the parallel combination CR475 and R468-R469-L469, and R467 to the +12-volt supply (see Fig. 3-9). Since the output pulse from the A Trigger Generator circuit is derived from the negative-going portion of the signal applied to the Trigger TD stage, the sweep is triggered on the negative-going portion of the input trigger signal (signal applied to Trigger TD stage is in phase with the input signal for – slope triggering). When the A SLOPE switch is set to +, conditions are reversed (see Fig. 3-10). Q464 is connected to the +12-volt supply through CR466 and R467. The anode of CR456 is grounded to divert the collector current of Q454 through the Trigger TD stage. The signal applied to the Trigger TD stage is now 180° out of phase with the input trigger signal, so the sweep is triggered on the positive-going portion of the input signal.

Trigger TD

The Trigger TD stage shapes the output of the Slope Comparator to provide a trigger pulse with a fast leading edge. Tunnel diode CR475 is quiescently biased so it operates in its low-voltage state. The current from one of the transistors in the Slope Comparator stage is diverted through the Trigger TD stage by the A SLOPE switch. As this current increases due to a change in the trigger signal, tunnel diode CR475 switches to its high-voltage state. L469 opposes the sudden change in current, which allows more current to pass through CR475 and switch it more quickly. As the current flow stabilizes, L469 again conducts the major part of the current. However, the current through CR475 remains high enough to hold it in its high-voltage state. The circuit remains in this condition until the current from the Slope Comparator stage decreases due to a change in the trigger signal applied to the input. Then, the current through CR475 decreases and it reverts to its low-voltage state.

Pulse Amplifier

The trigger signal from the Trigger TD stage is connected to the base of Pulse Amplifier Q473 through R472. The

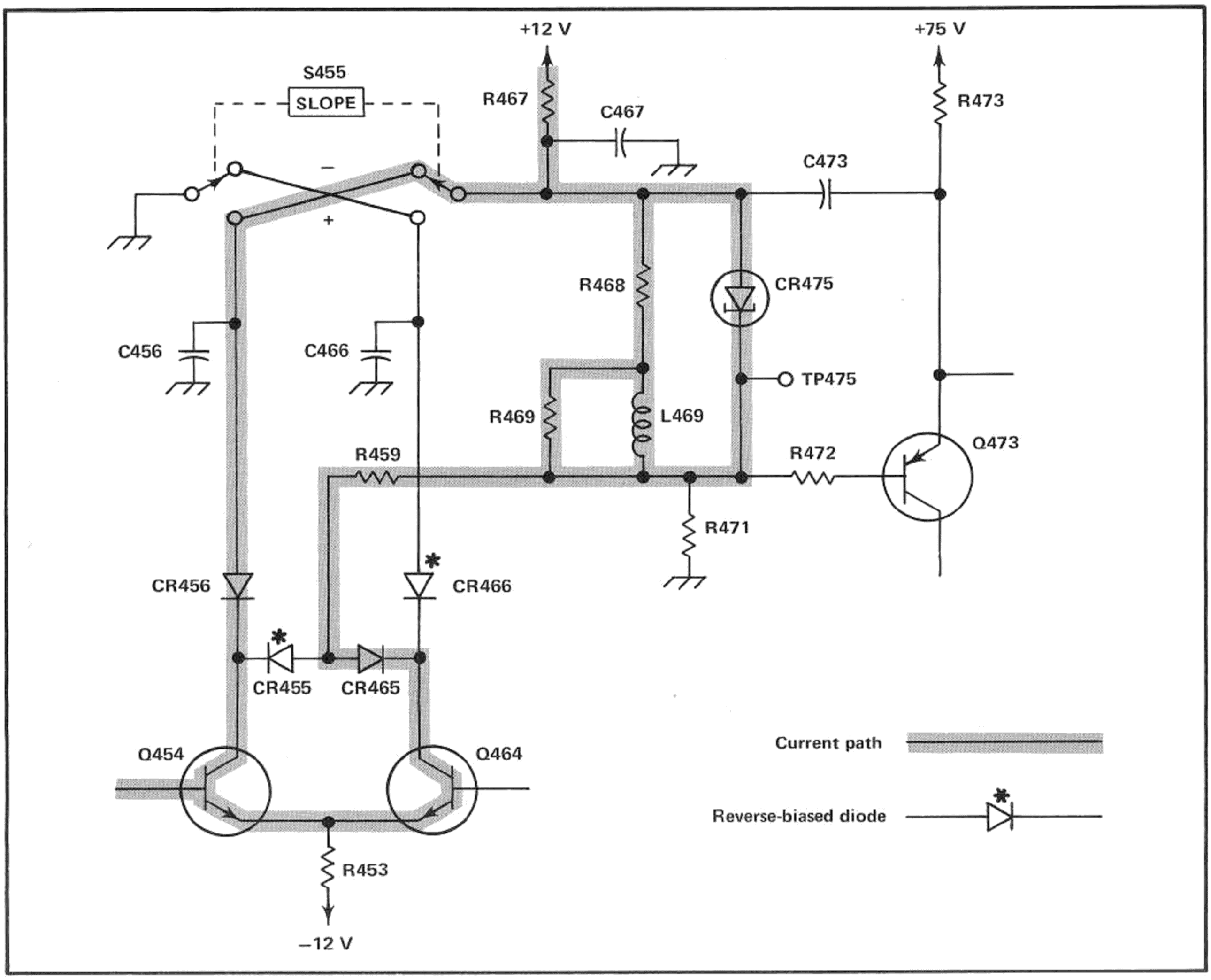


Fig. 3-9. Trigger path for negative-slope triggering (simplified A Trigger Generator diagram).

trigger pulse at this point is basically a negative-going pulse with a fast rise. The width of the pulse depends upon the waveshape of the input signal and the setting of the A LEVEL control. Q473 is connected as an amplifier with the primary of pulse transformer T474 providing the major collector load. The negative-going pulse at the base of Q473 drives it into heavy conduction and the resulting current increase of Q473 flows through T474, R474, Q473, C473, and C467. Due to the short time constant of the RC network involving C473, the current of Q473 quickly returns to the level determined by R473. The resultant signal at the collector of Q473 is a positive-going fast-rise pulse with the width determined by the time constants of the RC network in the circuit. T474 inverts the output pulse to produce a negative-going trigger pulse which is coincident with the rise of the output signal from the Trigger TD stage. This negative-going trigger pulse is connected to the A Sweep Generator circuit through C476-R476. CR474 limits the collector of Q473 from going more positive than about +0.5 volt. A simultaneous negative-going pulse with the same width as the trigger pulse is available at the emitter of Q473. This pulse is connected to the Auto Pulse Amplifier stage.

Auto Pulse Amplifier

The negative-going trigger pulse from the emitter of Q473 is connected to the base of Q484 through R481. This stage is similar to the Pulse Amplifier stage. Inductor L484 provides the collector load for this stage. The positive-going portion of the trigger pulse is coupled to the Auto Multivibrator stage through CR484. CR483 clamps the collector of Q484 at about −0.5 volt to eliminate negative transients.

Auto Multivibrator

The basic configuration of the Auto Multivibrator stage is a monostable multivibrator made up of Q485 and Q495.

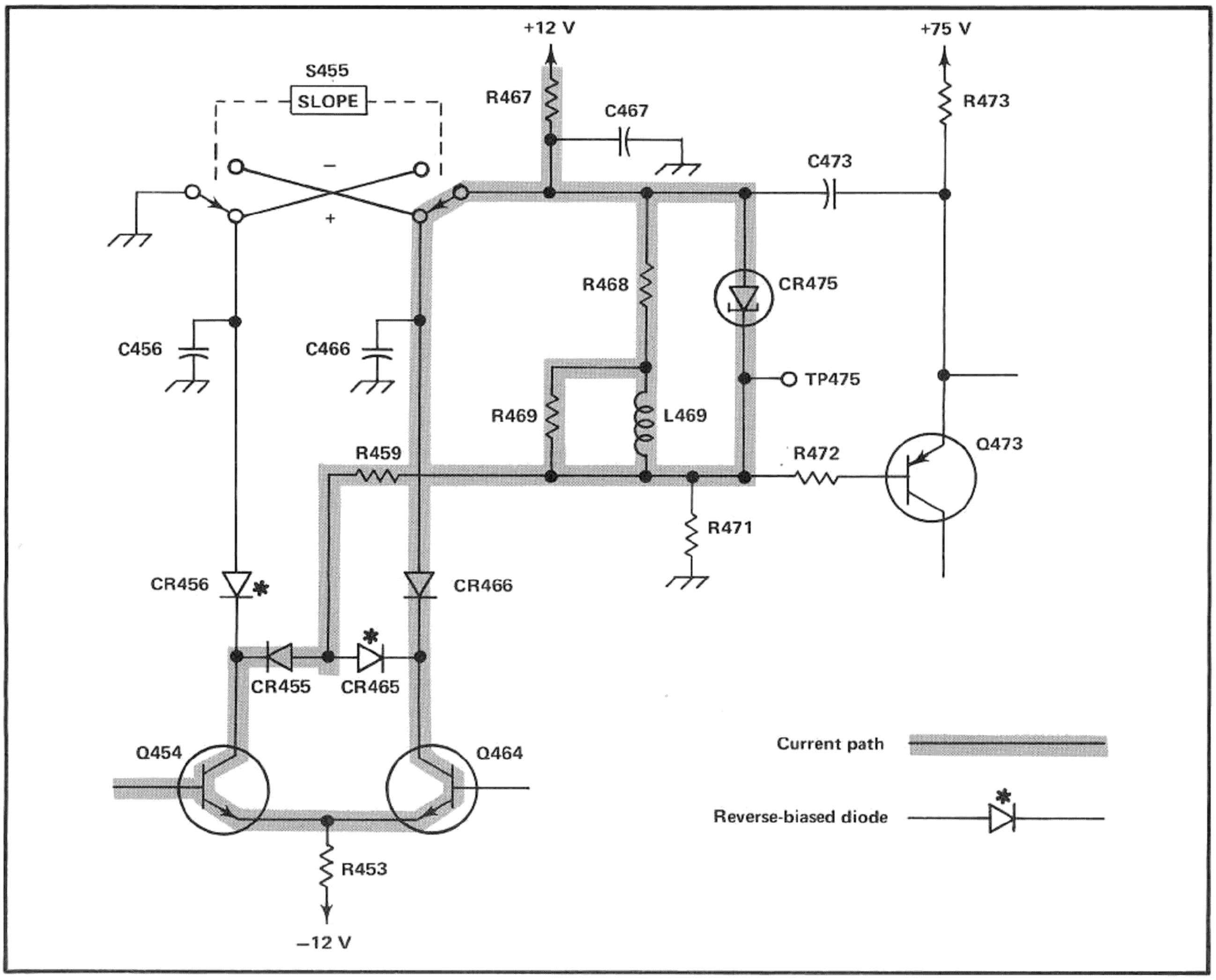


Fig. 3-10. Trigger path for positive-slope triggering (simplified A Trigger Generator diagram).

This stage produces the control gate for the auto trigger circuits located in the A Sweep Generator circuit. Under quiescent conditions (no trigger signal), the base of Q495 is near zero volts. The base of Q485 is held at about −0.65 volt by the forward voltage drop of CR484. Since the base of Q495 is the most positive, it conducts and raises the emitter level of Q485 positive enough to hold it off. C485 charges to about +13 volts where it is clamped by CR486 and CR493. The base of Q494 is clamped at about +12.6 volts by CR493, which reverse biases it. Since there is no current flow through Q494, its collector level goes negative.

When a trigger signal is present, the positive-going pulses from the Auto Pulse Amplifier stage turn Q485 on through CR484. The collector of Q485 goes negative and C485 discharges rapidly through Q485, R490, and R485. As C485 discharges, the current flow through R490 biases Q495 off. When C485 is fully discharged, the current flow through R490 ceases and Q495 comes back on to reset the multivibrator. Now C485 begins to charge towards +75 volts through R486. Current also flows through R494, and the base of Q494 goes negative to bias it on. The collector level of Q494 rises positive to produce the auto gate output for the A Sweep Generator circuit.

For low-frequency signals (below about 30 hertz), C485 recharges to about +13 volts in about 85 milliseconds. Then, Q494 is biased off to end the auto gate (display free runs or is unstable). However, if a repetitive trigger signal turns Q485 on again before C485 has charged to +13 volts, C485 is discharged completely again and once more starts to charge towards +75 volts. Since the base of Q494 remains negative enough with a repetitive trigger signal to hold it in conduction, the auto output level is continuous for a stable display (with correct A LEVEL control setting).

A SWEEP GENERATOR

General

The A Sweep Generator circuit produces a sawtooth voltage which is amplified by the Horizontal Amplifier circuit to provide horizontal sweep deflection on the CRT. This output signal is generated on command (trigger pulse) from the A Trigger Generator circuit. The A Sweep Generator circuit also produces an unblanking gate to unblank the CRT during the A sweep time. In addition, this circuit produces several control signals for other circuits within this instrument and several output signals to the side-panel connectors. Fig. 3-11 shows a detailed block diagram of the A Sweep Generator circuit. A schematic of this circuit is shown on diagram 9 at the rear of this manual.

The A SWEEP MODE switch allows three modes of operation. In the NORM TRIG position, a sweep is produced only when a trigger pulse is received from the A Trigger Generator circuit. Operation in the AUTO TRIG position is much the same as NORM TRIG except that a free-running trace is displayed when a trigger pulse is not present. In the SINGLE SWEEP position, operation is also similar to NORM TRIG except that the sweep is not recurrent. The following circuit description is given with the A SWEEP MODE switch set to NORM TRIG. Difference in operation for the other two modes are then discussed later.

Normal Trigger Mode Operation

Sweep Gate. The negative-going trigger pulse generated by the A Trigger Generator circuit is applied to the Sweep Gate stage through CR501. Tunnel diode CR505 is quiescently biased on in its low-voltage state. When the negative-going trigger pulse is applied to its cathode, the current through CR505 increases and it rapidly switches to its high-voltage state, where it remains until reset by the Sweep Reset Multivibrator stage at the end of the sweep. The negative-going level at the cathode of CR505 is connected to the base of Q504 through C503 and R503. Q504 is turned on and its collector goes positive. This positive-going step is connected to the Disconnect Diode through C509-R509 and to the Output Signal Amplifier through C506-R506.

Output Signal Amplifier. The positive-going gate pulse from the Sweep Gate stage applied to the base of Q514 produces a negative-going pulse at its collector. This pulse is connected to the Z Axis Amplifier circuit through R519 to unblank the CRT during sweep time. It is also connected to the Holdoff Capacitor through R517 and CR517 to discharge it completely at the beginning of each sweep.

The positive-going gate pulse at the base of Q514 is also coupled from the emitter of Q514 to the emitter of Q524. The resulting positive-going signal at the collector of Q524 is coupled to the Vertical Switching circuit through C526 to provide an alternate-trace sync pulse for dual-trace operation. It is also coupled to the A GATE output connector on the side panel through R529. CR528 and CR529 clamp the gate signal so it does not go more than about 0.5 volt negative and 12.5 volts positive.

Disconnect Diode. Disconnect Diode CR533 is quiescently conducting current through R506, R508, R509, R530, and R531. This prevents timing current from Timing Resistor R530 from charging Timing Capacitor C530. The positive-going gate signal from Q504 reverse biases CR533 and interrupts the quiescent current flow. Now the timing current through the Timing Resistor begins to charge Timing Capacitor C530 so the Sawtooth Sweep Generator stage can produce a sawtooth output signal. The positive-going gate signal also reverse biases CR547 to disconnect the Sweep Start Amplifier. The Disconnect Diode is a fast

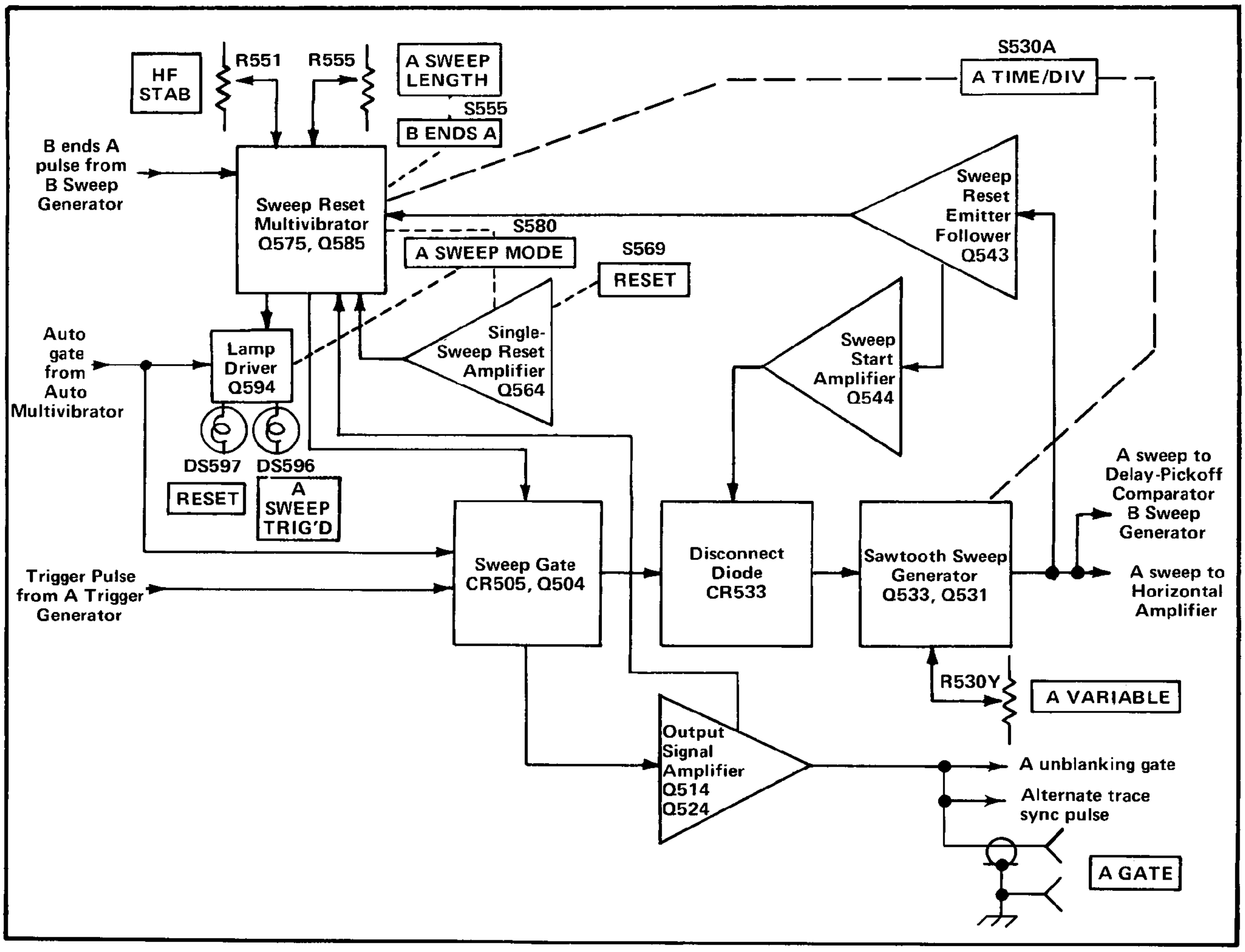


Fig. 3-11. A Sweep Generator detailed block diagram.

turn-off diode with low reverse leakage to reduce switching time and improve timing linearity at the start of the sweep.

Sawtooth Sweep Generator. The basic generator circuit is a Miller Integrator circuit. When the current flow through CR533 is interrupted by the Sweep Gate signal, the Timing Capacitor C530 begins to charge through Timing Resistor R530, and the A Sweep Cal Adjustment R531. The Timing Capacitor and Resistor are selected by the A TIME/DIV switch to change sweep rate. The A Sweep Cal adjustment allows calibration for accurate sweep timing. The A VAR control, R530Y (see Timing Switch diagram), provides variable sweep rates by varying the charge rate of the Timing Capacitor. UNCAL light DS530W (see Diagram 12) indicates when the sweep is not calibrated.

The positive-going voltage at the R530 side of C530 as it charges toward +75 volts is connected to the gate of FET Q533 through R533. This produces a positive-going output voltage which is connected to the base of Q531 through R536. Q531 amplifies and inverts the voltage change at its base to produce a negative-going sawtooth output. To provide a linear charging rate for the Timing Capacitor, the sweep output signal is connected to the negative side of C530. This feedback provides a constant charging current for C530 which maintains a constant charge rate to produce a linear sawtooth output signal. The output voltage continues to go negative until the circuit is reset through the Sweep Reset Multivibrator stage. The output signal from the collector of Q531 is connected to the Horizontal Amplifier circuit through R538, the Delay Pickoff Comparator stage in the B Sweep Generator circuit through R532, and the B Sweep Start stage through the HORIZONTAL DISPLAY switch.

Sweep Reset Emitter Follower. The negative-going sawtooth voltage at the collector of Q531 is connected to the base of the Sweep Reset Emitter Follower stage Q543. The negative-going signal at the emitter of Q543 is coupled to the Sweep Reset Multivibrator stage to determine sweep length and to the Sweep Start Amplifier stage to set the starting point for the sweep. CR542 connected to the base of Q543 protects this stage during instrument warmup.

Sweep Start Amplifier. The signal at the emitter of Q543 goes negative along with the applied sawtooth signal. This increases the forward bias on CR543, which in turn decreases the forward bias on CR545 as the sawtooth goes negative. When the anode of CR543 reaches a level about one volt more negative than the level on the base of Q544, it is reverse biased to interrupt the current flow through Q544.

The circuit remains in this condition until after the sweep retrace is complete. As the voltage at the emitter of Q543 returns to its original DC level at the end of the sweep, CR545 is again forward biased and Q544 conducts through CR547 to set the quiescent current through the Disconnect Diode CR533. This establishes the correct starting point for the sweep. CR546 clamps the collector of Q544 at about +0.5 volt. This reduces the voltage swing at the collector of Q544 and improves the response time. Sweep Start adjustment R758 (in the B Sweep Generator circuit) sets the base voltage level of Q544. The collector of Q531 is held at this same voltage level through the feedback loop comprised of Q533 and Q531, thereby setting the starting point of the sawtooth output signal. The level established by the Sweep Start adjustment is also connected to the B Sweep Start Amplifier so the B sweep starts at the same voltage level as the A sweep (except in MIXED).

Sweep Reset Multivibrator. The negative-going sawtooth signal at the emitter of Q543 is coupled to the cathodes of CR555 and CR556. These diodes are quiescently reverse biased at the start of the sweep. As the sawtooth voltage at its cathode goes negative, CR555 is forward biased at a level about 0.5 volt more negative than the base level of Q575 (A SWEEP LENGTH control in FULL position). Then the negative-going sawtooth signal from the Sweep Reset Emitter Follower stage is connected to the base of Q575. Q575 and Q585 are connected as a Schmitt bistable multivibrator. Quiescently, at the start of the sweep, Q585 is conducting and Q575 is biased off to produce a negative level at its collector. This negative level allows Sweep Gate tunnel diode CR505 to be switched to produce a sweep as discussed previously. When the negative-going sweep signal is connected to the base of Q575 through CR555, Q575 is eventually biased on and Q585 is biased off by the emitter coupling between Q575 and Q585. The collector of Q575 rises positive and CR505 is switched back to its low-voltage state through R502. CR505 is held in its low-voltage state so it cannot accept incoming trigger pulses until after the Sweep Reset Multivibrator stage is reset. This ends the Sweep Gate stage output and the Disconnect Amplifier stage is turned on to rapidly discharge the Timing Capacitor and pull the gate of Q533 rapidly negative to its original level to produce the retrace portion of the sawtooth signal. The Sawtooth Sweep Generator stage is now ready to produce another sweep as soon as the Sweep Reset Multivibrator stage is reset and another trigger pulse is received.

When Q575 is turned on to end the sweep, it remains in conduction for a period of time to establish a holdoff period and allow all circuits to return to their original conditions before the next sweep is produced. The holdoff time is determined by the charge rate of Holdoff Capacitor C550. At the start of the sweep, C550 is completely discharged by the unblanking gate at the collector of Q514. It is held at this level throughout the sweep time. When the Sweep Gate output ends, Q514 is cut off and C550 begins to charge toward +75 volts through R552 and R551. The positive-going voltage across the Holdoff Capacitor as it charges is connected to the base of Q575 through CR552 and VR559. When the base of Q575 rises positive enough so it is reverse biased, its collector level drops negative and Q585 comes back into conduction. The bias on the Sweep Gate tunnel diode CR505 returns to a level that allows it to accept the next trigger pulse (CR505 is enabled). Holdoff Capacitor C550 is changed by the A TIME/DIV switch for the various sweep rates to provide the correct holdoff time. Diagram 12 shows a complete diagram of the A TIME/DIV switch.

As the A SWEEP LENGTH control is rotated counterclockwise from the FULL position, R555 places a more positive level on the anode of CR556 than is on the anode of CR555 so CR555 remains reverse biased. The Sweep Reset Multivibrator is reset as described for FULL sweep length operation at the point where CR556 (instead of CR555) is forward biased. Since this occurs at a more positive level on the negative-going sawtooth, the displayed sweep is shorter. Thus, R555 provides a variable sweep length for the A sweep (from about 11 divisions in the FULL position to about four divisions in the fully clockwise position—not in B ENDS A detent). In the B ENDS A position (fully counterclockwise), a negative-going pulse from the B Sweep Generator circuit is connected to the base of Q575 through CR575 at the end of the B sweep time. If the A sweep is still running, this negative-going pulse turns Q575 on to end the A sweep also. Since the A sweep ends immediately following the end of the B sweep, this position provides the maximum repetition rate (brightest trace) for Delayed Sweep mode operation.

The HF STAB control, R551, varies the charging rate of the Holdoff Capacitor to provide a stable display at fast sweep rates. This change in holdoff allows sweep synchronization for less display jitter at the faster sweep rates. The HF STAB control has little effect at slow sweep rates.

Lamp Driver. The auto gate level from the Auto Multivibrator stage in the A Trigger Generator circuit is connected to Lamp Driver stage Q594, through CR591 and CR594. This gate level is coincident with the trigger pulse generated by the A Trigger Generator circuit and is present only when the instrument is correctly triggered. The positive-going auto-gate level saturates Q594 and its collector goes negative to about zero volts. This applies about 12 volts across DS596, A SWEEP TRIG'D light, and it comes on. This light remains on as long as the auto-gate level is present. When the auto-gate level goes negative because the instrument is no longer triggered, CR595 clamps the base level of Q594 at about −0.5 volt and Q594 is reverse biased. The collector of Q594 rises positive and DS596 goes off.

Auto Trigger Mode Operation

Operation of the A Sweep Generator circuit in the AUTO TRIG position of the A SWEEP MODE switch is the same as for the NORM TRIG position just described when a trigger pulse is applied. However, when a trigger pulse is not present, a free-running reference trace is produced in the AUTO TRIG mode. This occurs as follows:

The auto-gate level from the Auto Multivibrator stage in the A Trigger Generator circuit is also connected to CR592. When the auto-gate level is positive (instrument triggered), the current flowing through CR592 and R593 reverse biases CR593 and Sweep Gate tunnel diode CR505 operates as previously described for NORM TRIG operation. However, when the instrument is not triggered, the auto-gate level drops negative and the reduction in current through CR592 and R593 allows CR593 to become forward biased. Now, when the Sweep Reset Multivibrator stage resets at the end of the holdoff period, the additional current from R593-CR593 flows through CR505 and is sufficient to automatically switch the Sweep Gate tunnel diode back into its high-voltage state. The result is that the A Sweep Generator circuit is automatically retriggered at the end of each holdoff period and a free-running sweep is produced. Since the sweep free runs at the sweep rate of the A Sweep Generator circuit (as selected by the A TIME/DIV switch), a bright reference trace is produced even at fast sweep rates.

Single Sweep Operation

General. Operation of the Sweep Generator in the SINGLE SWEEP position of the A SWEEP MODE switch is similar to operation in the other modes. However, after one sweep has been produced, the Sweep Reset Multivibrator stage does not reset. All succeeding trigger pulses are locked out until the RESET button is pressed.

In the SINGLE SWEEP position, the A SWEEP MODE switch disconnects the charging current for the Holdoff Capacitor. Now, Q575 remains on when it is forward biased through CR555 or CR556 at the end of the sweep. With Q575 on, CR505 is held in its low-voltage state to lock out any incoming trigger pulses. The circuit remains in this condition until reset by the Single-Sweep Reset Amplifier stage.

Single-Sweep Reset Amplifier. Single-Sweep Reset Amplifier Q564 produces a pulse to reset the Sweep Reset Multivibrator stage so another sweep can be produced in the SINGLE SWEEP mode of operation. Quiescently, Q564 is biased off and the RESET switch is open. When the RESET button is pressed, DS568 ignites and the voltage at the base of Q564 goes negative. Q564 saturates and produces a positive-going output pulse. This pulse has sufficient amplitude to shut off Q575 and allow Q585 to conduct and enable Sweep Gate tunnel diode CR505. Now the A Sweep Generator circuit can be triggered when the next trigger pulse is received.

Lamp Driver. In the SINGLE SWEEP mode, the cathode of CR591 is connected to ground to block the incoming auto-gate level. A SWEEP TRIG'D light DS596 is disconnected from the collector of Q594 and RESET light DS597 is connected into the circuit. The anode of CR595 is also disconnected from ground. Now the condition of Q594 is determined by the Sweep Reset Multivibrator stage. When Q585 is off before the RESET button is pressed, the collector level of Q585 is negative. The current through R594-CR595-R587-R588 sets the base level of Q594 negative enough to bias it off. However, when the RESET button is pressed and Q585 turns on, its collector goes positive. This positive level allows the base of Q594 to go positive also and it is biased on. The collector of Q594 goes negative and the RESET light comes on. Q594 and the RESET light remain on until Q585 turns off again at the end of the next sweep.

B TRIGGER GENERATOR

General

The B Trigger Generator circuit is basically the same as the A Trigger Generator circuit. Only the differences between the two circuits are discussed here. Portions of the circuit not described in the following discussion operate in the same manner as for the A Trigger Generator circuit (corresponding circuit numbers are assigned in the 600-699 range). Fig. 3-12 shows a detailed block diagram of the B Trigger Generator circuit. A schematic of this circuit is shown on diagram 10 at the rear of this manual.

Input Stage

The B Input Stage operates in basically the same manner as described for the A Trigger Generator circuit. However, in the B Trigger Generator circuit, HORIZ DISPLAY switch S801A and CR638 block the B Trigger Generator input

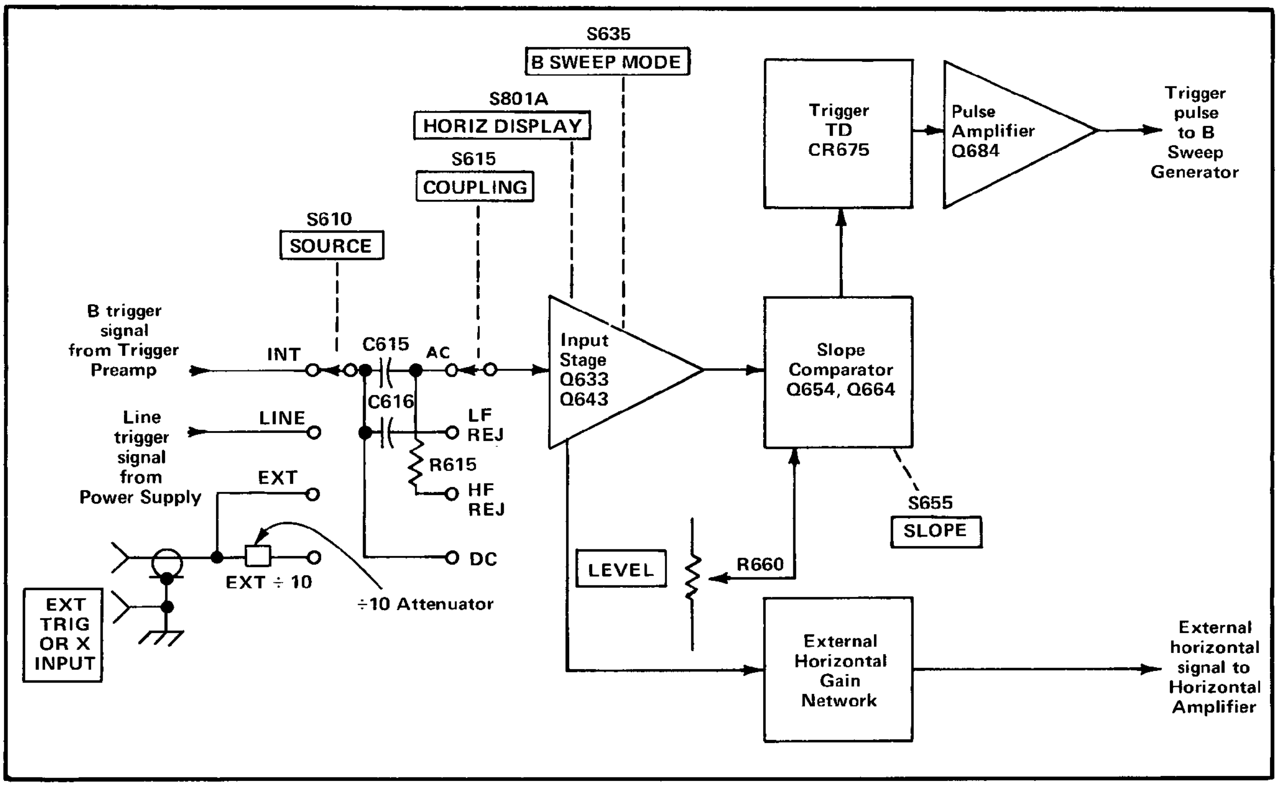


Fig. 3-12. B Trigger Generator detailed block diagram.

signal in the modes where B triggering is not desired. In the A position of the HORIZ DISPLAY switch, −12 volts is connected to the cathode of CR635 and it is forward biased. Since the cathode of CR638 is connected to +12 volts through R638, CR638 is reverse biased and it blocks the trigger signal. In the A INTEN DURING B, B (DELAYED SWEEP), and MIXED positions, a second switch, B SWEEP MODE S635 determines whether the B trigger signal is blocked or passed to the Slope Comparator stage. If the B SWEEP MODE switch is in the B STARTS AFTER DELAY TIME position, the trigger signal is blocked as in the A position. However, the B Sweep Generator essentially free runs in this position as controlled by another portion of the B SWEEP MODE switch located in the B Sweep Generator circuit (see B Sweep Generator discussion). In the TRIGGERABLE AFTER DELAY TIME position, −12 volts is connected to the cathode of CR638 through R639 rather than to CR635. This forward biases CR638 and allows the B trigger signal to pass to the B Slope Comparator stage.

In all positions of the HORIZ DISPLAY switch except X-Y, CR641 is back biased since it is connected to +12 volts through R641. In the X-Y position, CR638 is reverse biased because its cathode rises positive toward +12 volts applied through R638. Therefore, the trigger signal can not pass through CR638. CR641 is forward biased by −12 volts connected to its cathode through R642 by S801A. The signal from the Input Stage is connected to the Horizontal Amplifier through CR641 and External Horizontal Gain Network R644-R645-R646. Gain of the External Horizontal circuit is set by R645, Ext Horiz Gain, so a signal applied to the CH 1 OR X connector produces the indicated horizontal deflection.

The external horizontal signal can be obtained either externally from the B EXT TRIG OR X INPUT connector when the B SOURCE switch is set to EXT or EXT ÷ 10, or internally from Channel 1 when the INT TRIG switch is in the CH 1 OR X-Y position and the B SOURCE switch is set to INT.

Pulse Amplifier

The Pulse Amplifier in the B Trigger Generator operates much the same as in the A Trigger Generator. However, since there is no Auto circuit in the B Trigger Generator, a pulse is available only at the collector of Q684. The output pulse is applied to the B Sweep Generator through T686 and R688-C688.

B SWEEP GENERATOR

General

The B Sweep Generator circuit is basically the same as the A Sweep Generator circuit. Only the differences between the two circuits are discussed here. The following circuits operate as described for the A Sweep Generator (corresponding circuit numbers assigned in the 700-799 range): Sweep Gate (CR705, Q704), Disconnect Diode (CR742), Sawtooth Sweep Generator (Q743 and Q741), and the Sweep Reset Emitter Follower (Q753). Fig. 3-13 shows a detailed block diagram of the B Sweep Generator circuit. A schematic of this circuit is shown on diagram 11 at the rear of this manual.

Output Signal Amplifier

Basically, the B Output Signal Amplifier is the same as the corresponding circuit in the A Sweep Generator circuit. Two unblanking gates are available from the collector of Q714. An unblanking gate is connected to the Z Axis Amplifier circuit through R717 and the HORIZ DISPLAY switch to unblank the CRT to display the B sweep. For A INTEN DURING B operation, additional unblanking current is added to the A unblanking gate during the B sweep time. This produces a display which is partially unblanked during A sweep time and further unblanked during B sweep time to produce a display which has an intensified portion coincident with the B sweep time.

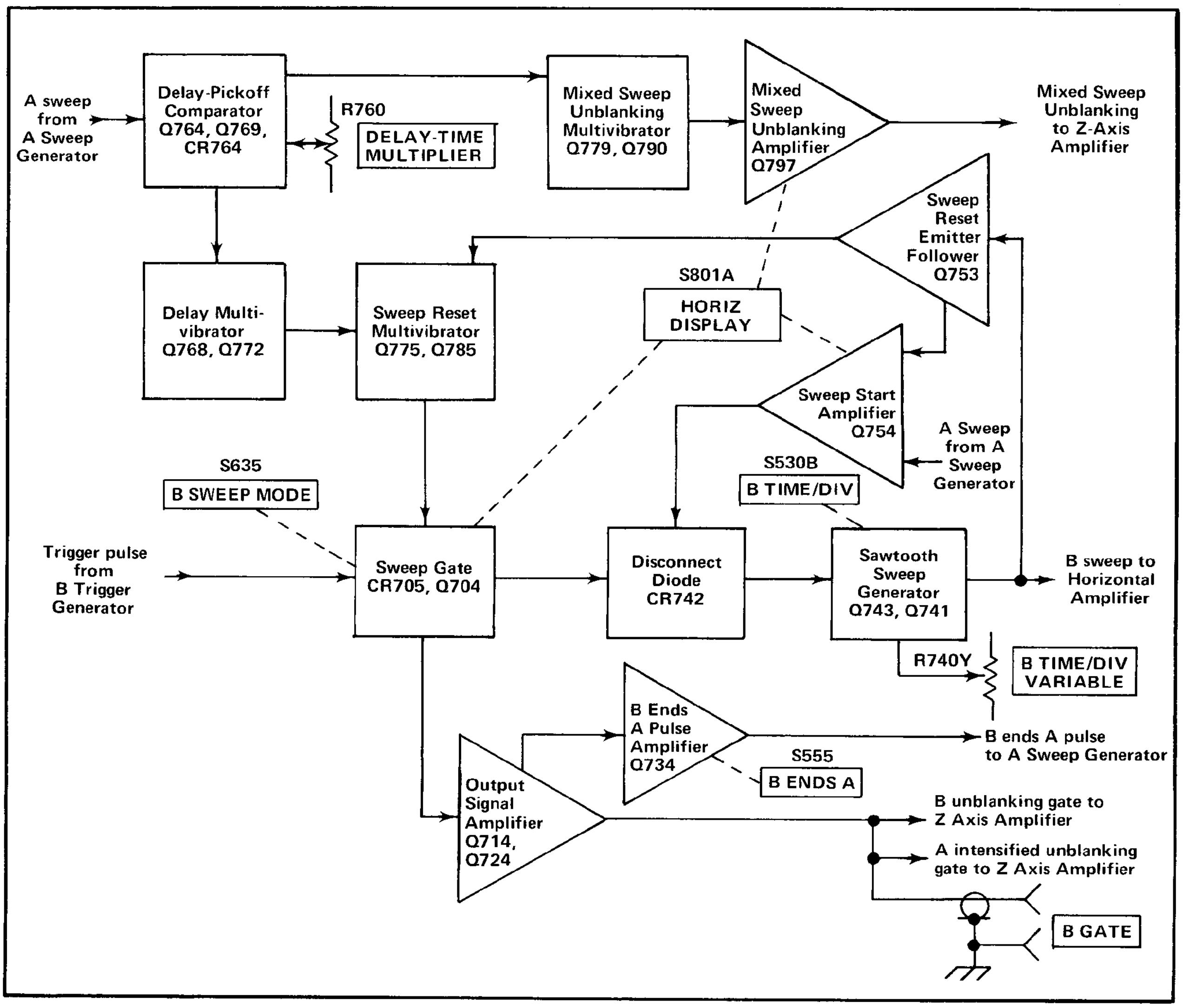


Fig. 3-13. B Sweep Generator detailed block diagram.

B Ends A Pulse Amplifier

The positive-going voltage as the B unblanking gate ends is coupled to B Ends A Pulse Amplifier Q734 through C731 and CR731. When the A SWEEP LENGTH control is in the B ENDS A position, this pulse saturates Q734 to produce a negative-going output pulse at its collector. This negative-going pulse is connected to the A Sweep Reset Multivibrator stage to reset the A sweep at the end of the B sweep for maximum delayed sweep repetition rate.

Delay-Pickoff Comparator

The Delay-Pickoff Comparator stage allows selection of the amount of delay from the start of the A sweep before the B Sweep Generator is turned on. This stage allows the start of B sweep to be delayed between 0.20 and 10.20 times the setting of the A TIME/DIV switch. Then, the B Sweep Generator is turned on and operates at a sweep rate independent of the A Sweep Generator (determined by setting of B TIME/DIV switch).

Q764A and B are connected as a voltage comparator. In this configuration, the transistor with the most positive base controls conduction. A dual transistor, Q764, and a dual diode, CR764, provide temperature stability for the comparator circuit. Q769 maintains a constant current through the conducting transistor. Reference voltage for the comparator circuit is provided by DELAY-TIME MULTIPLIER control R760. The voltage to this control is filtered by R759-C759 to hold it constant and allow precise delay pickoff. The instrument is calibrated so that the major dial markings of R760 correspond to the major divisions of horizontal deflection on the graticule. For example, if the DELAY-TIME MULTIPLIER dial is set to 5.00, the B Sweep Generator is delayed five divisions of the A sweep time before it can produce a sweep (B sweep delay time equals five times setting of A TIME/DIV switch).

The output sawtooth from the A Sawtooth Sweep Generator stage is connected to the base of Q764A. The quiescent level of the A sawtooth biases Q764A on and its collector is negative enough to hold Q772 in the Delay Multivibrator stage in conduction. As the A sweep output sawtooth begins to run down, the base of Q764A also goes negative. When it goes more negative than the level at the base of Q764B (established by the DELAY-TIME MULTIPLIER control), Q764B takes over conduction of the comparator and Q764A shuts off. This also switches the Delay Multivibrator stage to produce a negative-going reset pulse to the B Sweep Reset Multivibrator.

When the A sweep resets, Q764A is again returned to conduction and Q764B is turned off. This also resets the Delay Multivibrator to produce a positive-going output pulse. If the B sweep is still running, this positive-going pulse forces the B Sweep Reset Multivibrator to reset and end the B sweep also.

Delay Multivibrator

The Delay Multivibrator, Q768 and Q772, provides a lockout for the B Sweep Generator circuit during the A Sweep Generator reset and holdoff time to allow accurate delayed-sweep measurements when the DELAY-TIME MULTIPLIER dial is set near 0. This stage prevents the B Sweep Generator from being triggered before the A Sweep Generator is triggered (B Sweep Generator must always be triggered after the A Sweep Generator is triggered). This circuit also produces a pulse which resets the B Sweep Reset Multivibrator stage after the delay period so the B Sweep Gate tunnel diode can be enabled to produce a sweep.

Transistors Q768 and Q772 are connected as a Schmitt bistable multivibrator. Quiescently, Q772 is held on by the negative level at the collector of Q764A and Q768 remains off. The circuit remains in this condition until the incoming A sweep switches the Delay-Pickoff Comparator (see Delay-Pickoff Comparator discussion). Then, the base of Q772 goes positive and it turns off. At the same time, the base of Q768 is pulled negative by the collector level of Q764B and it turns on. The collector of Q772 goes negative and a negative-going output pulse is coupled to the B Sweep Reset Multivibrator stage through C774. This pulse resets the B Sweep Reset Multivibrator which in turn enables the B Sweep Gate stage.

Mixed Sweep Unblanking Multivibrator

Transistors Q779 and Q790 comprise a bistable multivibrator very similar in configuration to the Sweep Reset Multivibrator. The purpose of the Mixed Sweep Unblanking Multivibrator is to provide additional unblanking during the B sweep portion of a mixed sweep display. Because the B Sweep Generator is normally running at a faster sweep rate than the A Sweep Generator in a mixed sweep display, this additional unblanking reduces the intensity differences between the two parts of the display.

During the A Sweep portion of a mixed sweep display, transistor Q779 is off and Q790 is on. At the end of the delay time a negative pulse is coupled to the base of Q779 from the collector of Q772 by capacitor C774. Q779 is turned on and its collector goes positive. This positive movement is coupled to the base of Q790 through C780-R780, and Q790 turns off. At the same time that Q779 is turned on, the pulse from C774 turns Q775 on and its collector goes positive. The negative movement of the collector of Q790 and the positive movement of the collector of Q775 are added together so that the net change at the base of Q797 is an approximate 0.6 volt more positive level. The increased conduction of Q797 causes its collector to step slightly more negative to further unblank the CRT display. Then at the end of the B Sweep time, Q790 turns on and Q775 turns off. The negative movement at the base of Q797 is sufficient to cause total blanking of the CRT so any remaining part of A Sweep is not seen.

Mixed Sweep Unblanking Amplifier

In the MIXED position of the HORIZ DISPLAY switch, +12 volts is applied to the collector of the Mixed Sweep Blanking Amplifier Q797 through collector load resistor R797. This activates Q797 so it can amplify the mixed-sweep unblanking gate at its base. The output at the collector of Q797 is added to the A unblanking gate (see Horizontal Display Switch, Diagram 14) to produce a composite blanking gate for the Z-Axis Amplifier.

Sweep Start Amplifier

In all positions of the HORIZ DISPLAY switch except MIXED, the operation of B Sweep Start Amplifier Q754 is the same as described for the A Sweep Start Amplifier stage. In the MIXED position, the Sweep Start control R758 is disconnected from the base of Q754 and the A sweep sawtooth is applied. Now, the point at which the B Sweep Generator will start generating its sawtooth waveform is constantly being changed by the A sweep sawtooth. The output waveform from the B Sweep Generator takes the form of a composite sawtooth waveform with the first and last parts occurring at a rate determined by the A Sweep Generator (last part of composite sweep blanked out), and the middle part at a rate determined by the B Sweep Generator.

Sweep Reset Multivibrator

The basic B Sweep Reset Multivibrator configuration and operation is the same as for the A Sweep Generator. However, several differences do exist. The B Sweep Reset Multivibrator does not have a sweep length network for variable sweep length or a Holdoff Capacitor and associated circuit to reset the B Sweep Reset Multivibrator after the retrace. Instead, the negative-going sweep from the B Sweep Reset Emitter Follower, Q753, is connected to the base of Q785 through CR748. Diode CR748 is forward biased when the sweep voltage at the emitter of Q753 drops about 0.5 volt more negative than the level at the base of Q785 established by voltage divider R784-R785 between +12 volts and the collector of Q775. This negative-going sawtooth turns on Q785, and its collector goes positive to switch B Sweep Gate tunnel diode CR705 to its low-voltage state, which resets the B Sweep. Q785 remains on and holds the B Sweep Gate tunnel diode locked out until the B Sweep Reset Multivibrator is reset by the Delay Multivibrator.

When the B Sweep Reset Multivibrator is reset by the Delay Multivibrator, Q775 comes on and Q785 turns off. The collector of Q785 goes negative and B Sweep Gate tunnel diode CR705 is enabled. The state in which CR705 remains depends upon the B SWEEP MODE switch and the HORIZ DISPLAY switch. When B SWEEP MODE switch S635 is set to the TRIGGERABLE AFTER DELAY TIME position, CR705 is biased so it can be switched to its high-voltage state by the next trigger pulse from the B Trigger Generator. However, in the B STARTS AFTER DELAY TIME position, the setting of HORIZ DISPLAY switch S801A determines operation of the B Sweep Gate tunnel diode. In the A position, the B trigger pulses are blocked in the B Trigger Generator circuit so the B Sweep Generator cannot be triggered and does not produce a sweep. In the remaining positions of S801A, −12 volts is connected to the cathode of CR705 through R786 and R789. This voltage pulls the cathode of CR705 negative enough so it automatically switches to its high-voltage state after it is enabled by the B Sweep Reset Multivibrator stage. This produces a free-running B sweep reset similar to the no trigger AUTO TRIG mode in the A Sweep Generator. However, since the B Sweep is reset (and automatically re-triggered) at a fixed point on the A sweep sawtooth, the display is relatively stable. The best delayed sweep stability is provided in the TRIGGERABLE AFTER DELAY TIME position, since the B sweep is triggered by the trigger signal in this mode.

HORIZONTAL AMPLIFIER

General

The Horizontal Amplifier circuit provides the output signal to the CRT horizontal deflection plates. In all positions of the HORIZ DISPLAY switch except X-Y, the horizontal deflection signal is a sawtooth from either the A Sweep Generator circuit or the B Sweep Generator circuit. In the X-Y position, the horizontal deflection signal is obtained from the Input Stage of the B Trigger Generator. In addition, this circuit contains the horizontal magnifier circuit and the horizontal positioning network. Fig. 3-14 shows a detailed block diagram of the Horizontal Amplifier circuit. A schematic of this circuit is shown on diagram 13 at the rear of this manual.

Input Amplifiers

The input signal for the Horizontal Amplifier is selected by HORIZ DISPLAY switch S801A. In the A and A INTEN DURING B positions of the HORIZ DISPLAY switch, the sawtooth from the A Sweep Generator is connected to the base of the − Input Amplifier, Q814, through R803. In the B (DELAYED SWEEP) position, the B sawtooth is connected to the base of Q814 and in the MIXED position, the composite sawtooth from the B Sweep Generator is connected to the base of Q814. Whichever sawtooth signal is connected to the base of Q814 produces a

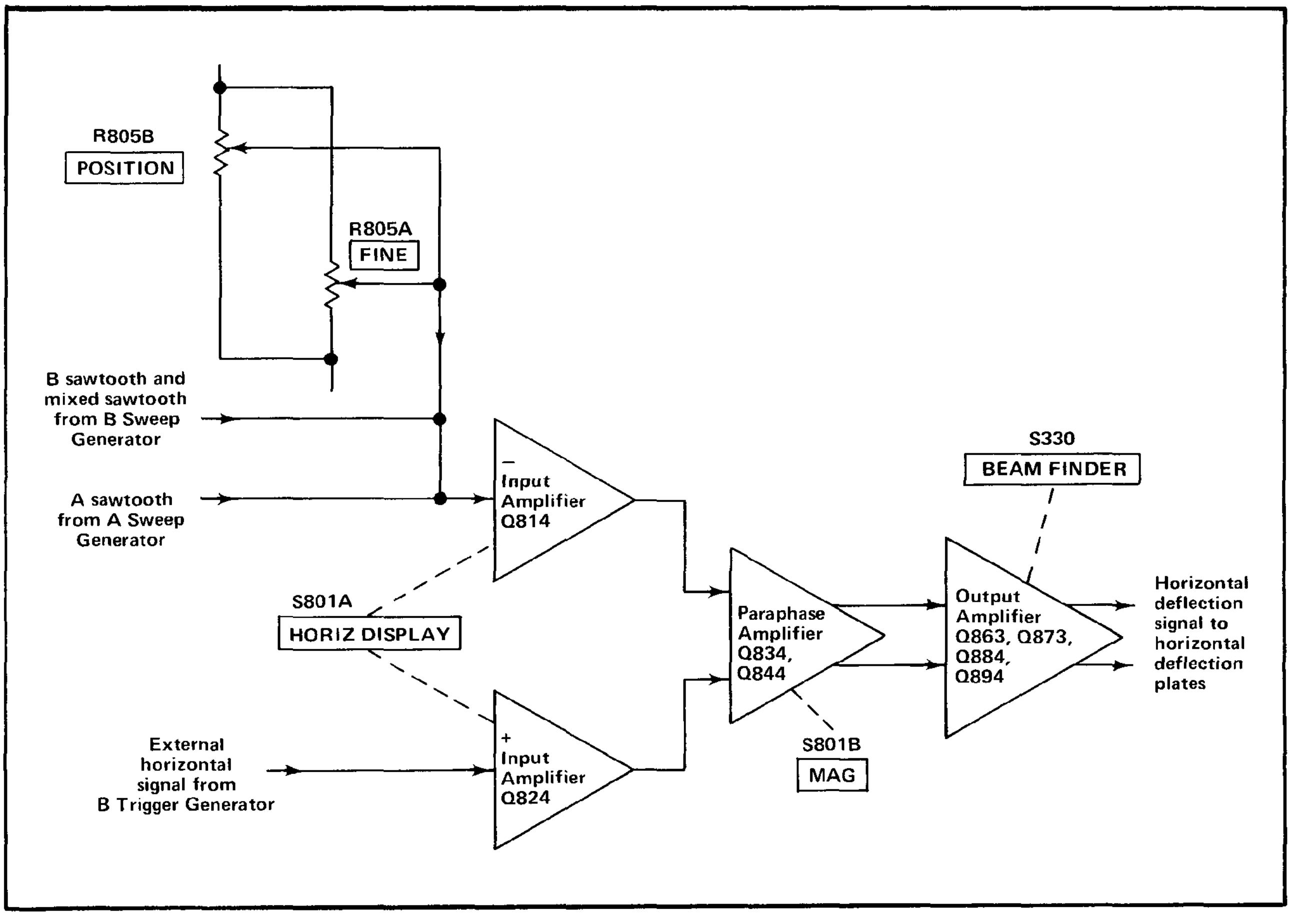


Fig. 3-14. Horizontal Amplifier detailed block diagram.

current change which is amplified to produce a positive-going sawtooth voltage at the collector. This positive-going sawtooth signal is connected to the base of Q834 in the Paraphase Amplifier stage.

In the X-Y position of the HORIZ DISPLAY switch, the external horizontal signal from the B Trigger Generator circuit is connected to the base of the + Input Amplifier, Q824, through R821. The A and B sawtooth signals are grounded by the HORIZ DISPLAY switch. The B SOURCE switch selects either the internal signal from Channel 1 (INT TRIG switch set to CH 1 OR X-Y) or an external signal connected to the EXT TRIG OR X INPUT connector. When the internal signal is selected, the Channel 1 deflection factor as indicated by the CH 1 VOLTS/DIV switch applies as Horizontal Volts/Division. More information on the external horizontal circuitry is contained in the B Trigger Generator circuit discussion.

Horizontal positioning is provided by POSITION control R805A, and FINE control R805B connected to the base of Q814. These controls vary the quiescent DC level at the base of Q814 which in turn sets the DC level at the horizontal deflection plates to determine the horizontal position of the trace. C804-R804 eliminate common-mode noise from the position controls.

Paraphase Amplifier

The output of the + and − Input Amplifier stages is connected to Paraphase Amplifier Q834 and Q844. This stage converts the single-ended input signal from either Input Amplifier stage to a push-pull output signal which is necessary to drive the horizontal deflection plates of the CRT. In all positions of the HORIZ DISPLAY switch except X-Y, a positive-going sawtooth signal is connected to the base of Q834 through Q814. This produces a negative-going sawtooth voltage at the collector of Q834. At the same time, the emitter of Q834 goes positive and this change is connected to the emitter of Q844 through the gain-setting network, R835-R836-R845-R846. In all positions of the HORIZ DISPLAY switch except X-Y, no signal is connected to the base of Q844 through Q824 so Q844 operates as the emitter-driven section of a paraphase amplifier. Then, the positive-going change at its emitter is amplified to produce a positive-going sawtooth signal at the collector. Thus the single-ended input sawtooth signal has been amplified and is available as a push-pull signal at the collectors of Q834 and Q844.

In the X-Y position of the HORIZ DISPLAY switch, the external horizontal deflection signal is connected to the base of Q844 through Q824 and the sawtooth signal at the base of Q814 is disconnected. Now, the circuit operates much the same as just described for a sawtooth input. A positive-going external horizontal deflection signal produces a negative-going change at the base of Q844 which decreases the current flow through this transistor. The collector of Q844 goes positive while the emitter-coupled signal to Q834 produces a negative-going change at the collector of Q834.

This stage also provides adjustment to set the normal and magnified gain of the Horizontal Amplifier circuit, and the MAG switch to provide a horizontal sweep which is magnified 10 times. For normal sweep operation (MAG switch set to OFF), R835 and R836 control the emitter degeneration between Q834 and Q844 to set the gain of the stage. R835, Normal Gain, is adjusted to provide calibrated sweep rates. When MAG switch S801B is set to the X10 position, R845 and R846 are connected in parallel with R835 and R836. This additional resistance decreases the emitter degeneration of this stage to increase the gain of the circuit 10 times. R845, Mag Gain, is adjusted to provide calibrated magnified sweep rates. When the MAG switch is set to X10, MAG ON light DS849 is connected to the +150-volt supply through R849. DS849 ignites to indicate that the sweep is magnified. In the X-Y position of the HORIZ DISPLAY switch, the magnifier is connected into the circuit by S801A so the horizontal gain is correct for external horizontal operation regardless of the setting of the MAG switch. However, both sides of DS849 are connected to ground so it can not ignite.

Output Amplifier

The push-pull output of the Paraphase Amplifier is connected to the Output Amplifier. Each half of the Output Amplifier can be considered as a single-ended, feedback amplifier which amplifies the signal current at its input to produce a voltage output to drive the horizontal deflection plates of the CRT. The amplifiers have a low input impedance and require very little voltage change at the input to produce the desired output change. Diodes CR851-CR852 and CR861-CR871 protect the amplifier from being overdriven by excessive current swing at the collectors of Q834 and Q844. Negative feedback is provided from the collectors of the final transistors, Q884 and Q894, to the bases of the input transistors through C882-R882 and C892-R892. C882 and C892 adjust the transient response of the amplifier so it has good linearity at fast sweep rates.

Mag Register adjustment R855 balances the quiescent DC current to the base of Q863 and Q873 so a center-screen display does not change position when the MAG switch is changed from X10 to OFF.

BEAM FINDER switch S330 reduces horizontal scan by limiting the current available to Q884 and Q894. Normally the collectors of these transistors are returned to +150 volts. However, when the BEAM FINDER switch is pressed in, the power from the unregulated +150-volt supply is interrupted and the collector voltage for Q884 and Q894 is supplied from +75 volts through CR884. Since the collectors are returned to a lower potential, the output voltage swing is reduced to limit the horizontal deflection within the graticule area.

Z AXIS AMPLIFIER

General

The Z Axis Amplifier circuit controls the CRT intensity level from several inputs. The effect of these input signals is to either increase or decrease the trace intensity, or to completely blank portions of the display. Fig. 3-15 shows a detailed block diagram of the Z Axis Amplifier circuit. A schematic of this circuit is shown on diagram 15 at the rear of this manual.

Input Amplifier

The input transistor, Q1014, in the Input Amplifier stage is a current-driven, low-input impedance amplifier. It provides termination for the input signals as well as isolation between the input signals and the following stages. The current signals from the various control sources are connected to the emitter of Q1014 and the sum or difference of the signals determines the collector conduction level. CR1015 and CR1016 in the collector provide limiting protection at minimum intensity. When the INTENSITY control is set fully counterclockwise (minimum), the collector current of Q1014 is reduced and its collector rises positive. CR1015 is reverse biased to block the control current at the base of Q1023, and CR1016 is forward biased to protect the circuit by clamping the collector of Q1014 about 0.5 volt more positive than the emitter level of Q1023. This limiting action also takes place when a blanking signal is applied. The clamping of CR1016 allows Q1014 to recover faster to produce a sharper display with sudden changes in blanking level. At normal intensity levels, CR1016 is reverse biased and the signal from Q1014 is coupled to emitter follower Q1023 through CR1015.

The input signals vary the current drive to the emitter of Q1014, which produces a collector level that determines the brilliance of the display. INTENSITY control R1005 sets the quiescent level at the emitter of Q1014. When R1005 is turned in the clockwise direction, more current

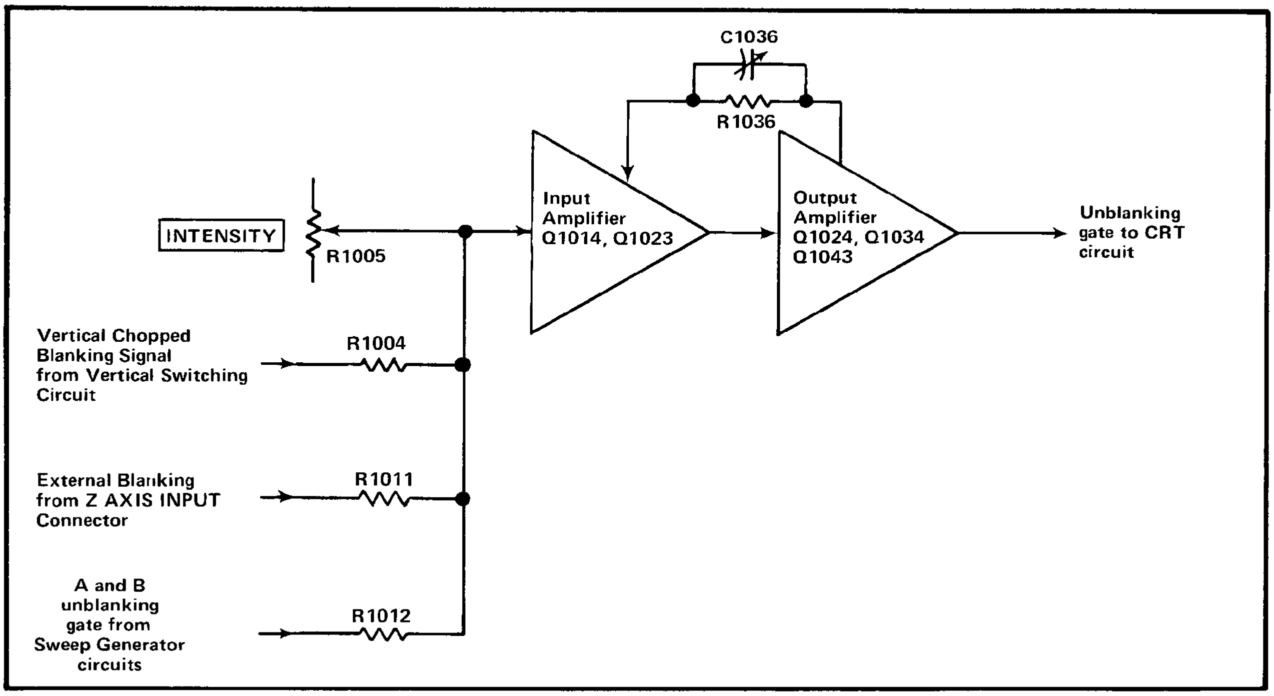


Fig. 3-15. Z Axis Amplifier detailed block diagram.

from the INTENSITY control is added to the emitter circuit of Q1014, which results in an increase in collector current to provide a brighter trace. However, the vertical chopped blanking, Z Axis Input, and sweep unblanking signals (A, B, and mixed) determine whether the trace is visible. The vertical chopped blanking signal blanks the trace during dual-trace switching. This signal decreases the current through Q1014 during the trace switching time to blank the CRT display. The external blanking input allows an external signal connected to the Z AXIS INPUT connector to change the trace intensity. A positive-going signal connected to the Z AXIS INPUT connector decreases trace intensity and a negative-going signal increases trace intensity. The A, B, and mixed unblanking gate signals from the A and B Sweep Generator circuits blank the CRT during sweep retrace and recovery time so there is no display on the screen. When the Sweep Generator circuits are reset and recovered (see A and B Sweep Generator discussion for more information), the next trigger initiates the sweep and an unblanking gate signal is generated by the A or B Sweep Generator circuit that goes negative to allow the emitter current of Q1014 to reach the level established by the INTENSITY control and the other blanking inputs.

Output Amplifier

The resultant signal produced from the various inputs by the Input Amplifier stage is connected to the base of Q1024 through C1029 and to the base of Q1034 through R1024. These transistors are connected as a collector-coupled complementary amplifier. This configuration provides a linear, fast output signal with minimum quiescent power.

The overall Z-Axis Amplifier circuit is a shunt-feedback operational amplifier with feedback from the Output Amplifier stage to the Input Amplifier stage through C1036-C1037-R1036. The output voltage is determined by the input current times the feedback resistor and is shown by the formula: $E_{out} = i_{in} \times R_{fb}$ where R_{fb} is R1036. The unblanking input current change is approximately two milliamperes. Therefore, the output voltage change is about 60 volts (2 mA X 30.1 kΩ). C1036 adjusts the feedback circuit for optimum high-frequency response.

Zener diode VR1043 connected between +75 volts and +150 volts through CR1044, R1044, and R1043 produces a +90-volt level at the cathode of VR1043. This voltage establishes the correct collector level for Q1043. CR1045 connected from base to emitter of Q1043 improves the response of Q1043 to negative-going signals. When the base of Q1043 is driven negative to cutoff, CR1045 is forward biased and conducts the negative-going portion of the unblanking signal. This provides a fast falling edge on the unblanking gate to quickly turn the display off. The output unblanking gate at the emitter of Q1043 is connected to the CRT circuit through R1046.

CRT CIRCUIT

General

The CRT Circuit provides the high voltage and control circuits necessary for operation of the cathode-ray tube (CRT). Fig. 3-16 shows a detailed block diagram of the CRT Circuit. A schematic of this circuit is shown on diagram 16 at the rear of this manual.

High-Voltage Oscillator

Q930 and associated circuitry comprise the high-voltage oscillator to produce the drive for high-voltage transformer T930. When the instrument is turned on, the current through R925 charges C913 positive and Q930 is forward biased. The collector current of Q930 increases and a voltage is developed across the collector winding of T930. This produces a corresponding voltage increase in the feedback winding of T930 which is connected to the base of Q930, and it conducts even harder. While Q930 is on, its base current exceeds the current through R925 and C913 charges negatively. Eventually the rate of collector current increase in Q930 becomes less than that required to maintain the voltage across the collector winding, and the output voltage drops. This turns off Q930 by way of the feedback voltage to the base. The voltage waveform at the collector of Q930 is a sine wave at the resonant frequency of T930. Q930 remains off until a little less than one cycle later when C913 discharges sufficiently to raise the voltage at the base of Q930 positive enough to bias Q930 into conduction again. The cycle repeats at a frequency of 40 to 50 kilohertz. The amplitude of sustained oscillation depends upon the average current delivered to the base of Q930.

Fuse F937 protects the +12-volt Supply if the High-voltage Oscillator stage is shorted. C937 and L937 prevent the current changes at the collector of Q390 from affecting the +12-volt regulator circuit.

High-Voltage Regulator

Feedback from the secondary of T930 is connected to the base of Q914 through the voltage divider network R903-R910. This sample of the output voltage is compared to the −12-volt level at the emitter of Q914. Any change in the level at the base of Q914 produces an error signal at the collector of Q914 which is amplified by Q914 and Q913 and applied to the base of Q923. Amplitude of the oscillations at the collector of Q930 is determined by the average DC level at the emitter of Q923.

Regulation occurs as follows: If the output voltage at the −1960 V test point starts to go positive (less negative),

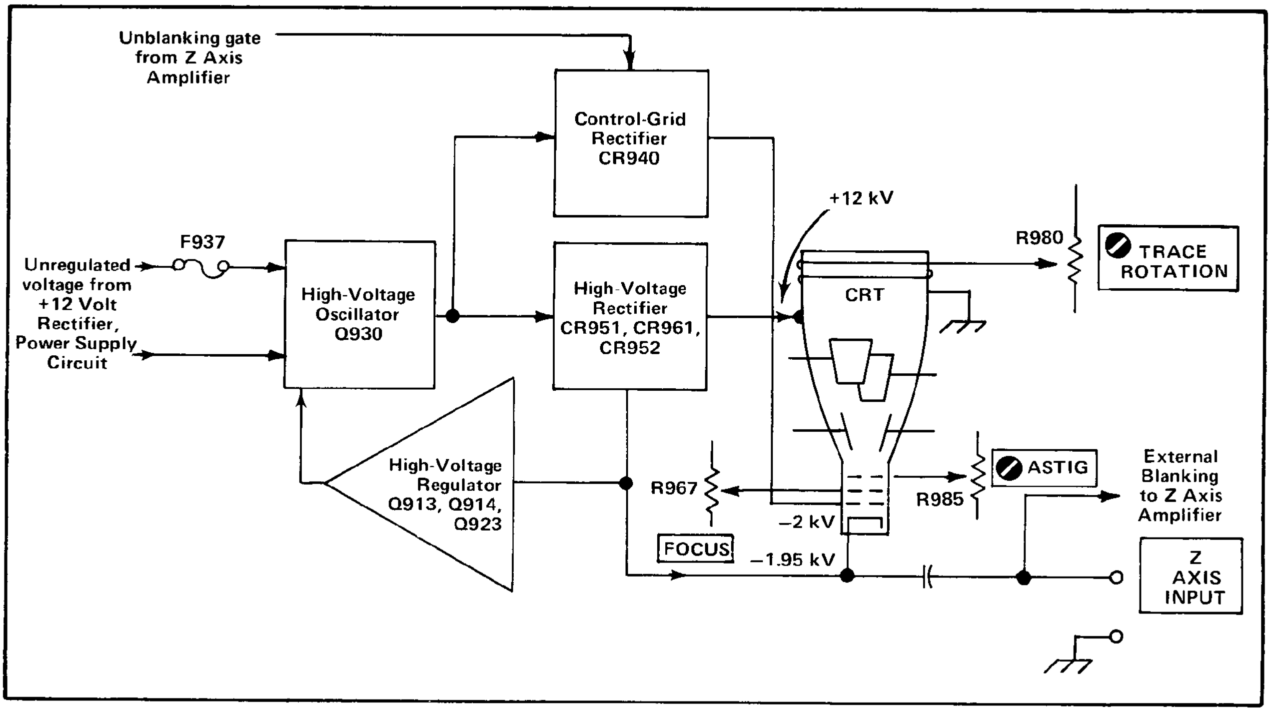


Fig. 3-16. CRT Circuit detailed block diagram.

a sample of this positive-going voltage is applied to the base of Q914. Q914 is forward biased and it, in turn, forward biases Q913 and Q923. This results in a greater bias current to the base of Q930 through the feedback winding of T930. Now, Q930 is biased closer to its conduction level so it comes into conduction sooner to produce a larger induced voltage in the secondary of T930. This increased voltage appears as a more negative voltage at the −1960 V test point to correct the original positive-going change. By sampling the output from the cathode supply in this manner, the total output of the high-voltage supply is held constant.

Output voltage level of the high-voltage supply is controlled by High Voltage adjustment R900 in the base circuit of Q914. This adjustment sets the conduction of Q914 to a level which establishes a −1960-volt operating potential at the CRT cathode.

High Voltage Rectifiers and Output

High-voltage transformer T930 has three output windings. One winding provides filament voltage for the cathode-ray tube. The filament voltage can be supplied from the high-voltage supply since the cathode-ray tube has a very low filament current drain. The cathode and filament are connected together through R975 to elevate the filament and prevent cathode-to-filament breakdown. Two high-voltage windings provide the negative and positive accelerating voltage and the CRT grid bias voltage. All of these outputs are regulated by the High-Voltage Regulator stage in the primary of T930 to hold the output voltage constant.

Positive accelerating potential is supplied by voltage tripler CR953, CR955, and CR957. Regulated voltage output is about +12 kilovolts. Ground return for this supply is through the resistive helix inside the cathode-ray tube to ground through VR963.

The negative accelerating potential for the CRT cathode is supplied by half-wave rectifier CR952. Voltage output is about −1.96 kilovolts. A sample of this output voltage is connected to the High-Voltage Regulator stage to provide a regulated high-voltage output.

Half-wave rectifier CR940 provides a negative voltage for the control grid of the CRT. Output level of this supply is set by CRT Grid Bias adjustment R940. Neon bulbs DS973, DS974, and DS975 provide protection if the voltage difference between the control grid and cathode exceeds about 165 volts. The unblanking gate from the Z Axis Amplifier is applied to the positive side of this circuit to produce a change in output voltage to control CRT intensity, unblanking, dual-trace blanking, and intensity modulation.

CRT Control Circuits

Focus of the CRT display is controlled by FOCUS control R967. ASTIG adjustment R985 which is used in conjunction with the FOCUS control to provide a well-defined display, varies the positive level on the astigmatism grid. Geometry adjustment R982 varies the positive level on the horizontal deflection plate shields to control the overall geometry of the display.

Two adjustments control the trace alignment by varying the magnetic field around the CRT. Y Axis Align adjustment R989 controls the current through L989 which affects the CRT beam after vertical deflection but before horizontal deflection. Therefore, it affects only the vertical (Y) components of the display. TRACE ROTATION adjustment R980 controls the current through L980 and affects both vertical and horizontal rotation of the beam.

External Z Axis Input

Signals applied to the Z AXIS INPUT connector (see Z Axis Amplifier schematic) are applied to the CRT cathode through C979-C976-R976. DC and low frequency Z-axis signals are blocked from the CRT Circuit by C979. However, they are connected to the Z Axis Amplifier circuit to produce an increase or decrease in intensity, depending upon polarity. C976 and C979 couple high-frequency signals directly to the CRT cathode to produce the same resultant display as the Z Axis Amplifier circuit produces for low-frequency signals. This configuration operates as a crossover network to provide nearly constant intensity modulation from DC to 50 megahertz.

LOW-VOLTAGE POWER SUPPLY

General

The Low-Voltage Power Supply circuit provides the operating power for this instrument from three regulated supplies and one unregulated supply. Electronic regulation is used to provide stable, low-ripple output voltages. Each regulated supply contains a short-protection circuit to prevent instrument damage if a supply is inadvertently shorted to ground. The Power Input stage includes the Line Voltage Selector assembly. This assembly allows selection of the nominal operating voltage and regulating range for the instrument. Fig. 3-17 shows a detailed block diagram of the Power Supply circuit. A schematic of this circuit is shown on diagram 17 at the rear of this manual.

Power Input

Power is applied to the primary of transformer T1101 through the 115-volt line fuse F1101, POWER switch S1101, thermal cutout S1104, Voltage Selector switch S1102, and Range Selector switch S1103. The Voltage

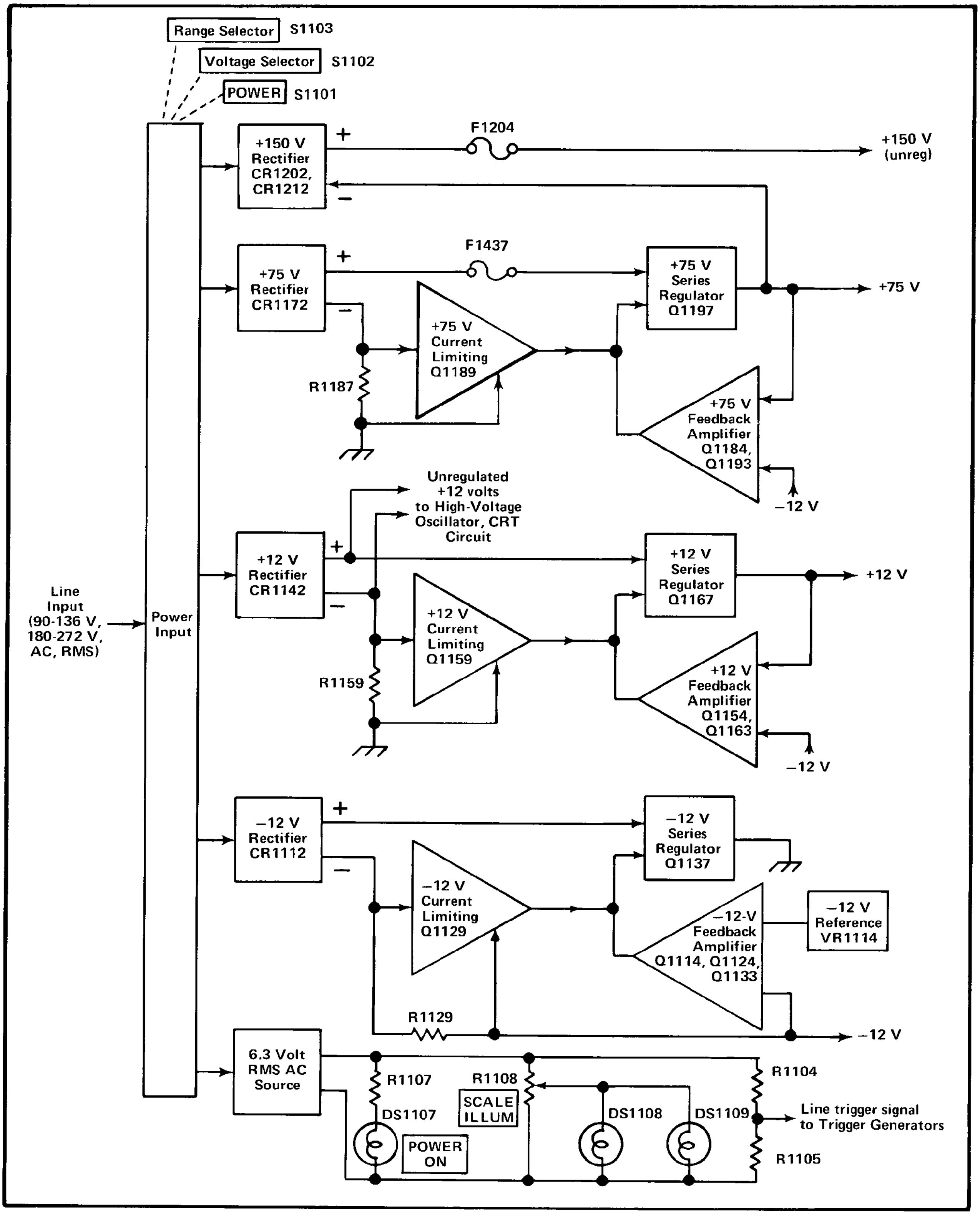


Fig. 3-17. Power Supply detailed block diagram.

Selector switch S1102 connects the split primaries of T1101 in parallel for 115-volt nominal operation, or in series for 230-volt nominal operation. A second line fuse, F1102, is connected into this circuit when the Voltage Selector switch is set to the 230 V position to provide the correct protection for 230-volt operation (F1102 current rating is one-half of F1101).

Range Selector switch S1103 allows the instrument to regulate correctly on higher or lower than normal line voltages. Each half of the primary has taps above and below the nominal voltage point (115 or 230 volts). As Range Selector switch S1103 is switched from LO to M to HI, more turns are effectively added to the primary winding and the turns ratio is decreased. This configuration compensates for higher or lower than normal line voltage to extend the regulating range of the Low-Voltage Power Supply.

Thermal cutout S1104 provides thermal protection for this instrument. If the internal temperature of the instrument exceeds a safe operating level, S1104 opens to interrupt the applied power. When the temperature returns to a safe level, S1104 automatically closes to re-apply the power.

−12-Volt Supply

The following discussion includes the description of the −12 V Rectifier, −12 V Series Regulator, −12 V Feedback Amplifier, −12 V Reference, and −12 V Current Limiting stages. Since these stages are closely related in the production of the −12-volt regulated output voltage, their operation is most easily understood when discussed as a unit.

The −12 V Rectifier assembly CR1112 rectifies the output at the secondary of T1101 to provide the unregulated voltage source for this supply. CR1112 is connected as a bridge rectifier and its output voltage is filtered by C1112 before it is applied to the −12 V Series Regulator Q1137. Transistors Q1114, Q1124, and Q1133 operate as a feedback-stabilized regulator circuit to maintain a constant −12-volt output level. Q1114 and Q1124 are connected as a differential amplifier to compare the feedback voltage at the base of Q1124 against the reference voltage at the base of Q1114. The error output at the collector of Q1114 reflects the difference, if any, between these two inputs. The change in error-output level at the collector of Q1124 is always in the same direction as the change in the feedback input at the base of Q1124 (in phase).

Zener diode VR1114 sets a reference level of about −9 volts at the base of Q1114. A sample of the output voltage from this supply is connected to the base of Q1124 through divider R1121-R1122-R1123. R1122 in this divider is adjustable to set the output level of this supply. Regulation occurs as follows: If the output level of this supply decreases (less negative) due to an increase in load, or a decrease in input voltage (as a result of line voltage changes or ripple), the voltage across divider R1121-R1122-R1123 decreases also. This results in a more positive feedback level at the base of Q1124 than established by the −12 V Reference stage at the base of Q1114. Since the transistor with the more positive base controls the conduction of the differential amplifier, the output current at the collector of Q1114 decreases. This decrease in output from Q1114 allows more current to flow through Q1133 to result in increased conduction of −12 V Series Regulator Q1137. The load current increases and the output voltage of this supply also increases (more negative). As a result, the feedback voltage to the base of Q1124 returns to the same level as the base of Q1114. Similarly, if the output level of this supply increases (more negative), the output current of Q1114 increases. The feedback through Q1133 reduces the conduction of the −12 V Series Regulator to decrease the output voltage of this supply.

The −12 Volts adjustment R1122 determines the divider ratio to the base of Q1124, and thereby determines the feedback voltage. This adjustment sets the output level of the supply in the following manner: If R1122 is adjusted so the voltage at its variable arm goes less negative (closer to ground), this appears as an error signal at the base of Q1124. In the same manner as described previously, this positive-going change at the feedback input of the differential amplifier increases the conduction of the −12 V Series Regulator to produce more current through the load, and thereby increase the output voltage of this supply. This places more voltage across divider R1121-R1122-R1123, and the divider action returns the base of Q1124 to about −9 volts. Notice that the feedback action of this supply forces a change in the output level which always returns the base of Q1124 to the same level as the base of Q1114. In this manner, the output level of the −12-Volt Supply can be set exactly to −12 volts by correct adjustment of R1122.

The −12 V Current Limiting stage Q1129 protects the −12-Volt Supply if excess current is demanded from this supply. All output current from the −12-Volt Supply must flow through R1129. Transistor Q1129 senses the voltage drop across R1129. Under normal operating conditions, there is about 0.3-volt drop across R1129, which is not sufficient to forward bias Q1129. However, when excess current is demanded from the −12 V Series Regulator due to a short circuit or similar malfunction at the output of this supply, the voltage drop across R1129 increases until it is sufficient to forward bias Q1129. The collector current of Q1129 results in a reduction of current through Q1133 to decrease the conduction of Q1137 and limit the output current.

+12-Volt Supply

The unregulated voltage applied to the +12-Volt Supply is also connected to the High-Voltage Oscillator stage in the CRT circuit.

Basic operation of all stages in the +12-Volt Supply is similar to the −12-Volt Supply. However, the +12 V Feedback Amplifier provides inversion in the feedback path. The reference level for this supply is established by the ground connection at the emitter of Q1154. Feedback voltage to the base of Q1154 is provided by divider R1151-R1152-R1153 between the output of this supply and regulated −12 volts. The −12 volts is held stable by the −12-Volt Supply as discussed previously. Therefore, any change at the output of the +12-Volt Supply appears at the base of Q1154 as an error signal. The output voltage is regulated in the manner described previously for the −12-Volt Supply. Diode CR1152 provides thermal compensation for the +12 V Feedback Amplifier. CR1164 protects Q1154 from damage if the output of this supply is shorted to a more positive supply.

+75-Volt Supply

Operation of the +75-Volt Supply is the same as described for the other supplies. The unregulated output of the +150-Volt Supply is connected to the +75 V Feedback Amplifier to provide sufficient collector supply for stable operation. The unregulated +150 volts connected to zener diode VR1209 through R1209 establishes a voltage level at the cathode of VR1209 of about +108 volts. The drop across R1186 sets the correct base level for Q1193 and the drop across VR1185-R1185 sets the correct collector level for Q1184. Diode CR1182 provides thermal compensation for the +75 V Feedback Amplifier.

Two means of overload protection are provided for this supply. The +75 V Current Limiting stage Q1189 operates in a manner similar to that described previously to control the conduction of the +75 V Series Regulator through CR1188 and Q1193. In addition, F1437 provides overload protection for this supply. Diode CR1198 protects the +75-Volt Supply from damage if it is shorted to the −12-Volt Supply.

+150-Volt Unregulated Supply

Rectifiers CR1202 and CR1212 provide the rectified voltage for the +150-Volt Supply. However, this secondary winding of T1101 does not supply the full potential necessary to obtain the +150-volt output level. To provide the required output level, the negative side of this supply is connected to the output of the +75-Volt Supply so the two supplies are effectively connected in series between ground and the +150-volt output. The output from this secondary winding of T1101 also provides the operating potential for the fan. The full-wave output of the +150 V Rectifier is filtered by C1202-C1204-R1204 to provide an output level of about +150 volts. Fuse F1204 protects this supply if the output is shorted.

6.3-Volt RMS AC Source

The 6.3-volt RMS secondary winding of T1101 provides power for the POWER ON light, DS1107, and the scale illumination lights, DS1108 and DS1109. The current through the scale illumination lights is controlled by the SCALE ILLUM control, R1108, to change the illumination of the graticule lines. Divider R1104-R1105 provides a sampling of the line voltage to the A and B Trigger Generator circuits for internal triggering at the line frequency. C1105 reduces noise on the line frequency signal.

VOLTAGE DISTRIBUTION

Diagram 17 also shows the distrubution of the output voltages from the Power Supply curcuit to the circuit boards in this instrument. The decoupling networks which provide decoupled operating voltages are shown on this Diagram and are not repeated on the individual circuit diagrams.

CALIBRATOR

General

The Calibrator circuit produces a square-wave output with accurate amplitude and frequency. This output is available as a square-wave voltage at the 1 kHz CAL connector or as a square-wave current through the side-panel PROBE LOOP. Fig. 3-18 shows a detailed block diagram of the Calibrator circuit. A schematic of this circuit is shown on diagram 18 at the rear of this manual.

Oscillator

Q1255 and its associated circuitry comprise a tuned-collector oscillator. Frequency of oscillation is determined by the LC circuit made up of the primary of variable transformer T1255 in parallel with C1255. The accuracy and stability required to provide an accurate time and frequency reference is obtained by using a capacitor and transformer which have equal but opposite temperature coefficients.

The oscillations of the LC circuit, T1255-C1255, are sustained by the feedback winding of T1255 connected to the base of Q1255. C1266 connects a sample of the output of the LC circuit to the base of Q1265. The regenerative feedback from the emitter of Q1265 to the emitter of Q1255 produces fast changeover between Q1255 and Q1265 to provide a fast risetime on the output square wave. Frequency of the output square wave can be adjusted by

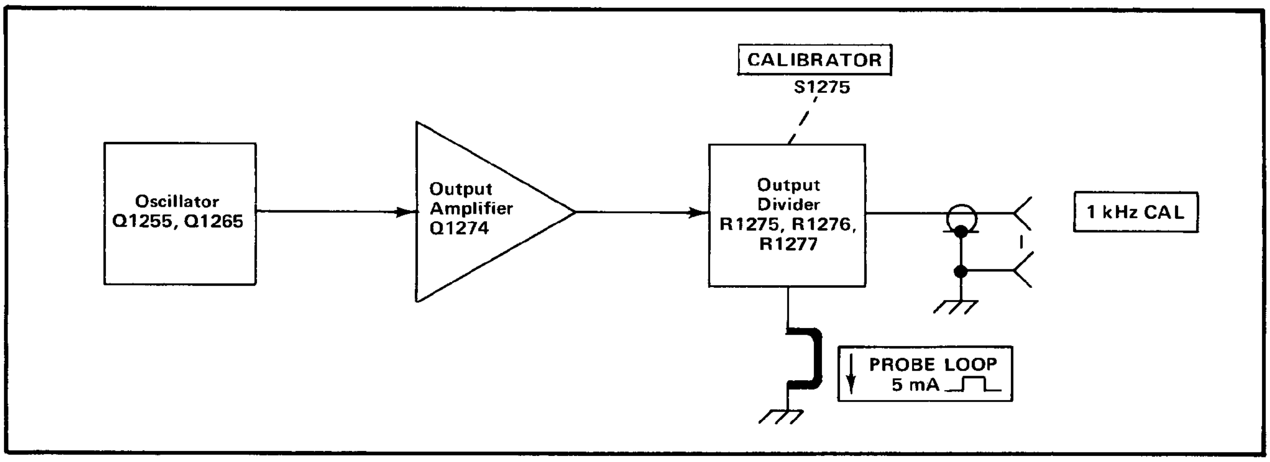


Fig. 3-18. Calibrator detailed block diagram.

varying the coupling to the feedback winding of T1255. The square-wave signal at the collector of Q1265 is connected to the Output Amplifier.

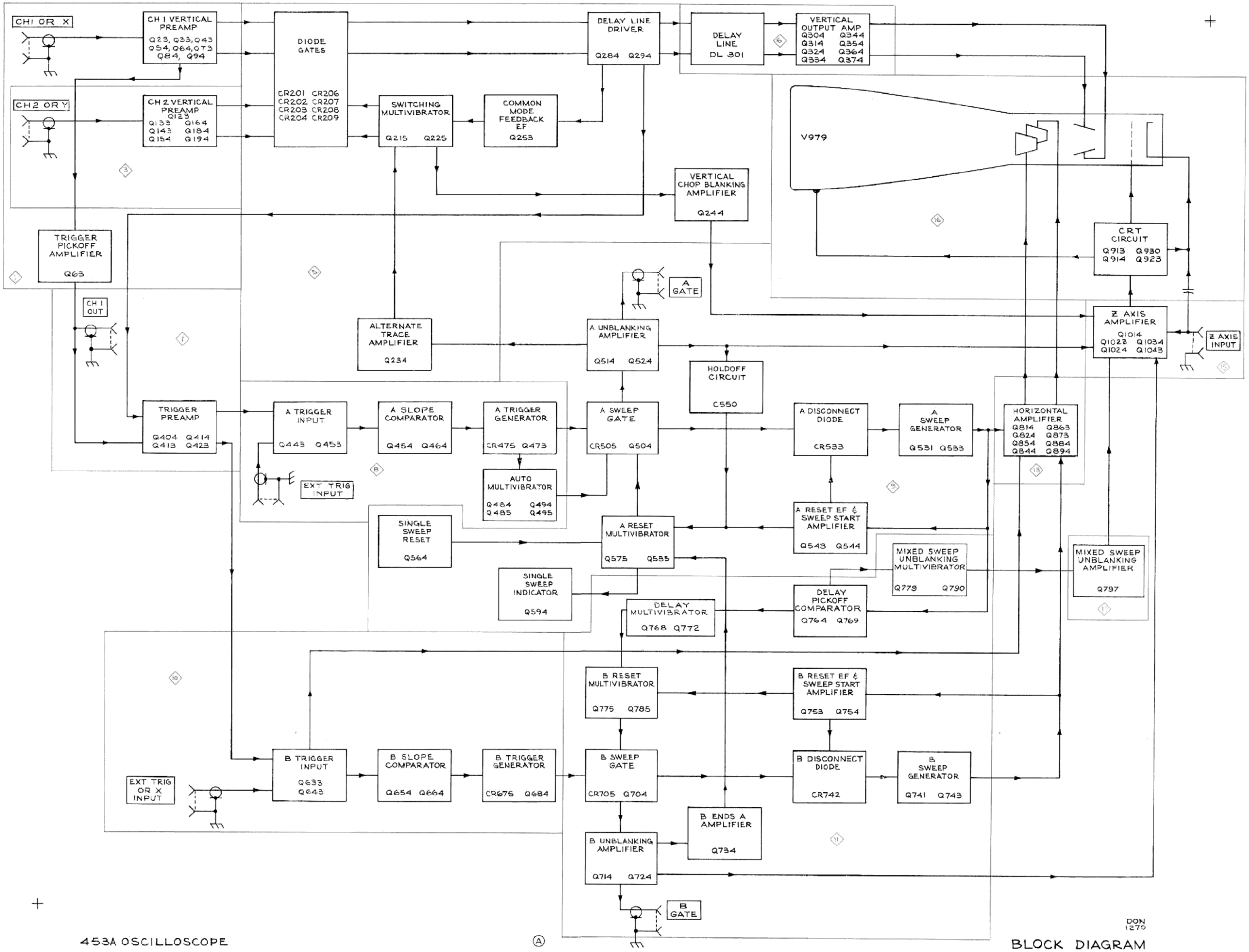
Output Amplifier

The output signal from the oscillator stage saturates Q1274 to produce the accurate square wave at the output. When the base of Q1274 goes positive, Q1274 is cut off and the output signal drops negative to ground. When its base goes negative, Q1274 is driven into saturation and the output signal rises positive to about +12 volts. The output of the +12-Volt Supply is adjusted for an accurate one-volt output signal at the 1 kHz CAL connector when the CALIBRATOR switch is set to 1 V.

Output Divider

Output Divider R1275-R1276-R1277 provides two output voltages from the Calibrator circuit. In the 1 V CALIBRATOR switch position, voltage is obtained from the collector of Q1274 through R1274. In the .1 V CALIBRATOR switch position, the output is obtained at the junction of voltage divider R1275 and R1276-R1277 to provide one-tenth of the previous output voltage.

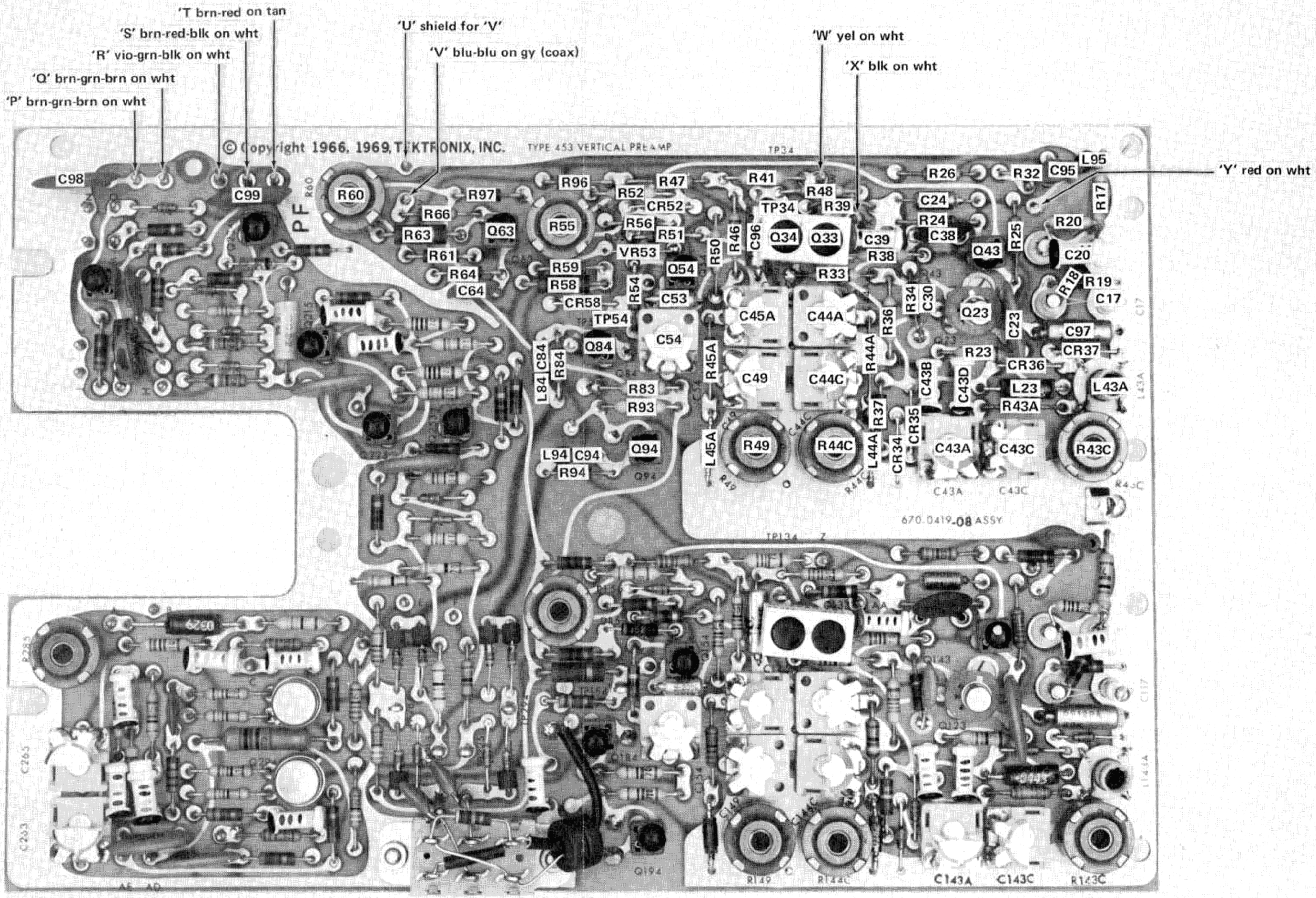
Collector current of Q1274 flows through the PROBE LOOP on the side panel. Output current is a five-milliampere square wave.



453A OSCILLOSCOPE

Ⓐ

BLOCK DIAGRAM

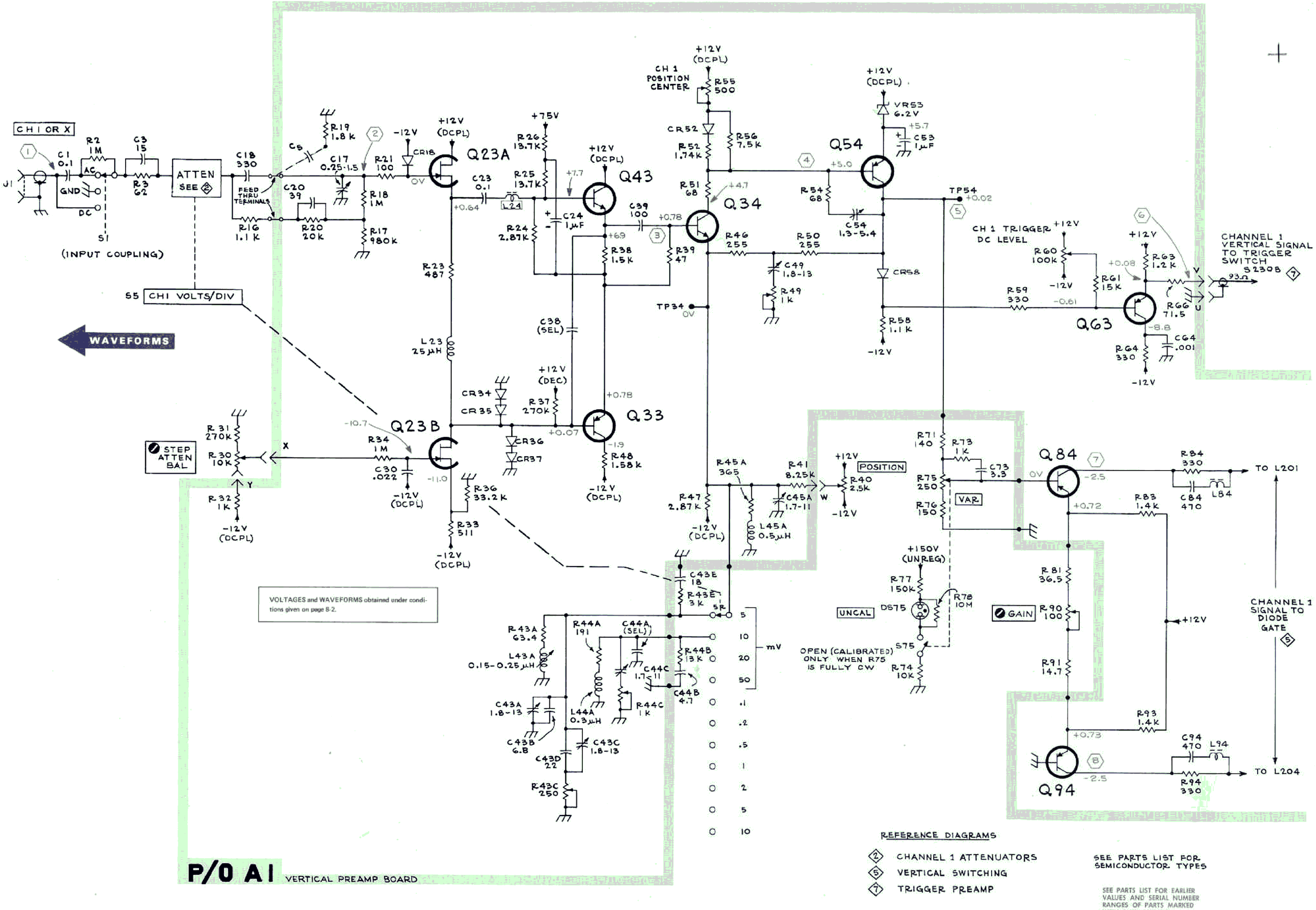


NOTE:
C18, CR18, R16, R21, R71, R76, R81, R91
mounted on rear of board.

See Figs. 8-2 and 8-3 for location of parts not identified here.

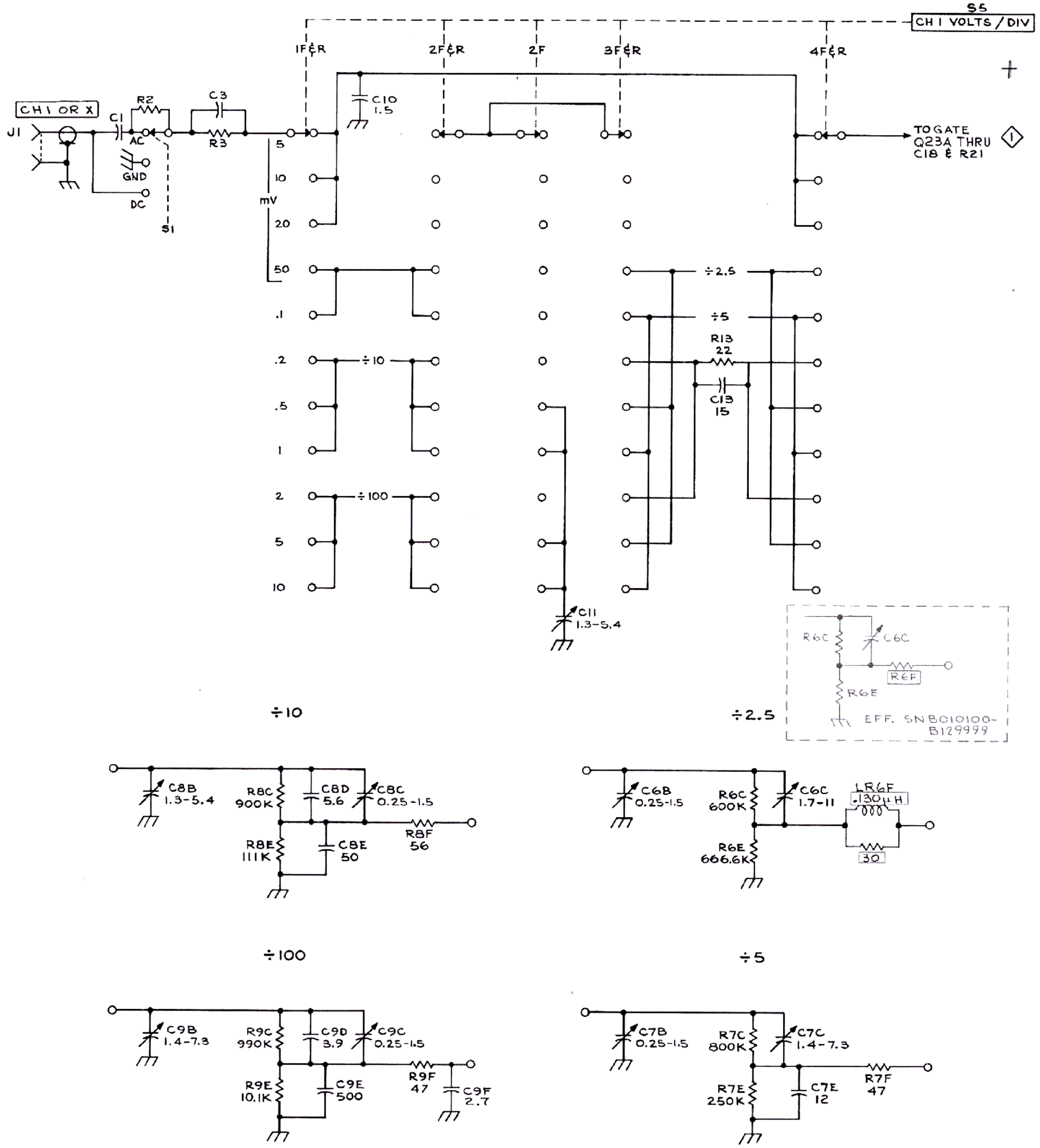
FRONT

Fig. 8-1. P/O A1. Partial Vertical Preamp circuit board.



453A OSCILLOSCOPE ® CHANNEL 1 VERTICAL PREAMP 1

1071 TRN

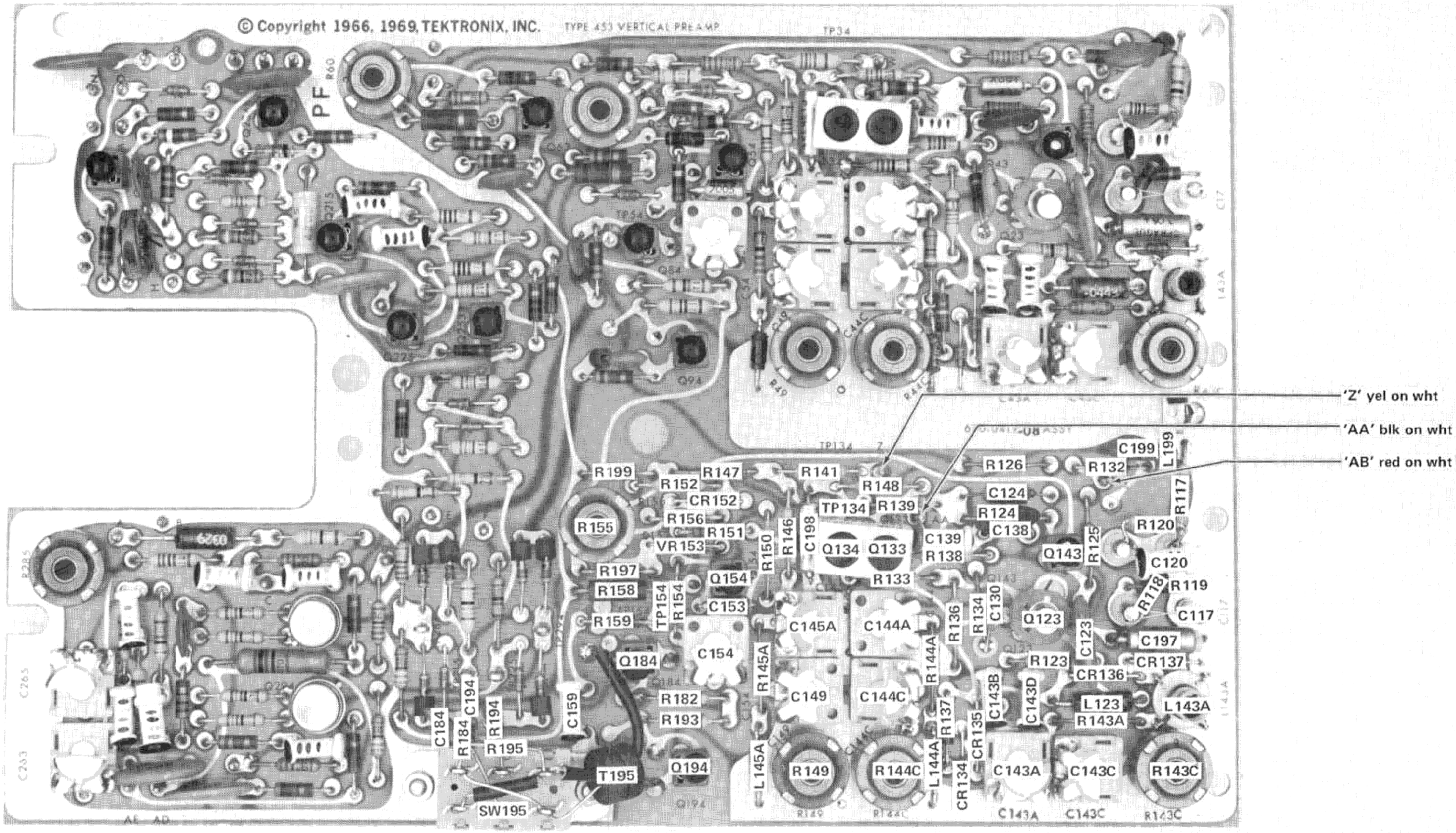


REFERENCE DIAGRAMS

1 CHANNEL 1 VERTICAL PREAMP

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

DON 1171

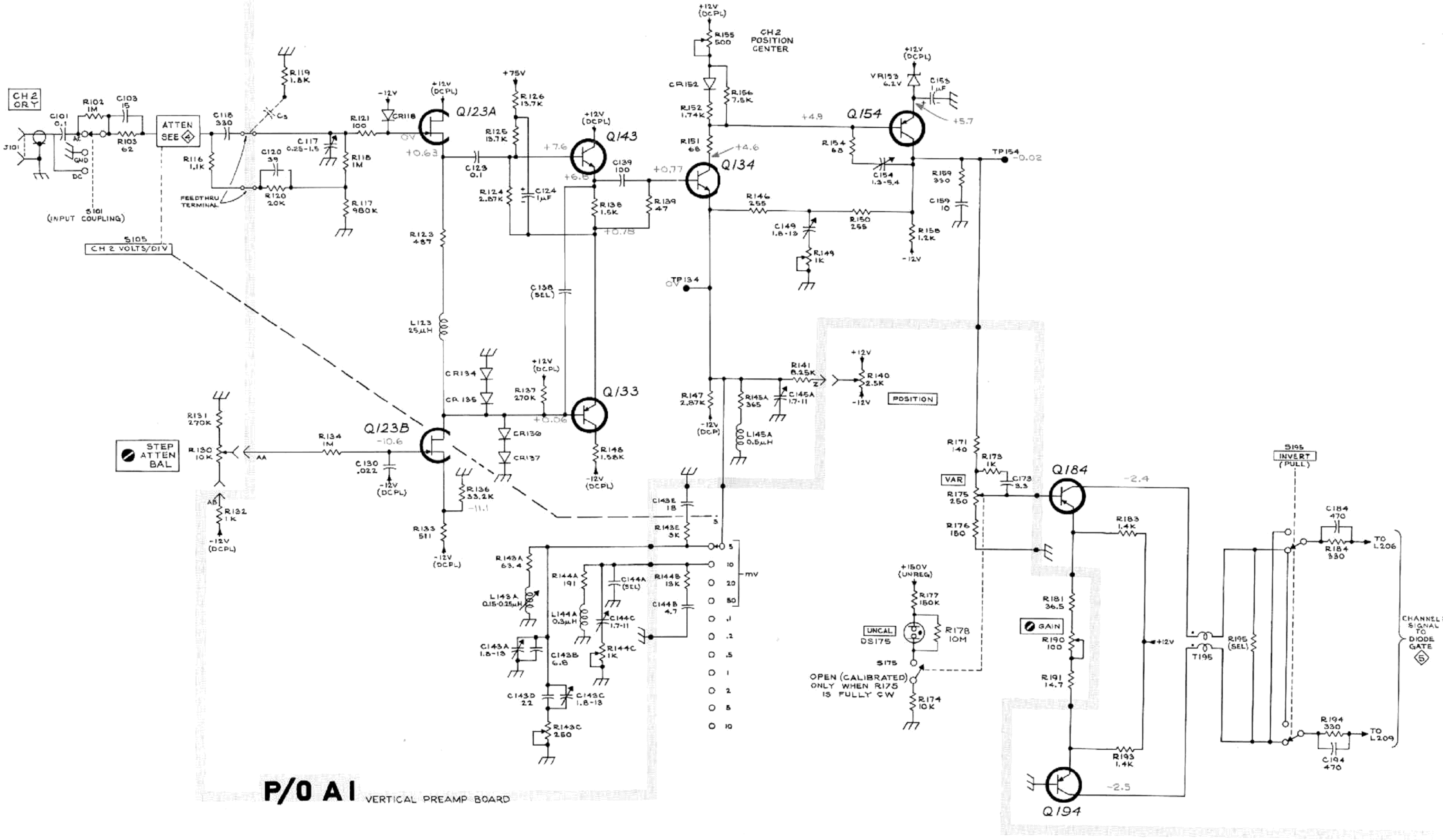


NOTE:
CR118, R116, R121, R171, R176, R181, R191
mounted on rear of board.

See Figs. 8-1 and 8-3 for location of parts not identified here.

FRONT

Fig. 8-2. P/O A1. Partial *Vertical Preamp* circuit board



REFERENCE DIAGRAMS
4 CHANNEL 2 ATTENUATORS
5 VERTICAL SWITCHING

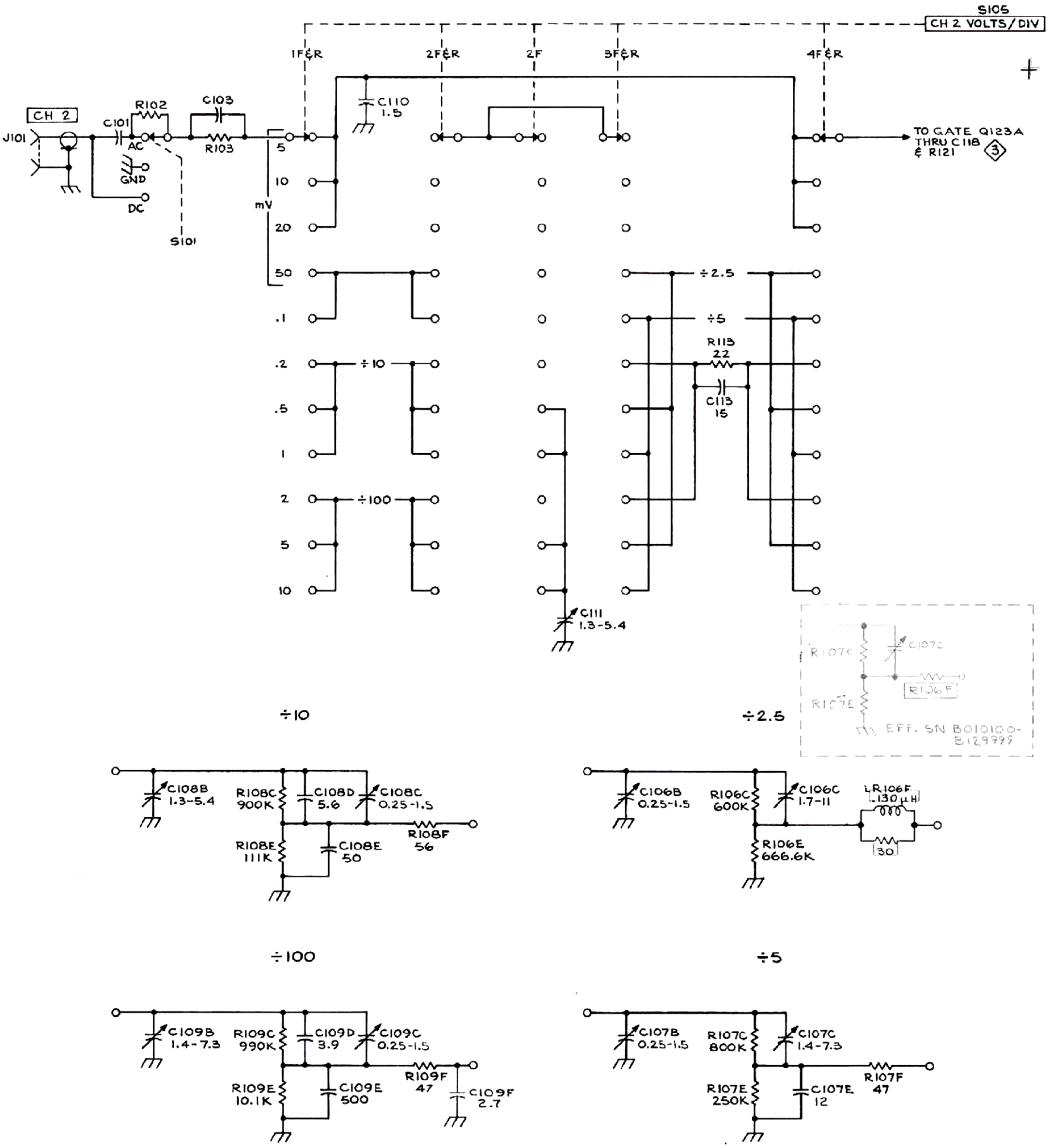
SEE PARTS LIST FOR SEMICONDUCTOR TYPES.

VOLTAGES obtained under conditions given on p3-2 except as follows (see diagram 1 for typical WAVEFORMS):

MODE CH 2

CMD 1270

CHANNEL 2 VERTICAL PREAMP

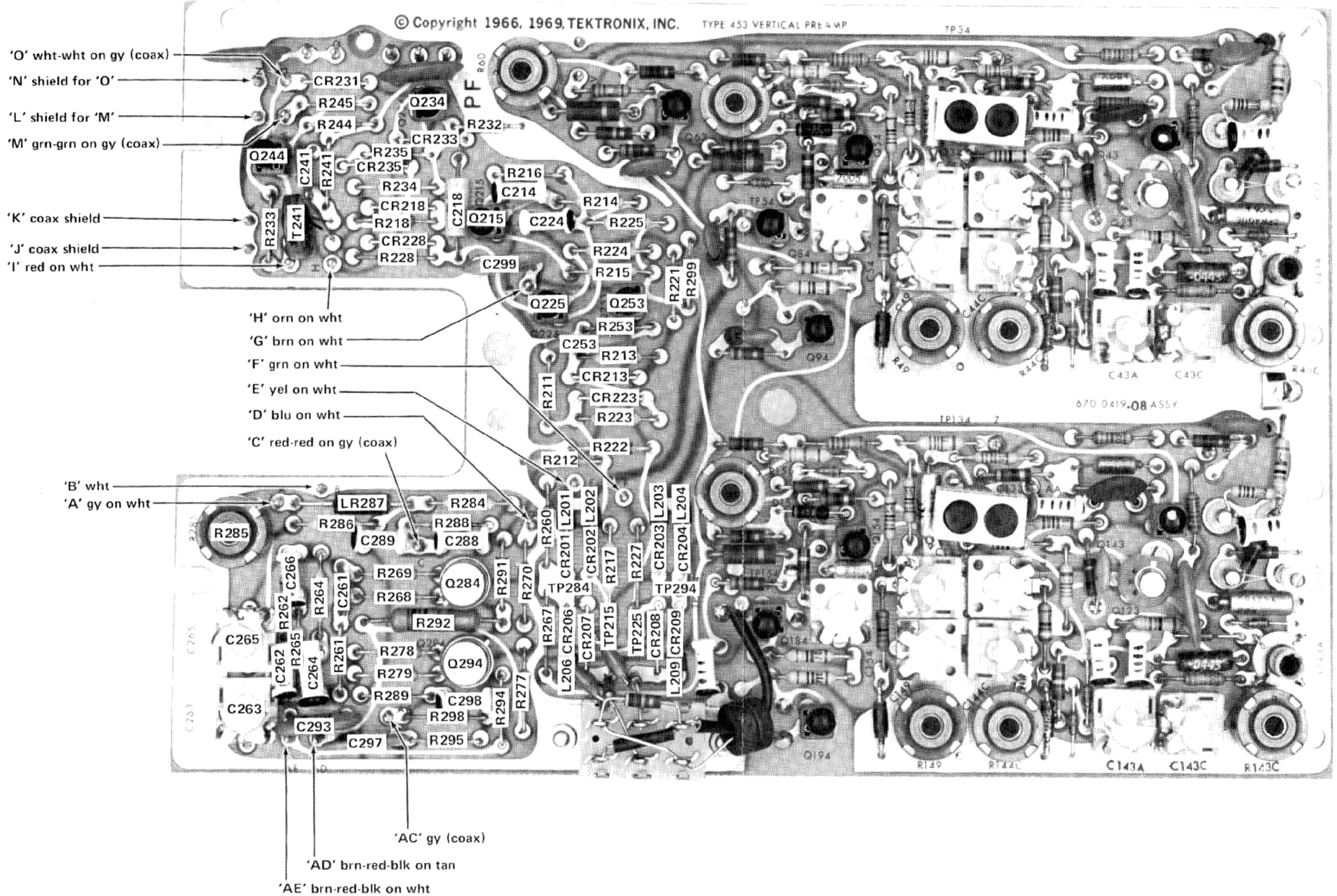


REFERENCE DIAGRAMS

(3) CHANNEL 2 VERTICAL PREAMP

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

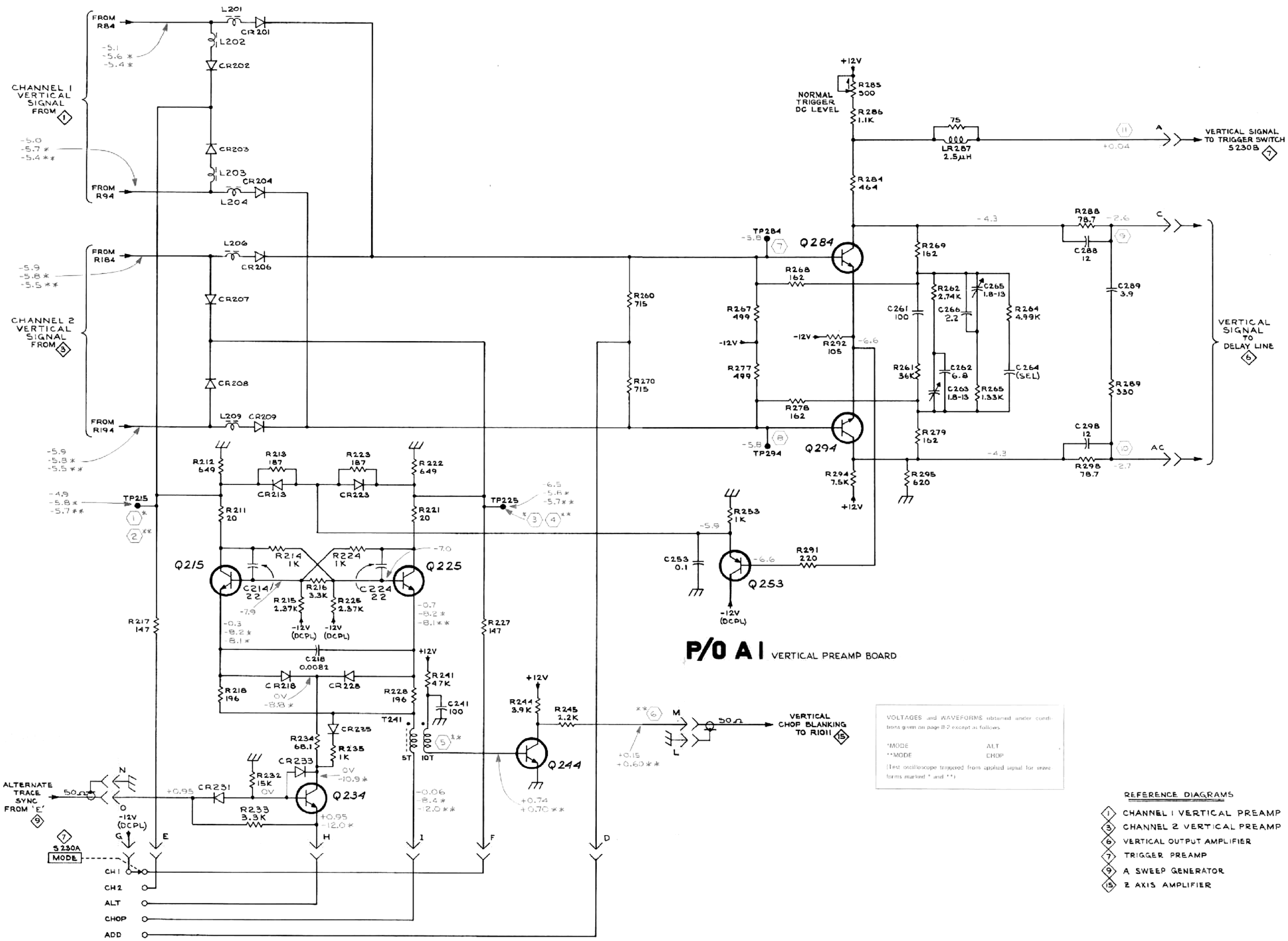
DON
1171

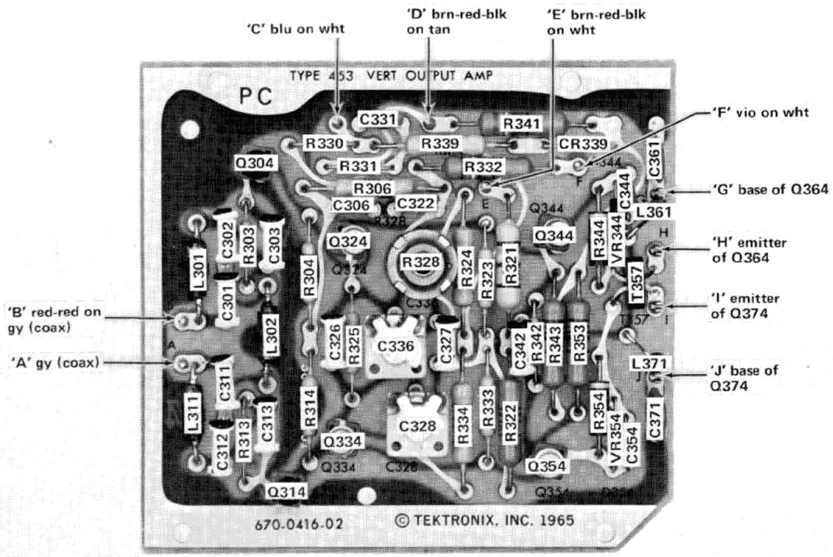


See Figs. 8-1 and 8-2 for location of parts not identified here.

FRONT

Fig. 8-3. P/O A1. Partial Vertical Preamp circuit board.


FROM R84
L201
CR201
L202
CR202
CHANNEL 1 VERTICAL SIGNAL FROM 1
CR203
L203
CR204
FROM R94
L204
FROM R184
L206
CR206
CR207
CHANNEL 2 VERTICAL SIGNAL FROM 3
CR208
FROM R194
L209 CR209
R212 649
R213 187
R223 187
R222 649
CR213
CR223
TP215
TP225
R211 20
R221 20
R214 1K
R224 1K
Q215
Q225
C214 22
C224 22
R216 3.3K
R215 2.37K
R225 2.37K
-12V (DCPL)
R217 147
R227 147
C218 0.0082
CR218
CR228
R218 196
R228 196
R241 47K
C241 100
T241
CR235
R234 68.1
R235 1K
CR233
R232 15K
Q234
R233 3.3K
CR231
ALTERNATE TRACE SYNC FROM 'E' 9
S230A MODE
CH1
CH2
ALT
CHOP
ADD
R244 3.9K
R245 2.2K
Q244
VERTICAL CHOP BLANKING TO R1011 15
R260 715
R270 715
+12V
R285 500
NORMAL TRIGGER DC LEVEL
R286 1.1K
75
LR287 2.5µH
VERTICAL SIGNAL TO TRIGGER SWITCH S230B 7
R284 464
TP284
Q284
R269 162
R268 162
R267 499
R277 499
R292 105
R262 2.74K
C265 1.8-13
C266 2.2
R264 4.99K
C261 100
R261 36K
C262 6.8
C263 1.8-13
R265 1.33K
C264 (SEL)
R278 162
Q294
TP294
R279 162
R294 7.5K
R295 620
R288 78.7
C288 12
C289 3.9
R289 330
C298 12
R298 78.7
VERTICAL SIGNAL TO DELAY LINE 6
R253 1K
C253 0.1
R291 220
Q253
P/O A1 VERTICAL PREAMP BOARD
VOLTAGES and WAVEFORMS obtained under conditions given on page 8-2 except as follows.
*MODE ALT
**MODE CHOP
(Test oscilloscope triggered from applied signal for waveforms marked * and **)
REFERENCE DIAGRAMS
1 CHANNEL 1 VERTICAL PREAMP
3 CHANNEL 2 VERTICAL PREAMP
6 VERTICAL OUTPUT AMPLIFIER
7 TRIGGER PREAMP
9 A SWEEP GENERATOR
15 Z AXIS AMPLIFIER



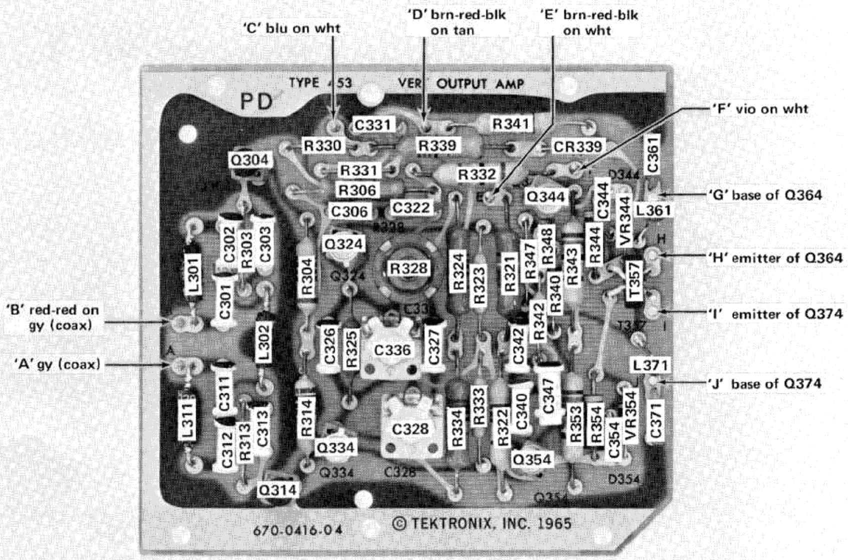
SN B010100-B049999

NOTE:
C340, C347, R340, R347, R348 mounted on rear of board.

FRONT

Fig. 8-4A. A-2. Vertical Output Amplifier circuit board.

Ⓑ

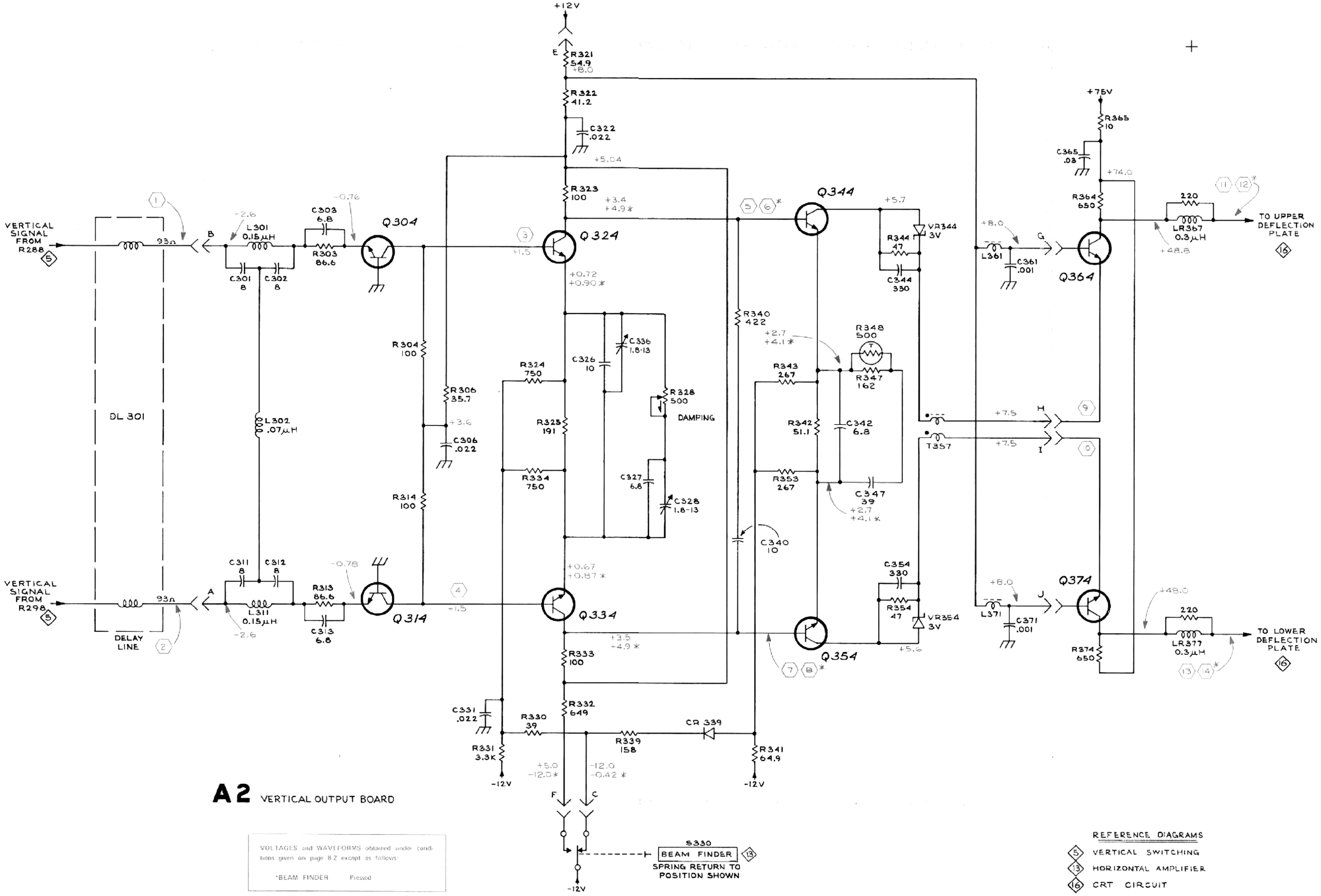


SN B050000-up

FRONT

Fig. 8-4B. A-2. Vertical Output Amplifier circuit board.

Ⓐ



CMD 1270

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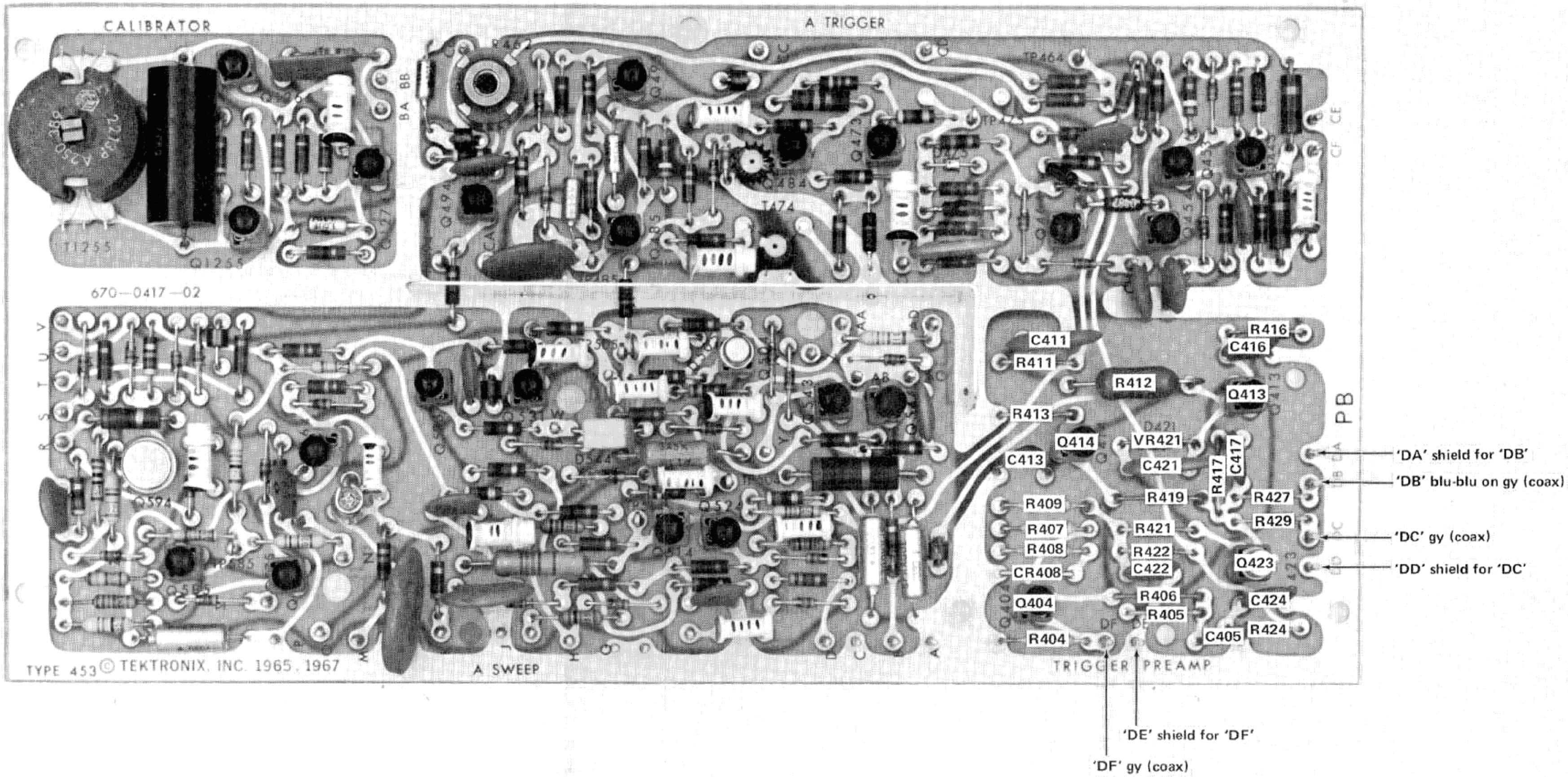
VERTICAL OUTPUT AMPLIFIER 6

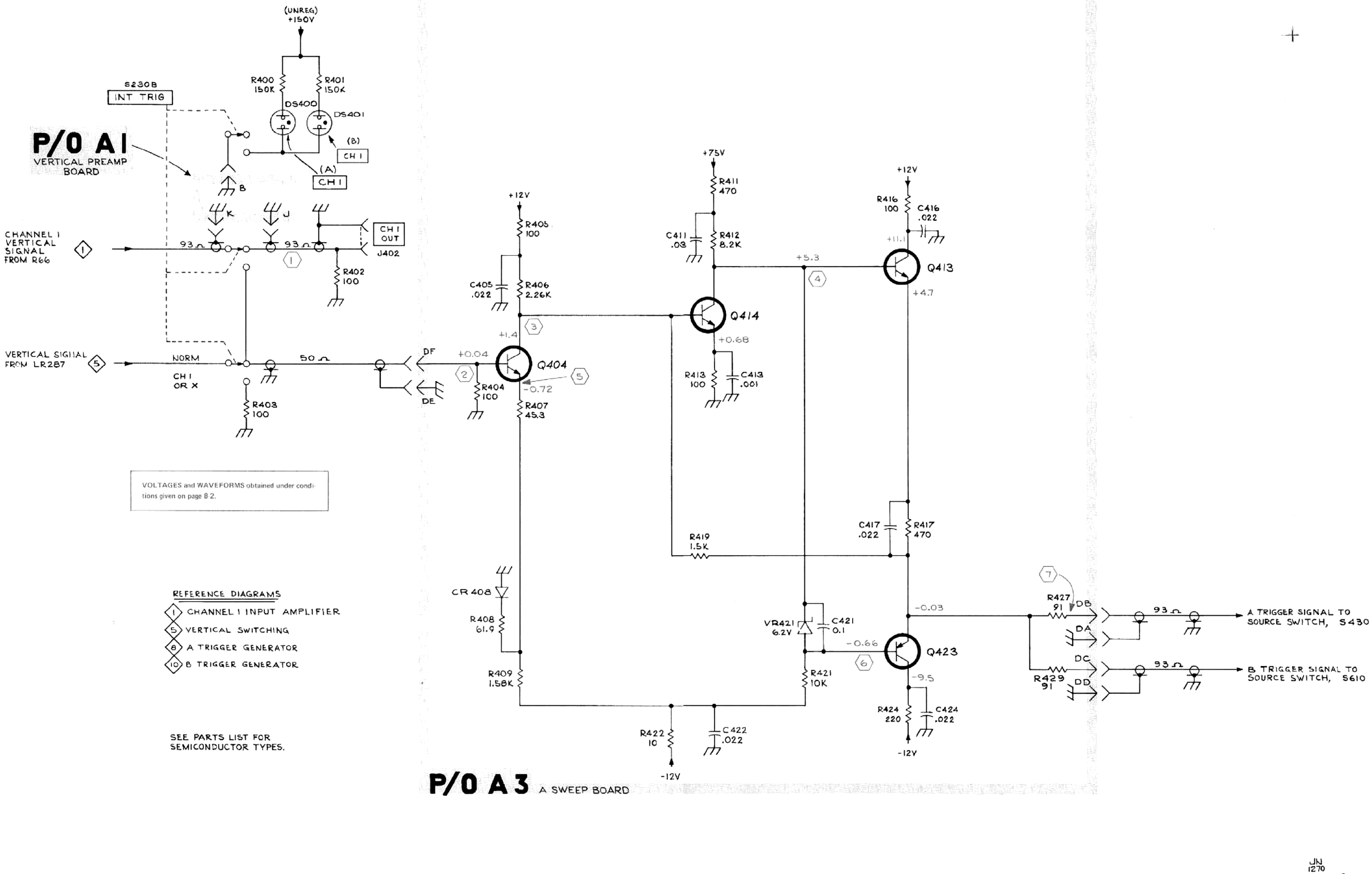


See Figs. 8-6, 8-7 and 8-14 for location for parts not identified here.

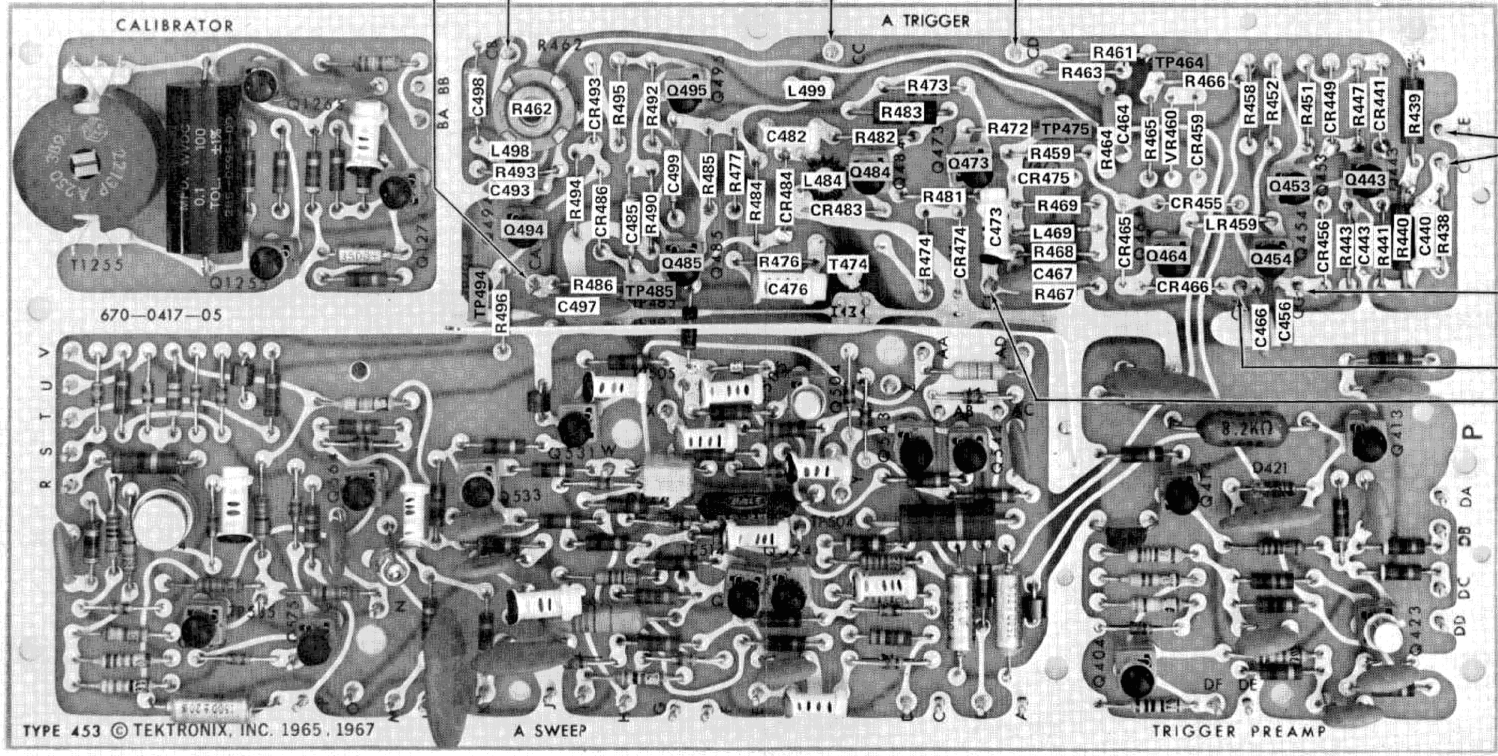
FRONT

Fig. 8-5. P/O A3. Partial A Sweep circuit board.

Ⓐ

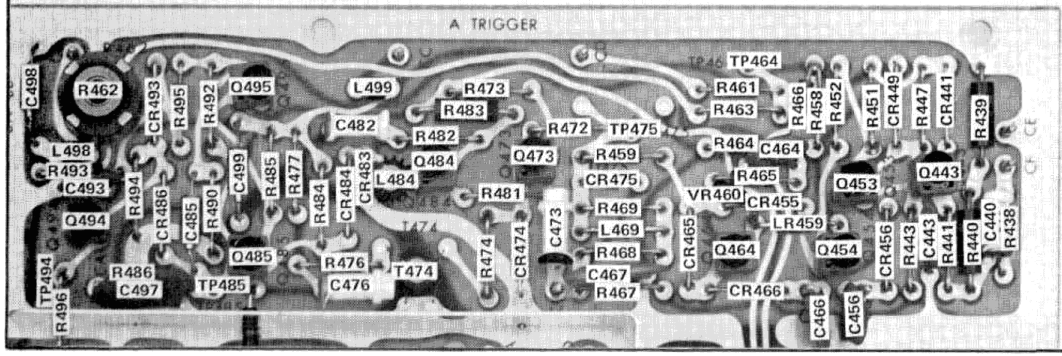


(UNREG) +150V
R400 150K
R401 150K
DS400
DS401
S230B
INT TRIG
P/0 A1
VERTICAL PREAMP BOARD
(B) CH 1
(A) CH 1
CHANNEL 1 VERTICAL SIGNAL FROM R66
93 Ω
CH 1 OUT
J402
R402 100
VERTICAL SIGNAL FROM LR287
NORM
CH 1 OR X
50 Ω
R403 100
DF
DE
+12V
R405 100
C405 .022
R406 2.26K
+1.4
+0.04
Q404
R404 100
-0.72
R407 45.3
+75V
R411 470
C411 .03
R412 8.2K
+5.3
Q414
+0.68
R413 100
C413 .001
+12V
R416 100
C416 .022
+11.1
Q413
+4.7
C417 .022
R417 470
R419 1.5K
CR408
R408 61.9
R409 1.58K
R422 10
C422 .022
-12V
VR421 6.2V
C421 0.1
-0.66
Q423
R421 10K
-9.5
R424 220
C424 .022
-12V
-0.03
R427 91
DB
DA
DC
DD
R429 91
93 Ω
A TRIGGER SIGNAL TO SOURCE SWITCH, S430
B TRIGGER SIGNAL TO SOURCE SWITCH, S610
VOLTAGES and WAVEFORMS obtained under conditions given on page 8-2.
REFERENCE DIAGRAMS
1 CHANNEL 1 INPUT AMPLIFIER
5 VERTICAL SWITCHING
8 A TRIGGER GENERATOR
10 B TRIGGER GENERATOR
SEE PARTS LIST FOR SEMICONDUCTOR TYPES.
P/0 A3 A SWEEP BOARD
JN 1270



SN B040000-up

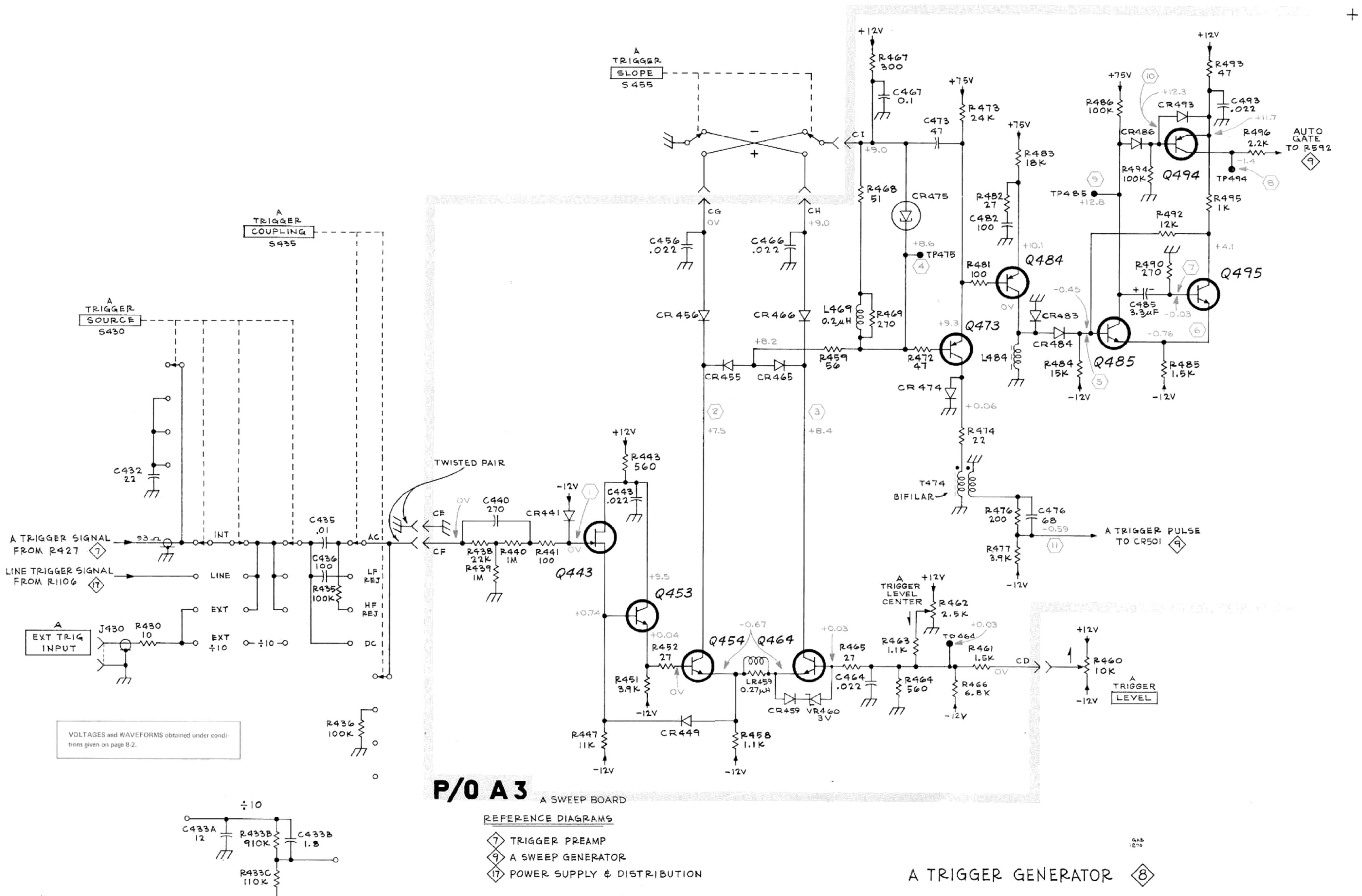
SN B010100-B039999



See Figs. 8-5, 8-7 and 8-14 for location of parts not identified here.

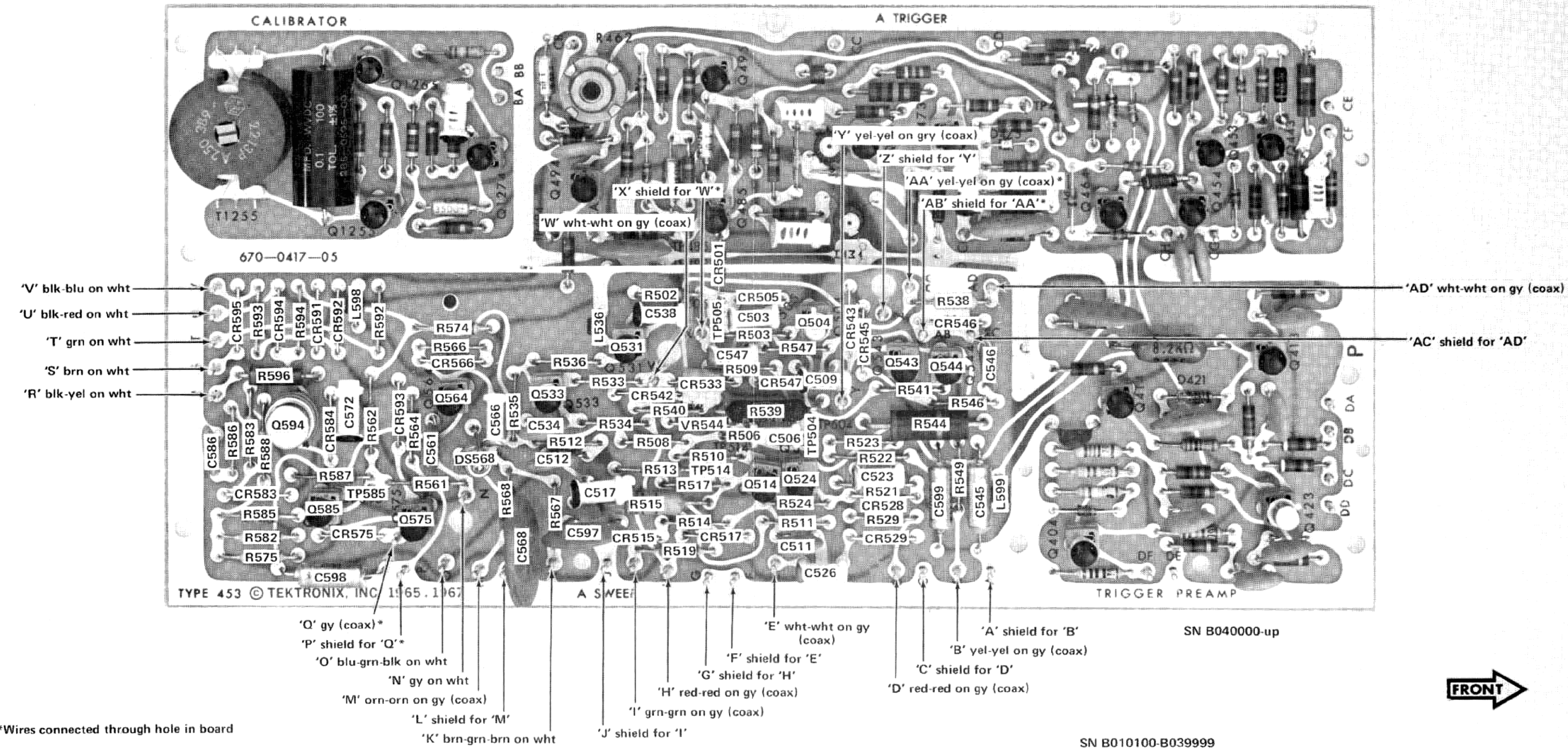
FRONT

Fig. 8-6. P/O A3. Partial A Sweep circuit board.



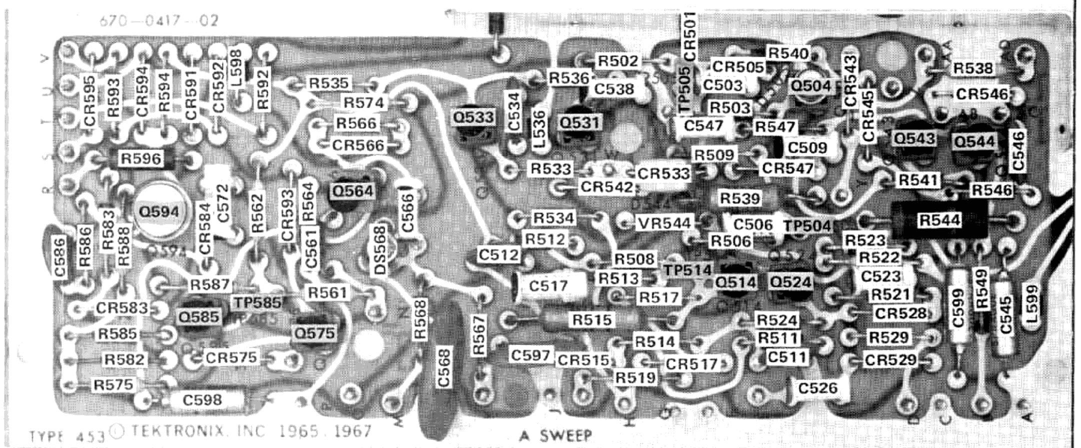
A TRIGGER GENERATOR 8

SN B040000-up



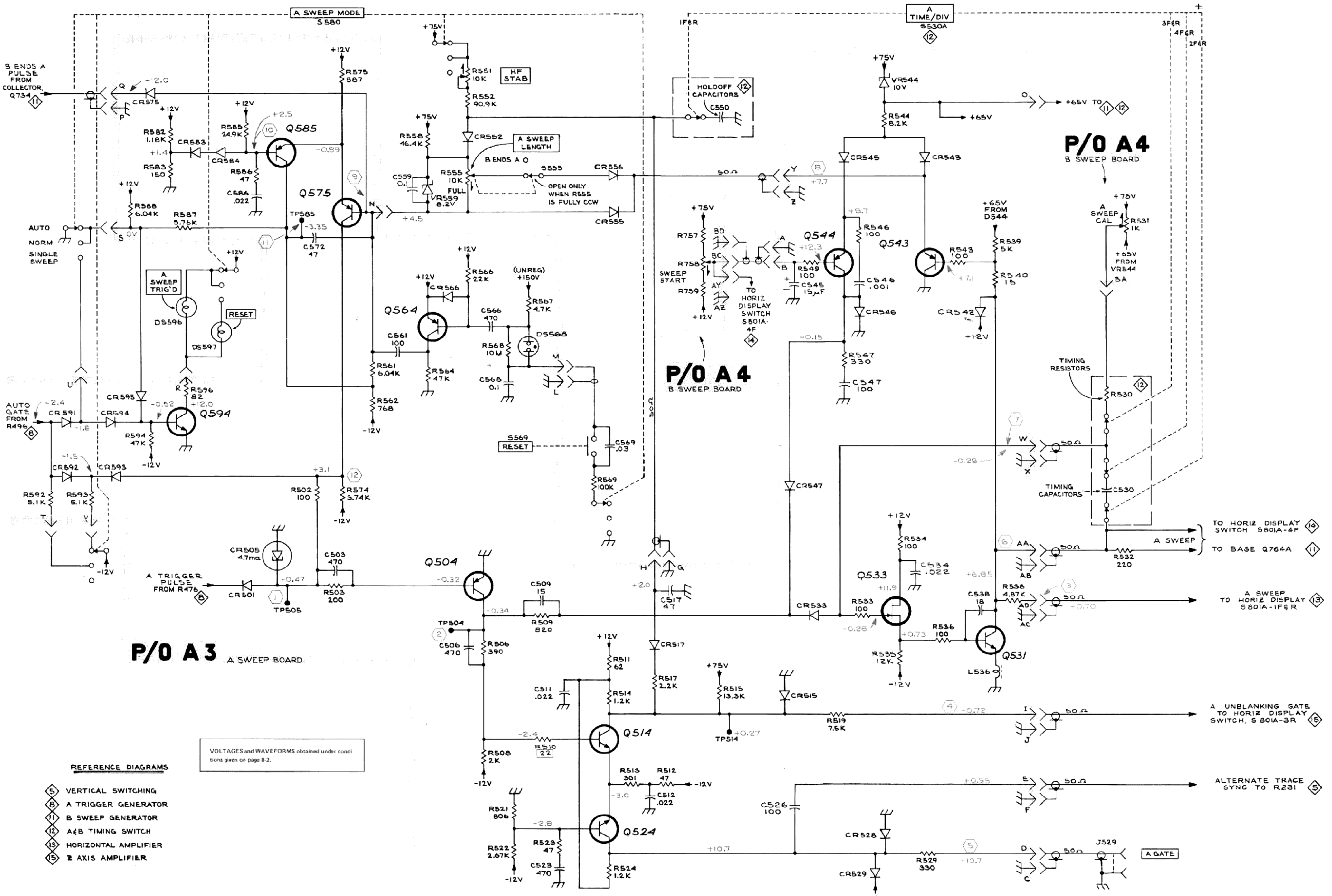
*Wires connected through hole in board

SN B010100-B039999



See Figs. 8-5, 8-6 and 8-14 for location of parts not identified here.

Fig. 8-7. P/O A3. Partial A Sweep circuit board.



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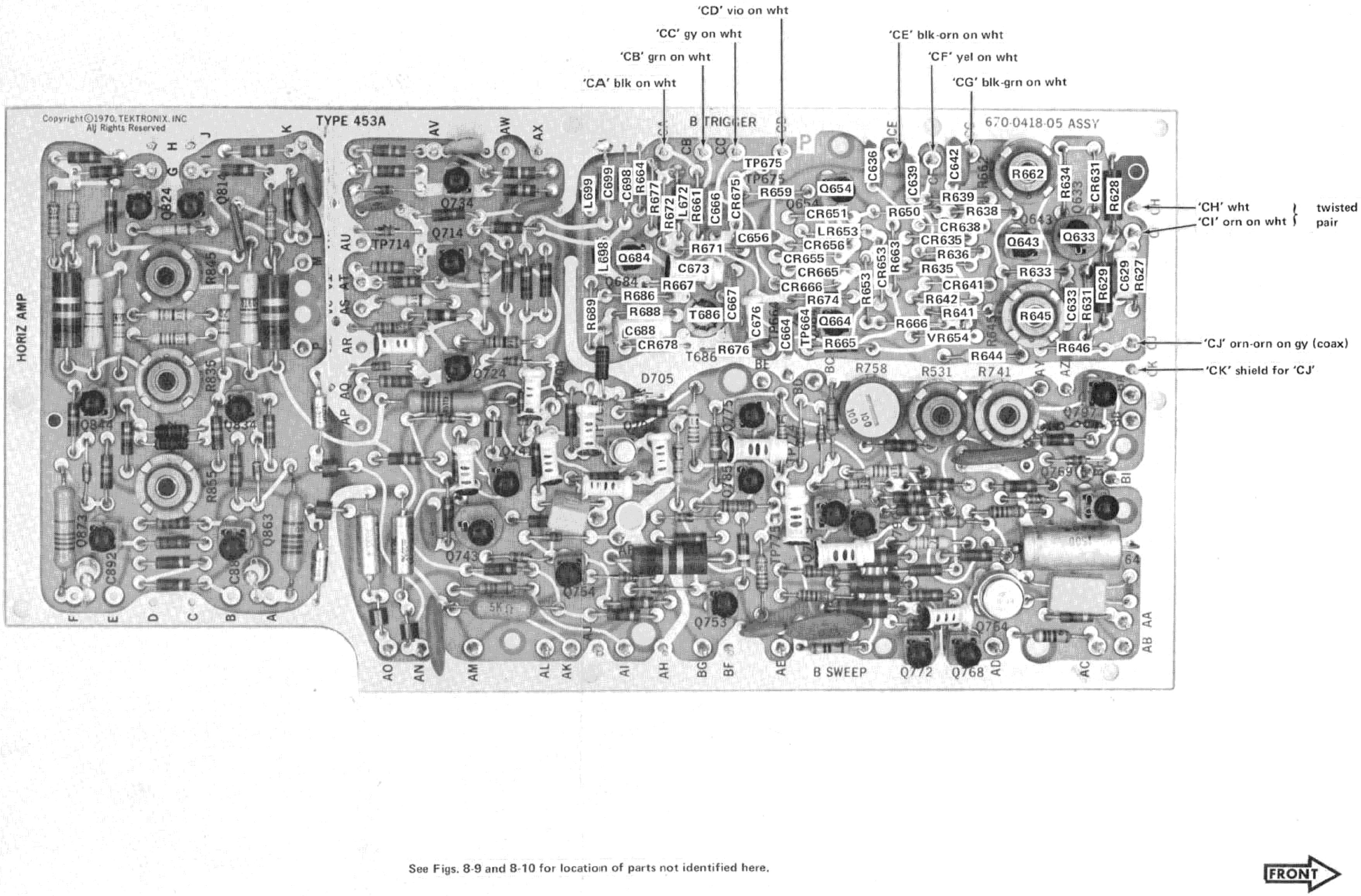
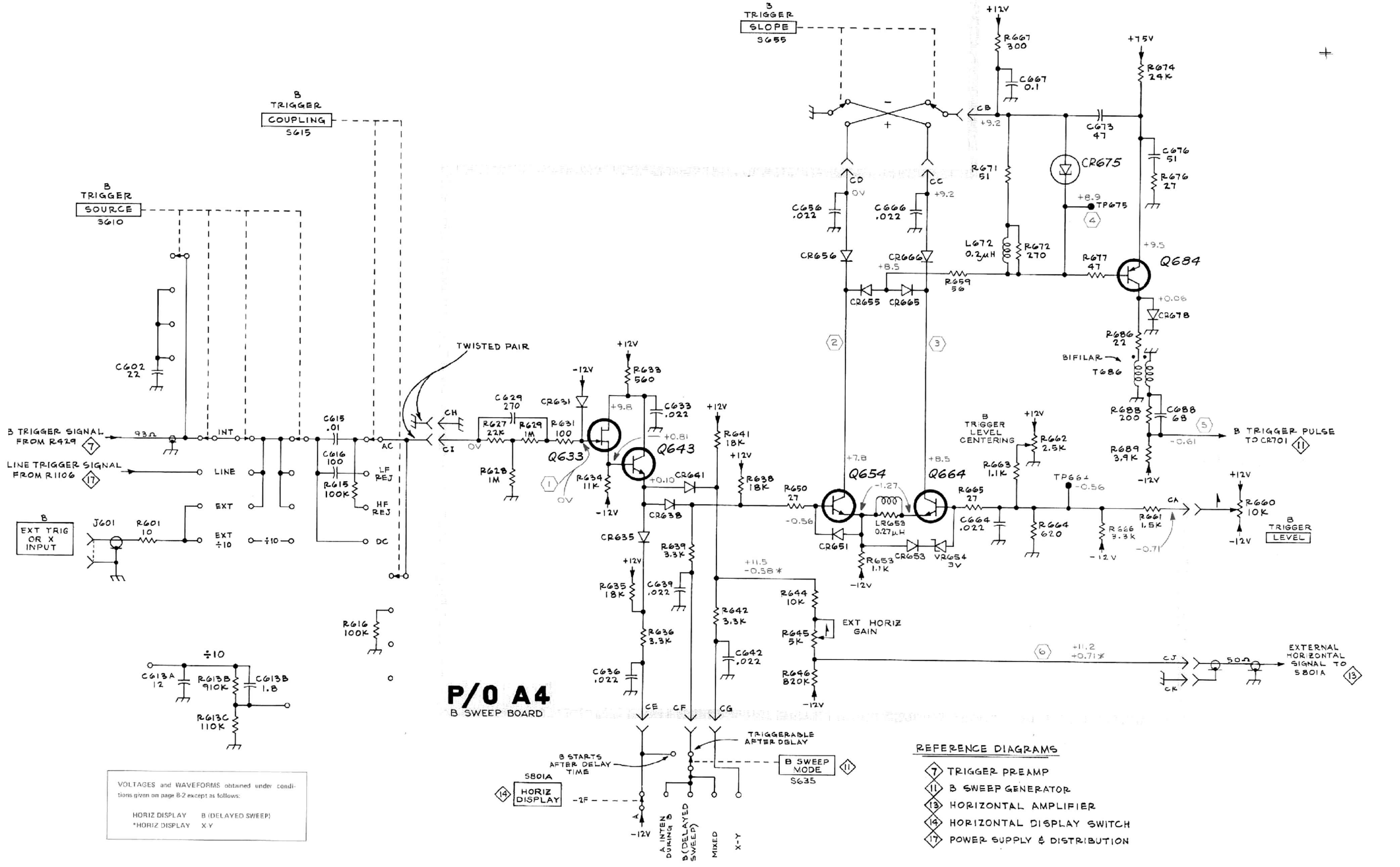
A SWEEP GENERATOR 9



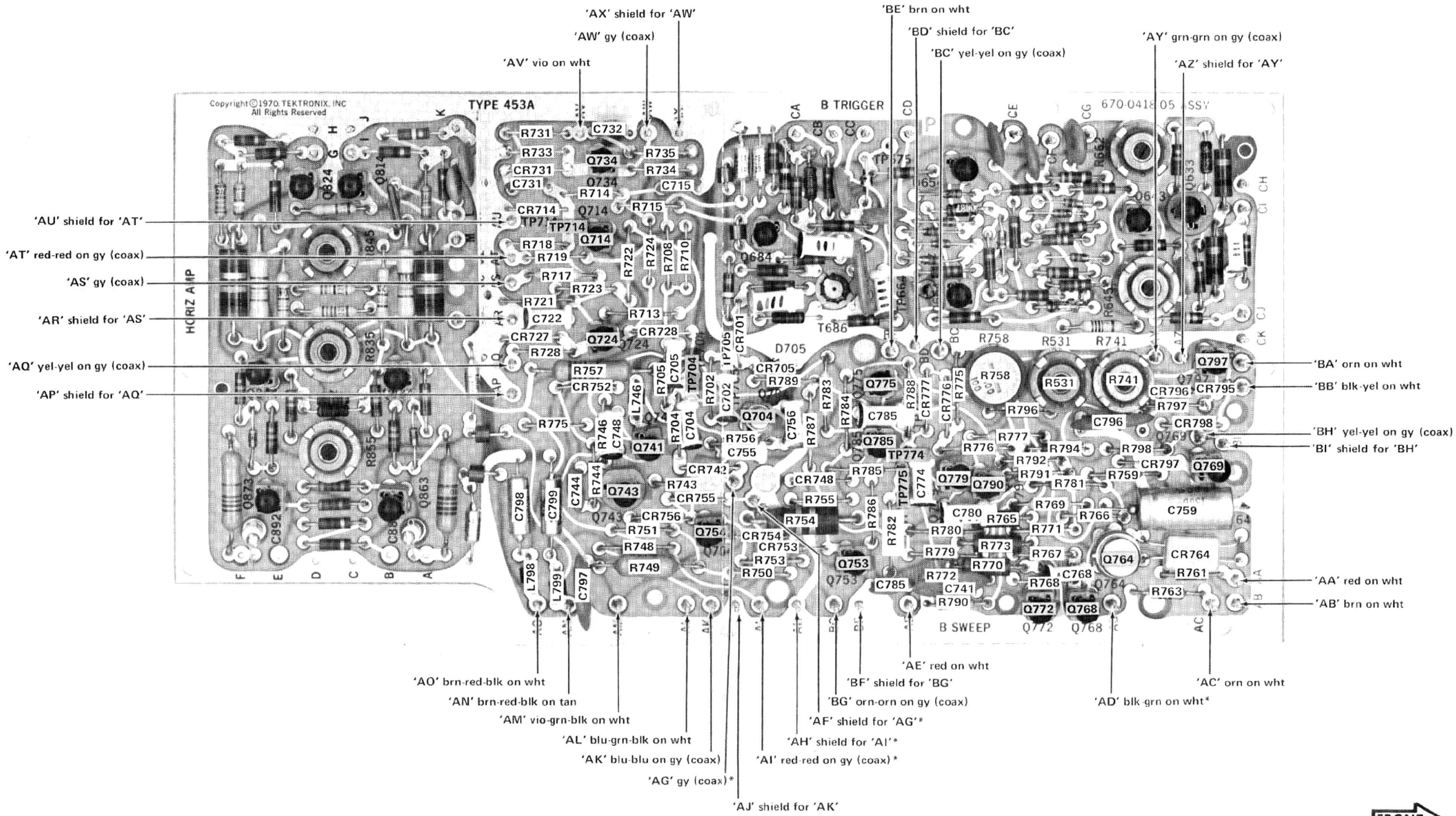
See Figs. 8-9 and 8-10 for location of parts not identified here.

Fig. 8-8. P/O A4. Partial B Sweep circuit board

Ⓐ



B TRIGGER GENERATOR (10)

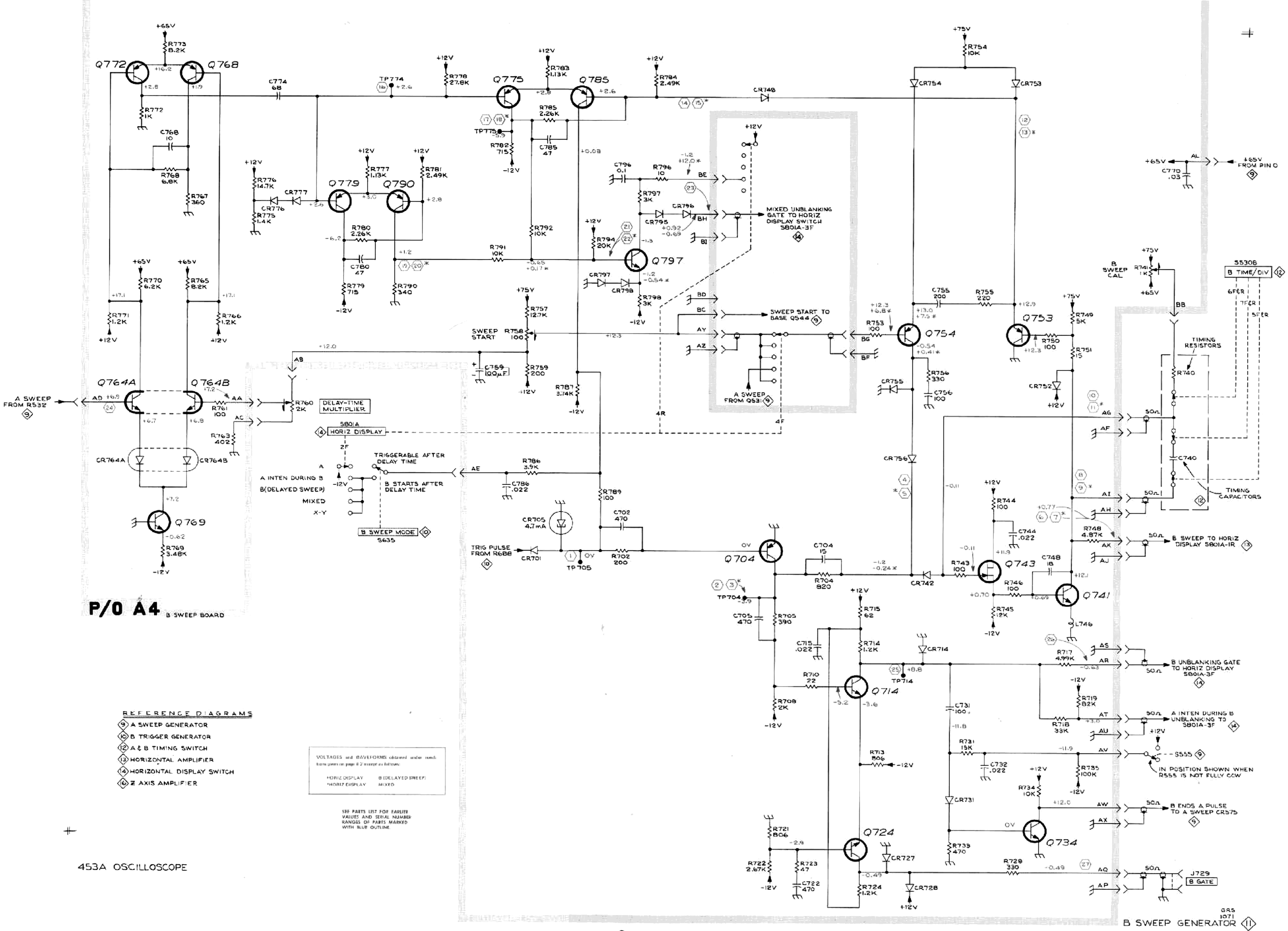


*Wires connected through hole in board

See Figs. 8-8 and 8-10 for location of parts not identified here.

Fig. 8-9. P/O A4. Partial B Sweep circuit board.

Ⓐ1



REFERENCE DIAGRAMS

(9) A SWEEP GENERATOR
(10) B TRIGGER GENERATOR
(12) A & B TIMING SWITCH
(13) HORIZONTAL AMPLIFIER
(14) HORIZONTAL DISPLAY SWITCH
(16) Z AXIS AMPLIFIER

VOLTAGES and WAVEFORMS obtained under conditions given on page 8-2 except as follows:

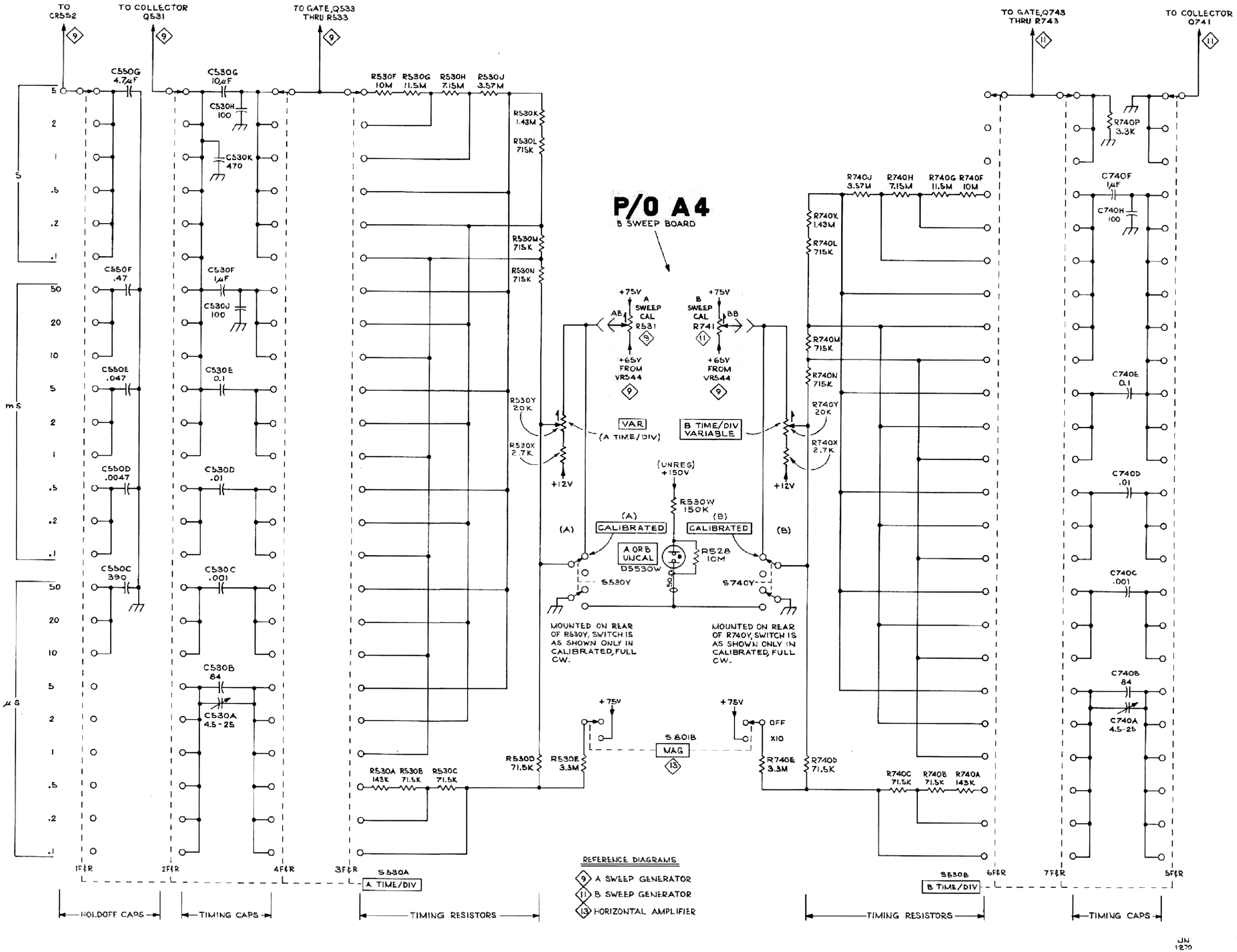
HORIZ DISPLAY	B (DELAYED SWEEP)
*HORIZ DISPLAY	MIXED

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

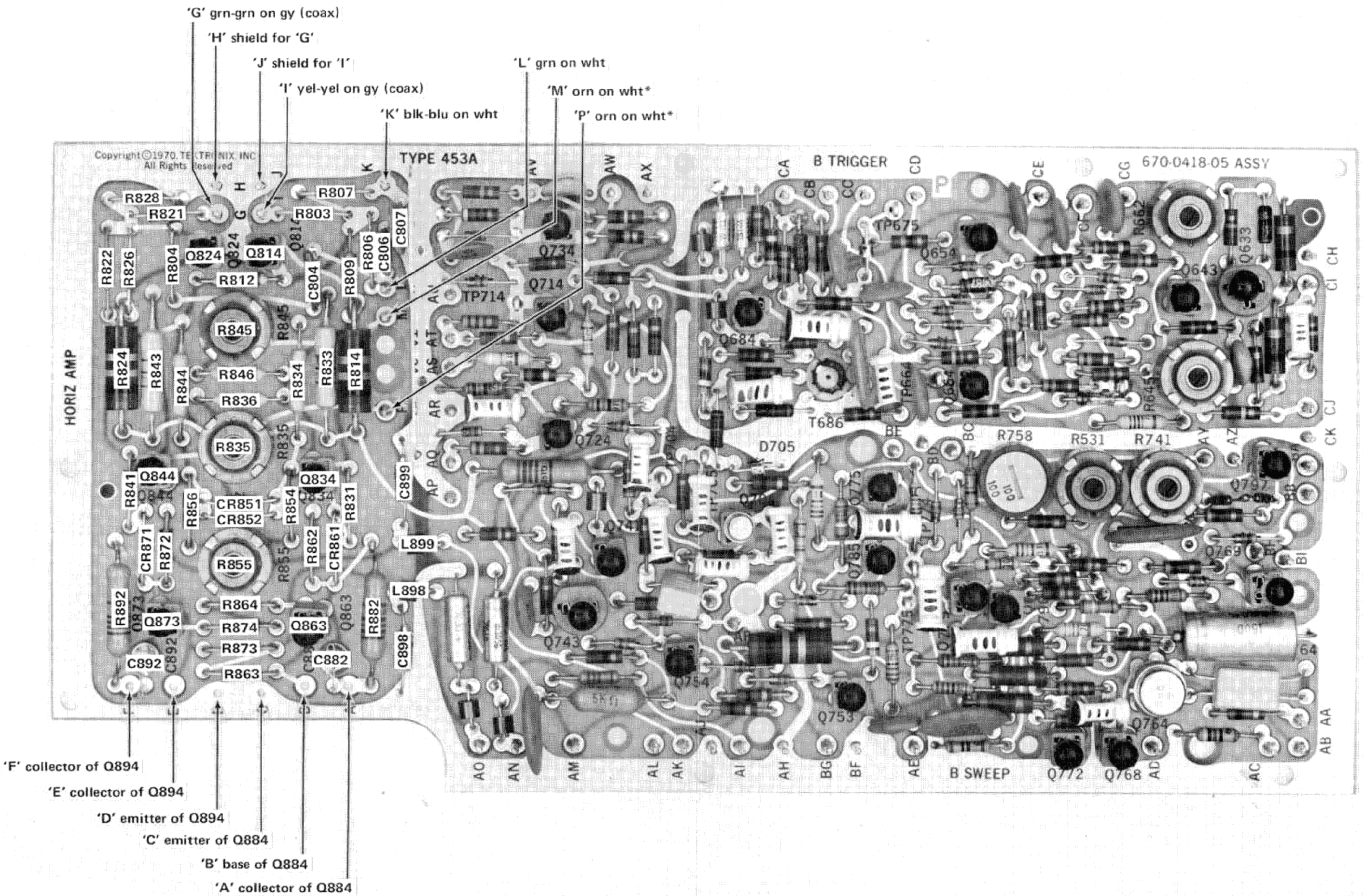
453A OSCILLOSCOPE

GRS 1071

B SWEEP GENERATOR (11)



A AND B TIMING SWITCH ⑫



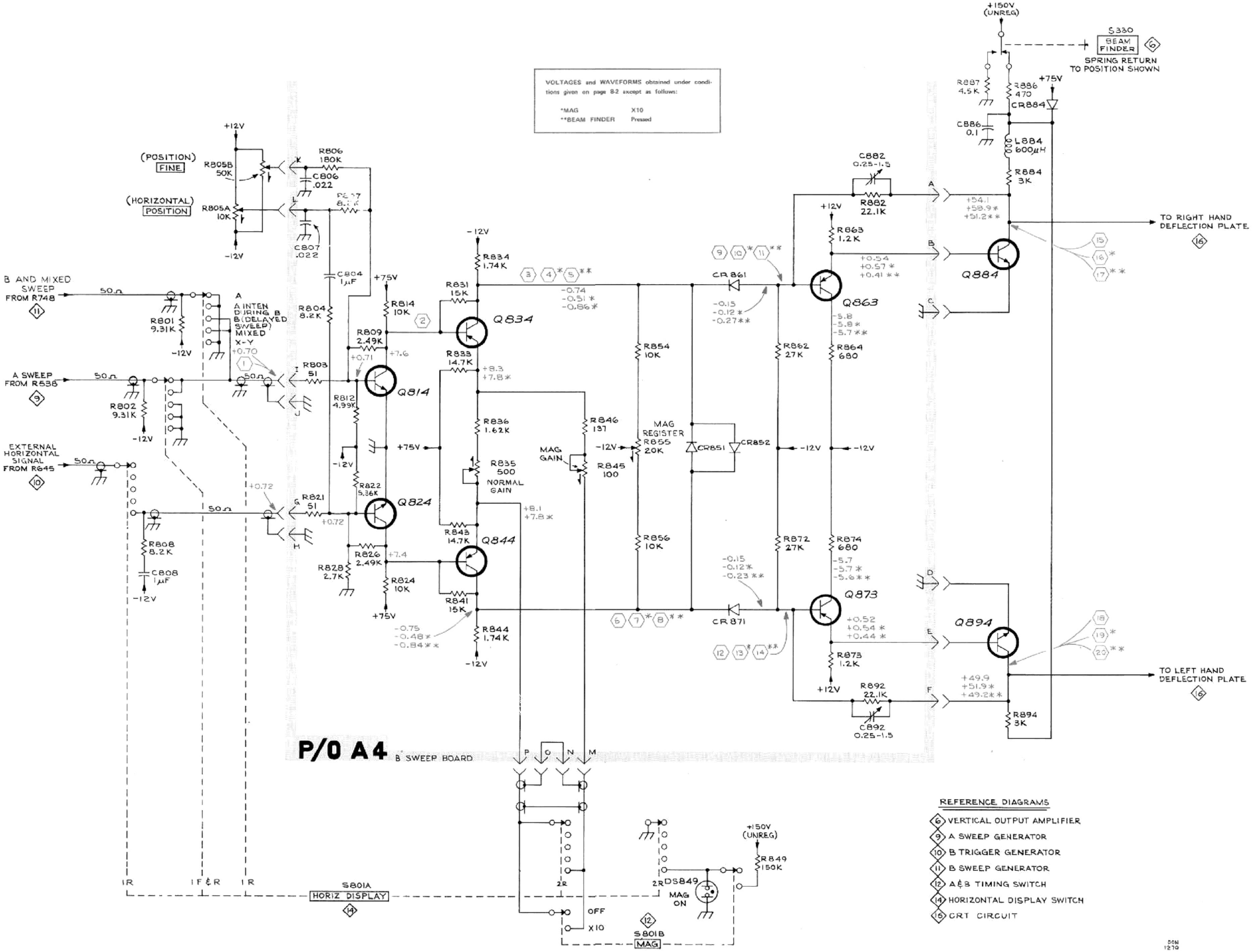
*Wires connected through hole in board

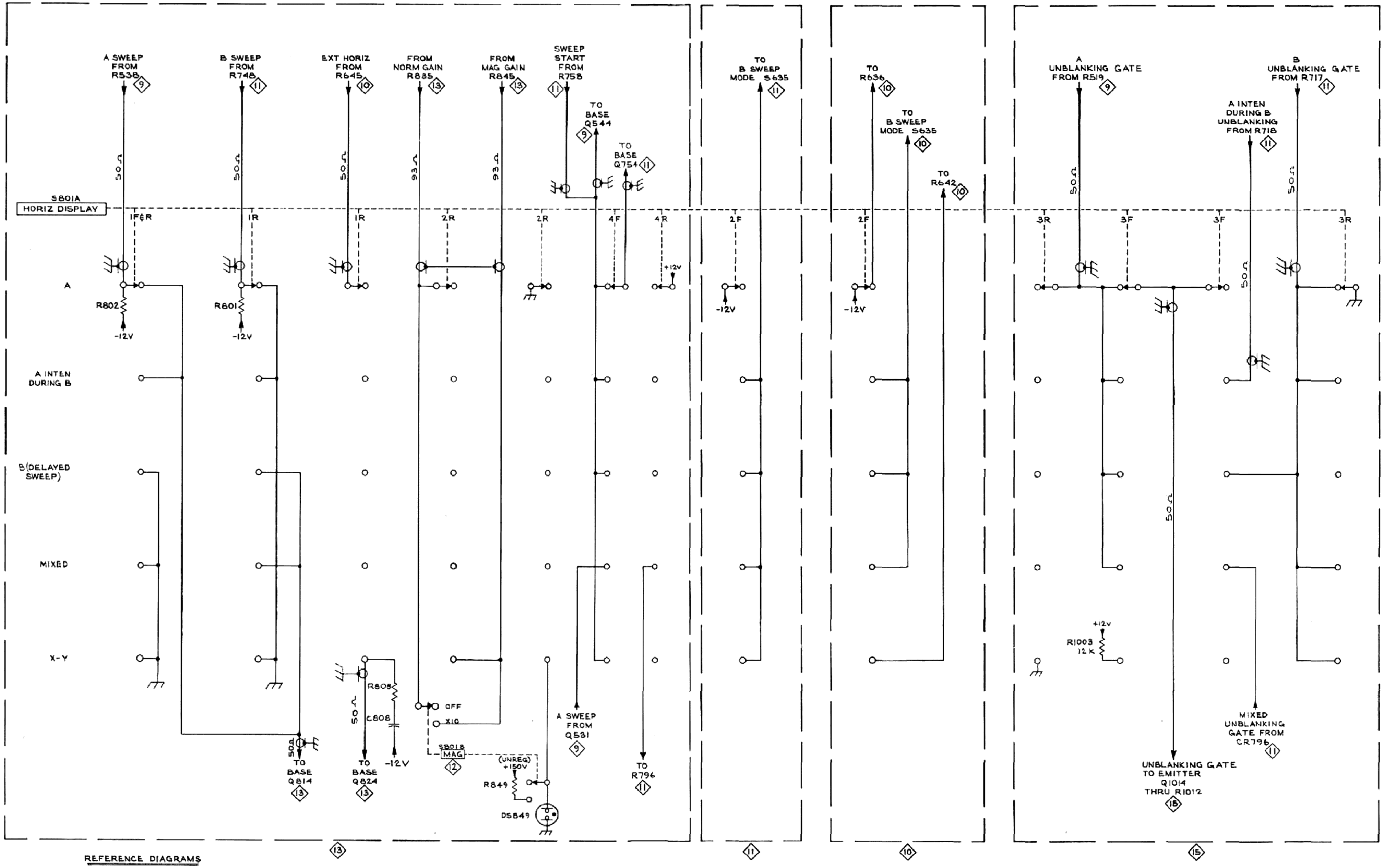
See Figs. 8-8 and 8-9 for location of parts not identified here.

FRONT

Fig. 8-10. P/O A4. Partial B Sweep circuit board.

Ⓐ


VOLTAGES and WAVEFORMS obtained under conditions given on page 8-2 except as follows:
*MAG X10
**BEAM FINDER Pressed
+150V (UNREG)
S330 BEAM FINDER
SPRING RETURN TO POSITION SHOWN
R887 4.5K
R886 470
+75V
CR884
C886 0.1
L884 600μH
R884 3K
C882 0.25-1.5
R882 22.1K
+12V
R863 1.2K
TO RIGHT HAND DEFLECTION PLATE
Q884
Q863
Q834
Q814
Q824
Q844
Q873
Q894
(POSITION) FINE
R805B 50K
(HORIZONTAL) POSITION
R805A 10K
R806 180K
C806 .022
C807 .022
C804 1μF
-12V
R834 1.74K
R831 15K
R814 10K
R804 8.2K
R809 2.49K
B AND MIXED SWEEP FROM R748
A SWEEP FROM R536
EXTERNAL HORIZONTAL SIGNAL FROM R645
R801 9.31K
R802 9.31K
A INTEN DURING B
B (DELAYED SWEEP)
MIXED
X-Y
R803 51
R833 14.7K
R812 4.99K
R836 1.62K
R835 500 NORMAL GAIN
R846 137
MAG GAIN
R845 100
MAG REGISTER R855 20K
R854 10K
R856 10K
CR861
CR851
CR852
CR871
R862 27K
R864 680
R872 27K
R874 680
R821 51
R822 5.36K
R843 14.7K
R826 2.49K
R828 2.7K
R824 10K
R841 15K
R844 1.74K
R808 8.2K
C808 1μF
R873 1.2K
R892 22.1K
C892 0.25-1.5
R894 3K
TO LEFT HAND DEFLECTION PLATE
P/0 A4 B SWEEP BOARD
S801A HORIZ DISPLAY
S801B MAG
OFF
X10
DS849 MAG ON
R849 150K
REFERENCE DIAGRAMS
6 VERTICAL OUTPUT AMPLIFIER
9 A SWEEP GENERATOR
10 B TRIGGER GENERATOR
11 B SWEEP GENERATOR
12 A&B TIMING SWITCH
14 HORIZONTAL DISPLAY SWITCH
15 CRT CIRCUIT
DON 1270

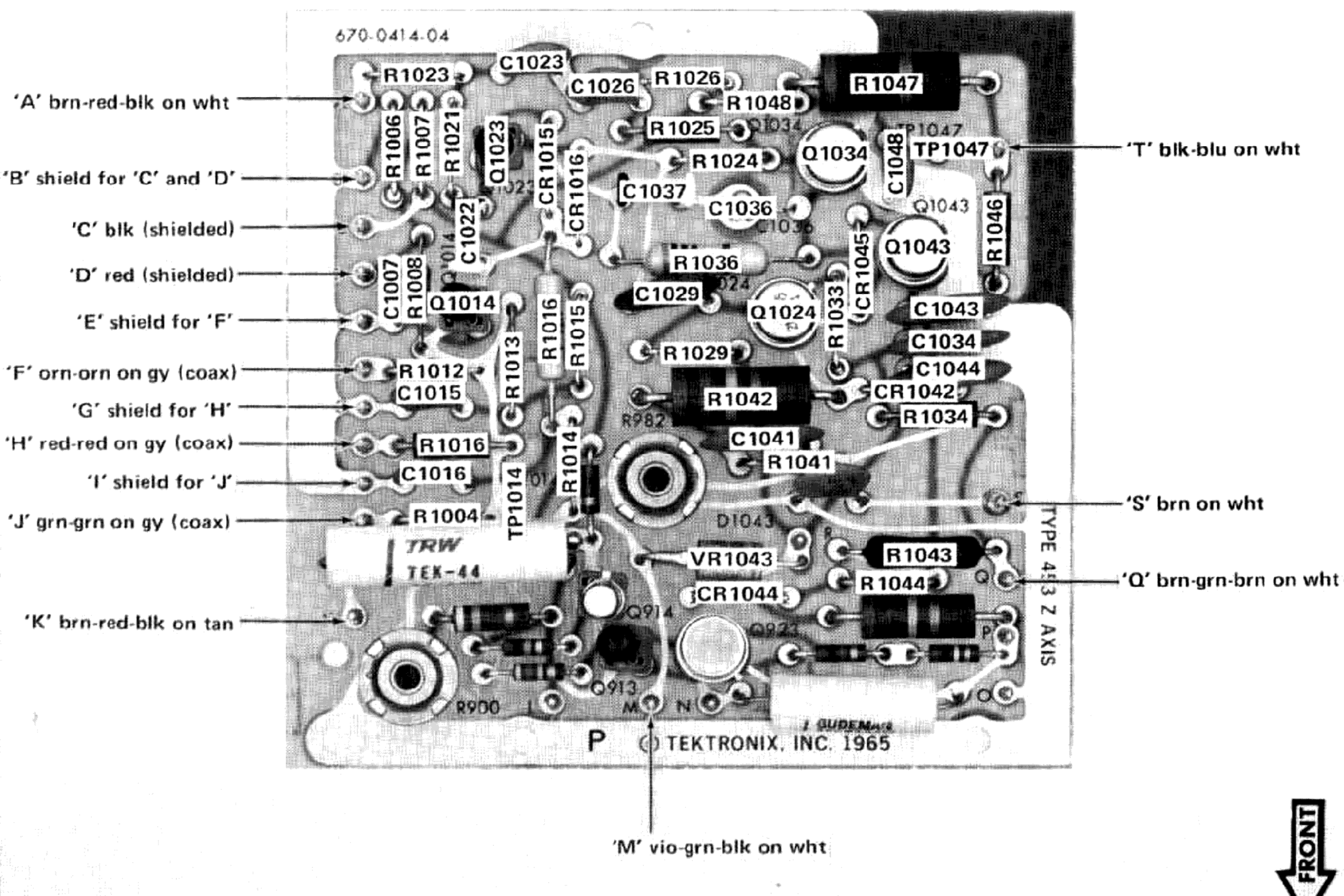


REFERENCE DIAGRAMS

- 9 A SWEEP GENERATOR
- 10 B TRIGGER GENERATOR
- 11 B SWEEP GENERATOR
- 12 A&B TIMING SWITCH
- 13 HORIZONTAL AMPLIFIER
- 15 Z AXIS AMPLIFIER

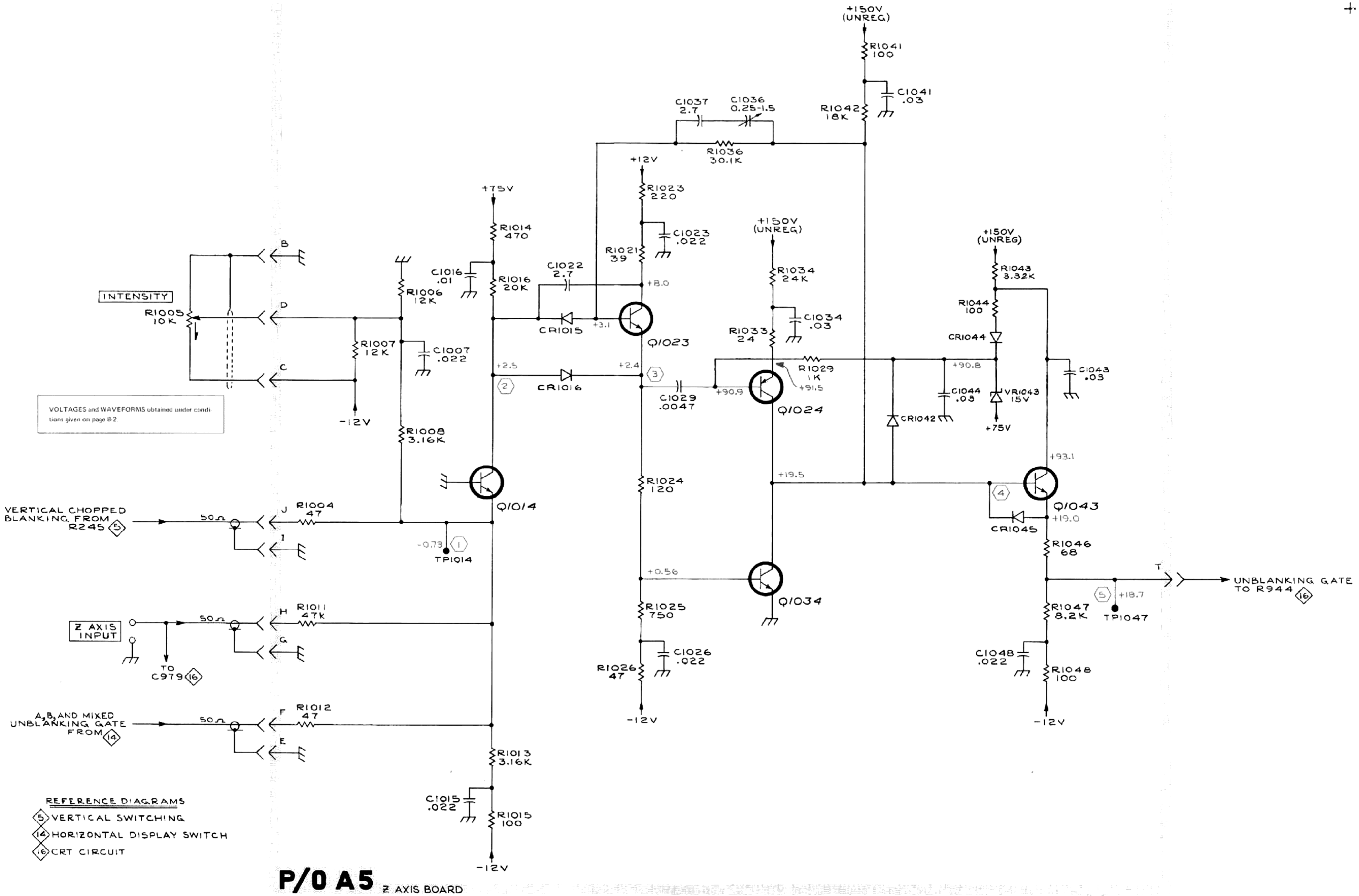
CMD 1270

HORIZONTAL DISPLAY SWITCH 14



See Fig. 8-12 for location of parts not identified here.

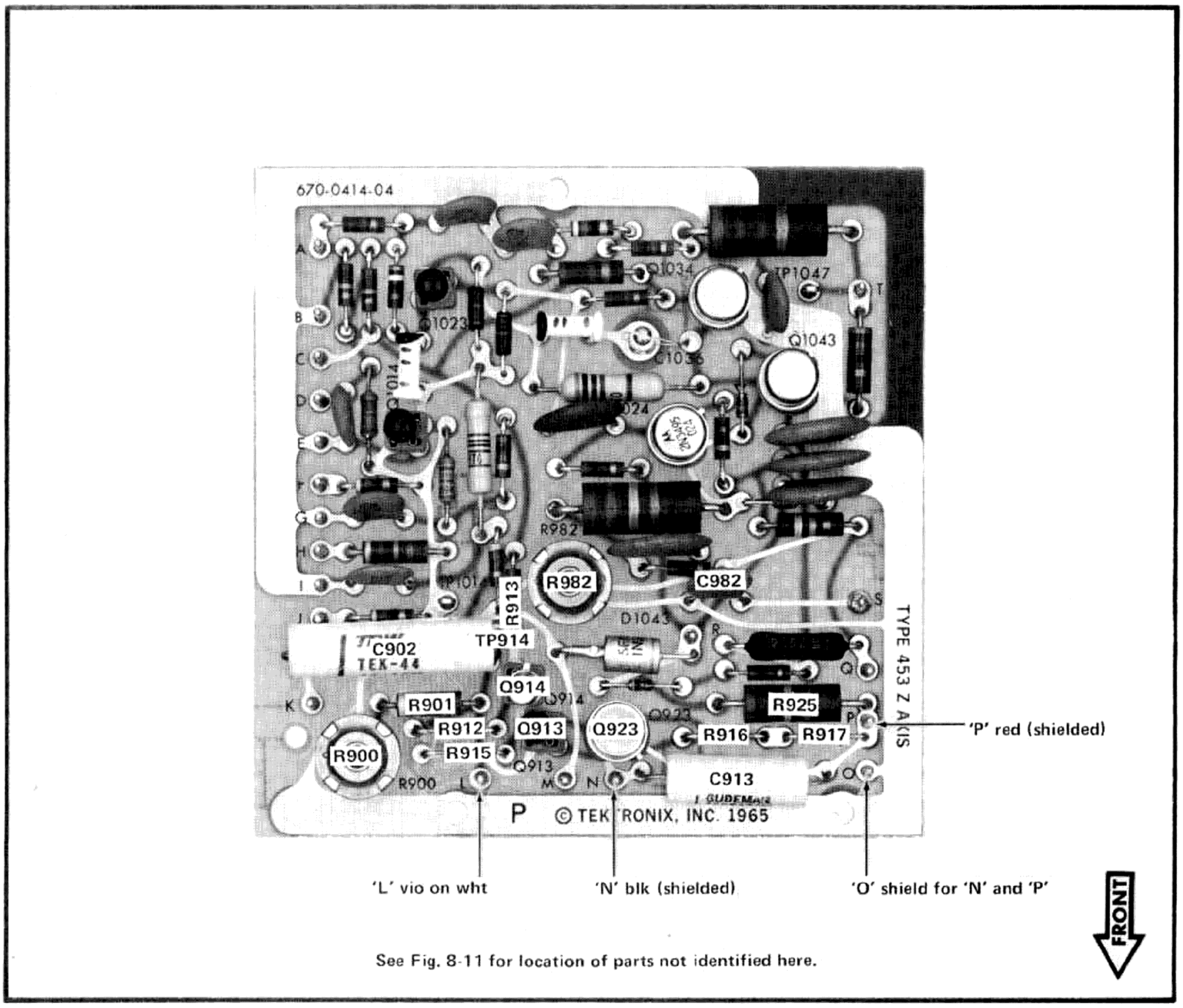
Fig. 8-11. P/O A5. Partial Z Axis circuit board.



SEE PARTS LIST FOR SEMICONDUCTOR TYPES

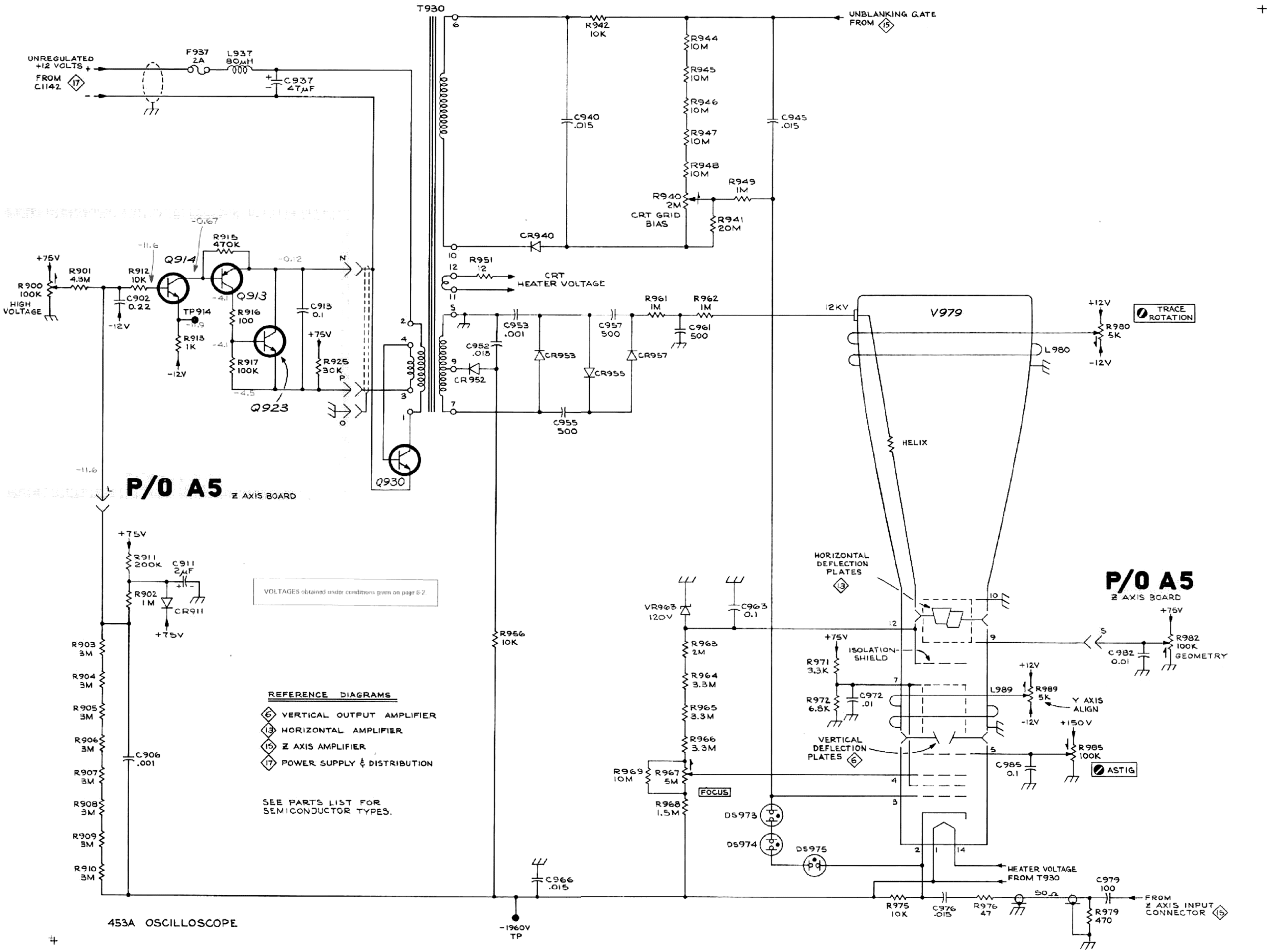
PLM 1270

Z AXIS AMPLIFIER 15



See Fig. 8-11 for location of parts not identified here.

Fig. 8-12. P/O A5. Partial Z Axis circuit board.



CRT CIRCUIT 16

DON 1270

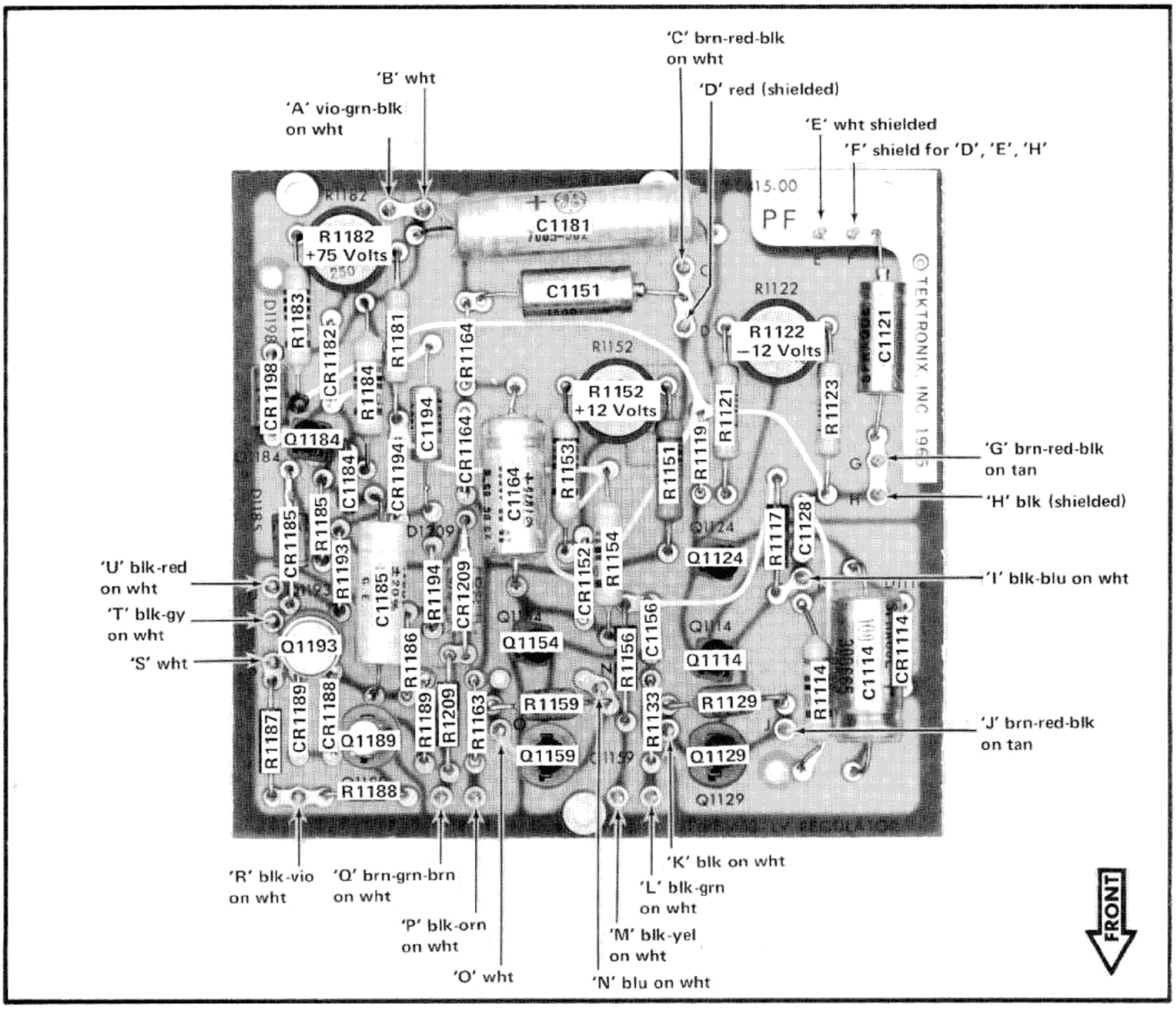
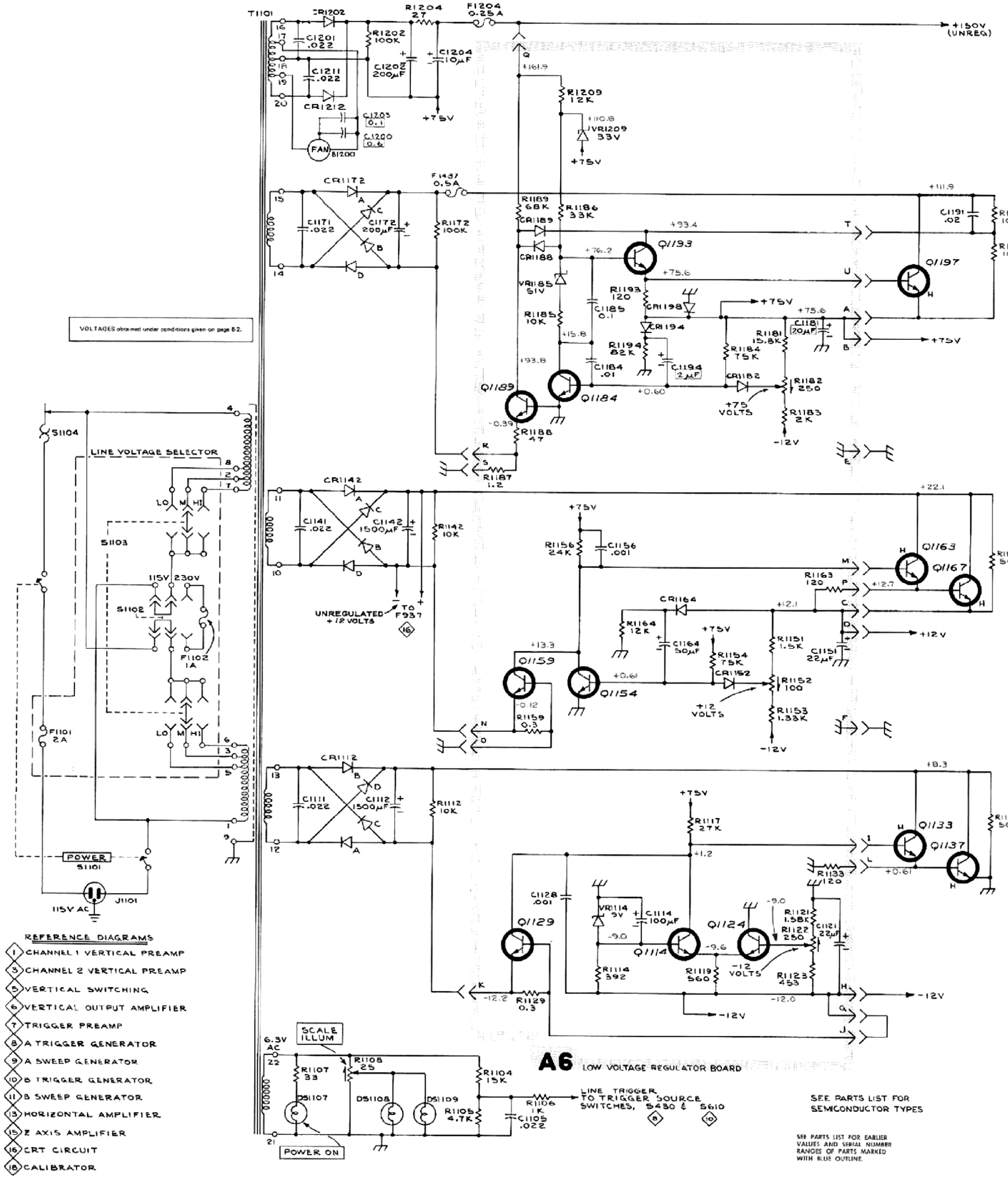
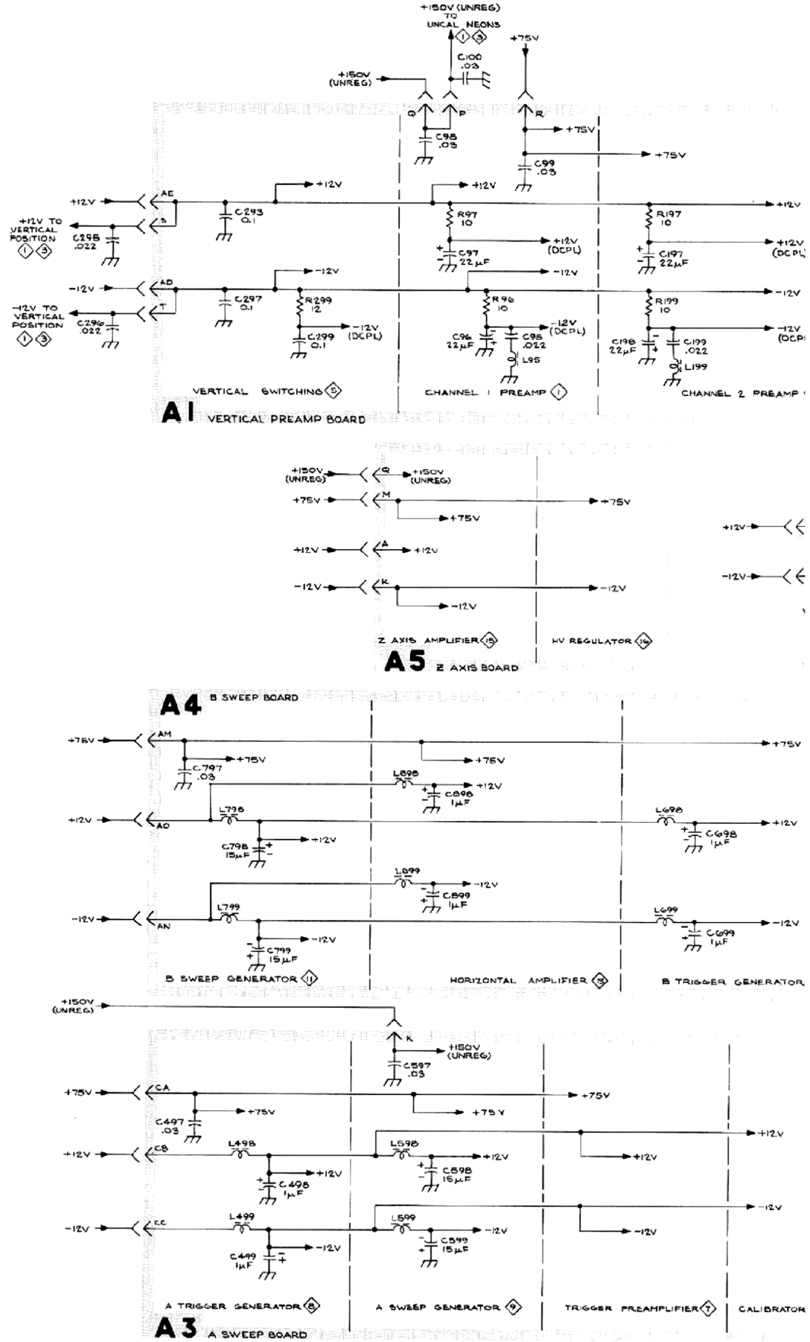


Fig. 8-13. A6. Low Voltage Regulator circuit board.

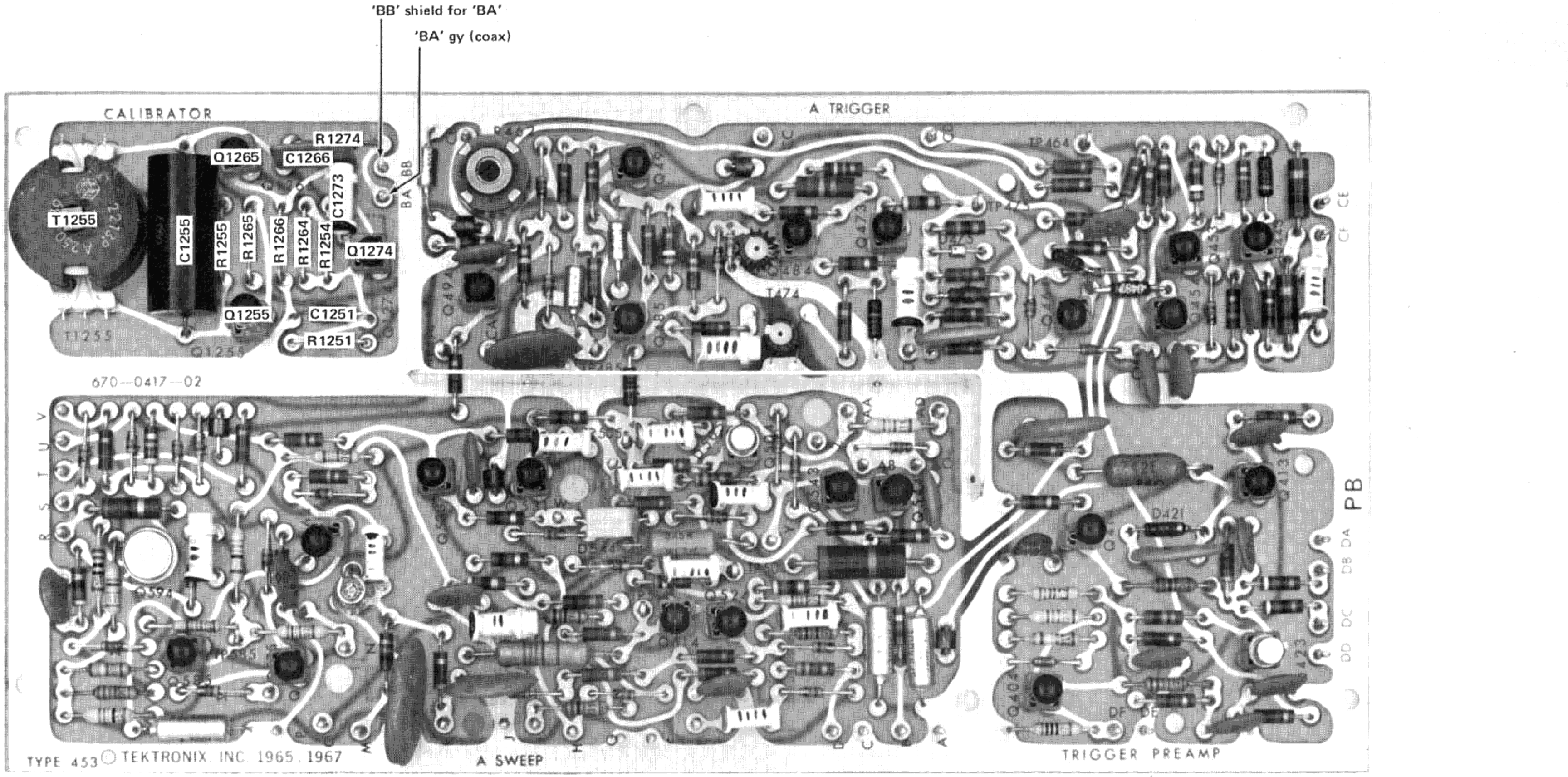
Ⓐ



453A OSCILLOSCOPE



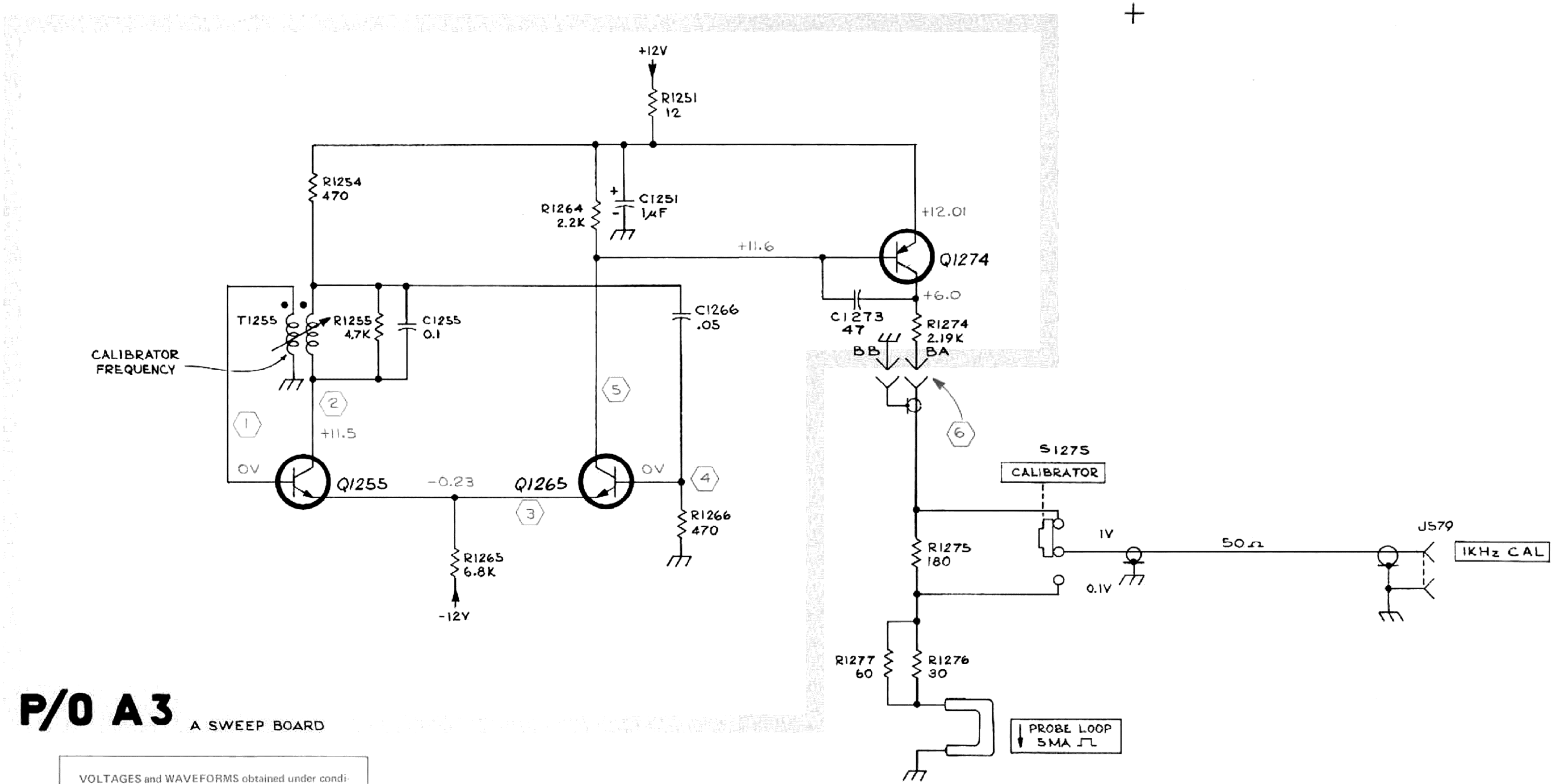
POWER SUPPLY & DISTRIBU



See Figs. 8-5, 8-6 and 8-7 for location of parts not identified here.

Fig. 8-14. P/O A3. Partial A Sweep board.

Ⓐ



P/O A3 A SWEEP BOARD

VOLTAGES and WAVEFORMS obtained under conditions given on page 8-2.

ELECTRICAL PARTS LIST CORRECTIONS

A6 LOW VOLTAGE REGULATOR Circuit Board Assembly

CHANGE TO:

(453A)	670-0415-03	Complete Board
(453A-1/2/3)	670-0415-04	Complete Board
(453A-4)	670-0415-04	Complete Board

CHANGE TO:

R1122	311-1223-00	250Ω Var.
R1152	311-1222-00	100Ω Var.
R1182	311-1223-00	250Ω Var.

MECHANICAL PARTS LIST CORRECTIONS

CHANGE TO:

453A Page 9-18 Fig. 3-110

670-0415-03	1	CIRCUIT BOARD ASSEMBLY-LOW VOLTAGE REG. A6

453A-1/2/3 Page 8-14 Fig. 2-110

670-0415-04	1	CIRCUIT BOARD ASSEMBLY-LOW VOLTAGE REG. A6

453A-4 Page 8-13 Fig. 2-98

670-0415-04	1	CIRCUIT BOARD ASSEMBLY-LOW VOLTAGE REG. A6