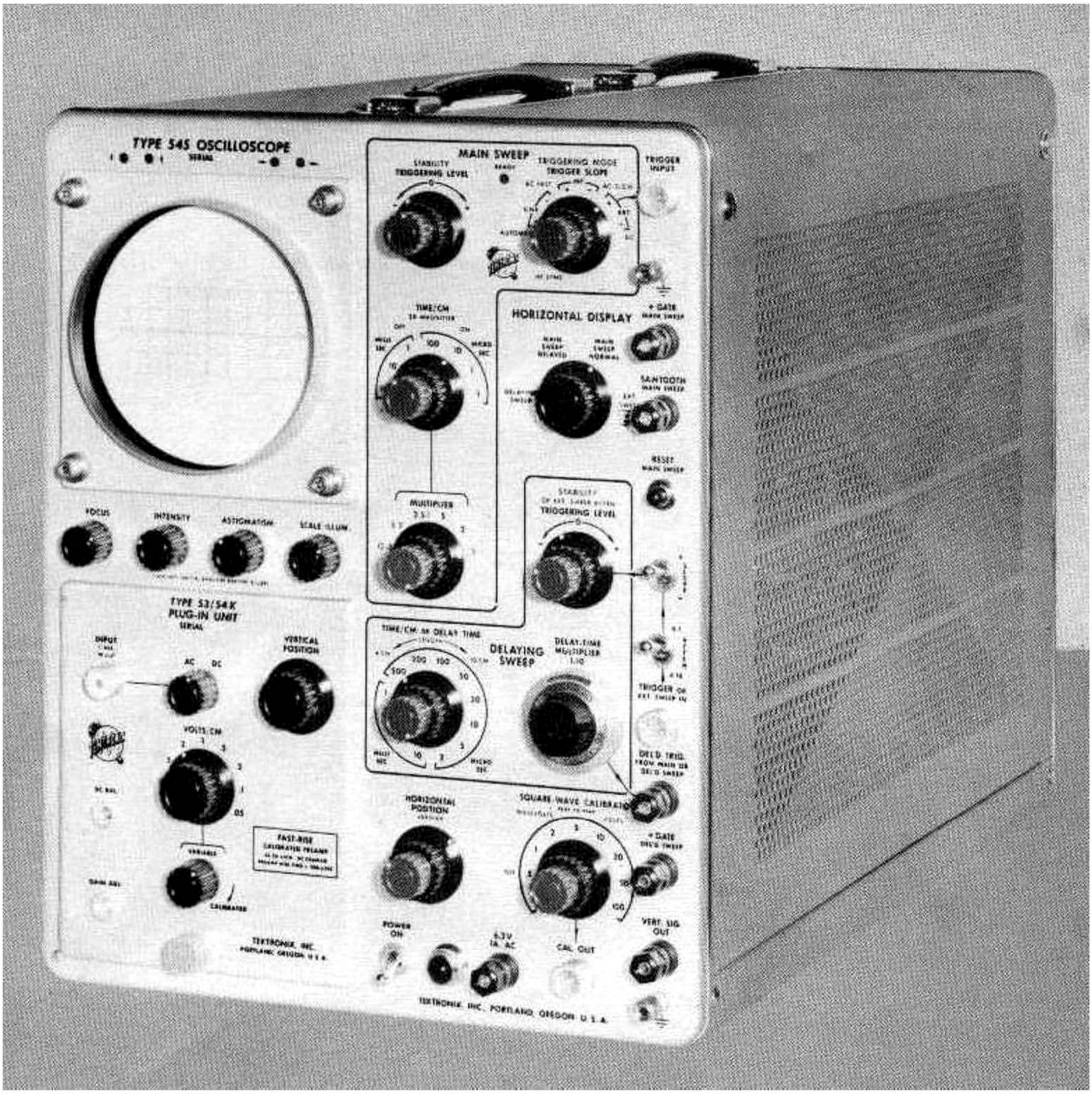


TEKTRONIX 545

SPECIFICATIONS

The Type 545 is a high-speed laboratory oscilloscope. Its fast rise time coupled with wide sweep-speed range and 10-kilovolt accelerating voltage opens the way to faster, easier analyses of fast-rising waveforms. Additional adaptability is provided by plug-in preamplifiers which extend its use to almost all laboratory-oscilloscope applications. Accurately calibrated sweep speeds and vertical-deflection sensitivity permit quantitative time and amplitude measurements to be made. Accurately-delayed triggered sweeps make possible the selection and detailed observation of minute portions of voltage waves.

Vertical-Deflection System

Output Amplifier

DC Coupled
Rise time — .01 μsec.

Delay Line

Balanced Network
Signal Delay — .2 μsec.

Linear Deflection — 4 cm.

With 53/54K Plug-In Unit (in 545)

Deflection Factor — .05 v/cm, ac or dc.

Rise Time — 12 millimicroseconds.

Frequency Response — DC to 30 mc.

2 cps to 30 mc, ac. Down 3 db ±½ db at 30 mc, 6 db at approximately 41 mc.

Step Attenuator

Nine positions, calibrated, from .05 v/cm to 20 v/cm, accurate within 3% when set on any one step.

Maximum Allowable Combined DC and Peak AC Voltage Input — 600 v.

Input Impedance — 1 megohm, 20 μμf.
With P410 probe — 10 megohms, 8 μμf.

Horizontal-Deflection System

Calibrated Sweeps

Twenty-four calibrated speeds from .1 μsec/cm to 5 sec/cm.

Accuracy — 3 per cent.

Continuously variable, uncalibrated, between ranges and to 12 sec/cm.

Calibrated Sweep Delay

Delay Time — 1 μsec to .1 sec, continuously variable.

Time Jitter — Less than 1 part in 20,000, untriggered; jitter free when triggered.

Range Accuracy — 2 per cent.
Incremental accuracy .2 per cent of full scale.

Magnifier

Magnification — 5 times to left and right of center. Extends fastest sweep speed to .02 μsec/cm.

Unblanking — DC coupled

Trigger Requirements

Internal — 2 mm of deflection.
External — .2 volts to 100 volts.
Frequency Range — dc to 30 mc.

Horizontal Input

Deflection Factor
Continuously variable, .2 v/cm to 20 v/cm.

Frequency Response
DC to 240 kc.

Other Characteristics

Cathode-Ray Tube

Type T54P2
P1, P7, and P11 phosphors optional.
Accelerating Potential — 10,000 volts.
Deflection Factor, Direct Connection
Vertical — 7 v/cm.
Horizontal — 30 v/cm.

Voltage Calibrator

Eighteen fixed voltages from .2 millivolts to 100 volts.

Accuracy — 3 per cent.

Waveform — square wave at about 1 kc.

Trigger-Rate Source — 10 cps to 40 kc, continuously variable, using free running delaying sweep as generator.

Output Waveforms Available

Positive gate of same duration as main sweep, 20 volts.

Positive gate of same duration as delaying sweep, 20 volts.

Main-sweep sawtooth waveform, 150 volts.

Delayed trigger pulse from main or delaying sweep, 5 volts.

A sample of the vertical signal with a limited passband, 20 cps to 4.5 mc.

Heater voltage, 6.3 v ac, 1 amp.

Beam Position Indicators

Indicator lights show direction of beam when it is off the screen.

Mechanical Specifications

Power Supply

Electronically regulated

Power Requirements — 105 to 125, or 210 to 250 v, 50-60 cycles, 545 watts with Type 53K/54K unit.

Ventilation — Filtered, forced air ventilation.

Finish — Photo-etched, anodized panel, blue wrinkle cabinet.

Dimensions — 24" long, 13" wide, 16¾" high.

Weight — 65 pounds.

Accessories Include:

2 — P410 probes

2 — Binding post adaptors

1 — Test lead

1 — Light filter

1 — Instruction manual

CIRCUIT DESCRIPTION

BLOCK DIAGRAM

The Block Diagram shows interconnections of the functional parts of the oscilloscope, except the power supplies. Functions of the switches are shown instead of their actual connections.

Vertical Amplifier

Plug-In Preamplifiers

In the upper left of the Block Diagram is shown the vertical-deflection system. The block labeled "Plug-Ins" represents one of the plug-in preamplifiers available. Connections for power in and signal out are made through a multiple-contact mating plug and socket. Output from these units is push-pull at low impedance.

Main-Unit Amplifier

The main-unit amplifier amplifies the signal and drives the delay line which terminates in the vertical deflection plates. The trigger pickoff circuits obtain a sample of the vertical signal for triggering the sweep.

Delay Line

The balanced, 50-section delay line adds .2 microseconds of delay to the signal so the sweep circuits will have time to get the cathode-ray spot unblanked and sweeping before the signal reaches the vertical deflection plates.

Trigger Cathode Followers

The trigger signal from the main-unit amplifier passes through two cathode followers. The first applies the signal at low impedance to the trigger amplifier and the second connects to the front-panel **VERT. SIG. OUT** binding post.

Main Sweep

Trigger Phase Inverter

This stage provides either in-phase or inverted output so as to provide negative-going output for either negative-going or positive-going input signals.

Trigger Shaper

The trigger-shaper makes a sharp pulse from the trigger signal at a time during the sloping part of the trigger signal determined by the setting of the triggering-level control. A sharpened negative-going pulse triggers the multivibrator.

Multivibrator

The multivibrator turns on the sweep generator and generates the cr-tube unblanking pulse when it is switched from its quiescent state. The sharp negative-going trigger signal from the trigger-shaper circuit trips the multivibrator, which thereafter stays in the second state until the sweep generator reverts it to its quiescent state.

Stability and Delayed-Trigger CF

When the main-sweep-normal function is in operation this circuit adjusts the dc level of the input grid of the gating multivibrator. When the delayed-trigger function is in operation the circuit sets the dc level and also amplifies the delayed trigger to trigger the multivibrator or sets a dc pedestal that places the multivibrator input grid within range of the main-sweep trigger signals.

Sweep Generator

The sweep generator is a Miller integrator that produces a positive-going sawtooth about 150 volts peak to peak. The sweep generator turns itself off when it reaches a prescribed level determined by the sweep-length control, by transmitting a signal through the trigger-holdoff circuits to the multivibrator.

Trigger Holdoff

The trigger-holdoff circuit transmits the sweep turn-off signal to the multivibrator but briefly holds off subsequent trigger signals from starting the sweep again until all parts of the circuit have reached their quiescent states.

Sweep Amplifier

The sweep amplifier converts the sawtooth output of the sweep generator into push-pull output at low impedance at the level required to sweep the beam across the cr-tube screen. The amplifier gain can be increased by a factor of five for sweep magnification. The horizontal-positioning control operates on this stage.

Delaying Sweep

The delaying sweep has essentially the same circuit elements as the main sweep. The phase inverter selects in-phase or inverted signals by means of a toggle switch. The trigger-shaper stage makes sharp pulses that trigger the multivibrator. The multivibrator turns on the sweep generator and is reverted by the sweep generator through a holdoff circuit.

Unblanking

Each multivibrator generates a positive unblanking pulse at the same time that it turns on the sweep generator. The main-sweep pulse is several volts higher than the delaying-sweep pulse and therefore brightens the trace more than the delaying sweep pulse. The pulses are transmitted to the crt grid by separate cathode followers with the same cathode resistor.

External Sweep Amplifier

The external-sweep amplifier uses the same tubes as the delayed-sweep trigger-inverter stage. One position of the **HORIZONTAL DISPLAY SWITCH** arranges the circuits so the amplified signal is connected to the sweep-output amplifier. A ten-to-one fixed attenuator and a continuous control of amplifier gain provide 100-to-1 adjustment of horizontal-deflection sensitivity.

Calibrator

The calibrator has no internal connection to the vertical amplifier system. It consists of a symmetrical multivibrator with a cathode-follower output tube whose cathode resistor is a calibrated voltage divider.

VERTICAL DEFLECTION SYSTEM

General

The vertical amplifier of the Type 545 Oscilloscope has separate preamplifier units that can be plugged into the main unit. These units provide a variety of passbands and sensitivities and allow for future developments in preamplifiers.

The plug-in units develop balanced push-pull output which is maintained push pull throughout the remainder of the amplifier. The units contain sensitivity adjustments and positioning controls.

Signal connections to the vertical amplifier in the main unit are made by means of terminals in a mating multiple-contact plug and socket. Power connections from the main unit are made through other connectors on the same plug-and-socket assembly.

Type 53/54K Preamplifier

The Type 53/54K preamp is capable of utilizing the full 30-mc pass band of the main-unit amplifier. It includes an input attenuator and a vertical positioning control. Power for all circuits as well as the tube heaters is obtained from the main-unit regulated dc supplies.

Main-Unit Input Stage

Signal input from the preamp is connected through terminals 1 and 3 to the grids of input amplifiers V1052B and V1040B. The cathodes of these two tubes are connected together through the degenerative network, R1026, R1027 and R1028. R1027 labeled GAIN ADJ. is variable to allow the amplifier gain to be varied over a small range. L1022 and L1041 provide series peaking and L1021 and L1042 provide shunt peaking for the stage. Triodes V1050A and V1052A provide the low impedance necessary for driving the distributed-amplifier grid line.

Beam-Position Indicators

Triodes V1025A and V1040A have as their plate loads neon glow lamps B1010 and B1014 across 1-megohm resistors. When the trace is centered, the plate current is insufficient to ignite these lamps, but as the trace is positioned off the screen vertically the current through one triode will increase causing the corresponding lamp to glow showing which way the trace is off the screen.

Trigger Pickoff

The trigger pickoff tubes, V1060 and V1066, convert the push-pull vertical signal on the distributed-amplifier grid lines to single ended output without disrupting the balanced configuration of the grid lines. The trigger cathode follower supplies the amplified vertical signal at low impedance to the oscilloscope trigger circuits and to the vertical-signal-out cathode follower. This cathode follower applies a sample of the vertical signal, somewhat limited in pass band, to the front-panel binding post labeled **VERT. SIG. OUT.**

DC-Shift Compensation

DC-shift compensation is accomplished in two ways and corrects for two different time constants. The series combination of R1080 and C1045B on plate line L1080, and R1084 and C1050B on plate line L1083, lowers the termination resistance of these lines to all but the very low frequencies. They provide a time constant which corrects for the initial dc shift in the amplifier. The second time constant is corrected by R1045 and C1045A and R1050 and C1050A. These rc networks have a negligible loading effect on the distributed-amplifier plate lines, but provide low-frequency positive feedback to the input-amplifier plates. This feedback corrects for the longer-time-constant dc shift. R1059, labeled DC SHIFT COMP. permits the amount of compensation to be adjusted to accommodate tube differences.

Distributed Amplifier

The output amplifier is a six-section, balanced, distributed amplifier. The grid lines are driven by V1050A and V1052A through rc frequency-compensating networks. The plate lines, L1080 and L1083, drive the delay line directly. Each section of the plate lines is tuned for optimum response to a square wave by trimmers connected line to line.

Termination Network

Unless the plate lines are terminated at the reverse end with a resistance equal to their characteristic impedance, signals traveling the reverse direction down the line will be reflected and appear in the output. Since resistors are not available, in a suitable power rating, which appear resistive over the wide pass band of the Type 545, an adjustable terminating network is used. The coils, L1070 and L1071, are wound with resistance wire and have a total resistance of 595 ohms. Each section has a characteristic impedance which is approximately equal to the impedance of the plate lines less the series dc resistance between it and the plate lines.

Calibrator

The calibrator is a symmetrical multivibrator with V670A and V670B connected so as to turn cathode follower V246A on and off as it oscillates. During the negative pulse at multivibrator V670A, the grid of the cathode follower is driven well below cutoff, so the cathode is at ground voltage. During the positive pulse at the multivibrator the plate is cut off and rests slightly below +100 volts. The voltage of the plate during cutoff is determined by the setting of R679, part of a divider between +100 volts and ground. R679 is a screwdriver adjustment labeled CAL. ADJ. Cathodes of the multivibrator are returned to —150 volts. The multivibrator frequency is about one kilocycle.

Cathode follower V246A has a tapped calibrated voltage divider for its cathode resistor. When the CAL. ADJ control is properly set, the cathode-follower cathode is at +100 volts when V670A is cut off. Taps on the divider divide the 100 volts down to 50, 20, 10, 5, 2, 1, .5 and .2 volts. A second divider with a division ratio of 1000 to 1, can be switched in if desired to divide these voltages into millivolts. C682 from the cathode to ground corrects a slight overshoot. No internal connection from the calibrator to the vertical-deflection circuits is provided.

MAIN-SWEEP CIRCUITS

Trigger Amplifier

The **TRIGGER SLOPE** switch selects the source of triggering voltage and arranges the trigger-amplifier input circuit to produce negative-going output for either negative-going or positive-going portions of the input signal.

The trigger amplifier, V8, is a grounded-grid cathode-coupled linear amplifier. A capacitor, C3, can be switched into the grid circuit to remove the dc component of the trigger signal. Output is always taken from the A-section plate, but the **TRIGGER SLOPE** selector connects either the A-section grid or the B-section grid to the input signal source. For positive-going signals, connection is made to the A-section grid, and for negative-going signals, connection is made to the B-section grid, and in each case the opposite grid is connected to an adjustable dc bias source, adjustable by means of the **TRIGGERING LEVEL** control. R14, adjusts the bias on one half or the other of V8 to adjust the dc level of the A-section plate output. The dc level of the plate output is important to the circuit operation in three of the five positions of the **TRIGGERING MODE** switch because in these three switch positions the input grid to the trigger shaper stage, V20A, is dc coupled to the plate of V8. The effect of the dc level is shown in a later paragraph.

Triggering Mode Switch

The **TRIGGERING MODE** switch, SW5, has five positions marked in red in the upper right-hand corner of the instrument panel: **DC, AC SLOW, AC FAST, AUTOMATIC,** and **HF SYNC.** This switch arranges the circuits of the trigger-amplifier and trigger-shaping stages to accomodate the five types of triggering.

DC, AC Slow and AC Fast

When the **TRIGGERING MODE** switch is in the **DC** position, the triggering signal is direct coupled through the trigger amplifier so that the dc component of the signal is applied to the trigger shaper. In the **AC SLOW** position, C3 removes the dc component of the signal, and in the **AC FAST** position, C4 and R6 form an rc filter to remove the low-frequency component of the triggering signal and allow fast recovery of the trigger circuits in the presence of dc level changes.

In these three positions, the trigger shaper, V20, is connected as a bistable multivibrator. In the quiescent state between triggers, the pentode section is conducting and its plate is therefore down. The grid of the triode section is dc coupled to the pentode-section plate through divider, R34, R35, R36, which holds the triode-section grid below plate-current cutoff. The negative-going trigger signal at the pentode grid raises the pentode plate which carries the triode grid positive into plate-current conduction. This also raises the triode cathode which is coupled to the pentode cathode through C28, R28, so that current is further reduced in the pentode, and the pentode cuts off. The transition is made very rapidly, regardless of how slowly the pentode grid signal falls. R28, connected between the two cathodes, is adjustable so that the trigger sensitivity can be adjusted. This is a screwdriver control marked SENSITIVITY on the chassis. No cathode current flows from the cathode not conducting through R28 when the trigger shaper is in either stable condition, so its effect is to lower the cathode voltage of the tube not conducting. For example, when the triode section is not conducting and its grid is below its cathode by the amount determined by plate current through R24, its cathode is below the cathode of the pentode section. R28, R27 for a voltage divider that places the triode cathode about two volts lower than the pentode cathode. This places the triode grid and cathode two volts closer together. The larger R28 becomes, the closer to conduction the triode will be. Increasing R28 therefore increases trigger sensitivity.

The steep negative-going step at the plate of the triode section is differentiated in an rc circuit, including C58 shown in the sweep diagram, with a time constant of about a tenth microsecond, and the sharpened pulse trips the multivibrator. The circuit will respond to trigger signals with a frequency up to 2 mc.

The **TRIGGERING LEVEL** control, R14, adds a bias to the plate-output signal of the inverter stage, V8. This changes the level of the cathode of the shaper stage, V20, and therefore changes the level on the triggering signal that must be reached to return the shaper-stage cathode to the transition point. For example, to adjust the triggering level so that triggering will occur at a point four volts positive on the positive-going portion of a 10-volt peak-to-peak trigger-input signal, the triggering-level bias would therefore rise about 20 volts. Positive-going input would become negative-going ouput, which starting 20 volts higher than the zero level, would need to drop twenty volts to return to the transition point and trigger the shaper stage.

Automatic

In the **AUTOMATIC** position of the TRIGtode section of trigger-shaper V20, drives the grid **GERING MODE** switch, the plate of the penof the triode section just as it does in the **AC SLOW** position. But in addition, it also drives its own grid through R30, a high resistance of several megohms.

When the transition takes place and the plate of the pentode rises, for example, the triode grid also rises carrying with it the right-hand end of R30. The left-hand end of R30 is connected to the pentode grid through R21. The time constant of the rc circuit between the triode grid and ac ground through C20, R30 and R21, is of such length that it takes about .01 seconds for the pentode grid to rise exponentially from its starting point below cutoff to a point where plate current can flow. During the .01-second period, the pentode grid rises, but the triode grid remains at a constant voltage until the next transition, when pentode plate current begins to flow.

When pentode plate current flows, the pentode plate drops, forcing the triode grid down, and thus the right-hand end of R30 is forced down. The left-hand end of R30 and the pentode grid immediately begin to drop exponentially toward pentode cutoff. When the pentode grid reaches cutoff again it has completed one cycle of the approximately 50-cycle sawtooth. The range of pentode grid voltage between pentode cutoff and triode cutoff is about six volts for the **AUTOMATIC** circuit. This is increased from about ¼ volt for the **DC** and **AC SLOW** circuit connections by addition of R32 to the plate load of the pentode.

Since the pentode grid is never more than six volts from cutoff, a trigger signal with a peak-to-peak voltage of six volts or more can drive the grid to cutoff at any time during the negative-going excursion and produce a trigger output. Smaller trigger signals can also trigger the shaper but only if they occur at a time when the grid is within their peak voltage of cutoff. The duty cycles of operation of the sweep is somewhat reduced therefore with smaller trigger signals.

This circuit configuration is useful because with it the sweep can be synchronized with repetitive signals over a wide range of frequencies without readjustment. When not triggered externally, the sweep continues at a fifty-cycle rate, and in the absence of any vertical signal, generates a base line that shows that the oscilloscope is adjusted so as to display any signal that might be connected to the vertical-deflection system.

HF Sync

When the **TRIGGERING MODE** switch is in the **HF SYNC** position, the trigger-amplifier and trigger-shaper stages are bypassed and the trigger signal is applied directly to the sweep multivibrator. In this position the **STABILITY** control is set so the sweep multivibrator free runs. The trigger signal is superimposed on the negative-going trigger-holdoff waveform at the grid of V58A and will cause the multivibrator to synchronize at a submultiple of the triggering-signal frequency. This circuit is suitable for signals in excess of five megacycles.

Multivibrator

The dc-coupled multivibrator, shown in the sweep generator diagram, turns on the sweep generator upon receipt of a negative trigger from the trigger shaper, and holds off subsequent trigger signals until after the sweep is completed. The multivibrator consists of V58 and V70 with both common-cathode and plate-to-grid coupling. Plate-to-grid coupling is by means of a cathode follower. V58 is the positive-going half of the multivibrator, which in the quiescent state is conducting. V70 is the negative-going half of the multivibrator which in the quiescent state is cut off.

In the quiescent state V58A is conducting and its plate is down. Cathode-follower V58B holds the grid of V70 below cutoff through voltage divider R65, R66. The plate load of V58A includes L61 to speed the rise of plate voltage, and R62 which raises the plate voltage a few volts above +100 when the plate is cut off. The use of cathode-follower V58B, between V58A plate and V70 grid, isolates the positive-going plate from the capacitances of the various loads that require a positive-going pulse, and thereby permits a steeper positive step. The voltage divider in the cathode of the cathode follower is compensated by C65 for the shunt capacitance to ground of the grid of V70.

While V70 is cut off its plate rests at —3.2 volts, because of diode current in V80A and V80B, which flows through R69. When the negative trigger pulse from the trigger-shaper stage reaches the grid of V58A, an amplified positive pulse at V58A plate is coupled through cathode follower V58B to the grid of V70. This raises the grid of V70 above cutoff and plate current raises the common-cathode voltage which further raises the plate voltage of V58A. The biases and plate loads are adjusted so that when V58A is conducting, the grid of V70 is held below cut off, and when V70 is conducting, the cathode of V58A is held above cutoff.

There are thus two stable states, in either of which the multivibrator will remain until a signal of the proper polarity and amplitude at the grid of V58A switches it to the other state. To return the multivibrator back to the quiescent state with V58A conducting, a positive voltage is required at the grid of V58A which is high enough to cause plate current to flow. The positive pulse for returning the multivibrator to its quiescent state is supplied from the sweep generator when it has completed its sweep.

Stability Cathode Follower

The **STABILITY** control, R43, adjusts the grid voltage of cathode follower V43A, which in turn determines the quiescent grid voltage of positive multivibrator V58A at about —40 volts, just above the threshold of triggering. Holdoff cathode follower V54A, and delay trigger cathode follower V37B, are normally cut off and do not contribute to the quiescent level of V58A grid.

Sweep Generator

The sweep generator is a Miller integrator circuit. The circuit includes the Miller tube V90, timing capacitor C99, timing resistor R99, cathode follower V85 and disconnect diodes V80A and V80B. In the quiescent state between sweeps, the plates of diodes V80A and V80B rest at —3.2 volts. Very little current flows through V80A to the grid circuit of V90, and V90 grid therefore rests at about —3.3 volts. More current flows through V80B so that its cathode is at about —5 volts. The timing capacitor C99, which is connected between these two points, therefore has only about 1.7 volts of charge.

The grid of cathode-follower V85 is connected to the plate of Miller tube V90 through neon glow tube B95. The grid of V90 therefore follows the plate changes of V90 but remains 55 volts below the plate. C95, R95 is a network around B95 to improve the rise time.

The —3.3-volt bias on the grid of V90 places the tube in the class-A region of its operating characteristic, where the plate-to-cathode voltage is inversely proportional to the grid-to-cathode voltage. The negative step from the multivibrator to the plates of diodes V80A and V80B lowers the plates below their cathodes, and they no longer conduct. The Miller-tube grid, and plate-coupling cathode follower, are thus released to seek their own voltage levels. The grid of Miller tube V90, which is returned to —150 volts through R99, starts negative. When the grid starts negative the plate starts positive carrying cathode-follower V85 grid and cathode capacitor C99 positive which thus tends to prevent the Miller tube grid from going negative.

The gain of the Miller tube as a class-A amplifier is so high that the plate signal coupled back through charging capacitor C99 keeps the grid voltage constant within a fraction of a volt. Meanwhile, C99 is charging with current flowing through R99 from the —150-volt bus. Since the grid of V90 remains constant within a small fraction of a volt, the current through R99 remains constant, and C99 thus charges at a constant rate. As C99 charges, the voltage of the upper end therefore rises linearly. Any departure from a linear rise of the cathode of cathode-follower coupled V85 will result in a change in grid voltage in the direction that will produce a change in plate voltage the right amount to correct the departure difference. The capacitor C96 helps to maintain a linear voltage rise at the faster sweeps.

The linear rise of the cathode of V85 is used as the sweep sawtooth. Charging capacitor C99 is selected by means of a step switch, SW55, labeled **TIME/CM** on the front panel. Charging resistor R99 is also selected by a step switch so that both the size of the capacitor being charged and the current charging the capacitor can be selected to cover a wide range of sawtooth slopes.

The cathode of V85 continues to rise linearly until a positive step from multivibrator V70 returns the disconnect-diode plates back to their quiescent state which raises the Miller tube grid. When the Miller tube grid rises, its plate drops carrying cathode-follower V85 with it until its cathode clamps again through V80B at the quiescent level of —3.3 volts.

Sweep Length

The positive step from multivibrator V70 occurs when a positive step is delivered to the grid of multivibrator V58A. The sawtooth to the multivibrator is delivered through cathode followers V40A and V55B from a tap on the cathode-load resistor of coupling cathode follower V85. This tap is adjustable by means of potentiometer R88, labeled SWEEP LENGTH on the chassis, a screwdriver adjustment. When the voltage of this tap is properly set the sawtooth will terminate when the spot has passed the right-hand limit of the graticule. C54 on the grid of V54A retards the return of V58A grid to the quiescent level after the passage of the positive pulse. This holds off any trigger signals from retriggering the multivibrator until all other capacitances in the circuit have had time to reach their quiescent voltage levels. Proper sizes of capacitor C54 are switched with the **TIME/CM** switch so that more recovery time is permitted for the slower sweeps and the least necessary recovery time is allowed for the faster sweeps.

Sync Amplifier

Synchronizing pulses for plug-in units under development are supplied by V78. When the negative multivibrator, V70, generates its positive plate step, it also generates a sharp differentiated positive trigger voltage at its screen, because of L72 and damping resistor R72 which connect the screen to +100 volts. The positive screen trigger pulse is coupled to the grid of V78 through C78. Grid bias of about —7 volts is set by divider R78, R79, between ground and —150 volts. Plate voltage and cathode return circuits are completed in the plug-in unit.

DELAYING-SWEEP CIRCUITS

Horizontal-Display Switch

The **HORIZONTAL DISPLAY** switch has seven sections that select the source of signal to the sweep amplifier and unblanking circuits, and connect the delayed trigger to the main-sweep circuits.

In the **MAIN SWEEP NORMAL** position, this switch connects the main-sweep generator to the sweep amplifier, grounds the grid of the delaying-sweep unblanking cathode follower and supplies main-sweep sawtooth to the delay pickoff.

In the **DELAYING SWEEP** position the switch connects the delaying-sweep generator to the sweep amplifier and to the delay-pickoff comparator circuit, V195B, and connects the delaying-sweep gate to the unblanking mixer. Both the main- and the delaying-sweep unblanking signals unblank the cathode-ray tube.

In the **MAIN SWEEP DELAYED** position of the switch the delaying-sweep is disconnected from the sweep amplifier, its unblanking mixer grid is grounded, the main-sweep generator is connected to the sweep amplifier and unblanking mixer, and the main-sweep trigger input is connected to the delay pickoff.

In the **EXT. SWEEP** position the switch rearranges the delaying-sweep trigger shaper into a cathode follower and connects its output to the sweep-amplifier input. It also biases off the delay-trigger circuit and the delaying-sweep multivibrator, and supplies a positive dc bias to the unblanking circuit to hold the cathode-ray tube unblanked.

Delayed-Trigger Amplifier

The delayed-trigger from the delay-pickoff circuit, described in a later paragraph, is amplified in V37A, and applied to the grid of delayed-trigger cathode follower V37B through compensated voltage-divider C50, R50, R51. The cathode voltage of V37B is determined by current through R53 which is returned to —150 volts.

Current through R53 can be contributed by cathode current through any of three cathode followers, V43A, the stability tube; V54A, the holdoff tube; or V37B, the delayed-trigger tube, depending on the position of the **HORIZONTAL DISPLAY** switch, the setting of the **STABILITY** control, and the stage of the trigger-and-sweep sequence.

With the **MAIN SWEEP NORMAL** position the plates of V37A and V43A are disconnected and screen current furnishes the cathode current of V43A. With the switch in the **MAIN SWEEP DELAYED** and the **DELAYING SWEEP** positions plate voltage is connected both to V37A and V43A. The plate of V43A is connected to the grid of V37B through compensated voltage divider C50, R50, R51, in such a way that V43A and V37B become a bistable multivibrator.

In the quiescent state V37B conducts and holds the common-cathode voltage so high V43A is cut off. A positive pulse at the grid of V37A will therefore become a negative pulse at its plate. The negative pulse drives the grid of V37B down below cutoff, and the multivibrator assumes the second stable state in which V43A conducts and V37B is cut off. The cathode level in this state can be set by means of the bias voltage determined by the setting of the **STABILITY** control.

By setting the cathode level past the threshold of triggering for the sweep-gating multivibrator, a sweep will not be triggered, but the grid will be placed close enough to triggering that a negative trigger pulse from the main-sweep trigger circuit will trigger a sweep.

Two methods of delayed triggering are thus available. The first method in which the delayed trigger actually triggers the sweep is the ordinary system. The second method permits the sweep to be triggered actually from the delayed pulse you want to observe. The delayed trigger opens up the normal trigger channel that has been closed up to that time so as to hold off undesired triggers.

Delay Pickoff

The delay pickoff circuit is a sawtooth comparator circuit arranged to produce a positive output voltage at the time of pickoff. Before the pickoff time, V195B is cut off. Its cathode is tied to the cathode of V195A which is conducting and therefore determining the common-cathode voltage.

The common-cathode voltage is adjustable by means of R209, a 10-turn helical resistor, labeled **DELAY-TIME MULTIPLIER** on the front panel. V228A is a constant-current pentode supplying cathode current to the comparators from the —150-volt supply. This arrangement permits the cathode of V195A to follow its grid over a wide range with very little variation of cathode voltage.

Plate current through R205 therefore also remains very nearly constant while V195A is conducting, no matter at what voltage the grid is set by the **DELAY-TIME MULTIPLIER** control, R209. This is important because the plate voltage of V195A is required to hold the grid voltage of the shaper stage, V216A, near the level for triggering.

The positive-going delaying-sweep sawtooth raises the grid of non-conducting V195B toward its cathode voltage. When the grid rises past the cathode voltage set by the **DELAY-TIME MULTIPLIER** control, V195B conducts and V195A cuts off.

Delayed-Trigger Shaper

When V195A cuts off, because of conduction in V195B, its plate rises carrying the grid of trigger shaper V216A positive past its transition point. The trigger-shaper stage is regenerative so as to produce a fast transition, and the resulting positive step at the plate of V216B is differentiated through C228 and used to arm or to trigger the main-sweep circuits. The sharp differentiated pulse is transmitted to the succeeding circuits through cathode follower V228B.

Two internal screwdriver controls accessible from the right side through holes in the cabinet permit you to adjust the delay time more accurately if necessary so you can read centimeters of delay within a fraction of one per cent directly from the micrometer dial of the 10-turn **DELAY-TIME MULTIPLIER** control. R208 adjusts the total dc voltage across R209 so that each of the ten turns of this resistor positions the point of delay pickoff one centimeter of horizontal beam displacement. R195 sets the dc level of the delay sawtooth accurately so that the zero setting of the **DELAY-TIME MULTIPLIER** control corresponds to the start of the delaying sawtooth.

Reset Button

The main-sweep circuits can be adjusted to perform a single sweep when triggered and then be unresponsive to any further triggers. This circuitry is set up when the **HORIZONTAL DISPLAY** switch is in the **MAIN SWEEP DELAYED** position, and the delaying sweep is deactivated by turning the delaying-sweep **STABILITY** control counterclockwise.

The main-sweep multivibrator **STABILITY** control is set at the level where it would normally be for main-sweep-triggered operation, and the desired trigger-signal source is connected to the main-sweep triggering circuits.

With the **MAIN SWEEP DELAYED** setting of the switch, V43A and V37B form a bistable multivibrator when the main-sweep **STABILITY** control is adjusted as described in the previous paragraph. In the stable state that exists after completion of one sweep and before the **RESET** button is pressed, V37B is conducting and thereby determining the voltage level of the common-cathode circuits. This level is high enough to hold off V58A from triggering. The RESET control, SW235, shown on the delay-pickoff diagram, applies a negative pulse to V37B and turns it off, thereby switching multivibrator V43A, V37B, to its second stable state with V43A controlling the common cathode level. This level is lower and it places the grid of V58A within the region where it will trigger, if the **STABILITY** control has been properly set, and the next trigger signal will initiate a sweep. At the end of the sweep, holdoff cathode-follower V54A raises the common-cathode level up momentarily, thereby switching V37B on and V43A off again, and the circuit returns to its first stable state.

Ready Light

The ready light, B42, shows whether V43A is conducting. When V43A conducts it pulls down the grid of V43B and thereby raises the plate high enough to light the neon glow lamp.

When the ready light is glowing a single negative pulse at the main-sweep multivibrator grid, V58A, will trigger a single sweep and the circuit will thereafter be disarmed for subsequent triggers.

SWEEP AMPLIFIER

Amplifier

Input to the amplifier is selected by one of the positions of the **HORIZONTAL DISPLAY** switch, SW200. A cathode follower, V240B, feeds the selected signal to a second cathode follower, V240A, which in turn feeds a common-cathode, grounded-grid phase inverter, V265A and V272A. Gain of the phase-inverter stage can be adjusted by adjusting R266 and R270, labeled SWP. CAL. and MAG. GAIN on the chassis, which determine the degree of coupling between the two cathodes. Output from the phase-inverter stage is applied to the horizontal-deflection plates of the cathode-ray tube through cathode followers, V265B and V272B.

Magnifier

A degenerative circuit path through R259, R254 and R253, between the negative-going cathode follower, V265B, and the —150-volt bus, accurately determines the gain of the amplifier. This degenerative path can be disconnected by means of SW254A, labeled **5X MAGNIFIER, ON** and **OFF**, in red on the front panel. When the network is removed, the gain of the amplifier is increased by a factor of five for the magnified sweep. R266 and R270 between cathodes of the phase-inverter stage V265A and V272A are also switched by the **5X MAGNIFIER** switch, to permit the gains to be individually adjusted so as to keep the ratio of gains exactly five times for the two positions while permitting the spot speeds to be accomodated to the graticule. An internal screwdriver adjustment, R262, labeled SWEEP/MAG REGIS, adjusts the bias of the degeneration cathode follower so that it is the same for both switch positions. This permits the magnified and normal sweep traces to be kept in accurate register, so that the center portion of the normal sweep will be centered when magnified.

Gated CF Current Booster

Cathode current for cathode follower V265B which drives the negative-going, left-hand plate of the crt, is determined by the plate current of pentode V282. The pentode is used because its plate current remains nearly constant over a large range of plate voltage, so that the cathode-follower current is kept nearly constant even though its cathode voltage drops through a range of about 150 volts. For the fastest sweeps, the maximum permissible continuous current through these tubes is too small to discharge the capacitance of the crt deflection plate and its associated wiring at the required rate. To increase the current through these tubes to the required value, a positive, flat-topped pulse is applied to the grid of the pentode during the period of the sweep. The positive pulse is derived by differentiating the positive-going sawtooth, through an rc network. Its amplitude is thus proportional to sweep speed. For the fastest sweep, the tube current is several times normal, but at the reduced duty cycle of the sweep, is well within the average dissipation limit of the tubes.

Beam-Position Indicators

Two neon glow lamps, B292 and B293, connected across the deflection plates and biased slightly below the average dc voltage of the plates, indicate which direction the spot is off the screen if it cannot be seen. If either plate assumes a voltage much higher than the average voltage, the glow lamp connected to that plate will glow.

Positioning

Horizontal positioning of the trace is adjustable through cathode follower V246B which sets the dc grid voltage of input cathode follower

V240B. The grid voltage of the positioning cathode follower is determined by potentiometer R250, labeled **HORIZONTAL POSITION** on the front panel, and by R248, labeled **VERNIER** in red on the front panel, which will move the spot about one-fifth as far as R250.

External Sweep Amplifier

When the **HORIZONTAL DISPLAY** switch, SW200, is in the **EXT. SWEEP** position, the **EXT. SWEEP** connector connects to an auxiliary amplifier which uses the tubes and circuits of delaying-sweep phase inverters.

External-sweep signals are applied either to the grid of V113A or V113B, depending on the setting of **SLOPE** switch, SW113. For in-phase amplification the **SLOPE** switch should be switched to —, and the signal will be connected to V113A.

The signal applied to V113A grid is cathode coupled to V120A, which, with V120B, is a cathode-coupled, grounded-grid amplifier. Gain of this amplifier can be adjusted by varying R122 which determines the amount of cathode coupling. The two cathodes must be at the same dc voltage, or variation of R122 will change the dc level. R114 labeled EXT. AMPL. DC BAL. on the chassis can be adjusted so that the cathodes of V120A and V120B are at the same voltage.

Plate output from V120B is connected to the sweep amplifier through cathode follower V130A in the **EXT. SWEEP** position of the **HORIZONTAL DISPLAY** switch.

Note that the external sweep signal must not have a dc component of its own or the dc balance will be upset, and adjustment of the 10-1 gain control will position the trace horizontally.

POWER SUPPLY

Transformer

Plate and heater power for the main unit and the plug-ins is provided by a single power transformer, T700. The primary is wound with two equal 117-volt windings that can be connected either in parallel for 117-volt operation, or in series for 234-volt operation. The power supply will operate satisfactorily over the voltage ranges 105 to 125 volts and 210 to 250 volts, 50 to 60 cycles. The secondary contains five separate high-voltage windings and seven separate heater windings.

Rectifiers

The ac voltage from the high-voltage windings is rectified by bridge-connected full-wave dry-disk selenium rectifiers.

Regulation, —150-Volt Supply

All dc voltages furnished by the power supply are regulated either in the power supply or in the circuit it supplies. Reference voltage for the regulators is established by means of a gas-diode voltage stabilizer that determines the grid potential of a comparator amplifier, V712, in the —150-volt supply. The grid potential of V712A established by the gas diode is compared against the grid voltage of V712B. The grid voltage of V712B is obtained from a divider, R715, R716, R718, which divides down the voltage of the —150-volt bus being regulated. R716, labeled —150 ADJ on the chassis, is a screwdriver adjustment which determines the percentage of voltage division that appears at V712B, and thereby determines the total voltage across the divider.

The voltage difference between the two grids of V712 appears as an amplified error signal at V712B plate. The amplified error signal is further amplified in V700, which is dc connected to V712B plate and to the grids of series tubes, V725, V726, and V727.

The series tubes change their plate-to-cathode resistance according to their grid-to-cathode voltage. The dc-coupled amplified error signal at their grids controls their plate resistance so as to introduce a change of drop through the tubes in the right direction to correct any difference in voltage between the two grids of the comparator tube. C707 and C717 bypassing the dc-coupled dividers, increase the ac gain of the feedback loop and thereby reduce ripple.

C115 connected between the —150-volt bus and ground keeps the output impedance down at frequencies above cutoff for the regulator feedback amplifiers. The screen of V700 has a small amount of the ripple that exists ahead of the regulators connected to it through R278. The phase of the amplified ripple voltage that appears at the plate of V700 is such as to out-phase most of the ripple at the —150-volt bus. R724 bypassing the series tubes reduces the amount of load current through them.

+100-Volt Supply

The comparator tube in the +100-volt supply, V742, compares its grounded cathode to the tapped-down voltage of divider, R750, R751 connected between the —150-volt bus as a reference voltage and the +100-volt bus to be regulated. The tapped-down point is a volt or so below ground. The screen of V742 receives a sample of the ripple signal through R744 to provide an outphasing signal that reduces the output ripple at the +100-volt bus. High-frequency gain of the feedback loop is increased by C750, and C751A reduces the high-frequency output impedance.

+225-Volt Supply

Rectified ac from terminals 7 and 14 is added to the unregulated dc of the +100-volt supply to provide about 320 volts to the plate of series tube V748A. The comparator tube is V765 and an additional gain stage with V757 increases the feedback-loop gain. C770 and C763 increase the ac gain, and C751B provides low output impedance at high frequencies. Unregulated voltage taken from a point ahead of the series tube supplies the regulator for the cathode-ray tube supply. R762 reduces the load current through the series tube.

+350-Volt Supply

Rectified ac from terminals 5 and 10 of transformer T700 is added to the unregulated input to the +225-volt series tube, and applied to the plates of series tube V784. The comparator tube is V782. Screen injection of ripple voltage is used. C787 increases ac gain and C751C lowers high-frequency output impedance. R785 reduces load current through the series tube.

+500-Volt Supply

Rectified ac from terminals 20 and 21 of transformer T700 is added to the regulated side of the +350 supply, and applied to the plate of series tube V794. The comparator tube is V791 with screen injection of ripple. C797 increases ac loop gain, and C790B in series with C751C to ground, reduces output impedance at high frequencies. C795 reduces load current through the series tube.

Time-Delay Relay

A thermal-delay relay, K700, delays application of high voltage to the external circuits for about 25 seconds so that the heaters have time to get up to temperature. The dc current to the heaters of the plug-in units bypasses the regulator tube, V748B, through R749 during this period. If the ac circuit is momentarily broken the thermal-delay relay operates and again waits for 25 seconds after reapplication of the ac before completing the dc high-voltage circuit connection.

High-Voltage Supply

Accelerating voltages for the cathode-ray tube are obtained by rectifying a 60-kc high ac voltage produced by a vacuum-tube oscillator. V803 is the oscillator tube connected as a Hartley oscillator with the primary of transformer T801 as the tapped inductor, and C806 as the capacitor.

A voltage-tripler rectifier, consisting of V821, V822, V823, C821, C822, and C823, supplies about 8650 volts positive for the post-deflection accelerating anode of the cathode-ray tube.

High-Voltage Regulator

A sample of the cathode voltage is tapped off by means of R814, R812, and adjustable R811, and applied to the grid of comparator tube V810A. The cathode of V810A is connected to —150 volts, and the grid is compared to that voltage. The difference voltage is amplified in the comparator tube and amplified again in shunt-regulator tube V810B, whose plate voltage determines the screen voltage of oscillator V803.

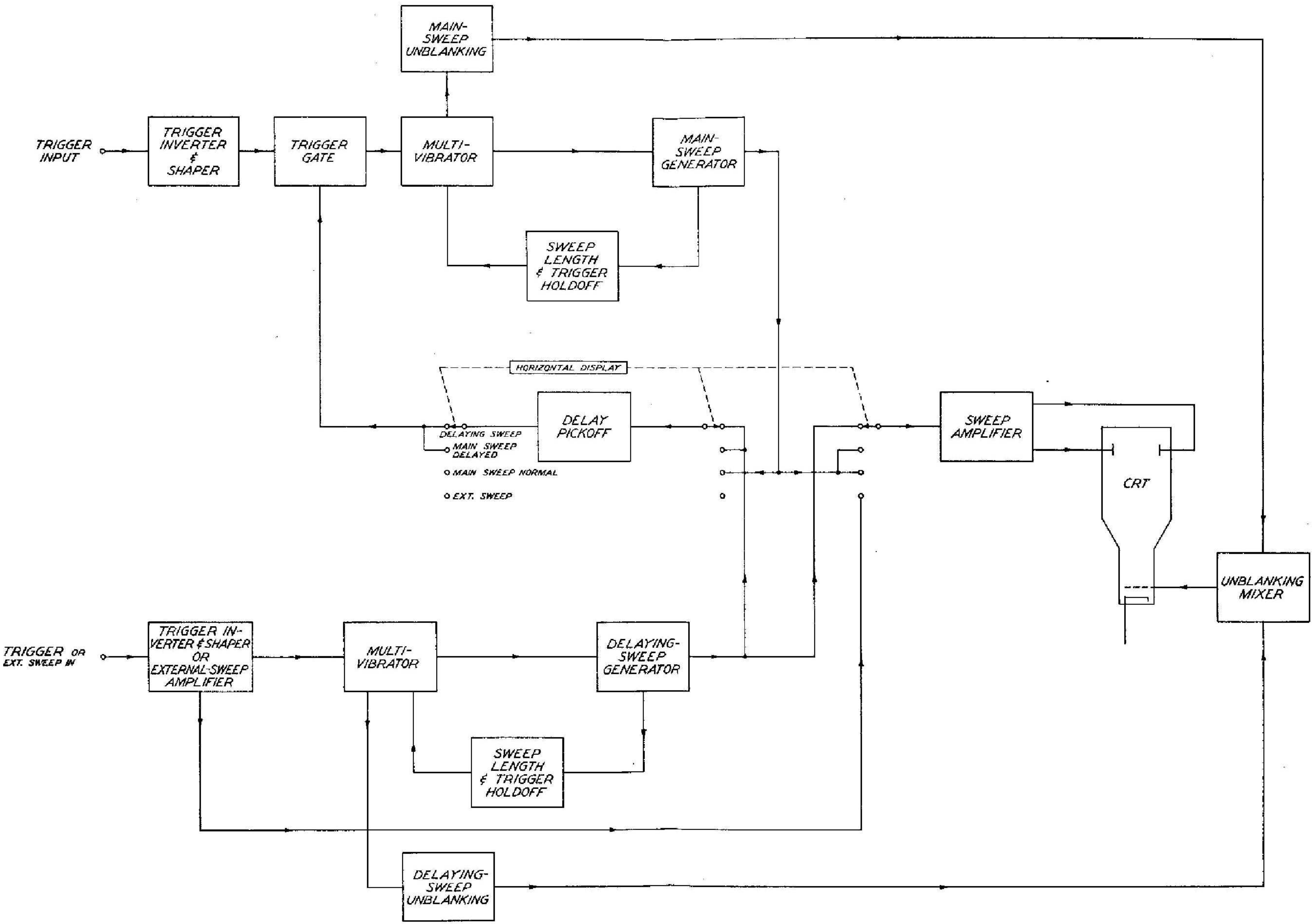
If, for example, the high voltage should become too high, it would make the grid of the comparator tube more negative with respect to its cathode. When the grid drops, the plate rises, thereby raising the grid of V810B. When its grid rises its plate drops, thereby dropping the screen voltage of the oscillator tube, and reducing the amplitude of oscillation. The reduction of primary voltage of T801 reduces the high voltage, thereby correcting the original departure. C814 at V810A grid reduces noise and hum.

Unblanking

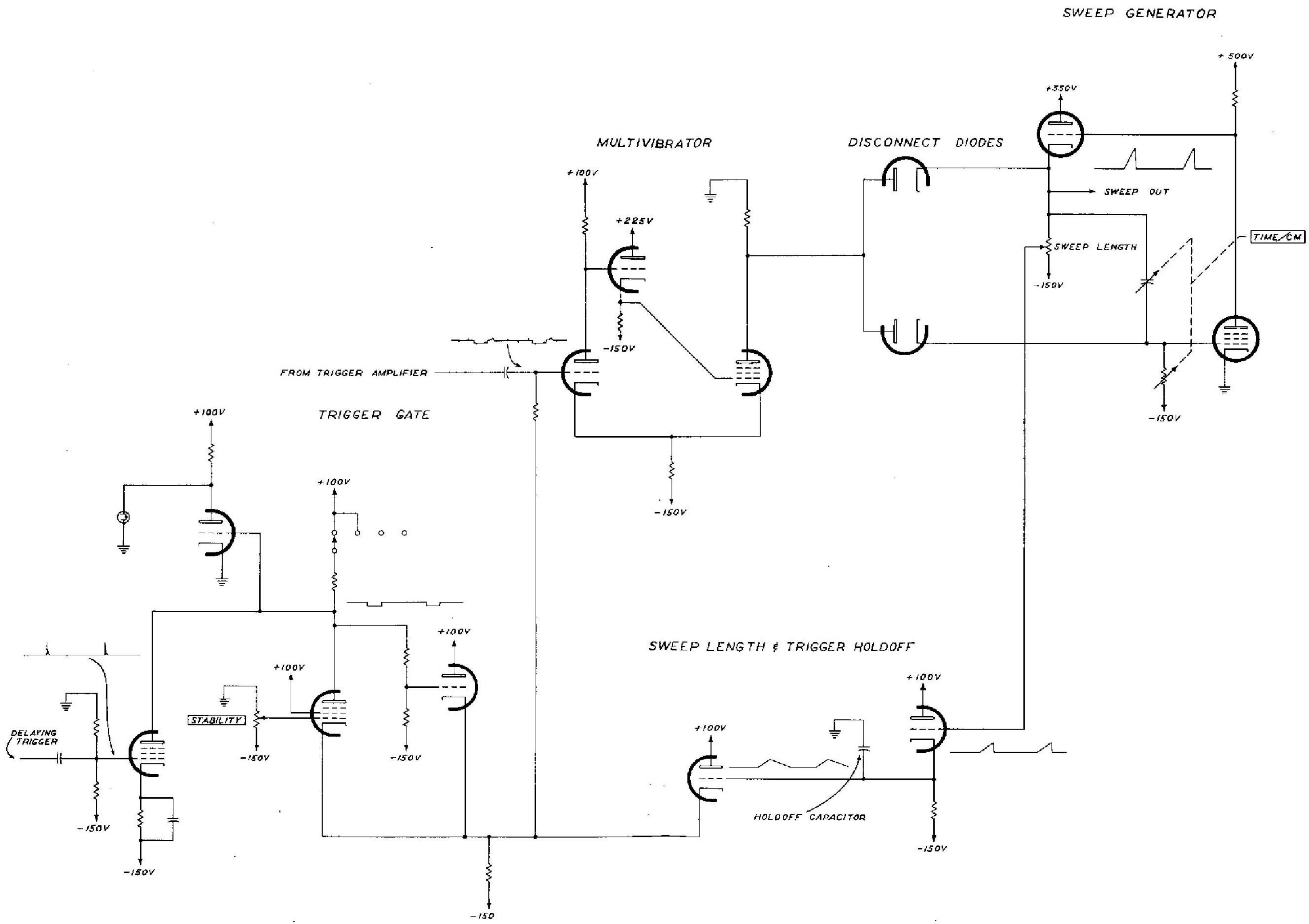
The control-grid voltage is produced by a winding and rectifier, V824, similar to the cathode supply, but insulated from it. The positive end of the control-grid supply is connected to the cathode of unblanking cathode-follower V54A, and the negative end at —1450 volts is connected to the control grid through potentiometer R831, labeled **INTENSITY** on the front panel. When the unblanking pulse is produced at the cathode of the unblanking cathode follower, it drives the whole grid-voltage supply with it, winding, filter, potentiometer, so that the same pulse appears at the cathode-ray tube grid 1550 volts below. Since this is a dc connection, the unblanking pulse may have any duration with no change in grid voltage. C834 transmits the leading edge of the unblanking pulse to reduce unblanking time for fast sweeps, and R834, R835, and R830, provide the right time constant to prevent overshoot.

CRT Geometry Adjust

The second-anode voltage required for best linearity at the extremes of deflection may vary somewhat between tubes. R861, a screwdriver control, labeled GEOM. ADJ. on the chassis, permits this voltage to be adjusted.



TYPE 545 OSCILLOSCOPE A SWEEP-CIRCUIT FUNCTIONAL BLOCK DIAGRAM 6-2-54 KF

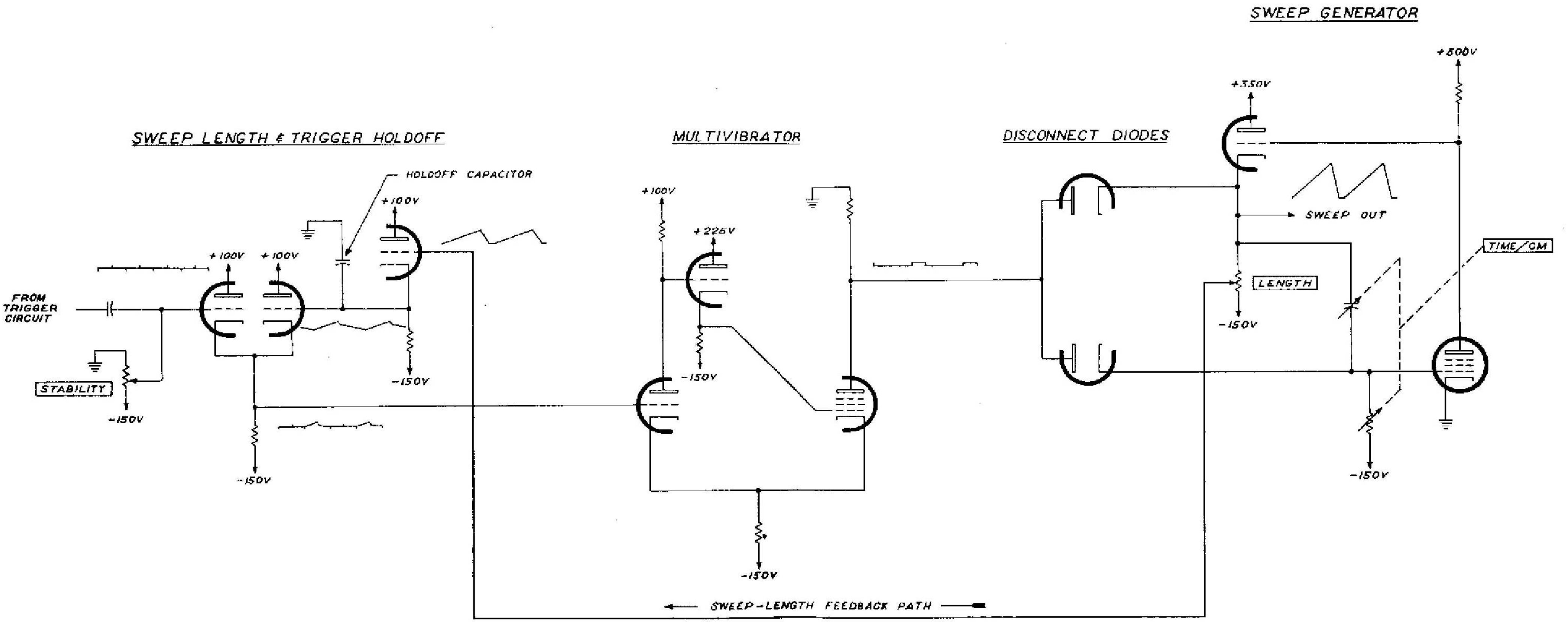


TYPE 545 OSCILLOSCOPE

A

SIMPLIFIED DIAGRAM
MAIN SWEEP

3-18-54
KF

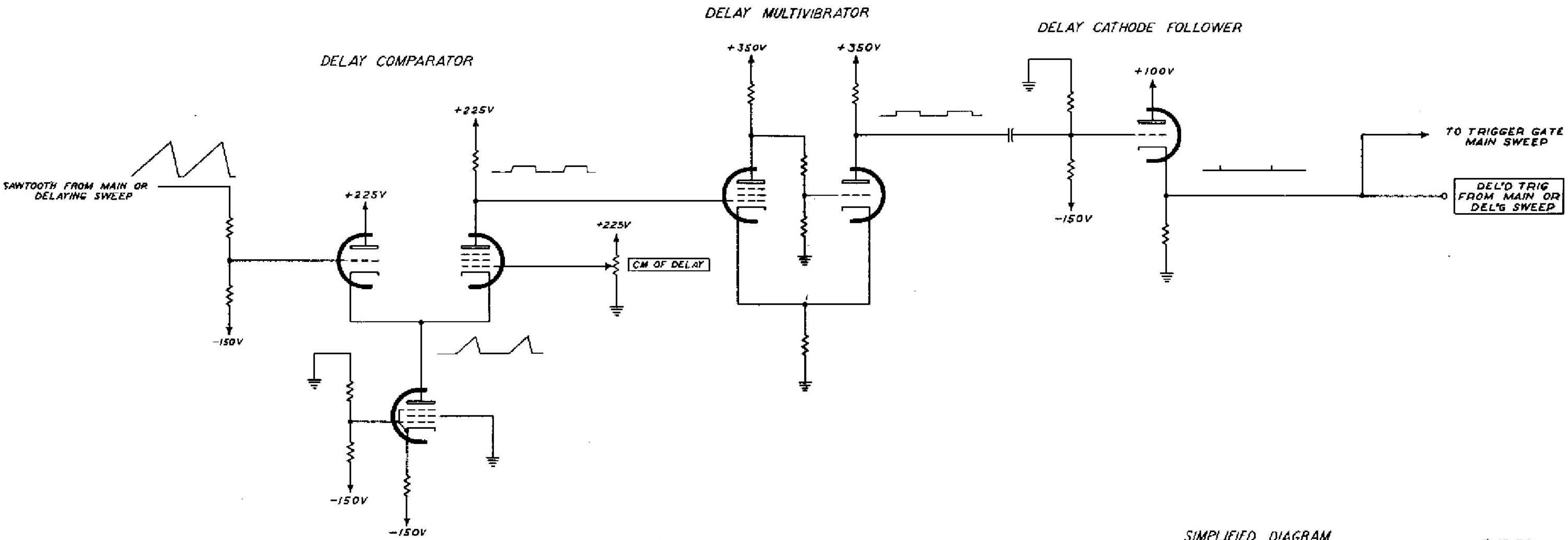


TYPE 545 OSCILLOSCOPE

A

SIMPLIFIED DIAGRAM
DELAYING-SWEEP GENERATOR

3-15-54
KF

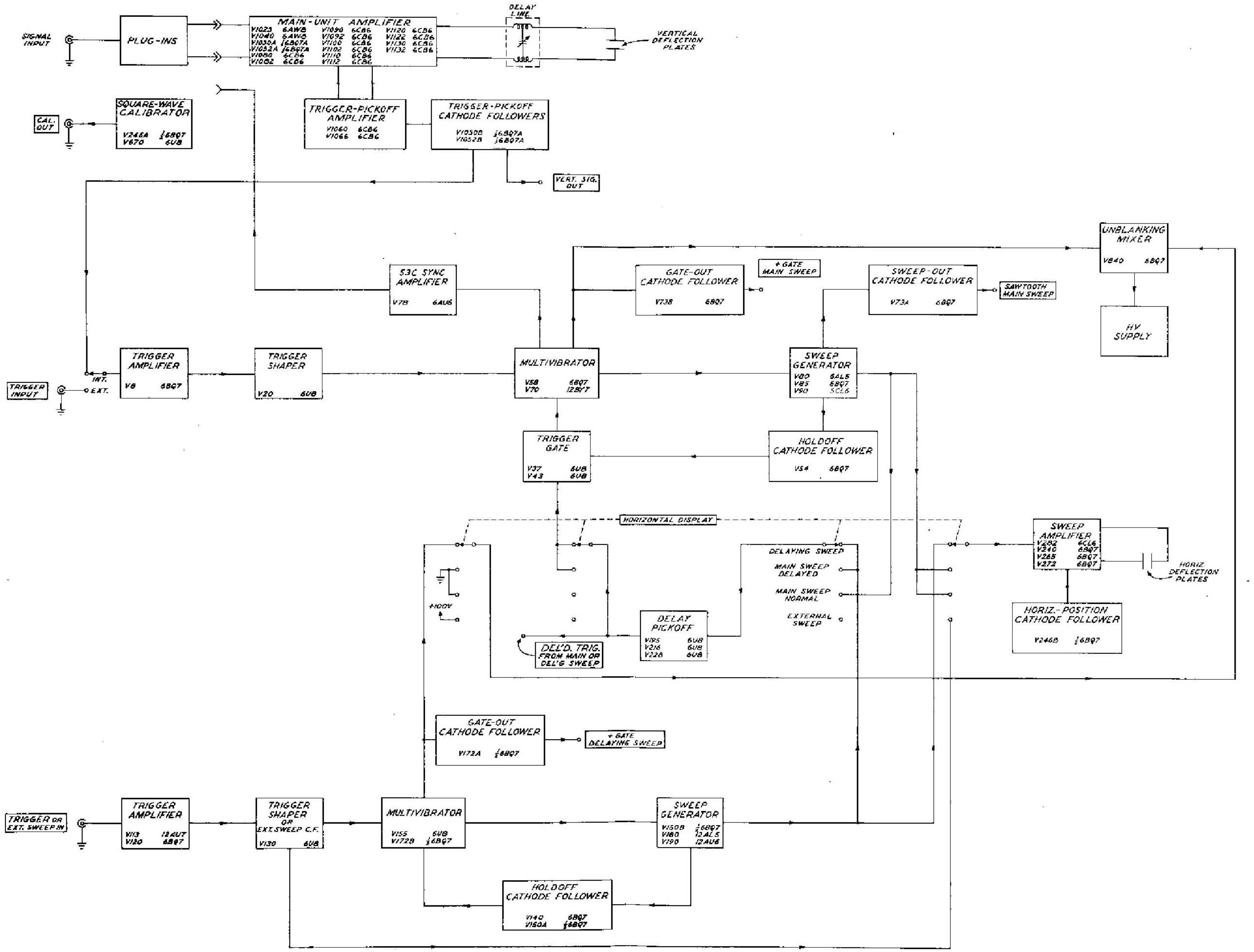


TYPE 545 OSCILLOSCOPE

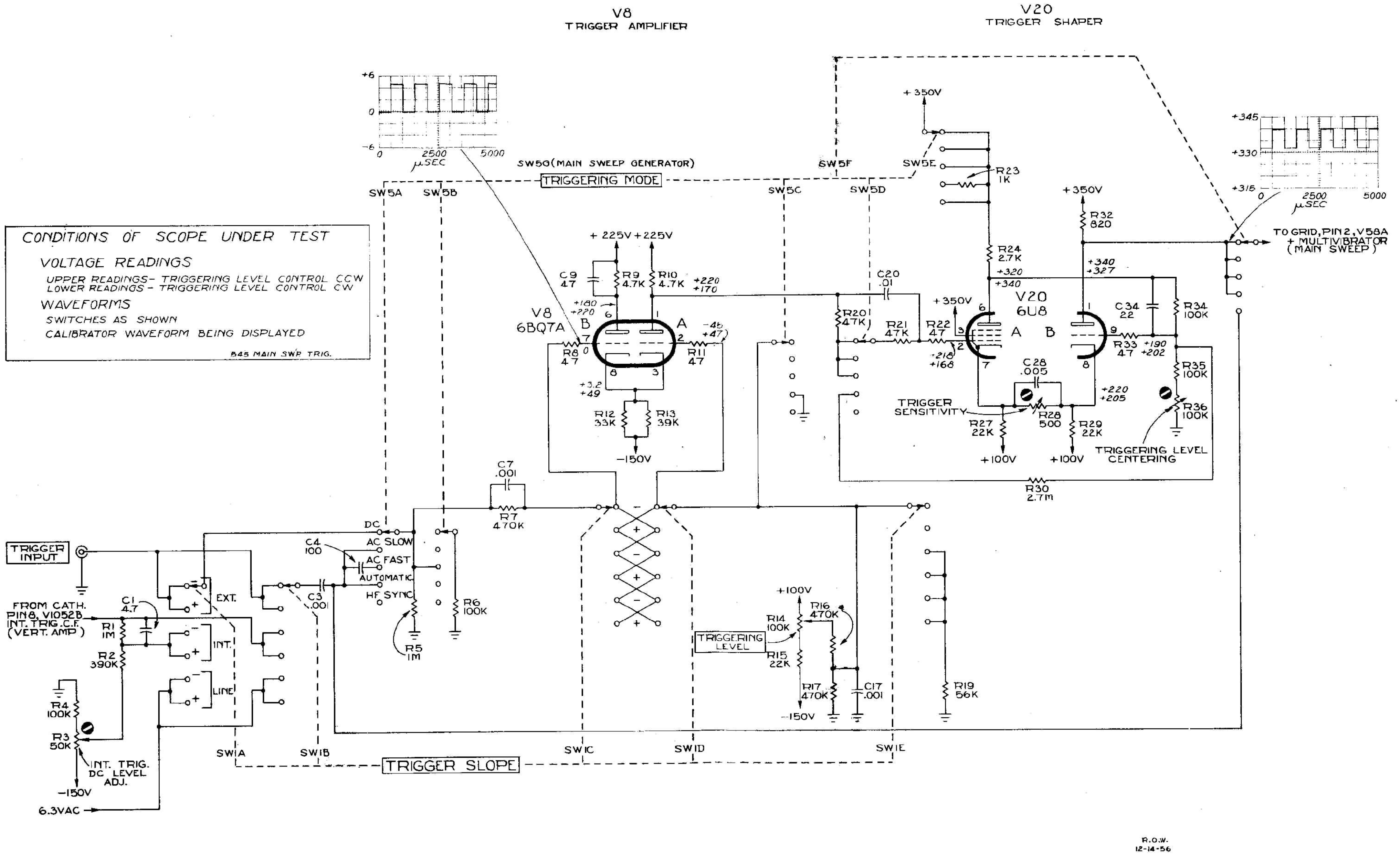
A

SIMPLIFIED DIAGRAM
DELAY PICKOFF

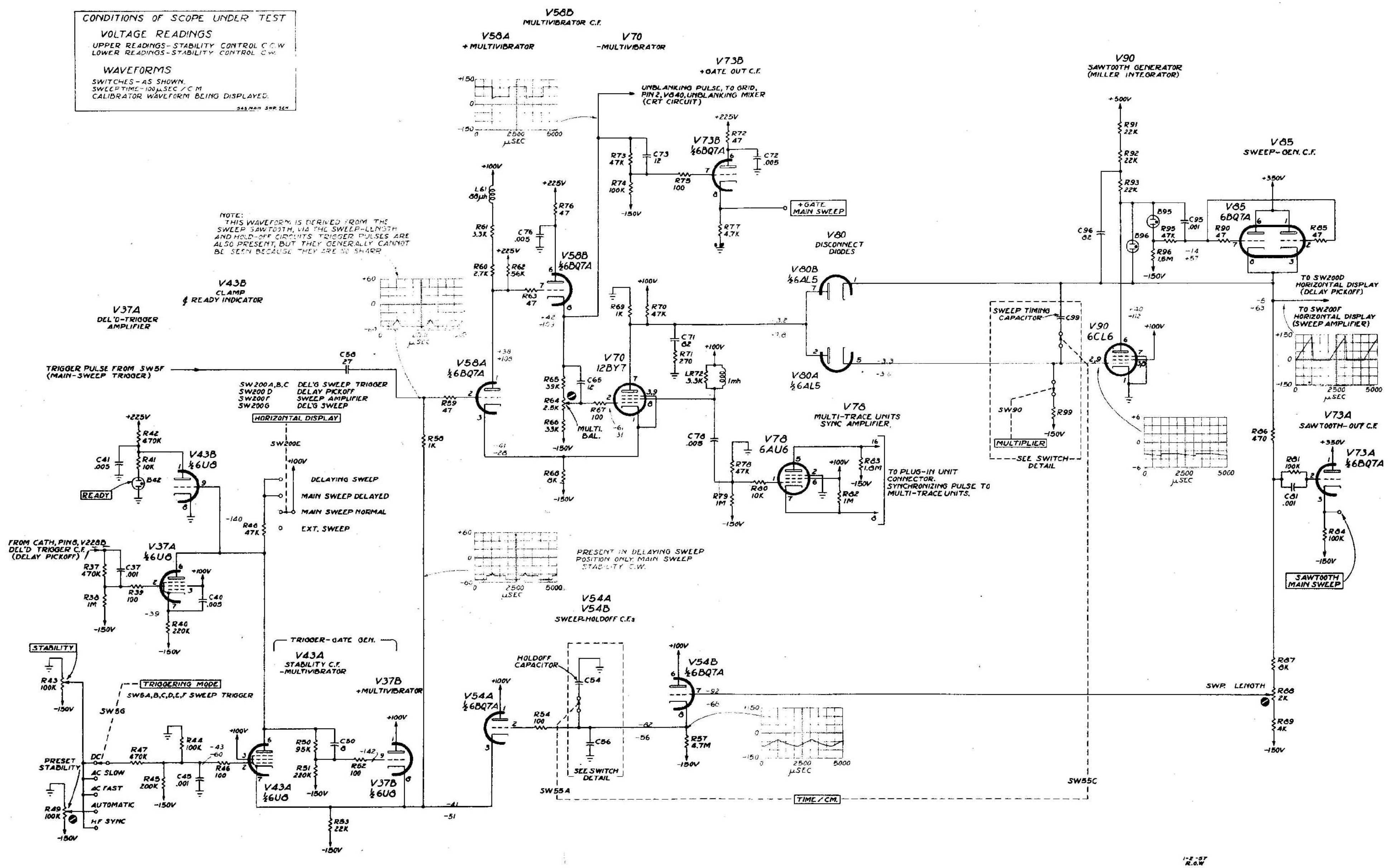
3-15-54
KF



TYPE 545 OSCILLOSCOPE A1 BLOCK DIAGRAM 10-5-56 KF



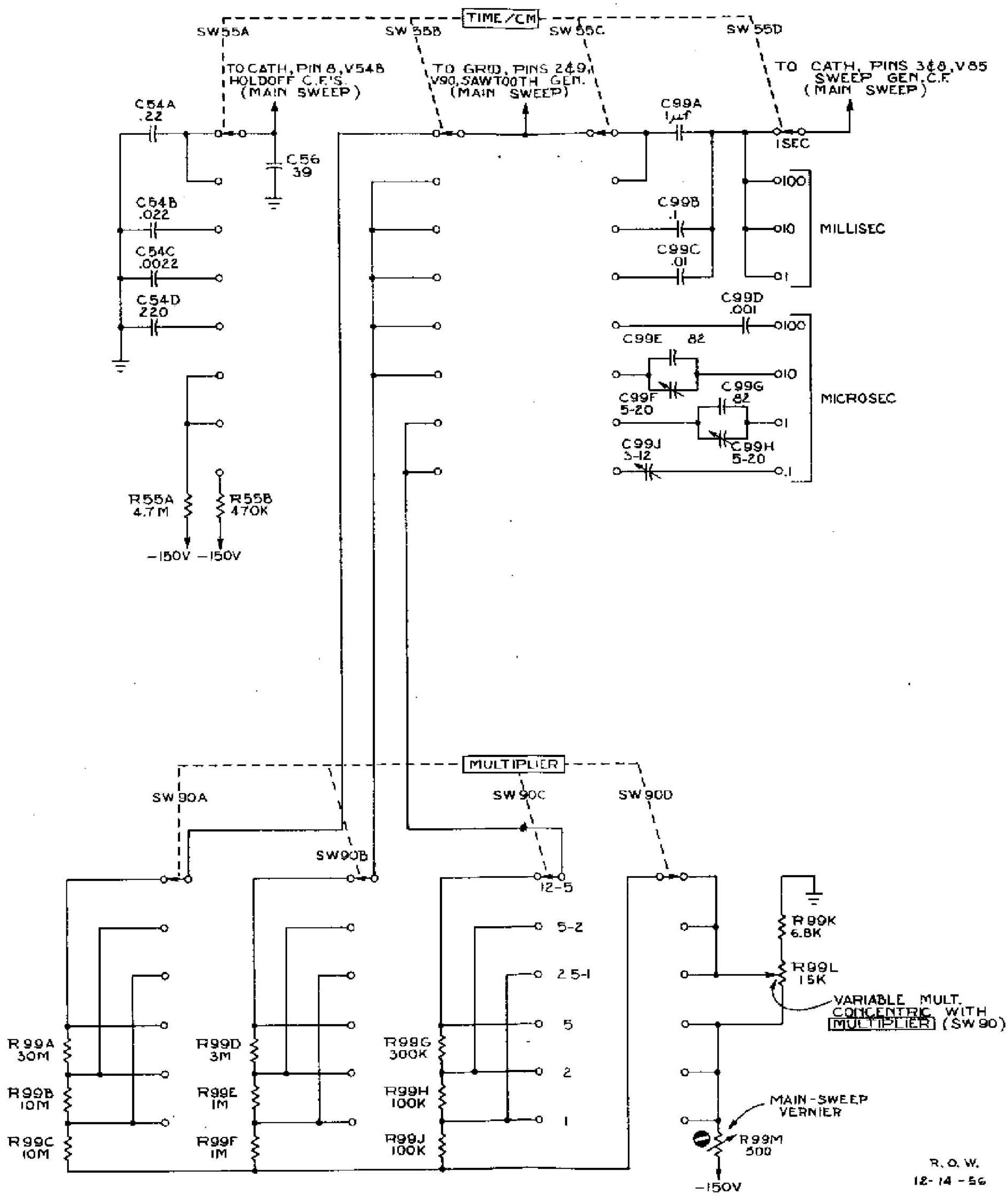
MAIN SWEEP TRIGGER



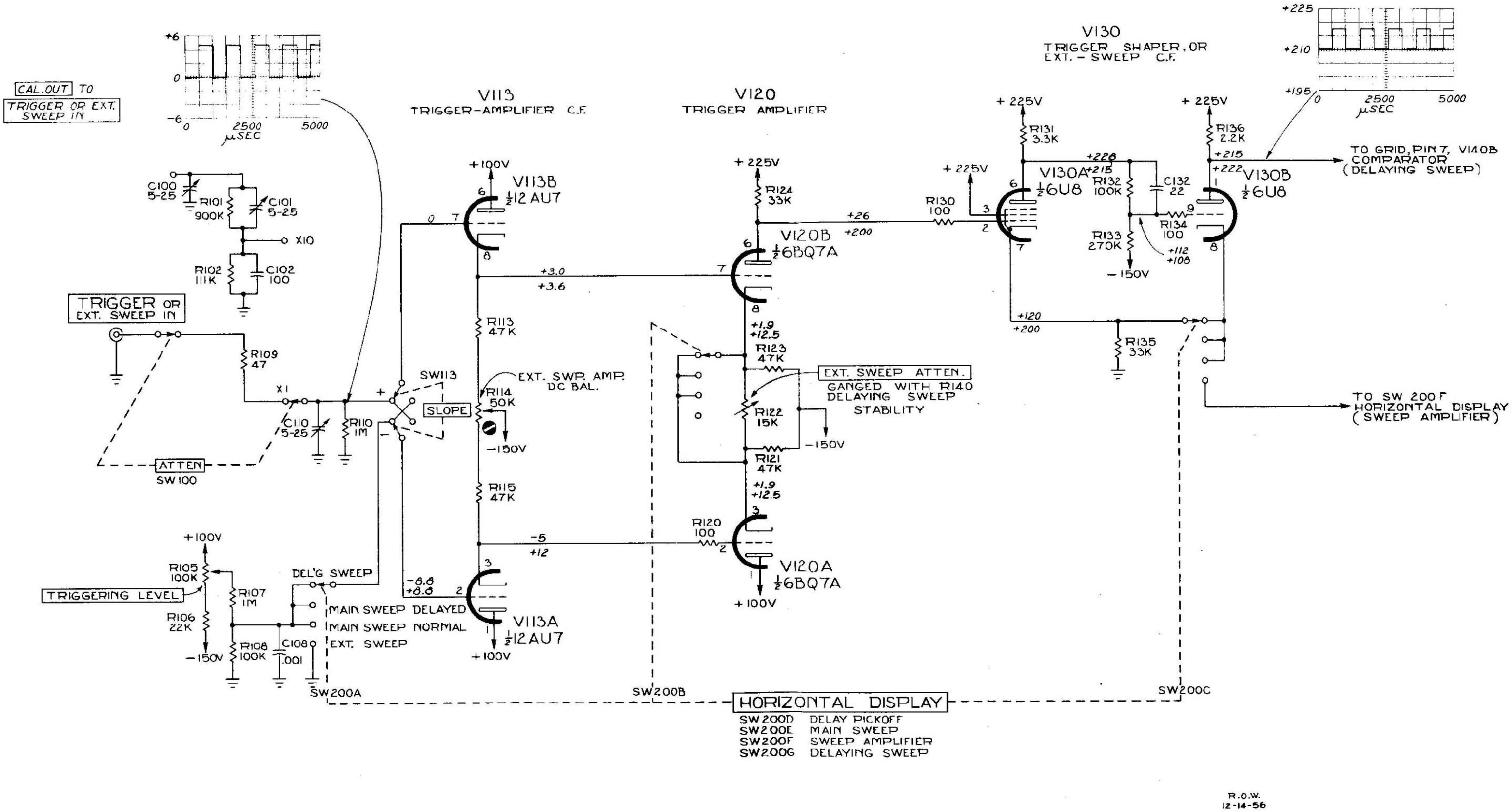
TYPE 545 OSCILLOSCOPE

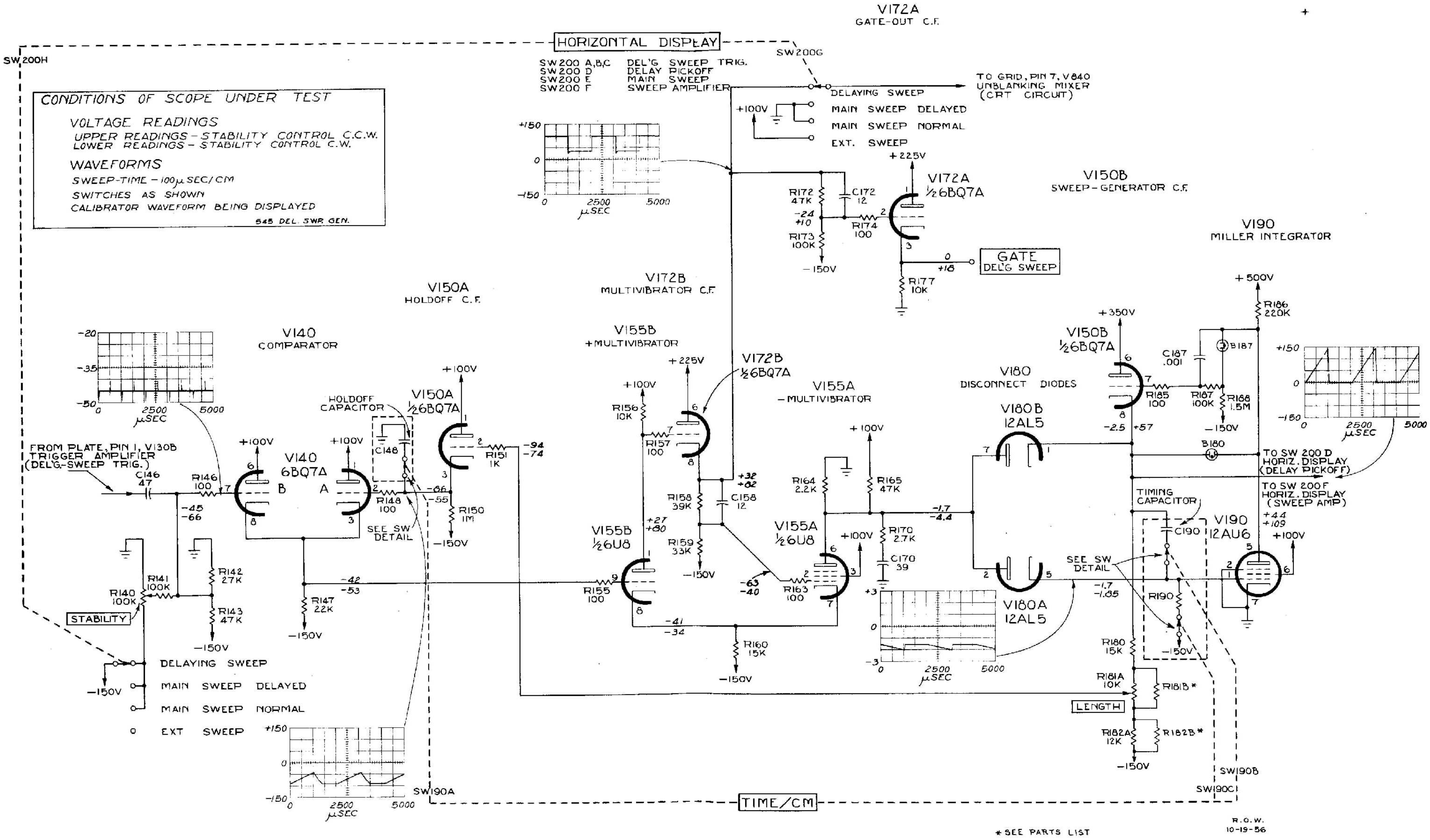
E

MAIN SWEEP GENERATOR



TYPE 545 OSCILLOSCOPE MAIN - SWEEP TIMING SWITCH

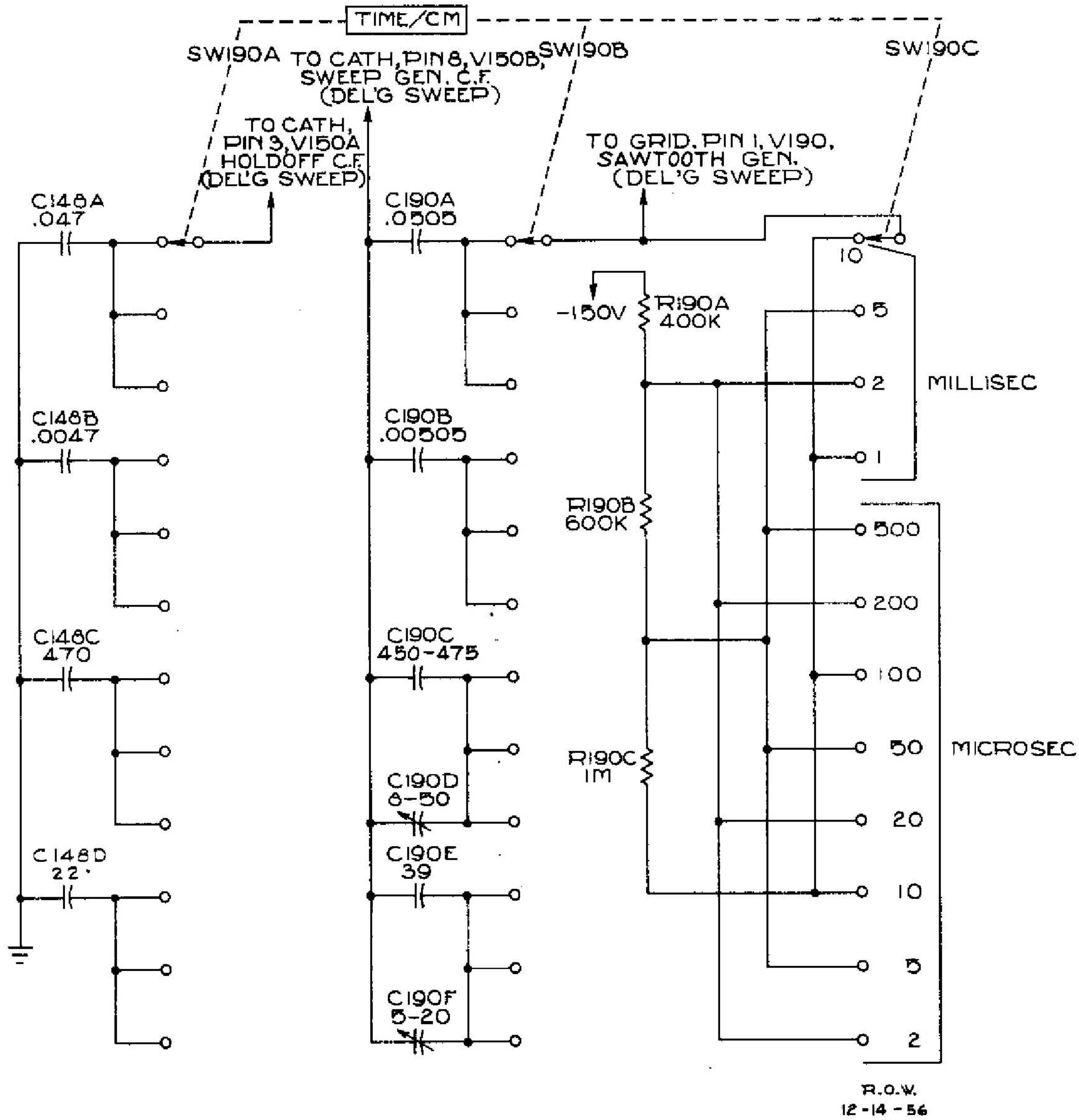

CAL.OUT TO
TRIGGER OR EXT. SWEEP IN
+6
0
-6
0
2500
5000
μSEC
V113
TRIGGER-AMPLIFIER C.F.
V120
TRIGGER AMPLIFIER
V130
TRIGGER SHAPER, OR EXT. - SWEEP C.F.
+225
+210
+195
TO GRID, PIN 7, V140B COMPARATOR (DELAYING SWEEP)
C100 5-25
R101 900K
C101 5-25
X10
R102 111K
C102 100
TRIGGER OR EXT. SWEEP IN
R109 47
X1
C110 5-25
R110 1M
ATTEN
SW100
+100V
V113B ½12AU7
SW113
SLOPE
R113 47K
EXT. SWP. AMP. DC BAL.
R114 50K
-150V
R115 47K
+100V
R105 100K
R106 22K
-150V
TRIGGERING LEVEL
R107 1M
R108 100K
C108 .001
DEL'G SWEEP
MAIN SWEEP DELAYED
MAIN SWEEP NORMAL
EXT. SWEEP
V113A ½12AU7
+100V
SW200A
+225V
R124 33K
V120B ½6BQ7A
R123 47K
EXT. SWEEP ATTEN.
GANGED WITH R140 DELAYING SWEEP STABILITY
R122 15K
-150V
R121 47K
R120 100
V120A ½6BQ7A
+100V
SW200B
+225V
R131 3.3K
R130 100
V130A ½6U8
R132 100K
C132 22
R133 270K
R134 100
-150V
R135 33K
+225V
R136 2.2K
V130B ½6U8
TO SW 200F HORIZONTAL DISPLAY (SWEEP AMPLIFIER)
SW200C
HORIZONTAL DISPLAY
SW200D DELAY PICKOFF
SW200E MAIN SWEEP
SW200F SWEEP AMPLIFIER
SW200G DELAYING SWEEP
R.O.W.
12-14-56



TYPE 545 OSCILLOSCOPE

C1

DELAYING - SWEEP GENERATOR



TYPE 545 OSCILLOSCOPE

DELAYED - SWEEP TIMING - SWITCH

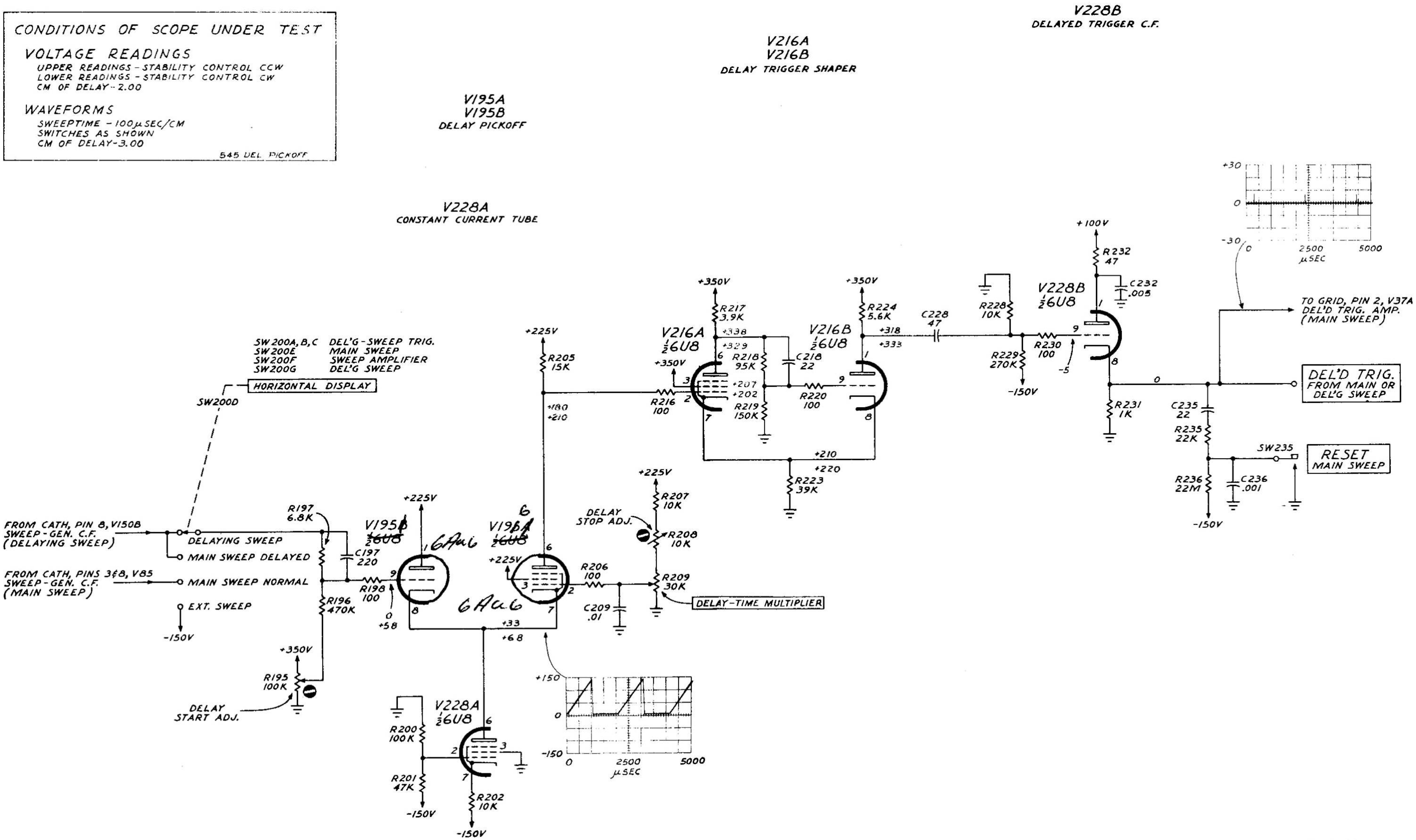
B2

CONDITIONS OF SCOPE UNDER TEST

VOLTAGE READINGS
UPPER READINGS - STABILITY CONTROL CCW
LOWER READINGS - STABILITY CONTROL CW
CM OF DELAY - 2.00

WAVEFORMS
SWEEPTIME - 100µSEC/CM
SWITCHES AS SHOWN
CM OF DELAY - 3.00

545 DEL PICKOFF

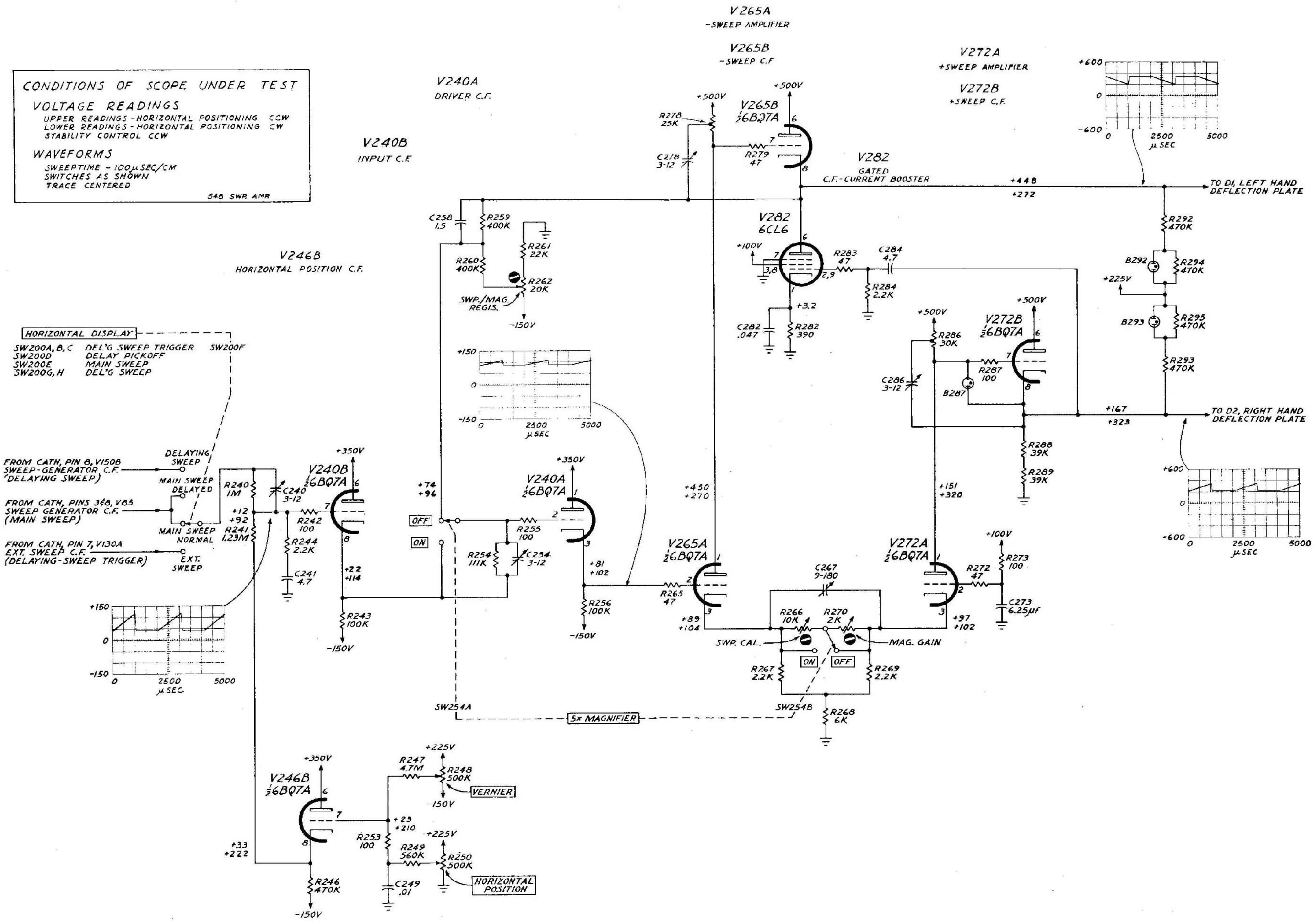


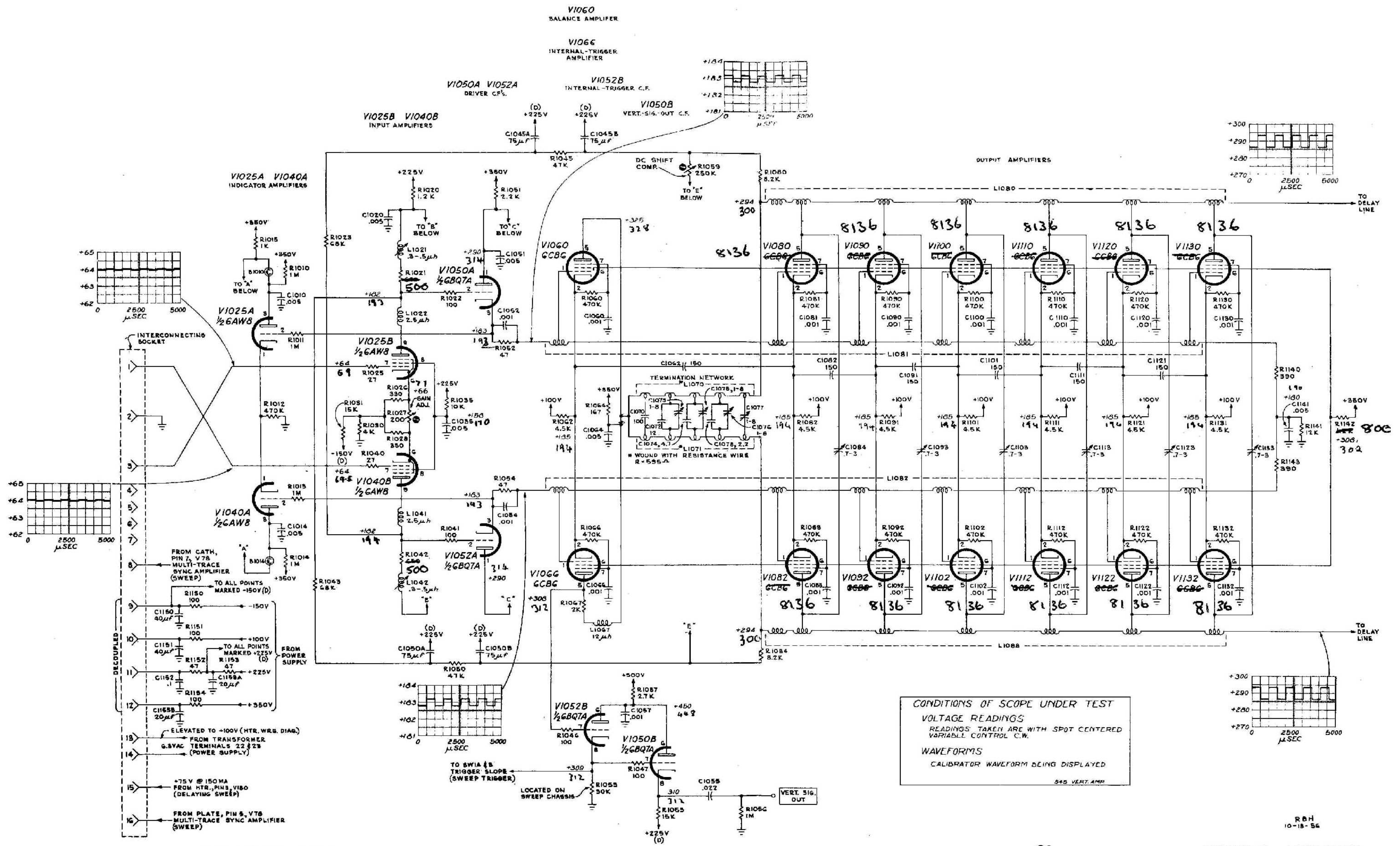
TYPE 545 OSCILLOSCOPE

D

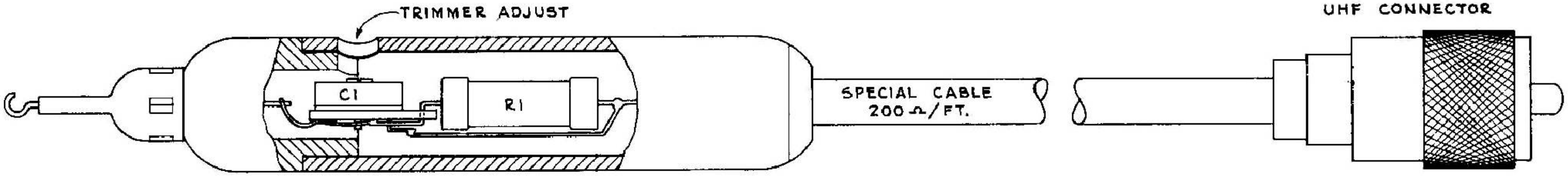
DELAY PICKOFF

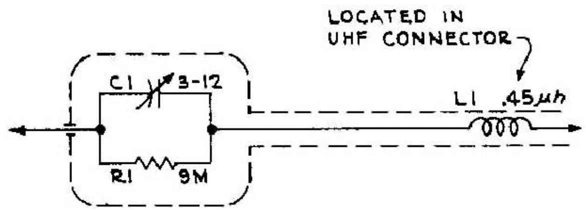
12-6-56 KF


CONDITIONS OF SCOPE UNDER TEST
VOLTAGE READINGS
UPPER READINGS - HORIZONTAL POSITIONING CCW
LOWER READINGS - HORIZONTAL POSITIONING CW
STABILITY CONTROL CCW
WAVEFORMS
SWEEPTIME - 100μSEC/CM
SWITCHES AS SHOWN
TRACE CENTERED
545 SWP. AMP.
V265A -SWEEP AMPLIFIER
V265B -SWEEP C.F.
V272A +SWEEP AMPLIFIER
V272B +SWEEP C.F.
V240A DRIVER C.F.
V240B INPUT C.F.
V282 GATED C.F.-CURRENT BOOSTER
V246B HORIZONTAL POSITION C.F.
HORIZONTAL DISPLAY
SW200A, B, C DEL'G SWEEP TRIGGER
SW200D DELAY PICKOFF
SW200E MAIN SWEEP
SW200G, H DEL'G SWEEP
SW200F
FROM CATH, PIN 8, V150B SWEEP-GENERATOR C.F. (DELAYING SWEEP)
FROM CATH, PINS 3&8, V85 SWEEP GENERATOR C.F. (MAIN SWEEP)
FROM CATH, PIN 7, V130A EXT. SWEEP C.F. (DELAYING-SWEEP TRIGGER)
DELAYING SWEEP
MAIN SWEEP DELAYED
MAIN SWEEP NORMAL
EXT. SWEEP
TO D1, LEFT HAND DEFLECTION PLATE
TO D2, RIGHT HAND DEFLECTION PLATE
SWP./MAG. REGIS.
SWP. CAL.
MAG. GAIN
5x MAGNIFIER
SW254A
SW254B
VERNIER
HORIZONTAL POSITION
OFF
ON
2500 μSEC 5000



TYPE 545 OSCILLOSCOPE C1 VERTICAL AMPLIFIER



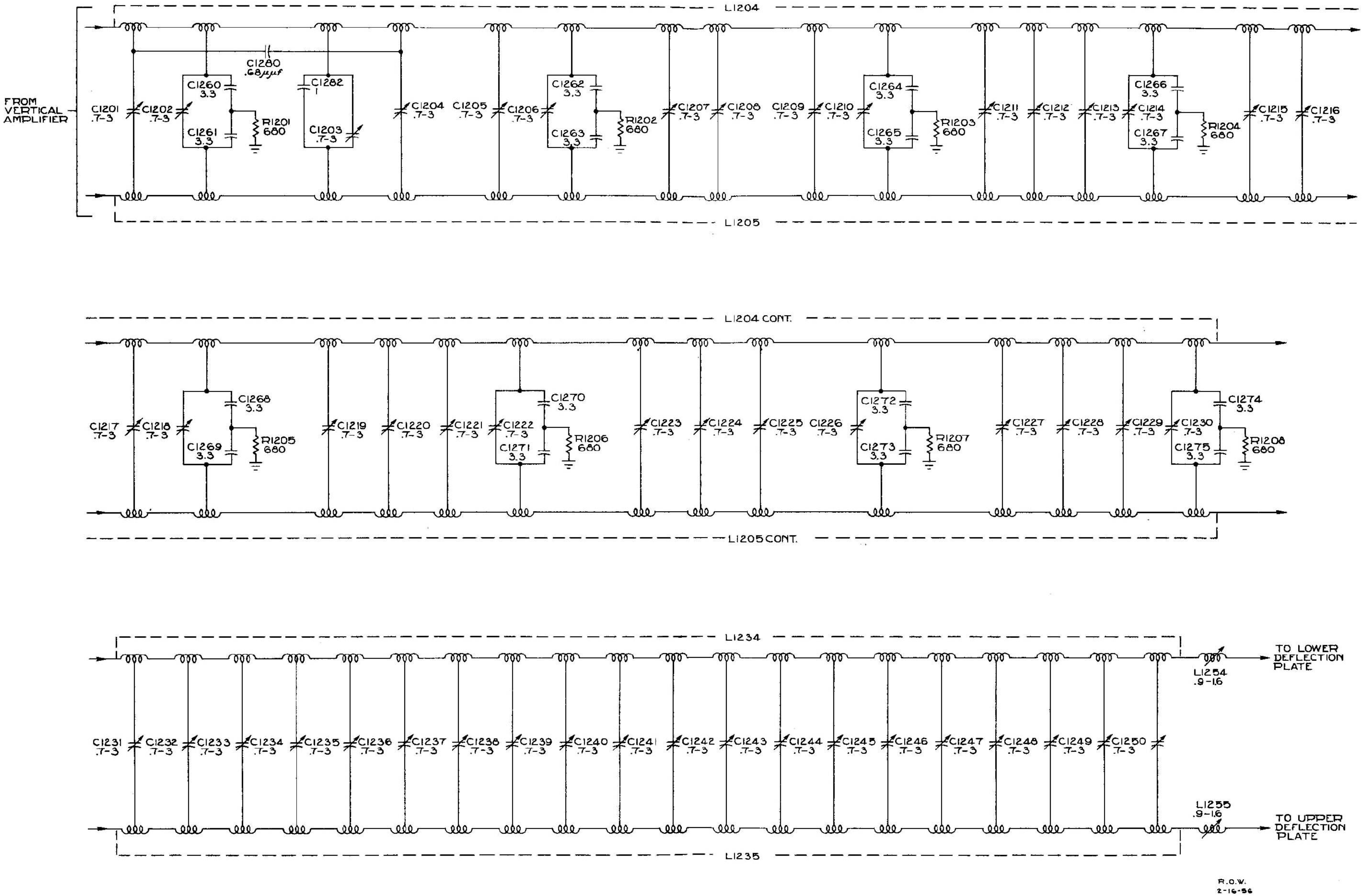


							PART NO.
C1	3-12 μμf	Cer.	Var.				281008
R1	9 meg.	1w	Fixed	Prec.	1%		310106
L1	0.45 μh	Fixed					108098

RBH
7-31-56

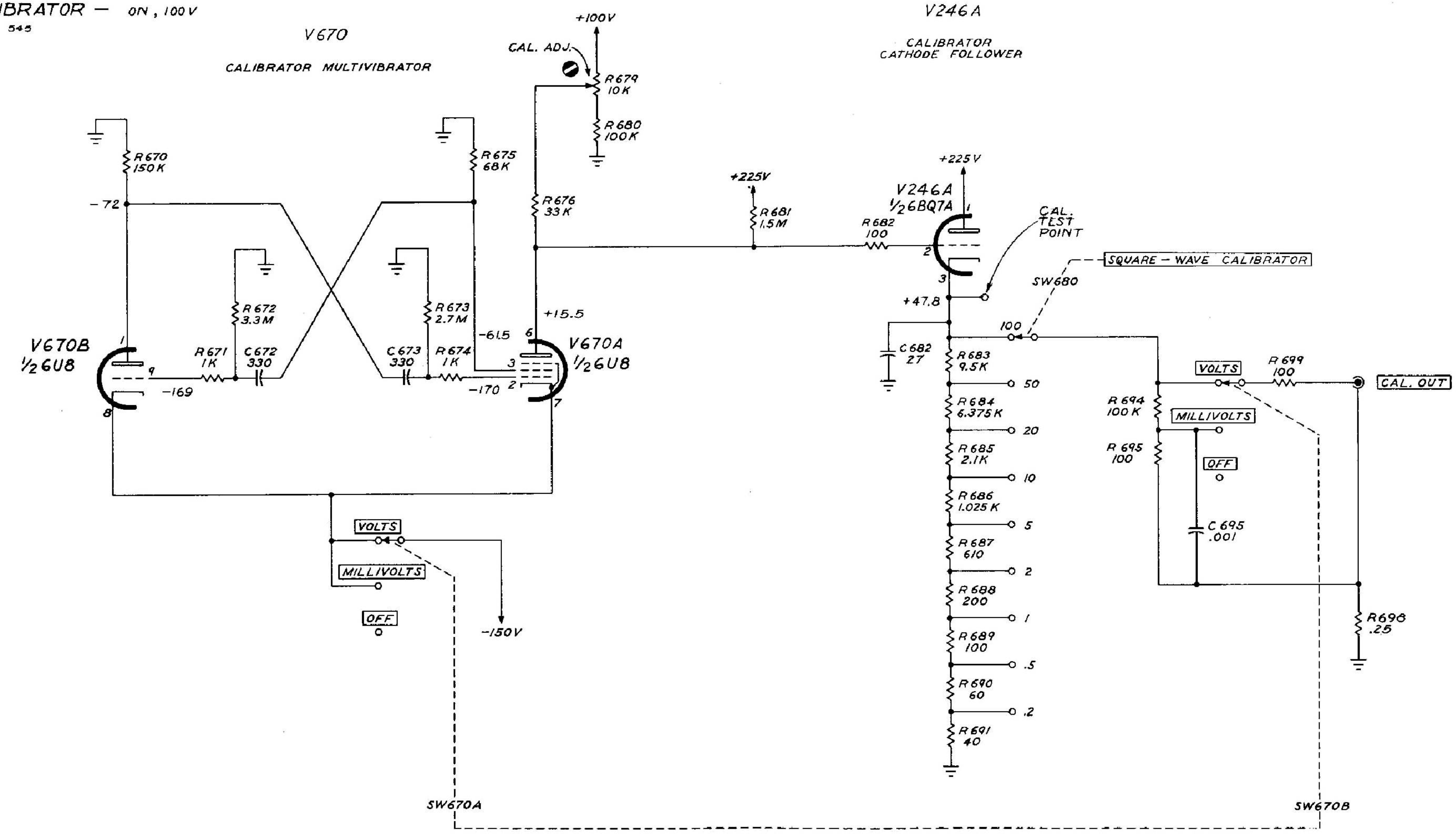
A

TEKTRONIX TYPE P410 PROBE

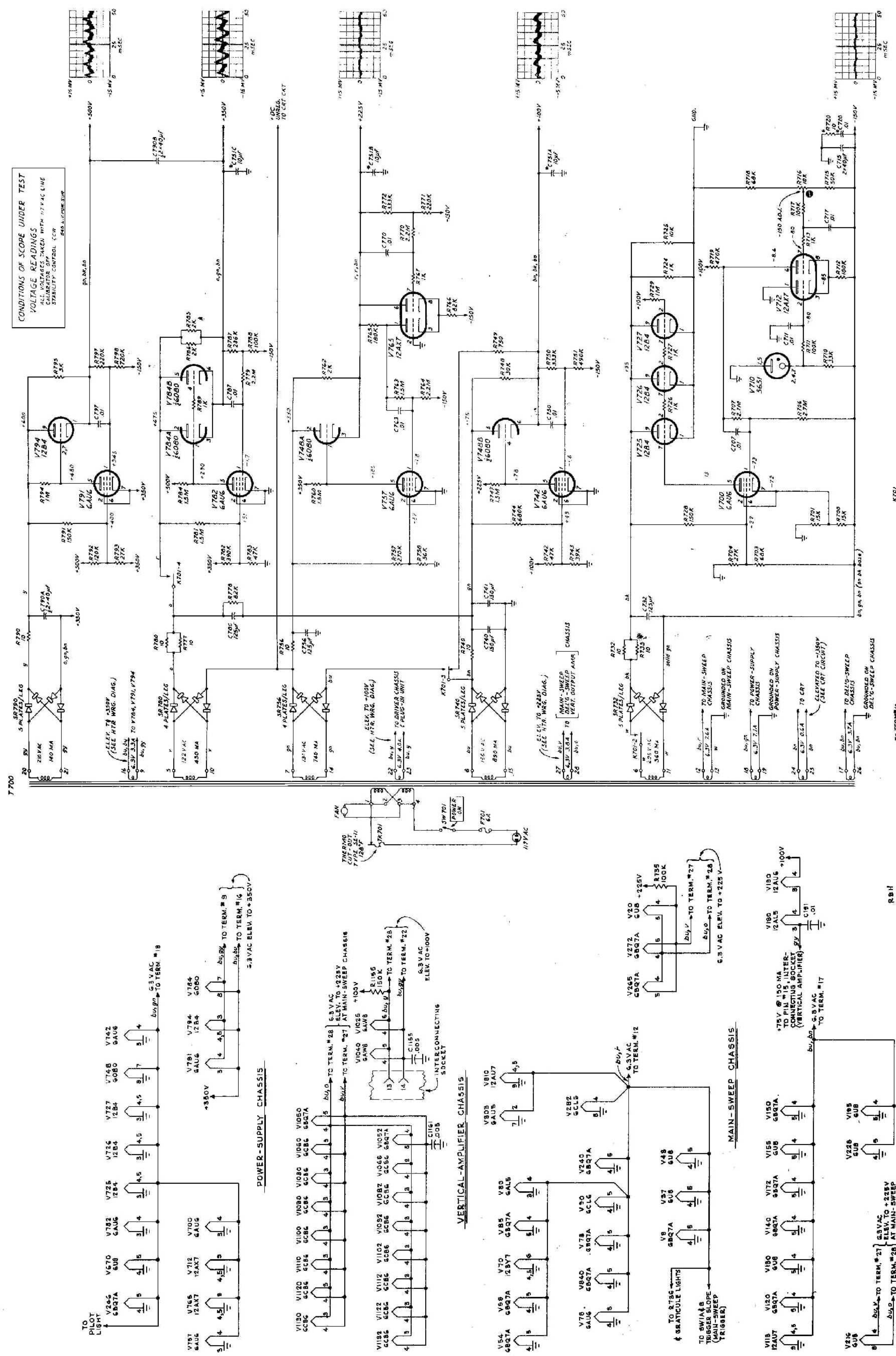


TYPE 545 OSCILLOSCOPE C DELAY LINE NETWORK

CALIBRATOR — ON, 100 V
545



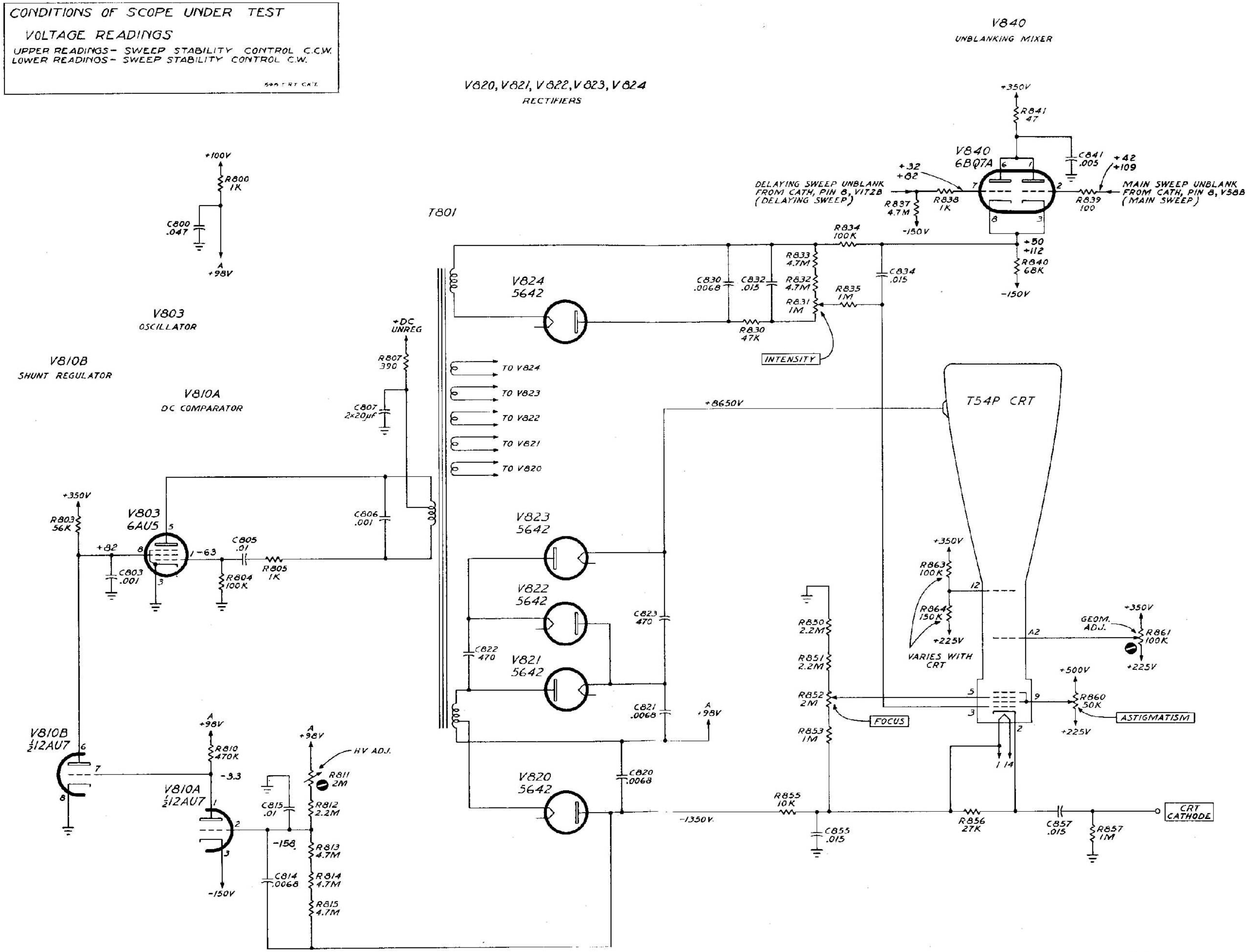
12-10-56
KF


CONDITIONS OF SCOPE UNDER TEST
VOLTAGE READINGS
LV POWER SUPPLY
TYPE 545 OSCILLOSCOPE
HEATER WIRING DIAGRAM
POWER-SUPPLY CHASSIS
VERTICAL-AMPLIFIER CHASSIS
MAIN-SWEEP CHASSIS
DELAYING-SWEEP CHASSIS
F

CONDITIONS OF SCOPE UNDER TEST

VOLTAGE READINGS

UPPER READINGS - SWEEP STABILITY CONTROL C.C.W.
LOWER READINGS - SWEEP STABILITY CONTROL C.W.



TYPE 545 OSCILLOSCOPE

C

CRT CIRCUIT

12-6-56
KF