INSTRUCTION MANUAL

Serial Number ____________

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TYPE 324 OSCILLOSCOPE

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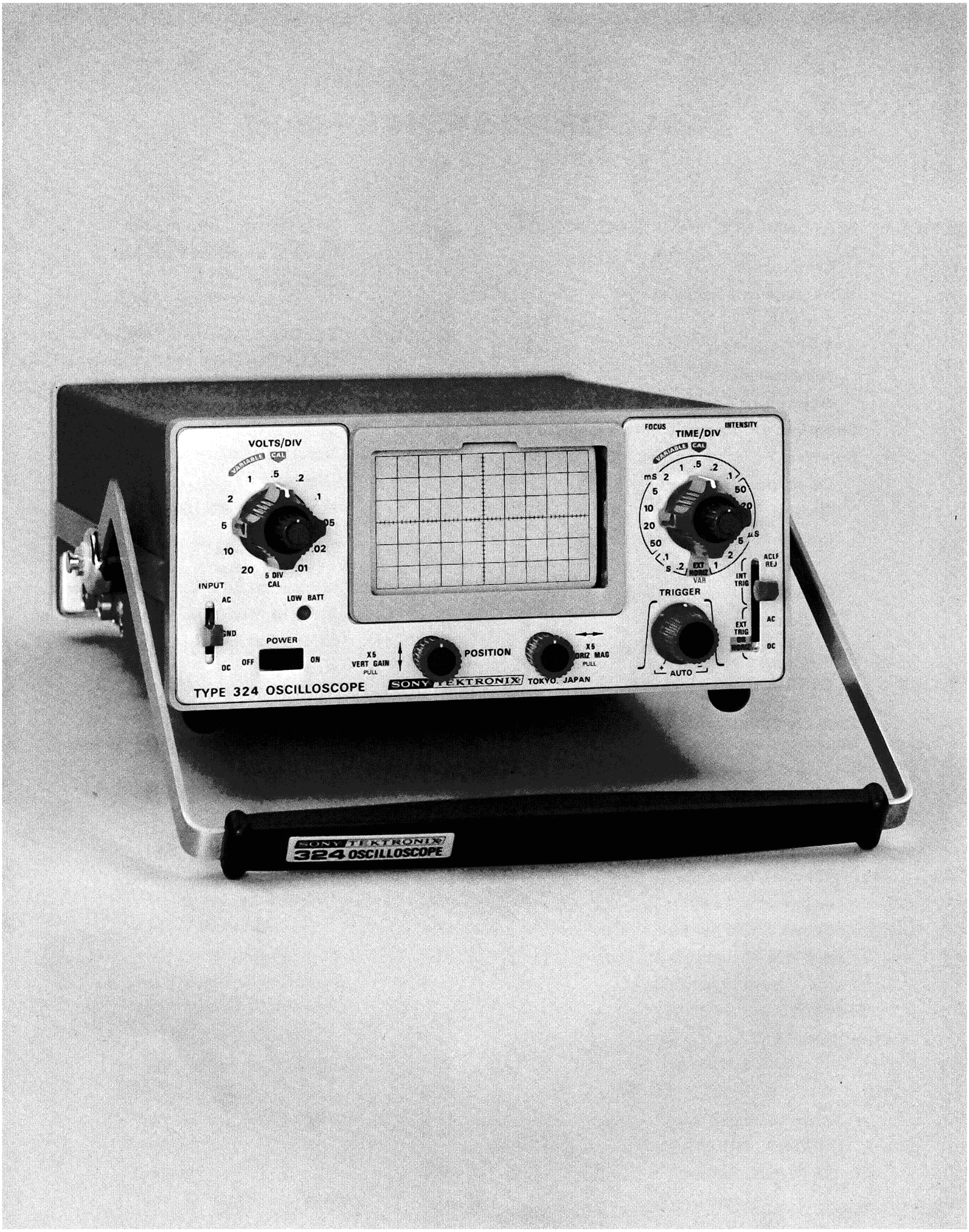
VOLTS/DIV
VARIABLE
CAL
5 DIV CAL
INPUT
AC
GND
DC
LOW BATT
POWER
OFF
ON
X5 VERT GAIN PULL
POSITION
X5 HORIZ MAG PULL
FOCUS
TIME/DIV
INTENSITY
EXT HORIZ
VAR
TRIGGER
AUTO
ACLF REJ
INT TRIG
EXT TRIG
AC
DC
TYPE 324 OSCILLOSCOPE
SONY TEKTRONIX
TOKYO, JAPAN
SONY TEKTRONIX
324 OSCILLOSCOPE

SECTION 1
TYPE 324 SPECIFICATION

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

Introduction

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

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

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

ELECTRICAL CHARACTERISTICS

VERTICAL DEFLECTION SYSTEM

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

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

TRIGGERING

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

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

HORIZONTAL DEFLECTION SYSTEM

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

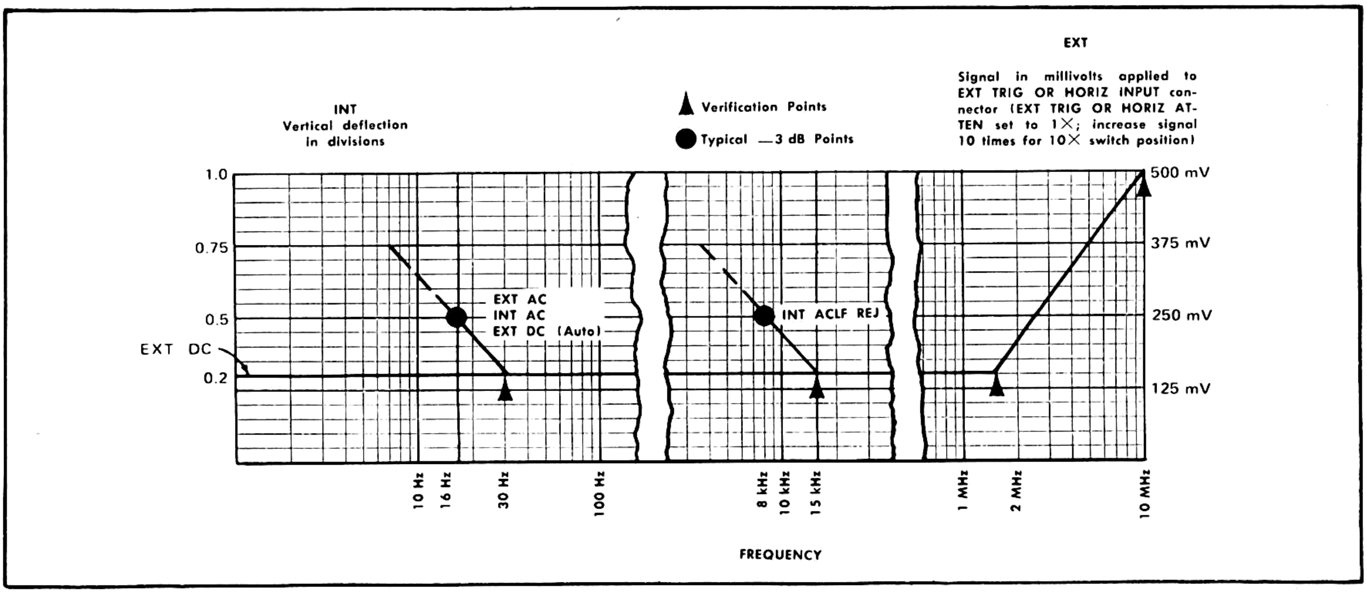

Fig. 1-2. Trigger sensitivity specification limit curve.

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

CALIBRATOR

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

EXTERNAL BLANKING

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

POWER SUPPLY

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

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

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

CATHODE-RAY TUBE (CRT)

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

ENVIRONMENTAL CHARACTERISTICS

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

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

Characteristic	Performance Requirement
Vibration	
Operating and non-operating	15 minutes along each of the three major axes at a total displacement of 0.025-inch peak to peak (4 g at 55 c/s) with frequency varied from 10-55-10 c/s in one minute cycles. Hold at 55 c/s for three minutes one each axis. All major resonances must be above 55 c/s.
Shock	
Operating and non-operating	Two shocks of 30 g, one-half sine, 11-millisecond duration each direction along each major axis. Guillotine-type shocks. Total of 12 shocks.
Electromagnetic Interference (EMI)	Test procedures and limits described in Mil-I-6181D and Mil-I-16910C.
Radiated interference	Interference radiated from the instrument within the given test limits from 14 kilohertz to 1000 megahertz.
Transportation	Meets National Safe Transit type of test when packaged as shipped by factory.
Package vibration	One hour vibration slightly in excess of 1 g.
Package drop	30-inch drop on any corner, edge or flat surface.

MECHANICAL CHARACTERISTICS

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

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

STANDARD ACCESSORIES

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

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SECTION 3 CIRCUIT DESCRIPTION

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

Introduction

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

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

BLOCK DIAGRAM DESCRIPTION

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

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

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

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

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

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

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

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

Alternate Modes of Operation

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

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

VERTICAL PREAMPLIFIER ⟨1⟩

Block Diagram Description

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

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

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

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

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

Vertical Input Circuitry

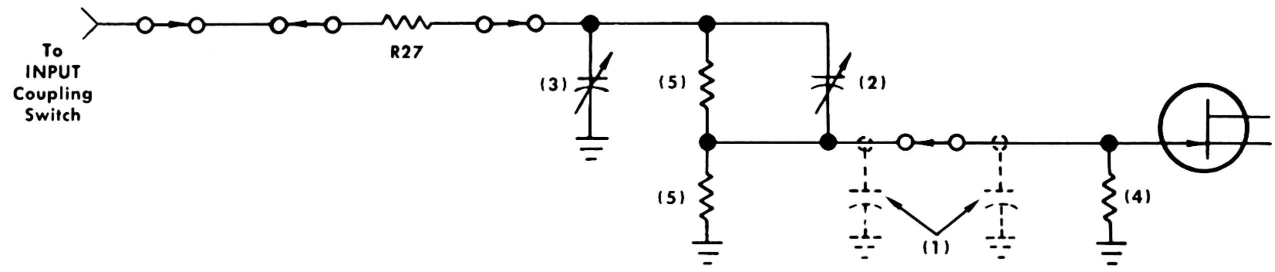
Refer to the Vertical Preamplifier schematic. The Vertical Input Circuitry consists of the VERT INPUT connector (J20), the INPUT Coupling Switch (S21), coupling capacitor C20, resistor R21, the input attenuators and the calibrator.

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

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

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

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



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

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

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

(4) 1 MΩ input resistance.

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

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

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

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

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

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

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

Source Followers

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

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

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

First Amplifier

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

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

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

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

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

Second Amplifier

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

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

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

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

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

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

VERTICAL OUTPUT AMPLIFIER ⟨2⟩

Block Diagram Description

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

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

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

Detailed Description

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

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

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

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

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

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

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

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

TRIGGER GENERATOR ⟨3⟩

General

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

Block Diagram Description

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

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

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

Protection and Source Follower Circuits

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

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

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

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

Comparator Amplifier

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

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

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

Trigger Multivibrator

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

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

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

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

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

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

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

SWEEP GENERATOR ⟨4⟩

General

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

Block Diagram Description

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

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

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

Sweep Generator

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

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

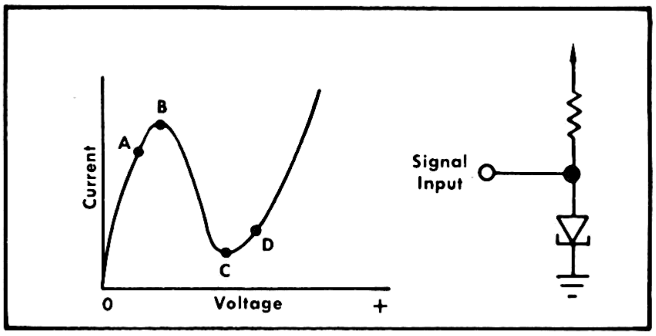


Fig. 3-2. Tunnel diode current-voltage graph and simplified circuit.

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

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

TABLE 3-1

Operating Status of Sweep Generator Components

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

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

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

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

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

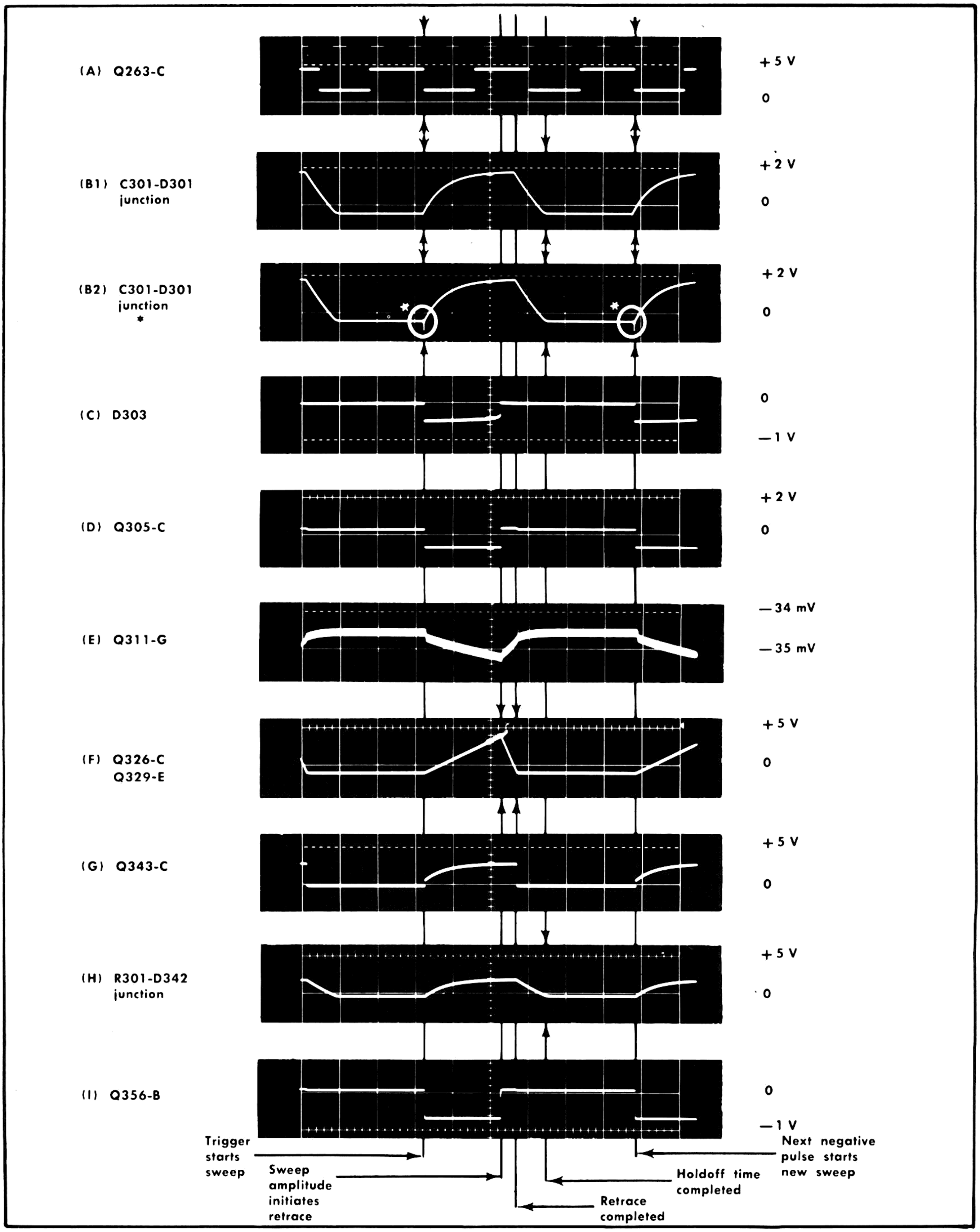


Fig. 3-3. Sweep Generator waveform analysis. Type 324 Oscilloscope sweep rate .1 ms/DIV. VOLTS/DIV switch set at 5 DIV CAL. Waveforms obtained with Type 547 Oscilloscope and C12 camera system; deflection factor 0.5 ms/div. *(B2) is the same as (B1) except that "B intens by 'A' " was used to show the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

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

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

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

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

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

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

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

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

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

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

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

HORIZONTAL AMPLIFIER ⟨6⟩

General

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

Block Diagram Description

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

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

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

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

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

Output Amplifier and Output Inverter

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

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

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

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

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

Current Control Circuits

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

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

EXT HORIZ Operation

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

POWER REGULATOR AND CRT CIRCUIT ⑦

General

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

Block Diagram Description

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

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

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

Blocking Oscillator Operation

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

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

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

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

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

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

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

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

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

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

+100 V Power Supply

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

+175 V Power Supply

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

+5 V Power Supply

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

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

−5 V Power Supply

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

+11 V and +8.5 V Power Supplies

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

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

High Voltage Power Supply

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

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

CRT Circuit

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

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

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

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

Low Battery Sensing Circuit

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

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

POWER PACK ⟨8⟩

General

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

Block Diagram Description

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

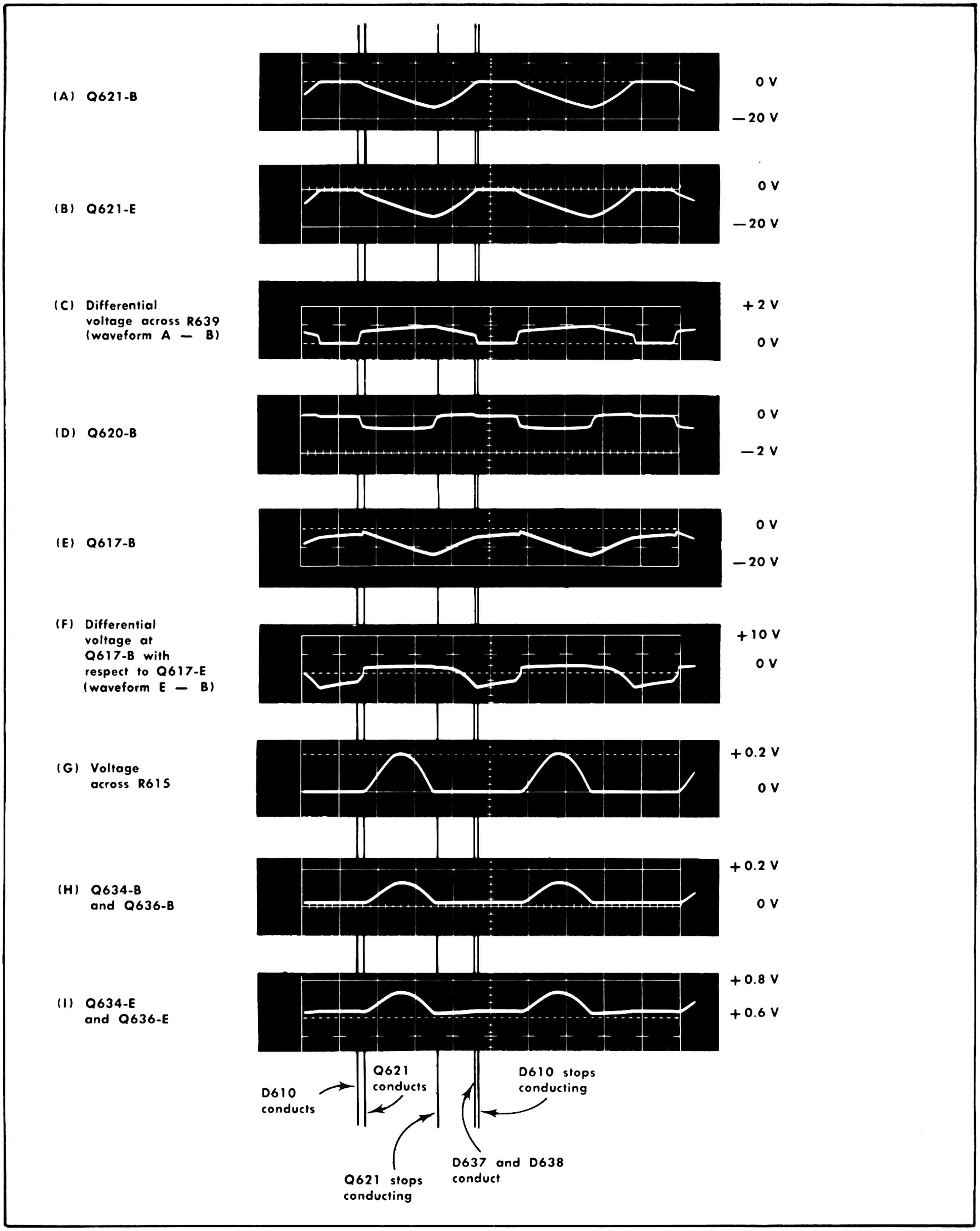


Fig. 3-4. Battery charger waveform analysis during full charge operation with oscilloscope OFF. Ground is used as reference except for (C) and (F). Waveforms are indicative of fully charged batteries. Amplitudes change with battery charge rate and ON/OFF status of the oscilloscope.

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

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

Battery Charger

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

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

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

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

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

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

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

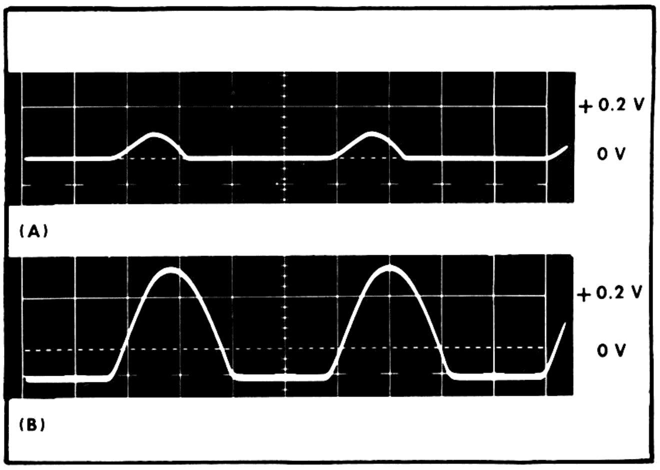


Fig. 3-5. Voltage across R615 during (A) TRICKLE CHG operation with the oscilloscope OFF, and (B) FULL CHG operation with the oscilloscope ON and INTENSITY at maximum brightness setting.

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

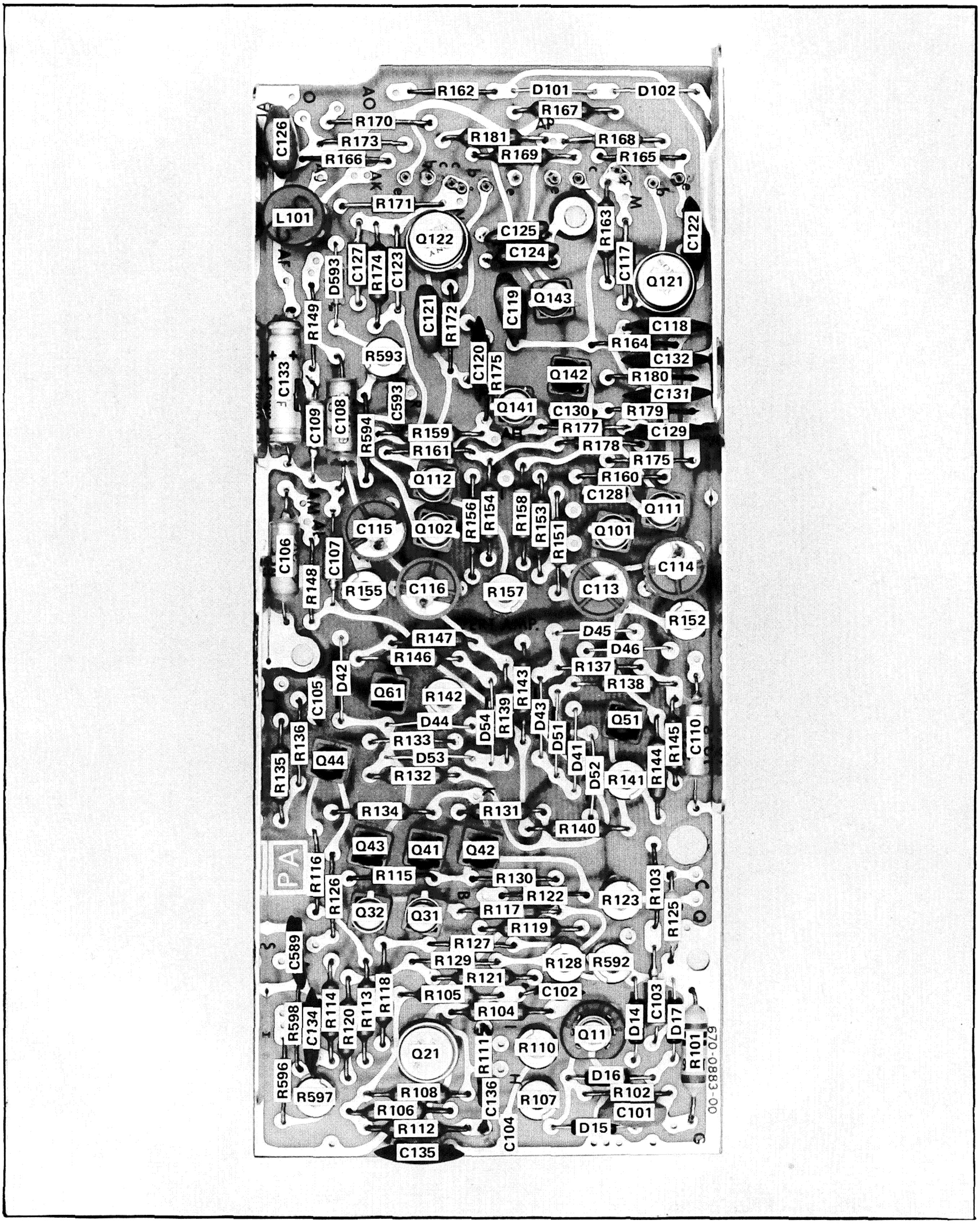


Fig. 4-14. Vertical circuit board circuit components.

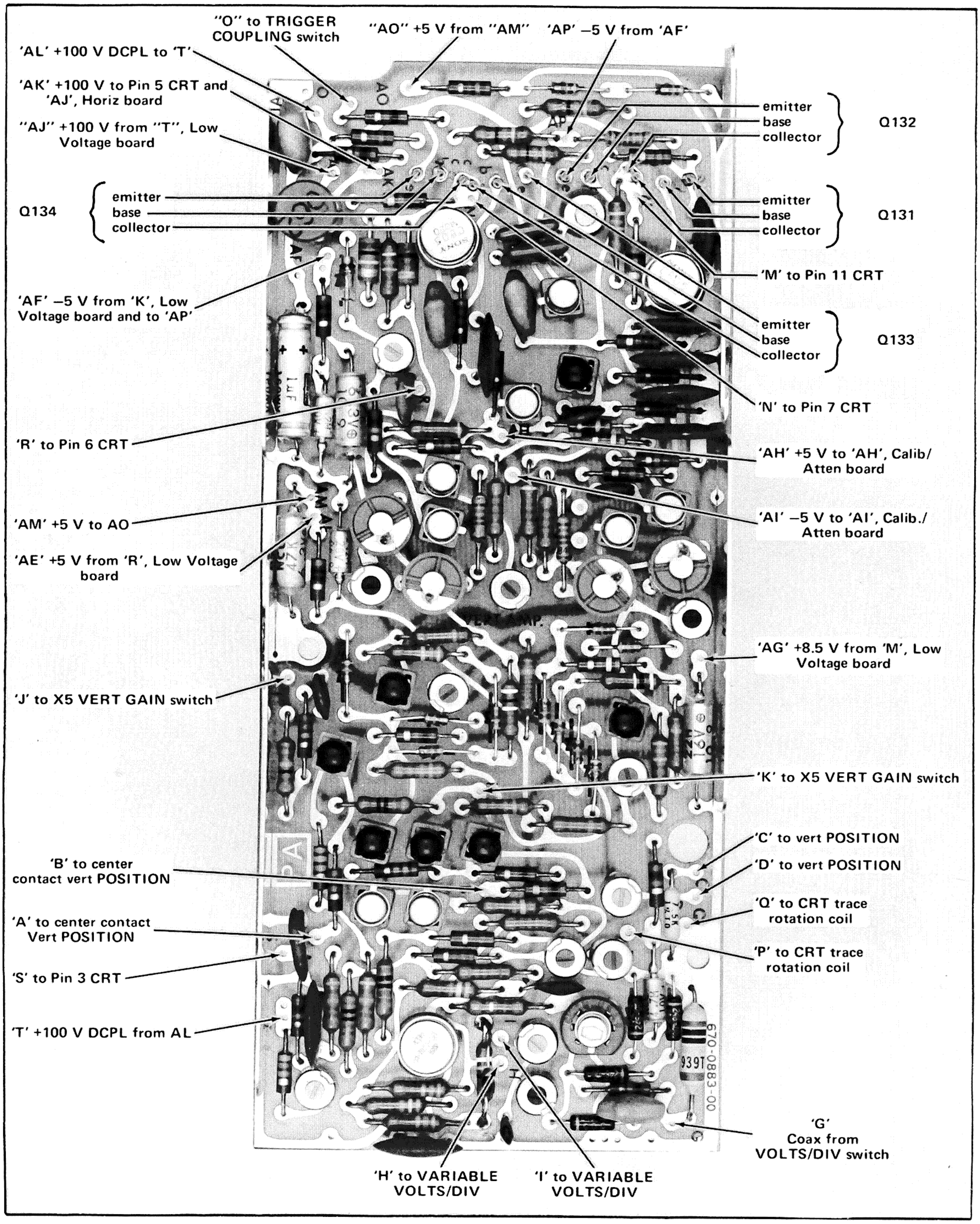


Fig. 4-15. Vertical circuit board wire connections.

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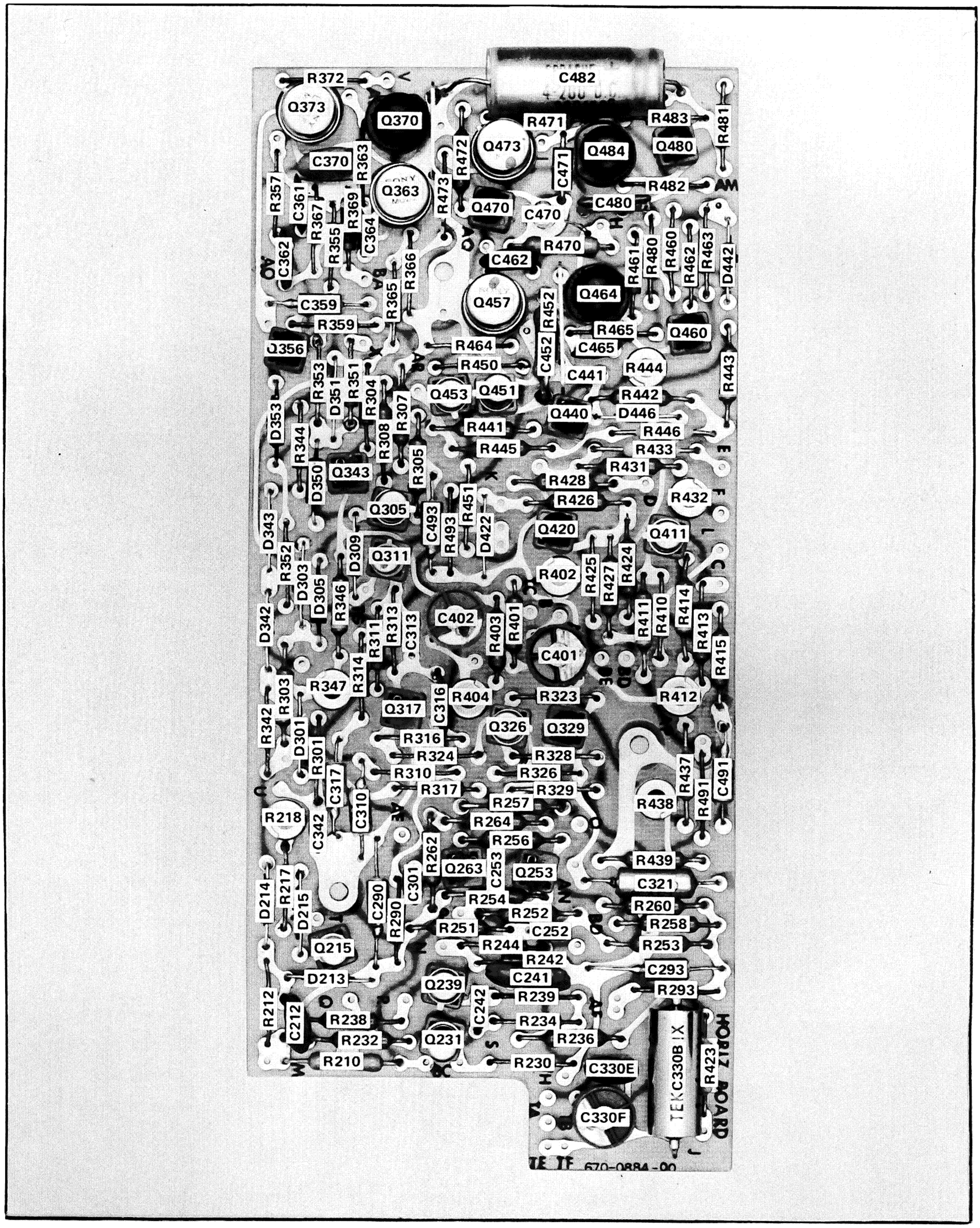


Fig. 4-16. Horizontal circuit board circuit components.

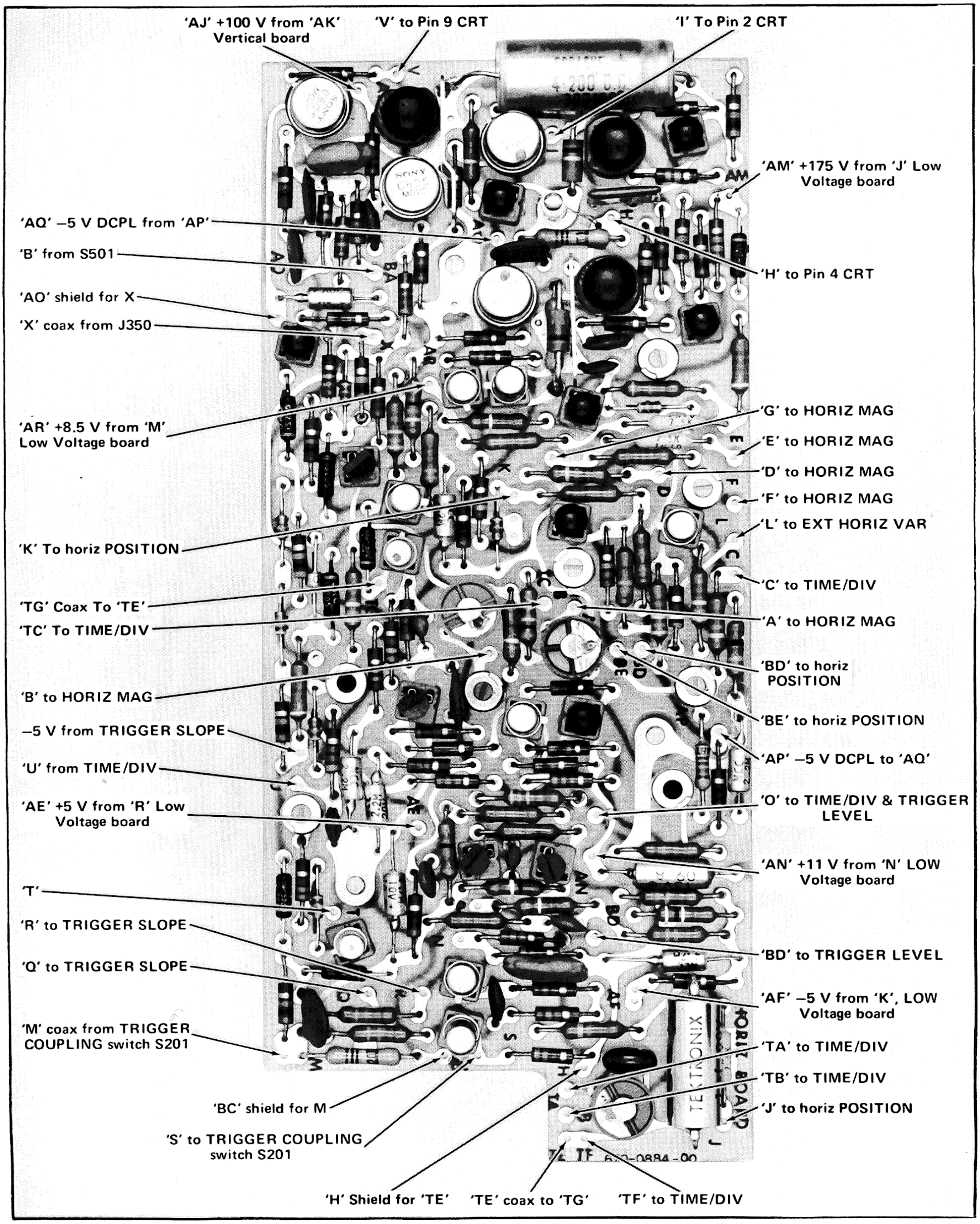


Fig. 4-17. Horizontal circuit board wire connections.

Ⓐ

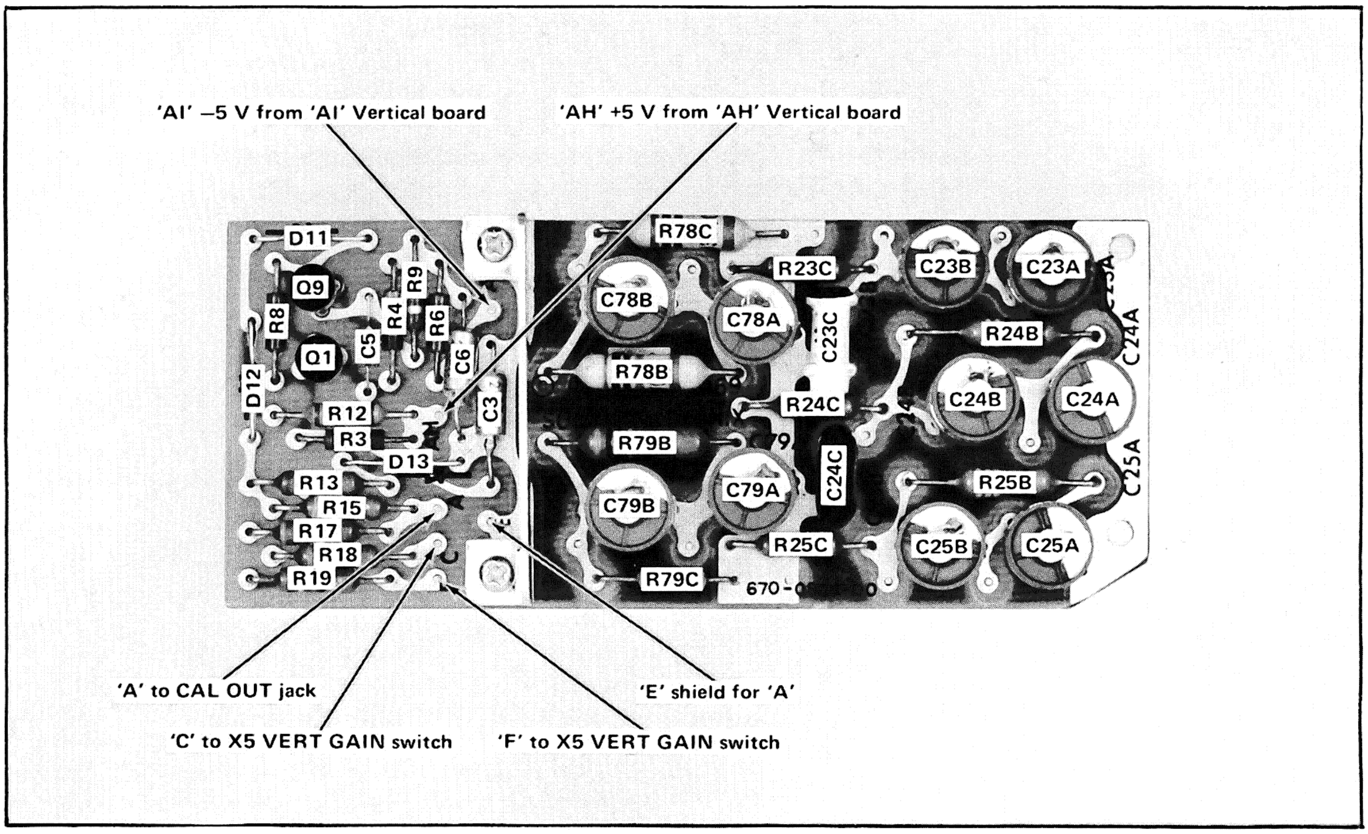


Fig. 4-18. Vertical Attenuator and Calibrator circuit board.

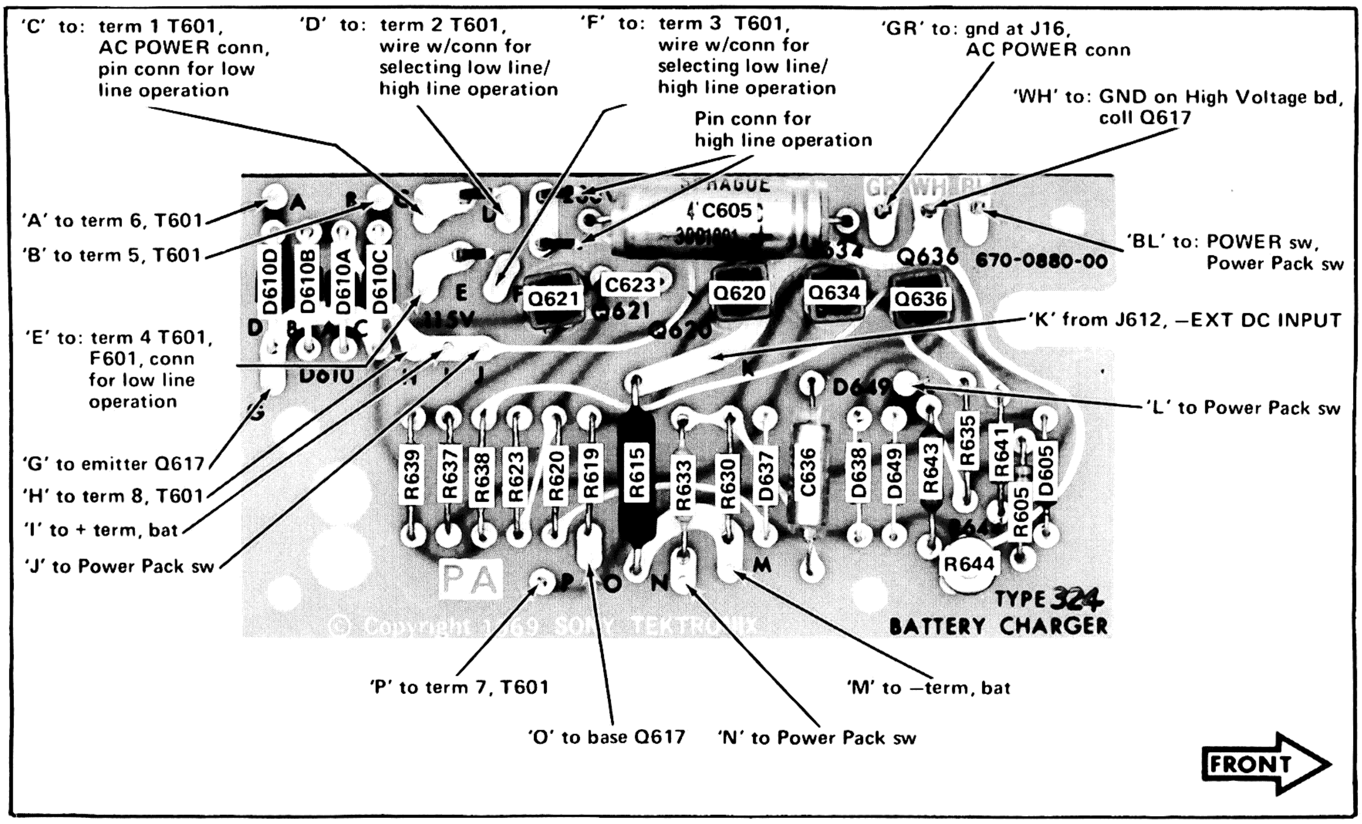


Fig. 4-19. Battery Charger circuit board.

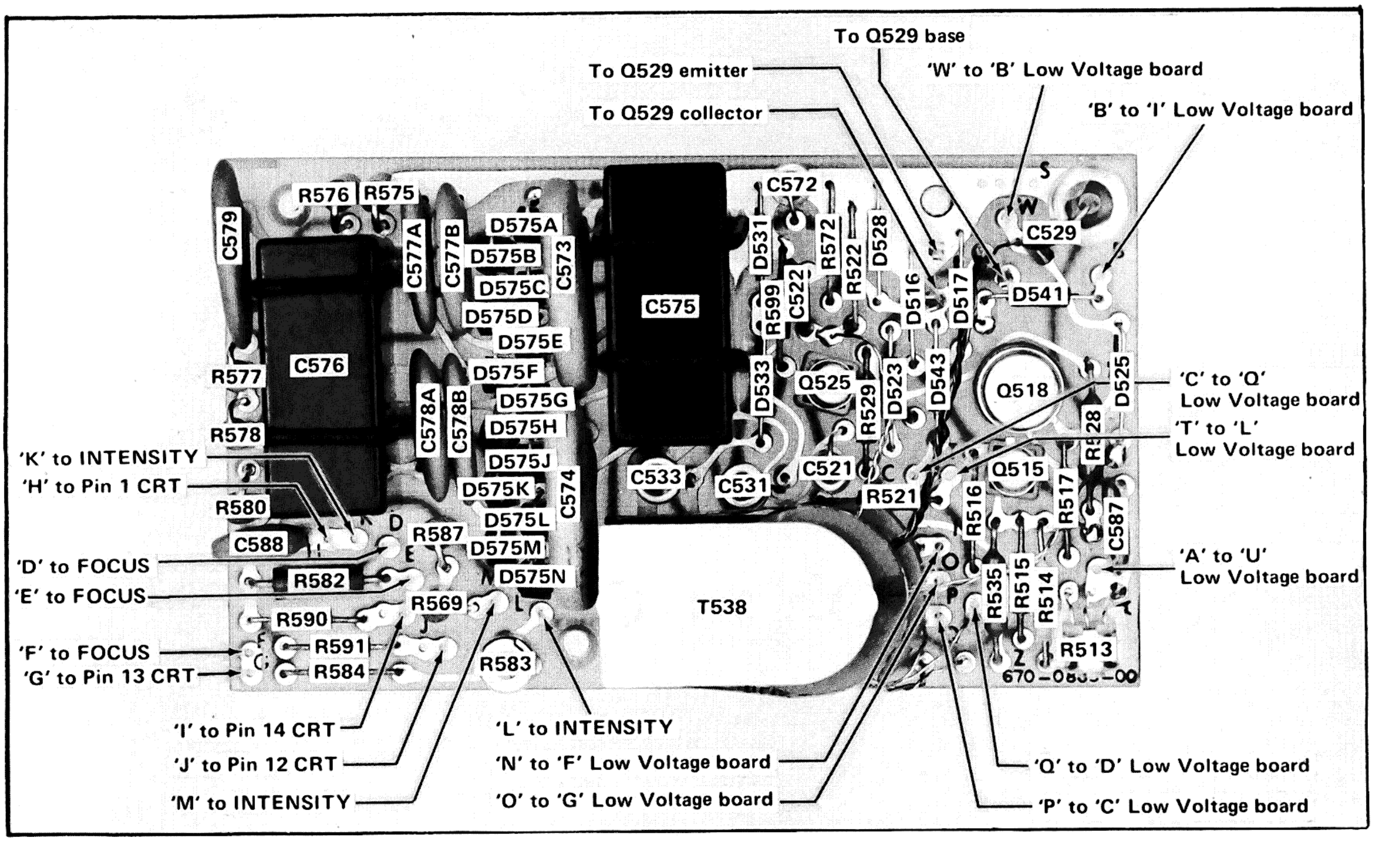


Fig. 4-20. High Voltage circuit board.

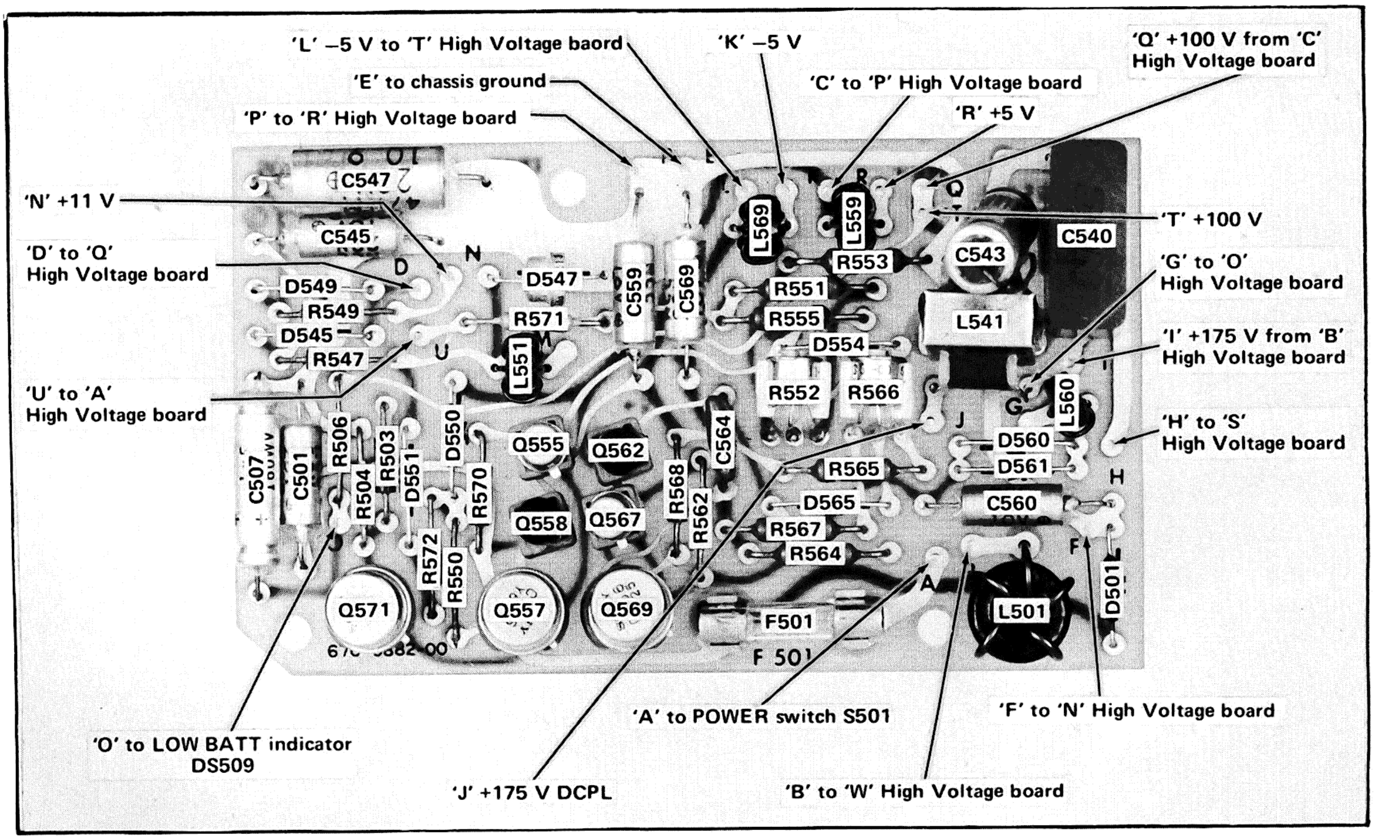
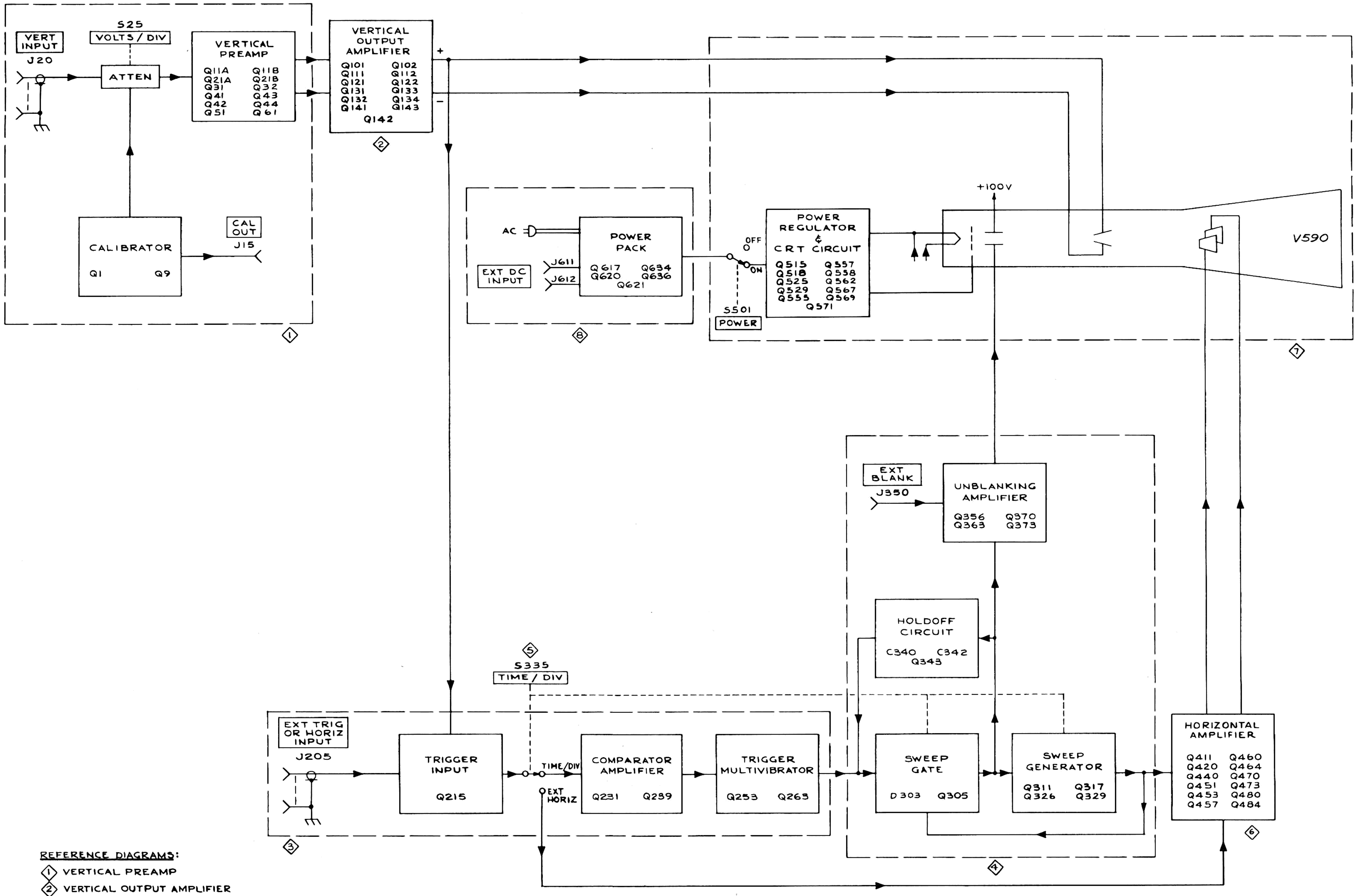


Fig. 4-21. Low Voltage circuit board.



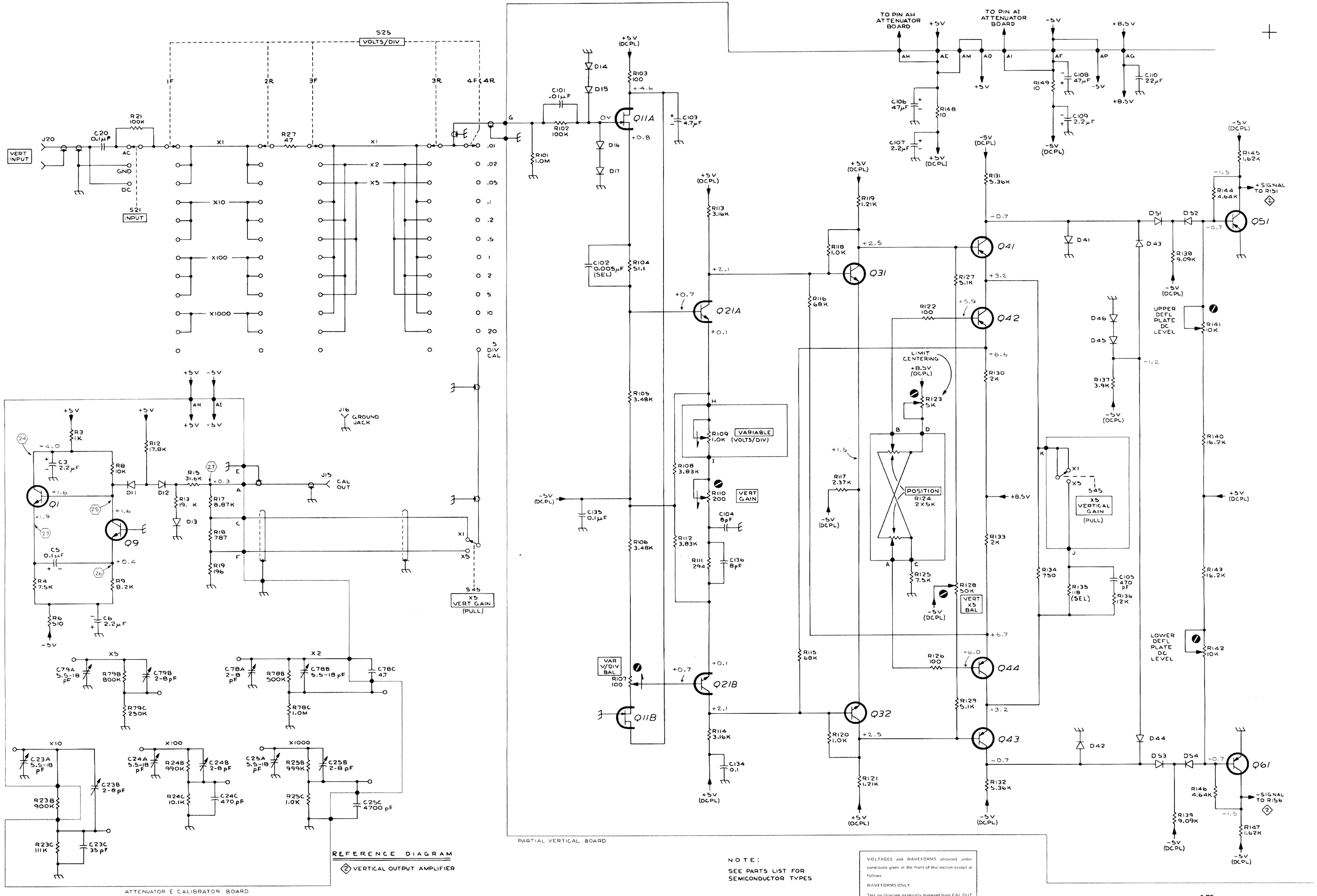
REFERENCE DIAGRAMS:

1. VERTICAL PREAMP
2. VERTICAL OUTPUT AMPLIFIER
3. TRIGGER GENERATOR
4. SWEEP GENERATOR
5. TIMING SWITCH
6. HORIZONTAL AMPLIFIER
7. POWER REGULATOR & CRT CIRCUIT
8. POWER PACK

TYPE 324

RMG
0370

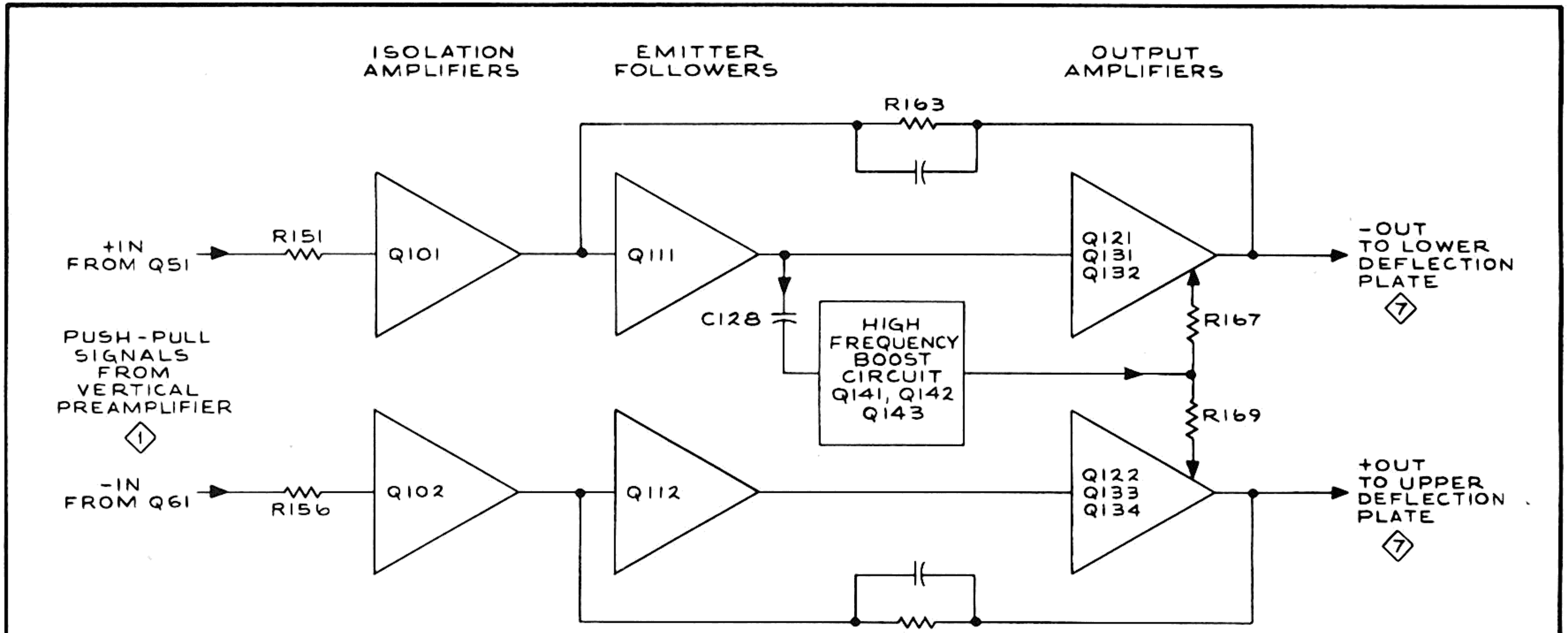
BLOCK DIAGRAM



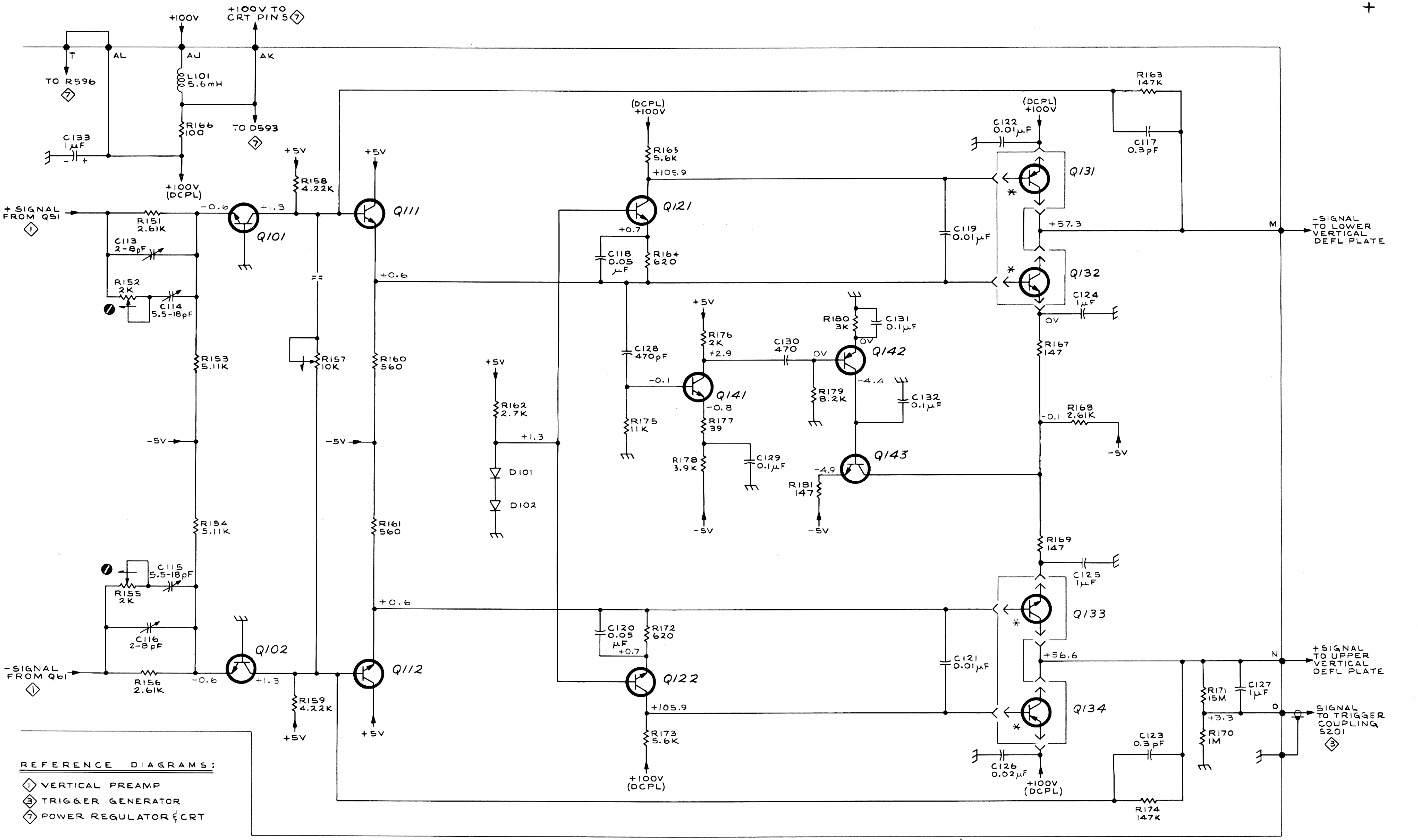
TYPE 324

GRS 0570

VERTICAL PREAMP 1



BLOCK DIAGRAM



VOLTAGES obtained under conditions given at the front of this section.

NOTES:

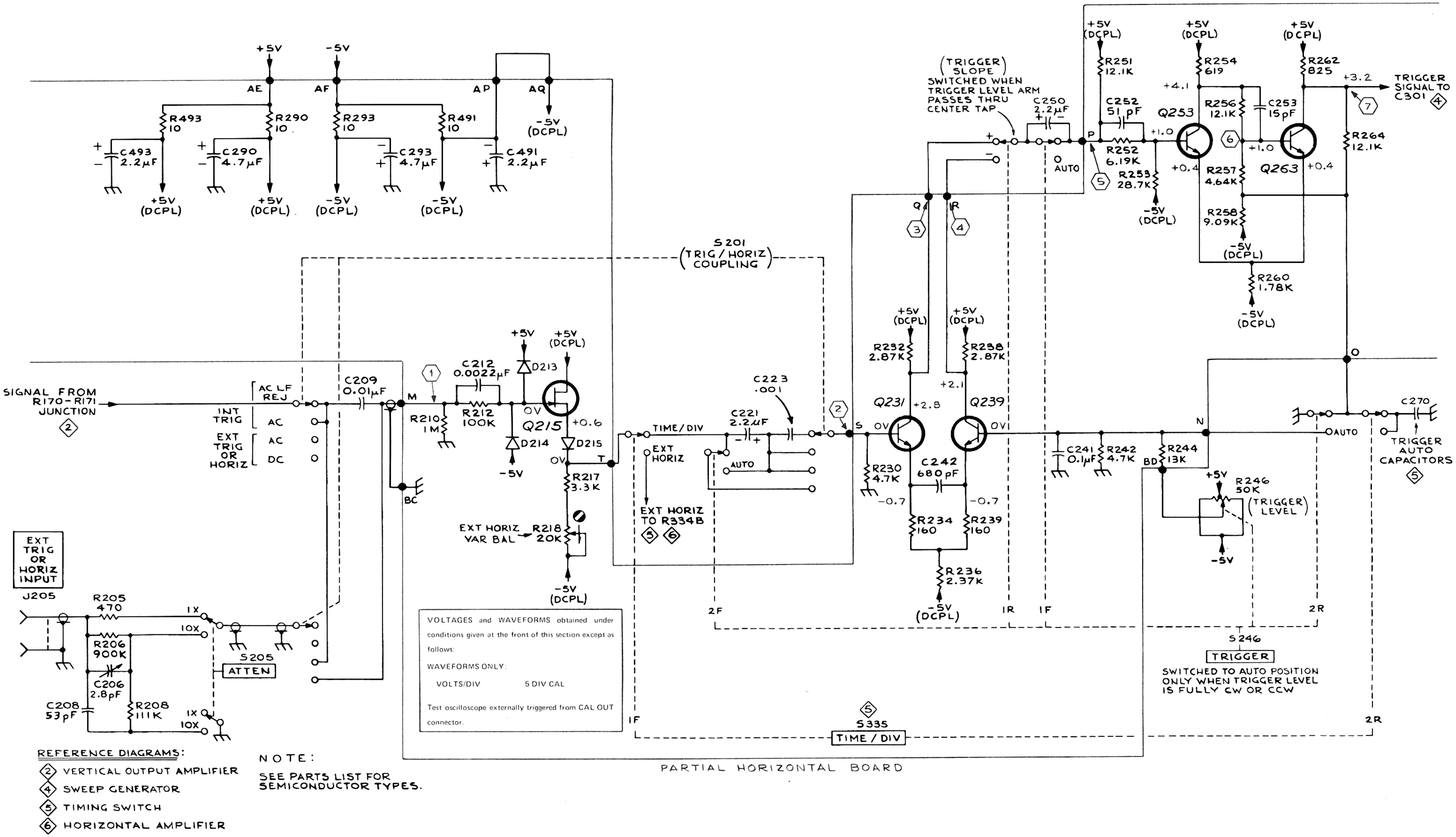
1. SEE PARTS LIST FOR SEMICONDUCTOR TYPES.
2. * HEAT SINK

RMG 0570

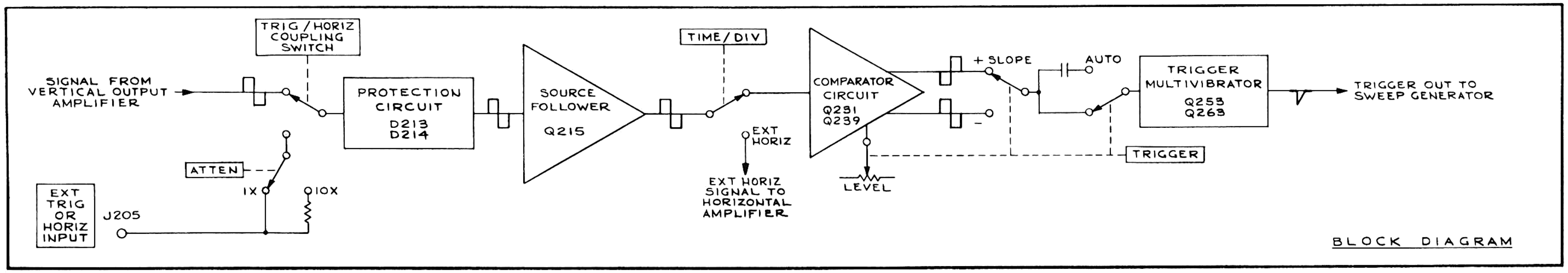
VERTICAL OUTPUT AMPLIFIER ②

TYPE 324

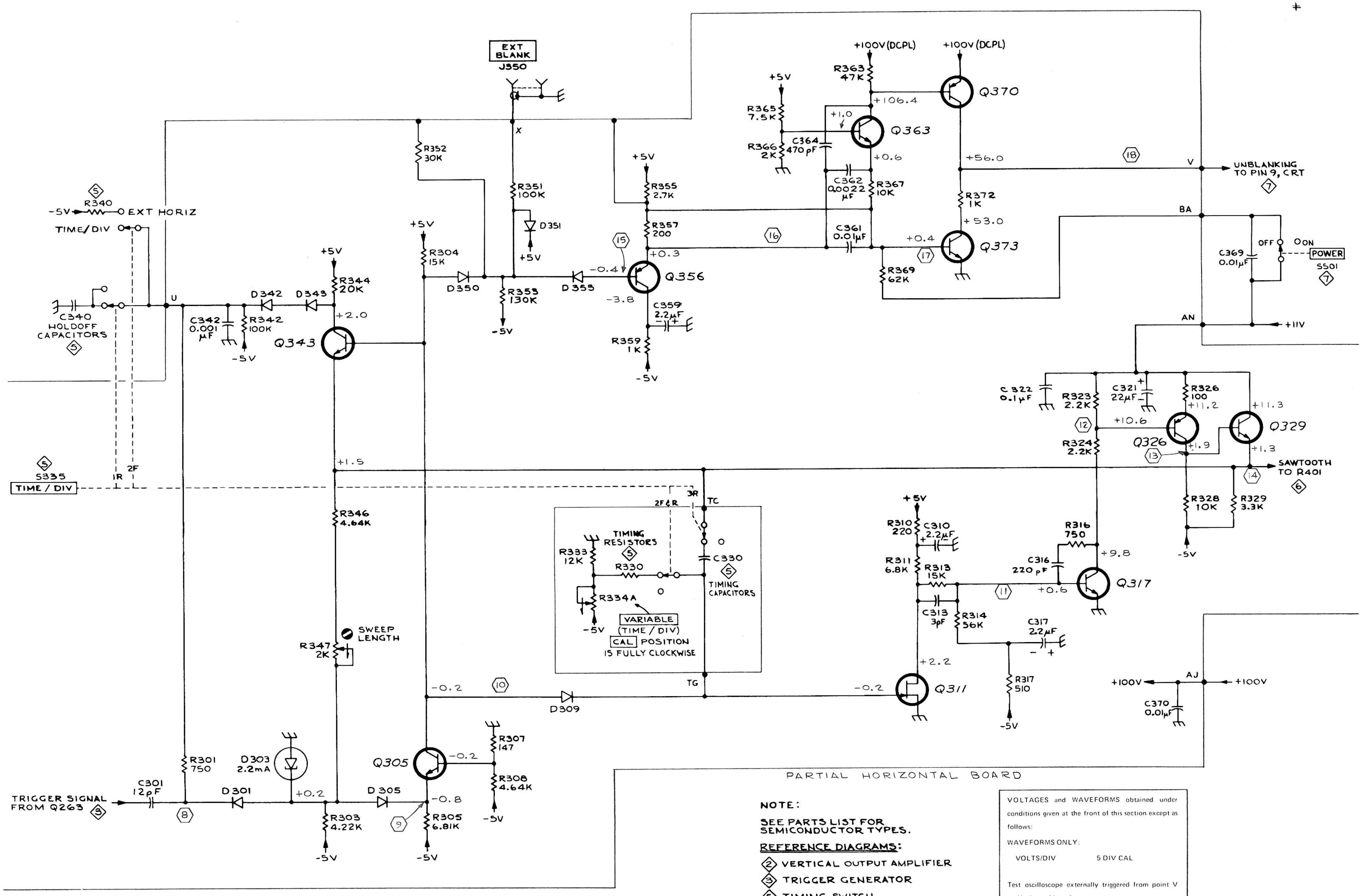
Ⓐ



SIGNAL FROM R170-R171 JUNCTION (2)
AC LF REJ
INT TRIG
AC
EXT TRIG OR HORIZ
AC
DC
C209 0.01μF
M
R210 1M
C212 0.0022μF
R212 100K
D213
D214
Q215
D215
R217 3.3K
EXT HORIZ VAR BAL R218 20K
+5V
-5V
+5V (DCPL)
-5V (DCPL)
BC
T
S201 (TRIG/HORIZ COUPLING)
TIME/DIV
EXT HORIZ
EXT HORIZ TO R334B (5) (6)
AUTO
C221 2.2μF
C223 .001
S
Q231
Q239
R232 2.87K
R238 2.87K
R230 4.7K
C242 680pF
R234 160
R239 160
R236 2.37K
C241 0.1μF
R242 4.7K
R244 13K
BD
N
R246 50K (TRIGGER LEVEL)
C270
AUTO
TRIGGER AUTO CAPACITORS (5)
S246 TRIGGER
SWITCHED TO AUTO POSITION ONLY WHEN TRIGGER LEVEL IS FULLY CW OR CCW
(TRIGGER SLOPE) SWITCHED WHEN TRIGGER LEVEL ARM PASSES THRU CENTER TAP
C250 2.2μF
P
R251 12.1K
C252 51pF
R252 6.19K
R253 28.7K
Q253
R254 619
R256 12.1K
C253 15pF
R257 4.64K
R258 9.09K
R260 1.78K
Q263
R262 825
R264 12.1K
TRIGGER SIGNAL TO C301 (4)
AE
AF
AP
AQ
R493 10
C493 2.2μF
R290 10
C290 4.7μF
R293 10
C293 4.7μF
R491 10
C491 2.2μF
EXT TRIG OR HORIZ INPUT
J205
R205 470
R206 900K
C206 2.8pF
C208 53pF
R208 111K
1X
10X
S205 ATTEN
2F
1R
1F
2R
S335 TIME/DIV
VOLTAGES and WAVEFORMS obtained under conditions given at the front of this section except as follows:
WAVEFORMS ONLY:
VOLTS/DIV 5 DIV CAL
Test oscilloscope externally triggered from CAL OUT connector.
PARTIAL HORIZONTAL BOARD
REFERENCE DIAGRAMS:
(2) VERTICAL OUTPUT AMPLIFIER
(4) SWEEP GENERATOR
(5) TIMING SWITCH
(6) HORIZONTAL AMPLIFIER
NOTE:
SEE PARTS LIST FOR SEMICONDUCTOR TYPES.



SIGNAL FROM VERTICAL OUTPUT AMPLIFIER
TRIG/HORIZ COUPLING SWITCH
PROTECTION CIRCUIT D213 D214
SOURCE FOLLOWER Q215
TIME/DIV
EXT HORIZ
EXT HORIZ SIGNAL TO HORIZONTAL AMPLIFIER
COMPARATOR CIRCUIT Q231 Q239
LEVEL
+ SLOPE
AUTO
TRIGGER
TRIGGER MULTIVIBRATOR Q253 Q263
TRIGGER OUT TO SWEEP GENERATOR
ATTEN
1X
10X
EXT TRIG OR HORIZ INPUT
J205
BLOCK DIAGRAM



NOTE:

SEE PARTS LIST FOR SEMICONDUCTOR TYPES.

REFERENCE DIAGRAMS:

- ② VERTICAL OUTPUT AMPLIFIER
- ③ TRIGGER GENERATOR
- ⑤ TIMING SWITCH
- ⑥ HORIZONTAL AMPLIFIER
- ⑦ POWER REGULATOR & CRT

VOLTAGES and WAVEFORMS obtained under conditions given at the front of this section except as follows:

WAVEFORMS ONLY:

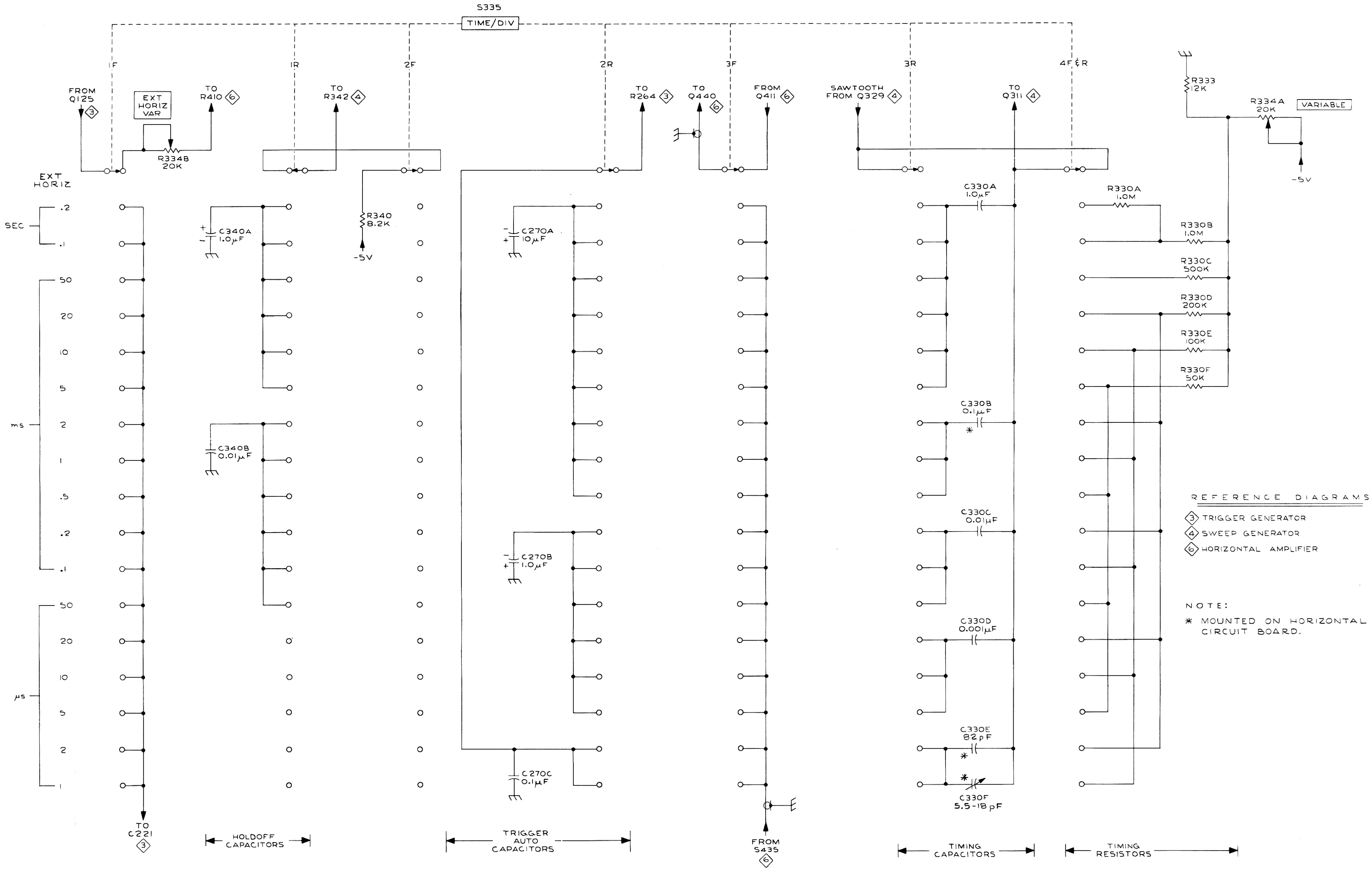
VOLTS/DIV 5 DIV CAL

Test oscilloscope externally triggered from point V on Horizontal board.

TYPE 324

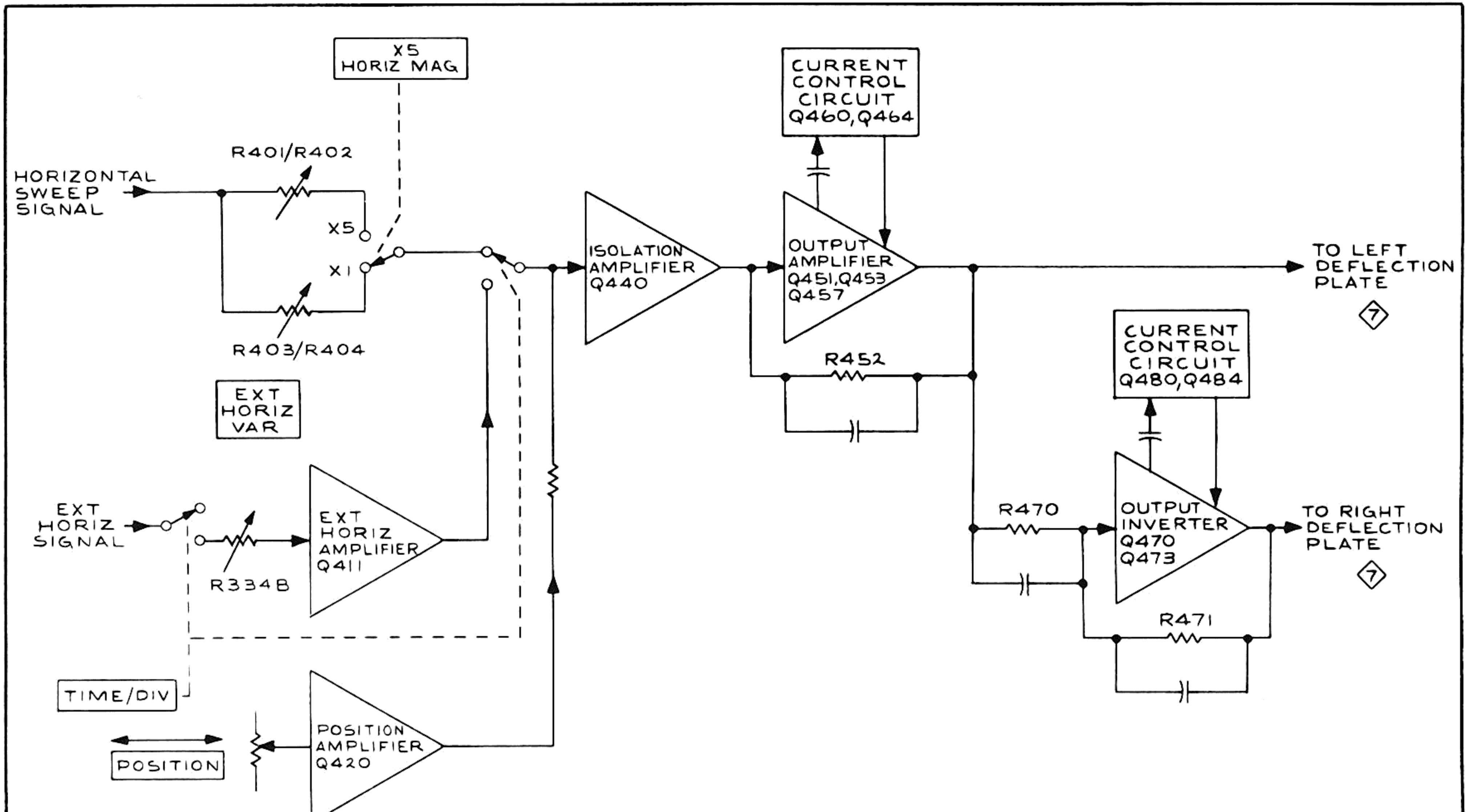
GRS 0570

SWEEP GENERATOR ④

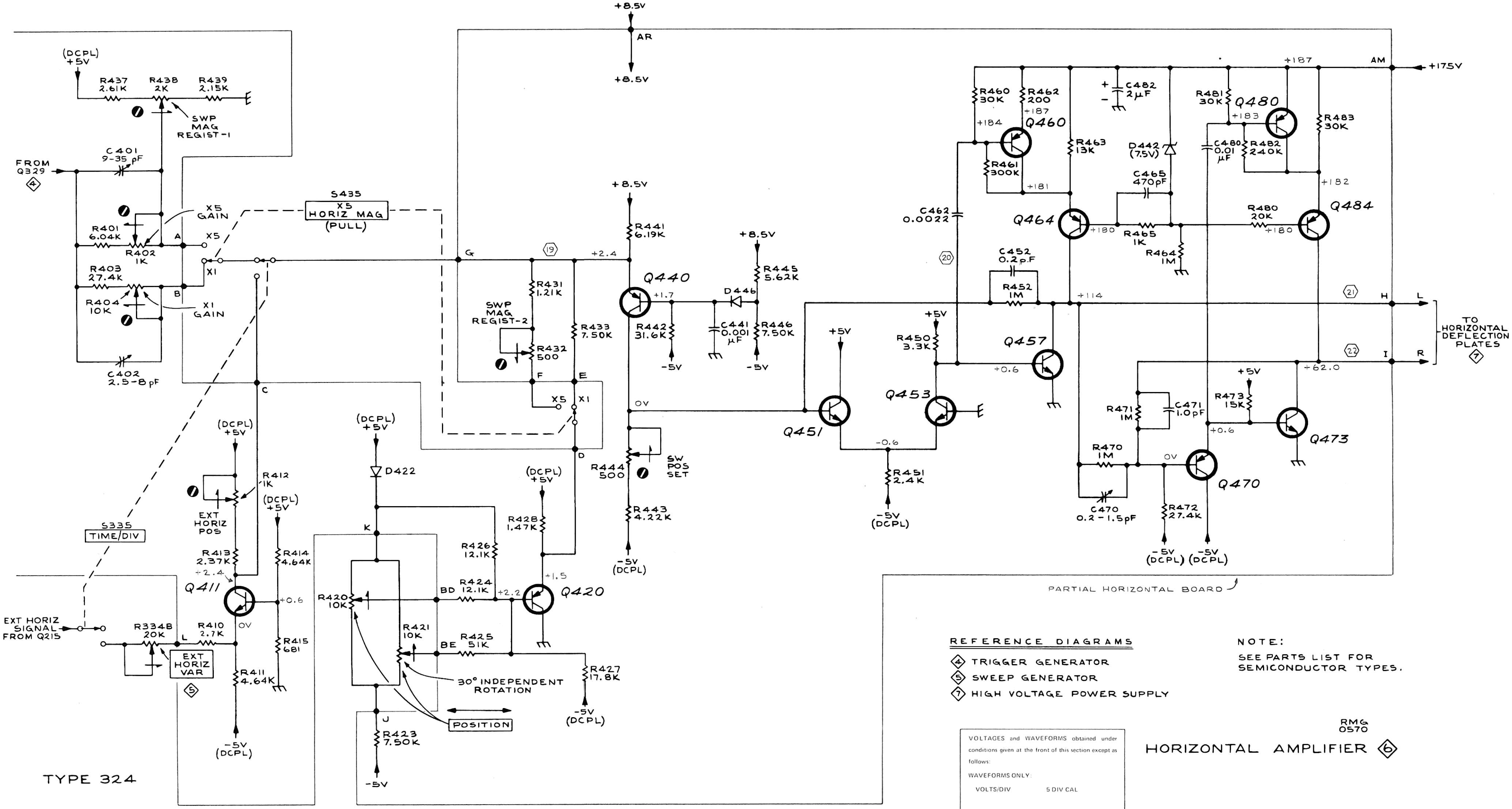


Ⓐ

TIMING SWITCH 5



BLOCK DIAGRAM



REFERENCE DIAGRAMS

4 TRIGGER GENERATOR
5 SWEEP GENERATOR
7 HIGH VOLTAGE POWER SUPPLY

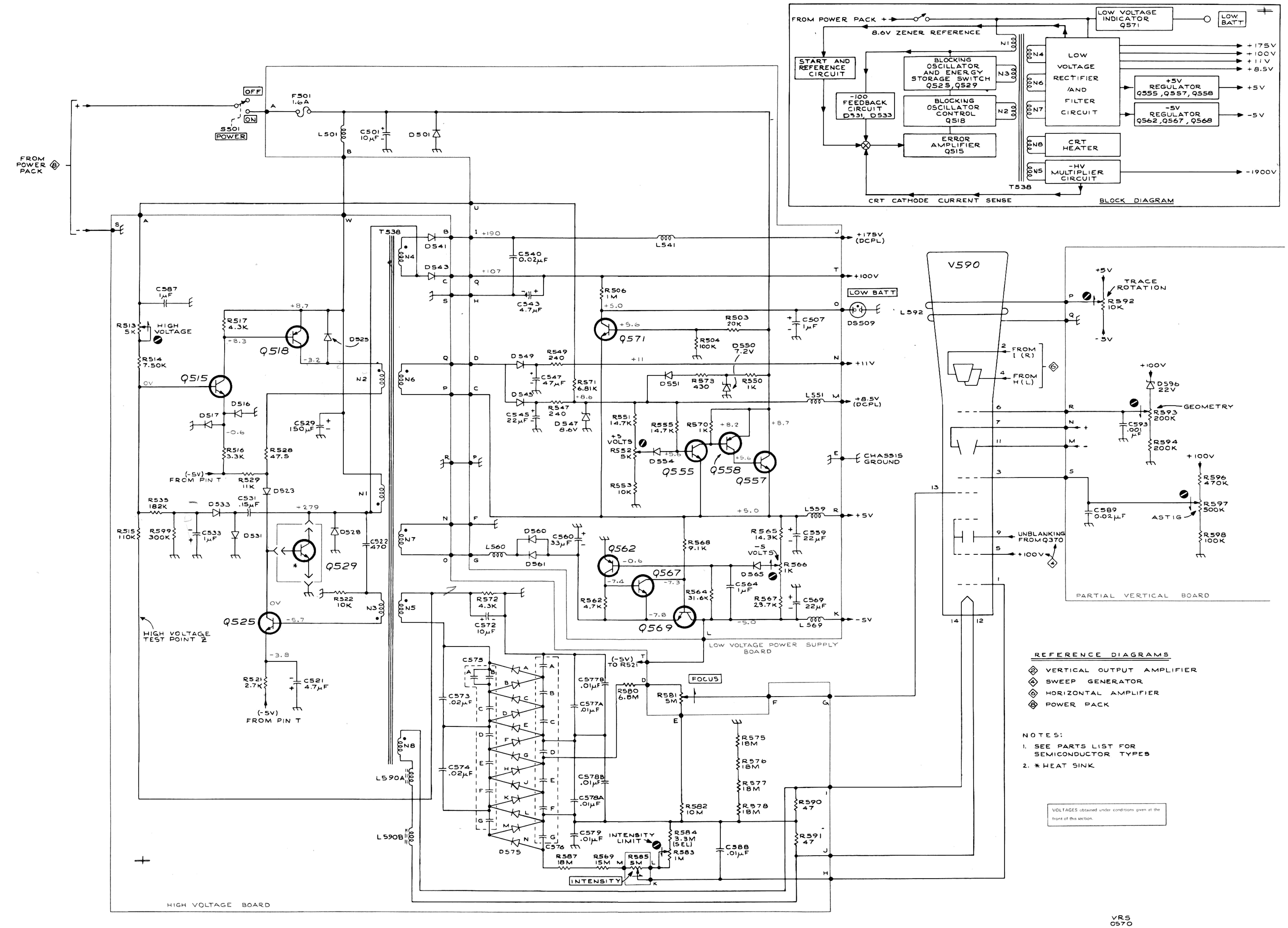
NOTE:
SEE PARTS LIST FOR SEMICONDUCTOR TYPES.

RMG 0570

HORIZONTAL AMPLIFIER 6

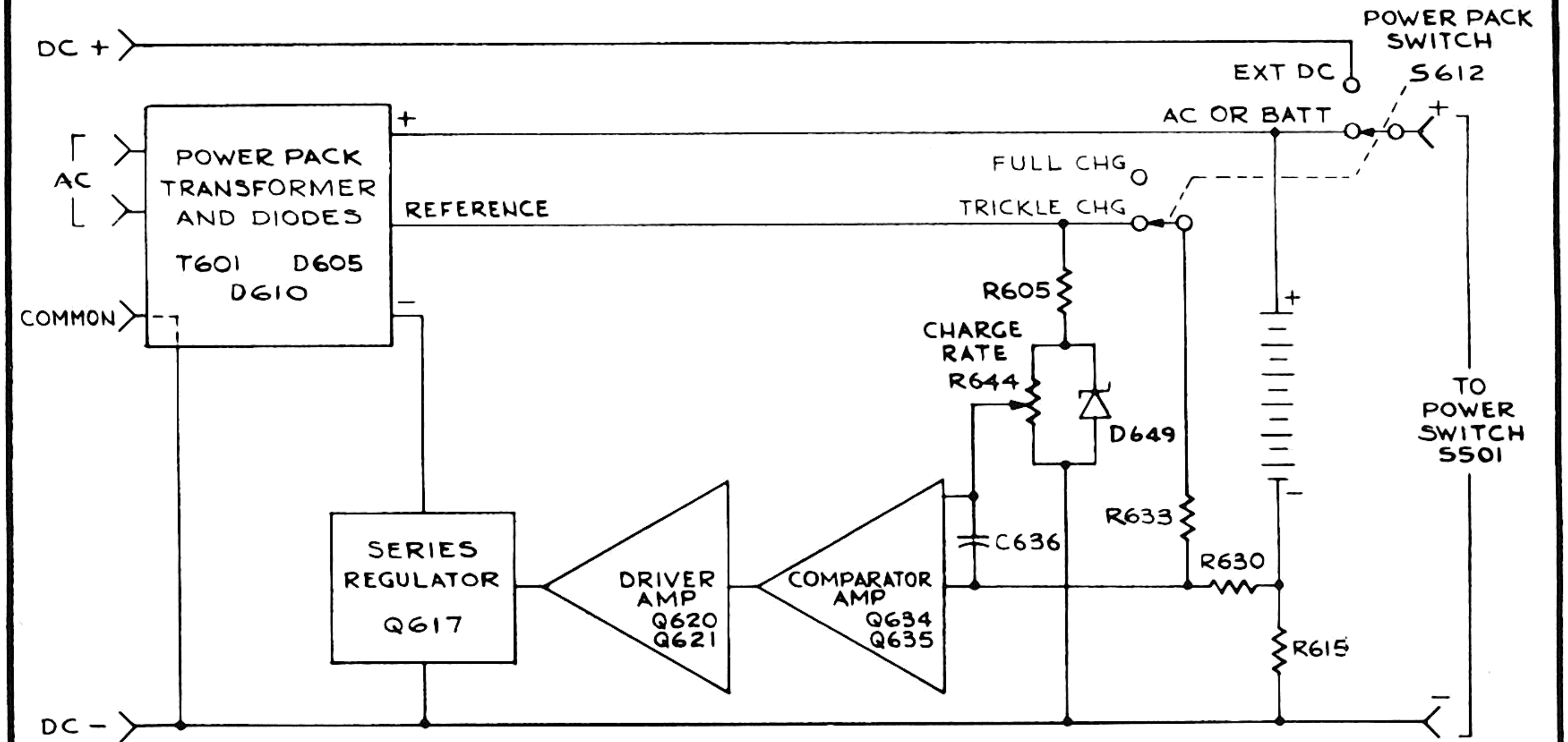
VOLTAGES and WAVEFORMS obtained under conditions given at the front of this section except as follows:
WAVEFORMS ONLY:
VOLTS/DIV 5 DIV CAL
Test oscilloscope externally triggered from point V on Horizontal board.

TYPE 324

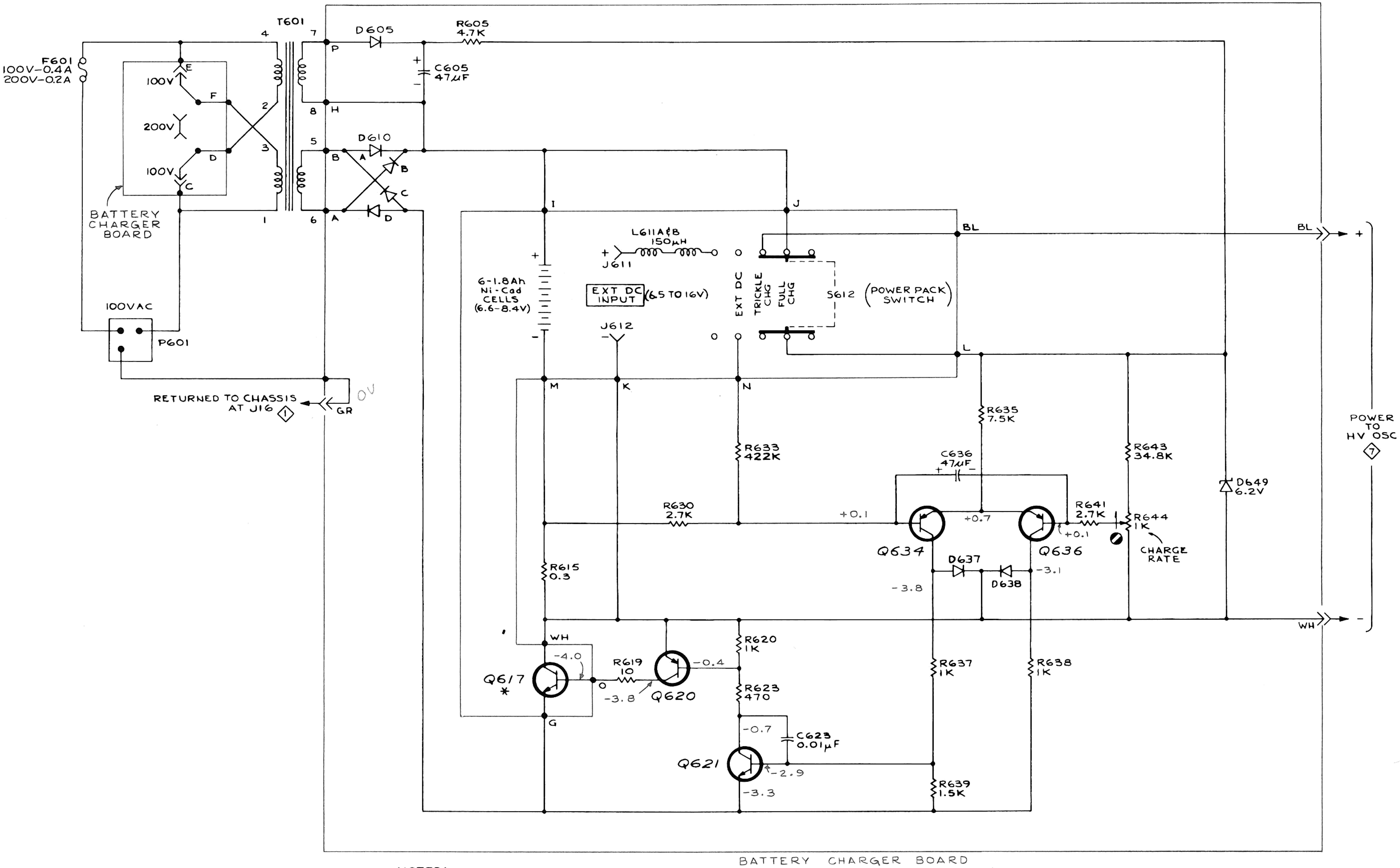


VRS 0570

TYPE 324 — POWER REGULATOR & CRT CIRCUIT (7)



BLOCK DIAGRAM



NOTES:
1. SEE PARTS LIST FOR SEMICONDUCTOR TYPES
2.* TRANSISTOR IS HEAT SINKED

REFERENCE DIAGRAMS:
⟨1⟩ VERTICAL PREAMP
⟨7⟩ POWER REGULATOR & CRT

TYPE 324

VOLTAGES obtained under conditions given at the front of this section except as follows:
Power Pack (S612) FULL CHG 100 volts AC applied to P601.

POWER PACK ⟨8⟩ MRH/grs 0570

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Sections of the manual are often printed at different times, so some of the information on the change pages may already be in your manual. Since the change information sheets are carried in the manual until ALL changes are permanently entered, some duplication may occur. If no such change pages appear in this section, your manual is correct as printed.

ELECTRICAL PARTS LIST CORRECTION

VERTICAL Circuit Board Assembly

CHANGE TO:

C102	283-0675-01	82 pF	Mica	300 V	1%
C107	283-0675-01	82 pF	Mica	300 V	1%

HORIZONTAL Circuit Board Assembly

CHANGE TO:

C330E	283-0675-01	82 pF	Mica	300 V	1%

M14,559/371

ELECTRICAL PARTS LIST CORRECTION

	HIGH VOLTAGE POWER SUPPLY	Circuit Board Assembly		
CHANGE TO:				
C531	290-0451-01	0.15 μF	Elect.	
C533	290-0453-01	1 μF	Elect.	
	LOW VOLTAGE POWER SUPPLY	Circuit Board Assembly		
CHANGE TO:				
C543	290-0454-01	4.7 μF		160 V

ELECTRICAL PARTS LIST CORRECTION

CHANGE TO:

C208	283-0602-01	53 pF	Mica	300 V	5%