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 out-phasing 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.

MAINTENANCE

Replacement of Components

Tektronix will supply replacement components at current net prices. However, since most of the components are standard electronic and radio parts we suggest you get them from your local dealer if you can. Be sure to consult your instruction manual first to see what tolerances are required.

We specially select some of the components, whose values must fall within prescribed limits, by sorting through our regular stocks. The components so selected will have standard RETMA color-code marks showing the values and tolerances of the stock they were selected from, but they will not in general be replaceable from dealers stocks.

Such selected parts, as well as the parts we manufacture at Tektronix, are identified in the parts lists either by notes or by our own stock numbers. Order these parts from the Tektronix factory in Portland, Oregon.

Parts-Ordering Information

You will find a serial number on the frontispiece of this manual. This is the serial number of the instrument the manual was prepared for. Be sure the manual number matches the number of the instrument when you order parts.

A Tektronix instruction manual usually contains hand-made changes to diagrams and parts lists, and sometimes text. These changes are in general only appropriate to the instrument the manual was prepared for, the instrument whose serial number appears on the manual frontispiece. The hand-made changes show changes to the instrument that have been made after the printing of the manual.

We make some of the instrument changes during the factory test procedure. Our technicians hand-tailor the circuits, if it seems appropriate, to provide the widest possible latitude of operation. Other changes are made to include the latest circuit improvements as they are developed in our engineering department, or when improved components become available. In any event, the changes are to your benefit. We have tried to give you the best instrument we can.

Soldering Precaution

The solder used on the ceramic terminals in this instrument must contain a small percentage of silver. If for any reason you resolder, be sure the solder you use contains silver. Silver-bearing solder is used in printed-circuit techniques, and is therefore available from all solder manufacturers. Repeated use of ordinary tin-lead solder will dissolve the fused bond of silver that makes the solder adhere to the porcelain, especially if the soldering iron is quite hot.

Color Coding

We use color-coded wires in this instrument to help you identify the various circuits. The ac power leads are yellow and coded 1-1-0 (brown-brown-brown) following the RETMA resistor color code. The +350-volt bus is white and coded 3-5-0 (orange-green-brown, beginning with the widest stripe). The heater leads are coded 6-1, 6-2, etc., not to indicate that the voltages are different but to differentiate between the leads. All signal leads have a single stripe. A few wire colors are indicated by small, lowercase letters on the diagrams.

Air Filter

The Type 545 Oscilloscope is cooled by filtered, forced air. If the filter gets too dirty it will restrict the flow of cooling air and may cause the instrument to overheat. The filter should be inspected every three or four months and cleaned or replaced if necessary.

Two types of air filters can be used with your Tektronix equipment. A washable air filter constructed of aluminum wool coated with an adhesive is usually supplied with your instrument. A disposable glass-wool filter is available through your local Tektronix field office or direct from the factory. If you are replacing an aluminum-type filter with the disposable glass-wool type, it is best to order No. 378-009, which includes two back-up screens that help to prevent damage to the filter. For future replacements of the glass-wool filter only, order No. 378-012.

To clean the aluminum filter, run hot water through it from the side that was inside. Or slosh it around in hot soapy water and rinse it in clear water. Then dry it thoroughly and coat it with new adhesive. When new, the filter is coated with "Filter Coat", a product of the Research Products Corporation. Pint cans are available under the name "Handi-Koter" from some air-conditioner suppliers. Other adhesive materials are no doubt satisfactory.

Fan Motor

The fan motor bearings will require oiling every few months or every thousand hours of operation. Use a good grade of light machine oil, and apply only a drop or two.

Trouble Shooting

If the instrument fails to operate at all, including the fan and the pilot light, check the source of power and determine that the power cord plug is firmly in place. Then check the fuse at the back of the instrument near the power receptacle. If the instrument has been operating but has just stopped, it may have overheated and tripped the thermal cutout. The thermal

cutout will reset itself when the instrument cools down enough. Possible causes of overheating are fan stoppage, restriction of air circulation or high room temperature. Be sure the air filter is clean.

If the fan and pilot light operate but there is no spot visible, there is a possibility that the spot is positioned off the screen for some reason. Check whether the beam-position-indicator lights are operating and if the positioning controls produce any effect. Advance the INTENSITY control and see if there is some unfocused glow on the screen to indicate the presence of beam current. If there is an indication that there is a beam positioned off the screen, look for a dc component in one of the input signals.

This is a complex electronic instrument. There is no simple way of locating troubles. An understanding of the functions of the circuits is the best help. With an understanding of the circuits, you will be able to make a good guess at the general source of troubles from their symptoms. Be doubly sure that the difficulty you are having is not caused by some misadjustment of the front-panel controls. If not, you will need to take the panels off for further checks.

Each side panel and the bottom panel are individually removable when service becomes necessary. To remove a side panel, release the fasteners near the front and back and swing the top of the panel out until the bottom hinge releases. To remove the bottom panel release the four fasteners and lift the panel off.

To replace the panels, reverse the process above. Each fastener is designed so that the first one-quarter turn engages an ear on the fastener with the oscilloscope frame. Further turning of the screw locks the ear in place.

Warning: When you have the panels off the instrument, be careful of high voltages. The lower-voltage busses are potentially more dangerous than the crt accelerating voltage because of the high current capabilities and rather large filter capacitors in these supplies. When you reach into the instrument while it is turned on, do not hold the metal frame with the other hand. If possible, stand on an insulating floor and use insulated tools.

Troubles are usually caused by tube failure, and you can frequently correct them by finding the bad tube and replacing it with a good one. However, sometimes a tube burns up resistors or overstresses capacitors when it fails, and in these cases you will also have to find the bad components. Sometimes you can find them by visual inspection. One way to find bad tubes is to try replacing suspected tubes with good ones. If possible, replace all suspected tubes at one time, and if the trouble is helped, return the old ones one at a time until the offending one is discovered.

Tube failure will often show up in the voltage readings of the power supply. So another early step to take when you look for troubles is to check voltages and currents from the regulated power supplies. The voltages can be checked from the top or right side of the instrument on a ceramic terminal strip near the rear of the instrument. The voltages are marked on the chassis. The —150-volt terminal should read within one per cent of 150 volts. The remainder of the voltages should be within about five per cent of their indicated voltages. Keep in mind that these are quite close tolerances, especially the 150-volt tolerance. Very few portable voltmeters have comparable accuracy, so be sure that any small discrepancy you may find is not due to voltmeter error.

All four positive voltage supplies refer to —150 volts for their control. If this voltage is off, all other voltages will also be off. Be especially sure of your —150-volt measurement before you draw any conclusions from other voltage measurements. The —150-volt supply can be adjusted by means of a screwdriver control marked —150 ADJ. on the right near the bottom of the instrument. The remaining supplies cannot be adjusted, and any large discrepancy you find in them will probably be caused by tube deterioration, or by unusual loads in the rest of the instrument.

Total current from each supply can be measured roughly by measuring the voltage drop across the protective resistors, R732, R740, R756, R780, and R790. Current indication is 200 ma per volt on R732 and R780; 100 ma per volt on all the others. The resistors are conveniently mounted on the under side of the instrument. R790 in the 500-volt supply is nearest the front panel, and the others follow in order of their voltage. These resistors are located on the unregulated side of the supplies, and their voltage to ground will depend on line voltage. Toward the back of the instrument from each resistor is a bare bus across the terminal strip. These have the regulated voltages on them.

Vertical-Amplifier Adjustments

1. Gain Adjustment

The main unit sensitivity is standardized at 0.1 volt per centimeter so that the calibrated gain controls of all plug-in units will be correct. Since this sensitivity is affected by the crt accelerating voltage, first check the voltage at the left end of the ceramic terminal strip near the crt socket. Adjust to —1350 volts if necessary with the H. V. ADJ. control at the right side of the instrument near the rear.

Now connect a voltmeter between pins 1 and 3 on the interconnecting plug. Position the trace two centimeters above and below center with the **VERTICAL POSITION** control and adjust the main amplifier GAIN ADJ. control, R1027, until there is a total voltage change of .4 volts.

a. Remove any vertical signal or triggering signal.

b. Set the controls as follows:

HORIZONTAL DISPLAY
DELAYING SWEEP

Delaying-Sweep **STABILITY**
CCW

Main-Sweep **STABILITY**
CW

MULTI BAL, R64
CW

(located about half way back on top chassis)

c. Connect a voltmeter from ground to pin 8 of V37, located just behind the **TRIGGERING MODE** switch.

d. Note the voltmeter reading — it should be about —40 volts.

e. Back the main-sweep **STABILITY** control all the way counterclockwise then advance it clockwise while watching the voltmeter until the reading is 10 volts more negative than the reading obtained in step d (about —50 volts).

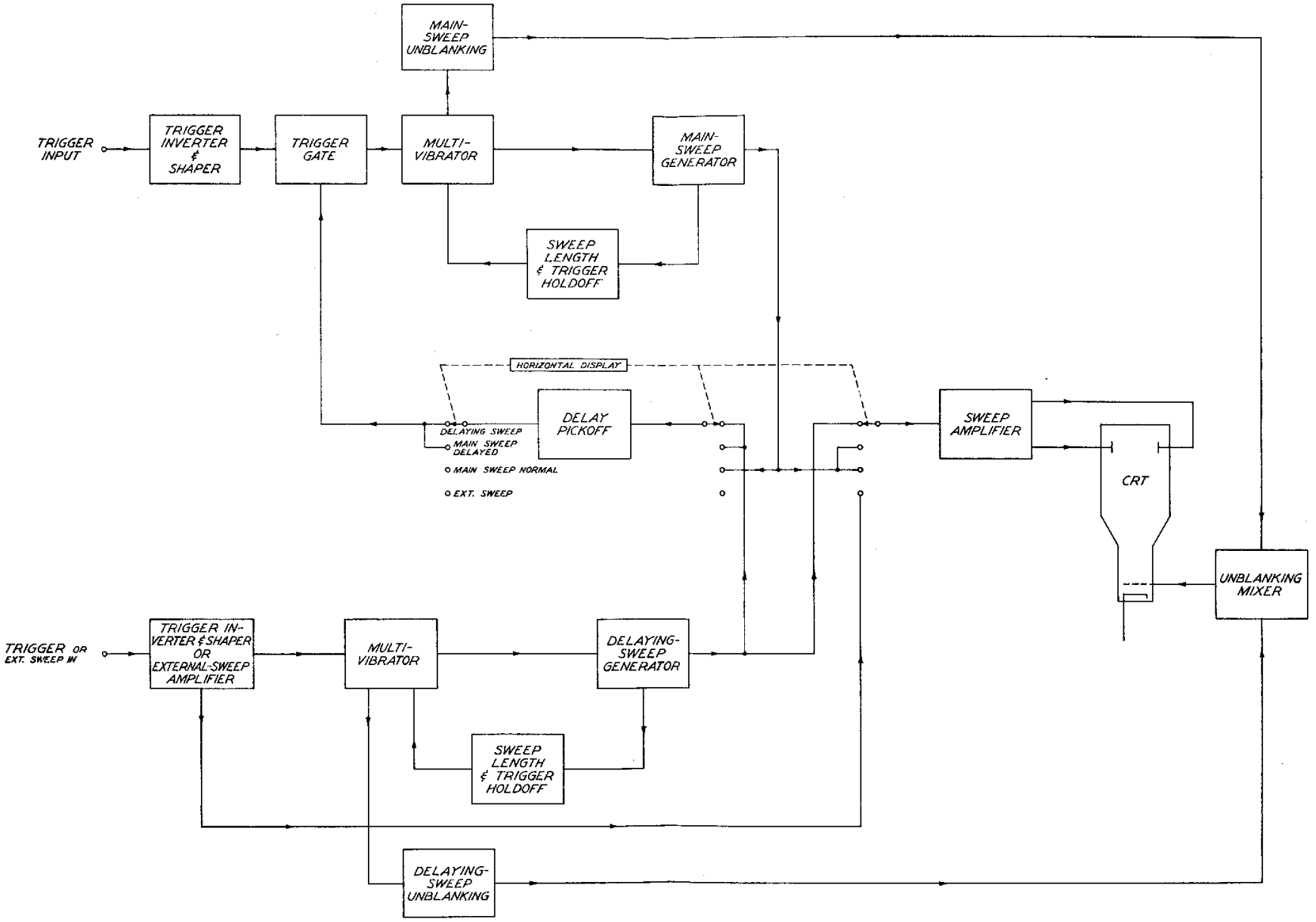
f. Slowly turn the MULTI BAL control, R64, counterclockwise until the voltmeter reading drops suddenly to a lower reading. This provides a holdoff voltage of 10 volts.

External Sweep DC Balance

Turn the **HORIZONTAL DISPLAY** switch to **EXT. SWEEP** and the **5X MAGNIFIER** to **ON.** Position the spot onto the screen and turn the **EXT. SWEEP ATTEN.** back and forth. If the spot moves horizontally as the **EXT. SWEEP ATTEN.** control is turned, adjust the EXT. SWEEP AMPL. DC BAL. control until the spot remains stationary. The EXT. SWEEP AMPL. DC BAL. control is located at the front of the vertically-mounted chassis at the right side of the instrument.

Calibrator Adjustment

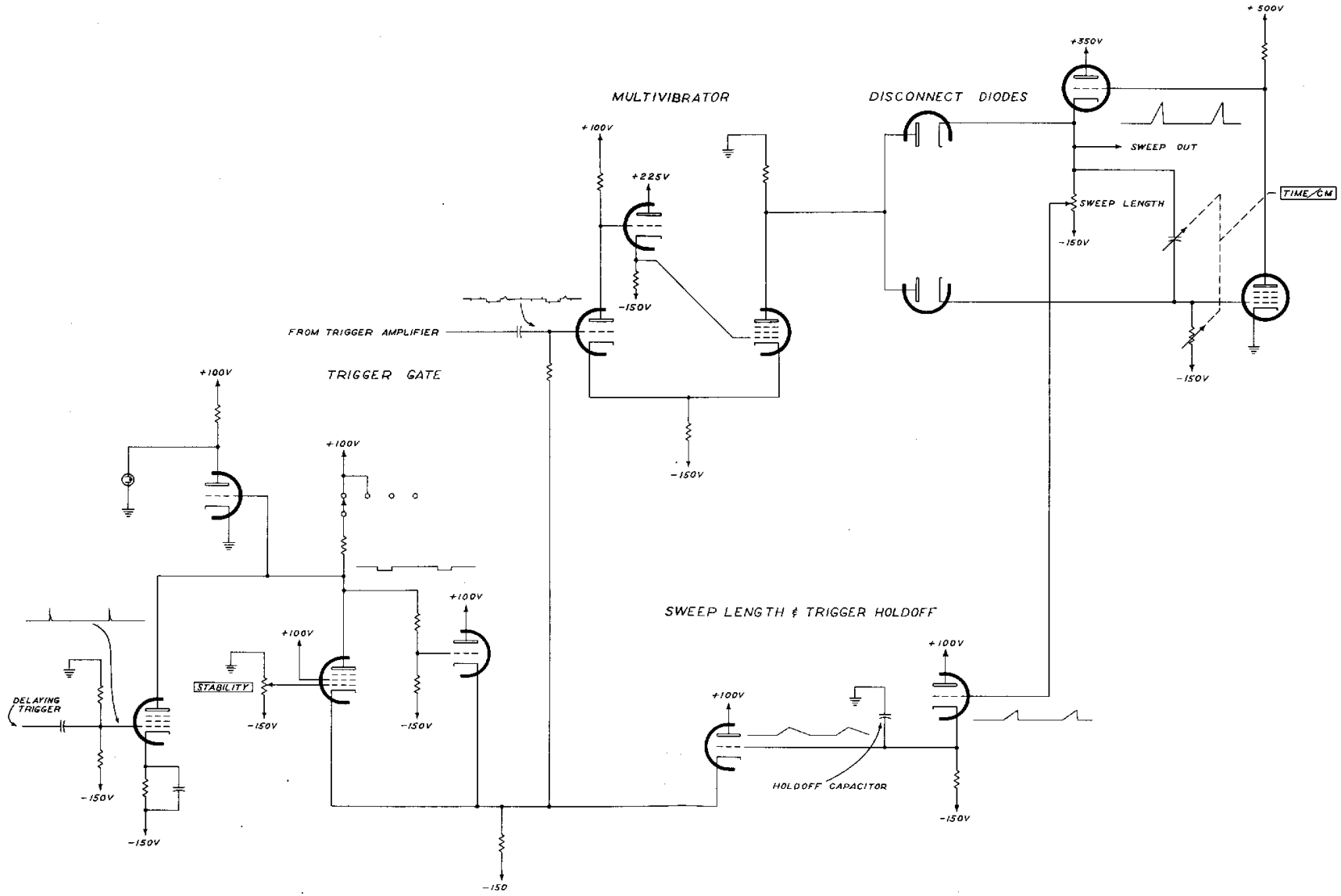
When the **CALIBRATOR** switch is turned to **OFF** the calibrator cathode follower, V246A, remains conducting at the current required to develop 100 volts across the voltage divider. To check the calibrator, turn the instrument on its side, and measure the cathode voltage at V246 cathode. This voltage appears at the pin jack labeled CAL. TEST POINT on the side of the chassis to the rear of the **CALIBRATOR** switch. If necessary, adjust R679, a screwdriver control labeled CAL. ADJ., accessible at the underside of the bottom chassis near the **CALIBRATOR** switch, so the cathode voltage measures 100 volts. Be sure of the accuracy of your test meter. Test meters are likely to be less accurate than the calibrator, which should be within about one per cent at this point.



SWEEP-CIRCUIT FUNCTIONAL BLOCK DIAGRAM

8-2-54 RF

SWEEP GENERATOR

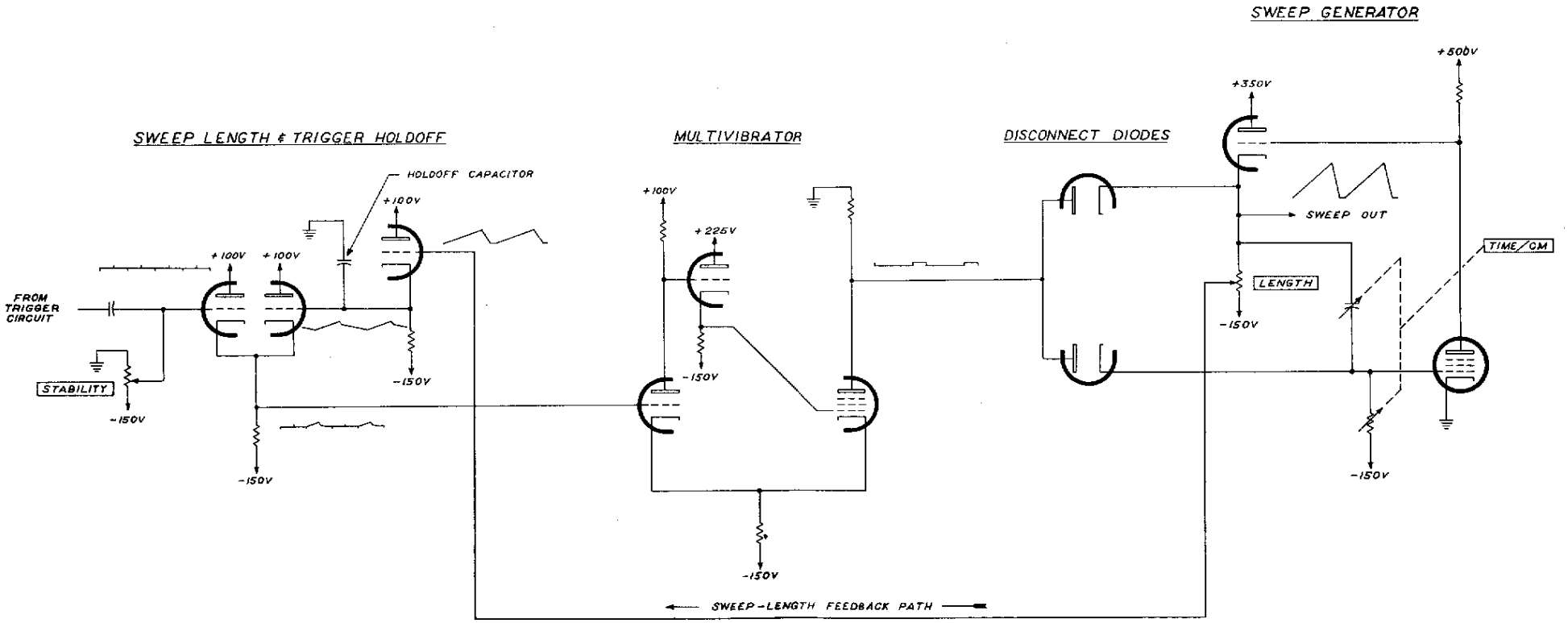


TYPE 545 OSCILLOSCOPE

A

SIMPLIFIED DIAGRAM
MAIN SWEEP

3-18-54
KF

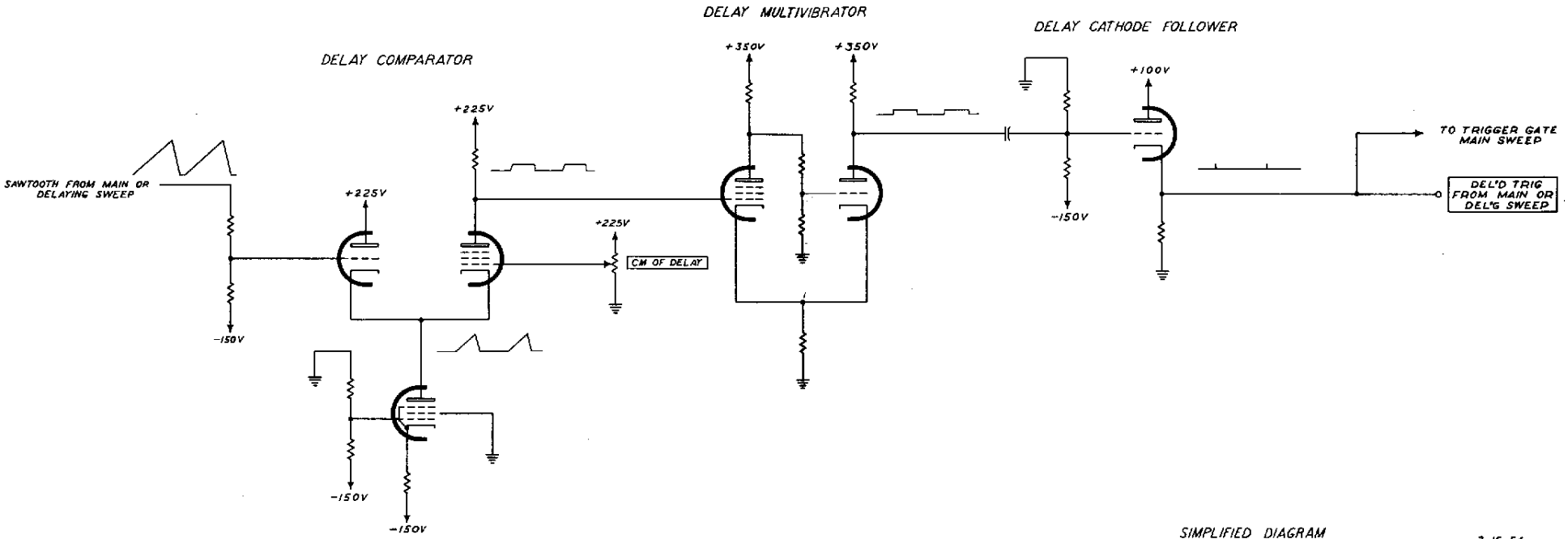


TYPE 545 OSCILLOSCOPE

A

SIMPLIFIED DIAGRAM
DELAYING-SWEEP GENERATOR

3-15-54
RF

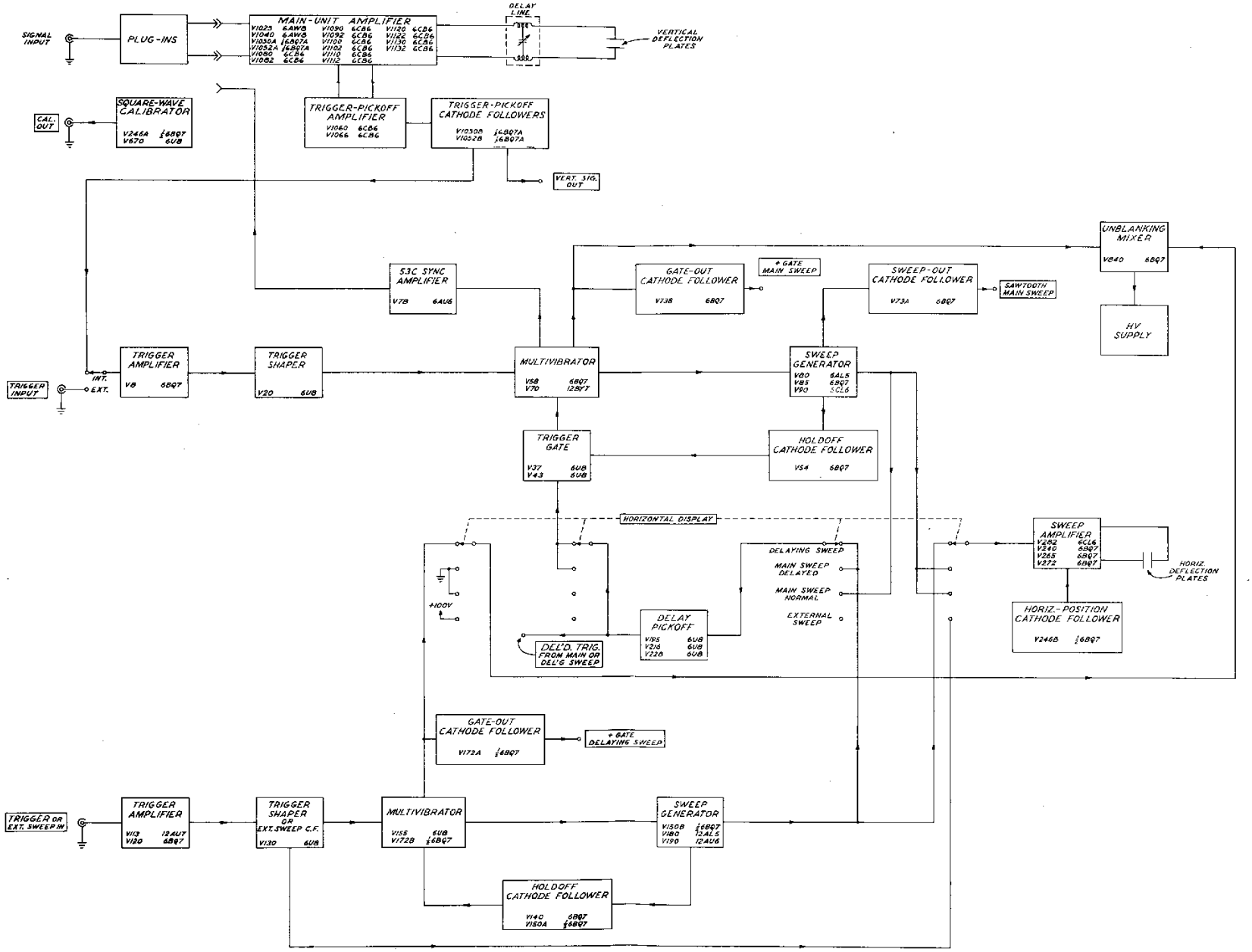


TYPE 545 OSCILLOSCOPE

A

SIMPLIFIED DIAGRAM
DELAY PICKOFF

3-15-54
KF



TYPE 545 OSCILLOSCOPE

A1

BLOCK DIAGRAM

10-5-56 KF

ABBREVIATIONS

Cer.	ceramic	m	milli or 10^{-3}
Comp.	composition	Ω	ohm
EMC	electrolytic, metal cased	Poly.	polystyrene
f	farad	Prec.	precision
GMV	guaranteed minimum value	PT	paper tubular
h	henry	Tub.	tubular
k	kilohm or 10^3 ohms	v	working volts dc
meg	megohm or 10^6 ohms	Var.	variable
μ	micro or 10^{-6}	w	watt
μμ	micromicro or 10^{-12}	WW	wire wound

MAIN-SWEEP TRIGGER

Capacitors

						Order Parts by Number
C1	4.7 μμf	Cer.	Fixed	500 v	±1 μμf	281501
C3	.001 μf	PT	Fixed	600 v	20%	285501
C4	100 μμf	Cer.	Fixed	350 v	20%	281523
C7	.001 μf	Cer.	Fixed	500 v	GMV	283000
C9	47 μμf	Cer.	Fixed	500 v	20%	281518
C17	.001 μf	Cer.	Fixed	500 v	GMV	283000
C20	.01 μf	PT	Fixed	400 v	20%	285510
C28	.005 μf	Cer.	Fixed	500 v	GMV	283001
C34	22 μμf	Cer.	Fixed	500 v	20%	281510

Resistors

R1	1 meg	½ w	Fixed	Comp.	5%		301105
R2	390 k	½ w	Fixed	Comp.	5%		301394
R3	50 k	2 w	Var.	Comp.	20%	Int. Trig. DC Level Adj.	311023
R4	100 k	½ w	Fixed	Comp.	10%		302104
R5	1 meg	½ w	Fixed	Comp.	10%		302105
R6	100 k	½ w	Fixed	Comp.	10%		302104
R7	470 k	½ w	Fixed	Comp.	10%		302474
R8	47 Ω	½ w	Fixed	Comp.	10%		302470
R9	4.7 k	1 w	Fixed	Comp.	10%		304472
R10	4.7 k	1 w	Fixed	Comp.	10%		304472
R11	47 Ω	½ w	Fixed	Comp.	10%		302470
R12	33 k	2 w	Fixed	Comp.	10%		306333
R13	39 k	2 w	Fixed	Comp.	10%		306393
R14	100 k	½ w	Var.	Comp.	20%	TRIGGERING LEVEL, conc. with R43	311030*
R15	22 k	½ w	Fixed	Comp.	10%		302223
R16	470 k	½ w	Fixed	Comp.	10%		302474
R17	470 k	½ w	Fixed	Comp.	10%		302474
R19	56 k	½ w	Fixed	Comp.	10%		302563
R20	47 k	½ w	Fixed	Comp.	10%		302473
R21	47 k	½ w	Fixed	Comp.	10%		302473
R22	47 Ω	½ w	Fixed	Comp.	10%		302470
R23	1 k	½ w	Fixed	Comp.	10%		302102
R24	2.7 k	½ w	Fixed	Comp.	10%		302272
R27	22 k	2 w	Fixed	Comp.	10%		306223
R28	500 Ω	2 w	Var.	Comp.	20%	Trigger Sensitivity	311005
R29	22 k	2 w	Fixed	Comp.	10%		306223
R30	2.7 meg	½ w	Fixed	Comp.	10%		302275
R32	820 Ω	½ w	Fixed	Comp.	10%		302821
R33	47 Ω	½ w	Fixed	Comp.	10%		302470
R34	100 k	½ w	Fixed	Comp.	10%		302104

* Furnished as unit with R43, STABILITY.

Resistors (continued)

								Order Parts by Number
R35	100 k	½ w	Fixed	Comp.	10%			302104
R36	100 k	2 w	Var.	Comp.	20%	Triggering Level Centering		311026

Switches

					not wired	wired
SW1*	2 wafer	6 position	rotary	TRIGGER SLOPE	260099	262080
SW5*	3 wafer	5 position	rotary	TRIGGERING MODE		

Vacuum Tubes

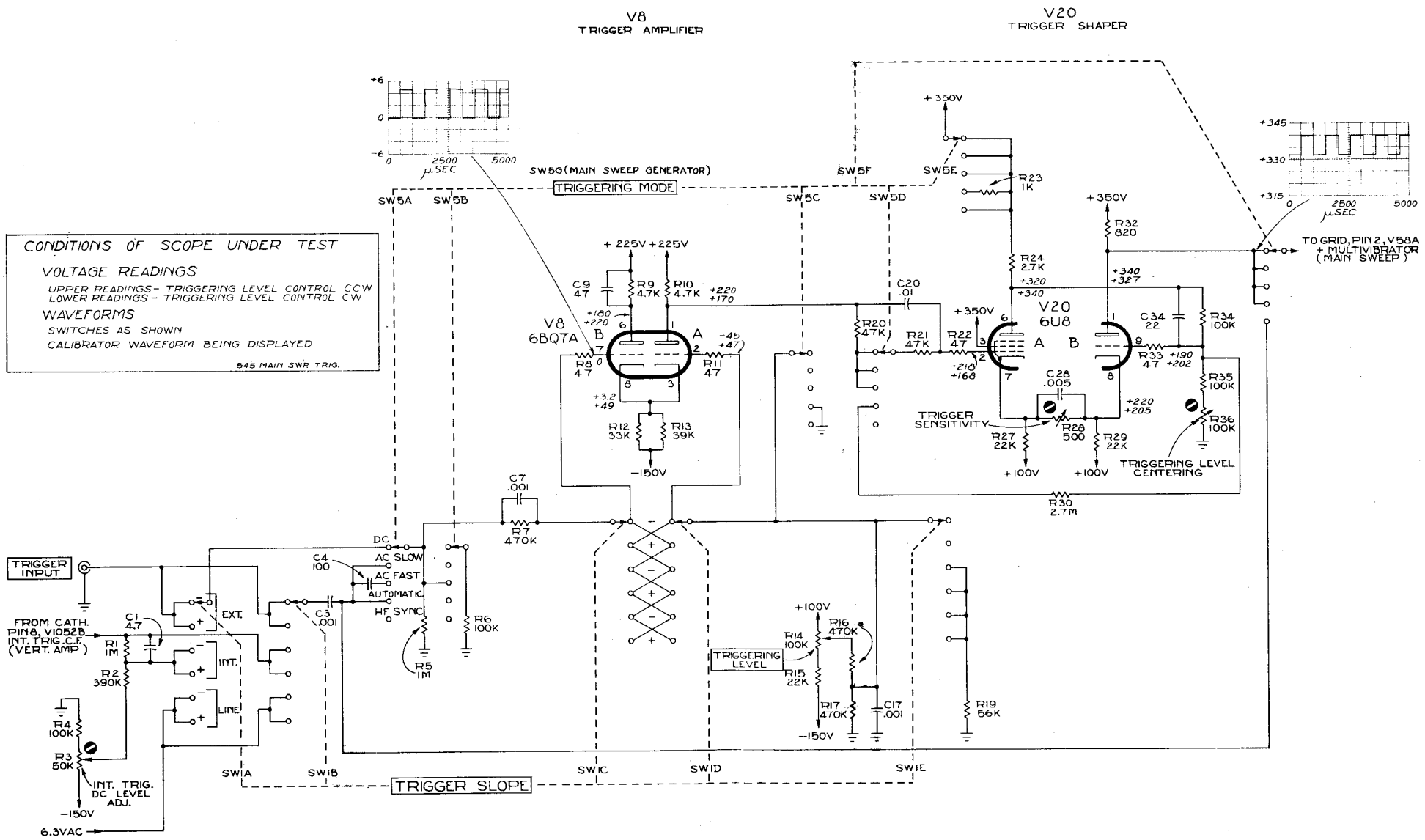
V8	6BQ7A	Trigger Amplifier	154028
V20	6U8	Trigger Shaper	154033

*** SW1 and SW5 shafts are concentric. Furnished as a unit.**

NOTE

Unless otherwise specified, all of the voltage readings were taken with a dc vacuum-tube voltmeter having an input resistance of 11 megohms. The waveforms shown were reproduced from actual photographs. There will be considerable variation between instruments because of normal manufacturing tolerances and vacuum-tube characteristics. Therefore, the significance of any discrepancies observed should be determined by referring to the circuit diagram.

All readings are in volts unless otherwise specified. Where two voltage readings are given, they represent the voltage as read by a voltmeter under two sets of conditions, and, as such, do not indicate the peak-to-peak excursion of voltage at the point.



TYPE 545 OSCILLOSCOPE

C

MAIN SWEEP TRIGGER

ABBREVIATIONS

Cer.	ceramic	m	milli or 10^{-3}
Comp.	composition	Ω	ohm
EMC	electrolytic, metal cased	Poly.	polystyrene
f	farad	Prec.	precision
GMV	guaranteed minimum value	PT	paper tubular
h	henry	Tub.	tubular
k	kilohm or 10^3 ohms	v	working volts dc
meg	megohm or 10^6 ohms	Var.	variable
μ	micro or 10^{-6}	w	watt
μμ	micromicro or 10^{-12}	WW	wire wound

MAIN SWEEP GENERATOR

Bulbs

			Order Parts by Number
B42	65–75 v ignition	1/25 w	150014
B95	55 v	1/25 w	150009
B96	65 v	1/25 w	150011

Capacitors

C37	.001 μf	Cer.	Fixed	500 v	GMV		283000
C40	.005 μf	Cer.	Fixed	500 v	GMV		283001
C41	.005 μf	Cer.	Fixed	500 v	GMV		283001
C45	.001 μf	Cer.	Fixed	500 v	GMV		283000
C50	8 μμf	Cer.	Fixed	500 v	±0.5 μμf		281503
C58	27 μμf	Cer.	Fixed	500 v	20%		281513
C65	12 μμf	Cer.	Fixed	500 v	10%		281506
C71	82 μμf	Cer.	Fixed	500 v	10%		281528
C72	.005 μf	Cer.	Fixed	500 v	GMV		283001
C73	12 μμf	Cer.	Fixed	500 v	10%		281506
C76	.005 μf	Cer.	Fixed	500 v	GMV		283001
C78	.005 μf	Cer.	Fixed	500 v	GMV		283001
C81	.001 μf	Cer.	Fixed	500 v	GMV		283000
C95	.001 μf	Cer.	Fixed	500 v	GMV		283000
C96	82 μμf	Cer.	Fixed	500 v	10%		281528

Inductors

L61	88 μh	Fixed	108022
LR72	#40 wire, 450 turns, on 3.3 k 1 w resistor		108058

Resistors

R37	470 k	½ w	Fixed	Comp.	10%		302474
R38	1 meg	½ w	Fixed	Comp.	10%		302105
R39	100 Ω	½ w	Fixed	Comp.	10%		302101
R40	220 k	½ w	Fixed	Comp.	10%		302224
R41	10 k	½ w	Fixed	Comp.	10%		302103
R42	470 k	½ w	Fixed	Comp.	10%		302474
R43	100 k	½ w	Var.	Comp.	20%	**STABILITY**, conc. with R14	311030**
R44	100 k	½ w	Fixed	Comp.	5%		301104
R45	200 k	½ w	Fixed	Comp.	5%		301204
R46	100 Ω	½ w	Fixed	Comp.	10%		302101
R47	470 k	½ w	Fixed	Comp.	5%		301474
R48	47 k	1 w	Fixed	Comp.	10%		304473
R49	100 k	2 w	Var.	Comp.	20%	Preset Stability	311026
R50	95 k	½ w	Fixed	Prec.	1%		309044
R51	220 k	½ w	Fixed	Prec.	1%		309052

** Furnished as a unit with R14, **TRIGGERING LEVEL.**

Resistors (continued)

						Order Parts by Number
R52	100 Ω	½ w	Fixed	Comp.	10%	302101
R53	22 k	2 w	Fixed	Comp.	10%	306223
R54	100 Ω	½ w	Fixed	Comp.	10%	302101
R57	4.7 meg	½ w	Fixed	Comp.	10%	302475
R58	1 k	½ w	Fixed	Comp.	10%	302102
R59	47 Ω	½ w	Fixed	Comp.	10%	302470
R60	2.7 k	1 w	Fixed	Comp.	Selected*	312569
R61	3.3 k	1 w	Fixed	Comp.	Selected*	
R62	56 k	1 w	Fixed	Comp.	5%	303563
R63	47 Ω	½ w	Fixed	Comp.	10%	302470
R64	2.5 k	1/10 w	Var.	Comp.	20% Multi Bal	311010
R65	39 k	1 w	Fixed	Comp.	Selected**	312570
R66	33 k	1 w	Fixed	Comp.	Selected**	
R67	100 Ω	½ w	Fixed	Comp.	10%	302101
R68	8 k	5 w	Fixed	WW	5%	308053
R69	1 k	½ w	Fixed	Comp.	10%	302102
R70	47 k	½ w	Fixed	Comp.	10%	302473
R71	270 Ω	½ w	Fixed	Comp.	10%	302271
R72	47 Ω	½ w	Fixed	Comp.	10%	302470
R73	47 k	½ w	Fixed	Comp.	10%	302473
R74	100 k	½ w	Fixed	Comp.	10%	302104
R75	100 Ω	½ w	Fixed	Comp.	10%	302101
R76	47 Ω	½ w	Fixed	Comp.	10%	302470
R77	4.7 k	1 w	Fixed	Comp.	10%	304472
R78	47 k	½ w	Fixed	Comp.	10%	302473
R79	1 meg	½ w	Fixed	Comp.	10%	302105
R80	10 k	½ w	Fixed	Comp.	10%	302103
R81	100 k	½ w	Fixed	Comp.	10%	302104
R82	1 meg	½ w	Fixed	Comp.	10%	302105
R83	1.8 meg	½ w	Fixed	Comp.	10%	302185
R84	100 k	1 w	Fixed	Comp.	10%	304104
R85	47 Ω	½ w	Fixed	Comp.	10%	302470
R86	470 Ω	½ w	Fixed	Comp.	10%	302471
R87	8 k	5 w	Fixed	WW	5%	308053
R88	2 k	2 w	Var.	Comp.	20% Sweep Length	311008
R89	4 k	5 w	Fixed	WW	5%	308051
R90	47 Ω	½ w	Fixed	Comp.	10%	302470
R91	22 k	2 w	Fixed	Comp.	10%	306223
R92	22 k	2 w	Fixed	Comp.	10%	306223
R93	22 k	2 w	Fixed	Comp.	10%	306223
R95	47 k	½ w	Fixed	Comp.	10%	302473
R96	1.5 meg	½ w	Fixed	Comp.	10%	302155

Switches

SW200	See parts list, Delaying Sweep Trigger

* R60 and R61 selected to total 6 k ±2½%. Furnished as a unit.

** Selected with ratio 39/33 ±2½%. Furnished as a unit.

Vacuum Tubes

			Order Parts by Number
V37A	½ 6U8	Delayed Trigger Amplifier	154033
V37B	½ 6U8	+ Multivibrator, Trigger Gate Generator	
V43A	½ 6U8	— Multivibrator, Trigger Gate Generator	154033
V43B	½ 6U8	Clamp and Ready Indicator	
V54	6BQ7A	Sweep Holdoff Cathode Followers	154028
V58A	½ 6BQ7A	+ Multivibrator	154028
V58B	½ 6BQ7A	Multivibrator Cathode Follower	
V70	**12BY7**	— Multivibrator	**154047**
V73A	½ 6BQ7A	Sawtooth-out Cathode Follower	154028
V73B	½ 6BQ7A	+ Gate-out Cathode Follower	
V78	**6AU6**	Multi-Trace Units Sync Amplifier	**154022**
V80	6AL5	Disconnect Diodes	154016
V85	6BQ7A	Sweep-generator Cathode Follower	154028
V90	6CL6	Miller Integrator	154031

NOTE

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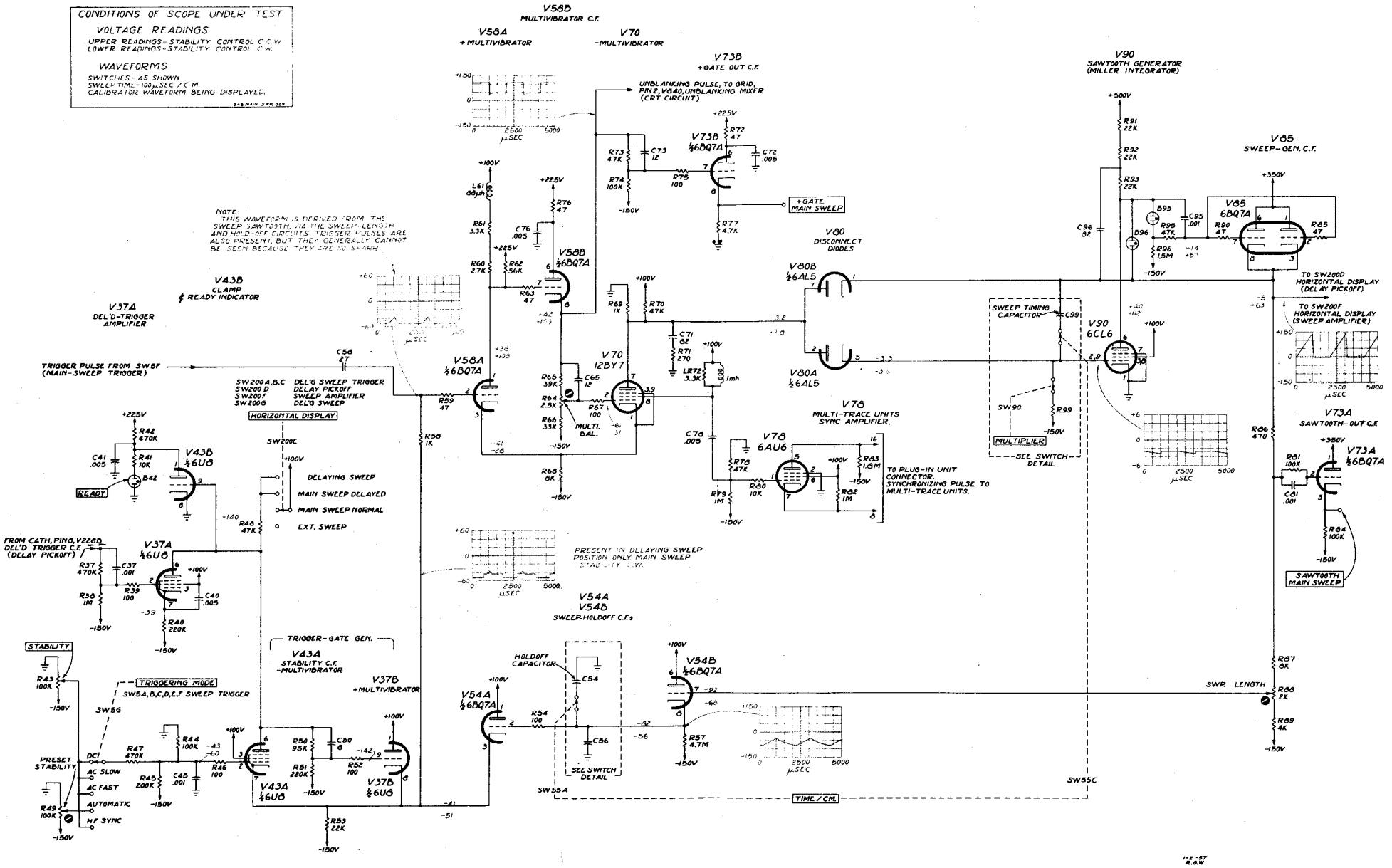

CONDITIONS OF SCOPE UNDER TEST
VOLTAGE READINGS
UPPER READINGS - STABILITY CONTROL C.C.W.
LOWER READINGS - STABILITY CONTROL C.W.
WAVEFORMS
SWITCHES - AS SHOWN.
SWEEP TIME - 100 μSEC / C.M.
CALIBRATOR WAVEFORM BEING DISPLAYED.
V58B MULTIVIBRATOR C.F.
V58A + MULTIVIBRATOR
V70 - MULTIVIBRATOR
V73B + GATE OUT C.F.
UNBLANKING PULSE, TO GRID, PIN 2, V640, UNBLANKING MIXER (CRT CIRCUIT)
+GATE MAIN SWEEP
V90 SAWTOOTH GENERATOR (MILLER INTEGRATOR)
V85 SWEEP-GEN. C.F.
V80 DISCONNECT DIODES
V43B CLAMP & READY INDICATOR
V37A DEL'D-TRIGGER AMPLIFIER
TRIGGER PULSE FROM SW5F (MAIN-SWEEP TRIGGER)
SW200A,B,C SW200D SW200F SW200G
DEL'G SWEEP TRIGGER DELAY PICKOFF SWEEP AMPLIFIER DEL'G SWEEP
HORIZONTAL DISPLAY
DELAYING SWEEP
MAIN SWEEP DELAYED
MAIN SWEEP NORMAL
EXT. SWEEP
V78 MULTI-TRACE UNITS SYNC AMPLIFIER.
TO PLUG-IN UNIT CONNECTOR. SYNCHRONIZING PULSE TO MULTI-TRACE UNITS.
SWEEP TIMING CAPACITOR
SEE SWITCH DETAIL
MULTIPLIER
TO SW200D HORIZONTAL DISPLAY (DELAY PICKOFF)
TO SW200F HORIZONTAL DISPLAY (SWEEP AMPLIFIER)
V73A SAWTOOTH-OUT C.F.
SAWTOOTH MAIN SWEEP
FROM CATH, PIN 8, V220B DEL'D TRIGGER C.F. (DELAY PICKOFF)
V37A
TRIGGER-GATE GEN.
V43A STABILITY C.F. -MULTIVIBRATOR
V37B +MULTIVIBRATOR
STABILITY
TRIGGERING MODE
SW5A,B,C,D,E,F SWEEP TRIGGER
SW5G
PRESET STABILITY
AC SLOW
AC FAST
AUTOMATIC
HF SYNC
PRESENT IN DELAYING SWEEP POSITION ONLY MAIN SWEEP STABILITY C.W.
V54A V54B SWEEP-HOLDOFF C.F.s
HOLDOFF CAPACITOR
SEE SWITCH DETAIL
SW55A
SW55C
TIME/CM.
SWP. LENGTH
NOTE: THIS WAVEFORM IS DERIVED FROM THE SWEEP SAWTOOTH, VIA THE SWEEP-LENGTH AND HOLD-OFF CIRCUITS. TRIGGER PULSES ARE ALSO PRESENT, BUT THEY GENERALLY CANNOT BE SEEN BECAUSE THEY ARE SO SHARP.

ABBREVIATIONS

Cer.	ceramic	m	milli or 10^{-3}
Comp.	composition	Ω	ohm
EMC	electrolytic, metal cased	Poly.	polystyrene
f	farad	Prec.	precision
GMV	guaranteed minimum value	PT	paper tubular
h	henry	Tub.	tubular
k	kilohm or 10^3 ohms	v	working volts dc
meg	megohm or 10^6 ohms	Var.	variable
μ	micro or 10^{-6}	w	watt
μμ	micromicro or 10^{-12}	WW	wire wound

MAIN-SWEEP TIMING SWITCH

Capacitors

							Order Parts by Number
C54A	.22 μf	PT	Fixed	400 v	20%		285533
C54B	.022 μf	PT	Fixed	400 v	20%		285515
C54C	.0022 μf	PT	Fixed	400 v	20%		285543
C54D	220 μμf	Mica	Fixed	500 v	10%		283536
C56	39 μμf	Cer.	Fixed	500 v	10%		281516
C99A C99B C99C	1.0 μf .1 μf .01 μf	Special timing series manufactured by Tektronix. Order replacements from factory.					291007
C99D	.001 μf	Special			±¼%		291008
C99E	82 μμf	Mica	Fixed	500 v	5%		283534
C99F	5-20 μμf	Cer.	Var.	500 v	20%		281010
C99G	82 μμf	Mica	Fixed	500 v	5%		283534
C99H	5-20 μμf	Cer.	Var.	500 v	20%		281010
C99J	3-12 μμf	Cer.	Var.	500 v	20%		281007

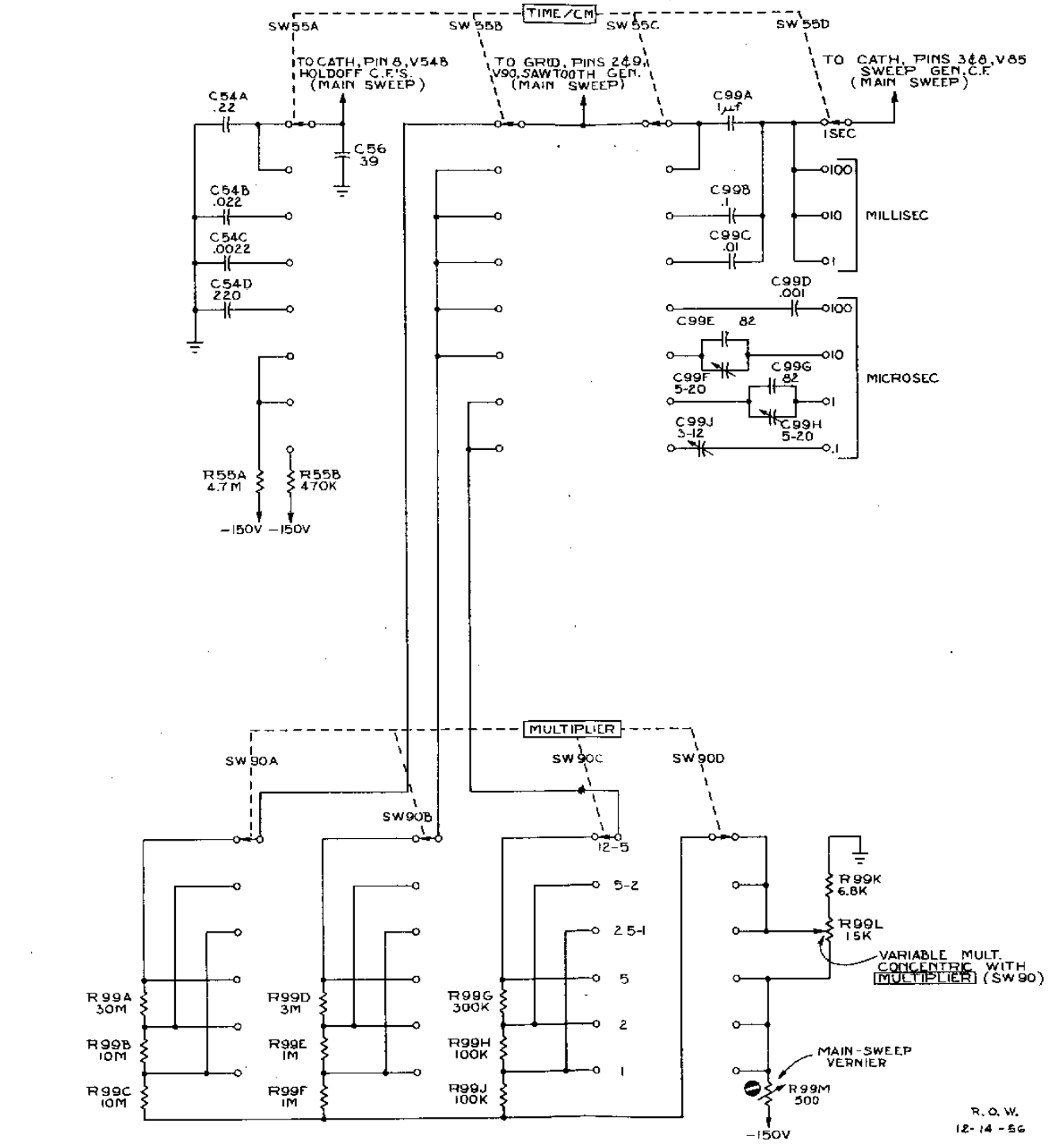
Resistors

R55A	4.7 meg	½ w	Fixed	Comp.	10%		302475
R55B	470 k	½ w	Fixed	Comp.	10%		302474
R99A	30 meg	2 w	Fixed	Prec.	1%		310505
R99B	10 meg	1 w	Fixed	Prec.	1%		310107
R99C	10 meg	1 w	Fixed	Prec.	1%		310107
R99D	3 meg	½ w	Fixed	Prec.	1%		309026
R99E	1 meg	½ w	Fixed	Prec.	1%		309014
R99F	1 meg	½ w	Fixed	Prec.	1%		309014
R99G	300 k	½ w	Fixed	Prec.	1%		309125
R99H	100 k	½ w	Fixed	Prec.	1%		309045
R99J	100 k	½ w	Fixed	Prec.	1%		309045
R99K	6.8 k	1 w	Fixed	Comp.	10%		304682
R99L	15 k	2 w	Var.	Comp.	20%		311045
R99M	500 Ω	½ w	Var.	Comp.	20%	MAIN SWEEP VERNIER	311056

Switches

					not wired	wired
SW55*	4 wafer	8 position	rotary	TIME/CM	260010	262063
SW90	4 wafer	6 position	rotary	MULTIPLIER	260011	262064

*SW55 and SW254, 5X MAGNIFIER, shafts are concentric. Furnished as a unit.



TYPE 545 OSCILLOSCOPE

MAIN - SWEEP TIMING SWITCH

ABBREVIATIONS

Cer.	ceramic	m	milli or 10^{-3}
Comp.	composition	Ω	ohm
EMC	electrolytic, metal cased	Poly.	polystyrene
f	farad	Prec.	precision
GMV	guaranteed minimum value	PT	paper tubular
h	henry	Tub.	tubular
k	kilohm or 10^3 ohms	v	working volts dc
meg	megohm or 10^6 ohms	Var.	variable
μ	micro or 10^{-6}	w	watt
μμ	micromicro or 10^{-12}	WW	wire wound

DELAYING-SWEEP TRIGGER

Capacitors

							Order Parts by Number
C100	5-25 μμf	Cer.	Var.	500 v			281011
C101	5-25 μμf	Cer.	Var.	500 v			281011
C102	100 μμf	Cer.	Fixed	500 v	10%		281530
C108	.001 μf	Cer.	Fixed	500 v	GMV		283000
C110	5-25 μμf	Cer.	Var.	500 v			281011
C132	22 μμf	Cer.	Fixed	500 v	20%		281510

Resistors

R101	900 k	½ w	Fixed	Prec.	1%		309111
R102	111 k	½ w	Fixed	Prec.	1%		309046
R105	100 k	½ w	Var.	Comp.	20%	TRIGGERING LEVEL, conc. with R122 and R140	311046*
R106	22 k	½ w	Fixed	Comp.	10%		302223
R107	1 meg	½ w	Fixed	Comp.	10%		302105
R108	100 k	½ w	Fixed	Comp.	10%		302104
R109	47 Ω	½ w	Fixed	Comp.	10%		302470
R110	1 meg	½ w	Fixed	Prec.	1%		309014
R113	47 k	1 w	Fixed	Comp.	10%		304473
R114	50 k	2 w	Var.	Comp.	20%	Ext. Sweep Ampl. DC Bal.	311023
R115	47 k	1 w	Fixed	Comp.	10%		304473
R120	100 Ω	½ w	Fixed	Comp.	10%		302101
R121	47 k	1 w	Fixed	Comp.	10%		304473
R122	15 k	½ w	Fixed	Comp.	20%	EXT. SWEEP ATTEN., ganged with R140	311046*
R123	47 k	1 w	Fixed	Comp.	10%		304473
R124	33 k	2 w	Fixed	Comp.	10%		306333
R130	100 Ω	½ w	Fixed	Comp.	10%		302101
R131	3.3 k	½ w	Fixed	Comp.	10%		302332
R132	100 k	½ w	Fixed	Comp.	10%		302104
R133	270 k	½ w	Fixed	Comp.	10%		302274
R134	100 Ω	½ w	Fixed	Comp.	10%		302101
R135	33 k	2 w	Fixed	Comp.	10%		306333
R136	2.2 k	½ w	Fixed	Comp.	10%		302222

* R105, R122 and R140 furnished as a unit.

Switches

					Order Parts by Number	
					not wired	wired
SW100	double pole	double throw	toggle	ATTEN	260014	—
SW113	double pole	double throw	toggle	SLOPE	260014	—
SW200	4 wafer	4 position	rotary	HORIZONTAL DISPLAY	260007	262061

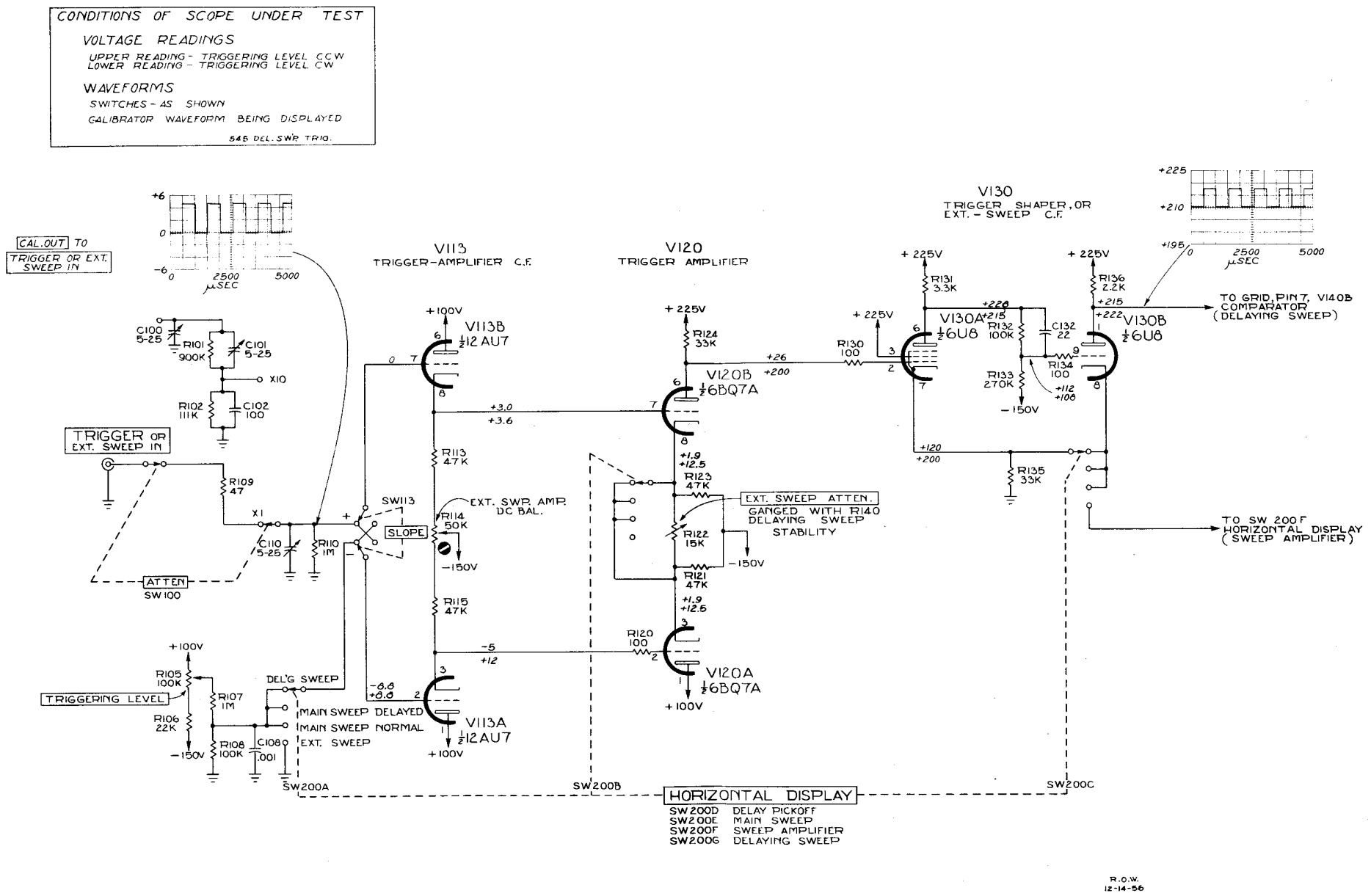
Vacuum Tubes

V113	12AU7	Trigger Amplifier Cathode Follower	154041
V120	6BQ7A	Trigger Amplifier	154028
V130	6U8	Trigger Shaper Ext. Sweep Cathode Follower	154033

NOTE

Unless otherwise specified, all of the voltage readings were taken with a dc vacuum-tube voltmeter having an input resistance of 11 megohms. The waveforms shown were reproduced from actual photographs. There will be considerable variation between instruments because of normal manufacturing tolerances and vacuum-tube characteristics. Therefore, the significance of any discrepancies observed should be determined by referring to the circuit diagram.

All readings are in volts unless otherwise specified. Where two voltage readings are given, they represent the voltage as read by a voltmeter under two sets of conditions, and, as such, do not indicate the peak-to-peak excursion of voltage at the point.


CONDITIONS OF SCOPE UNDER TEST
VOLTAGE READINGS
UPPER READING - TRIGGERING LEVEL CCW
LOWER READING - TRIGGERING LEVEL CW
WAVEFORMS
SWITCHES - AS SHOWN
CALIBRATOR WAVEFORM BEING DISPLAYED
545 DEL. SWP. TRIG.
CAL. OUT TO TRIGGER OR EXT. SWEEP IN
V113 TRIGGER-AMPLIFIER C.F.
V120 TRIGGER AMPLIFIER
V130 TRIGGER SHAPER, OR EXT. - SWEEP C.F.
V113B ½12AU7
V113A ½12AU7
V120B ½6BQ7A
V120A ½6BQ7A
V130A ½6U8
V130B ½6U8
TRIGGER OR EXT. SWEEP IN
ATTEN SW100
SLOPE
SW113
EXT. SWP. AMP DC BAL.
EXT. SWEEP ATTEN. GANGED WITH R140 DELAYING SWEEP STABILITY
TRIGGERING LEVEL
DEL'G SWEEP
MAIN SWEEP DELAYED
MAIN SWEEP NORMAL
EXT. SWEEP
TO GRID, PIN 7, V140B COMPARATOR (DELAYING SWEEP)
TO SW 200F HORIZONTAL DISPLAY (SWEEP AMPLIFIER)
HORIZONTAL DISPLAY
SW200D DELAY PICKOFF
SW200E MAIN SWEEP
SW200F SWEEP AMPLIFIER
SW200G DELAYING SWEEP
SW200A
SW200B
SW200C
R.O.W. 12-14-56

ABBREVIATIONS

Cer.	ceramic	m	milli or 10^{-3}
Comp.	composition	Ω	ohm
EMC	electrolytic, metal cased	Poly.	polystyrene
f	farad	Prec.	precision
GMV	guaranteed minimum value	PT	paper tubular
h	henry	Tub.	tubular
k	kilohm or 10^3 ohms	v	working volts dc
meg	megohm or 10^6 ohms	Var.	variable
μ	micro or 10^{-6}	w	watt
μμ	micromicro or 10^{-12}	WW	wire wound

DELAYING SWEEP GENERATOR

Bulbs

			Order Parts by Number
B180	65 v	1/25 w	150011
B187	55 v	1/25 w	150009

Capacitors

							Order Parts by Number
C146	47 μμf	Cer.	Fixed	500 v	20%		281518
C158	12 μμf	Cer.	Fixed	500 v	10%		281506
C170	39 μμf	Cer.	Fixed	500 v	10%		281516
C172	12 μμf	Cer.	Fixed	500 v	10%		281506
C187	.001 μf	Cer.	Fixed	500 v	GMV		283000

Resistors

							Order Parts by Number
R140	100 k	½ w	Var.	Comp.	20%	STABILITY, ganged with R122	311046*
R141	100 k	½ w	Fixed	Comp.	10%		302104
R142	27 k	½ w	Fixed	Comp.	10%		302273
R143	47 k	½ w	Fixed	Comp.	10%		302473
R146	100 Ω	½ w	Fixed	Comp.	10%		302101
R147	22 k	1 w	Fixed	Comp.	10%		304223
R148	100 Ω	½ w	Fixed	Comp.	10%		302101
R150	1 meg	½ w	Fixed	Comp.	10%		302105
R151	1 k	½ w	Fixed	Comp.	10%		302102
R155	100 Ω	½ w	Fixed	Comp.	10%		302101
R156	10 k	1 w	Fixed	Comp.	5%		303103
R157	100 Ω	½ w	Fixed	Comp.	10%		302101
R158	39 k	1 w	Fixed	Comp.	5%		303393
R159	33 k	1 w	Fixed	Comp.	5%		303333
R160	15 k	2 w	Fixed	Comp.	5%		305153
R163	100 Ω	½ w	Fixed	Comp.	10%		302101
R164	2.2 k	½ w	Fixed	Comp.	10%		302222
R165	47 k	½ w	Fixed	Comp.	10%		302473
R170	2.7 k	½ w	Fixed	Comp.	10%		302272
R172	47 k	½ w	Fixed	Comp.	10%		302473
R173	100 k	½ w	Fixed	Comp.	10%		302104
R174	100 Ω	½ w	Fixed	Comp.	10%		302101
R177	10 k	½ w	Fixed	Comp.	10%		302103
R180	15 k	2 w	Fixed	Comp.	10%		306153
R181A	10 k	2 w	Var.	Comp.	20%	LENGTH	311016
R181B**		½ w	Fixed	Comp.	10%		
R182A	12 k	2 w	Fixed	Comp.	10%		306123
R182B**		½ w	Fixed	Comp.	10%		
R185	100 Ω	½ w	Fixed	Comp.	10%		302101
R186	220 k	2 w	Fixed	Comp.	10%		306224

* R140, R105, and R122 furnished as a unit.
Selected to adjust the range of the **DELAYING SWEEP LENGTH control.

Resistors (Continued)

						Order Parts by Number
R187	100 k	½ w	Fixed	Comp.	10%	302104
R188	1.5 meg	½ w	Fixed	Comp.	10%	302155

Vacuum Tubes

V140	6BQ7A	Comparator	154028
V150A	½ 6BQ7A	Holdoff Cathode Follower	154028
V150B	½ 6BQ7A	Sweep-Generator Cathode Follower	
V155A	½ 6U8	— Multivibrator	154033
V155B	½ 6U8	+ Multivibrator	
V172A	½ 6BQ7A	Gate-Out Cathode Follower	154028
V172B	½ 6BQ7A	Multivibrator Cathode Follower	
V180	12AL5	Disconnect Diodes	154038
V190	12AU6	Miller Integrator	154040