TEKTRONIX®

TYPE 547 OSCILLOSCOPE

INSTRUCTION MANUAL

Tektronix, Inc.
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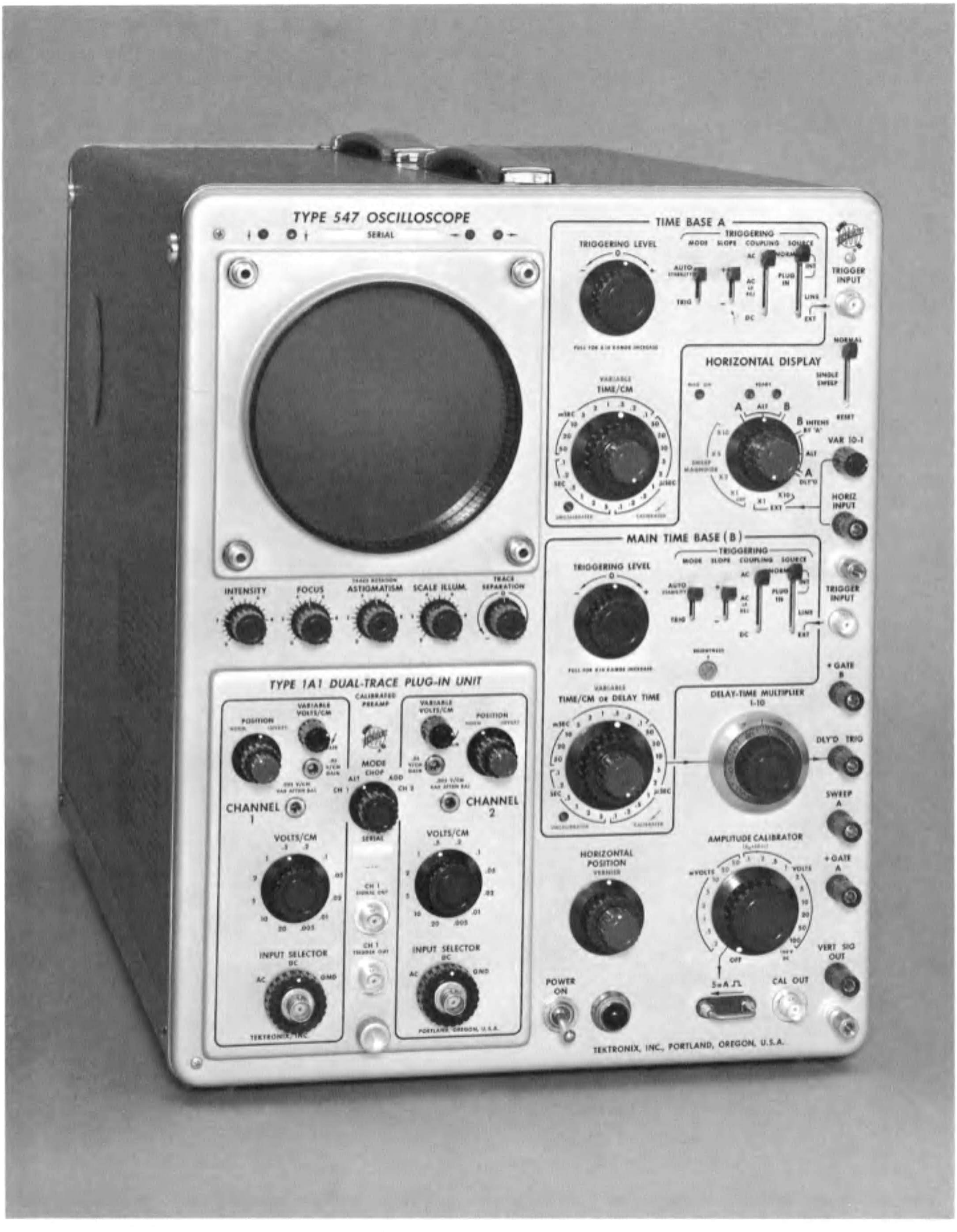
Serial Number ____________________

070-0398-00


TYPE 547 OSCILLOSCOPE
SERIAL
TIME BASE A
TRIGGERING
TRIGGERING LEVEL
TRIGGER INPUT
HORIZONTAL DISPLAY
SINGLE SWEEP
RESET
VAR 10-1
HORIZ INPUT
MAIN TIME BASE (B)
TRIGGERING
TRIGGERING LEVEL
TRIGGER INPUT
TIME/CM
TIME/CM OR DELAY TIME
DELAY-TIME MULTIPLIER 1-10
DLY'D TRIG
SWEEP A
+GATE B
+GATE A
VERT SIG OUT
AMPLITUDE CALIBRATOR
CAL OUT
HORIZONTAL POSITION
POWER ON
INTENSITY
FOCUS
ASTIGMATISM
SCALE ILLUM.
TRACE SEPARATION
TYPE 1A1 DUAL-TRACE PLUG-IN UNIT
CHANNEL 1
CHANNEL 2
VOLTS/CM
POSITION
MODE
INPUT SELECTOR
TEKTRONIX, INC.
PORTLAND, OREGON, U.S.A.
TEKTRONIX, INC., PORTLAND, OREGON, U.S.A.

SECTION 1
CHARACTERISTICS

Introduction

The Type 547 Oscilloscope is a versatile laboratory instrument designed for use with all Tektronix lettered or 1-Series plug-in units. The instrument features two identical time-base generators that can be used singly or electronically alternated for viewing a single signal or multiple signals at two sweep rates.

The two time-base generators can also used in "delaying" and "delayed" sweep operation for highly accurate time measurements.

Vertical Deflection System

Refer to Table 1-1 for the characteristics.

Sweep Generation

Trigger features and sweep rates of both Type 547 time-base circuits are identical.

Sweep Rates (at 1X magnification)	0.1 μsec/cm to 5 sec/cm in 24 calibrated steps. Displayed Sweep-rate accuracy is ±2% for both sweeps. An uncalibrated variable sweep-rate control permits either sweep to be slowed to at least 0.4 of the indicated rate.
Sweep Magnification	Any sweep rate can be increased by expanding the center portion of the display horizontally in fixed steps of 2X, 5X, and 10X. Sweep-rate accuracy is within ±5% in the magnified positions.
Trigger Source Selection	Internal normal, internal plug in, external, and line.
Trigger Coupling Selection	Dc, ac, and ac low-frequency rejection.
Trigger Signal Requirements	Internal (ac): Minimum deflection is 2 mm, rising to 1 cm at about 50 mc.

TABLE 1-1

Plug-In Characteristics for the Type 547 Oscilloscope

Plug-In Unit	Calibrated Deflection Factor	Bandpass at —3 dB***	Fastest Risetime	Approx Input Capacitance
Type 1A1**	50 mv/cm to 20 v/cm 5 mv/cm	dc to 50 mc dc to 28 mc	7 nsec 13 nsec	15 pf
Type 1A2	50 mv/cm to 20 v/cm	dc to 50 mc	7 nsec	15 pf
Type 1A7	10 mv/cm to 10 v/cm	dc to 100 cps —500 kc	.7 μsec	47 pf
Type 1S1	2 mv/cm to 200 mv/cm	dc to 1000 mc	.35 nsec	50 Ω input Z
Type B	0.005 v/cm to 20 v/cm 0.05 v/cm to 20 v/cm	2 cps to 12 mc dc to 20 mc	30 nsec 18 nsec	47 pf
Type CA**	0.05 v/cm to 20 v/cm	dc to 24 mc	15 nsec	20 pf
Type D	1 mv/cm to 50 v/cm	dc to 300 kc-2 mc	0.18 μsec	47 pf
Type E	50 μv/cm to 10 mv/cm	0.06 cps to 20 kc —60 kc	6 μsec	50 pf
Type G	0.05 v/cm to 20 v/cm	dc to 20 mc	18 nsec	47 pf
Type H	5 mv/cm to 20 v/cm	dc to 15 mc	24 nsec	47 pf
Type K	0.05 v/cm to 20 v/cm	dc to 30 mc	12 nsec	20 pf
Type L	5 mv/cm to 2 v/cm 0.05 v/cm to 20 v/cm	3 cps to 24 mc dc to 30 mc	15 nsec 12 nsec	20 pf
Type M**	0.02 v/cm to 10 v/cm	dc to 20 mc	18 nsec	47 pf
Type O*	0.05 v/cm to 20 v/cm	dc to 25 mc	14 nsec	47 pf
Type Q*	10 μstrain/cm to 10,000 μstrain/cm	dc to 6 kc	60 μsec	Adjustable
Type R*	0.5 ma/cm to 100 ma/cm			
Type S*	0.05 v/cm and 0.5 v/cm			
Type W	1 mv/cm to 50 v/cm	dc to 8 mc dc to 23 mc	44 nsec 16 nsec	20 pf
Type Z*	0.05 v/cm to 25 v/cm	dc to 13 mc	27 nsec	24 pf

*Special feature plug-in units. See your Tektronix catalog for more information on any of these plug-in units.
**Multiple-trace plug-in units.
***Not more than —3 dB at indicated frequencies.

	Internal (dc): Minimum deflection is 5 mm at dc rising to 2.5 cm at 50 MHz.
	Internal (ac low-frequency rejection): Minimum deflection is 2 mm with signals at about 2 kc, rising to 1 cm at about 50 mc.
	External: Frequency ranges are the same as internal. Minimum amplitude is 200 mvolts peak-to-peak (ac), 200 mvolts change in dc level (dc) and, 200 mvolts peak-to-peak (ac low-frequency reject). A MAXIMUM INPUT OF ± 30 VOLTS must not be exceeded in the EXTERNAL trigger position. Minimum trigger level range is greater than ±2 volts with the TRIGGER LEVEL control pushed in and ±20 volts with the control pulled out
Sweep Delay	The time-base A sweep can be delayed by the main time base (B) sweep. Delay is continuously variable over the range of 0.1 μsec to 50 sec with the DELAY TIME and DELAY-TIME MULTIPLIER controls. Delay time is accurate to ±1% of indicated delay ±2 minor divisions of the DELAY-TIME MULTIPLIER at sweep rates from 50 μsec to 50 sec. At delay times shorter than 50 μsec, indicated delay accuracy is the same as above plus approximately 75-100 nsec. The 75-100 nsec represents the fixed inherent delay of the internal trigger circuitry of the Type 547. Incremental delay accuracy is ±4 minor divisions of the DELAY-TIME MULTIPLIER dial at sweep rates from 1 μsec to 50 sec. Incremental accuracy at the three fastest sweep rates (0.1, 0.2, and 0.5 μsec) is ±10 minor divisions. Stated accuracies apply only when the VARIABLE controls are set to CALIB. Delay jitter is no greater than 1 part in 20,000.

Horizontal Deflection System

The following characteristics apply when the HORIZONTAL DISPLAY switch is set to the EXT positions.

Deflection Factor	Continuously variable from approximately 0.1 volt/cm to 10 volts/cm.
Frequency Response	Dc to 400 kc (3-db down).
Input Characteristics	1 megohm paralleled by approximately 55 pf.

Amplitude Calibrator

Output Voltages	0.2 mvolts to 100 volts peak-to-peak in 18 steps. In addition, a 100-volt dc output is available.
Frequency	Approximately 1-kc square wave.
Output Current	5 ma square wave available at the front-panel current loop.
Output Impedance	50 Ω in .2 to 200 mVOLTS positions. Progressively higher output impedances in the .5 to 50 VOLT positions up to about 4 k in the 50 VOLT position. Output impedance of the 100 VOLT position (ac and dc) is about 420 Ω.
Amplitude Accuracy	Peak-to-peak amplitude accuracy is ±3% of indicated value when working into an impedance of 1 megohm. The .2 to 200 mVolts position will be within ±3% of one-half of the indicated voltage when working into an impedance of 50 ohms. The 5 ma current accuracy is ±3%.

Front-Panel Output Signals

+GATE B	Approximately 20-volt peak-to-peak square-wave pulse having the same duration as the B sweep. Minimum dc load resistance is 5 k.
DLY'D TRIG	Approximately a 10-volt peak-to-peak pulse occurring at the end of the delay period.
SWEEP A	Approximately a 90-volt, peak-to-peak sawtooth voltage having the same duration as the A sweep. Minimum load impedance is 10 k.
+GATE A	Approximately 20-volt peak-to-peak square-wave pulse having the same duration as the A sweep. Minimum dc load resistance is 5 k.
VERT SIG OUT	Vertical signal output connector. Output amplitude is approximately 0.3 volt per centimeter of deflection on the crt. Risetime is 20 nsec or faster. Output is ac coupled.
External Single-Sweep Reset Input-Signal Requirements	Requires a positive-going step or pulse of at least +20 volts with a risetime of 0.5 μsec or faster.

Cathode-Ray Tube

Type	T5470-31-2
Unblanking	Dc coupled.
Accelerating Potential	10 kv.
Usable Viewing Area	6-cm high by 10-cm wide.
Focus	Vertical: 2 horizontal lines/mm distinguishable over the center 4 cm. 1.5 horizontal lines/mm distinguishable in the top and bottom 1 cm.
	Horizontal: 2 time markers/mm distinguishable over the middle 8 cm. 1.5 time markers/mm distinguishable in the first and tenth cm.

Graticule	Internal, adjustable edge lighting. 6X10 cm with vertical and horizontal 1-cm divisions with 2-mm markings on the centerlines. Provision made for risetime measurement.

Power Supplies

Line Voltage	±10% of nominal line voltage. (See Operating Instructions)
Line Frequency	50-60 and 400 cps.*
Power Consumption	510 watts typical.

Mechanical

Construction	Front panel is anodized. Chassis is aluminum alloy.
Dimensions	See Dimension Drawing.

*With line frequencies other than 50-60 cycles, a special fan modification is required; contact your local Tektronix Field Representative.

SECTION 3
CIRCUIT DESCRIPTION

Introduction

This section contains the theory of operation of the various circuits in the Type 547. A simplified block diagram analysis is given first to explain the operation of each circuit in general terms, then the operation of each circuit is covered in detail.

BLOCK DIAGRAM ANALYSIS

In the following analysis, it is assumed that the oscilloscope is equipped with a dual-channel vertical plug-in preamplifier, and that the horizontal display switch is set in the ALT position between the A DLY'D BY B and the B INTENS BY 'A' positions. Fig. 3-1 is a simplified block diagram showing the Type 547 operating in this mode. Detailed block diagrams showing circuit configuration for this and other modes of operation are contained in Section 6. The functions of the various blocks in Fig. 3-1 are explained in the following paragraphs.

Low-Voltage Power Supply. The low-voltage power supply produces all operating voltages for the oscilloscope with the exception of parts of the crt circuit. The low-voltage supply provides regulated —150, +100, +225, and +350 volts. It also provides heater voltages and an unregulated +325-volt output.

Vertical Plug-In Preamplifier. Any Tektronix letter-Series or 1-Series vertical plug-in preamplifier can be used with the Type 547. For a circuit description of the plug-in unit refer to the plug-in unit instruction manual.

Vertical Input Amplifier. The vertical input amplifier is a balanced, hybrid amplifier that amplifies the output of the plug-in vertical preamplifier and applies the amplified vertical signal to the trigger-pickoff circuit and the vertical output amplifier.

Delay Line. The push-pull output of the vertical input amplifier is applied through the balanced delay line to the vertical output amplifier. The delay line is a specially braided 186-ohm line which delays the application of the vertical signal to the vertical output amplifier for 170 nsec. This provides time for unblanking crt and starting the horizontal sweep before the vertical signal reaches the deflection plates. The delay allows the leading edge of a single fast-rising pulse to be displayed. The delay line requires no adjustment because of the precision construction.

Vertical Output Amplifier. The vertical output amplifier is a push-pull three-stage, transistor amplifier that takes the output of the delay line and amplifies it to a level sufficient to drive the vertical deflection plates of the crt.

Trigger-Pickoff Circuit. The trigger-pickoff circuit applies a sample of the input waveform to the trigger circuits of both time bases. The trigger is picked off at the output of the vertical input amplifier.

Main Time Base (B) Generator. The main time base (B) generator provides accurate ramp voltages for the horizontal deflection system, unblanking for the crt, sync pulse for the sweep switching circuit, and a +B gate to a front-panel connector. The main time base (B) generator may be triggered by signals derived from either internal or external sources.

Delay-Pickoff Circuit. The delay-pickoff circuit compares the ramp-voltage output of the main time base (B) generator with a variable reference voltage, and assuming indentical characteristics in the two halves of the comparator, generates a trigger pulse when the two voltages are equal. The trigger output of the delay-pickoff circuit may be used to arm or trigger Time Base A, and is also available at a front-panel connector.

Alternate-Sweep Switching Circuit. When the HORIZONTAL DISPLAY switch is in either of the alternate modes, the alternate-sweep switching circuit performs the following functions:

1. Gates the ramp signals from the time-base generators into the horizontal amplifier and thereby decides which of the two time-base generators is to be displayed.
2. Provides the vertical plug-in preamplifier with dual-trace slaving pulses.
3. Applies trace-separation voltage to the vertical amplifier during the A sweep.
4. Disables the B sweep unblanking circuit during presentation of the delayed A sweep.

In the A ALT B position of the HORIZONTAL DISPLAY switch, the alternate-sweep switching circuit provides sweep-generator lockout voltages to the horizontal display switch.

Horizontal Amplifier. The input to the horizontal amplifier is selected from the outputs of the main time base (B) generator, time base A generator, or the external horizontal input amplifier. The selected input is split in phase and amplified to provide push-pull drive to the horizontal deflection plates of the crt.

External Horizontal Amplifier. The external horizontal input amplifier provides the necessary gain to drive the horizontal amplifier from external signals. An input attenuator and a gain control provide horizontal deflection factors from 0.1 to about 10 volts/cm.

Crt Power Supply. The crt power supply provides the high voltages for operating the crt. The power supply is of the rf type, using a 50-kc Hartley oscillator. Secondary windings on the oscillator transformer supply voltages to the high-voltage rectifiers.

Cathode Ray Tube (Crt). The cathode-ray tube used in the Type 547 is a flat-faced, internal graticule, 5-inch tube

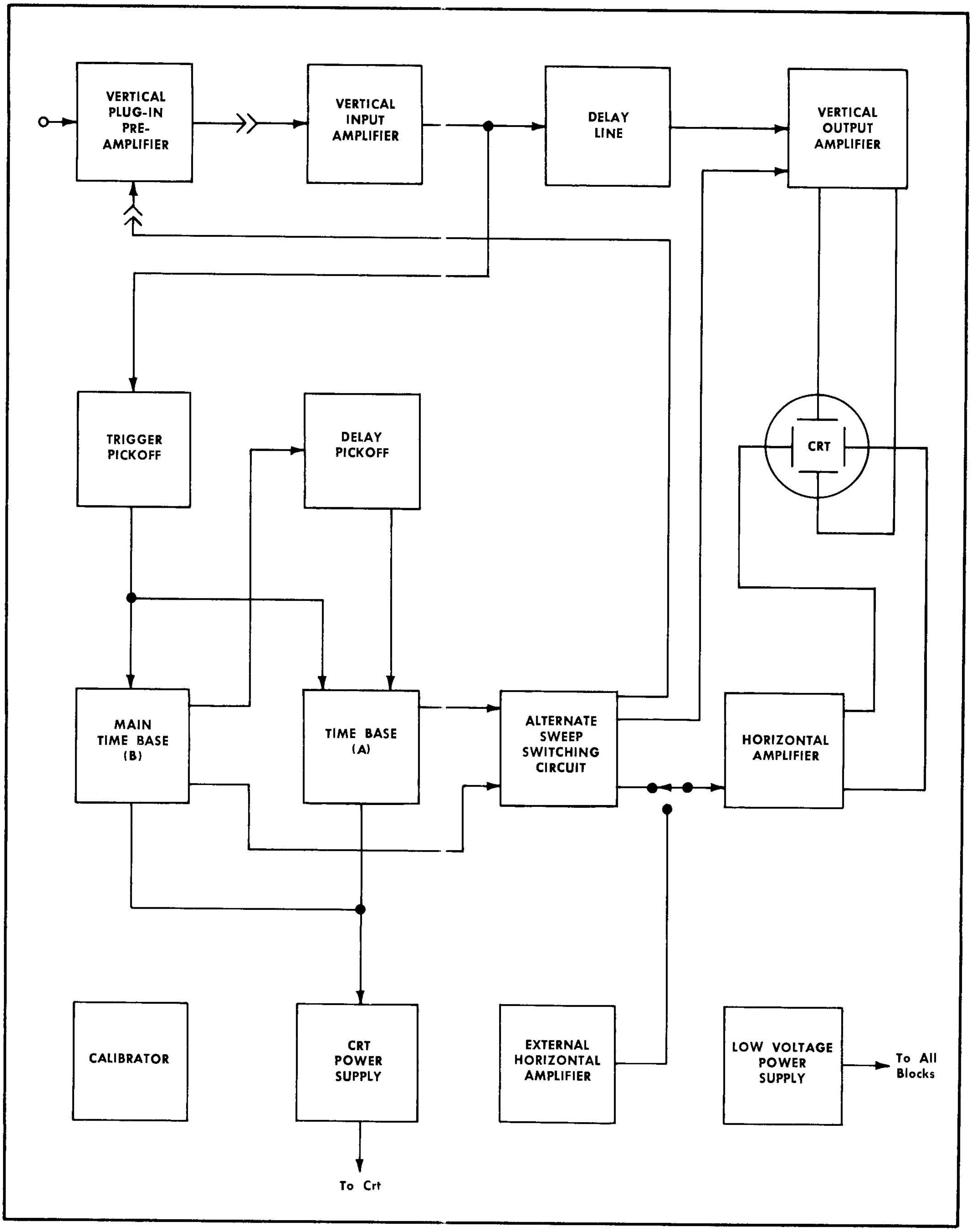


Fig. 3-1. Type 547 simplified block diagram.

with 6 cm of usable vertical scan area. The tube is designed for low input capacitance to the vertical deflection plates and minimum x-axis center-to-edge defocusing.

Calibrator. The calibrator in the Type 547 is a multivibrator and cathode follower that provides a square-wave output with a maximum amplitude of 100 volts at a nominal 1 kc. A step attenuator permits switching the output amplitude from the front panel. In the 0.2-mvolt to 200-mvolt range, the output impedance is 50 Ω.

Time Base A Generator. The time base A generator closely resembles the main time base (B) generator. The description of functions and the circuit analysis given for the time base (B) generator in most instances apply also to the time base A generator.

CIRCUIT ANALYSIS

The following circuit analysis of the Type 547 describes the operation of the various circuits in detail. While reading through the description of a particular circuit, refer to the circuit diagram being discussed (see Section 6).

Low-Voltage Power Supply

The low-voltage power supply in the Type 547 (see Power Supply schematic) actually consists of four interrelated supplies that operate together as as system. This system delivers filtered and regulated voltages of —150, +100, +225, and +350 volts as well as an unregulated dc voltage of +325 volts. A common power transformer, T601, supplies the input power to each of the supplies, as well as heater power to thermal time-delay relay K600 and the tubes in the oscilloscope. Unless otherwise specified, the Type 547 is shipped with T601 wired for 115-volt ac input. A connection diagram on the side of the transformer shows alternate connections for other input voltaes for SN 7979 and below. For SN 7980 and above, a Voltage Selector assembly is provided (see Operating Instructions section of this manual).

The 115-volt ac input power is applied to T601 through POWER ON switch SW601. Overload protection is provided by fuse F601. Thermal cutout TK601 in the primary circuit of T601 is a protective device that opens the transformer primary circuit if the temperature inside the oscilloscope rises above a safe value. TK601 resets automatically when temperatures return to normal; and to shorten the cooling time, the fan continues to run while TK601 is open (except when T601 is connected for 210-250-volt operation). Thermal time-delay relay K600 provides a filament warmup time of approimately 30 seconds before the dc power supplies are activated. The heater of K600 is rated at 6 volts and is connected to 6.3 volts on the T601 secondary winding. During heater warmup time, contacts 4 and 9 of relay K600 remain open. At the end of heater warmup time, contacts 4 and 9 close and apply power to magnetic relay K601. Contacts K601-1 of relay K601 remove the heater power from K600, but before K600 can open, contacts K601-1 lock the holding circuit to the coil of K601. K601 now remains energized until the power to the oscilloscope is switched off or otherwise interrupted. When K601 is energized, contacts K601-2, K601-3, K601-4, K601-5, and K601-6 are also closed and thus activate their respective dc supplies.

—150-Volt Supply. The —150-volt supply in the Type 547 is the reference voltage source for the other supplies and must be very stable. The —150-volt supply includes a high-gain electronic voltage regulator designed to give good regulation under extreme operating conditions. This regulator circuit contains a series regulator, a glow-discharge tube reference source, an error detector, and an amplifier.

In operation, the input power to the —150-volt supply is supplied by one secondary winding of T601. The ac output of the secondary winding is rectified by silicon-diode rectifier bridge D642 and filtered by capacitor C642A. In series with the positive side of the supply and ground are series regulator tubes V637 and V647, paralleled by shunting resistors R646 and R647. The output of the —150-volt supply is taken from the negative side.

Error sensing in the voltage-regulator circuit is accomplished by comparator tube V624. Current flow through V624 is established by the setting of the tap on R616 in the voltage divider R615, R616, and R617. The voltage on the grid of V624A is held at approximately +85 volts by reference tube V609. Assuming that the output voltage of the —150-volt supply increases due to increased line voltage or some other cause, the voltage increase appears on the cathodes of V624 and throngh the tap on R616, on the grid of V624B. Due to the voltage divider, only a part of the voltage increase appears between the grid and cathode of V624B, but the full change appears on the grid and cathode of V624A. The increase is in the negative direction, therefore, V624A increases its conduction to maintain the proper bias between grid and cathode, and this holds both cathodes more or less fixed while the grid of V624B is pulled negative by the increasing negative voltage across the voltage divider. The increasing negative voltage on the grid of V624B causes a decrease in current; thus the plate voltage goes positive.

The positive change in plate voltage is amplified and inverted to a negative change by amplifier tube V634. The amplified error signal from V634 is applied to the grids of series regulator tubes V637 and V647. The negative-going error signal on the grids of V637 and V647 decreases the current through the tubes, effectively increasing their resistance and the voltage drop across them. The voltage necessary to provide the increased drop across the series regulator tubes and shunt resistor can only be obtained by subtracting it from the negative side of the supply, so the undesired increase in negative voltage is absorbed in the series regulators and shunt resistors. If the output of the —150-volt suppy had decreased instead of increased, then the error voltage applied to the grids of the series regulators would have been positive-going. The positive-going error voltage on the grids of the series regulators would lower the resistance of the series regulator tubes, and the voltage drop across them would decrease, leaving more voltage for the negative side of the supply. Since the output voltage of the —150-volt supply depends upon the relationship of the voltage on the tap of R616 and the reference voltage from V609, accurate adjustment of the output voltage is provided by making R616 variable.

Filter capacitor C642A does not remove all the ripple from the output of the bridge rectifier, and the series regulator circuit functions also to reduce this output ripple voltage. Any ripple between the —150-volt output point and ground reaches the grid (pin 2) of V624A via capacitor C610. This input ripple voltage is amplified by V624 acting as a cathode-coupled amplifier. The ripple output voltage at the plate (pin 6) of V624B has the same polarity as the ripple voltage at the —150-volt output. C628 couples this ripple output voltage to the grid of V634. The ripple voltage is further amplified by V634 and applied to the grids of the series regulator tubes with a polarity that opposes the original ripple voltage. Ripple in the positive side of the —150-volt supply is coupled into a degenerative feedback loop through R637 to the screen of V634.

Some of the components in the —150-volt supply are not necessary in normal operation but are included to insure proper operation of the circuit under adverse conditions. C636 provides for proper operation of the circuit when extremely low temperatures reduce the capacitance of the electrolytic filter capacitors. R640 and R641 protect against large surge currents, and C642B suppresses sudden load changes that fall outside the bandwidth of the regulator circuit.

+100-Volt Supply. The input to the +100-volt supply is the output of secondary winding 19-20 of transformer T601 and silicon-diode bridge D672. In addition to its other loads, the +100-volt supply is required to supply current to a series string of filaments at all times. When the Type 547 is first turned on, relay K601 contacts are open and all the regulated supplies are inoperative. During this time, the series-string filaments are supplied by the unregulated side of the +100-volt supply through relay contacts K601-4. By the time thermal relay K600 activates K601, the series-string filaments have reached operating temperature. When K601 is activated by K600, relay contacts K601-4 shift the series-string filaments to the regulated output of the +100-volt supply.

The reference voltage source is the regulated output of the —150-volt supply. V664A is the error amplifier, V664B compensates for V664A grid-cathode contact bias changes caused by changing line voltage, and V677 is the series regulator tube. The error-feedback circuit is through R650 and R651, the junction of which is connected to the grid of V664A. The top end of R650 is connected to the regulated +100-volt output, and the lower end of R651 is connected to the output of the regulated —150-volt supply to obtain reference voltage. With normal line voltages and loads, the voltage at the junction of R650 and R651 is about —1.7 volts with reference to ground; this is the operating bias of V664A.

If the load current, output voltage, or the input voltage changes (including changes due to ripple), the output of the regulated +100-volt supply starts to change also, but any change appears across R650 and R651 and is applied to the grid of V664A as a change in operating bias. Assuming that the output of the regulated +100-volt supply tries to decrease, the reduced voltage at the top end of R650 permits the voltage at the junction of R650 and R651 to go more negative than the normal —1.7-volt level at that point. The increase in negative bias on the grid of V664A reduces the flow of plate current through V664A, the voltage drop across plate load resistor R663 decreases, and the plate voltage of V664 and the grid bias of V677 go more positive. As the grid of V667 goes more positive, the resistance that V677 offers to the flow of current is decreased and the output voltage rises, compensating for the drop in output voltage which initiated regulating action. Of course, the regulator circuit can never completely compensate for a change in output voltage, for there must be an error input for the circuit to operate, but any error in output is reduced by a factor equal to the loop gain of the regulator circuit.

The screen grid of V664A is used as a signal grid for injecting a sample of any ripple or transient voltage present in the unregulated side of the +100-volt supply into the regulator circuit. The regulator circuit thereby becomes a dynamic filter for ripple reduction. The ripple signal is applied to the screen of V664A, amplified and inverted in phase by V664A, then applied to the grid of V677. By the time the amplified and inverted ripple gets to the grid of V677, it is of proper amplitude and phase to cancel out the ripple appearing at the plate of V677.

To keep the proper load on the +100-volt supply when the vertical plug-in preamplifier is removed, a plug-in sensing switch is built into the main frame of the Type 547 at the top rear of the plug-in compartment. When the plug-in unit is removed, the sensing switch connects a resistive load in place of the series-filament string. When it is desired to operate the plug-in unit outside the Type 547 by means of a test harness, the sensing switch must be manually operated. To manually operate the switch, pull the plastic plunger outward to the stop position.

Unregulated +325-Volt Supply. The unregulated +325-volt supply voltage source differs somewhat from the voltage sources for the —150- and +100-volt supplies. A center-tapped secondary (13-14-15) on T601 and silicon diodes D702 and D732 form a center-tapped bridge rectifier circuit with the negative side connected to the positive unregulated side of the voltage source for the +100-volt supply. The unregulated +325-volt output is taken from the transformer center-tap (14) connection.

The unregulated output of the voltage source for the +100-volt supply is approximately +180 volts. The unregulated output of the center-tapped bridge circuit is approximately +290 volts; this, added to the unregulated +180 volts provides the +470 volts. However, for the unregulated +325-volt output, the connection is made at the center tap (+145 volts) of the bridge (the midpoint of the +290 volts). Adding the +180 and +145 volts provides the desired output of +325 volts.

+225-Volt Supply. The voltage source for the regulated +225-volt supply is the unregulated +325-volt supply described in the preceding paragraphs. The regulator circuit is similar to the regulator circuit found in the —150-volt supply; the main difference being that instead of using a glow discharge tube as a reference voltage source, the reference voltage is from the —150-volt supply. The error signal is picked off the junction of precision resistors R680 and R681. The upper end of R680 is connected to the +225-volt output, and the lower end of R681 is connected to the regulated —150-volt supply. The voltage at the junction between R680 and R681 is approximately —0.9 volt which is applied through R682 and R683 to the grid of V684B. The cathodes of V684 are longtailed to the —150-volt supply through 82 k resistor R685. The grid of V684A is grounded. The error signal is fed from the grid of V684B through the common-cathode circuit to the A side of the tube. Notice that this comparator is somewhat different from the comparator used in the —150-volt supply; the output is taken from the A side. The error signal is amplified by V684 and fed, unchanged and in phase, to the voltage divider in the grid of V694. V694 also amplifies and inverts the error signal and applies it out of phase with any change in the +225-volt output, to the grid of series regulator tube V707.

Here again, the screen of the error amplifier tube is acting as an injection grid for ripple reduction. A sample of the unregulated supply ripple is applied to the screen of V694. V694 amplifies the ripple, inverts it in phase, and applies it to the grid of series regulator tube V707. The result is that the same ripple appears simultaneously on the grid and plate of V707, but 180° out of phase; thus the ripple cancels out.

+350-Volt Supply. The input to the +350-volt supply is the full voltage output of the center-tapped bridge (see description of unregulated +325-volt supply) added to the unregulated side of the +100-volt supply. The operation of the regulator circuit is very similar to the operation of the +100-volt regulator except for different component values and no grid-cathode contact-bias compensating diode.

Crt Circuit

The crt circuit (see Crt schematic) includes the crt, the high-voltage power supply, and the controls necessary to focus and orient the display. The crt (Tektronix Type T5470-31-2) is an aluminized, 5-inch, flat-faced, glass crt with a helical post-accelerator and electrostatic focus and deflection. The crt circuit provides connections for externally modulating the crt cathode. The high-voltage power supply is composed of a dc-to-50-kc power converter, a voltage-regulator circuit, and three high-voltage outputs. Front-panel controls in the crt circuit adjust the trace rotation (screwdriver adjustment), intensity, focus, and astigmatism. Internal controls adjust the geometry and high-voltage output level.

High-Voltage Power Supply. The high-voltage power supply is a dc-to-ac converter operating at approximately 50 kc with the transformer providing three high-voltage outputs. The use of a 50-kc input to the high-voltage transformer permits the size of the transformer and filter components to be kept small. A modified Hartley oscillator converts dc from the +325-volt unregulated supply to the 50-kc input required by high-voltage transformer T801. C808 and the primary of T801 form the oscillator resonant tank circuit. No provisions are made for precise tuning of the oscillator tank since the exact frequency of oscillation is not important.

Voltage Regulation. Voltage regulation of the high-voltage outputs is accomplished by regulating the amplitude of oscillations in the Hartley oscillator. The —1850-volt output is referenced to the +350-volt regulated supply through a voltage divider composed of R841, R842, R843, R845, R846, R847, R853, and variable resistors R840 and R846. Through a tap on the voltage divider, the regulator circuit samples the —1850-volt output of the supply, amplifies any errors and uses the amplified error voltage to adjust the screen voltage of Hartley oscillator V800. If the —1850-volt output changes, the change is detected at the grid of V814B. The detected error is amplified by V814B and V814A. The error signal at the plate of V814A is direct coupled to the screen of V800 by making the plate-load resistor of V814A serve as the screen-dropping resistor for V800. Any change in the —1850-volt output thus changes the screen voltage of V800 and the amplitude of the 50-kc oscillations. R840 provides a means of controlling the high-voltage output through controlling oscillation amplitude.

Crt Grid Supply. The approximately —1950-volt output of the high-voltage power supply is the rectified output of one of the two high-voltage secondaries on T801. To provide dc-coupled unblanking signals to the crt grid, the crt grid supply is floating (the dc voltage levels on the components shift in accordance with the unblanking signals). The positive side of the crt grid supply is returned to the —150-volt supply through the unblanking cathode-follower load resistor of the selected sweep generator and through R831 and R832. The negative side of the crt grid supply is applied through the INTENSITY control to the crt grid.

At the fastest sweep rates, the stray capacitance of the floating crt grid circuit makes it difficult for the crt grid to rise fast enough to unblank the crt in the required time. An isolation network consisting of R827, R828, C828, C829, and C830 isolates the capacitive loading. By this arrangement, the fast leading edge of the unblanking pulse is coupled through C830 and C828 to the grid of the crt. For short-duration unblanking pulses, such as those that occur at the fastest sweep rates, the dc levels on the rectifier and secondary winding are not appreciably affected. Longer unblanking pulses, such as those that occur at the slower sweep rates, charge the stray capacitance in the —1950-volts output through R827. This pulls up the floating crt grid circuit and holds the crt grid at the unblanked potential for the duration of the unblanking pulse.

+8150-and —1850-Volt Outputs. Both the +8150-and the —1850-volt outputs are derived from the same secondary winding on T801. The full secondary voltage of approximately 2900 volts is applied to a voltage tripler consisting of rectifiers V832, V842, and V852 and associated capacitors. A tap on the secondary provides the input for half-wave rectifier V862 in the —1850-volt output. Both outputs are referenced to the regulated +350-volt supply through a voltage divider network. The +8150-volt output is connected to the crt post-deflection-accelerator anode and the —1850-volt output is connected to the crt cathode, providing a total accelerating voltage of 10,000 volts.

Crt Circuit Controls and Connectors. Optimum size and shape of the fluorescent spot on the crt is obtained by adjusting the front-panel FOCUS and ASTIGMATISM controls. FOCUS control R846 provides the correct voltage for the second anode (focus ring) in the crt. Proper voltage for the third anode is obtained by adjusting ASTIGMATISM control R864. In order to obtain optimum spot size and shape, both the FOCUS and ASTIGMATISM controls are adjusted to provide the proper electronic lens configuration in the region of the second and third anodes of the crt. Spot intensity is adjusted by means of front-panel INTENSITY control R826. Varying the INTENSITY control changes the voltage on the crt grid, which in turn varies the density of the electron stream. Internal GEOMETRY control R861 adjusts the isolation shield voltage in the crt, and is adjusted to minimize "bowing" or "tilting" of the display. Front-panel TRACE ROTATION control R778 permits minor adjustments in trace orientation. By adjusting the TRACE ROTATION control, the trace can be made parallel with the horizontal lines on the graticule, eliminating the need to physically turn the crt to correct for minor deviations of the trace from the horizontal.

An input binding post on the rear panel of the Type 547 provides an input for externally modulating the crt cathode. The input binding post is normally grounded by a link. If it is desired to intensity modulate the display from an external source, the link is opened, and the modulating signal is coupled to the crt cathode through C858.

When the Type 547 is used with a multichannel vertical plug-in preamplifier that provides dual-trace chopped blanking pulses, the blanking pulses are applied to rear-panel CRT CATHODE SELECTOR switch SW858. With the vertical plug-in preamplifier operating in the chopped mode and SW858 set to the CHOPPED BLANKING position, a positive pulse of approximately 20-volts amplitude is applied through C858 to the cathode of the crt. At normal intensity levels, this pulse is sufficient to cut off the crt during the time the amplifier channels in the vertical plug-in preamplifiers are being switched.

Vertical Amplifier System

The vertical amplifier system in the Type 547 consists of an appropriate vertical plug-in preamplifier, a push-pull cathode-follower input stage, a push-pull transistorized delay-line driver, a delay line, and a push-pull transistorized output amplifier. In addition, the trigger-pickoff circuit functions as a part of the vertical amplifier by providing reverse termination for the delay line.

Vertical Input Amplifier. The push-pull output of the vertical plug-in preamplifier, with a fixed dc level of approximately +67.5 volts, is applied to the input of the vertical amplifier through terminals 1 and 3 of the plug-in connector.

Transient-response compensation switch SW1000, capacitor C1000, and resistor R1000 at the input of the vertical amplifier compensate for the difference in transient response that exists between different models of vertical plug-in preamplifiers. SW1000 is actuated by a mechanical sensing device when the plug-in unit is inserted into the oscilloscope, and requires no attention on the part of the operator.

R1001 and R1011, in series with the grids of the push-pull cathode-follower stage, are parasitic suppressors. Input cathode followers V1003A and V1003B are the two halves of a 12AT7 twin triode. The cathodes of the cathode followers are returned to ground through vertical dc balance control R1004, which is adjusted to equalize the dc voltage (about +68.5 volts) on the bases of delay-line driver transistors Q1014 and Q1024. The heaters of V1003 are operated as part of the series string which receives power from the +100-volt dc supply. The use of dc on the heater prevents changes in line voltage from affecting the gain of the vertical amplifier.

The balanced delay-line driver stage is a push-pull amplifier with an adjustable vertical gain control (R1017) connected in the emitter circuit of the two transistors. Gain is adjusted by controlling the amount of degeneration in the emitter circuit. Zener diode D1018 sets the operating points of the termination transistors on both ends of the delay line.

The RC networks in the collectors of Q1014, Q1024, Q1144, Q1154, and in the emitter leads of Q1034 and Q1044 set the individual transistor operating points to achieve thermal balance. The 5-turn center-tapped coils at the input of the delay line and the collector-base capacitance of the delay-line driver transistors form a T-section matching network. C1029 provides a means of varying the impedance of the T section.

Vertical Output Amplifier. The vertical output amplifier must properly terminate the delay line and provide broad-band amplifiication of the vertical signals. Proper termination of the delay line is obtained by connecting forward-termination transistors in a common-base configuration. The common-base configuration also operates well in broad-band amplifier applications. To help meet the broad-band requirement, the collector load circuit of the termination transistors contains RC low-frequency compensation networks, and in addition, LR network in the collectors of transistors Q1034 and Q1044 compensate for losses due to skin effect within the delay line.

Following the forward-termination amplifier is a wide-band amplifier stage consisting of Q1074 and Q1084 and associated elements. High-frequency compensation in this stage is provided by shunt peaking coils L1072 in the collector circuits. The high-frequency response is varied by adjusting C1076, which provides variable high-frequency degeneration in the emitter circuit of Q1074 and Q1084.

The output stage of the vertical amplifier is a transistorized equivalent of a push-pull cascode amplifier. This circuit configuration is used to match the low impedance of the transistorized vertical-amplifier system to the higher impedance required at the crt vertical deflection plates. High-frequency compensation is provided by rc networks between the collector of the driving transistor and the emitter of the driven transistor on each side. C1105 and C1106 provide a means of varying the high-frequency response of the output stage. The outputs from Q1114 and Q1134 are connected to the deflection plate of the crt via series-peaking coils L1115 and L1135.

Trigger-Pickoff Circuit. The trigger-pickoff circuit provides reverse termination for the delay line as mentioned in the preceding paragraphs. The input stage of the trigger-pickoff circuit, which provides the delay-line reverse termination, is a common-base circuit. The output stage of the trigger-pickoff circuit is a push-pull emitter-follower amplifier that not only provides trigger signals to the two time bases, but supplies the VERT SIG OUT jack with a vertical signal and drives position-indicator amplifier V1184.

Main Time Base (B)

The main time base (B) consists of the B sweep trigger and the B sweep generator circuits. The B sweep trigger circuit is a wide-band hybrid amplifier driving a tunnel diode. The B sweep trigger circuit includes controls for selecting the type, source, and level of the trigger to be used, and circuit elements for regenerating the selected trigger into a pulse suitable for triggering the B sweep generator. The B sweep generator circuit is basically a Miller-runup circuit. The B sweep generator provides ramp voltages for the horizontal deflection system, alternate-trace sync pulses, unblanking pulses, and +B gate pulses.

Trigger Generator

The input to the B sweep trigger circuit (see B Sweep Trigger Generator schematic) is selected by SOURCE switch SW1 from the trigger-pickoff circuit in the vertical amplifier, the trigger output of the vertical plug-in preamplifier, the power transformer for line triggering, or from the front-panel TRIGGER INPUT connector. COUPLING switch SW5 permits further selection of the type of triggering signal; either ac, ac with low frequencies rejected, or dc. Once the type and source of triggering signal has been selected, the slope on which triggering is desired is selected by SLOPE switch SW10. The level of the triggering signal required by the B sweep trigger circuit is selected by adjusting TRIGGERING LEVEL control R15. After this triggering signal has been selected by the foregoing controls and switches, it is applied to trigger input amplifier V24.

Circuit Description SN 6740-UP. V24A and V24B form a switching comparator. The voltage level at which the comparator switches is set by the B TRIGGERING LEVEL control R15. V24 drives Q34 and Q44, which form a current type switching comparator. Q34 and Q44 drive tunnel diode D45 which in turn drives sweep gating tunnel diode D85.

If no triggering signal is applied to V24 the stage consisting of V24A and V24B is unbalanced. One section (which one depends upon the setting of the B SLOPE and B TRIGGERING LEVEL controls) is conducting more current than the other. The voltages at the plates of V24A and V24B should therefore be different. However, diodes D21 and D22 clamp the two plate voltages to within 0.3 volt of each other, with the plate of the section which is conducting the most current being the most negative.

The second stage, made up of Q34 and Q44, is also unbalanced. The transistor whose base is the most negative conducts most of the current supplied by R36. This current is not sufficient to cause the conducting transistor to saturate. The conducting transistor merely acts as a constant current source.

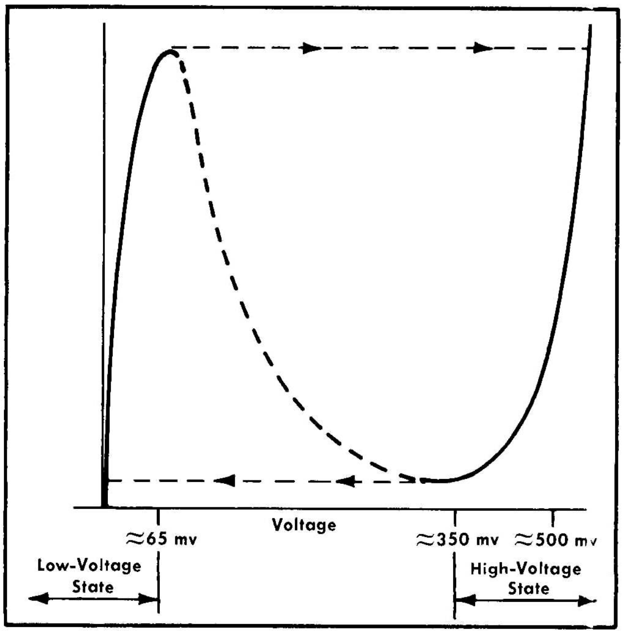


Fig. 3-2. Tunnel diode characteristics.

Tunnel diode D45 is biased to its low voltage state by current through R32, R33, R45, and R42. If the comparator stages are unbalanced in such a manner as to cause Q34 to conduct, an additional current flows through D45. This additional current biases D45 to its high voltage state (see Fig. 3-2 for tunnel diode characteristic curve).

When the current through D45 reaches a total of 10 mA the voltage across D45 will suddenly increase to approximately 0.5 volts. This sudden voltage change is coupled to the sweep gating tunnel diode D85 by C56, D59, and C57. C56 differentiates the triggering signal which provides a fast rising pulse for D85. L56 and the low impedance of conducting diode D57 decrease the fall time of the triggering pulse. D59 ensures that D85 is only triggered when D45 turns on, and not when D45 turns off.

Circuit Operation SN 101-6739. In operation, V24A and V24B form a push-pull amplifier which drives a push-pull input, single-ended output amplifier consisting of Q34 and Q44. Tunnel diode D45 is biased at its low-voltage state (see Fig. 3-2 for trigger tunnel-diode curve) by current flow through the voltage divider consisting of R44, R45, R47, and R48. When the desired slope of the triggering signal selected arrives at the grids of V24, V24B and Q44 are biased into conduction. The conduction of Q44 increases the current flow through D45, and D45 switches to its high-voltage state. The sudden voltage change across D45 as it switches to its high-voltage state produces a uniform fast-rising trigger pulse which is used to trigger the main time base (B) sweep generator.

Sweep Generator

For purposes of explanation, assume that the HORIZONTAL DISPLAY switch (see B Sweep-Generator schematic) is in the B posittion, the SINGLE SWEEP switch is in the NORMAL position, the TRIGGERING MODE switch is in the TRIG position and that no trigger is being applied. Under these conditions, V145A in the holdoff multivibrator is conducting and V145B is cut off. The paths for the current in V145A are from the —150-volt supply through R164 and D163 in parallel with R163. When V145A is conducting and no trigger is being received from the trigger generator, D85 is in its low-voltage state since the dc current supplied from the +100-volt supply through R82 and R81 is less than the peak current of D85. Under these conditions, Q84 is cut off. For SN 12480 and above, the collector voltage of Q84 is positive, thereby forward biasing Q86, D86, Q89 and Q103. (For units with serial numbers below SN 12480, the collector voltage of Q84 is positive, thereby forward biasing D86, Q89 and Q103.) Miller tube V91 is conducting. The circuit is now ready to be triggered.

Assuming that a trigger pulse is now applied, the positive trigger from the B sweep trigger circuit is coupled through C56 to L56 and D57. C56 and L56 form a differentiating network that narrows the trigger pulse to approximately 4 nsec in width. The sharpened trigger pulse passes through D59 to tunnel diode D85 and causes D85 to switch to its high state, where it remains after the trigger pulse decays to zero. When D85 switches to its high state, Q84 is biased into saturation and the voltage change across Q84 applies forward bias to Q173 and reverse biases Q89, Q103, and D86. When D86 is reverse biased, the voltage on the grid of V91 goes negative and the Miller circuit starts to run up. As the voltage on the cathode of V93A goes positive, it starts to charge timing capacitor C90 through D98. At high sweep rates, boot-strap capacitor C94 couples the rising cathode voltage to the plate circuit of V91 and effectively increases the plate supply voltage for V91, compensating for losses introduced by stray capacitance. In addition, the positive-going cathode voltage of V93A forward biases D129 and starts putting a positive voltage on the grid of V145B in the holdoff multivibrator. At a point determined by sweep-length resistor R125, the rising positive voltage biases V145B into conduction, and the holdoff multivibrator changes state, cutting off V145A. When V145A cuts off, its cathode voltage drops to —20 volts and reverse biases D85 and Q84. As current flow through Q84 ceases, the voltage increase across it again forward biases D86. When D86 becomes forward biased, it applies a positive-going voltage to the grid of V91 which resets the Miller circuit and ends the sweep.

Disconnect diode D100 ensures that the sweep starts from the same voltage point each time. Q103 is included in the circuit to reduce the amount of current that D100 has to switch, and thereby improves the linearity at the start of the sweep.

When the sweep ends, V145B has control of the holdoff multivibrator, and remains in control until the charge on holdoff capacitor C130 discharges through R130. During the time that V145B has control of the holdoff multivibrator, tunnel diode D85 cannot be triggered; but when the holdoff capacitor discharges to the point where V145A can again assume control, D85 is again biased to a point where it can accept another trigger.

Automatic Stability Circuit. Q65, Q75, and associated circuit components form a monostable multivibrator that controls the stability of the B sweep generator. When the trigger MODE switch is in the TRIG position, the switch grounds the collector of Q75 and disables the automatic stability feature of the Type 547. When the triggering MODE switch is in the AUTO STABILITY position, the sweep generator free runs if no trigger pulses are received from the trigger generator.

In normal operation, Q65 is conducting due to the positive voltage applied to its base. Q75 is normally cut off due to its base being grounded through R69. When the trigger MODE switch is set to the AUTO position, C76 starts to charge through R76. When the voltage across C76 exceeds the breakdown of Zener diode D76, D76 breaks down and provides an additional current path for tunnel diode D85. The additional current through D85 causes it to switch to its high state and start the sweep. When the sweep ends and the holdoff multivibrator switches, the voltage on the cathode of V145A drops to approximately —20 volts, reverse biasing D85. When the holdoff period ends, the cathode voltage of V145A goes slightly positive, and the current through D76 again switches D85. If no trigger is applied, the cycle repeats only if the trigger MODE switch is in the AUTO position.

When a trigger pulse is received at T52, a negative output from the secondary is applied to the base of Q65 and causes the monostable multivibrator to switch. With Q65 now cut off, its collector voltage goes more positive, and C67 charges through R69, applying a positive voltage to the base of Q75. The positive voltage on the base of Q75 biases it to saturation, and Q75 provides a low-resistance path that discharges C76 and reverse biases D79 and D76. With the collector of Q75 below the D76 breakdown voltage, the collector circuit does not provide switching current for tunnel diode D85, so the only way D85 can be switched is by the application of a trigger pulse. If no further trigger pulses are received, Q75 is kept in saturation until the charge current for C67 decays and removes the positive voltage from the base of Q75.

During the charge time of C67, Q65 is kept cut off by the forward voltage drop across D71. When the decaying charge current removes saturation bias from Q75, the voltage drop across D71 decreases and permits Q65 to conduct, and the multivibrator switches back to its normal state. If no further trigger pulses are received, C76 charges through R76 and R75 until D76 again breaks down and provides switching current for D85.

Unblanking Circuit. With the HORIZONTAL DISPLAY switch set in the B position, an unblanking pulse is generated and applied to the crt unblanking circuit during B sweep time. The unblanking pulse is initiated when tunnel diode D85 switches to its high state and biases Q84 into conduction. When Q84 conducts, its collector voltage drops and removes the cutoff bias from Q173, biasing Q173 into conduction. When Q173 conducts, it removes the negative bias from the emitter of Q184 and the grid of V193A. The base of Q184 is negative by the amount of forward voltage drop across D182, while the emitter is positive by the amount of forward voltage drop across D183. The sum of the forward voltage drops across the two diodes is sufficient to bias Q184 into conduction. When Q184 conducts, it puts a positive-going voltage on the grid of cathode follower V195B, and the positive-going voltage is coupled to the crt-unblanking supply.

Single-Sweep Circuit. When single-sweep operation is desired, NORMAL-SINGLE SWEEP-RESET switch SW135 is set to the SINGLE SWEEP position. When SW135 is pushed to the RESET position it operates switch SW369 which discharges C369 (see A Sweep Generator schematic) through R369, R368, and R367, generating a positive pulse which is applied through C166 and D164 to the cathode of holdoff tube V145B. The positive pulse on the cathode of V145B causes the holdoff multivibrator to switch, and V145A biases sweep tunnel diode D85 to the ready point as previously explained. Since Q84 and V145B are both cut off, the positive voltage on the collector of Q84 and the voltage on the plate of V145A combine through R87 and R142 produce turn-on bias for Q89. When Q89 conducts, it completes the circuit for the NE-23 READY lamp (B89). With the application of a trigger pulse, Q84 conducts and the voltage on its collector drops, removing the bias on Q89 and thereby extinguishing the READY lamp. The runup of the Miller circuit causes the hold-off mulitvibrator to switch, and V145B takes control. NORMAL-SINGLE SWEEP-RESET switch SW135 applies a positive voltage through D132 to the grid of V145B, and this positive voltage prevents the holdoff multivibrator from resetting until NORMAL-SINGLE SWEEP-RESET switch SW369 has been moved to either the RESET or NORMAL position.

Main Time Base (B) Sweep Timing. The sweep rate (the rate at which the spot moves across the face of the crt) is determined by the rate at which the timing capacitor and timing resistor permit the Miller circuit to run up. By means of TIME/CM or DELAY TIME switch SW90 (see B Sweep Timing-Switch schematic), both the size of the capacitor being charged and the charging current can be selected to cover a wide range of sawtooth slopes (sweep rates). Note that SW90 is connected so that switching 8 capacitors and 6 resistors provides 24 different sweep rates, varying from 5 sec/cm to 0.1 μsec/cm without magnification. The TIME/CM or DELAY TIME switch also selects the proper holdoff capacitor and discharge resistor for the sweep rate in use.

Continuously variable uncalibrated sweep rates are provided by R90Z and SW90Z (VARIABLE control). When SW 90Z is switched to the UNCAL position, it removes the short from around R90Z and switches on UNCAL lamp B90W. By turning VARIABLE control R90Z, the charging time of the timing capacitor selected by the TIME/CM or DELAY TIME switch may be increased by a least 2.5 times the calibrated rate, providing continuously variable sweep rates.

Delay-Pickoff Circuit. The delay-pickoff circuit (see Delay Pickoff schematic) generates a trigger pulse that is delayed form the start of the B sweep by an amount determined by the settings of the Main Time Base (B) TIME/CM or DELAY TIME switch and the DELAY-TIME MULTIPLIER dial. A comparator in the delay-pickoff circuit continuously monitors the ramp output voltage of the main time base (B) Miller runup circuit and compares the ramp voltage with a voltage level established by the setting of the DELAY-TIME MULTIPLIER dial. When the ramp voltage biases V404A into conduction, the comparator switches a tunnel diode. The tunnel diode generates a trigger pulse that is delayed from the start of the B sweep by the time it takes the ramp voltage to rise to a value approximately equal to the voltage established by the DELAY-TIME MULTIPLIER dial setting. After being amplified, the delayed trigger is applied through the HORIZONTAL DISPLAY switch as a source of delayed trigger for the time base A generator, and to the DLY'D TRIG output connector on the front panel for use in external equipment. Delayed trigger pulses are connected to the time base A sweep generator when the HORIZONTAL DISPLAY switch is in the B INTENS BY 'A', A DLY'D BY B positions, and the ALT position between the two.

In actual operation, the comparator is longtailed through a constant-current tube that keeps the current through the comparator relatively constant despite the large voltage swings applied to the grids. The grid voltage of constant-current tube V93B is fixed at approximately —56 volts by the voltage divider consisting of R406 and R407. With the grid of V93B biased at approximately —56 volts, R409 maintains the current through V93B (and thereby the comparator tube) to approximately 5 ma.

Comparator tube V404 receives the ramp output of the main time base (B) sweep generator on one grid and the voltage from the tap on delay-time heliopot R416 on the other. At the start of the ramp, V404B is conducting and V404A is cut off. Assume that the ramp input to the comparator is increasing at the rate of 10 volts/msec, and the DELAY-TIME MULTIPLIER dial is set at 2.0 (2.0 is equal to 20 volts of a 100-volt ramp), then the voltage on each grid of the comparator becomes 20 volts, 2 msec after the ramp starts. At this point, V404A starts conducting. V404A draws current through R404, L404, and tunnel diode D405. The current flow through D405 causes it to switch to its high state, generating a sharp trigger pulse. R404 and L404 narrow the hysteresis zone of D405. The low resistance of R404 would attenuate the trigger pulse if it were not for the high-frequency peaking effects of L404. The trigger voltage developed across D405 is amplified by Q424 and applied to Q433 through a differentiating network. The output of Q433 is applied to the DLY'D TRIG connector on the front panel and to the HORIZONTAL DISPLAY switch as previously mentioned.

Jack J435 provides a means of coupling in an externally-generated delayed trigger. Terminals B and C provide function information to the external trigger generator, and the externally-generated delayed trigger is applied to terminal A. It is also necessary to apply sufficient dc bias to terminal A to back bias D433.

Time Base A

Time base A in the Type 547 is very similar to the main time base (B) and the circuit description for main time base (B) generally applied to time base A. The two trigger-generator schematics, in particular, show few differences other than circuit symbols.

The major differences in the two time bases are Q344 and cathode follower V293B which appear on sweep generator A but not on B, and Q184 (the function of which is described in the discussion of main time base (B) which appears on sweep generator B but not on A. Q344 is part of the alternate-sweep lockout circuit which is explained later in this section. Cathode follower V293B is a conventional long-tailed cathode follower that provides a sample of the output of the A sweep generator to the A SWEEP front-panel output connector.

Alternate Sweep Switching Circuit

The alternate sweep switching circuit gates the desired sweep voltage to the horizontal deflection plates of the crt, provides trace-positioning voltages, and when a dual-channel vertical plug-in preamplifier is used, slaves the alternate trace multivibrator in the plug-in unit.

When the HORIZONTAL DISPLAY switch is in either ALT position, the alternate sweep switching circuit prevents B sweep from being unblanked whenever A sweep is being displayed.

Sweep Switching Multivibrator. The sweep-switching multivibrator (see Alternate Sweep Switching schematic) consisting of Q465, Q475, and associated circuit components is a conventional bistable transistor multivibrator. In alternate-sweep operation, the multivibrator is switched by the trailing edge of a sweep-gating pulse from either time base. As the sweep-gating pulse ends and starts to go positive, Q464 is biased into conduction and applies a negative-going signal to the differentiating network consisting of C459 and R459. The sharpened pulse is applied through D469 and D479 to the bases of both transistors in the multivibrator, cutting off the conducting transistor and turning on the other.

Assuming that Q465 is the conducting transistor, the resistance between its emitter and collector is quite low, effectively grounding its collector. With the collector of Q465 at ground, the voltage division across R467 and R479 applies approximately —3 volts to the base of Q475, keeping it cut off. With Q475 cut off, the voltage division across R467 and R479 applies sufficient bias to the base of Q465 to keep it saturated.

Sweep Gates. D461, D462, D471, D472, and associated circuit components form an exclusive "or" gate. With Q465 saturated and Q475 at cutoff as described in the preceding paragraph, current flow through Q465 and D461 reverse biases D462, preventing the B sweep ramp voltage from passing through D462. With Q475 cut off, its collector voltage is held at approximately +27 volts by Zener diode D475. This +27 volts reverse biases D471. The A sweep circuit then forward biases D472. D472 forward biased, the A sweep gate is open, and the A sweep ramp voltage passes through to the horizontal amplifier. When Q475 is the conducting transistor, it forward biases D471 and reverse biases D472, closing the gate for the A sweep. When Q475 conducts, Q465 cuts off and opens the B sweep gate.

Trace-Separation Amplifier. In the ALT positions of the HORIZONTAL DISPLAY switch, the collector of Q475 is connected through the switch to D482 and D492 in the trace-separation amplifier. When Q475 is cut off, D482 and D492 are reverse biased, and the operating points of V494A and V494B are determined by the setting of TRACE SEPARATION control R484. The outputs of V494A and V494B are applied to opposite sides of the push-pull vertical amplifier and position the A trace in accordance with the setting of the TRACE SEPARATION control. When Q475 is saturated (during B sweep), D482 and D492 are forward biased, effectively grounding out the positioning voltage from the TRACE SEPARATION control. Since Q475 alternates between cutoff and saturation with the HORIZONTAL DISPLAY switch in the ALT positions as explained in the preceding paragraphs, the bias on trace-separation amplifier V494 is shifted in synchronism with the alternate sweeps, thus providing trace separation.

A Sweep Terminating Circuit. When the HORIZONTAL DISPLAY switch is in B INTENS BY 'A' or the adjacent ALT position and the B sweep intensified by A sweep is being displayed, it is desirable that the A sweep be terminated not later than the end of the B sweep. When the HORIZONTAL DISPLAY switch is in either of the foregoing positions, the signal at the plate of V145A (in the B sweep-generator holdoff multivibrator) is coupled through the HORIZONTAL DISPLAY switch and C449 to the base of Q444. At the instant that the B sweep ends the B sweep-holdoff multivibrator switches, the voltage at the plate of V145A goes positive, and a differentiated positive spike is applied to Q444. The positive spike is amplified and inverted by Q444, and the now negative spike is coupled through C441 and D347 to the grid of V345B in the A sweep-holdoff multivibrator. If the A sweep-holdoff multivibrator has not yet switched and stopped the A sweep, the negative spike from Q444 triggers the sweep-holdoff multivibrator and stops the sweep. If the A sweep has not yet started, the negative pulse resets the A sweep-holdoff multivibrator.

When the HORIZONTAL DISPLAY switch is in the ALT position (between B INTENS BY 'A' and A DLY'D) some means must be used to disable the B sweep terminating pulse during the time that the delayed A sweep is being displayed. At this time, Q465 in the alternate-sweep switching multivibrator is saturated, so the B sweep terminating pulse is coupled through D449 to the collector of Q465, where it is effectively grounded.

Alternate Trace Blanking. When the Type 547 is operated in the B INTENS BY 'A' — ALT — A DLY'D mode, it is necessary to keep the B sweep unblanking circuit cut off during the part of the sweep-switching cycle in which only the delayed A sweep is displayed. Cutoff is accomplished by applying the positive A sweep-gating voltage from the collector of Q475 to the base of Q184. When the HORIZONTAL DISPLAY switch is in either ALT position, the A sweep-gate voltage taken from the collector of Q475 is applied through the switch to D481. When the A sweep-gate voltage is positive, D481 is forward biased, and applies the positive voltage through R181 to the base of Q184. The positive voltage applied to the base of Q184 during the time that the A sweep gate is open is sufficient to keep Q184 cut off despite the unblanking signal from Q173.

Alternate-Sweep Lockout and Blanking Circuits

When alternate A and B sweeps are to be displayed, the horizontal amplifier and the crt must be time-shared between the two displays. Alternate-sweep lockout and blanking circuits are employed to ensure that the sweeps are displayed in proper sequence. The operations of the circuits for each position of the HORIZONTAL DISPLAY switch are described in the following paragraphs.

A Position. In this position of the HORIZONTAL DISPLAY switch, only the A sweep is displayed. The main time base (B) generator is blanked out by grounding the collector of Q465 in the alternate-sweep switching circuit. In the A position of the HORIZONTAL DISPLAY switch (SW530), the collector of Q564 is grounded through terminals 1 and 5 of wafer 8F. Grounding the collector of Q465 closes the B sweep gate composed of D461 and D462. With the B sweep gate closed, any output from the main time base (B) generator does not get through to the horizontal amplifier.

B Position. This position of the HORIZONTAL DISPLAY switch grounds the collector of Q475, closing the A sweep gate composed of D471 and D472. In this case, the output of the A sweep generator is prevented from reaching the horizontal amplifier.

A—ALT—B Position. When the HORIZONTAL DISPLAY switch is placed in the ALT position midway between A and B, the horizontal amplifier and crt must be time-shared between the two time-base sweep generators. Note that in this position of the HORIZONTAL DISPLAY switch, the collector of Q475 is connected through D133 and terminals 9 and 11 of wafer 4R to the B sweep-holdoff multivibrator. Likewise, the collector of Q465 is connected through terminals 3 and 10 of wafer 4F to the holdoff circuit of A sweep-holdoff multivibrator. This means that at the instant of turn on, the nonconducting transistor of the alternate-sweep switching multivibrator permits a lockout voltage to be applied to the holdoff multivibrator to which it is connected. The switching inputs to the sweep-switching multivibrator are taken from the plate of V345B in the A sweep-holdoff multivibrator, and from the plate of V145A in the B sweep-holdoff multivibrator. If, at the instant of turn on, no triggering signals are being applied and both TRIGGERING MODE switches are in the TRIG position, there is no sweep. Under these conditions, if Q465 in the alternate-sweep switching multivibrator is the conducting transistor, the main time base (B) sweep generator is locked out and cannot be triggered until A sweep generator has been triggered. If a trigger is now applied to the A sweep generator, it runs up, its holdoff multivibrator switches, and a switching signal is sent by the holdoff multivibrator to the alternate-sweep switching multivibrator via Q464. B sweep can now be triggered. If Q475 is the conducting transistor at the moment of turn on, and the TRIGGERING MODE switches are in the TRIG position, then the A sweep generator cannot be triggered until the main time base (B) has been triggered.

B INTENS BY 'A' Position. In this position of the HORIZONTAL DISPLAY switch and with the TRIGGERING MODE switch in the TRIG position, the pulse from the delay-pickoff circuit switches the A sweep-holdoff multivibrator, but the sweep waits for a trigger before starting to run up. When the A sweep generator completes its runup and goes into holdoff, this fact is signaled to the main time base (B) generator by Q344. The conduction of V345A during the A sweep-holdoff time is sufficient to reverse bias D356, cutting off Q344. Cutting off Q344 permits the voltage at the junction of R135 and R136 to go more positive, keeping the main time base (B) sweep generator locked in holdoff. As the holdoff capacitor in the A sweep generator discharges, the voltage on the grid of V345A falls, decreasing the current flow through V345A. When the holdoff capacitor in the A sweep generator is finally discharged, the current flow through V345A has decreased to where D356 is no longer reverse biased, and Q344 conducts, removing the lockout voltage from the main time base (B) generator holdoff multivibrator. The main time base (B) generator resets and is triggerable.

B INTENS BY 'A' —ALT — A DLY'D Position. In this position of the HORIZONTAL DISPLAY switch, the alternate-sweep switching multivibrator alternately gates A sweep delayed by B and B sweep intensified by A into the horizontal amplifier. Note that in this mode of operation the main time base (B) generator sends a sweep-terminating pulse to the A sweep-generator holdoff circuit at the end of the intensified B sweep, and that A sweep-generator holdoff multivibrator keeps the main time base (B) sweep generator locked out (in holdoff) until the A sweep generator has completed its holdoff period and is triggerable. The foregoing actions can be determined by tracing the signals through wafers 7R, 8F, 8R, 4F, 4R, 2R, and 1F of the HORIZONTAL DISPLAY switch.

B INTENS BY 'A' Position. In this mode of operation, the collector of Q475 in the alternate-sweep switching multivibrator is grounded through the contacts of wafer 8R, and the A sweep gate is closed. Contacts 5 and 10 of wafer 4F apply a positive voltage to the grid of V345A in the A sweep-holdoff multivibrator. The positive voltage on the grid of V345A assures that the A sweep generator will stay in holdoff until the delayed trigger pulse from the delay-pickoff circuit overrides the holdoff voltage and resets the holdoff multivibrator. If the TRIGGERING MODE switch is in the TRIG position, runup of the A sweep generator does not commence until a trigger is received from the A sweep-trigger circuit. At the end of the B sweep, Q444 in the alternate-sweep switching circuit sends a termination pulse to the grid of V345B (in the A sweep-generator holdoff multivibrator) that resets the holdoff multivibrator and terminates the A sweep.

A DLY'D Position. In this position of the HORIZONTAL DISPLAY switch, the collector of Q465 in the alternate-sweep switching multivibrator is grounded, closing the B sweep gate. The A sweep-generator holdoff multivibrator is kept in holdoff by a positive voltage applied through wafer 4F of the HORIZONTAL DISPLAY switch, and, as in the case where the B sweep is intensified by the A sweep, can be brought out of holdoff only by a reset pulse from the delay-pickoff circuit. When the HORIZONTAL DISPLAY switch is in the A DLY'D position, the action starts when the main time base (B) generator receives a trigger and starts its runup. After a period of time selected by the DELAY-TIME MULTIPLIER dial, the delay-pickoff circuit generates a pulse that takes the A sweep generator out of holdoff. If the TIME BASE A-TRIGGERING-MODE switch is in the AUTO STABILITY position, the A sweep generator starts its runup.

Alternate-Trace Sync Amplifier

The alternate-trace sync amplifier (see Interconnecting Jack J11 schematic) amplifies and shapes the alternate-trace sync pulses and applies them to the vertical plug-in preamplifier, provides a sample of the pulse to the crt for blanking purposes, and amplifies the chopped blanking pulses from the vertical plug-in preamplifer for application to the crt.

Horizontal Amplifier

The dc-coupled horizontal amplifier (see Horizontal Amplifier schematic) consists of a transistor input amplifier, an emitter follower, a transistor paraphase amplifier, a push-pull vacuum-tube output amplifier, a pair of output cathode followers, and a capacitance-driver tube. In addition, the Type 547 contains a cathode-coupled preamplifier that is used to amplify externally applied horizontal deflection signals. The input to the horizontal amplifier is received from either the alternate-sweep switching circuit or the external HORIZ INPUT connector, depending upon the setting of the HORIZONTAL DISPLAY switch.

Input Stages. The selected input signal is applied to the base of Q534 along with dc-positioning voltages from the horizontal positioning controls. The composite signal output of Q534 is applied to emitter follower Q543, and from that transistor to the paraphase amplifier. Negative feedback from the emitter of Q543 to the base of Q534 keeps the input and output impedance of the two stages low. R544 in the feedback loop provides a means of adjusting the amount of feedback, thereby providing amplifier gain adjustment.

Paraphase Amplifier. Q554, Q564, and associated circuit components form a paraphase amplifier that splits the signal from Q543 into push-pull output. The signal from Q554 to Q564 is coupled through the emitter circuit, and by changing the value of the coupling resistor, the gain of the paraphase amplifier is changed to provide sweep magnification. Four selectable values of coupling resistor are available providing X1, X2, X5, or X10 sweep magnification.

The feedback loop from the collector of Q554 stabilizes the gain and balance of the paraphase amplifier. D542 and D561 provide base-operating bias. The feedback loops from the output cathode followers (V574B and V584B) to the emitters of Q554 and Q564 assist in stabilizing the gain of the horizontal amplifier.

Output Amplifier and Cathode Followers. The ramp-voltage outputs of the paraphase amplifier are applied to the grids of amplifiers V574A and V584A. The ramp voltages are amplified by the two triodes, which then apply the ramp voltages to the output cathode followers. To maintain the desired linearity at high sweep rates, part of the output from each amplifier is bypassed around the cathode followers through small variable capacitors C572 and C582. C576 and C586 together with stray capacitance across R576 and R586 form a capacitance bridge to provide correct high-frequency feedback.

Capacitance Driver. The cathode of V574B drives the left-hand deflection plate and, during the sweep, the cathode voltage should go linearly in a negative direction. At high sweep rates, when V574B tries to drive the deflection plate negative, the deflection-plate capacitance and the output capacitance of cathode follower V574B tend to distort the ideal linear ramp voltage into an rc discharge curve. To overcome this tendency toward nonlinearity, the positive-going ramp voltage at the cathode of V584B is applied through C591 to the grid of capacitance driver tube V589. The positive-going voltage on the grid of V589 forces it into heavy conduction, and the current supplied through the tube provides extra current to the cathode of V574B and helps to discharge the capacitance in the output of V574B. Since the crt is blanked during the return trace, there is no need for a similar current driver at the cathode of V584B.

External Horizontal Preamplifier. The preamplifier applies external horizontal deflection voltages through the HORIZONTAL DISPLAY switch to the grid of V514B. For large-amplitude signals, a X10 attenuator position is provided on the HORIZONTAL DISPLAY switch. V514B and V514A form a cathode-follower grounded-grid amplifier, with the gain controlled by adjusting the value of the coupling resistor between the two cathodes. In this case, R511 provides at least a 10:1 range of adjustment. The output of V514A is applied through the HORIZONTAL DISPLAY switch to the base of Q534.

Amplitude Calibrator

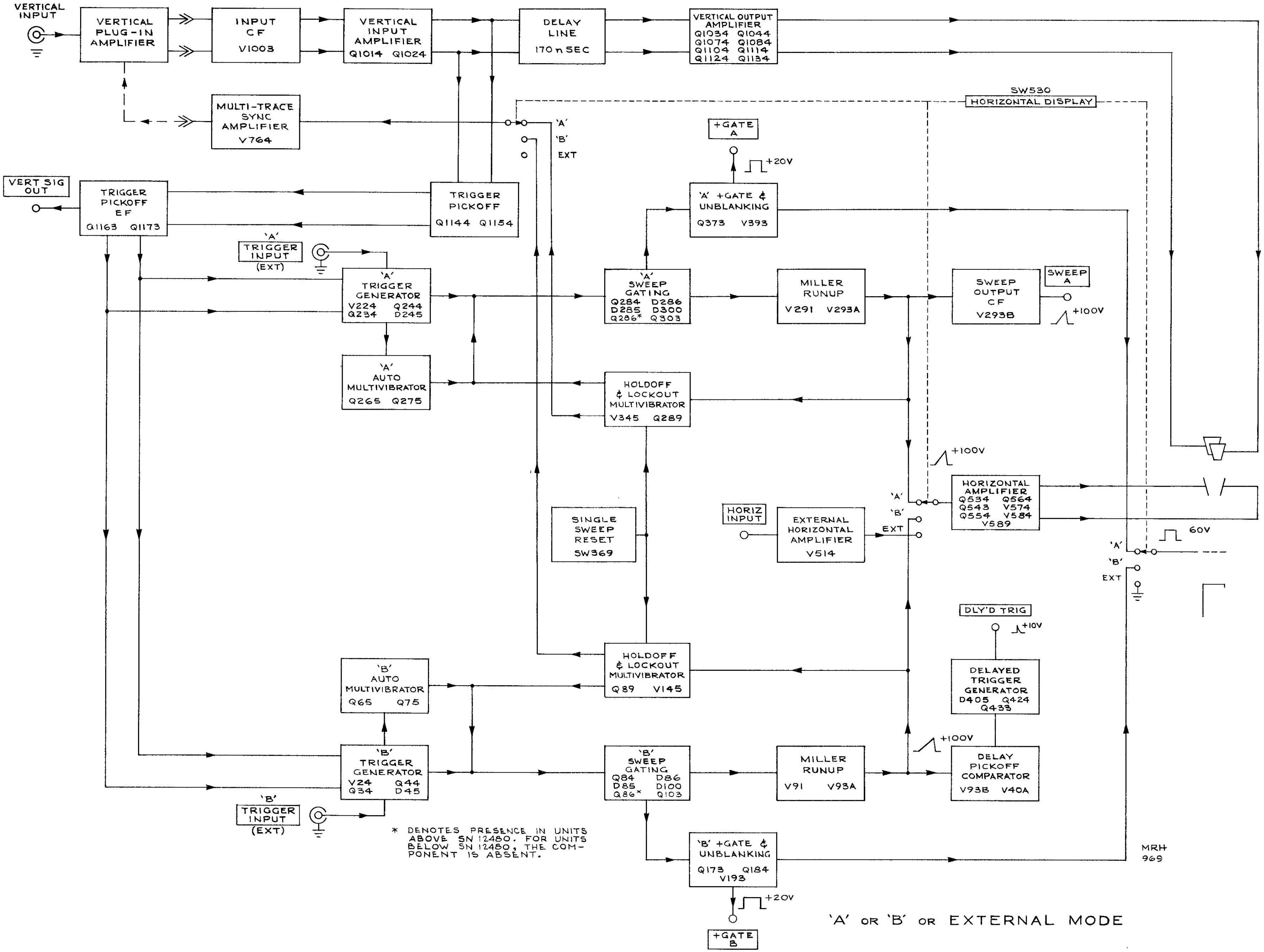
The amplitude calibrator in the Type 547 is a 1-kc square-wave generator (see Amplitude Calibrator schematic) that provides both voltage and a 5-ma current output to the front-panel connectors. The voltage output is taken from the CAL OUT connector on the front panel, where either a selectable-amplitude squarewave or a steady +100-volt dc reference voltage is available. By turning the AMPLITUDE CALIBRATOR switch, the amplitude of the square-wave output may be varied from 0.2 mvolt to 100 volts peak-to-peak. The current output is applied to the link marked 5 mA Ω, with the arrow indicating conventional current flow. When the AMPLITUDE CALIBRATOR switch is in the 100 V DC position, the link has 5 ma dc flowing through it; when the switch is in the 5 mA Ω position, the current through the link is in the form of a 1-kc, 5 ma square wave.

CAUTION

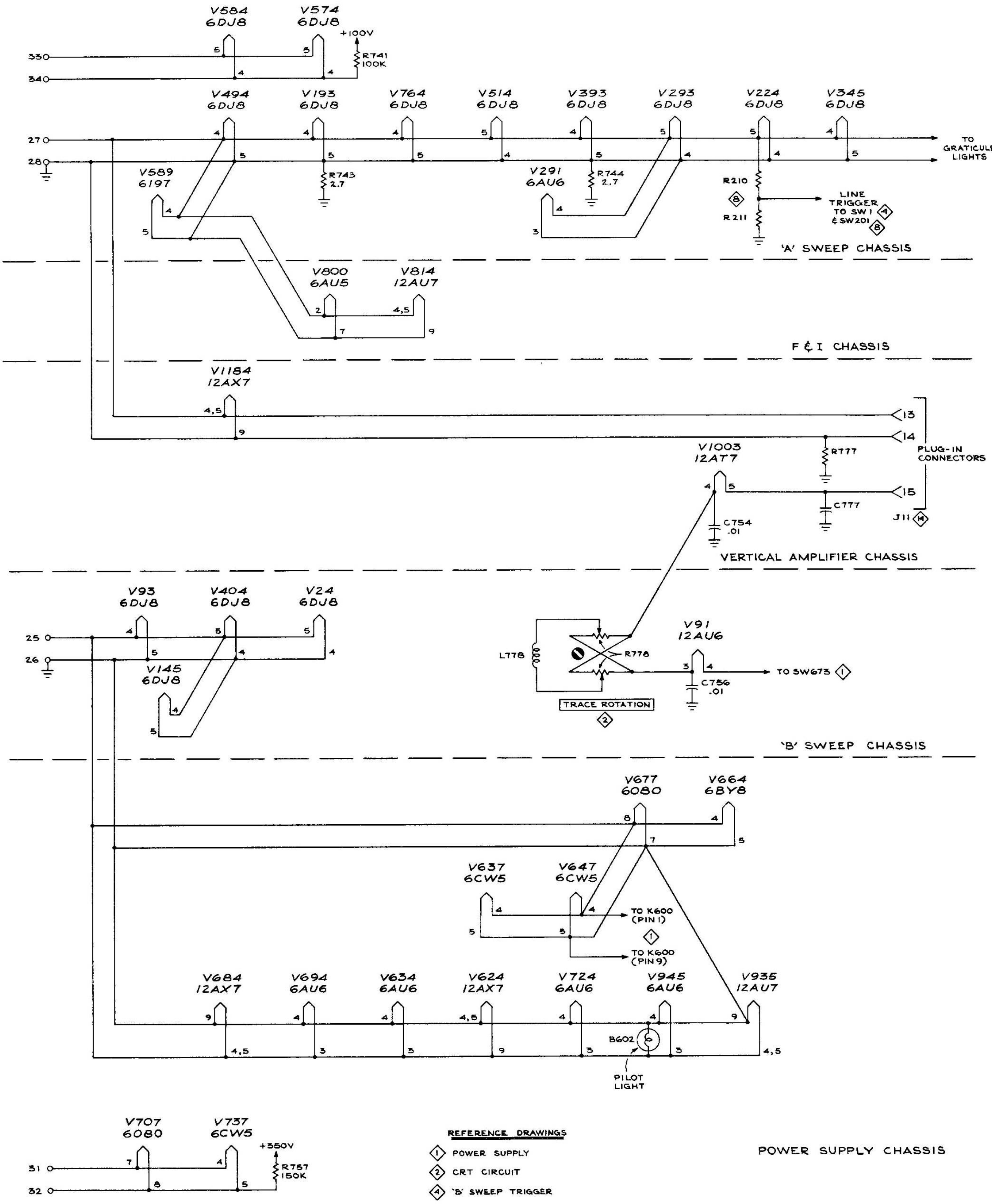
The link is designed for use with a snap-on current probe and does not unplug.

Square-Wave Generator. The square-wave generator is an astable multivibrator direct-coupled to a cathode follower. V935A and V945 are the multivibrator tubes, with the screen of V945 serving as an anode and furnishing feedback to V935A. The plate of V945 operates as an electron-coupled amplifier. The time constants in the grid circuits of the tubes are different to compensate for the difference in their characteristics. When the amplitude calibrator is turned on, the multivibrator cathodes are returned directly to the dc-coupled —150-volt supply. Since the plate load and grid resistors are grounded, this means that the supply potential of the multivibrator is 150 volts. The plate of V945 operates from the +225-volt supply, but is clamped slightly above 100 volts by D942 and D948. The voltage on the plate of V945 swings from about —30 volts to about +102 volts. The plate of V945 is coupled through Zener diode D948 to the grid of cathode follower V935B. CAL AMPL control R943 is adjusted so that when the signal to V935 is positive, its cathode voltage rises to +100-volts. When the signal from the V945 plate goes negative, V935B is cut off and the cathode voltage goes to ground potential.

Output Level Selection. The cathode load for V935B is essentially the string of precision resistors starting with R950 and ending with R958. The junctions of the precision resistors are connected to the CAL OUT connector through AMPLITUDE CALIBRATOR switch SW950. The values of the precision resistors are selected to give output amplitude steps in multiples of 1, 2, or 5. In the steps from 200 mvolts to 100 volts, the junctions of the precision resistors are switched through R962 to the CAL OUT connector, while in the steps from 0.2 to 100 mvolts, an additional divider with a ratio of 1000:1 is inserted between the precision resistors and the CAL OUT connector. In the 0.2 mvolt to 200 mvolt range, the output impedance is 50 Ω.



'A' OR 'B' OR EXTERNAL MODE



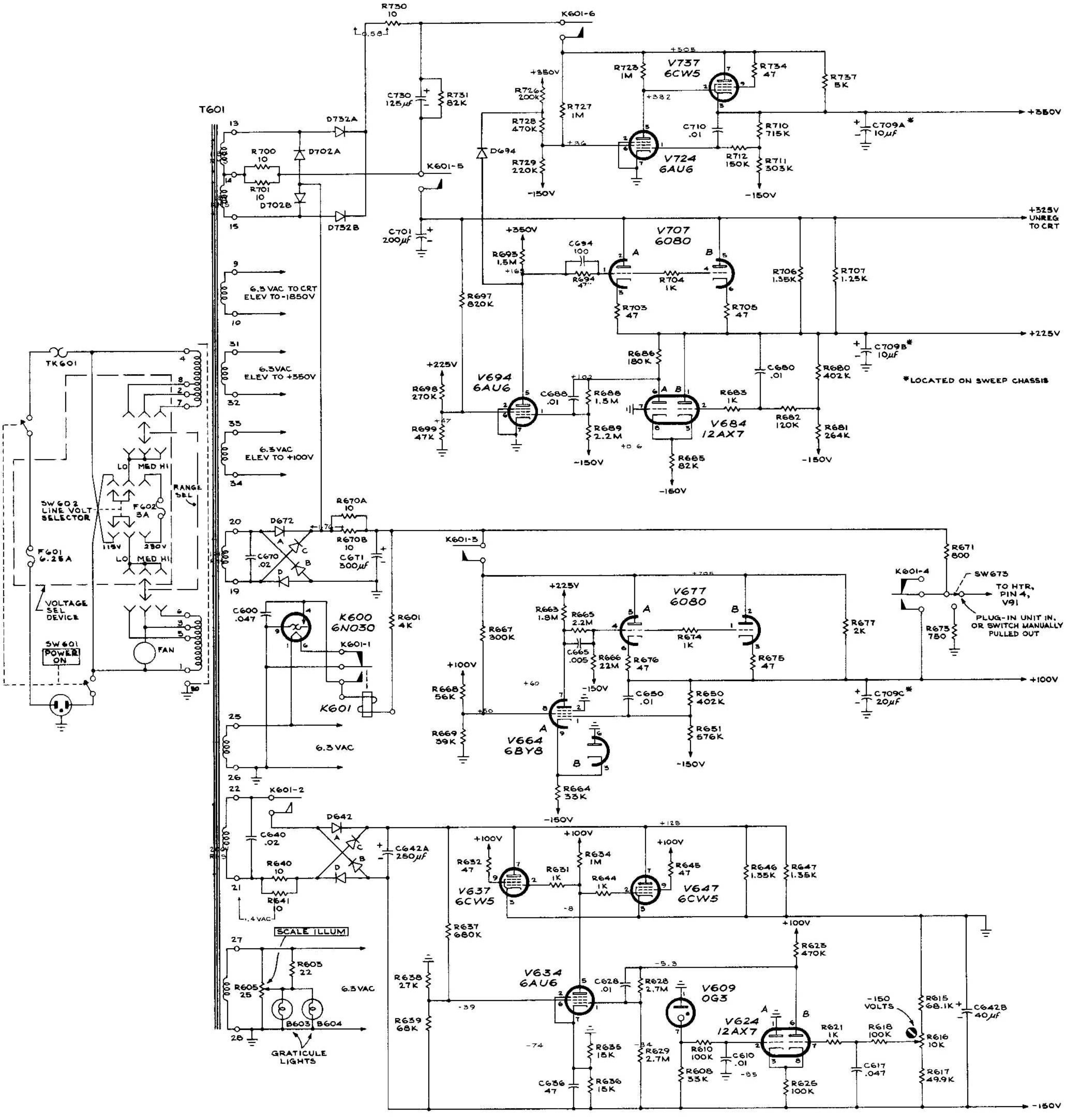
REFERENCE DRAWINGS

1. POWER SUPPLY
2. CRT CIRCUIT
A. 'B' SWEEP TRIGGER
B. 'A' SWEEP TRIGGER
M. PLUG-IN CONNECTOR

POWER SUPPLY CHASSIS

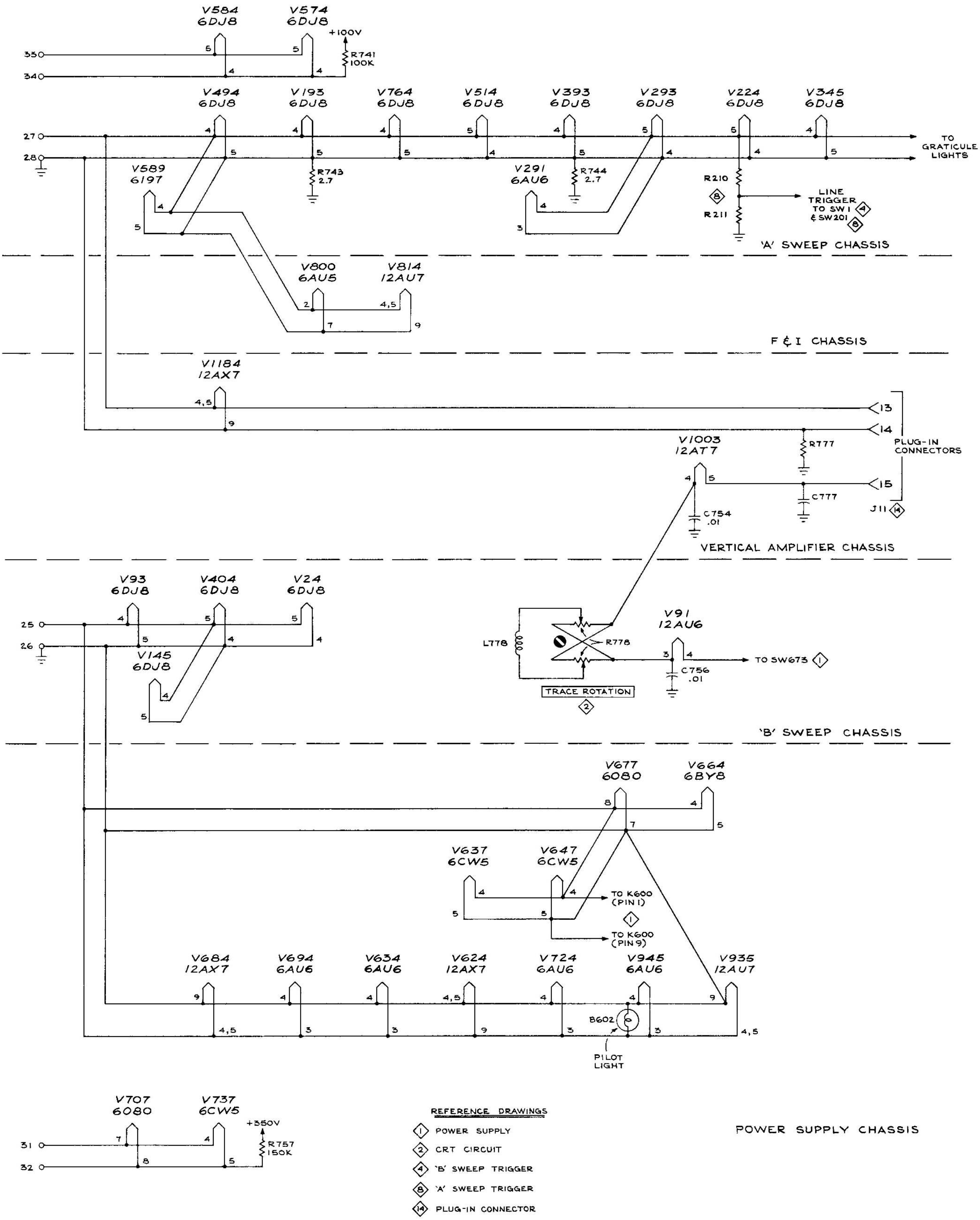
TYPE 547 OSCILLOSCOPE

HEATER WIRING DIAGRAM
SN 7980-UP



1266

POWER SUPPLY ⟨1⟩
SN 7980-UP

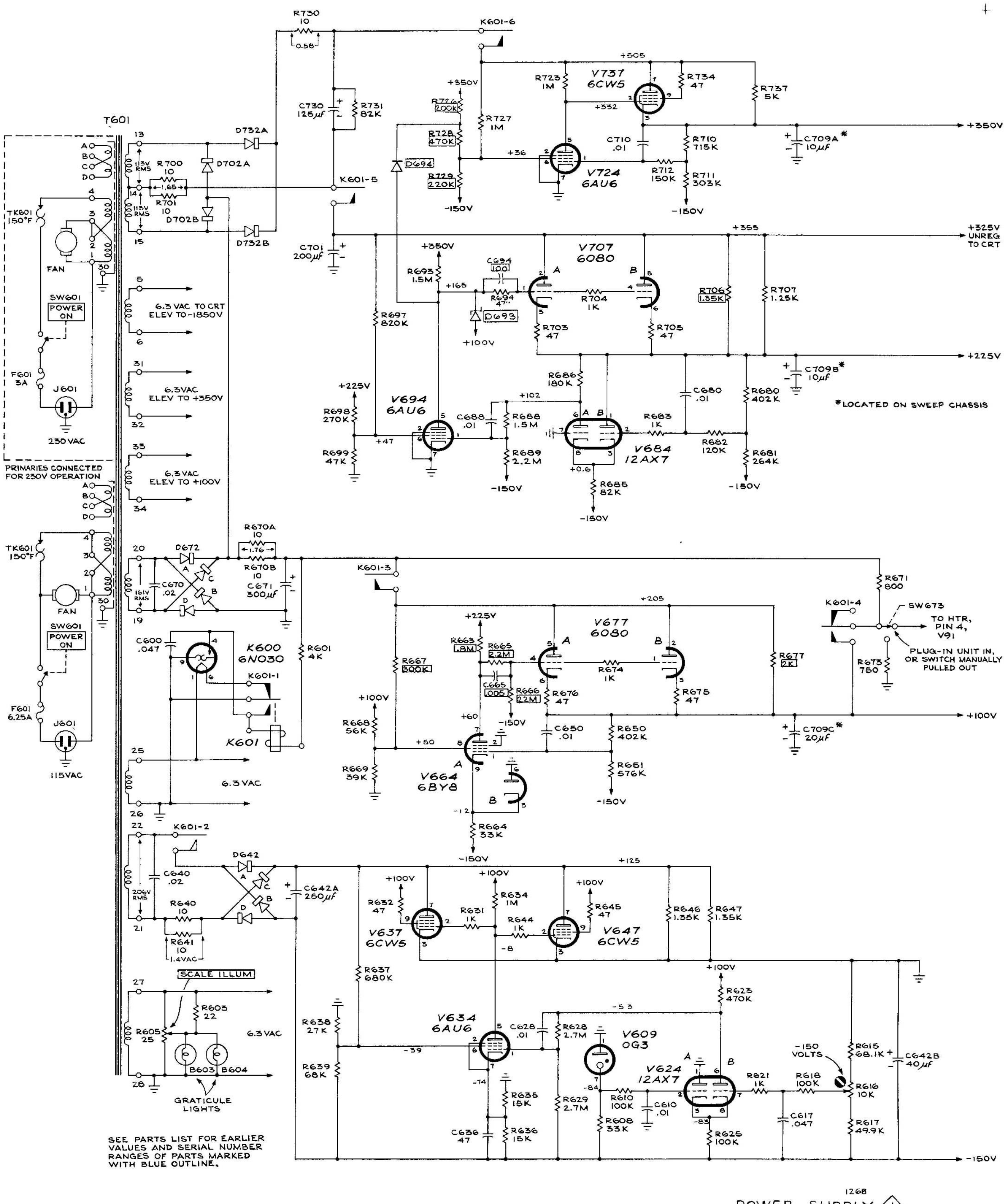


TYPE 547 OSCILLOSCOPE

HEATER WIRING DIAGRAM

SCILLOSCOPE

HEATER WIRING DIAGRAM



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

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POWER SUPPLY ①

SN 100-7979

CRT CIRCUIT

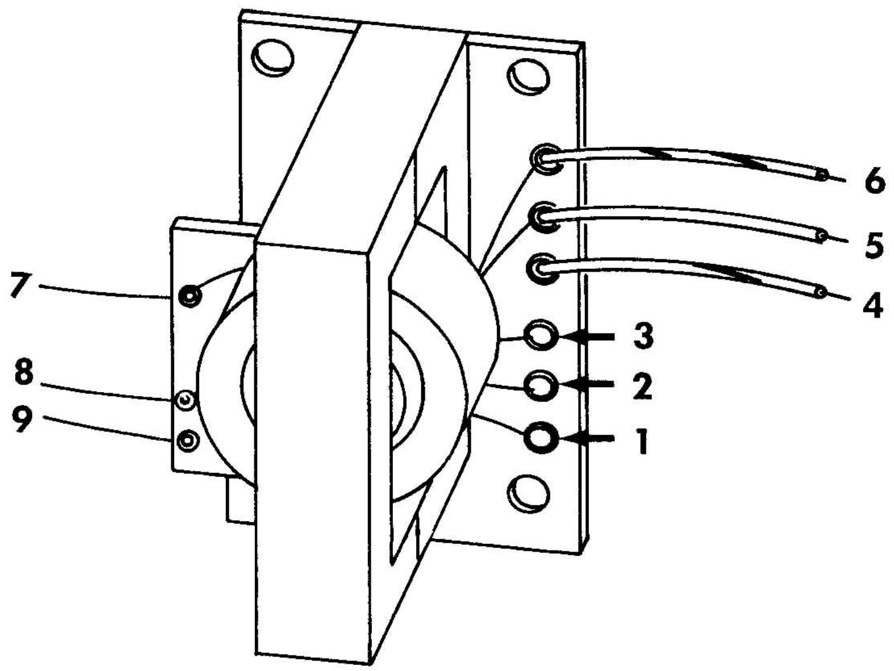
WAVEFORM AND DYNAMIC VOLTAGE READINGS were obtained under the following conditions:

INTENSITY . . . . ccw

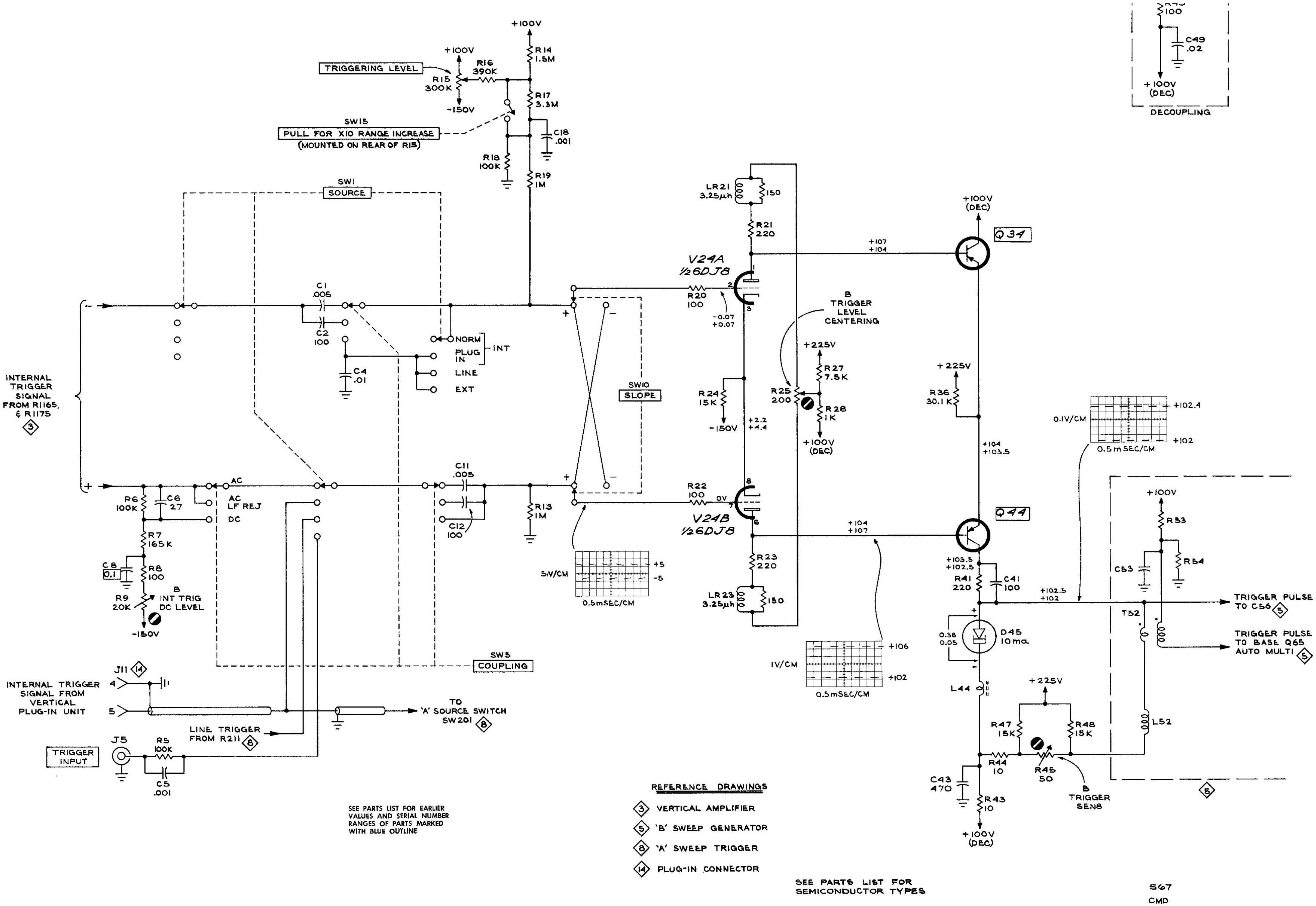
POWER . . . . ON

* Voltage reading obtained with associated control set for normal operation. Voltage is dependent on position of the control.

Also see IMPORTANT note on "A or B or External Mode" Block diagram.



T801 TRANSFORMER DETAILS



567
CMD

TYPE 547 OSCILLOSCOPE

'B' SWEEP TRIGGER 4
(S/N 100-6739)