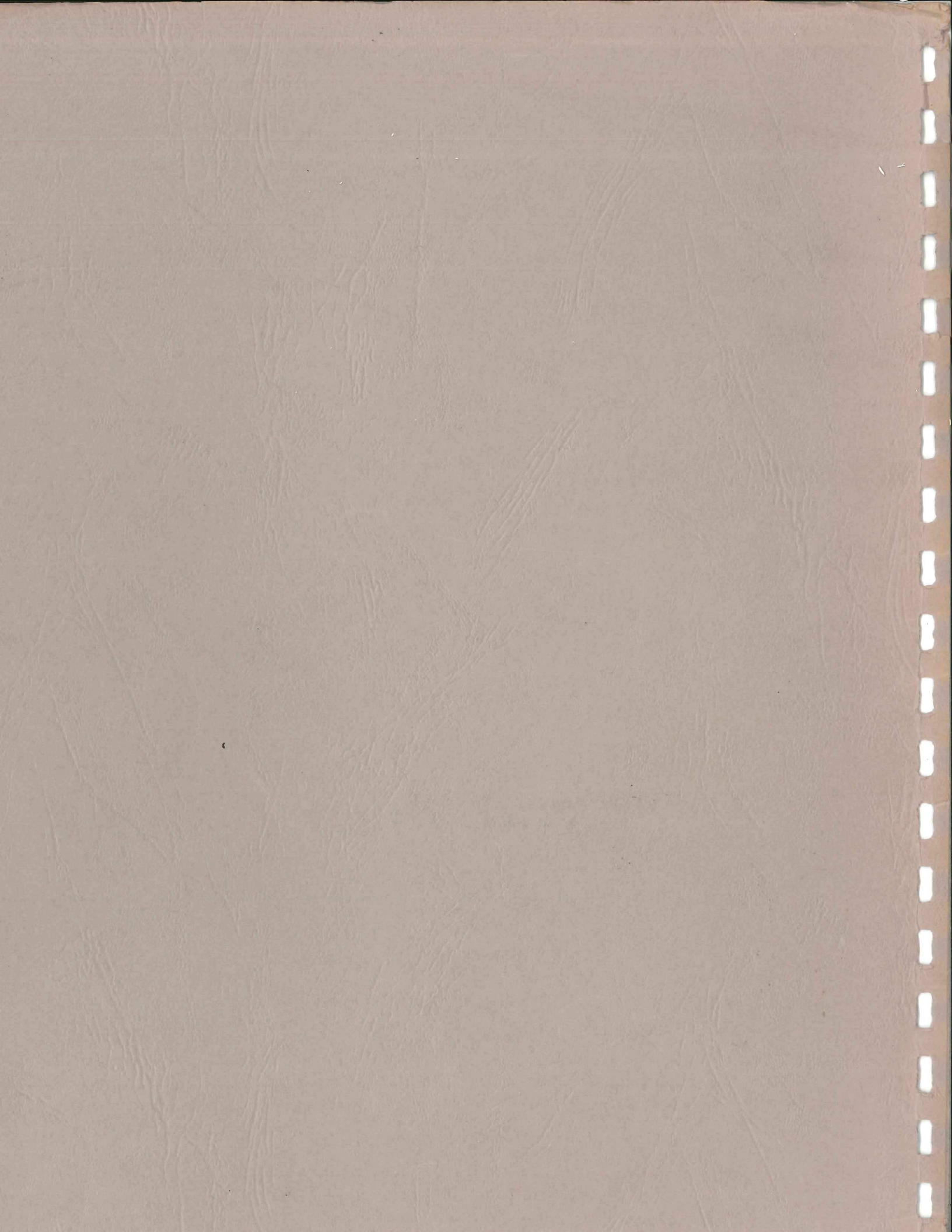


**TECHNICAL
INSTRUCTION and
TRAINING for the**

547

546 - 544



547

546 - 544

Written and Produced in Field Training

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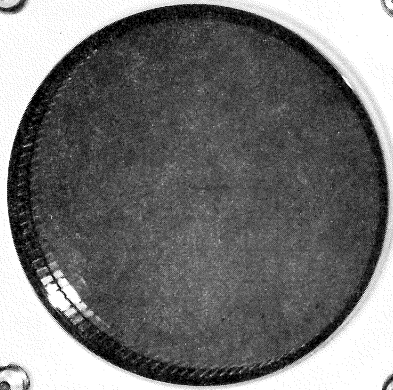
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1. General Information
2. Circuit Description
3. Graphic Calibration Procedure
4. Schematics

TYPE 547 OSCILLOSCOPE

SERIAL



INTENSITY FOCUS TRACE ROTATION ASTIGMATISM SCALE ILLUM. TRACE SEPARATION

TYPE 1A1 DUAL-TRACE PLUG-IN UNIT

CHANNEL 1 CHANNEL 2

VARIABLE VOLTS/CM POSITION

MODE CHOP SERIAL

INPUT SELECTOR

TEKTRONIX, INC. PORTLAND, OREGON, U.S.A.

TIME BASE A

TRIGGERING LEVEL

TRIGGERING MODE SLOPE COUPLING SOURCE

TRIGGER INPUT

HORIZONTAL DISPLAY

MAIN SWEEP

VAR 10-1

HORIZ INPUT

MAIN TIME BASE (B)

TRIGGERING LEVEL

TRIGGERING MODE SLOPE COUPLING SOURCE

TRIGGER INPUT

DELAY-TIME MULTIPLIER 1-10

VARIABLE TIME/CM OR DELAY TIME

DLY'D TRIG

AMPLITUDE CALIBRATOR

HORIZONTAL POSITION VERNIER

POWER ON

5mA FL CAL OUT

TEKTRONIX, INC., PORTLAND, OREGON, U.S.A.

GENERAL INFORMATION

The Type 547 Oscilloscope offers a host of new features for a new standard of performance and ease of operation. Automatic Display switching, exclusive in the Type 547, offers single-beam economy for many complex dual-beam applications.

VERTICAL DEFLECTION

Plug-In Preamplifiers adapt the Type 547 to a wide range of measurement capabilities. The vertical system in the Type 547 accepts the new Type 1A1 Dual-Trace Unit and also all present Letter-Series Units.

FREQUENCY RESPONSE with the Type 1A1 Plug-In Unit is dc-to-50 Mc from 50 mv/cm to 20 v/cm, dc-to-28 Mc at 5 mv/cm. Letter-Series Plug-In Units provide response from dc-to-30 Mc, depending on the unit used. Specialized Letter-Series Units adapt the Type 547 to strain-gage, operational amplifier, multi-channel, and other applications.

SIGNAL DELAY permits observation of the leading edge of the waveform that triggers the sweep. The specially-braided 170-nanosecond delay line requires no tuning.

SIGNAL OUTPUT from the front panel provides approximately 0.4 v/cm of displayed signal. This ac-coupled signal output has a risetime capability of 20 nsec.

HORIZONTAL DEFLECTION

Two separate and identical wide-range time bases are featured in the Type 547. Either time base can be used alone,

or Time Base B can be used to accurately delay the start of Time Base A. Automatic Display Switching between the time bases allows an alternate presentation of the same signal at different sweep rates, or 2 different signals at the same or different sweep rates (with dual-trace plug-ins).

TIME BASE A and B SWEEP RANGE from 0.1 μ sec/cm to 5 sec/cm is in 24 calibrated steps with 1-2-5 sequence. Time Base A is accurate within $\pm 2\%$. Time Base B (the main time base) is accurate within $\pm 1\%$. Sweep rates are also continuously variable, uncalibrated from 0.1 μ sec/cm to approximately 12 sec/cm. Front-panel lamps indicate uncalibrated sweep rates.

2, 5 or 10X SWEEP MAGNIFICATION expands the center portion of the normal display to fill 10 cm. Accuracy is within $\pm 5\%$. The 10X magnifier can be used to extend the calibrated sweep rate to 10 nsec/cm.

SINGLE-SWEEP OPERATION facilitates photographic recording of waveforms displayed on either or both time bases. A front-panel reset control arms the sweep to fire on the next received trigger. After firing once, the sweep is locked out until reset at the front panel, or with a +20-volt pulse applied through a rear-panel connector. Time Base A and B are both reset by the same switch. Front-panel lamps just above the Horizontal Display switch indicate which time base is ready to fire. The lamp extinguishes as soon as the sweep starts.

EXTERNAL HORIZONTAL INPUT provides for horizontal beam deflection with an external source. Horizontal Amplifier passband is dc to at least 400 kc (3-db down). Sensitivity

is at least 0.1 v/cm or 1 v/cm with 10X step attenuation. Sensitivity potentiometer is continuously variable over a 10:1 range. Input impedance is 1 megohm paralleled by approximately 55 pf.

FRONT-PANEL OUTPUTS include +20-v gates from both time bases, 100-v sawtooth from Time Base B, and a 10-v delayed trigger pulse (all voltages are approximate).

TRIGGER

Triggering is separate and identical for both time bases. Wide-range trigger circuits allow triggering to beyond 50 Mc. The Trigger signal for each time base trigger circuit is selected and processed by a series of four lever switches. The control logic of these switches has been human-engineered for operator ease.

TRIGGER SOURCE can be internal, external, or line. The internal source can be selected from the oscilloscope vertical amplifier, or direct from Channel 1 of the Type 1A1 Dual-Trace Plug-In Unit. With a Type 1A1 operating in one of its channel-switching modes, the internal trigger signal can be selected from Channel 1 before switching occurs, or from the composite signal after the two channels have been combined. When triggering from Channel 1, the true time relationship between Channel 1 and 2 signals is displayed. With the Type 1A1 Unit in "Alternate" switching mode, triggering internally from Channels 1 and 2 composite signal allows observation of 2 signals which are not harmonically related.

TRIGGER COUPLING can be direct or ac-coupled. AC Low-Frequency Reject (approximately 3-db down at 1.5 kc) prevents low-frequency components such as 60-cps hum from interfering with stable operation.

TRIGGER MODE selects either Triggered or Automatic operation. Automatic triggering provides a bright reference trace (regardless of sweep speed) when no input signal is applied, or when the trigger-signal repetition rate is less than 20 cps. Above 20 cps, the time base is triggered at the repetition rate of the incoming trigger signal to achieve jitter-free displays to beyond 50 Mc.

TRIGGER LEVEL adjusts to allow sweep triggering at any selected point on either the rising or falling portion of the waveform. A two-position control permits trigger-level selection between ± 2 or ± 20 volts.

TRIGGER REQUIREMENTS for internal triggering are a minimum of 2mm (5mm with DC coupling) of displayed signal, increasing to 1 cm at approximately 50 Mc (either ac-coupled mode). External triggering requires 0.2 v, ac or dc. (Minimum)

SWEEP DELAY

Highly-accurate time measurements can be made with the 2 time bases used for sweep delay. Two modes of delay are available: triggered and conventional. Lockout-reset circuitry permits single-shot use of the calibrated delay features.

CALIBRATED DELAY RANGE is continuously variable from

0.1 μ sec to 50 sec. Accuracy from 50 μ sec to 50 sec is within $\pm 1\%$ of indicated delay ± 2 minor dial divisions on the Delay-Time Multiplier control. For delays less than 50 μ sec, accuracy is within $\pm 1\%$ ± 2 minor dial divisions plus 75 to 100 nsec (typical fixed-circuit delay). Incremental accuracy of the Delay-Time Multiplier is within ± 2 minor dial divisions for calibrated sweep rates up to 1 μ sec/cm. The variable control extends the delay range (uncalibrated) from 0.1 μ sec to approximately 120 sec.

TRIGGERED OPERATION holds off the start of the delayed sweep until the arrival of the first trigger signal following the selected delay time. Because the delayed sweep is actually triggered by the signal under observation, the display is completely jitter free. A steady display is thus provided for time-modulated pulses and signals with inherent jitter.

CONVENTIONAL OPERATION holds off the start of the delayed sweep for the precise amount of the selected delay time. Any time-modulation or jitter on the signal will be magnified in proportion to the amount of sweep expansion.

The time jitter in the delayed trigger or delayed sweep is less than one part in 20,000.

WIDE-RANGE MAGNIFICATION is readily accomplished when Time Base A is operated at a faster rate than Time Base B. For example, if Time Base A is operating at 1 μ sec/cm and Time Base B is operating at 50 μ sec/cm, the magnification is 50 times.

TRACE BRIGHTENING indicates the exact portion of the

signal that will appear on the magnified display, and also the point-in-time relationship of the magnified display to the original display. The Time Base B unblanking level is adjustable at the front panel to normalize trace brightness when the 2 time bases are alternately displayed and running at widely different sweep rates.

CRT AND DISPLAY FEATURES

TEKTRONIX CRT is a new, aluminized, flat-faced, tube with electrostatic focus and deflection. It has a helical post accelerator and is operated at 10-kv total accelerating potential. Small spot size (nominally 9 mils) and uniform focus provide fine trace definition across the entire viewing area. A P31 phosphor is normally supplied.

INTERNAL 6 X 10-CM GRATICULE with variable edge lighting provides no-parallax viewing and photography for greater accuracy and convenience of measurement readout. The graticule is marked in centimeter squares, with 2-mm divisions on the vertical and horizontal center lines.

FRONT-PANEL CONTROLS include trace rotation (a screwdriver adjustment), intensity, focus, and astigmatism. Internal screwdriver adjustments control display geometry and the high-voltage output level.

BEAM-POSITION INDICATORS show the direction of the crt beam when it is deflected away from the center-screen area.

DC-COUPLED UNBLANKING to the crt grid assures uniform beam current for all sweep speeds and repetition rates at

any setting of the intensity control.

Z-AXIS INPUT through a terminal at the rear of the instrument permits external modulation of the crt cathode. The input is ac-coupled and requires approximately 15 volts, pk-to-pk for visible modulation.

OTHER CHARACTERISTICS

AMPLITUDE CALIBRATOR provides 18 square-wave voltages from 0.2 mv to 100 volts in a 1-2-5 sequence, accuracy within 3%. Output resistance is 50 ohms from 0.2 mv to 0.2 v. Frequency is approximately 1 kc. Risetime and falltime is 0.5 μ sec from 0.2 mv to 5 v, and 1.0 μ sec from 10 v to 100 v. A 100-volt dc output is also provided. Reference currents supplied through the front-panel loop are 5-ma dc and a 5-ma, 1-kc square wave. Current probes can be slipped directly over the loop for calibration.

ELECTRONICALLY-REGULATED DC SUPPLIES insure stable, low-drift operation from 103.5 to 126.5 volts (115 v \pm 10%) or 207 to 253 volts (230 v \pm 10%). Power consumption is approximately 540 watts. The standard model operates from a 50 to 60-cycle line. An optional ac-to-ac solid state converter for the fan motor is available for 50 to 60 and 400-cycle operation. It can be ordered installed in the instrument as MOD 101G.

DIMENSIONS are 16-7/8" high by 13-1/8" wide by 23-7/8" deep. Net weight is 62 pounds.

TYPE 547 OSCILLOSCOPE, without plug-in units . . \$1875

TYPE 547 MOD 101G, without plug-in units \$

The Type RM547 Rack-Mount Oscilloscope

The Type RM547 is electrically identical to the Type 547, but mechanically rearranged to fit a standard 19-inch rack. It withdraws from its cabinet on slide-out tracks and can be tilted and locked in any of 7 positions. Dimensions are 14" high by 19" wide by 22 3/4" deep. Net weight is 87 pounds.

The Type 546 & 544 Oscilloscopes --

each with DC-to50 MC Passband

Two wide-range time bases (identical to those in the Type 547), calibrated sweep delay, 6 x 10-cm display -- all featured on the Type 546 Oscilloscope. It is similar to the Type 547, but does not have Automatic Display Switching.

Type 546 Oscilloscope, less plug-in units \$1750

Type 546 MOD 101G Oscilloscope, as above but operates at 400-cps line frequency as well as 50 to 60 cps \$

Sweep magnification from 2 to 100X and a single wide-range time base (identical to that in the Type 547 and 546) are featured in the Type 544 Oscilloscope. Other characteristics are similar to those in the Type 546.

Type 544 Oscilloscope, less plug-in units \$1550

Type 544 MOD 101G Oscilloscope, as above but operates at 400-cps line frequency as will as 50 to 60 cps \$

Rack-Models are electrically identical to their corresponding cabinet models, and mechanically identical to the Type RM547.

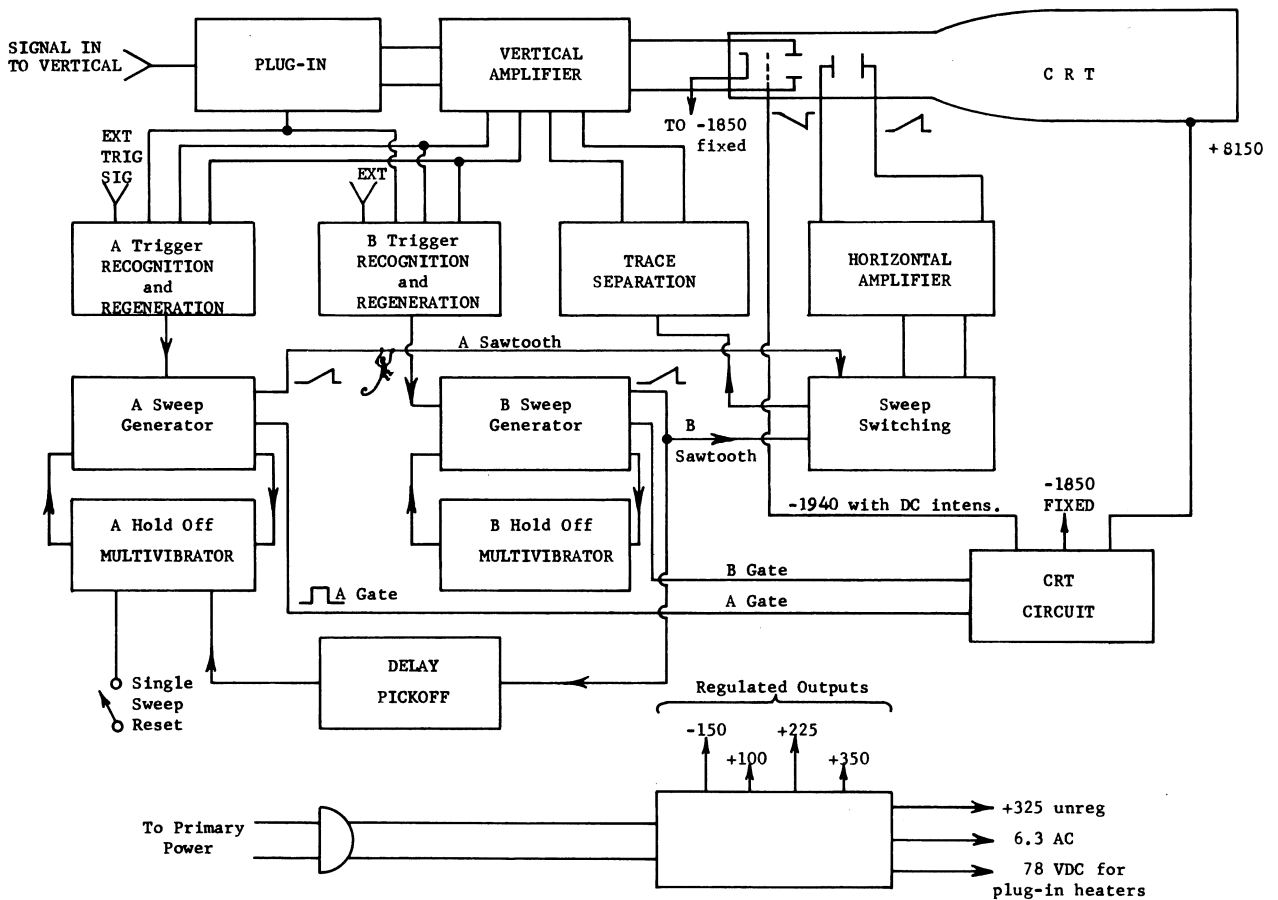
547

**BLOCK ANALYSIS
AND
CIRCUIT DESCRIPTION**

CIRCUIT DESCRIPTION

SECTION:

1. Vertical Amplifier
2. A TRIGGER Circuit
3. B TRIGGER Circuit
4. B Sweep (Main) Generator
5. A Sweep Generator
 - a. Delay Pickoff Circuit
 - b. Horizontal Display Modes
6. Sweep Switching
7. Horizontal Amplifier
8. CRT Circuit
9. Calibrator
10. Power Supply



547 SYSTEM BLOCK DIAGRAM

Figure 1-0

TYPE 547

What this scope is:

The Type 547 is a further development of the 545A, with many changes and improvements. (See block diagram, Fig.1-0) Many circuits have been transistorized. The unit has been designed to use letter-series plug-ins, but has an added bandpass capability which brings it up to 50 mc with a new dual trace plug-in, the 1A1 (also known as the J). With letter series plug-ins, performance must be limited to a lower figure because the output of some plug-ins contains poor response and ripples above 30 mc. A switch on the Type 547, which is pressed in by the older plug-ins, connects a filter which reduces the bandpass. The whole vertical amplifier, except for the input cathode followers, is transistorized. Letter series plug-ins are designed to look into a high impedance, thus the input tubes are necessary.

Two sweep generators are provided, with the same delaying sweep as the 545. The sweep trigger circuits now are both tunnel diode type, similar to the 585 A sweep trigger. Output of the sweep generators is fed to a sweep switching circuit, which is similar to a dual-trace vertical in function. This allows a signal to be displayed with alternating sweep rates (between A and B), or allows dual-trace signals to be displayed with different sweep rates (Channel 1 vertical displayed with time base A; Channel 2 with time base B). Also possible is alternate display of the B intensified by A and the A delayed by B. In the alternate sweep display modes (2 positions on the HORIZONTAL DISPLAY switch), a trace separation circuit shifts the position of the B sweep display vertically. The amount of trace separation can be adjusted by a control under the CRT. Since sweep rates may differ widely, alternate mode situations may result in having one trace bright and the other dim. A screwdriver adjustment of the relative brightness of the B sweep is provided to allow front panel adjustment for actual viewing conditions. The horizontal amplifier now is provided with X1, X2, X5, and X10 magnification.

The calibrator is similar to the older style 530-540-580 calibrator, but now has 50 Ω output impedance in the lower output positions, and a 5 ma current loop is provided for checking current probe calibration.

1. VERTICAL AMPLIFIER

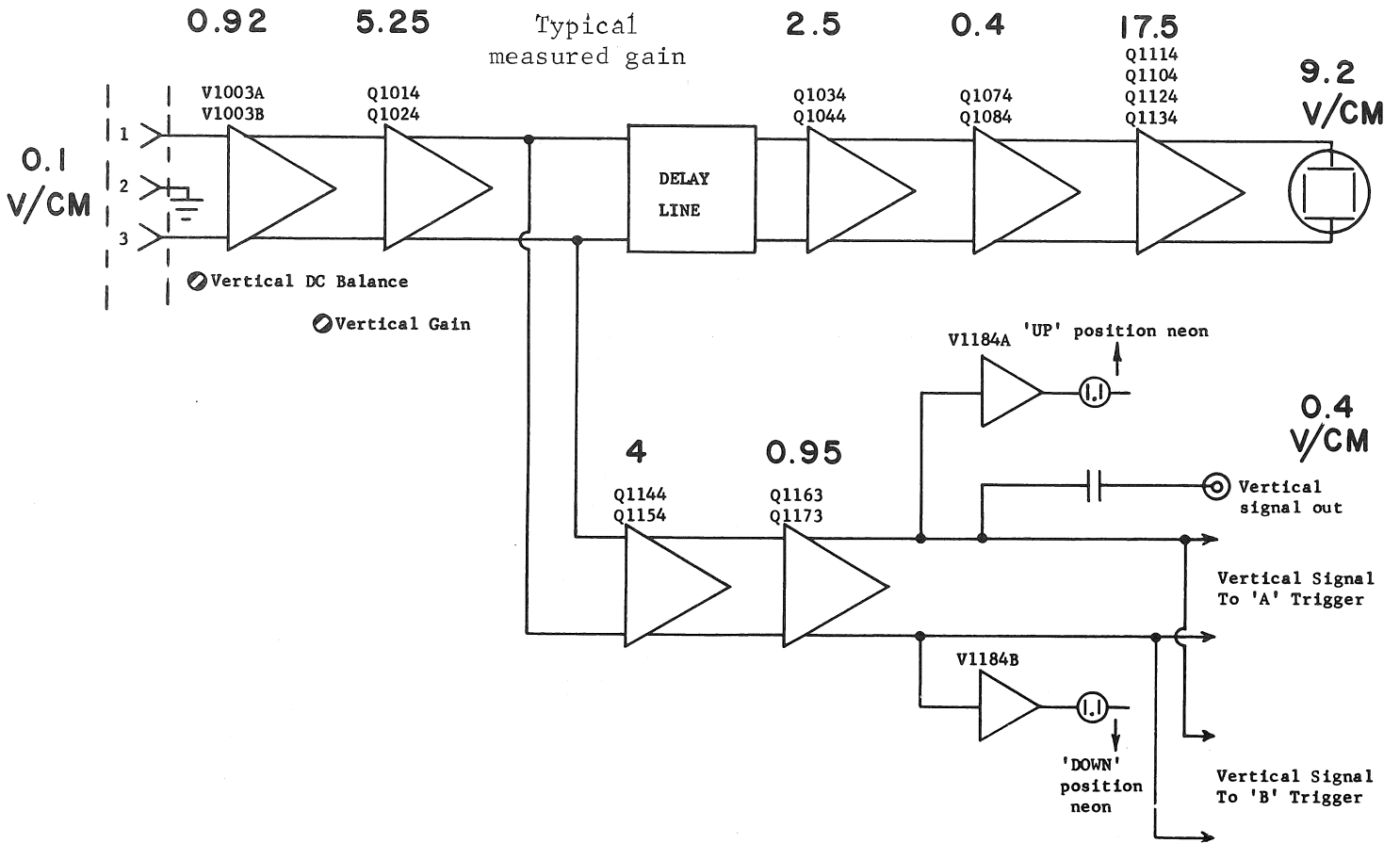


Figure 1-1

1. See vertical amplifier stage gain diagram, Fig. 1-1. Five stages plus delay line converts high impedance input signal to high impedance output signal to drive the CRT.

a. Input signal is 100 mv/cm, elevated 67 volts.

(1) Actual DC elevation is determined by plug-in used.

b. Output signal is 8 volts/cm, elevated 140 volts.

c. Delay line is 170 nsec.

(1) Line exhibits "dribble up" which is compensated for by overpeaking other stages.

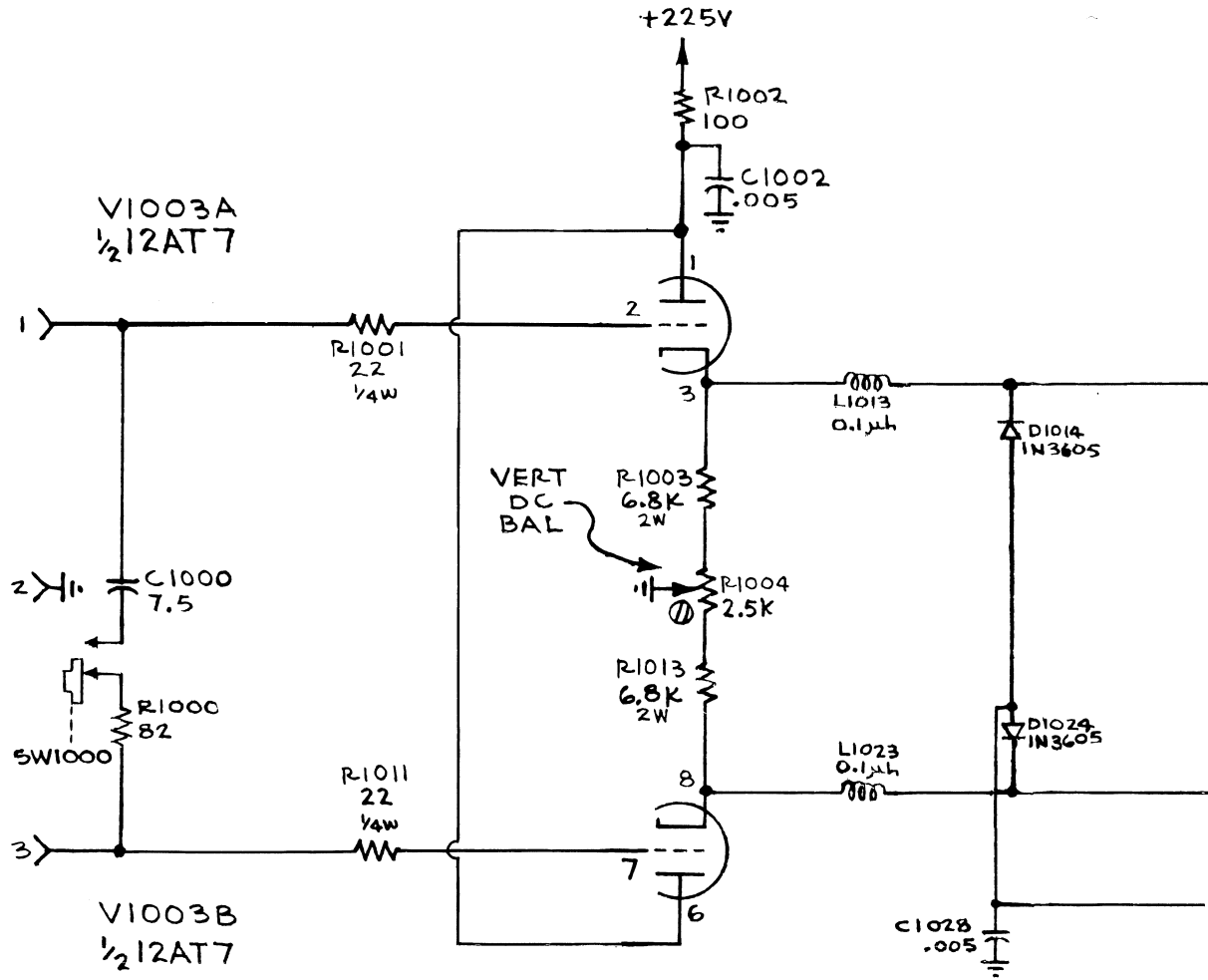


Figure 1-2

2. First stage (V1003) (Fig. 1-2)

- a. Functions as cathode follower.
- b. Input impedance is high.
- c. Input can be shunted by R 1000 and C1000 when SW1000 plunger is pushed in.
 - (1) This limits bandpass for older letter series plug-ins.
 - (2) Letter series plug-in response was not controlled above 30 mc.

(3) Operating a letter series plug-in on an extension with a TU-5 input pulse will allow you to see these aberrations, plus any introduced in the extension.

(4) Plug-ins (1A1, etc.) that can use full bandpass have a hole cut in the back plate to prevent pressing the switch plunger in.

d. R1003, R1004, and R1013 are cathode load resistors.

(1) R1004 can be adjusted to DC balance the vertical amplifier.

e. R1002 and C1002 are decoupling in the plate circuit.

f. L1013 and L1023 are parasitic suppressors.

g. D1014 and D1024 are tied to +55 volt bus, preventing cathodes of input tube from going below this level.

(1) This would occur when the plug-in is removed with power on.

(2) Holding voltage at this level prevents transistorized stages from being damaged by excessive voltages and currents.

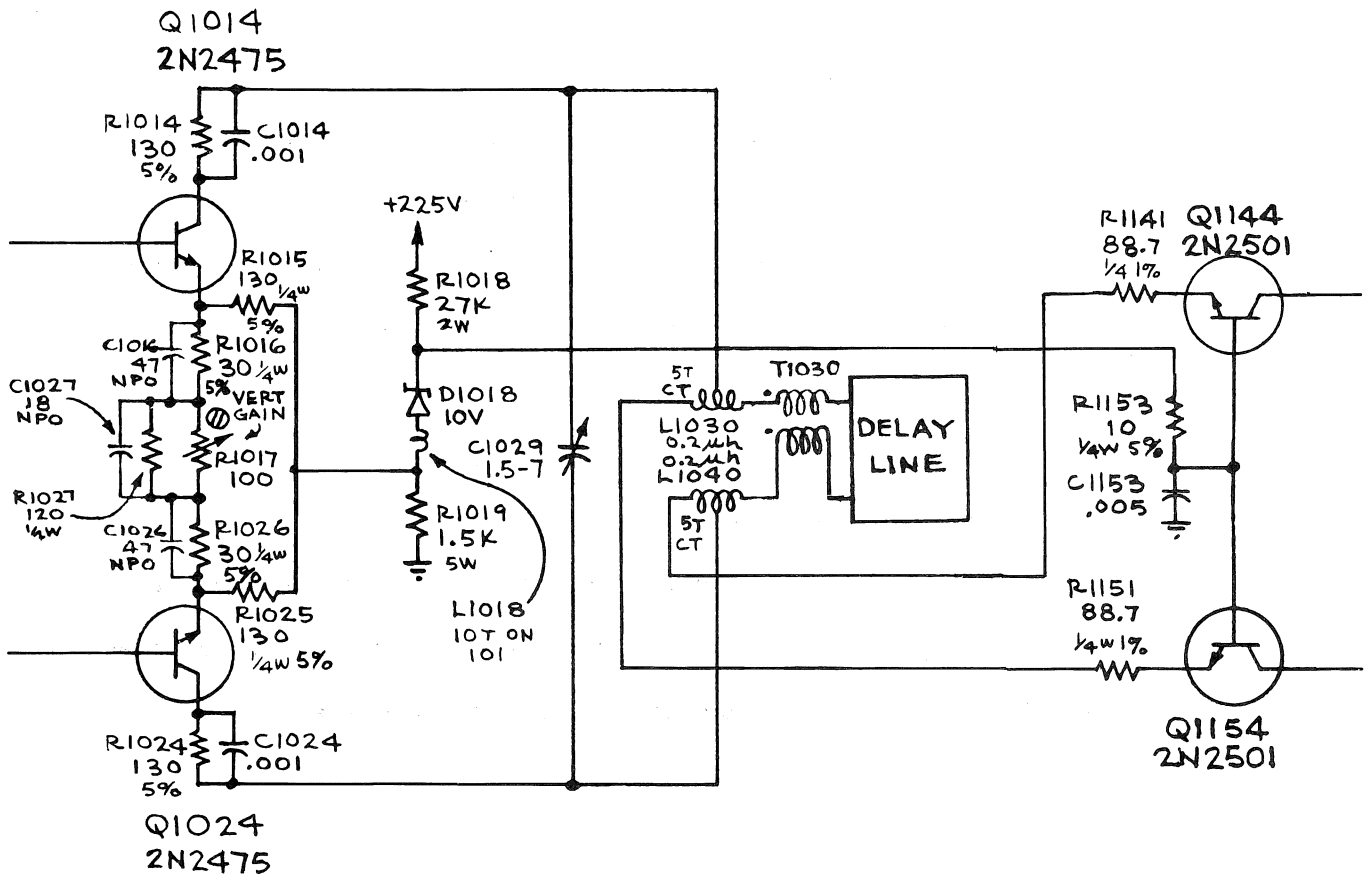


Figure 1-3

3. Second stage (Q1014 and Q1024) (Fig. 1-3)

a. Functions as a push-pull collector coupled amplifier.

- (1) Coupling between emitters controls overall gain and stage frequency response.
- (2) Input is from cathode follower V1003.
- (3) Output is into high impedance points of Tee matching coils L1030 and L1040.

b. Output circuit is through Q1034 and Q1044 emitter circuits, Q1144 and Q1154 emitter circuits, the delay line, L1030 and L1040, R1014 and R1024.

(1) R1014 and R1024 are paralleled by C1014 and C1024 to peak up high frequency response.

(2) Each end of Tee coils L1030 and L1040 look into 93 ohm circuits.

(3) C1029, inparallel with the transistor collector circuits, is adjusted to provide 186 ohms characteristic impedance across the coil taps.

(4) The ends of the Tee coils connected to R1141 and R1151 look directly into first the 88.7 ohm resistors and then into the 5 ohm dynamic impedance of the grounded base transistors, making a total of 93 ohms each side.

(5) The ends of the Tee coil connected to the delay look first into balancing transformer T1030, and then through the delay line, into R1032 and R1041, which are in series with the emitters of Q1034 and Q1044. This circuit looks like 93 ohms, each side.

(6) T1030 balances signals in phase and magnitude.

(7) The delay line is fixed, and has a 186 ohms impedance across it.

(8) C1031 and C1041 raise high frequency response, helping to remove "dribble up" caused by skin effect in the delay line.

c. The emitter current for Q1014 and Q1024 is supplied through R1019 and through R1018 and D1018.

(1) D1018 provides a 10 volt shift and R1018 supplies current for D1018.

(2) AC voltage in the emitter circuit is the result of common mode signals. This circuit feeds the common mode signals to the bases of Q1034, Q1044, Q1144, Q1154 as negative feedback. The feedback prevents common mode signals from being fed through the vertical amplifier and robbing dynamic range, which would cause compression.

- d. R1015 and R1025 connect the transistor emitters to the current supply.
- e. R1016, R1017, R1027 and R1026 shunt R1015 and R1025 between emitters.
 - (1) R1017 is adjustable, and is used to standardize gain to provide 100 mv/cm sensitivity at the input.
 - (2) Because these resistors are not connected to the emitter current source, adjusting R1017 does not affect DC currents in the emitter circuits. of the transistors.
- f. C1016, C1027, and C1026 are connected in series between emitters.
 - (1) These capacitors prevent deterioration of high frequency response.

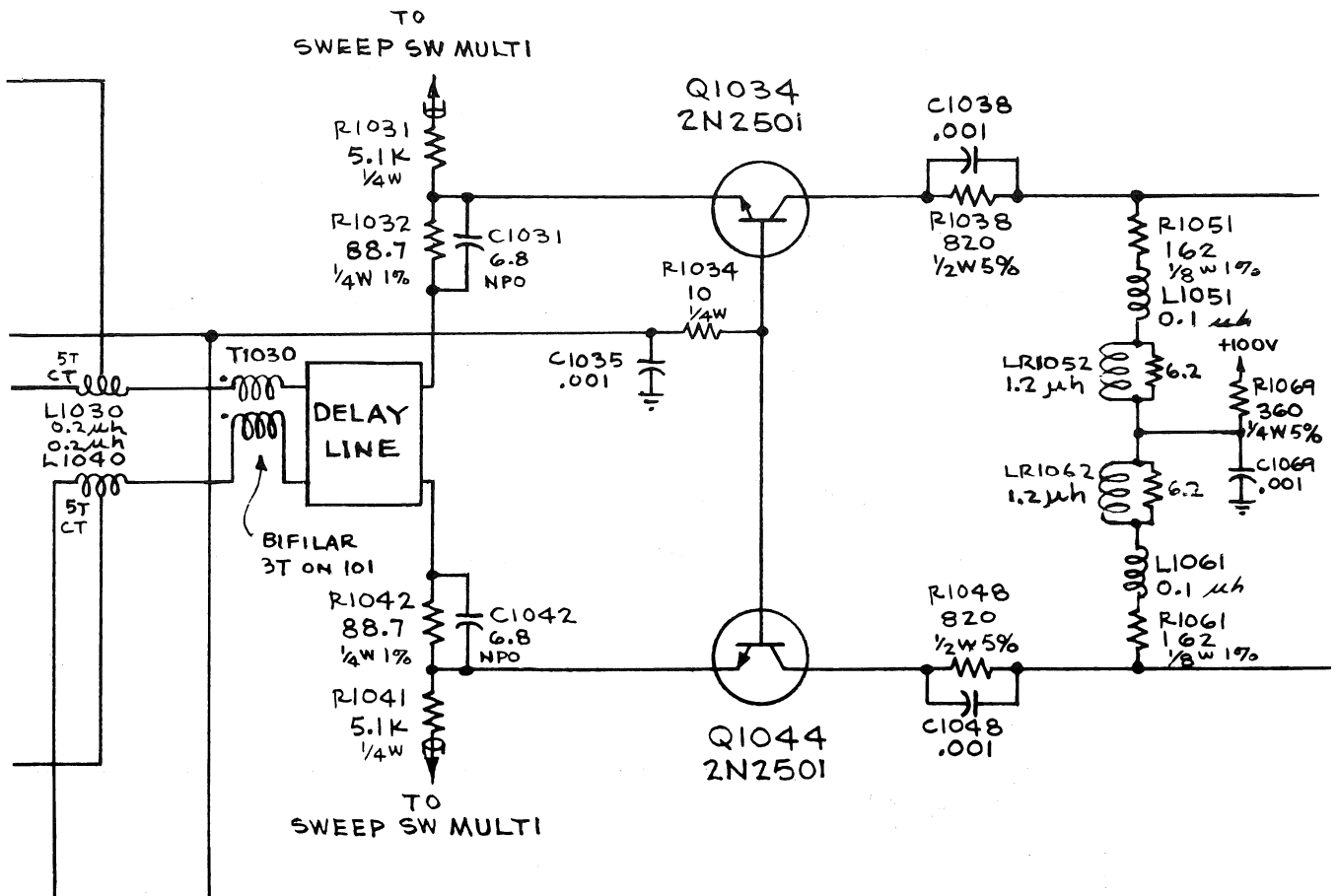


Figure 1-4

4. Third stage (Q1034 and Q1044) (Fig. 1-4)
 - a. Functions as grounded base amplifier on each side.
 - b. Provides 93 ohms termination for each side of the delay line, through R1023, R1042, and the 5 ohm dynamic impedance of the emitter circuits.
 - c. Common mode feedback signals, from D1018 and R1018, are fed to the transistor bases through R1034 and C1035.
 - (1) These signals prevent overdriving from common mode signals.

(2) The R-C circuit limits frequency response of the feedback loop and prevents oscillation.

d. Collector current for the output is supplied through R1069 and series components.

(1) R1069 and C1069 also provide decoupling.

(2) LR1052 and LR1062 provide peaking to help cancel the effects of delay line dribble up.

(3) R1051 and R1061 complete the collector load resistance.

(4) R1038 and C1038 allow output to increase with frequency.

R1048 and C1048 does the same. This compensates both for dribble up and for response rolloff.

e. Currents are supplied through R1031 and R1041 for vertical trace separation.

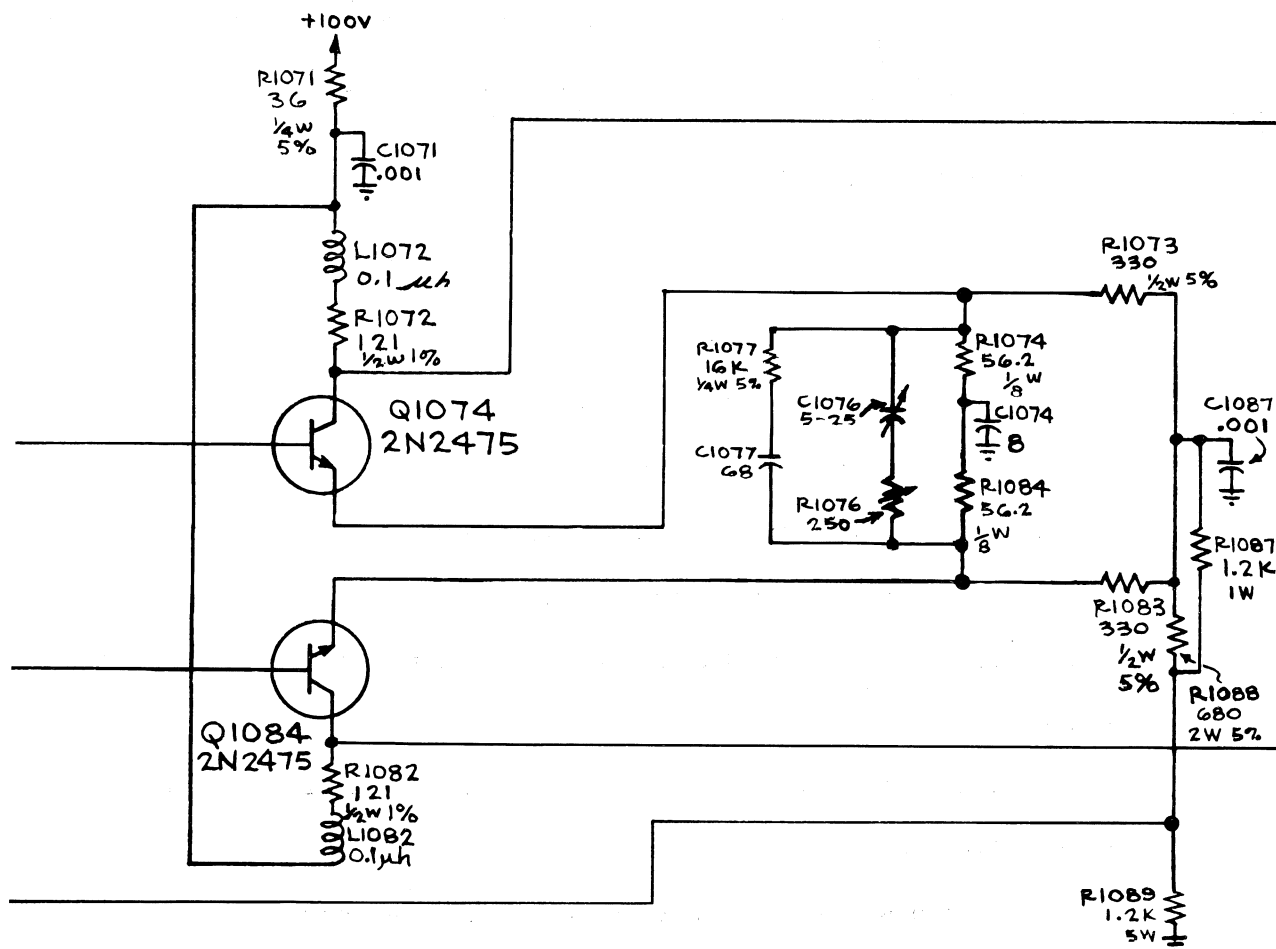


Figure 1-5

5. Fourth stage (Q1074 and Q1084) (Fig. 1-5)
 - a. Functions as push-pull collector coupled amplifier.
 - b. Input is from collector circuit of the previous stage.
 - c. Collector loads are L1072, R1072, L1082 and R1082.
 - (1) The coils provide high frequency boost of the output by shunt peaking.
 - (2) R1071 and C1071 are decoupling.
 - d. Emitter current is supplied by R1089 in series with R1088 and R1087.
 - (1) The current through R1089 sets the voltage on D1014 and D1026 at 55 volts.
 - (2) C1028 and C1087 are decoupling. Since this circuit has a constant current with normal operation, the capacitors do not affect frequency response.
 - e. Current for the individual emitters flows through R1073 and R1083.
 - f. Additional resistive coupling for the emitters is through R1074 and R1084.
 - (1) C1074 provides a high frequency ground to bypass common mode signals.
 - g. Coupling time constants are provided by R1076, C1076, R1077, C1077.
 - (1) These improve high frequency response.
 - (2) These compensate for dribble-up.
 - (3) R1076 and C1076 provide response adjustment.

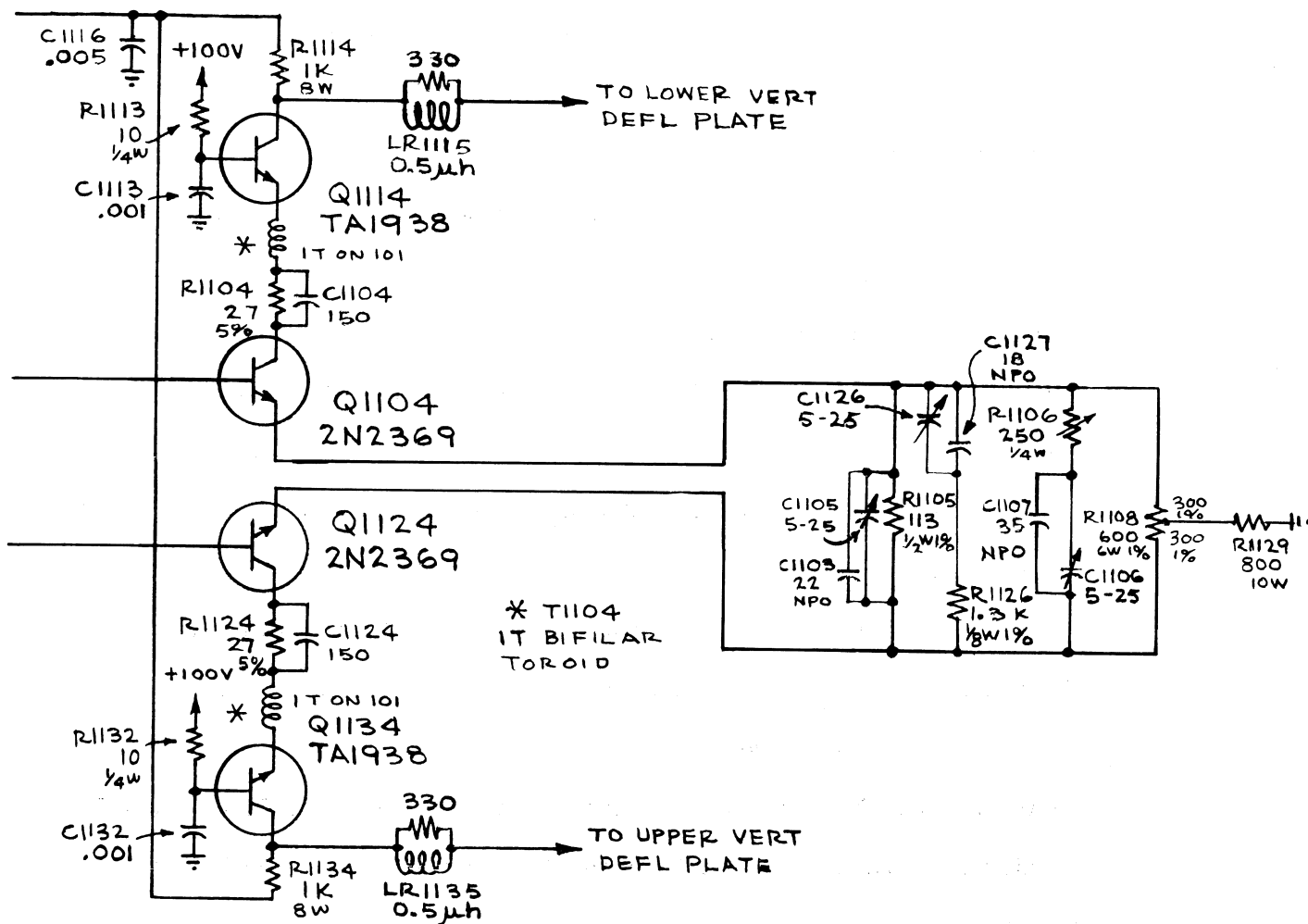


Figure 1-6

6. Fifth (output) stage (Q1104, Q1114, Q1124, Q1134) (Fig. 1-6)
 - a. Functions as a push-pull pair of cascode amplifiers.
 - b. Input is from collector circuit of previous stage.
 - c. Output of Q1104 and Q1124 is from collectors, which drive Q1114 and Q1134 as grounded base amplifiers.
 - (1) Gain is derived in Q1104 and Q1124.
 - (2) Output load resistors are R1114 and R1134.

(3) Gain of Q1114 and Q1134 is nearly 1 (actually about .98).

(4) Q1114 and Q1134 isolate the circuit output from Q1104 and Q1114.

d. R1104, C1104, R1124, and C1124 prevent oscillation, along with the ferrite beads on the interconnecting wires.

e. LR1115 and LR1135 are parasitic suppressors.

f. Base current for Q1114 and Q1134 is supplied through R1113 and R1132.

(1) These resistors, with C1113 and C1132, are actually decoupling, rather than current limiters.

(2) Base voltage is not critical, since the emitters look into the high impedance collectors of Q1104 and Q1124.

(3) Base current is controlled solely by emitter current supplied through Q1104 and Q1124.

g. R1118 and C1116 are decoupling.

h. Emitter current for both sides is supplied through R1129.

i. Resistive coupling between stages is supplied by R1105, R1128, & R1108.

j. C1103, C1105, C1106, C1107, C1126, C1127, R1106, and R1126 all are parts of frequency response correction circuits.

(1) These circuits are adjusted to assure correct frequency response on the CRT.

(2) Corrections are needed for input signal, output response, and non-linear amplitude and phase response within the amplifier.

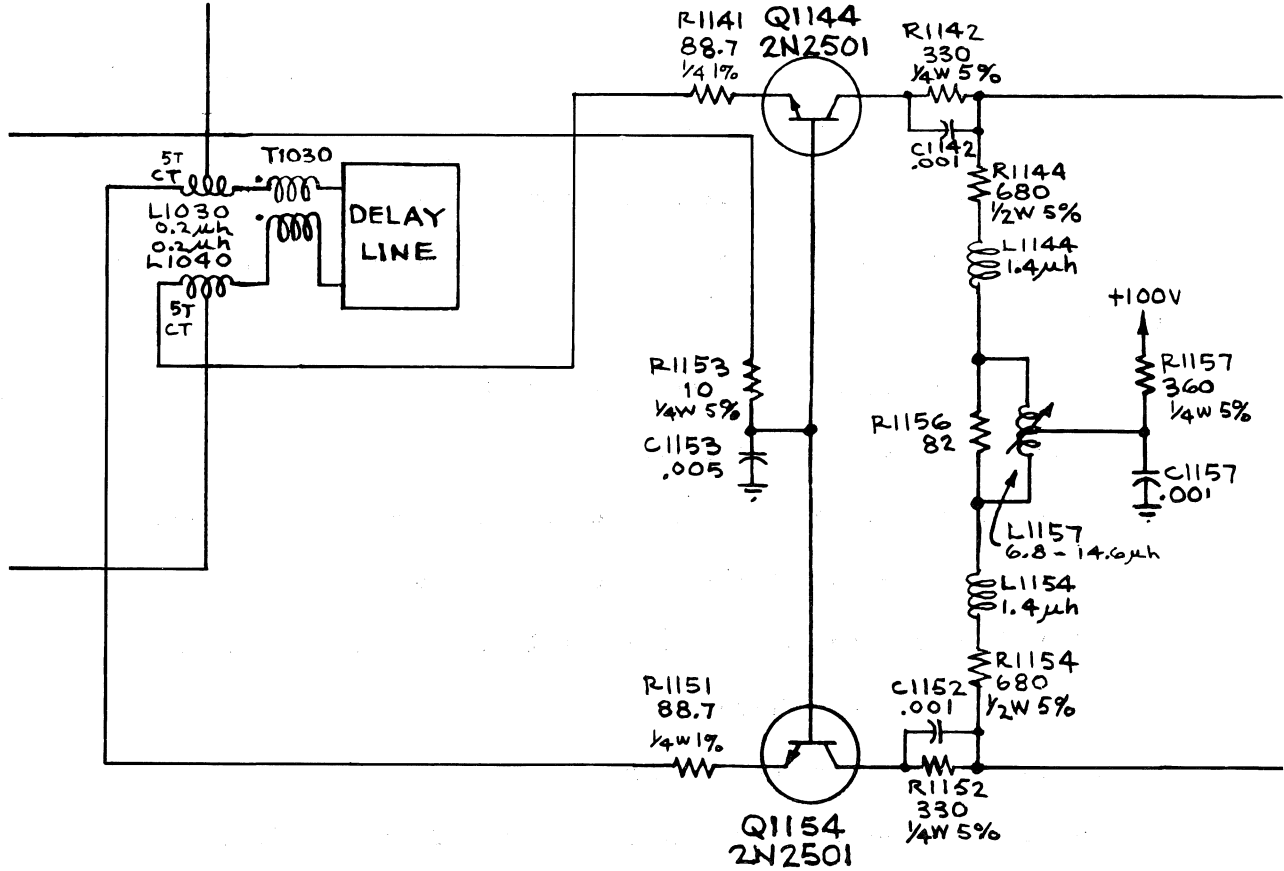


Figure 1-7

7. Trigger takeoff first stage. (Q1144 and Q1154) (Fig. 1-7)
 - a. Input is from 93 ohm Tee coils L1030 and L1040.
 - b. Each transistor emitter looks like 5 ohms dynamic impedance, in series with R1141 and R1151.
 - (1) The resistors and transistor emitters terminate the Tee coils in their characteristic impedance.
 - c. Collector transistors provide base current for the next stage.

- (1) Q1144 and Q1154 are for termination and isolation of the delay line circuit from the rest of the trigger takeoff circuit.
- (2) R1142, C1142, R1152, and C1152 form high frequency boosting networks that help cancel the effects of delay line "dribble up".
- (3) Collector current is supplied through decoupling circuit R1157 and C1157.
- (4) R1156, L1157, L1144, L1154, R1144, and R1154 are collector loads which provide high frequency boost to help cancel the effects of delay line "dribble up".

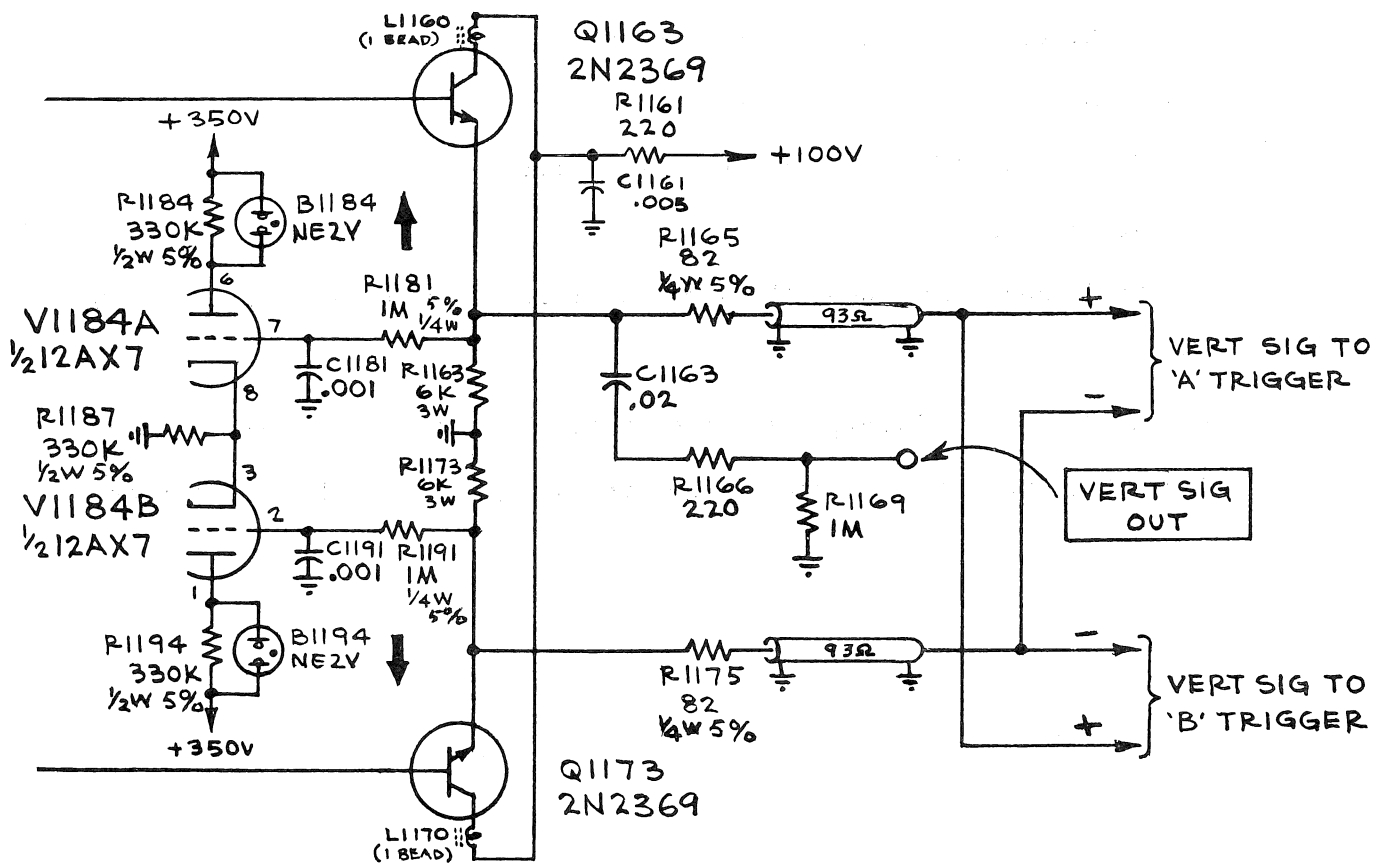


Figure 1-8

8. Trigger takeoff output stage (Q1163 and Q1173) (Fig. 1-8)
 - a. Functions as emitter follower.
 - b. Output is through R1165 and R1175 into 93 ohm cable which transmits signal to sweep trigger circuits.
 - (1) R1165 and R1175, in series with the transistor emitter circuits, terminate the cables.
 - c. Emitter current is supplied through R1163 and R1173.
9. Vertical Signal Out
 - a. Provides + vertical signal through C1163 and R1166 to front panel connector.
 - b. Output is 400 mv/cm of display, through 300 ohms.
 - c. R1169 keeps average DC level out at 0 volts.
10. Screen position indicator lamps.
 - a. V1184A and B light B1184 and B1194 when one section of tube is forward biased.
 - b. R1184 and R1194 shunt the indicators to carry plate current for the tubes.
 - c. R1181, C1181, R1191, C1191 are decoupling circuits to isolate the indicator circuit and present a low frequency signal only to the tubes.

2. "A" TRIGGER CIRCUIT

1. The A and B trigger circuits on the 546 and 547 are identical, except for circuit numbers. This discussion will refer to the A trigger circuit only. The 544 has only 1 trigger circuit, corresponding to the A trigger circuit on the other two oscilloscopes.

2. Input is selected by front panel switches. The source may be from the vertical amplifier, the plug-in, and the external jack (J5), SW201 selects the source. In the NORM position, a push-pull signal (800 mv/cm of display) is fed through SW201 to the SLOPE switch, SW210. In the other input positions, the - signal from the vertical amplifier is not used, and the trigger - input is referenced to ground through C204. SW205 selects the coupling, AC, ACLF Reject, and DC. In the DC position, the - input is also referenced to ground through C204, if NORM is selected on SW201.

3. TRIGGERING LEVEL control:

a. Control sets DC level on - trigger input.

(1) This is why there is no DC trigger connection to the - input.

b. Current is supplied through R214, R215, R216, and R217 with R218 shunting, to provide a 25 volt range of trigger adjustment (with the trigger level knob pulled out). With the knob pushed in, the range is reduced to 2.5 volts, by cutting out R217.

(1) Two ranges allow both a wide dynamic range for big signals, and sensitive adjustment when the dynamic range is not needed.

c. C218 decouples any transients that may appear in the power supplies feeding the level control circuit.

d. R219 provides a 1 megohm input impedance for - trigger signals

when AC internal coupling is used.

4. The SLOPE switch, SW210, can feed trigger and level signals either straight in to the trigger amplifier, or reverse inputs to reverse the polarity of the trigger recognition circuit.

5. Trigger amplifier: The trigger amplifier is a two stage push-pull amplifier with a single ended output, driving the trigger recognition diode.

A vacuum tube input circuit drives a transistor output circuit.

a. V224A and B are a differential input amplifier.

(1) The positive-going input is fed to the grid of V224B, when a Trigger is regenerated by D245,

(2) The negative going input is fed to the grid of V224A.

(3) The triggering level control voltage is fed to the - input.

(4) The trigger signal and the level control voltage have a common-mode and a differential component. The common-mode component is nulled out by the triggering level signal, leaving the differential component to operate the trigger recognition diode.

(5) The cathodes of both tube sections are fed through R224, a long-tail source. This allows the cathodes to move up and down over the 5 volt dynamic range of trigger recognition without substantial change in tube current.

(6) The section of V224 having the higher grid voltage conducts the most current, of the 10 ma supplied to the cathode circuit.

The trigger recognition section recognizes a trigger signal when current is transferred from V224A to V224B.

(7) R225, in the plate supply, sets the output voltage balance of the two tube sections to allow the trigger recognition diode to operate at the desired point. This point is where the grid voltage of the two tube section is equal.

b. Q234 and Q244 are emitter coupled, with the collector current through Q244 operating the trigger recognition diode.

(1) This stage is slightly unbalanced, because one side draws current through the tunnel diode. A 10 ma diode is used as the best compromise between noise and trigger jitter.

(2) The vacuum tube input amplifier provides a high input impedance for external trigger signals.

(3) The common mode rejection ratio of the two stages is essentially multiplied, reducing trigger jitter.

c. The trigger recognition diode, D245, is switched when Q244 conducts.

(1) R245 allows close adjustment of sensitivity.

(2) L244, a ferrite bead, prevents the tunnel diode from breaking into sustained oscillation. This allows the tunnel diode circuit to be more sensitively adjusted.

(3) Output to the sweep generator gating circuit is taken directly from the tunnel diode. T252 inverts the output signal and feeds it, with stepped-up voltage, to the Auto circuit. The Auto circuit uses this pulse to stop free-running for a period, allowing the next trigger pulse to operate gating circuit.

(4) L252 raises the output impedance of the regenerated trigger signal, and forces the trigger recognition diode to count down high frequency input signals (above 2 mc). This counting down, or the prevention of high rep-rate trigger regeneration, prevents jitter in the gating circuit.

3. "B" TRIGGER CIRCUIT

The B trigger circuit, except for component designations, is identical to the A trigger circuit. Except for the external input, trigger inputs are shared with the A trigger circuit. Refer to the preceding chapter for a discussion of circuit operation.

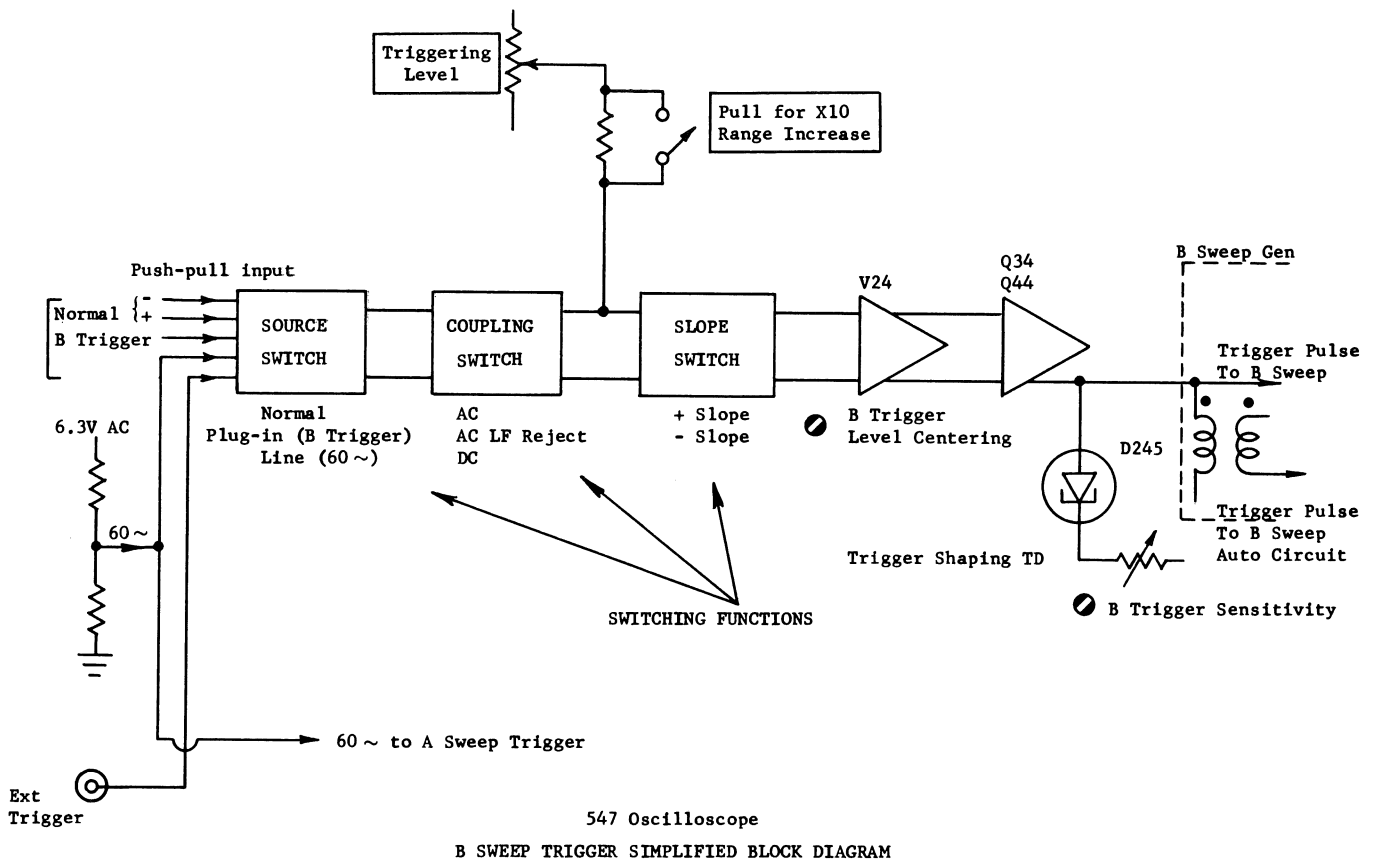


Figure 3 - 0

'B' SWEEP GENERATOR CIRCUIT DESCRIPTION

- I. Preliminary Circuit Description
(From 547 Preliminary Training Package)
- II. Detailed Circuit Description (B Sweep Generator)
- III. B Sweep Generator DC Voltage Measurements

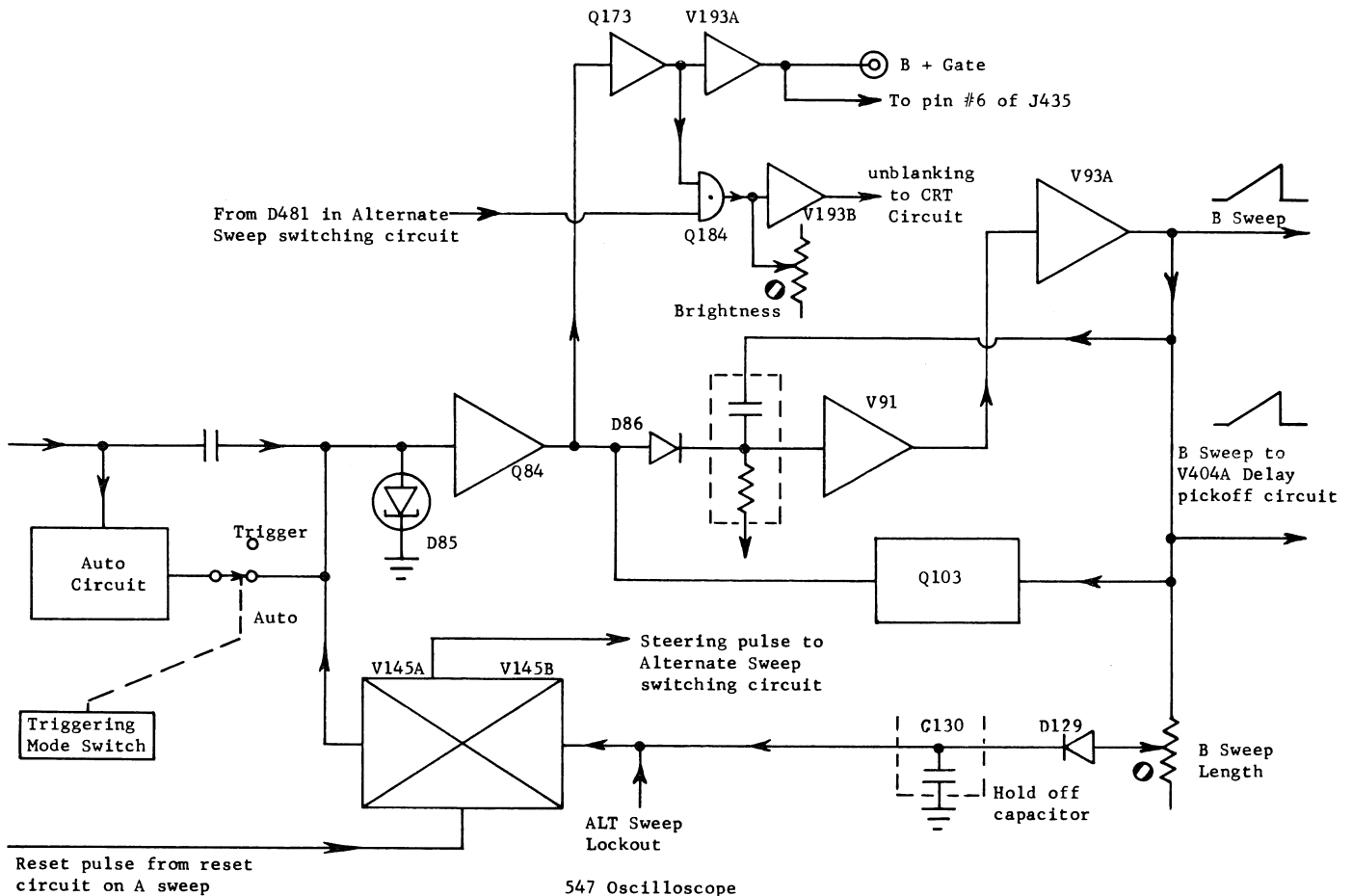
547 B Sweep Generator

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Sweep Generator

For purposes of explanation, assume that the HORIZONTAL DISPLAY switch is in the B position, the SINGLE SWEEP switch is in the NORMAL position, the TRIGGERING MODE switch is in TRIG position and that no trigger is being applied. A block diagram is shown in Fig. 1. Under these conditions, tube V145A in the holdoff multivibrator is conducting and has V145B cut off. When V145A is conducting and no trigger is being received from the trigger generator, D85 is in its low voltage state. Under these conditions, transistor Q84 is cut off, and D86 is conducting. Miller tube V91 is conducting. The circuit is now ready to be triggered.



547 Oscilloscope

B SWEEP BLOCK DIAGRAM

The B sweep is similar to the A sweep

Figure 1

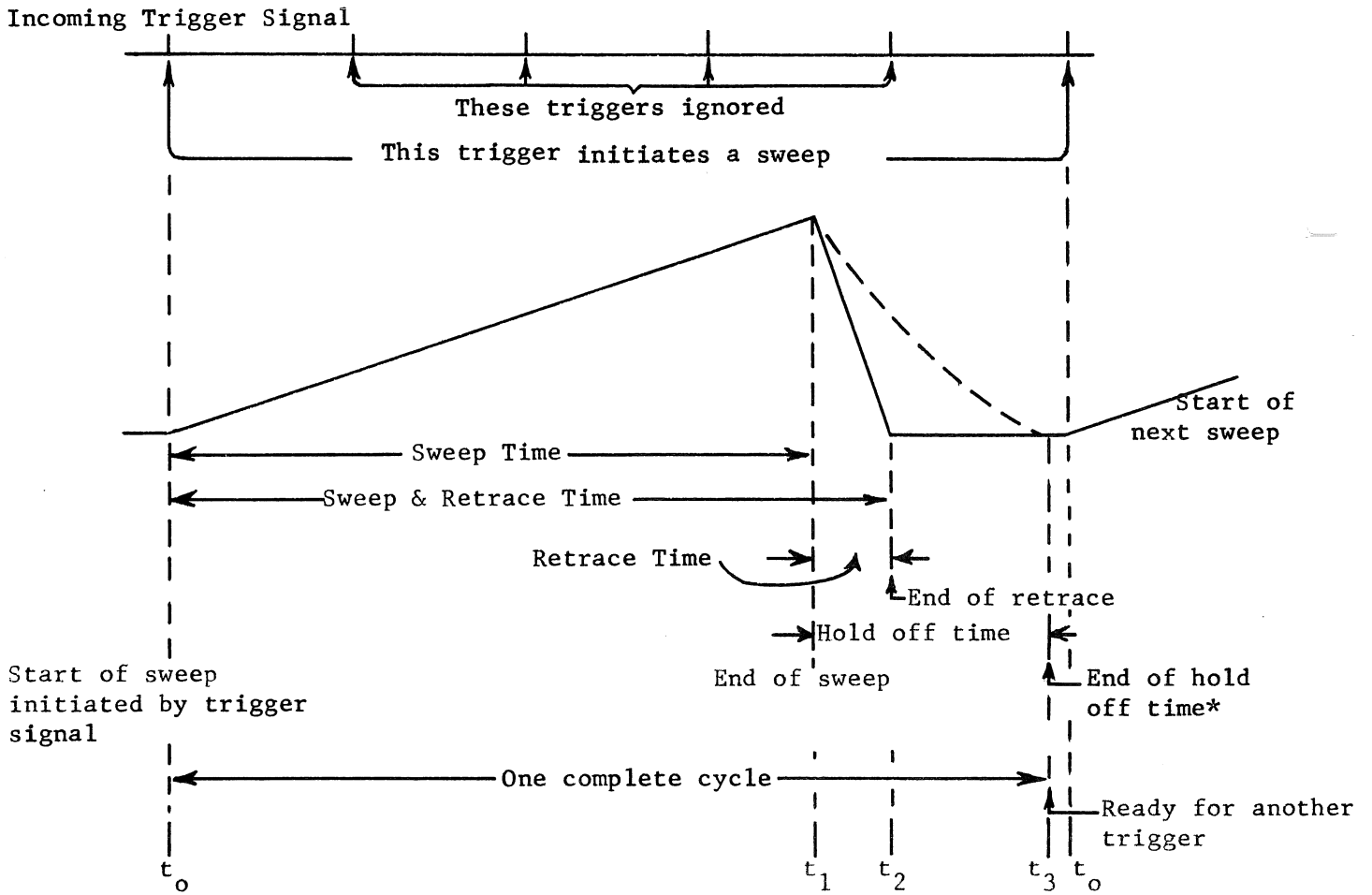
Assuming a trigger pulse is now applied, the positive trigger from the B sweep trigger circuit is coupled to tunnel diode D85 and causes D85 to switch to its high state, where it remains after the trigger pulse decays to zero. When D85 switches to its high state, it biases Q84 into saturation, and the voltage change across Q84 applies forward bias to Q173 and reverse biases Q89, Q103, and diode D86. When D86 is reverse biased, current is fed through R90 to C90. 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 bootstrap capacitor C94 (Refer to schematic) couples the rising cathode voltage to the plate circuit of V91, compensating for losses introduced by stray capacity. The positive going cathode voltage of V93A forward biases D129 and starts raising the voltage on the grid of tube V145B in the holdoff multivibrator. At a point determined by the setting of sweep length control 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 diode D86. When D86 becomes forward biased, it applies a positive current to the grid circuits of V91 which runs back the Miller circuit and ends the sweep. When the sweep ends, V145B conducts and 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 conduct and assume control, D85 is again biased to a point where it can accept another trigger signal.

Automatic Stability Circuit

Transistors Q65 and 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 TRIG position, the switch grounds the collector of Q75 and disables the AUTO STABILITY circuit. When the triggering MODE switch is in AUTO STABILITY position, the sweep generator free runs if no trigger pulses are received from the trigger generator.

When the auto multi is allowing the B sweep generator to free run, Q65 is conducting, and Q75 is cut off. The collector voltage of Q75, dropped by D76, is high enough to keep D79 forward biased, which supplies enough current to return D85 to the high state at the end of the holdoff period. This state continues, causing the sweep generator to free run, as long as a trigger signal is not recognized and regenerated by the trigger circuit. When a trigger signal is regenerated, it appears across the primary of T52 and induces a signal that goes negative at the base of Q65, cutting Q65 off. The resulting rise at the collector of Q65 is coupled across C67 to the base of Q75, turning Q75 on. This lowers the collector voltage of Q75, discharging C76 through R76 and holds D79 reverse biased until the collector of Q75 can again rise to 22 volts, biasing the zener and supplying current to D79. The multivibrator, Q65 and Q75, quickly resets, turning Q75 off, and allowing C76 to charge through R75 and R76. Since the collector of Q75, when turned off, presents a very high impedance, it can be ignored in the recovery time. Thus, the circuit of D85 remains triggerable for about 50 milliseconds or longer before

free running operation occurs. This is different from the 545 type auto circuit in that it is located in the sweep gating circuit, and that it is locked out whenever trigger signals are being received more often than the recovery time.



*End of lockout can extend total holdoff time. (See alternate Sweep lockout)

SWEEP WAVEFORM

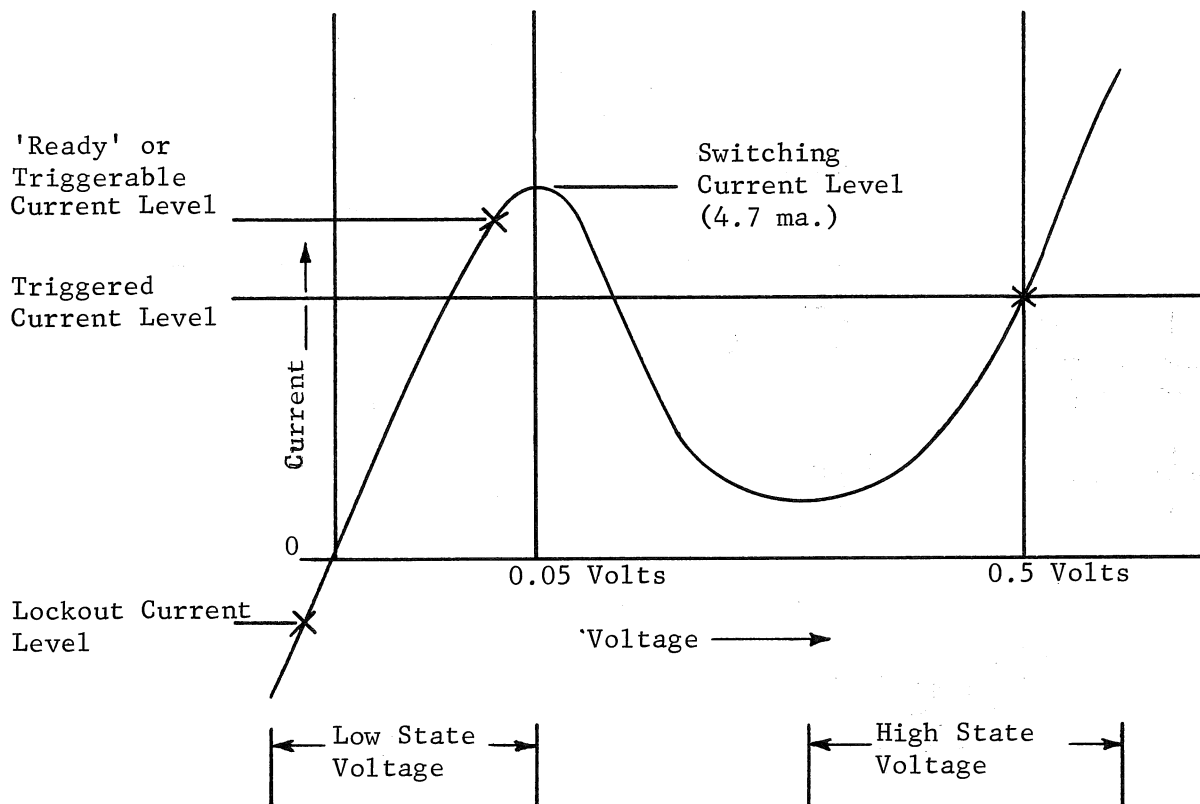
Figure 2

SWEEP GENERATOR

PART II DETAILED CIRCUIT DESCRIPTION (B SWEEP GENERATOR)

The preliminary circuit description (Part I) is suggested as a prerequisite to the following discussion. All voltages herein were obtained from type 547 serial #111 with a 20,000 ohm/volt multi-meter. Refer to the schematics and voltage tables during this discussion.

1. OPERATING MODE (Preset Conditions): Unless otherwise stated, the appropriate controls are set as follows:
 - A. HORIZONTAL DISPLAY switch to B
 - B. SINGLE SWEEP switch to NORMAL
 - C. TRIGGERING MODE to TRIG



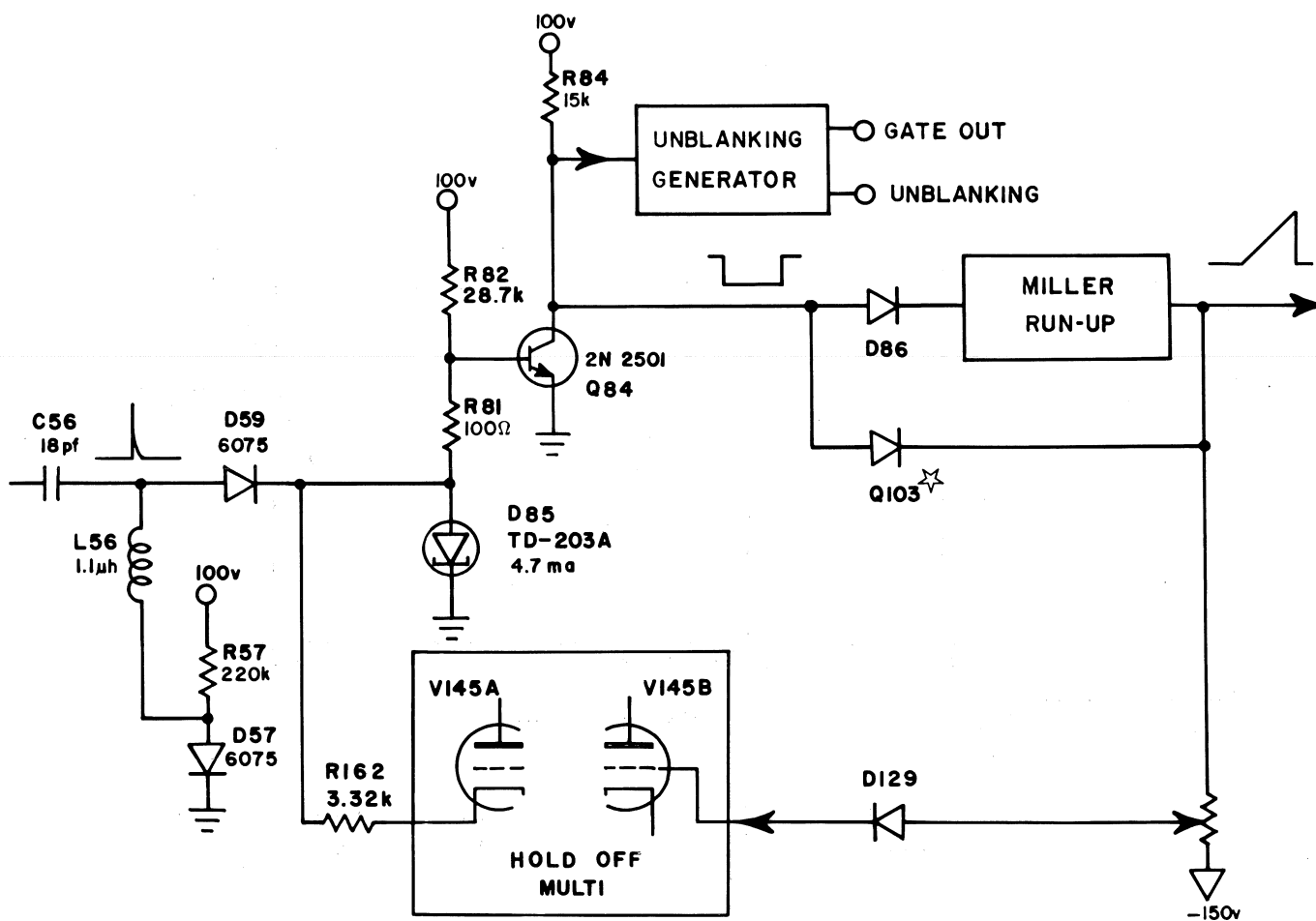
Voltage and current levels for D85 Tunnel Diode
Figure 3

2. SWEEP GATING CIRCUIT (See Figure 2 and the schematic)

A. Consists of D85 and Q84

B. D85, the tunnel diode, has two stable voltage states, low voltage and high voltage. (See Figure 3)

1. In the low voltage (50mv) state D85 can be biased to a very low current (or even reverse biased) to the point where it cannot be triggered. Just after a sweep, the Hold-off and lockout circuit V145A & B (to be discussed later) biases D85 down into its low current (or reverse current) condition where it cannot be triggered by the trigger circuit. This is a 'Hold-off' condition. The hold-off period is illustrated in Figure 2 between times t_1 and t_3 .
2. In the low voltage state D85 can also be biased high on its $I_p - E_p$ curve where a small increase in current caused by a positive going trigger pulse can trigger it into the high voltage (500mv) state.



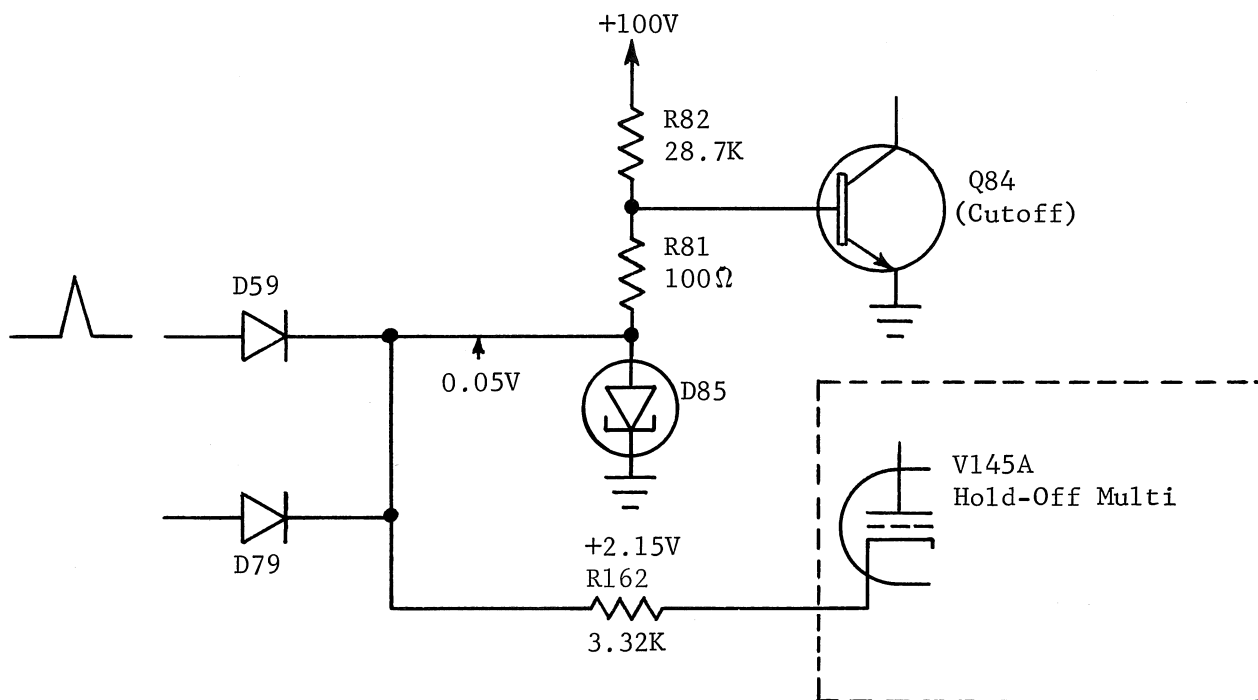
547 SWEEP GENERATOR

☆Q103 in its simplified function acts like a diode similar to that in the 530 & 540 series sweep generators.

Figure 4

C. Current paths for D85 (See Figure 5 and 6).

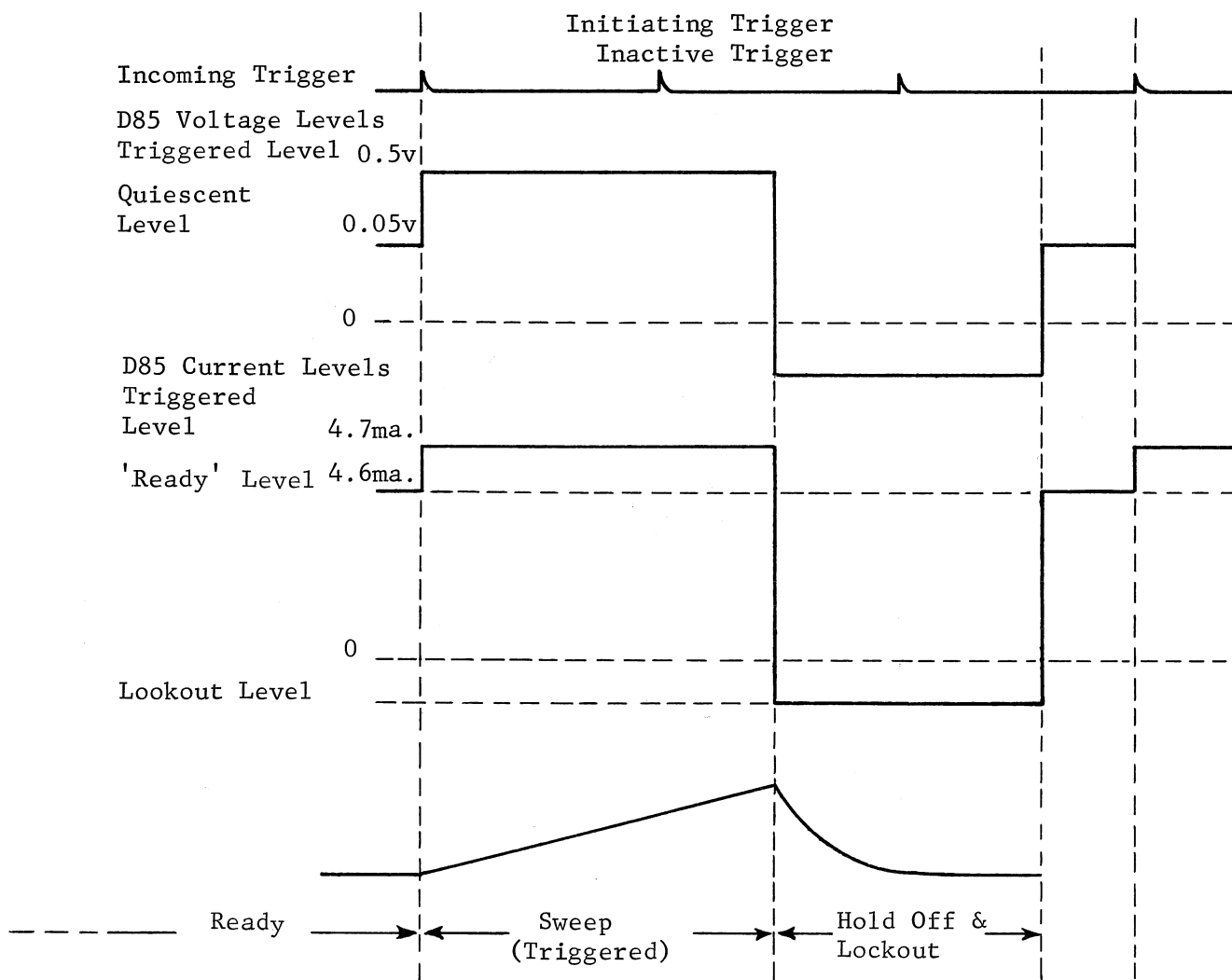
1. D79 (a Silicon diode) is back-biased since D76 zener diode cathode is grounded when in the TRIG mode.
2. D59 (a Germanium diode) is cut-off but biased very near conduction (within about .05 volts) because D57 is conducting about $\frac{100v}{220K}$ or about 0.455 ma. Through R57 to the 100v supply. During conduction D57 has about 0.4 volt across it. For D59 to conduct it must also have about 0.4 volt forward drop but the D85 tunnel diode 'ready' level is .05 volts holding D59 just below its required 0.4v conducting level.



D85 Tunnel Diode is 'ready' for a trigger

Figure 5

3. One current path to establish D85 bias current is through R81 & R82 to the 100v supply and another is through R162 to the cathode of V145A which is at +2.15v.
4. D85 tunnel diode is rated at 4.7 ma. This is the current required to switch it from the .05 volt 'low' state to the 0.5 volt 'high' state (approximate voltages) which will initiate one sweep waveform.
5. Knowing the 'ready' voltage level of D85 and of V145A we can compute the approximate bias current for D85 which must be somewhat below 4.7 ma.



D85 voltage and current levels during 'ready', sweep, & hold-off periods.
Figure 6

6. The current from D85 to the +100v supply is:

$$\frac{100\text{v} - .05\text{v}}{28.7\text{K} + 100\Omega} = \frac{99.9\text{v}}{28.8\text{K}} = \underline{3.46 \text{ ma.}}$$

7. The current from D85 through R162 to V145A cathode is:

$$\frac{+2.15\text{v} - .05\text{v}}{3.32\text{K}} = \underline{0.632 \text{ ma.}}$$

8. Total D85 bias current is:

$$3.46 \text{ ma.} + 0.632 \text{ ma.} = \underline{4.092 \text{ ma.}}$$

9. The trigger circuit must supply enough additional current in the form of a trigger (its AC coupled) to pull 4.7 ma. through D85. This additional trigger current must be at least:

$$4.7 \text{ ma.} - 4.092 \text{ ma.} = \underline{0.608 \text{ ma.}}$$

10. Figure 6 shows the relationship of D85 current and voltage to time, and to the resulting sweep output waveform.

D. Q84 is the Sweep Gating Amplifier.

1. With D85 in its low state of .05 volts, Q84 is cut-off. Q84 is actually forward biased but not enough for conduction. It (being a silicon transistor) requires a forward bias of about 0.6 volts to conduct.
2. When D85 switches to the high state of 0.5 volts it is still about 0.1 volt below the conduction level for Q84. Therefore, a 100 ohm resistor is located between D85 and R82. It sets Q84 base at a higher Quiescent DC Voltage (closer to its conduction level).
3. During the 'ready' state Q84 is cut-off and its base bias can be estimated as follows:

From step C6 the current through R81 & R82 is 3.46 ma, therefore, the voltage across R81 is:

$$3.46 \text{ ma.} \times 100\Omega = \underline{0.346 \text{ volts}}$$

Adding D85 'ready' voltage to this we get:

$$0.346 \text{ volts} + 0.05 \text{ volts} = \underline{0.396 \text{ volts}}$$

4. When D85 is triggered from the .05 volt level to the 0.5 volt level, this change of about 0.45 volts is more than enough to insure that Q84 collector will conduct to the saturation level.

5. In the 'ready' state Q84 is cut-off and its collector is at about 5.1 volts. This voltage is established by current from R87, R85, R86, R83, D86 and Q103 through R85 along with the current of R87 through R84 to the 100v supply.

6. The Quiescent voltage level of D86 anode is -0.32v.

7. With Q84 collector at 5.1v the total current through R84 is:

$$I_{R85} = \frac{100v - 5.1v}{15K} = \frac{94.9v}{15K} = \underline{6.31 \text{ ma.}}$$

8. Since D86 anode is Quiescently at about -0.32 volts the current through R85 is:

$$\frac{5.1v + 0.32v}{1K\Omega} = \underline{5.42 \text{ ma.}}$$

9. The major portion of this current is through R86 and is about:

$$I_{R86} = \frac{150v - 0.32v}{51K} = \underline{2.93 \text{ ma.}}$$

10. The current through R83 & D83 is about:

$$\frac{150v - 0.32v - 0.4v}{390K} = \underline{0.383 \text{ ma.}}$$

This is a very small portion of the total current through R85. The 0.4v figure in the above calculations is due to the forward voltage drop of D83, a type 6075 Germanium diode.

11. Now the remainder of the current through R85 is supplied by Q103 and D86 and is about:

$$I = 5.42 \text{ ma.} - 2.93 \text{ ma.} - 0.383 \text{ ma.}$$

$$= 2.1 \text{ ma.}$$

12. The current of 2.1 ma. is shared by Q103 and D86 in a ratio depending on the value of R90, the timing resistor. If the sweep range switch is in the 1 msec/cm range R90 is about 1.4 meg. so the current through D86 from the -150 supply is:

$$I_{D86} = \frac{-150v + 1.17v}{1.4 \text{ meg.}} = \underline{10.6\mu\text{amp.}}$$

The -1.17v in the above equation is the measured voltage at V91 grid. Apparently then, most of the current is from Q103 and this current is:

$$2.1 \text{ ma.} - 0.106 \text{ ma.} \simeq 2 \text{ ma.}$$

13. Actually the total Quiescent current through D86 can not exceed about:

$$\frac{150\text{v} - 1.17\text{v}}{143.9\text{K}} = \underline{1.03 \text{ ma.}}$$

where 143.9K is the lowest value of R90 (timing resistor) encountered in any range of the sweep time/cm switch.

E. D86 and Q103 are the Sweep Gating 'diodes'

1. For those of you who are familiar with the sweep gating diodes of the 530 & 540 series sweep generator circuits, Q103 and D86 function nearly the same. It is suggested in step D-13 that some of the current through R85 & R84 to the +100 volt supply is shared by D86 and Q103 in the Quiescent state. This current established an equilibrium voltage at V91 grid with the help of the feedback loop through V91, V93A, Q103 & D86. The voltage on V91 grid is about -1.17 v.
2. With -1.17 volts on V91 grid, the plate is conducting at maximum current and sets at +27 volts. The CRT beam is at the left hand side of the screen.
3. Since the gain of V91 is high, the feedback loop described above insures that the sweep will always start at the same point for various sweep ranges, tube characteristics, trigger rates etc.
4. Q103 could have been a diode as in the 530 & 540 series oscilloscopes. However, with its current gain we have a better feed-back loop which will maintain a constant starting point even if the timing resistor is changed by moving the sweep range switch.
5. When the sweep is triggered Q84 conducts. Its collector drops from 5.1 volts to the saturation level of about 0.12 volts.
6. This causes Q103 emitter to drop below the base reverse biasing it.
7. It also reverse biases D86 whose cathode cannot drop faster than C90 is allowed to charge through R90.
8. Thus, Q103 and D86 are reverse biased releasing the miller sweep generator which immediately begins sweep.

3. The Sweep Generator

- A. This is a Miller Run-up type of sweep generator consisting of V91 and V93A.
- B. The Sweep timing is determined by C90, R90 and the -150 volt supply voltage.

C. Quiescent Conditions

1. The current through Q103 and D86 through R85 holds V91 Grid Voltage at -1.17 volts.
2. The V91 plate voltage is thus held at +27 volts.
3. The Feedback loop through V91, V93A, D100, Q103 and quiescently D86 insures equilibrium with V91 plate quiescently at +27 volts.
4. Not only does this establish a stable starting point for the sweep but V91 is always biased at an operating point below the zero bias grid current level for V91. If V91 were operated too close to zero bias the start of the sweep would be non-linear.
5. Total voltage across the timing capacitor is:

$$\begin{aligned}
 E_c &= E_k - E_g \\
 &= -1.97 + 1.17 \\
 &= \underline{-0.8 \text{ volts}}
 \end{aligned}$$

where E_c is total voltage across C90, E_k is the voltage at the top of C90 (Same as D98 cathode in voltage tables) and E_g is the voltage on V91 grid. The timing cap actually has a reverse voltage across it. However, this is of no consequence.

6. The quiescent current through R90 (when sweep time/cm is at 1 msec/cm) is:

$$\frac{E_r}{R_{90}} = \frac{150 \text{ v} - 1.17}{1.4 \text{ meg } \Omega} = \underline{0.106 \text{ ma.}}$$

where E_r is the voltage across R_{90}

7. V91 plate quiescently holds V93A grid at +27 volts. This causes the cathode voltage to be at +33.7. The grid bias is:

$$27 \text{ volts} - 33.7 \text{ volts} = -6.7 \text{ v}$$

The operating plate voltage is:

$$+225 \text{ v} - 33.7 \text{ v} = 191.3 \text{ volts}$$

Looking at the 6DJ8 tube curves, we find that the cathode current is approximately 0.9 ma.

8. D97 (Zener diode) drops the 33.7 v at V93A cathode to -1.32 volts at D98 Anode.

9. Note in the B Sweep voltage tables that the total sawtooth amplitude at D98 cathode is about +98 v - (-1.97) or approximately 100 volts while at the output (Junction of R99 and C98) the voltage swing is only (2.25 v - 1.84 v) or 0.41 volts, indicating that the output is current driven. Further analysis of the Horizontal Amplifier schematic will show that the input stage is an operational amplifier where R99 here (49.9K) serves as R_i and R544 and R545 in the Horizontal Amp. serve as R_f (operational amplifier theory).

D. Sweep Waveform is Generated.

1. An incoming trigger causes D86 and Q103 to disconnect.
2. The 106 μ amp from -150 v supply through R90 timing resistor can no longer go through D86 so it is diverted to the bottom end of C90.
3. This current tends to build up a negative charge on the bottom end of C90.
4. As the bottom of C90 goes slightly negative V91 grid is carried down with it, thus reducing plate current.
5. As plate current decreases, the plate voltage increases (goes more positive).
6. V93A is a cathode follower and its cathode moves approximately as much as V91 plate.
7. The cathode voltage of D98 rises carrying the top of C90 with it.
8. Actually, as E_g went slightly negative you will find that E_p (and top of C90) moved "gain" times as much positive so the total voltage change across C90 is 'gain + 1' times as much as the incremental grid change.
9. In the voltage tables we find the total grid swing for V91 is -1.17 to -1.6 volts and the output swing at D98 cathode (top of C90) is about -1.97 to +98 volts so the approximate gain of V91 and the cathode follower V93A together is about:

$$A = \frac{\Delta E_o}{\Delta E_g} \approx \frac{98 - (-1.97)}{-1.17 - (-1.6)} \approx \frac{99.97}{0.43} \approx 232$$

10. Thus, for every small increment of grid voltage change in the negative direction the top of C90 will move positive 232 times as much. For all practical purposes we could say all of the change occurs at the top side of C90 and the grid was virtually stationary.

11. In this example the grid moved negative only 0.43 volts to get an output swing of about 100 volts. This is important to the concept of generating a very linear sweep waveform.

If we recall that a capacitor charges along an RC curve (the voltage change is non-linear) because as it charges, the voltage drop across the charging resistor gets less. Therefore the current, $\frac{E}{R}$

the resistor diminishes along with the voltage drop. Progressively there is less and less current available to charge the capacitor so the rate of change of voltage gets slower and slower.

This is not the case with the Miller Sweep generator (sometimes called a Miller Integrator) where the timing capacitor C90 builds up its voltage on the top end. Since the voltage at the junction between C90 and R90 changes very little (only 0.43 volts) as compared to the total drop of about -150 v across R90, the charging current to C90 is relatively constant at:

$$\frac{E_r}{R_{90}} = \frac{150v - (1.17 + \frac{0.43}{2} \text{ volts})}{1.4 \text{ meg}} = \frac{148.6}{1.4} = 106 \mu \text{ amp}$$

where the figures in the parentheses represent the average grid voltage throughout the sweep and 1.4 meg Ω is the value for R90 for the 1 msec/cm sweep time range.

12. Notice here that there is an equilibrium condition during a sweep where the feedback loop maintains a stable or linear rate of change of voltage at the output. The feedback loop is now from grid through V91, V93A, D97, D98, C90 and back to V91 grid. The loop through Q103 and D100, described previously, is open during sweep and has no affect.
13. If timing errors are suspected somewhere in the sweep generator, one should check components such as R90, C90, the -150 supply, reverse leakage in D86 or grid current (gassy) V91. The G_m of V91 or the value of its plate load Resistors have relatively nothing to do with timing.
14. D86 is a special Tek made Galium Arsenide diode with very low reverse leakage.

4. The Hold-off and Lock-out Circuit

- A. V145A and V145B form a bistable Multi.
- B. The sweep generator cannot respond to triggers and cannot Free Run unless the Hold-off multi is in the "ready" state; Namely with V145A conducting and V145B cutoff. (See Figure 7)

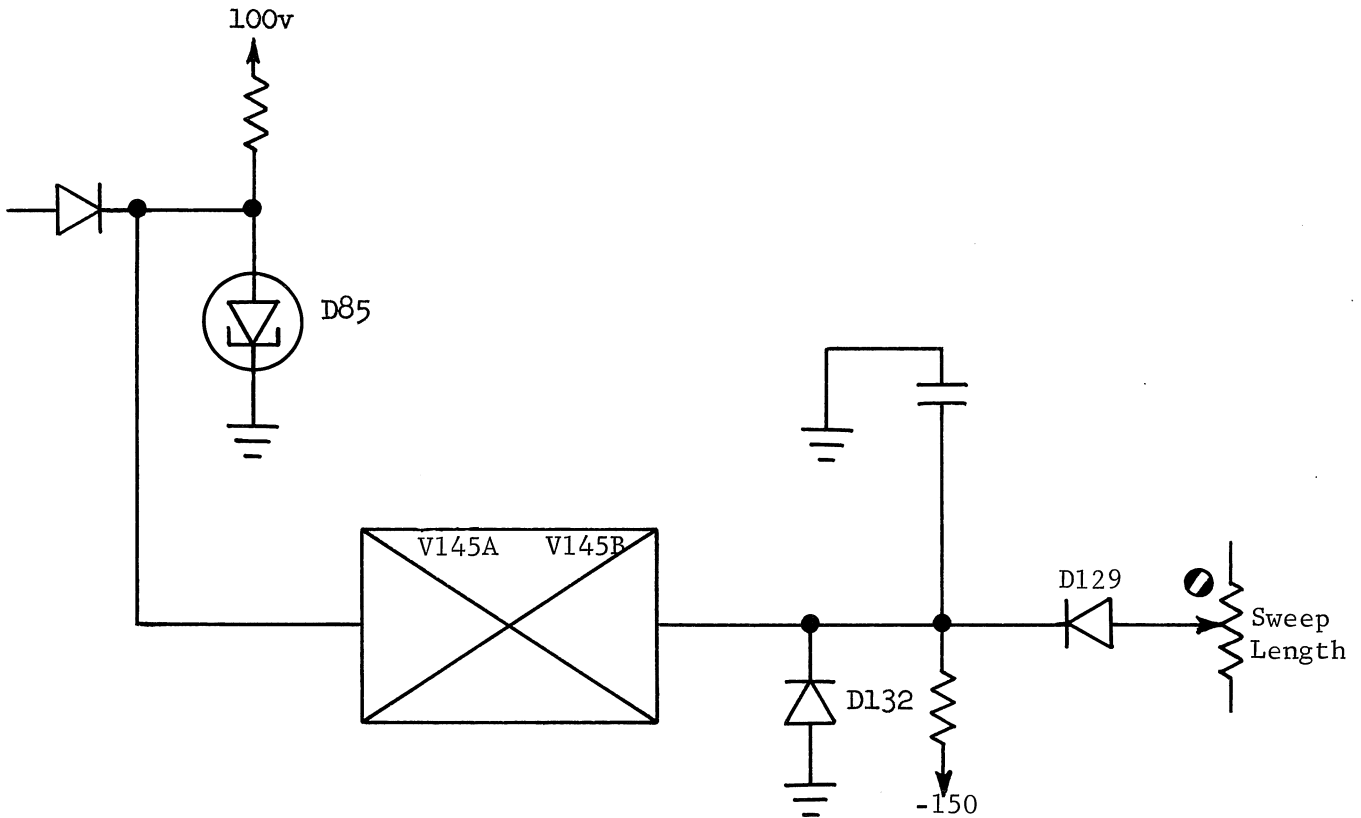


Figure 7

The Hold-off and Lockout circuit consists of V145A and B.

C. In the 'ready' state (Quiescent conditions)

1. The sweep sawtooth waveform is at its Quiescent low level (-46 volts on the anode of D129).
2. D129 is Reverse biased and its cathode is held at zero volts by D132 clamping action.
3. Zero volts at D129 cathode holds V145B Grid (via R137 & R138) at about:

$$E_g = -150 \text{ v} \left(\frac{1 \text{ meg}}{5.9 \text{ Meg} + 1 \text{ meg}} \right)$$

$$= -21.8 \text{ volts}$$

In the Voltage tables you will find that V145B grid measured -18 volts on the 250 volt scale of a 20,000 ohm/volt meter. Meter loading is 5 meg-ohms across R137 and accounts for the discrepancy.

4. -21.8 volts at V145B grid holds it cut-off. This can be seen on the type 6DJ8 plate characteristic curves (Figure 12). With the cathode to plate voltage at 100, it takes a grid bias of only -3.5 volts to achieve cut-off.

5. With V145B cut off, we can prove that V145A is conducting by first calculating V145B open circuit plate supply voltage and impedance, then find out if D147 at V145A Grid is forward biased as it should be. By using Thevenins theorem the open circuit voltage and impedance at the junction of R143 and R145 is:

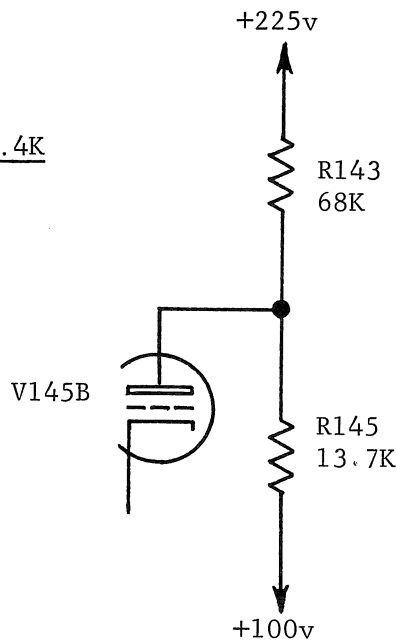
$$E_p = +100v + (225v-100v) \left(\frac{13.7K}{68K + 13.7K} \right)$$

$$= 100 + (125) \left(\frac{13.7}{81.7} \right)$$

$$= 100 + 20.9$$

$$= \underline{120.9v}$$

$$R_L = \frac{13.7K (68K)}{13.7K + 68K} = \underline{11.4K}$$



The Circuit

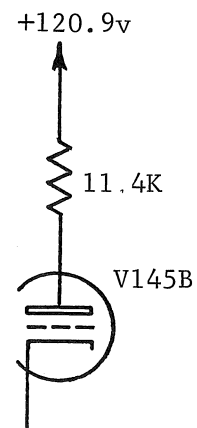
The Equivalent
Circuit

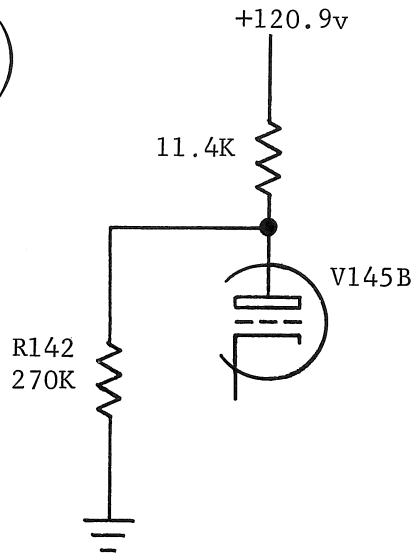
Figure 8

6. Since the 'Ready' light is on when the sweep is ready for a Trigger Q89 must be conducting. Therefore its base-emitter junction is forward biased and the base is about +0.6 volts or very nearly at ground (low resistance). We can now calculate the effect of R142 (270K) on V145 plate supply voltage. Using the equivalent circuit of step 5, the new plate supply voltage E_b and Load Resistance R_L will be:

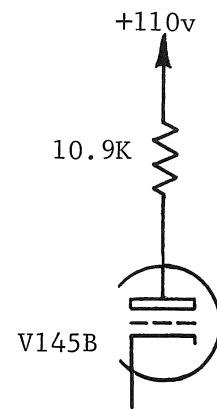
$$E_p = 120.9v \left(\frac{270K}{270K + 11.4K} \right)$$

$$= \underline{116 \text{ volts}}$$

$$R_L = \frac{270K(11.4K)}{270K + 11.4K} = 10.9K$$



The Equivalent Circuit



The New Equivalent Circuit

Figure 9

7. We cannot calculate the actual plate voltage on V145B until we know if D147 is conducting. Find the voltage at D147 Anode (assuming diode is temporarily disconnected).

$$\begin{aligned}
 E &= \left[116\text{v} - (-150\text{v}) \right] \left(\frac{R147}{10.9\text{K} + R147 + R146} \right) - 150\text{v} \\
 &= (266 \text{ volts}) \left(\frac{150}{10.9 + 150 + 100} \right) \\
 &= 266 \left(\frac{150}{260.9} \right) - 150 \\
 &= 153\text{v} - 150 = \underline{\underline{+3 \text{ volts}}}
 \end{aligned}$$

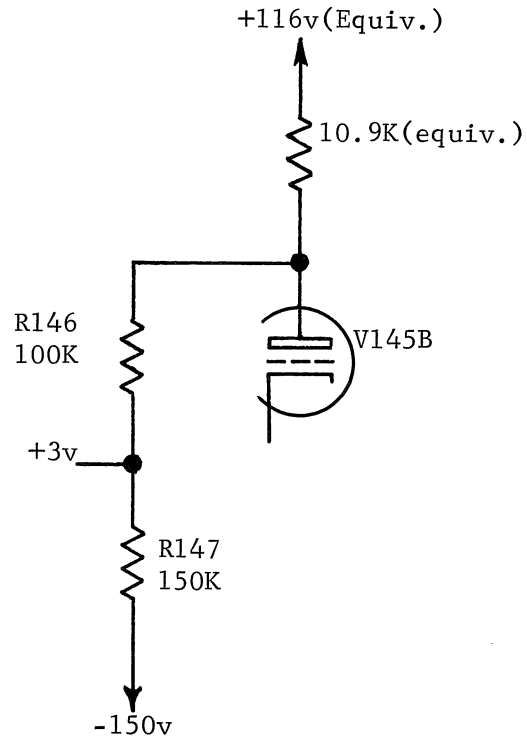


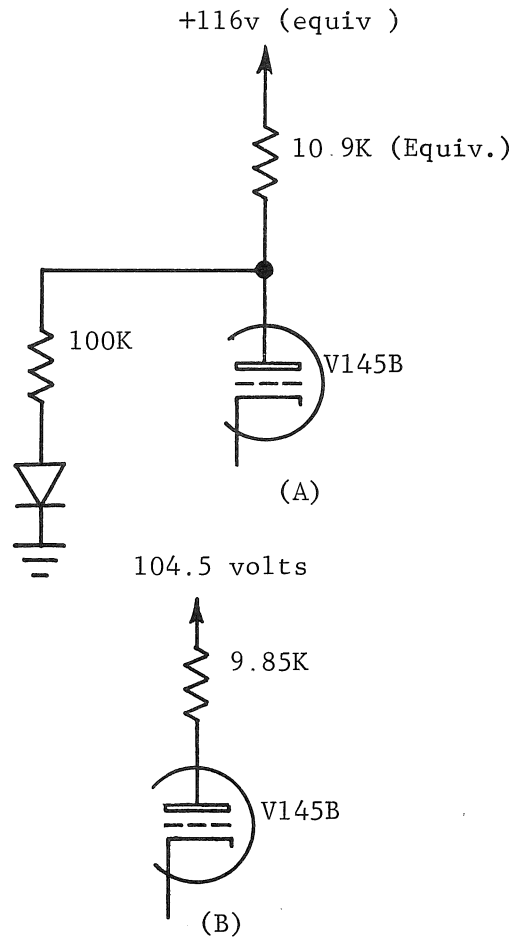
Figure 10

+3 volts at the junction of R146 & R147 with D147 disconnected indicates that the diode would indeed be forward biased and conducting. We can now say that the grid voltage at V145A will be at ground potential (actually at about 0.6 volts* due to diode clamping).

*This is a silicon diode. Our voltage tables show this to be 0.45 volts due to meter loading.

8. Now let's calculate the actual voltage and R_L at V145B Plate, knowing that D147 is conducting. Since the bottom end of R146 is nearly at Zero volts;

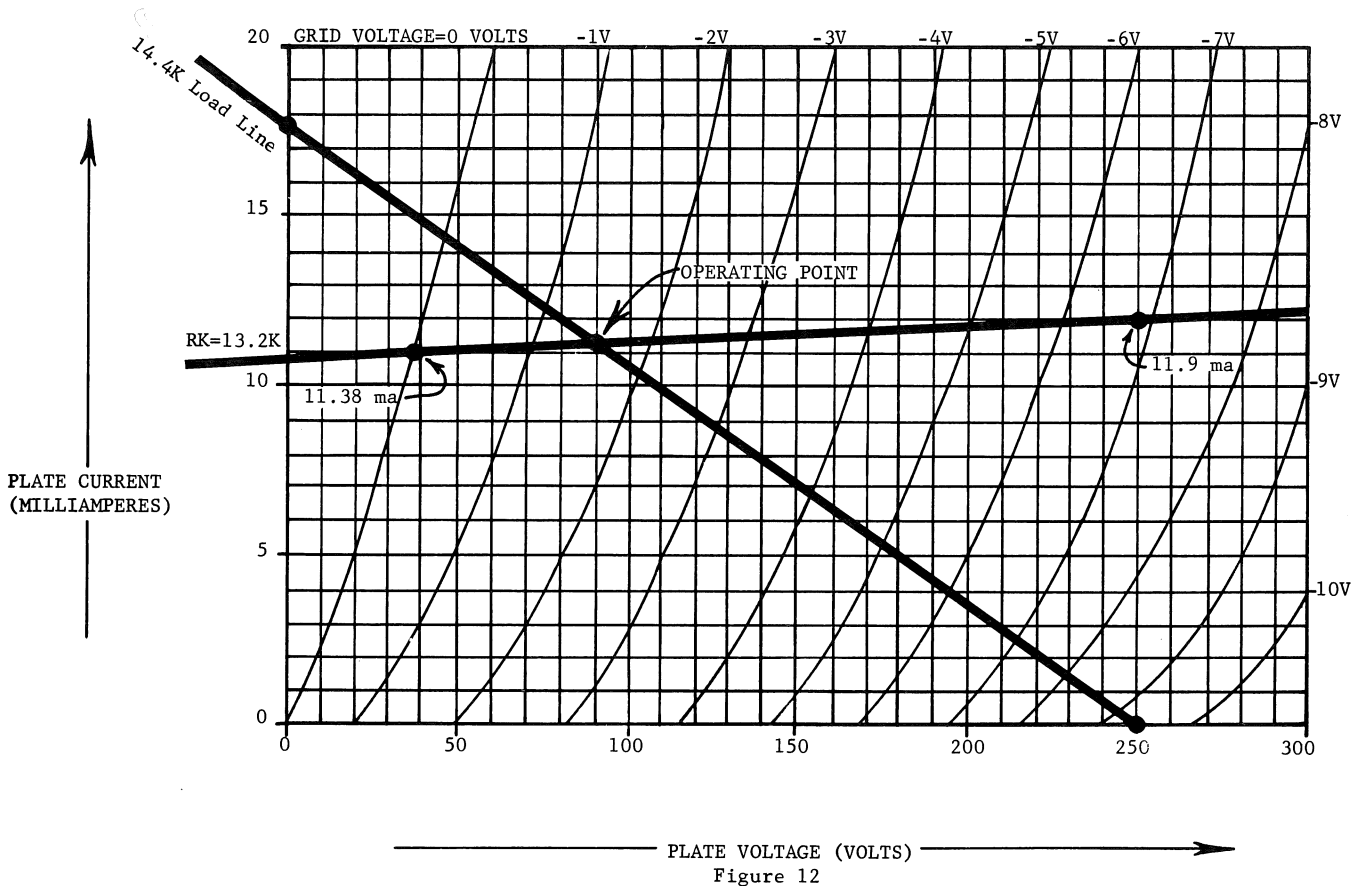
$$\begin{aligned}
 E_p &= (116v) \left(\frac{100K}{100K + 10.9K} \right) \\
 &= 116 \frac{100K}{110.9K} \\
 &= \underline{\underline{104.5 \text{ volts}}} \\
 R_L &= \frac{100K (10.9K)}{110.9K} \\
 &= 9.85K
 \end{aligned}$$



Looking in the voltage table you will find the measured plate voltage to be +103 volts.

Figure 11

9. With V145A grid at ground and its cathode returned to the -150 volt supply we can be quite certain that it is conducting. From the Voltage tables we see that the cathode is at +2.15 volts and the grid is at +0.45 volts as set by D147. The grid to cathode bias is $-(2.15 - 0.45) = -1.7$ volts.
10. Using the type 6DJ8 tube characteristic curves in (Figure 12) we can prove out the approximate operating point for V145A in the 'ready' or maximum conduction state. Note that V145A plate is supplied by the +100 v supply from sweep switching diagram when HORIZONTAL DISPLAY switch is in 'B' display.



11. Since V145B is cut-off we can forget about its cathode connection. The cathode load resistance will be R163 and R164 in parallel, neglecting the low forward resistance of D163 and the effect of R162 (since it is returned to .05 volts, very nearly ground at D85 Anode) D164 is reverse biased and is not involved.

$$R_k = \frac{22K (33.2K)}{22K + 33.2K} = 13.2K$$

12. A cathode load line can be constructed on the 6DJ8 tube curves by assuming two arbitrary values of grid bias. First assume the bias to be zero then calculate the cathode current:

$$I_k = \frac{E}{R_k} = \frac{150\text{v}}{13.2\text{K}} = \underline{11.38 \text{ ma.}}$$

Plot a point where the zero bias curve intersects the value of 11.38 ma. level of plate current. (Same as cathode current).

13. Now assume another arbitrary bias point. We selected -7 volts for this example. With the grid still at ground the cathode will be at +7 volts and the cathode current would be:

$$\frac{150\text{v} + 7 \text{ v}}{13.2\text{K}} = \underline{11.9 \text{ ma.}}$$

Plot a point where the -7 volt bias curve crosses the 11.9 ma. level for plate current. Draw a line (almost horizontal) between the two plotted points.

14. Next determine the total voltage that would be developed across V145A plate to cathode if the grid bias voltage was high enough to cause plate current cutoff. This voltage would be the total of the two supply voltages:

$$E = +100 \text{ volts} - (-150\text{v}) = 250 \text{ v.}$$

Plot a point at 250 v on the horizontal and zero current on the vertical.

15. Find the total resistance in the path of plate and cathode current for V145A. This will be R149 in series with the parallel combination of R163 and R164 or:

$$R = 1.2\text{K} + 13.2\text{K} = 14.4\text{K}$$

16. If the plate of V145A were shorted to the cathode (maximum theoretical conduction or zero tube resistance) the maximum plate current would be:

$$\frac{E}{R} = \frac{250 \text{ v}}{14.4\text{K}} = \underline{17.36 \text{ ma.}}$$

At 17.36 ma vertically and zero volts horizontally on the 6DJ8 curves, plot a point. Draw a line between the 250 v point on the horizontal axis and the 17.36 ma point on the vertical axis.

17. The diagonal load line intersects the cathode load line at the operating point. The bias at the operating point is about -1.5 volts. When we consider that the grid is actually at 0.6 volts as clamped by D147 the cathode voltage would be at about 0.45 volts + 1.5 or 2.1 volts. Our voltage tables show a measurement of +2.15 volts for V145A cathode which is not unreasonable considering tolerances involved. The plate voltage at the operating point is about +84 volts and the plate current is about 11.5 ma.
18. The error involved in neglecting current through R162 from the TD is small. This current is approximately:

$$I = \frac{E_k - E_{D85}}{R162} = \frac{2.15v - 0.05v}{3.32K} = \frac{2.1}{3.32} = 0.632 \text{ ma.}$$

Where E_k is the cathode voltage (from voltage tables) and E_{D85} is the 'ready' voltage of the tunnel diode.

C. Hold-off condition of V145 A and B at end of sweep.

1. As D85 is triggered to the high state (0.5 volts), it causes Q84 to conduct and D86 to decouple allowing the sweep to run up.
2. Quiescently, the sweep output (at D98 cathode) sets at about -1.97 volts and when triggered, goes up to about +98 volts, a level determined by the sweep length control R125.
3. Before a sweep is initiated, D129 is cut off because the arm of R125 is at about -47 volts and D129 cathode is at -0.42 volts (almost ground). As the sweep voltage at the arm of R125 rises from the -47 volt level through zero volts, D129 conducts. The rising sweep voltage therefore, carries the cathode as well as the anode of D129 on up to about +22 volts. It could have gone higher except that V145B conducts when D129 cathode gets up to 22 volts and terminates the sweep. As the top of R137 reaches +22 volts, the voltage divider R137 and R138 causes the grid to be at about:

$$E_g = (150v + 22v) \left(\frac{5.9 \text{ meg}}{5.9 \text{ meg} + 1 \text{ meg}} \right) -150$$

$$= 172 \left(\frac{5.9}{6.9} \right) -150$$

$$= 147 - 150$$

$$= \underline{-3 \text{ volts}}$$

4. With V145B cut off, its plate sets at 103 volts (as established earlier). Its cathode is at about +1.5v because of V145A conduction. Looking on the 6DJ8 curves for E_p 101.5v, you will find that V145B comes out of plate current cut off when its grid gets up to about -3.7 volts. Since the cathode is already at +1.5 volts, the plate current cut-off level for V145B grid would be at -2.2v with respect to ground. With a test scope, we observed V145B to start conducting when the sawtooth waveform at its grid gets up to about -3 volts. There is a discrepancy of about 0.8 volts between the cut off bias value from tube curves and our measurements (perhaps due to tube variations). Use a X10 probe with your test scope if you wish to duplicate this measurement. There will be some probe loading (10 meg Ω) but this should not affect the cut-off voltage measurement.
5. When V145B conducts, its plate voltage drops forcing V145A grid down. Also V145B conduction causes its cathode voltage to increase which causes D163 to reverse bias. In effect this disconnects R164 from

V145A. This reduces cathode current in V145A. A regenerative switching action takes place where V145A is cut-off by V145B conduction.

6. When V145A cuts off, its cathode cannot go below -19.7v because of divider action of R162 and R163 where:

$$E_k = -150v \left(\frac{R162}{R162 + R163} \right) = -150v \left(\frac{3.32K}{3.32K + 22K} \right) = \underline{-19.7v}$$

The top of R162 is essentially at ground potential since D85 is very low impedance. If V145A were cut-off its plate would be at 100v and its cathode would be at -19.7v. Looking on the 6DJ8 tube curves along the zero plate current line, we find that for E = 119.7 volts, plate current cut-off grid voltage to be about -4.3 volts. When V145B conducts, (during hold-off period) its plate drops to about +56 volts. This will cause V145A grid to drop to:

$$E_g = -150v + (56v + 150) \left(\frac{150K}{150K + 100K} \right)$$

$$= -150 + 123.8 = \underline{-26.2 \text{ volts}}$$

The grid bias then is:

$$-26.2v + 19.7v = \underline{-6.5 \text{ volts}}$$

which insures that the grid will be beyond the plate current cut off value of 4.3v observed from the curves.

7. When hold-off time starts (at end of sweep) V145A cuts off and its cathode drops to about -19.7V as shows above. This causes D85 sweep gating tunnel diode to switch from its triggered high state of about 0.5 volts to its low state of 0.05 volts (or less). In fact, D85 is actually reverse biased (voltage and current) during the holdoff period by a few multivolts and milliamps respectively which insures that it will reset to its low voltage state. It is not yet ready for another trigger.
8. The above action caused Q84 sweep gating Amplifier to cut off which causes D86 to conduct heavily. This terminates the sweep which retraces to its quiescent level of about -1.97 volts (at D98 cathode).
9. As the sweep retraces back to -1.97 volts the voltage at the arm of R125 drops down to its quiescent level of -47 volts. As it does so, it decouples or cuts off D129. C130 hold-off capacitor which was previously charged to nearly 22 volts by the positive-going sweep

now starts to discharge through the hold-off resistor, R130, to the -150v supply. Some discharge current also goes through R137, and R138 to the -150v supply. The total hold-off time is determined essentially by this RC combination.

10. The hold-off period ends when the capacitor C30 discharges far enough for V145B to cut off which causes V145A to conduct.
11. When V145A conducts, its cathode voltage moves up to about +2.15 volts again increasing the bias current through D85 sweep gating tunnel diode to its quiescent level near peak current (Refer back to Fig. 4) which is the 'triggerable' level. At this level Q84 is still cut off.
12. The sweep circuit is now ready to receive another positive going trigger.

5. The Auto Circuit

A. Operating characteristics

1. In the Auto mode the sweep is allowed to free run at a rep rate depending on time/cm setting, unless or until a trigger is received.
2. This allows a base line to be observed even though no trigger is available.
3. Our measurements on one instrument showed that two triggers within 55 msec (a rep rate of about 18 PPS) are needed to get one triggered sweep. For example: if you connect a type 180 pulse generator to the vertical, the 547 Auto Triggering will give a normal display at 50 msec and shorter periods but will not work on the 100 msec and slower periods.
4. The spec sheet says it must trigger down to 20 cps in AUTO triggering MODE.

B. Sequence of operation in the AUTO mode.

1. Assume no triggers are being received.
2. The sweep is free running at a rep rate determined by its sweep and holdoff time (depending on setting of TIME/CM control).
3. One trigger is received.
4. The AUTO circuit uses this trigger to stop the sweep from free running (makes it triggerable) for a period of only 50 msec. The 50 msec figure is from the published 547 specs. This is a minimum period and most instruments will have longer triggerable periods.
5. If a second trigger does not come within 50 msec, the AUTO circuit lets the sweep go back into a free running condition.
6. If a second trigger comes any time after the 50 msec triggerable interval the AUTO again readies the sweep (as in step 4).
7. However, if after step 4 a second trigger is received before the triggerable interval of 50 msec has ended, the sweep will be triggered.
8. After the second trigger (or following triggers) terminates and the sweep has completed its excursion, the AUTO circuit recovers and allows the sweep to go back into its free running operation.

9. NOTE: As each trigger pulse appears (after the initial one) it triggers a sweep but also causes the AUTO circuit to reset for an additional 50 msec keeping the sweep 'triggerable' for this period.
10. To recap: In the AUTO MODE, the sweep free runs and it takes one trigger to stop the sweep and 'ready' it, and it requires a second trigger within a 50 msec interval to trigger a useful sweep. It takes two triggers to get the first useful sweep. The sweep is triggerable thereafter as long as the trigger rep rate is greater than 20 cycles/sec, which is the reciprocal of 50 msec.

C. Detailed circuit description (AUTO circuit)

1. With the MODE switch in the TRIG position, Q75 collector is grounded. D76 zener diode cathode and anode are at zero volts. This causes D79 to be slightly reverse biased, so, in effect, the AUTO circuit is disconnected and D85 is in its triggerable state. The sweep will not free run.
2. With the MODE switch in the AUTO position and no triggers coming in, Q65 is conducting because its base is at about:

$$\begin{aligned}
 E_b &= 100v \left(\frac{R54}{R54 + R53} \right) \\
 &= 100 \left(\frac{0.28k}{0.28k + 69.8k} \right) \\
 &= \underline{0.4 \text{ volts}} \quad (\text{We measured } 0.38v - \text{ see voltage tables})
 \end{aligned}$$

and its emitter is at -0.27 volts (measured). It takes only a forward base bias of 0.6 volts for this silicon transistor to conduct and we have about 0.65 volts (as measured).

3. D71 is cut off with -0.27 volts on its anode.
4. Q75 is like-wise cut off since its base is at ground and its emitter is at -0.27 volts, not enough forward bias for a transistor to conduct.
5. From the above observation we can say that all the current through R71 goes into Q65 emitter. This current is:

$$\begin{aligned}
 I &= \frac{150v - 0.27v}{51k} \\
 &= \underline{2.93 \text{ ma}}
 \end{aligned}$$

6. To determine Q65 collector voltage we must first determine the collector load resistance and supply voltage. The collector load resistance is:

$$R_1 = \frac{R65 (R67)}{R65 + R67} = \frac{30K (9.1K)}{30K + 9.1K} = \underline{7K}$$

where R_1 is the equivalent load resistance of the parallel combination.

$$E_b = 100v \left(\frac{R67}{R67 + R65} \right) = 100v \left(\frac{9.1K}{9.1K + 30K} \right) = \underline{23.2v}$$

where E_b is the collector voltage if Q65 were cut off.

7. If we neglect the very small amount of base current we can assume that collector current is approximately equal to emitter current (from step 5). Then, the collector voltage for Q65 is approximately:

$$E_c \sim E_b - I_e R_1 = 23.2v - (2.93ma)(7K) = +2.7 \text{ volts}$$

where E_c is collector voltage, E_b is equivalent supply voltage (from step 6) and R_1 is equivalent collector load resistance (from step 6). The voltage table seems to confirm this value for E_c .

8. In the above example, if we assumed β for Q65 to be very low, (worst case condition at say, 20) then for each unit of base current, emitter current would be $\beta + 1$ or 21 units, and collector current would be 20 units so the ratio between collector current and emitter current would be 20/21. Thus by neglecting base current in step 7 our error would be less than 5%. If β were 50, the ratio would be 50/51 and the error would be less than 2%.
9. C67 has a charge of 2.7 volts on it.
10. Q75 is cut off because its base is grounded and its emitter is held up at -0.27 volts by Q65 conduction.
11. Q75 collector is cut off and therefore D76 and D79 are forward biased. This circuit adds some current to the normal 'Ready' current of 4.092 ma through D85 tunnel diode (described in Section 2C8) which causes D85 to switch to its high (0.5V) state immediately after each sweep and holdoff period.
12. We can calculate the additional current through D85 from the AUTO circuit which is more than enough to switch the TD.

13. Since Q75 is cut off it will not enter into our calculations. The electron flow will be from ground through D85 tunnel diode, up through D79, R79, D76 zener diode, then through R75 to the 100 volt supply. The current through R78 will influence our calculations.
14. First, by Thevenins theorem, consider the equivalent open-circuit voltage and current at D76 Anode, assuming R79 disconnected. See Fig. 13

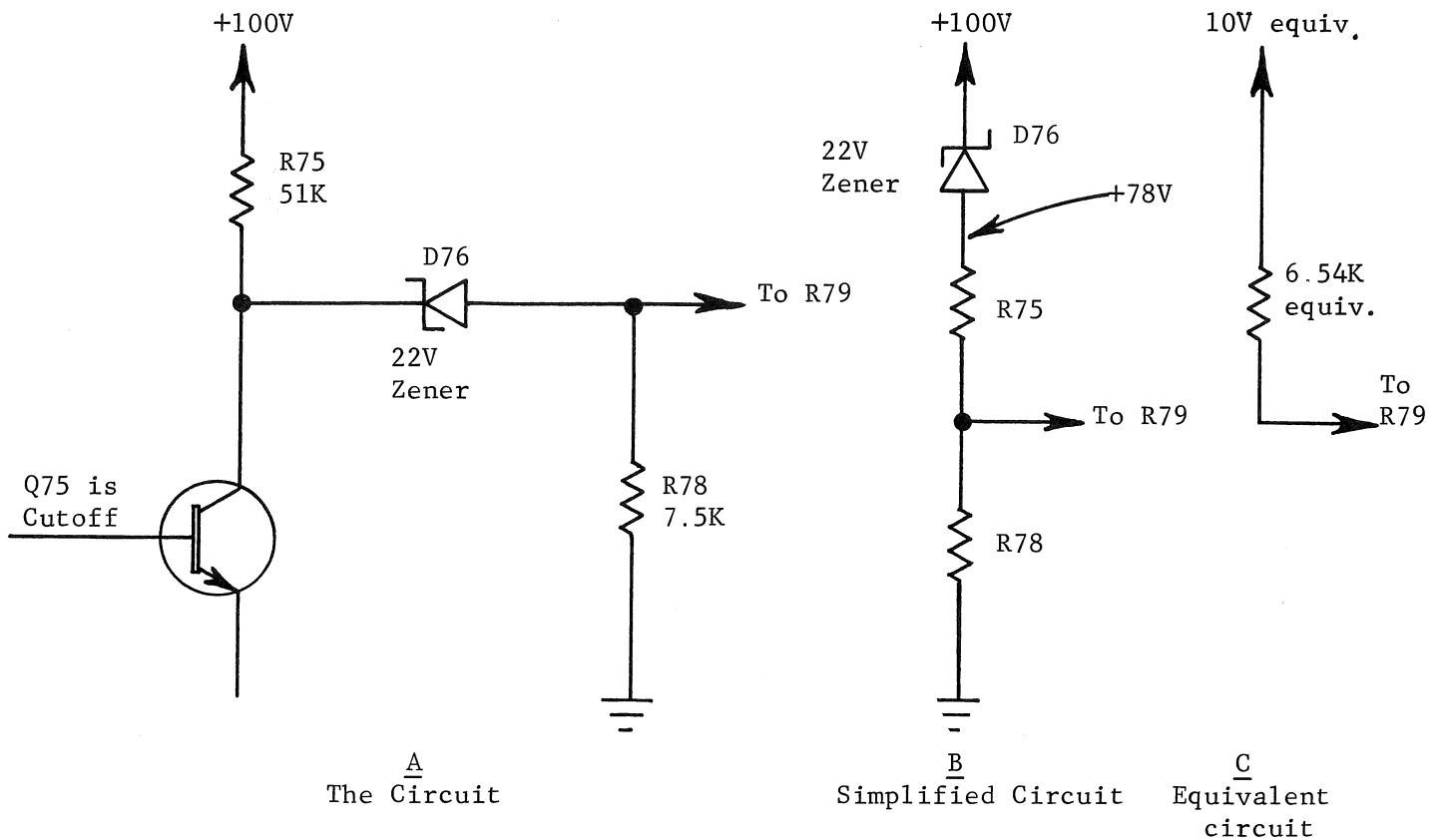


Figure 13

15. In the simplified circuit (Fig. 13B), we must subtract the zener voltage of 22 volts from +100 volts which gives us 78 volts, then find the equivalent open-circuit voltage at the top of R78 as follows:

$$\begin{aligned}
 E_{\text{equiv}} &= (100\text{v} - 22\text{v}) \left(\frac{R78}{R78 + R75} \right) \\
 &= 78\text{v} \left(\frac{7.5\text{K}}{7.5\text{K} + 51\text{K}} \right) \\
 &= \underline{10 \text{ volts}}
 \end{aligned}$$

16. The equivalent output resistance is:

$$\begin{aligned} R_{\text{equiv}} &= \frac{R78 (R75)}{R78 + R75} \\ &= \frac{7.5K (51K)}{7.5K + 51K} \\ &= 6.54K \end{aligned}$$

Thus Fig. 13C shows the equivalent voltage and current if R79 were disconnected.

17. Now, reconnecting R79 to this equivalent circuit, a second equivalent circuit is obtained as shown in Fig. 14.

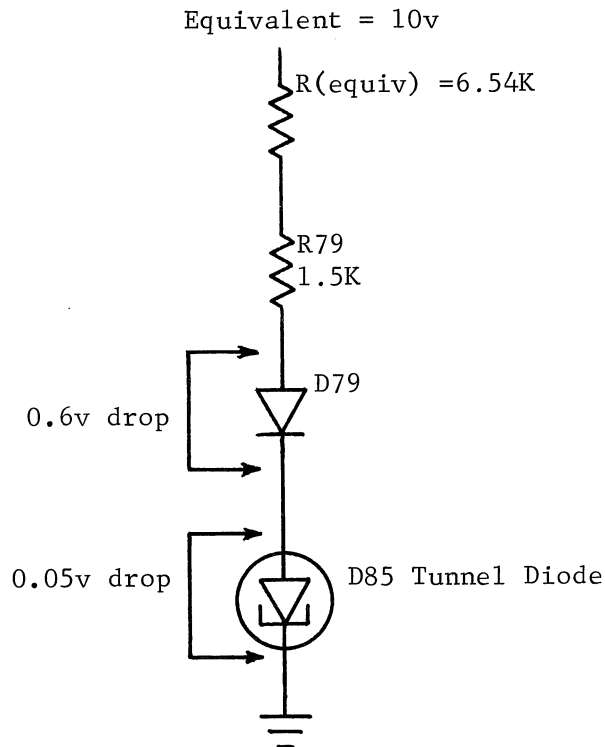


Figure 14

18. Now figure the current added to D85 by the AUTO circuit. The approximate diode voltage drops must be subtracted from the equivalent voltage shown and then divided by the resistance as follows:

$$\Delta I_{D85} = \frac{(10 - 0.6v - 0.05v)}{R_{equiv} + R79} = \frac{9.35v}{6.54K + 1.5K}$$

$$= \frac{9.35v}{8.04K} = \underline{1.16 \text{ ma}}$$

19. When the AUTO circuit current of 1.16 ma is added to the 'ready' current of about 4.092 ma (described in Section 8C) we get:

$$1.16 \text{ ma} + 4.092 = \underline{5.25 \text{ ma}}$$

which is more than enough to trip the 4.7 ma tunnel diode into the 'high' state for a free running sweep.

D. Detailed operating sequence (AUTO MODE)

1. Q65 is conducting and Q75 is cut off causing the sweep to free run.
2. A trigger pulse comes through C56 and D59 to D85 but does nothing to the sweep since its probably already under way or in its lockout phase of the cycle.
3. The same trigger pulse described above, simultaneously, is inverted by T52 and sent to Q65 to cut it off.
4. As Q65 cuts off, its collector rises toward its maximum value of about +23.5 volts in about 6.4 msec. This rate of rise is determined by R65, R67, and C67.
5. As Q65 collector rises, the charging current for C67 through Q75 base causes Q75 to conduct. D71 also conducts which prevents the Q75 emitter from rising along with its base which would cause degeneration.
6. Q75 will conduct as long as C67 continues to rise toward the 23.5v collector supply voltage for Q65.
7. As Q75 conducts, it discharges C76 at a rather fast rate since its collector is low impedance and R76 is only 470Ω.
8. As Q75 collector voltage falls, it also causes D76 and D79 to cut off. This causes the sweep to stop free running and stay in the 'ready' state where it can be triggered by the next incoming trigger pulse.
9. Very soon, (in about 6.4 msec as measured on one instrument), C67 becomes fully charged so Q75 stops conducting. Its collector starts to rise, but at a slow rate, as determined by C76 and R75, a rather long time constant compared to that of step 7 above.

10. C76 and R75 time constant and the +100 volt supply are the primary factors controlling the 'triggerable' period during AUTO operation.

11. The time constant for C76 and R75 is:

$$T = RC = 5.1 \times 10^{-3} \text{megohms} \times 4.7 \times 10^{-6} \text{mfd.} = \underline{0.24 \text{ seconds}}$$

12. C76 tries to charge to +100 volts but the voltage across the zener diode gets up to the zener level. The zener conducts, causing Q75 collector voltage to clamp at about +23v or 23% of the +100v supply.

13. Looking at the RC curve, you will see that 23% of the total voltage will appear across the capacitor in approximately 0.3 RC. (See Fig. 15)

$$0.3 \times 0.24 \text{ sec} = \underline{72 \text{ msec}}$$

This is a bit long compared to our measured time of 55 msec, however, C76 is an electrolytic type capacitor which generally has a wide tolerance. The tolerance of the zener voltage itself could account for some of the difference.

6. Reset Circuits.

A. General Information.

1. Sometimes it is necessary to insure that the sweep will be locked out and not triggered until the proper time after the reset button is depressed. Further, it should be allowed to sweep only once from an initial trigger but ignore all subsequent triggers.
2. This technique is useful for waveform photography, especially when photographing pulses with ringing characteristics, Relay contact bounce, etc.
3. The SINGLE SWEEP switch is located near the horizontal display switch on the front panel. When it is depressed to RESET, the 'ready' lights go on to indicate that the sweeps are triggerable.
4. Part of the switching labeled SW 135 SWEEP MODE is shown on 'B' sweep generator, and 'A' sweep generator schematics. Another part of the switch, the RESET pulse generating switch, SW 369, is shown on 'A' sweep generator schematic in the lower left hand corner.
5. The reset pulse controls both sweep generator circuits through their respective holdoff circuits.
6. Both sweeps can be externally reset by connecting a positive-going pulse of about 20 volts and 0.5 μ sec risetime. The external jack labeled SINGLE RESET INPUT is located at the rear of the instrument.

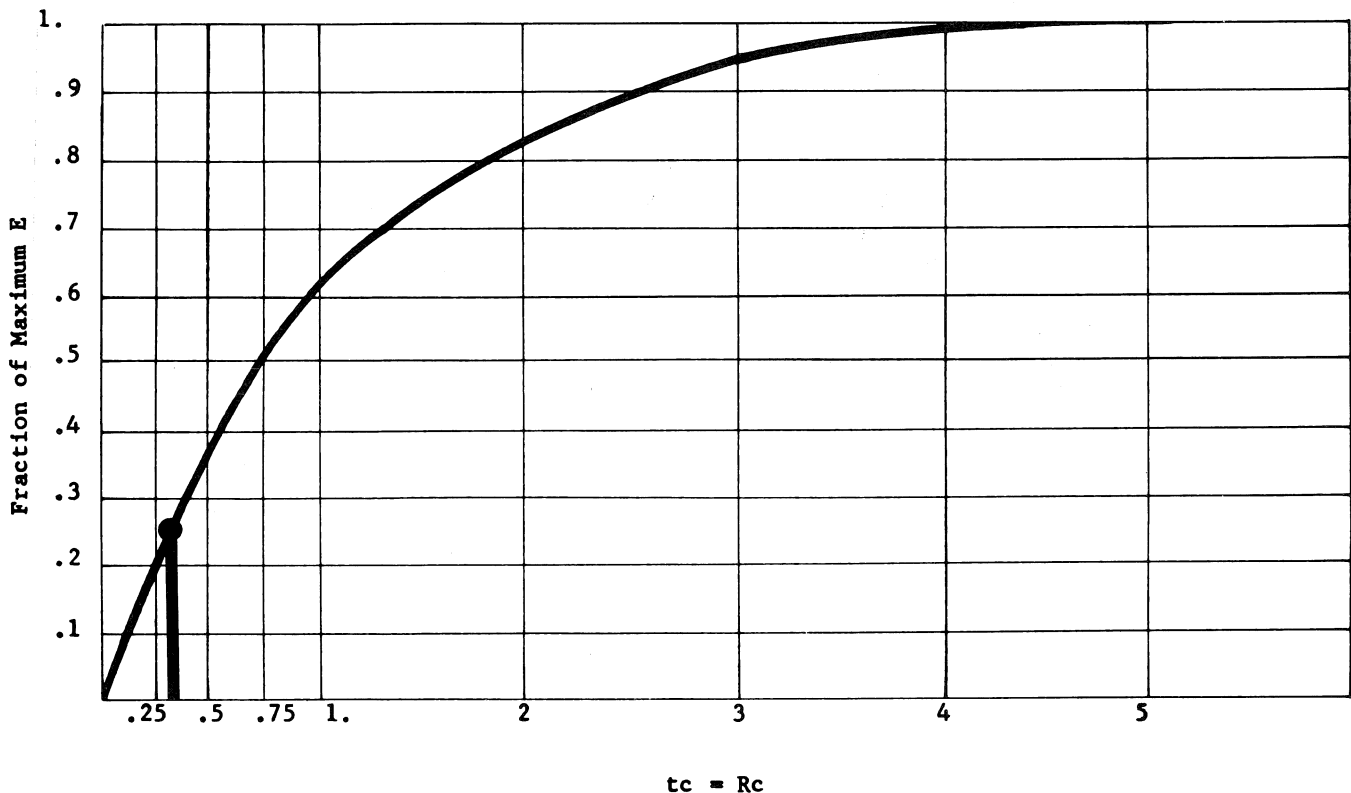
B. Circuit description.

The following discussion centers around B sweep generator operation; however, A sweep applies as well.

1. When SW 135 SWEEP MODE switch is set to SINGLE SWEEP, it holds D329 cathode in the A sweep generator and D129 cathode in the B sweep generator up at about +6.7v via D332 and D132 respectively. This would hold the grids of V345A and V145B up at about:

$$\begin{aligned}
 E_g &= (150v + 6.7v) \left(\frac{5.9 \text{ meg}}{5.9M + 1M} \right) - 150v \\
 &= 156.7 \left(\frac{5.9}{6.9} \right) - 150v \\
 &= 134 - 150v \\
 &= \underline{\underline{-16 \text{ volts}}}
 \end{aligned}$$

2. V345A in A sweep generator and V145B in B sweep generator are conducting so the lockout and hold-off circuits are in the locked out condition and no triggers can activate the sweeps.
3. Specifically, in the B sweep, the V145A cathode is at -12.8v and conducting and V145A is off holding the sweep gating tunnel diode D85 in its 'low-low' or reverse bias state where it cannot be triggered.
4. Look at the RESET pulse generation switch SW369, on the A sweep generator schematic. When the switch is in the SINGLE SWEEP position, C369 charges up to +100 volts through R369 and R370. C369 remains charged until SW369 is momentarily depressed.
5. Depressing SW369 causes the 100v on C369 to discharge through R369, R368 and R367, forming the reset pulse. We can get a rough estimate of the pulse amplitude by looking at the equivalent discharge circuit (assuming no load).



UNIVERSAL RC CHARGE CURVE

Figure 15

6. With a test scope, we measured this pulse to be 17 volts in amplitude. Actually, R165, R166, R164, R365, R366 and R364 are all in parallel with R369. If we included the loading of these components, we would get closer to the measured value. We refigured this and came up with 19.1 volts - still too high. Perhaps the stray shunt wiring capacity is integrating the pulse.
7. In the B sweep circuit the voltage divider R165 and R166 have a DC voltage of:

$$-150 \left(\frac{18K}{18K + 130K} \right) = -18.3V$$
8. The cathode of V145B sets at -12.8 volts before reset so D164 is back biased by 5.5 volts.
9. A positive pulse of 17 volts from the RESET switch is more than adequate to forward bias D164 and raise the cathode of V145B high enough to cut it off. V145A conducts, biasing D85 up near its 4.7 ma triggerable level.
10. The sweep runs up, decouples D132 from R135 and R136, and raises the grid of V145B high enough to cause conduction which cuts off V145A to reset D85 and retrace the sweep. However, after the sweep retraces, it cannot cut off V145B to end hold-off time because as the sweep retraces, it allows D132 to reconnect the voltage divider R135 and R136 and V145B up at -16 volts (per step B-1). The sweep cannot be triggered until the spring loaded SINGLE SWEEP switch is again depressed.

7. Blanking Circuit.

A. Preliminary Information.

1. Q84 sweep gating amplifier drives the CRT Blanking circuit and + GATE output as well as the sweep generator.
2. Q173 is a blanking amplifier.
3. Q184 is a combination amplifier and AND GATE where it mixes B sweep blanking and sweep switching information.
4. V193B is the B sweep blanking output cathode follower.
5. V193A is the + GATE output cathode follower.
6. Unblanking occurs when Q84 conducts (collector voltage goes down).

B. Quiescent Conditions

1. Q84 is cut-off and its collector sets at 5.1 volts (as described in Section 2).
2. Q173 is a Germanium PNP transistor which requires about 0.4v forward bias to conduct. It is quiescently off, since it is reverse biased at about 1.8 volts (see voltage tables).
3. Since Q173 is cut-off, its collector voltage is at -49v (measured) as set by the voltage divider resistors R174, R177 and the diode D181 (conducting) connected between -150 volts and ground. The calculated value is:

$$\begin{aligned}
 E_c &= -0.6v - (0.6v - 150v) \left(\frac{10K}{10K + 20K} \right) \\
 &= -0.6v - 149.4v \left(\frac{10}{30} \right) \\
 &= \underline{-50 \text{ volts}}
 \end{aligned}$$

where the value -0.6v is the approximate drop across D181 during conduction.

4. Under these conditions D172 is reverse-biased, since its cathode is at -0.6v as measured. The calculated value for D172 cathode voltage when Q173 base is at +1.8v is:

$$\begin{aligned}
 E &= 1.8v - (150v + 1.8v) \left(\frac{4.7K}{4.7K + 270K} \right) \\
 &= 1.8 - 2.6 = \underline{-0.8 \text{ volts}}
 \end{aligned}$$

5. The emitter of Q184 is at -0.6 volts as set by D181 conduction. Its base is set at -0.6 volts because of D182 forward bias. The bias current for D182 is about:

$$I = \frac{(-150 + 0.6v)}{270K} = \underline{0.554 \text{ ma}}$$

There is no current through R181 since D481 anode (in sweep switching circuit) is grounded when HORIZONTAL DISPLAY switch is in 'B' as stated under (1) operating MODE (preset conditions). If D481 is active (in other HORIZONTAL DISPLAY modes) it holds Q184 cut off and unblanking cannot be accomplished by B sweep under this condition.

6. Since Q184 base and emitter are at -0.6v, it is cut off.
7. With Q184 cut-off, its collector is at -68 (measured) as set primarily by R183 and R184. By calculation, we find this voltage to be:

$$E = (-150v) \left(\frac{41.2K}{41.2 + 46.4K} \right)$$

70.5 volts (neglecting the small current through the R186 branch.)

8. R189 is a brightness control for B sweep unblanking. The INTENSITY control sets the beam brightness for both A and B sweep displays, but the BRIGHTNESS control (a small plastic screw driver slotted knob just above the DELAY TIME MULTIPLIER knob) R189 sets the relative brightness of the B sweep display.

C. Circuit Operation.

1. Upon receiving a trigger, Q84 conducts causing the sweep to start its run-up. Simultaneously, as Q84 conducts, lowering its collector voltage to the saturation level of about +1.2 volts, it drives Q173 base down to about 0.52 volts.
2. Q173 conducts with its base at 0.52 volts and its emitter at 0.2 showing a forward base emitter voltage of about 3.2v. The relatively lower forward voltage drop indicates that this transistor is a Germanium type. Looking at a spec sheet will varify this.
3. When Q173 conducts, its collector moves up from -49v to -1 volt; a change of about 48 volts.
4. At this time Q173 collector is prevented from going into saturation by conduction of D172. From the voltage tables we see that D172 is now conducting with -1.5v on its cathode and -1 volt on its anode. If Q173 tries to conduct heavier, its collector pulls up on D172 cathode which, by R170, R171, and R172 voltage divider action opposes the saturation tendency of Q173.* A saturated transistor requires more base drive, but more important, its collector 'stored charge' slows down turn off time.

*Further discussion on preventing saturation can be found in General Electric's TRANSISTOR MANUAL, 6th edition page 97 and 98.

5. When Q173 was cut off (collector at -49 volts) D181 conducts holding its cathode at -0.6 volts.
6. Now with Q173 conducting (during sweep) D181 has only about -0.15 volts on its cathode (very nearly cut off) and Q184 conducts. Remember that quiescently there was current from the -150 volt supply through R177 and D181 to ground. Now the current path (electron flow) is from -150v supply, through R182, through Q184 base and emitter towards R177 and R179. Thus Q184 is now conducting with its collector up at -0.54 volts (saturated).
7. D183 does not come into play except when the HORIZONTAL DISPLAY switch is in the ALT positions. This is when the sweep switching circuit (operating through R181) moves the base of Q184 positive far enough to hold it cut-off. Since Q184 emitter is longtailed to the +100v supply, it would take a very large base voltage to cut-off Q184. D183 conducts if Q184 emitter gets up to about +0.6v so Q184 base need only be moved to about +0.6v to achieve cut-off. The sole purpose for the input to Q184 through R181 is to prevent the B sweep from unblanking (displaying) simultaneously with A sweep unblanking (A sweep display).
8. With the arm of R189 (BRIGHTNESS) counter clockwise at the -150 volt position, the quiescent level of V193B cathode is -72 volts but during sweep V173 cathode is at -18v.
9. V193A is the + GATE output cathode follower.
10. The blanking signal at Q173 collector switches from -49v to -1 volt during sweep. This average DC level must be raised by the voltage divider R175 and R195 so that V193A grid is quiescently at -16.5 volts, then changes to +16.5 volts during sweep. Thus V193A is cut-off with its cathode at ground quiescently. During a sweep, the cathode (B GATE output) raises to about +25 volts.

III B SWEEP GENERATOR DC VOLTAGE MEASUREMENTS

Type 547

The following measurements were taken on 547 #1111 using a triplet 20,000 ohm/volt meter, Model 630 PL. Voltages have been measured under two different conditions; 'Ready' for a trigger (quiescent), and during a very slow sweep (as the CRT beam progresses to the right). Voltages marked with an asterisk indicate that meter loading influences the reading. If meter loading is appreciable, use the next higher range. The controls were preset as follows:

For Quiescent DC Voltages:

TIME BASE A

TRIGGERING	
MODE	TRIG
SLOPE	+
COUPLING	AC
SOURCE	EXT (No trigger signal connected)
TIME/CM	1 msec/cm (Calibrated)
The ready light will be 'ON'	

TIME BASE B

TRIGGERING LEVEL	Clockwise (Push knob in for X1 range)
TRIGGERING	
MODE	TRIG
SLOPE	+
COUPLING	AC
SOURCE	EXT
TIME/CM	1 msec/cm
The ready light will be 'ON'	
BRIGHTNESS	Set at extreme counter clockwise position.
HORIZONTAL DISPLAY	B (Not intensified)
SWEEP MAGNIFIER	OFF
SINGLE SWEEP	NORMAL

For voltages during a very slow sweep:

Connect and read the meter only while the sweep is in progress.

Excessive voltages, or reverse voltages during retrace or quiescent condition may damage the meter. Leave all controls as above

except:

TIME BASE B

TIME/CM
TRIGGERING
MODE

5 sec/cm

AUTO

	Quiescent (Triggerable)	Slow Sweep
Junction of R53 & R54	+0.38 volts	+0.38 volts
Anode of D57	*	*
Q65 emitter	-0.27	-0.27
base	+0.38	+0.38
collector	+2.7	+2.7
Q75 emitter	-0.27	-0.27
base	0	0
collector	(grounded)	+23.2
D76 cathode	0	+23
D76 Anode (zener diode)	0	+2.7
D79 Anode	0	
D85 Anode (tunnel diode)	+0.05 'Ready'	+0.5 'Triggered'
Q84 emitter	gnd.	gnd.
base	+0.37	+0.7
collector	+5.1	+0.12
V145A cathode	+2.15	+2.17
grid	+0.45	+0.45
plate	+83	+83
Junction of R149 & R455#	+100	+100
D164 Anode	-17.6	-17.6
V145B cathode	+1.5	+1.5
grid	-18 (250v scale)*	-18 to $\approx -3 \times \square$
plate	+103	+103
Q89 emitter	gnd.	gnd.
base	+0.55	-1.3*(10v scale)
collector	+0.05	+85 (250v scale)
Junction of R88 & R89	+46.5	+83 (250v scale)
Q184 emitter	-0.6	-0.15
base	-0.6	-0.5
collector	-68	-0.54
D182 cathode	+0.56	-0.5
Junction R186 & R191	-72	-22 (250v scale)
Junction R185 & R188	-150	-150
Arm of R189 (ccw)	-150	-150
V193B cathode	-72	-18
grid	*	-22*(250v scale)
plate	+225	+225

	Quiescent (Triggerable)	Slow Sweep
D86 cathode	-0.32	-1 to -1.6 [#] (10v)
Q103 emitter	-0.32	-3 (scale)
base	-0.62	0
collector	-4.6	-7.65
D100 cathode	-1.05	-1.1 to +100 [□]
V91 cathode	gnd.	gnd.
grid	-1.17	-1.17 to -1.6 [□] (10v scale)
screen	+98	+98
plate	+27	+27 to +132 [□]
Junction of R93 & R94	+183	+183 to +230 [□]
V93A cathode	+33.7	+33.7 to +134 [□]
grid	+27	+27 to +134 [□]
plate	+225	+225
D97 cathode (zener diode)	+33.7	+33.7 to +134 [□]
D97 Anode	-1.32	-1.32 to +98 [□]
D98 cathode	-1.97	-1.97 to +98 [□]
Junction of R99 & C98	+1.84	+1.84 to +2.25 [□]
Junction of R124 & R125	-40.5	-40.5 to +33.5 [□]
Arm of R125 (as calibrated)	-47	-47 to +22 [□]
Junction of R125 & R126	-50	-50 to +14.8 [□]
D129 cathode	-0.42	-0.42 to +22 [□]
D132 Anode	0 (gnd.)	
D133 Anode	0	
D133 cathode	0	

Located on Alternate Sweep switching schematics.

* Indicates appreciable meter loading.

□ Indicates moving voltage (sweep in progress).

A Sweep Circuit

The A sweep and trigger circuits operate in the same manner as the B sweep and trigger circuits. They have the same circuit blocks and features as the B circuit. No separate lockout circuit is used. Instead, the sweep holdoff multivibrator can be switched by the SINGLE SWEEP switch or the HORIZONTAL DISPLAY switch so that it will not reset after the holdoff period. In these modes, the holdoff multivibrator requires a trigger signal to reset it, which makes the sweep triggerable again. This pulse can be supplied either by the SINGLE SWEEP switch (when pushed to RESET) or by the delay pickoff circuit. When the trigger MODE is in AUTO, the A sweep will run immediately after this reset pulse is received. The HORIZONTAL DISPLAY and trigger MODE switches combine in the delaying-auto modes to disable the A auto circuit and allow free run. When the MODE switch is in TRIG, the A sweep becomes triggerable after the delay interval or single sweep reset. Note that a pulse from the B sweep is connected, through the HORIZONTAL DISPLAY switches and some logic, to terminate the A sweep at the end of B sweep, preventing the intensified signal from appearing in the retrace. The logic prevents the A sweep from terminating the B sweep.

DELAY PICK-OFF

I. REQUIREMENTS

- A. Deliver a delayed trigger to A Sweep.
 - 1. Variable delay to full range of B Sweep.
 - 2. Delay controlled by DELAY-TIME MULTIPLIER.
 - a. 10k ten-turn Helipot.
 - b. Front panel control.

II. INPUT

- A. Ramp from the B Sweep generator.
 - 1. 100v positive going ramp starts at about ground.

III. OUTPUTS

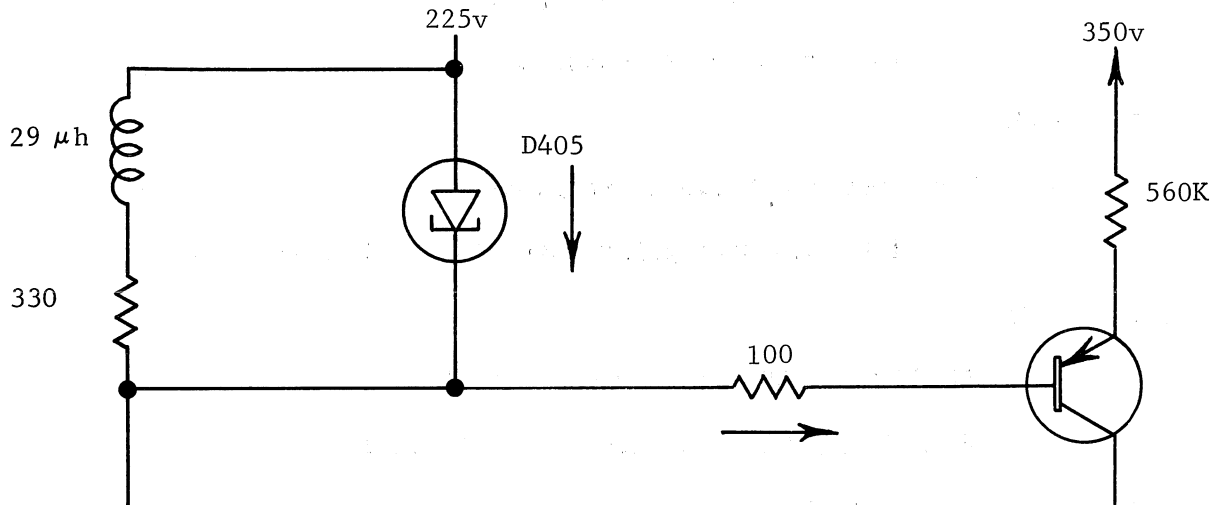
- A. DELAYED TRIGGER to A Sweep Generator.
- B. DELAYED TRIGGER out jack on front panel.

IV. DELAY COMPARATOR

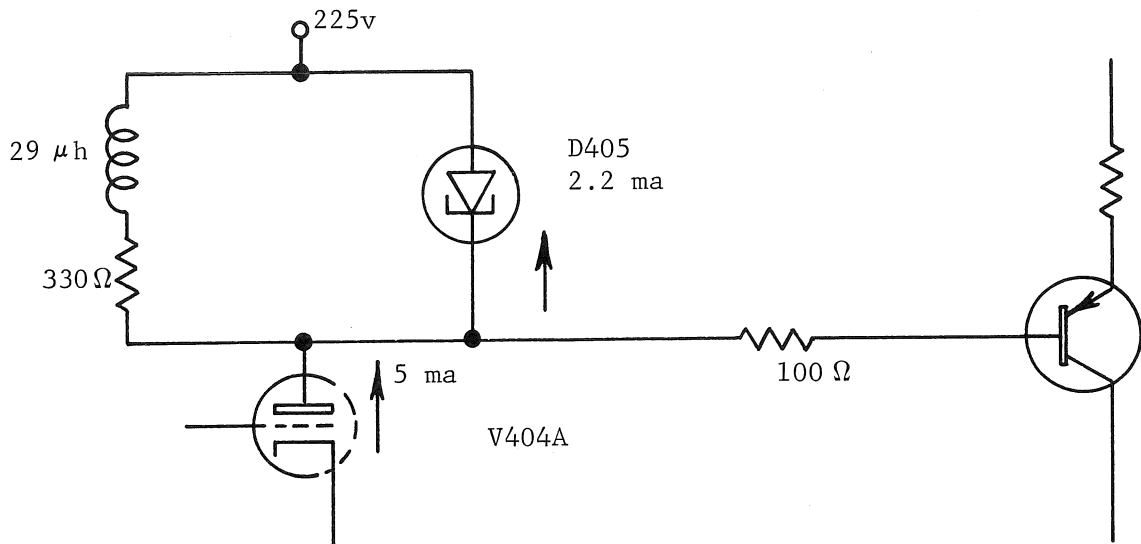
- A. Operation
 - 1. Positive going ramp from B Sweep Generator applied to the comparator left grid, V404A.
 - a. Ramp starts at -2v.
 - b. 100v P-P.
 - 2. Right grid level is set by the DELAY-TIME MULTIPLIER, R416.
 - a. With START and STOP ADJ at mid range the control has range from -6.5v to 104v.
 - 3. Constant current tube (V93B) grid sets at -57v.
 - a. 5.2 ma in quiescent state.
 - b. Cathode resistance presented $r_p + R_K (\mu + 1)$.
 - (1) About 500k.

DELAY PICK-OFF

4. In quiescent state the TD (D405) is reverse biased, in its low state.
- a. Reverse bias current is base current of driver transistor.



5. A comparator has no feedback so it has inherently slow transition.
- a. TD flip provides fast switching.
- b. 29 μh inductor (L404) as a part of the TD load improves switching time.
6. As the comparator tube (V404A) comes into conduction, the TD flips into the high state.
- a. Negative going step pulls down on driver transistor base.
- b. TD remains in this position until retrace returns the comparator to the quiescent condition.

DELAY PICK-OFF

7. Q424 has a collector load resistor of 18k to 202.5v.
(Equivalent circuit of R425 and R426.)
 - a. With 223 μa flowing in the quiescent state the collector sets at 210v.
 - b. Emitter is long-tailed to 350v through a 560k resistor.
 - c. The .001 μf capacitor (424) bypasses the emitter resistor for the fast step.
 - d. Long-tail cathode degeneration prevents anything but the fast step from passing.
8. The positive step, taken across the collector resistor, is differentiated sharply and applied to the base of the output EF. (Q433)
 - a. Time constant of the coupling network is .68 μsec.
(C426 - R429)
9. The output emitter follower (Q433) is cut off in the quiescent state.

DELAY PICK-OFF

9. (Con't)

- a. The NPN has 100v (decoupled) on the collector
(BV_{CE} is 120v).
 - b. The transistor is turned on for about 500 nsec.
10. The disconnect diode (D433) opens when EXT DELAYED TRIGGERS are used.
 11. DELAYED TRIGGER output voltage is about 14v at about 250 Ω .
 12. DELAYED TRIGGER PULSE is delivered to the A Sweep Generators.

HORIZONTAL DISPLAY MODES

A. Seven Display modes are available.

1. A - Only A Sweep is displayed.
2. B - Only B Sweep is displayed.
3. A ALT B - Both A and B Sweeps are displayed alternately.
4. B INTENS BY A - The B Sweep is displayed, but the A Sweep intensifies a portion of the display.
 - a. In this mode, an anti-wraparound feature prevents A Sweep from running beyond the end of B Sweep.
5. A DLY'D BY B - The A Sweep is displayed, having been delayed a calibrated time interval by B Sweep.
6. B INTEN - ALT - A DLY'D - The INTENS and DLY'D modes are displayed alternately.
7. EXT. HORIZONTAL INPUT

B. B INTEN BY A mode

1. Initially, only the B sweep can accept a trigger - A Sweep is locked out.
 - a. B Sweep is displayed.
2. As B Sweep begins to run up, a trigger arrives from the Delay Pickoff circuit.
 - a. A Sweep begins to run up.
3. A composite of the two sweeps is displayed; the A Sweep intensifying the B Sweep display.
4. A Sweep condition in AUTO mode
 - a. R255 connects to ground instead of to +100v thru R258.

- (1) D259 anode pulls down to -20v cutting off the diode.
 - (2) No triggers can reach the Sweep Gating T.D.
 - b. D265 clamps Q265 collector to ground disabling the Auto Multi.
 - (1) D279 is conducting 1.5ma from the Sweep Gating T.D.
 - c. D332 anode ties thru an equivalent 6.25k to 8.4v.
 - (1) Holdoff cannot flip the Holdoff Multi to its armed state.
 - (2) The Holdoff Multi is flipped by a Dly'd trigger from the Delay Pickoff circuit.
 - d. R330 in the Holdoff circuit returns to +350v instead of ground.
 - (1) Extends holdoff time.
 - e. Q344 collector ties to a 10v point on a divider in the B Sweep Generator.
 - f. An output from the Delay Pickoff is connected to C270.
 - g. Single Sweep circuit is disabled.
5. B Sweep condition in AUTO mode
- a. The Auto circuit is functioning.
 - (1) In the absence of triggers, B Sweep will free run.
 - (2) With triggers, the circuit will trigger normally.
 - b. D132 anode is tied thru the Horizontal Display switch and the AUTO switch to 10v.
 - (1) Divider R135, R136 is equivalent 10k to 10v.
 - (2) Holdoff cannot flip the multi to its ready state.
 - (3) D136 clamps the bottom of the divider to ground.
 - (4) At the end of A Sweep, the bottom of the divider drops to -11v.

- (5) D132 anode pulls down to ground.
 - (6) B Holdoff can be completed.
 - (7) The B Holdoff Multi can switch to the
 - c. The B Sweep ramp is fed to the Delay Pickoff.
6. Operation in the AUTO mode at start of Sweep.
- a. B Sweep begins to run up.
 - b. The B Sweep ramp is fed to the Delay Pickoff.
 - c. At a time delay determined by the B Sweep timing and the DELAY TIME MULTIPLIER, a positive going Delayed Trigger arrives at the A Sweep Generator.
 - d. Coupled thru C360, R360, the Delay Trigger pulls a 6ma current pulse out of the A Sweep Gating T.D.
 - (1) This current pulse plus the 1.5ma flowing thru D279 is enough to overcome the 2.2ma reverse current thru the T.D. and flip it to its high state to start sweep.
 - e. The same Delayed Trigger lifts D367 into conduction.
 - f. V345A cathode current is diverted thru D363.
 - g. V345A cuts off and the Holdoff Multi flips.
 - (1) Sweep has already started 100 nsec earlier.
 - (2) The Multi is now in the position to hold the Sweep Gating T.D. in its high state until the end of sweep.
 - h. As sweep starts, the A Sweep unblanking waveform adds to B sweep unblanking to intensify the portion of the B display that represents A Sweep duration.
7. Operation in the AUTO mode at the end of sweep.
- a. AUTO mode in this instance has a different function than AUTO triggering.

- (1) In this mode, the A Sweep will start as soon as armed by the Delay Trigger.
 - (2) The Auto Multi is disabled.
- b. If A Sweep terminates before B, the A Sweep Holdoff Multi switches in the normal manner and Holdoff starts.
- (1) Holdoff is not completed as D332 clamps the Holdoff bus at 8.4v.
 - (2) The A Holdoff Multi remains in its locked out mode.
- c. As A Sweep Holdoff Bus reaches its 8.4v lock out point, V345A cathode will have dropped to -12v.
- d. As V345A reaches -12v, D355 cuts off and D356 turns on.
- e. Current thru D356 pulls Q344 into saturation.
- (1) Q344 base sets at -11v.
 - (2) Q344 collector pulls down to -11v.
 - (3) D136 (B Sweep Diagram) disconnects.
 - (4) D132 anode pulls down to 0v.
 - (5) B Holdoff can be completed.
- f. As B Sweep is completed, the B Holdoff Multi switches in the normal manner and holdoff starts.
- (1) With D132 anode at 0v, B holdoff can be completed.
 - (2) At the end of B Holdoff, the B Holdoff Multi flips to its Ready state.
 - (3) The next trigger will start sweep again.
- g. If A Sweep is set to run longer than the end of B Sweep:
- (1) B Sweep ends in the normal manner.
 - (2) As the B Holdoff Multi flips and V145A cuts off, a positive step is generated at V145A plate.

- (3) The step is differentiated, amplified and inverted in Q444 circuit (Sweep Switching diagram).
 - (4) The negative pulse pulls down on D347, flipping the A Holdoff Multi and stopping sweep.
 - (5) This is called the anti-wraparound feature.
- h. A and B holdoff begin at about the same time.
- (1) Neither sweep can complete holdoff in the normal manner.
 - (2) A Sweep holdoff bus is clamped at 8.4v.
 - (3) B Sweep holdoff bus is clamped at 10v.
- i. As A holdoff reaches its 8.4v level, V345A cathode will have dropped to -12v.
- (1) D355 cuts off, D356 turns on, biasing Q344 to saturation.
 - (2) Q344 collector pulls D132 anode down to 0v.
 - (3) B Sweep can now complete holdoff.
 - (4) The B Holdoff Multi will flip to its Ready state.
 - (5) The next trigger will start another sweep cycle.
8. Circuit conditions in the TRIG mode.
- a. The A Sweep can accept a trigger.
 - (1) The ground on R255 is removed.
 - b. The Delayed Trigger path thru C360, R360 is opened.
 - c. D132 anode in the B Sweep holdoff is tied to ground.
 - d. A Holdoff Multi is in its locked out state.
 - e. D279 is cut off.
9. Operation in the TRIG mode at the start of sweep.
- a. B Sweep is initiated by a trigger.
 - b. The Sweep ramp is fed to the Delay Pickoff.

- c. After a calibrated delay, a Delayed Trigger conducted thru C365 lifts D363 anode into conduction.
 - d. V345A cathode current is directed thru D363.
 - e. V345A cuts off and the Multi flips to its armed state.
 - f. The Sweep Gate T.D., D285, is in its low state with 4.1ma flowing.
 - g. The next trigger will flip the T.D. starting sweep.
-
10. Operation in the TRIG mode at the end of sweep.
- a. A Sweep ends in the normal manner.
 - b. A holdoff is clamped at 8.4v so it cannot arm the A Hold-off Multi.
 - c. B Sweep and Holdoff operate the same as in the normal manner.
 - (1) B Sweep does not wait for the end of A holdoff before triggering.
 - d. If A Sweep does not receive a trigger after being armed (triggers too far apart for the sweep rate), the end of B Sweep disarms the A Holdoff Multi thru D347 and the anti-wraparound feature.
 - e. A portion of the A Sweep AUTO-TRIG switch places D132 anode to ground when in the TRIG position.
 - (1) If D132 anode was connected to Q344 lockout circuit as in the AUTO mode, a condition could develop when no trigger arrives to start A Sweep.
 - (2) A Sweep Multi is disarmed by a pulse thru D347 from the B Holdoff Multi.
 - (3) Under this condition, B Sweep lockout would in turn be removed by A Holdoff Multi turning on Q344.

- (4) An accidental interruption during this cycle could lock up the system and the operator would lose trace.

11. Single Sweep operation.

- a. The B Sweep can be armed by the Single Sweep RESET switch while in the B INTENS BY A mode.
- b. In SINGLE SWEEP mode, the B holdoff bus cannot fall below 10v while A Sweep is running.
- c. The RESET pulse arms the B Sweep circuit (in TRIG mode).
 - (1) The Ready light goes on.
- d. With the next trigger, B Sweep starts its run up.
- e. The Delayed trigger arrives and A Sweep starts.
- f. Both sweeps end like in normal B INTENS BY A operation.
- g. In SINGLE SWEEP mode, the connection between Q344 collector and D132 is opened.
 - (1) The end of A Sweep cannot remove the B Sweep holdoff lockout.
 - (2) B Sweep can be armed only by a RESET pulse.

C. A DLY'D BY B MODE

1. Operation of A and B Sweeps is essentially the same as in the B INTENS BY A mode.
2. In this mode, however, A Sweep is displayed.
3. The B Sweep Unblanking Gate turns off B Unblanking.
4. The anti-wraparound feature does not function.
 - a. The B terminating pulse path from V145A plate is opened.
5. B Sweep can be operated SINGLE SWEEP in the same manner as in B INTENS BY A mode.

D. B INTENS BY A - ALT - A DLY'D BY B MODE

1. This mode alternates B INTENS BY A and A DLY'D BY B modes utilizing switching and logic circuits discussed in the Sweep Switching notes.

E. A - ALT - B

1. Switching and logic circuitry is discussed in the Sweep Switching notes.

F. EXT

1. Both sweeps can run either TRIGGERED AUTO or SINGLE SWEEP modes.
2. The sweeps are not displayed, but GATE and SWEEP waveforms are available at the front panel jacks.

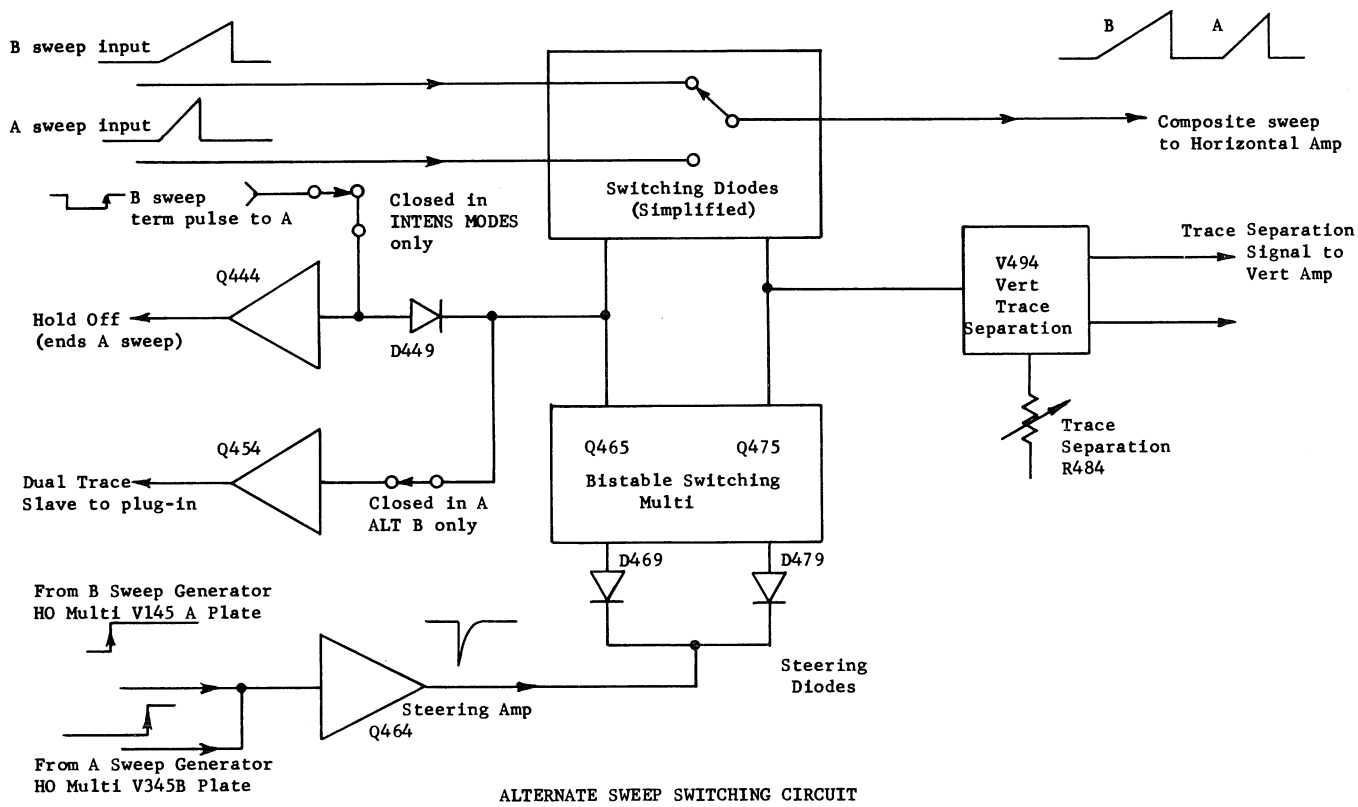


Figure 6-0

6. SWEEP SWITCHING

1. The sweep switching circuit, provided on the 547 only, can alternate between the display of A and B sweeps, much as a dual-trace plug-in such as the 82 operates in the alternate mode. A locking signal is sent to the dual trace plug-in via the blue-ribbon connector and may be used to lock alternate A and B displays with alternate Channel 1 and Channel 2 displays. The 1A1 has this circuit already wired in. The CA requires additional wiring to use the signal.
2. The 546 has no provision for sweep switching, and the time-base display is selected by the operator through the HORIZONTAL DISPLAY switch. Display modes available in the 546 are the same as in the 545A, although they are placed in a more convenient order on the switch. They are: A, B, B Intensified by A, A delayed by B, and X1 and X10 external horizontal input.
3. In the 547, two more horizontal display positions are provided. A ALT B, between the A and B only positions, allows alternate display of A and B sweep rates, slaved to the dual trace preamplifier. (If a single trace or M unit are used, there is no slaving). In the ALT position between intensified and delayed sweeps, both the intensified and delayed sweeps are displayed alternately, but the dual-trace plug-in is switched at the end of the B trace, so that the signal is displayed by both traces. In the case of the M unit, operating in the alternate mode, each channel is displayed through both sweep traces. Chopped mode is controlled by the plug-in, and is not affected by the sweep switching.

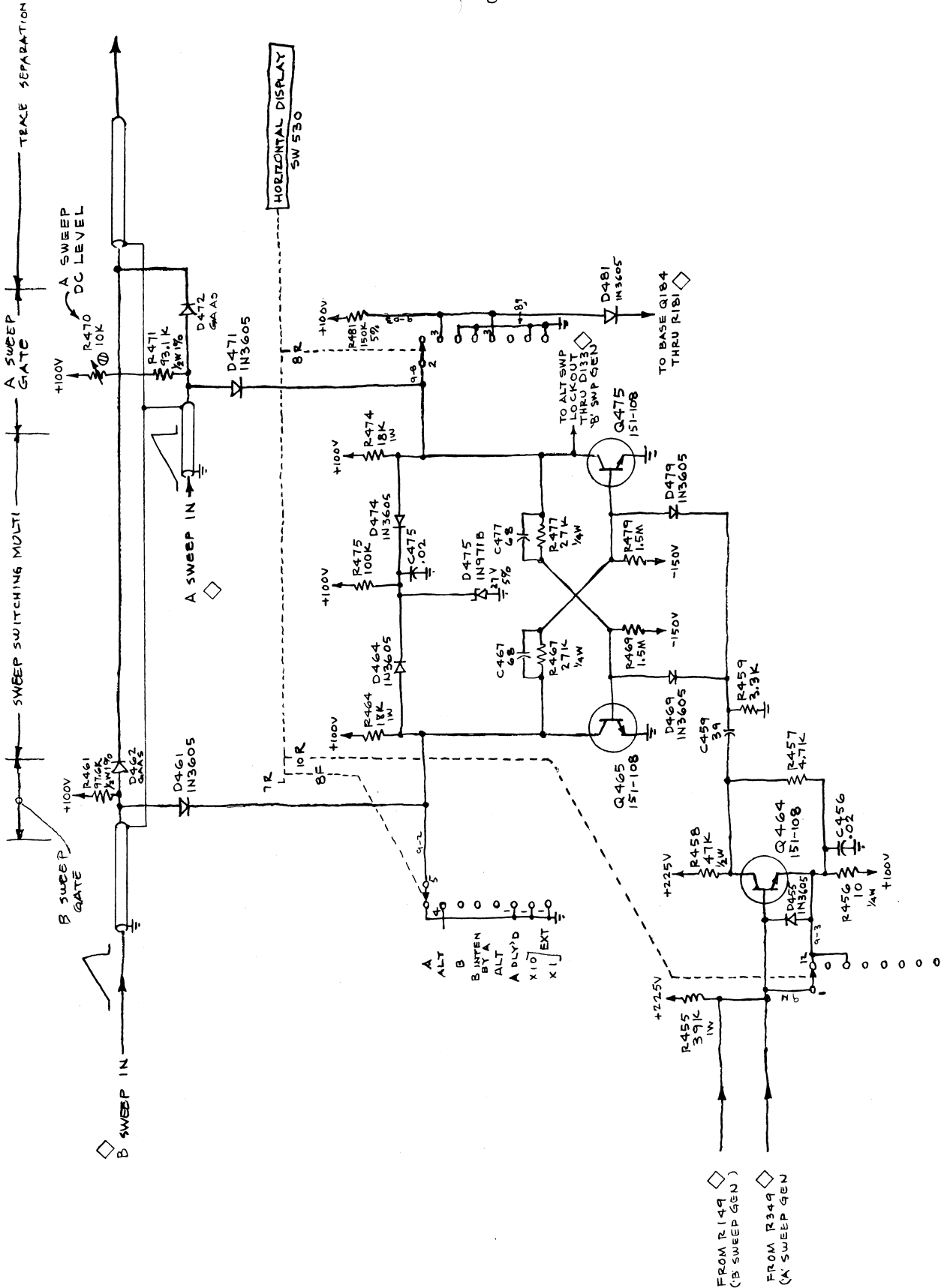


Figure 6-1 Switching Circuit

4. In the alternate display positions, the circuit also operates a trace separation circuit that allows the A trace to be displayed vertically. A front panel control allows the amount of displacement to be controlled. This displacement is independent of the settings of the vertical position controls.

5. Switching circuit: (Figure 1)

a. The A and B sweep generator outputs are fed to the sweep switching circuit as current signals.

(1) Each signal is a current sawtooth running up to 2ma, near 1 volt above ground.

(2) The A sweep signal is fed to D471 and D472. When Q475 is on, D471 conducts the signal to ground, and D472 is reverse biased, cutting signal from the A sweep generator to the Horizontal amplifier off.

(3) The B sweep signal is fed to D461 and D462. When Q465 is off, and the Horizontal display switch is in a position allowing B display, D461 is cut off by the clamp voltage (27v from D475). D462 is forward biased, allowing the current signal from the B sweep generator to be fed to the Horizontal amplifier and be displayed.

(4) A 1 ma current through R461 keeps either D461 or D462 forward biased, depending on whether D461 see 0 volts or +27 volts.

(5) R470 and R471 in series also supply a current to keep one of the switching diodes (D471 or D472) forward biased. The current supplied is adjustable by R470 to exactly match the current supplied through the A sweep path. The adjustment

is made by setting the starting point of both sweeps at the same point (adjusting A to coincide with B).

b. The switching circuit allows one sweep signal to pass and shunts the other to ground through the diode logic.

(1) In either of the alternate sweep positions, the collector voltages of Q465 and Q475 operate the diodes. If Q465 is conducting, D461 is forward biased. Q475 is cut off, and D472 is cut off, allowing D472 to conduct. The A sweep is displayed. D462 is cut off preventing the B sweep from being displayed. D462 also prevents the A sweep from leaking back into the B sweep circuit, and for this reason, low leakage Gallium Arsenide diodes are used, for both D462 and D472.

(2) When the multivibrator is switched by a pulse from the collector of Q464, Q475 conducts, shunting the A sweep through D471. At the same time, Q465 is cut off, allowing D461 to be cut off. The B sweep then passes through D462.

(3) When the HORIZONTAL DISPLAY switch is moved to A or to A DELAYED position, the A sweep only is to be displayed. Contacts on the switch ground the collector of Q465, holding D461 forward biased and D462 reverse biased. The B sweep signal is shunted to ground. With Q465 collector held at ground, the DC level at the base of Q475, determined by R467 and R479, will be a little below ground, and Q475 will be cut off.

(4) In this mode, when a switching signal appears at D469, it will pass through, but cannot switch the multivibrator because the base of Q465 is held by the separate ground path.

(5) In B only or B INTENSIFIED, by A the collector of Q475 is grounded, forward biasing D471, and reverse biasing D472, thus shunting the A signal to ground. At the same time, Q465 is left cut off, and the B sweep signal is transmitted.

(6) In the X10 and X1 external display modes, the collectors of Q465 and Q475 are both grounded, grounding the A and B sweep outputs. This is to prevent cross-talk.

c. Positive signals from both the A and B holdoff multivibrators appear at the base of Q464, the switching amplifier. Either of these positive signals, which appears at the end of the sweep, can forward bias Q464, pulling its collector down. D455 prevents reverse breakdown across the emitter-base junction of Q464.

d. A negative signal from Q464 passes through blocking capacitor C459, and forward biases one of the switching diodes, D469 or D479.

(1) The diode that is forward biased depends on the state of multivibrator transistors Q465 and Q475. The base of the transistor that is turned on will be at a higher voltage (about $\frac{1}{2}$ volt).

(2) Q465 and Q475 are in a common Eccles-Jordan bistable multivibrator circuit. The collectors of the transistors are switched between +27 volts (clamped by D464, D474, and D475) and 0 volts (saturation).

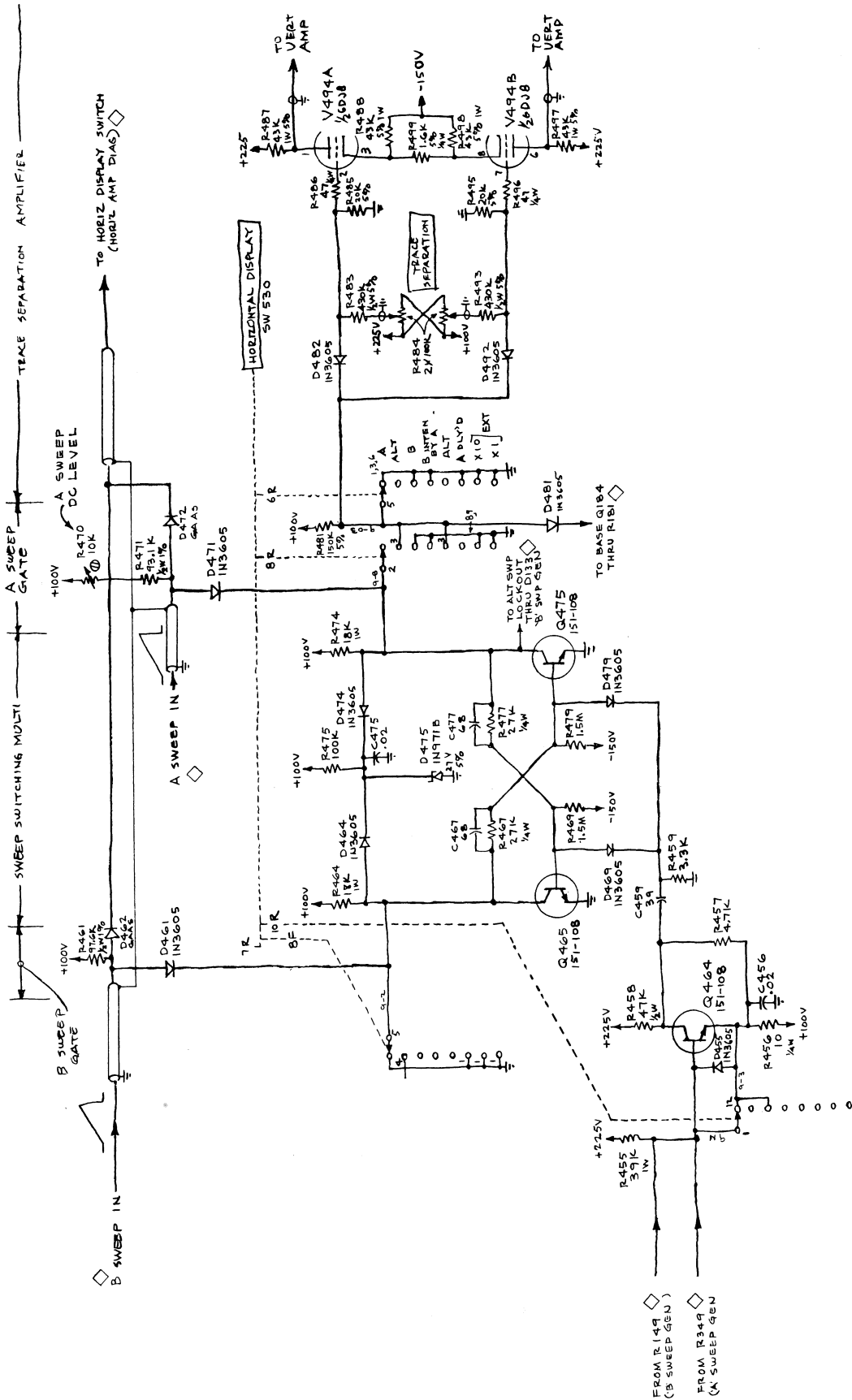


Figure 6-2 Trace Separation

6. Trace Separation: (Figure 6-2)

In the alternate display modes, the collector voltage of Q475 is also used to operate the A and B trace separation circuit. In all other horizontal display modes, the trace separation circuit is held inoperative.

a. Contacts on the HORIZONTAL DISPLAY switch connect the collector of Q475 to D482 and D492 in the alternate display modes.

b. When trace separation is not used, other contacts on HORIZONTAL DISPLAY switch ground the connection between D482, D492, and the sweep switching multivibrator.

(1) When this connection is grounded, the diodes are forward biased by current through R484, R483, and R493.

(2) The low impedance across the forward biased diodes causes the voltage at the grids of V494A and B to about $\frac{1}{2}$ volt, regardless of the setting of the TRACE SEPARATION control, R484.

(3) This same condition is obtained in the ALTERMATE modes when Q475 is on. The collector of Q475 is then at ground, D482, and D492, are forward biased, and the grids of Q494A and B see the same voltage.

(4) When operating in the ALTERNATE mode, when Q475 is off, its collector rises to +27 volts. This cuts D482 and D492 off. The voltage on the grids of V484A and B are determined by dividers R484, R483, R486, and R484, R493, R496. R484 can be adjusted to increase or decrease the differential of voltage, and to reverse its polarity.

(5) When Q475 is cut off, the A sweep is displayed. The trace separation voltage thus can only appear at the grids of the tubes when the A trace is displayed.

(6) V484A and B are an ordinary push-pull cathode coupled amplifier. The DC balance of the amplifier is shifted when the A trace is displayed, and this shift is sent, from the tube plates, to the end of the delay line in the vertical amplifier, through 5.1 K resistors. This resistance is high enough to prevent interaction between the delay line impedance and the trace separation circuit. The cathode coupling allows common-mode signal cancellation that might be sent to the vertical amplifier, and thus eliminates compression problems that might occur.

(7) When the trace separation circuit is in use, and A sweep is selected, a current is supplied through R481 and D481 which locks out the B blanking signal to the CRT. This allows the normal A blanking and unblanking to occur.

7. A Sweep Termination: (Figure 6-3)

In the older oscilloscopes, in the intensified mode, the B sweep could be made to end before the A sweep. When this happened, the A sweep would intensify the retrace and the beginning of the next sweep. In the 547, the sweep switching circuit has additional logic which prevents the "runaround".

a. When the HORIZONTAL DISPLAY switch is in B INTENSIFIED or the adjacent ALTERNATE position, the signal from the plate of V145A, the B holdoff multi, is fed through the HORIZONTAL DISPLAY switch

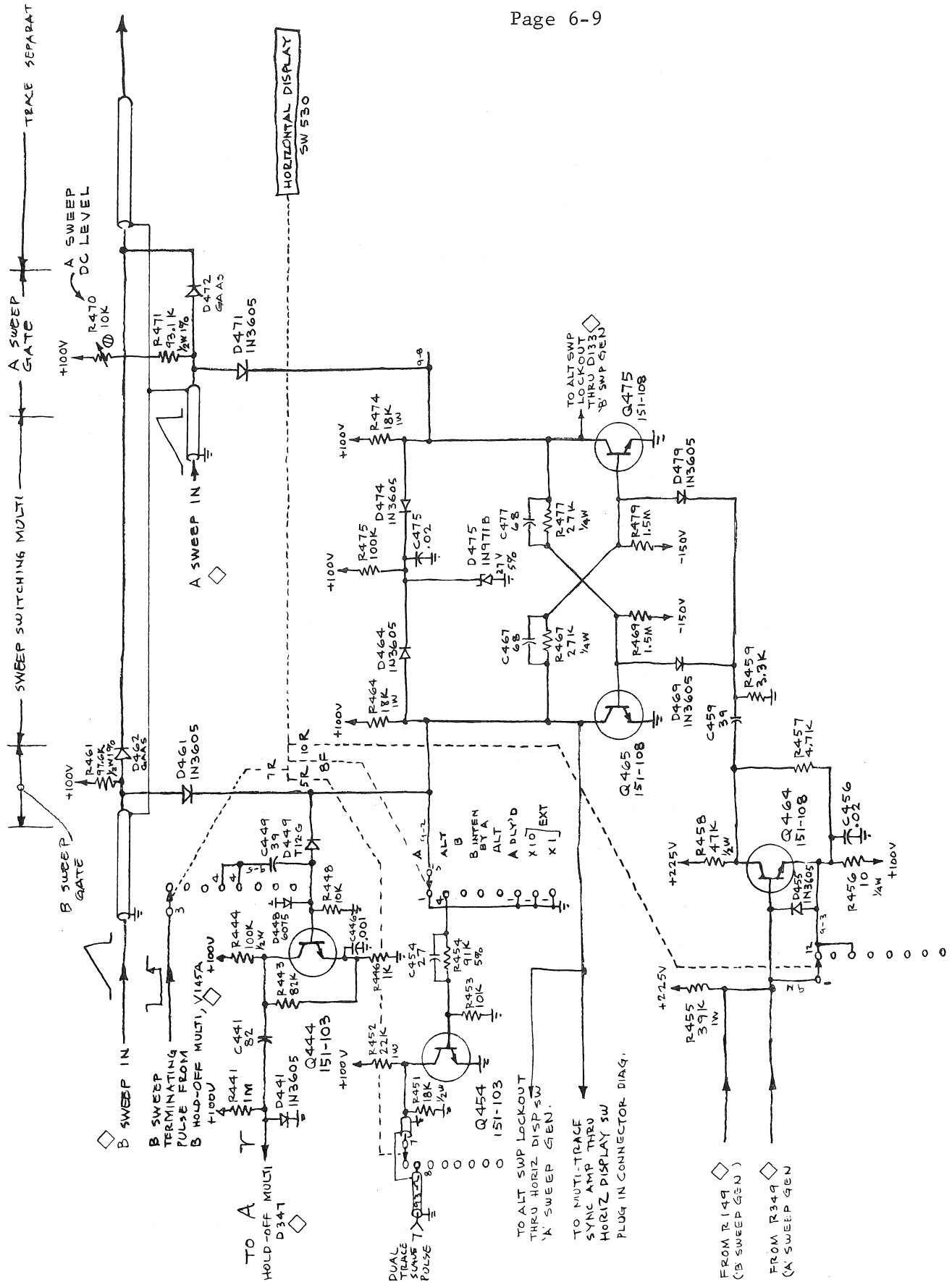


Figure 6-3 Time Base Switching

to the base of Q444, through C449. This signal can only reach Q444 when Q465 is off, raising its collector and back-biasing D449. This occurs only when the intensified display is present. D449 shorts out the signal when the delayed trace (A) is shown, because the circuit would shorten the A trace, to no advantage, otherwise.

b. At the end of the B sweep, a positive pulse differentiated by C449 & R448 arrives at the base of Q444, forward biasing the transistor, and pulling its collector down. This collector pulse is fed through C441 to the A hold off multi, ending the A sweep.

(1) D441, R441, D448, R448 are DC restoration circuits that allow changes in circuit operating repetition rate.

8. Alternate Trace Signal: In the intensified-delayed alternate mode only, the collector signal from Q465, inverted by Q454, is used to provide the alternate trace sync pulse to the multi-trace plug-in unit. This allows the display of both intensified and delayed signal with each trace before the plug in switching circuit is switched to the next trace (works with M, C, and 1A1). In the A and A delayed modes, the alternate trace signal is provided by the A holdoff multivibrator (plate, V345A). In A ALT B, B, B Intensified, and Ext Horizontal, the B holdoff multivibrator (plate, V145A) supplies the alternate trace signal.

a. Alternate trace signals are a positive pulse which occurs at the end of a sweep, from all sources. This pulse is fed to the grid of V764B. (Plug-in connector diagram).

(1) C760 blocks and shapes the signal into a pulse.

(2) R761 and R762 set the level of the grid of V764B at -8 volts. L760 raises the impedance seen by the pulse, and provides sharp differentiation.

(3) The cathode of V764B is grounded through the mode switch of dual trace (or M unit) plug-ins only in the alternate display mode. In other modes, the tube is cut off by the 100 volt signal through R764. Thus, the alternate trace circuit is cut off except when the plug-in actually uses it.

b. When the cathode of V764B is grounded, the alternate trace signal causes a negative pulse at the plate of V764B, which is fed through C765 to the grid of V764A.

(1) When the plug-in operates in chopped mode, a switching signal (negative pulse) also appears at pin 16 of the blue ribbon connector.

(2) This signal is used to provide dual-trace blanking. It is amplified and inverted back to a positive pulse by V764A and then fed through the switch on the back of the scope, SW858, to the cathode of the CRT.

(3) D759, R758, and R759 are a DC restoring circuit which prevents a charge from building up across C765.

(4) D769 clamps the plate of V764A at 100 volts when the tube is cut off.

(5) C768 bootstraps the blanking circuit into operation at the beginning of blanking, providing a sharper waveform to the CRT.

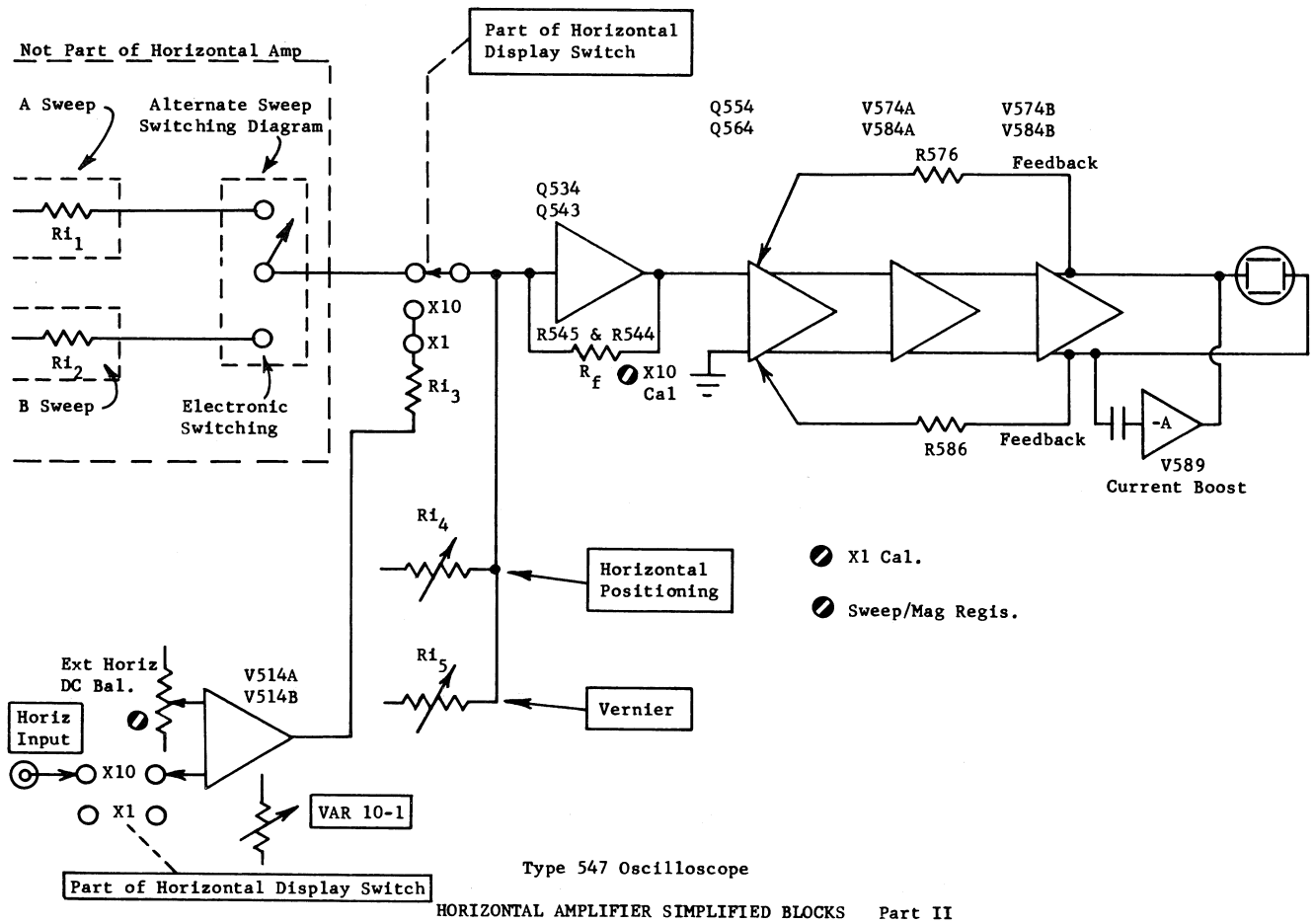


Figure 7-0

7. HORIZONTAL AMPLIFIER

1. Horizontal amplifiers for 544, 546 and 547 are basically the same.
 - a. Maximum linear sweep rate that can be displayed is 10 nsec/cm.
 - b. Range of linearity is at least 225 volts peak to peak.
 - c. Measured horizontal sensitivity of CRT is 22 v/cm.
 - d. Magnification causes amplifier to "bottom out" at either or both ends, depending on control settings. Maximum swing is limited by the +350 plate supply used by V574 and V584 (both sections).
 - e. X1 presentation is obtained with R557 (between emitters of Q554 and Q564) open. Magnification is obtained by decreasing the impedance between these emitters. The 544 amplifier has an adjustment between the emitters for X100 gain, when R557 is shorted out. The 546 and 547 amplifiers have no adjustment, but the circuit is the same otherwise.
 - f. The 544 external horizontal input is also provided with a X100 attenuator, in addition to the X1 and X10 that the others have.
 - g. Basic sensitivity of the external horizontal input is 70 mv/cm.
 - h. Basic (X1) sensitivity of the horizontal amplifier is 200 microamp/cm into the virtual ground of an operational amplifier.
2. Horizontal amplifier has five stages.
 - a. First and second stage (Q534 and Q543) form feedback pair.
 - (1) First section is collector coupled amplifier, providing the gain.
 - (2) Second section is emitter follower, providing low output impedance.
 - b. Third stage is emitter coupled push-pull paraphase amplifier.
 - (1) X1 gain is set by fixed degeneration between the emitters.
 - (2) Magnification is switched in by decreasing degeneration.

c. Fourth and fifth stage are push-pull feedback pairs.

(1) Vacuum tubes are used, because of the limited dynamic range of transistors.

(2) Fourth stage (V574A and V584A) is plate-loaded, providing the gain.

(3) Fifth stage (V574B and V584B) is cathode follower, providing low output impedance. CRT plates are driven by output of fifth stage.

(4) V589 can supply extra current to charge the left hand deflection plate capacitance for fast sweep speeds.

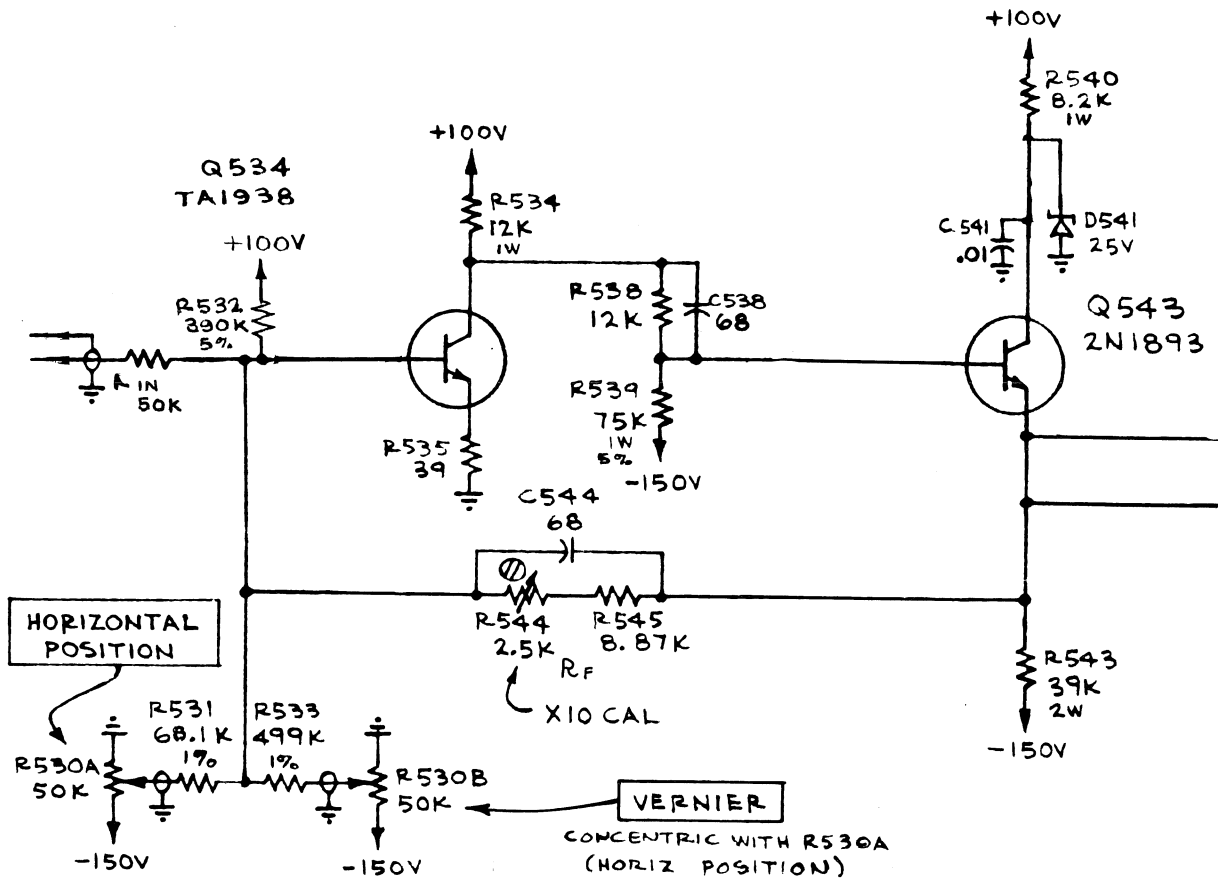


Figure 7-1

3. First and second stage (Fig. 7-1):

a. Input to Q534, through the horizontal display switch, is the virtual ground point of the operational amplifier.

(1) Input sensitivity is set by feedback resistance R544 and R545, to be 200 microamp/cm, with XI presentation.

(2) Input resistances which meter current output of sweep generators are in the sweep generator circuits.

(3) Sweep switching (547 only) is placed between input resistance and virtual ground.

b. Positioning is by current fed in through the HORIZONTAL POSITION controls.

(1) R532, connected to the -150 is a 5.5 cm correction that allows convenient values to be used for R534, R538, and R539.

(2) R530A and R530B are both 50K pots. R533 meters current fed from R530B, limiting control range to about 2 cm. R531 meters current from R530A, allowing 11 cm of adjustment.

c. Network R534, R538, and R539 sets the DC level at the emitter of Q543 with no input.

(1) C538 couples high frequency signals.

d. R545 and R544 are the feedback loop.

(1) They set the gain of the operational amplifier.

(2) The voltage developed across the feedback resistors develop a current through them that balances out the input current at the virtual ground. This feedback current is diminished by $1/\text{gain}$

of the stage, without feedback. It is this current that makes the virtual ground a low impedance point.

(3) C544 speeds up the operation of the feedback loop at high frequencies.

e. R540, R541, D541, and C541 make a low impedance collector supply for Q543.

(1) Collector current is low impedance supplied because of D541 until current draw exceeds 9 ma, when D541 no longer conducts.

(2) Maximum collector current is limited by R540, protecting the transistor. This circuit also limits maximum voltage to 25 volts at the collector.

(3) R541 and C541 are decoupling.

f. Output of Q543, fed to the base of Q554, is 20 volts, over the range of the sweep sawtooth. (10cm)

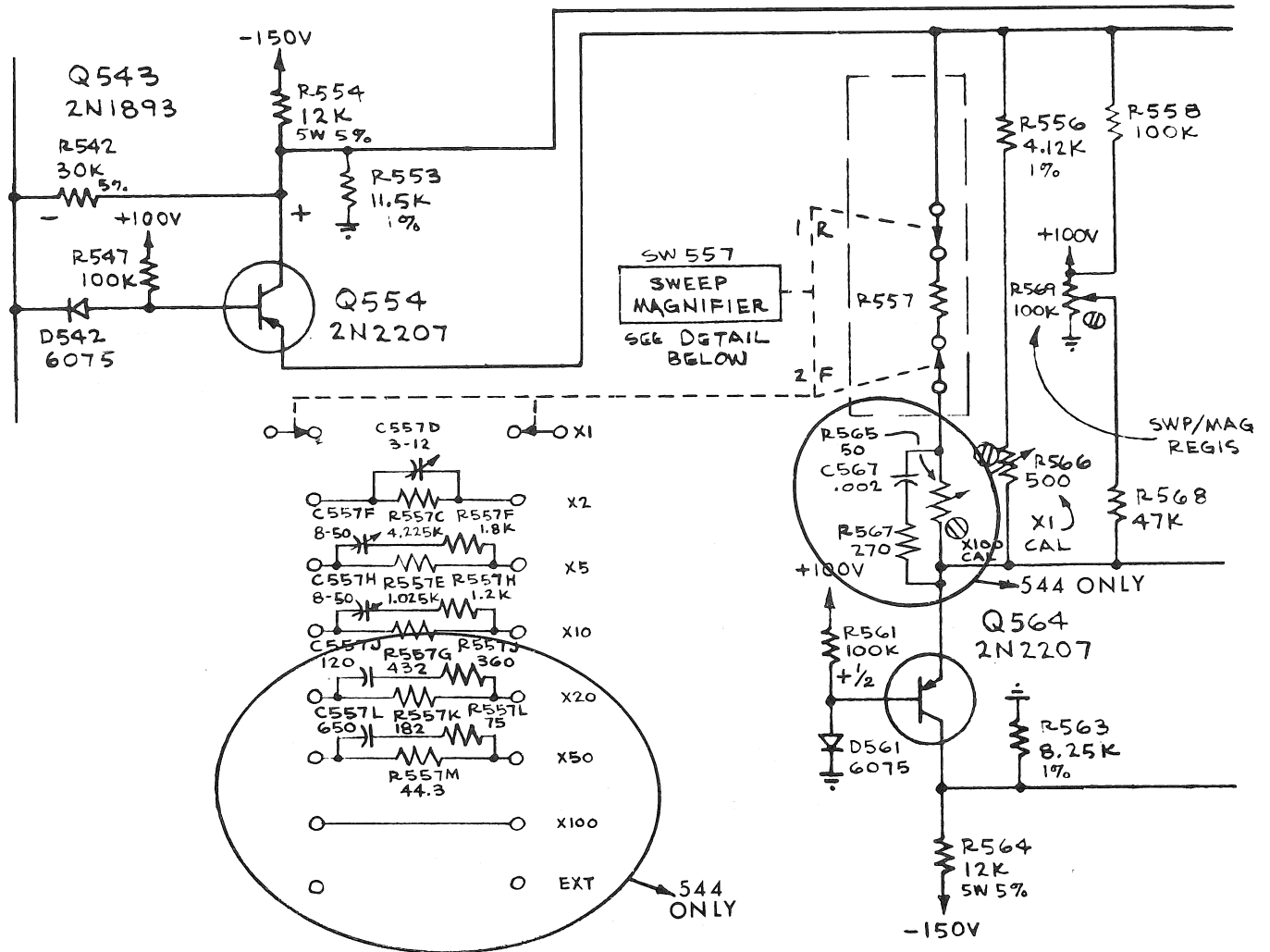


Figure 7-2

4. Third stage (Q554 and Q564) (Fig. 7-2)

a. Input is 2 v/cm (X1), through D542.

(1) D542 in the input decouples when the positioning voltage is moved to the extreme left side (off screen) of the CRT. If D542 did not decouple Q554 could break down due to the high current supplied.

(2) R547 keeps D542 forward biased plus limits the base current to a safe value (≈ 1 ma) during the time when D542 is decoupled.

b. Q554 and Q564 operate as an emitter coupled paraphase amplifier.

c. The emitter circuits of Q554 and Q564 supply current for the cathode circuits of V574B and V584B.

(1) Currents through these coupling paths assist in cancelling common-mode signals.

d. In X1 gain, coupling is through R556 and R566.

(1) The circuit of R558, R569, and R568 allows current to be added or subtracted from the Q564 side of the circuit, shifting the unmagnified trace. When magnification is switched in, the current unbalance is reduced, proportionate to the magnification. This circuit allows registration of unmagnified and magnified displays.

e. With magnification, R557 and C557 are switched in. In the X5 and X10, C557 is in series with another resistor (labeled R557) which provides an RC correction to maintain display linearity. In the type 544, the same circuit is used in X20 and X50, and a short is placed in the R557 position in X100 gain.

(1) The 544 horizontal amplifier also has a resistance in series with the magnifier shunts, R565. This resistance is used to calibrate X100 gain. Its value becomes negligible in the lower magnifications.

(2) The values of R557 used in the 546 and 547 are about 40 ohms higher than in the 544, allowing for the resistance of R565 in the 544.

(3) R567 and C567 are used in the 544 for RC compensation in the X100 position.

f. X1 gain is adjusted in this stage by R566. This resistance shunts the X10 shunt substantially. The X10 gain is raised by decreasing feedback in the Q534 and Q543 pair, and the two adjustments interact, requiring several checks to set both properly.

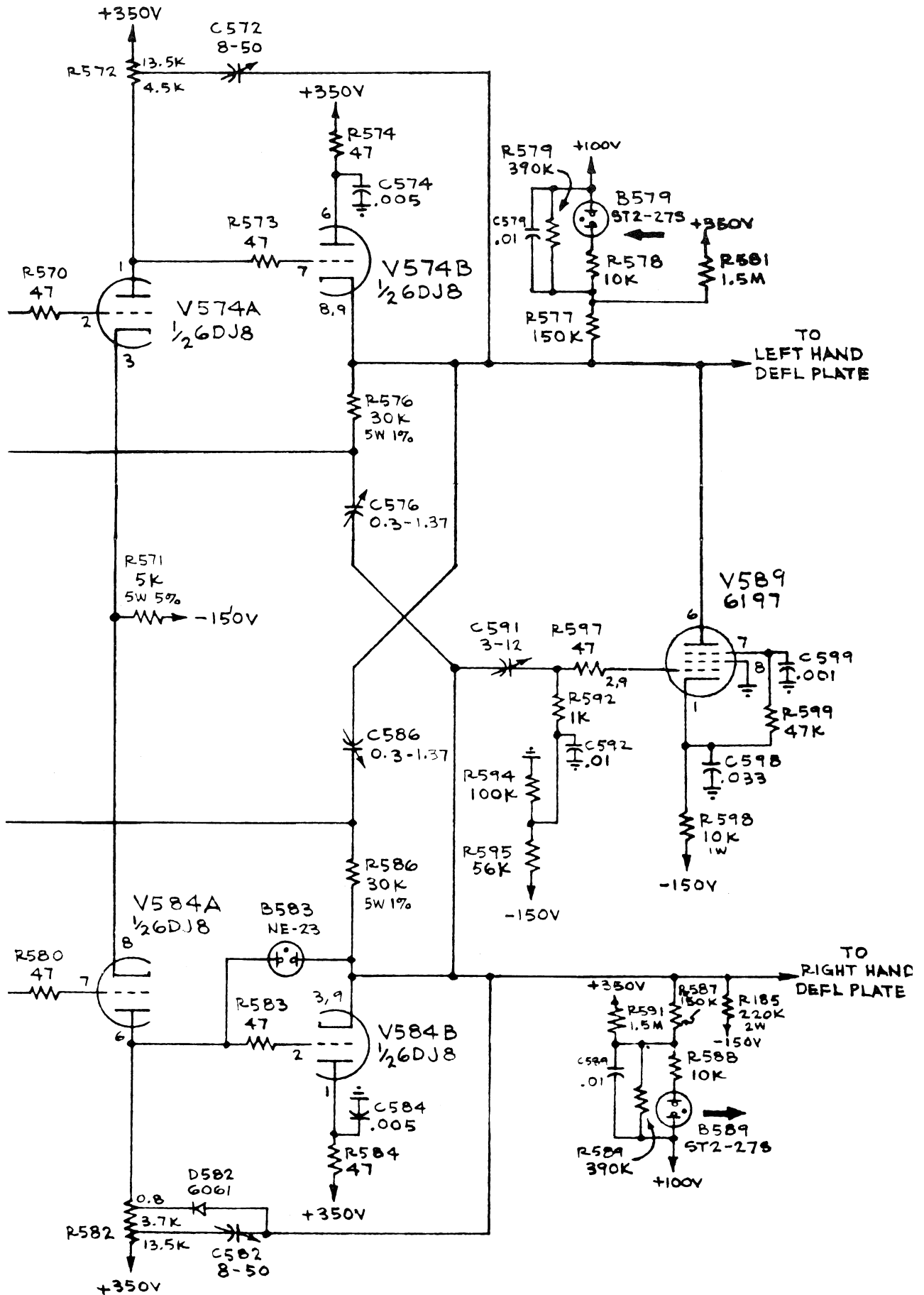
(1) The X100 gain adjustment in the 544 does not have a substantial effect on the X1 and X10 gain adjustments, and should be adjusted last.

g. R561 and D561 supply current to the effectively grounded base of Q564.

(1) D561 provides temperature compensation for D542.

h. R553, R554, R563, and R564 set the DC levels of the output at -32 volts with the spot centered on the CRT.

(1) The resistance of R553, in parallel with R542, equals R563 alone.



HORIZONTAL AMPLIFIER
Figure 7-3

5. Fourth stage (V574A and V584A) (Fig. 7-3)

a. This stage is a common ordinary plate loaded push-pull amplifier with cathode coupling.

(1) Cathode current is supplied through R571.

(2) Unity coupling between cathodes balances out common mode signals. Since there is degeneration between emitters of the preceding stage, there will always be common mode signals to balance out. Common mode signals appearing on the CRT plates will spoil focus.

(3) Total current shared by the tubes is 23 ma. This value changes when the trace travels off the CRT, because the tubes can be bottomed out against the available plate voltage.

b. Plate loads R572 and R582 are center tapped. Bootstrapping voltage is supplied through C572 and C582 to improve linearity at fast sweep rates.

(1) The reduction in gain that appears at the faster sweep rates is made up by increasing the output voltage of the sweep generators at the faster rates.

(2) The maximum sweep rate that is calibrated is 10 nsec/cm. increasing this rate by improved design is not desirable because of writing rate limitations in the CRT.

(3) D582 is forward biased during the retrace, allowing V584A to lower the voltage on the cathode of V584B. This speeds the retrace.

6. Fifth stage (V574B, V584B, and V589)

a. This stage functions as a push-pull cathode follower.

- b. V589 supplies extra current to charge the left hand deflection plate capacitance. The tube normally conducts a constant current (5 ma) which is increased by coupling through C591 on fast sweep rates.
- c. C576 and C586 provide positive feedback to the emitters of Q554 and Q564 at high sweep speeds to increase the gain.
- d. B579 and B589 are beam position indicators.

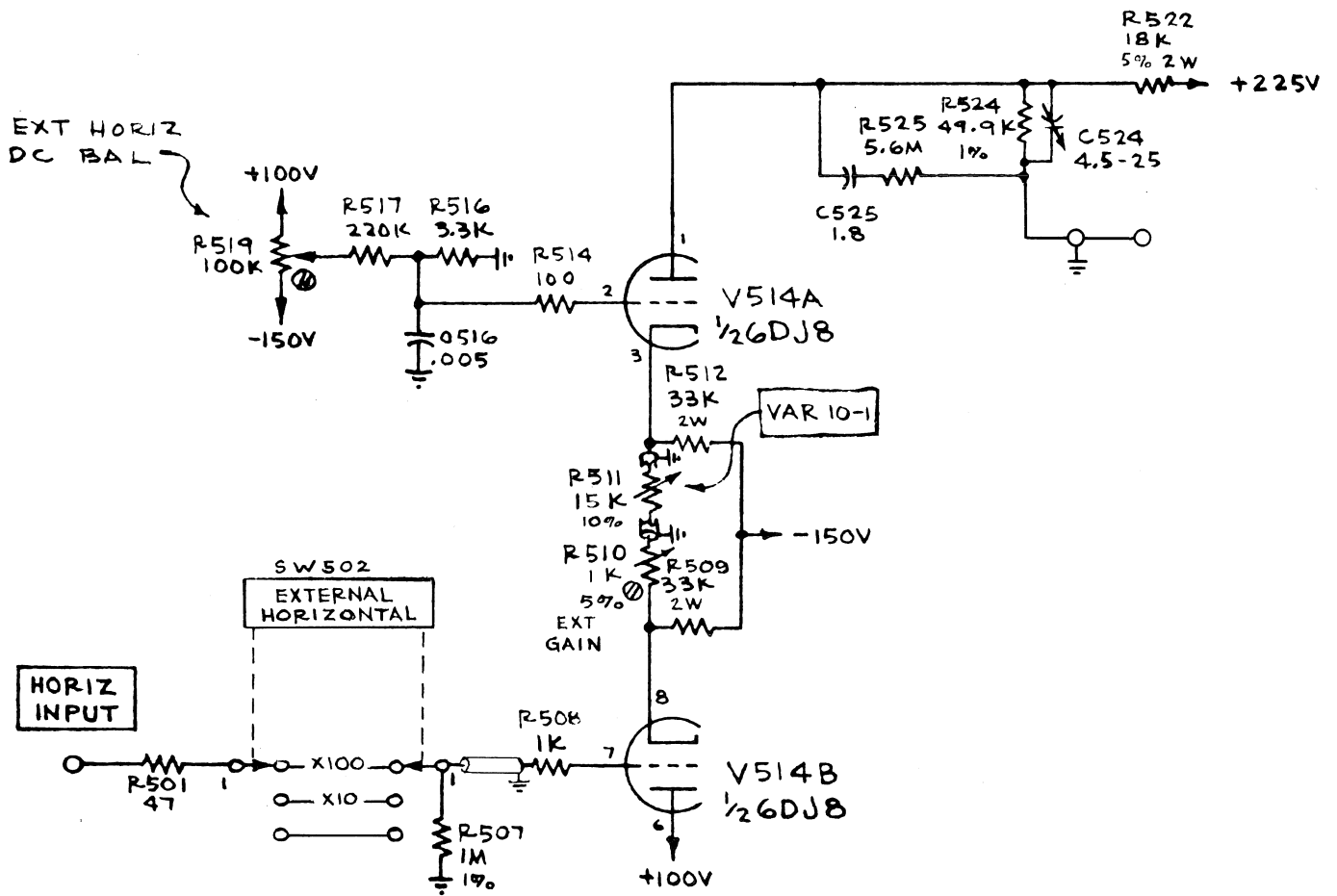
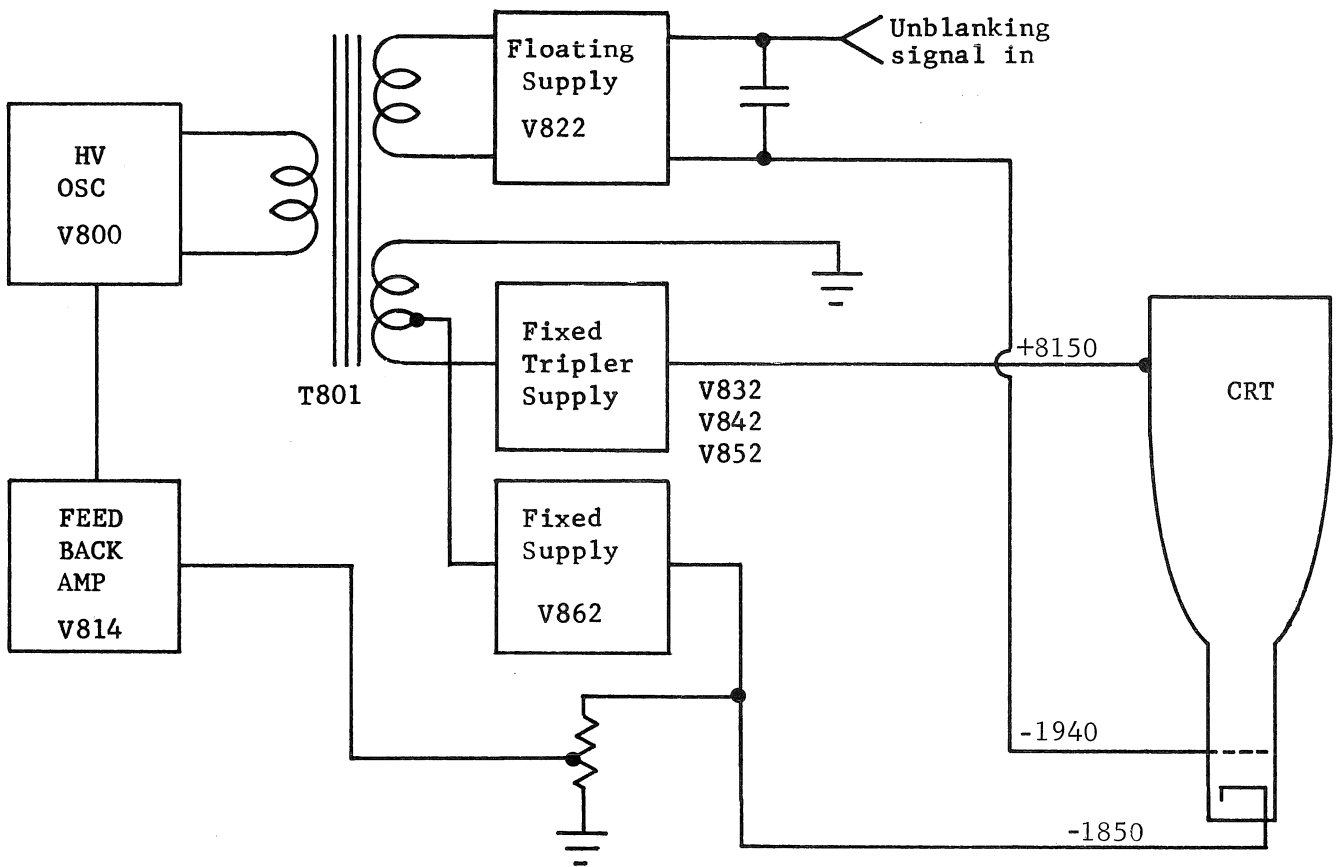


Figure 7-4

7. External Horizontal amplifier (V514) (Figure 7-4)
 - a. Cathode coupled amplifier gain is controlled by varying the coupling (R511) to the grounded grid stage V514A. Maximum measured sensitivity, 083 v/cm.
 - b. X10 (and also X100 on 544 only) attenuators can be switched into the input by HORIZONTAL DISPLAY switch.
 - c. R511 provides adjustable attenuation up to X10.
 - d. DC balance is set by dividers R519, R517, R516. C516 is decoupling, and R514 suppresses parasitics.
 - e. R524 converts output to a current signal, 200 micro amp/cm.
 - f. C524, R525 and C525 are frequency response boosters.
 - g. Output is fed through HORIZONTAL DISPLAY switch to input of horizontal amplifier, when external horizontal input is selected.



CRT CIRCUIT BLOCK DIAGRAM

Figure 8-0

8. CRT CIRCUIT

1. The CRT circuit is similar to that used in the 530/540 series.
 - a. A Hartley oscillator, V800, uses the primary of T800 as the coil and C808, in parallel with stray capacity, to tune the circuit to 50 kc.
 - b. Input is from the +325 unregulated output.
 - c. There are three high voltage supplies, the -1850 fixed, the -1940 floating, and the +8150 post deflection acceleration (PDA).
 - (1) The floating supply uses V822 as a rectifier, and provides voltage for the CRT grid.
 - (2) C820, C821, C822, and R822 filter.
 - (3) The selected unblanking pulse from the sweep generators (selected by the HORIZONTAL DISPLAY switch). This signal sets the positive voltage of the supply. Because the positive end of the supply is referenced to the unblanking signal rather than ground, the negative end of it moves with it, effectively raising and lowering the grid voltage.
 - (4) R824, R825, and R826 are a voltage divider that can change the DC level on the grid with respect to the cathode, controlling the overall beam current and thus the intensity.
 - (5) Fast rising corners of the unblanking signal are coupled across the supply through C828, C830, R828, and C829. This reduces the time needed to unblank the trace before the sweep can be displayed, and gives clean unblanking.
 - d. The +8150 volt supply is a tripler circuit, using V832, V842, and V852 as rectifiers, and C823, C833, C834 as boosting capacitors. Voltage triplers have been thoroughly described in Tektronix literature; this will not be repeated here.

(1) The function of the high post deflection acceleration is to increase the kinetic energy of the electron beam and thus increase the writing rate.

(2) The practical limitations of PDA voltage are the reduction in deflection sensitivity, and problems with beam edge aberrations.

e. The fixed -1850 supply uses V862 as the rectifier and taps off a section of the winding used for the PDA voltage supply. It is a straightforward half-wave rectifier.

(1) The CRT heater is connected in parallel with the cathode to prevent insulation breakdown.

(2) The dual trace chopped blanking signal, or an external signal, is coupled through C858 to the cathode. R857 provides 27K impedance for the signals to work into.

(3) R858 prevents a charge from building up across the capacitor.

(4) This supply supplies the focus voltage and the feedback signal for the oscillator.

f. Oscillator feedback signal: The -1850 fixed supply has a voltage divider that provides a signal fed back to the screen of the oscillator tube, V800. This signal is inverse to the output voltage, and is used to regulate the output voltage.

(1) R840, R841, R842, R843, R845, R846, R847, R853 make up the voltage divider. R846 adjusts focus voltage, and is paralleled by R845 to keep dissipation down. R840 adjusts the division ratio to set the high voltage level.

(2) Signal from the divider is fed to the grid of V814B, a voltage amplifier with a gain of about 2,000. It is then fed

to the grid of V814A, another voltage amplifier with a gain of about 200.

(3) Screen current for V800 comes through V814A and R803. The current through these sources controls the amount of screen current, and thus the plate current, that V800 can draw. By decreasing screen current in V800, the amplitude of oscillations can be lowered, reducing the energy supplied to the transformer secondaries, and thus the output voltages.

9. CALIBRATOR

1. Calibrator is modified version of 530/540/580 circuit.
 - a. Risetime has been reduced to about 180 nsec.
 - b. Basic change is to clip the square wave out from the multivibrator, rather than control multivibrator output amplitude.
 - c. The change can be installed in the older scopes to give faster risetime.
 - (1) Risetime is not fast enough to calibrate compensating box of P6008.
 - (2) Risetime will allow calibrator to be used for some adjustments now requiring a separate generator.
 - d. The lower 8 voltages have 50 ohm output impedance.
 - (1) Feeding 50 ohm output into a 50 ohm system will reduce amplitude by 50%.
2. Operation of multivibrator is the same as the older circuit. Some component values, as well as all of the designations, have been changed.
 - a. C932 was 330 pf.
 - b. R932 was 2.7 meg.
 - c. C934 was 330 pf.
 - d. R935 was 68K.
 - e. V945 operates with about 11 ma of plate current.
3. Output circuit has had clipping circuit added, plus power supply decoupling.
 - a. When V945 is conducting, its plate goes to -22 volts.
 - (1) D942 is reverse biased.
 - (2) D948 connects voltage to the grid of V935B, 7 volts lower than at the plate of V945.
 - (3) Cathode of V935B cannot go below ground, thus clipping

waveform at ground potential.

b. When multivibrator switches, V945 cuts off.

(1) Plate rises toward 225 volts, but voltage is clipped near +105 volts by D942.

(a) R942 sets exact clipping potential.

(b) D948 couples this voltage to the grid of V935B. The 7 volt offset allows the clipping circuit to be connected through low impedance to the +100 volt supply, with adjustment range, within the range of grid bias needed by V935B.

(c) If +100 supply is out of tolerance, calibrator output cannot be adjusted, within the 8 volt range provided.

(d) Current supplied through R949 keeps D948 biased properly.

(e) R941, C941, R944, and C944 are decoupling.

4. Attenuator

a. R960 and R964 look like 25K input impedance with 50 volt square wave on all but 100 volt positions, to the switch arm connected to their junction.

b. R950 through R958 look like shunt resistances to the 25K, with 50 volts at the junction of R950 and R951, divided down by the other resistors,

(1) This technique lowers the output impedance from that of the older calibrator to 4.17K in the 50 volt position, to 50 ohm in the 0.1 volt position.

(2) R965 holds output impedance at 50 ohms in lower voltage positions.

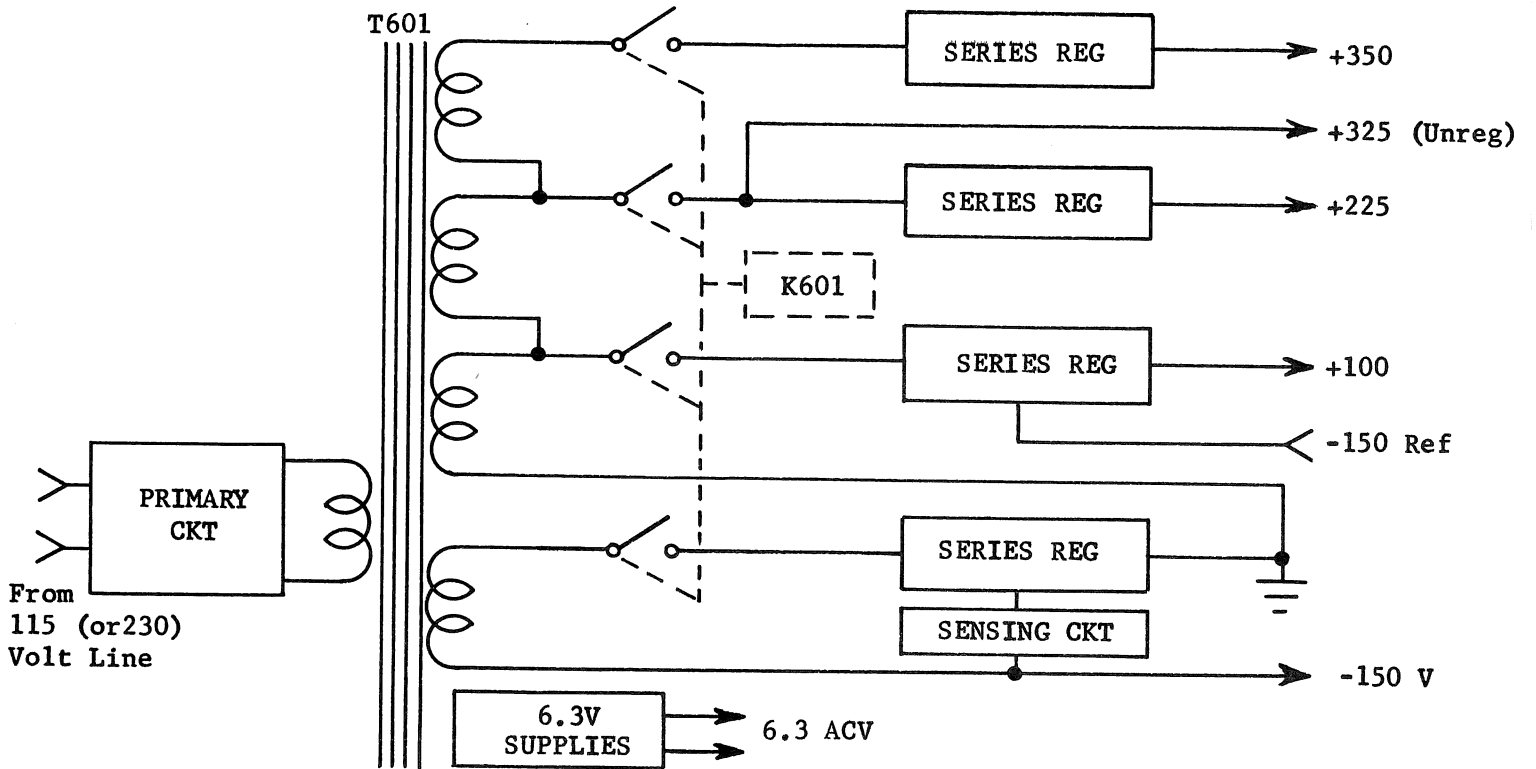
c. The current loop is in the return path of the R950 through R958 divider, when the output switch is in the 100 VDC and the 5 ma positions.

(1) The whole divider is 20K, giving 5 ma through the loop.

(2) In the 100 VDC position, 5 ma DC flow through the loop.

In the 5 ma positions, a 0-5 pk ma square wave flows through the loop.

(3) The front panel arrow indicates conventional current flow (plus to minus).



POWER SUPPLIES

Figure 10- 0

10. POWER SUPPLY

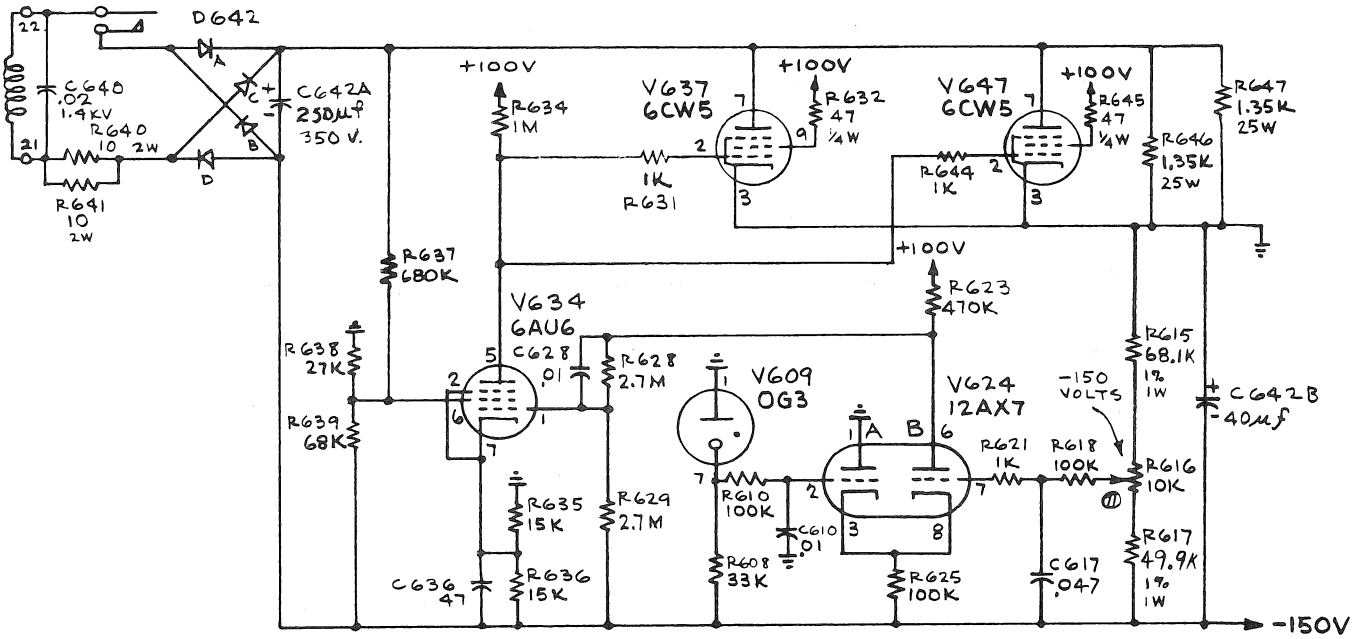


Figure 10-1

-150v Supply

1. Rectifier is a full wave bridge type.

- a. C640, R640, and R641 filter out high frequency riding on the primary power, and provide surge protection for the rectifier.
- b. D642 is four separate silicon diodes, which may be individually replaced.
- c. C642A filters the rectifier output. 250mfd capacitor stores energy that can be used for short duty cycle loads, with good regulation.

2. Series regulator.

a. Uses V609 as an 85 volt reference.

- (1) V609 is an OG3 glow discharge tube.
- (2) About 2ma are supplied through R608 to operate the tube.
- (3) Output of tube is -85 volts, going to the grid of V624 through filter R610 and C610.

b. V624 is used as a comparator.

- (1) Cathodes of A and B sections are tied together and are supplied about 1/2ma through R625. This current is divided between the two sections.
- (2) Grid of A side is held at -85 volts by reference voltage from V609.
- (3) Grid of B side is fed by voltage from divider R615, R616, R617, through filter R618, C617, R621. This voltage matches the reference voltage when -150 output is at voltage set by R616.
- (4) Current through B side will cause enough voltage drop to set the grid of V634 at about -78 volts.
- (5) If -150 output changes, current through B side of tube will change, causing the output, seen at the grid of V634, to change.

c. V634 is an inverting amplifier.

- (1) Cathode voltage is set at -75 volts by divider R635 and R636.
- (2) Ripple on output is fed to cathode by C636. Ripple on input is fed to screen grid through R637. These inputs operate the regulator so as to cancel the ripple. They operate much more quickly than the reference tube circuit.

(3) R628 and R629 divide the output voltage from V624B and R623 to about -78 volts.

(a) Difference between this voltage and cathode voltage is grid bias.

(b) Division of signal by 2 gives stage gain of about 2500. This gain requires a long time constant back in the reference tube circuit---47 msec for C617 and R618, to prevent oscillation.

(c) * High stage gain means that small voltage change in the output will result in prompt correction of output voltage.

(4) Output is across R634, with about 100 micro amp flowing in the resistor and plate circuit. This output drives the series regulator tube grids.

d. V637 and V647 are regulator tubes, connected in parallel.

(1) The output of V634 is connected to their grids through R631 and R644.

(a) Input impedance to grids is high.

(b) Resistors provide parasitic suppression by preventing grid current.

(2) Cathodes of the regulator tubes are grounded.

(a) The cathode circuits are the returns of current for the -150 supply, in parallel with R646 and R647.

(b) R646 and R647 carry some current, reducing plate dissipation in the regulator tubes.

(3) Plate supply voltage for the tubes is from the return side of the -150 supply.

(a) It is about 40 volts above ground, to provide sufficient plate voltage for the regulator tubes under all conditions.

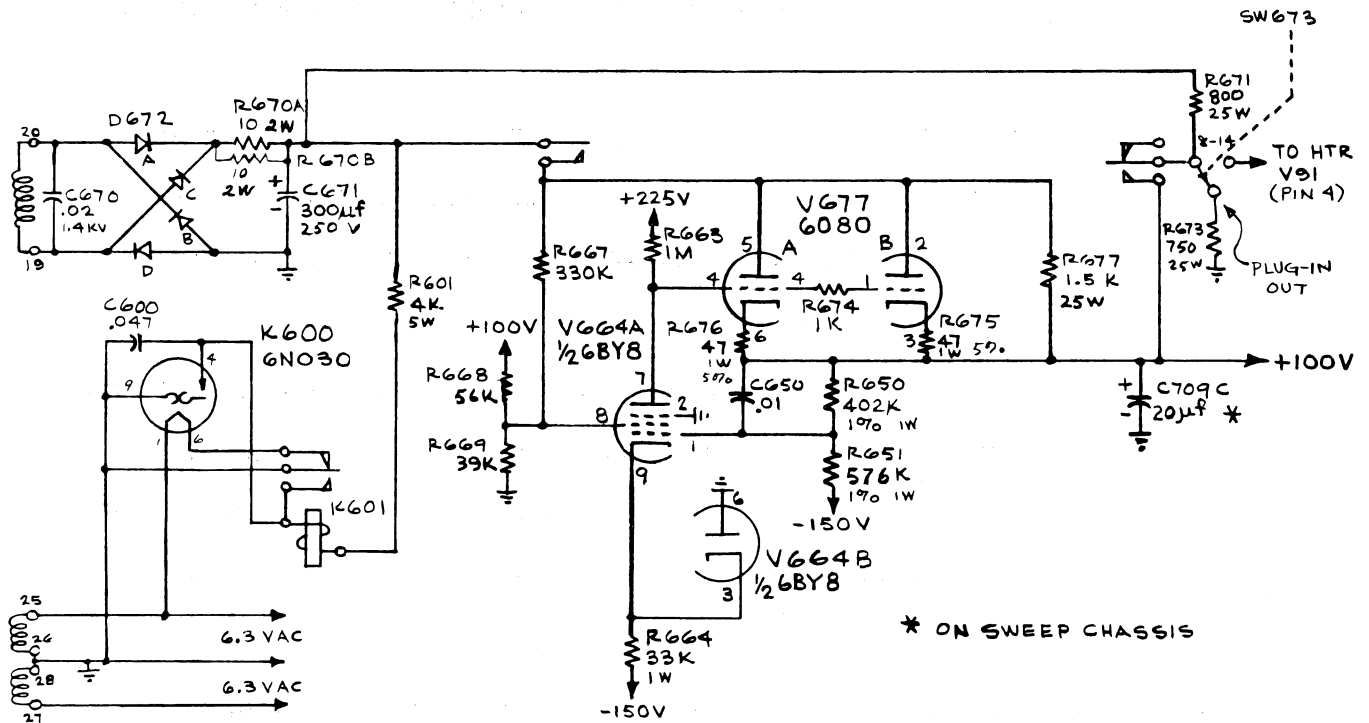


Figure 10-2

+100 Volt Supply

1. Rectifier is full wave bridge type.

a. See discussion of -150 volt rectifier circuit.

(1) Surge protection R670 and R671 are placed after the diodes, to allow direct connection of rectifier output to higher voltage supplies.

2. Unregulated outputs.

a. During warmup, with K601 not energized, current flows through

R671 and K601-4 to the VA and plug-in heater circuit.

(1) R671 provides voltage drop normally supplied by regulator circuit.

(2) Current normally flows through heater of V91 (B sweep miller tube) and to pin 15 of the blue ribbon connector for plug-in heaters.

(a) Power for plug-in heaters is 75 volts at 150 ma.

(b) If plug-in is pulled out, SW673, at top of plug-in housing, springs out, connecting the 100 volts through R673 to ground. This balances load on supply, keeping it in regulation if plug-in is removed.

(c) To operate plug-in on extension, pull the plunger of SW673 out by hand. This overrides the normal action, supplying power to the plug-in. The switch resets automatically when a plug-in is reinstalled normally.

b. When warmup is completed, K601 becomes energized, and 100 volts for the heater supply is taken from the regulated output. Notes above apply.

c. Output from rectifier diodes (normally 142 volts) is fed to 225 and 350 volt supplies as return reference.

(1) Power for higher voltage supplies flows through 100 volt supply rectifier and filter.

d. Power for coil of K601 is supplied through R601.

(1) R601 limits coil current.

3. Series Regulator

a. The regulator circuit uses the -150 volts as a reference to control an amplifier which, in turn, controls the series regulator tubes.

(1) R650 and R651 is a divider between the +100 and -150 outputs. The junction is at -4 volts (104 below the +100). This voltage varies directly with the +100, and is fed to the grid of V664A.

b. V664A inverts and amplifies any voltage change seen at the divider junction.

(1) Overall gain (including the divider) is about 3200.

(2) C650 provides feedback, preventing parasitic oscillations.

(3) High gain assures little slope in output voltage from low to high load.

(4) Cathode of V664A is clamped at (nominal) ground by V664B.

(a) A low voltage (about 1/2 volt) appears across the diode.

This voltage decreases at high line and high tube heater voltage, raising cathode voltage of V664A nearer ground.

The change increases bias on V664A to compensate for higher DC transconductance with higher heater voltage, minimizing slope in output voltage due to changes in tube characteristics induced by heater voltage changes.

(5) Ripple is fed through R667 to the screen of V664A. R668 and R669 are also in the screen supply, setting screen voltage.

(a) Current through R667 helps cancel ripple in the output.

c. Both sections of V677 (in parallel) are cathode followers in series with output of +100 supply.

(1) Plate voltage of V664A, through tube and R663, set grid voltage of regulator tubes.

(2) Cathodes of regulator tubes are held at +100 volts by grid voltage.

- (a) R674 prevents parasitic oscillations.
- (b) R676 and R675 assure that currents in the triodes will be balanced.
- (3) R677 carries part of the current.
 - (a) This reduces the dissipation in the triodes.
- d. C709C filters the output of the +100 supply.
 - (1) It reduces the need for high frequency response of the regulator circuit.
 - (2) It helps prevent the circuit from oscillating.
 - (3) It provides current for short-term regulation of the output voltage.

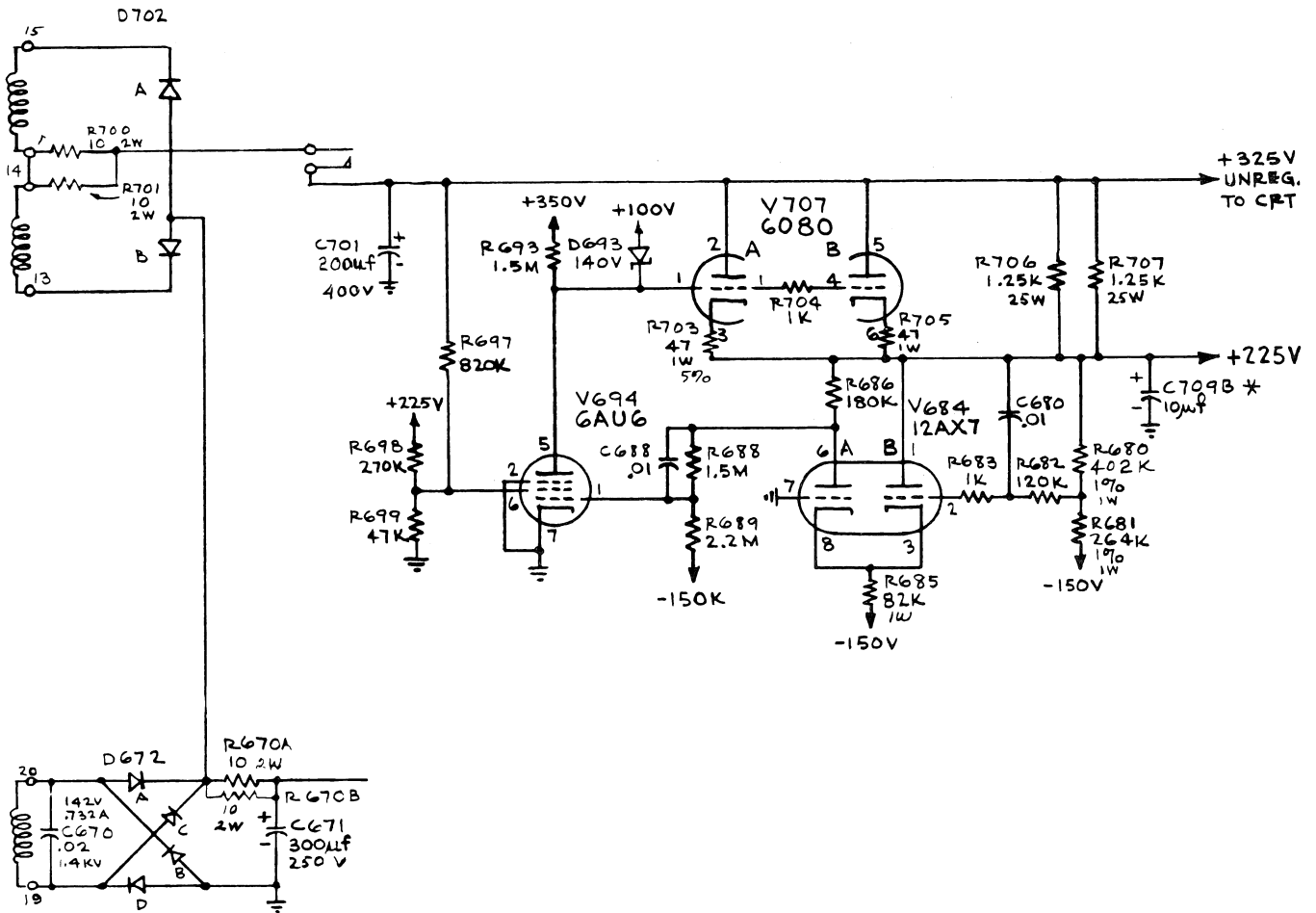


Figure 10-3

+325 Volt Supply (see Fig. 10-3)

1. Rectifier is center tapped full wave type.
 - a. Supply is stepladdered on +100 supply rectifier output (about 200 volts/peak).
 - b. Rectifier diodes are D702A and B (ignore D732 in this supply).
 - c. Positive output is taken from center tap of two 115 volt coils.
 - (1) 115 volts RMS X 1.4 is 161 volts.
 - (2) Loading on peak voltage reduces output to about 325 volts.

d. R700 and R701 are current limiting resistors that protect against damage from current peaks.

e. Output is filtered by C701 and supplied to the CRT circuit and the +225 volt series regulator.

(1) The CRT circuit has its own regulator circuit.

+225 Volt Supply

1. Series regulator is fed from +325 unregulated supply, above.

2. Series regulator is similar to -150 volt series regulator.

a. V684 is comparator, with grid of comparison side grounded.

(1) Divider R680 and R681 is between the 225 volt output and the -150, which is used as a reference voltage, setting the grid of the right section of V684 near ground when output is correct.

(2) R685 sets total current through V684 at 1.8 ma, divided between the halves of the tube.

(3) Plate voltage of V684A must be 98 volts, divided by R688 and R689, for proper bias on V694. About 1.3 ma flows through V684A and R686 to set this voltage.

(4) R682 and C680 limit high frequency response of the comparator circuit. R683 prevents parasitic oscillations. Output of comparator circuit, at grid of V694, is in phase with input at grid of V684B.

b. V694 is inverter-amplifier.

(1) Gain of circuit, including divider R688 and R689, is about 4500.

(2) Screen supply is through R697, R698, and R699. R697 supplies a ripple signal that helps cancel ripple in the output.

- (3) Output from plate of V694A is fed to grids of V707.
- c. V707 (2 sections) is series regulator.
- (1) Operates as a cathode follower.
 - (2) R704 prevents oscillations between tube halves.
 - (3) R703 and R705 assure that tube halves carry equal currents.
 - (4) Tubes shunted by R706 and R707, which reduce dissipation in the tubes.
 - (5) Output is filtered by C709B, which supplies peak currents and reduces need for fast series regulator action.

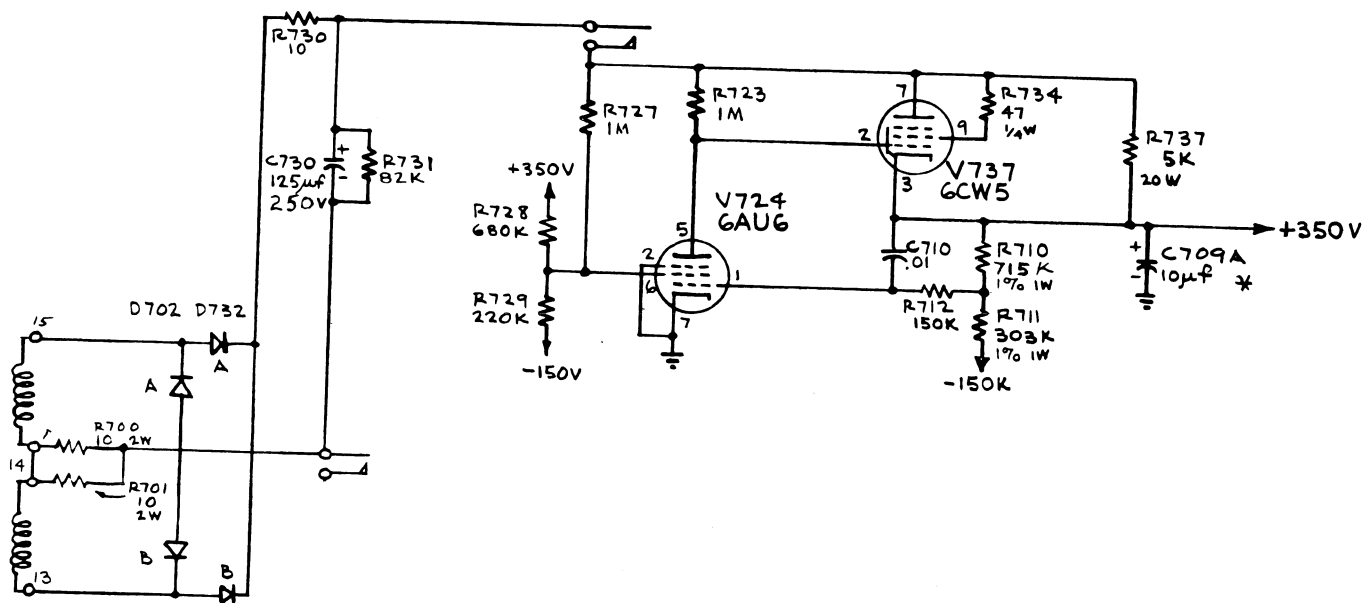


Figure 10-4

+350 Volt Supply

1. Rectifier is full wave bridge type.
 - a. D702A and B are the negative supply diodes, which return to the +100 volt rectifier output.
 - b. D732A and B are the positive supply diodes.
 - c. Currents in the negative half of the transformer coil and the forward biased diode of D702 are shared with the +325 unregulated supply, over the input cycle.
 - d. Rectifier output is filtered by C730, with R730 limiting current peaks in the circuit.
 - e. R731 is a bleeder, to remove charge from capacitors when circuit is shut off. (Other supplies have no separate bleeder, since there is a discharge path in each.)
2. Series regulator has an inverter-amplifier, and one series regulator.
 - a. See discussion of +100 volt regulator for operating details.
 - b. No reference diode is used in the cathode circuit of V724, since output slope is less critical.
 - c. Series regulator tube is a single pentode.

CALIBRATION

547 GRAPHIC CALIBRATION PROCEDURE

The following calibration procedure is a step by step graphic training device. This plan is intended for the use of Tektronix personnel. The specifications listed are factory specs and not guaranteed, unless they also appear as catalog or instruction manual specifications. Factory specs are usually tighter than catalog specs. This assures the instrument of meeting or exceeding advertised specification after shipment and over years of use.

The following procedure was written utilizing the TU-7 test load unit.

Equipment Required:

1. Type TU-7 Test Load Unit.
2. Test Scope - 540 Series and L Unit or equivalent.
3. X1 Probe.
4. X10 Probe.
5. Fluke DC voltmeter.
6. DC voltmeter, 20,000 Ω /volt, 1% at 2 kc.
7. Various adjusting tools.
8. VARIABLE line source (variac).
9. 180A time mark generator.
10. 190B constant amplitude signal generator.
11. Several BNC cables, patch cords, and adapters.

OUTLINE OF ADJUSTMENTS

SECTION I

- I. LOW VOLTAGE SUPPLIES
- II. AMPLITUDE CALIBRATOR
- III. HIGH VOLTAGE SUPPLY
- IV. CRT

SECTION II

- I. VERTICAL AMPLIFIER

SECTION III

- I. A SWEEP TRIGGERING ADJUSTMENTS
- II. B SWEEP TRIGGERING ADJUSTMENTS
- III. A and B LOW FREQUENCY CHECKS

SECTION IV

- I. ALTERNATE OPERATION
- II. SINGLE SWEEP

SECTION V

- I. BASIC SWEEP TIMING ADJUSTMENTS
- II. A to B SWEEP MATCHING

SECTION VI

- I. DELAY PICK-OFF
- II. B SWEEP SLOW SPEED TIMING
- III. A SWEEP SLOW SPEED TIMING

SECTION VII

- I. B FAST SPEED TIMING
- II. HORIZONTAL AMPLIFIER and SWEEP MAGNIFIER COMPENSATIONS
- III. A SWEEP FAST SPEED TIMING

SECTION VIII

- I. EXTERNAL HORIZONTAL AMPLIFIER
- II. VERTICAL AMPLIFIER
- III. HIGH FREQUENCY TRIGGERING
- IV. 547 FRONT PANEL WAVEFORMS

Preset the 547 panel controls as follows:

A and B TIME/CM	1 msec
A and B TIME/CM VARIABLE	CALIBRATED
DELAY TIME MULTIPLIER	5.00 (approximately)
A and B TRIGGERING	
MODE	TRIG
SLOPE	+
COUPLING	AC
SOURCE	INTERNAL-NORMAL
TRIGGERING LEVEL	CW(push in)
HORIZONTAL DISPLAY	B
SWEEP MAGNIFIER	X1 (off)
SWEEP MODE	NORMAL
HORIZONTAL POSITION	Midrange
HORIZONTAL POSITION VERNIER	Midrange
VAR 10:1	CW
AMPLITUDE CALIBRATOR	OFF
INTENSITY	0
FOCUS	0
ASTIGMATISM	0
SCALE ILLUMINATION	0
BRIGHTNESS	CW
TRACE ROTATION	--
TRACE SEPARATION	--

Preset the TU-7 front panel controls as follows:

TEST FUNCTION	LOW LOAD
VERTICAL POSITION	Midrange
VARIABLE	--
AMPLITUDE	--
REPETITION RATE	--

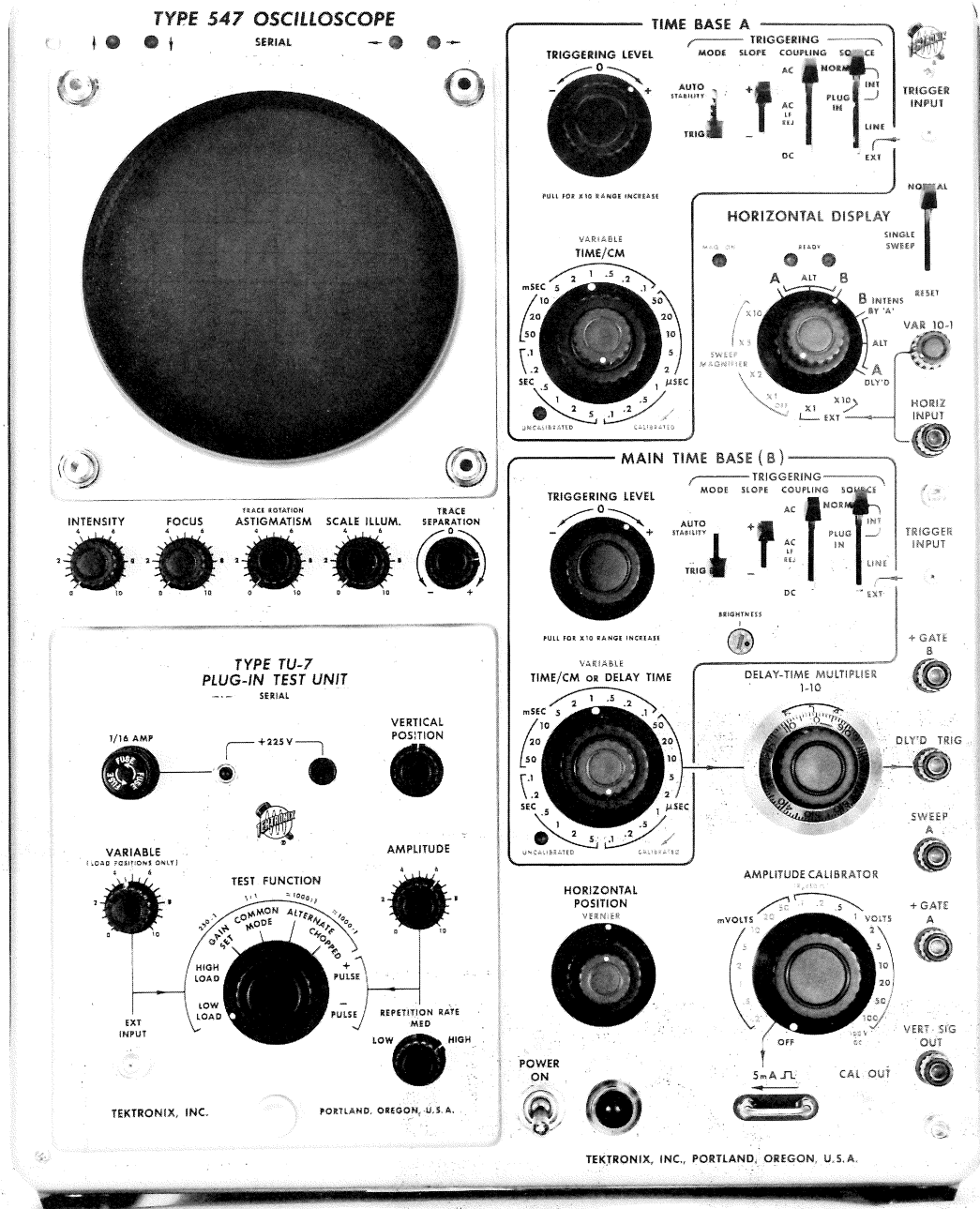


Figure 1

SECTION 1

1. LOW VOLTAGE SUPPLIES

A. -150 Adjustment (R616)

1. Adjust the -150 Adj. (R616-see Figure 2) for -150 volts as measured with a voltmeter. (see Figure 3)

B. Check the other power supplies for correct voltages. (see Figure 4)

1. +100v +2v
2. +225v +4.5v
3. +350v +7v

NOTE: The -150 supply can be misadjusted within +3v to bring in another supply that is out of tolerance. The -150 supply should be adjusted as close to -150 as possible.

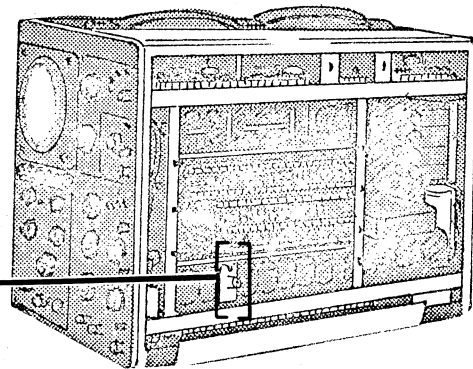
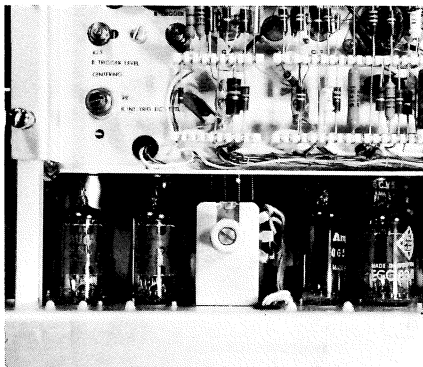


Figure 2

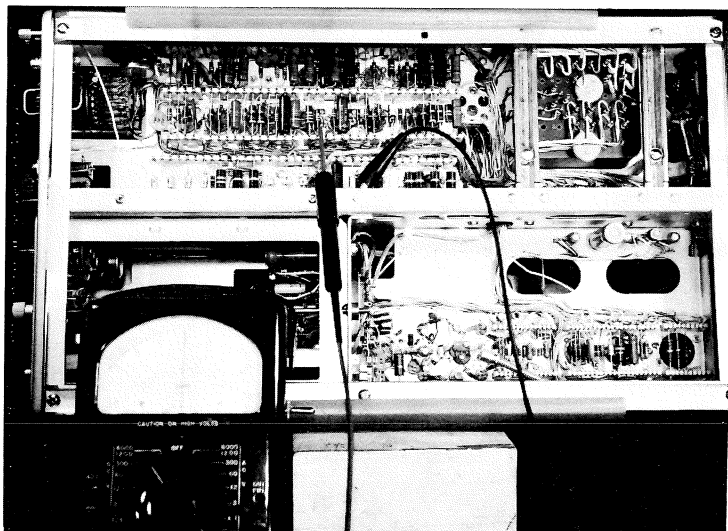


Figure 3

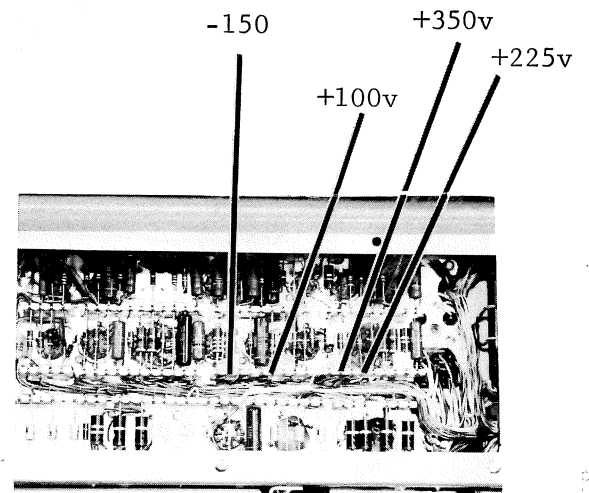


Figure 4

C. LOW VOLTAGE SUPPLY REGULATION CHECK

1. Regulation specifications

Maximum Allowable Ripple		Normal	
		High Load	Low Load
-150v	3mv	1mv	1mv
+100v	7mv	4mv	2mv
+225v	3mv	1mv	1mv
+350v	20mv	10mv	5mv

NOTE: Each supply must remain within $\pm 2\%$ of it's rated value at LOW LOAD-HIGH LINE and HIGH LOAD-LOW LINE.

2. LOW LOAD-HIGH LINE check

- a. Set VARIABLE AC SOURCE to 126.5v and monitor each supply.

3. HIGH LOAD-LOW LINE check

- a. Set TEST FUNCTION TO HIGH LOAD, SWEEP MAGNIFIER to x10, A and B TRIGGERING MODE to AUTO, and AMPLITUDE CALIBRATOR to any position except OFF and 100vdc.
- b. Set VARIABLE AC SOURCE to 103.5v and monitor each supply.

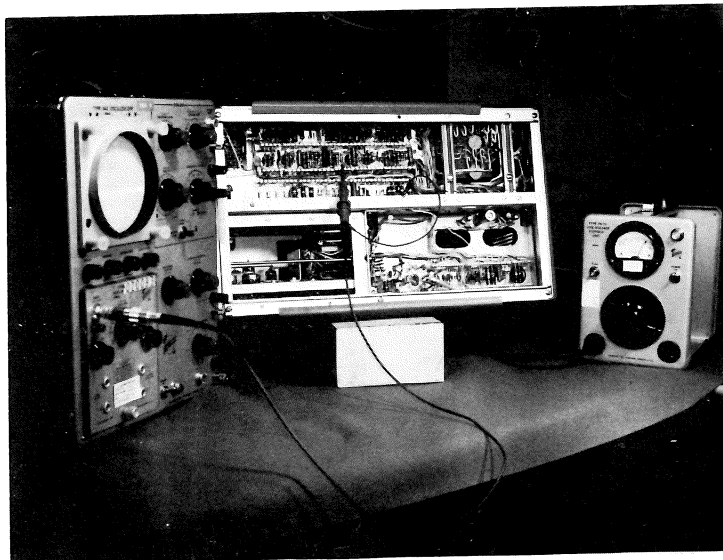
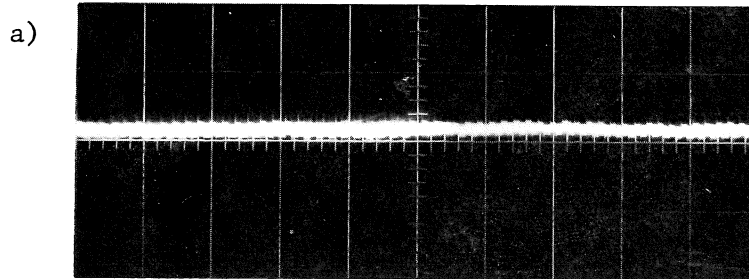


Figure 5

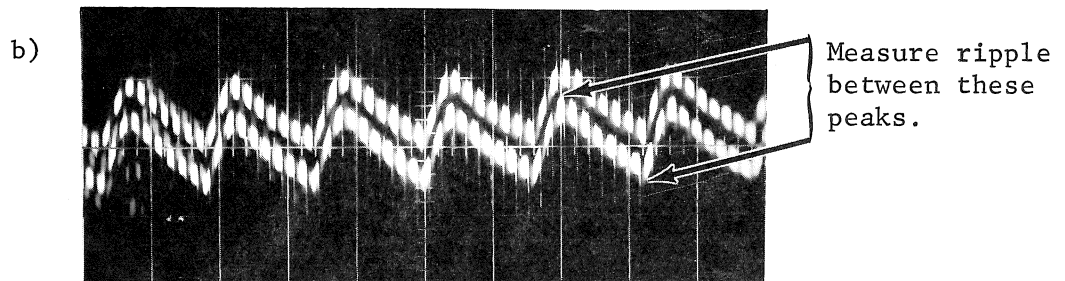
- c. Return line to 117v

The following waveforms were taken with a 543A and an L unit. Sensitivity set to 5 mv/cm.

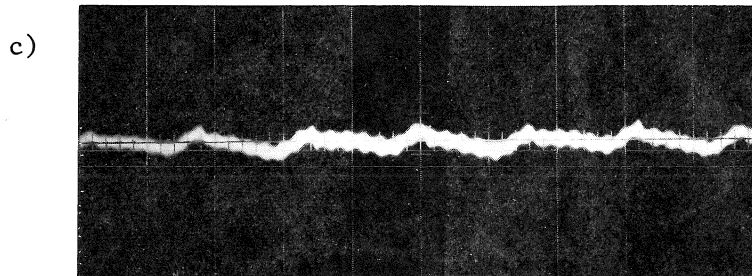
-150v High Load



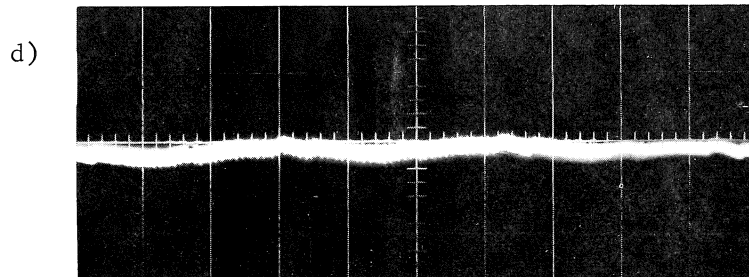
+100v High Load



+100 Low Load



+225 High Load



+350v High Load

e)

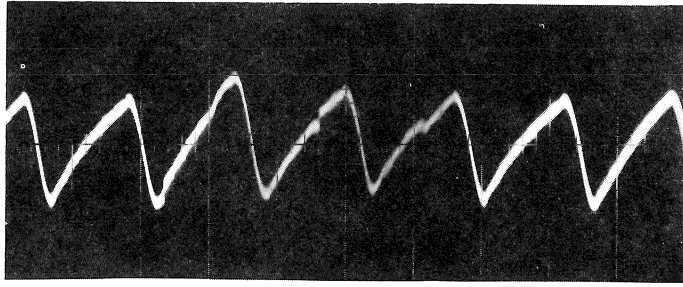


Figure 6

II. AMPLITUDE CALIBRATOR

A. Calibrator Adj.

1. Set the AMPLITUDE CALIBRATOR to the +100vdc position.
2. Adjust the CAL. AMPL. control (R943) for exactly +100v at the center of the CAL. OUT connector. (See Fig. 7)

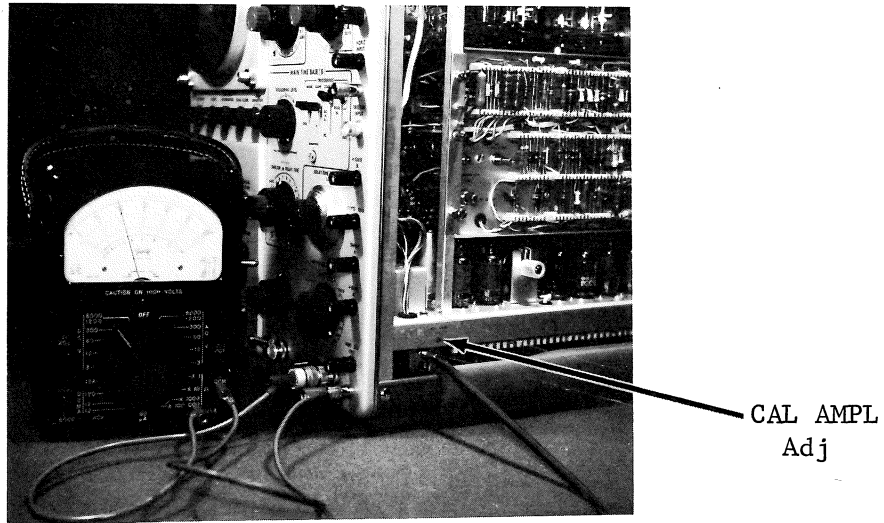


Figure 7

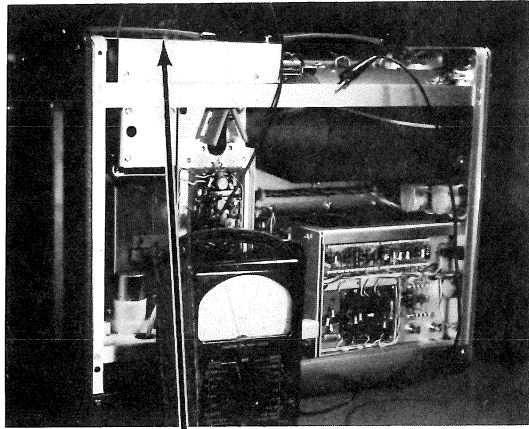
B. AMPLITUDE CALIBRATOR duty cycle check.

1. While monitoring the voltage at the CAL. OUT connector, set the AMPLITUDE CALIBRATOR to 100v position only. The meter should read between 45v and 55v, indicating a duty cycle of $50\% \pm 10\%$.
2. Disconnect the meter.

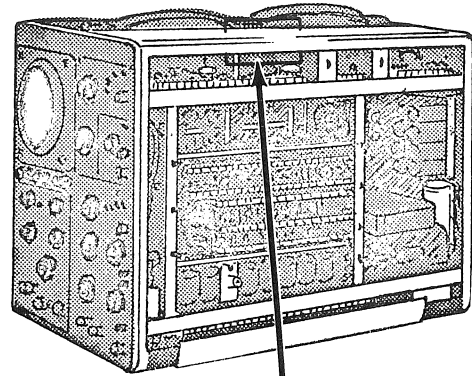
III. HIGH VOLTAGE SUPPLY

A. HIGH VOLTAGE ADJUSTMENT.

1. Adjust the HIGH VOLTAGE ADJ. (R840) for exactly -1850v as measured with the voltmeter. (See Fig. 8)



HIGH VOLTAGE TEST POINT



HIGH VOLTAGE Adj.
Set for -1850v

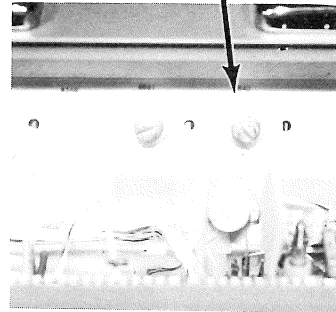


Figure 8

B. HIGH VOLTAGE REGULATION check.

1. Obtain a defocused trace on CRT. (See Fig. 9)

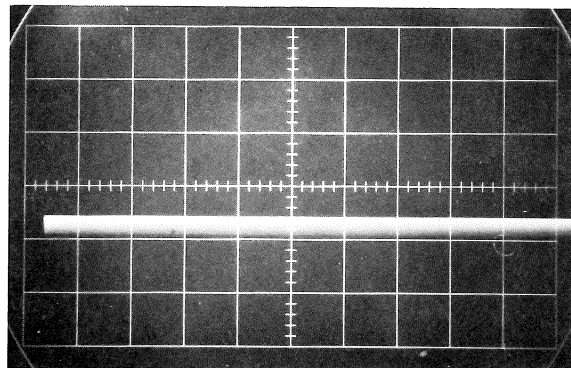


Figure 9

2. Set line voltage to 103.5vac
3. While monitoring the High Voltage supply with the voltmeter, turn the INTENSITY control between 0 and 10 and insure that the High Voltage supply regulates within $\pm 2\%$ ($\pm 37v$).
4. Set the line voltage to 126.5 and repeat Step 3.
5. Return line voltage to 117vac.

IV. CRT

A. TRACE ROTATION

1. With the ASTIGMATISM and FOCUS controls obtain a sharply defined trace.
2. Align the start of the trace with the center horizontal graticule line.
3. Rotate the TRACE ROTATION control full cw and ccw. (Located in the center of the ASTIGMATISM control - see Fig. 10.) The right side of the trace should move 0.5 cm above and below the center graticule line.
 - a. This will insure that the TRACE ROTATION control has normal range and that the CRT graticule is aligned within $\pm 3\%$.
4. Align the trace with the center graticule line.

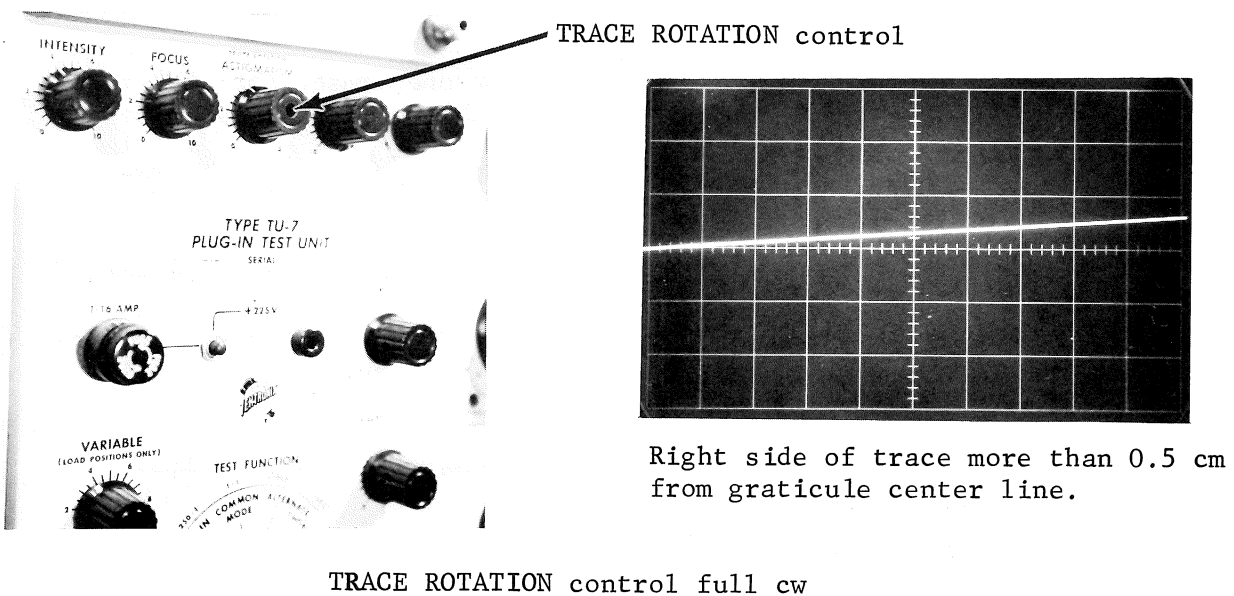


Figure 10

B. GEOMETRY ADJUSTMENT

1. Apply 1 msec and 100 μ sec markers from Type 180 to the TU-7. Adjust VARIABLE (TU-7) for 6 cm of vertical deflection. (See Fig. 11)

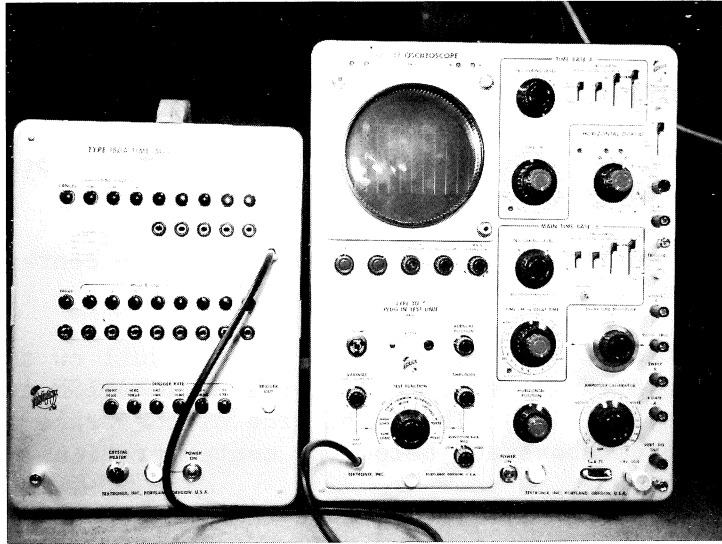


Figure 11

2. With B TRIGGERING LEVEL control (pull-out), obtain a stable display.
3. Adjust B TIME/CM VARIABLE for one, 1msec (bright) marker per cm. (100 μ sec markers will be 1 per mm.)
4. Adjust GEOMETRY ADJUSTMENT (R861 - see Fig. 12) for minimum bowing. Max. 1mm (See Fig. 13A)
5. Check focus for no overlap of markers over 10 cm scan.
6. Remove signal from Type 180 and check horizontal bowing at the top and bottom of the graticule. Max. 1mm (See Figure 13B)

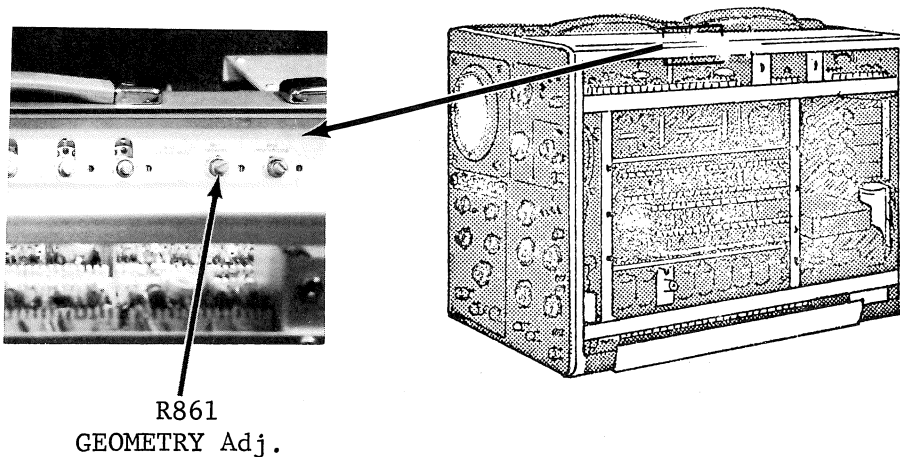
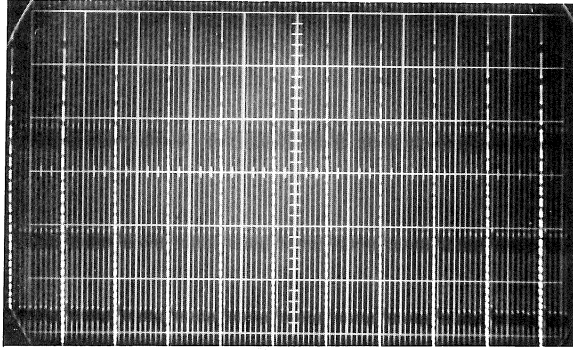
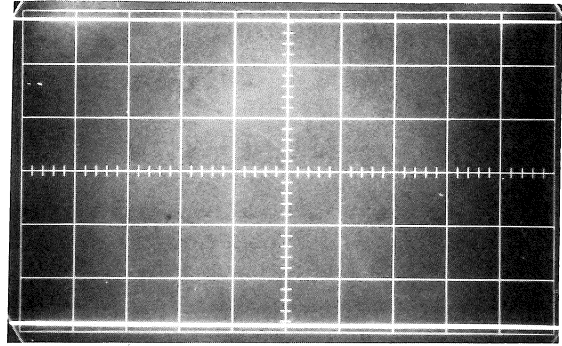


Figure 12



A



B

Vertical and Horizontal Bowing
Max 1mm

Figure 13

SECTION II

I. VERTICAL AMPLIFIER

A. VERTICAL DC BALANCE ADJUSTMENT

Two methods will be described for setting the vertical DC balance. Method I will use a TU-7 test load unit. Method II can be used with any lettered series vertical plug-in.

METHOD I (TU-7 test load unit utilized)

1. Produce a free running trace by presetting the front panel controls as follows:

HORIZONTAL DISPLAY	B
SWEEP MAGNIFIER	X1
B TRIGGERING	
MODE	AUTO
SLOPE	+
COUPLING	AC
SOURCE	INTERNAL-NORMAL
TRIGGERING LEVEL	Push-in
B TIME/CM	1 msec
B TIME/CM VARIABLE	CALIBRATED
INTENSITY	Adjust for a sharply defined trace.
FOCUS	
ASTIGMATISM	
TEST FUNCTION (TU-7)	COMMON MODE

2. Adjust VERTICAL DC BALANCE adjustment (R1004 - see Fig. 14) to position the trace to the center of the graticule as viewed on the CRT.

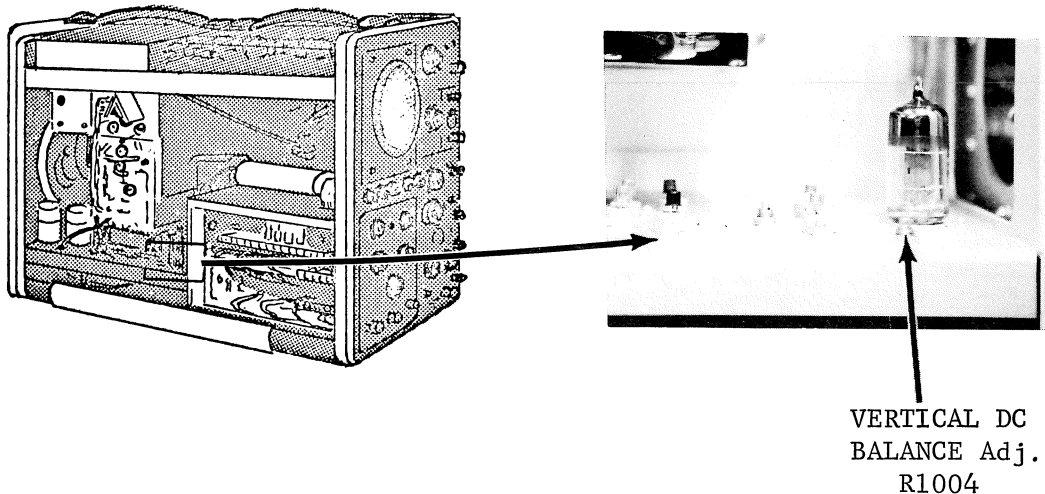


Figure 14

METHOD II (Any lettered series plug-in can be used)

1. Produce a free running trace by setting the front panel controls as follows:

HORIZONTAL DISPLAY	B
SWEEP MAGNIFIER	X1
B TRIGGERING	
MODE	AUTO
SLOPE	+
COUPLING	AC
SOURCE	INTERNAL-NORMAL
TRIGGERING LEVEL	Push-in
B TIME/CM	1 msec
B TIME/CM VARIABLE	CALIBRATED
INTENSITY	Adjust for a sharply defined trace.
FOCUS	
ASTIGMATISM	
VERTICAL POSITION (plug-in)	CENTERED

2. Using a shorting strap (example shown in Fig. 15) short pins 1 and 3 of the interconnecting plug. (Fig. 16 shows pins 1 and 3 shorted at the SPOILER SWITCH.)

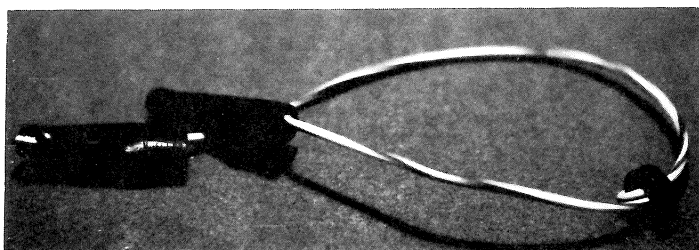


Figure 15

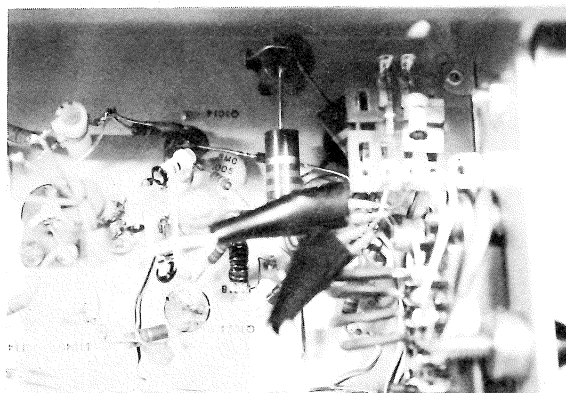
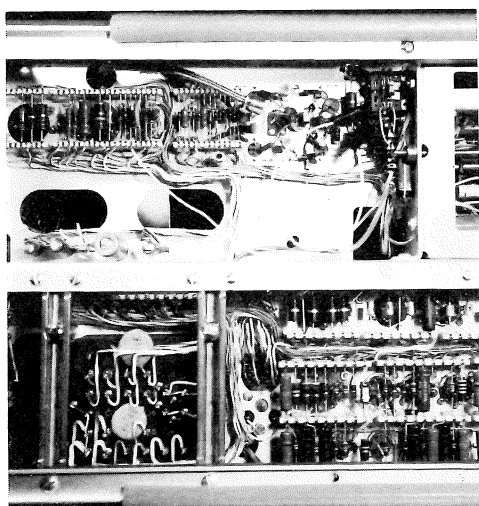


Figure 16

3. Adjust VERTICAL DC BALANCE adjustment (R1004 - see Fig.17) to position the trace to the center of the graticule as viewed on the CRT.
4. Remove the shorting strap.

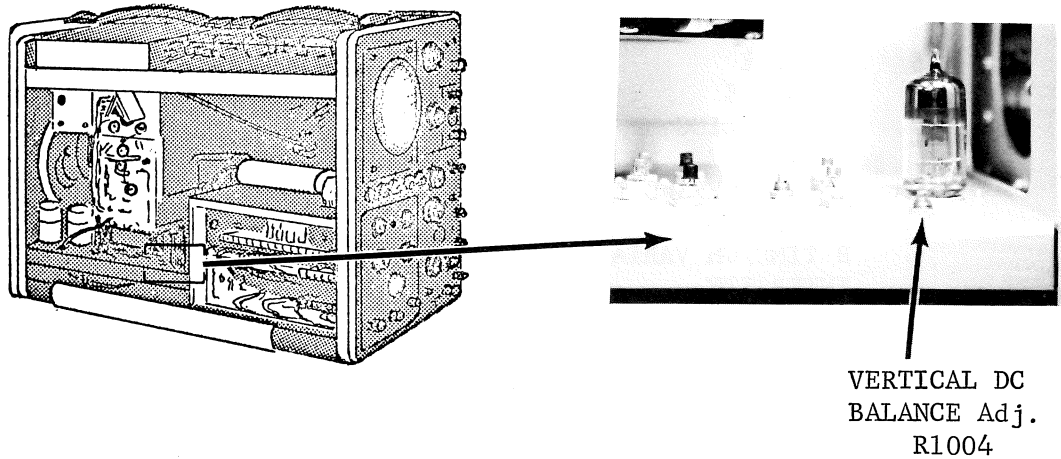


Figure 17

B. VERTICAL GAIN Adjustment

Two methods will be described for setting the VERTICAL GAIN adjustment. Method I utilizes the TU-7 test load unit. Method II can be used with any lettered series vertical plug-in unit.

METHOD I (TU-7 test load unit utilized)

1. Set TEST FUNCTION to GAIN SET.
2. Apply a 100v square wave from the AMPLITUDE CALIBRATOR to the TU-7. (See Fig. 18)

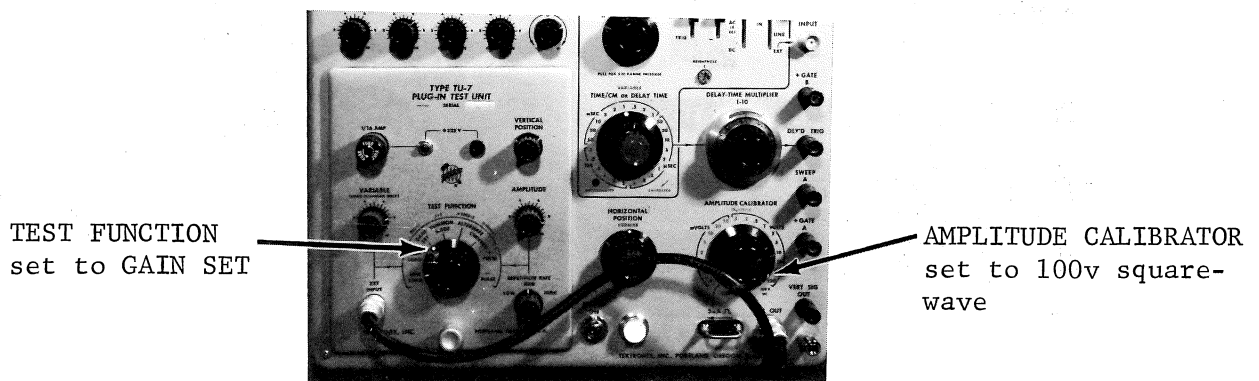


Figure 18

3. Adjust the VERTICAL GAIN adjustment (R1017 - see Fig. 19) for exactly 4 cm of vertical deflection.
4. Disconnect AMPLITUDE CALIBRATOR signal.

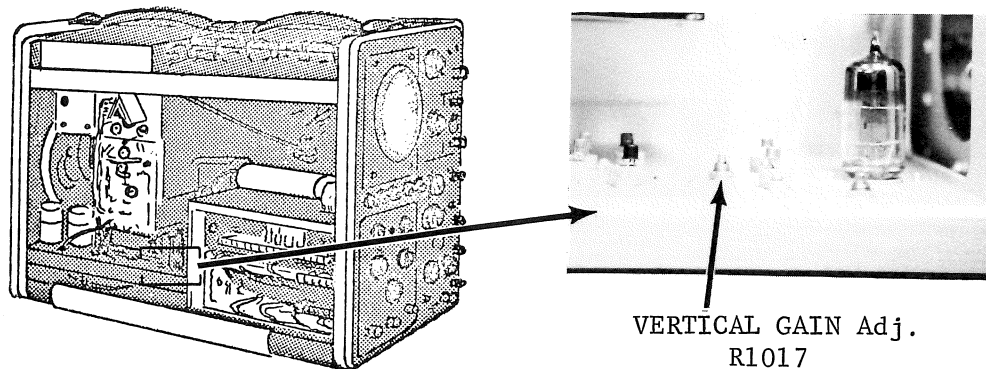


Figure 19

METHOD II (Any lettered series plug-in can be used.)

This method utilizes the GAIN ADJUST ADAPTER (013-005). (See Fig. 20) With this adapter inserted between the plug-in and the main frame vertical, the vertical gain can be set for a vertical deflection of exactly 100 mv/cm.

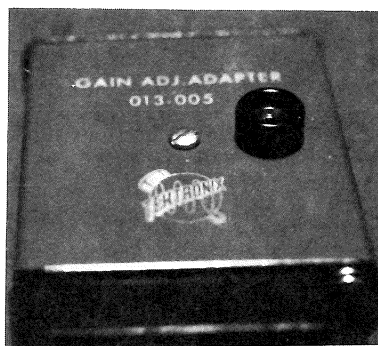


Figure 20

1. Insert the GAIN ADJUST ADAPTER between the plug-in and the main frame vertical. (See Fig. 21)
2. Set the 100v load switch (SW673 - located in the upper right hand corner of the plug-in box - see Fig. 21) to the pull-forward position.
3. Connect a 0.2v square wave from the AMPLITUDE CALIBRATOR to the banana plug on the GAIN ADJUST ADAPTER. (See Fig.22)

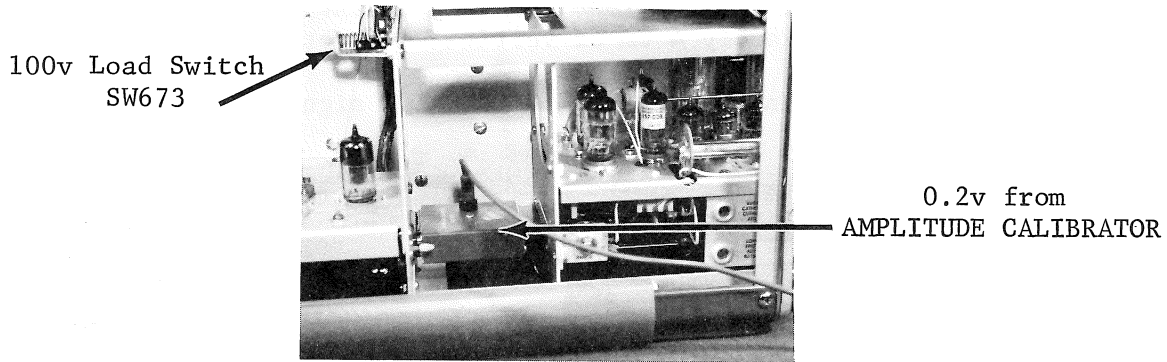


Figure 21

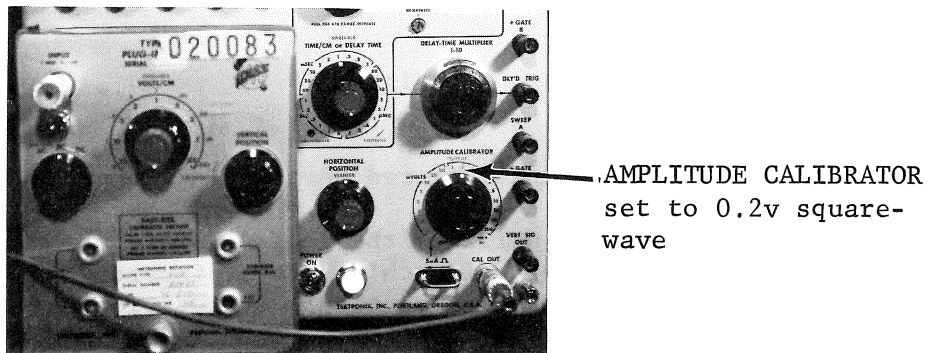


Figure 22

4. Adjust the VERTICAL GAIN adjustment (R1017 - see Fig.23) for exactly 2 cm of vertical deflection.
5. Remove the AMPLITUDE CALIBRATOR signal and the GAIN ADJUST ADAPTER and reinsert the vertical plug-in.

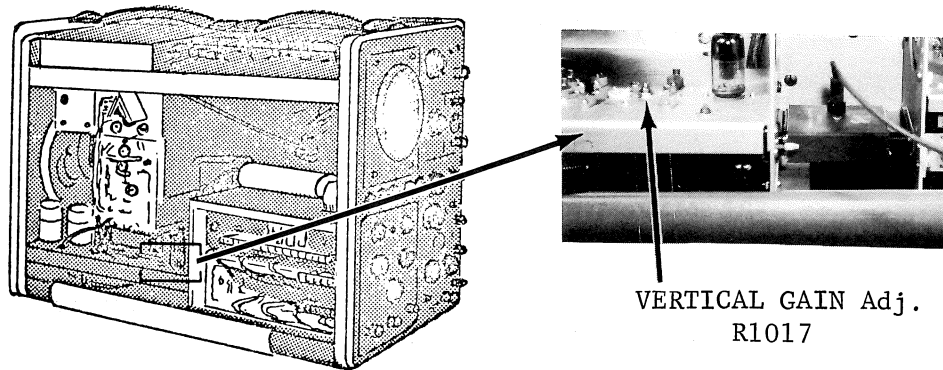
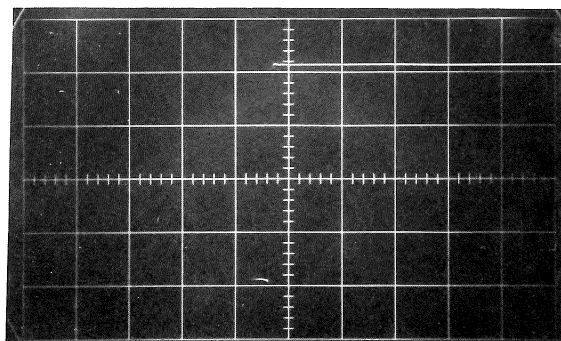


Figure 23

C. VERTICAL AMPLIFIER HIGH FREQUENCY ADJUSTMENTS

NOTE: To insure a correct reading of the VERTICAL AMPLIFIER risetime, B Sweep Generator and the Horizontal Amplifier must be calibrated. Since the calibration of B Sweep Generator and the Horizontal Amplifier may not be verified to the operators satisfaction at this time, this step is also included in Section VIII.

1. Set the TEST FUNCTION control to +PULSE, REPITION RATE to HIGH, and with the AMPLITUDE control and the VERTICAL POSITION control, obtain a display of 4 cm of vertical deflection centered on the CRT.
2. Set B TIME/CM to 0.1 μ sec. (See Fig. 24)



+PULSE displayed
0.1 μ sec

Figure 24

3. While switching the SWEEP MAGNIFIER from X1 to X10, adjust the Vertical Amplifier H.F. adjustment for a flat top with minimum aberations at the leading edge and a risetime of 6.25 nsec as read with the SWEEP MAGNIFIER set at X10.
 - a. Aberation: 0.4 mm max.
 - b. Risetime : 6.25 nsec max.

L1157	Adjust for min wrinkles at leading edge.	Bottom of main amp chassis-see Fig.25
C1029	Delay line termination, approx 340 nsec from start of sweep.	Top of main amp chassis-see Fig.26B
C1076	Med time constant compensation.	PC board-see Fig.26A
R1076	Adjust with C1076	"
C1105	Fast time constant compensation.	"
C1106	Med time constant compensation.	"
R1106	Adjust with C1106	"
C1126	Long time constant compensation.	"



L1157
Adjust for
min wrinkles.

Figure 25

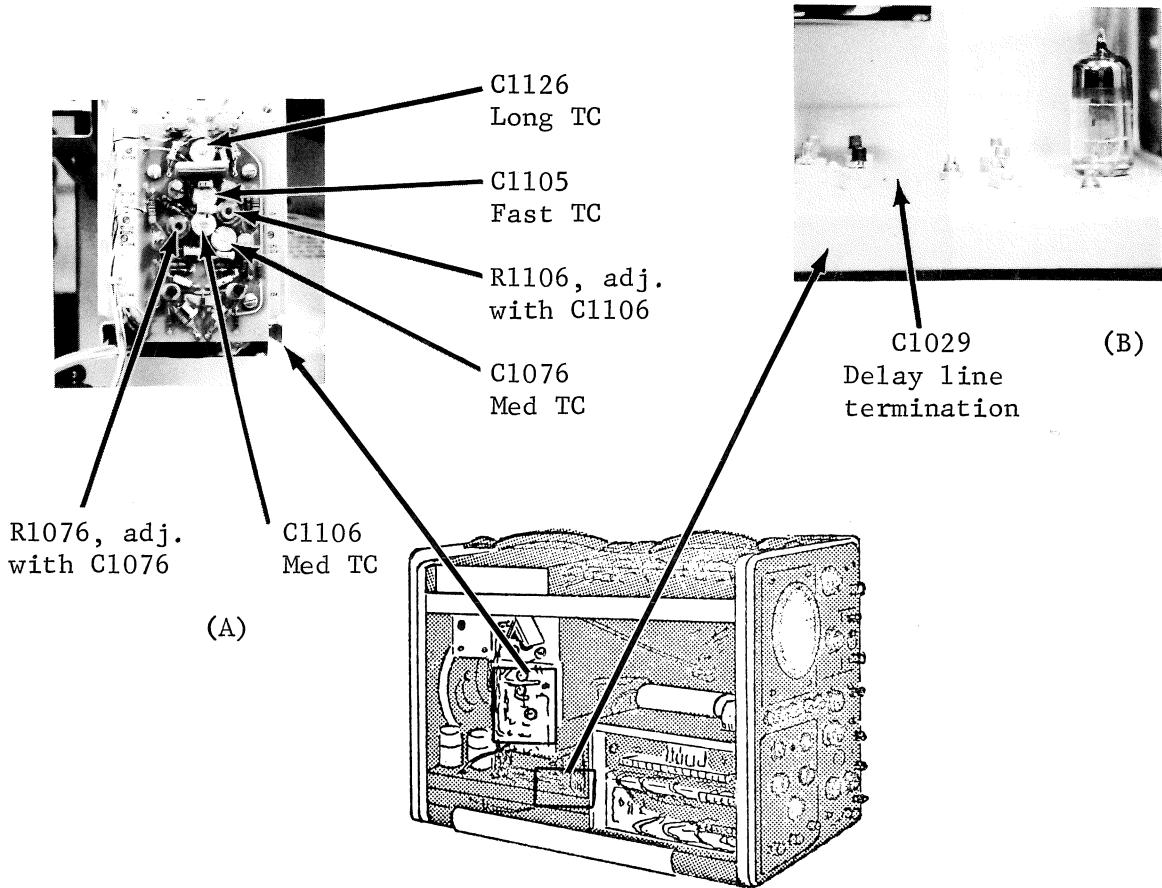
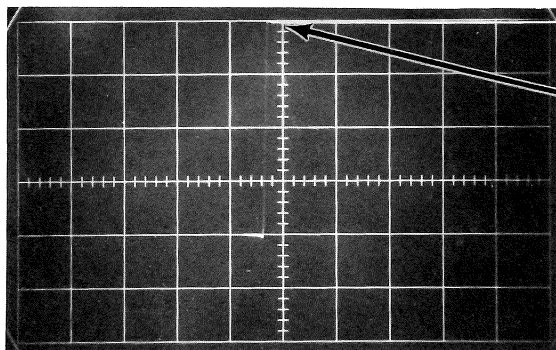


Figure 26

4. Transient Response Check.

- a. Set pulse upper edge to top of graticule and note change in leading edge aberation. 1.5 mm, max.
- b. Set pulse upper edge to bottom of graticule and note change in leading edge aberation. 1.5 mm, max. (See Fig. 27)



Upper edge of pulse set to top of graticule.

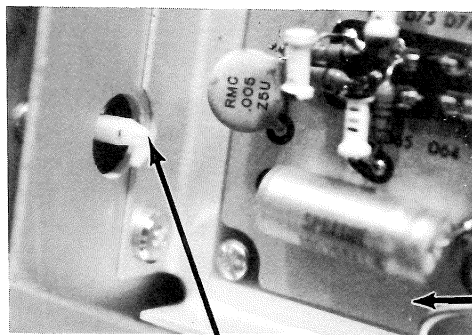
Less than 1.5 mm aberation.

Response will peak as display is moved to the top of the graticule and will roll off as display is moved to the bottom of the graticule.

Figure 27

5. SPOILER SWITCH

- a. With SWEEP MAGNIFIER set to X10, depress the SPOILER SWITCH (located in the lower left hand corner of the plug-in box - see Fig. 28).



SPOILER SWITCH

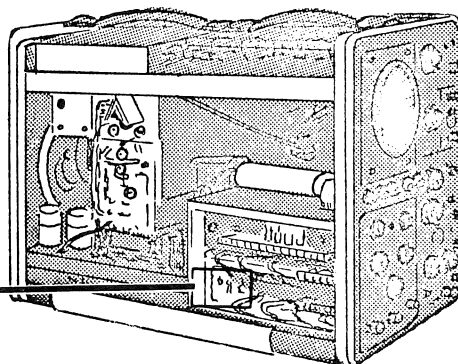
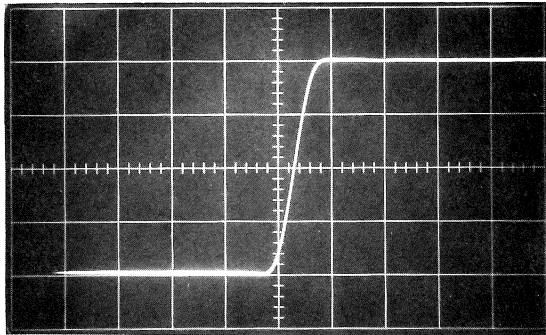
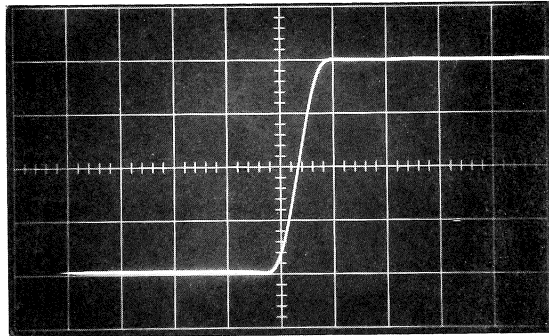


Figure 28

- b. Risetime will typically reduce by 1 nsec. The minimum allowable risetime with the SPOILER SWITCH depressed, is 7 nsec.; maximum 10 nsec. (See Fig.29)



Risetime = 6.25 nsec



SPOILER SWITCH depressed
Risetime \cong 7.25 nsec

Figure 29

SECTION III

I. A SWEEP TRIGGERING ADJUSTMENTS

A. TRIGGER LEVEL CENTERING and TRIGGER SENSITIVITY ADJUSTMENTS

1. Preset the 547 front panel controls as follows:

HORIZONTAL DISPLAY	A
A TRIGGERING	
MODE	AUTO or TRIG
SLOPE	+
COUPLING	AC
SOURCE	EXTERNAL
A TIME/CM	1 msec
A TIME/CM VARIABLE	CALIBRATED

For this step A TRIGGERING MODE can be set to either AUTO or TRIG as the operator wishes. The use of an external trigger signal has been found to be the quickest and most reliable way to "set" the triggers.

2. Set the AMPLITUDE CALIBRATOR to 200 mv (0.2v) and connect the CAL OUT jack to the vertical input of the TU-7, and to the TRIGGER INPUT jack (A TRIGGER).

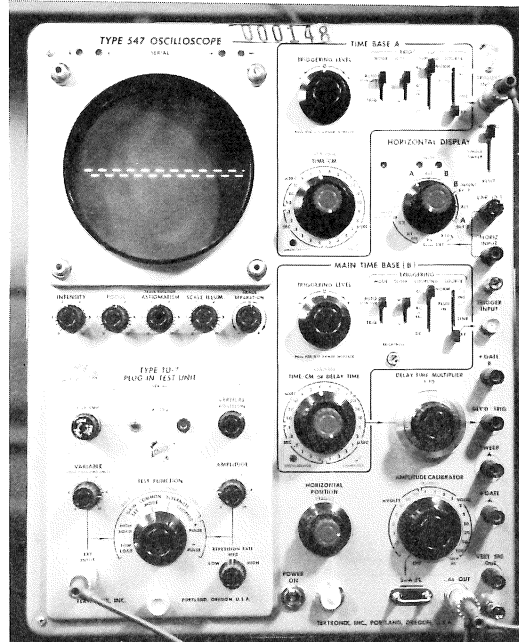
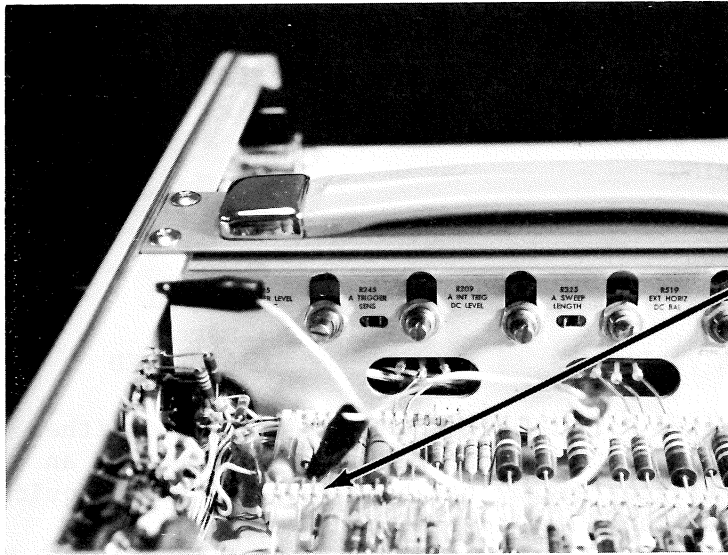


Figure 30

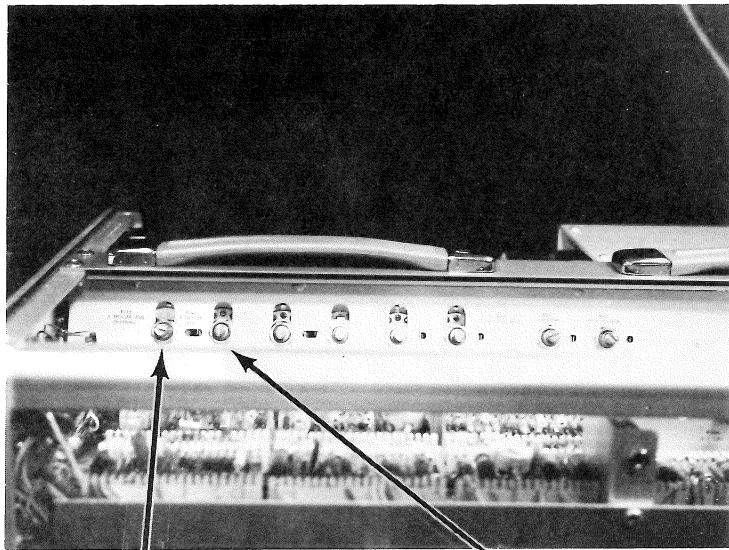
3. Disable the TRIGGERING LEVEL control by shorting the junction of R217, R218, and R219 to ground. (See Figure 31)



Junction of R217,
R218 & R219

Figure 31

4. Adjust a TRIGGER LEVEL CENTERING adjustment (R225) to produce a triggered display while moving the SLOPE switch from + (plus) to - (minus). If a triggered display can not be obtained adjust the TRIGGER SENSITIVITY adjustment (R245) cw. (See Figure 32)
5. Set the AMPLITUDE CALIBRATOR to 100mv and obtain a stable display as per step 4.
6. Set the AMPLITUDE CALIBRATOR to 50mv. The signal should not trigger. The TRIGGER SENSITIVITY can be adjusted ccw to "untrigger" the display (trace disappears or free runs).
7. Check to see if the display still triggers at 100mv. Repeat steps 5 & 6 until a stable display is obtained at 100mv and an "untriggered" display is obtained at 50mv.



A TRIGGER LEVEL centering R225 (adjust for + & - triggering)

A TRIGGER SENSITIVITY R245 (adjust for triggered display at 100mv but not at 50mv)

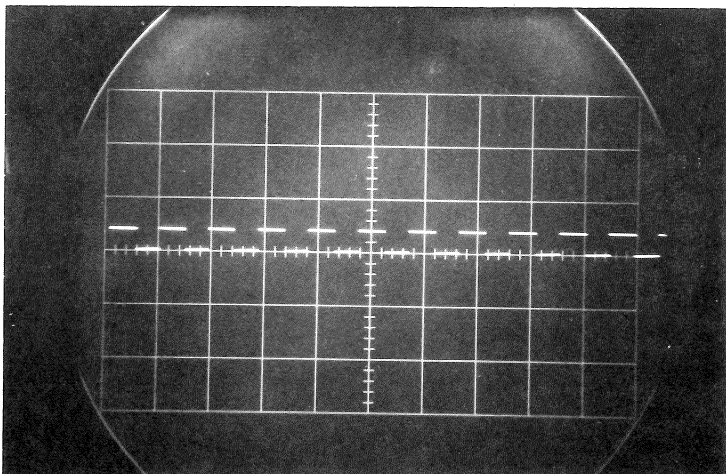
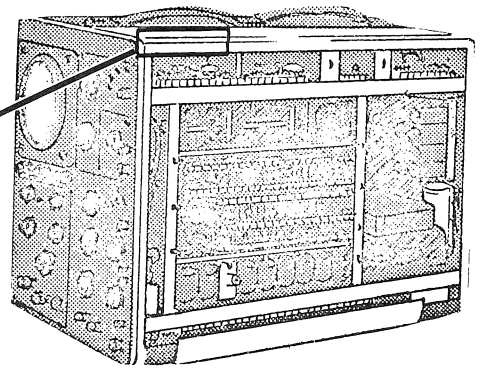


Figure 32

B. A INTERNAL DC LEVEL ADJUSTMENT

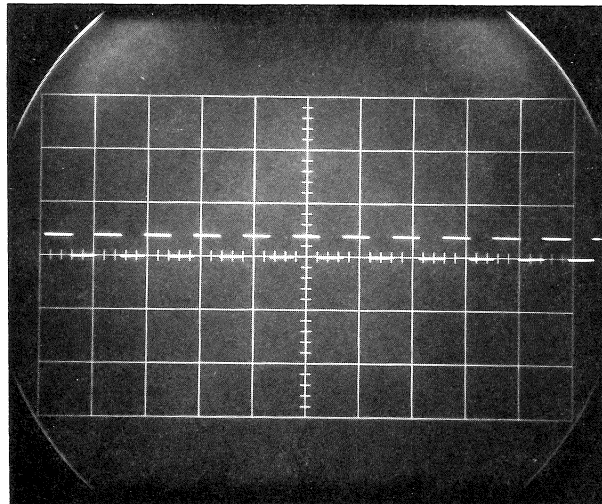
Before this adjustment can be made, the VERTICAL DC BALANCE must be adjusted as per SECTION 11 step 1 A.

1. Set A TRIGGERING controls as follows:

MODE	AUTO
SLOPE	+
COUPLING	DC
SOURCE	INTERNAL-NORMAL

2. Adjust AMPLITUDE CALIBRATOR and TU-7 VARIABLE for 4mm of vertical deflection as displayed on the CRT.
3. Position the baseline of the display to the graticule center. (See Figure 33)

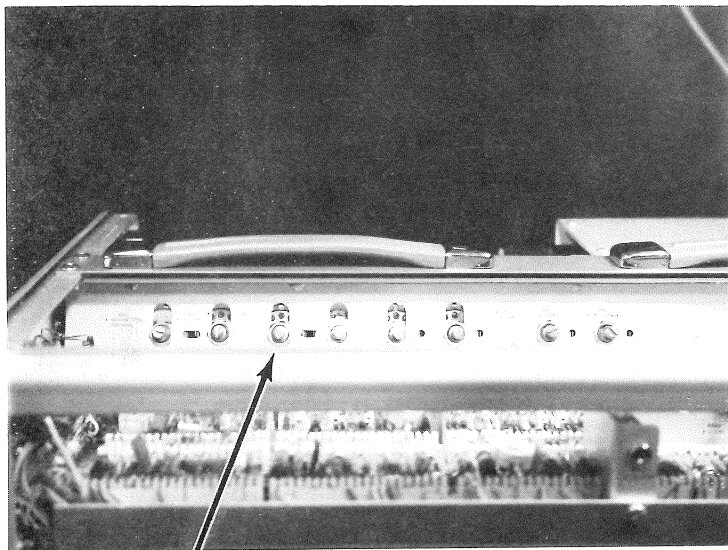
4mm of vertical deflection



Baseline of display set at graticule center

Figure 33

4. Adjust A INTERNAL DC LEVEL adjustment (R209-see Figure 34) for a triggered display while moving the SLOPE switch from + (plus) to - (minus).
5. Remove the shorting strap from the junction of R217, R218, and R219.



INTERNAL DC LEVEL adjustment R209

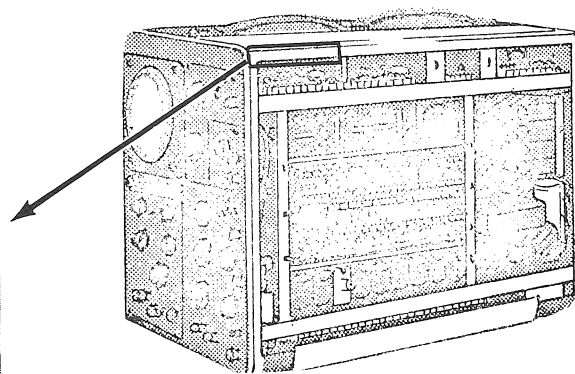


Figure 34

II. B SWEEP TRIGGERING ADJUSTMENTS

A. TRIGGER LEVEL CENTERING and TRIGGER SENSITIVITY ADJUSTMENTS

1. Preset the 547 front panel controls as follows:

HORIZONTAL DISPLAY	B
B TRIGGERING	
MODE	AUTO or TRIG
SLOPE	+
COUPLING	AC
SOURCE	EXTERNAL
B TIME/CM	1 msec
B TIME/CM VARIABLE	CALIBRATED

For this step B TRIGGERING MODE can be set to either AUTO or TRIG as the operator wishes. The use of an external trigger signal has been found to be the quickest and most reliable way to "set" the triggers.

2. Set the AMPLITUDE CALIBRATOR TO 200mv (0.2v) and connect the CAL OUT jack to the vertical input of the TU-7 and to the TRIG INPUT jack (B TRIGGER).

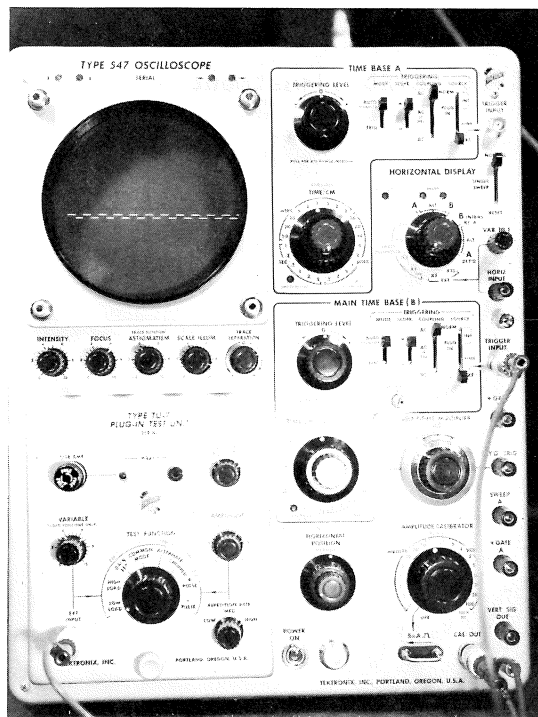
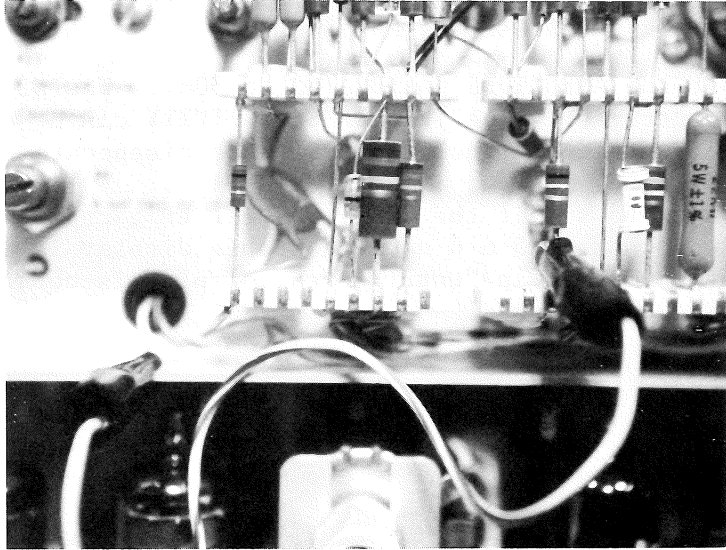


Figure 35

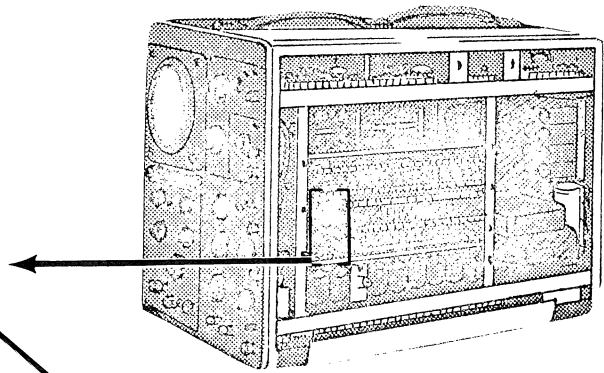
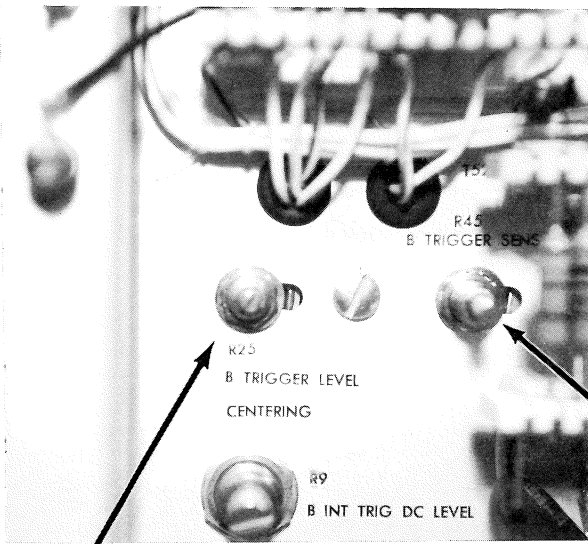
3. Disable the TRIGGERING LEVEL control by shorting the junction of R7, R8, and R9 to ground. (See Figure 36)



Junction of
R7, R8, & R9

Figure 36

4. Adjust B TRIGGER LEVEL CENTERING adjustment (R25) to produce a triggered display while moving the SLOPE switch from + to - (minus). If a triggered display can not be obtained, adjust the TRIGGER SENSITIVITY adjustment (R45) cw. (See Figure 37)
5. Set the AMPLITUDE CALIBRATOR to 100mv and obtain a triggered display as per step 4.
6. Set the AMPLITUDE CALIBRATOR to 50mv. The signal should not trigger. The TRIGGER SENSITIVITY can be adjusted ccw to "untrigger" the display (trace disappears or free runs).
7. Check to see if the display still triggers at 100mv. Repeat steps 5 & 6 until a stable display is obtained at 100mv and an "untriggered" display is obtained at 50mv.



B TRIGGER LEVEL CENTERING R25
(adjust for + and - triggering)

B TRIGGER SENSITIVITY R45 (adjust
for a triggered display at 100mv
but not at 50 mv).

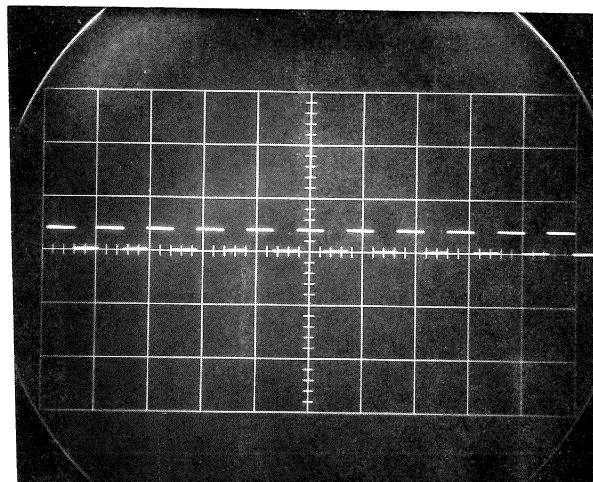


Figure 37

B. INTERNAL DC LEVEL ADJUSTMENT

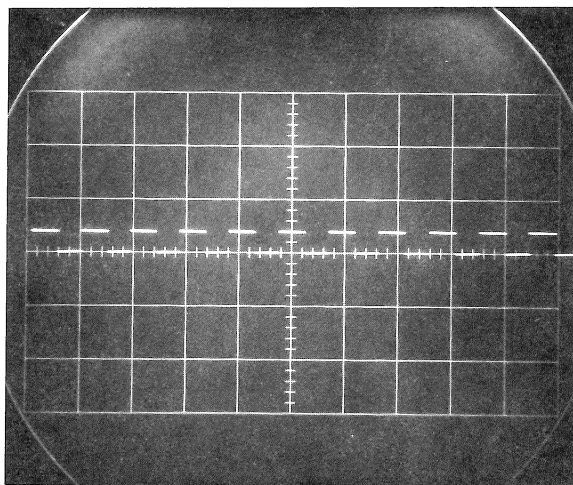
Before this adjustment can be made, the VERTICAL DC BALANCE must be adjusted as per SECTION II step 1 A.

1. Set B TRIGGERING controls as follows:

MODE	AUTO
SLOPE	+
COUPLING	DC
SOURCE	INTERNAL-NORMAL

2. Adjust the AMPLITUDE CALIBRATOR and the TU-7 VARIABLE 4mm of vertical deflection as displayed on the CRT.
3. Position the baseline of the display to the graticule center. (See Figure 38)

4mm of vertical deflection



baseline of display set at graticule center

Figure 38

4. Adjust the INTERNAL DC LEVEL adjustment (R9-See Figure 39) for a triggered display while moving the SLOPE switch from + (plus) to - (minus).
5. Remove the shorting strap from the junction of R7, R8, and R9.

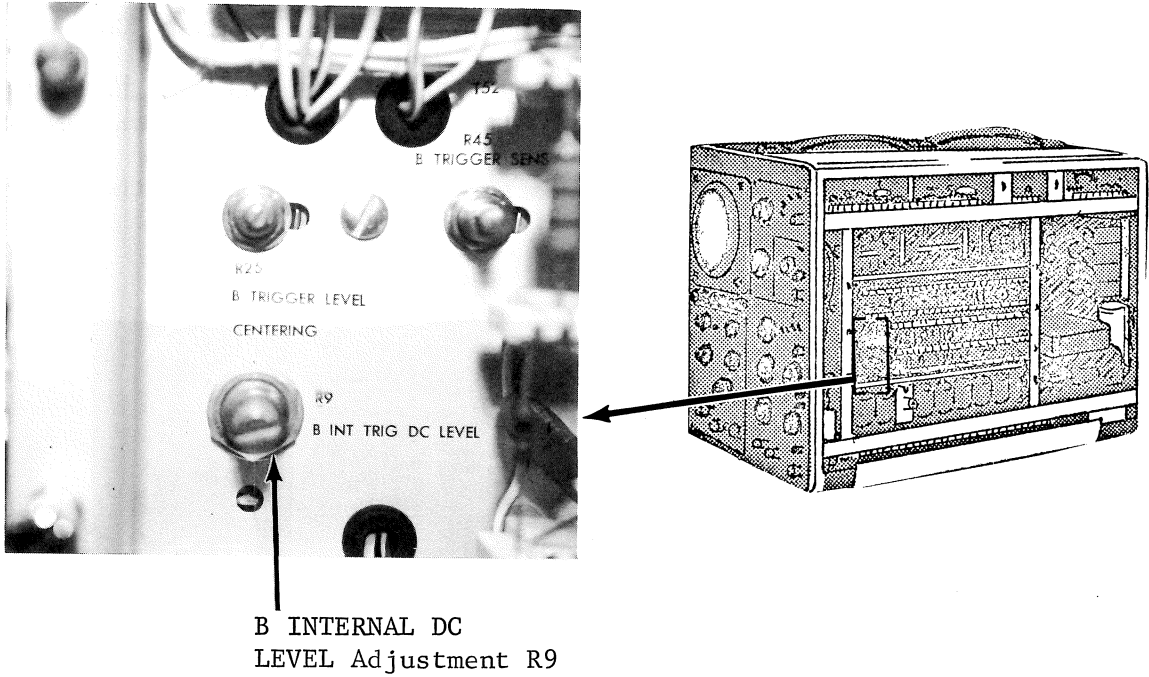


Figure 39

III. A and B LOW FREQUENCY TRIGGERING CHECKS

Since the A and B Triggering circuits are identical, the low frequency checks are written to apply to either trigger circuit. The checks are similar to checks on the 545A and thus are put in statement form.

A. INT-NORM

1. With COUPLING set to AC the 547 must trigger, both + and - polarity, on 2mm of vertical deflection without an adjustment of the TRIGGERING LEVEL.
2. With COUPLING set to DC the 547 must trigger on 4mm of vertical deflection with an adjustment of the TRIGGERING LEVEL anywhere on the graticule.

B. INT-PLUG-IN

1. With COUPLING set to AC the 547 must trigger on 4cm of vertical deflection with an adjustment of the TRIGGERING LEVEL.

C. EXT

1. With 100mv applied to the TRIGGER INPUT and COUPLING set to AC, the 547 must trigger, both + and - polarity, without an adjustment of the TRIGGERING LEVEL.
2. With 100mv applied to the trigger INPUT and COUPLING set to DC, the 547 must trigger with an adjustment of the TRIGGERING LEVEL.

SECTION IV

The purpose of this section is to check the horizontal switching, single sweep operation of the time base generators, and the dual trace capabilities of the 547.

Preset the front panel controls as follows:

SWEEP MODE	NORMAL
HORIZONTAL DISPLAY	A ALT B
SWEEP MAGNIFIER	X1(off)
A and B TIME/CM	1 msec
A and B TIME/CM VARIABLE	CALIBRATED
A and B TRIGGERING	
MODE	AUTO
SLOPE	+
COUPLING	AC
SOURCE	INT-NORM
DELAY TIME MULTIPLIER	Approximately 5.00
TEST FUNCTION	LOW LOAD

I. ALTERNATE OPERATION

A. A ALT B OPERATION

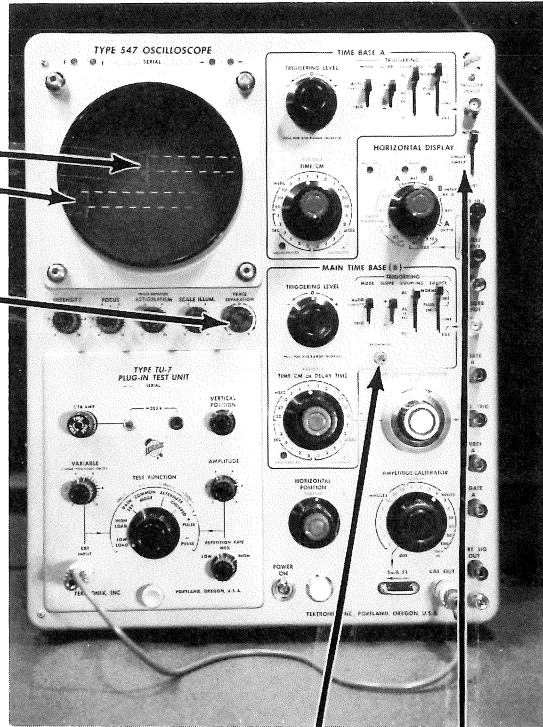
1. Connect a signal from the CAL OUT jack to the TU-7 and adjust the AMPLITUDE CALIBRATOR and VARIABLE for 1cm of vertical deflection.
2. With the VERTICAL POSITION and TRACE SEPARATION controls position the two (2) traces about 1cm apart. (The TRACE SEPARATION control is located immediately below the CRT to the right).
3. With the INTENSITY and BRIGHTNESS controls adjust both traces for equal intensity. (The BRIGHTNESS control is located below the B TRIGGERING selectors-fingernail type adjustment. (See Figure 40)

About 1cm of vertical deflection each trace. Traces are positioned about 1cm apart.

A SWEEP
B SWEEP

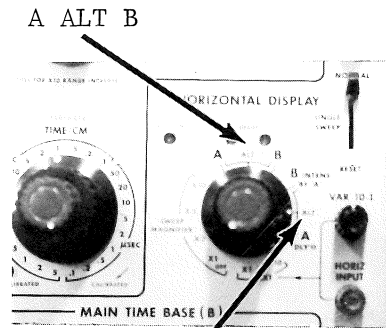
TRACE SEPARATION control

TRACE SEPARATION control will change position of A SWEEP in relation to B SWEEP. VERTICAL POSITION control affects both traces equally.



BRIGHTNESS CONTROL SWEEP MODE SWITCH

In B INTENS BY A ALT A DLY'D the 547 alternately displays a B intensified sweep and an A delayed sweep.



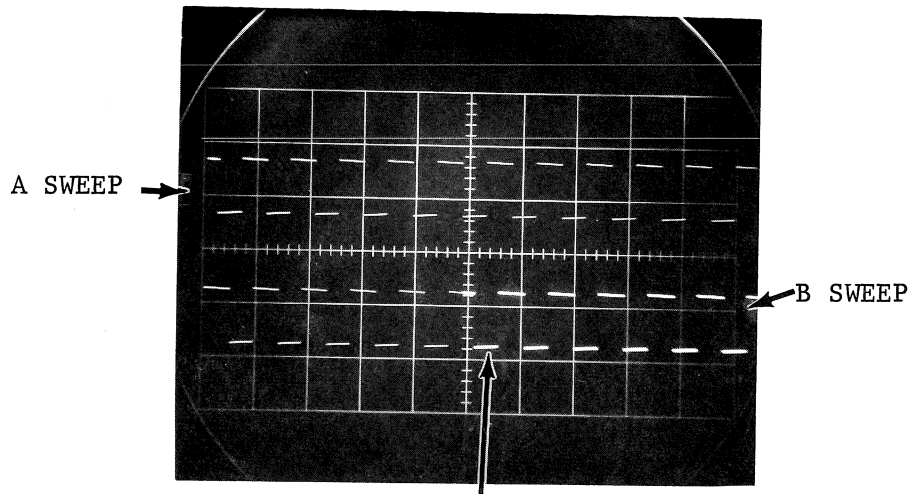
B INTENS BY A ALT A DLY'D

Figure 40

4. Obtain a stable display on the CRT (both sweeps must be triggered).
5. Insure that TRACE SEPARATION control and A TIME/CM control affect the same trace.

B. B INTENS BY A ALT A DLY'D

1. Set HORIZONTAL DISPLAY to B INTENS BY A ALT A DLY'D
2. Adjust BRIGHTNESS control for an easily discernible intensified portion on B sweep (lower trace). With the DELAY TIME MULTIPLIER set to 5.00 the intensified portion should start at the center of the screen. (See Figure 41)



Adjust Brightness Control
for easily discernible
intensified portion of trace.

Figure 41

C. VERTICAL ALTERNATE

1. Set HORIZONTAL DISPLAY TO A and TEST FUNCTION TO ALTERNATE. Check for two (2) traces.
2. Set AMPLITUDE CALIBRATOR for 100v square wave. Cal signal will be displayed on one (1) trace only.
3. Set HORIZONTAL DISPLAY to B. Same display as step 2. BRIGHTNESS or INTENSITY controls may have to be readjusted before both traces can be seen. (See Figure 42)

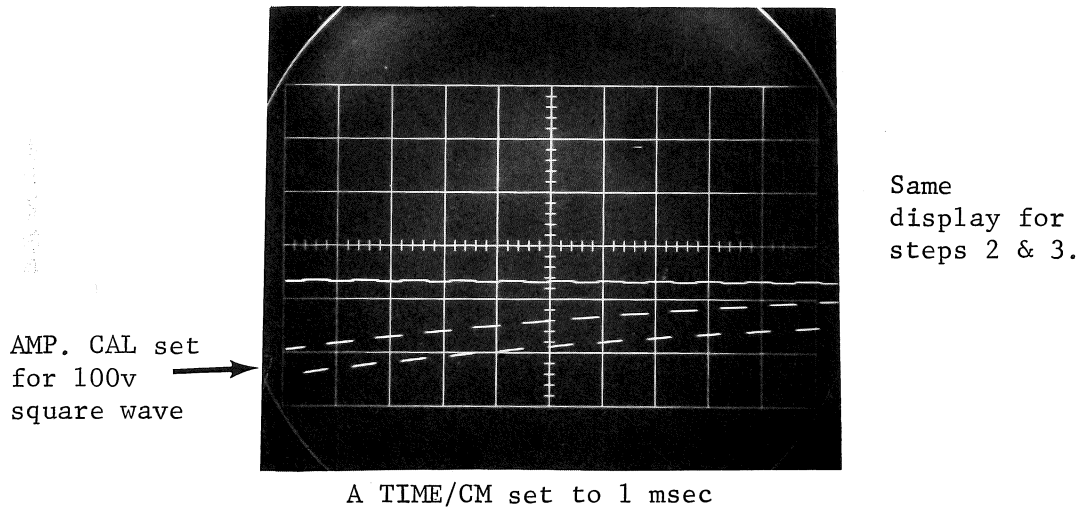
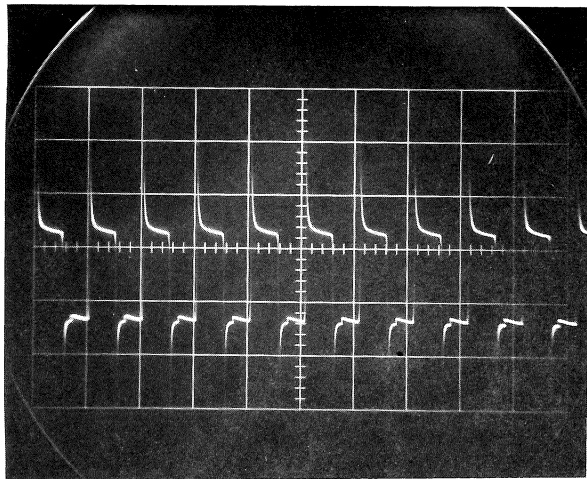


Figure 42

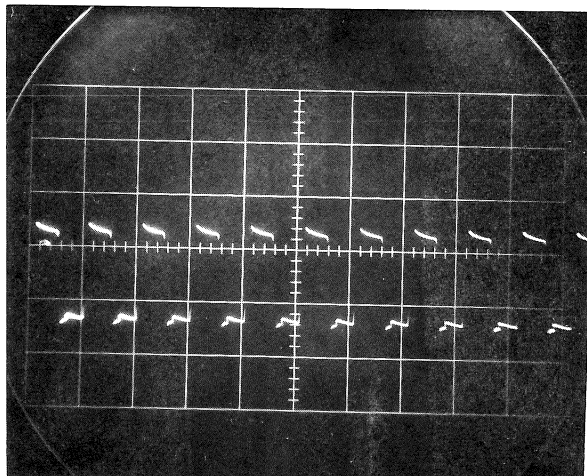
D. CHOPPED BLANKING

1. Remove Cal signal. Set TEST FUNCTION to CHOPPED and B TIME/CM to $10\mu\text{sec}$.
2. Set CRT CATHODE SELECTOR to CHOPPED BLANKING and check for proper operation. (CRT CATHODE SELECTOR is located on the back panel of scope). (See Figure 43)
3. Set HORIZONTAL DISPLAY to A and A TIME/CM to $10\mu\text{sec}$. Repeat step 2.



547 intensity set
about 4.1 for this
picture

Unblanked chopped waveform A & B sweeps



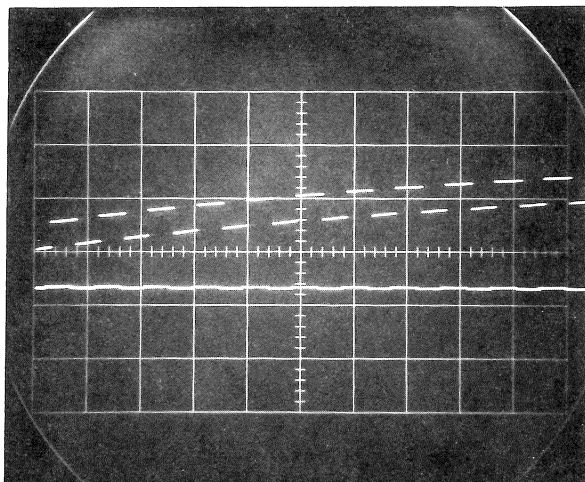
547 intensity set
about 3.75 for
this picture

Figure 43

Blanked chopped waveform A & B sweeps

E. ALTERNATE SLAVE

1. Set HORIZONTAL DISPLAY to A ALT B, A and B TIME/CM to 1msec, and TEST FUNCTION to ALTERNATE. Apply CAL signal and set AMPLITUDE CALIBRATOR for 100v square wave.
2. Insure that CAL signal is displayed on A sweep.
(See Figure 44)



CAL signal
displayed on
A Sweep

Figure 44

II. SINGLE SWEEP

The check-out procedure for the 547 single sweep operation has been written in a SHORT and a LONG FORM. The SHORT FORM is a procedure that would be used by an experienced 547 operator. The LONG FORM has been provided as a visual aid check to be used in conjunction with the circuit description and as a method of acquainting the operator with the "Assets and Liabilities" of the 547 sweep switching.

SHORT FORM

A. SINGLE SWEEP CHECK-OUT

1. Set HORIZONTAL DISPLAY to A ALT B, A and B TIME/CM to 1 msec, TEST FUNCTION to LOW LOAD, and AMPLITUDE CALIBRATOR and VARIABLE for 1 cm of vertical deflection.
2. Adjust A and B TRIGGERING LEVEL for a stable display.
3. Remove CAL signal. B ready lamp goes on. Set SWEEP MODE switch to SINGLE SWEEP.
4. Apply CAL signal. Both sweeps run up. B will sweep first.
5. Remove CAL signal and RESET SWEEP MODE. Repeat step 4.
6. Check all functions of Horizontal display similarly:

HORIZONTAL DISPLAY	READY LAMP	DISPLAY
A	A and B on	A Sweep
A ALT B	B only on	Both Sweeps (B Sweeps first)
B	A and B on	B Sweep
B INTENS BY A	B only on	B intensified Sweep
B INTENS BY A ALT A DLY'D	B only on	Either an intensified or delayed sweep
A DLY'D	B only on	A delayed sweep
EXT X1	A and B	
EXT X10	A and B	

NOTE: To check A single sweep operation A TRIGGERING MODE must be set to TRIG. To obtain the condition indicated for the other single sweep functions A TRIGGERING MODE must be set to AUTO.

LONG FORM

A. A SINGLE SWEEP

1. Set HORIZONTAL DISPLAY TO A, A TIME/CM to 1 msec, TEST FUNCTION to LOW LOAD, and AMPLITUDE CALIBRATOR and VARIABLE for about 1 cm of vertical deflection.
2. Set A TRIGGERING to TRIG and obtain a stable display.
3. Remove signal. A ready lamp goes on.
4. Set B TRIGGERING MODE to TRIG. B ready lamp goes on. (If B TRIGGERING MODE has previously been set to TRIG, B ready lamp will be on while A sweeps in a normal manner).
5. Set SWEEP MODE to SINGLE SWEEP and apply signal. An A single sweep will be observed.
6. Remove signal and RESET SWEEP MODE. Both ready lamps go on. Apply signal and observe an A single sweep.

B. B SINGLE SWEEP

1. Set HORIZONTAL DISPLAY to B and SWEEP MODE to NORMAL.
2. Obtain a stable display and then remove signal. Both ready lamps go on.
3. Set SWEEP MODE to SINGLE SWEEP and apply signal. Observe a B single sweep.
4. Remove signal and RESET SINGLE SWEEP MODE. Apply signal and observe a B single sweep.

C. A ALT B SINGLE SWEEP

1. Set HORIZONTAL DISPLAY TO A ALT B and remove signal.
2. Set A and B TIME/CM to 0.1 sec.
3. RESET SWEEP MODE. B ready lamp goes on. Apply signal. B will sweep first and then A will sweep.
4. Set SWEEP MODE to NORMAL. Remove signal while A sweep is running. B ready lamp will go on when A has completed runup.
5. Set SWEEP MODE to SINGLE SWEEP and apply signal. B will sweep first and then A will sweep.

6. Set SWEEP MODE to NORMAL and remove signal while B is running. A ready lamp will go on when B has completed runup. This indicates that A is now ready to sweep. If the SWEEP MODE is set to SINGLE SWEEP, A will occasionally runup without an applied signal. The reason for the runup of A sweep is thought to be a transient generated by the SWEEP MODE switch.

D. B INTENS BY A SINGLE SWEEP

1. Set HORIZONTAL DISPLAY to B INTENS BY A, SWEEP MODE to NORMAL and A TIME/CM to 10 msec.
2. Adjust BRIGHTNESS for an easily discernible intensified portion.
3. Remove signal and wait for B ready lamp to go on. Set SWEEP MODE to SINGLE SWEEP. B ready lamp will go on as soon as the sweep completes runup. (If SWEEP MODE is set to SINGLE SWEEP before the sweep completes runup, B ready lamp will not go on.)
4. Apply signal and observe an intensified sweep.
5. Remove signal and RESET SWEEP MODE. B ready lamp goes on. Apply signal and observe an intensified sweep.

NOTE: There may be an occasional bright spot on the left of the CRT when switching from NORMAL to SINGLE SWEEP and there may also be an intensified portion at the start of the sweep. This effect is thought to be caused by a transient generated by the SWEEP MODE. This effect appears to be more predominate if A TRIGGERING MODE is set to AUTO.

E. A DLY'D SINGLE SWEEP

1. Set HORIZONTAL DISPLAY to A DLY'D, SWEEP MODE to NORMAL, and A TIME/CM to 0.1 sec, and B TIME/CM to 1 sec.
2. Remove signal while A runs up. Wait for B ready lamp to go on. Set SWEEP MODE to SINGLE SWEEP. Apply signal, after approximately 5 sec. delay A will sweep. (If the DELAY TIME MULTIPLIER is set at a position other than 5.00, the length of delay will vary accordingly.)
3. Set SWEEP MODE to NORMAL. Set A TRIGGERING MODE to TRIG if it is not already there. After B sweep starts to runup remove signal. (The start of B sweep can be determined by watching B ready lamp closely. The ready lamp will flicker just as B starts to runup. Remove signal just after the lamp flickers.) A ready lamp will go on after a short delay.

4. Set SWEEP MODE to SINGLE SWEEP and apply signal. A sweep will run up immediately.

NOTE: If a TRIGGERING MODE was set to AUTO in step 3, A would have run up as soon as it received a DELAYED TRIGGER from B.
If during these checks the SWEEP MODE is set to SINGLE SWEEP before the appropriate lamp goes on the sweep switching action of the 547 will not allow the sweeps to be put in a triggerable mode. The indicated lamps will not go on and single sweep action will not occur.

F. B INTENS BY A ALT A DLY'D SINGLE SWEEP

1. Set HORIZONTAL DISPLAY to B INTENS BY A ALT A DLY'D and apply signal.
2. Set SWEEP MODE to NORMAL.
3. Remove signal while a B intensified sweep runs up. Wait for ready lamp to go on and then RESET SWEEP MODE. (If a TRIGGERING MODE is set to TRIG and the signal is removed before the intensified portion of the trace A ready lamp will go on. It will go out as soon as B completes runup.)
4. Apply signal. B ready lamp goes out and after about 5 sec delay A will sweep.
5. Remove signal and RESET SWEEP MODE. B ready lamp goes on. Apply signal. An intensified sweep will be seen.
6. Set SWEEP MODE to NORMAL. Remove signal while an A delayed sweep runs up. Wait for B ready lamp to go on and then set SWEEP MODE to SINGLE SWEEP.
7. Apply signal. An intensified sweep will be seen. Remove signal and RESET SWEEP MODE. B ready lamp goes on. Apply signal. B ready lamp goes out and after 5 sec delay A will sweep.

NOTE: The peculiarities mentioned in parts D and E also may be noticed during this part of the procedure.

SECTION V

In the 547, B sweep generator is the main time base. The basic sweep timing and horizontal amplifier compensations will be adjusted with B sweep generator. A sweep timing will be matched to B sweep timing.

A type TU-7 test load unit was utilized in the following procedure. Any lettered series pulg-in unit can be substituted for the TU-7. (Example: CA, B, L, K, Z, TU-2)

A type 180A time mark generator was used to provide the timing signals.

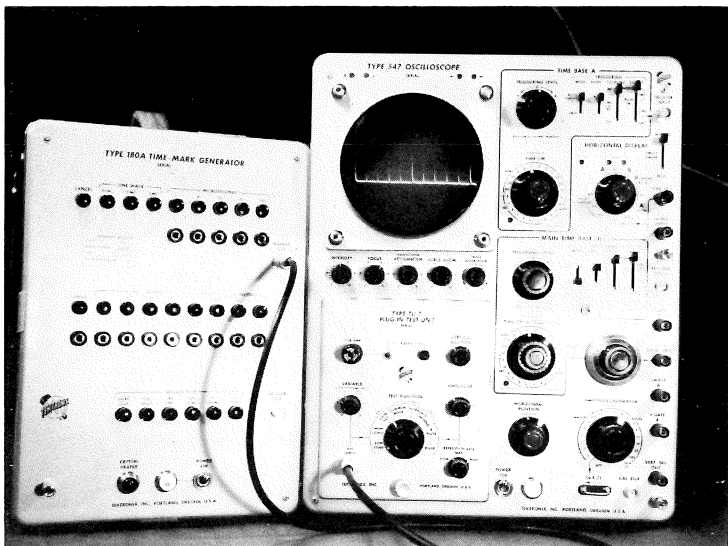
Preset the front panel controls as follows:

HORIZONTAL DISPLAY	B
SWEEP MAGNIFIER	X1(off)
B TRIGGERING	
MODE	TRIG
SLOPE	+
COUPLING	AC
SOURCE	INT-NORM
B TIME/CM	1 msec
B TIME/CM VARIABLE	CALIBRATED
DELAY TIME MULTIPLIER	---
TEST FUNCTION	LOW LOAD

I. BASIC SWEEP TIMING ADJUSTMENTS

A. SWEEP MAG REGIS

1. Connect a type 180A time mark generator to the TU-7. Set the 180 for 100 μ sec, 1 msec, and 5 msec time marks. (See Figure 45)



100 μ sec, 1 msec,
& 5 msec applied
from type 180A to
TU-7.

Figure 45

2. With the VARIABLE control, set signal amplitude to a convenient level and with the B TRIGGERING LEVEL control obtain a stable display. (See Figure 46)

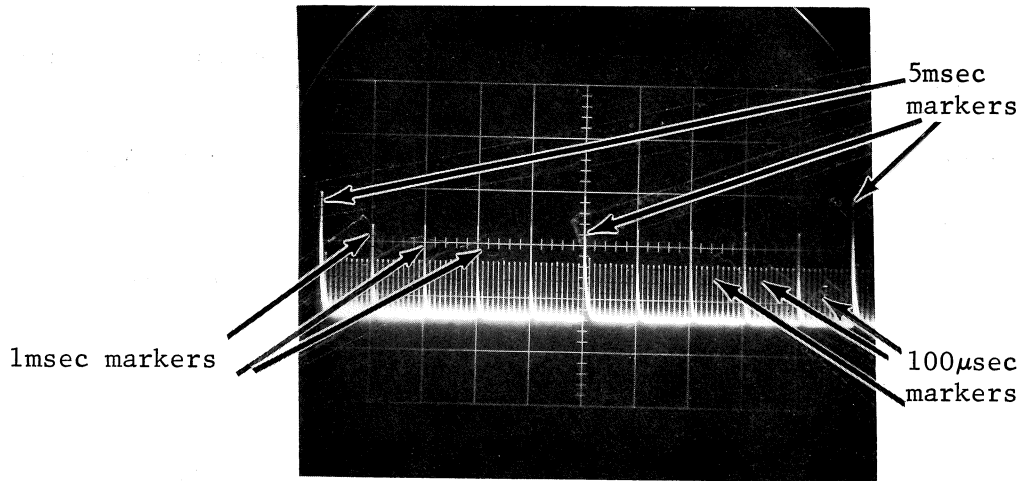


Figure 46

Set SWEEP MAGNIFIER TO X10 (See Figure 47). With the HORIZONTAL POSITION control position the middle 5 msec marker to the center of the graticule. (See Figure 48)

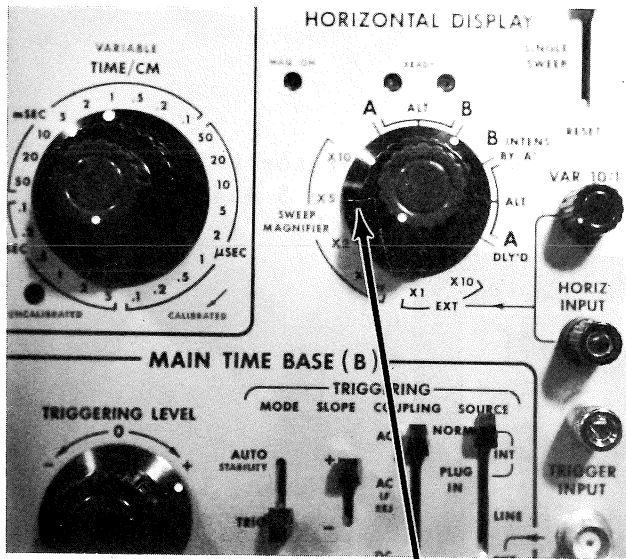


Figure 47 Sweep Magnifier set at X10

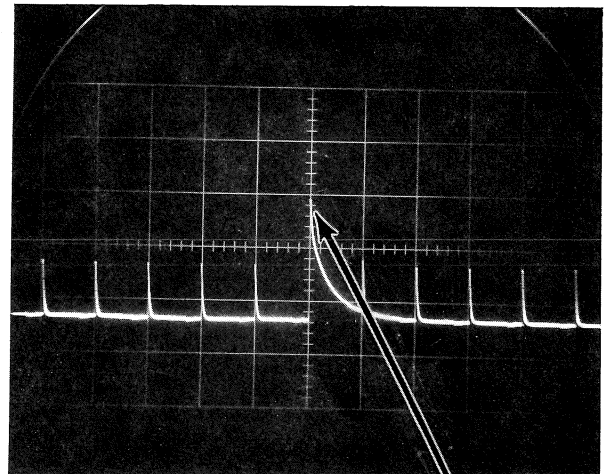


Figure 48

Middle 5msec Marker

4. Set SWEEP MAGNIFIER to X1 and adjust the SWEEP MAG REGIS (R569-See Figure 49) to position the middle 5 msec marker to the center of the graticule. (See Figure 50) Repeat steps 3 and 4 until there is no horizontal movement of the middle 5 msec marker while switching the SWEEP MAGNIFIER from X1 to X10.

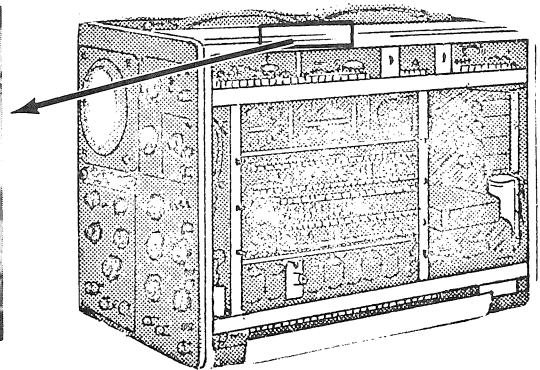
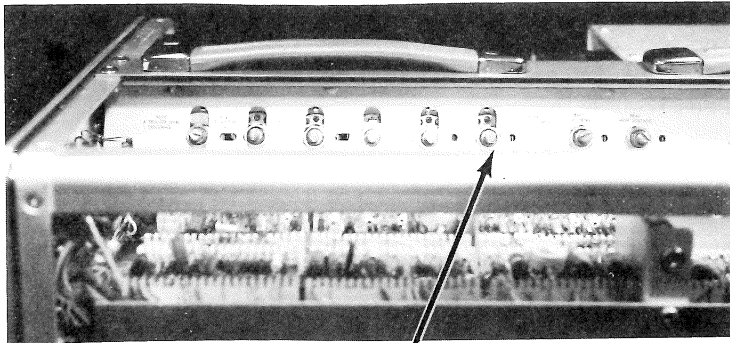


Figure 49 SWEEP MAG REGIS
Adj. R569

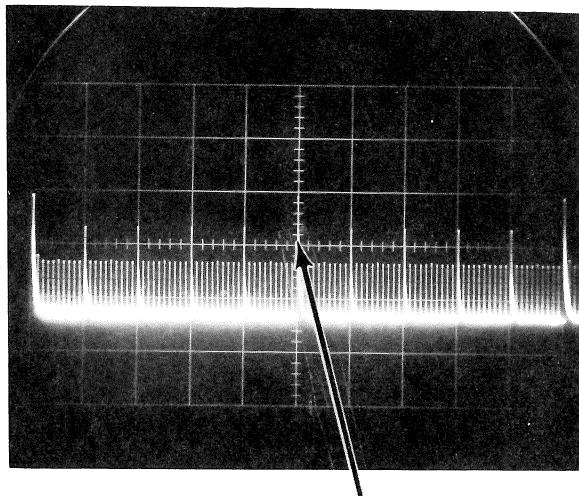


Figure 50 Adjust R569 - SWEEP MAG REGIS
to position middle 5msec marker
to graticule center.

B. HORIZONTAL AMPLIFIER GAIN

There are two (2) adjustments for setting the HORIZONTAL AMPLIFIER gain. The X10 CAL adjust affects all SWEEP MAGNIFIER positions and is the most sensitive. The X1 CAL adjust primarily affects the X1 SWEEP MAGNIFIER position. These adjustments set the basic sweep timing.

Unless otherwise stated, all timing adjustments will be made from the 2nd to the 10th cm lines. (See Figure 51. This area is referred to as the middle eight (8) cm of horizontal deflection.

Timing set between 2nd & 10th cm lines

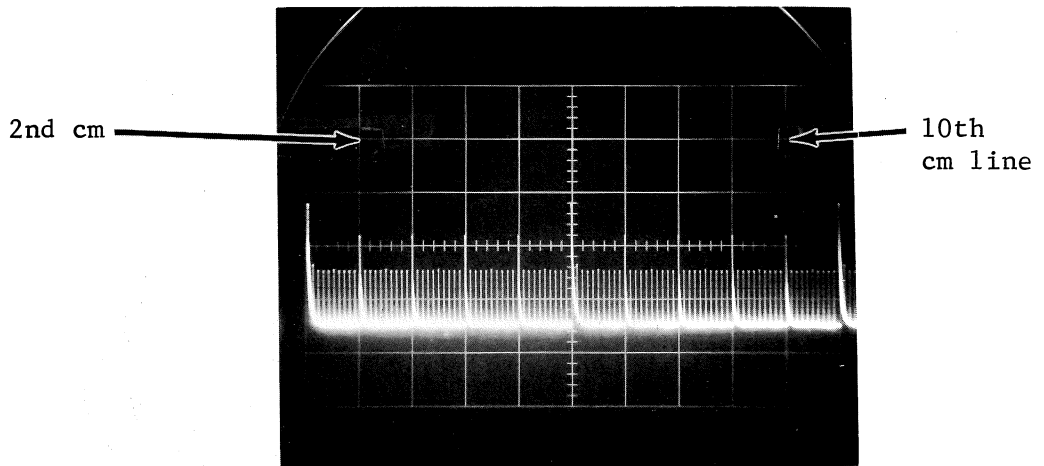


Figure 51

1. With the display centered on the graticule, set the SWEEP MAGNIFIER to X10. Adjust X10 CAL adjust (R544-See Figure 52) for one (1) 100 μ sec marker per cm. (See Figure 53)

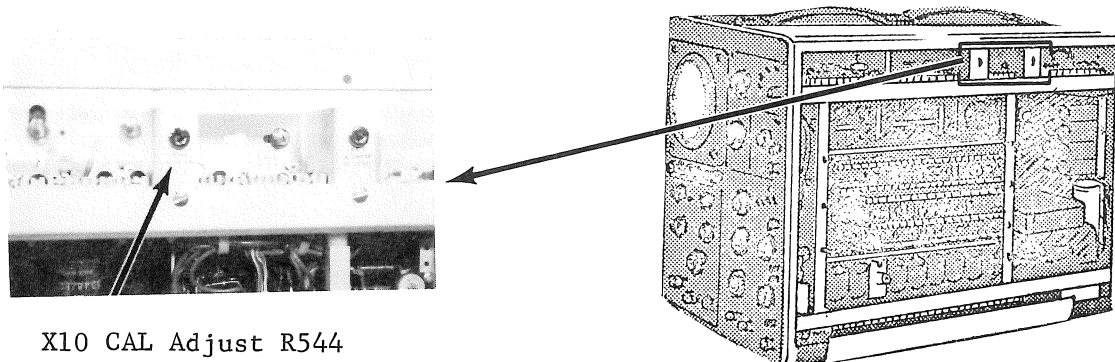
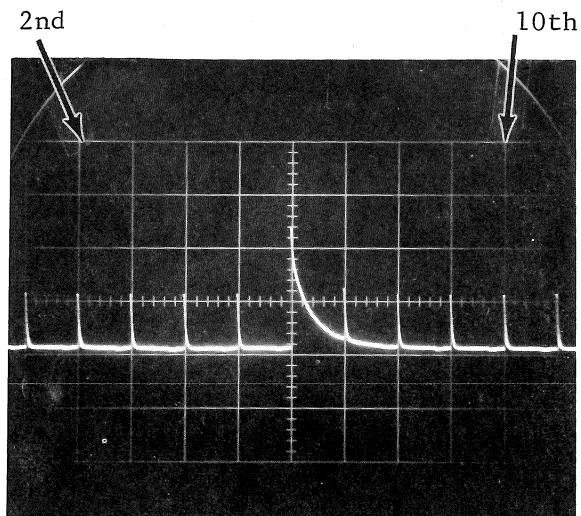


Figure 52

Timing set in this area



100 μ sec marker/cm

Figure 53

2. Set SWEEP MAGNIFIER to X1. Adjust X1 CAL adjust (R566- See Figure 54) for one (1) 1 msec marker per cm. (See Figure 55)
3. The X1 CAL and X10 CAL adjusts interact. Repeat steps 1 and 2 until timing is correct for both adjustments.

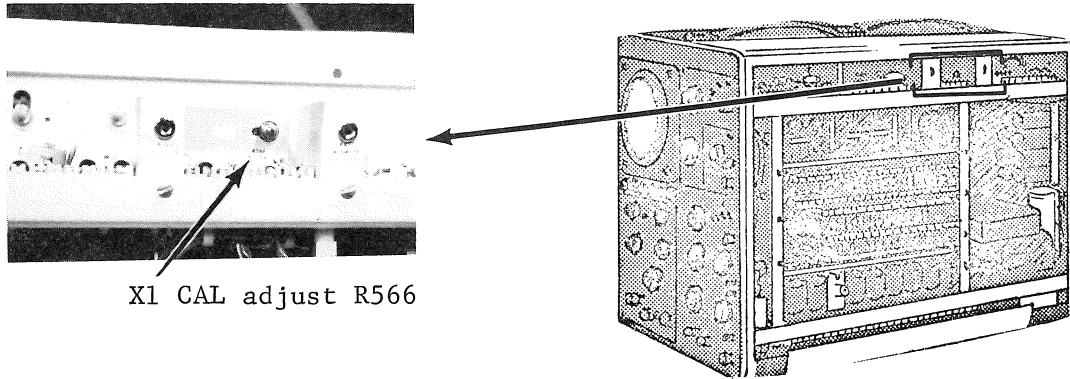
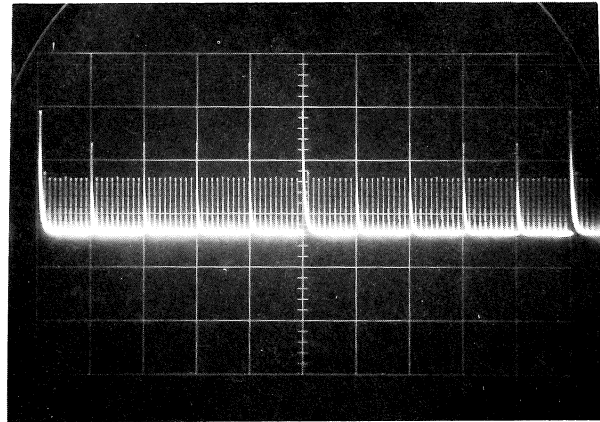


Figure 54



Adjust for one
1 msec
marker/cm

Figure 55

II. A to B SWEEP MATCHING

A. A to B SWEEP TIMING

1. Preset A SWEEP and A TRIGGERING controls as follows:

A TIME/CM	1 msec
A TIME/CM VARIABLE	CALIBRATED
A TRIGGERING	
MODE	AUTO
SLOPE	+
COUPLING	AC
SOURCE	INT-NORM
2. Set HORIZONTAL DISPLAY to A ALT B. With A TRIGGERING LEVEL control obtain a stable display.
3. With the TRACE SEPARATION and VERTICAL POSITIONS controls set the trace so they overlap. (See Figure 56)

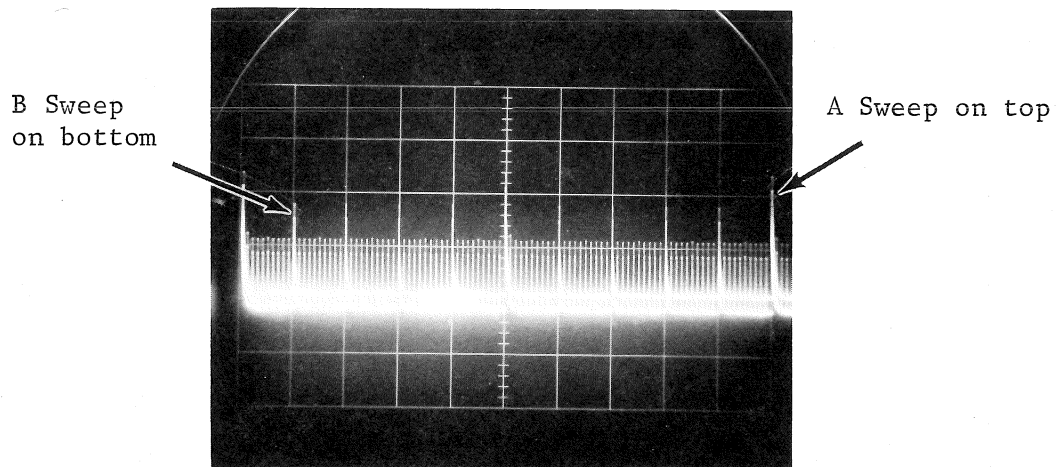
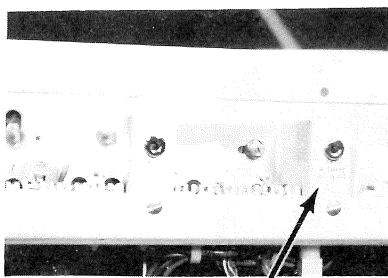


Figure 56

Set SWEEP MAGNIFIER to X10 and with the HORIZONTAL POSITION control position the start of the sweeps to the center area of the graticule. Adjust A SWEEP DC LEVEL adjustment (R470- See Figure 57) so that the two (2) sweeps start at the same point. (See Figure 58)



A SWEEP DC LEVEL
Adjust R470

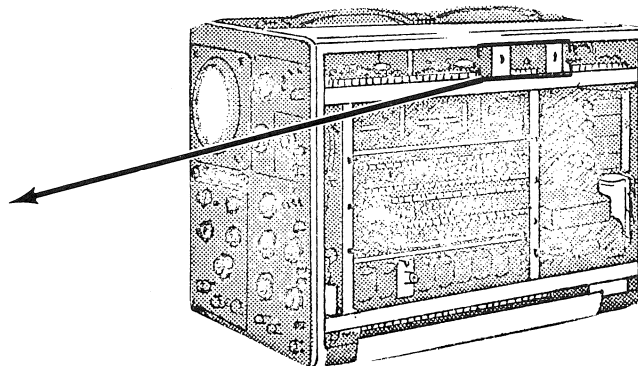
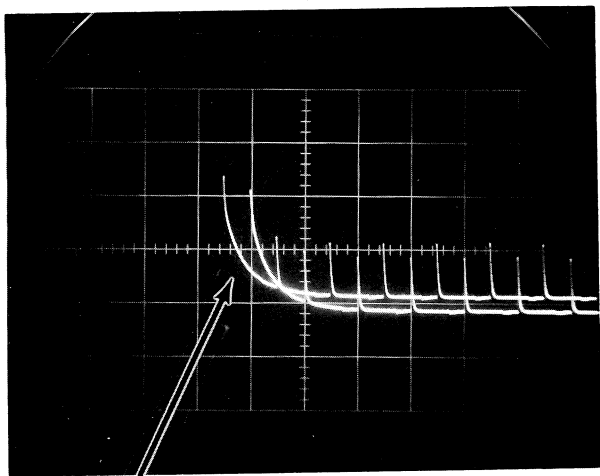
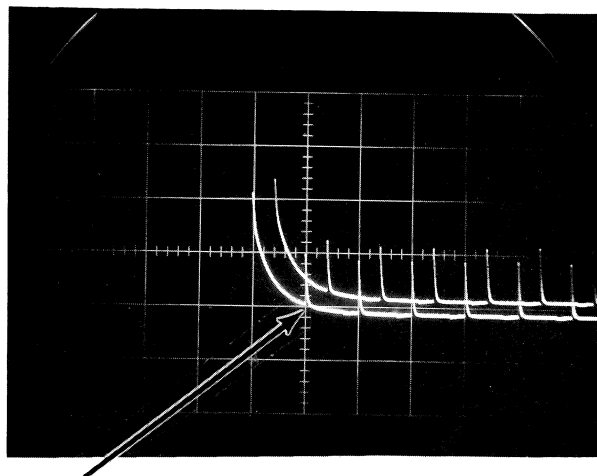


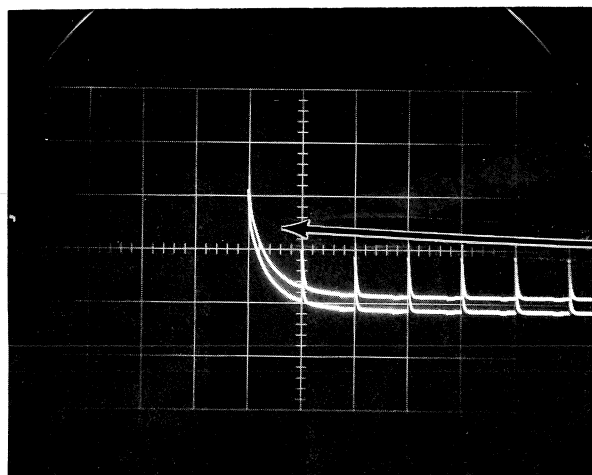
Figure 57



Start of A SWEEP to the left of the start of B SWEEP



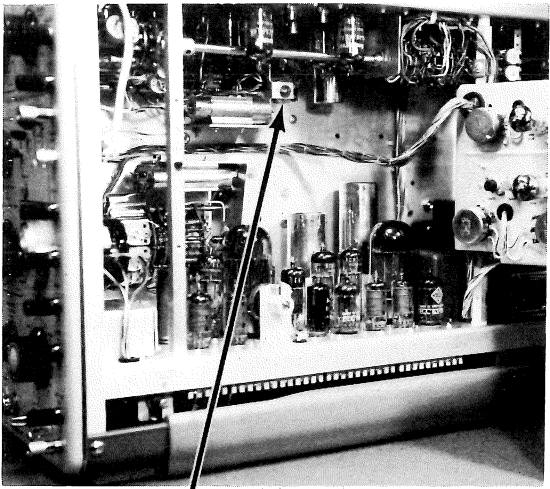
Start of A SWEEP to the right of the start of B SWEEP



Start of both sweeps coincide when R470 is properly adjusted.

Figure 58

5. With the HORIZONTAL POSITION control, position the traces to the left until the last 5 msec marker is set to the center area of the graticule. Adjust A SWEEP CAL adjustment (R290Y-See Figure 59) so that the last 5 msec marker of both sweeps are at the same point. (See Figure 60)
6. A SWEEP DC LEVEL and A SWEEP CAL adjustments interact. Repeat steps 4 and 5 until A sweep timing matches B sweep timing.



A SWEEP CAL
R290Y

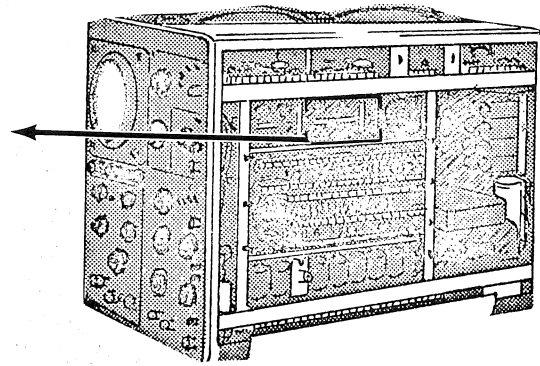
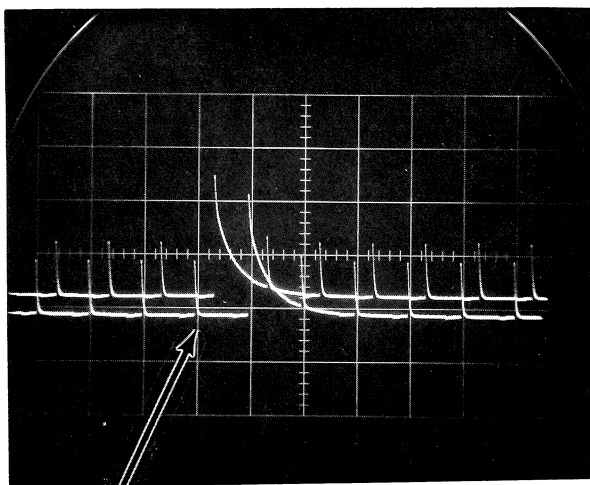
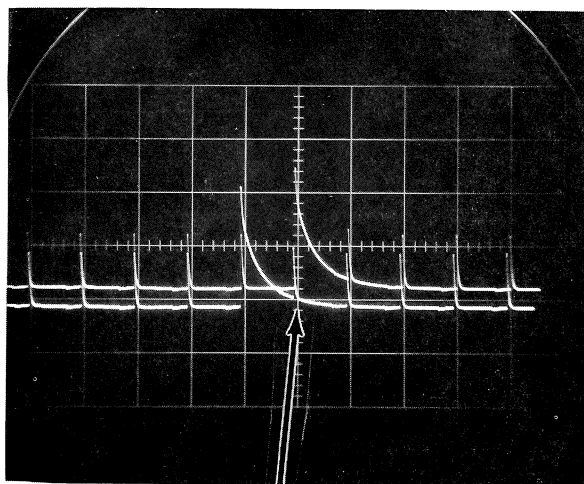


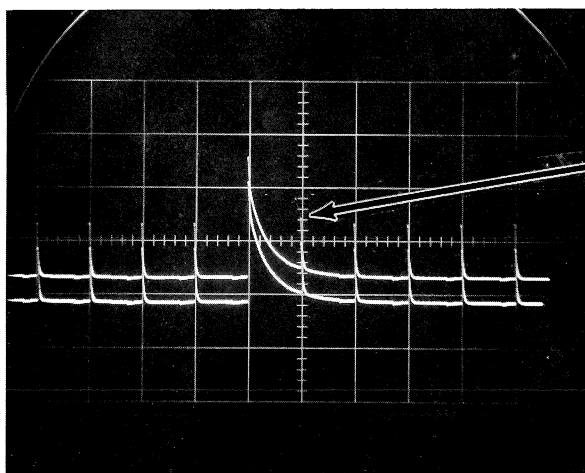
Figure 59



Last 5 msec marker of A sweep set to the left of the last 5 msec marker of B sweep.



Last 5 ms marker of A sweep set to the right of the last 5 ms marker of B sweep.



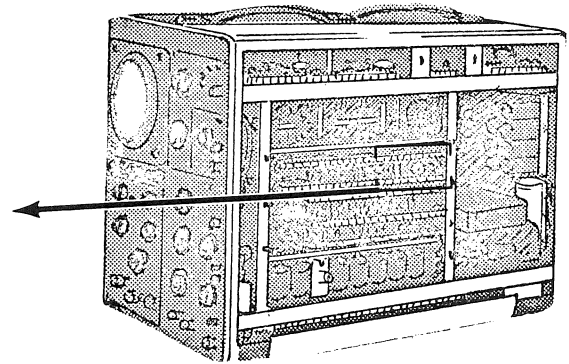
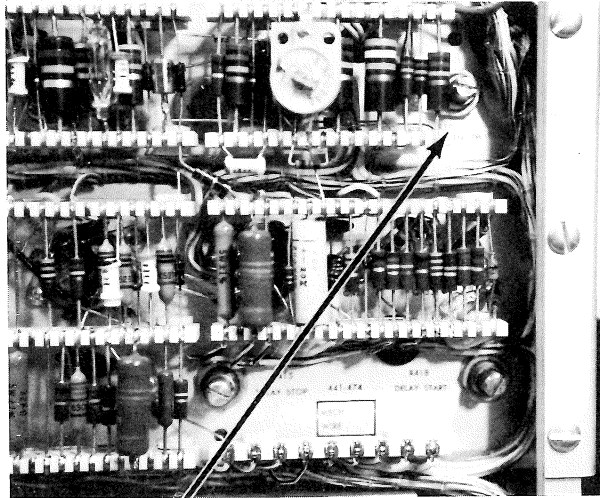
Last 5 ms marker of both sweeps coincide when R290Y is properly adjusted.

Figure 60

B. A and B SWEEP LENGTH

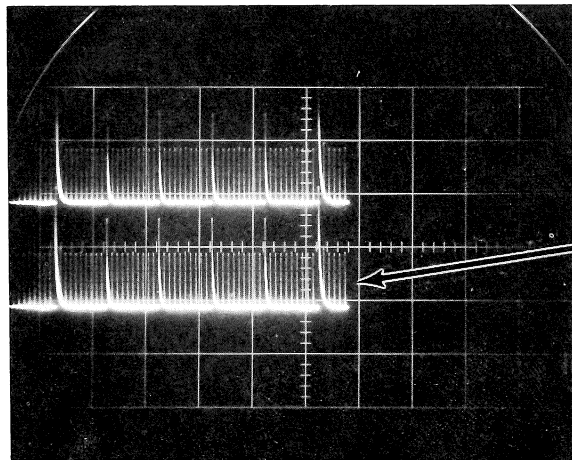
1. Set SWEEP MAGNIFIER to X1. With the HORIZONTAL POSITION control position the sweeps so that the last 5 msec marker is set to the center area of the graticule.

2. Adjust B SWEEP LENGTH adjustment (R125-See Figure 61) for 10.5 cm of horizontal deflection --- 5 100 μ sec markers to the right of the last 5 msec marker. (See Figure 62) It may be helpful to separate the 2 sweeps for this adjustment.



B sweep length
Adjust R125

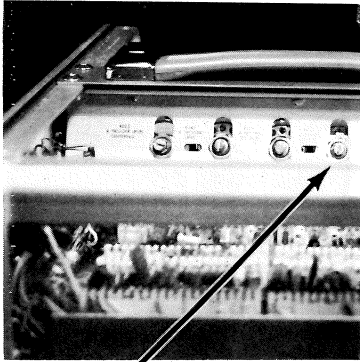
Figure 61



B sweep length
set for 10.5 cm
(5 100 μ sec
markers to the
right of the
last 5 msec
marker)

Figure 62

3. Adjust A SWEEP LENGTH adjustment (R325-See Figure 63) for 10.5 cm of horizontal deflection --- 5 100 μ sec markers to the right of the last 5 msec marker. (See Figure 64)



A sweep length
Adjust R325

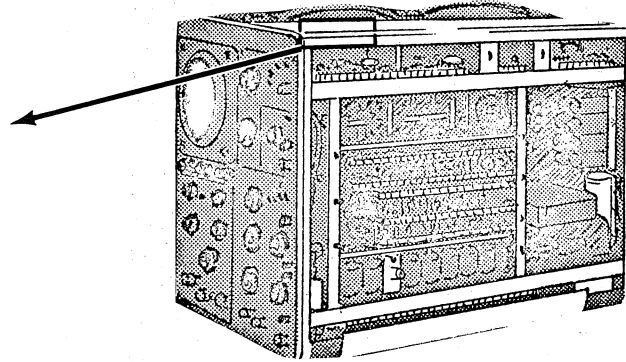
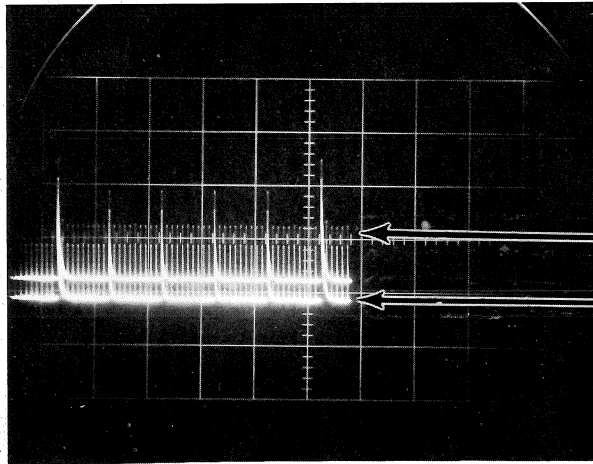


Figure 63

A sweep length
set to 10.5 cm

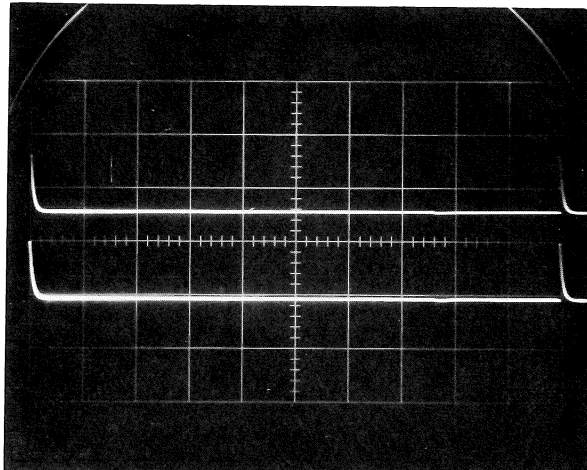


A sweep length
set by matching
it to B sweep
length.
A sweep
B sweep

Figure 64

C. A & B TIME/CM VARIABLE

1. From the 180, apply 10 msec markers only. With A and B TRIGGERING LEVEL controls obtain a stable display.
2. With the HORIZONTAL POSITION control center the display on the graticule. (See Figure 65)

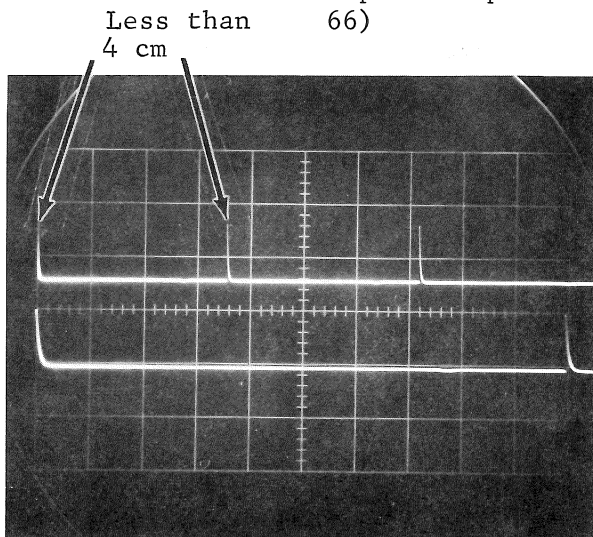


A & B TIME/CM = 1msec

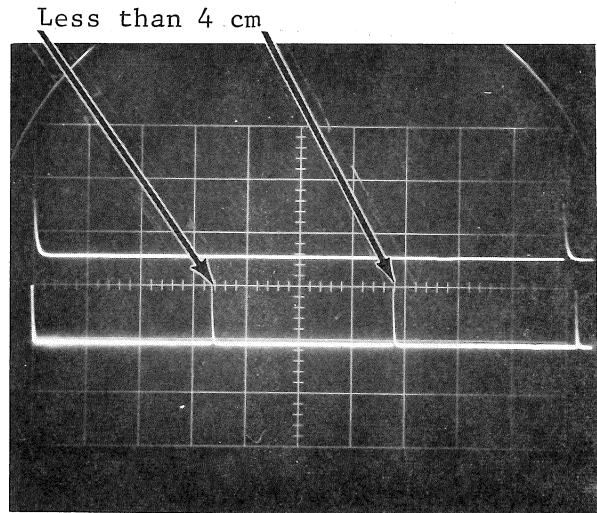
10 msec markers
from 180

Figure 65

3. Turn A TIME/CM VARIABLE full ccw. There should be less than 4 cm distance between successive time marks. (See Figure 66) Return A TIME/CM VARIABLE to the CALIBRATED position.
4. Repeat step 3 with B TIME/CM VARIABLE. (See Figure 66)



A Sweep



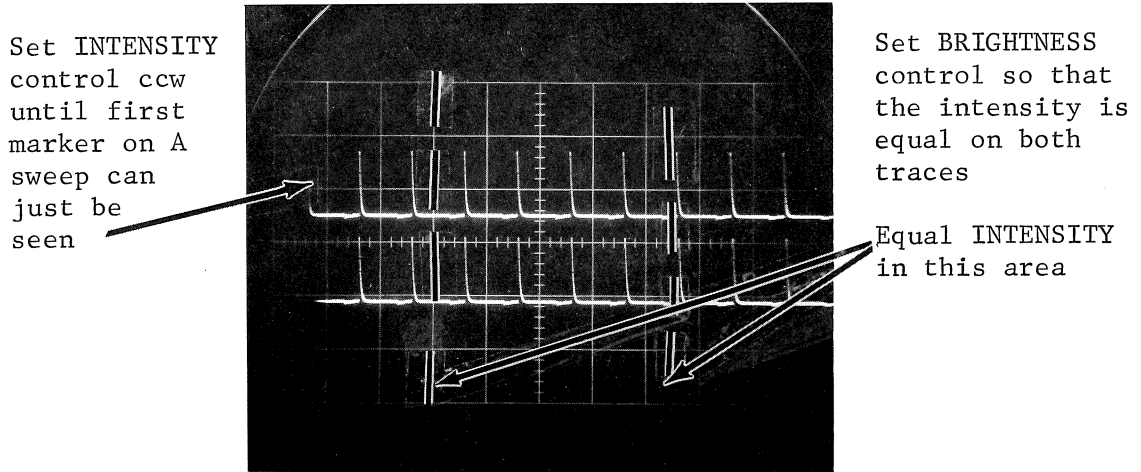
B Sweep

Less than 4 cm distance between successive marker when
TIME/CM VARIABLE is turned fully ccw. (2.5:1)

Figure 66

D. B UNBLANKING COMPENSATION

1. Set A & B TIME/CM to 0.1 msec. Apply 100 μ sec markers from the 180. Obtain a stable display.
2. Rotate the INTENSITY control ccw until the first time mark on A sweep can just be seen. Adjust the BRIGHTNESS control for equal intensity on both traces. (See Figure 67)



A & B TIME/CM set to 0.1 msec 100 μ sec markers from 180
Figure 67

3. Adjust B SWEEP UNBLANKING compensator (C186-See Figure 68) so that the intensity at the start of B sweep (the first time mark) matches the intensity at the start of A sweep. (See Figure 69)

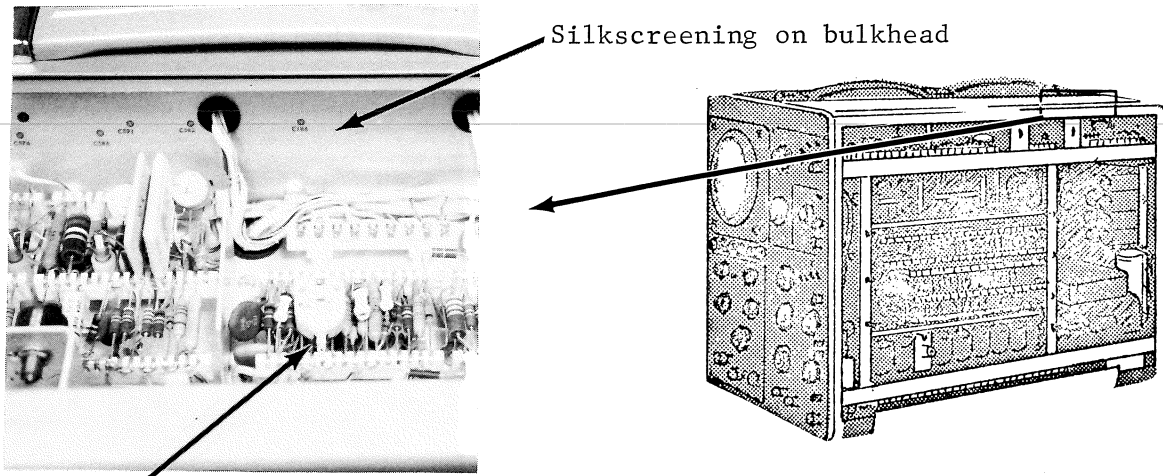


Figure 68

Adjust C186 for equal
INTENSITY on the
first marker of both
sweeps.

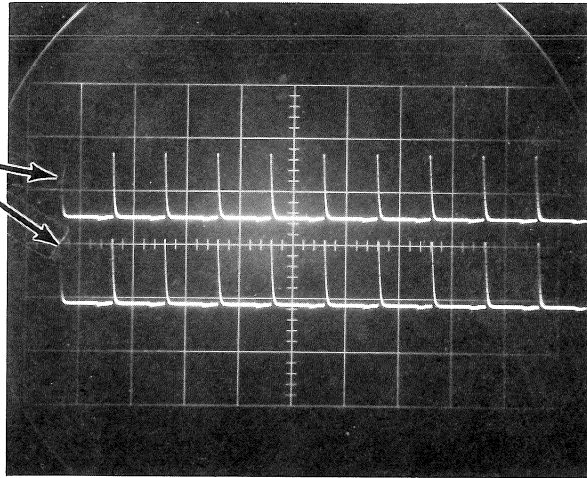


Figure 69

SECTION VI

I. DELAY PICK-OFF

Preset the front panel controls as follows:

HORIZONTAL DISPLAY	B INTENS BY A ALT A DLY'D
SWEEP MAGNIFIER	X1 (off)
A TIME/CM	0.1 msec
A TIME/CM VARIABLE	CALIBRATED
A TRIGGERING	
MODE	AUTO
SLOPE	+
COUPLING	AC
SOURCE	INT-NORM
B TIME/CM	1 msec
B TIME/CM VARIABLE	CALIBRATED
B TRIGGERING	
MODE	TRIG
SLOPE	+
COUPLING	AC
SOURCE	INT-NORM

A. DELAY START-STOP

1. Apply 1 msec markers from the 180 and obtain a stable display. Adjust the BRIGHTNESS and INTENSITY controls for an easily discernible delayed sweep and intensified portion. (See Fig. 70)

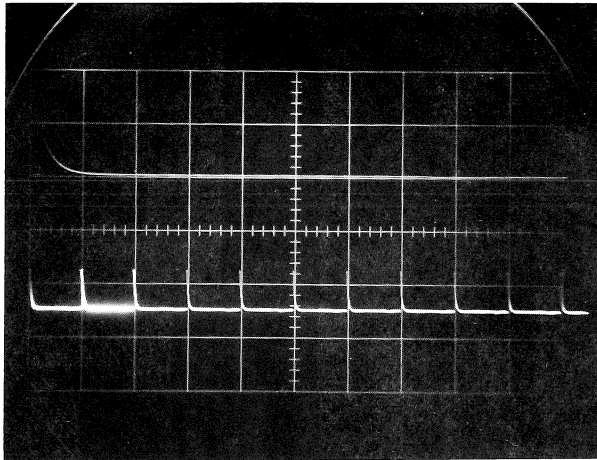


Figure 70

2. Set the DELAY TIME MULTIPLIER to 1.00 and adjust the DELAY START adjustment (R418 - see Fig. 71) so the intensified zone starts on the 2nd marker and the delayed sweep starts on the top point of its marker. (See Fig. 72)

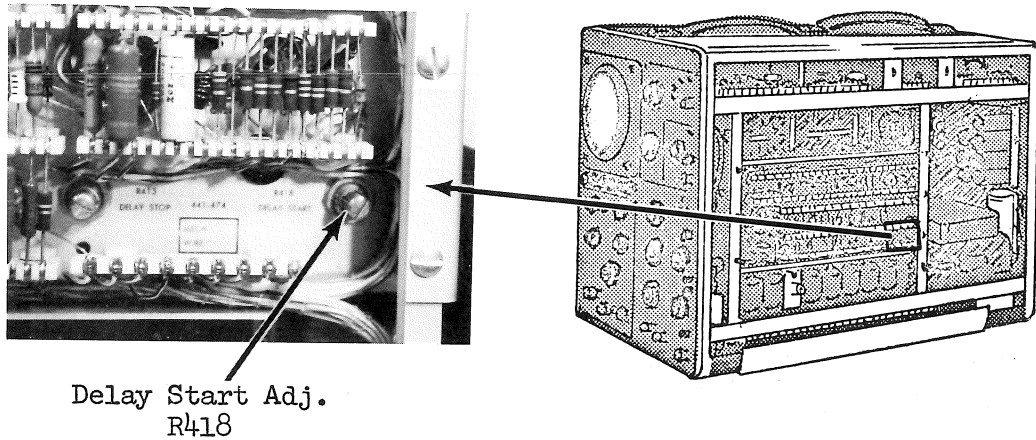
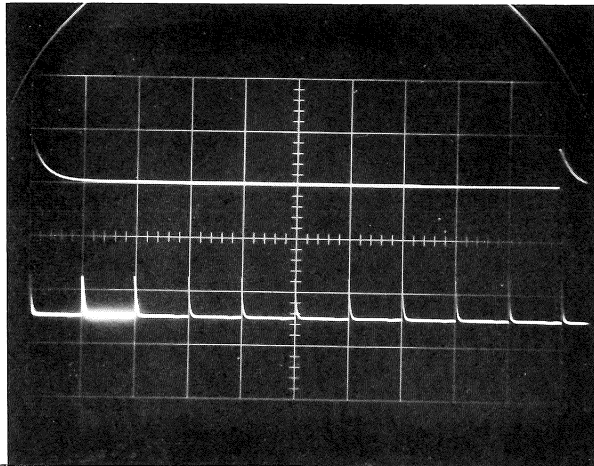


Figure 71



Adj. R418 so the
Delayed Sweep starts
on the top point of
its marker.

The start of the delayed sweep corresponds to
the start of the intensified portion.

Figure 72

3. Set the DELAY TIME MULTIPLIER to 9.00 and adjust the DELAY STOP adjustment (R415 - see Fig. 73) so the intensified zone starts on the 10th marker and the delayed sweep starts on the top point of its marker. (See Fig. 74)

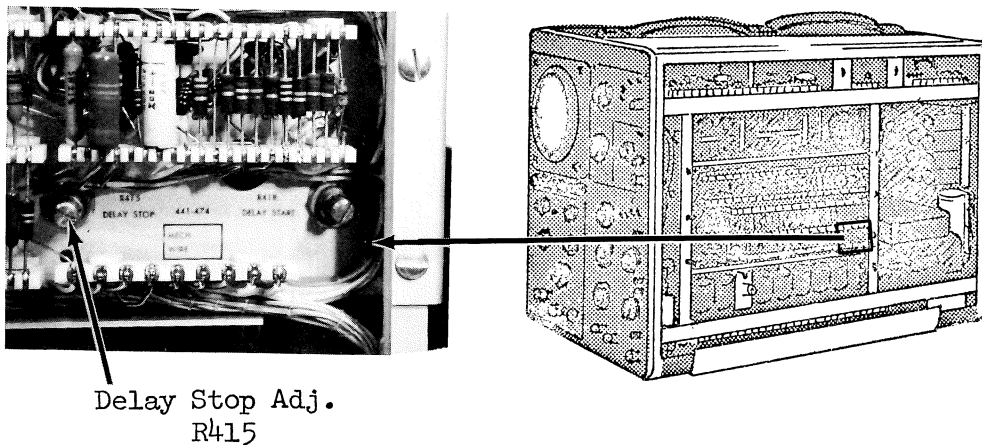
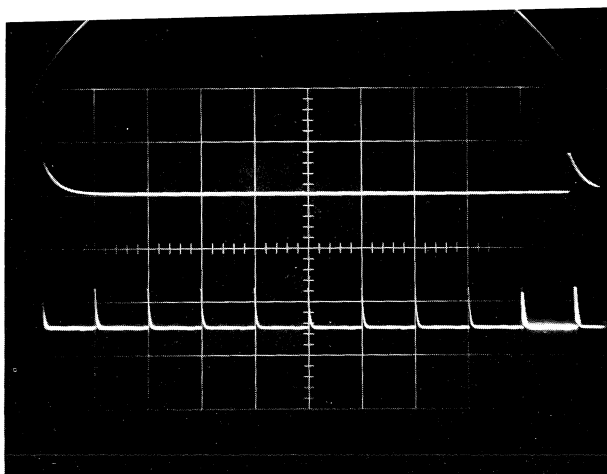


Figure 73



Adj. R415 so the Delayed Sweep starts on the top point of its marker.

The second marker on the Delayed Sweep corresponds to the marker immediately following the start of the intensified portion.

Figure 74

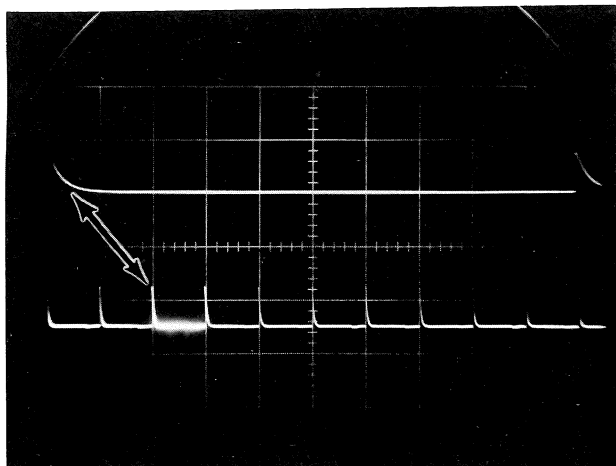
B. INCREMENTAL ACCURACY

1. Adjust the DELAY TIME MULTIPLIER so the intensified zone starts on the 3rd marker and the delayed sweep starts on the rising portion of its marker.

2. Note helidial error:

EXAMPLE: Optimum reading 2.00
 Actual reading 1.99
 Error 0.01 1 minor division
 Allowable error: 1.5 minor divisions max

3. Repeat steps 1 and 2 for all markers between the 2nd and 10th markers on the intensified sweep.



Start of the delayed sweep
and start of the intensified
zone correspond.

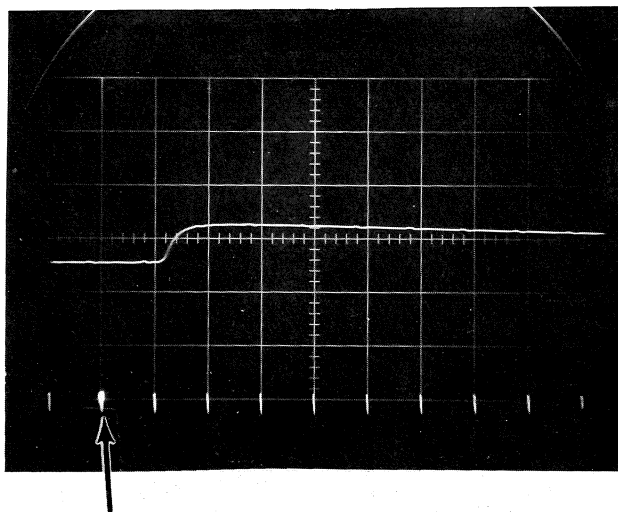
Delay Time Multiplier set so
the intensified zone starts
on the 3rd marker.

Error read on helidial indicates the amount
of non-linearity in the Delay Time Multiplier
pot (R416)

Figure 75

C. DELAY PICK-OFF JITTER

1. Set A TIME/CM to 1 μ sec.
2. Set the DELAY TIME MULTIPLIER to 1.00 and check the horizontal jitter of the marker on the delayed sweep. 2.5mm max.
3. Set the DELAY TIME MULTIPLIER to 9.00 and check the horizontal jitter of the marker on the delayed sweep. 2.5mm max. (See Fig. 76)



Check for less than 2.5mm max jitter at 1.00 and 9.00.

Picture taken with the Delay Time Multiplier set at 1.00. Note intensified marker.

Figure 76

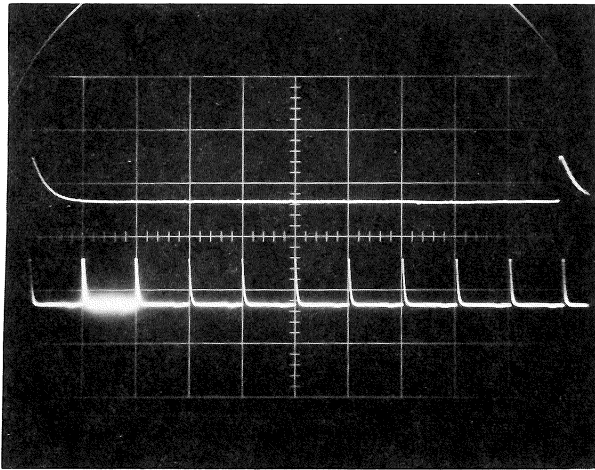
II B SWEEP SLOW SPEED TIMING

A. 0.1 msec TIMING

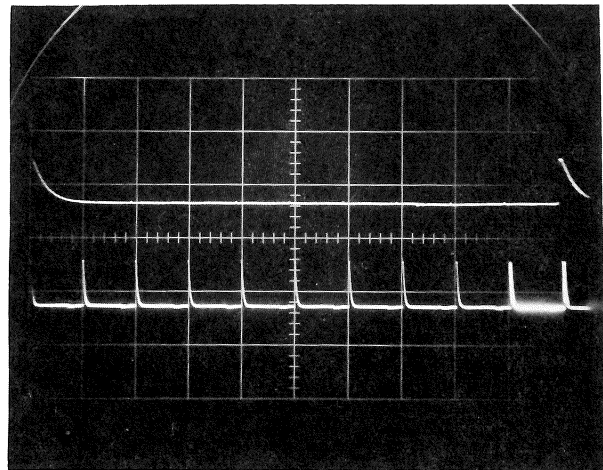
1. Set B TIME/CM to 0.1 msec and A TIME/CM to 10 μ sec. Apply 100 μ sec markers from the 180.
2. Set the DELAY TIME MULTIPLIER so the intensified zone starts on the 2nd marker and the delayed sweep starts on the top point of its marker. Note the helidial reading.
EXAMPLE: Optimum 1.00 Actual 1.01
3. Set the DELAY TIME MULTIPLIER so the intensified zone starts on the 10th marker and the delayed sweep starts on the top point of its marker. Note the helidial reading.
EXAMPLE: Optimum 9.00 Actual 9.05
4. Compute the 0.1 msec timing error using the helidial readings.
EXAMPLE:

Optimum	Actual
9.00	9.05
<u>1.00</u>	<u>1.01</u>
8.00 - No error.	8.04 - 4 minor divisions of error.

Allowable error: 6.4 minor divisions.



Intensified zone starts on 2nd marker and delayed sweep starts on the top point of its marker when heliodial reads 1.01.



Intensified zone starts on 10th marker and delayed sweep starts on the top point of its marker when heliodial reading is 9.05.

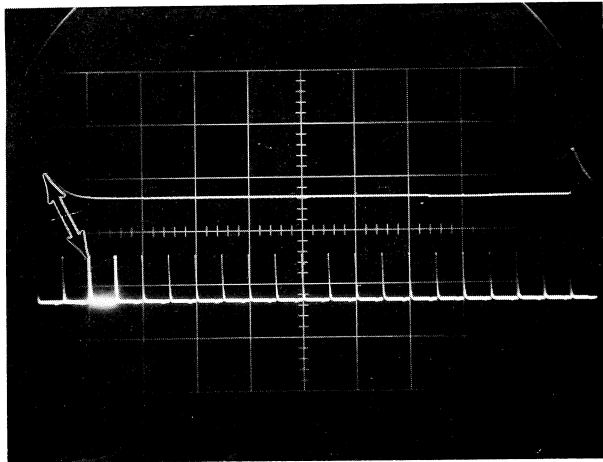
Figure 77

B. 0.2 msec to 5 sec TIMING.

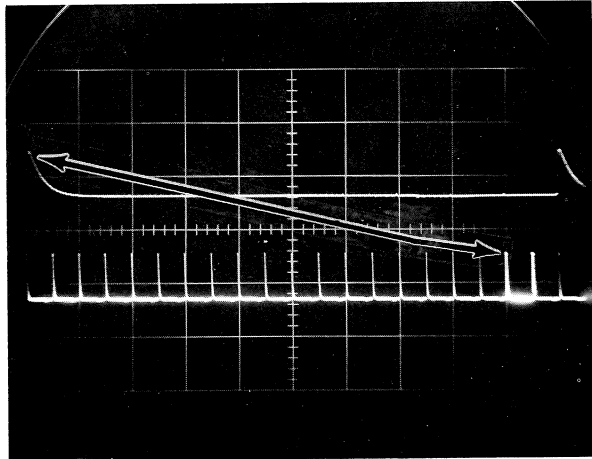
1. Check B sweep timing from 0.2 msec to 5 sec by repeating steps 2 through 4 in Part A with the chart given below.

B TIME/CM	A TIME/CM	180A SIGNAL	Max error, 1.00 to 9.00 (minor div)
0.1 msec	10 μsec	100 μsec	6.4
0.2 msec	10 μsec	100 μsec	6.4
0.5 msec	10 μsec	500 μsec	6.4
1 msec*	0.1 msec	1 msec	0.
2 msec	0.1 msec	1 msec	6.4
5 msec	0.1 msec	5 msec	6.4
10 msec	1 msec	10 msec	6.4
20 msec	1 msec	10 msec	6.4
50 msec	1 msec	50 msec	6.4
0.1 sec	10 msec	100 msec	6.4
0.2 sec	10 msec	100 msec	6.4
0.5 sec	10 msec	500 msec	6.4
1 sec	0.1 sec	1 sec	6.4
2 sec	0.1 sec	1 sec	6.4
5 sec	0.1 sec	5 sec	6.4

*Adjusted previously



Delay Time Multiplier set at 1.00



Delay Time Multiplier set at 9.00

Figure 78

Figure 78 illustrates 2 msec timing check. Intensified zones start on the 3rd and 19th markers. Timing is still checked from the 2nd to the 10th cm lines.

III. A SWEEP SLOW SPEED TIMING.

A. 0.1 msec TIMING.

1. Set HORIZONTAL DISPLAY to A and A TIME/CM 0.1 msec. Apply 100 μ sec markers from 180.
2. Align the 2nd marker with the 2nd graticule line. Check the alignment of the succeeding markers with the graticule lines. Max deviation from 2nd to 10th graticule lines: 0.8mm

B. 0.2 msec to 5 sec TIMING.

A TIME/CM	180 SIGNAL	Check for markers/cm
0.1 msec	100 μ sec	1
0.2 msec	100 μ sec	2
0.3 msec	500 msec	1
1 msec	1 msec	1
2 msec	1 msec	2
5 msec	5 msec	1

A TIME/CM	180 SIGNAL	Check for markers/cm
10 msec	10 msec	1
20 msec	10 msec	2
50 msec	50 msec	1
0.1 sec	100 msec	1
0.2 sec	100 msec	2
0.5 sec	500 msec	1
1 sec	1 sec	1
2 sec	1 sec	2
5 sec	5 sec	1

SECTION VII

1. B FAST SPEED TIMING

Preset the front panel controls as follows:

HORIZONTAL DISPLAY	B INTENS BY A ALT A DLY'D
SWEEP MAGNIFIER	X1 (off)
B TIME/CM	10 μ sec
B TIME/CM VARIABLE	CALIBRATED
B TRIGGERING	
MODE	TRIG
SLOPE	+
COUPLING	AC
SOURCE	INT-NORM
A TIME/CM	1 μ sec
A TIME/CM VARIABLE	CALIBRATED
A TRIGGERING	
MODE	AUTO
SLOPE	+
COUPLING	AC
SOURCE	INT-NORM

A. 10 μ sec TIMING

1. Apply 10 μ sec markers from 180 and obtain a stable display.
2. Coarse adjust
 - a. Adjust the 10 μ sec adjustment (C90C-see Fig.79) for 1 marker/cm on the intensified trace. (See Fig.80)

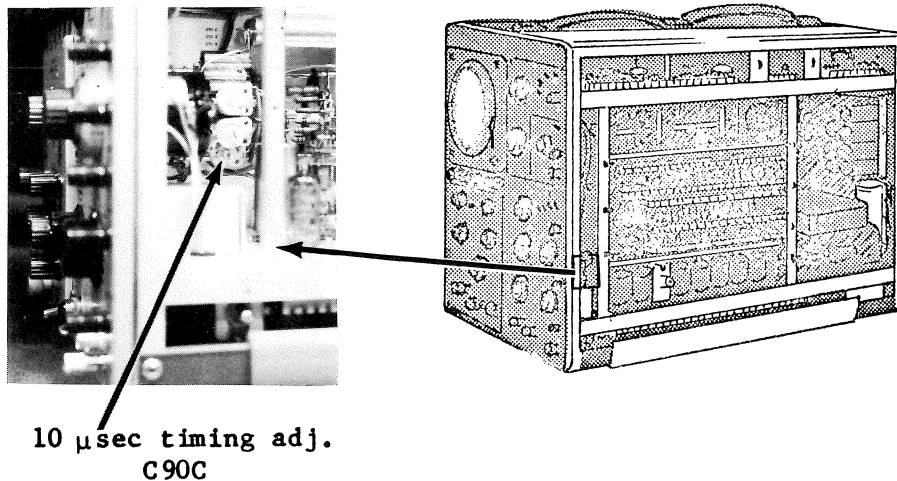
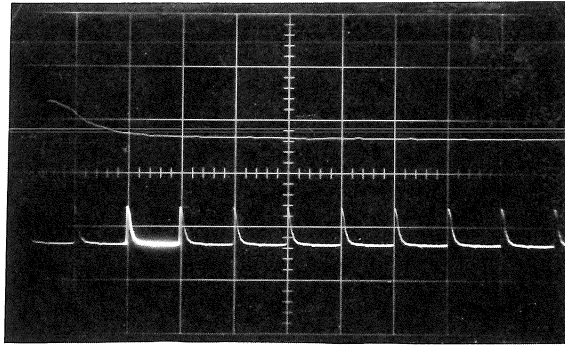


Figure 79



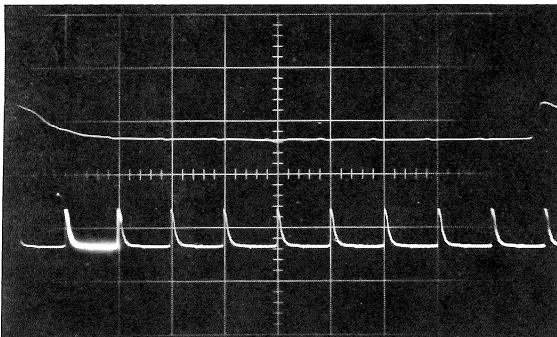
C90C adjusted
for 1 marker/cm

Coarse adjust 10 μ sec timing

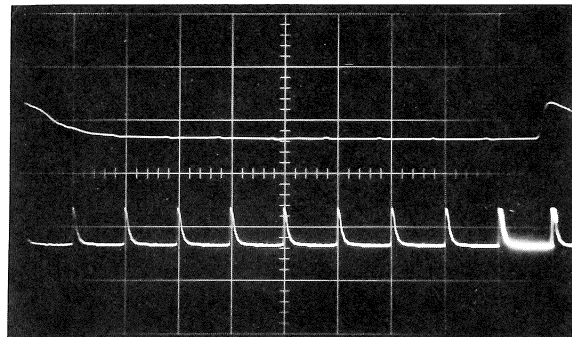
Figure 80

3. Fine adjust.

- a. Set the DELAY TIME MULTIPLIER so the intensified zone starts on the 2nd marker and the delayed sweep starts on the top point of its marker. Note helidial reading.
- b. Set the DELAY TIME MULTIPLIER to 8.00 + the helidial reading in "a". Adjust C90C so the intensified zone starts on the 10th marker and the delayed sweep starts on the top point of its marker.



Set the Delay Time Multiplier so the intensified zone starts on the second marker and the delayed sweep starts on the top point of its marker.



With the Delay Time Multiplier set at 8.00 + the reading in "a", adjust C90C.

Fine adjust 10 μ sec timing.

Figure 81

- c. The adjustment of C90C will probably change the reading obtained in "a". If the new reading is other than obtained in "a", repeat "b". Continue to repeat "a" and "b" until the difference in reading is 8.00 ± 6.4 minor divisions.

NOTE: The 10 μ sec timing adjustment also sets the 20 and 50 μ sec timing. All three timing ranges must be within ± 6.4 minor divisions.

4. Check 20 μ sec timing.

5. Check 50 μ sec timing.

B. 1 μ sec TIMING COARSE ADJUST.

1. Set B TIME/CM to 1 μ sec and A TIME/CM to 0.1 μ sec. Apply 1 μ sec markers from 180.
2. Adjust the 1 μ sec timing adjustment (C90B - See Fig. 82) for 1 marker/cm on the intensified sweep. Since the 1 μ sec timing adjustment interacts with the 0.1 μ sec and the B sweep generator fast speed gain adjustment, these two adjustments will be accomplished before the fine adjustment of the 1 μ sec timing adjustment. (See Fig. 83)

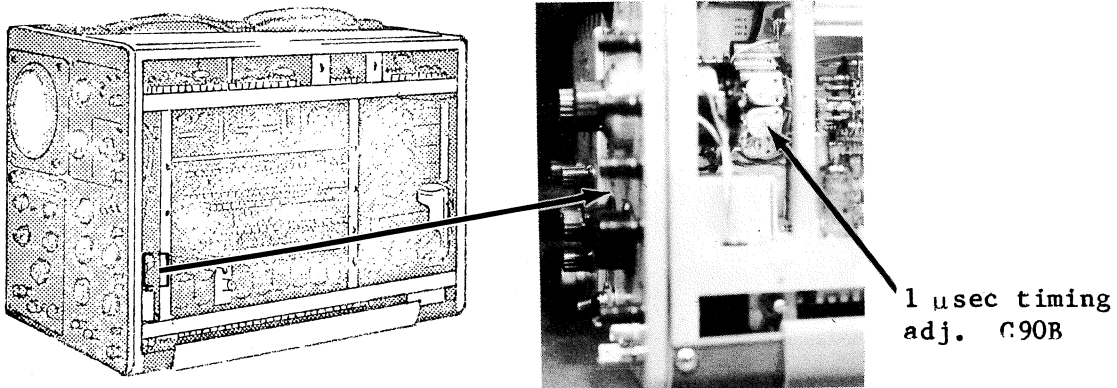
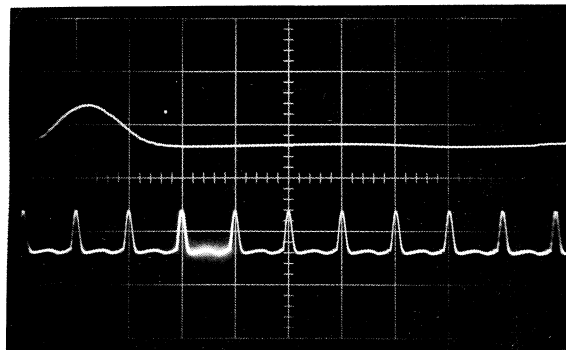


Figure 82



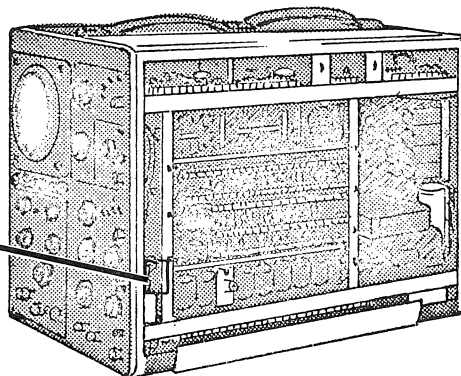
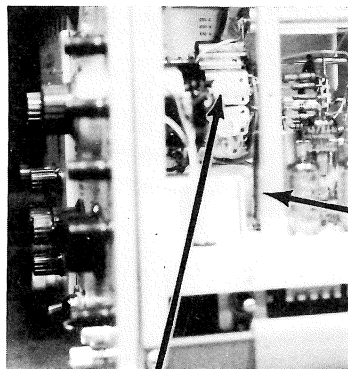
C90B adjusted for 1 marker/cm

Coarse adjust 1 μ sec timing

Figure 83

C. B SWEEP GENERATOR FAST SPEED GAIN ADJUSTMENT and 0.1 μ sec TIMING.

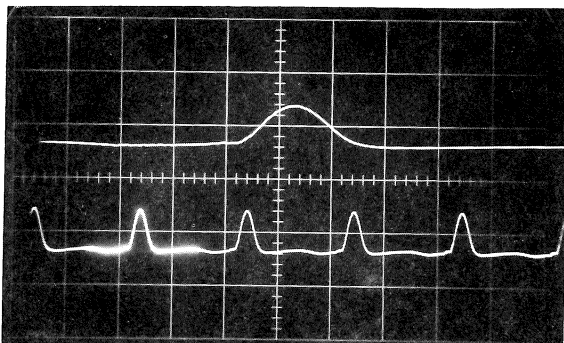
1. Set B TIME/CM to 0.5 μ sec and apply 1 μ sec markers from 180.
2. Adjust C90A for 1 marker/2cm on the intensified sweep. (See Figs. 84 and 85)



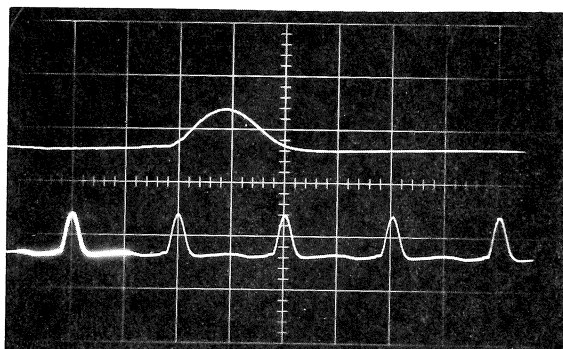
0.1 μ sec timing
adj. C90A

Figure 84

1 μ sec markers applied from 180



B TIME/CM set to 0.5 μ sec.
Ignore first marker on
B sweep.



Adjust C90A for 1 marker/2cm

Coarse adjust 0.1 μ sec timing.

Figure 85

3. Set B TIME/CM to 0.1 μ sec and apply 10 MC from 180.
4. Adjust the B sweep generator fast speed gain adjustment (C99 - See Fig. 86) for 1 cycle/cm. (See Fig. 87)

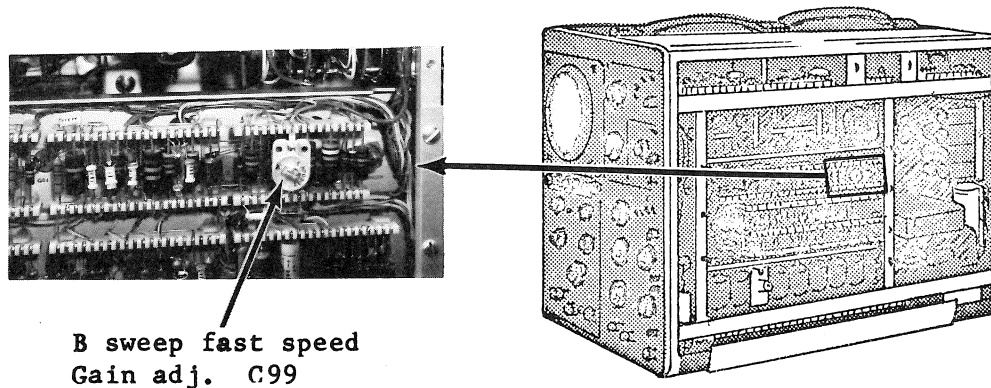
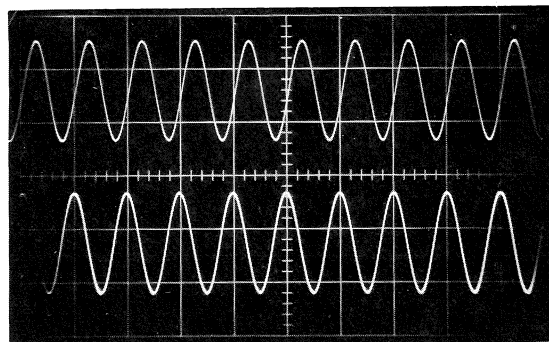


Figure 86



Adjust C99 for
1 cycle/cm on
B sweep.

B sweep fast speed Gain adj.

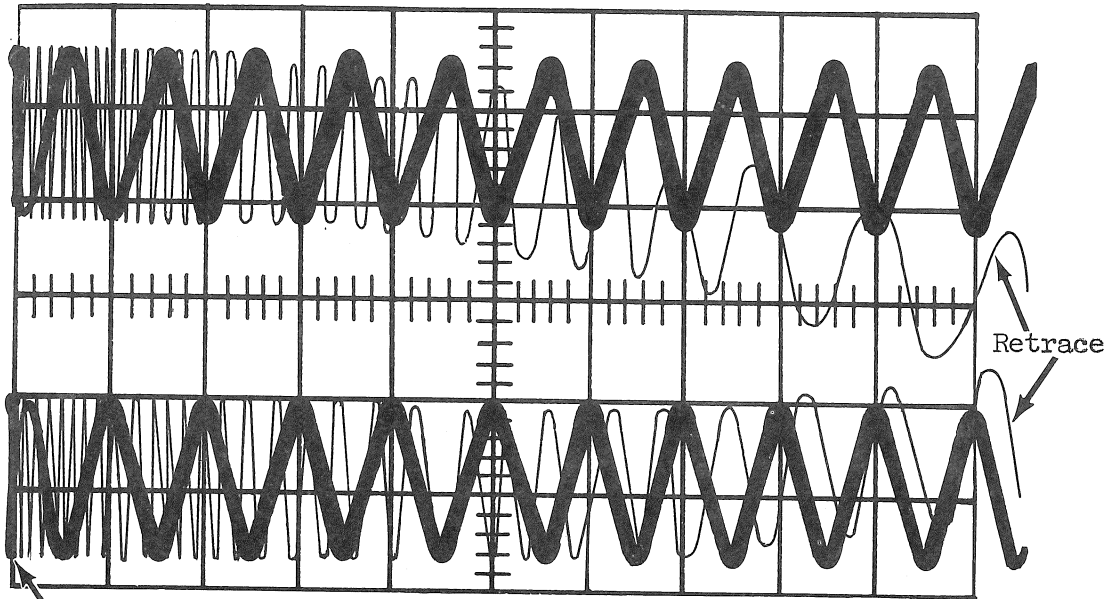
Figure 87

5. C90A and C99 interact. Repeat steps 2 and 4 until C90A and C99 are properly adjusted.

NOTE: Step 2 is the coarse adjustment for C90A and step 4 is the fine adjustment for C99. When C99 is properly adjusted, it will eliminate the interaction between the horizontal amplifier fast speed compensations and the fast speed timing adjustments.

6. Set A and B TIME/CM to 0.1 μ sec. Apply 10 MC from the 180. Set B trigger source to ext and apply a 10 μ sec trigger from the 180.

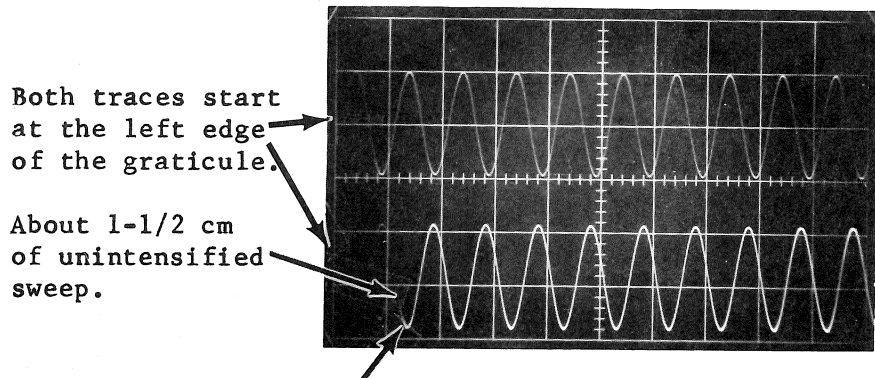
7. Set VARIABLE control for 2 cm of vertical deflection on each sweep.
8. Set the INTENSITY control cw until the start of each trace can be seen. Align the start of the sweeps with the left hand edge of the graticule. Return the INTENSITY control to a normal setting. (See Fig. 88)



The start of the sweep will appear as a vertical line.

Figure 88

9. Set the DELAY TIME MULTIPLIER to about 1.00. All of B sweep should be intensified except the first two (2) cycles. (See Fig. 89)



Both traces start at the left edge of the graticule.

About 1-1/2 cm of unintensified sweep.

First 2 cycles on B sweep are not intensified.

Figure 89

The first cycle is very non-linear. The portion of the sine wave displayed at the beginning of sweep, will depend on the setting of the B TRIGGERING LEVEL control. The first cycle is actually a part of a complete cycle. The unintensified area will equal approximately 1-1/2 cm.

10. Note the display at the intersection of the 2nd vertical cm line and the 3rd horizontal cm line counting from the top. A + (positive) going portion of a 10 MC sine wave on the delayed sweep should be approaching this intersection.

NOTE: The intersection of the 2nd vertical graticule line and the 3rd horizontal graticule line, is a reference point and for discussion purposes will be termed the intercept point.

(See Fig. 90)

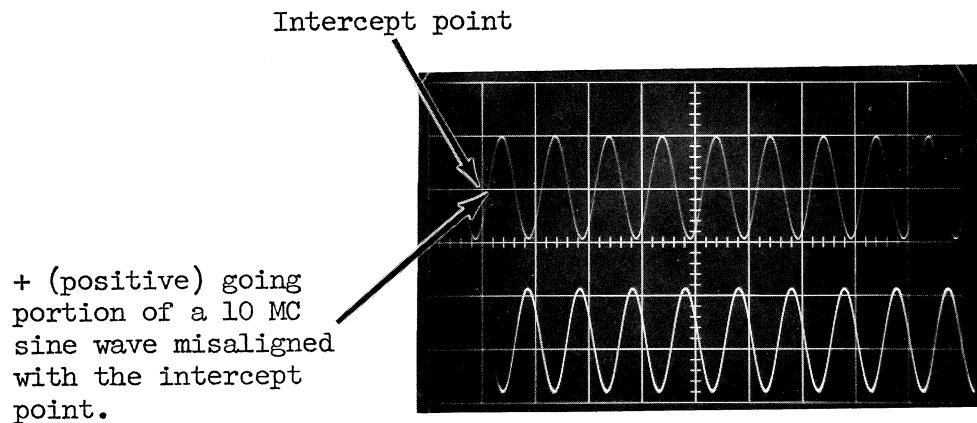


Figure 90

11. Set the DELAY TIME MULTIPLIER so the + (positive) going portion of a 10 MC sine wave on the delayed sweep, is aligned with the intercept point. Note the helical reading. (See Fig. 91) Example: 0.99

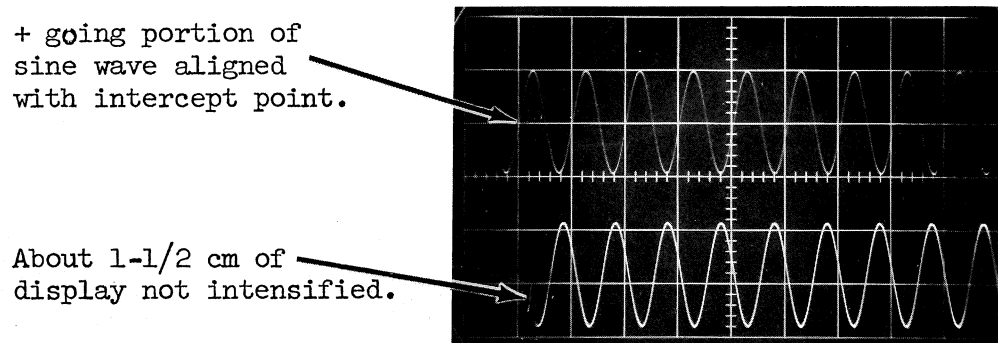


Figure 91

12. Set the DELAY TIME MULTIPLIER to 8.00 + the helidial reading in step 11. Adjust the 0.1 μ sec timing adjustment C90A so only the last cycle is intensified and a + (positive) going portion of the 10 MC sine wave on the delayed sweep is aligned with the intercept point. (See Fig. 92)

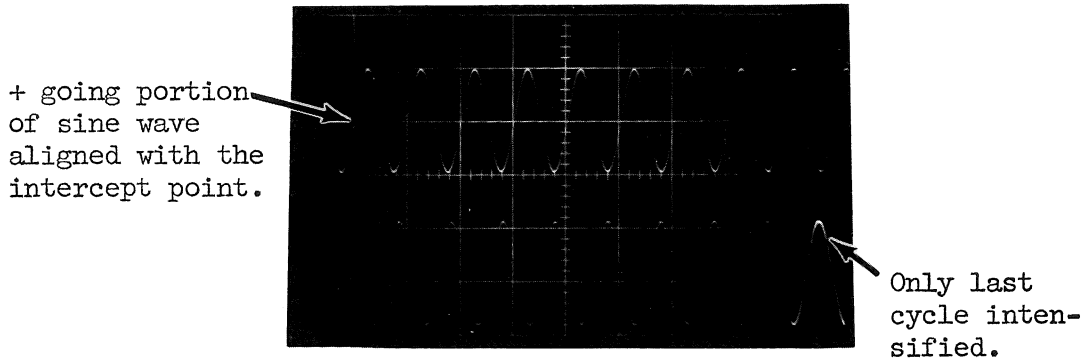


Figure 92

13. The adjustment of C90A may change the reading obtained in step 11. Repeat step 11. If the reading is other than obtained in step 11, repeat step 12. Continue to repeat steps 11 and 12 until there is no difference in the helidial readings. This condition will be achieved when the numerical difference is exactly 8.00.

D. B SWEEP FAST SPEED LINEARITY CHECK

1. Adjust the DELAY TIME MULTIPLIER so three (3) cycles are not intensified, and a + (positive) going portion of a 10 MC sine wave on the delayed sweep is aligned with the intercept point.

2. Note the helidial reading error.

EXAMPLE: Optimum reading 1.99

Actual reading 2.01

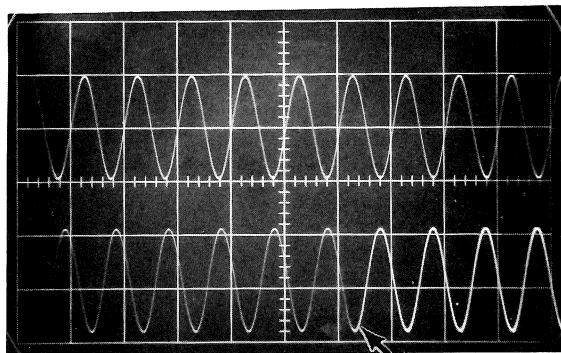
Error + 0.02 2 minor divisions

Allowable error: 4 minor divisions

3. Repeat steps 1 and 2 for each cycle between the 1st and 9th cycles on the intensified sweep.

Figure 93 shows seven cycles not intensified (about 6-1/2 cm). The helidial reading is 5.98 - an error of 0.01 or 1 minor division.

About 6-1/2 cm of display not intensified.

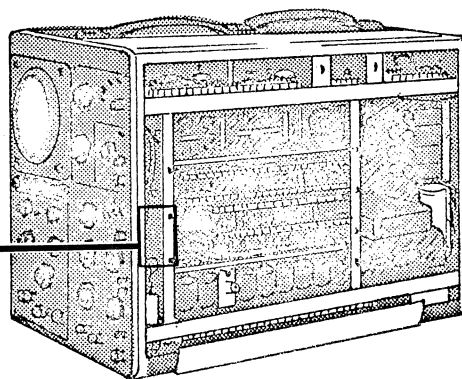
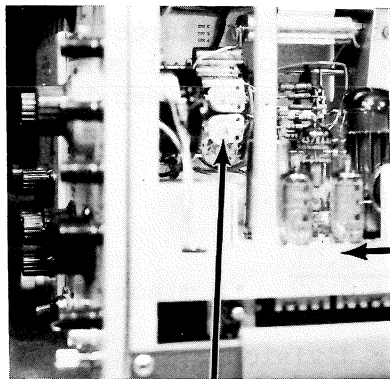


Start of intensified portion.

Figure 93

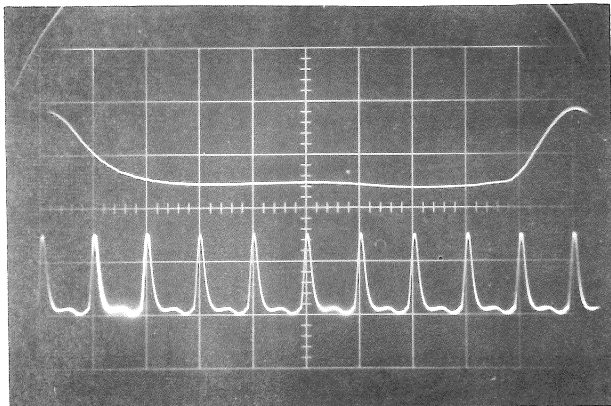
E. 1 μ sec TIMING FINE ADJUST.

1. Set B TIME/CM to 1 μ sec and apply 1 μ sec markers from the 180. Set B TRIGGERING SOURCE to INT-NORM.
2. Set the DELAY TIME MULTIPLIER so the intensified zone starts on the 2nd marker and the delayed sweep starts at the top point of its marker. Note the helidial reading.
3. Set the DELAY TIME MULTIPLIER to 8.00 + the helidial reading in step 2. Adjust the 1 μ sec. TIMING adjustment (C90B - See Fig. 94) so the intensified zone starts on the 10th marker and the delayed sweep starts on the top point of its marker. (See Fig. 95)

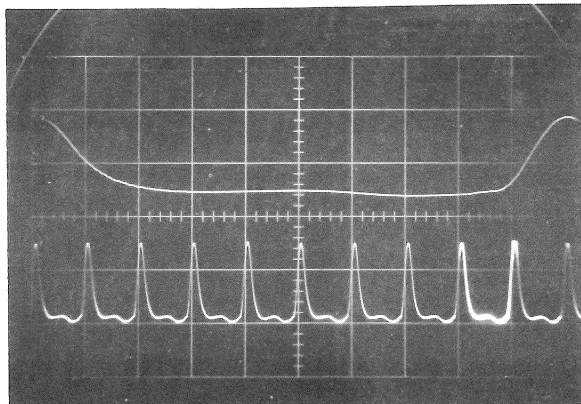


1 μ sec timing
adj. C90B

Figure 94



Set the Delay Time Multiplier so the intensified zone starts on the 2nd marker and the delayed sweep starts on the top point of its marker.



With the Delay Time Multiplier set at 8.00 + the reading in step 1, adjust C90B.

Fine adjust 1 μ sec timing

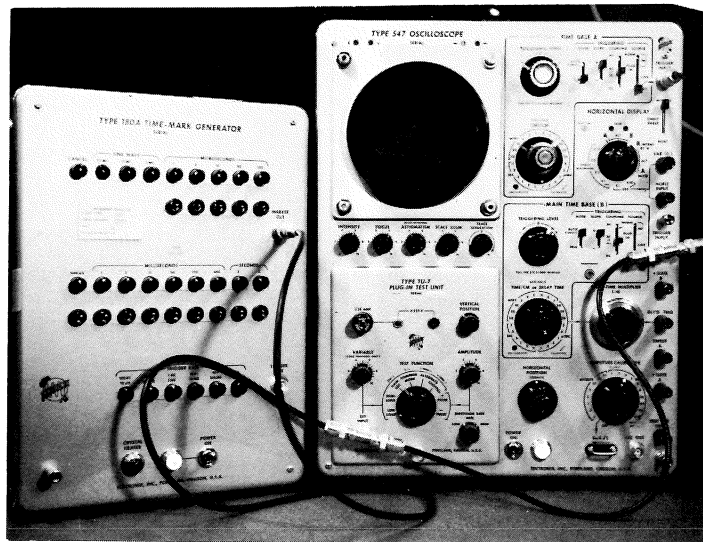
Figure 95

4. The adjustment of C90B will probably change the reading obtained in step 1. Repeat step 1. If the new reading is other than obtained in step 1, repeat step 2. Continue to repeat steps 1 and 2 until the difference in readings is 8.00 ± 6.4 minor divisions.
5. Check the 2 and 5 μ sec timing ranges.

II. HORIZONTAL AMPLIFIER AND SWEEP MAGNIFIER COMPENSATIONS.

A. HORIZONTAL AMPLIFIER and X10 SWEEP MAGNIFIER COMPENSATIONS

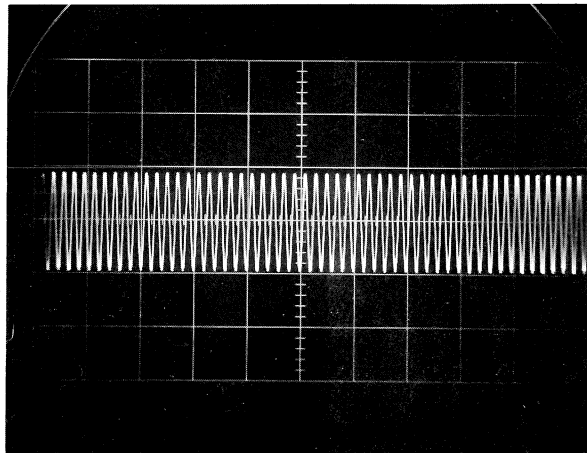
1. Set the HORIZONTAL DISPLAY to B and apply 50 MC from the 180.
2. Set B TRIGGERING SOURCE to EXT and apply 50 MC triggers. Obtain a stable display. (See Fig. 96)



A method of obtaining a 50 MC trigger signal.

Figure 96

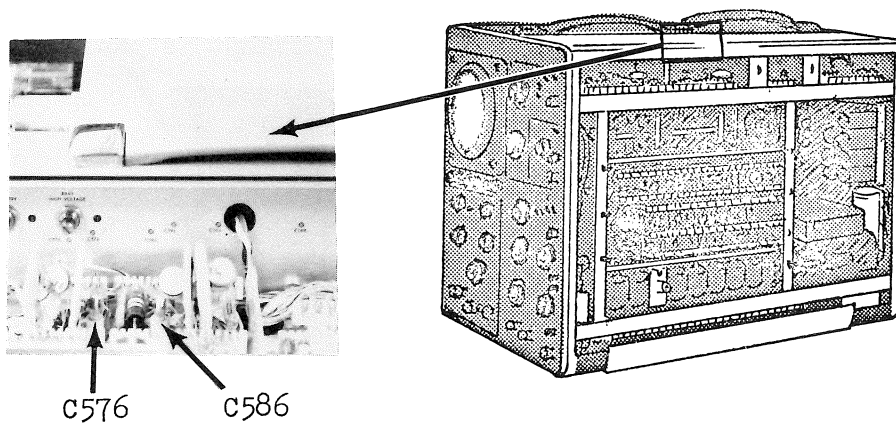
3. Position the start of the sweep to the left of the graticule (see Fig. 97) and then set the SWEEP MAGNIFIER to X10.



Start of trace positioned to left of side of graticule. Intensity is set for normal brilliance.

Figure 97

4. Preset C576 and C586 to 6 turns from maximum. (See Fig.98)



Preset about 6 turns
from max. (slugs all
the way in)

Figure 98

5. Adjust C572 and C582 (See Fig. 99) for maximum expansion of the display. (See Fig. 100)

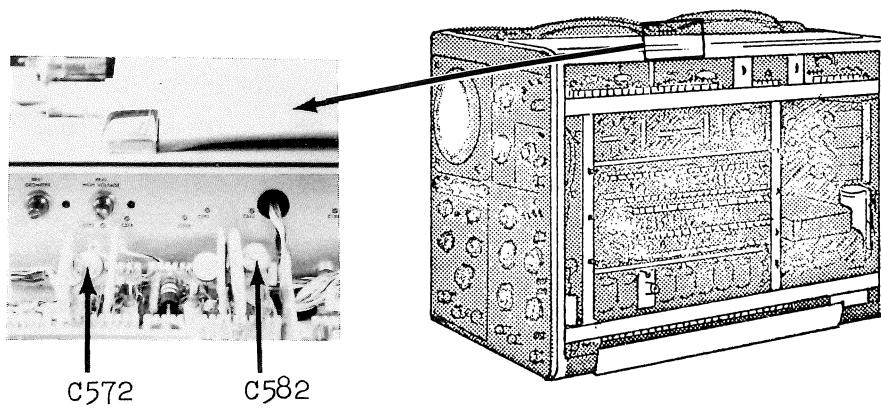
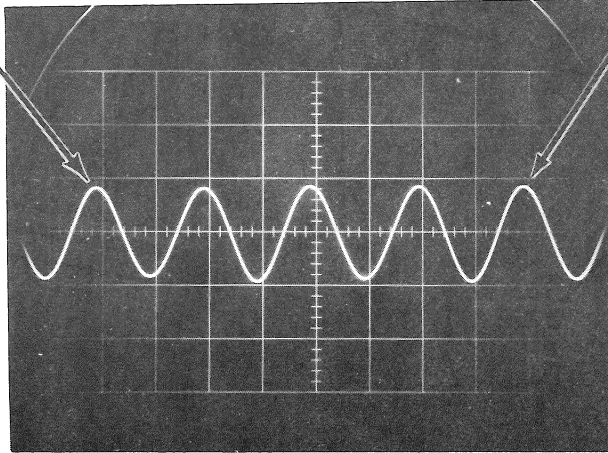


Figure 99

Remains stationary as point of proper adjustment is approached.

Will "jump in" (toward center) as point of proper adjustment is passed.



As each cap approaches the point of proper adjustment, the left side of the sweep remains still and the right side will expand slowly. Watch for right side of sweep to "jump in" just after the point of proper adjustment is passed.

Adjust C572 and C582 for max expansion.
Tweak caps slowly for best results.

Figure 100

6. Adjust C591 (see Fig. 101) for best linearity and max expansion. (See Fig. 102)

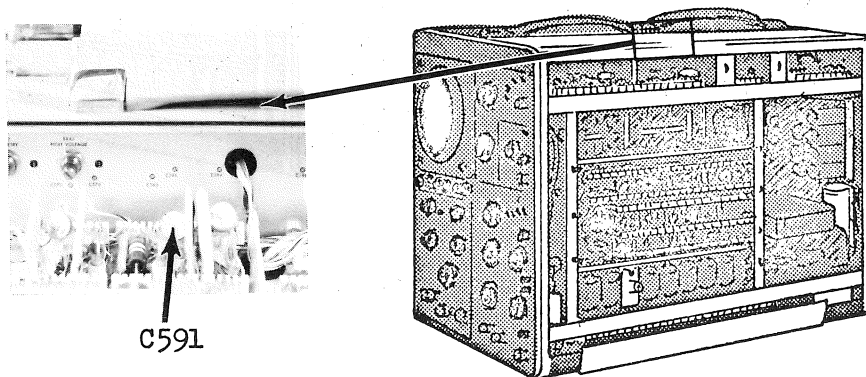


Figure 101

Watch for pronounced movement at both ends of the sweep.

Both ends of the sweep will "jump out" at the point of max expansion.

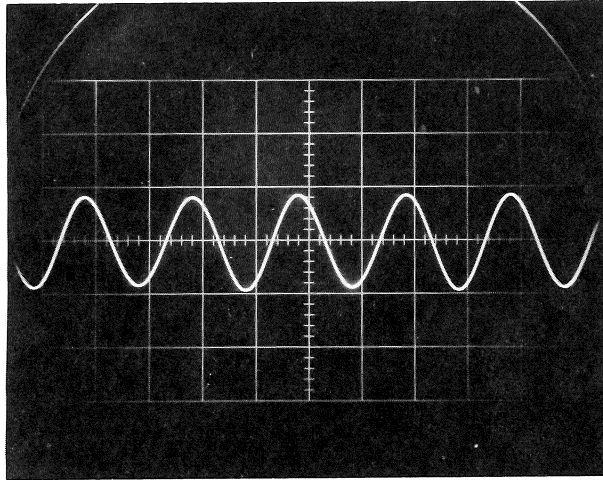


Figure 102

Adjust C591 for best linearity and max expansion. Since this cap will be readjusted later in the procedure, the best results are usually obtained by setting the cap for max expansion.

7. Position the start of the sweep to the left of the graticule. Set the INTENSITY cw until the start of the sweep can be seen. Position the 5th cycle to the 2nd graticule line. (See Fig. 103)

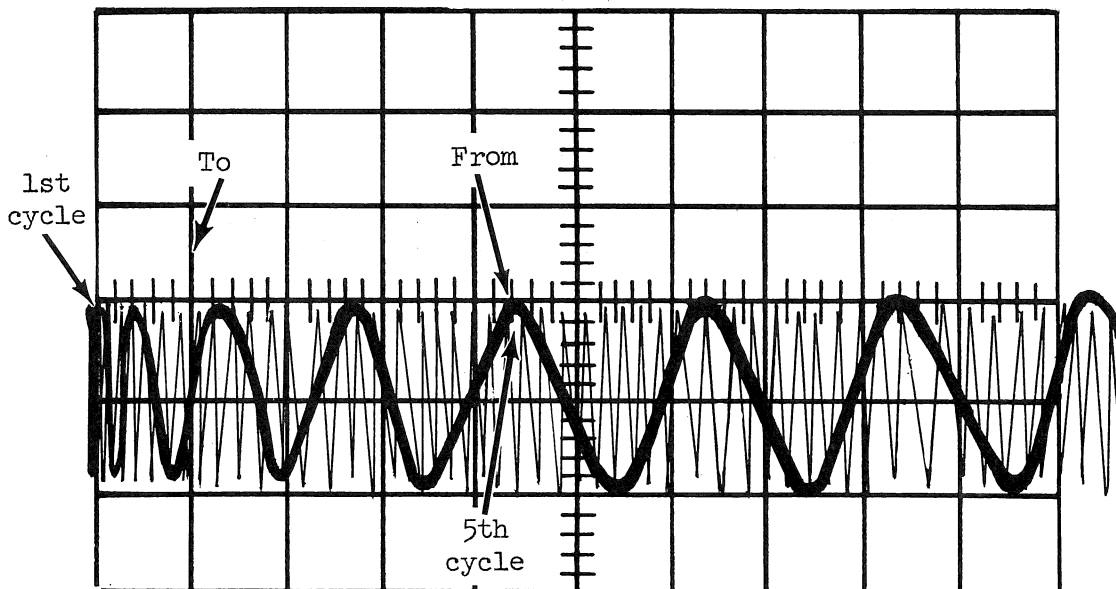


Figure 103

8. Adjust the X10 SWEEP MAGNIFIER compensator (C557H - see Fig. 104) for 1 cycle/2cm. (See Fig. 105)

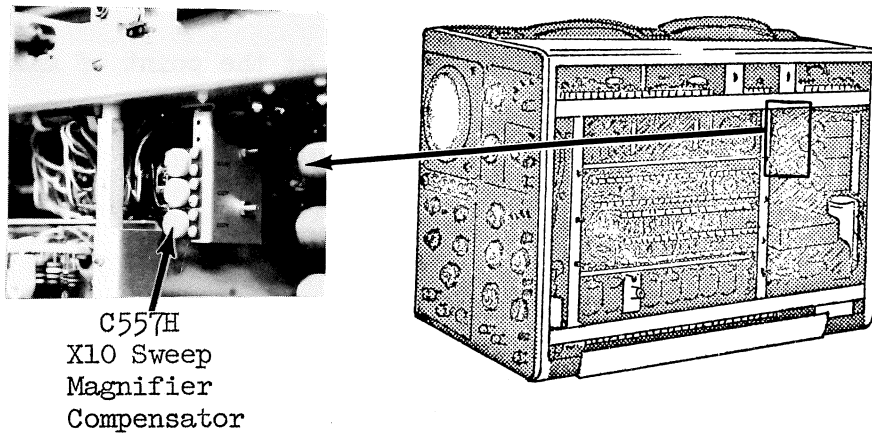


Figure 104

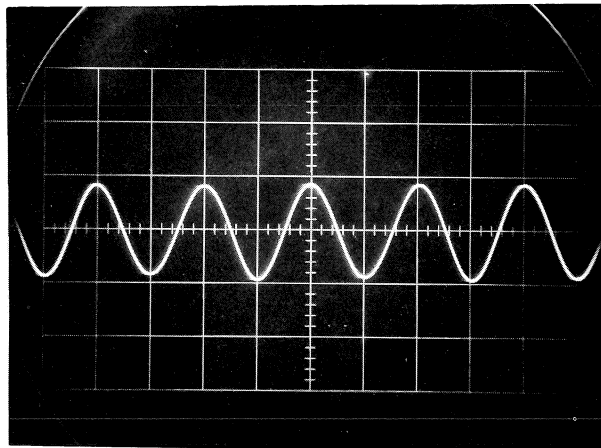
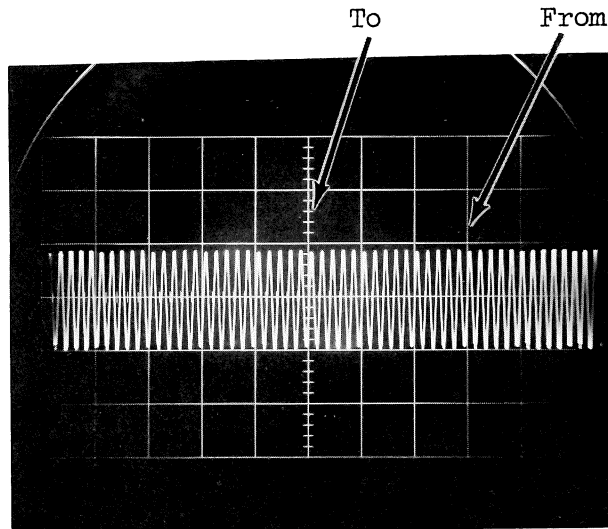


Figure 105

9. Readjust C591 for best linearity.
 - a. C591 and C557H interact. Repeat steps 8 and 9 until C591 and C557H are properly adjusted.
Allowable error: 3mm
10. Recheck the linearity and timing at the center of the sweep.
Allowable error: 3mm

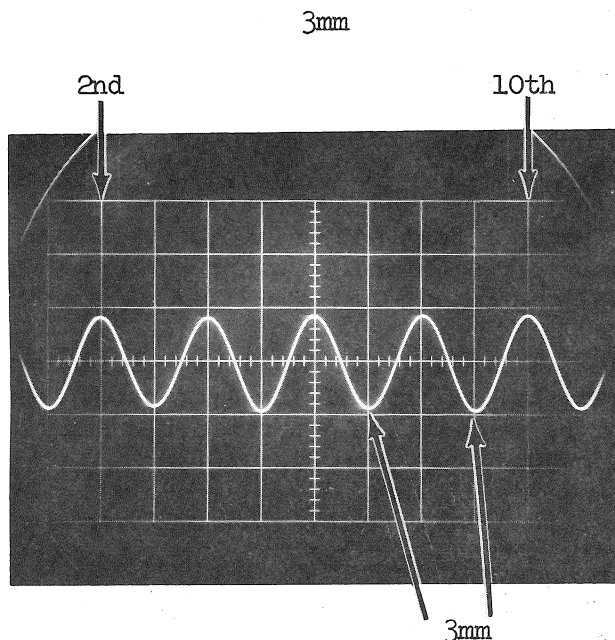
- a. A slight adjustment of C576 and C586 should bring the center within specs.
 - b. If C576 and C586 do not bring the center of the sweep within specs, readjust C572, C582, C591 and C557H. These adjustments interact and are very sensitive.
 - c. If step b does not bring the timing within specs, back off C576 and C586 a turn or two and readjust C572, C582, C591, and C557H.
11. Set the SWEEP MAGNIFIER to X1 and position the start of the sweep to the left of the graticule. Set the + (positive) peak at the 9th graticule line to the center of the graticule. (See Fig. 106)



Start of sweep positioned to the left of the graticule with the intensity at a normal setting.

Figure 106

12. Set the SWEEP MAGNIFIER to X10 and check timing and linearity.
- Allowable error: 3mm
- a. Adjust C591 slightly to bring timing within specs at the 80th cm.
13. Recheck timing at the start and at the center of the sweep.
- a. It may be necessary to readjust C591 and C557H to bring the timing within specs for the entire sweep.



The timing must be within 3mm from the 2nd to the 10th graticule lines.
The linearity from one cycle to the next cycle also must be within 3mm.

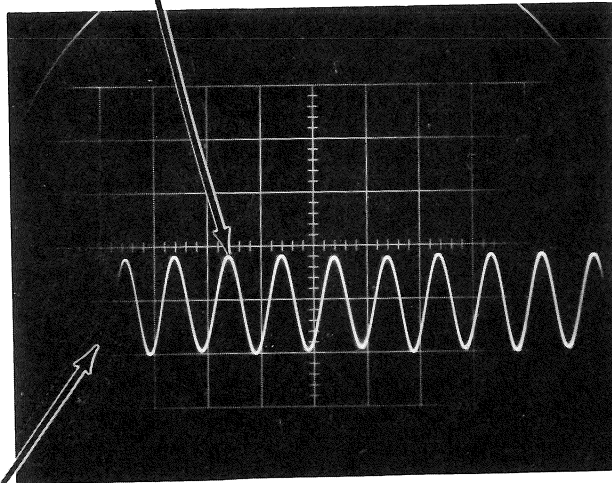
Figure 107 shows the timing and linearity of our particular scope anywhere between the 5th and the 90th cm of horizontal display. Many of the 547's will not "tune" this accurately from the 5th to the 90th cm. Factory specs state that the timing must be within 3mm from the 5th to the 90th cm. With any portion of the sweep displayed on the CRT, it must meet this spec between the 2nd and 10th graticule lines. To obtain a more accurate reading of the vertical risetime, it is recommended that the timing at the 5th cm be set to within 1mm.

Figure 107

B. X5 SWEEP MAGNIFIER COMPENSATION

1. Set the SWEEP MAGNIFIER to X5.
2. With the display intensity at a normal setting, position the 3rd cycle to the 2nd graticule line. (See Fig. 108)

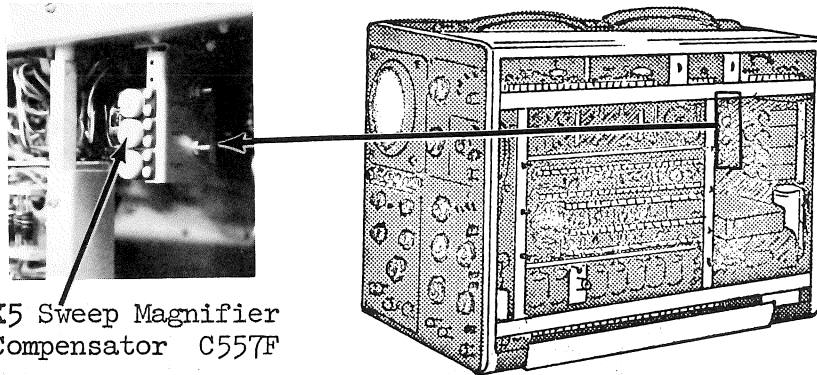
Position the 3rd cycle to the 2nd graticule line.



Start of sweep at a normal intensity setting.

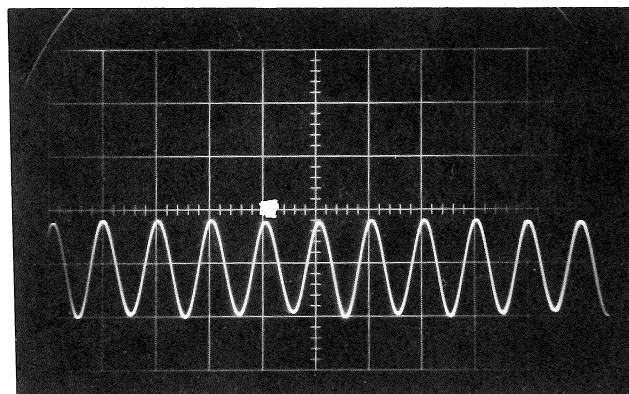
Figure 108

3. Adjust the X5 SWEEP MAGNIFIER compensator (C557F - see Fig. 109) for 1 cycle/cm. (See Fig. 110)



X5 Sweep Magnifier
Compensator C557F

Figure 109

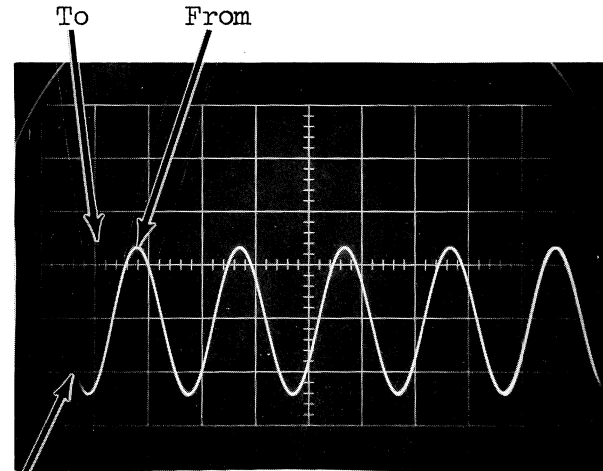


Adjust C557F for 1 cycle/cm

Figure 110

C. X2 SWEEP MAGNIFIER COMPENSATION

1. Set the SWEEP MAGNIFIER to X2 and apply 10 MC from the 180. Apply 10 μ sec triggers from the 180 and obtain a stable display.
2. With the display intensity at a normal setting and B TRIGGERING SLOPE set to +, position the first + (positive) peak to the 2nd graticule line. (See Fig. 111)

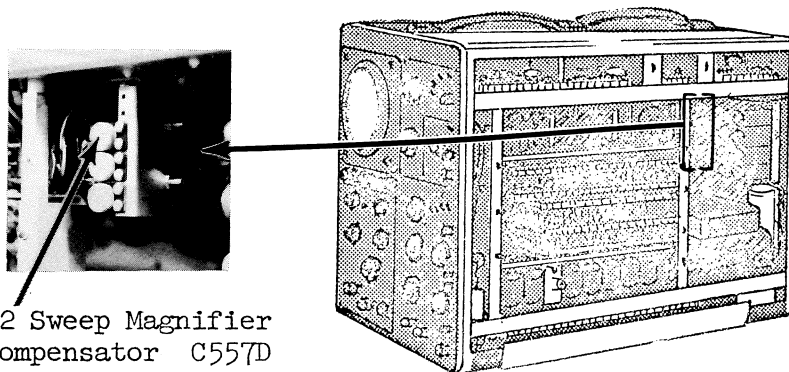


Start of sweep at a normal intensity setting.

Figure 111

3. Adjust the X2 SWEEP MAGNIFIER compensator (C557D - see Fig. 112) for 1 cycle/2cm. (See Fig. 113)

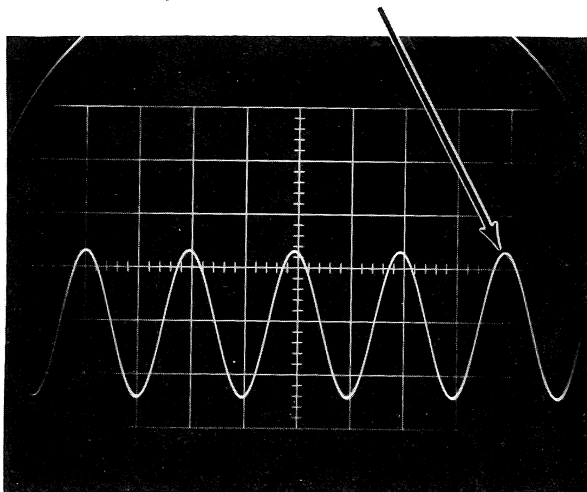
Allowable error: 3mm



X2 Sweep Magnifier
Compensator C557D

Figure 112

The 5th cycle is about 1mm short of the 10th cm line. C557D in our scope did not have sufficient range to set the timing right on, but it is still within specs (3mm).



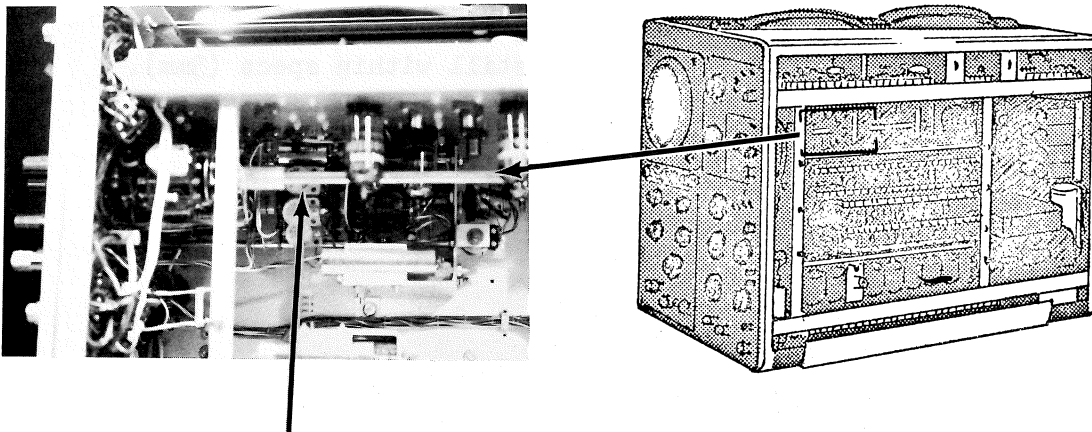
Adjust C557D for 1 cycle/2cm

Figure 113

III. A SWEEP FAST SPEED TIMING

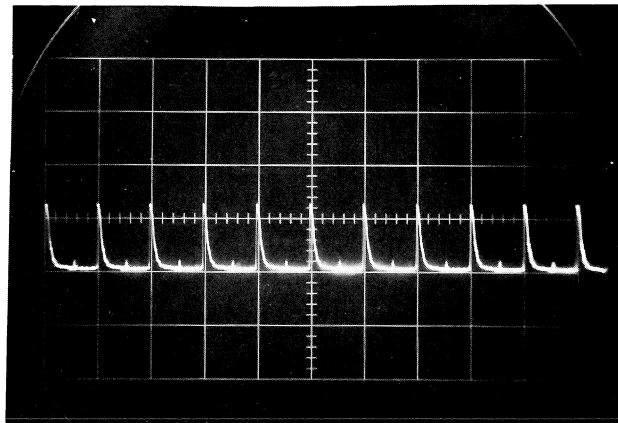
A. 10, 20, and 50 μ sec TIMING.

1. Set the HORIZONTAL DISPLAY to A and apply 10 μ sec markers from the 180.
2. Set A TRIGGERING SLOPE to + and SOURCE to INT-NORM.
3. Adjust the 10 μ sec timing adjustment (C290C - see Fig. 114) for 1 marker/cm. (See Fig. 115)



10 μ sec timing adjustment C290C - behind Horizontal Display switch shaft. (Picture taken with B Sweep deck open.)

Figure 114



Adjust C290C for 1 cycle/cm

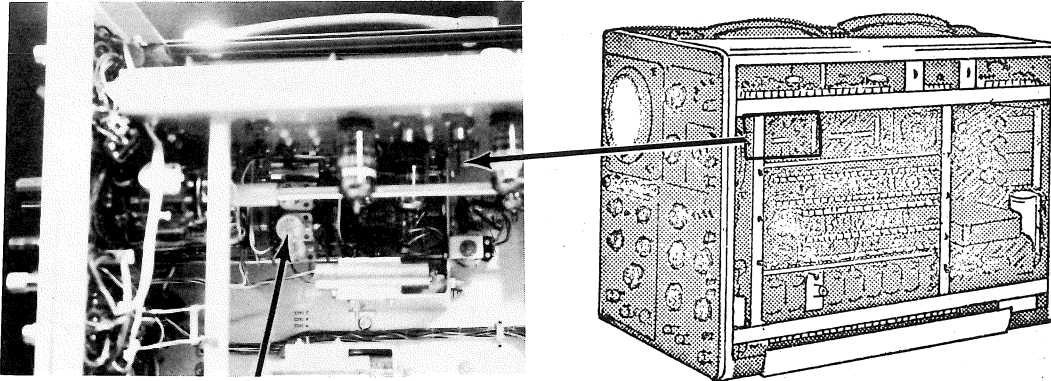
Figure 115

4. Check the 20 and 50 μ sec ranges.

Allowable error: 1mm

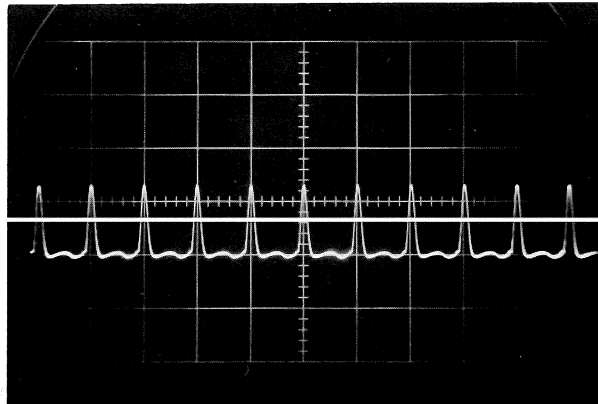
B. 1 μ sec TIMING COARSE ADJUST

1. Set A TIME/CM to 1 μ sec and apply 1 μ sec markers from the 180.
2. Adjust the 1 μ sec TIMING adjustment (C90B - see Fig. 116) for 1 marker/cm. (See Fig. 117)



1 μ sec timing adj. C290B.
(Picture taken with B Sweep
deck open.)

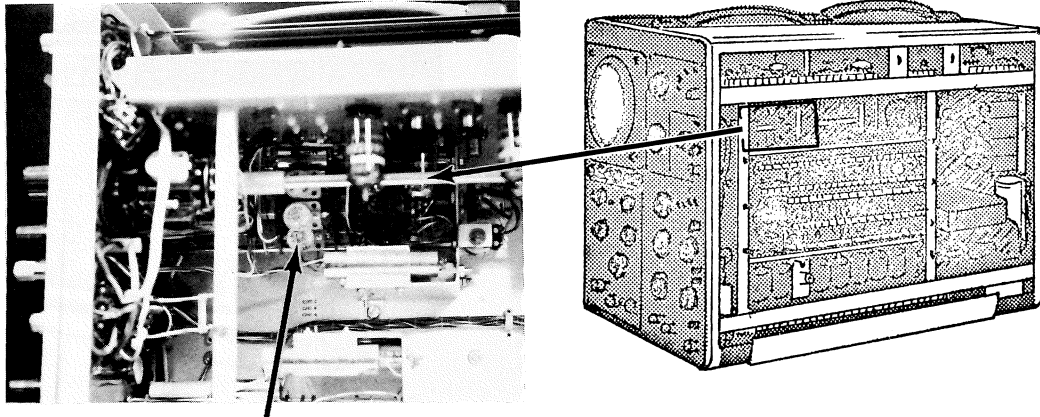
Figure 116



Adjust C290B for 1 marker/cm

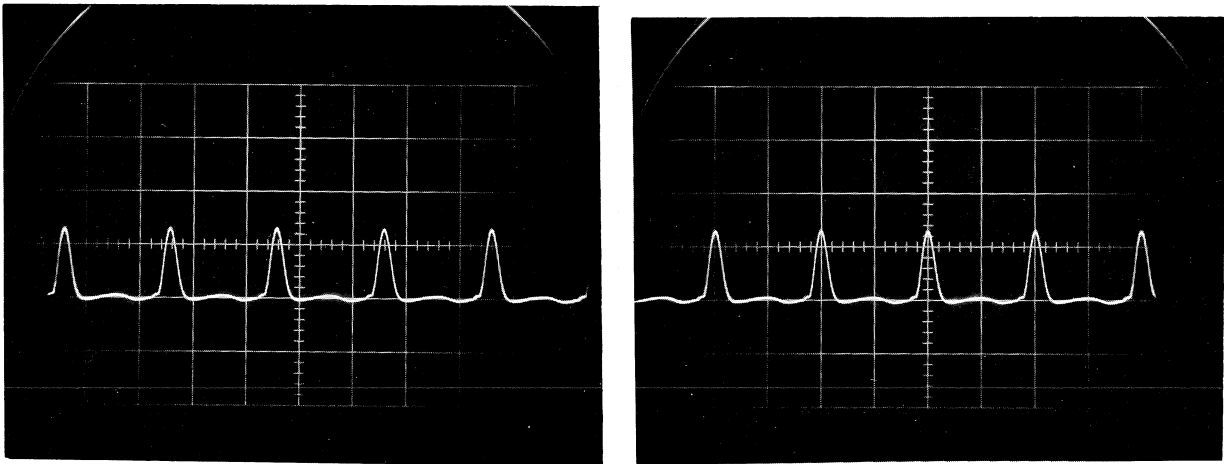
Figure 117

- C. 0.1, 0.2, and 0.5 μ sec TIMING and A SWEEP FAST SPEED GAIN ADJUSTMENT.
1. Set A TIME/CM to 0.5 μ sec and apply 1 μ sec markers from the 180.
 2. Adjust the 0.1 μ sec TIMING adjustment (C290A - see Fig. 118) for 1 marker/2cm. (See Fig. 119)



0.1 μ sec timing adj. C290A
(Picture taken with B Sweep
deck open.)

Figure 118



Ignore the first marker

Adjust C290A for 1 marker/2cm

Figure 119

3. Set A TIME/CM to 0.1 μ sec and apply 10 MC from the 180.
4. Adjust A SWEEP FAST SPEED GAIN adjustment (C299 - see Fig. 120) for 1 cycle/cm. (See Fig. 121)

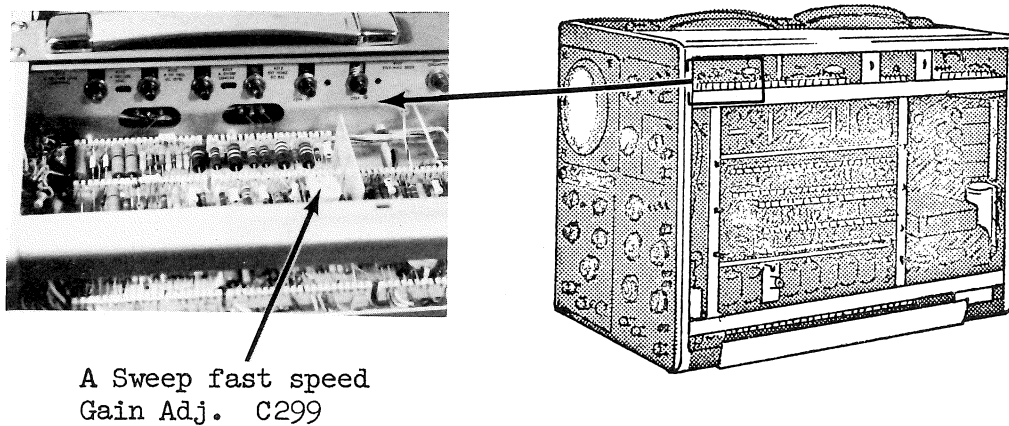
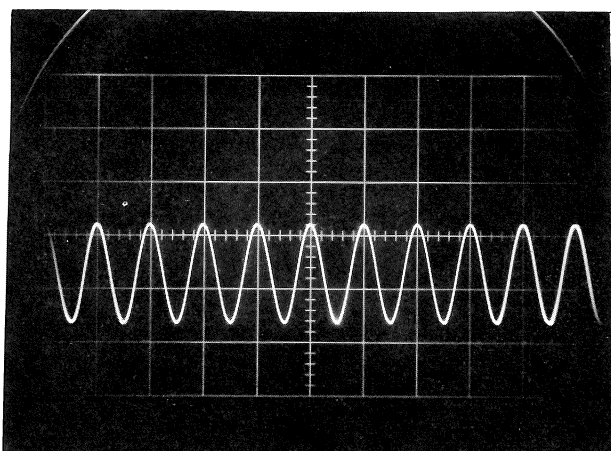


Figure 120

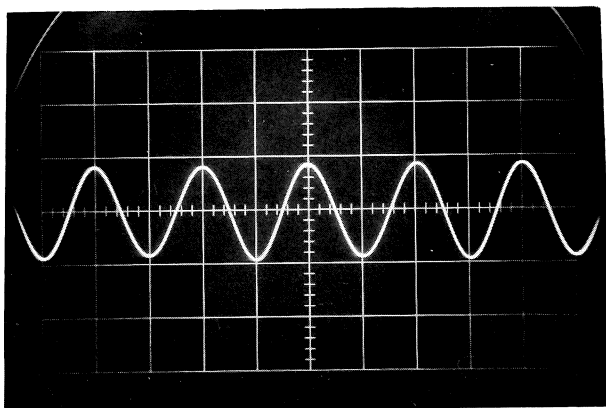


Adjust C299 for 1 cycle/cm

Figure 121

5. C290A and C299 interact. Repeat steps 2 and 4 until C290A and C299 are properly adjusted.
6. Apply 50 MC from the 180.
7. Set A TRIGGERING SOURCE to EXT and obtain a stable display.
8. Set the SWEEP MAGNIFIER to X10 and check timing and linearity.

Allowable error: 3mm



50 MC displayed on A Sweep

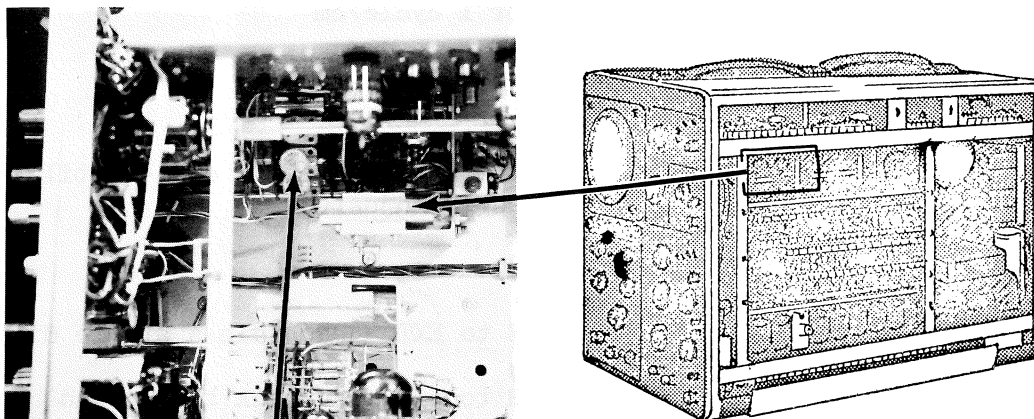
Figure 122

9. Set the SWEEP MAGNIFIER to X1 and apply 10 MC from the 180.
10. Set A TIME/CM to 2 μ sec and check for 2 cycle/cm.

Allowable error: 1mm

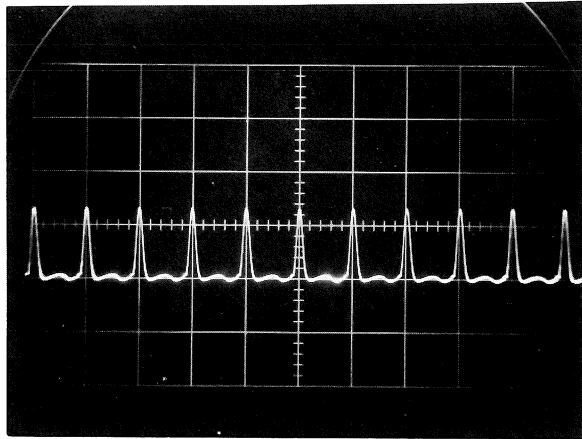
D. 1, 2, and 5 μ sec TIMING.

1. Set A TIME/CM to 1 μ sec and apply 1 μ sec markers from the 180.
2. Adjust, if necessary, the 1 μ sec TIMING adjustment (C290B - see Fig. 123) for 1 marker/cm. (See Fig. 124)



1 μ sec timing adj. C290B

Figure 123



Adjust C290B for 1 marker/cm

Figure 124

3. Check the 2 and 5 μ sec timing ranges.

Allowable error: 1mm

SECTION VIII

I. EXTERNAL HORIZONTAL AMPLIFIER

A. EXTERNAL HORIZONTAL AMPLIFIER DC BALANCE

1. Connect the CAL OUT jack to the HORIZ INPUT (located about in the center of the right side of the scope). Set the AMPLITUDE CALIBRATOR to 0.5v.
2. Set the HORIZONTAL DISPLAY to EXT. X1. (See Fig. 125)

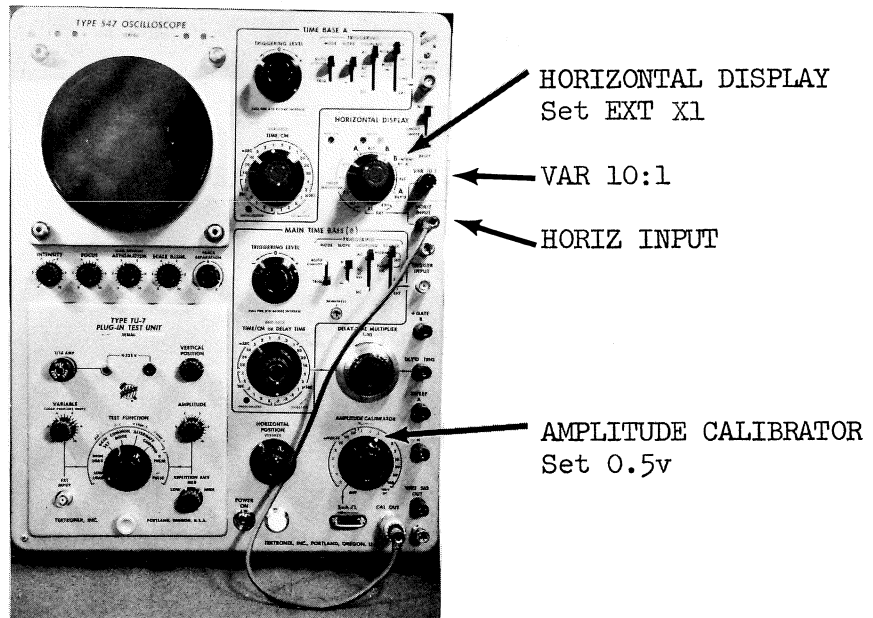
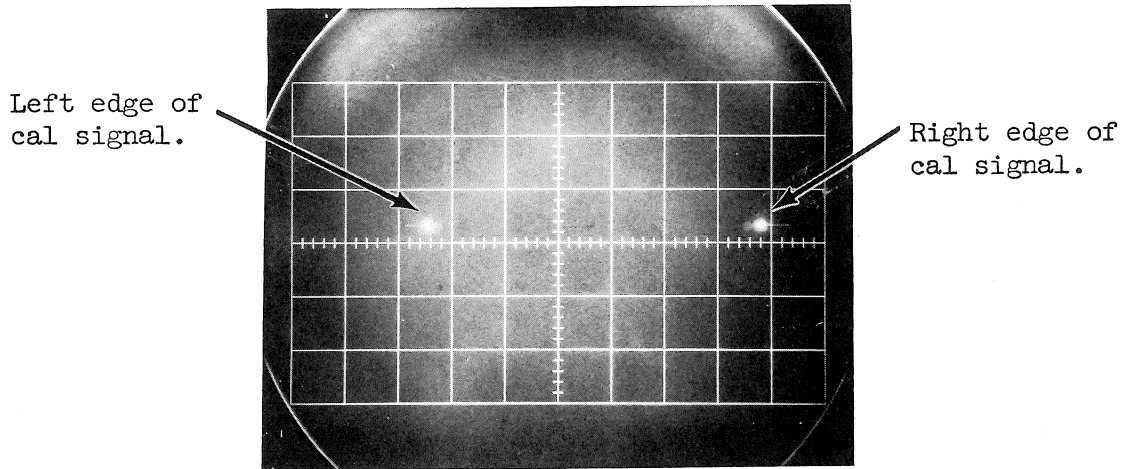


Figure 125

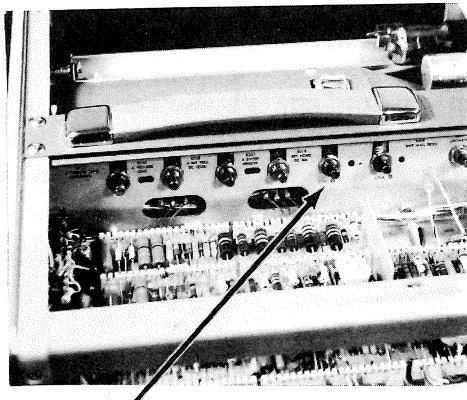
3. With the HORIZONTAL POSITION control, position the left edge of the cal signal to the left side of the graticule. (See Fig. 126)



Left edge of cal signal set to the left side of the graticule.

Figure 126

4. While rotating the VAR 10:1 (located directly above the HORIZ INPUT) from cw to ccw, adjust the EXT HORIZ DC BAL adjustment (R519 - see Fig. 127) for no shift of the left edge of the cal signal. (See Fig. 128)



EXT HORIZ DC BAL
Adj. R519

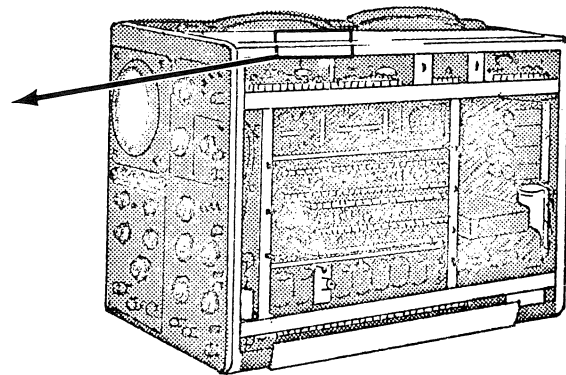
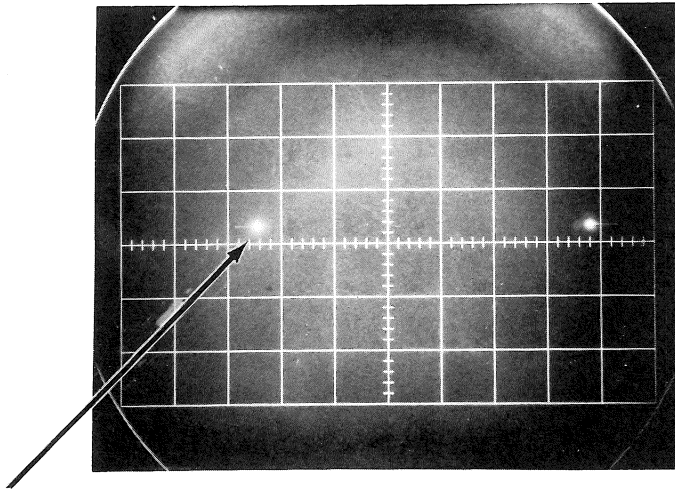


Figure 127

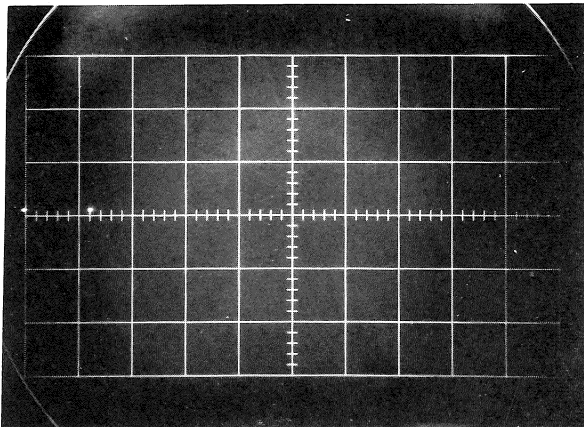


When R519 is properly adjusted, the left edge of the cal signal will not move as the VAR 10:1 is rotated from fully cw to fully ccw.

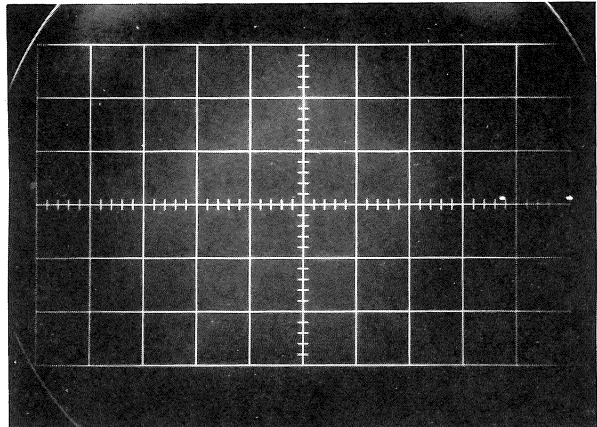
Figure 128

B. EXTERNAL HORIZONTAL AMPLIFIER GAIN CHECK

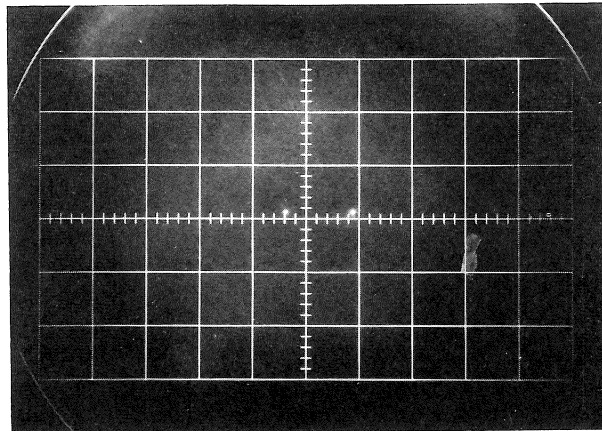
1. Set the AMPLITUDE CALIBRATOR to 0.1v.
2. Check for more than 1.2 cm of horizontal deflection at the left side, in the center, and at the right side of the graticule, with the VAR 10:1 set fully cw. (See Fig. 129)



More than 1.2 cm of horizontal deflection when the display is positioned to the left of the graticule.



More than 1.2 cm of horizontal deflection when the display is positioned to the right side of the graticule.



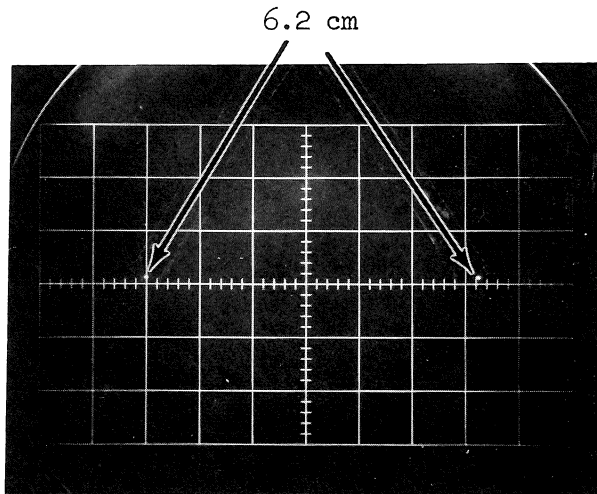
More than 1.2 cm of horizontal deflection when the display is positioned to the center of the graticule.

Figure 129

C. VAR 10:1 and X10 ATTENUATION CHECK

1. Set the AMPLITUDE CALIBRATOR to 0.5v. Note the amount of horizontal deflection with the VAR 10:1 set fully cw. (See Fig. 130)

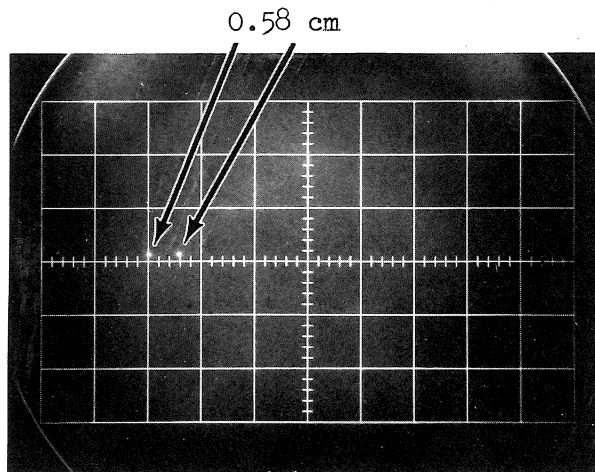
EXAMPLE: 6.2 cm



With 0.5v applied from the AMPLITUDE CALIBRATOR and the HORIZONTAL DISPLAY set to EXT X1, the horizontal deflection is 6.2 cm.

Figure 130

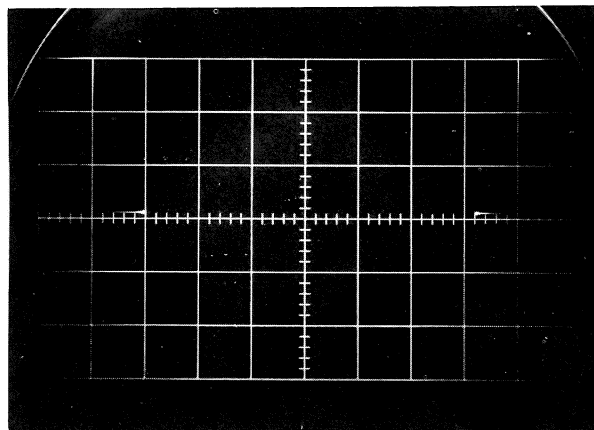
2. Set the VAR 10:1 fully ccw. Check for less than 1/10th the horizontal deflection seen in step 1.
EXAMPLE: 0.58 cm (See Fig. 131)



0.58 cm of horizontal deflection with the VAR 10:1 set fully ccw.

Figure 131

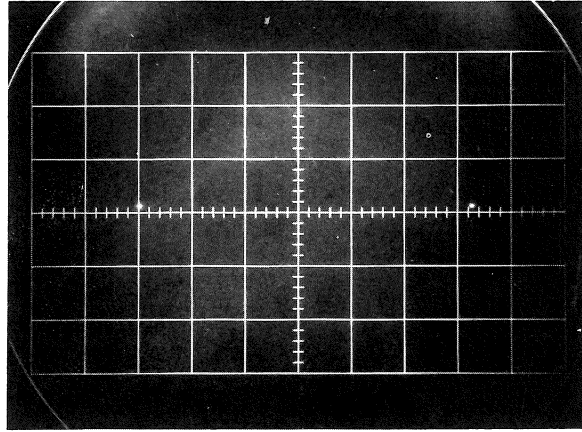
3. Return the VAR 10:1 to the fully cw position.
4. Set the HORIZONTAL DISPLAY to EXT X10 and the AMPLITUDE CALIBRATOR to 5v. Note the amount of horizontal deflection. (See Fig. 132)



With HORIZONTAL DISPLAY set to EXT X10 and AMPLITUDE CALIBRATOR set to 5v, check horizontal deflection.

Figure 132

5. Set the HORIZONTAL DISPLAY to EXT X1 and the AMPLITUDE CALIBRATOR to 0.5v. The amount of horizontal deflection should be within $\pm 2\%$ of the amount seen in step 4. (See Fig. 133)

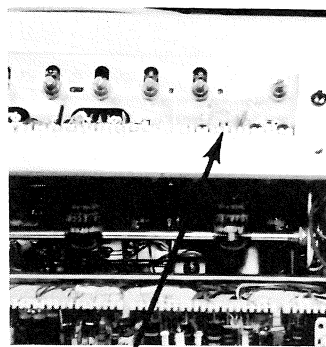


The horizontal deflection seen in Fig. 133 should be within $\pm 2\%$ of the horizontal deflection seen in Fig. 132.

Figure 133

D. EXTERNAL HORIZONTAL AMPLIFIER COMPENSATIONS

1. With the HORIZONTAL DISPLAY set to EXT X1 and the AMPLITUDE CALIBRATOR set to 0.5v, adjust the EXTERNAL HORIZONTAL AMPLIFIER OUTPUT compensator (C525 - see Fig. 134) for a finely defined dot at the right edge of the cal signal. (See Fig. 135)



EXTERNAL HORIZONTAL
AMPLIFIER OUTPUT
compensator C524

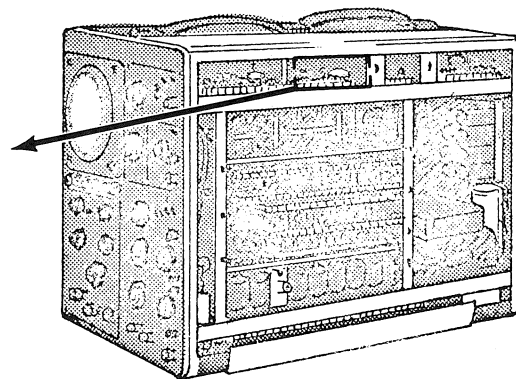
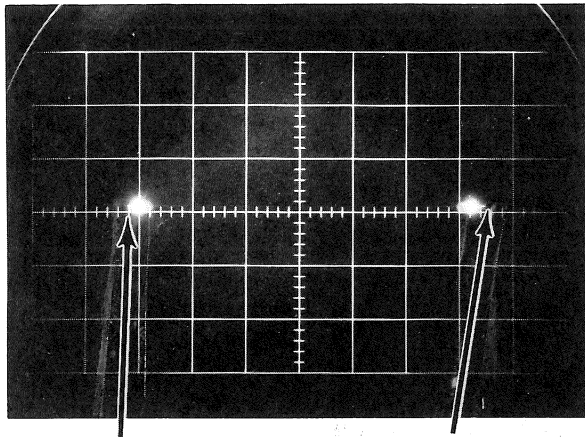
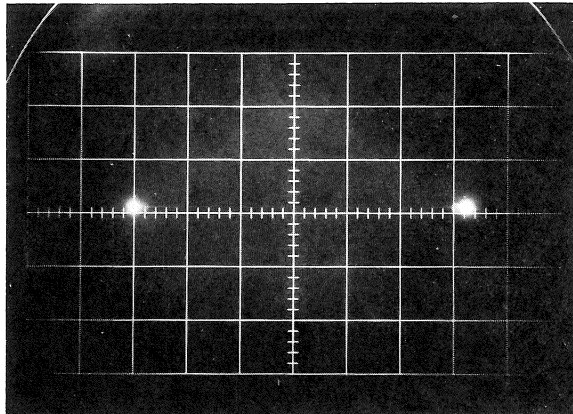


Figure 134



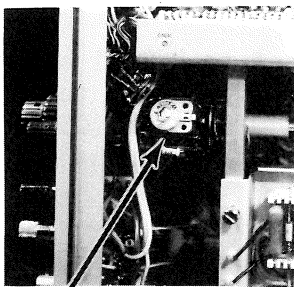
C524 misadjusted. Note "wings" extending from dots.



C524 properly adjusted.

Figure 135

2. Set the HORIZONTAL DISPLAY to EXT X10 and the AMPLITUDE CALIBRATOR to 5v. Adjust the X10 compensator (C503C - see Fig. 136) for a finely defined dot at the right edge of the cal signal. (See Fig. 137)



X10 compensator
C503C

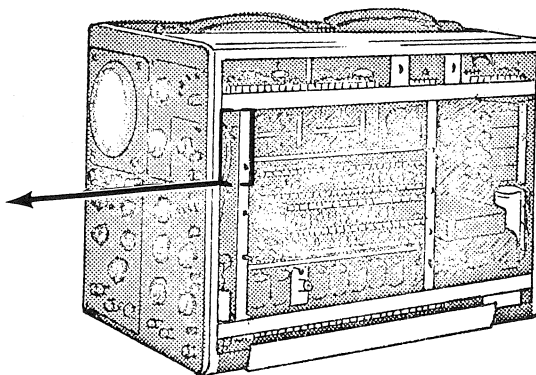
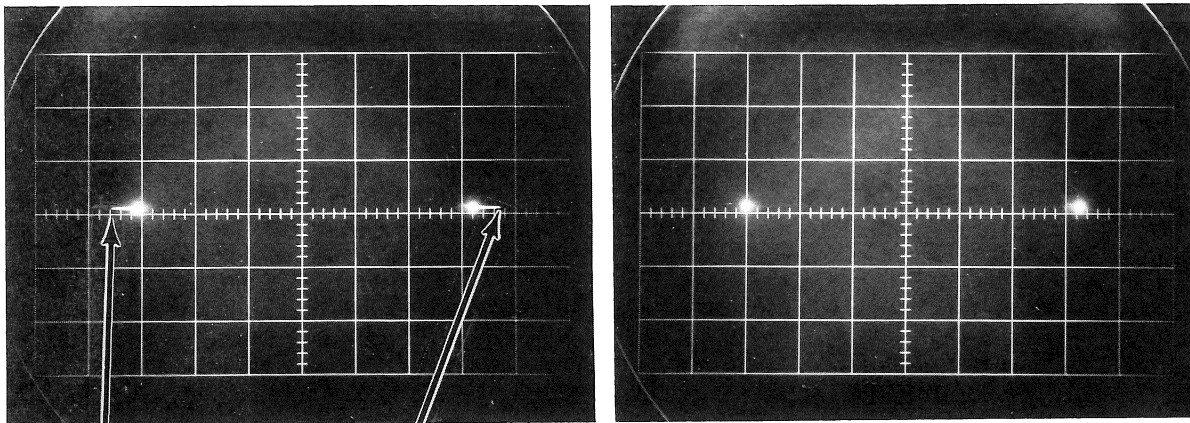


Figure 136



C503C misadjusted. Note "wings" extending from the dots.

C503C properly adjusted.

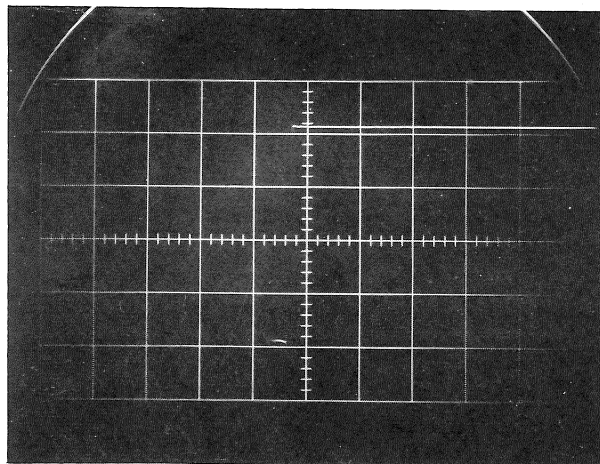
Figure 137

II VERTICAL AMPLIFIER

A. VERTICAL AMPLIFIER HIGH FREQUENCY ADJUSTMENTS

These adjustments were outlined previously in SECTION II Part C.

1. Set the HORIZONTAL DISPLAY to B, the TEST FUNCTION control to + PULSE, REPITION RATE to HIGH, and with the AMPLITUDE control and the VERTICAL POSITION control obtain a display of 4 cm vertical deflection centered on the CRT.
2. Set B TIME/CM to 0.1 μ sec. (See Fig. 138)



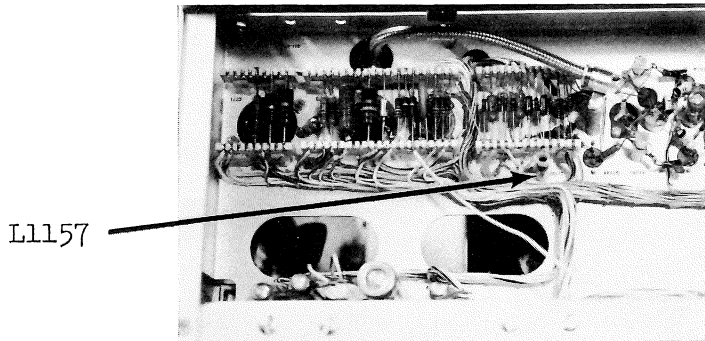
4 cm of vertical deflection from the TU-7 pulse generator. B TIME/CM is set to 0.1 μ sec and the sweep magnifier is set to X1 (off).

Figure 138

3. While switching the SWEEP MAGNIFIER from X1 to X10, adjust the VERTICAL AMPLIFIER H.F. adjustments for a flat top with minimum aberations at the leading edge and a rise-time of 6.25 nsec as read with the SWEEP MAGNIFIER set at X10.

- a. Aberations max: 0.4mm
- b. Risetime max: 6.25 nsec

L1157	Adjust for min wrinkles at the leading edge.	Bottom of main amp chassis - see Fig. 139
C1029	Delay line termination, approx 340 nsec from start of sweep.	Top of main amp chassis - see Fig. 140
C1076	Med time constant compensation.	PC board - see Fig. 140
R1076	Adjust with C1076.	"
C1105	Fast time constant compensation.	"
C1106	Med time constant compensation.	"
R1106	Adjust with C1106.	"
C1126	Long time constant compensation.	"



Picture taken with scope laying on the right side.

Figure 139

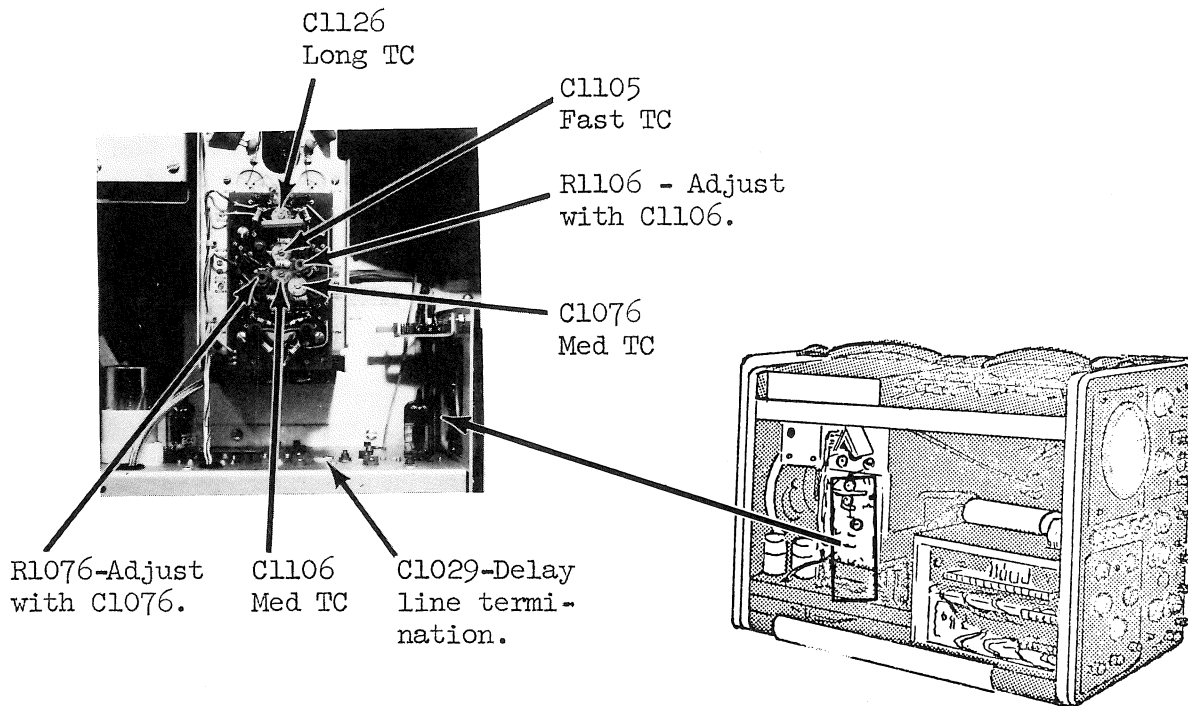
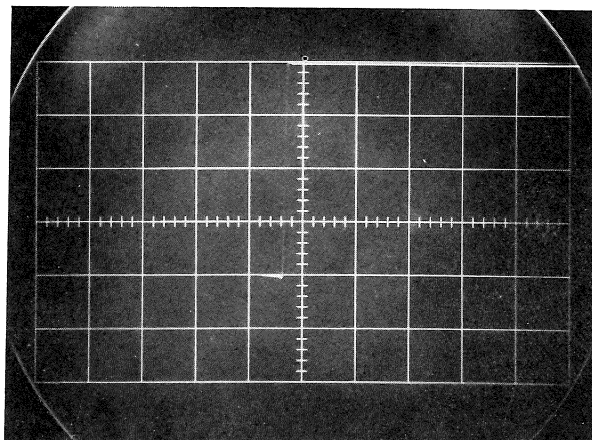


Figure 140

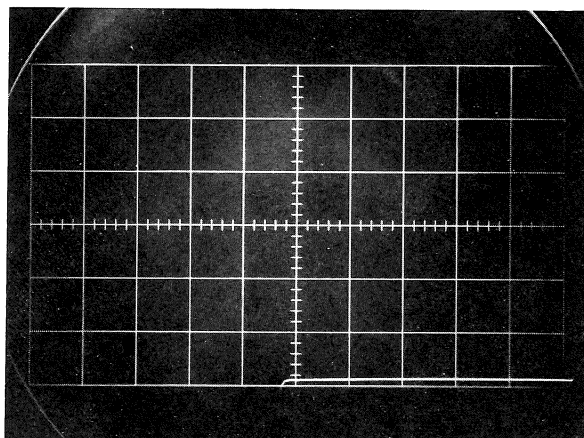
4. Transient Response check.

- a. Set pulse upper edge to the top of the graticule and note the change in leading edge aberrations.
- b. Set pulse upper edge to bottom of the graticule and note change in the leading edge aberrations.

Allowable change: 1.5mm max



Pulse positioned to top
of graticule front corner
peaks.

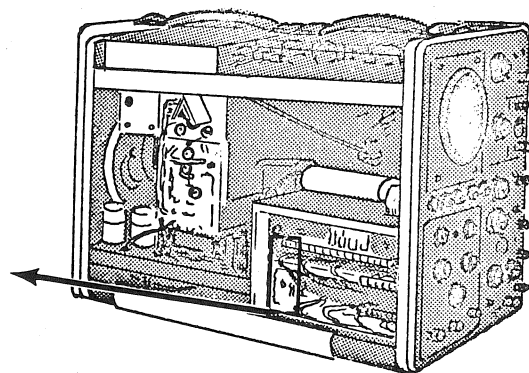
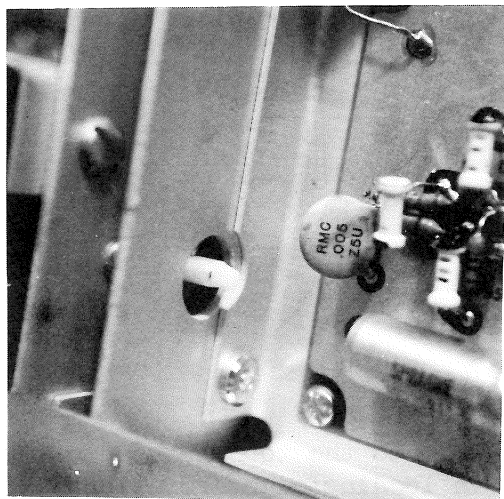


Pulse positioned to bottom
of graticule front corner
rolls off.

Figure 141

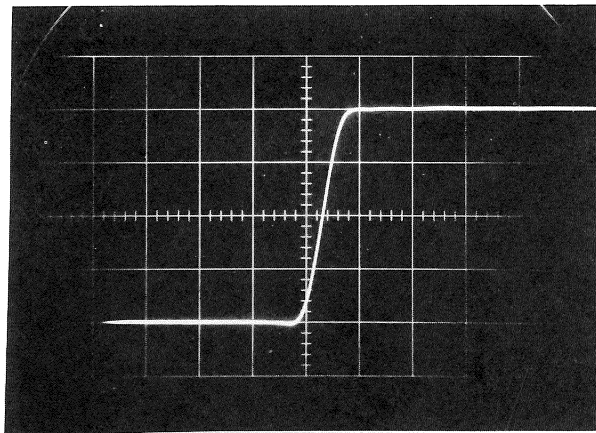
5. Spoiler Switch check.

- a. With the SWEEP MAGNIFIER set to X10, depress the SPOILER SWITCH (located in the lower left hand corner of the plug-in box - see Fig. 142).
- b. Risetime will typically reduce by 1 nsec. The minimum allowable risetime with the SPOILER SWITCH depressed is 7 nsec; maximum is 10 nsec. (See Fig. 143)

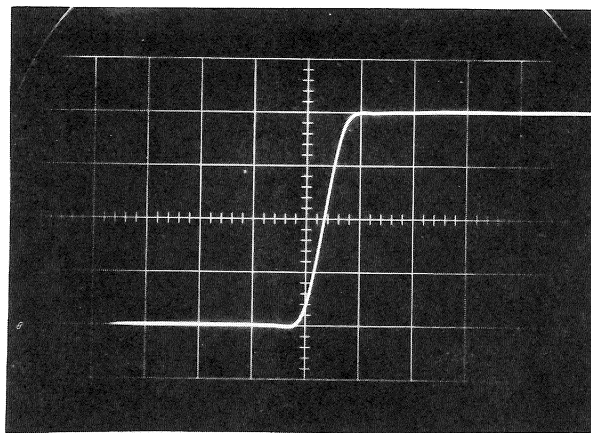


SPOILER SWITCH

Figure 142



Vertical risetime
6.25 nsec



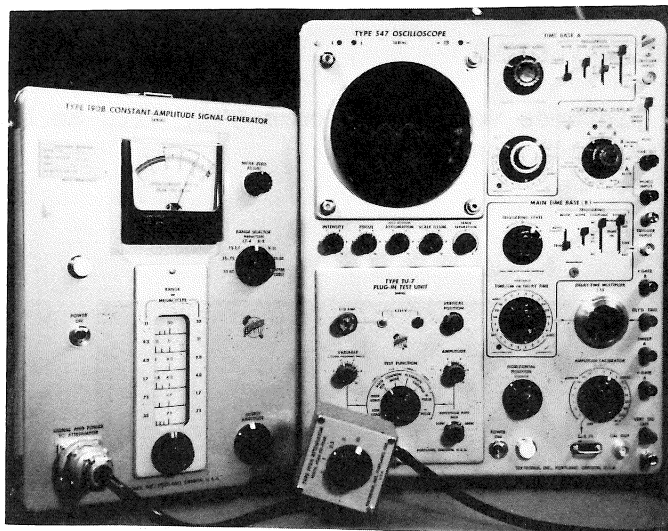
Vertical risetime with
SPOILER SWITCH depressed
7.5 nsec

Figure 143

III. HIGH FREQUENCY TRIGGERING

A. A HIGH FREQUENCY TRIGGERING CHECK

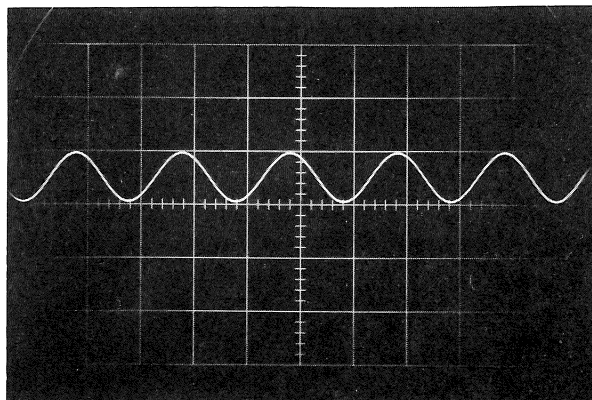
1. Set the HORIZONTAL DISPLAY to A and A TIME/CM to 0.1 μ sec.
2. Connect the output of a 190B to the vertical input.
(See Fig. 144)



190B set up to apply 50 MC to 547

Figure 144

3. Apply 50 MC from the 190B and obtain 1 cm of vertical deflection. (See Fig. 145)
4. With A TRIGGERING SOURCE set to INT-NORM, obtain a stable display. Check for less than 2 nsec of jitter with SWEEP MAGNIFIER set to X10.



1 cm of 50 MC triggered internally on 547

Figure 145

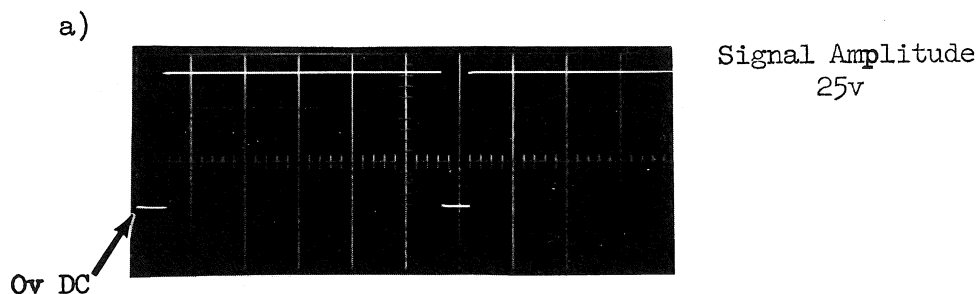
B. B HIGH FREQUENCY TRIGGERING CHECK

1. Set the HORIZONTAL DISPLAY to B and B TIME/CM to 0.1 μ sec.
2. With B TRIGGERING SOURCE set to INT-NORM, obtain a stable display. Check for less than 2 nsec of jitter with the SWEEP MAGNIFIER set to X10.

IV. 547 FRONT PANEL WAVEFORMS

The following pictures were taken on a 543, with an L plug-in unit, under the conditions stated.

A. + GATE B

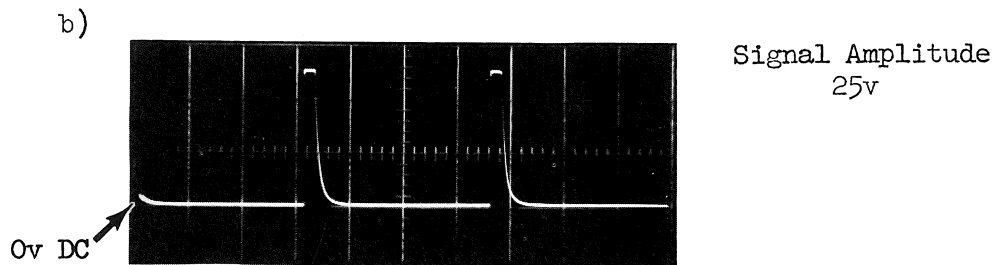


547 - B sweep freerunning at 1 msec.

543 - Triggered on - slope, AC FAST, INT.
TIME/CM - 2 msec.

L UNIT - 1 v/cm DC coupled

X10 probe connected to + GATE B

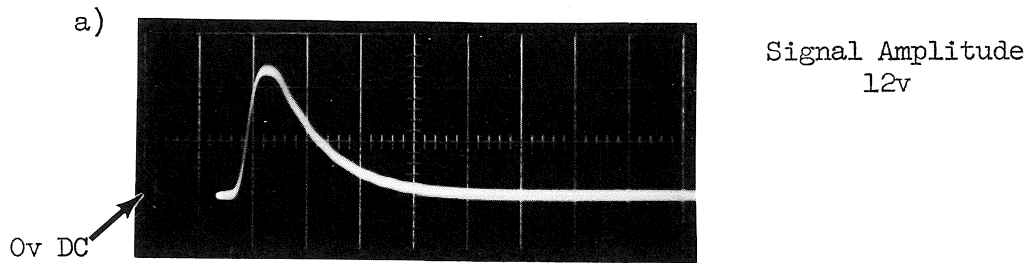


547 - B TIME/CM - 0.1 μ sec

543 - TIME/CM - 5 μ sec

Figure 146

B. DLY'D TRIG

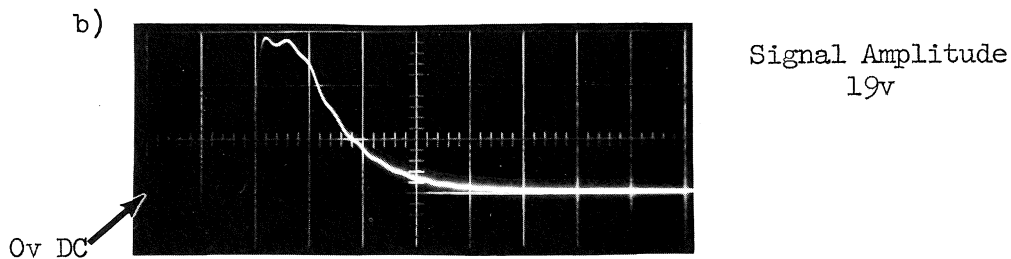


547 - B TIME/CM - 1 msec. Sweep freerunning

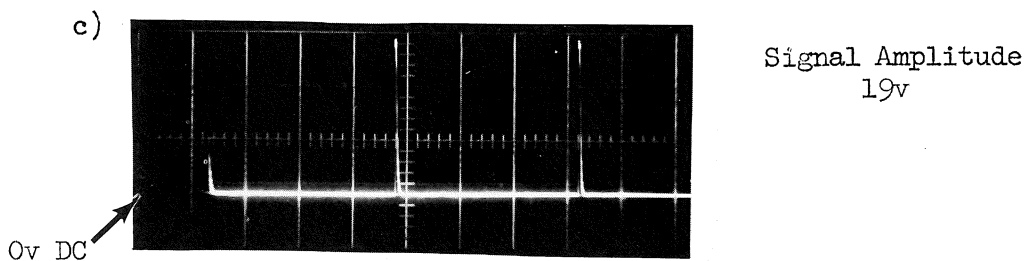
543 - Triggered on + slope, AC FAST, INT.
TIME/CM - 0.1 μ sec

L UNIT - 0.5 v/cm DC coupled

X10 probe connected to DLY'D TRIG



547 - B TIME/CM - 0.1 μ sec

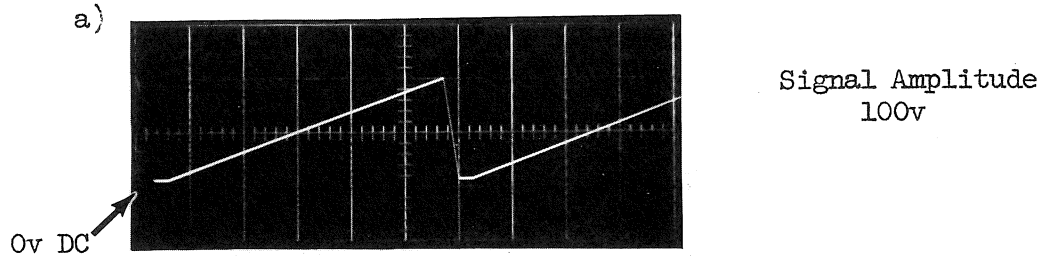


547 - B TIME/CM - 0.1 μ sec

543 - TIME/CM - 5 μ sec

Figure 147

C. SWEEP A

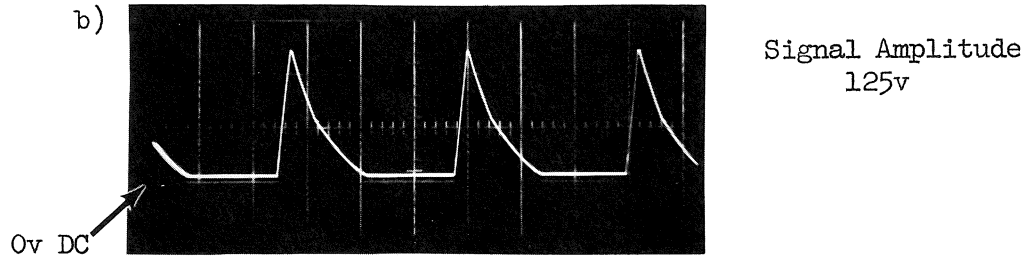


547 - A TIME/CM - 1 msec

543 - Triggered on - slope, AC FAST, INT.,
TIME/CM - 2 msec

L UNIT - 5 v/cm DC coupled

X10 probe connected to SWEEP A

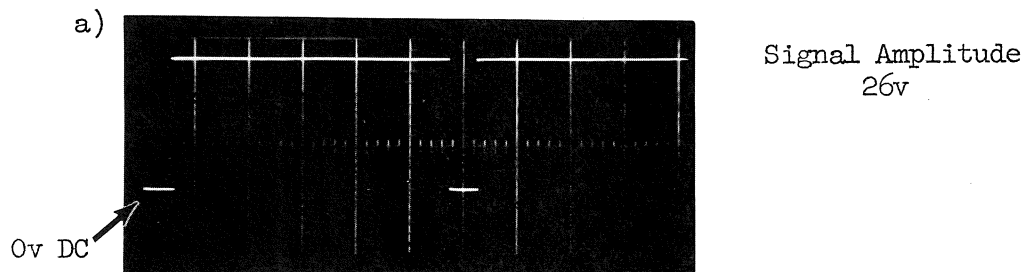


547 - A TIME/CM - 0.1 μ sec

543 - TIME/CM - 5 μ sec

Figure 148

D. + GATE A



547 - A TIME/CM - 1 msec Sweep freerunning

543 - Triggered on - slope, AC FAST, INT.
TIME/CM - 2 msec

L UNIT - 1 v/cm DC coupled

X10 probe connected to + GATE A

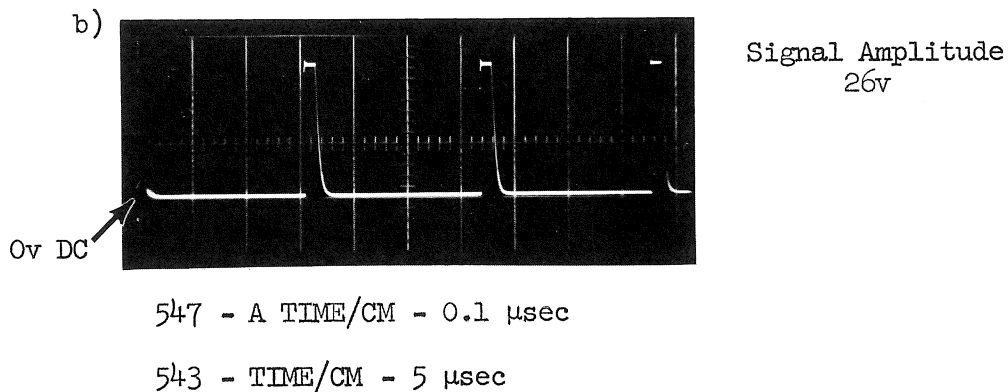
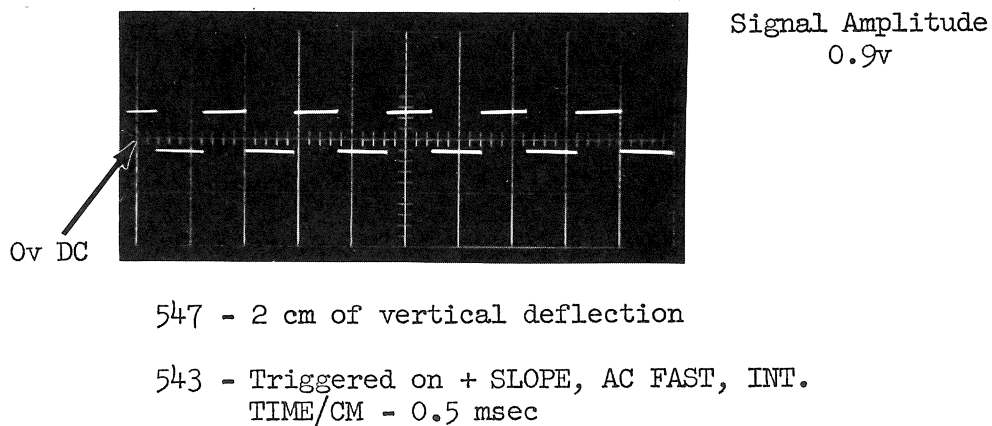


Figure 149

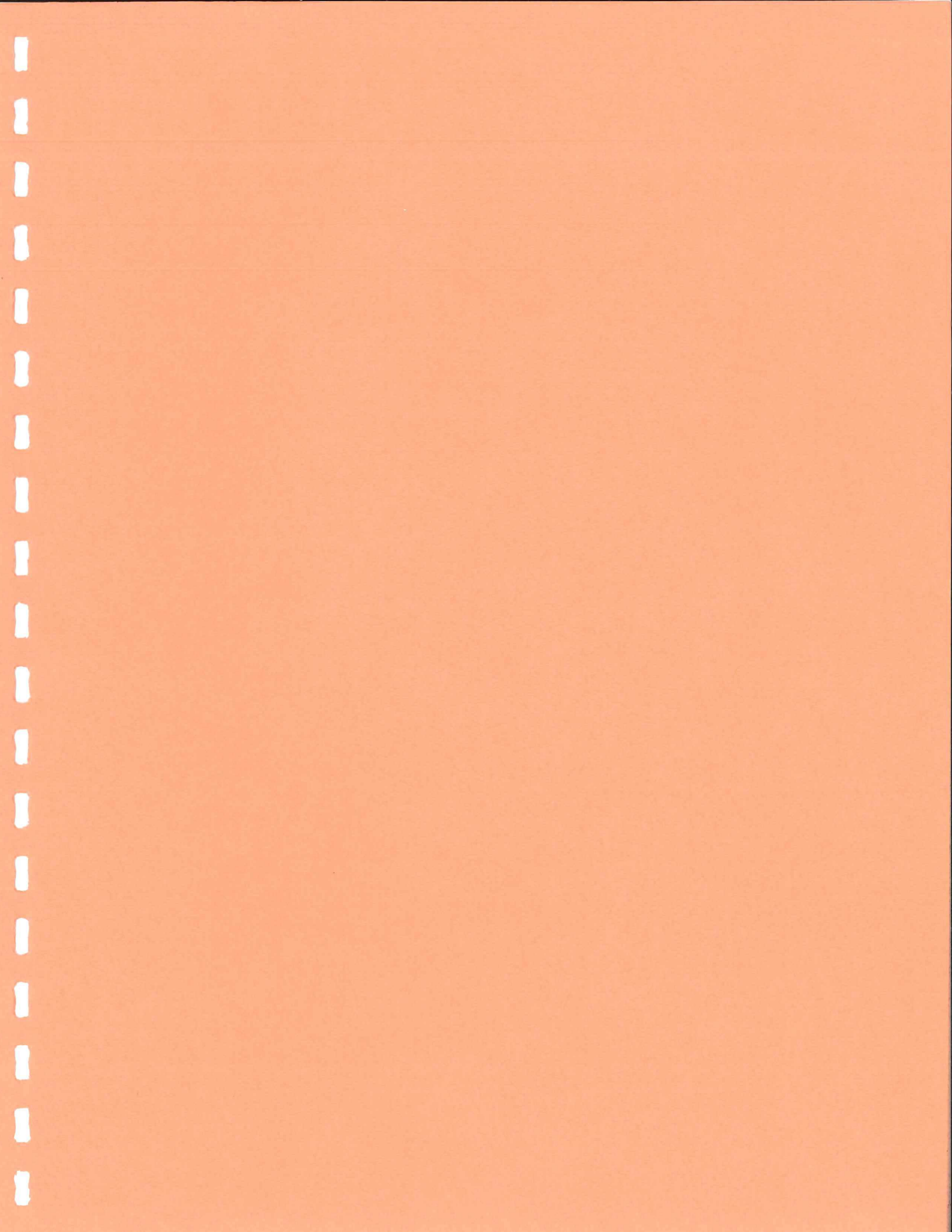
E. VERT SIG OUT

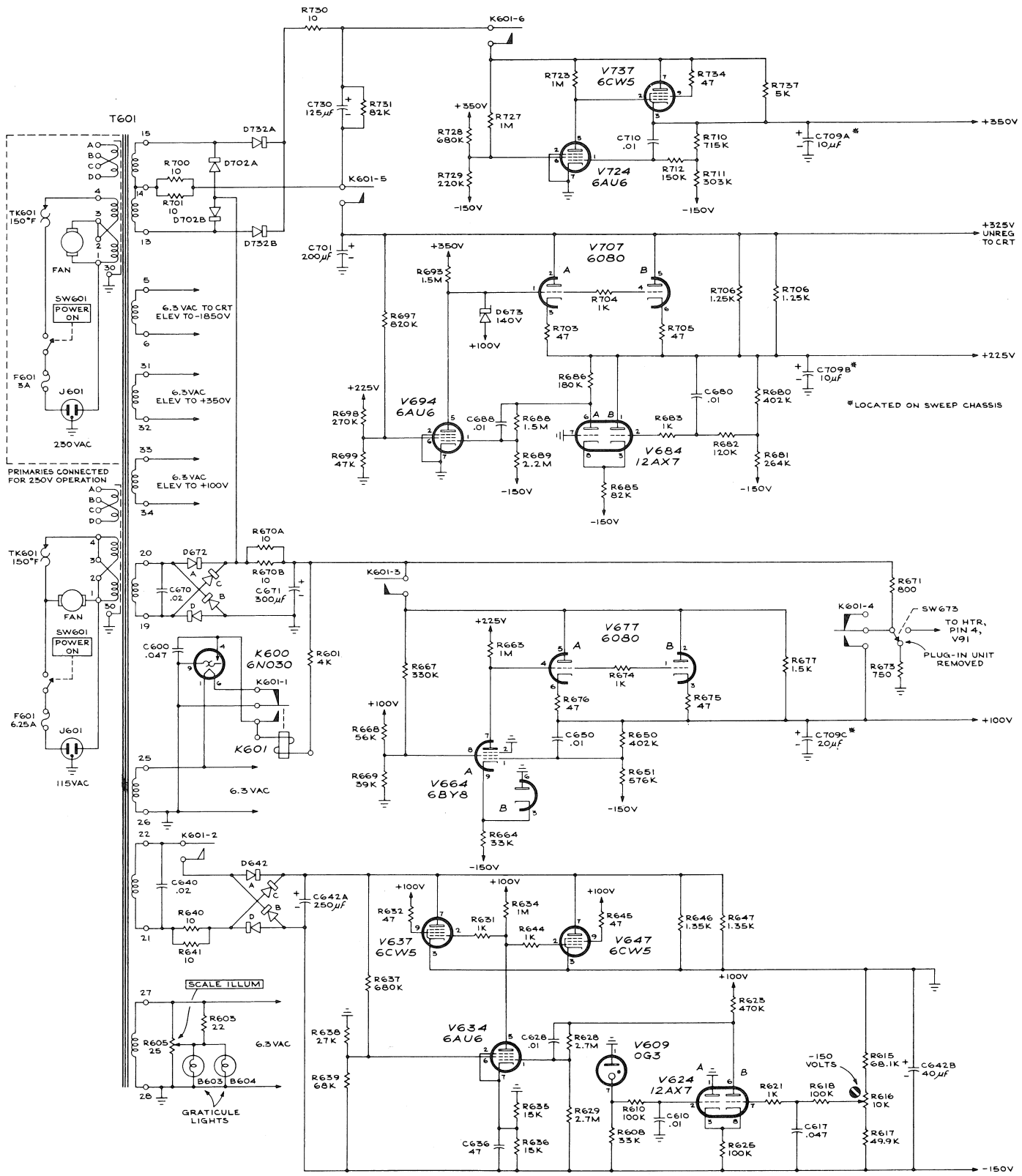


L UNIT - 0.1 v/cm DC coupled

X10 probe connected to VERT SIG OUT

Figure 150

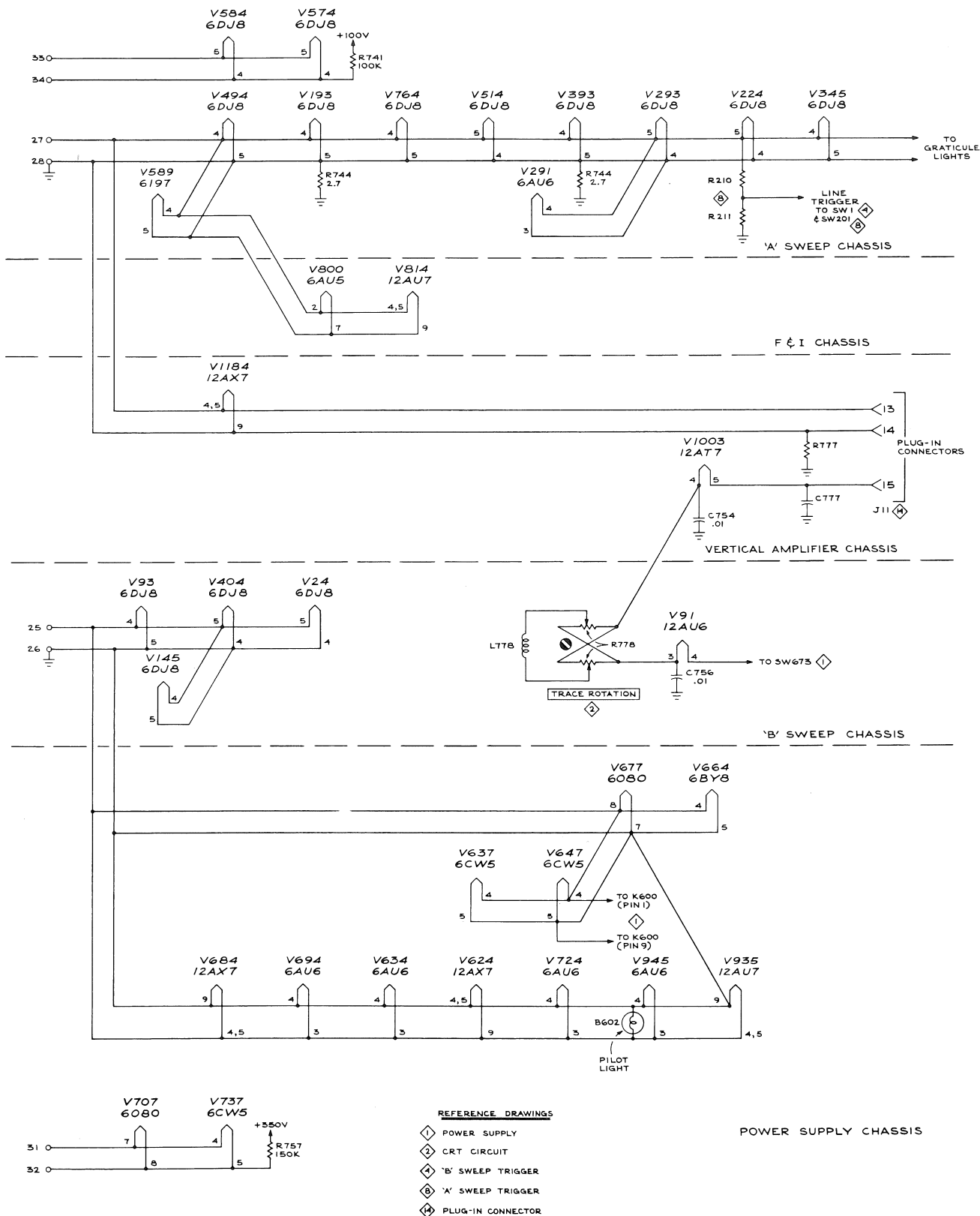




A

POWER SUPPLY

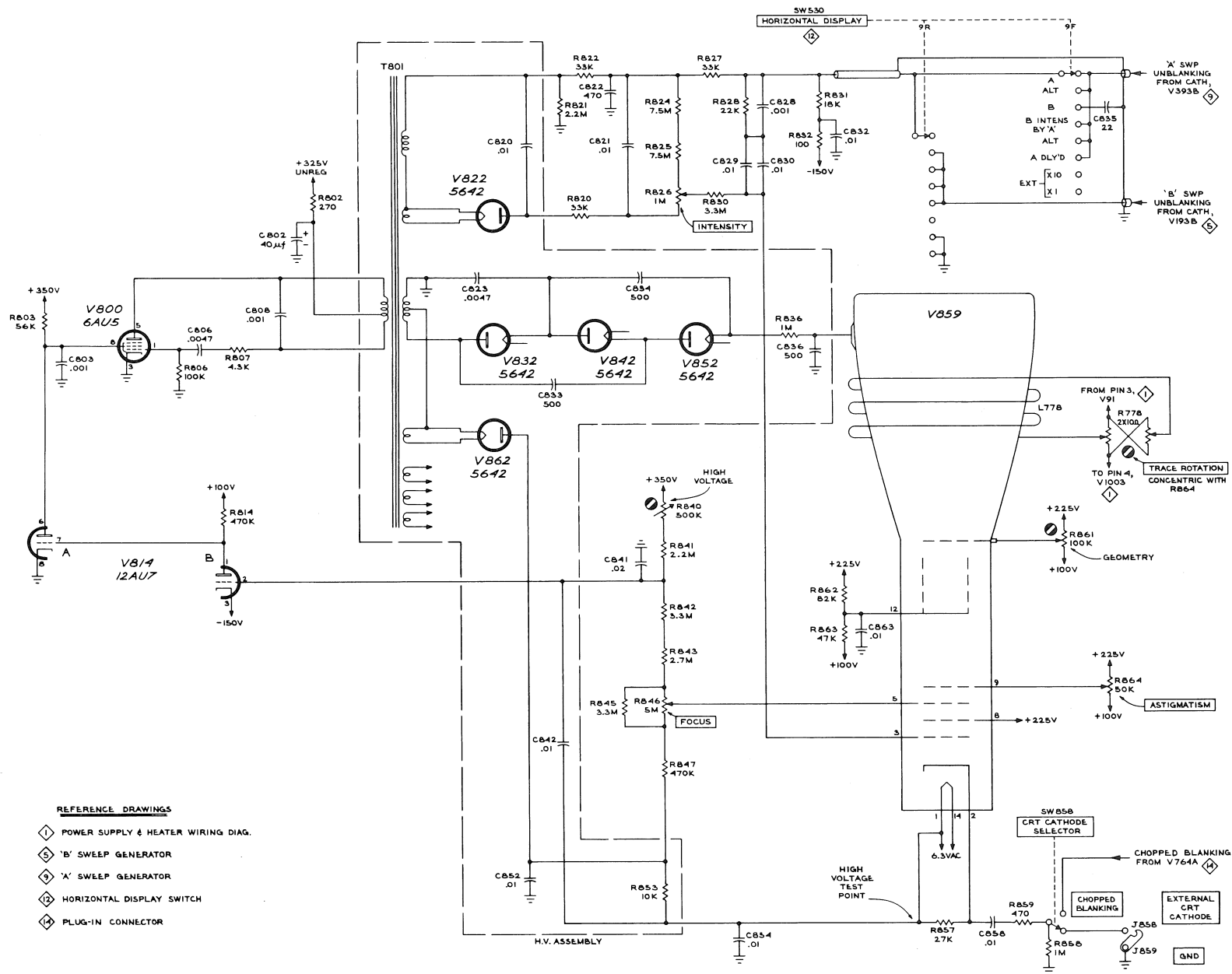
DON 164



TYPE 547 OSCILLOSCOPE

A

HEATER WIRING DIAGRAM



- REFERENCE DRAWINGS
- ① POWER SUPPLY & HEATER WIRING DIAG.
 - ② 'B' SWEEP GENERATOR
 - ③ 'A' SWEEP GENERATOR
 - ④ HORIZONTAL DISPLAY SWITCH
 - ⑤ PLUG-IN CONNECTOR

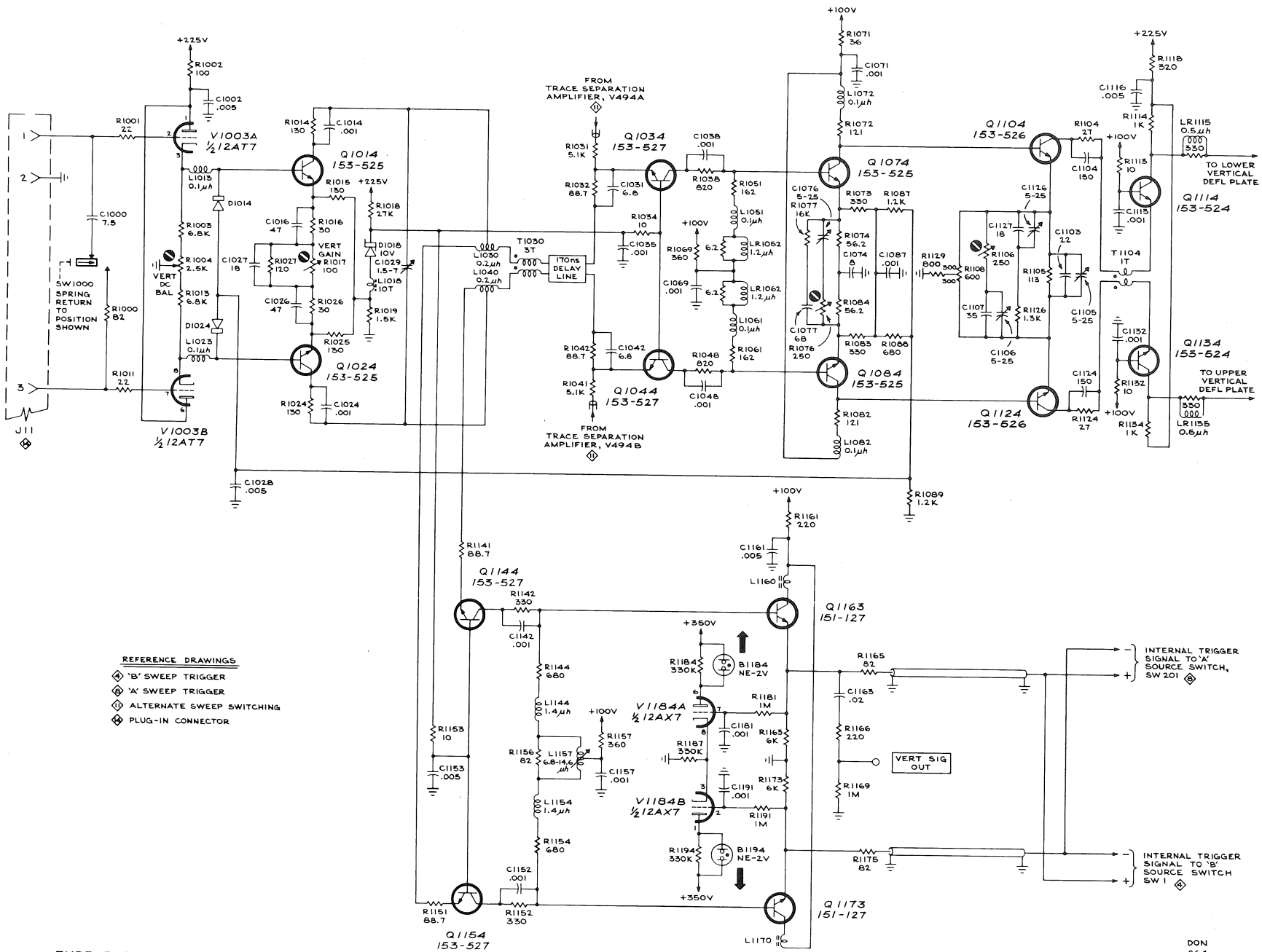
TYPE 547 OSCILLOSCOPE

A

CRT CIRCUIT ②

C-547-0013

CMP
164



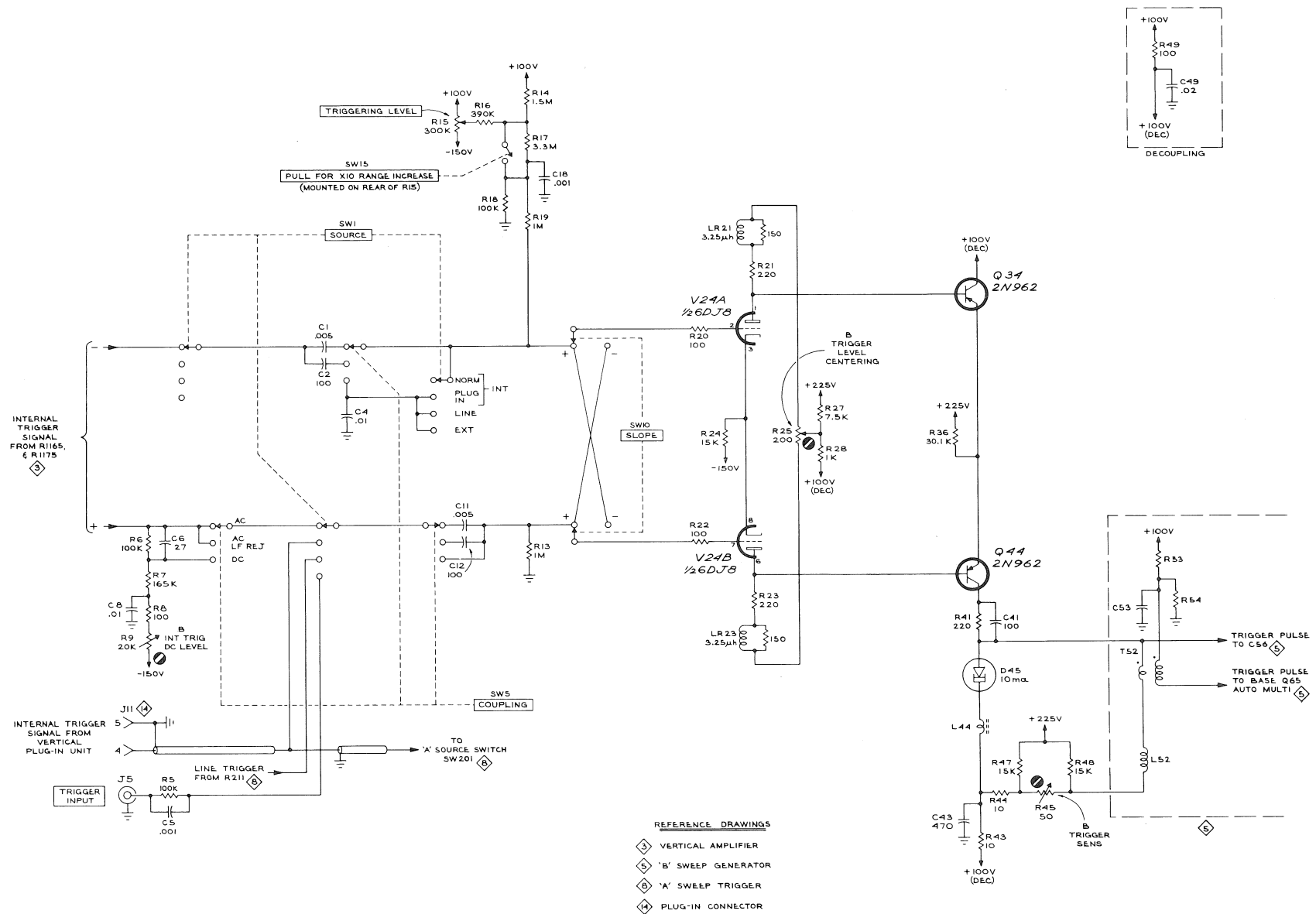
- REFERENCE DRAWINGS**
- ◆ 'B' SWEEP TRIGGER
 - ◆ 'A' SWEEP TRIGGER
 - ◆ ALTERNATE SWEEP SWITCHING
 - ◆ PLUG-IN CONNECTOR

TYPE 547 OSCILLOSCOPE

A

DON
264
VERTICAL AMPLIFIER

C-547-0019

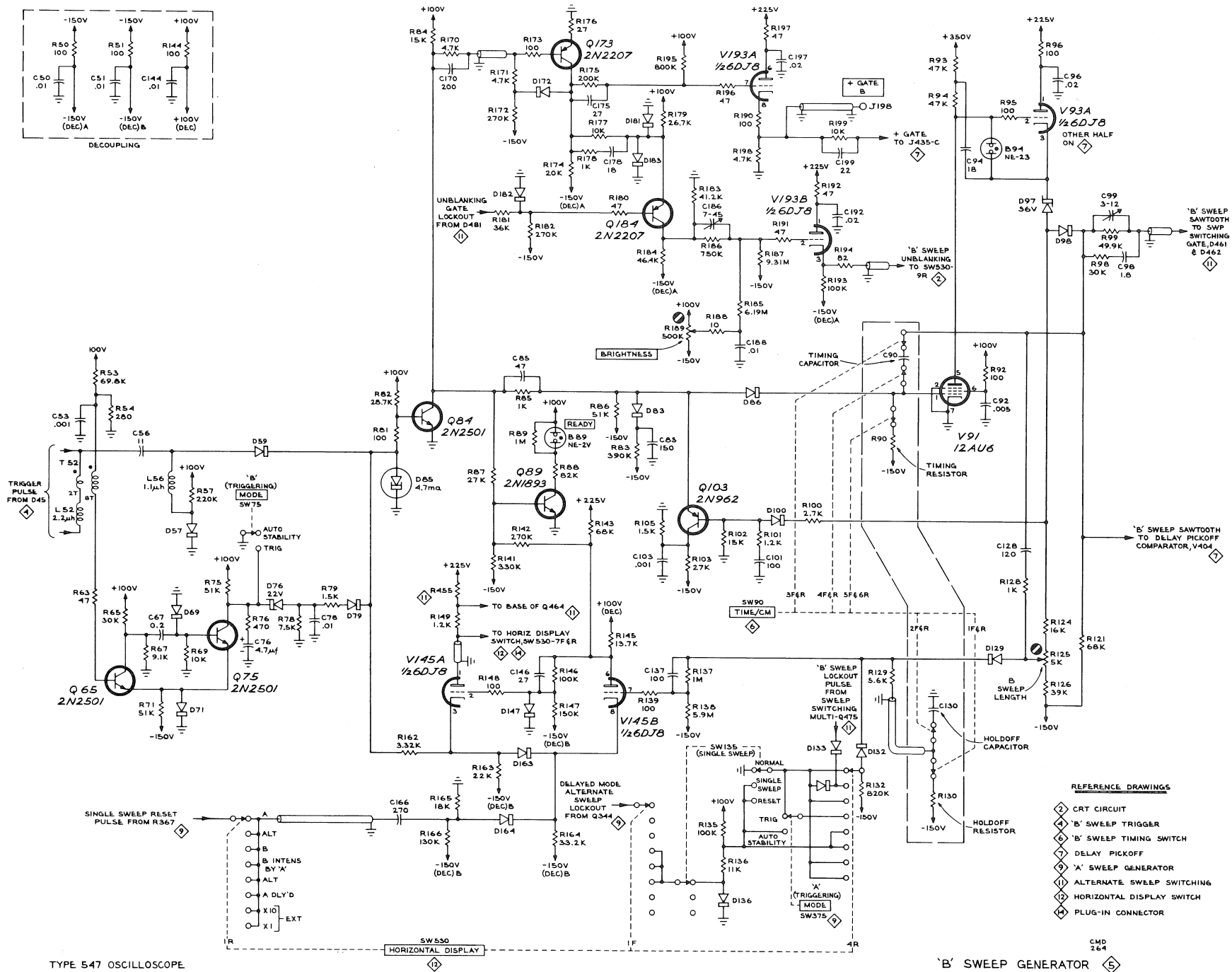
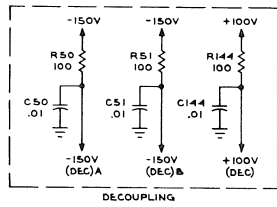


TYPE 547 OSCILLOSCOPE

A

CMD
264
B SWEEP TRIGGER 4

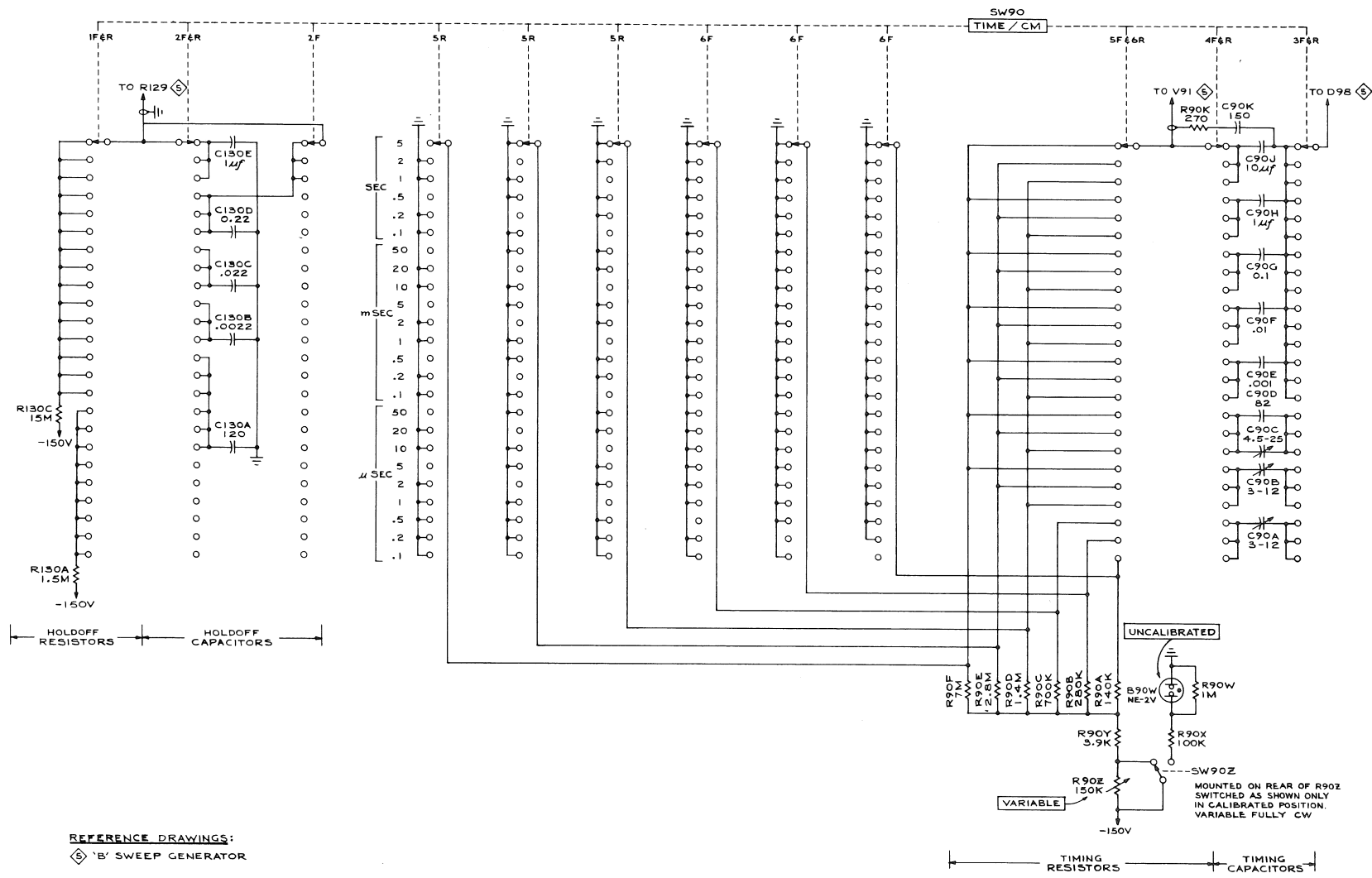
C-547-0011



TYPE 547 OSCILLOSCOPE

'B' SWEEP GENERATOR

C-547-0009



REFERENCE DRAWINGS:
 ⬡ 'B' SWEEP GENERATOR

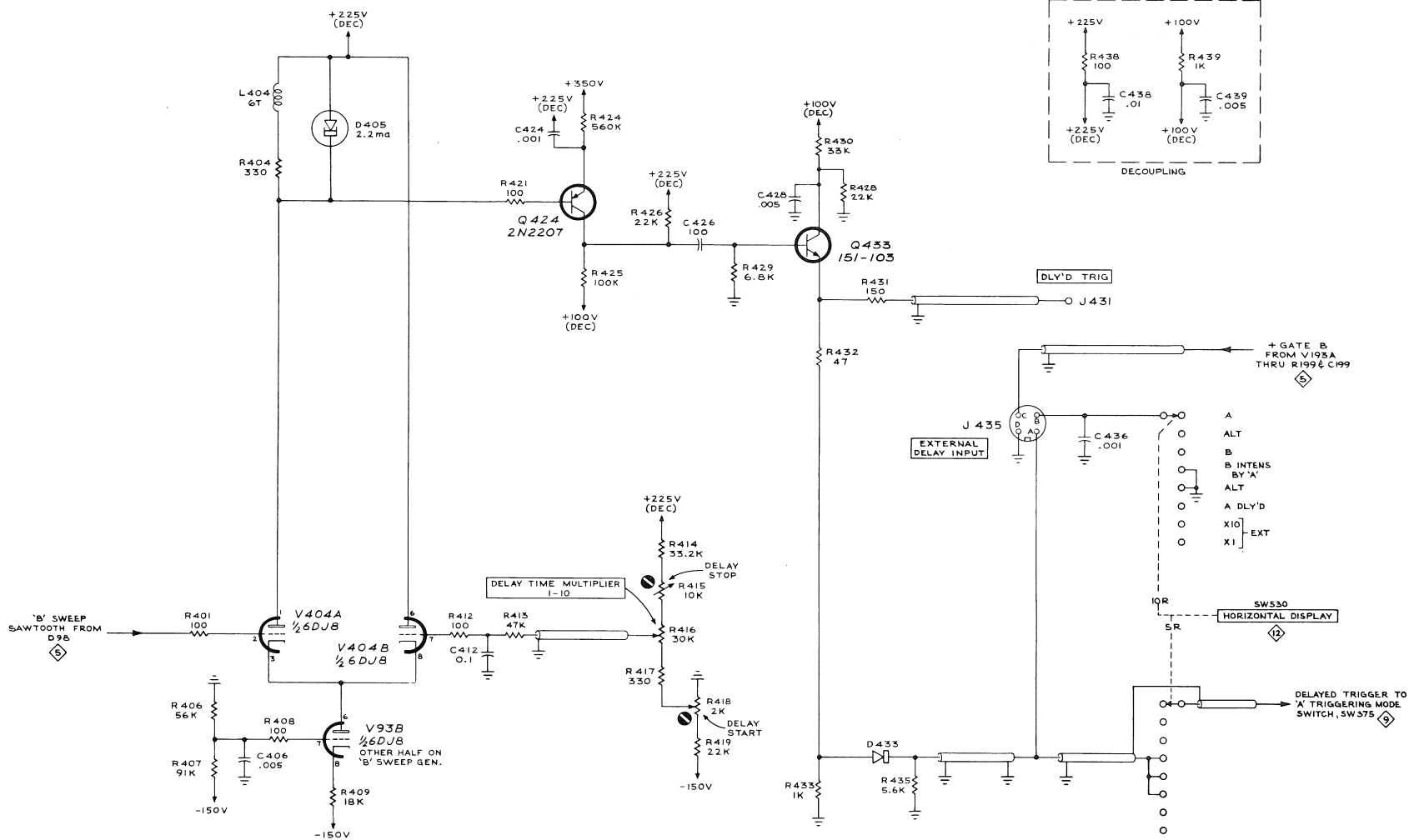
UNCALIBRATED
 MOUNTED ON REAR OF R90Z
 SWITCHED AS SHOWN ONLY
 IN CALIBRATED POSITION.
 VARIABLE FULLY CW

TYPE 547 OSCILLOSCOPE

A

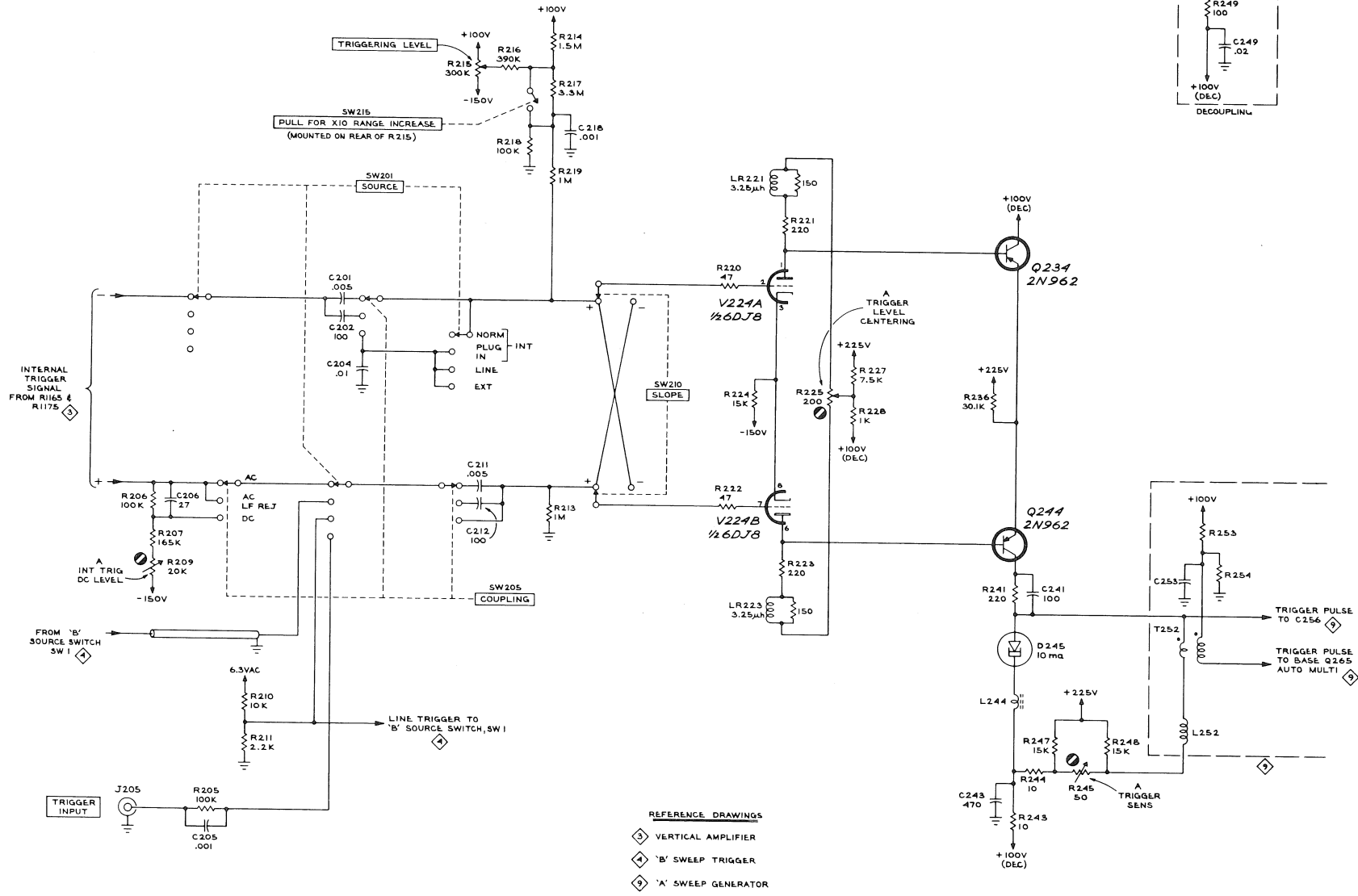
MRH
 264
 'B' SWEEP TIMING SWITCH ⬡

C-547-0010



REFERENCE DRAWINGS

- ⑤ 'B' SWEEP GENERATOR
- ⑥ 'A' SWEEP GENERATOR
- ⑦ HORIZONTAL DISPLAY SWITCH



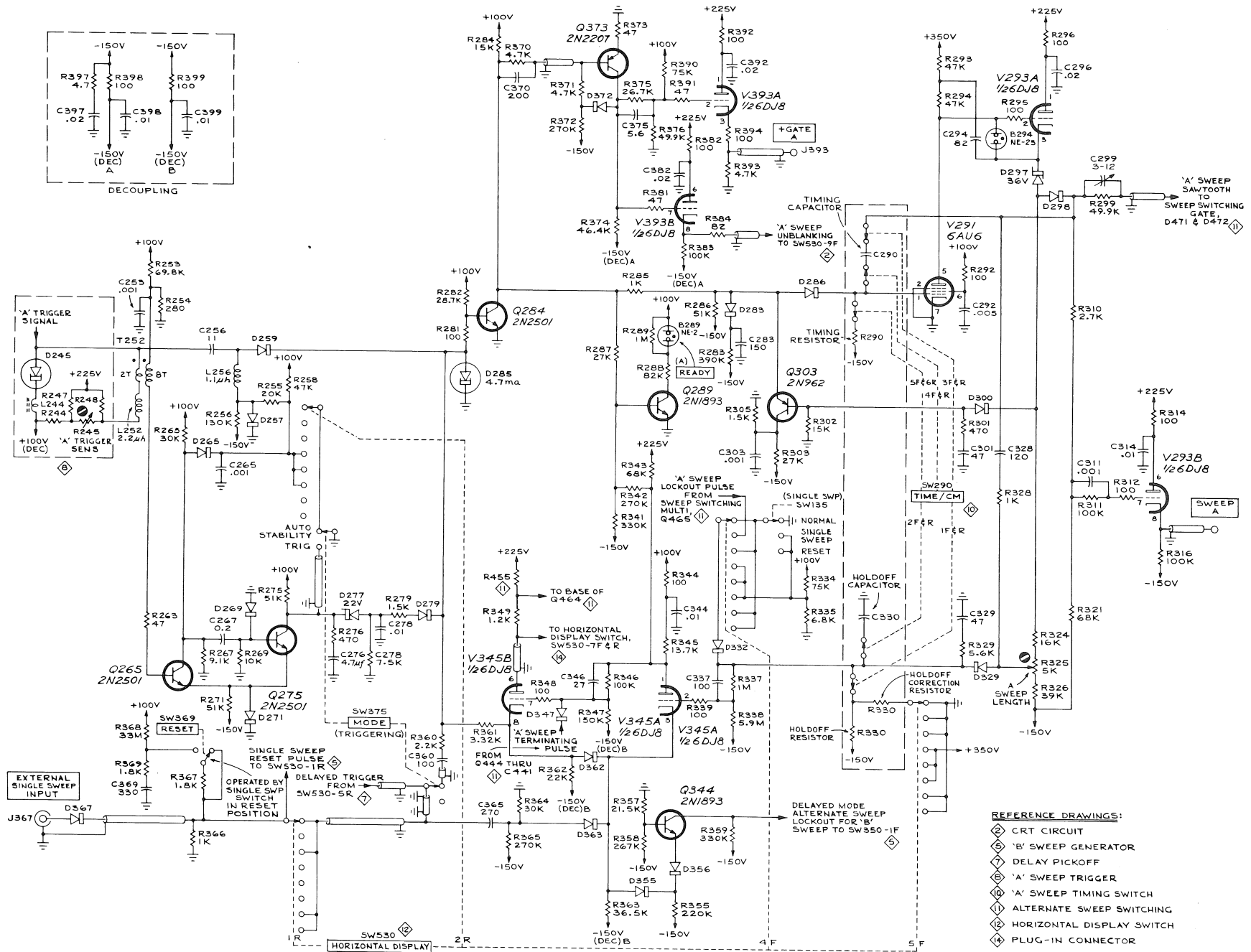
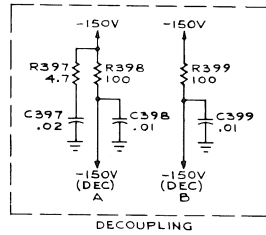
TYPE 547 OSCILLOSCOPE

A

CMD
264

'A' SWEEP TRIGGER ⊠

C-547-0007



- REFERENCE DRAWINGS:**
- ① CRT CIRCUIT
 - ② 'B' SWEEP GENERATOR
 - ③ DELAY PICKOFF
 - ④ 'A' SWEEP TRIGGER
 - ⑤ 'A' SWEEP TIMING SWITCH
 - ⑥ ALTERNATE SWEEP SWITCHING
 - ⑦ HORIZONTAL DISPLAY SWITCH
 - ⑧ PLUG-IN CONNECTOR

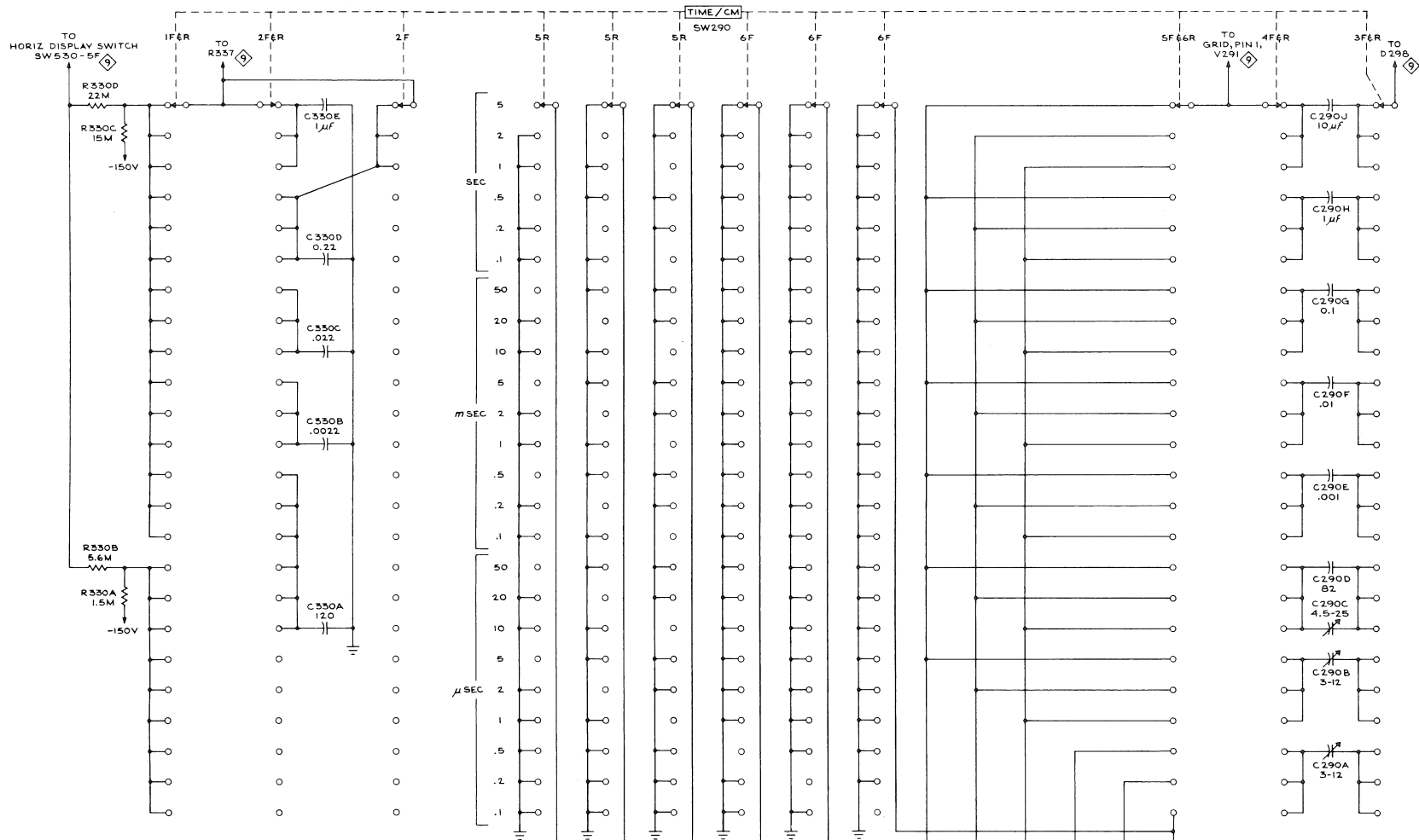
TYPE 547 OSCILLOSCOPE

A

MRH
264

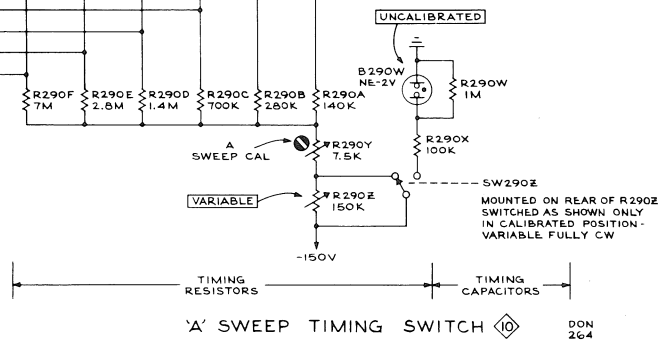
'A' SWEEP GENERATOR ⑧

C-547-0005



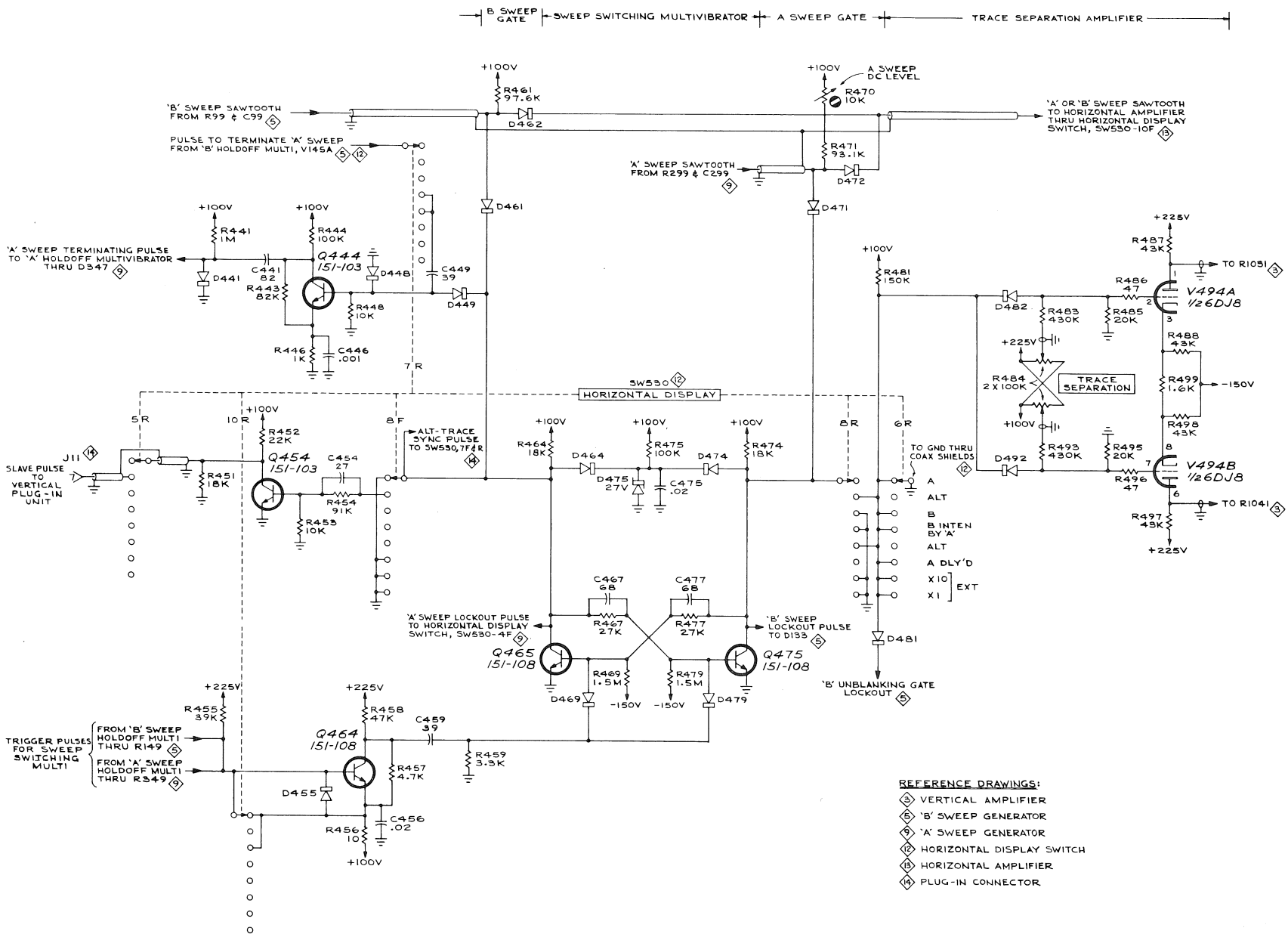
REFERENCE DRAWINGS
 9 'A' SWEEP GENERATOR

HOLDOFF RESISTORS HOLDOFF CAPACITORS
 TYPE 547 OSCILLOSCOPE



A

DON 264

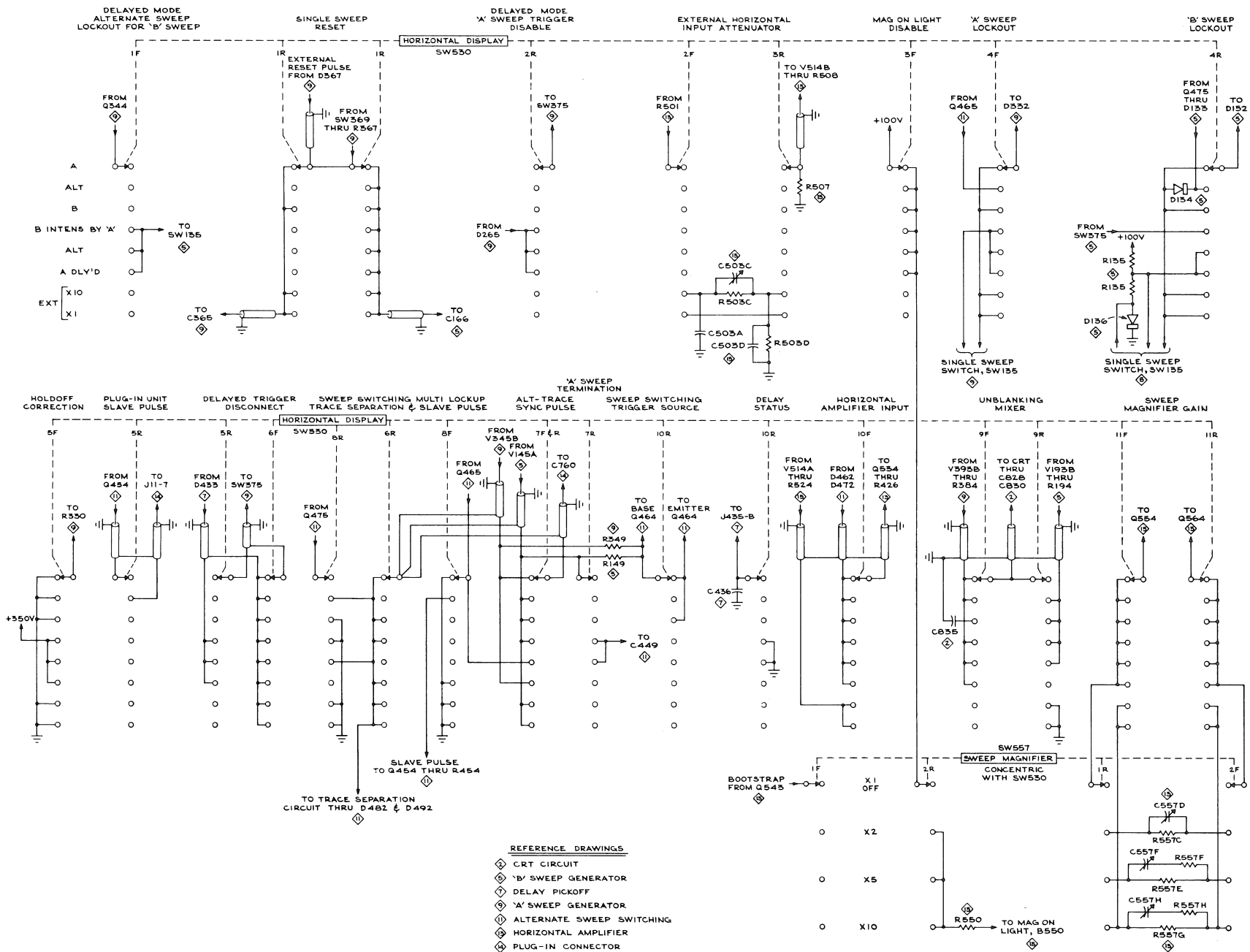


TYPE 547 OSCILLOSCOPE

A

MRH
264
ALTERNATE SWEEP SWITCHING Ⓢ

C-547-0008

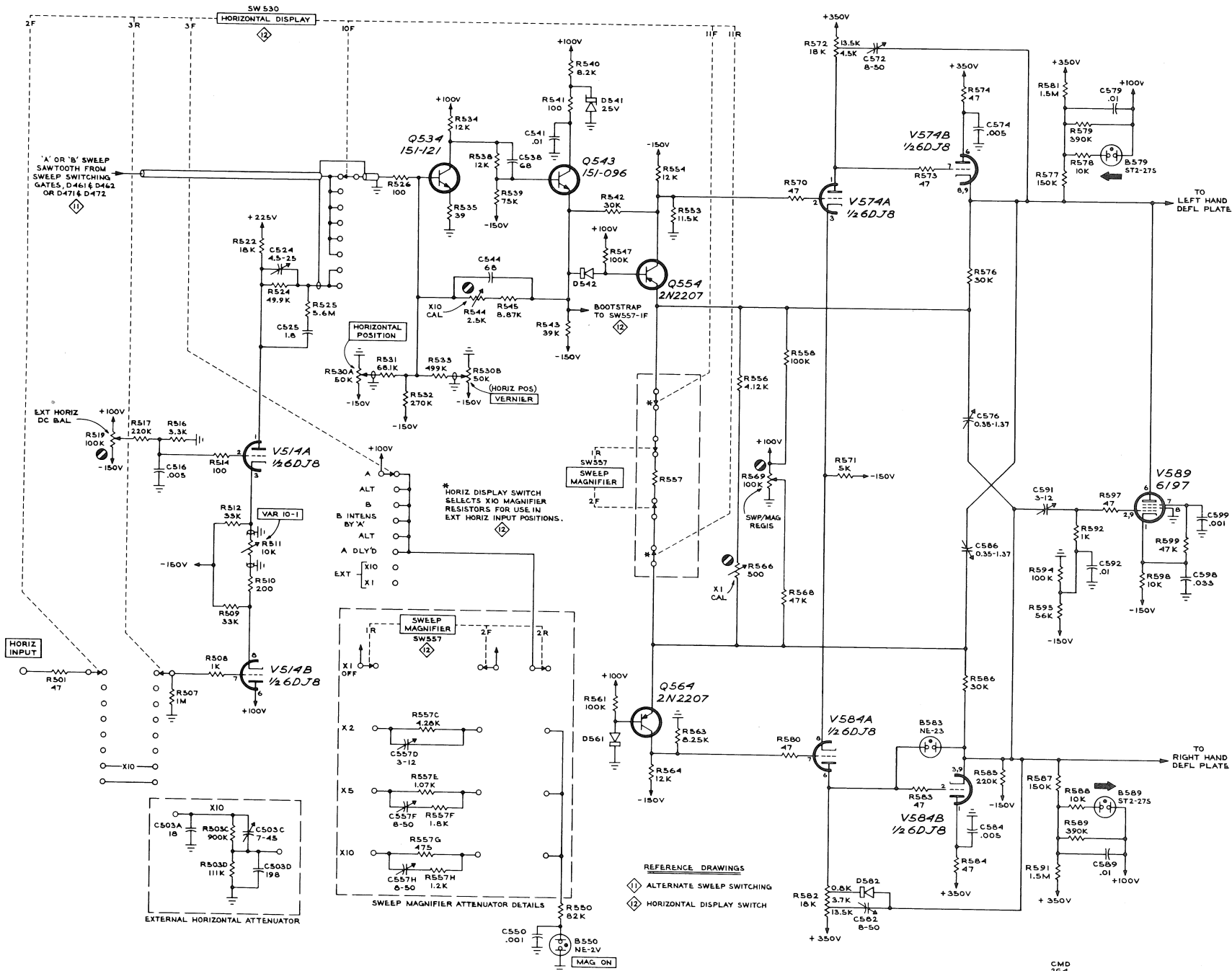


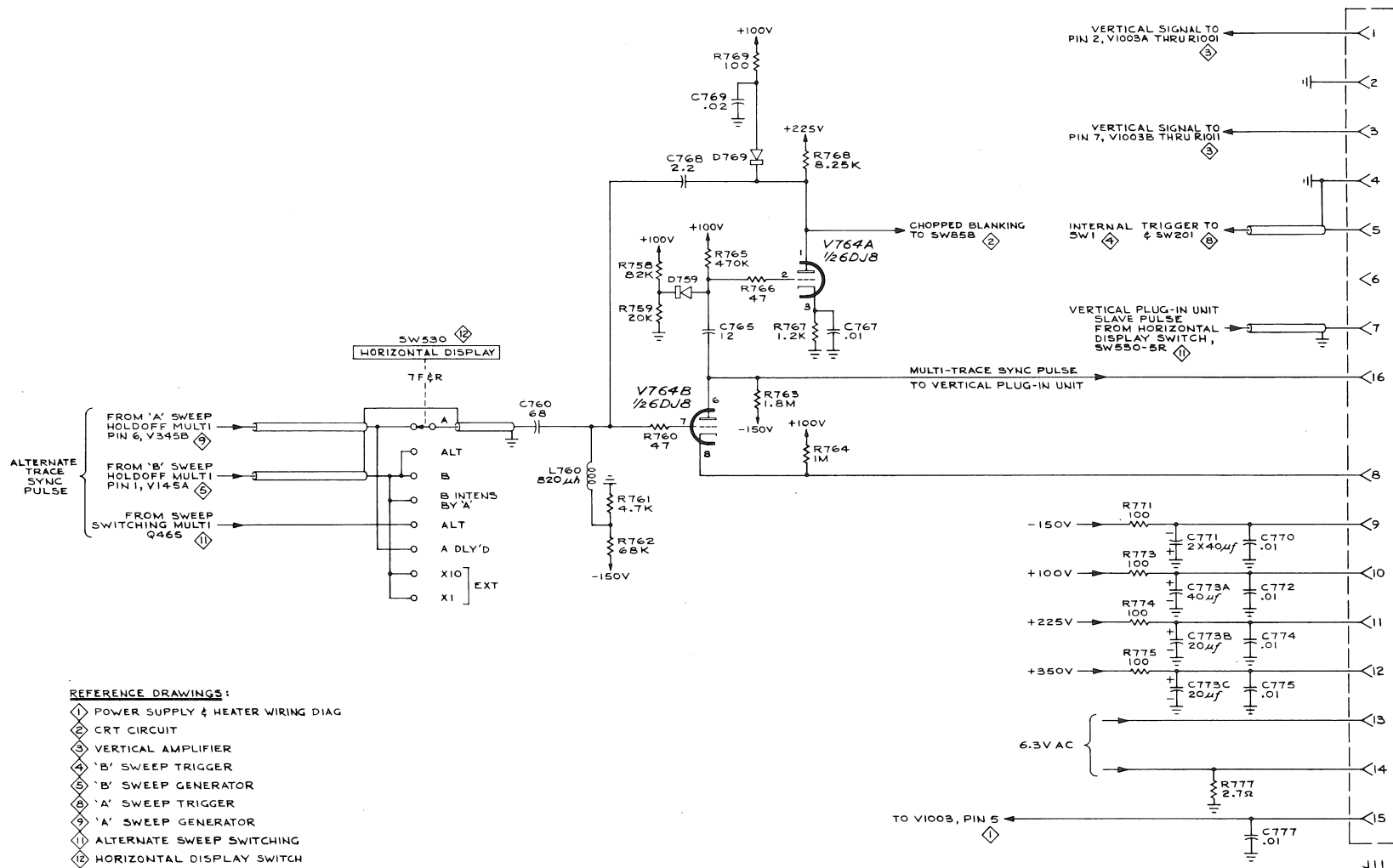
TYPE 547 OSCILLOSCOPE

A

HORIZONTAL DISPLAY SWITCH DON 264

C-547-0020





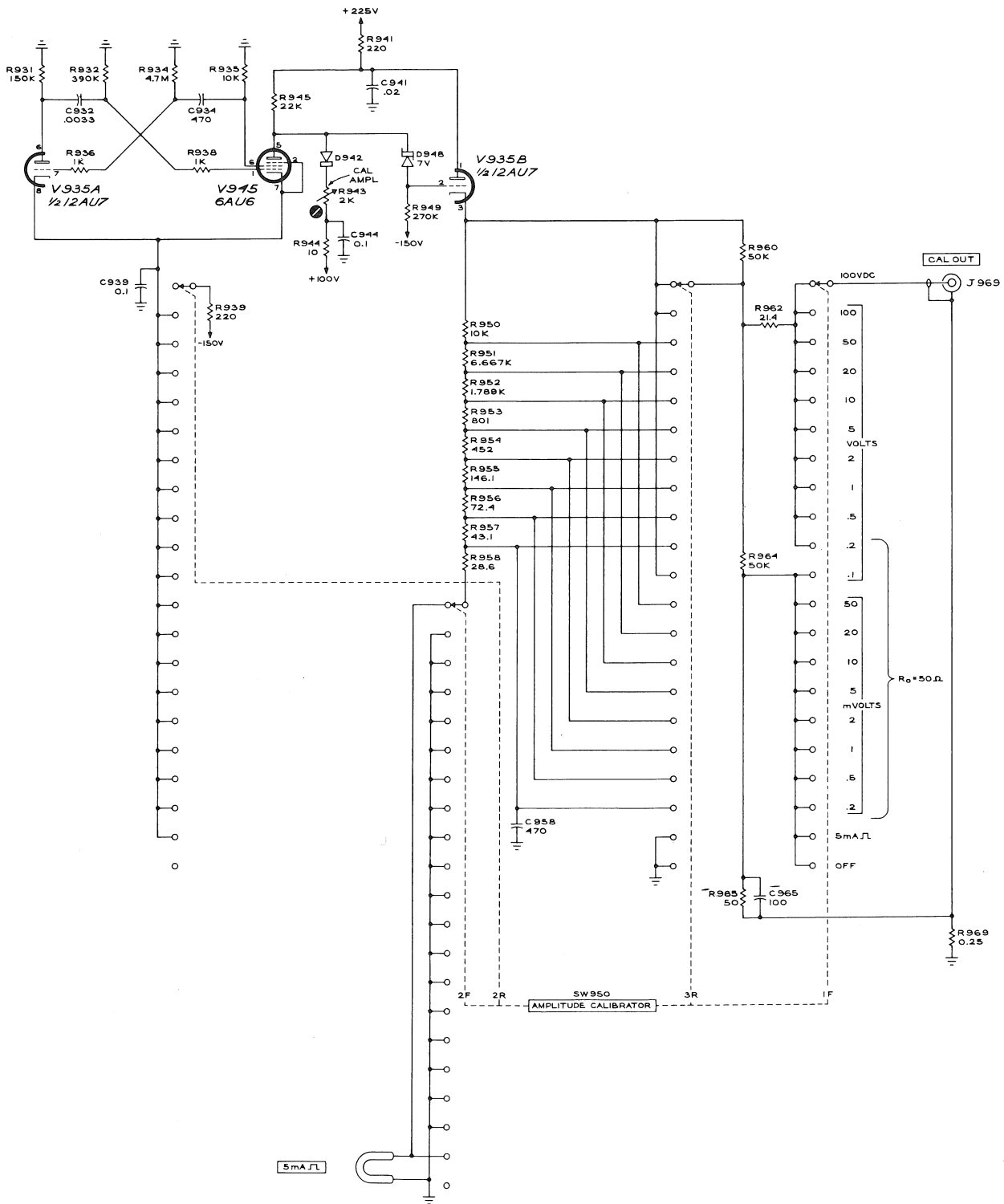
TYPE 547 OSCILLOSCOPE

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MRH
264
PLUG-IN CONNECTOR ④

C-547-0014

C-547-0012



TYPE 547 OSCILLOSCOPE

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CMD
264
CALIBRATOR 15