

CATHODE-RAY OSCILLOSCOPE TYPE 543

INSTRUCTION MANUAL



TEKTRONIX, INC.

MANUFACTURERS OF CATHODE-RAY AND VIDEO TEST INSTRUMENTS

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SECTION 1

SPECIFICATIONS

The Type 543 Oscilloscope is a laboratory-type instrument well suited to oscilloscope applications involving fast-rise pulses and transients. Plug-in preamplifiers are used in the vertical-deflection system, permitting the instrument to be used in many specialized applications.

VERTICAL-DEFLECTION SYSTEM

TABLE 1-1

Characteristics of Plug-In and Type 543 Combinations.

PLUG-IN	DEFLECTION FACTOR (Calibrated)	PASS BAND	RISETIME	*INPUT CHARACTERISTICS
Type A	0.05 v/cm to 20 v/cm	dc to 20 mc	0.018 μ sec	47 $\mu\mu$ f, 1 meg
Type B	0.05 v/cm to 20 v/cm 5 mv/cm to 0.05 v/cm	dc to 20 mc 5 cps to 12 mc	0.018 μ sec 0.03 μ sec	47 $\mu\mu$ f, 1 meg 47 $\mu\mu$ f, 1 meg
Type CA	0.05 v/cm to 20 v/cm	dc to 24 mc	0.015 μ sec	20 $\mu\mu$ f, 1 meg
Type D	1 mv/cm to 50 v/cm	dc to 350 kc at 1 mv/cm, in- creasing to 2 mc at 50 v/cm		47 $\mu\mu$ f, 1 meg
Type E	50 μ v/cm to 10 mv/cm	0.06 cps to 30 kc at full gain, increasing to 60 kc at 0.5 v/cm		47 $\mu\mu$ f, 1 meg
Type G	0.05 v/cm to 20 v/cm	dc to 20 mc	0.018 μ sec	47 $\mu\mu$ f, 1 meg
Type H	0.005 v/cm to 20 v/cm	dc to 15 mc	0.023 μ sec	47 $\mu\mu$ f, 1 meg
Type K	0.05 v/cm to 20 v/cm	dc to 30 mc	0.012 μ sec	20 $\mu\mu$ f, 1 meg
Type L	0.05 v/cm to 20 v/cm 0.005 v/cm to 2 v/cm	dc to 30 mc 3 cps to 24 mc	0.015 μ sec	20 $\mu\mu$ f, 1 meg 20 $\mu\mu$ f, 1 meg

*Characteristics at the input connector to the plug-in. The Type P410 probes furnished with the Type 543 will reduce the 47- $\mu\mu$ f input capacitances to 11 $\mu\mu$ f

and the 20- $\mu\mu$ f input capacitances to 8 $\mu\mu$ f. The input resistance in all cases is increased to 10 megohms when a Type P410 probe is used.



Oscilloscope Amplifier

Risetime—0.01 μ sec.

Linear Deflection 4 cm.

DC coupled.

Delay Line

Balanced Network,

Signal Delay 0.2 μ sec.

HORIZONTAL-DEFLECTION SYSTEM

Sweep Rates

Twenty-four calibrated sweep rates from 0.1 μ sec/cm to 5 sec/cm. Accuracy typically within 1% of full scale; in all cases within 3% of full scale.

Continuously variable sweep rates are available from 0.1 μ sec/cm to 12 sec/cm.

Magnifier

Six degrees of sweep magnification are provided: 2, 5, 10, 20, 50 and 100 times.

Accuracy within 5% when the magnified sweep speed does not exceed the maximum calibrated rate of 0.02 μ sec/cm.

Unblanking

DC coupled.

Triggering Signal Requirements

Internal—2 mm of vertical deflection.

External—2 v to 50 v, peak-to-peak.

Frequency range—dc to 5 mc.

Synchronizing Signal Requirements

Internal—2 cm of vertical deflection.

External—2 v to 50 v, peak-to-peak.

Frequency range—5 mc to 30 mc.

External Horizontal Signal Input

Deflection factor—calibrated ranges of 0.1 v, 1 v, and 10 v/cm.

Continuously variable from 0.1 v to approximately 100 v/cm.

Frequency range—dc to 500 kc in the calibrated positions.

Input impedance—approximately 45 μ mf paralleled by 1 megohm.

OTHER CHARACTERISTICS

Cathode-Ray Tube

Type T543 P2—P1, P7, P11 phosphors optional.

Accelerating potential—10,000 volts.

Vertical deflection factor—nominal 7 v/cm.

Horizontal deflection factor—nominal 30 v/cm.

Voltage Calibrator

Square-wave output at approximately 1 kc.

Eighteen fixed voltages from .2 millivolts to 100 volts, peak-to-peak.

Accuracy—3%.

Output Waveforms

Positive gate of same duration as sweep, 30 volts.

Positive-going sweep sawtooth, 150 volts.

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

Beam-Position Indicators

Indicator lamps to show which way the beam is off the screen if it cannot be seen.

Power Requirements

Line voltage—105 v to 125 v, or 210 v to 250 v, 50-60 cycles.

Power—530 watts at 117 v line voltage with a Type CA Plug-In Preampifier installed.

Mechanical Specifications

Ventilation—filtered, forced air.



Finish—photo-etched, anodized panels. Blue wrinkle, perforated cabinets.
Dimensions—24" long, 13" wide, 16³/₄" high.
Weight—61¹/₂ pounds.

Accessories

1—Power cord and adapter.

2—Type A510 Binding Post Adapters.

2—Type P410 Probes with tips.

2—Test clip assemblies.

1—Green filter.

1—Test lead.

1—Instruction Manual.

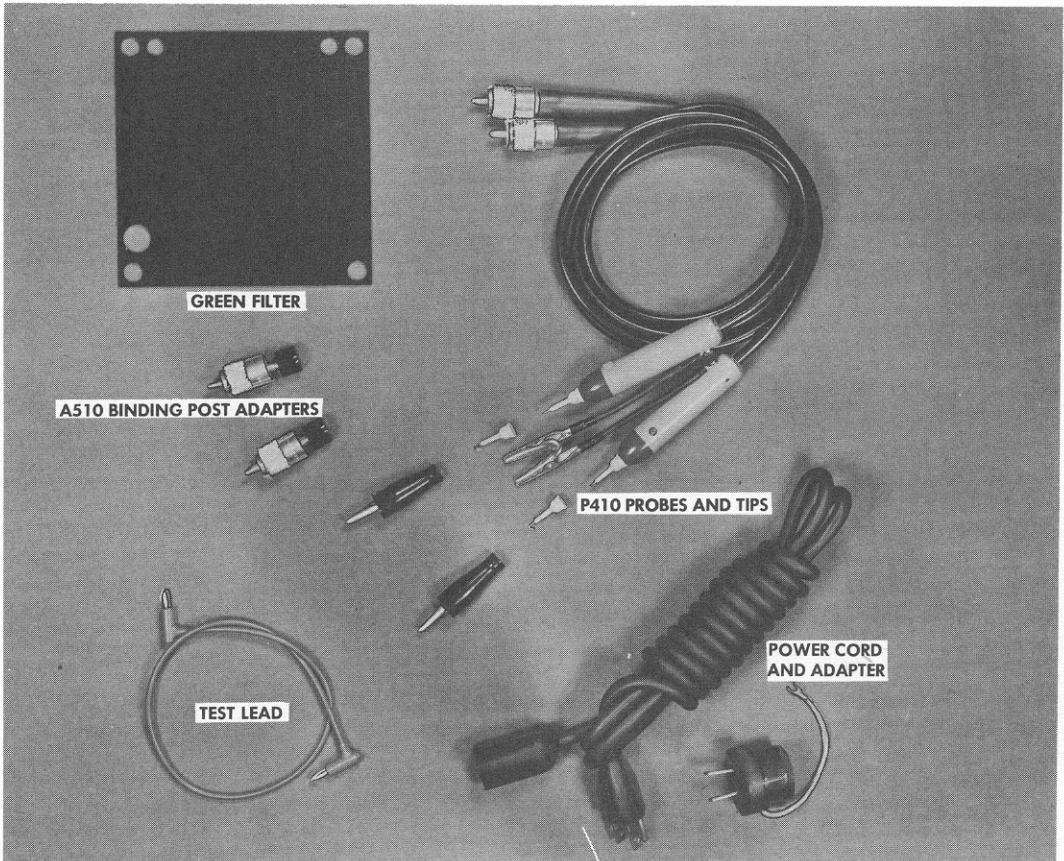


Fig. 1-1. Accessories for the Type 543 Oscilloscope.



SECTION 2

INSTALLATION INSTRUCTIONS

Cooling

A fan maintains safe operating temperature in the Type 543 by circulating filtered air over the rectifiers and other components. The instrument must be placed so that there is free air passage around the air intake. The filter must be clean to permit adequate circulation. Instructions for cleaning the filter are found in the Maintenance section of the manual.

WARNING: The Type 543 should not be operated unless the fan is running. The interior temperature will rise to a dangerous level in five to ten minutes of such operation. Moreover, the bottom and side panels must be in place for proper air circulation. Do not remove the panels except for moderate periods of time during maintenance.

Power Requirements

Unless tagged otherwise your instrument is connected at the factory for operation at 105 to 125 volts, 50 to 60 cycles ac, (117 volts nominal). However, provisions are made for easy conversion to operation at 210 to 250 volts, 50 to 60 cycles (234 volts nominal). The power transformer T700 is provided with split input windings which are normally connected in parallel for 117-volt operation, but which can be connected in series for 234-volt operation. Each of these split windings terminates in a nest of four terminal lugs arranged in a square on the underside of the transformer, and numbered 1, 2, 3 and 4 in a clockwise rotation.

Terminals 1 and 3 are connected to one winding and terminals 2 and 4 are connected to the second winding. The ac input leads are con-

nected to terminals 1 and 4 for both 117-volt and 234-volt operation, so these connections do not have to be changed when converting from one line voltage to the other.

When wired for 117-volt operation terminals 1 and 2 are joined by a bare bus wire, and terminals 3 and 4 are similarly joined, as shown in Fig. 2-1(a). To convert to 234-volt operation remove the bare bus wires between these terminals and substitute a single connecting wire between terminals 2 and 3, as shown in Fig. 2-1(b).

Fan Connections

The cooling fan is powered by a 117-volt ac motor. If the instrument is converted to operate from a 234-volt line, a change in the fan wiring must be made so that it operates from a 117-volt source.

The leads that connect to the fan motor terminate in a four-terminal ceramic strip adjacent to the power transformer and to R724. The black wire closest to R724 is connected by another wire to terminal 3 of the power transformer for both 117-volt and 234-volt operation; this wire does not have to be changed when converting from one line voltage to the other.

The other black wire should be lifted free of the notch in which it is soldered and moved one notch closer to R724, as shown in Fig. 2-2.

Fuse Data

Fuse data is silk-screened on the rear panel of the instrument adjacent to the fuse holder. Use only the recommended fuse for maximum over-current protection.



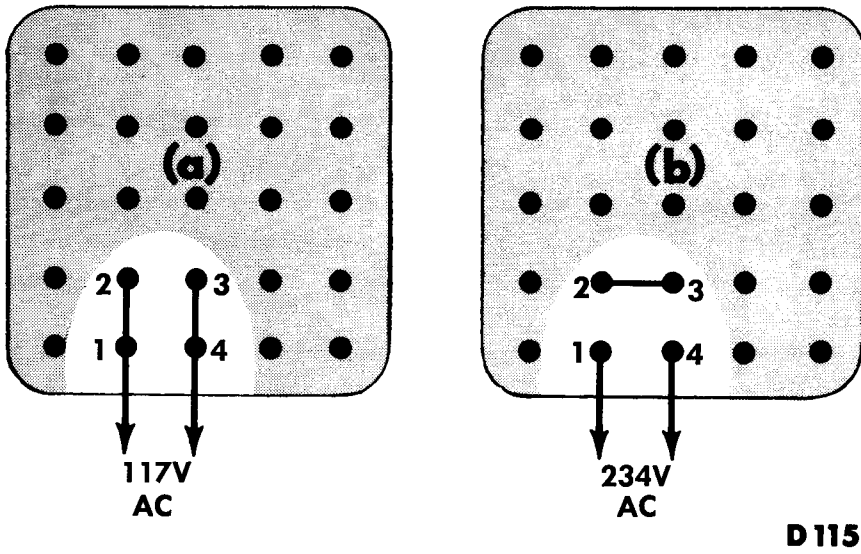


Fig. 2-1. Converting the power transformer from 105-125 volt operation to 210-250 volt operation.

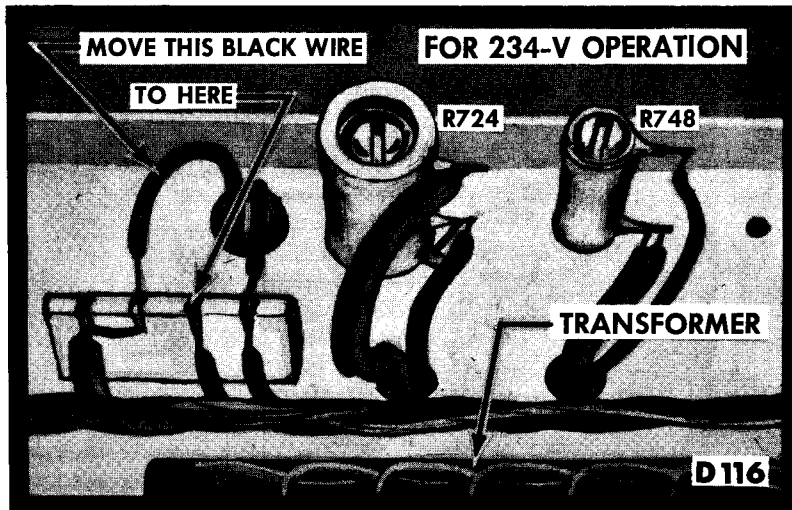


Fig. 2-2. Converting the fan motor from 105-125 volt operation to 210-225 volt operation.

SECTION 3

OPERATING

INSTRUCTIONS

We know you are anxious to begin using your new Type 543 oscilloscope. This section of the manual is intended to help you accomplish this as rapidly as possible. It describes some of the most common applications of the oscilloscope.

CAUTION: The cathode ray tube in this instrument has an accelerating potential of 10,000 volts. The intensity of a sharply focused spot can be bright enough to burn the screen phosphor if the spot remains in one place. Be careful not to leave a fixed bright spot on the screen. Turn the intensity down so that the spot is dim or extinguished if you leave the instrument unattended.

HORIZONTAL DEFLECTION SYSTEM

TRIGGERED OPERATION

For most uses of the oscilloscope a stable display of some waveform is required. To accomplish this the oscilloscope can be operated so that the horizontal sweep starts at a given point on the displayed waveform; this is known as "triggered" operation. For the present, then, we can refer to the starting of the sweep, at the left side of the graticule, as "triggering" the sweep.

Triggered operation is also useful for observing a waveform which may occur only once, or which may occur at random intervals.

For any of these uses the oscilloscope can alternatively be used in such a way that each horizontal sweep is triggered by some waveform other than the one being observed, but which bears a time relationship to the observed waveform.

The waveform used to start the horizontal sweep is called the "triggering signal", whether it is the waveform being observed or some other waveform. The following instructions tell you how to select this signal. They also contain

information on triggering according to various modes, depending on the nature of the triggering signal.

How to select the triggering signal

1. To trigger the sweep from the waveform being observed set the black TRIGGER SLOPE knob to INT. (+ or -).
2. To trigger the sweep from the power-line wave, as in the case when observing a waveform which has a time relationship to the power-line wave, set the black TRIGGER SLOPE knob to LINE (+ or -).
3. To trigger the sweep from some external waveform (one having a time relationship to the waveform being observed), connect the source of the triggering signal to the TRIGGER INPUT connector and set the black TRIGGER SLOPE knob to EXT. (+ or -).



If you want the start of the display, at the left side of the graticule, to occur at a time when the triggering signal is rising (has a positive slope), use the + INT., + LINE, or + EXT. position of the TRIGGER SLOPE knob. For the start of the display to occur when the triggering signal is falling (has a negative slope), use the —INT., —LINE, or —EXT. position.

How to select the triggering mode

AUTOMATIC

This is an especially useful triggering mode, providing automatic triggering from periodic signals in the range from 60 cycles to 2 mc. When not being triggered, the sweep runs at approximately a 50-cycle rate in this mode, generating a base line which indicates that the oscilloscope is adjusted to display any signal that might be connected to the vertical deflection circuit.

To trigger the sweep in the AUTOMATIC mode:

1. Select the desired triggering signal as described previously.
2. Set the red TRIGGERING MODE knob to AUTOMATIC.
3. Set the HORIZONTAL DISPLAY switch to NORMAL.
4. Set the TIME/CM control to a sweep rate suited to the waveform being observed.

AC SLOW

This mode is useful for triggering from transients or from periodic signals in the range from about 30 cycles to 5 mc. Reliable triggering is also possible at frequencies lower than 30 cycles provided the product of the trigger-signal amplitude (in volts for external triggering or in centimeters of deflection for internal triggering) and the frequency (in cycles) is 10 or greater. For example, a trigger signal having a frequency of 10 cycles should have an amplitude of at least 1 volt when triggering from an external source (+ or — EXT.), or the displayed waveform should have an amplitude of at least 1 centimeter when internal triggering (+ or — INT.) is employed.

To trigger in the AC SLOW mode:

1. Select the desired triggering signal as described previously.
2. Set controls as follows:
HORIZONTAL DISPLAY NORMAL

TRIGGERING MODE	AC SLOW
TRIGGERING LEVEL	full left or full right
STABILITY	*PRESET

3. Set the TIME/CM control to a sweep rate suited to the waveform being observed.
4. Turn the TRIGGERING LEVEL slowly toward the 0 position until the sweep starts at the desired point on the waveform.
*Turn the STABILITY control full left to actuate the PRESET switch.

AC FAST

This mode of triggering is similar to the AC SLOW mode except that an rf filter is connected into the circuit making it insensitive to low frequencies and allowing it to recover quickly from dc level changes. In this mode the sweep can be triggered from signals in the range from 16 kc to 5 mc.

For most uses of the instrument the AC SLOW mode is preferable to the AC FAST mode. The AC FAST mode is principally for use with a Dual-Trace Plug-In unit (Type C or CA). Operating instructions for the use of a Dual-Trace Unit are contained in the Instruction Manual for that unit.

Aside from this use, the AC FAST mode may reduce waveform jitter due to hum in the triggering signal. Operating instructions are similar to those for the AC SLOW mode except the TRIGGER MODE knob is set to the AC FAST position.

DC

In the DC mode the sweep can be triggered from periodic signals in the range from dc to 5 mc. This mode is especially useful with trigger signals that change slowly...that is, signals below the low-frequency limit of the AC SLOW mode. This mode is also useful when it is desired to trigger at a certain point (voltage) on a waveform with respect to ground.

Another application of the DC triggering mode is to attain a stable display of a random-pulse train. The average voltage of this type of signal is dependent upon the time duration and amplitude of each pulse and the time lapse between successive pulses. Since these are variable quantities in a random-pulse train the average voltage will also vary and this can cause unstable triggering in the AC modes. In the DC mode, however, the circuits are only sensitive to the instantaneous voltage and



changes in the average voltage do not alter the operation of the circuits. As a result the TRIGGERING LEVEL control can be adjusted to initiate a sweep whenever a pulse reaches the desired voltage.

How to use the STABILITY control

For particularly difficult triggering applications it may be necessary to use a setting of the STABILITY control other than the one available in the PRESET position. The STABILITY control may be operated manually when triggering in the AC FAST, AC SLOW or DC modes.

To operate the STABILITY control manually:

1. Select the desired slope and mode of triggering.
2. Turn the STABILITY control full right; the sweep free-runs in this position.
3. Turn the TRIGGERING LEVEL full right or full left.
4. Turn the STABILITY control left until the trace disappears, then two or three degrees further left.
5. Turn the TRIGGERING LEVEL control slowly toward the O position until the trace begins at the desired point on the waveform being observed.
6. Set the TIME/CM control for a sweep rate suited to the waveform being observed.

How to use the TRIGGERING LEVEL control

The TRIGGERING LEVEL control is adjusted so that the display will start at a given point (voltage) on the displayed waveform. By means of this control the sweep can be triggered at any point on a waveform so long as the slope at

that point is sufficient to provide stable triggering. For example, while the sweep can be triggered at any point on the rise or fall of a square wave (depending on the setting of the TRIGGER SLOPE switch), it cannot be triggered along the top or bottom as the voltage is constant for this period and the slope is zero.

Figures 3-1 and 3-2 illustrate the action of the TRIGGERING LEVEL control in initiating the sweep. In these illustrations the sweep is being triggered internally by the sine-wave vertical signal.

Fig. 3-1 illustrates the triggering of the sweep on the positive slope (+INT.) of the waveform. Observe the two settings of the TRIGGERING LEVEL control illustrated, and the resultant start of the sweep for each setting. Notice that when the TRIGGERING LEVEL control is in the — part of its range the trace starts when the instantaneous voltage is negative, and when in the + part of its range the trace starts when the instantaneous voltage is positive. In either case, however, the trace is initiated on the voltage rise of the displayed waveform, because the TRIGGER SLOPE switch is set to + INT. to trigger on the positive slope.

Fig. 3-2 illustrates the triggering of the sweep on the negative slope (—INT) of the waveform. The action of the TRIGGERING LEVEL control, however, is the same as in Fig. 3-1. When in the — part of its range the trace starts when the instantaneous voltage is negative, and when in the + part of its range the trace starts when the instantaneous voltage is positive. The only difference is that the trace is initiated on the voltage fall of the displayed waveform because the TRIGGER SLOPE switch is set to —INT. to trigger on the negative slope.

SYNCHRONIZED OPERATION

When the TRIGGERING MODE switch is set to the HF SYNC position the circuit is arranged so that the triggering signal is applied directly to the sweep circuit to synchronize it with the triggering waveform. The sweep must be free running for this type of operation. In this mode the recurrent sweep can be synchronized with signals in the range from 5 mc to 30 mc.

Normal operation in the HF SYNC mode is to synchronize the sweep with the waveform being displayed. However, the sweep can also be synchronized with an external waveform by connecting the source of signal to the TRIGGER INPUT connector and setting the TRIGGER SLOPE switch to EXT. (+ or —).

To synchronize the sweep internally (from the displayed waveform):

1. Set the controls as follows:

HORIZONTAL DISPLAY	NORMAL
TRIGGER SLOPE	INT. (+ or —)
TRIGGER MODE	HF SYNC
STABILITY	full right
TRIGGERING LEVEL	not used in HF SYNC mode
2. Set the TIME/CM switch to a sweep rate suited to the waveform being observed.
3. Turn the STABILITY control slowly left to obtain a stable display.



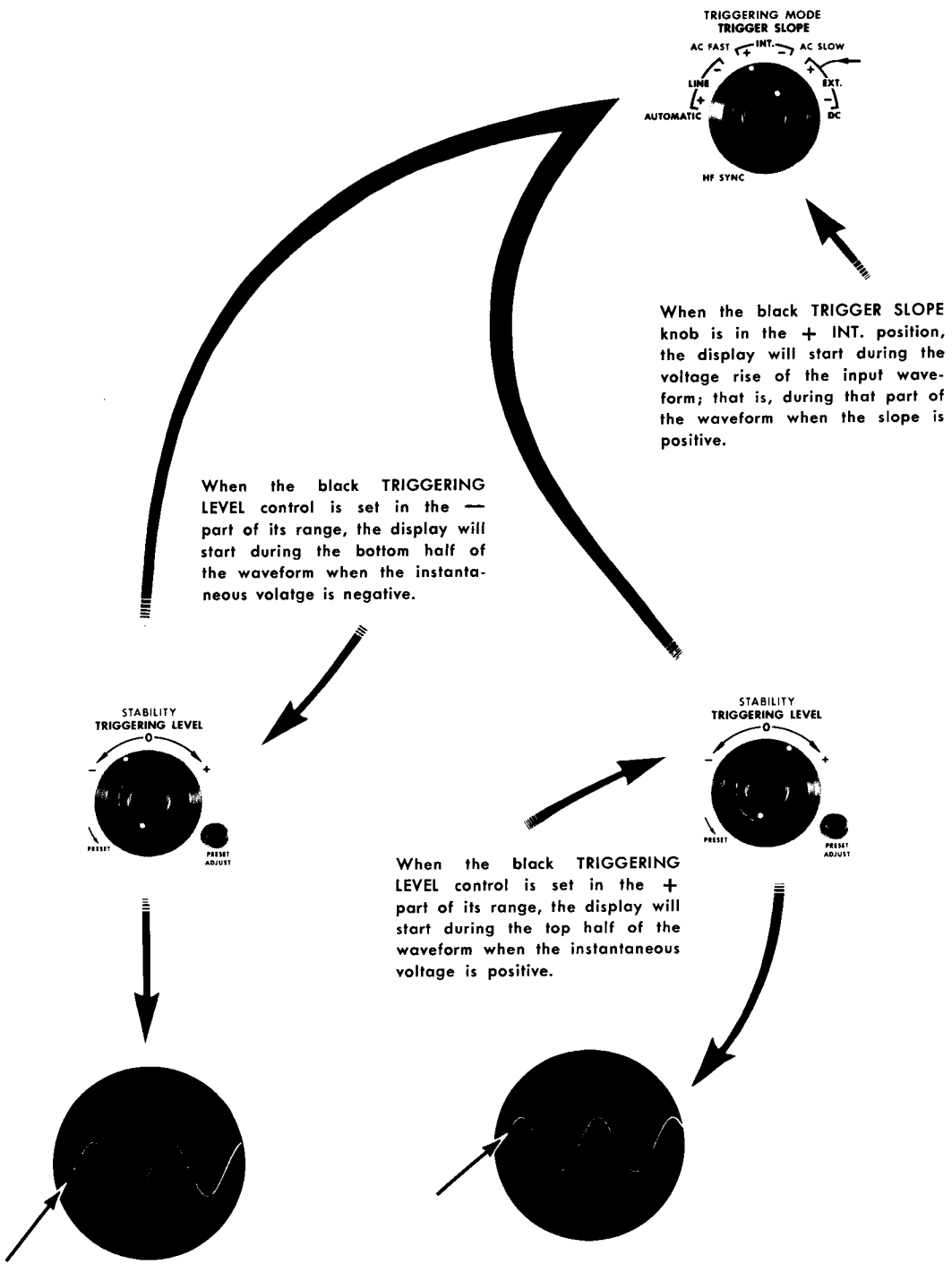


Fig. 3-1. Triggering on the positive-going portion of the input waveform.



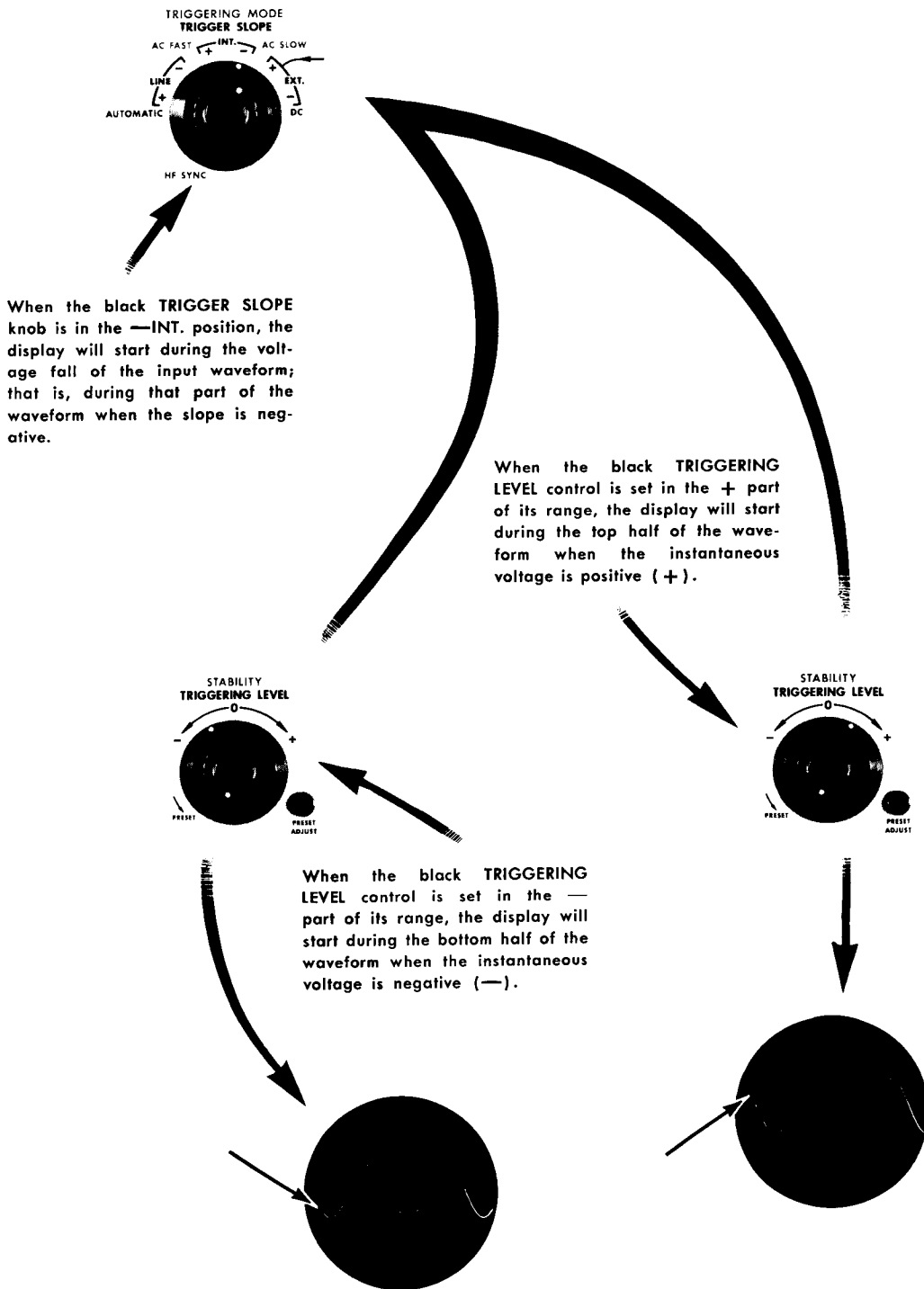


Fig. 3-2. Triggering on the negative-going portion of the input waveform.



FREE-RUNNING OPERATION

The sweep can be made to free-run, at a periodic rate, independent of any external triggering or synchronizing signal. This type of operation is useful when it is desired to view a waveform that is initiated by an output pulse from the Type 543. Two output pulses are available for this purpose, one from the + GATE OUT connector and the other from the SAWTOOTH OUT connector (see Output Waveforms, below). The waveforms available from these connectors have a starting time and duration equal to that of the horizontal sweep. (Note that this reverses the usual procedure where the oscilloscope sweep is timed to the waveform under investigation; with free running operation the system being investigated is timed to the oscilloscope sweep.)

For free-running operation:

1. Use no input to the TRIGGER INPUT connector.
2. Set the controls as follows:

HORIZONTAL DISPLAY	NORMAL
TRIGGER MODE	AC SLOW or DC
STABILITY	full right
TRIGGERING LEVEL	any position
TRIGGER SLOPE	INT. (+ or -) or EXT. (+ or -).
3. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.

Alternatively, a free-running sweep at a repetition rate of about 50 cycles is available, for this purpose, by operating in the AUTOMATIC mode instead of in the AC SLOW or DC mode.

SWEEP MAGNIFICATION

To magnify a particular portion of a display, position that portion of the display (with the HORIZONTAL POSITION control) so that it falls near the center of the graticule. Then turn the HORIZONTAL DISPLAY control to the desired SWEEP MAGNIFIED position. That part of

the display which formerly occupied the middle section of the graticule will now be expanded horizontally by the selected magnification factor. The time calibration or the horizontal axis will now be equal to the setting of the TIME/CM control divided by the magnification factor.

EXTERNAL HORIZONTAL DEFLECTION

In some instances it may be necessary to deflect the beam horizontally by means of an externally derived waveform, rather than by means of the internal sweep. To accomplish this, set the HORIZONTAL DISPLAY switch to EXT. and connect the source of the waveform to the EXTERNAL HORIZ. IN connector. Set the

EXTERNAL HORIZONTAL controls (VOLTS/CM and VARIABLE) for the desired amount of horizontal deflection. Three ranges of fixed attenuation of the external sweep signal are provided, with a variable control to interpolate between ranges.

OUTPUT WAVEFORMS

For certain external applications, the sawtooth sweep waveform is available at the SAWTOOTH OUT connector on the front panel. This positive waveform starts at about ground and rises linearly to a peak amplitude of about 150 volts.

The start and duration of the rising part of the sawtooth is coincident with the start and duration of the horizontal sweep on the crt; the rate

at which the sawtooth rises is therefore determined by the setting of the TIME/CM control.

A positive rectangular waveform is available at the + GATE OUT connector. This waveform starts at ground and rises to about 30 volts. The starting time and duration of each pulse corresponds to the starting time and duration of the positive-going portion of the sawtooth available at the SAWTOOTH OUT connector.



SINGLE SWEEP

The Type 543 contains a single-sweep (sweep-lockout) feature which permits a waveform to be displayed for one horizontal sweep only, subsequent sweeps (and waveform displays) being locked out until the circuit is rearmed. This feature is particularly useful for photographing random or nonrepetitive signals.

To use the single-sweep feature, set up the instrument for normal manually-triggered operation. Then depress the spring-loaded NORMAL

SWEEP-SINGLE SWEEP switch to the RESET position and let it return to the SINGLE SWEEP position. The READY light will ignite indicating that the sweep circuit is ready to produce a horizontal sweep upon reception of a trigger. The next trigger pulse to arrive will then produce a single horizontal sweep. Subsequent triggers will have no effect on the circuit until the READY light is ignited with the RESET switch.

VERTICAL DEFLECTION SYSTEM

PLUG-IN UNIT

The Type 543 is constructed to accept a Tektronix plug-in unit in the vertical deflection circuit. For most applications, one of the preamplifier-type plug-in units will be employed al-

though special type plug-in units, for specific applications, are available. Refer to the short-form catalog at the back of this manual for a listing of currently available plug-ins.

INPUT COUPLING

The input circuit of the preamplifier-type plug-in units is arranged so that either ac- or dc-coupling may be employed. When it is desired to display or measure the dc component of a waveform, the appropriate control should be set

to the DC position. If the dc component of the waveform is not required or desired, the control should be set to the AC position. Refer to the Instruction Manual for the plug-in unit employed.

DEFLECTION FACTOR

The VOLTS/CM switch on the plug-in unit controls the vertical deflection factor (sensitivity) of the oscilloscope/plug-in unit combination in accurately calibrated steps. The VARIABLE control provides uncalibrated deflection factors

between the fixed steps of the VOLTS/CM switch. For calibrated deflection factors the VARIABLE control must be turned full right to the CALIBRATED position.

CONNECTING THE OSCILLOSCOPE TO THE SIGNAL SOURCE

Following are some precautions to observe when connecting the instrument to the source of the signal to be displayed.

1. Avoid errors in readings due to stray electric or magnetic coupling between circuits, particularly in the leads connected to the input

connectors of the instrument. In general, unshielded leads of appreciable length are unsuited for this purpose. This is true even in the audio-frequency range, except possibly when making measurements in low-impedance circuits. When shielded leads are used, ground the shields to both the oscilloscope chassis and the



chassis of the equipment under test. Coaxial cables are recommended for many purposes.

2. In certain high-frequency applications it may be necessary to terminate the signal cable with an impedance equal to the characteristic impedance of the cable to prevent resonance effects and ringing. Cable terminations become more important as the frequency and cable length are increased. The termination is generally placed at the oscilloscope end of the cable, although in some instances an additional termination may be required at the source end. Refer to the Accessories section in the back of this manual for a listing of cables, terminating resistors and attenuation pads.

3. As nearly as possible, simulate actual operating conditions in the equipment being tested. For example, the equipment should work into a load impedance equal to that it sees in actual operation.

4. Consider the loading effect of the oscilloscope on the signal. The input impedance of most preamplifier-type plug-in units is 1 megohm shunted by either 20 $\mu\mu\text{f}$ or 47 $\mu\mu\text{f}$ (see front panel of plug-in unit being used). With a few feet of shielded cable, the capacitances may well be 100 $\mu\mu\text{f}$ or so. In some instances this amount of capacitance may not be negligible. In cases of this type a probe should be used in the manner described in the following section.

USE OF PROBES

An attenuator probe lessens both capacitive and resistive loading, at the same time reducing sensitivity. The attenuation introduced by the probe permits measurement of signal voltages in excess of those that can be accommodated by the preamplifier alone. When making ampli-

tude measurements with an attenuator probe, be sure to multiply the observed amplitude by the attenuation of the probe (marked on probe).

A Type P410 Probe is furnished as an accessory to the Type 543 Oscilloscope. The probe is easily identified by its brown, molded-plastic nose. Connected to the input circuit of a Tektronix plug-in unit, the probe presents an input resistance of 10 megohms and has an attenuation ratio of 10:1. For information concerning the input capacitance, see the Instruction Manual for the plug-in unit being used.

The maximum voltage which may be applied to the probe is 600 volts. Exceeding this rating, either in peak ac or dc volts, may result in damage to the components inside the probe body.

If the waveform being displayed contains fast changing portions, it is generally necessary to clip the probe lead to the chassis of the equipment being tested; select a ground point near the tip of the probe.

An adjustable capacitor in the probe body compensates for variations in input capacitance from one instrument to another. To insure the accuracy of pulse and transient measurements, this adjustment should be checked frequently.

To make this adjustment, set the calibrator control for a calibrator output signal of suitable amplitude. Touch the probe tip to the CAL. OUT connector and adjust the oscilloscope controls to display several cycles of the waveform. Adjust the probe capacitor for a flat top on the calibrator square wave, as shown in Fig. 3-3(a).

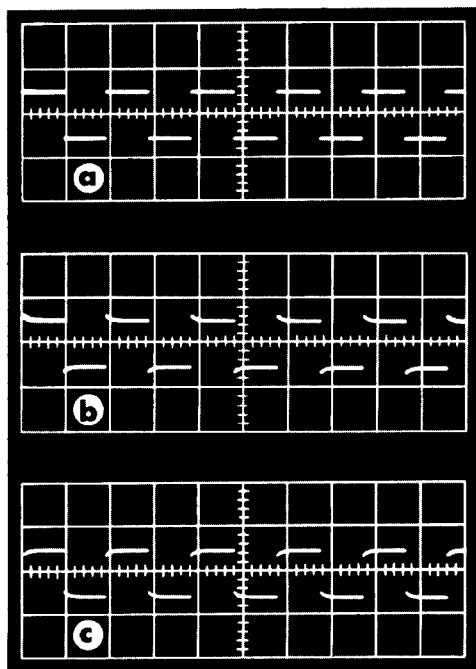


Fig. 3-3. When the probe is properly adjusted, the display of the calibrator waveform will have a flat top and bottom, as shown in waveform (a). Improper adjustment of the probe will produce a display similar to (b) or (c).

VOLTAGE MEASUREMENTS

This section describes two categories of voltage measurements with the Type 543. One is the measurement of the peak-to-peak voltage of the displayed waveform; the other is the measurement of the peak voltage of a waveform with respect to ground or some other voltage. While these examples are intended only to show the general procedure for obtaining voltage measurements they can be modified to suit any particular application within the limits of the instrument.

In measuring signal amplitudes it is important to remember that the width of the trace may be an appreciable part of the overall measurement. This is particularly true when measuring signals of small amplitude. In cases of this type the measurement should be from the upper side of the trace at the positive peak to the upper side of the trace at the negative peak, or from the under side of the trace at one point to the under side of the trace at the other point. For signals whose amplitude is relatively large compared to the trace width, however, the measurements usually do not have to be this critical.

To determine the peak-to-peak voltage of a displayed waveform:

1. Measure the amount of vertical deflection between the positive and negative peaks (in centimeters and/or decimal parts of a centimeter).
2. Multiply the amount of vertical deflection by the setting of the VOLTS/CM control on the plug-in unit (make sure the VARIABLE gain control on the plug-in unit is set to the CALIBRATED position).
3. Multiply the result obtained in step 2 by the attenuation of the probe (10 for the Type P410 Probe); the result is the peak-to-peak voltage of the waveform.

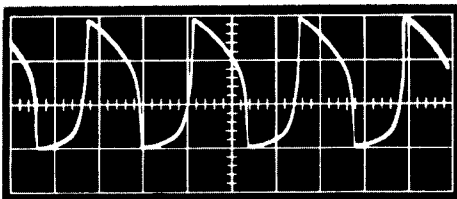


Fig. 3-4. Using the Type 543 to measure the peak-to-peak voltage of a waveform.

To illustrate this procedure, consider the waveform shown in Fig. 3-4. This waveform has

a vertical deflection of 3 centimeters between the positive and negative peaks. If, for this waveform, the VOLTS/CM control on the plug-in unit were set to .1 and a 10X probe used, the peak-to-peak voltage would be 3 volts.

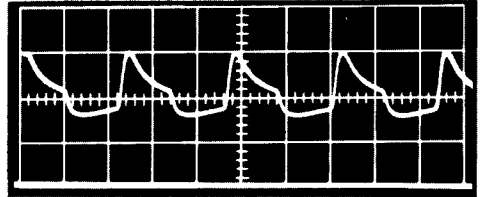


Fig. 3-5. Using the Type 543 to measure the dc level of a waveform.

To determine the dc level at some point on a waveform, with respect to a reference voltage:

1. Set the AC-DC input coupling switch on the plug-in unit to DC, and set the VARIABLE gain control to CALIBRATED.
2. Adjust the Time-Base controls on the oscilloscope for a free-running trace.
3. Touch the probe tip to the reference voltage (if ground, touch the probe tip to the chassis) and position the trace to any reference position. If the dc voltage to be measured is positive with respect to the reference, position the reference trace toward the lower portion of the graticule; if negative with respect to the reference, position the reference trace toward the upper portion of the graticule. The top and bottom graticule lines are often convenient positions for the reference trace. Do not adjust the VERTICAL POSITION control once the reference position is established.
4. Connect the probe tip to the waveform source. If the trace is deflected off the screen, increase the setting of the VOLTS/CM control until the trace reappears; do not adjust the VERTICAL POSITION control.
5. Obtain a stable display of the waveform.
6. Determine the amount of vertical deflection (in centimeters and/or decimal parts of a centimeter) between the reference position and the point on the waveform at which you wish to know the voltage.
7. Multiply the amount of vertical deflection by the setting of the VOLTS/CM control



on the plug-in unit (make sure the VARIABLE gain control is set to the CALIBRATED position).

8. Multiply the result obtained in Step 7 by the attenuation of the probe. The result is the dc voltage of the point selected with respect to the reference.

To illustrate this procedure, consider Fig. 3-5. (A double exposure was used in this photograph to show both the reference trace and the waveform.) The bottom graticule line is used as the

reference voltage; in this case the reference voltage is ground potential.

There are 1.6 centimeters of vertical deflection between the reference and the bottom of the waveform, and 3 centimeters between the reference and the top of the waveform. If the VOLTS/CM control on the plug-in unit is set to 1 and a 10X probe used, it can be seen that the waveform "bottoms" at 16 volts above ground and peaks at 30 volts above ground. In a similar manner the level at any other point on the waveform could be determined.

AUXILIARY FUNCTIONS

Calibrator

The calibrator provides a source of square waves of known amplitude at approximately one kilocycle ($\pm 30\%$). The output amplitude is accurate within 3 percent of the VOLTS setting and within 5 percent of the MILLIVOLTS setting of the SQUARE-WAVE CALIBRATOR switch. The primary function of the Calibrator is to provide a convenient method for verifying the calibration of the vertical-deflection system and for adjusting the probes. It can be used for other purposes, however, if certain limitations are kept in mind.

TABLE 2-1

Approx. Output Impedance of Calibrator

SWITCH SETTINGS	OUTPUT IMPEDANCE
100	*290 Ω
50	5.1 k
20	3.3 k
10	1.9 k
5	1 k
2	500 Ω
1	300 Ω
.5	200 Ω
.2	140 Ω

*Do not load with less than 4000 ohms.

Impedance values are for settings of the red knob at VOLTS. When the red knob is at MILLIVOLTS the output impedance is 200 ohms for all settings of the black knob.

The output impedance of the Calibrator varies with the output-voltage setting. It is as low as 140 ohms in the .2-volt position of the VOLTS switch and as high as 5.1 kilohms in the 50-volts position. In the 100-volts position, the output impedance is 290 ohms when the circuit is loaded by a resistance of not less than 4000 ohms. When the switch is at a setting other than 100 volts, the output may be loaded with any impedance without damaging the components. See Table 2-1 for the approximate output impedance for each position of the VOLTS switch.

Trace-brightness modulation

To couple markers or other signals to the crt cathode for trace-brightness modulation, disconnect the ground strap at the rear of the instrument and apply the signal between the EXTERNAL CRT CATHODE binding post and GND. Positive pulses of about 10 volts peak will cut the beam off from normal brightness. Always replace the ground strap when not using this feature.

Graticule illumination

The graticule lighting control, labeled SCALE ILLUM., can be adjusted to suit the lighting conditions of the room. A green filter is supplied which can be used for increased contrast. This filter should be mounted next to the crt screen so it does not block the light from the graticule lines.



As a general rule, white graticule lines are superior to red for photographic purposes. The graticule can be mounted in either of two positions, with the red-lined holes either at the top or at the bottom. In one position the illumination is colored red, in the other position, white. For photographic purposes, the white illumina-

tion should be used with the green filter placed in front of the graticule. In this manner both the graticule lines and the display photograph equally well. Where the volume of photographic work warrants it, you may want to obtain a clear graticule from your Tektronix Field Engineer.

OPERATING DESCRIPTIONS OF CONTROLS AND CONNECTORS

TRIGGER SLOPE (black knob)	The black TRIGGER SLOPE switch selects triggering signals...either power line (+LINE or —LINE), the signal being displayed (+INT. or —INT.), or some signal fed into the TRIGGER INPUT connector (+EXT. or —EXT.). In all positions marked +, triggering occurs during the voltage rise of the waveform. In all positions marked —, triggering occurs during the voltage fall of the waveform.
TRIGGERING MODE (red knob)	A five-position switch (red knob) selects one of four types of triggering (AC FAST, AC SLOW, DC or AUTOMATIC), or synchronized operation (HF SYNC).
TRIGGERING LEVEL	Black TRIGGERING LEVEL control determines at what voltage on the triggering waveform the horizontal trace will start. This control is disabled when the red TRIGGERING MODE switch is in the AUTOMATIC or HF SYNC position.
STABILITY	The red STABILITY control adjusts the time base generator for triggered or for free-running operation. Normally, it can be left in the PRESET position. It is disabled when the red TRIGGERING MODE switch is in the AUTOMATIC position. It also serves as the synchronizing control in the HF SYNC position.
HORIZONTAL DISPLAY	The HORIZONTAL DISPLAY switch is an eight position control which selects either NORMAL operation of the sweep circuits, in which case the markings on the TIME/CM control indicate the sweep rates, or operation of the horizontal amplifiers from some external source. When the HORIZONTAL DISPLAY switch is in any of the SWEEP MAGNIFIED positions the horizontal length of the display is magnified by 2, 5, 10, 20, 50, or 100, depending on the range selected.
TIME/CM (black knob)	A twenty-four position switch to control the horizontal sweep rate. When the UNCALIBRATED light is out the sweep rates marked on the panel represent the calibrated sweep rate.
VARIABLE (red knob)	The VARIABLE CONTROL provides uncalibrated sweep rates to interpolate between the fixed rates provided by the TIME/CM switch. As soon as the VARIABLE control is moved from the CALIBRATED position the UNCALIBRATED light will come on to warn the operator that the sweep rate is no longer accurately known.
SINGLE SWEEP NORMAL SWEEP	This control provides a means of displaying a waveform for one horizontal sweep only. When the switch is in the SINGLE SWEEP position and the sweep circuit is adjusted for triggered operation, the operator need only depress the switch to the RESET position to arrange the circuitry in condition to produce a single horizontal sweep when the next triggering signal arrives. When the RESET circuit is activated the READY light will ignite and remain on until the next triggering signal initiates the sweep. Upon completion of the sweep the READY light will go out.
HORIZONTAL POSITION (black knob)	This control positions the display horizontally on the face of the crt.



VERNIER (red knob)	This control provides a fine adjustment of the horizontal position of the display.
EXTERNAL HORIZONTAL VOLTS/CM (black knob)	This switch provides calibrated horizontal deflection factors of .1, 1, and 10 volts per centimeter when the VARIABLE control is in the CALIBRATED position.
VARIABLE (red knob)	This control provides continuously variable horizontal deflection factors to interpolate between the fixed ranges of the VOLTS/CM switch. This control must be in the CALIBRATED position when the accuracy of the VOLTS/CM calibration is to be used.
SQUARE-WAVE CALIBRATOR (black knob)	This is a nine-position switch whose ranges may be read in volts or in millivolts, depending upon the setting of the red SQUARE-WAVE CALIBRATOR knob.
SQUARE-WAVE CALIBRATOR (red knob)	This is a three-position switch which either turns the calibrator off or selects the range or output amplitude. . . either volts or millivolts.
POWER	On-off switch for applying power to the oscilloscope.
INTENSITY	Controls brightness of spot or trace.
FOCUS	Controls the sharpness of the spot or trace.
ASTIGMATISM	Controls spot shape.
SCALE ILLUM.	Controls the graticule-scale illumination.
TRIGGER INPUT	UHF connector for accepting an external triggering signal when the TRIGGER SLOPE switch is in the +EXT. or -EXT. position.
EXTERNAL HORIZ. IN.	UHF connector for accepting an externally derived signal to provide horizontal deflection.
VERT. SIG. OUT	Binding post connector which provides a sample of the vertical signal.
CAL. OUT	UHF connector for accepting an external triggering signal when the TRIGGER SLOPE switch is in the +EXT. or -EXT. position.
+GATE OUT	Binding post connector supplying a positive-going rectangular pulse having a peak value of about +30 volts. Its starting time and duration correspond to the starting time and duration of the positive-going part of the sawtooth available at the SAWTOOTH OUT connector.
SAWTOOTH OUT	Binding post connector supplying a positive-going sawtooth having a peak value of about +150 volts. The rising part of the sawtooth corresponds to the oscilloscope horizontal sweep, when the HORIZONTAL DISPLAY switch is in the NORMAL or SWEEP MAGNIFIED positions. The rate at which the sawtooth rises is controlled by the TIME/CM switch.
BEAM-POSITION INDICATORS	These are indicator lamps marked with arrows. The arrow nearest the illuminated indicator shows which way the beam is off the screen if it cannot be seen.
EXTERNAL CRT CATHODE	Binding post connector at the rear of the cabinet for accepting beam-intensity-modulation voltage. Capacitively coupled. This connector should be tied to the GND connector when not in use.



SECTION 4

CIRCUIT DESCRIPTION

BLOCK DIAGRAM

General

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

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 Vertical Amplifier amplifies the signal and drives the delay line which terminates in the vertical deflection plates. The trigger pick-off circuits obtain a sample of the vertical signal for triggering the sweep.

Delay Line

The balanced, 50-section delay line adds 0.2 microsecond 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.

Time-Base Trigger Circuit

The trigger circuits convert the triggering signal into sharp negative triggers for triggering the sweep-gating multivibrator. Triggers may be produced on either the rise or fall of the triggering signal at a level determined by a triggering-level control.

Sweep-Gating Multivibrator

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

Miller Runup Circuit

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 sweep gating multivibrator.

Holdoff Circuit

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

Sweep Lockout Circuit

The sweep lockout circuit permits the sweep-gating multivibrator to turn on the sweep gen-



erator for one sweep when the next trigger pulse arrives; subsequent trigger pulses are locked out . . . prevented from starting a sweep . . . until the circuit is reset.

Horizontal Amplifier

The horizontal 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 crt screen. The amplifier gain can be increased up to 100 times for sweep magnification. The horizontal-positioning control operates in this circuit.

Unblanking

The sweep-gating multivibrator generates a positive-going unblanking pulse at the same time it turns on the sweep generator. The positive pulse

is transmitted by means of two cathode followers through a floating high-negative-voltage supply to the control grid of the crt.

External Horizontal Amplifier

The external horizontal amplifier provides a means of using external sweep voltage. It includes a fixed attenuator and a variable control. Choice of internal or external sweep can be made by means of a horizontal display switch. The sweep-magnifier circuits cannot be used with external sweeps.

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 precision voltage divider.

VERTICAL DEFLECTION SYSTEM

General

The dc-coupled, push-pull, main Vertical Amplifier provides the necessary gain to drive the Delay Line and the vertical deflection plates of the crt. The main units of the Vertical Amplifier are the Input Amplifier stage V1014 and V1024, the cathode follower stages V1033 and V1043, and the 6-section Distributed Amplifier output stage. Other circuits of importance are the Trigger Pickoff Amplifier V1054 and V1064, the Trigger Pickoff C.F. V1223B, the Vert. Sig. Out C.F. V1223A, and the Indicator Amplifiers and Lamps, V1084A and B1083, and V1084B and B1087, respectively.

Input Circuit

The signal input from the plug-in unit is coupled through terminals 1 and 3 of the interconnecting plug to the grids of the Input Amplifier stage. R1027 varies the cathode degeneration, and thus sets the gain of the stage to agree with the Pre-amplifier's front-panel calibration when the VARIABLE knob is in the CALIBRATED position.

The Input Amplifier is coupled to the Distributed Amplifier by the cathode followers V1033 and V1043. The cathode followers isolate the Distributed Amplifier from the Input Amplifier, and provide the necessary low-impedance drive for the Distributed Amplifier's grid line.

High-frequency compensation for the Input Amplifier is provided by the variable peaking coils L1014 and L1024. Variable inductors L1036 and L1046 provide additional peaking at the very high frequencies.

Output Stage

The output stage is a 6-section Distributed Amplifier. The tapped inductors in the transmission line, between each grid and between each plate, isolate each section from the capacitance of the adjacent sections.

The input signal for each tube is obtained from the grid line, which is driven by the cathode followers V1033 and V1043. The amplified signal at each plate, fed to the plate line, becomes an integral part of the wave traveling down the line toward the deflection plates.

The vertical signal is delayed 0.2 microsecond between the input to the grid line and the vertical deflection plates. This delay insures that the very "front" of fast vertical signals can be observed. About 0.015 microsecond of the total delay time occurs in the Distributed Amplifier; the remaining 0.185 microsecond occurs in the Delay Line.

The tapped inductors between each section of the Distributed Amplifier provide about 0.003 microsecond of delay. By making the delay time



in the grid and plate lines equal, the signal arriving at each plate, through the electron stream of the tube, will be synchronous with the signal moving down the plate line from the preceding sections.

DC Shift Compensation

DC shift in the amplifier—a condition whereby the dc and very low-frequency transconductance is less than at mid-frequencies—is compensated for in two ways. R1090 and C1093B, in plate line L1104, and R1095 and C1093D in plate line L1114, form a low-frequency boost network; the time constant of this network is such that the termination resistance of the line is increased in the range from very low frequencies to dc. A longer time constant, for extremely low-frequency and dc compensation, is provided by R1092, R1094 and C1093A in one plate line, and by R1097, R1099 and C1093C in the other, which provide a small amount of positive feedback from the plate lines to the plate circuits of the Input Amplifier. A variable resistor R1091, the DC SHIFT control, is connected between the two networks to adjust for the proper amount of compensation.

Beam-Positioning Indicators

The beam-position indicators B1083 and B1087, located on the front panel above the crt, indicate the relative vertical position of the trace with respect to the center of the graticule. When the beam is centered vertically, the potential across either neon is insufficient to light it. As the beam is positioned up or down the screen, however, the current through the Indicator Amplifiers, and hence the voltage across the neons, will change. The voltage across one neon will increase, causing it to light, and the voltage across the other will decrease, causing it to remain extinguished. The neon that lights will indicate the direction in which the beam has been moved.

Trigger Pickoff

When internal triggering of the Time Base Generator is desired (black TRIGGER SLOPE knob in either the + or —INT. position), a "sample" of the vertical signal is used to develop the triggering pulse. This "sample" is obtained from the trigger pickoff circuit consisting of the Trigger Pickoff Amplifier V1054 and V1064, and Trigger Pickoff C.F. V1223B.

This "sample" of the vertical signal is also ac-coupled, through V1223A and C1228, to a front-panel binding post labeled VERT. SIG. OUT.

Delay Line

The output signal from the Vertical Amplifier is coupled through the balanced Delay Line to the vertical deflection plates of the crt. The function of the Delay Line is to retard the arrival of the waveform at the deflection plates until the crt has been unblanked and the horizontal sweep started. This delay, as mentioned previously, insures that the very "front" of fast vertical signals can be observed. The line is adjusted, by means of the variable capacitors connected across the line, for optimum transient response.

The entire Delay Line, which includes the plate line in the Distributed Amplifier, is reverse-terminated in its characteristic impedance. The Termination Network, shown on the Vertical Amplifier diagram, is designed to dissipate both the dc and signal energy in the line by presenting a constant resistance over the frequency range of the amplifier. The terminating resistors R1071 and R1073 are specially made, wirewound, noninductive, distributed resistors. The 600 ohms total resistance in each is "tapered", or distributed, in steps. The largest segment of the terminating resistance appears nearest the line; the smallest segment appears at the opposite end. Each step of the resistance is then tuned, by means of the variable capacitors, so that the network will present an optimum load to the line.

HORIZONTAL-DEFLECTION SYSTEM

TIME-BASE TRIGGER

Trigger Slope

The function of the Time-Base Trigger circuitry is to develop a negative-going triggering pulse to trigger the Time Base Generator in the proper

time sequence. The signal from which the negative-going triggering pulse is produced may emanate from one of three sources, as determined by the setting of the TRIGGER SLOPE switch SW10A. When the switch is in the + or —EXT. position,



an external signal is employed in the development of the triggering pulse. When the switch is in the + or —INT. position, the vertical signal itself is used to develop the triggering pulse. In the + or —LINE position of the switch, a voltage at the power line frequency is used to develop the triggering pulse.

In addition to selecting the source of the triggering voltage, the TRIGGER SLOPE switch also arranges the input circuit of the Trigger-Input Amplifier so that a negative-going pulse is always produced at the plate of V45B regardless of whether the switch is in the + or — position of the EXT., INT. or LINE setting.

Trigger-Input Amplifier

The Trigger-Input Amplifier V24 is a polarity-inverting, cathode-coupled amplifier. The output is always taken from the plate of V24B, but the grid of either stage may be connected to the input signal source. When the TRIGGER SLOPE switch is in the — position (EXT., INT. or LINE range), the grid of V24A is connected to the input source. The grid of V24B is connected to a dc bias source, adjustable by means of the TRIGGERING LEVEL control. This bias voltage establishes the quiescent voltage at the plate of V24B. When the TRIGGER SLOPE switch is in the + position (for any of the three ranges) the grid of V24B is connected to the signal input and the grid of V24A is connected to the bias source.

The voltage at the grid of V24A and the voltage at the plate of V24B are in phase with each other. Therefore, when the switch is in any of the — positions (the signal applied to the grid of V24A), the voltage at the plate of V24B is in phase with the input signal voltage. By this arrangement V24A acts as a cathode follower, having a gain of approximately unity, and the signal voltage developed across the cathode resistor becomes the signal input to V24B.

When the switch is moved to any of the + positions, the grid of V24B is connected to the input signal source. With this configuration, the signal at the plate of V24B will be 180 degrees out of phase with the input signal. Thus, depending on the setting of the switch (+ or —), the plate-signal swing of V24B may be in phase, or 180 degrees out of phase, with the input signal.

Trigger Multivibrator

A Schmitt Trigger circuit V45 is used as the Trigger Multivibrator. In the quiescent state, i.e., ready to receive a signal, V45A is conducting and its plate is down. This holds the grid of V45B below cutoff, since the two circuits are dc-coupled. With V45B cutoff its plate voltage is up; hence no output is being developed.

A negative-going signal is required at the grid of V45A to drive the multivibrator into its other state in which a triggering pulse can be produced. However, the signal coupled to the grid of V45A is a component of the vertical input signal, and therefore contains both negative- and positive-going voltages.

The negative-going portion will drive the grid of V45A in the negative direction, and the cathodes of both tubes will follow the grid down. At the same time the plate voltage of V45A starts rising, which causes the grid voltage at V45B to rise. With the grid of V45B going up and its cathode going down, V45B starts conducting. The cathodes will now follow the grid of V45B; hence the cathode voltages start going up. With the grid of V45A down and its cathode up, this tube cuts off. As V45B conducts its plate voltage drops, creating a negative step at the output. This transition occurs very rapidly, regardless of how slowly the grid signal of V45A falls.

When the signal at the grid of V45A starts in the positive direction, just the opposite will occur. That is, V45A will start conducting again, V45B will be cutoff, and the circuit will revert to its original state with the plate voltage of V45B up. This completes the negative step-voltage output from the Schmitt Trigger circuit.

The operation of the Schmitt Trigger circuit is exactly the same for + or — positions of the TRIGGER SLOPE knob. However, since there is a reversal in signal polarity—between these two settings—at the output of the Trigger-Input Amplifier, triggering will occur at different points with respect to the signal being observed. For example, when the switch is in the + position, triggering will occur during the positive slope of the waveform being observed. That is, the start of the trace will occur when the waveform is going in the positive direction. Conversely, when the switch is in the — position the trace will start when the waveform is going in the negative direction.



Trigger Sensitivity

The hysteresis of the Trigger Multivibrator is determined by the setting of the TRIGGER SENSITIVITY control R37. Increasing the resistance of R37 reduces the loop gain and decreases the hysteresis. The lower the hysteresis the greater the sensitivity of the circuit. Increasing the resistance of R37 therefore increases the trigger sensitivity.

The TRIGGERING LEVEL CENTERING control R39 is adjusted to set the dc quiescent condition of the Multivibrator about the same as that of the Trigger Amplifier.

Triggering Mode

The TRIGGERING MODE switch SW10B selects the type or mode of triggering. In the DC position the triggering signal is dc-coupled to the Trigger Input stage, which in turn is dc-coupled to the Trigger Multivibrator circuit.

In the AC SLOW and AC FAST modes, capacitor C10 removes the dc component of the triggering signal; the Trigger Input stage is still dc-coupled to the Multivibrator, however. The AC FAST mode contains a high-pass filter C11-R13 to remove any low-frequency components from the triggering signal and allow fast recovery of the trigger circuits in the presence of dc level changes.

In the AUTOMATIC mode the Schmitt circuit is converted from a bistable multivibrator to a recurrent configuration. This is accomplished by coupling the grid circuit of V45B to the grid circuit of V45A via R41. In addition, the dc coupling between the Trigger Input stage and the Multivibrator is removed in this mode of triggering.

The addition of R41 to the circuit causes the Multivibrator to free-run in the absence of a triggering signal. For example, assume the grid of V45A is just being driven into cutoff. The voltage at its plate starts to rise, carrying with it the voltage at the grid of V45B. Since the two grids are dc coupled through R41 and R33, this action will pull the grid of V45A back up. The time constant of the r-c network R41, R33 and C32 is such that it takes about .01 second for the grid voltage of

V45A to rise exponentially from its starting point below cutoff to a value where plate current can flow.

As V45A starts to conduct its plate voltage drops, which in turn lowers the grid voltage of V45B. The voltage at the grid of V45A then starts dropping exponentially toward cutoff. When this tube cuts off, the circuit has completed one cycle of its approximately 50-cycle rectangular waveform.

The hysteresis of the circuit (the range of voltage at the grid of V45A between V45A cutoff and V45B cutoff) is about 6 volts when triggering in the AUTOMATIC mode. This is increased from about 0.25 volt, for the DC, AC SLOW and AC FAST modes, by the addition of R41 and R46 to the circuit. Since the grid of V45A is never more than 6 volts from cutoff, a triggering signal with a peak-to-peak amplitude of 6 volts can drive the grid to cutoff at any time and produce a trigger output. Smaller signals can also produce a trigger output, but only if they occur at a time when the sum of the signal voltage and the triangular grid voltage is sufficient to drive the grid of V45A to cutoff. However, the duty cycle of operation is somewhat reduced when smaller triggering signals are being received.

With the circuit configuration just described, the horizontal sweep can be triggered with repetitive signals, over a wide range of frequencies, without readjustment. When not receiving triggers, the sweep continues at approximately a 50-cycle rate. Thus, in the absence of any vertical signal, the sweep generates a base line which indicates that the oscilloscope is adjusted to display any signal that might be connected to the vertical deflection system.

With the TRIGGER SLOPE switch in the HF SYNC position, the Trigger circuits are bypassed and the input "triggering" signal is applied directly to the Time Base Generator. This signal now acts as a synchronizing voltage, superimposed on the holdoff waveform (to be discussed in the section that follows). This synchronizes the Time-Base Generator at a sub-multiple of the triggering-signal frequency. This mode is useful for input signals in the range from 5 mc to 30 mc.



TIME-BASE GENERATOR

The Trigger circuit produces a negative-going waveform which is coupled to the Time-Base Generator. This waveform is differentiated in the grid circuit of V135A to produce a sharp negative-going triggering pulse to trigger the Time-Base Generator in the proper time sequence. Positive-going pulses are also produced in the differentiation process, but they are not used in the operation of the Time-Base Generator.

The Time-Base Generator consists of three main circuits: a Sweep-Gating Multivibrator, a Miller Runup Circuit, and a Hold-Off Circuit. The Sweep-Gating Multivibrator consists of V135A, V146 and the cathode follower V135B. The essential components in the Miller Runup circuit are the Miller Tube V161, the Runup C.F. V173, the On-Off Diodes V152, the Timing Capacitor C160 and the Timing Resistor R160. The Hold-Off Circuit consists of the Hold-Off C.F.'s V183A-V133B, the Hold-Off Capacitor C180 and the Hold-Off Resistors R181-R180.

Sweep-Gating Multivibrator

The Sweep-Gating Multivibrator operates as a bistable circuit. In the quiescent state V135A is conducting and its plate is down. This cuts off V146 through V135B and the divider R141-R143, and the common cathode resistor R144. With V146 cutoff, its plate is clamped about 3 volts below ground by the conduction of diodes V152 (A & B) through R147 and R148. Conduction of the lower diode V152A through the Timing Resistor R160 then clamps the grid of the Miller tube at about -3.5 volts.

Miller Runup Circuit

The quiescent state of the Miller circuit is determined by a dc network between plate and grid. This network consists of the neon glow tube B167, the Runup CF V173 and the On-Off Diodes V152. The purpose of this network is to establish a voltage at the plate of the Miller tube of such a value that the tube will operate above the knee, and thus over the linear region, of its characteristic curve. This quiescent plate voltage is about $+43$ volts.

Sweep Generation

If the STABILITY and TRIGGERING LEVEL controls are now adjusted for triggered operation, a

negative trigger will drive the grid of V135A below cutoff and force the Sweep-Gating Multivibrator into its other state in which V146 is the conducting tube. As V146 conducts its plate drops, cutting off the On-Off Diodes V152. Any spiking that many occur during this transition is attenuated by the C150-R150 network.

With V152 cutoff the grid of the Miller tube and the cathode of the Runup C.F. are free to seek their own voltages. The grid of the Miller tube then starts to drop, since it is connected to the -150 -volt bus through the Timing Resistor R160. The plate of the Miller tube starts to rise, carrying with it the grid and cathode of V173. This raises the voltage at the top of the Timing Capacitor C160, which in turn pulls up the grid of the Miller tube and prevents it from dropping. The gain of the Miller tube, as a Class A amplifier, is so high that the voltage coupled back through C160 keeps the grid constant within a fraction of a volt.

The Timing Capacitor then starts charging with current from the -150 -volt bus. This charging current flows through the Timing Resistor R160. Since the voltage at the grid of the Miller tube remains essentially constant the voltage drop across the Timing Resistor remains essentially constant. This provides a constant source of current for charging C160. By this action C160 charges linearly, and the voltage at the cathode of V173 rises linearly. Any departure from a linear rise in voltage at this point will produce a change in the voltage at the grid of the Miller tube in a direction to correct for the error.

Timing Switch

The linear rise in voltage at the cathode of V173 is used as the sweep time-base. Timing Capacitor C160 and Timing Resistor R160 are selected by the TIME/CM switch SW160. R160 determines the current that charges C160. By means of the TIME/CM switch both the size of the capacitor being charged and the charging current can be selected to cover a wide range of sawtooth slopes (sweep rates). For high-speed sweeps bootstrap capacitor C165 helps supply current to charge the stray capacitance at the plate of the Miller tube; this permits the plate voltage to rise at the required rate.

If uncalibrated sweep rates are desired, the VARIABLE TIME/CM (red knob) control may be turned away from the CALIBRATED position. (See Timing Switch diagram.) This control, R160Y, varies



the sweep rate over a $2\frac{1}{2}$ to 1 range. Switch 160F is ganged with the VARIABLE control in such a way that the UNCALIBRATED light comes on when the control is turned away from the CALIBRATED position.

Sweep Length

As explained previously, the sweep rate (the rate at which the spot moves across the face of the crt) is determined by the timing circuit C160 and R160. The length of the sweep (the distance the spot moves across the face of the crt), however, is determined by the setting of the SWP. LENGTH control R176. As the sweep voltage rises linearly at the cathode of V173 there will be a linear rise in voltage at the arm of the SWP. LENGTH control R176. This will increase the voltage at the grid and cathode of V183A and at the grid and cathode of V133B. As the voltage at the cathode of V133B rises, the voltage at the grid of V135A will rise. When the voltage at this point is sufficient to bring V135A out of cutoff, the multivibrator circuit will rapidly revert to its original state with V135A conducting and V146 cutoff. The voltage at the plate of V146 rises, carrying with it the voltage at the diode plate V152A. The diode then conducts and provides a discharge path for C160 through R147 and R148 and through the resistance the cathode circuit of V173. The plate voltage of the Miller Tube now falls linearly, under feedback conditions essentially the same as when it generated the sweep portion of the the waveform except for a reversal of direction. The resistance through which C160 discharges is much less than that of the Timing Resistor (through which it charges). The capacitor current for this period will therefore be much larger than during the sweep portion, and the plate of the Miller Tube will return rapidly to its quiescent voltage. This produces the retrace portion of the sweep sawtooth during which time the crt beam returns rapidly to its starting point.

Hold-Off

The Hold-off Circuit prevents the Time-Base Generator from being triggered during the retrace interval. That is, the hold-off allows a finite time for the Time-Base circuits to regain a state of equilibrium after the completion of a sweep.

During the trace portion of the sweep sawtooth the Hold-Off Capacitor C180 charges through V183A, as a result of the rise in voltage at the cathode of V183A. At the same time the grid of V135A is being pulled up, through V133B, until V135A comes out of cutoff and starts conducting. As mentioned previously, this is the action that

initiates the retrace. At the start of the retrace interval C180 starts discharging through the Hold-Off Resistor R181. The time constant of this circuit is long enough, however, so that during the retrace interval (and for a short period of time after the completion of the retrace) C180 holds the grid of V135A high enough so that it cannot be triggered. However, when C180 discharges to the point the V133B is cut off, it loses control over the grid of V135A and this grid returns to the level established by the STABILITY control. The hold-off time required is determined by the size of the Timing Capacitor. For this reason the TIME/CM switch changes the time constant of the Hold-Off Circuit simultaneously with the change of Timing Capacitors. (In the μ SEC positions of the TIME/CM switch R181 is shunted by either R180A or R180B, shown on the Timing Switch diagram.)

Stability

The operational mode of the Time-Base Generator is determined by the setting of the STABILITY control R110. By means of this control the sweep can be turned off, adjusted for triggered operation, or adjusted for free-running operation. The STABILITY control, through cathode follower V125, regulates the grid level of V135A. (V133A is inoperative for NORMAL SWEEP operation.)

For triggered operation, the STABILITY control is adjusted so that the grid of V135A is just high enough to prevent the Sweep-Gating Multivibrator from free-running. Adjusted in this manner a sweep can only be produced when an incoming negative trigger pulse drives the grid of V135A below cutoff.

Moving the arm of the STABILITY control toward ground (ccw rotation), but not so far as to actuate the PRESET switch, will raise the grid level of V135A and prevent the Sweep-Gating Multivibrator from being triggered. This action turns off the sweep. Moving the arm toward -150 volts drops the grid of V135A to the point that the discharge of the Hold-Off Capacitor C180 can switch the multi. Adjusted in the manner, the Sweep-Gating Multivibrator will free-run and produce a recurrent sweep.

When the STABILITY control is turned full ccw to the PRESET position, R110 is switched out of the circuit and R111 is switched in. This control, a front-panel screwdriver adjustment labeled PRESET ADJUST, provides a fixed dc voltage for the grid of V135A. When properly adjusted, PRESET operation can be used for most triggering applications. Where triggering may be difficult, however, the manual STABILITY control R110 should be used.



Single Sweep Operation

When the NORMAL SWEEP-SINGLE SWEEP switch is in the SINGLE SWEEP position, plate voltage is applied to V133A and this tube operates in conjunction with V125 as a bistable multivibrator.

In the first stable state that exists after the completion of a sweep, V125 is cut off and V133A is conducting. In this state the divider between the plate of V125 and the grid of V133A sets the cathode voltage of the Lockout Multivibrator and consequently the grid voltage of V135A. The LOCKOUT LEVEL ADJ. R125 is adjusted to set the grid of V35A high enough so that the Sweep-Gating Multivibrator cannot be triggered; this "locks out" the sweep.

Depressing the RESET switch grounds C121 through R117. The resulting positive pulse at the grid of V125 forces the Lockout Multivibrator into its other stable state with V125 conducting and V133A cut off. With V133A cut off its plate voltage rises and ignites the READY light. With V125 conducting the STABILITY control regains control over the grid level of V135A.

Depending on the adjustment of the STABILITY control, a sweep can now be produced in one of two ways. If the STABILITY control is turned full right (cw) the grid of V135A will be pulled down and cause the Sweep-Gating Multivibrator to switch to its other state and initiate a sweep. If the STABILITY control is adjusted for triggered operation, the sweep will be initiated by the first negative trigger pulse to arrive at the grid of V135A.

As the sweep begins, the rising sawtooth voltage pulls up the cathode of V133B by the hold-off action previously described. As the cathodes of the Lockout Multivibrator follow the cathode of V133B up, V125 cuts off and V133A conducts. As the cathodes continue to rise, following the rise in the sawtooth sweep voltage, V133A cuts off again. Both tubes are then held cutoff for the remainder of the sweep and the READY light stays on. When the grid of V135A rises to the point that the Sweep-Gating Multivibrator is reverted, the sweep is terminated.

As the Hold-Off Capacitor C180 discharges, the cathodes of the Lockout Multivibrator start to fall. The grid level of V133A is such that this tube comes out of cutoff first; thus, V133A conducts and V125 remains in cutoff. As V133A conducts its

plate drops, extinguishing the READY light. A new sweep cannot be initiated until the RESET switch is depressed again.

Unblanking

The positive rectangular pulse at the cathode of V135B, in the Sweep-Gating Multivibrator circuit, is coupled through a cathode follower V183B (shown on the CRT circuit diagram) to the grid supply for the crt. This pulse, whose start and duration are coincident with the rising portion of the sawtooth sweep waveform, pulls up the grid of the crt. This unblanks the crt during the trace portion of the sweep and permits the trace to be observed.

Output Waveforms

The positive pulse coupled to the crt circuit for unblanking is also coupled through a cathode follower V193B to a front-panel binding post labeled + GATE OUT. This positive gate waveform starts at ground and rises to + 30 volts.

The sweep sawtooth voltage at the cathode of V173 is coupled through a cathode follower V193A to a front-panel binding post labeled SAWTOOTH OUT. This waveform, which starts at about ground, provides a 150-volt linear rise in voltage.

Dual Trace Sync and Blanking

Synchronizing pulses for dual-trace plug-in preamplifiers are supplied by V154A. When multi tube V146 cuts off a sharply differentiated positive pulse is developed at its screen. This pulse, coupled to the grid of V154A, produces a negative trigger at the plate of V154A. This trigger then switches the multivibrator in the dual-trace unit employed for alternate sweeps.

When the dual-trace multi is connected for free-running operation to produce chopped sweeps, a negative pulse is coupled from the multi to the grid of V154B. The resultant positive pulse at the plate of V154B is coupled to the cathode of the crt to blank out the beam during switching. Refer to the manual for the dual-trace unit for a detailed description of the switching multi.



HORIZONTAL AMPLIFIER

The dc-coupled Horizontal Amplifier consists of a cathode-follower input stage, two stages of push-pull amplification and a cathode-follower output stage. The gain of Input Amplifier V354-V364 is controlled by negative feedback from the cathodes of the Output C.F. stage V374B-V384B. The amount of negative feedback applied to the Input Amplifier, and hence the gain of the stage, is determined by the setting of the HORIZONTAL DISPLAY switch. As the magnification factor is increased the gain is increased by decreasing the feedback.

Input Circuit

The positive-going sweep sawtooth voltage produced by the Time-Base Generator circuit is coupled through a frequency-compensated voltage divider to the grid of the Input C.F. V343. The attenuation of the divider can be altered slightly by the adjustment of R342 (labeled X10 CAL. on the circuit diagram). The small time-constant network C339-R339 improves the start of the waveform at the faster sweep speeds. The two positioning controls HORIZONTAL POSITION R340 and VERNIER R346 affect the beam positioning by altering the dc level at the grid of V343. The voltage and resistance values in the positioning circuits are such that the VERNIER can move the spot about 1 centimeter while the HORIZONTAL POSITIONING control can move the spot about 10 centimeters when the HORIZONTAL DISPLAY switch is in the NORMAL position. Because of their low impedance, an adjustment of the positioning controls does not alter the attenuation of the divider network.

Input Amplifier

The Input Amplifier V354-V364 is a cathode-coupled phase inverter; the positive-going sawtooth at the grid of V364 is converted to a push-pull sawtooth in the plate circuit.

The impedance network connected between the two cathode circuits plays an important role in determining the amount of negative feedback applied to the Input Amplifier. Two of the components in this network, R361 and C361, have their value selected by the HORIZONTAL DISPLAY switch. The negative feedback, which comes from the cathodes of the Output C.F. stage, is applied through a frequency-compensated divider consisting of R387-C387 on one side and R388-C388 on the other, and the impedance connected between

the cathodes of the Input Amplifier. The smaller the impedance connected between the two cathodes the greater the drop across the series components and the less the amount of feedback applied to the Input Amplifier. Details of the R361-C361 network are shown in the switch layout in the upper left corner of the Horizontal Amplifier diagram. In the X100 SWEEP MAGNIFIED position of the HORIZONTAL DISPLAY switch R361 and C361 are replaced with a bare bus wire; this decreases the negative feedback and increases the gain of the stage 100 times over that of the NORMAL (X1) position of the switch. The X100 CAL. control R356 is adjusted to calibrate the maximum gain of the stage; the minimum gain (HORIZONTAL DISPLAY switch in the NORMAL (X1) position) is adjusted with the X1 CAL. control R368.

For dc and extremely low frequencies, a small amount of positive feedback is coupled from the cathode of V374B to the grid of V354. The D.C. SHIFT control R365 is adjusted so that the time constant of the feedback network is equal to the time constant of the slump distortion in the tubes.

The SWP/MAG. REGIS control R359 is adjusted to preserve the dc balance of the amplifier as the degeneration networks in the cathode circuit of the Input Amplifier are changed. This will ensure that the portion of the trace in the exact center of the crt, when the HORIZONTAL DISPLAY switch is in the NORMAL position, will be expanded symmetrically about the center when the switch is moved to any of the SWEEP MAGNIFIED positions.

Two MAGNIFIER neon glow lamps are located on the front panel immediately below the HORIZONTAL DISPLAY switch; circuitry for the lamps is shown in the switch-detail section of the Horizontal Amplifier diagram. The MAGNIFIER ON lamp glows whenever the HORIZONTAL DISPLAY switch is in any of the SWEEP MAGNIFIED positions. The MAGNIFIER UNCALIBRATED lamp is connected to glow whenever the sweep speed exceeds the maximum calibrated rate of $.02 \mu\text{sec}/\text{cm}$. This lamp will not glow so long as the setting of the TIME/CM switch, divided by the magnification factor, is not less than $.02 \mu\text{sec}$.

Output Stage

The Output Amplifier stage V374A-V384A operates as a conventional push-pull, plate-loaded



amplifier. The cathode followers V374B-V384B provide a high-impedance, low-capacitance load to help maintain the gain of the stage constant over the sweep range of the instrument. The cathode followers also provide the necessary low-impedance output to drive the capacitance of the horizontal deflection plates. Bootstrap capacitors C378 and C382 improve the response at the faster sweep rates by supplying additional current from the Output C.F. stage to charge and discharge the stray capacitance in the plate circuit of the Output Amplifier.

Capacitance Driver

At the faster sweep rates the current through the Output C.F. tubes is too small to discharge the capacitance of the horizontal deflection plates and its associated wiring at the required rate. Additional current for this purpose is provided by the gated pentode V394 connected in the cathode-return circuit of V374B. This permits the cathode of V374B, the negative-sawtooth cathode follower, to run down at the required rate. A similar current boost is not required for V384B since this tube is the positive-sawtooth cathode follower and the cathode runs down during the retrace.

Because the plate current of a pentode is fairly constant over a large range of plate voltage, the cathode current of V374B will remain nearly constant even though its cathode falls about 150 volts during the trace portion of the negative sweep waveform.

The additional current required for faster sweep rates is obtained by applying a positive flat-topped pulse to the grid of the pentode V394 during the period of the sweep. This pulse is derived by differentiating the positive-going sawtooth, available at the cathode of V384B, in C394 and the resistance in the grid circuit of V394. The amplitude of this pulse is proportional to the slope

of the sawtooth, and thus proportional to the sweep speed.

External Sweep

A front-panel binding post labeled EXTERNAL HORIZ. IN couples an externally-derived signal to the Horizontal Amplifier circuit when the HORIZONTAL DISPLAY switch is in the EXT. position. A preamplifier stage V324 is also connected into the circuit. The setting of the EXTERNAL HORIZONTAL VOLTS/CM switch determines whether the signal is directly coupled to the grid circuit of V324A, or whether one of two frequency-compensated attenuators is connected in the signal path. For all positions of this switch the input impedance is 1 megohm shunted by approximately 45 μf .

The External-Horizontal Preamplifier V324 operates as a cathode-coupled amplifier. . . V324A is the cathode-follower and V324B is the grounded-grid stage. The VARIABLE control R325 provides a means for adjusting the gain over a 10 to 1 range. The EXT. HORIZ. AMP. DC. BAL. control R334 adjusts the dc level of V324B so that its cathode will be at the same voltage as the cathode of V324A when no signal is applied to the grid of V324A. With the cathodes at the same voltage there will be no current through the VARIABLE control R325. By this arrangement an adjustment of the VARIABLE gain control will not change the dc level at the plate of V324B and will therefore not affect the positioning of the beam.

The gain of the Horizontal Amplifier, when connected for external operation, is calibrated by means of the EXT. HORIZ. AMP. CAL. control R361M, shown in the Switch Details section of the circuit diagram. This control is adjusted so that the horizontal deflection will agree with the setting of the EXTERNAL HORIZONTAL VOLTS/CM switch when the VARIABLE control is turned full right to the CALIBRATED position.

LOW-VOLTAGE POWER SUPPLY

Plate and filament power for the tubes in the Type 543 is furnished by a single power transformer T700. The primary has two equal windings which may be connected in parallel for 117-volt operation, or in series for 234-volt operation. The power supply will maintain regulation over line voltage ranges of 105 to 125 volts, or 210 to 250 volts, rms, 50-60 cycles. Bridge rectifiers are employed for the five separate, full-wave, power

supplies. The five supplies furnish regulated output voltages of -150, +100, +225, +350 and +500 volts.

- 150-Volt Supply

Reference voltage for the -150-volt supply is furnished by a gas diode voltage-reference tube V710. This tube, which has a constant voltage



drop, establishes a fixed potential of about -87 volts at the grid of V712A, one-half of a difference amplifier. The grid voltage for the other half of the difference amplifier, V712B, is obtained from a divider consisting of R715, R716 and R718. The -150 ADJ. control R716 determines the percentage of total voltage that appears at the grid of V712B and thus determines the total voltage across the divider. This control is adjusted so that the output voltage is exactly -150 volts.

If line-voltage or load fluctuations tend to change the output voltage, an error signal exists between the two grids of the difference amplifier. The error signal is amplified in V712B and V700 and applied to the grids of the series tubes V725, V726 and V727. The resulting change in voltage at the plates of the series tubes, which will be in a direction to compensate for any change in output voltage, is coupled through the rectifiers to the output to keep this voltage constant. Capacitors C707 and C717 improve the ac gain of the feedback loop to increase the response of the regulator circuit to sudden changes in output voltage.

A small amount of unregulated bus ripple is coupled to the screen of V700 through R728. The phase of the amplified ripple voltage at the plate of V700 is such as to cancel most of the ripple on the -150 -volt bus.

+ 100-Volt Supply

The $+100$ -volt supply is regulated by comparing to ground (the cathode of V742) the voltage of a point near ground potential obtained from the divider R750-R751 connected between the $+100$ -volt bus and the regulated -150 -volt supply. Any error voltage that exists is amplified and inverted in polarity by V742 and coupled through the cathode follower V748B to the output to prevent the output voltage from changing. Capacitor C750 improves the ac gain of this circuit.

A small sample of the unregulated bus ripple appears at the screen of V742 through R744. This produces a ripple component at the grid of the cathode follower V748B that is opposite in polarity to the ripple at the plate; this tends to cancel the ripple at the cathode and hence on the $+100$ -volt bus. This same circuit also improves the regulation in the presence of line-voltage variations.

+ 225-Volt Supply

Rectified voltage from terminals 7 and 14 of the power transformer is added to the voltage supply-

ing the $+100$ -volt regulator to furnish power for the $+225$ -volt regulator. This supply is regulated by comparing to ground (the grid of V765A) the voltage of a point near ground obtained from the divider R772-R771 connected between the $+225$ -volt bus and the regulated -150 -volt supply. Any error voltage that exists between the grids of the difference amplifier (V765) is amplified in both V765 and V757, and coupled through the cathode follower V748A to the $+225$ -volt bus. The change in voltage at the cathode of V748A, due to the regulator action, will be opposite in polarity to the original error signal and will thus tend to keep the output constant. This supply also furnishes an unregulated output of about $+340$ volts for the oscillator in the crt high-voltage supply. It is unnecessary to regulate this voltage as the crt supply has its own regulator circuits.

+ 350-Volt Supply

Rectified voltage from terminals 5 and 10 of T700 is added to voltage supplying the $+225$ -volt regulator to furnish power for the $+350$ -volt regulator. This supply is regulated by comparing to ground the voltage of a point near ground obtained from the divider R787-R788 connected between the $+350$ -volt bus and the regulated -150 -volt supply. The operation of the regulator circuit is the same as that described for the $+100$ -volt supply.

+ 500-Volt Supply

Rectified voltage from terminals 20 and 21 of T700 is added to the regulated side of the $+350$ -volt supply to furnish power for the $+500$ -volt regulator. This supply is regulated by comparing to the regulated $+350$ -volts the voltage of a point near $+350$ obtained from the divider R797-R798 connected between the $+500$ -volt bus and the regulated -150 -volt supply. The regulator action of this circuit is the same as that described for the $+100$ -volt supply.

Time-Delay

A time-delay relay K700 delays the application of dc voltages to the amplifier tubes in the instrument for about 25 seconds. This delay is to allow the tube heaters time to bring the cathodes up to emission temperature before operating potentials are applied.



CRT CIRCUIT

Cathode Ray Tube Control Circuits

The INTENSITY control R831 varies the voltage at the grid of the crt to control the beam current. The FOCUS control R852 varies the voltage at the focusing ring to focus the trace. The ASTIGMATISM control R860 varies the voltage at the astigmatism anode to focus the spot in both dimensions simultaneously. The GEOM. ADJ. R842 varies the field the beam encounters as it emerges from the deflection system to control the linearity at the extremes of deflection.

The CRT CATHODE SELECTOR switch SW800 connects the cathode of the crt through C857 to either a rear-panel binding post labeled EXTERNAL CRT CATHODE or to the plate of V154B in the Time-Base Generator circuit. When in the DUAL-TRACE CHOPPED BLANKING position, the cathode of the crt is connected to receive positive pulses from the Time-Base Generator circuit to blank the crt during switching while operating a dual-trace plug-in unit in the chopped mode.

When SW800 is in the EXTERNAL CRT CATHODE position, the cathode circuit of the crt is connected to the binding post mentioned previously. A bare bus bar normally connects the binding post to ground. When intensity modulation of the beam is desired, the bus bar can be removed so that the modulating signal can be coupled to the crt cathode.

High-Voltage Supply

A single 60-kc Hartley oscillator furnishes power for the three power supplies that provide accelerating potentials for the crt. The main components in the Oscillator circuit are the pentode V800 and the primary of T801 tuned by C806.

A half-wave rectifier V820 provides -1350 volts for the crt cathode. A half-wave voltage-tripler circuit, V821, V822 and V823, provides $+8650$ volts for the post-anode accelerator. This provides a total accelerating voltage of 10,000 volts. Both supplies are tied to the $+100$ -volt regulated supply through the decoupling filter R800-C800.

A floating half-wave rectifier V824 furnishes bias voltage (about -1450 volts) for the crt grid. This floating grid supply, independent of the

cathode supply, is required in order to provide dc-coupled unblanking to the crt grid. All three supplies employ capacitor-input filters.

The -1350 -volt cathode supply is regulated by comparing to the -150 -volt regulated supply (the cathode of V814B) a voltage near -150 volts obtained from a tap on the divider connected between the decoupled $+100$ -volt bus and the -1350 -volt bus. The total resistance of the divider, and hence the voltage across the divider, is determined by the setting of R811 labeled HV ADJ. When this control is properly adjusted, the voltage at the HV ADJ. TEST POINT will be exactly -1350 volts.

If variations in loading should tend to change the voltage on the -1350 -volt bus, an error signal will exist between the grid and cathode of V814B. The error signal will be amplified by V814B and V814A; the output of V814A varies the screen voltage of the oscillator tube V800, thereby controlling its output.

The $+8650$ -volt supply and the negative bias supply are regulated indirectly, as the output voltage of all three supplies is proportional to the output of the Oscillator circuit.

Unblanking

As mentioned previously, dc-coupled unblanking is accomplished by employing separate power supplies for the grid and cathode of the crt. The unblanking pulses from the Time-Base Generator are transmitted to the crt grid through the cathode follower V183B and the floating grid supply.

At the faster sweep rates the stray capacitance in the circuit makes it difficult to pull up the floating supply fast enough to unblank the crt in the required time. To overcome this, an isolation network composed of C834, R834 and R835 is employed. By this arrangement the fast leading edge of the unblanking pulse is coupled through C834 to the grid of the crt. For short-duration unblanking pulses, at the faster sweep rates, the power supply itself is not appreciably moved.

The longer unblanking pulses, at the slower sweep rates, charges the stray capacitance in the circuit through R834. This pulls up the floating supply and holds the grid at the unblanked potential for the duration of the blanking pulse.



CALIBRATOR

The Calibrator is a square-wave generator whose approximately 1-kc output is available at a front-panel connector labeled CAL. OUT. It consists of a multivibrator V670 connected so as to switch the cathode follower V246A between two operating states . . . cutoff and conduction.

During the negative portion of the Multivibrator waveform the grid of V246A is driven well below cutoff and its cathode rests at ground potential. During the positive portion of the waveform V670A is cutoff and its plate rests slightly below +100 volts. The voltage at the plate of V670A, when this tube is cutoff, is determined by the set-

ting of the CAL. ADJ. control R679, part of a divider connected between +100 volts and ground.

Cathode-follower V246A has a precision, tapped divider for its cathode resistor. When the CAL. ADJ. control is properly adjusted, the cathode of V246A is at +100 volts when V670A is cutoff. By means of the tapped divider R683 through R691 and a second 1000/1 divider R694-R695, output voltages from .2 millivolts to 100 volts, in steps, are available. C682, connected between the cathode of V246A and ground, corrects the output waveform for a slight overshoot.



SECTION 5

MAINTENANCE

PREVENTIVE MAINTENANCE

Air Filter

Care must be taken to assure free ventilation of the Type 543 inasmuch as some of the components are operated at dissipation levels such that excessive interior temperatures will result without adequate air circulation. To assure free passage of air the instrument must be placed so that the air intake is not blocked, and the filter must be kept clean. Moreover, the side panels and bottom cover must be in place for proper air circulation; do not remove the covers except during maintenance.

A washable "E-Z KLEEN" filter is used at the air intake port of the instrument. Under normal operating conditions the filter should be inspected, and cleaned if necessary, every three to four months. More frequent inspection is required when the operating conditions are more severe.

The following cleaning instructions are issued by the filter manufacturer:

- (1) If grease or dirt load is light, remove filter from installation and rap gently on hard surface to remove loose dirt. Flush remaining dirt or grease out of filter with a stream of hot water or steam; flush from dirty side.
- (2) If load is too heavy for treatment described in (1), prepare mild soap or detergent solution in pan or sink deep enough to cover filter when laid flat. Agitate filter up and down in solution until grease or dirt is loosened and floated off.
- (3) Rinse filter and let dry.
- (4) Dip or spray filter with fresh Filter Coat or Handi-Coater. These products are available from the local representative of the Research Products Corporation, and from most air-conditioner suppliers.

Fan Motor

The bearings in the fan motor should be oiled every three to four months with a few drops of light machine oil.

Recalibration

The Type 543 is a stable instrument and will provide many hours of trouble-free operation. To insure the reliability of measurements obtained on the Type 543, we suggest that its calibration be checked after each 500 hours of operation, or at least every six months if used intermittently. A check of the calibration also provides a means for checking the operation of each circuit. Minor operational deficiencies that are not apparent in normal use are often detected during a calibration check.

A complete step by step procedure for checking the calibration of the instrument is included in the Recalibration Procedure section of this manual.

Soldering Precautions

In the production of Tektronix instruments a special silver-bearing solder is used to establish a bond to the ceramic terminal strips. This bond may be broken by repeated use of ordinary tin-lead solder, or by excessive heating of the terminal strip with a soldering iron. Occasional use of ordinary solder will not break the bond if too much heat is not applied.

In those shops responsible for the maintenance of several Tektronix instruments it is advisable to have a stock of solder containing about 3% silver. This type of solder is used frequently in printed-circuit work and is generally available. Or it can be purchased from Tektronix in one-pound rolls; order by part number 251-514.



REPLACEMENT PARTS

Standard Parts

Replacement parts can be obtained from Tektronix at current net prices. However, since most of the components are standard parts they can usually be purchased locally. Before ordering or purchasing parts, however, be sure to consult the Parts List to determine the tolerances required.

Selected Tubes

To obtain maximum reliability and performance, some of the tubes in Tektronix instruments are checked for certain characteristics; other tubes are aged to stabilize their characteristics. Specially selected tubes are labeled and identified with a part number beginning with 157—. The 12BY7 tubes in the Vertical Amplifier are specially selected tubes assigned the part number 157-053. These tubes are aged and selected to meet certain bias requirements at a constant cathode current. For replacement purposes we suggest that you obtain these specially selected tubes from the local Tektronix field office.

Tektronix-Manufactured Parts

Tektronix manufactures almost all of the mechanical parts, and some of the electronic components, used in this instrument. The Tektronix-manufactured electronic components are identified in the Parts List. These components, as well as the mechanical parts, may be ordered from the local Tektronix field office.

Parts Ordering Information

The serial number on the frontspiece of this

manual is the serial number of the instrument for which this manual was prepared. Be sure that the number in the manual matches the serial number of the instrument.

Each component in this instrument has a six-digit Tektronix part number. This number, together with a description of the part, will be found in the Parts List. To expedite filling your order be sure to include the following information when ordering parts:

1. A description of the part.
2. The part number.
3. The instrument type and serial number.

For example, a certain resistor should be ordered as follows: R1055, a 4.5-k, 5-watt wirewound resistor, tolerance 5%, part number 308-066, for a Type 543 serial number _____. When parts are ordered in this manner we are able to fill the order promptly and delays that might result from transposed digits in the part number are avoided.

Since the production of this instrument some of the components may have been superceded with newer, improved components. If we receive an order for a component that has been superceded by a newer one, the new one will be shipped in place of the original. All Tektronix field offices have knowledge of these changes, and your local Field Engineer may call you if a change in your purchase order is necessary.

Replacement information notes sometimes accompany the new components to aid in their installation.

TROUBLESHOOTING PROCEDURE

This section of the manual contains information for troubleshooting the Type 543 oscilloscope. Before attempting to troubleshoot the instrument, however, make sure that any apparent trouble is actually due to a malfunction within the instrument and not to improper control settings or to a faulty plug-in unit. Instructions for the operation of the Type 543, and general information concerning plug-in operation, are contained in the Operating

Instructions section of this manual. Operating instructions for a specific plug-in unit will be found in the manual for that unit.

To determine that the oscilloscope is at fault, the plug-in unit may be replaced with another known to be in good operating condition. If the trouble is still apparent, it is almost a certainty that the Type 543 is at fault. However, should the



trouble appear to have been corrected by replacing the plug-in unit, the trouble most likely lies within the original plug-in unit and not with the Type 543.

Tube failure is the most prevalent cause of circuit failure. For this reason, the first step in troubleshooting any circuit in the instrument is to check for defective tubes, preferably by direct substitution. Do not depend on tube testers to adequately indicate the suitability of a tube for certain positions within the instrument. The criterion for usability of a tube is whether or not it works satisfactorily in the instrument. Be sure to return all good tubes to their original socket; if this procedure is followed less recalibration of the instrument will be required upon completion of the servicing.

When replacing any tube in the instrument, check first to see that components through which the tube draws current have not been damaged. Shorted tubes will sometimes overload and damage plate-load and cathode resistors. These damaged components can generally be located by a visual inspection of the wiring. If no damaged

components are apparent, and if tube replacement does not restore operation, it will be necessary to make measurements or other checks within the circuit to locate the trouble.

The component number of each resistor, inductor, capacitor, vacuum tube, control and switch is shown on the circuit diagrams. The following chart lists the component numbers associated with each circuit.

All numbers less than 100	Time-Base Trigger
All 100 numbers	Time-Base Generator
All 300 numbers	Horizontal Amplifier
All 600 numbers*	Square-Wave Calibrator
All 700 numbers	Low-Voltage Power Supply
All 800 numbers	CRT Circuit and High-Voltage
All 1000, 1100 & 1200 numbers	Vertical Amplifier
All 1300 numbers	Delay Line

*The Calibrator circuit has one tube with a V246 number.

CIRCUIT TROUBLESHOOTING

Although the Type 543 is a complex instrument, it can be thought of as consisting of six main circuits, in addition to the Calibrator circuit. These are the

1. Low-Voltage Power Supply
2. CRT Circuit and High-Voltage Power Supply
3. Vertical Amplifier and Delay Line
4. Time-Base Trigger Circuit
5. Time-Base Generator
6. Horizontal Amplifier

The first circuit to check, for practically any type of trouble, is the Low-Voltage Power Supply. Because of the circuit configuration employed in the Type 543, it is possible for an improper power supply voltage to affect one circuit more than the others. For example, if the gain of the Vertical Amplifier should decrease slightly, while the other circuits appear to be functioning normally, this could be due to an improper supply voltage and not to any condition originating in the Vertical

Amplifier. In cases of this type, valuable time can be saved by checking the power supply first.

On the other hand, the crt display can often be used to isolate trouble to one particular circuit when trouble obviously exists in that circuit. If there is no vertical deflection, for example, when the intensity and horizontal deflection appear to be normal, it is apparent that an open condition exists in the Vertical Amplifier and this circuit should be investigated first.

The material that follows contains information for troubleshooting each circuit for troubles that may be caused by a defect in the circuit. A method is described, in some instances, for locating the stage in which the trouble may be originating; once the stage at fault is known, the component(s) causing the trouble can be located by voltage and resistance measurements or by substitution. In certain other instances the information is more specific and the trouble can be traced to a particular component.



TROUBLESHOOTING THE LOW-VOLTAGE POWER SUPPLY

Proper operation of every circuit in the Type 543, including the plug-in unit, depends on proper operation of the Low-Voltage Power Supply. The regulated dc voltages must remain within their specified tolerances for the instrument and plug-in unit to retain their calibration.

CAUTION

Exercise care in checking the power supply. Because of their high current capabilities and low impedance, the Low-Voltage supplies can produce more harmful shocks than the high-voltage supply in the CRT circuit.

Open Power Circuit (Dead Circuit)

If the pilot lamp and the fan do not come on when the power is turned on, check the source of power and the power cord connections. Check the fuse at the rear of the instrument. If the fuse is blown replace it with one of the proper value and turn the instrument on again. If the new fuse blows immediately, check the power transformer for shorted primary or secondary windings. Also check for a shorted rectifier stack. If the new fuse does not blow until the time-delay relay has activated (a "click" can be heard), check for a shorted condition in the regulator circuits and the loading on the supply.

If the fuse is good, check for an open primary winding in the power transformer. If your instrument is wired for 234-volt operation, check for an open Thermal Cutout Switch; the resistance of this switch is about $.1 \Omega$. (If your instrument is wired for 117-volt operation, the fan will come on even though the Thermal Cutout Switch may be open). The Thermal Cutout Switch is located on the vertical chassis toward the right rear of the instrument.

If both the fan and pilot lamp come on, the primary circuit of the power transformer is operating normally.

Incorrect Output Voltage

Test points for checking the Low-Voltage Power Supply are located on the right side of the instrument, near the top, in front of the shield covering the high-voltage transformer. The voltage for each test point is silk-screened on the lip of the chassis adjacent to the ceramic strip on which the test points are located. Each regulated bus is identi-

fied by a color-coded wire. The -150 -volt bus is coded brown, green and brown on a black wire; the $+100$ -volt bus is coded brown, black and brown on a white wire; the $+225$ -volt bus is coded red, red and brown on a white wire; the $+350$ -volt bus is coded orange, green and brown on a white wire; and the $+500$ -volt bus is coded green, black and brown on a white wire.

If any of the supplies fail to regulate the first thing to check is the line voltage. The supplies are designed to regulate between 105 and 125 volts with the design center at 117 volts, or between 210 and 250 volts with the design center at 234 volts, rms, 50-60 cycle single phase ac.

If the line voltage is the correct value, the next step is to remove the plug-in unit and measure the resistance between each regulated bus and ground. The following resistance values are approximate minimum readings; the actual resistance between each bus and ground will generally be higher than the values indicated here.

REGULATED BUS	APPROX. MINIMUM RESIST. TO GROUND
-150 v	3.5 k
$+100$ v	5 k
$+225$ v	10 k
$+350$ v	30 k
$+500$ v	35 k

If the resistance values between the regulated buses and ground check out, check the tubes (if this has not already been done). Then make sure that the line voltage is set near the design center for your instrument (117 or 234 v) and check the



rms voltage across the secondary winding for each supply; the nominal value of each secondary voltage, when the line is set to the design center, is indicated on the circuit diagram. If the secondary voltages are all correct, check the operation of the bridge rectifiers. This can be done by measuring the rectified voltage at the input to each regulator. These values are also indicated on the circuit diagram. Then check for off-value resistors, especially in the dividers, and for open or leaky capacitors.

The material that follows may be used as a quick index for troubleshooting the regulator circuits.

If the output voltage is high with excessive ripple, check:

- a. For high line voltage.
- b. For open voltage-regulator tube V710.
- c. The amplifier tubes V700, V712, V742, V757, V765, V782 and V791.
- d. For insufficient loading.

If the output voltage is high with normal ripple, check:

- a. For proper resistance values in the dividers (R715, R716 and R718, R750 and R751, R771 and R772, R787 and R788, and R797 and R798).

If the output is low with excessive ripple, check:

- a. For low line voltage.
- b. For shorted voltage-regulator tube V710.
- c. The series tubes V725, V726, V727, R748, V784, and V794.
- d. For excessive loading.
- e. Open or leaky filter capacitors.
- f. Defective rectifiers.

If the output is low with normal ripple, check:

- a. The resistance values in the dividers.
- b. The capacitors across the dividers.

IMPORTANT: If any components in the —150-volt supply are changed, or if the setting of the —150 ADJ. control is changed, it will be necessary to recalibrate the instrument.

TROUBLESHOOTING THE CRT CIRCUIT

The intensity, focus, geometry and calibration of the crt display depend on proper operation of the three high-voltage supplies in the CRT Circuit.

No Intensity

If the low-voltage power supply is operating normally, but no spot or trace is visible on the crt, the trouble could be a defective crt, a defect in the crt cathode circuit including the —1350-volt supply, or an unbalanced dc condition in either or both of the deflection amplifiers. In the latter case the dc unbalance is producing improper positioning voltages and the beam is being deflected off the screen.

To determine which circuit is at fault, turn the INTENSITY control full right (cw). If a flare is observed on the crt screen (it may be necessary to darken the room), one of the deflection amplifiers is probably at fault; the procedure for troubleshooting these circuits follows a bit later in this

section. If no flare is observed with the INTENSITY control turned full right, the trouble will either be due to a defective crt or to an inoperative cathode supply circuit (V820 rectifier circuit). The cathode supply can be checked by measuring the voltage at the HV ADJ. TEST POINT. This test point is accessible through a hole in the shield at the top left rear of the instrument. The voltage at this point should be —1350 volts, although it will vary with the setting of the HV ADJ. control R811. If a voltage reading in the vicinity of —1350 volts is obtained, turn the instrument off and remove the shield covering the test point. Then measure the resistance of R856, the 27-k resistor connected to the test point. If this resistor is not open a defective crt is indicated.

If the voltage at the HV ADJ. TEST POINT is zero or abnormally low replace the Oscillator tube V800 and the Error-Signal Amplifier tube V814. If this does not restore operation the Oscillator circuit should be checked.



A quick check on the operation of the Oscillator circuit can be made by observing for heater glow in the 5642 rectifier tubes, located under the shield at the upper right rear of the instrument. These tubes are visible through the opening in the side of the shield. If no heater glow is visible the Oscillator circuit is inoperative. This could be due to an open transformer T800, or to a defective component in the circuit of V800 or V814.

If heater glow is visible in the rectifier tubes, the Oscillator circuit is operating. If the heater glow appears to be dim, however, the output of the Oscillator may be insufficient for proper operation. A more accurate check on the Oscillator may be made by removing the shield covering the high-voltage transformer and measuring the bias at the grid of V800. This can be measured at the junction of the 100-k resistor R804 and the .01- μ fd capacitor C805, located on the ceramic terminal strip near the post that supports the front of the shield. The voltage at this point should measure about -65 volts.

CAUTION: Do not let your hand or body touch the chassis when making this check. Secondary reactions to an otherwise harmless shock might result in a painful injury.

If the Oscillator circuit is operating properly, but the voltage at the HV ADJ. TEST POINT does not measure in the vicinity of -1350 volts, the 5642 rectifier tube V820 is most likely defective.

Abnormal Intensity

If a trace is visible on the crt, the relative intensity of the trace may be used to identify trouble in either the negative bias supply or the positive anode supply.

If the trace is excessively brilliant, and if the brilliancy does not change as the INTENSITY control is adjusted, check the negative bias supply including the lead to pin 3 on the crt socket. Check for a defective rectifier tube V824, an open supply winding or filament winding, an open resistor including the INTENSITY control, or a shorted or leaky capacitor. If trouble is not found in any of these components, a defective crt is indicated.

If the intensity of the trace is extremely low, check for an inoperative positive supply. Also check the anode connection to the crt, including R825 and C825.

If the accelerating potentials appear to be too high, as evidenced by decreased deflection sensitivity, check the Error-Signal Amplifier circuit.

If a badly distorted trace or spot is visible on the crt, check the GEOM. ADJ. control R842 and its connection to the neck pin on the crt, and the ASTIGMATISM control R860 and its connection to the crt base socket. If the FOCUS control has no effect on the trace, check this control (R852) and its connection to the crt base socket.

IMPORTANT: If any components in the Oscillator, Error-Signal Amplifier or -1350 -volt cathode supply circuit are changed, or if the setting of the HV ADJ. control is changed, it will be necessary to recalibrate the instrument.

TROUBLESHOOTING THE VERTICAL AMPLIFIER

No Spot or Trace Visible on CRT

If all power supply voltages are normal, and the crt is known to be good, failure to obtain a spot or trace on the screen will be due to improper positioning voltages. This condition is caused by a dc unbalance in either or both of the deflection amplifier circuits.

To determine which circuit is at fault, adjust the Time-Base controls for a free-running sweep at 1 millisc/cm (STABILITY control full right) and set the INTENSITY control to midscale. Using a screwdriver with an insulated handle, short the vertical deflection plates together at the neck pins on the crt. These are the pins marked BLUE (UPPER) and BROWN (LOWER). Be extremely careful not to

short either pin to the metal shield around the crt, or to the pin marked ORANGE (GEOM). If the dc unbalance is being produced in the vertical deflection circuit the trace will appear at or near the center of the crt when the vertical deflection plates are shorted together. If the trace does not appear, however, the trouble does not lie in the vertical circuit and the dc balance of horizontal circuit can be checked in a like manner.

If it is determined that the vertical deflection circuit is unbalanced, the next step is to check the Delay Line. For this check, and for others to follow, it is convenient to have a short lead (about 8 or 10 inches) with a rubber-covered alligator clip on each end. Connect this lead across the input to the Delay Line (at the output from the Distributed



Amplifier). If the trace appears on the crt the Delay Line is not at fault. If the trace does not appear, check for an open line. This can be done by turning off the instrument and checking the continuity of both sides of the line with an ohmmeter.

If the Delay Line is not at fault, connect the shorting strap across the input of the Distributed Amplifier (grid (pin 1) of V1054 to the grid (pin 1) of V1064). If the trace does not appear, when these grids are connected together, the trouble lies in the Distributed Amplifier. Check for an open grid or plate line (L1103, L1104, L1113 or L1114). Check R1206 and R1216 at the grid-line termination, and R1071 and R1073 and the associated circuitry at the plate-line termination.

If the trouble is being caused by tubes, it may help to connect the shorting strap between the grids of V1204 and V1214, then move the strap back stage by stage toward V1054 and V1064 until a point is reached where the trace will no longer appear as the opposite grids are connected together. The trouble will then lie in that part of the circuit between the shorting strap and the Delay Line. It is unlikely that just one tube in the Distributed Amplifier could be responsible for the trouble because the current from each tube is only a small portion of the total current flowing in the plate circuit.

If the trace appears when the input grids to the Distributed Amplifier are connected together, the trouble is occurring ahead of the Distributed Amplifier in one of the input stages. If tube replacement does not correct the trouble, then look for open peaking coils, defective resistors, and shorted or leaky capacitors.

Insufficient or No Vertical Deflection

Insufficient deflection indicates a change in the gain characteristics of the Vertical Amplifier. If only a slight change in deflection is apparent, the circuit can normally be recalibrated for gain. In this event, refer to the Recalibration Procedure section of this manual.

If the change in deflection is more pronounced, or if there is no deflection at all, the tubes should first be checked. Then check for components which can affect the gain of the circuit but not the dc balance. Such components would be the common cathode resistors R1016, R1017, R1055 and R1208, and the GAIN ADJ. control R1027; common screen resistors R1031 and R1218; and common plate-load resistors R1013, R1033 and R1054.

Waveform Distortion

Any waveform distortion that may be produced by the Type 543 will generally be of a high-frequency nature. There will be no low-frequency distortion since the deflection circuit is dc-coupled from input to output (unless one or more of the tubes enter into heavy grid current, a condition that will produce other types of distortion as well).

A distortion-free positive step function, having a risetime of 10 millimicroseconds or less, may be used to observe the high-frequency characteristics of the oscilloscope/plug-in combination. This is illustrated in the waveform photographs of Figs. 5-1, 5-2, 5-3 and 5-4. Fig. 5-1 (a) shows a display of the 3-millimicrosecond risetime square-wave output of the Tektronix Type 107 Square-Wave Generator; this photograph was taken on a standard Type 543 Oscilloscope with a Type K Plug-In Unit. The straight leading edge, square corner and flat top are indicative of the frequency response of a properly adjusted Type 543/K-Unit combination. Fig. 5-1 (b) shows the same waveform except for a small aberration in the top about 2 centimeters to the right of the leading corner. This aberration is known as the termination "bump", and was obtained by detuning the Delay Line termination network slightly. The oscilloscope was adjusted for a sweep rate of $.2 \mu\text{sec}/\text{cm}$ for these photographs; the termination bump therefore occurs $.4$ microsecond after the leading corner. Since the Delay Line is reverse terminated, this corresponds to twice the $.2$ -microsecond delay time of the circuit.

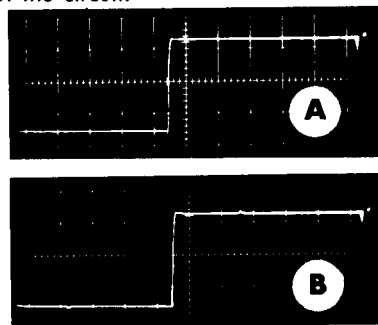


Fig. 5-1. (a) A 450-kc, 3-millimicrosecond risetime square wave display on properly adjusted Type 543/K-unit combination.

(b) The small aberration in the top of the waveform is a termination bump produced by an improperly terminated Delay Line.

Any waveform distortion that may be produced by the vertical deflection circuit will occur between the leading corner and the termination bump. The vertical deflection circuit in the Type 543 may be divided into three parts, and each



part will affect the waveform in a different manner. An analysis of the distortion is therefore helpful in determining which part of the circuit is at fault. The three parts are:

- (1) The plug-in unit and input stage of the main Vertical Amplifier.
- (2) The Distributed Amplifier.
- (3) The Delay Line.

The plug-in unit and the input stage of the main Vertical Amplifier will affect only the leading corner of the step function. Assuming the trouble is not being caused by the plug-in unit, the Input Amplifier stage V1014 and V1024, and the cathode follower circuit V1033 and V1043 can be investigated for the type of distortion shown in Fig. 5-2. Fig. 5-2 (a) shows rolloff, or undershoot, at the leading corner of the step function. Rolloff is the result of insufficient high-frequency compensation. A small amount of rolloff is normally due to a change, with age, in the characteristics of the circuit components, and can usually be compensated by adjusting the variable peaking coils. If the rolloff is more pronounced the tubes should be checked. If a tube cannot deliver current, instantaneously on demand, the transients in the signal will not be produced.

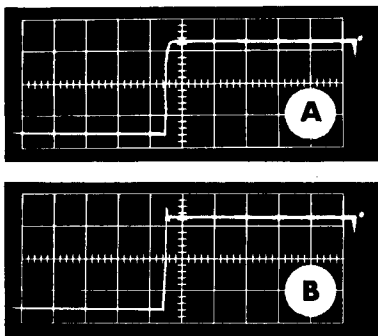


Fig. 5-2. (a) Rolloff at leading corner caused by an undercompensated Input Amplifier stage. (b) Ringing produced by an overcompensated Input Amplifier stage.

Shorted or partially shorted peaking coils will result in a rolloff. Be especially careful when soldering around the peaking circuits as hot solder dropping on a coil may burn through the insulation and short the turns.

Ringing at the leading corner, shown in Fig. 5-2(b), is produced by an overcompensated amplifier. This is generally caused by misadjusting the peaking coils. An overshoot at the leading edge, without ringing, can also be produced by an over-

compensated amplifier; in this case the degree of compensation is not sufficient to produce ringing. In both of these cases the distortion can generally be eliminated by readjusting the variable peaking coils.

An overshoot at the leading edge of a fast-rise pulse may also be the result of cathode interface in one of the amplifier tubes. Since the time constant of the interface layer is normally in the range from .1 to 3 μ sec, this effect is most noticeable on waveforms whose period is long compared to the interface time constant. This condition is produced by the tubes themselves, so it is important to first check the tubes when such distortion is evident.

The Distributed Amplifier will affect the step function both at the leading corner and in the vicinity of the termination bump. A typical example is that shown in Fig. 5-3. The rounded corner, and the aberrations about .4- μ sec following the corner, were produced by replacing V1204 with a tube whose G_m was quite low. This points up the importance of the tubes in maintaining the proper frequency response in pulse amplifiers. Other factors causing similar effects would be shorted coils in the plate and grid lines, off-value resistors, leaky or open capacitors, or improper adjustment of the capacitors across the plate lines.

The Delay Line will affect the pulse from the corner to the termination bump. If the line is badly detuned the top of the pulse will be uneven, instead of smooth and flat as shown in Fig. 5-1(a), and the leading corner may either overshoot or rolloff. If just one or two sections of the line are detuned, either due to a shorted coil or a defective capacitor, an aberration will appear in the waveform in the region affected by the defective component. Since the Delay Line is reverse terminated, the end of the line nearest the cathode ray tube will affect the start of the pulse, and the beginning of the line (at the output of the Distributed Amplifier) will affect the waveform in the region of the termination bump. Sections of the line between the two ends will affect the waveform in the region between the corner and the termination bump. The location of any aberration in the top of the pulse, with respect to the leading corner and the termination bump, will indicate the relative section of the line in which the trouble is occurring. For example, the small aberrations shown in Fig. 5-4 were produced by slightly detuning two sections of the line about midway between the Distributed Amplifier and the cathode ray tube.



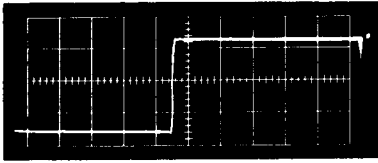


Fig. 5-3. Rolloff and aberrations in top of pulse are due to a low-Gm tube in the Distributed Amplifier.

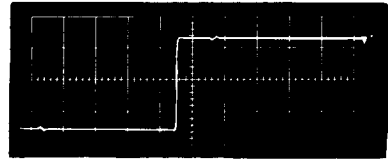


Fig. 5-4. Small aberrations in top of pulse are caused by a slightly misadjusted portion of the Delay Line.

TROUBLESHOOTING THE HORIZONTAL AMPLIFIER

No Spot or Trace Visible on CRT

To determine that the Horizontal Amplifier is in a state of dc unbalance, short the horizontal deflection plates together at the neck pins of the crt in the manner explained for troubleshooting the Vertical Amplifier. The horizontal deflection plates are marked RED (LEFT) and GREEN (RIGHT). The INTENSITY control should be set to midscale. If a spot appears when the horizontal deflection plates are shorted together (it may be necessary to adjust the Vertical POSITIONING control), the trouble lies in the Horizontal Amplifier.

CAUTION: Do not permit the spot to remain on the crt at this setting of the INTENSITY control. Either reduce the intensity until the spot is just visible, or remove the short from the horizontal deflection plates.

The procedure for troubleshooting the Horizontal Amplifier, to locate the defective stage, is similar to that explained for troubleshooting the Vertical Amplifier for unbalance. The shorting strap can be moved from the deflection plates back toward the Input Amplifier stage, until a point is reached where the trace does not appear. When the stage at fault is determined, check for defective tubes and components associated with that stage.

Insufficient or No Horizontal Deflection

If the gain of the Horizontal Amplifier decreases, the trace will not extend from the left to the right side of the graticule. In addition, the timing will no longer correspond to the calibrated value indicated by the TIME/CM switch. (This is to distinguish the condition of insufficient sweep produced by a malfunction in the Horizontal Amplifier from that produced by a malfunction in the Hold-Off circuit in the Time-Base Generator, e.g., an improper adjustment of the SWP. LENGTH control. In the latter case the trace will start at the left side of the graticule, for the normal setting of the HORIZONTAL POSITION control, and the timing will not be affected.)

If the change in gain is slight, as indicated by improper timing and a slightly decreased sweep, the amplifier can usually be recalibrated. Since the gain of the Horizontal Amplifier regulates the timing of the sweep, care must be taken to insure that the gain adjustments are accurately made. Be sure to refer to the Recalibration Procedure if it is necessary to adjust the gain of the Horizontal Amplifier.

If the decrease in gain of the Horizontal Amplifier is more pronounced, or if there is no sweep at all (in which case only a spot will be visible on the horizontal axis), check for defective components which can affect the gain but not the dc balance. In addition to the tubes, such components would be the common cathode resistors and controls.

TROUBLESHOOTING THE TIME-BASE TRIGGER CIRCUIT

Unstable Triggering

If the sweep generator is not being properly triggered a stable display of a waveform will not be possible. If the sweep can be turned off and

on with the STABILITY control (for any setting of the TRIGGERING MODE switch except AUTOMATIC) the sweep generator is capable of being triggered; this indicates the trigger circuitry is not functioning properly. The first step is to replace



the Trigger Pickoff tube V1223 in the Vertical Amplifier. The operation of this stage can also be checked by observing the signal available at the VERT. SIG. OUT binding post with another oscilloscope. If no signal is available at this connector the Trigger Pickoff stage is defective; a proper signal at this connector indicates the stage is functioning correctly.

If the Trigger Pickoff stage is operating correctly, trouble exists in the Time-Base Trigger circuit. To check the quiescent stage of the circuit, set the TRIGGERING MODE switch to AC SLOW, the TRIGGER SLOPE switch to —INT., and the TRIGGERING LEVEL control to O. Next, connect a jumper wire from the junction of R19, R20 and C20 (on the Trigger Switch; see Fig. 6-2) to ground. This fixes the voltage at the grid of V24B at ground potential. Then measure the voltage at the plate of V24B; this should be about +85 volts. If this voltage does not measure very close to +85 volts, replace the Trigger Input tube V24. If necessary, check for off-value resistors, broken leads and poor switch contacts.

The next step is to connect the voltmeter between the plate of V24B and the grid of V45B (the junction of R40, R42, C42 and R47 is more convenient than the grid of V45B). The voltage between the plate of V24B and the grid of V45B (or the divider side of R47) should not exceed about 2.75 volts. It is the function of the TRIGGERING LEVEL CENTERING control R39 to set the voltage at the grid of V45B approximately equal to the

voltage at the grid of V45A. With the grids of the V45 at about the same voltage the center of the hysteresis of the Schmitt Trigger circuit will be at the proper level. It is difficult to measure the voltage directly between the two grids of V45 due to the loading of the voltmeter; for this reason we suggest the voltage be measured between the plate of V24B and the grid circuit of V45B. A voltage of 2.5 to 2.75 volts between these points will indicate proper quiescent operation.

If the voltage at the grid of V45B cannot be adjusted to within 2.5 to 2.75 volts of the voltage at the plate of V24B, trouble in the Schmitt multivibrator is indicated. Replace the tube; then, if necessary, check for off-value resistors, broken leads and poor switch connections.

Conversely, if the voltages are found to be correct, the adjustment of the TRIGGER SENSITIVITY control R37 can be checked. Refer to Step (7) in the Recalibration Procedure for the proper method of checking the adjustment of this control.

When triggering in the DC mode from the signal being observed (TRIGGER SLOPE at + or — INT.), the INT. TRIG. DC LEVEL ADJ. R3 and its associated components are connected to the input grid of V24. This control is adjusted so that the input grid (pin 7 at — INT; pin 2 at + INT.) is at ground potential when the trace is centered vertically on the crt. If the voltage at the input grid cannot be adjusted to zero, when the triggering-switch controls are in the indicated positions, this control and its associated components should be checked.

TROUBLESHOOTING THE TIME-BASE GENERATOR

No Horizontal Sweep

If the Time-Base Generator is not producing a sawtooth sweep voltage, when the STABILITY control is adjusted for a free-running sweep, some defect in the generator is hanging up the Miller circuit. Depending on the on-off characteristics of the diodes V152, the Miller circuit may be hung up at either the high end or the low end of the sawtooth. The manner in which it is hung up may be determined by measuring the voltage at the SAWTOOTH OUT binding post. If the Miller circuit is hung up at the high end of the sawtooth the voltage at the front-panel binding post will measure about +200 volts; if hung up at the low end, the voltage at this point will measure anywhere between ground and —20 to —30 volts, depending on the cause.

If the Miller circuit is hung up at the high end of the sawtooth, a check of the voltage at the grid of the Miller tube will offer a clue to the cause of the trouble. The static voltage at the Miller grid is determined by conduction through the Timing Resistor R160 (from —150-volt bus), the lower diode V152A, and the divider R147-R148. It will be impossible to measure the exact voltage at the Miller grid because of the loading of the meter. However, if a 20,000- Ω /v meter, or a vacuum-tube voltmeter is used, the voltage reading obtained will be sufficient to indicate the source of the trouble. For example, if a voltage reading more negative than about —15 volts is obtained, there is probably no conduction through the Timing Resistor. This would indicate an open divider R147-R148, assuming the diode V152 to be good.



If the Miller circuit is hung up at the low end of the sawtooth, as indicated by a voltage reading of zero or a few volts negative, a check of the voltage at the plate of the Miller tube will offer a clue to the cause. If this voltage is quite high (about + 350 volts), check the neon lamp B167 and the Runup CF tube V173. If the voltage at the plate of the Miller tube is zero or slightly negative, check for an open plate-load resistor R164, R165 or R166.

However, if the voltage at the plate of the Miller tube is near the quiescent level (about + 45 volts) the trouble will generally lie ahead of the Miller tube. The result of the trouble is that the On-Off Diodes V152 cannot be gated off; they are conducting heavily and clamping the grid of the Miller tube near ground. If all of the tubes have been checked, then check for open plate and cathode resistors in the Sweep-Gating Multivibrator circuit, the Hold-Off circuit and the Runup CF circuit. Also check that the STABILITY control can vary the voltage at the grid of V135A.

Improper Triggering

If the sweep cannot be triggered properly, the gating pulse from the Multivibrator is not turning the diodes V152 off and on properly. The start of the gating pulse, which turns the diodes off and starts the sweep, is initiated by the triggering pulse at the grid of V135A. The end of the gating pulse,

which turns the diodes on and initiates the retrace, is controlled by the hold-off waveform at the grid of V135A. The Sweep-Gating Multivibrator can be eliminated as the cause of the trouble if the sweep can be turned off and on with the STABILITY control. The main component to check, in addition to the tubes, is the differentiating capacitor C131.

Nonlinear Sweep

A nonlinear sweep voltage will be generated if the current charging the Timing Capacitor C160 does not remain constant. If the nonlinearity occurs at all sweep rates a defective Miller tube will be the probable cause. If the nonlinearity occurs only at certain sweep rates a leaky Timing Capacitor will be the probable cause but the Miller tube should not be overlooked. A defective bootstrap capacitor C165 can cause the sweep to be nonlinear at the faster sweep rates.

Insufficient Horizontal Deflection

If the horizontal trace starts at the left side of the graticule, but does not extend to the right side, the Hold-Off circuit is causing V135A to conduct too soon after the triggering pulse had forced it into cutoff. If the trace cannot be expanded the full length of the graticule with the SWP. LENGTH control R176, check the resistance values in the cathode circuit of V173.

TROUBLESHOOTING THE CALIBRATOR

Asymmetrical Output

If the output square wave is not symmetrical (the positive portion has a duration different from that of the negative portion) the two tubes in the Multivibrator circuit are not being held cutoff for equal periods. This will normally be caused by a defective tube. If tube replacement does not correct the waveform the circuit components must be checked. The triode in the Multivibrator is held cutoff for an interval determined by the discharge of C672, and the pentode is held cutoff for an interval determined by the discharge of C673. A change in the value of either capacitor, or in the value of the resistor through which they discharge, could produce an asymmetrical waveform.

In addition, the time needed for these capacitors to discharge a given amount is affected by the potential toward which they discharge; this would be the voltage at the plate of the triode in the case of C673, and the voltage at the screen of the pentode in the case of C672. Since these voltages are affected by the value of R670 and R675, these

resistors should be checked. The resistors in the plate circuit of the pentode should also be checked, since they will affect the plate-to-screen ratio of the pentode.

Incorrect Output Voltage

The amplitude of the output square wave is determined almost entirely by the resistance values in the divider in the cathode-follower stage. A quick check of the resistance values can be made by turning off the Calibrator and measuring the voltage at the CAL. TEST PT; if this point does not measure exactly +100 volts the output voltages, when the Calibrator is turned on, will not be correct.

The CAL. ADJ. control R679 will vary the voltage at the test point over about a 10-volt range. If this voltage cannot be set to exactly +100 volts, and if the tubes have been replaced, then one or more of the precision resistors in the divider have changed in value.



SECTION 6

RECALIBRATION PROCEDURE

EQUIPMENT REQUIRED

The following equipment is required for a full recalibration of the Type 543.

1. DC voltmeter (sensitivity at least 5000 Ω/v) calibrated for an accuracy of at least 1% at 100, 150, 225, 350 and 500 volts, and for an accuracy of 3% at 1350 volts. Be sure the meter is accurate; few portable meters have comparable accuracy, particularly after a period of use.
2. Accurate rms-reading ac voltmeter, 0-150 volts (0-250 or 0-300 volts for 234-volt operation).
3. Variable autotransformer (Powerstat, Variac, etc.) having a rating of at least 6.25 amperes.
4. Time-Mark Generator, Tektronix Type 180 or Type 180A or equivalent. Time-Mark Generator used must have markers at 1 μ sec, 10 msec, 100 msec, 1 sec and 5 sec, and since-wave output of 10 mc and 50 mc, with an accuracy of at least 1%.
5. Constant-Amplitude Signal Generator, Tektronix Type 190 or 190A. Signal Generator used must provide a 200-millivolt signal vari-

able in frequency from 500 kc to over 30 mc. The signal amplitude must remain constant (200 mv) over the entire frequency range.

6. Low-Capacitance Recalibration tools: Part numbers 003-000 and 003-007 (See page A-14, Accessories section).
7. Type K Plug-In Unit
If a Type K Unit is not available, another of the Tektronix preamplifier-type plug-in units may be used. Variations in the Recalibration Procedure, when a Type K unit is not used, are explained at the appropriate time.
8. Type P Plug-In Unit, or a Square-Wave Generator, Tektronix Type 107 or equivalent. The Tektronix Type P Unit is designed especially for adjusting the Delay Line and high frequency compensating circuits in the Type 543. If a Type P Unit is not available, a fast-rise Square-Wave Generator, having a rise time of no more than 3 millimicroseconds, may be used. A B52-R Terminating Resistor is required if the Type 107 or equivalent is used (see page A-2, Accessories section).

ADJUSTMENT PROCEDURE

Preliminary

Remove the side covers and the bottom plate from the Type 543 and install the Type K (or other type plug-in) unit. Set up the front-panel controls as follows:

Type 543

INTENSITY	full left (ccw)
TRIGGERING MODE	AUTOMATIC
TRIGGER SLOPE	+INT.

TIME/CM	.5 MILLI SEC
VARIABLE	CALIBRATED (full right)
HORIZONTAL	
DISPLAY	NORMAL
NORMAL SWEEP/ SINGLE SWEEP	NORMAL SWEEP
CALIBRATOR	OFF

Plug-In Unit

The following controls are those associated with the Type K Plug-In Unit; the nomenclature will differ slightly with other types.



AC/DC	DC
VOLTS/CM	.05
VARIABLE	CALIBRATED (full right)

Note: For those controls not listed, their adjustment is not pertinent to this part of the procedure and the controls may be left in any position. Adjustment of these controls will be made at the appropriate time in the following procedure.

Check the rear panel of the instrument to be sure the ground strap is connected between the GRD. and EXTERNAL CRT CATHODE binding

posts, and that the CRT CATHODE SELECTOR switch is turned away from the DUAL-TRACE CHOPPED BLANKING position. Connect the Type 543 to the autotransformer, and turn on all equipment. Set the output of the autotransformer to the design center voltage for which your instrument is wired (117 v or 234 v). Allow at least five minutes for warmup before making any adjustments.

If the instrument fails to calibrate in any of the following steps, refer to the Troubleshooting Procedure section of the manual for information concerning the circuit involved.

POWER SUPPLY, CALIBRATOR AND CRT CIRCUIT

(1) —150-Volt Adjust.

Connect voltmeter to —150-volt bus at the test point indicated on the upper chassis on the right side of the instrument. Adjust the —150 ADJ. control for a reading of exactly —150 volts. Use a voltmeter you know to be accurate. Check voltage on +100, +225, +350 and +500-volt buses; all should be within 3% of rated value. If any of the regulated buses that must measure within 3% of its rated value does not measure between these limits, readjust the —150 ADJ. control until the voltage measures within specifications. At the final setting of the —150 ADJ. control, the —150-volt bus must measure between —147 and —153 volts ($\pm 2\%$).

Check regulation of each bus by varying line voltage between 105 and 125 volts (or 210 and 250 volts); all regulated voltages should remain constant over this range.

(2) Calibrator

Connect voltmeter to CAL. TEST POINT (make sure calibrator is turned off). Adjust CAL. ADJ. control for reading of +100 volts. Turn Calibrator on (to any output voltage); voltage at test point should fall to $+50 \pm 5$ volts.

(3) —1350-Volt Adjust

Connect voltmeter to HV. ADJ. TEST POINT. Adjust HV ADJ. control for reading of exactly —1350 volts. (If your voltmeter has a 1200-volt scale, connect common lead of voltmeter to —150-

volt bus, and adjust HV ADJ. for dial reading of 1200 volts). This voltage should not vary more than 10 volts between the following limits:

Lower limit: Line voltage 105 volts (or 210 volts) INTENSITY control full right.

Upper limit: Line voltage 125 volts (or 250 volts) INTENSITY control full left.

(4) CRT Alignment

Turn up INTENSITY control until trace is visible (it may be necessary to adjust the Vertical Positioning control on the plug-in unit) and adjust FOCUS and ASTIGMATISM for sharpest trace (narrowest trace width). Position trace directly behind center graticule line. If the trace and graticule line do not coincide over the length of the graticule, loosen the crt base clamp and rotate the tube with the alignment ring. When the trace and the graticule line are in coincidence, push the tube forward so that it rests snugly against the graticule. Then tighten the crt base clamp. Recheck the alignment after tightening the clamp to be sure it didn't move while the clamp was being tightened.

(5) Graticule Alignment

Position the trace directly behind the center graticule line; then using a screwdriver with an insulated handle (or a shorting strap) short the vertical deflection plates together at the neck pins on the crt. These are the plates marked BLUE (UPPER) and BROWN (LOWER). Be careful not to short the pins to the crt shield. Observe the verti-



cal position of the trace on the crt when the vertical deflection plates are shorted together; this is the electrical center of the crt. If the electrical center of the crt does not coincide with the center line of the graticule, remove the short from the deflection plates and position the trace to the electrical center. Remove the graticule cover and loosen the set screw in the nylon cam in the lower left corner of the graticule. Check to be sure the trace is at the electrical center of the crt, and position the center line of the graticule to coincide with the trace. Tighten the set screw in the positioning cam and replace graticule cover.

(6) CRT Geometry

Connect a test lead from the CAL. OUT connector to the INPUT connector on the plug-in unit, and set the CALIBRATOR for an output of .5 volt. Position the display vertically so that only the rising and falling portions of the signal are visible on the crt (it may be necessary to reduce the ambient light to see the trace). Adjust the INTENSITY, FOCUS and ASTIGMATISM controls for best definition; then adjust the GEOM. ADJ. control for minimum curvature in the vertical traces.

TRIGGERING CIRCUITS

Reset front-panel controls as follows:

Type 543

STABILITY	full right (cw)
TRIGGERING LEVEL	0
TRIGGERING MODE	AC SLOW
TRIGGER SLOPE	+INT.
TIME/CM	.5 MILLI SEC
VARIABLE	CALIBRATED
HORIZONTAL DISPLAY	NORMAL
NORMAL SWEEP/SINGLE SWEEP	NORMAL SWEEP
CALIBRATOR	10 MILLI VOLTS
Plug-In Unit	
AC/DC	DC
VOLTS/CM	.05
VARIABLE	CALIBRATED

Connect a test lead from the CAL. OUT connector to the INPUT connector on the plug-in unit; this should result in a free-running trace having an amplitude of about 2 millimeters (1 minor division). Center the trace vertically on the screen and adjust the INTENSITY, FOCUS and ASTIGMATISM controls for best definition. Then ground the junction of R19, R20 and C20 with a short clip lead. This junction is located on top of the Trigger switch (see Fig. 6-1).

(7) Triggering Sensitivity and Level

Preset the TRIGGER SENSITIVITY control full left (ccw) and the TRIGGERING LEVEL CENTERING control full right (cw). Turn the STABILITY control left until the trace just disappears from

the crt screen, then two or three degrees further left.

Turn the TRIGGERING LEVEL CENTERING control to the left until the display reappears on the screen. If the display does not appear, turn the TRIGGER SENSITIVITY control to the right a few degrees, and repeat the adjustment of the TRIGGERING LEVEL CENTERING control until the display reappears. Reduce the amplitude of the signal by turning the VARIABLE gain control on the plug-in unit slowly toward the full left position, at the same time continuing the adjustment of the TRIGGERING LEVEL CENTERING and TRIGGER SENSITIVITY controls to keep the trace on the screen. Then switch the TRIGGER SLOPE control to —INT.; it may be necessary to turn the TRIGGERING LEVEL CENTERING control back to the right a bit to obtain a stable display. Switch the TRIGGER SLOPE control back and forth between —INT. and +INT., each time readjusting the TRIGGERING LEVEL CENTERING control to obtain a display. Then set the TRIGGERING LEVEL CENTERING control half way between the settings at which the waveform is stable in the +INT. and —INT. positions (the TRIGGER SLOPE switch may be left in either position) and adjust the TRIGGER SENSITIVITY control slowly to obtain a stable display. Then while switching back and forth between +INT. and —INT., slightly readjust both the TRIGGERING LEVEL CENTERING and TRIGGER SENSITIVITY controls for stable triggering in both positions.

(8) Internal Triggering DC Level

Return the VARIABLE gain control to the CALIBRATED position, center the display vertically, and turn the TRIGGERING MODE switch to the DC



position. Then, while switching the TRIGGER SLOPE control back and forth between +INT. and -INT., adjust the INT. TRIG. DC LEVEL ADJ. control for stable triggering in both positions. It may be necessary to slightly adjust the VERTICAL POSITION control to obtain stable triggering.

(9) Preset Stability and Automatic Triggering

Leave setup unchanged from previous step except for the following: Remove the jumper grounding the junction of R19, R20 and C20, remove the test lead connecting the CAL. OUT and vertical

INPUT connectors, and set the TRIGGERING MODE switch to the AUTOMATIC position. Set the PRESET STABILITY control (screwdriver adjustment, front panel) to its full left position and connect a voltmeter between the center arm of the PRESET STABILITY potentiometer and ground. Next, advance the PRESET STABILITY control to the right until a trace is just visible on the crt; note voltmeter reading for this setting of the control. Then, advance the PRESET STABILITY control further right until the trace brightens and note the voltmeter reading for this setting. Finally, back off the control until the voltmeter indicates a reading midway between the two previous readings.

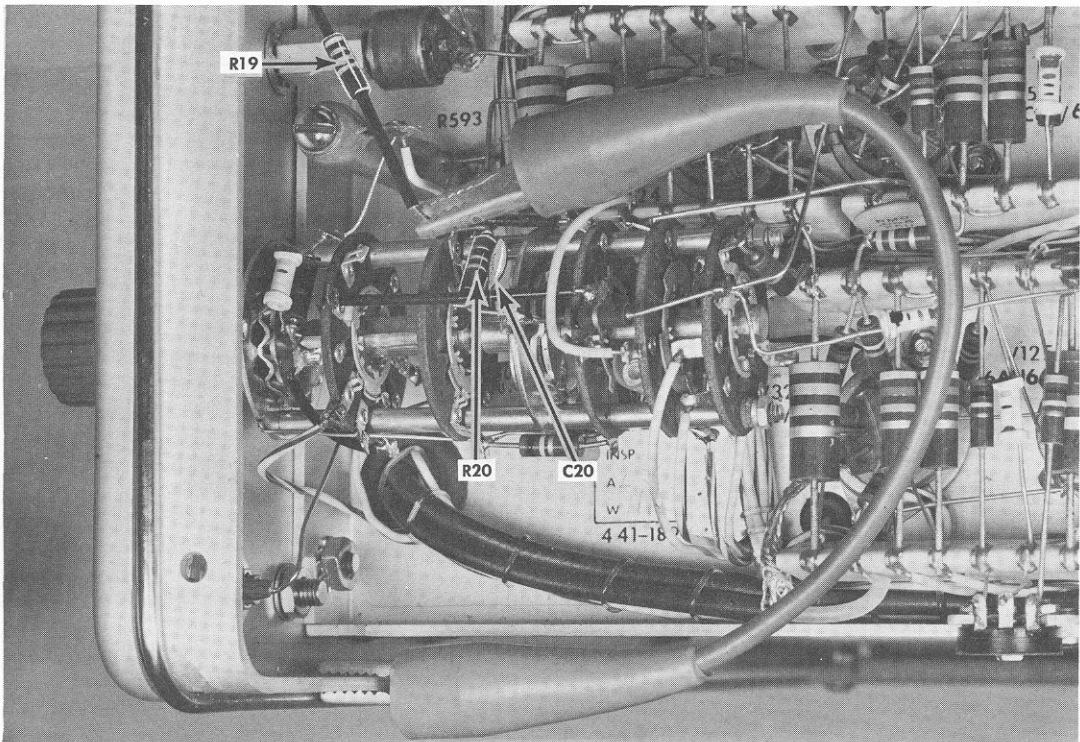


Fig. 6-1. Grounding the junction of R19, R20 and C20 to simplify the adjustment of the triggering controls.

TIME-BASE GENERATOR AND HORIZONTAL AMPLIFIER

Set up the Type 543 controls as follows:

STABILITY	PRESET
TRIGGERING LEVEL	full right
TRIGGERING MODE	AC SLOW
TRIGGERING SLOPE	+INT.
TIME/CM	1 MILLI SEC
*VARIABLE	CALIBRATED
HORIZONTAL DISPLAY	X10 SWEEP MAGNIFIED
NORMAL SWEEP/ SINGLE SWEEP	NORMAL SWEEP
CALIBRATOR	OFF

Set up the following oscilloscope and plug-in unit controls for best presentation: FOCUS, INTENSITY, ASTIGMATISM, SCALE ILLUM., HORIZONTAL POSITION, VERTICAL POSITION and VOLTS/CM.

*Make sure the VARIABLE TIME/CM control is locked in the CALIBRATED position for all timing adjustments.

(10) X10 Sweep Magnified Calibration

Apply 100-microsecond markers from the Time-Mark Generator to the INPUT connector of the plug-in unit, and adjust the TRIGGERING LEVEL control for a stable display. Adjust the X10 CAL. control R342 for one marker per centimeter (use the HORIZONTAL POSITION control to align the markers with the graticule lines). The circuit must calibrate between the 1- and 9-centimeter graticule lines in steps (10), (11) and (12).

(11) Normal (X1) Calibration

Turn the HORIZONTAL DISPLAY switch to the NORMAL position, remove the 100-microsecond markers and apply 1000-microsecond (1 millisecond) markers to the INPUT connector of the plug-in unit. Adjust the X1 CAL. control R368 for one marker per centimeter.

(12) X100 Sweep Magnified Calibration

Turn the Horizontal Display to the X100 SWEEP MAGNIFIED position, remove the 1-millisecond markers and apply 10-microsecond markers to the INPUT connector. Adjust the X100 CAL. control R356 for one marker per centimeter.

Repeat steps (10), (11) and (12) as there is interaction between these three controls.

(13) Horizontal DC Shift Compensation

Remove any signal from the INPUT connector of the plug-in unit, leave the TIME/CM control at 1 MILLI SEC and set the HORIZONTAL DISPLAY switch to the X100 SWEEP MAGNIFIED position. Turn the STABILITY control away from the PRESET position toward the right until the sweep free-runs, and adjust the HORIZONTAL POSITION control so that the start of the trace coincides with one of the vertical graticule lines. Slowly turn the trace off and on with the STABILITY control and observe the start of the trace for drift. Adjust the DC SHIFT control R365 for minimum drift in the start of the trace.

(14) Sweep Length

Set the HORIZONTAL DISPLAY switch to the NORMAL position and free-run the sweep by turning the STABILITY control to the right. Position the trace to the left side of the graticule and adjust the SWP. LENGTH control R176 for a sweep length of 10.5 centimeters.

(15) Sweep/Magnifier Registration

Apply 1-millisecond markers to the INPUT connector of the plug-in unit, turn the sweep off with the STABILITY control, and turn up the intensity so that a vertical trace is visible at the left side of the graticule; then use the HORIZONTAL POSITION control to position the trace to the horizontal center of the graticule. Set the HORIZONTAL DISPLAY switch to the X100 SWEEP MAGNIFIED position and reposition the trace to the exact horizontal center of the graticule. (The HORIZONTAL POSITION controls will appear extremely sensitive to touch in the X100 position). Then turn the HORIZONTAL DISPLAY switch back



to the NORMAL position and adjust the SWP/MAG. REGIS. control R359 so that the trace falls exactly under the center graticule line. Repeat this adjustment as necessary to obtain exact coincidence of the trace for both positions of the HORIZONTAL DISPLAY switch.

Set the HORIZONTAL DISPLAY switch to NORMAL, the STABILITY control to PRESET and the INTENSITY control for normal brilliancy. Then obtain a stable display with the TRIGGERING LEVEL control and position the start of the display to the left side of the graticule. Observe the marker that appears in the center of the graticule and position the display, if necessary, so that the center marker is aligned with the center graticule line. Then turn the HORIZONTAL DISPLAY switch to the X100 position and position the marker so that the leading edge is exactly aligned with the center graticule line. Turn the HORIZONTAL DISPLAY switch through all SWEEP MAGNIFIED positions back to NORMAL and observe the leading edge of the marker; it should remain stationary, aligned with the center line of the graticule.

(16) Check Sweep Timing: 5 Seconds/cm to .1 Millisecond/cm

Table 6-1, below, lists the time markers to be applied for the indicated setting of the TIME/CM switch and the number of markers per centimeter to be observed for each setting. There are no adjustments to be made in this step; this is a check on the accuracy of the components that make up R160 and C160 in the indicated range of sweep rates.

TABLE 6-1

TIME/CM	TIME MARKERS	OBSERVE
.1 MILLI SEC	100 μ sec	1 marker/cm
1 MILLI SEC	1 msec	1 marker/cm
2 MILLI SEC	1 msec	2 marker/cm
5 MILLI SEC	5 msec	1 marker/cm
10 MILLI SEC	10 msec	1 marker/cm
.1 SEC	100 msec	1 marker/cm
1 SEC	1 sec	1 marker/cm
2 SEC	1 sec	2 marker/cm
5 SEC	5 sec	1 marker/cm

(17) Check and Adjust Sweep Timing: 50 Microseconds/cm to .1 Microsecond/cm.

Reset the following controls to the indicated position:

TRIGGERING MODE AC FAST
TRIGGER SLOPE +EXT.

Connect a lead (preferably coaxial cable) from the trigger-output connector of the Time-Mark Generator to the TRIGGER INPUT connector of the Type 543. Check to see that the VARIABLE TIME/CM control is locked in the CALIBRATED position. Adjust the TRIGGERING LEVEL control as required in the following steps to obtain a stable display.

Table 6-2, page 6-7, lists the time markers or sine-wave frequencies to be applied for the indicated setting of the TIME/CM switch, and the number of markers or cycles to be observed. All SWEEP MAGNIFIED linearity checks should be made at 10% from start of sweep, the center of the sweep and 10% from end of sweep (the 1-, 5- and 9-centimeter points).

Recheck timing from 50 μ SEC/CM to .1 μ SEC/CM.

(18) Sweep Lockout Level

Reset the following controls to the indicated position:

STABILITY full left, but not to PRESET
TRIGGERING LEVEL 0
TRIGGERING MODE AC SLOW
TRIGGER SLOPE +INT.
TIME/CM .5 MILLI SEC
HORIZONTAL DISPLAY NORMAL (X1)
CALIBRATOR .5 VOLTS
VOLTS/CM .5
(plug-in unit)

Connect a voltmeter to the cathode, pin 7, of V125 and advance the STABILITY control to a point just before the sweep free runs; observe the voltmeter reading at this setting. Set the NORMAL SWEEP/SINGLE SWEEP switch to the SINGLE SWEEP position and trigger the sweep by turning the STABILITY control full right; the READY light should extinguish indicating the sweep is now locked out. Then adjust the LOCKOUT LEVEL ADJ. control R125 for a voltmeter reading 11 volts below (less negative) the previous reading.

Return the switch to the NORMAL SWEEP position, connect a test lead between the CAL. OUT connector and the vertical INPUT connector, and adjust the STABILITY and TRIGGERING LEVEL controls for a stable, triggered display. Remove



TABLE 6-2

TIME/CM	SWEEP MAGNIFIED	TIME MARKERS OR SINE WAVE FREQ.	CHECK OR ADJUSTMENT
50 μ SEC and .1 MILLI SEC	X1	50 μ sec	C337 for same starting position while switching TIME/CM control between settings.
.1 μ SEC	X1	10 mc	C160A for timing, C361A for linearity; 1 cycle/cm
10 μ SEC	X1	10 μ sec	C160E for 1 marker/cm
1 μ SEC	X1	1 μ sec	C160C for 1 marker/cm
2 μ SEC	X1	1 μ sec	Resistor check; 2 markers/cm
5 μ SEC	X1	1 μ sec	Resistor Check; 5 markers/cm
2 μ SEC	X100	50 mc	C387 and C388, *C378 and C382, and **C394 for linearity and timing; 1 cycle/cm.
1 μ SEC	X50	50 mc	Check timing and linearity for 1 cycle/cm.
.5 μ SEC	X20	50 mc	Check timing and linearity for 5 cycles over 4 cm.
.2 μ SEC	X10	50 mc	†C361G for 1 cycle/cm.
.1 μ SEC	X5	50 mc	C361E for 1 cycle/cm.
.1 μ SEC	X2	50 mc	C361C for 5 cycles over 2 cm.

*C378 and C382 will normally be adjusted for maximum capacitance.

**On some instruments C394 is a fixed capacitor.

† On some instruments C361G is a fixed capacitor.

the lead from the INPUT connector, depress the switch to RESET and let it return to SINGLE SWEEP; the READY light should ignite indicating the sweep circuit is armed. Touch the test lead from the CAL. OUT connector to the INPUT connector to produce one sweep; the ready light should extinguish upon completion of the sweep. Then turn the STABILITY control left (ccw) but not to PRESET; the READY light should ignite but the sweep should not retrigger. Return switch to NORMAL SWEEP.

(19) External Horizontal Preampfier Balance

Obtain a free-running trace by turning the STABILITY control full right, and connect a test lead between the vertical INPUT connector and

the SAWTOOTH OUT connector (be extremely careful not to ground the SAWTOOTH OUT signal). Turn the HORIZONTAL DISPLAY switch to the EXT. position, and center the vertical trace on the crt with the HORIZONTAL POSITION controls. Adjust the EXT. HORIZ. AMP. DC BAL. control R334 for no horizontal shift in trace position as the EXTERNAL HORIZONTAL VARIABLE control is rotated through its range.

(20) External Horizontal Preampfier Gain

Set controls as follows:

STABILITY	full right
HORIZONTAL DISPLAY	EXT.



EXTERNAL HORIZONTAL VOLTS/CM	.1
VARIABLE CALIBRATOR	CALIBRATED (full right) .5 VOLTS

Apply signal from CAL. OUT connector to EXTERNAL HORIZ. IN connector, and adjust the EXT. HORIZ. AMP. CAL control R361M (located on top of HORIZONTAL DISPLAY switch) for 5 centimeters of horizontal deflection. Check the 1 and 10 VOLTS/CM positions with 5 volts and 50 volts, respectively, of calibrator signal (deflection should be 5 centimeters for all three positions of switch).

(21) External Horizontal Attenuator Compensation

Set up controls as follows:

Type 543

STABILITY	PRESET
TRIGGERING MODE	AC SLOW
TRIGGER SLOPE	+EXT.

TIME/CM	.5 MILLI SEC
HORIZONTAL DISPLAY	EXT.
EXTERNAL HORIZONTAL VOLTS/CM	1
VARIABLE CALIBRATOR	CALIBRATED 5 VOLTS

Plug-In Unit

VOLTS/CM	20
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Apply the signal from the CAL. OUT connector to both the EXTERNAL HORIZ. IN connector and the TRIGGER INPUT connector; apply the signal from the SAWTOOTH OUT connector to the vertical INPUT connector (do not ground the signal from the SAWTOOTH OUT connector). Adjust the TRIGGERING LEVEL control to obtain a stable display of the signal (this will be a vertical display of the calibrator waveform). Adjust C310 for optimum square wave presentation. Turn EXTERNAL HORIZONTAL VOLTS/CM control to 10 and CALIBRATOR to 50 VOLTS, and adjust C313 for optimum square wave presentation.

VERTICAL AMPLIFIER

Set up front-panel controls as follows:

Type 543

TRIGGERING MODE	AUTOMATIC
TRIGGER SLOPE	+INT.
TIME/CM	.5 MILLI SEC
HORIZONTAL DISPLAY	NORMAL (X1)
CALIBRATOR	100 MILLIVOLTS

Plug-in Unit

AC/DC	DC
VOLTS/CM	.05
VARIABLE	CALIBRATED (full right)

Before proceeding with the calibration of the Vertical Amplifier the dc balance of the plug-in unit should be checked. Rotate the VARIABLE

control; if any vertical displacement of the trace is apparent adjust the DC BAL control (accessible through the front panel) until the trace remains stationary as the VARIABLE control is rotated. (On some plug-in units this control is called VARIABLE ATTEN BAL.). Be sure to return the VARIABLE control to the CALIBRATED position after completing the adjustment. IMPORTANT NOTE: Be sure the plug-in unit used for the following adjustment has been correctly calibrated for gain.

(22) Vertical Amplifier Gain

Apply 100 millivolts of signal from the Calibrator to the Vertical INPUT connector. Adjust the GAIN ADJ. control R1027 for exactly 2 centimeters of vertical deflection. NOTE: This is the GAIN ADJ. control for the main Vertical Amplifier, not the one for the plug-in unit. The GAIN ADJ. control R1027 is accessible from the under side of the instrument.



(23) DC Shift Compensation

Remove the Calibrator signal from the Vertical INPUT connector, set the VOLTS/CM control to .5 and position the trace near the bottom line of the graticule. Connect an ohmmeter, set to the R x 1 scale, between the vertical INPUT connector and the chassis. The voltage at the INPUT connector is zero so there is no danger of damaging the meter. If the polarity of the ohmmeter leads is correct, and if a 1½-volt cell is used on the R x 1 scale, the trace should jump toward the upper line of the graticule. If the trace is deflected off the screen it may be necessary to reverse the ohmmeter leads, increase the setting of the

VOLTS/CM control, or both. When the proper polarity for the ohmmeter leads has been established, find a setting for the VOLTS/CM control (if other than .5) where the trace is visible on the crt with the ohmmeter both connected and disconnected.

Alternately connect the lead to the INPUT connector and disconnect it, observing the trace as it comes to rest. If there is any vertical drift to the trace, as it comes to rest in either position, adjust the DC SHIFT control R1091 until the trace remains stationary. This is a very slow drift and must be observed for a few seconds to determine the amount and direction.

DELAY LINE AND HIGH-FREQUENCY COMPENSATION

This section describes two methods for adjusting the Delay Line and high-frequency compensation of the Type 543 Oscilloscope. The first and preferable method requires a Tektronix Type P Plug-In Test Unit, which generates a fast-rise step function of known characteristics. This signal simulates the output of an ideally compensated Type K Pre-amplifier Plug-In Unit driven by a Tektronix Type 107 Square-Wave Generator. The Type P Unit permits the standardization of the main Vertical Amplifier and Delay Line transient response of Type 543 (and other Tektronix convertible-type) oscilloscopes. After standardization, the Type 543 (or other convertible-type oscilloscope) may be used in conjunction with a Type 107 Square-Wave Generator to standardize the transient response of preamplifier-type plug-in units. Standardized oscilloscopes and plug-in units may then be used interchangeably without readjustment of the high-frequency compensating circuits.

The other method requires a properly adjusted Type K (or other fast-rise, wide-band preamplifier) Plug-In Unit and a Tektronix Type 107 (or equivalent) fast-rise Square-Wave Generator. Unlike the first method, this method is used to compensate the main Vertical Amplifier and Delay Line to match the plug-in unit being used. Depending on the adjustment of the plug-in unit employed, the oscilloscope may or may not be suited for use with other plug-in units, in high frequency applications, if this method is used. This method is entirely satisfactory, however, if the same plug-in unit (the one employed during the adjustment procedure) is used with the oscilloscope.

(24) Method using Type P Plug-In Unit

Install the Type P Unit in the Type 543 and position the oscilloscope physically so that either of the UP arrows on the P Unit points upward. Set the front-panel controls as follows:

Type 543

STABILITY	full right
TRIGGERING LEVEL	full right
TRIGGERING MODE	AC FAST
TRIGGER SLOPE	+INT.
TIME/CM	.2 μSEC
VARIABLE	CALIBRATED
HORIZONTAL DISPLAY	NORMAL (X1)
NORMAL SWEEP/ SINGLE SWEEP	NORMAL SWEEP

Type P Unit

COIL CURRENT	ON
AMPLITUDE	White dot at 3 o'clock

Adjust the COIL CURRENT ADJUST control for the loudest steady hum, and adjust the INTENSITY and VERTICAL POSITION controls so that the two free-running traces are visible on the crt. Then turn the STABILITY control to the PRESET position and advance the INTENSITY control until two spots are just barely visible at the left side of the



graticule (it may be necessary to adjust the HORIZONTAL POSITION controls to properly position the spots). Turn the TRIGGERING LEVEL control slowly toward the O position until a waveform similar to Fig. 6-2 is obtained. Readjust the AMPLITUDE control for a deflection of about 3 centimeters, adjust the INTENSITY, FOCUS and ASTIGMATISM controls for sharpest detail, and position the waveform as shown in Fig. 6-2.

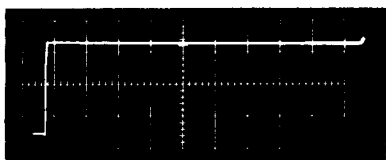


Fig. 6-2. The Type P Unit waveform displayed on a properly adjusted Type 543; sweep rate: 2 $\mu\text{sec}/\text{cm}$.

The unretouched photograph of Fig 6-2 shows the P-Unit waveform on a properly adjusted Type 543 oscilloscope, at a sweep rate of .2 $\mu\text{sec}/\text{cm}$. The flat, level top indicates proper adjustment of the Delay Line and the Termination Network, and the fast rise and square corner indicate proper

adjustment of the peaking circuits in the amplifier ahead of the line.

If the P-Unit waveform, when displayed on the Type 543, does not appear as shown in Fig. 6-2, the Delay Line and/or peaking circuits are in need of adjustment.* The following important facts should be remembered when adjusting the circuit:

1. The Delay Line is reverse-terminated. The Delay-Line capacitors nearest the crt will affect the start of the pulse, i.e., the leading corner. The Delay-Line capacitors nearest the Vertical Amplifier will affect the pulse in the region of the termination bump.
2. The delay time of the line is 0.2 $\mu\text{seconds}$; but since the line is reverse-terminated, the termination bump will appear 0.4 $\mu\text{seconds}$ after the corner.
3. The termination bump is affected by the adjustment of the Termination Network, however the Termination Network also affects the corner of the pulse.
4. The peaking adjustments ahead of the Distributed Amplifier and those at the crt deflection plates affect the leading corner of the waveform.

*See also "Waveform Distortion", page 5-7, in the Maintenance section of this manual.

Adjustment Procedure

Minor Adjustment Required

A minor adjustment of the Delay Line and/or peaking circuits will be required when only the leading corner is rounded off or has a slight overshoot (similar to the waveforms shown in Fig. 5-2, page 5-8), when aberration appear both at the leading corner and in the vicinity of the termination bump (see Fig. 5-3), or when there are slight aberrations in the top of the pulse (similar to those shown in Fig. 5-4). By analyzing the type of distortion according to the information presented in the preceding paragraph and that presented in the Troubleshooting Procedure (under Waveform Distortion), it is generally an easy matter to locate the components that have been misadjusted and correct their adjustment.

Major Adjustment Required

A major adjustment of the Delay Line and peaking circuits may be required:

1. If the Delay Line and/ or Distributed Amplifier have been replaced;
2. If the instrument has been subjected to severe vibration;
3. If the adjustments have been tampered with.

There are four steps involved in making a major adjustment to the Delay Line and the Vertical Amplifier:

1. Presetting the adjustments;
2. Establishing a level display;
3. Removing the "wrinkles" in the top of the pulse;
4. Compensating the amplifier.

Presetting the Adjustments

If the displayed pulse on the crt indicates that the Delay Line and peaking circuits are considerably out of adjustment, presetting the controls before starting the adjustment procedure will generally render the best results.

The variable inductors in the Vertical Amplifier (L1014, L1024, L1036 and L1046) should be preset so that the slugs are positioned deeper into the coil forms than the windings of the coils extend. The two variable inductors at the crt end of the line (L1354 and L1355) should be preset so that the slugs are just out of the winding. When the slugs are positioned in this manner light can be observed between the slugs and the windings. By presetting the inductors in this manner their effect in the circuit is reduced and the adjustment of the Delay Line is simplified.

The variable capacitors in the delay line should be preset so that the top of the adjusting screw extends about one-quarter of an inch above the top of the contact springs, or if preferred about three-eighths of an inch above the body of the capacitor. The important characteristic is that the tops of all the adjusting screws should be at about the same height, both after the preset procedure and after the final adjustment.

The inductors and the capacitors in the termination network are the first to be adjusted in the adjustment procedure; for this reason it is unnecessary to preset these adjustments. However, it is important to check the inductors for balance; the slugs in each inductor should be set to the same depth within the coil form.

Establishing a Level Display

The reference level for the displayed waveform is established by that portion of the pulse following the termination bump. The first step, therefore, is the adjustment of the termination network. Observe the pulse closely about two centimeters to the right of the leading corner, and adjust the three capacitors and two inductors for the minimum termination bump. Be sure to check the inductors for balance as described in the preceding paragraph.

The level of that portion of the pulse preceding the termination bump is determined by the collective effect of all the Delay-Line capacitors. The top of the pulse should be level (not necessarily wrinkle-free at this time); that is, there should be neither an upward nor a downward slant to the top of the pulse between the termination bump and the corner. The level can best be checked by reducing the sweep rate to about $20 \mu\text{SEC}/\text{CM}$; this reduces the width of the top of the pulse and "crowds" the wrinkles into a smoother display. The reduction in pulse width makes any departure from a level display more easily observed.

To improve the level of the display, start at the terminated end of the line (that is, start with the Distributed Amplifier) and adjust each capacitor a small amount, carefully observing the top of the waveform for the result. Be sure to retain a level top when progressing toward the crt end of the line.

After making the preceding adjustments and establishing an average level for the display, advance the sweep rate to $2 \mu\text{SEC}/\text{CM}$ and repeat the procedure. This time, try to adjust the capacitors for a smooth transition from bump to bump, at the same time maintaining the level. Do not try to obtain a wrinkle-free display at this time; just try to reduce the amplitude of all the bumps the same amount. The important consideration is to retain the level of the display.

Removing the Bumps and Wrinkles

After making the preceding adjustments and reducing the amplitude of the bumps a bit, you can start removing the wrinkles and bumps to a greater degree. Again start at the Distributed Amplifier and work into and through the line to the crt.

Advance the sweep rate to $.5 \mu\text{SEC}/\text{CM}$ and adjust the termination network again to reduce the wrinkles in the vicinity of the termination bump. Do not try to achieve a perfectly straight line across the top of the display at this time; just reduce the amplitude of the bumps by about one-half. Then advance to the capacitors in the Distributed Amplifier and adjust them for a reasonably smooth line over that portion of the display they affect. Keep in mind that each capacitor will require only a slight adjustment, and that it is the combined effect of a group of capacitors with which you must be concerned. Then advance to the first group of capacitors in the Delay Line (about four or five) and adjust them in the same manner. As you advance along the line, from one group of capacitors to the next, reduce the sweep rate from time to time to check the level. It is just as important to maintain the level of the display as it is to obtain a wrinkle-free display.

After traversing the entire length of the line, advance the sweep rate to $.2 \mu\text{SEC}/\text{CM}$ and repeat the process. Be extremely careful in your adjustments at this time. Any capacitors that require adjustment will need only a slight touch...any overadjustment might nullify all of your efforts up to this point. From time to time switch back to a sweep rate of $20 \mu\text{SEC}/\text{CM}$ to check the level.



Final Compensation

Upon completing this portion of the adjustment, the display should appear similar to Fig. 6-3. That is, the display should be level and free from aberrations, with a pronounced rolloff at the leading corner. Then adjust the inductors in the Vertical Amplifier and those at the crt and of the line, being careful to adjust any two that make up one pair the same amount. Continue adjusting each pair of inductors, maintaining balance, until the corner begins to square up. This process will introduce some new wrinkles in the display, but these can easily be removed by adjusting the first few capacitors in the Delay Line at the crt end of the line. When the Delay Line and Vertical Amplifier are in proper adjustment, the display should appear similar to Fig. 6-2.

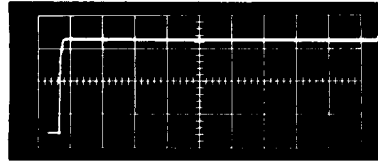


Fig. 6-3. The level, wrinkle-free display indicates proper adjustment of the Delay Line; the rounded corner is due to the fact that the variable inductors in the Vertical Amplifier and at the crt end of the line have not as yet been adjusted from their preset position.

METHOD USING THE TYPE 107 SQUARE-WAVE GENERATOR AND TYPE K PLUG-IN UNIT

Install the Type K Unit (or other type preamplifier) in the Type 543. Connect a B52 R Terminating Resistor to the INPUT connector of the plug-in unit, and connect a 52-ohm coaxial between the Terminating Resistor and the OUTPUT connector of the Type 107. Set the front-panel controls as follows:

Type 543

STABILITY	full right
TRIGGERING LEVEL	full right
TRIGGER SLOPE	—INT.
TRIGGERING MODE	AC FAST
TIME/CM	.2 μ SEC
VARIABLE	CALIBRATED
HORIZONTAL DISPLAY	NORMAL (X1)
NORMAL SWEEP/ SINGLE SWEEP	NORMAL SWEEP

Type K Unit*

AC/DC	DC
VOLTS/CM	.05
VARIABLE	CALIBRATED

*Set the VOLTS/CM control to the most sensitive DC range for the plug-in unit being used. It is very important to bypass the effect of the attenuators in all plug-in units, and the effect of any ac-coupled preamplifier that some plug-in units employ. Again, make sure that the VOLTS/CM control is set to the most sensitive DC range, and that the VARIABLE control is in the CALIBRATED position.

Type 107

APPROXIMATE FREQUENCY	White dot at 9 o'clock
APPROXIMATE AMPLITUDE	Adjust for 3 centimeters deflection



Adjust the INTENSITY and VERTICAL POSITION controls so that two free-running traces are visible on the crt. Then turn the STABILITY control to PRESET and adjust the TRIGGERING LEVEL control to obtain a stable display. Adjust the HORIZONTAL POSITION control so that the entire positive half-cycle is visible on the crt, and adjust the FOCUS and ASTIGMATISM controls for the sharpest display. The display should then appear similar to Fig. 6-4. From this point the adjustment procedure is identical to that presented for using the Type P Unit.

(25) Check Bandwidth of Vertical Deflection System

Install a properly calibrated Type K Unit in the Type 543 and connect the output cable from the Constant-Amplitude Signal Generator to the INPUT connector of the Type K unit. Set up the front-panel controls as follows:

STABILITY	full right
TRIGGERING LEVEL	any position
TRIGGER SLOPE	INT. (+ or -)
TRIGGERING MODE	AC FAST, AC SLOW or DC
TIME/CM	1 MILLI SEC
VARIABLE	CALIBRATED
HORIZONTAL DISPLAY	NORMAL
NORMAL SWEEP/ SINGLE SWEEP	NORMAL SWEEP

Type K Unit

AC/DC	DC
VOLTS/CM	.05
VARIABLE	CALIBRATED

Set the frequency controls on the Signal Generator for an output frequency of 500 kc, and adjust the amplitude controls for a vertical deflection of exactly 4 centimeters. Position the display on the crt (with the VERTICAL POSITION control) so that the deflection extends exactly from the top graticule mark to the bottom graticule mark.

Then increase the output frequency of the signal Generator to 30 Megacycles (make sure the VOLTS/CM and VARIABLE controls are set to .05 and CALIBRATED, respectively); the deflection should be at least 2.8 centimeters at 30 mc. If not, the Vertical Amplifier and the Delay Line (and possibly the Type K Unit) are in need of further adjustment. For plug-in units other than the K unit the bandpass will be different; see Table 1-1 in the Specifications section of this manual for the bandpass characteristics of other plug-in units in conjunction with the Type 543.

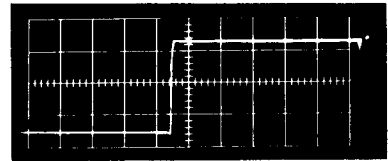
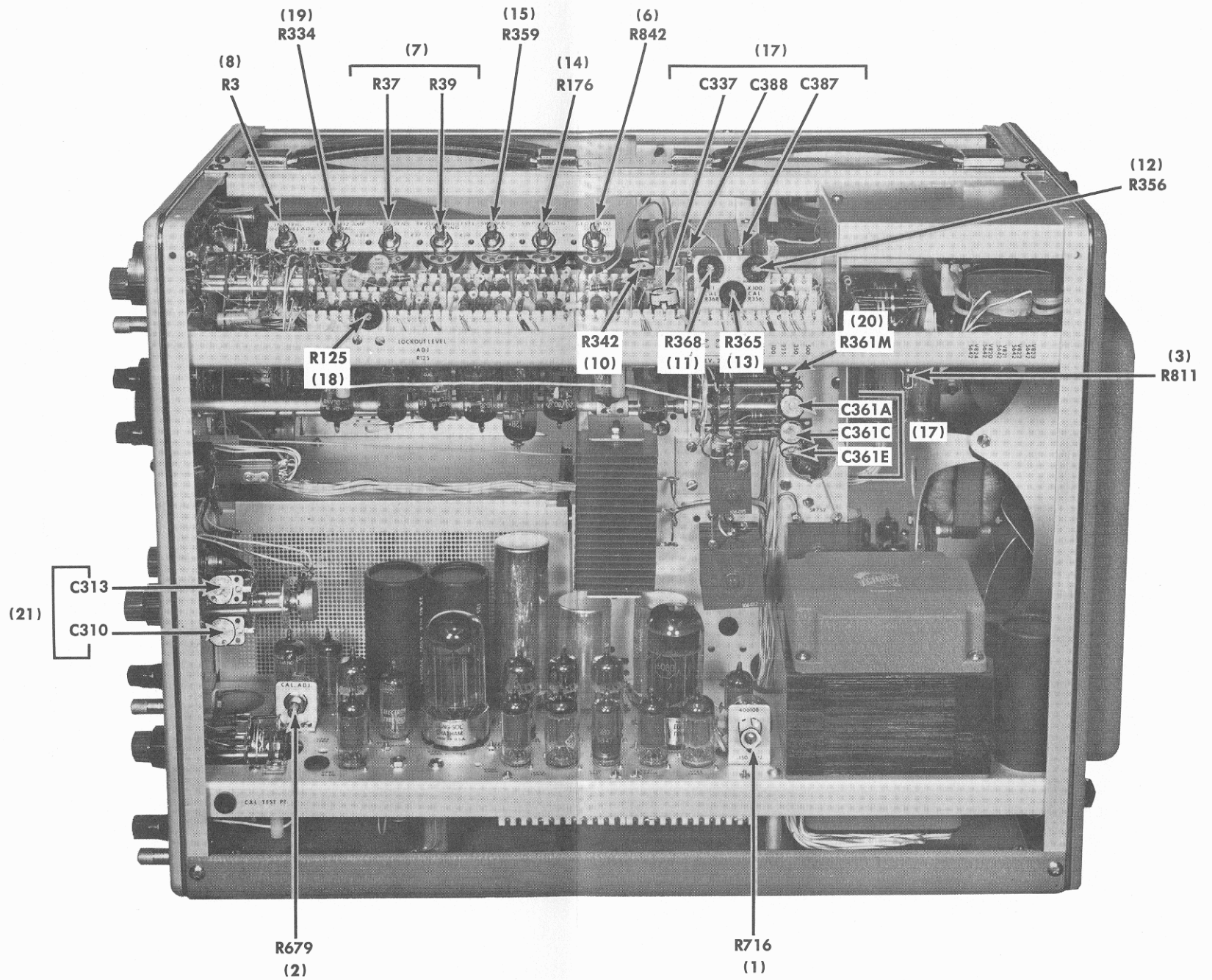
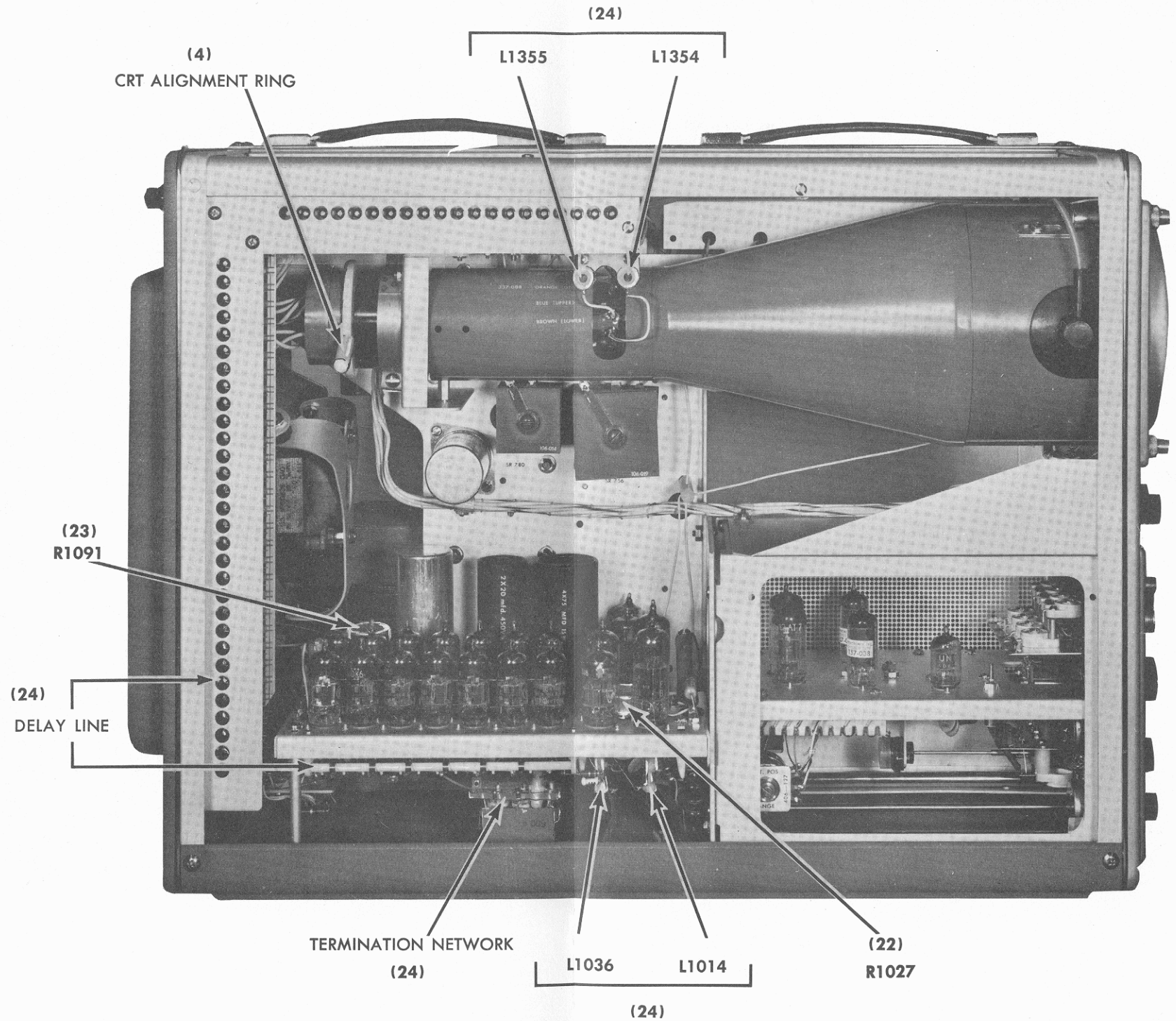


Fig. 6-4. The Type 107 waveform displayed on a properly adjusted Type 543/K-Unit combination; sweep rate: .2 μ sec/cm.



RIGHT SIDE VIEW

(The numbers in parenthesis refer to steps in the Recalibration Procedure)



LEFT SIDE VIEW

(The numbers in parenthesis refer to steps in the Recalibration Procedure)

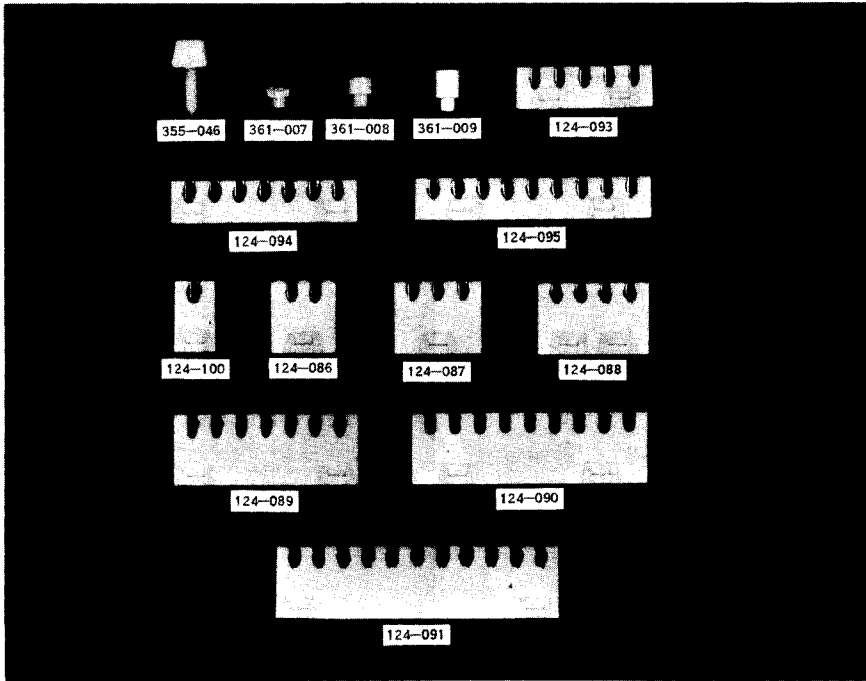
MODIFICATION NOTICE

CLIP-MOUNTED CERAMIC STRIPS

YOUR INSTRUMENT MAY BE EQUIPPED WITH CLIP-MOUNTED CERAMIC STRIPS. IF YOU FIND IT NECESSARY TO ORDER THESE STRIPS FOR REPLACEMENT, BE SURE TO CONSULT THIS SHEET. INCLUDE A DESCRIPTION OF THE PART, PART NUMBER, INSTRUMENT TYPE AND SERIAL NUMBER.

CERAMIC STRIP PARTS LIST

	PART NUMBER
STUD, CLIP, MOLDED NYLON	355-046
SPACER, MOLDED NYLON, 5/32" HEIGHT	361-007
SPACER, MOLDED NYLON, 1/4" HEIGHT	361-008
SPACER, MOLDED NYLON, 3/8" HEIGHT	361-009
CERAMIC STRIP, 7/16" BY 3 NOTCHES	124-092
CERAMIC STRIP, 7/16" BY 5 NOTCHES	124-093
CERAMIC STRIP, 7/16" BY 7 NOTCHES	124-094
CERAMIC STRIP, 7/16" BY 9 NOTCHES	124-095
CERAMIC STRIP, 7/16" BY 11 NOTCHES	124-106
CERAMIC STRIP, 3/4" BY 1 NOTCH	124-100
CERAMIC STRIP, 3/4" BY 2 NOTCHES	124-086
CERAMIC STRIP, 3/4" BY 3 NOTCHES	124-087
CERAMIC STRIP, 3/4" BY 4 NOTCHES	124-088
CERAMIC STRIP, 3/4" BY 7 NOTCHES	124-089
CERAMIC STRIP, 3/4" BY 9 NOTCHES	124-090
CERAMIC STRIP, 3/4" BY 11 NOTCHES	124-091



CERAMIC STRIPS AND MOUNTINGS USED IN
TEKTRONIX EQUIPMENT.

PARTS LIST

For an explanation of the abbreviations used in this parts list, see the indexed sheet marked ABBREVIATIONS & WARRANTY. It is recommended that those components marked with an asterisk in front of the Part Number be purchased from the factory or from a Tektronix Field Engineering Office.

Lamps

		Tektronix Part Number
B129	Neon, Type NE-2	150-002
B163	Neon, Type NE-2	150-002
B167	Neon, Type NE-2	150-002
B170	Neon, Type NE-2	150-002
B361Y	Neon, Type NE-2	150-002
B361Z	Neon, Type NE-2	150-002
B380	Neon, Type NE-2	150-002
B390	Neon, Type NE-2	150-002
B700	Pilot light, Type 47	150-001
B701	Graticule, Type 47	150-001
B702	Lights, Type 47	150-001
B1083	Neon, Type NE-2	150-002
B1087	Neon, Type NE-2	150-002

Capacitors

C1	4.7 $\mu\mu f$	Cer.	Fixed	500 v	$\pm 1 \mu\mu f$	281-501
C10	.0047 μf	PTM	Fixed	400 v		285-506
C11	100 $\mu\mu f$	Cer.	Fixed	350 v		281-523
C15	.001 μf	Cer.	Fixed	500 v		283-000
C20	.001 μf	Cer.	Fixed	500 v		283-000
C27	47 $\mu\mu f$	Cer.	Fixed	500 v	$\pm 9.4 \mu\mu f$	281-518
C32	.01 μf	PTM	Fixed	400 v		285-510
C37	.005 μf	Cer.	Fixed	500 v		283-001
C42	22 $\mu\mu f$	Cer.	Fixed	500 v		281-510
C116	.001 μf	Cer.	Fixed	500 v		283-000
C117	.005 μf	Cer.	Fixed	500 v		283-001
C121	270 $\mu\mu f$	Cer.	Fixed	500 v	$\pm 10\%$	281-543
C124	8 $\mu\mu f$	Cer.	Fixed	500 v	$\pm 0.5 \mu\mu f$	281-503
C129	.005 μf	Cer.	Fixed	500 v		283-001
C131	27 $\mu\mu f$	Cer.	Fixed	500 v	$\pm 5.4 \mu\mu f$	281-513
C138	.005 μf	Cer.	Fixed	500 v		283-001
C141	12 $\mu\mu f$	Cer.	Fixed	500 v	$\pm 1.2 \mu\mu f$	281-506
C149	.005 μf	Cer.	Fixed	500 v		283-001
C150	82 $\mu\mu f$	Cer.	Fixed	500 v	$\pm 8.2 \mu\mu f$	281-528
C158	27 $\mu\mu f$	Cer.	Fixed	500 v	$\pm 5.4 \mu\mu f$	281-513



Capacitors (continued)

Tektronix
Part Number

C160A	3-12 $\mu\mu\text{f}$	Cer.	Var.				281-007
C160B	82 $\mu\mu\text{f}$	Mica		500 v		5%	283-534
C160C	4.5-25 $\mu\mu\text{f}$	Cer.	Var.				281-010
C160D	82 $\mu\mu\text{f}$	Mica		500 v		5%	283-534
C160E	4.5-25 $\mu\mu\text{f}$	Cer.	Var.				281-010
C160F**	.001 μf	} Special Timing Series Manufactured by Tektronix. Order replacements from the factory.					291-007
C160G	.01 μf						
C160H	.1 μf						
C160J	1 μf						
C165	82 $\mu\mu\text{f}$		Cer.	Fixed	500 v		
C167	.001 μf	Cer.	Fixed	500 v			283-000
C174	27 $\mu\mu\text{f}$	Cer.	Fixed	500 v		$\pm 5.4 \mu\mu\text{f}$	281-513
C180A	220 $\mu\mu\text{f}$	Mica	Fixed	500 v		10%	283-536
C180B	.0022 μf	PTM	Fixed	400 v			285-543
C180C	.022 μf	PTM	Fixed	400 v			285-515
C180D	.1 μf	PTM	Fixed	400 v			285-526
C180E	.1 μf	PTM	Fixed	400 v			285-526
C181	39 $\mu\mu\text{f}$	Cer.	Fixed	500 v		$\pm 3.9 \mu\mu\text{f}$	281-517
C191	.001 μf	Cer.	Fixed	500 v			283-000
C195	12 $\mu\mu\text{f}$	Cer.	Fixed	500 v		$\pm 1.2 \mu\mu\text{f}$	281-506
C198	.005 μf	Cer.	Fixed	500 v			283-001
C310	7-45 $\mu\mu\text{f}$	Cer.	Var.				281-012
C311	330 $\mu\mu\text{f}$	Mica	Fixed	500 v		10%	283-518
C312	27 $\mu\mu\text{f}$	Cer.	Fixed	500 v		$\pm 2.7 \mu\mu\text{f}$	281-512
C313	3-12 $\mu\mu\text{f}$	Cer.	Var.				281-007
C314	500 $\mu\mu\text{f}$	Mica	Fixed	500 v		5%	283-523
C331	.005 μf	Cer.	Fixed	500 v			283-001
C337	4.5-25 $\mu\mu\text{f}$	Cer.	Var.				281-010
C339	39 $\mu\mu\text{f}$	Cer.	Fixed	500 v		$\pm 3.9 \mu\mu\text{f}$	281-516
C361A	3-12 $\mu\mu\text{f}$	Cer.	Var.				281-036
C361C	5-25 $\mu\mu\text{f}$	Cer.	Var.				281-011
C361E	8-50 $\mu\mu\text{f}$	Cer.	Var.				281-022
C361G	68 $\mu\mu\text{f}$	Cer.	Fixed	500 v		10%	281-549
C361J	120 $\mu\mu\text{f}$	Cer.	Fixed	500 v		10%	281-550
C361K	390 $\mu\mu\text{f}$	Cer.	Fixed	500 v			281-551
C361L	470 $\mu\mu\text{f}$	Cer.	Fixed			$\pm 94 \mu\mu\text{f}$	281-525
C364	8 μf	EMT	Fixed	450 v			290-094
C365	.01 μf	Cer.	Fixed	150 v			283-003
C378	8-50 $\mu\mu\text{f}$	Cer.	Var.				281-022
C382	8-50 $\mu\mu\text{f}$	Cer.	Var.				281-022
C387	0.7-3 $\mu\mu\text{f}$	Tub.	Var.				281-027
C388	0.7-3 $\mu\mu\text{f}$	Tub.	Var.				281-027
C391	0.02 μf	Cer.	Fixed	150 v			283-004
C394	1.5 $\mu\mu\text{f}$	Cer.	Fixed	500 v		+0.5 μf	281-526
C395	470 $\mu\mu\text{f}$	Cer.	Fixed			$\pm 94 \mu\mu\text{f}$	281-525

**This timing capacitor can be ordered separately. When ordering, note the color band painted on the end of the capacitor. The .001 μf capacitor may be ordered by part number 291-008. If the capacitor has a white color band, order 291-008A. If the capacitor has a black color band, order 291-008B.



Capacitors (continued)

Tektronix
Part Number

C672	330 $\mu\mu\text{f}$	Mica	Fixed	500 v	10%	283-518
C673	330 $\mu\mu\text{f}$	Mica	Fixed	500 v	10%	283-518
C682	27 $\mu\mu\text{f}$	Cer.	Fixed	500 v	20%	281-513
C695	.001 μf	Cer.	Fixed	500 v		283-000
C700	.02 μf	Cer.	Fixed	150 v		283-004
C707	.01 μf	PTM	Fixed	400 v		285-510
C711	.01 μf	PTM	Fixed	400 v		285-510
C715	2x40 μf	EMC	Fixed	250 v	20-50%	290-040
C717	.01 μf	PTM	Fixed	400 v		285-510
C720	.01 μf	Cer.	Fixed	500 v	GMV	283-002
C732	125 μf	EMC	Fixed	350 v	20-50%	290-044
C740	150 μf	EMC	Fixed	250 v		290-048
C741	150 μf	EMC	Fixed	250 v		290-048
C750	.01 μf	PTM	Fixed	400 v		285-510
C751A,B,C	3x10 μf	EMC	Fixed	450 v		290-033
C752	2x1000 μf	EMC	Fixed	15 v		290-050
C756	125 μf	EMC	Fixed	450 v		290-045
C763	.01 μf	PTM	Fixed	400 v		285-510
C770	.01 μf	PTM	Fixed	400 v		285-510
C780	125 μf	EMC	Fixed	350 v		290-044
C787	.01 μf	PTM	Fixed	400 v		285-510
C790A,B	2x40 μf	EMC	Fixed	450 v		290-042
C797	.01 μf	PTM	Fixed	400 v		285-510
C800	.047 μf	PTM	Fixed	400 v	20%	285-519
C803	.001 μf	PTM	Fixed	600 v	20%	285-501
C805	.01 μf	PTM	Fixed	400 v	20%	285-510
C806	.001 μf	PTM	Fixed	600 v	20%	285-501
C807	2x20 μf	EMC	Fixed	450 v	20-50%	290-037
C814	.0068 μf	PTM	Fixed	3000 v	20%	285-508
C815	.01 μf	Cer.	Fixed	500 v		283-002
C820	.0068 μf	PTM	Fixed	3000 v	20%	285-508
C821	.0068 μf	PTM	Fixed	5000 v	20%	285-509
C822	470 $\mu\mu\text{f}$	PTM	Fixed	10000 v	20%	285-500
C823	470 $\mu\mu\text{f}$	PTM	Fixed	10000 v	20%	285-500
C830	.0068 μf	PTM	Fixed	3000 v	20%	285-508
C832	.015 μf	PTM	Fixed	3000 v	20%	285-513
C834	.015 μf	PTM	Fixed	3000 v	20%	285-513
C841	.005 μf	Cer.	Fixed	500 v		283-001
C855	.015 μf	PTM	Fixed	3000 v	20%	285-513
C857	.015 μf	PTM	Fixed	3000 v	20%	285-513
C1003	2x20 μf	EMC	Fixed	450 v		290-036
C1005A	40 μf	}	EMC	Fixed	475 v	290-063
C1005B	20 μf					
C1005C	10 μf					
C1007	.1 μf	PTM	Fixed	400 v	20%	285-526
C1013	.005 μf	Cer.	Fixed	500 v		283-001
C1029	.001 μf	Cer.	Fixed	500 v		283-000
C1031	.005 μf	Cer.	Fixed	500 v		283-001
C1033	.005 μf	Cer.	Fixed	500 v		283-001



Capacitors (continued)

Tektronix
Part Number

C1039	.001 μ f	Cer.	Fixed	500 v	10 %	281-536
C1049	.001 μ f	Cer.	Fixed	500 v	10 %	281-536
C1052	.001 μ f	Cer.	Fixed	500 v		283-000
C1054	.005 μ f	Cer.	Fixed	500 v		283-001
C1056	150 μ μ f	Cer.	Fixed	500 v	20%	281-524
C1062	.001 μ f	Cer.	Fixed	500 v		283-000
C1075	8-50 μ μ f	Cer.	Var.			281-022
C1077	8-50 μ μ f	Cer.	Var.			281-022
C1078	.7-3 μ μ f	Tub.	Var.			281-027
C1085	.005 μ f	Cer.	Fixed	500 v		283-001
C1089	.005 μ f	Cer.	Fixed	500 v		283-001
C1093A,B	75 μ f	} EMC	Fixed	150 v		290-071
C1093C,D	75 μ f		Fixed	500 v		283-000
C1102	.001 μ f	Cer.	Fixed	500 v		283-000
C1104	.7-3 μ μ f	Tub.	Var.			281-027
C1105	150 μ μ f	Cer.	Fixed	500 v	20%	281-524
C1106	150 μ μ f	Cer.	Fixed	500 v	20%	281-524
C1112	.001 μ f	Cer.	Fixed	500 v	20%	283-000
C1122	.001 μ f	Cer.	Fixed	500 v		283-000
C1124	.7-3 μ μ f	Tub.	Var.			281-027
C1126	150 μ μ f	Cer.	Fixed	500 v	20%	281-524
C1132	.001 μ f	Cer.	Fixed	500 v		283-000
C1142	.001 μ f	Cer.	Fixed	500 v		283-000
C1144	.7-3 μ μ f	Tub.	Var.			281-027
C1146	150 μ μ f	Cer.	Fixed	500 v	20%	281-524
C1152	.001 μ f	Cer.	Fixed	500 v		283-000
C1162	.001 μ f	Cer.	Fixed	500 v		283-000
C1164	.7-3 μ μ f	Tub.	Var.			281-027
C1166	150 μ μ f	Cer.	Fixed	500 v	20%	281-524
C1172	.001 μ f	Cer.	Fixed	500 v		283-000
C1182	.001 μ f	Cer.	Fixed	500 v		283-000
C1184	.7-3 μ μ f	Tub.	Var.			281-027
C1186	150 μ μ f	Cer.	Fixed	500 v	20%	281-524
C1192	.001 μ f	Cer.	Fixed	500 v		283-000
C1202	.001 μ f	Cer.	Fixed	500 v		283-000
C1204	.7-3 μ μ f	Tub.	Var.			281-027
C1205	150 μ μ f	Cer.	Fixed	500 v	20%	281-524
C1208	.005 μ f	Cer.	Fixed	500 v	20%	283-001
C1212	.001 μ f	Cer.	Fixed	500 v		283-000
C1223	.001 μ f	Cer.	Fixed	500 v		283-000
C1224	.005 μ f	Cer.	Fixed	500 v		283-001
C1228	.022 μ f	PTM	Fixed	600 v	20%	285-517
C1301-50	.7-3 μ μ f	Tub.	Var.	500 v		281-027
C1360-75	1.5 μ μ f	Cer.	Fixed	500 v	$\pm 0.5 \mu$ μ f	281-526
C1380	.68 μ μ f	Cer.	Fixed	500 v	20%	281-537
C1381	.68 μ μ f	Cer.	Fixed	500 v	20%	281-537
C1382	1 μ μ f	Cer.	Fixed	500 v	20%	281-538



Inductors

				Tektronix Part Number		
L133	88 μ h		Fixed	108-022		
LR149	1 μ h		Fixed	108-058		
L1014	1.7-3.7 μ h		Var.	114-088		
L1024	1.7-3.7 μ h		Var.	114-088		
L1036	.5-1 μ h		Var.	114-087		
L1046	.5-1 μ h		Var.	114-087		
L1064	14 μ h		Fixed	108-134		
L1071	.9-1.6 μ h		Var.	114-051		
L1073	.9-1.6 μ h		Var.	114-051		
L1103		}	Distributed-amplifier grid lines manufactured by Tektronix.	108-145		
L1113						
L1104		}	Distributed-amplifier plate lines manufactured by Tektronix.	108-139		
L1114						
L1304					Delay Line	108-133
L1305					Delay Line	108-133
L1334			Delay Line	108-132		
L1335			Delay Line	108-132		
L1354	0.9-1.6 μ h		Var.	114-038		
L1355	0.9-1.6 μ h		Var.	114-038		

Resistors

R1	1 meg	$\frac{1}{2}$ w	Fixed	Comp.	5%	301-105
R2	390 k	$\frac{1}{2}$ w	Fixed	Comp.	5%	301-394
R3	50 k	2 w	Var.	Comp.	20%	311-023
R4	100 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-104
R12	1 meg	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-105
R13	100 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-104
R15	470 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-474
R17	100 k		Var.	Comp.		† 311-096
R18	22 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-223
R19	470 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-474
R20	470 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-474
R21	56 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-563
R23	33 k	2 w	Fixed	Comp.	10%	306-333
R24	39 k	2 w	Fixed	Comp.	10%	306-393
R25	47 Ω	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-470
R26	47 Ω	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-470
R27	4.7 k	1 w	Fixed	Comp.	10%	304-472
R29	4.7 k	1 w	Fixed	Comp.	10%	304-472
R32	47 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-473
R33	47 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-473
R34	47 Ω	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-470
R35	22 k	2 w	Fixed	Comp.	10%	306-223
R37	500 Ω	2 w	Fixed	Comp.		*311-005
R38	22 k	2 w	Fixed	Comp.	10%	306-223
R39	100 k	2 w	Fixed	Comp.		*311-026

†R17 concentric with SW110 and R110.



Resistors (continued)

Tektronix
Part Number

R40	100 k	1/2 w	Fixed	Comp.	10%	302-104
R41	2.7 meg	1/2 w	Fixed	Comp.	10%	302-275
R42	100 k	1/2 w	Fixed	Comp.	10%	302-104
R44	2.7 k	1/2 w	Fixed	Comp.	10%	302-272
R45	1 meg	1/2 w	Fixed	Comp.	10%	302-105
R46	1 k	1/2 w	Fixed	Comp.	10%	302-102
R47	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R48	1.5 k	1/2 w	Fixed	Comp.	10%	302-152
R110	100 k	2 w	Var.	Comp.		†*311-096
R111	100 k	2 w	Var.	Comp.	±20%	*311-110
R114	470 k	1/2 w	Fixed	Comp.	5%	301-474
R115	100 k	1/2 w	Fixed	Comp.	5%	301-104
R116	200 k	1/2 w	Fixed	Comp.	5%	301-204
R117	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R118	10 meg	1/2 w	Fixed	Comp.	10%	302-106
R121	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R122	22 k	1/2 w	Fixed	Comp.	10%	302-223
R124	100 k	1/2 w	Fixed	Comp.	5%	301-104
R125	50 k	.1 w	Var.	Comp.		*311-078
R126	300 k	1/2 w	Fixed	Comp.	5%	301-304
R127	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R128	12 k	1/2 w	Fixed	Comp.	10%	302-123
R129	27 k	1/2 w	Fixed	Comp.	10%	302-273
R130	22 k	2 w	Fixed	Comp.	10%	306-223
R131	1 k	1/2 w	Fixed	Comp.	10%	302-102
R132	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R133	3.9 k	1 w	} Checked to 6 k, 2 w, 2 1/2 %			312-569
R134	2.2 k	1 w				
R136	56 k	1 w	Fixed	Comp.	5%	303-563
R137	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R138	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R141	33 k	1 w	} Checked to ratio of 5% of each other			312-570
R143	39 k	1 w				
R144	8 k	5 w	Fixed	WW	5%	308-053
R146	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R147	1 k	1/2 w	Fixed	Comp.	10%	302-102
R148	39 k	1/2 w	Fixed	Comp.	10%	302-393
R150	270 Ω	1/2 w	Fixed	Comp.	10%	302-271
R152	36 k	1/2 w	Fixed	Comp.	5%	301-363
R153	1 meg	1/2 w	Fixed	Comp.	10%	302-105
R154	10 k	1/2 w	Fixed	Comp.	10%	302-103
R155	1 meg	1/2 w	Fixed	Comp.	10%	302-105
R156	1.8 meg	1/2 w	Fixed	Comp.	10%	302-185
R158	220 k	1/2 w	Fixed	Comp.	10%	302-224
R159	1.2 k	1/2 w	Fixed	Comp.	10%	302-122

†R110 concentric with SW110 and R17.



Resistors (continued)

Tektronix
Part Number

R160A	100 k	1/2 w	Fixed	Film	1%	*309-045
R160B	200 k	1/2 w	Fixed	Film	1%	*309-051
R160C	500 k	1/2 w	Fixed	Film	1%	*309-003
R160D	1 meg	1/2 w	Fixed	Film	1%	*309-014
R160E	2 meg	1/2 w	Fixed	Film	1%	*309-023
R160F	5 meg	1/2 w	Fixed	Film	1%	*309-087
R160G	10 meg	1 w	Fixed	Film	1%	*310-107
R160H	10 meg	1 w	Fixed	Film	1%	*310-107
R160J	30 meg	2 w	Fixed	Film	1%	*310-505
R160X	10 k	1/2 w	Fixed	Comp.	10%	302-103
R160Y	20 k	2 w	Var.	Comp.	20%	311-083
R160Z	100 k	1/2 w	Fixed	Comp.	10%	302-104
R162	6.8 k	1 w	Fixed	Comp.	10%	304-682
R163	12 k	1 w	Fixed	Comp.	10%	304-123
R164	22 k	2 w	Fixed	Comp.	10%	306-223
R165	22 k	2 w	Fixed	Comp.	10%	306-223
R166	22 k	2 w	Fixed	Comp.	10%	306-223
R167	1.5 meg	1/2 w	Fixed	Comp.	10%	302-155
R168	47 k	1/2 w	Fixed	Comp.	10%	302-473
R170	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R172	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R173	470 Ω	1/2 w	Fixed	Comp.	10%	302-471
R174	8 k	5 w	Fixed	WW	5%	308-053
R176	2 k	2 w	Var.	Comp.		*311-008
R178	4 k	5 w	Fixed	WW	5%	308-051
R180A	470 k	1/2 w	Fixed	Comp.	10%	302-474
R180B	4.7 meg	1/2 w	Fixed	Comp.	10%	302-475
R181	4.7 meg	1/2 w	Fixed	Comp.	10%	302-475
R183	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R191	100 k	1/2 w	Fixed	Comp.	10%	302-104
R193	100 k	1 w	Fixed	Comp.	10%	304-104
R195	47 k	1/2 w	Fixed	Comp.	10%	302-473
R196	100 k	1/2 w	Fixed	Comp.	10%	302-104
R197	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R198	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R199	4.7 k	1 w	Fixed	Comp.	10%	304-472
R310	900 k	1/2 w	Fixed	Film	1%	*309-111
R311	111 k	1/2 w	Fixed	Film	1%	*309-046
R313	990 k	1/2 w	Fixed	Film	1%	*309-013
R314	10.1 k	1/2 w	Fixed	Film	1%	*309-034
R320	1 meg	1/2 w	Fixed	Film	1%	*309-014
R321	1 k	1/2 w	Fixed	Comp.	10%	302-102
R323	47 k	1 w	Fixed	Comp.	10%	304-473
R325	15 k	2 w	Var.	Comp.	20%	*311-112
R327	47 k	1 w	Fixed	Comp.	10%	304-473
R328	33 k	2 w	Fixed	Comp.	10%	306-333
R330	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R331	3.3 k	1/2 w	Fixed	Comp.	10%	302-332
R332	220 k	1/2 w	Fixed	Comp.	10%	302-224
R334	100 k	2 w	Var.	Comp.		*311-026



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Resistors (continued)

Tektronix
Part Number

R337	2 meg	1/2 w	Fixed	Film	1%	*309-023
R338	2 meg	1/2 w	Fixed	Film	1%	*309-023
R339	330 Ω	1/2 w	Fixed	Comp.	10%	302-331
R340†	50 k	2 w	Var.	Comp.		*311-109
R342	2 meg	0.1 w	Var.	Comp.		*311-082
R343	1.5 meg	1/2 w	Fixed	Film	1%	*309-017
R344	10 meg	1/2 w	Fixed	Film	1%	*309-095
R346†	50 k	2 w	Var.	Comp.		*311-109
R347	47 k	1/2 w	Fixed	Comp.	10%	302-473
R348	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R349	47 k	1 w	Fixed	Comp.	10%	304-473
R351	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R353	30 k	1 w	Fixed	Comp.	5%	303-303
R354	6 k	1/2 w	Fixed	Film	1%	*309-099
R355	136 Ω	1/2 w	Fixed	Film	1%	*309-174
R356	500 Ω	1/10 w	Var.	Comp.	20%	*311-056
R358	10 k	5 w	Fixed	WW	10%	308-008
R359	5 k	2 w	Var.	Comp.		*311-011
R360	12 k	8 w	Fixed	WW	5%	308-093
R361A	5.6 k	1/2 w	Fixed	Comp.	10%	302-562
R361B	11.76 k	1/2 w	Fixed	Film	1/4%	*309-200
R361C	3.3 k	1/2 w	Fixed	Comp.	10%	302-332
R361D	2.85 k	1/2 w	Fixed	Film	1/4%	309-201
R361E	1.2 k	1/2 w	Fixed	Comp.	10%	302-122
R361F	1.2 k	1/2 w	Fixed	Film	1/4%	*309-202
R361G	680 Ω	1/2 w	Fixed	Comp.	10%	302-681
R361H	505.4 Ω	1/2 w	Fixed	Film	1/4%	*309-203
R361J	390 Ω	1/2 w	Fixed	Comp.	10%	302-391
R361K	122.5 Ω	1/2 w	Fixed	Film	1/4%	*309-204
R361L	1 k	1/2 w	Fixed	Comp.	10%	302-102
R361M	2.5 k	0.1 w	Var.	Comp.		*311-010
R361Y	100 k	1/2 w	Fixed	Comp.	10%	302-104
R361Z	100 k	1/2 w	Fixed	Comp.	10%	302-104
R363	330 k	1/2 w	Fixed	Comp.	10%	302-334
R364	330 k	1/2 w	Fixed	Comp.	10%	302-334
R365	500 Ω	0.1 w	Var.	Comp.		*311-056
R368	5 k	0.1 w	Var.	Comp.		*311-074
R369	31.1 k	1/2 w	Fixed	Film	1%	*309-037
R371	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R372	30 k	1 w	Fixed	Comp.	5%	303-303
R373	6 k	1/2 w	Fixed	Film	1%	*309-099
R376	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R377	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R378	6-25 k	5 w	Manufactured by Tektronix		1%	*310-506
R379	470 k	1/2 w	Fixed	Comp.	10%	302-474

†R340 and R346 concentric.



Resistors (continued)

						Tektronix Part Number
R380	820 k	1/2 w	Fixed	Comp.	10%	302-824
R381	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R382	6-25 k	5 w	Fixed	Manufactured by Tektronix		*310-506
R384	12 k	8 w	Fixed	WW	5%	308-093
R386	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R387	41.5 k	5 w	Fixed	Manufactured by Tektronix		*310-512
R388	41.5 k	5 w	Fixed	Manufactured by Tektronix		*310-512
R389	820 k	1/2 w	Fixed	Comp.	10%	302-824
R390	470 k	1/2 w	Fixed	Comp.	10%	302-474
R391	10 k	1/2 w	Fixed	Comp.	10%	302-103
R394	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R395	2.2 k	1/2 w	Fixed	Comp.	10%	302-222
R397	100 k	1/2 w	Fixed	Comp.	10%	302-104
R398	150 k	1/2 w	Fixed	Comp.	10%	302-154
R593	30 k	10 w	Fixed	WW	5%	308-027
R670	150 k	1/2 w	Fixed	Comp.	10%	302-154
R671	1 k	1/2 w	Fixed	Comp.	10%	302-102
R672	3.3 meg	1/2 w	Fixed	Comp.	10%	302-335
R673	2.7 meg	1/2 w	Fixed	Comp.	10%	302-275
R674	1 k	1/2 w	Fixed	Comp.	10%	302-102
R675	68 k	1/2 w	Fixed	Comp.	10%	302-683
R676	33 k	1 w	Fixed	Comp.	10%	304-333
R679	10 k	2 w	Var.	Comp.		311-016
R680	100 k	1/2 w	Fixed	Comp.	10%	302-104
R681	1.5 meg	1/2 w	Fixed	Comp.	10%	302-155
R682	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R683	9.5 k	1/2 w	Fixed	Film	1%	*309-121
R684	6.375 k	1/2 w	Fixed	Film	1%	*309-119
R685	2.1 k	1/2 w	Fixed	Film	1%	*309-117
R686	1.025 k	1/2 w	Fixed	Film	1%	*309-116
R687	610 Ω	1/2 w	Fixed	Film	1%	*309-113
R688	200 Ω	1/2 w	Fixed	Film	1%	309-073
R689	100 Ω	1/2 w	Fixed	Film	1%	*309-112
R690	60 Ω	1/2 w	Fixed	Film	1%	*309-067
R691	40 Ω	1/2 w	Fixed	Film	1%	*309-066
R694	100 k	1/2 w	Fixed	Film	1%	*309-045
R695	100 Ω	1/2 w	Fixed	Film	1%	*309-112
R698	.25 Ω	1 w	Special	WW	±10%	308-090
R699	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R700	15 k	1 w	Fixed	Comp.	10%	304-153
R701	15 k	1 w	Fixed	Comp.	10%	304-153
R703	68 k	1/2 w	Fixed	Comp.	10%	302-683
R704	27 k	1/2 w	Fixed	Comp.	10%	302-273
R706	2.7 meg	1/2 w	Fixed	Comp.	10%	302-275
R707	2.7 meg	1/2 w	Fixed	Comp.	10%	302-275
R708	12 Ω	1 w	Fixed	Comp.	10%	304-120



Resistors (continued)

Tektronix
Part Number

R710	33 k	1/2 w	Fixed	Comp.	10%	302-333
R711	100 k	1/2 w	Fixed	Comp.	10%	302-104
R712	100 k	1/2 w	Fixed	Comp.	10%	302-104
R713	1 k	1/2 w	Fixed	Comp.	10%	302-102
R715	50 k	1 w	Fixed	Film	1%	*310-086
R716	10 k	2 w	Var.	WW		311-015
R717	100 k	1/2 w	Fixed	Comp.	10%	302-104
R718	68 k	1 w	Fixed	Film	1%	*310-054
R719	470 k	1/2 w	Fixed	Comp.	10%	302-474
R720	10 Ω	1/2 w	Fixed	Comp.	10%	302-100
R724	1 k	25 w	Fixed	WW	5%	308-037
R726	1 k	1/2 w	Fixed	Comp.	10%	302-102
R728	150 k	1/2 w	Fixed	Comp.	10%	302-154
R729	1 meg	1/2 w	Fixed	Comp.	10%	302-105
R732	10 Ω	1 w	Fixed	Comp.	10%	304-100
R733	10 Ω	1 w	Fixed	Comp.	10%	304-100
R736	50 Ω	2 w	Var.	WW		*311-055
R740	10 Ω	1 w	Fixed	Comp.	10%	304-100
R742	47 k	1 w	Fixed	Comp.	10%	302-473
R743	39 k	1/2 w	Fixed	Comp.	10%	302-393
R744	680 k	1/2 w	Fixed	Comp.	10%	302-684
R747	1.5 meg	1/2 w	Fixed	Comp.	10%	302-155
R748	30 k	10 w	Fixed	WW	5%	308-027
R749	750 Ω	10 w	Fixed	WW	5%	308-016
R750	333 k	1 w	Fixed	Film	1%	*310-056
R751	490 k	1 w	Fixed	Film	1%	*310-057
R752	2.2 Ω	1/2 w	Fixed	WW	5%	308-116
R756	10 Ω	2 w	Fixed	Comp.	10%	306-100
R757	270 k	1/2 w	Fixed	Comp.	10%	302-274
R758	56 k	1/2 w	Fixed	Comp.	10%	302-563
R760	1.5 meg	1/2 w	Fixed	Comp.	10%	302-155
R762	2.5 k	10 w	Fixed	WW	5%	308-018
R763	1.5 meg	1/2 w	Fixed	Comp.	10%	302-155
R764	2.2 meg	1/2 w	Fixed	Comp.	10%	302-225
R765	100 k	1/2 w	Fixed	Comp.	10%	302-104
R766	82 k	1 w	Fixed	Comp.	10%	304-823
R767	1 k	1/2 w	Fixed	Comp.	10%	302-102
R770	2.2 meg	1/2 w	Fixed	Comp.	10%	302-225
R771	220 k	1 w	Fixed	Film	1%	*310-055
R772	333 k	1 w	Fixed	Film	1%	*310-056
R777	10 Ω	1 w	Fixed	Comp.	10%	304-100
R778	82 k	2 w	Fixed	Comp.	10%	306-823



Resistors (continued)

Tektronix
Part Number

R779	2.2 meg	1/2 w	Fixed	Comp.	10%	302-225
R780	10 Ω	1 w	Fixed	Comp.	10%	304-100
R781	1 meg	1/2 w	Fixed	Comp.	10%	302-105
R782	560 k	1/2 w	Fixed	Comp.	10%	302-564
R783	47 k	1/2 w	Fixed	Comp.	10%	302-473
R784	1.5 meg	1/2 w	Fixed	Comp.	10%	302-155
R785	1.5 k	25 w	Fixed	WW	5%	308-040
R786	1.5 k	25 w	Fixed	WW	5%	308-040
R787	236 k	1 w	Fixed	WW	1%	308-083
R788	100 k	1/2 w	Fixed	WW	1%	308-084
R789	1 k	1/2 w	Fixed	Comp.	10%	302-102
R790	10 Ω	1/2 w	Fixed	Comp.	10%	302-100
R791	150 k	1/2 w	Fixed	Comp.	10%	302-154
R792	120 k	1/2 w	Fixed	Comp.	10%	302-124
R793	27 k	1/2 w	Fixed	Comp.	10%	302-273
R794	1 meg	1/2 w	Fixed	Comp.	10%	302-105
R795	3 k	8 w	Fixed	WW	5%	308-113
R797	220 k	1 w	Fixed	Film	1%	*310-055
R798	720 k	1 w	Fixed	Film	1%	*310-059
R800	1 k	1/2 w	Fixed	Comp.	10%	302-102
R803	56 k	2 w	Fixed	Comp.	10%	306-563
R804	100 k	1/2 w	Fixed	Comp.	10%	302-104
R805	1 k	1/2 w	Fixed	Comp.	10%	302-102
R807	390 Ω	2 w	Fixed	Comp.	10%	306-391
R810	470 k	1/2 w	Fixed	Comp.	10%	302-474
R811	2 meg	2 w	Var.	Comp.		311-042
R812	2.2 meg	1/2 w	Fixed	Comp.	10%	302-225
R813	4.7 meg	1/2 w	Fixed	Comp.	10%	302-475
R814	4.7 meg	1/2 w	Fixed	Comp.	10%	302-475
R815	4.7 meg	1/2 w	Fixed	Comp.	10%	302-475
R830	47 k	1/2 w	Fixed	Comp.	10%	302-473
R831	1 meg	1/2 w	Var.	Comp.	20%	311-041
R832	4.7 meg	2 w	Fixed	Comp.	10%	306-475
R833	4.7 meg	2 w	Fixed	Comp.	10%	306-475
R834	100 k	1/2 w	Fixed	Comp.	10%	302-104
R835	1 meg	1/2 w	Fixed	Comp.	10%	302-105
R838	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R840	68 k	2 w	Fixed	Comp.	10%	306-683
R841	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R842	100 k	2 w	Var.	Comp.	20%	311-026
R850	2.2 meg	2 w	Fixed	Comp.	10%	306-225
R851	2.2 meg	2 w	Fixed	Comp.	10%	306-225
R852	2 meg	1/2 w	Var.	Comp.	20%	311-043
R853	1 meg	2 w	Fixed	Comp.	10%	306-105
R855	10 k	1/2 w	Fixed	Comp.	10%	302-103



Ⓐ

Resistors (continued)

Tektronix
Part Number

R856	27 k	1/2 w	Fixed	Comp.	10%	302-273
R857	1 meg	1/2 w	Fixed	Comp.	10%	302-105
R860	50 k	2 w	Var.	Comp.	20%	311-023
R1003	100 Ω	1 w	Fixed	Comp.	10%	304-101
R1005	100 Ω	1 w	Fixed	Comp.	10%	304-101
R1007	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R1008	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R1009	100 Ω	1 w	Fixed	Comp.	10%	304-101
R1011	27 Ω	1/2 w	Fixed	Comp.	10%	302-270
R1013	910 Ω	2 w	Fixed	Comp.	5%	305-911
R1014	500 Ω	1/2 w	Manufactured by Tektronix		2%	310-515
R1016	4 k	5 w	Fixed	WW	5%	308-051
R1017	12 k	8 w	Fixed	WW	5%	308-069
R1018	330 Ω	1/2 w	Fixed	Comp.	10%	302-331
R1019	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1021	27 Ω	1/2 w	Fixed	Comp.	10%	302-270
R1023	150 k	1/2 w	Fixed	Comp.	10%	302-154
R1024	500 Ω	1/2 w	Manufactured by Tektronix		2%	310-515
R1026	330 Ω	1/2 w	Fixed	Comp.	10%	302-331
R1027	200 Ω	2 w	Var.	Comp.		311-004
R1029	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1031	4.7 k	1 w	Fixed	Comp.	10%	304-472
R1033	1.5 k	5 w	Fixed	WW	5%	308-061
R1036	27 k	2 w	Fixed	Comp.	10%	306-273
R1039	39 Ω	1/2 w	Fixed	Comp.	10%	302-390
R1046	27 k	2 w	Fixed	Comp.	10%	306-273
R1049	39 Ω	1/2 w	Fixed	Comp.	10%	302-390
R1052	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1054	167 Ω	5 w	Fixed	WW	5%	308-104
R1055	4.5 k	5 w	Fixed	WW	5%	308-066
R1062	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1064	2 k	1 w	Fixed	Comp.	5%	303-202
R1071	600 Ω	5 w	} Tektronix Manufactured, paired to within 1/2% of each other			312-587
R1073	600 Ω	5 w				
R1075	220 Ω	1/4 w	Fixed	Comp.	10%	316-221
R1077	47 Ω	1/4 w	Fixed	Comp.	10%	316-470
R1078	150 Ω	1/4 w	Fixed	Comp.	10%	316-151
R1080	150 k	1/2 w	Fixed	Comp.	10%	302-154
R1081	330 k	1/2 w	Fixed	Comp.	10%	302-334
R1083	390 k	1/2 w	Fixed	Comp.	10%	302-394
R1084	180 k	1/2 w	Fixed	Comp.	10%	302-184
R1085	1 meg	1/4 w	Fixed	Comp.	10%	316-105
R1087	390 k	1/2 w	Fixed	Comp.	10%	302-394
R1089	1 meg	1/4 w	Fixed	Comp.	10%	316-105
R1090	8.2 k	1/4 w	Fixed	Comp.	10%	316-822
R1091	250 k	2 w	Var.	Comp.	20%	311-061



Resistors (continued)

						Tektronix Part Number
R1092	47 k	1/2 w	Fixed	Comp.	10%	302-473
R1094	68 k	0.1 w	Fixed	Comp.	10%	307-006
R1095	8.2 k	1/4 w	Fixed	Comp.	10%	316-822
R1097	47 k	1/2 w	Fixed	Comp.	10%	302-473
R1099	68 k	0.1 w	Fixed	Comp.	10%	307-006
R1102	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1105	4.5 k	5 w	Fixed	WW	5%	308-066
R1112	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1122	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1125	4.5 k	5 w	Fixed	WW	5%	308-066
R1132	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1142	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1145	4.5 k	5 w	Fixed	WW	5%	308-066
R1152	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1162	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1165	4.5 k	5 w	Fixed	WW	5%	308-066
R1172	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1182	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1185	4.5 k	5 w	Fixed	WW	5%	308-066
R1192	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1202	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1205	4.5 k	5 w	Fixed	WW	5%	308-066
R1206	360 Ω	1/2 w	Fixed	Comp.	5%	301-361
R1208	12 k	8 w	Fixed	WW	5%	308-069
R1212	470 k	1/2 w	Fixed	Comp.	10%	302-474
R1216	360 Ω	1/2 w	Fixed	Comp.	5%	301-361
R1218	1 k	5 w	Fixed	WW	5%	308-106
R1221	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R1223	2.7 k	2 w	Fixed	Comp.	10%	306-272
R1226	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R1227	15 k	2 w	Fixed	Comp.	10%	306-153
R1228	1 meg	1/2 w	Fixed	Comp.	10%	302-105
R1301-R1308	1 k	1/2 w	Fixed	Comp.	10%	302-102
R1224	30 k	10 w	Fixed	WW	5%	308-027

Switches

SW10	Trigger Slope Triggering Mode	}	unwired	wired
SW30			260-099	262-150
SW110†				
SW120	Single Sweep Reset Sweep Time/CM	}	260-190	
SW160			260-203	262-147

†SW110 concentric with R17 and R110. Furnished as a unit.



Switches (continued)

		Tektronix Part Number	
		unwired	wired
SW310	Horiz. Volts/CM	260-207	262-152
SW360	Horiz. Display	260-210	262-151
SW670*	Volts, Millivolts, OFF	260-177	262-132
SW680*	Square Wave Calibrator		
SW701	Power	260-134	
TK701	Thermal Cutout	260-070	
SW800	CRT Cathode Selector	260-209	

Transformer

T700	Plate & Heaters	120-037
T801	CRT Supply	120-036

Vacuum Tubes

V24	6BQ7A	154-028
V45	6U8	154-033
V55	6BQ7A	154-028
V125	6AU6	154-022
V133	6BQ7A	154-028
V135	6BQ7A	154-028
V146	12BY7	154-047
V152	6AL5	154-016
V154	6U8	154-033
V161	12AU6	154-040
V173	6BQ7A	154-028
V183	6BQ7A	154-028
V193	6BQ7A	154-028
V246	6BQ7A	154-028
V324	6BQ7A	154-028
V343	12AU6	154-040
V354	6DK6	154-149
V364	6DK6	154-149
V374	6BA8	154-163
V384	6BA8	154-163
V394	6DK6	154-149
V670	6U8	154-033
V700	6AU6	154-022
V710	5651	154-052
V712	12AX7	154-043
V725	12B4	154-044
V726	12B4	154-044
V727	12B4	154-044
V742	6AU6	154-022
V748	6080	154-056



Vacuum Tubes (continued)

			Tektronix Part Number
V757	6AU6		154-022
V765	12AX7		154-043
V782	6AU6		154-022
V784	6080		154-056
V791	6AU6		154-022
V794	12B4		154-044
V800	6AU5		154-021
V803	6AU5		154-021
V810	12AU7		154-041
V814	12AU7		154-041
V820	5642		154-051
V821	5642		154-051
V822	5642		154-051
V823	5642		154-051
V824	5642		154-051
V859	T65 P2	CRT Standard Phosphor	154-175
V1014	12BY7A		157-053
V1024	12BY7A		157-053
V1033	6BQ7A		154-028
V1043	6BQ7A		154-028
V1054	6DK6		154-149
V1064	6DK6		154-149
V1084	12AU7		154-041
V1104	6DK6		154-149
V1114	6DK6		154-149
V1124	6DK6		154-149
V1134	6DK6		154-149
V1144	6DK6		154-149
V1154	6DK6		154-149
V1164	6DK6		154-149
V1174	6DK6		154-149
V1184	6DK6		154-149
V1194	6DK6		154-149
V1204	6DK6		154-149
V1214	6DK6		154-149
V1223	6BQ7A		154-028

Rectifiers

SR732	5 plates/ leg	106-012
SR740	5 plates/ leg	106-013
SR752	1 250 ma plates/leg	106-038
SR756	4 plates/ leg	106-019
SR780	4 plates/ leg	106-014
SR790	5 plates/ leg	106-015



Fuses

Tektronix
Part Number

F701	6 amp. Fast-Blo	117 v	60 cycles
F701	3 amp. Fast-Blo	234 v	50 cycles

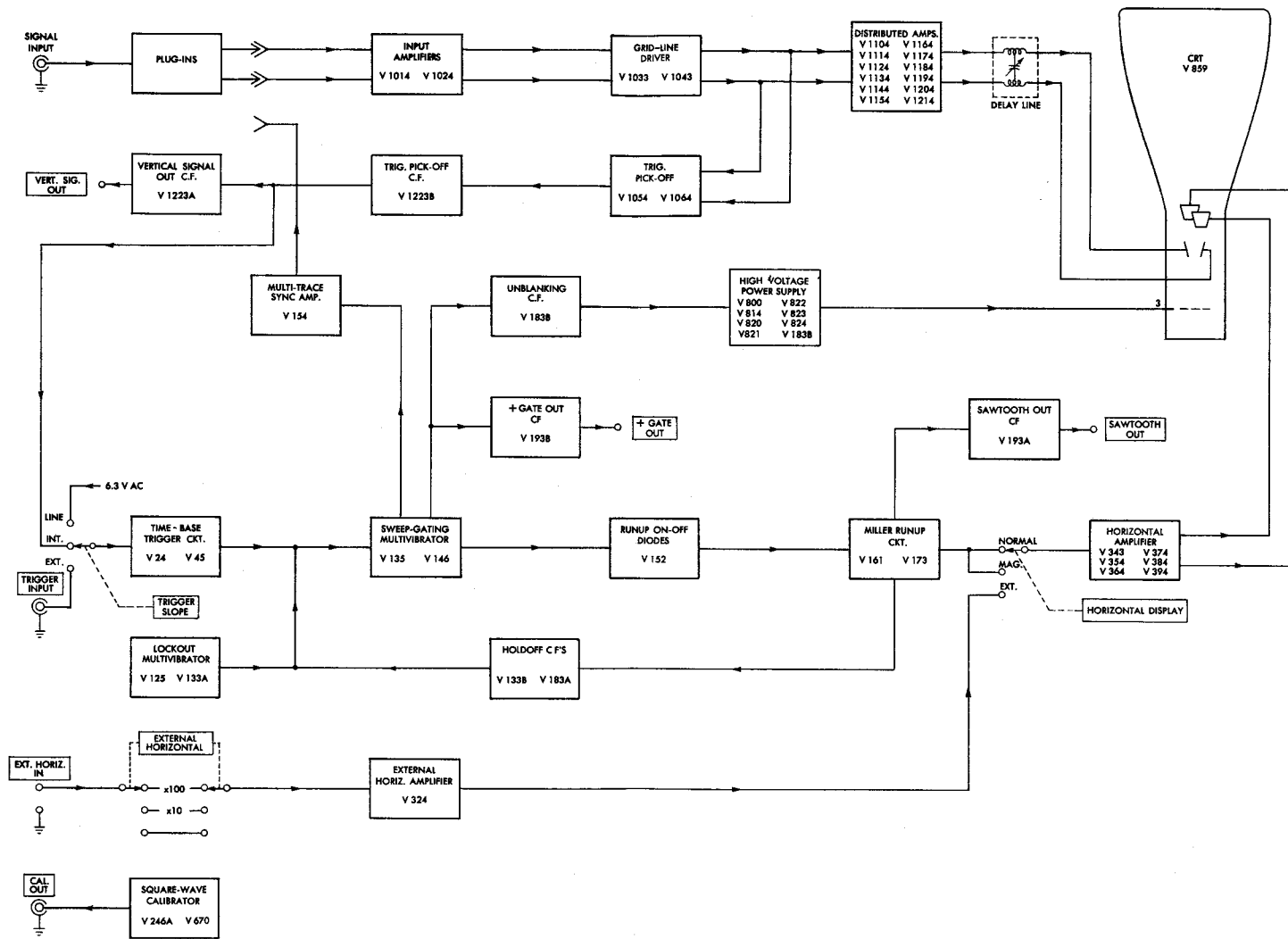
159-013
159-005

Relays

K700	45-sec.	Thermal time delay tube
K701	6 v	4 pole, 2 throw

148-002
148-004

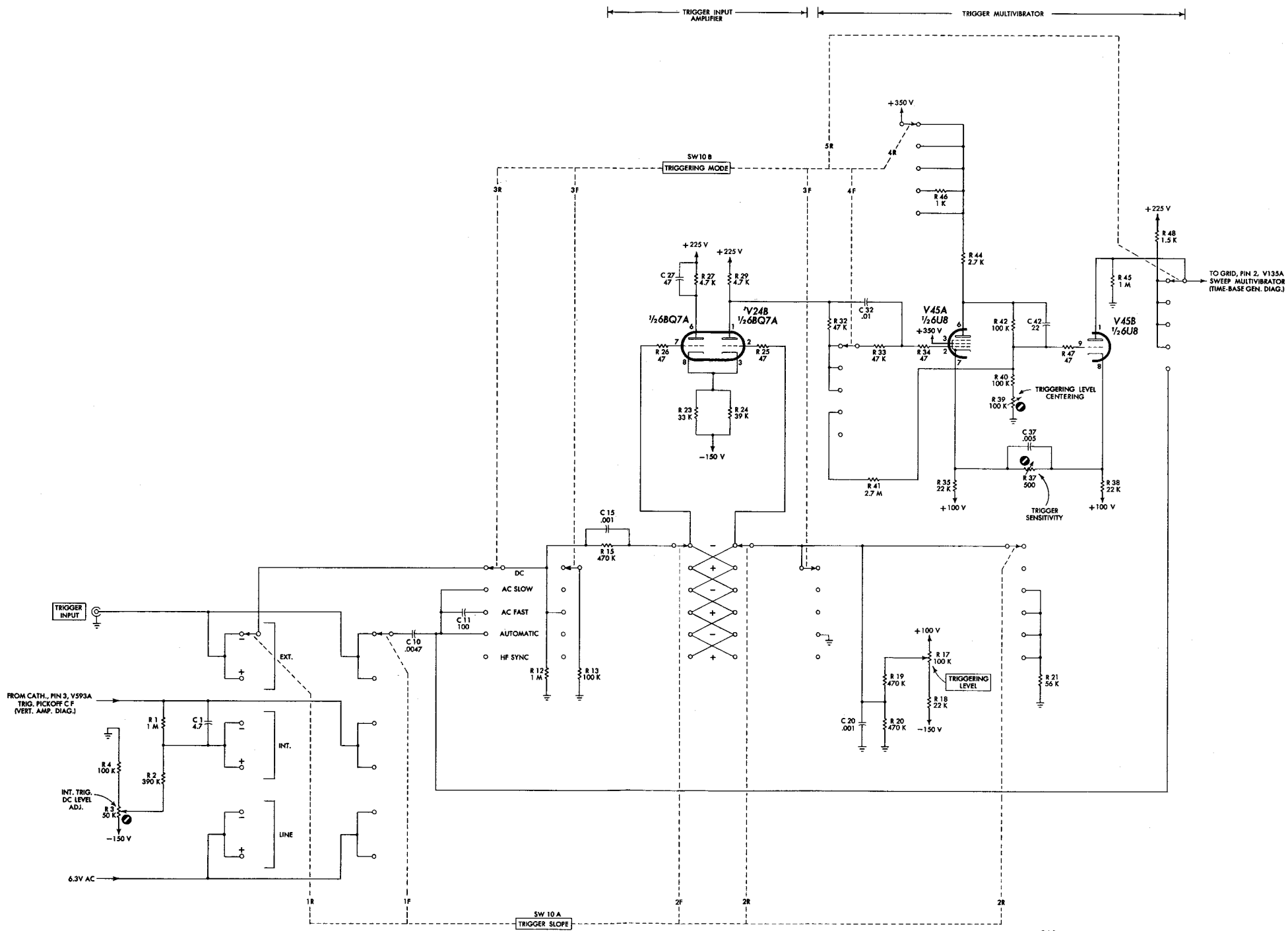


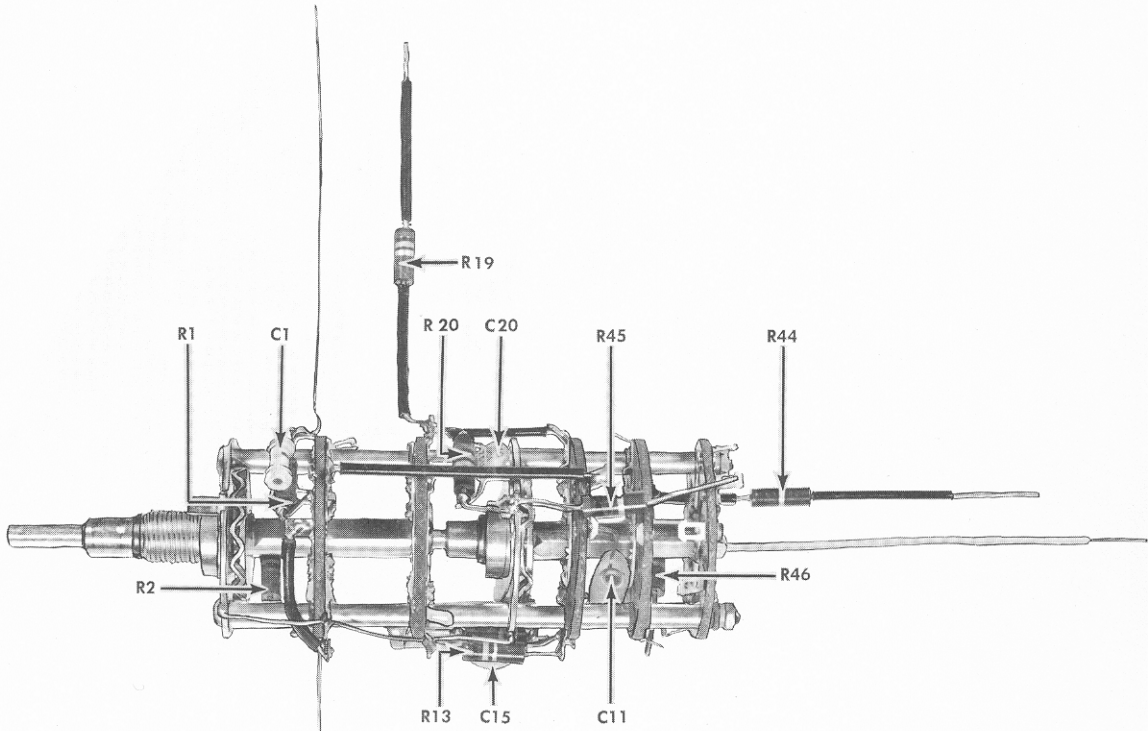


TYPE 543 OSCILLOSCOPE

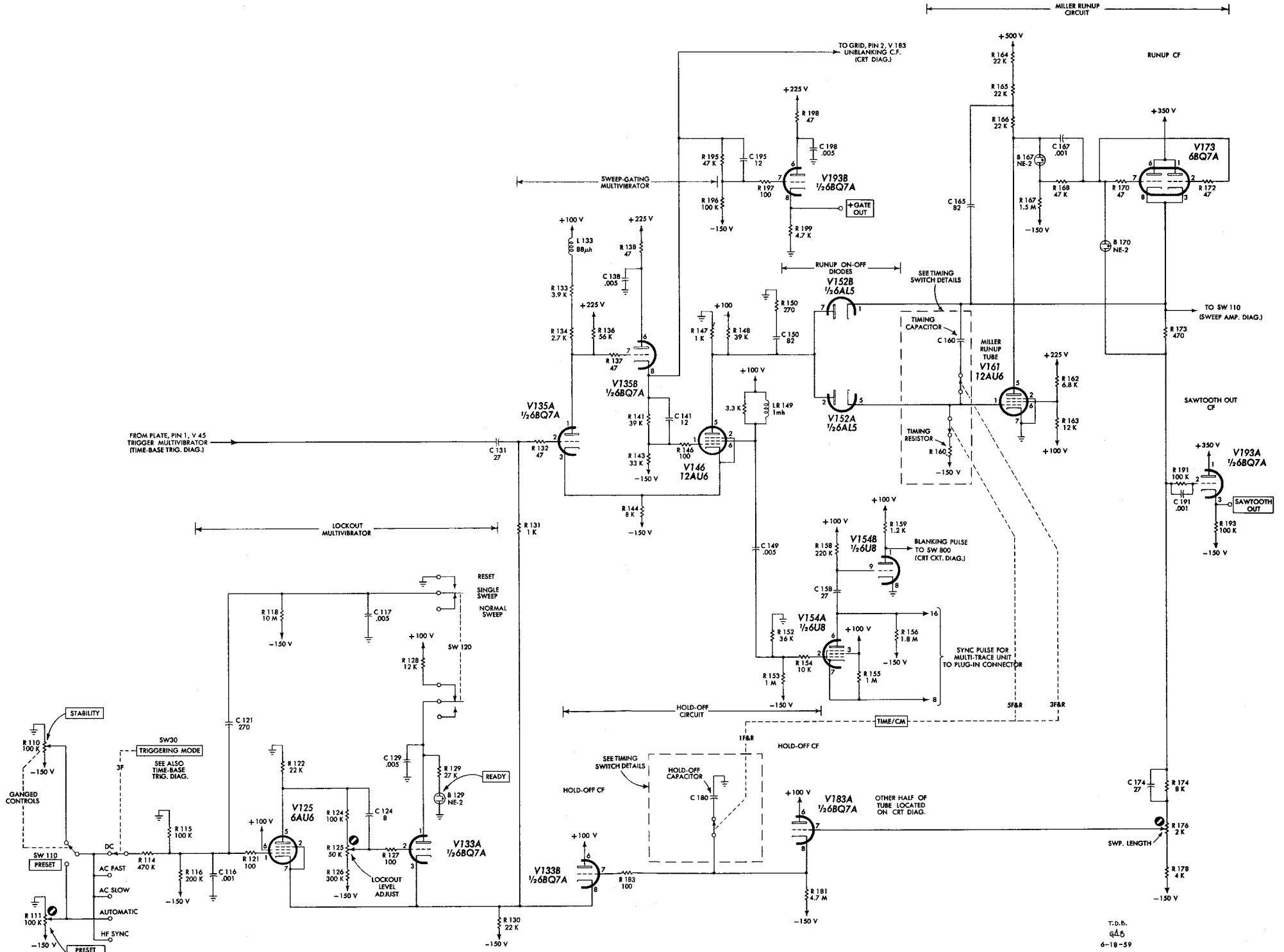
A

MH
6-10-59
BLOCK DIAGRAM





TRIGGER SLOPE AND MODE SWITCH
TOP VIEW



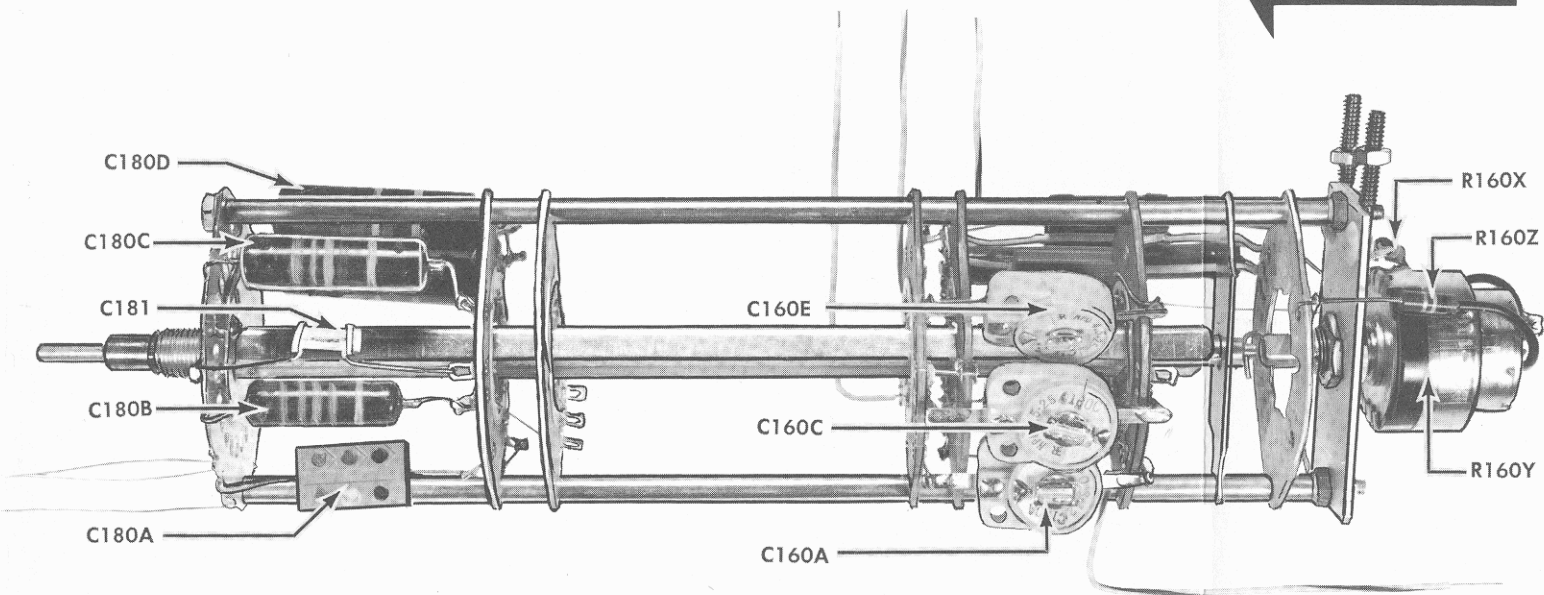
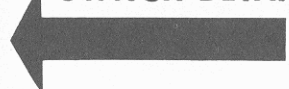
TYPE 543 OSCILLOSCOPE

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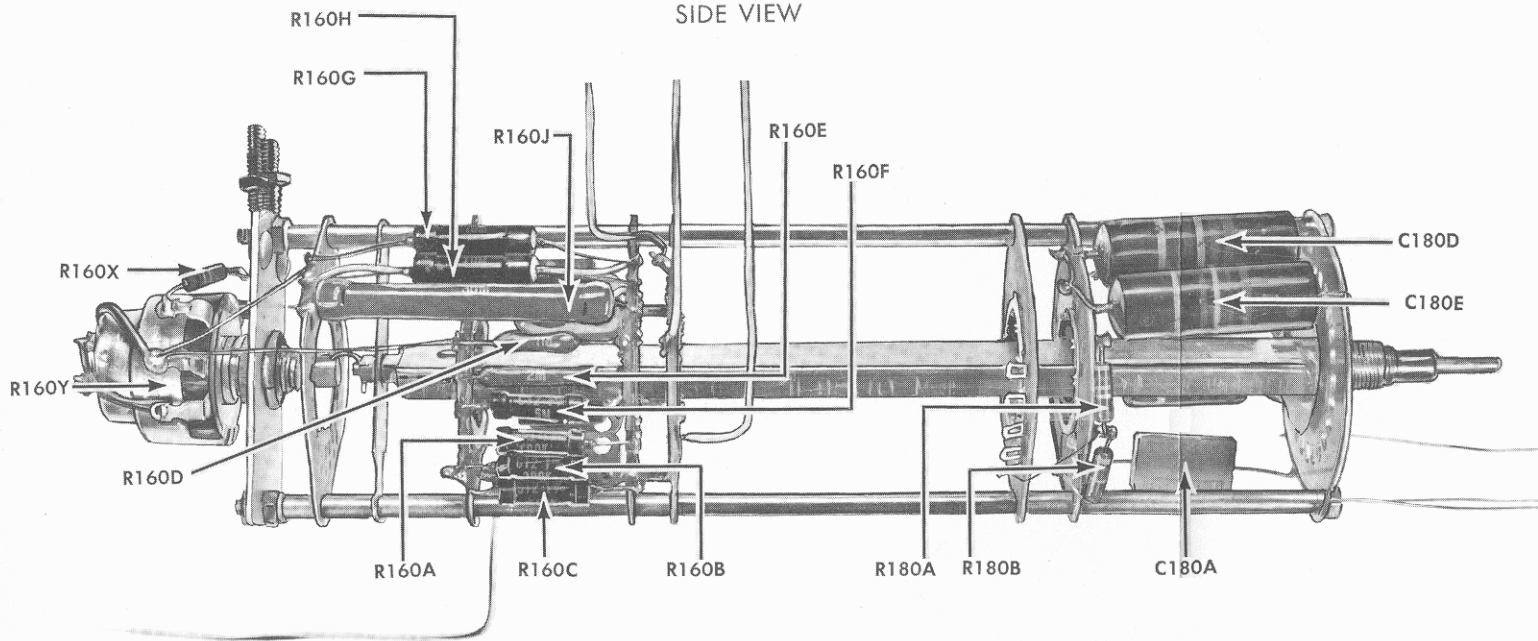
TIME-BASE GENERATOR

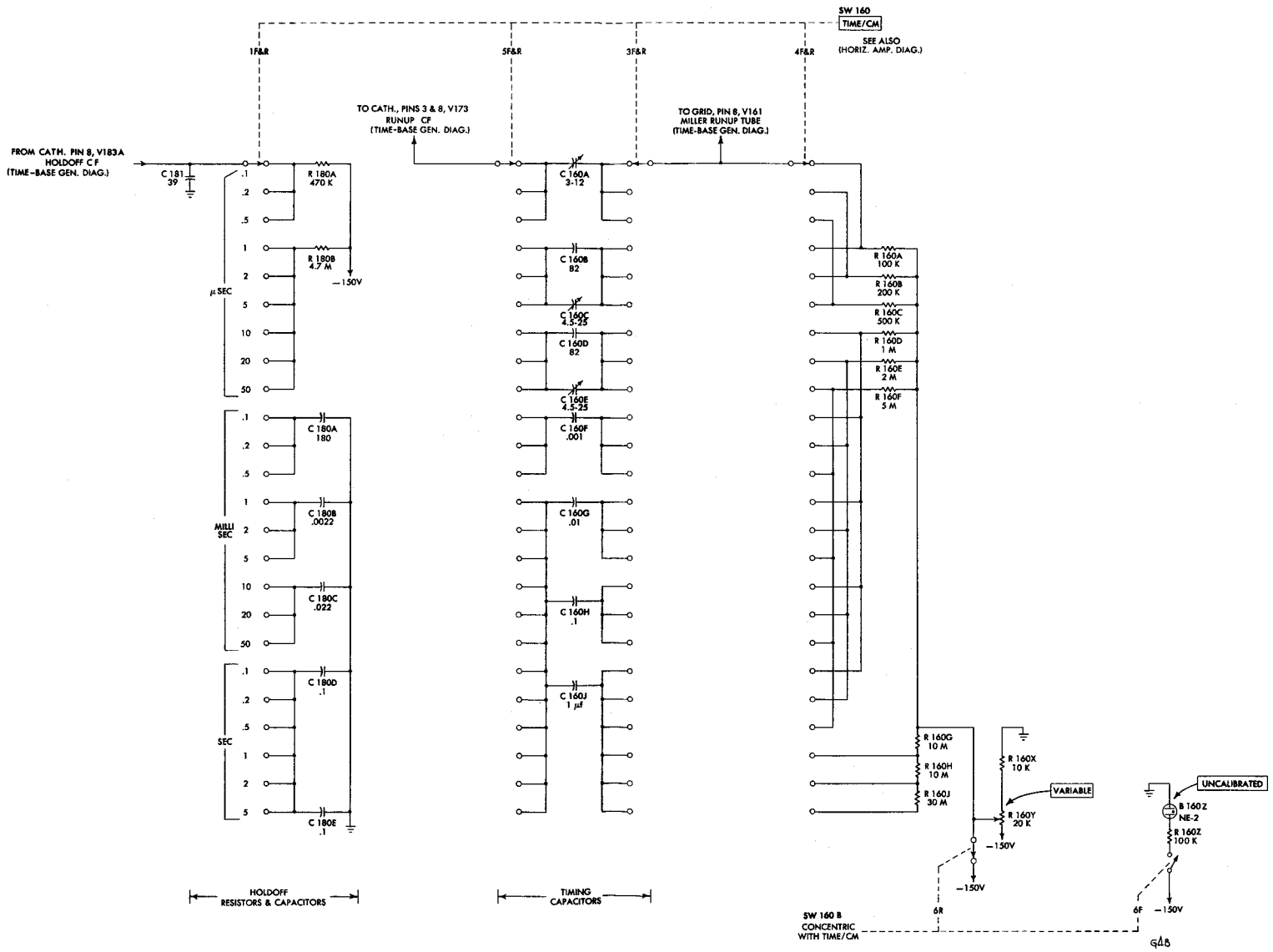
T.D.S.
6A6
6-18-59

SWITCH DETAIL



**TIME/CM SWITCH
SIDE VIEW**



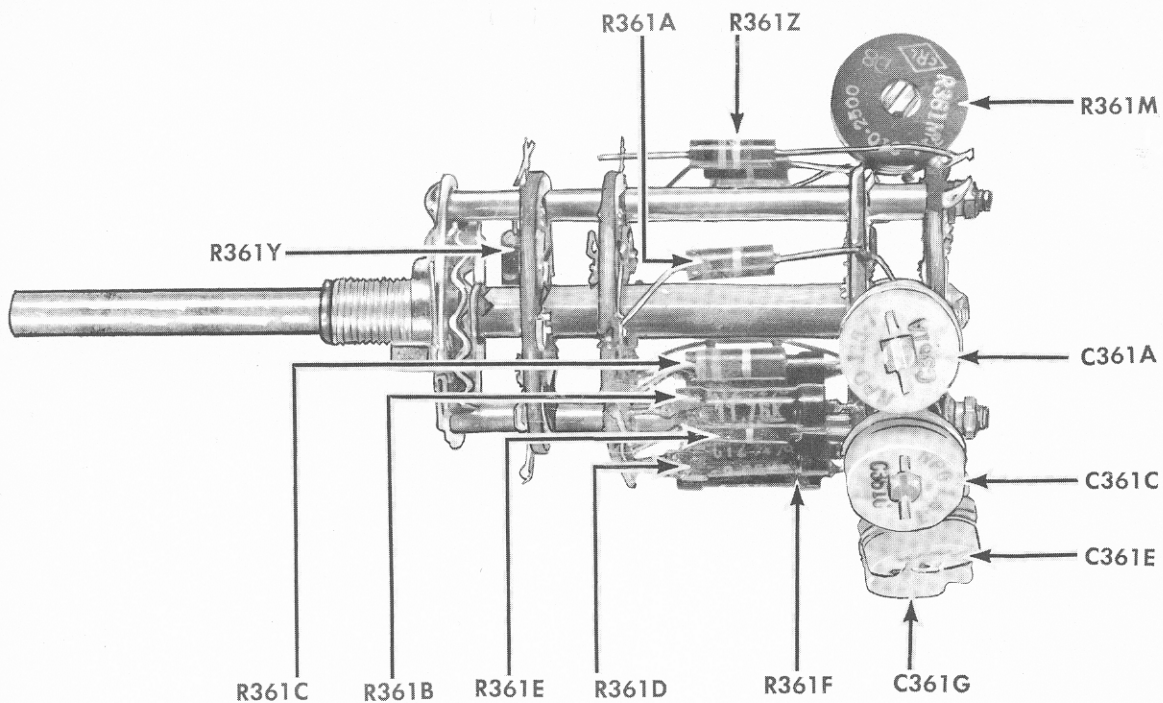


TYPE 543 OSCILLOSCOPE

A

TIMING RESISTORS

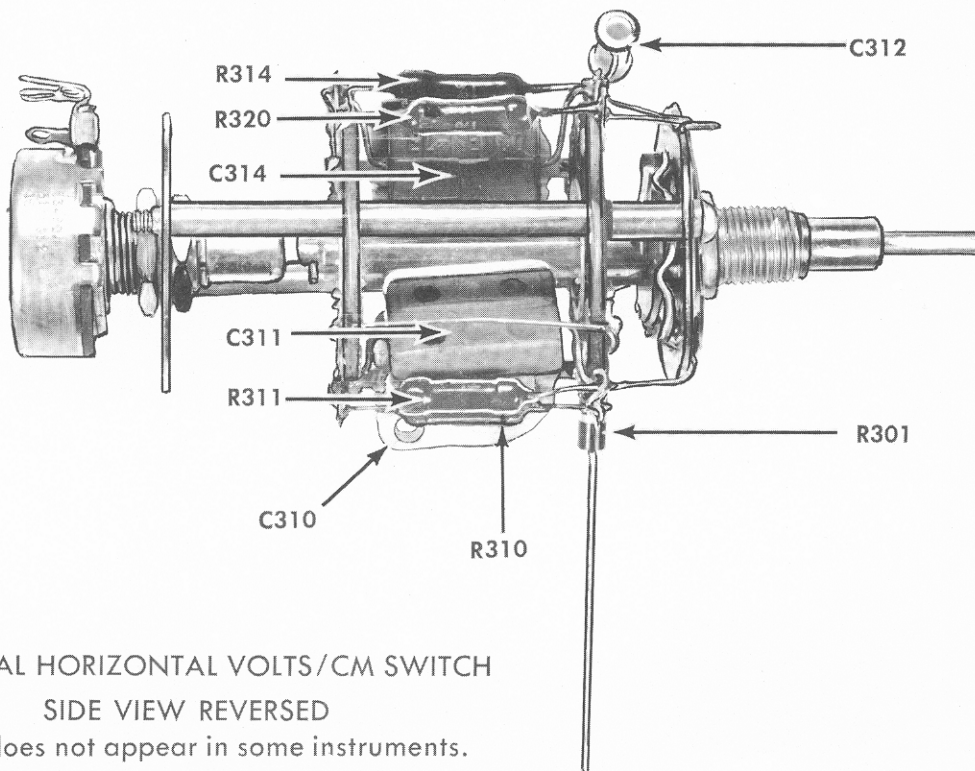
TIMING SWITCH



HORIZONTAL DISPLAY SWITCH

SIDE VIEW

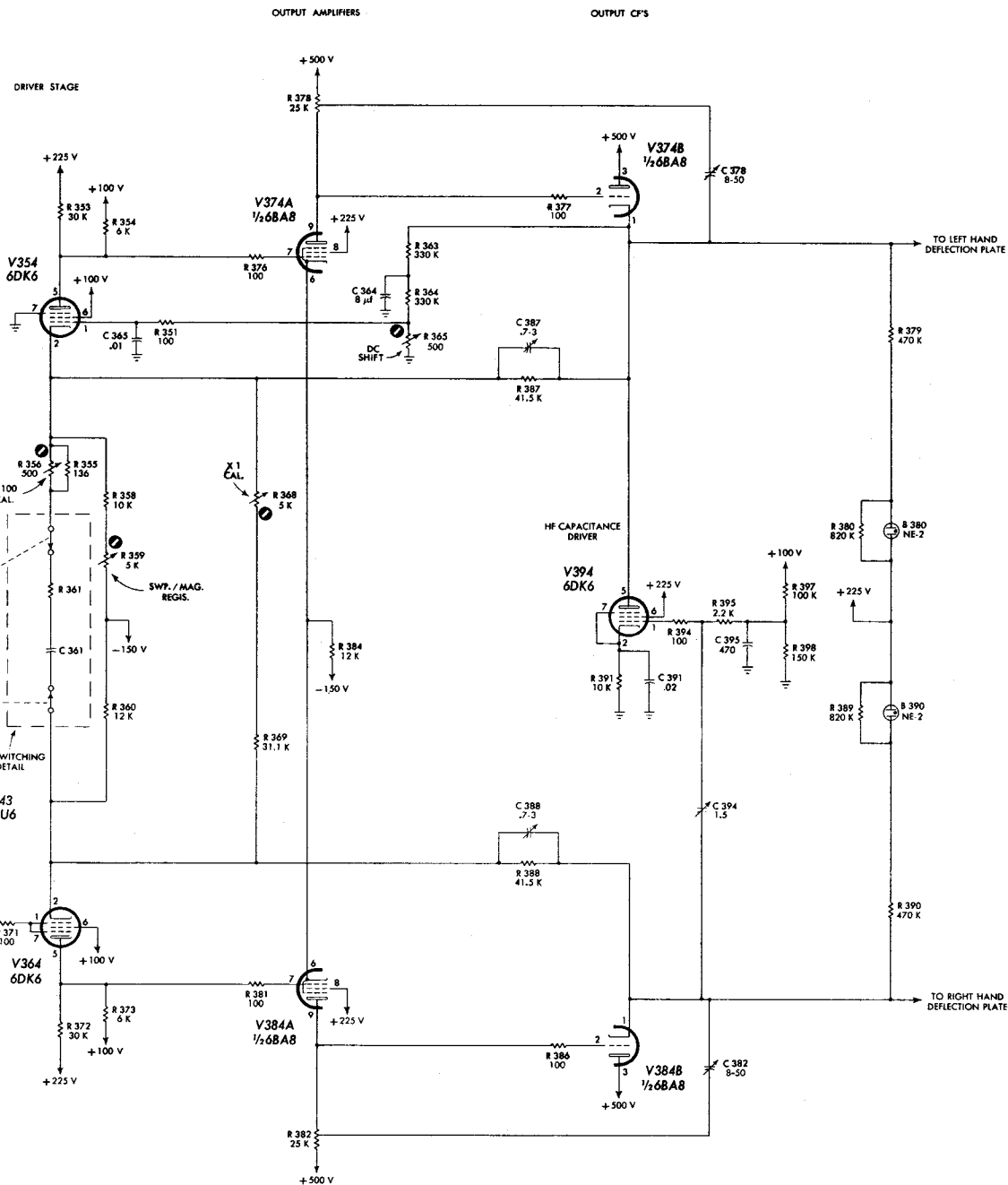
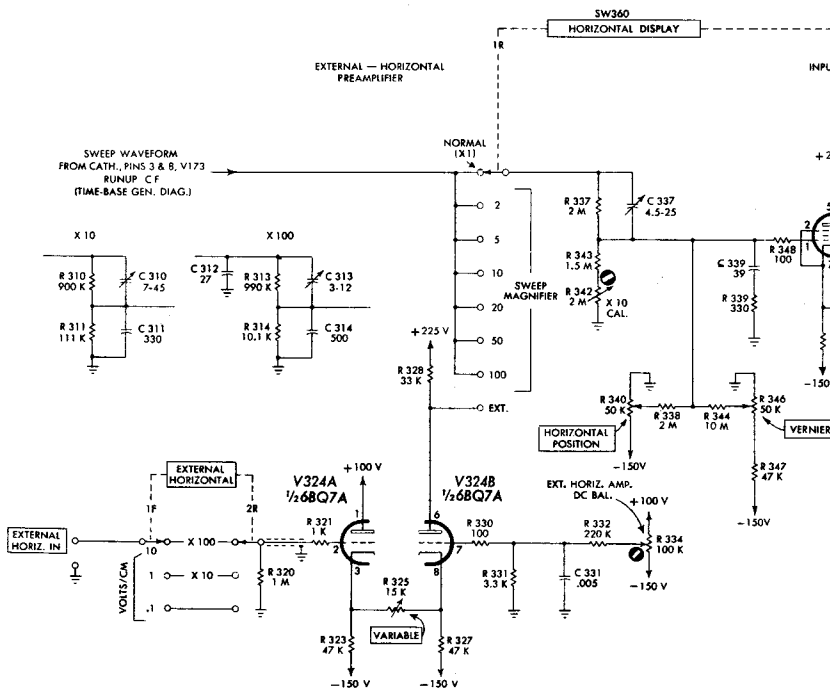
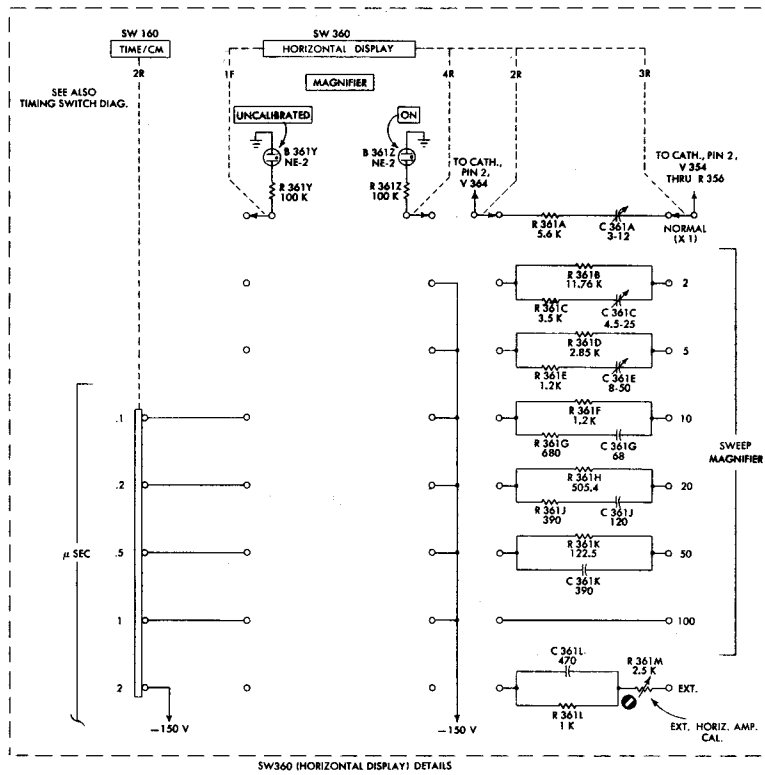
In some instruments C361G is a fixed capacitor, instead of variable as shown in the photograph.

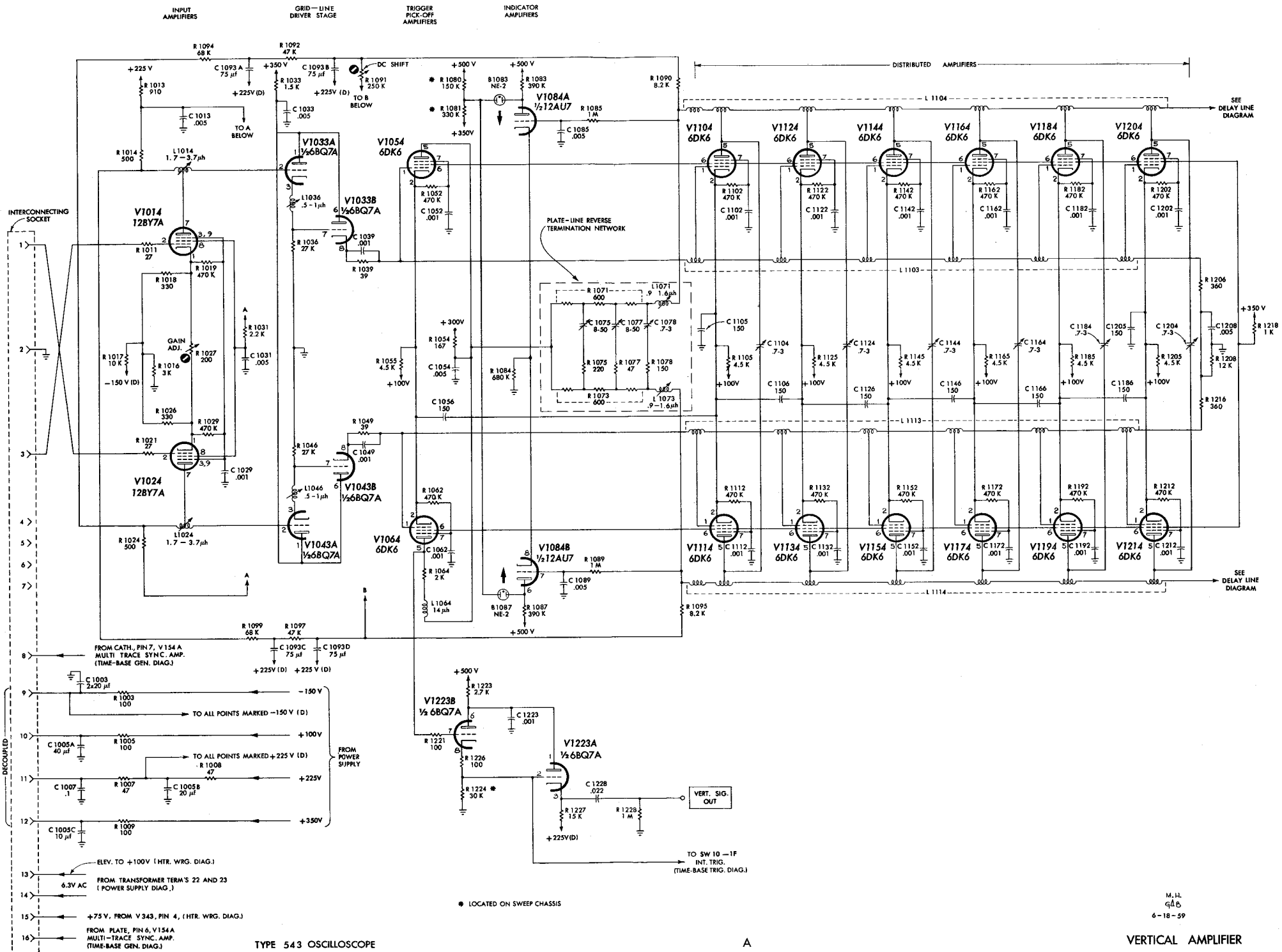


EXTERNAL HORIZONTAL VOLTS/CM SWITCH

SIDE VIEW REVERSED

R301 does not appear in some instruments.

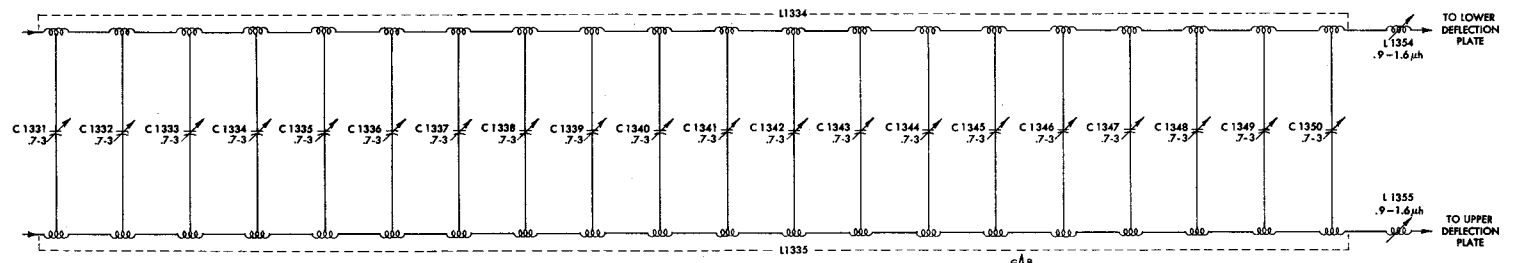
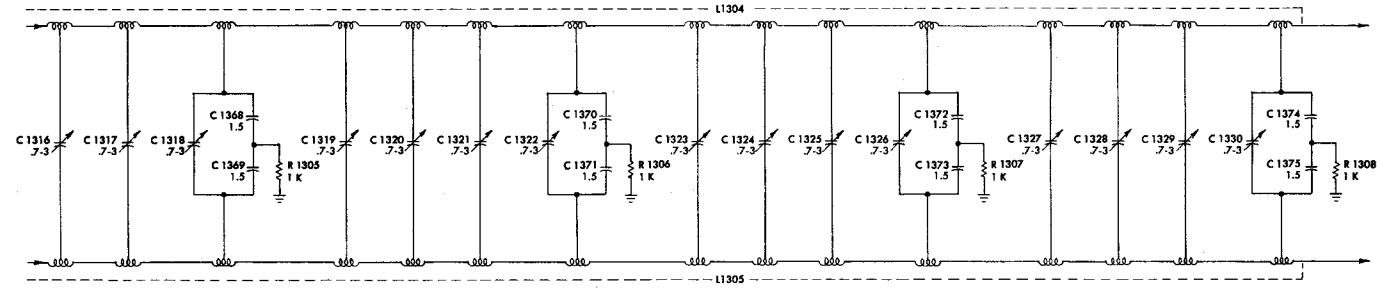
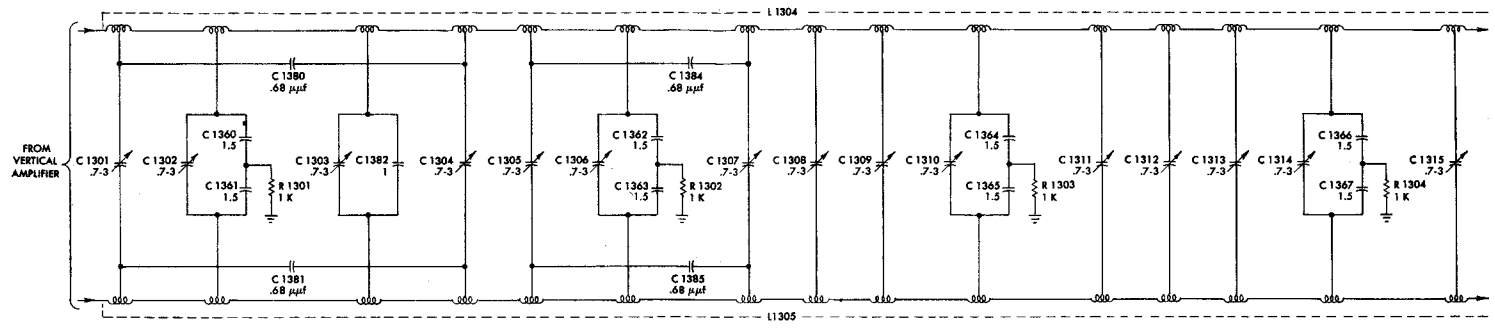




TYPE 543 OSCILLOSCOPE

A

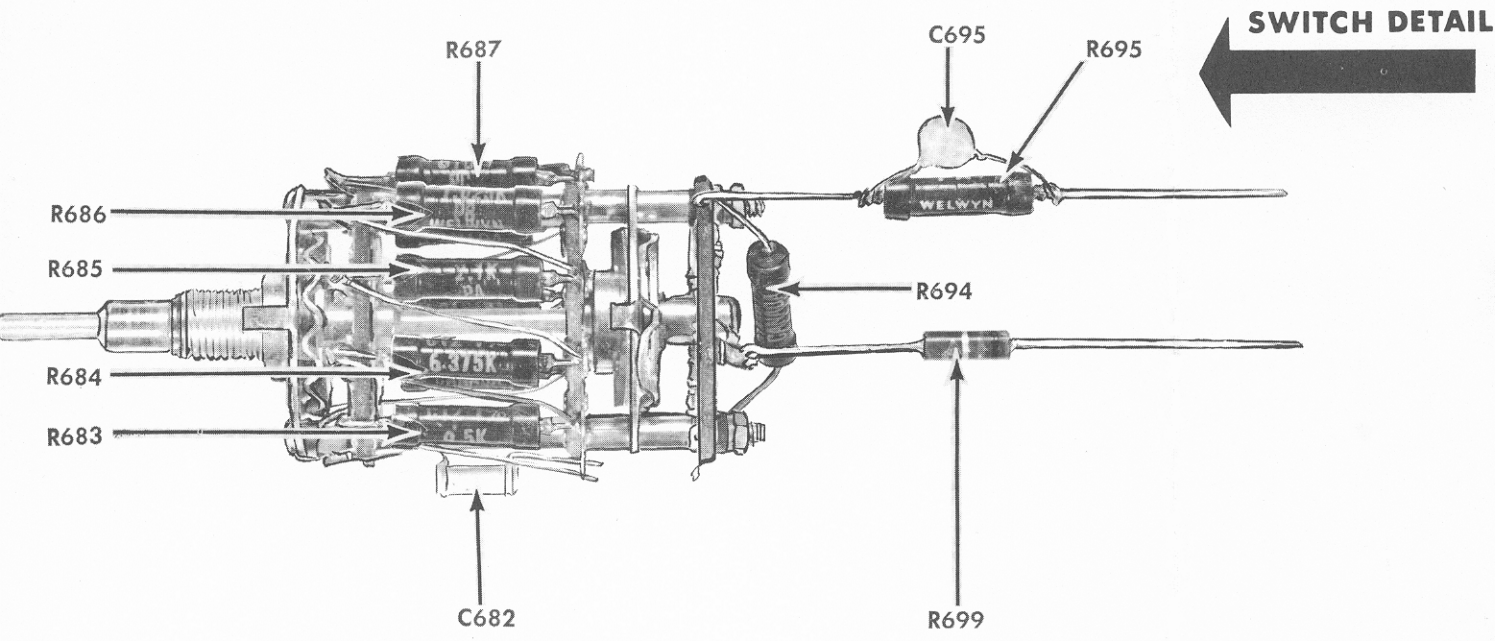
VERTICAL AMPLIFIER



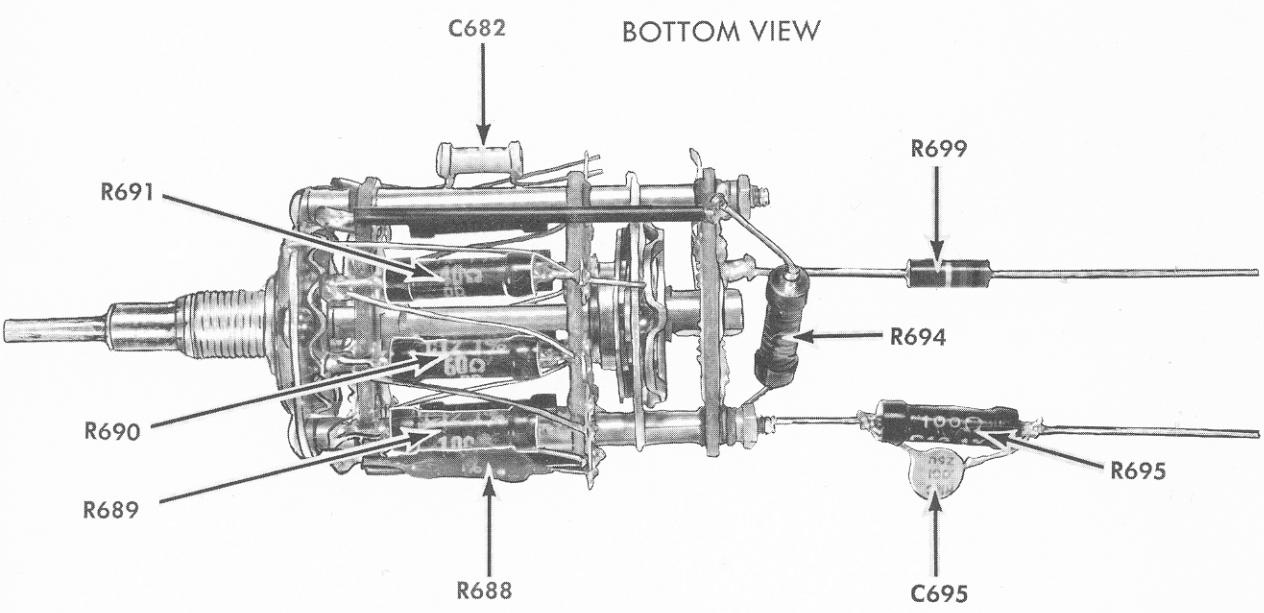
TYPE 543 OSCILLOSCOPE

A

6A5
6-18-59
DELAY LINE NETWORK

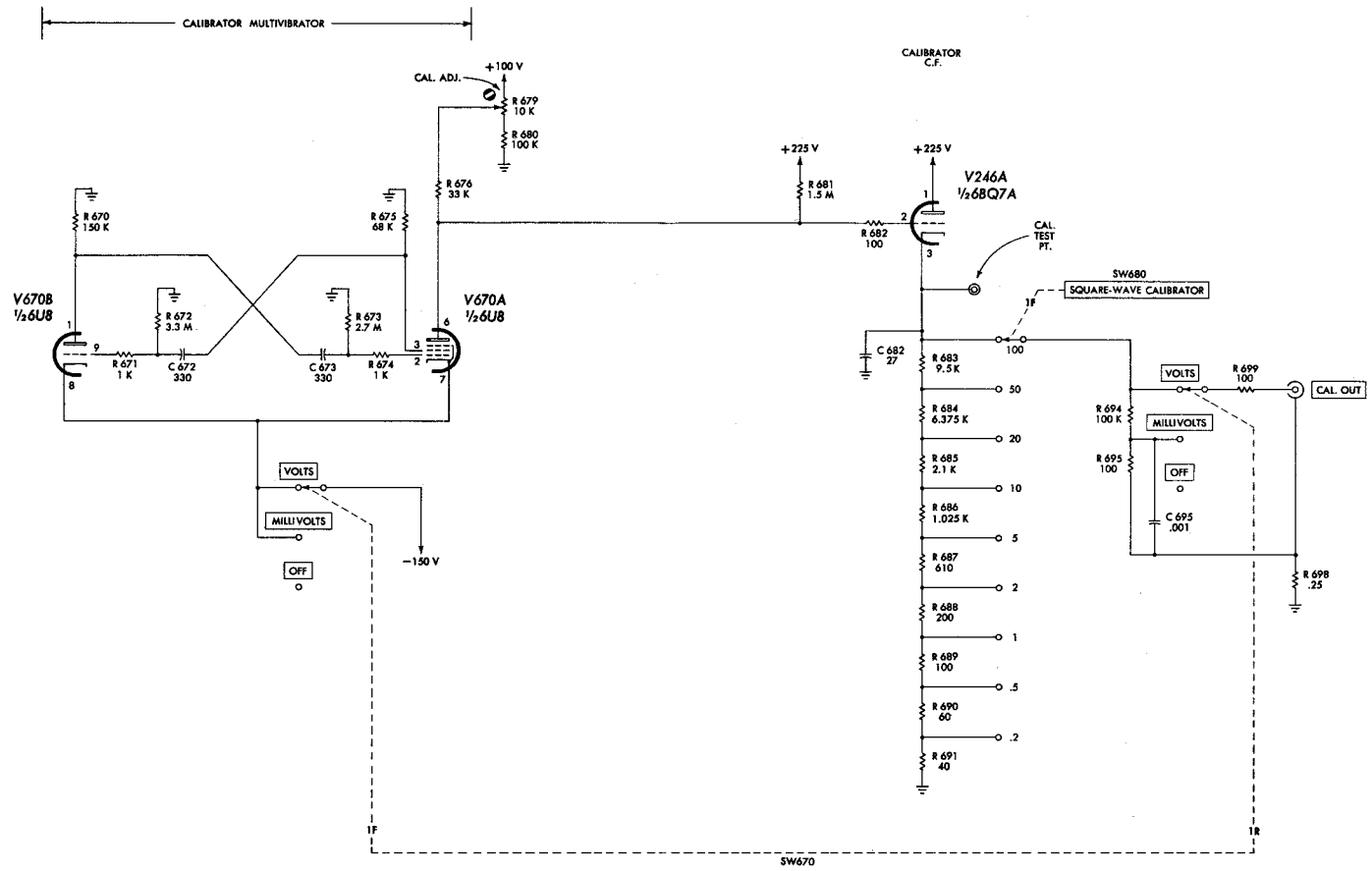


CALIBRATOR SWITCH
BOTTOM VIEW



CALIBRATOR SWITCH
TOP VIEW

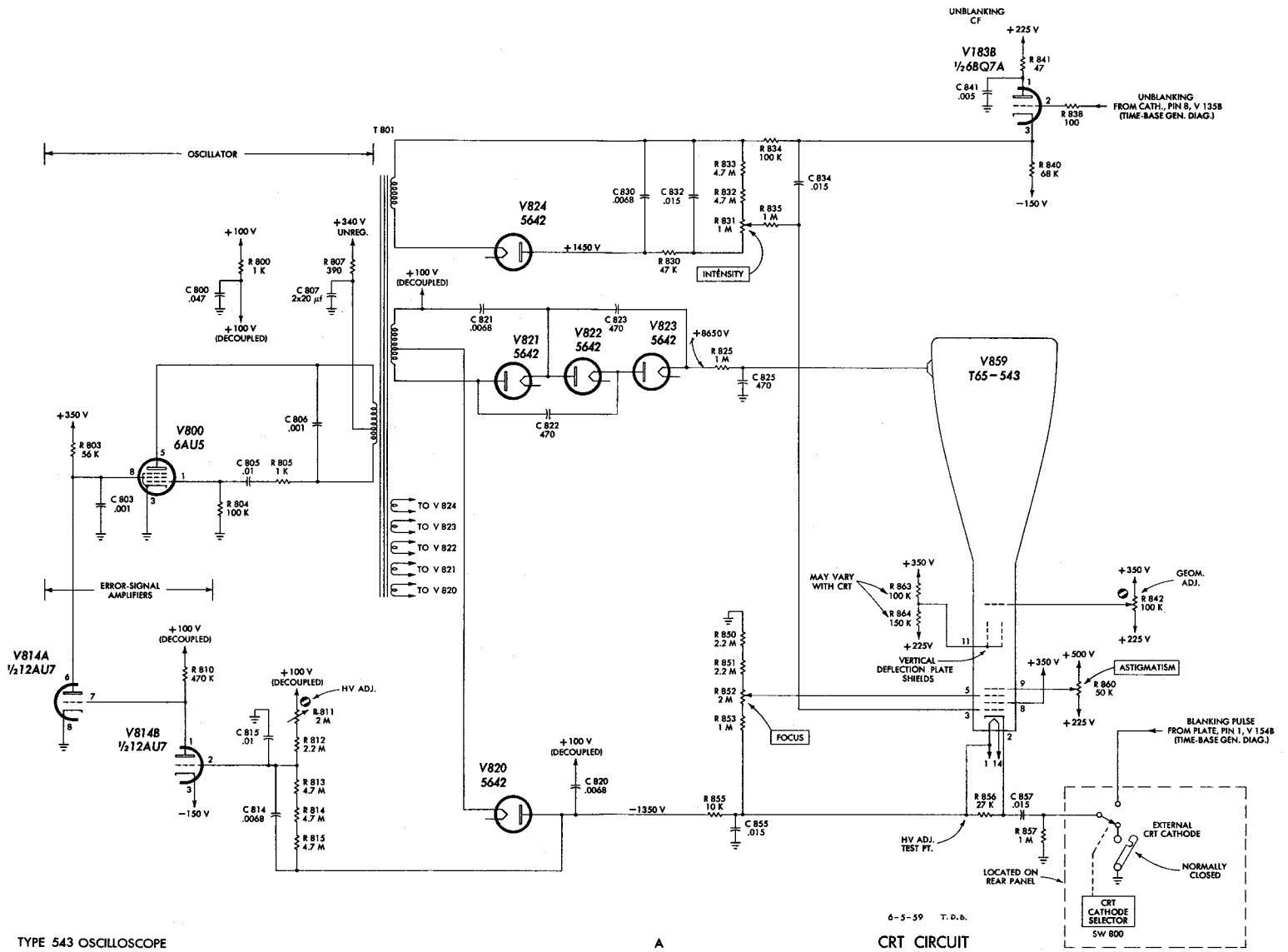
SWITCH DETAIL



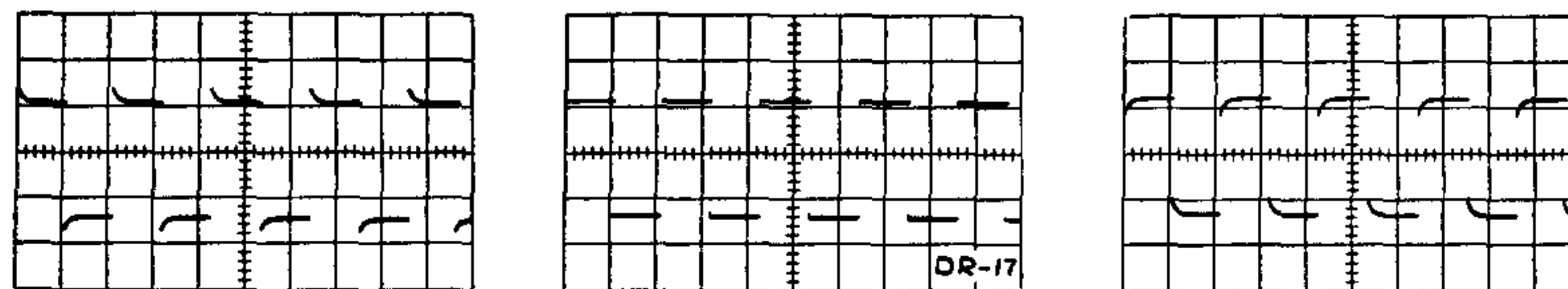
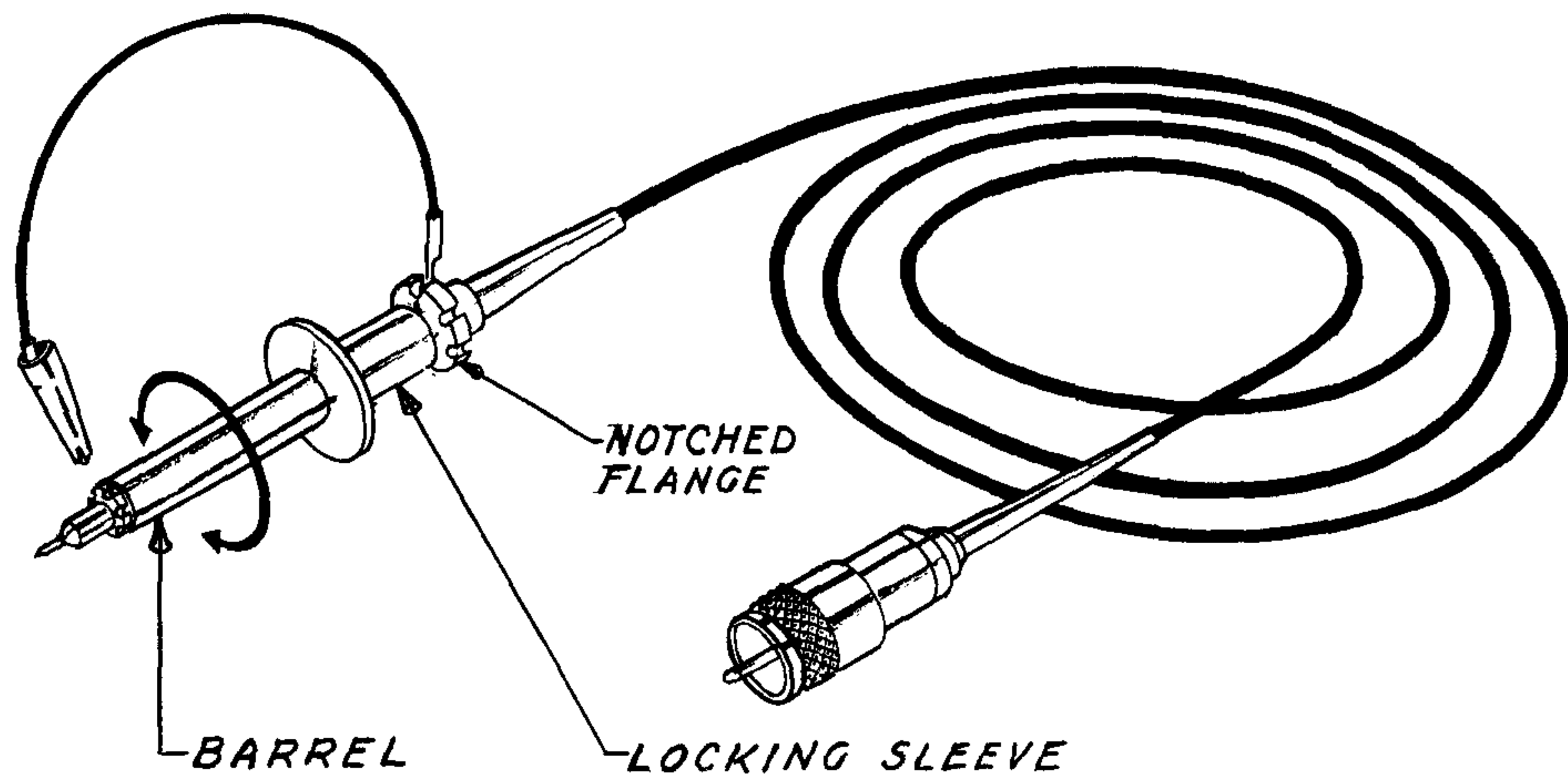
TYPE 543 OSCILLOSCOPE

A

T.D.B.
GAB
6-18-59
CALIBRATOR



P6000 PROBE



ADJUSTMENT PROCEDURE

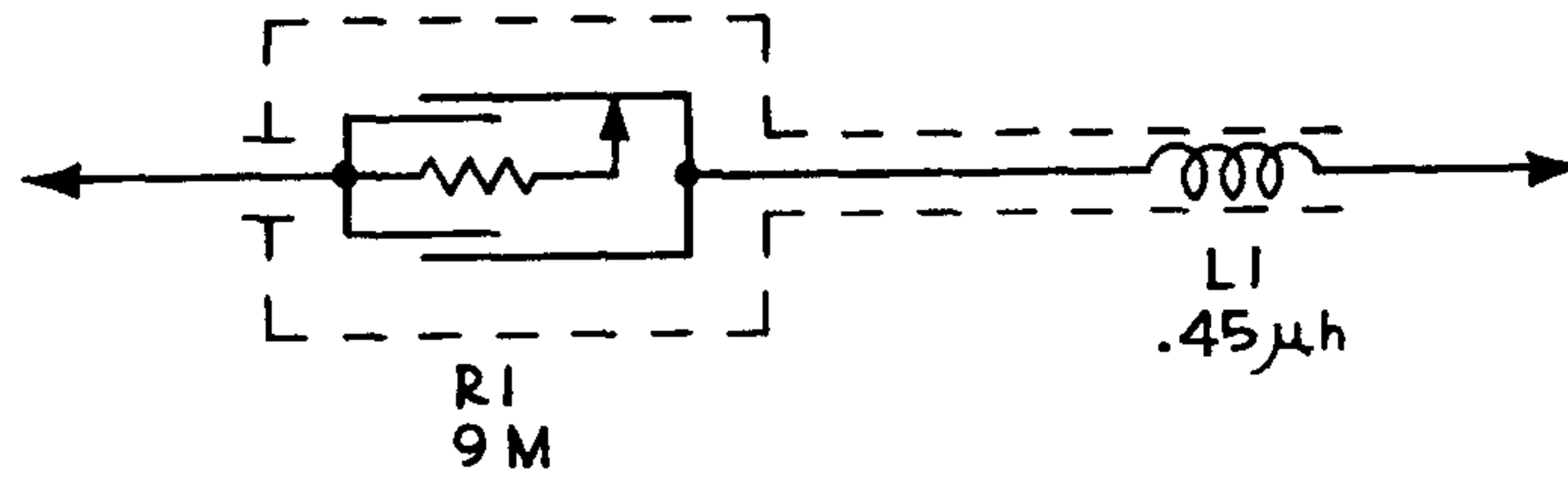
A Type P6000 Probe is furnished as an accessory with your oscilloscope. Connected to the INPUT connector of the oscilloscope, the probe presents an input characteristic of 10 megohms shunted by 10 micromicrofarads and has an attenuation ratio of 10:1. The maximum voltage which may be applied to the probe is 1200 volts. Exceeding this rating, either in peak ac volts or dc volts, may result in damage to the components inside the probe body.

An adjustable capacitor in the probe body compensates for variations in input capacitance from one instrument to another. To insure the accuracy of pulse and transient measurements, this adjustment should be checked frequently.

To adjust the P6000 probe, set the calibrator

control for a calibrator output signal of suitable amplitude. Touch the probe tip to the CAL. OUT connector and adjust the oscilloscope controls to display several cycles of the waveform. Unlock the probe for adjustment by turning the locking sleeve at the rear of the probe body 4 or 5 turns counterclockwise. Hold the probe firmly by the notched flange at the base of the probe, and adjust by turning the probe barrel for an optimum waveshape as shown in the center waveform illustration.

After a good flat-top square-wave is achieved, turn the locking ring clockwise until it is fairly snug but not tight. Holding the probe by the barrel, make fine adjustments by turning the notched flange. Then carefully turn the locking ring down tight.



P 6000 PROBE _{GAB}

PARTS LIST

6000 Complete Probe Assembly	010-020
6000 Probe Tip Assembly	206-015
6000 Ground Lead Assembly	175-039
6000 Probe Pincher Tip Assembly	013-027
6000 Tek-Tip, Hook	206-023
6000 Tek-Tip, Straight	206-034
6000 Probe Holder	352-024

TYPE 543 PARTS LIST MODIFICATIONS

NOTE: If, in troubleshooting your Type 543 Oscilloscope, you find that values of components in your instrument in some cases do not conform to those shown in the Parts List or Circuit Diagrams, refer to this list for modifications which may have changed the components since the original printing of your Instruction Manual. An X preceding the Serial Number information indicates the component was added at that Serial Number. If an X follows the Serial Number information, the component was removed from the circuit at that Serial Number.

CAPACITORS

Ckt. No.	S/N Range	Value	Description				Part No.
C10	461 and up	.0047 μ f	PTM	Fixed	400 v		285-561
C158	301 and up	12 μ μ f	Cer.	Fixed	+or-1.2 μ μ f		281-506
C361A	748 and up	1.5-7 μ μ f	Cer.	Var.			281-034
C361C	748 and up	1.5-7 μ μ f	Cer.	Var.			281-034
C361G	748 and up	8-50 μ μ f	Cer.	Var.			281-022
C361J	748 and up	8-50 μ μ f	Cer.	Var.			281-022
C361K	748 and up	100 μ μ f	Cer.	Fixed	350 v +or-20.0 μ μ f		281-523
C385	X398 and up	.005 μ f	Cer.	Fixed	500 v		283-001
C394	748 and up	1.5-7 μ μ f	Cer.	Var.			281-034
C787	1220 and up	.01 μ f	PTM	Fixed	600 v		285-511

INDUCTORS

L1014	319 and up	1.8-3.9 μ h	Var.				114-112
L1015	X660 and up	.45 μ h	Fixed				108-062
L1024	319 and up	1.8-3.9 μ h	Var.				114-112
L1025	X660 and up	.45 μ h	Fixed				108-062
L1036	319 and up	.3-.55 μ h	Var.				114-111
L1046	319 and up	.3-.55 μ h	Var.				114-111
L1064	600 and up	8.4 μ h	Fixed				108-157
L1304	1200 and up	Delay line	30 section				108-177
L1305	1200 and up	Delay line	30 section				108-177
L1334	1200 and up	Delay line	20 section				108-176
L1335	1200 and up	Delay line	20 section				108-176

RESISTORS

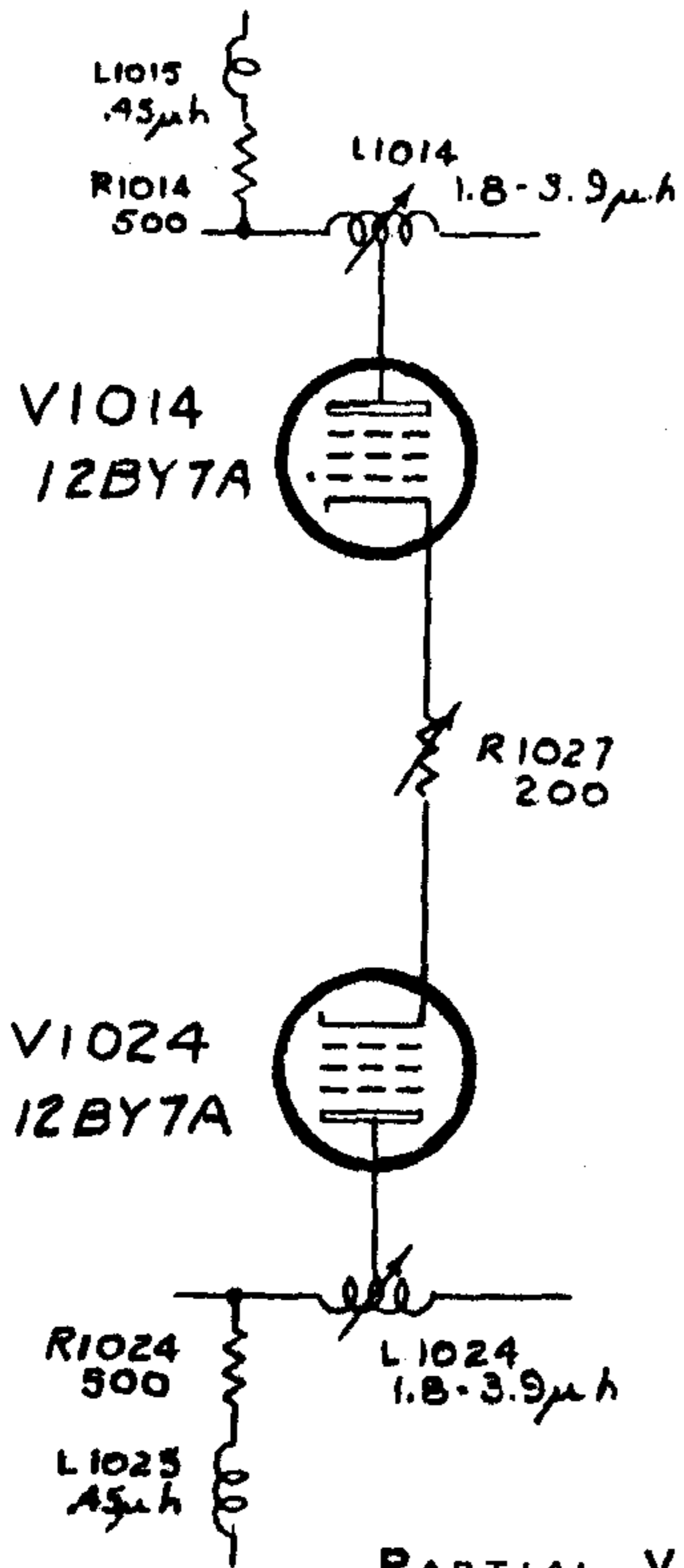
R20	301 and up	56 k	1/2 w	Fixed	Comp.	10%	302-563
R21	101-301X	56 k	1/2 w	Fixed	Comp.	10%	302-563
R35	301 and up	18 k	1 w	Fixed	Comp.	10%	304-183
R38	301 and up	18 k	1 w	Fixed	Comp.	10%	304-183
R40	301 and up	120 k	1/2 w	Fixed	Comp.	10%	302-124
R44	301 and up	1.5 k	1/2 w	Fixed	Comp.	10%	302-152
R46	301 and up	680 Ω	1/2 w	Fixed	Comp.	10%	302-681
R117	X519 and up	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R152	301 and up	68 k	1/2 w	Fixed	Comp.	10%	302-683
R157	X301 and up	1 k	1/2 w	Fixed	Comp.	10%	302-102
R158	301 and up	470 k	1/2 w	Fixed	Comp.	10%	302-474
R159	301 and up	3.3 k	2 w	Fixed	Comp.	10%	306-332
R160	316 and up	20 k		Var.	WW	10%	311-108
R301	X474 and up	47 Ω	1/2 w	Fixed	Comp.	10%	302-470

R323	1220 and up	33 k	2 w	Fixed	Comp.	10%	306-333
R325	103 and up	15 k	2 w	Var.	Comp.		311-112
R327	1220 and up	33 k	2 w	Fixed	Comp.	10%	306-333
R328	1220 and up	27 k	2 w	Fixed	Comp.	10%	306-273
R672	301 and up	3.9 meg	1/2 w	Fixed	Comp.	10%	302-395
R680	527 and up	68 k	1/2 w	Fixed	Comp.	10%	302-683
R730	X950 and up	22 Ω	2 w	Fixed	Comp.	10%	306-220
R731	X9500 and up	22 Ω	2 w	Fixed	Comp.	10%	306-220
R741	X950 and up	7.5 Ω	10 w	Fixed	WW	+or-5%	308-125
R753	X950 and up	1 w	1/2 w	Fixed	WW	+or-5%	308-141
R754	X950 and up	10 Ω	2 w	Fixed	Comp.	10%	306-100
R755	X950 and up	10 Ω	2 w	Fixed	Comp.	10%	306-100
R762	301 and up	2 k	20 w	Fixed	WW	5%	308-031
R775	X950 and up	22 Ω	2 w	Fixed	Comp.	10%	306-220
R776	X950 and up	22 Ω	2 w	Fixed	Comp.	10%	306-220
R785	381 and up	2 k	25 w	Fixed	WW	5%	308-065
R786	381 and up	2 k	25 w	Fixed	WW	5%	308-065
R1014	660 and up	500 Ω	1/2 w	Fixed	Prec.	1%	309-179
R1016	182 and up	3 k	5 w	Fixed	WW	5%	308-062
R1017	182 and up	10 k	8 w	Fixed	WW	5%	308-126
R1024	660 and up	500 Ω	1/2 w	Fixed	Prec.	1%	309-179
R1031	182 and up	2.2 k	1 w	Fixed	Comp.	10%	304-222
R1033	319 and up	2.5 k	5 w	Fixed	WW	5%	308-127
R1039	319 and up	33 Ω	1/2 w	Fixed	Comp.	10%	302-330
R1049	319 and up	33 Ω	1/2 w	Fixed	Comp.	10%	302-330
R1064	101-599X	2 k	1 w	Fixed	Comp.	5%	303-202
R1223	319 and up	4.7 k	2 w	Fixed	Comp.	10%	306-472

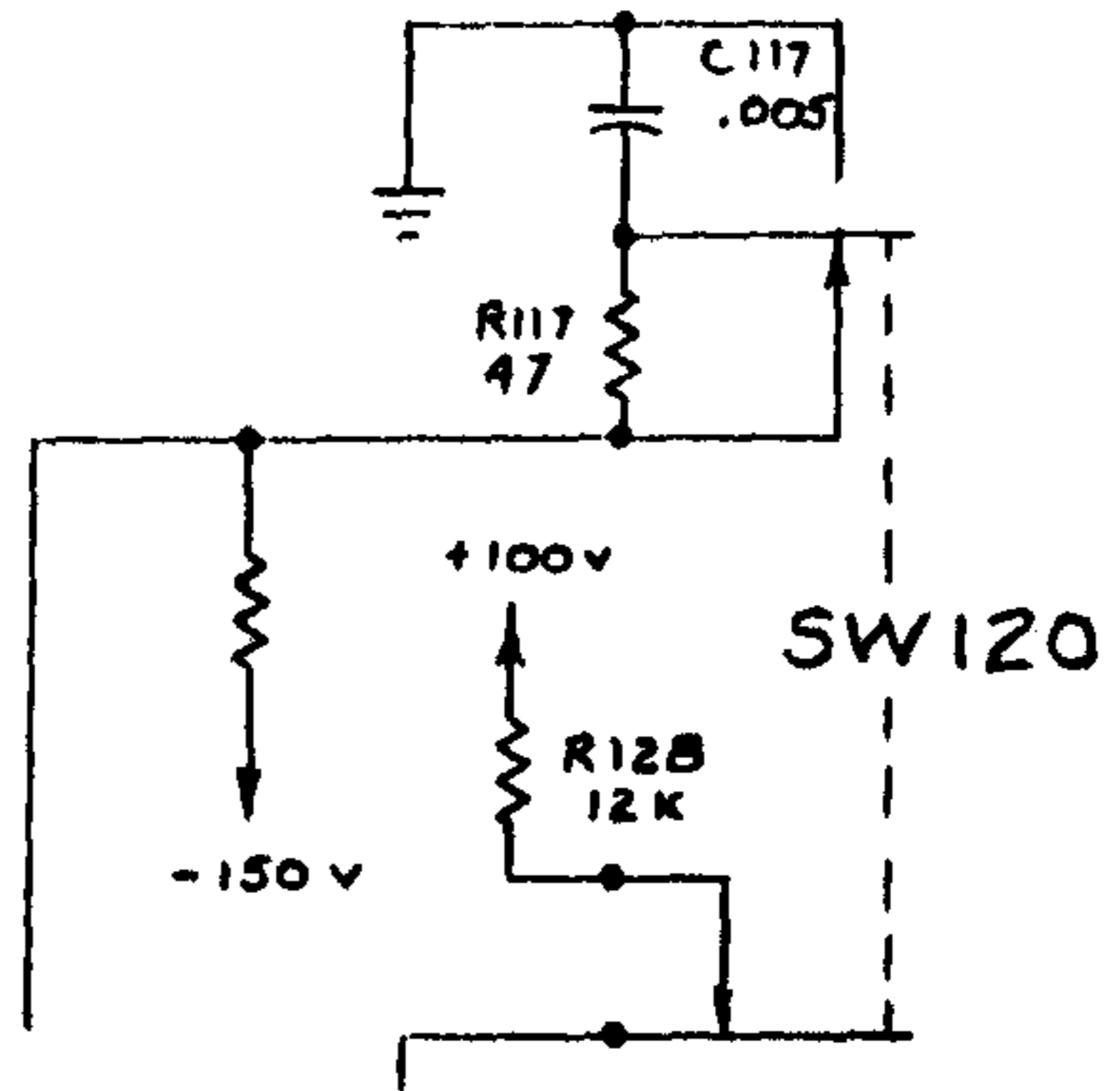
VACUUM TUBES

V24	301 and up	6DJ8	154-187
V45	301 and up	6DJ8	154-187
V133	301 and up	6DJ8	154-187
V135	301 and up	6DJ8	154-187
V154	301 and up	6DJ8	154-187
V173	301 and up	6DJ8	154-187
V183	301 and up	6DJ8	154-187
V193	301 and up	6DJ8	154-187
V246	301 and up	12AU7	154-041
V324	301 and up	6DJ8	154-187
V670	301 and up	6AU6	154-022
V732 A,B,C,D	X950 and up	Silicon Diodes	106-056
V740 A,B,C,D	X950 and up	Silicon Diodes	106-056
V752 A,B	X950 and up	Silicon Diodes	106-056
V756 A,B,C,D	X950 and up	Silicon Diodes	106-056
V780 A,B,C,D	X950 and up	Silicon Diodes	106-056
V790 A,B,C,D	X950 and up	Silicon Diodes	106-056
V1033	319 and up	6DJ8	154-187
V1043	319 and up	6DJ8	154-187
V1223	319 and up	6DJ8	154-187

SR732, SR740, SR752, SR756, SR780 and SR790 removed at Serial Number 950 when Silicon Diodes were substituted.

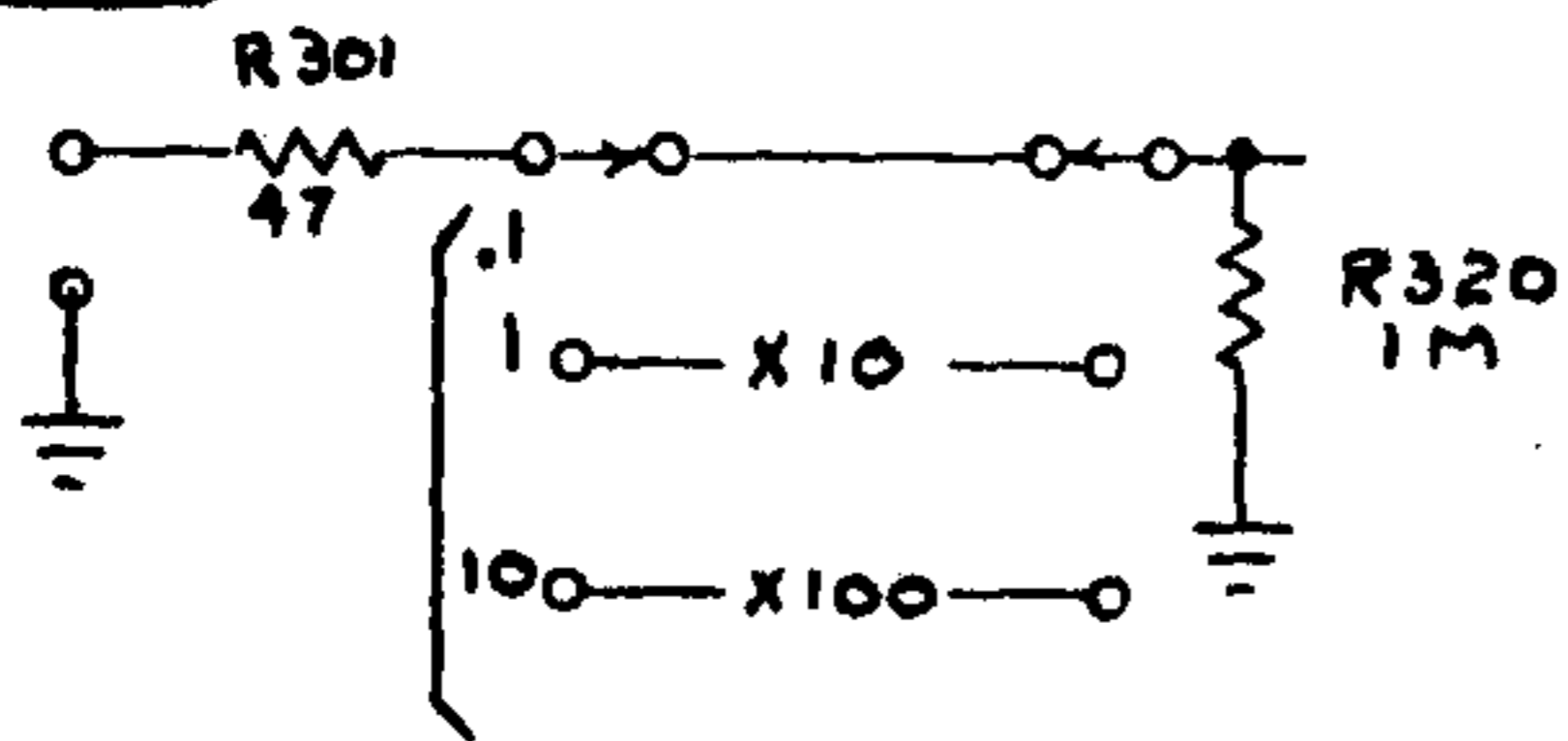


PARTIAL VERTICAL AMPLIFIER SCHEMATIC SHOWING LOCATION OF ADDED COMPONENTS L1015 AND L1025



PARTIAL TIME-BASE GENERATOR SCHEMATIC SHOWING LOCATION OF ADDED COMPONENT R117 IN LOCKOUT MULTIVIBRATOR

EXTERNAL HORIZ. IN



PARTIAL EXTERNAL HORIZONTAL AMPLIFIER SCHEMATIC SHOWING LOCATION OF ADDED COMPONENT R301

LOCATION OF ADDED CIRCUIT COMPONENTS