

INSTRUCTION MANUAL



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WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our own plant, are warranted for the life of the instrument.

Any questions with respect to the warranty mentioned above should be taken up with your Tektronix Field Engineer.

Tektronix repair and replacement-part service is geared directly to the field, therefore all requests for repairs and replacement parts should be directed to the Tektronix Field Office or Representative in your area. This procedure will assure you the fastest possible service. Please include the instrument Type and Serial number with all requests for parts or service.

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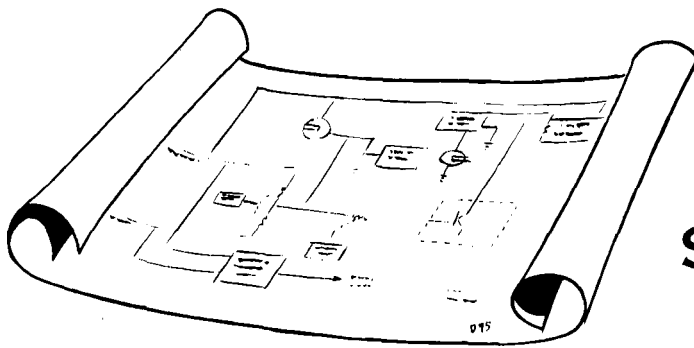
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Type 551



SPECIFICATIONS

The Type 551 Oscilloscope is a dual-beam, laboratory-type instrument, well suited to oscilloscope applications involving fast-rise pulses and transients. Separate, and

identical, vertical amplifiers are provided for each beam. Plug-in preamplifiers are used in the vertical-deflection systems, permitting the instrument to be used in many specialized applications.

TABLE I-I
INPUT CHARACTERISTICS

Plug-In	Deflection-Factor (Calibrated)	Pass Band	Risetime	*Input Characteristics
Type A	0.05 v/cm to 20 v/cm	dc to 18 mc	0.02 μ sec	47 μ f, 1 meg
Type B	0.05 v/cm to 20 v/cm 5 mv/cm to 0.05 v/cm	dc to 18 mc 5 cps to 10 mc	0.02 μ sec 0.035 μ sec	47 μ f, 1 meg 47 μ f, 1 meg
Type CA	0.05 v/cm to 20 v/cm	dc to 22 mc	0.016 μ sec	20 μ f, 1 meg
Type D	1 mv/cm to 50 v/cm	dc to 350 kc at 1 mv/cm increasing to 2 mc at 50 mv/cm		47 μ f, 1 meg
Type E	0.05 mv/cm to 10 mv/cm	0.06 cps to 60 kc— depending upon de- flection factor		50 μ f, 10 meg
Type G	0.05 v/cm to 20 v/cm	dc to 18 mc	0.02 μ sec	47 μ f, 1 meg
Type H	0.005 v/cm to 20 v/cm	dc to 14 mc	0.25 μ sec	47 μ f, 1 meg
Type K	0.05 v/cm to 25 mc	dc to 25 mc	0.014 μ sec	20 μ f, 1 meg
Type L	0.05 v/cm to 20 v/cm 0.005 v/cm to 2 v/cm	dc to 25 mc dc to 22 mc	0.014 μ sec 0.016 μ sec	20 μ f, 1 meg 20 μ f, 1 meg

Risetime—0.012 μ sec

Linear Deflection—4 cm for each beam. (2 cm overlap is available)

DC coupled

Delay Line—Balance Network Signal Delay —0.2 μ sec.

Delay Lines

The balanced delay lines delay the arrival of the vertical deflection signals at the crt plates 0.2 μ sec.

Special Purpose Plug-In Units

Type N

The Type N Sampling Unit is designed for use with Tektronix plug-in type Oscilloscopes. The sampling system

thus formed permits the display of repetitive signals with fractional nanosecond (10^{-9} second or nsec) risetimes. By taking successive samples at a slightly later time at each recurrence of the pulse under observation, the Type N reconstructs the pulse on a relatively long time-base. Specifications of the Type N include a risetime of 0.6 nsec, corresponding to a maximum bandpass of approximately 600 mc; a sensitivity of 10 mv/cm with 2 mv or less noise; and a dynamic range of ± 120 mv minimum linear range before overloading occurs. Accidental overload of ± 4 volts is permissible.

Type P

The Type P Plug-In Unit generates a fast-rise step-function test signal of known waveform, simulating the output of an ideally compensated Type K Unit driven with a Tektronix Type 107 Square-Wave Generator. The Type P permits the standardization of the main-unit vertical amplifier transient response of a Tektronix convertible oscilloscope. Risetime of

Specifications—Type 551

the Type P when used with a Type 581 or 585 Oscilloscope is approximately 4 nanoseconds. Pulse repetition rate is 240 step functions per second, with either positive or negative polarity. Step function amplitude is continuously adjustable between 0 and 3 major graticule divisions.

Type Q

The Type Q Plug-In Unit permits any Tektronix convertible oscilloscope to be operated with strain gages and other transducers. Excitation voltages for the strain gages and transducers are provided by the plug-in unit. The unit provides high gain, low noise, and extremely low drift. Frequency response of the Type Q Plug-In Unit is DC to 6 kc; risetime is approximately 60 microseconds. Strain sensitivity is calibrated in 10 steps from 10 microstrain per major graticule division to 10,000 microstrain per division, and is continuously variable between steps.

Type R

The Type R Plug-In Unit is a combined power supply and pulse generator which is used to measure the high-frequency characteristics of junction transistors by the pulse-response method. When the Type R Unit is used in an oscilloscope incorporating a delay line, a display may be obtained which shows delay time, risetime, storage time and falltime simultaneously. In addition, operation of a push-button switch connects a front-panel terminal directly to the input of the oscilloscope. This connection permits you to observe other waveforms, such as the input waveform of the transistor under test.

Specifications of the Type R include a risetime of less than 5 nanoseconds; pulse amplitudes in 8 fixed, calibrated steps from .05 to 10 volts, adjustable between steps—and pulse recurrence frequency of 120 pulses/sec.

Type S

The Type S Plug-In Unit is designed for use with Tektronix Wide-Band convertible oscilloscopes, with its primary application being as a diode tester. The crt switching display depicts voltage across a test diode as a function of time. Certain diode parameters, such as junction resistance, junction capacitance, and the stored charge at the junction, can be measured readily and reliably from the display. Performance of a diode in a particular circuit can be predicted by analyzing the recovery and "turn-on" characteristics. Since it is essentially a means for plotting voltage across an element while passing constant current through it, the unit can be used for other applications as well...for example, observing the junction characteristics of transistors, or to measure the resistance, capacitance or inductance of circuit components. The Type S offers calibrated forward currents in five fixed steps from 1 to 20 milliamps, and reverse currents calibrated in six steps from 0 to 2 milliamps. Diode shunt capacitance is 9 picofarads, and amplifier sensitivity measure 0.05 v/cm and 0.5 v/cm, calibrated.

Type Z

The Type Z Plug-In Unit extends the accuracy of oscilloscope voltage measurements. It can be used in three modes of operation: (1) as a conventional preamplifier, (2) as a differential input preamplifier, or (3) as a calibrated differential comparator. With sensitivity of 50 mv/cm and dynamic range of ± 100 volts, the effective scale length is ± 2000 cm; hence, the resolution of the Type Z Unit is a maximum of .005%. As a conventional preamplifier, the Type Z Unit offers a risetime of 24 nanoseconds for signals that do not overscan the screen, and sensitivities of 0.05 volts/cm to 25 volts/cm in 9 fixed, calibrated steps.

As a differential Input Preamplifier, the Type Z accepts a common-mode Signal Level of ± 100 volts with input attenuation X1; and offers a common-mode rejection ratio of 40,000 to 1. Input signals must not exceed +1 volt/7 nsec, or -1 volt/5 nsec in order to avoid grid current.

As a calibrated differential comparator, the Type Z makes available three comparison voltage ranges; from zero to ± 1 volt, zero to ± 10 volts, and zero to ± 100 volts.

HORIZONTAL-DEFLECTION SYSTEM

Sweep Rates

Twenty-four calibrated sweep rates from .1 $\mu\text{sec/cm}$ 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 .1 $\mu\text{sec/cm}$ to .12 sec/cm.

Magnifier

Expands sweep five times to the right and left of the crt-screen center. Extends the fastest sweep rate to .02 $\mu\text{sec/cm}$. Accurate within 5%.

Unblanking.

DC coupled.

Triggering Signal Requirements

Internal—2 mm of vertical deflection.

External—.2 v to 100 v, peak-to-peak.

Frequency range—dc to 5 mc.

Synchronizing Signal Requirements

Internal—2 cm of vertical deflection.

External—0.5 to 20 v, peak-to-peak.

Frequency range—5 mc to 30 mc.

External Horizontal Signal Input

Deflection factor—continuously variable from 0.2 v/cm to 20 v/cm.

Frequency response—dc to 400 kc, with maximum attenuation, dc to 100 kc with amplitude control at mid-range.

OTHER CHARACTERISTICS

Cathode-Ray Tube

Type T551 P2—P1, P7 and 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 0.2 mv to 100 v, peak-to-peak.

Accuracy—3%.

Output Waveforms

Positive gate of same duration as sweep, 20 volts.

Positive-going sweep sawtooth, 150 volts.

Beam-position Indicators

Indicator lamps to show which way either 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—850 watts at 117 v line voltage using two Type CA Plug-In Preamplifiers.

Mechanical Specifications

Ventilation—filtered, forced air is supplied to both units by independent fan systems.

Finish—photoetched, anodized panels. Blue wrinkle, perforated cabinets.

Dimensions—Indicator: 13" wide, 16³/₄" high, case 24" deep.

Power Supply—13¹/₂" wide, 10" high, case 17¹/₂" deep.

Weight—Indicator-52 pounds.

Power Supply—42 pounds.

Accessories

4—Type P6000 Attenuator Probes, 010-020.

2—Type A510 Binding-Post Adapters, 013-004.

1—Test Lead, 012-031.

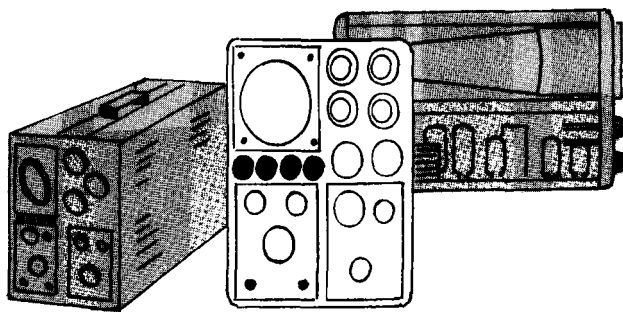
1—Type F510-5 Green Graticule Filter, 378-514.

2—Instruction Manuals.

1—3 to 2-wire Adapter, 103-013.

1—3-conductor power cord, 161-010.

1—Type W160 Interconnecting Cable, 012-032.



SECTION 2

GETTING ACQUAINTED

To help you get acquainted with your Type 551, we have outlined in this section some of the more frequently encountered oscilloscope applications.

The oscilloscope provides us with the means of actually looking at waveforms we are interested in. To accomplish this, we feed the waveforms into the input connectors on the oscilloscope so that the display on the screen shows how the voltage of the waveforms changes with time.

The following instructions illustrate the use of the Type 551 in conjunction with the two Type A Plug-In Preamplifiers. The square-wave calibrator of the oscilloscope is used for the vertical signal in this demonstration.

Initial Control Settings

Insert the Type A Plug-In Units into the UPPER BEAM and LOWER BEAM plug-in receptacles in the front panel of the oscilloscope.

Set the front-panel controls as follows:

Type 551:

FOCUS	centered
INTENSITY	full left (counterclockwise)
ASTIGMATISM	centered
SCALE ILLUM.	centered
TIME/CM (black)	.5 MILLISEC
VARIABLE (red)	CALIBRATED
HORIZONTAL DISPLAY (black)	NORMAL
SINGLE SWEEP (red)	OUT
STABILITY	PRESET
TRIGGERING LEVEL	full left or full right
TRIGGERING MODE	AUTO.
TRIGGER SLOPE	+UPPER
HORIZONTAL POSITION	centered
VERNIER (red knob)	centered
SQUARE-WAVE CALIBRATOR (black)	10
SQUARE-WAVE CALIBRATOR (red)	VOLTS
POWER	ON

Type A (both units):

INPUT SELECTOR	INPUT A, AC
VOLTS/CM	5
VARIABLE	CALIBRATED
VERTICAL POSITION	centered

Turn the INTENSITY control to the right until a horizontal trace of useful brightness appears on the screen. Adjust the FOCUS and ASTIGMATISM controls for the sharpest trace. Connect a pair of leads from the CAL. OUT connector to the INPUT A connectors of both plug-ins. The display on the screen should now be two square waves, positioned one above the other. Slightly readjust the ASTIGMATISM, FOCUS, and INTENSITY controls so that the display has the best sharpness and suitable brightness as shown in Fig. 3-1. Center the display on the graticule, each square-wave about its own center line, by means of the VERTICAL- and HORIZONTAL-POSITION controls.

Triggering in the Automatic Mode

The SQUARE-WAVE CALIBRATOR waveform you have been looking at is a periodic signal—that is, recurs at regular intervals. We got a stable (stationary) display of this waveform by setting the oscilloscope controls so that each horizontal sweep of the spot across the screen started at a given point on the waveform. These settings were given in the table above. For present purposes then, the starting of each horizontal sweep across the screen can be called "triggering" the sweep. As in the procedure above, this can be accomplished with a minimum of adjustment by setting the red TRIGGERING MODE knob in the AUTO. position. That is, we used the AUTO. mode of triggering.

Because of its simplicity of operation, the AUTO. mode is one of the most useful triggering modes. In particular, you don't have to adjust the TRIGGERING LEVEL or STABILITY controls when you use the AUTO. mode. Uses of these controls are described later in this manual.

EFFECTS OF THE TYPE A PLUG-IN CONTROLS

Effect of the Input Selector Switch

Turn the INPUT SELECTOR switch of the UPPER BEAM plug-in unit to INPUT A, DC. Notice the vertical shift in the position of the trace. This is due to the fact that the output

Getting Acquainted—Type 551

waveform from the SQUARE-WAVE CALIBRATOR has both an ac (square wave) component and a dc component. When the INPUT SELECTOR switch is in the AC position, the effect of the DC component of the waveform is excluded from the display. When this switch is in the DC position, the display indicates both the ac and dc component of the waveform being viewed. The dc component of the waveform causes the entire display to rise or fall on the screen.

With the INPUT SELECTOR switch, you can select for display either a signal fed into the INPUT A connector or a signal fed into the INPUT B connector. This arrangement is provided so that you can quickly compare the two waveforms.

With no signal source connected to INPUT B, turn the INPUT SELECTOR switch to INPUT B, AC. Since no signal is now being displayed, only a horizontal reference trace will appear on the screen. Now remove the SQUARE-WAVE CALIBRATOR lead from the INPUT A connector and connect it to INPUT B. The square-wave display should now reappear on the screen.

Now return the SQUARE-WAVE CALIBRATOR lead to the INPUT A connector and reset the INPUT SELECTOR switch to INPUT A, AC. This again produces the square-wave display.

Effects of the Volts/Cm Controls

Turn the black VOLTS/CM knob on either plug-in successively to positions both to the right and left of the 5 position. Notice that when you set the VOLTS/CM switch to higher-numbered positions, the amount of vertical deflection produced on the screen by the SQUARE-WAVE CALIBRATOR waveform is reduced, and vice versa.

Reset the black VOLTS/CM knob to the 5 position.

Turn the red variable knob to the left. Notice that this reduces the amount of vertical deflection produced on the screen by the SQUARE-WAVE CALIBRATOR waveform.

Preset the VARIABLE control to the CALIBRATED position.

The above operations point up the fact that the VOLT/CM switch (black knob) and the VARIABLE control (red knob) provide control to the amount of vertical deflection which results from feeding a waveform having a given peak-to-peak voltage into the INPUT connector.

Effect of the Vertical Position Control

Turn the VERTICAL POSITION control back and forth, and notice that this raises and lowers the display on the screen. Note especially that if you position the display off the graticule in either direction, one or both of the beam-position indicator lamps, located above the graticule, will indicate in which direction the display is positioned off the screen. This tells you which way to turn the VERTICAL POSITION control to bring the display back on the screen.

Notice that, as you position the upper beam toward the bottom of the graticule, the upper beam display disappears approximately at the center line of the lower beam. Similarly, as you position the lower beam toward the top of the graticule it disappears at approximately the center line of the upper beam.

With the VERTICAL POSITION controls of both the UPPER BEAM and LOWER BEAM plug-ins, position both displays at the center of the graticule. You will notice that the square wave appears to consist of a single display when this is done. Waveform comparisons may be made easily by using the center two centimeters of the graticule in this manner.

EFFECT OF THE TYPE 551 OSCILLOSCOPE CONTROLS

Effect of the Horizontal Position Control

Turn the HORIZONTAL POSITION control back and forth and notice that the display moves to the left and right of the screen. Note especially that if you position the knob to the extreme right, one of the beam position indicators (located above the graticule) will indicate that the display is positioned off center towards the right.

Now reset the HORIZONTAL POSITION control to return the display to the center of the screen.

Effect of the Time/CM Controls

Turn the black TIME/CM knob successively to positions both to the right and left of the .5 MILLISEC position. Notice that the display expands or contracts horizontally as the switch is turned.

Reset the TIME/CM switch to the .5 MILLISEC position.

Rotate the red VARIABLE knob. Notice that as you do so the display contracts horizontally. Turn the red knob to the CALIBRATED position and then slightly away from the CALIBRATED position. Notice that as soon as the red knob leaves the CALIBRATED position, the UNCALIBRATED light will light.

Return the red VARIABLE knob to the CALIBRATED position.

The above operations point up the fact that the TIME/CM and VARIABLE controls provide control of the sweep rate, and thus of the number of cycles of the display which appear on the screen when a waveform having a fixed repetition rate is displayed.

Effect of the 5X Magnifier

Turn the HORIZONTAL DISPLAY switch to the 5X MAG. position. Observe that as you do so, the MAG. ON light comes on. Turn the HORIZONTAL DISPLAY switch from 5X MAG. to NORMAL and back several times. Observe that the portion of the display which occupies the middle two centimeters of the graticule is expanded to fill the entire graticule length when the HORIZONTAL DISPLAY switch is turned to the 5X MAG. position.

With the HORIZONTAL DISPLAY switch in the 5X MAG. position, turn the HORIZONTAL POSITION control through its range and notice that the display has been expanded throughout its entire length.

Now reset the HORIZONTAL DISPLAY switch to the NORMAL position.

Effect of the Trigger Slope Switch

Carefully observe that part of the display which appears at the left-hand end of the graticule. Notice that the trace begins during the rising portions of the square waves. That is, the sweep is triggered at a time when the slope of the wave is positive (see Fig. 2-1). This is because the black TRIGGER SLOPE knob is set at +UPPER rather than at -UPPER.

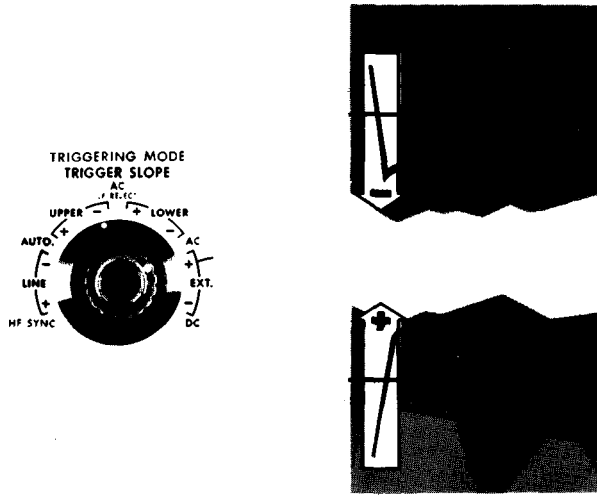


Fig. 2-1. The setting of the TRIGGER SLOPE switch determines whether the display will start during the rise (+ slope) or fall (-slope) of the triggering waveform.

Now turn the TRIGGER SLOPE knob to -UPPER. Observe that both traces appear to turn upside down, so that they now begin during the falling portion of the square wave, at the left-hand end of the graticule. That is, the sweep is triggered at a time when the slope of the wave is negative. Note that one of the purposes of the TRIGGER SLOPE switch is to provide control over whether the sweep is triggered when the slope of the waveform is positive, or whether the sweep is triggered when the slope of the waveform is negative.

Now turn the TRIGGER SLOPE switch to -LOWER. Observe that the display has the same appearance that it had when the TRIGGER SLOPE switch was in the -UPPER position. This is because the sweep is triggered when the slope of the square wave is negative, as was the case when the TRIGGER SLOPE switch was in the -UPPER position. Now turn the TRIGGER SLOPE switch to the +LOWER position. Notice that the display has the same appearance in the +LOWER and +UPPER positions of the TRIGGER SLOPE switch.

Further use of the TRIGGER SLOPE knob will be described in the Operating Instructions under the heading "Horizontal Deflection System".

Now return the TRIGGER SLOPE knob to the +UPPER position.

The AC Triggering Mode

Check that the TRIGGER SLOPE switch is set at +UPPER, that the TRIGGERING LEVEL control is turned full right or full left, and that the STABILITY control is at PRESET. Turn the red TRIGGERING MODE switch to AC. The trace should now disappear from the screen.

Slowly turn the TRIGGERING LEVEL control toward the center of its range until the trace reappears; adjust this control for a stable display of the two waveforms. Triggering is now being effected in the AC mode.

Remove the SQUARE-WAVE CALIBRATOR lead from the INPUT A connector of the UPPER BEAM plug-in. Note that this causes the display to disappear. Now reconnect the SQUARE-WAVE CALIBRATOR lead to the INPUT A connector of the UPPER BEAM plug-in so that the display reappears.

Remove the SQUARE-WAVE CALIBRATOR lead from the INPUT A connector of the LOWER BEAM plug-in. Note that the square-wave display of the lower beam is replaced by a horizontal reference trace, while the upper beam display is unaffected. This is because the sweep is triggered from the waveform displayed by the UPPER BEAM.

Now reconnect the SQUARE-WAVE CALIBRATOR lead to the INPUT A connector of the LOWER BEAM plug-in.

Slowly turn the TRIGGERING LEVEL control several times back and forth throughout its range from - through +. Carefully observe the left-hand end of the display while you do this. Note that there is a certain part of the range of this control that provides a display; settings too far toward the - or + marks on the panel result in no display.

Also notice that, in that part of the range of the TRIGGERING LEVEL control where you get a display, this control determines the height or "level" of the point on the waveform where the trace starts. If you set this control more toward the + part of its range, the display starts higher on the waveform (see Fig. 2-2). Since the TRIGGER SLOPE knob is set at +UPPER, the display in each case starts on the rising part of the waveform (where the slope is positive).

Next, set the VOLTS/CM control on the UPPER BEAM plug-in to 10. The display will now be smaller and may disappear from the screen. If the display does disappear, turn the TRIGGERING LEVEL control towards its mid-range position (indicated by the 0 on the front panel). By carefully ad-

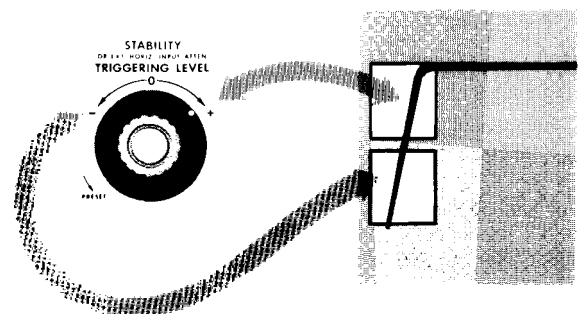


Fig. 2-2. With the TRIGGER SLOPE switch at +UPPER in the AC triggering mode, the TRIGGERING LEVEL control determines the point on the rising part of the UPPER-BEAM waveform at which the display will start.

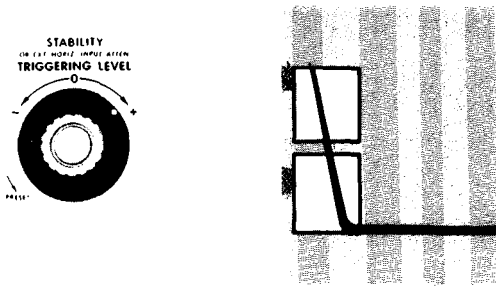


Fig. 2-3. With the TRIGGER SLOPE switch at —UPPER in the AC triggering mode, the TRIGGERING LEVEL control determines the point on the falling part of the UPPER-BEAM waveform at which the display will start.

justing this control a point will be found near the 0 mark which will return the display to the crt screen. Notice that the range of settings for the TRIGGERING LEVEL control is also reduced. Conversely, as the signal amplitude is increased, reliable triggering is possible over a wider range of settings of the TRIGGERING LEVEL control and selecting the desired starting point for the display will be correspondingly easier.

Return the VOLTS/CM switch of the UPPER BEAM plug-in to 5.

Now turn the TRIGGER SLOPE knob to —UPPER, so that the waveform appears upside down—that is, it starts on the falling part of the waveform (where the slope is negative). Repeat the observations of the previous paragraph, and note that you can still control the height of the point where the trace starts by means of the TRIGGERING LEVEL control (see Fig. 2-3).

Reset the TRIGGER SLOPE knob to +UPPER. Now turn the VERTICAL POSITION control of the UPPER BEAM plug-in back and forth, so that the display is moved up and down on the graticule. Observe the left-hand end of the display while you do this. Notice that, for a fixed setting of the TRIGGERING LEVEL control, the trace always starts at the same point on the waveform, regardless of the setting of the VERTICAL POSITION control.

The information given in these Getting Acquainted instructions, for the AC triggering mode, applies as well to the AC LF REJECT mode. The two modes are different in that the AC mode responds to signals well below the lower frequency limit of the AC LF REJECT mode. This difference is difficult to demonstrate with the SQUARE-WAVE CALIBRATOR waveform, and for that reason, a demonstration of the AC LF REJECT mode is not included in these instructions.

These brief statements can be made to compare the AC, AC LF REJECT, and AUTO. modes of triggering:

1. It is necessary to adjust the TRIGGERING LEVEL control when you use the AC and AC LF REJECT mode of triggering, but not when you use the AUTO. mode.
2. When you use the AUTO. mode you get a desirable horizontal reference trace on the screen, even when no input signal is used. This will be especially handy when you are testing equipment by moving the probe from one point to another in the equipment. When you use AC or AC LF REJECT modes, no trace appears when there is no input signal.

3. In the AC and AC LF REJECT modes the TRIGGERING LEVEL control provides control of the height or "level" at which the trace starts on the waveform being observed. The TRIGGERING LEVEL control is inoperative in the AUTO. mode.

4. The AUTO. mode is useful when you are looking at periodic waveforms. The AC and AC LF REJECT modes are useful for both periodic waveforms and for waveforms which occur only once.

The DC Triggering Mode

After completing the previous operations, use the VERTICAL POSITION control to center the display vertically on the screen. Set the TRIGGERING LEVEL control for a stable display with the control located as close as possible to 0.

Turn the TRIGGERING MODE switch to DC. If necessary, readjust the TRIGGERING LEVEL control for a stable display. You are now triggering in the DC mode.

Slowly turn the TRIGGERING LEVEL control several times back and forth throughout its range from —, through 0, and to +. Carefully observe the left-hand end of the display while you do this. Note that the results are very like those you get when you use the AC and AC LF REJECT modes.

Turn the TRIGGER SLOPE switch to —UPPER, and repeat the above operation. Again note that the results are similar to those you obtained when you used the AC and AC LF REJECT modes. Return the TRIGGER SLOPE switch to +UPPER.

Now turn the VERTICAL POSITION control back and forth, so that the display is moved up and down on the graticule. Observe the left-hand end of the display while you do this. Notice that, for a given setting of the TRIGGERING LEVEL control the trace always starts at a given point on the graticule, regardless of the setting of the VERTICAL POSITION control (see Fig. 2-4). (If you position the trace too high or too low, so that the waveform doesn't include this starting point, the trace disappears.) When the TRIGGERING LEVEL control is set near 0, the starting point will be near the cen-

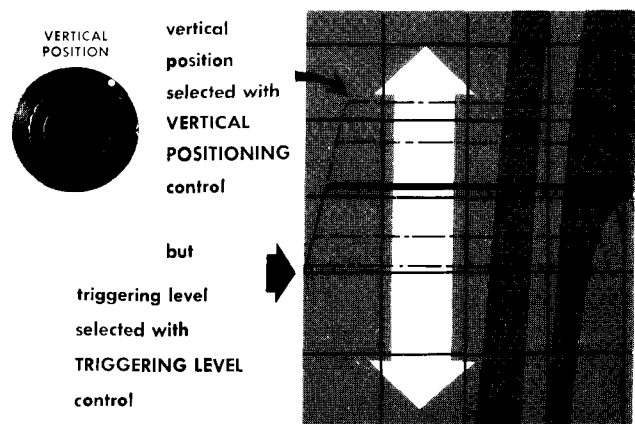


Fig. 2-4. Changing the position of the display with the vertical-position control will change the starting point of the display in the DC triggering mode.

ter of the graticule (for the beam on which triggering is occurring. If you move the TRIGGERING LEVEL control towards +, the starting point will be raised, while if you move the TRIGGERING LEVEL control towards —, the starting point will be lowered. (Fig. 2-5).

The four comments at the close of the section on the AC and AC LF REJECT triggering mode apply also to triggering in the DC mode. The following statements can be made to compare the DC with the AC and AC LF REJECT modes of triggering:

1. When you use the DC mode, the trace always starts at a given point on the graticule, for a given TRIGGERING LEVEL setting, and the display must be positioned to pass through this point. But when you use the AC or AC LF REJECT mode of triggering, the trace always starts at a given point on the waveform, for a given TRIGGERING LEVEL setting (regardless of the VERTICAL POSITION setting).
2. The DC mode is especially useful for viewing waveforms which change slowly.

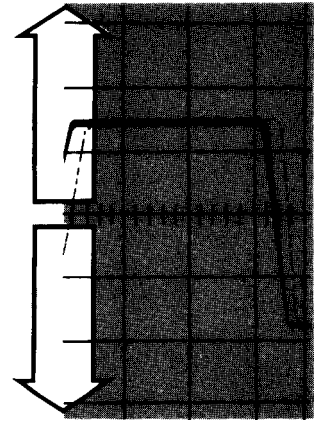
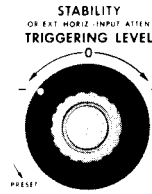
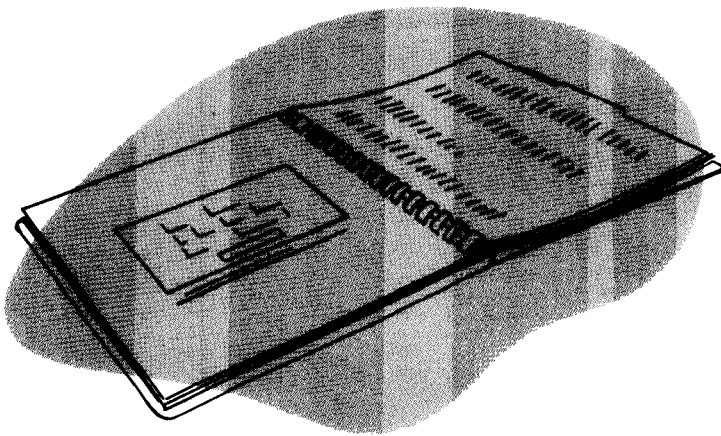


Fig. 2-5. In the DC triggering mode, the TRIGGERING LEVEL control determines the point on the graticule at which the display will start.

OPERATING INSTRUCTIONS



HORIZONTAL-DEFLECTION SYSTEM

TRIGGERED OPERATION

For many uses of your oscilloscope you will need to get a stable display of one or two recurrent waveforms. To accomplish this, you can operate the oscilloscope so that the horizontal sweep of the spots across the screen starts at a given point on one of the waveforms you are observing. This is called "triggered" operation. For present purposes, then, we can refer to the starting of the horizontal sweep at the left-hand end of the graticule as "triggering" the sweep.

Triggered operation is also useful in looking at a waveform which occurs only once, or which occurs at random intervals.

For any of the above uses, the oscilloscope can alternately be used in such a way that the horizontal sweep of the spots is triggered by some waveform other than the one you are observing, but which has a time relationship to the observed waveform.

The waveform used to start the horizontal sweep is called a "triggering signal" (whether it is one of the waveforms being observed, or some other waveform). The following instructions tell you how to select the triggering signal. They also contain information on triggering according to various modes, depending upon the nature of the triggering signal.

How to Select The Triggering Signal Source

1. To trigger the sweep from the waveform connected to the UPPER BEAM plug-in unit, set the black TRIGGER SLOPE knob to +UPPER or —UPPER.
2. To trigger the sweep from the waveform connected to the LOWER BEAM plug-in unit, set the black TRIGGER SLOPE knob to +LOWER or —LOWER.
3. To trigger the sweep from the power-line wave, as in the case where you are observing waveforms which have a time relationship to the power-line wave, set the black TRIGGER SLOPE knob to +LINE or to —LINE.
4. To trigger the sweep from some externally derived waveform which has a time relationship to the observed waveforms, connect the source of triggering waveform to the TRIGGER INPUT connector. Set the black TRIGGER SLOPE knob to +EXT. or to —EXT.

If you want the start of the display, at the left-hand end of the graticule, to occur at a time when the triggering signal is rising (has a positive slope), use the +LINE, the +UPPER, the +LOWER, or the +EXT. position of the black TRIGGER SLOPE knob, as described above. If you want the start of the display to occur when the triggering signal is falling (has a negative slope), use the —LINE, the —UPPER, —LOWER, or the —EXT. position of the black TRIGGER SLOPE knob.

AUTO. mode

This is an especially useful triggering mode, providing automatic triggering from periodic signals in the range from 60 cycles to 2 megacycles.

1. Select the desired triggering signal.
2. Set the HORIZONTAL DISPLAY switch to NORMAL, and set the red TRIGGERING MODE knob to AUTO.
3. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.

AC mode

This mode is useful for triggering either from transients or from periodic signals in the range from 16 cycles to 5 megacycles. Under certain conditions reliable triggering is possible at frequencies lower than 16 cycles. For example: a triggering signal having a frequency of 10 cycles should have an amplitude of at least 0.5 volt when triggering from an external source (+ or —EXT.) or 0.5 major divisions of vertical deflection when triggering from the displayed signal (+ or —UPPER, + or —LOWER). The rule to follow in this case is that the product of the triggering signal amplitude, in volts (external triggering) or in divisions of vertical deflection (internal triggering), and the frequency, in cycles, must be five or greater.

1. Select the desired triggering signal.
2. Set the controls as follows:

HORIZONTAL DISPLAY	NORMAL
TRIGGERING MODE	AC
TRIGGERING LEVEL	full right or full left
STABILITY	PRESET

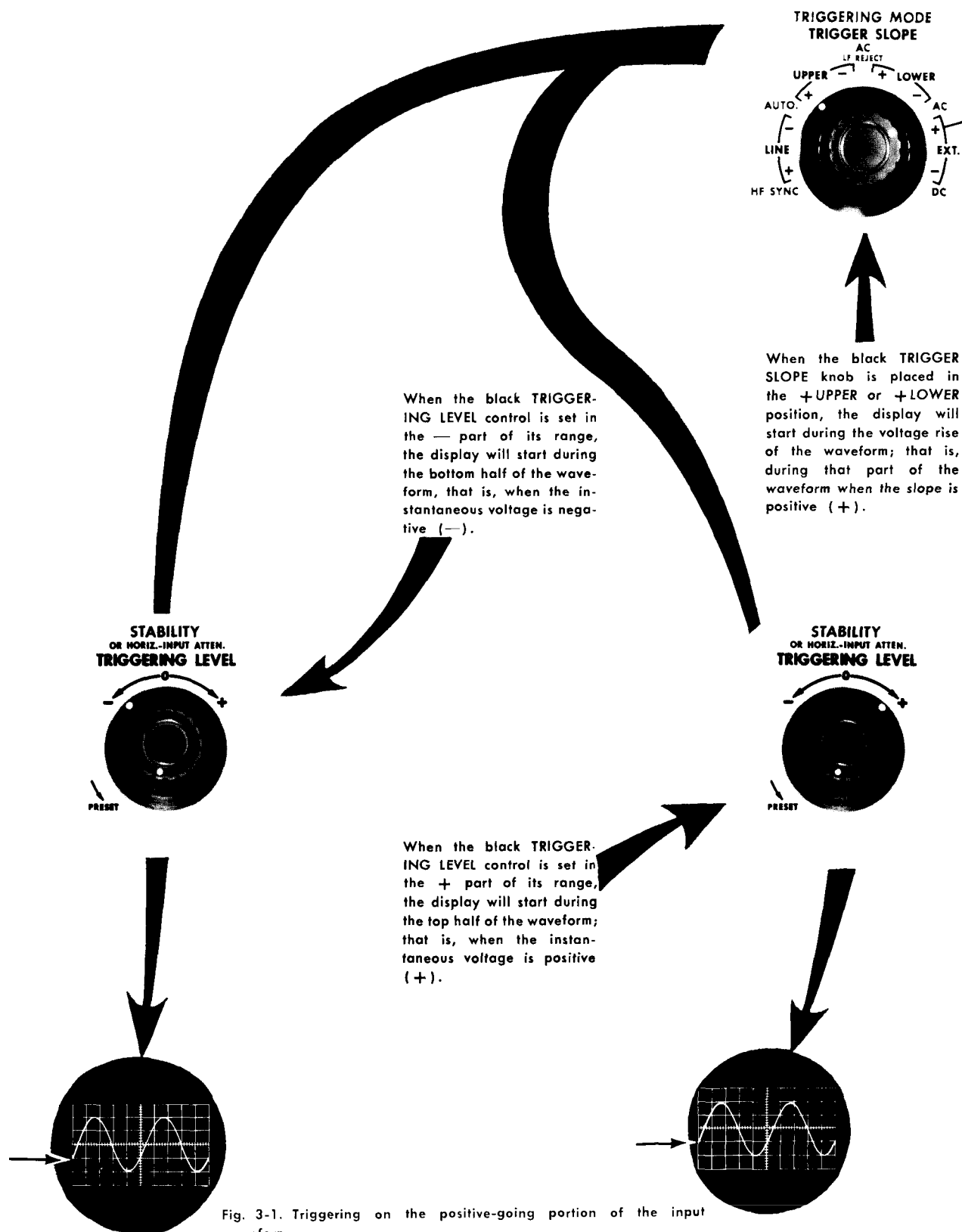


Fig. 3-1. Triggering on the positive-going portion of the input waveform. The displayed signal is internally connected to trigger the sweep circuits when the black TRIGGER SELECTOR control is set at + or —INT. Notice that the red TRIGGER SELECTOR control is set at AC for triggering in the AC mode.

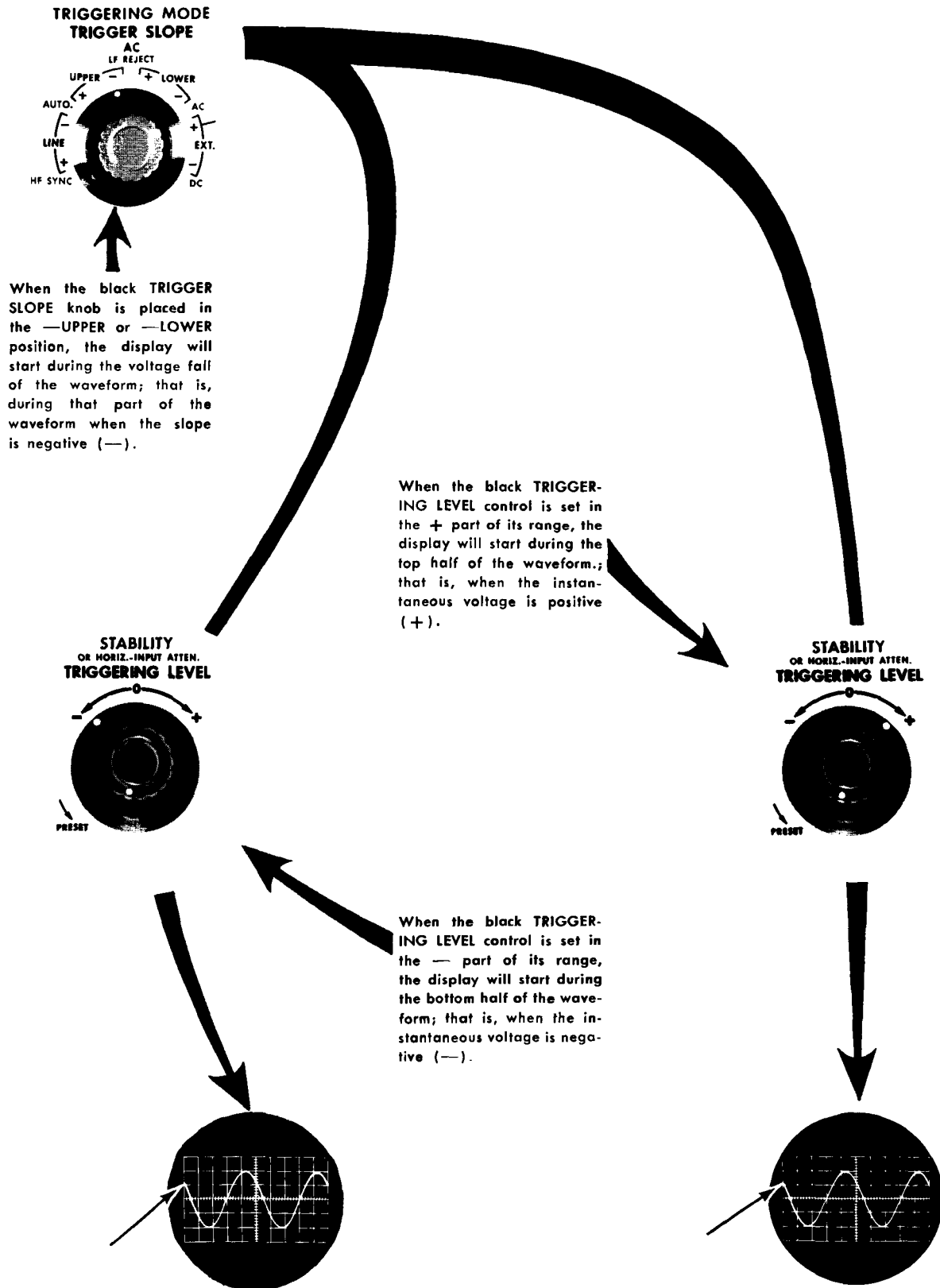


Fig. 3-2. Triggering on the negative-going portion of the input waveform. The displayed signal is internally connected to trigger the sweep circuits when the black **TRIGGER SELECTOR** control is set at + or —INT. Notice that the red **TRIGGER SELECTOR** control is set at AC for triggering in the AC mode.

Operating Instructions—Type 551

3. Turn the TRIGGERING LEVEL control slowly toward the center of its range until the trace begins at the desired point on the waveform being observed.

4. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.

AC LF REJECT mode

This mode is useful for triggering either from transients or from periodic signals in the range from 16 kilocycles to 5 megacycles. Using this triggering mode, a short-time-constant, high-pass filter circuit is inserted in the trigger circuit which appreciably reduces the low-frequency components of the triggering signal. When triggering on signals which have a large hum component, or large changes in level, use the AC, LF REJECT mode results in jitter-free triggering.

1. Select the desired triggering signal.

2. Set the controls as follows:

HORIZONTAL DISPLAY	NORMAL
TRIGGERING MODE	AC LF REJECT
TRIGGERING LEVEL	full right or full left
STABILITY	PRESET

3. Turn the TRIGGERING LEVEL control slowly toward the center of its range until the trace begins at the desired point on the waveform being observed.

4. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.

DC mode

In the DC mode, triggering can be effected from periodic signals in the range from dc to 5 megacycles, or from transients. This mode is especially useful with trigger signals that change slowly; that is, signals below the lower frequency limit of the AC mode.

A typical 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 quantities are variable in a random pulse train, the average voltage will also vary and this can cause unstable triggering in the AC mode. 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 circuit. As a result, the TRIGGERING LEVEL control can be set to initiate a sweep whenever a pulse reaches the desired voltage.

Operating instructions are similar to those given previously for the AC mode, except that you set the TRIGGERING MODE switch to DC. It is important to remember, however, that the trace always starts at a given point on the graticule for a given TRIGGERING LEVEL setting. This is true regardless of the setting of the VERTICAL POSITIONING controls.

How to use the variable STABILITY control

For a few difficult triggering applications, you may wish to use a setting of the STABILITY control other than the one

available in the PRESET position. You can do this if you are using triggered operation in either the AC, AC LF REJECT, or the DC mode.

1. Start with the STABILITY control turned full right. Use other control settings as given in the instructions for the desired triggering mode.

2. Turn the STABILITY control left until the trace disappears, then two or three degrees further left.

3. Turn the TRIGGERING LEVEL control slowly toward the center of its range until the trace begins at the desired point on the waveform being observed.

4. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.

SYNCHRONIZED OPERATION

HF SYNC mode

When you use the HF SYNC mode, you get a recurrent horizontal sweep which can be synchronized, by means of the STABILITY control, with waveforms in the range from 5 megacycles to 30 megacycles.

When using the HF SYNC mode, you will usually want to synchronize the horizontal sweep with one of the waveforms being displayed. To do this, set the controls as outlined in Step 1, at right. If, however, you want to synchronize the sweep with some external waveform, connect the source of this waveform to the TRIGGER INPUT connector and set the TRIGGER SELECTOR knob to the +EXT. or —EXT.

1. Set controls as follows:

HORIZONTAL DISPLAY	NORMAL
TRIGGER SLOPE	+UPPER, —UPPER
(black)	+LOWER or —LOWER
TRIGGERING MODE	HF SYNC
TRIGGERING LEVEL	not used in HF SYNC mode
STABILITY	full right

2. Set the TIME/CM control for a sweep rate suited to the waveform being observed.

3. Turn the STABILITY control slowly to the left until you get a stable display of the waveforms being observed.

Free-Running Operation

With the Type 551, you can get a periodic, free-running sweep, independent of any external triggering or synchronizing signal. This operation is useful where the waveforms being observed are initiated by the output from either the +GATE OUT or the SAWTOOTH OUT connector.

As an application of free-running operation, you can actuate the system under investigation by means of a signal from either the +GATE OUT or the SAWTOOTH OUT connector.

(See "Output Waveforms" on next page.) The signals from these connectors have a starting time and a duration corresponding to the starting time and duration of the horizontal sweep of the crt spot. Note that this reverses the usual situation where the oscilloscope sweep is timed to the waveform under investigation. Here, the system being investigated is timed to the oscilloscope sweep. Thus a stable display is presented of the waveforms resulting from actuating the system under investigation.

1. Use no input to the TRIGGER INPUT connector.

2. Set controls as follows:

HORIZONTAL DISPLAY	NORMAL
TRIGGERING MODE	AC, AC LF REJECT or DC
STABILITY	full right
TRIGGERING LEVEL	full right or full left
TRIGGER SLOPE	UPPER (+ or —)
(black)	LOWER (+ or —) or EXT. (+ or —)

3. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.

Alternately, you can get a free-running sweep at a fixed repetition rate of approximately 50 cycles, using the AUTO. mode:

1. Use no input to the TRIGGER INPUT connector.

2. Set controls as follows:

HORIZONTAL DISPLAY	NORMAL
TRIGGER SLOPE	UPPER (+ or —) LOWER (+ or —) or EXT. (+ or —)
TRIGGERING MODE	AUTO.
TRIGGERING LEVEL	not used in
STABILITY	AUTO. mode

3. Set the TIME/CM switch for a sweep rate suited to the waveform being observed.

Magnifier

To expand a particular part of the display horizontally, first use the HORIZONTAL POSITION control to position that part of the display so that it falls near the center of the graticule. Then turn the HORIZONTAL DISPLAY switch to 5X MAG. That part of the display which occupied the middle two divisions of the graticule will now be expanded to fill the graticule horizontally. At the same time, the MAG. ON indicator lamp will be lighted, indicating that the display has been expanded. Each major graticule will have a time value one-fifth of the value indicated by the TIME/CM switch. When the HORIZONTAL DISPLAY switch is in the NORMAL position, read the black scale associated with the TIME/CM switch.

External Horizontal Input

You might need to effect horizontal deflection of the spot across the screen by means of some externally derived waveform, rather than by means of the time base in the Type 551. To accomplish this, connect the source of this waveform to the HORIZ. INPUT connector, and turn the HORIZONTAL DISPLAY switch to EXT. Set the STABILITY OR HORIZ. —INPUT ATTEN. control for the desired amount of horizontal deflection.

The 5X MAG. is automatically switched into the circuit when the HORIZONTAL DISPLAY switch is in the EXT. position. This is necessary to keep the input amplifier within its linear range.

The horizontal amplifier is primarily designed to amplify the linear positive-going portion of the sweep sawtooth waveform. When sine waves are used as the input signal to the HORIZ. INPUT connector the response of the horizontal amplifier will be 3 db down at 400 kilocycles. The effect of the HORIZ. —INPUT ATTEN. must also be taken into consideration when connecting signals to the HORIZ. INPUT connector. When the HORIZ. —INPUT ATTEN. control is turned toward the left the response of the horizontal amplifier will drop to the 3-db-down point at 100 kilocycles.

Single Sweep

The SINGLE SWEEP switch is mounted on a concentric shaft with the HORIZONTAL DISPLAY switch. In the OUT position of the SINGLE SWEEP switch it has no effect upon the operation of the sweep circuitry. To use the SINGLE SWEEP feature of your Type 551 set all controls as you would for normal operation of the sweep circuits. Back the STABILITY control well to the left. Switch the SINGLE SWEEP knob to IN. To prepare the sweep circuits for single sweep operation depress the RESET button. When the RESET button is operated the READY light will light. The next trigger pulse which arrives will cause the sweep circuit to make one complete cycle of operation. Subsequent triggers will have no effect on the circuit until the RESET button is operated.

Output Waveforms

A sawtooth waveform is available at the SAWTOOTH OUT connector on the front panel. This positive-going waveform starts at about ground and rises linearly to a peak amplitude of about 150 volts.

The start of the rising part of the sawtooth is determined in the same way as the start of the horizontal sweep on the oscilloscope. That is the rising part of the sawtooth can be initiated by a triggering or synchronizing signal (see "Triggered Operation" or "Synchronized Operation"). Or the sawtooth can be generated in a periodic, free-running manner, without regard to any triggering or synchronizing signal (see "Free-Running Operation"). The rate at which the sawtooth rises is controlled by the TIME/CM switch, and by the VARIABLE knob.

A rectangular waveform is available at the +GATE OUT connector on the front panel. This waveform starts at ground and rises to a peak amplitude 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.

VERTICAL-DEFLECTION SYSTEM

Input Coupling

The vertical-deflection system of the Type 551 consists of two amplifiers driving separate sets of vertical-deflection plates in the crt. As a result, each input system operates independently of the other.

Plug-in units must be installed in both vertical channels of the Type 551 before the oscilloscope can be operated. You can display two waveforms simultaneously by using two plug-in units and connecting the signals to be displayed to the INPUT connectors for each channel. The vertical position and amplitude of each waveform is controlled by the corresponding controls on each plug-in unit.

If you wish to operate the Type 551 as a conventional, single-channel oscilloscope you must have a plug-in unit installed in each channel to maintain power-supply regulation. The beam which is not being used may be positioned off the screen. Triggering is then effected from the displayed signal through an appropriate setting of the TRIGGER SLOPE switch.

It is sometimes neither necessary nor desirable to display the dc component of the input waveform. A capacitor placed in series with the input connector will block this dc component, but at the same time, will allow the ac component to be displayed. This is done when the AC-DC switch of the plug-in unit is placed in the AC position.

Deflection Factor

The plug-in VOLTS/CM switch controls the vertical-deflection factor (vertical sensitivity) in accurately calibrated steps. The VARIABLE control provides variable deflection factors between the fixed steps of the VOLTS/CM control.

NOTE: To make the deflection factor equal to that indicated by the VOLTS/CM switch, set the VARIABLE control to the CALIBRATED position.

Connecting the Oscilloscope to the Signal Source

Here are some precautions you should observe in connecting your oscilloscope to the source of signals 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 connector. In general, unshielded leads of appreciable length are unsuited to this use. This is true even in the audio-frequency range, except possibly when making measurements in low-impedance circuits. When shielded leads are used, the shields should be grounded to the oscilloscope and to the chassis of the equipment being tested. Coaxial cables are recommended for many purposes.

2. In broadband applications, it might be necessary to terminate a coaxial cable with a resistor or an attenuating pad presenting a resistance equal to the characteristic impedance of the cable. This is to prevent resonance effects and ringing—that is, high-frequency damped oscillation. It becomes more necessary to terminate the cable properly as the length of the cable is increased. The termination is generally placed at the oscilloscope end of the cable, although many sources require an additional termination at the source end of the cable as well. Refer to the Accessories section in the back of this manual for a listing of cables, terminating resistors and 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 which it will see in actual use.
4. Consider the effect of loading upon the signal source due to the input circuit of the plug-in. The input circuit at the INPUT connector can be represented by a resistance shunted by a capacitance. With a few feet of shielded cable, the capacitance may well be 100 micromicrofarads. In many cases, the effects of these resistive and capacitive loads are not negligible, and to minimize them, you might want to use a probe in the manner described in the next section.

Use of Probes

An attenuator probe lessens both capacitive and resistive loading, at the same time reducing sensitivity. When making amplitude measurements with an attenuator probe, be sure to multiply the observed amplitude by the attenuation of the probe (marked on probe).

A Type P6000 Probe is furnished as an accessory to the Type 551 Oscilloscope. The probe is easily identified by its brown, molded-plastic nose. Connected to the input circuit of a Tektronix plug-in, the probe presents an input resistance of 10 megohms and has an attenuation ratio of 10:1. For information concerning the input capacitance, see Table 1-1 on Page 1-1. The maximum voltage which may be applied to the probe is 600 volts. Exceeding this rating, either in peak ac volts 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 probe-input connection.

Before using the probe, always check its adjustment

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.

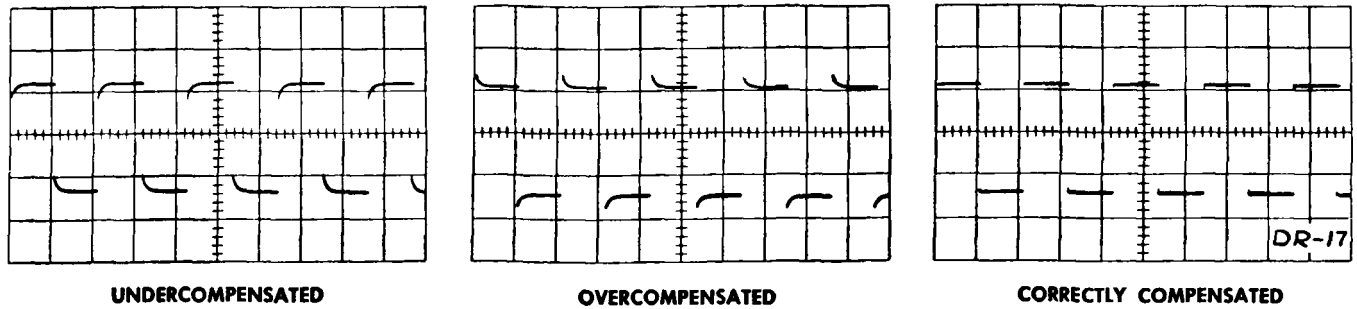


Fig. 3-3. Displaying the Calibrator waveform provides a convenient means for compensating the probe input capacitance.

Adjust the probe capacitor for a flat top on the calibrator square wave, as shown in the right-hand picture of Fig. 3-3.

VOLTAGE MEASUREMENT

We describe here two categories of voltage measurements with the Type 551 Oscilloscope: (1) measurement of the peak-to-peak voltage of a displayed waveform, and (2) measurement of the peak voltage of a waveform with respect to a reference voltage. The specific examples that follow are intended to show the general procedure. These examples can be modified to suit any particular application.

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. Notice in Fig. 3-4 that points a and b correspond to the bottom side of the trace. The measurement would be just as accurate if points a and b correspond to the top or center of the trace.

How to measure peak-to-peak-voltages

Suppose a given waveform produces the trace shown in Fig. 3-4 when a 10X probe is used and when the controls of the plug-in preamplifiers are set as follows:

AC-DC	AC
VOLTS/CM	.1
VARIABLE	CALIBRATED

The first step in measuring the peak-to-peak voltage of this waveform is to measure the amount of vertical deflection. The vertical distance from point a, the positive peak, to point b, the negative peak, is 4 divisions. Multiply this figure by the VOLTS/CM setting, .1, and the result is .4 volt. This figure represents the voltage present at the INPUT connector of the plug-in. Multiply this result by 10— the attenuation ratio of the probe. This gives 4 volts as the peak-to-peak voltage of the displayed waveform.

How to measure a peak waveform voltage with respect to ground

Set the plug-in AC-DC switch to DC, and set the VARIABLE control to CALIBRATED. Adjust the oscilloscope for a free-running trace. Touch the probe tip to the oscilloscope ground terminal. Use the VERTICAL POSITIONING control to set the trace to a convenient position, such as b in Fig. 3-5. Next, disconnect the probe tip from the ground terminal and connect it to the waveform source without disturbing the VERTICAL POSITION control.

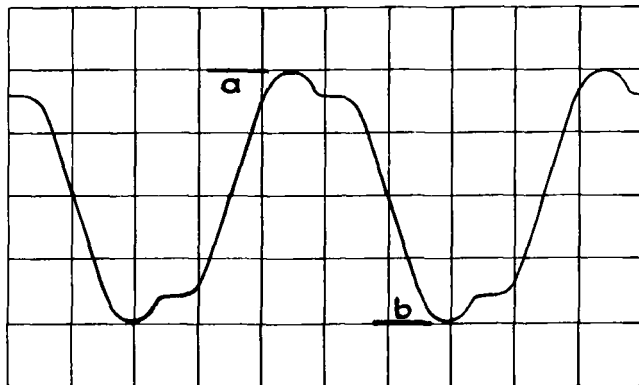


Fig. 3-4. Measuring the peak-to-peak amplitude of a displayed waveform.

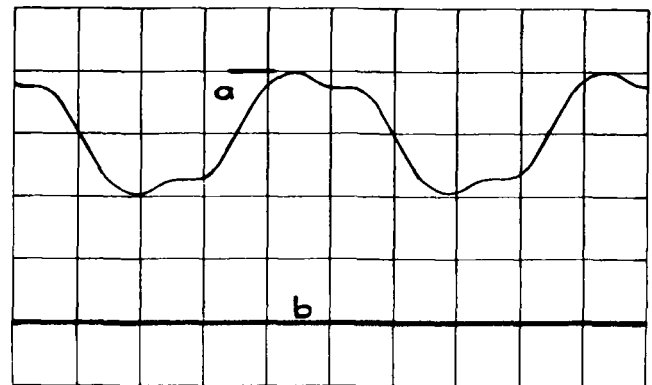


Fig. 3-5. Measuring the peak voltage of a displayed waveform with respect to ground.

Operating Instructions—Type 551

Adjust the oscilloscope controls for a stable display. Observe the vertical distance between the peak waveform voltage *a* and the original trace position *b*. If this distance is inconveniently large or small, reset the VOLTS/CM switch to a more suitable position and repeat the above procedure.

As an example, suppose the vertical distance between *a* and *b* is 4 divisions when a 10X probe is used and when the VOLTS/CM switch is set at .1. Multiply the distance between *a* and *b* (4 div.) by the VOLTS/CM setting (.1 v/div.) and by the probe attenuation ratio (10). This shows the peak voltage of the waveform with respect to ground to be 4 volts.

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% of the VOLTS-switch settings. 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.

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 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 four kilohms. 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 3-1 for the approximate output impedance for each position of the VOLTS switch.

TABLE 3-1

Approx. Output Impedance of Calibrator	
*Switch Setting	Output Impedance
100	*290 ohms
50	5.1 kilohms
20	3.3 kilohms
10	1.9 kilohms
5	1 kilohms
2	500 ohms
1	300 ohms
.5	200 ohms
.2	140 ohms

* Do not load with less than 4 Kilohms.

† 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.

Trace-brightness modulation

To couple markers or other signals into the crt cathode for trace-brightness modulation, disconnect the ground strap at

the rear of the instrument and apply the signal between the CRT CATH. binding post and GND. Positive pulses of about 25 volts will cut the beam off from normal brightness. Always replace the ground strap when you are 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 must be mounted outside the graticule.

As a general rule, white graticule lines are superior to red for photographic purposes. Where it is desired to photograph a display, it may be desirable to turn the graticule so that the red lined holes are at the bottom. When this is done the graticule lines will appear white, rather than red, and will appear to equal the trace intensity in a photograph. It is generally desirable to place the green filter on the outside of the graticule when making photographs to insure that the display and graticule lines give the most satisfactory display. Where the volume of photographic work warrants it you may want to obtain a clear graticule from your Tektronix Field Engineer.

Connection to crt deflection plates

In some applications, it may be desirable to connect a signal directly to either one or both sets of crt deflection plates—bypassing the internal oscilloscope amplifiers. This can be done in the Type 551 if certain precautions are observed. One of these precautions is to maintain the average dc voltage on the deflection plates at +300 volts.

For many applications, ac coupling of the signal to the deflection plates is permissible. It has the advantage of allowing the use of front-panel controls to position the display and permits the display of signals not having an average dc voltage of +300 volts. A diagram of this method of coupling is shown in Figure 3-6. Here, the leads from the oscilloscope amplifier are removed and a resistor is connected between each lead and its respective crt pin.

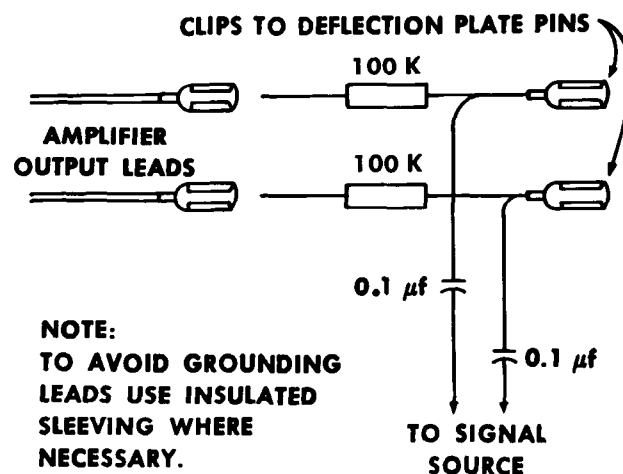


Fig. 3-6. Typical circuit for ac-coupling a signal directly to the crt deflection plates.

In order to realize the desired amount of deflection sensitivity in the Type T57 Cathode-Ray Tube, the deflection plates have been placed as close as possible to the path of the electron beam. As a result, a small amount of current will flow in the deflection-plate circuits. This current flow varies non-linearly with the beam position, increasing rapidly in that plate toward which the beam is being positioned. In the Type 551, the effects of these currents are negligible because of the low resistance of the horizontal- and vertical-deflection-plate circuits. However, if the resistance is increased, these currents can cause objectionable voltage drops. For values of resistance greater than 1 megohm the voltage drops may become relatively large and cause serious defocusing or distortion. These effects are most noticeable when the display is positioned close to the limits of the crt graticule. For this reason, series resistors having a value greater than 1 megohm are not recommended.

A convenient method for connecting the resistors to the crt pins is to use clips removed from standard miniature tube sockets. Before connecting the resistors to the leads from the amplifier, slip a piece of insulated sleeving (spaghetti) over the wire. Then, after making the connections, draw the sleeving back over the uninsulated resistor pigtail. This will protect the leads from accidentally shorting to the chassis. The crt pins are easily bent and you must exercise care when making these connections to avoid breaking the pins.

CAUTION

Do not allow the leads from the oscilloscope amplifiers to touch the chassis when the power is on. A short circuit of this type can damage the amplifier circuits.

If it is desired to couple the signal directly to the crt plates (dc coupling), it will be necessary to supply positioning voltages from the signal source. These voltages, of course, should be +300 volts as mentioned previously. To dc couple the signal to the deflection plates, remove the leads from the crt pins and fold them back, out of the way. Taping the ends of the wires will prevent accidental shorting to the chassis. Connect the external signal source to the pins of the crt.

OPERATING DESCRIPTIONS OF CONTROLS AND CONNECTORS

TRIGGER SLOPE (black knob)	The TRIGGER SLOPE switch selects triggering signals—either power-line wave (+LINE or —LINE), or the signal being displayed (+ or —, UPPER or LOWER beam), or some signal fed into the TRIGGER INPUT connector. In all positions marked +, triggering occurs on the rising part of the waveform. In all positions marked —, triggering occurs on the falling part of the waveform.
TRIGGERING MODE	Five-position switch (red knob) selects one of four types of triggering (AC LF REJECT, AC, DC, or AUTO.) or synchronized operation (HF SYNC).

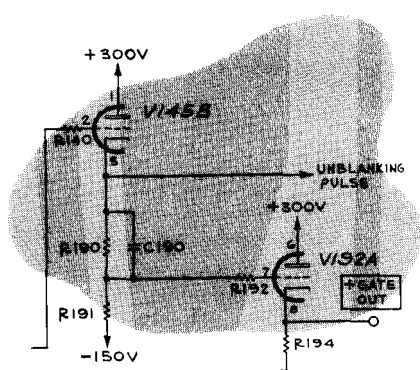
TRIGGERING LEVEL	Black TRIGGERING LEVEL control determines at what voltage on the triggering waveform the horizontal trace will start. This control is disabled when the TRIGGER MODE switch is in either the AUTO. or HF SYNC position.
STABILITY OR HORIZ.-INPUT ATTEN.	Red STABILITY control adjusts the time base for triggered or free-running operation. Normally, it can be left in the PRE-SET position. It is disabled when the red TRIGGER MODE switch is in the AUTO. position. It also serves as the synchronizing control when the TRIGGER MODE switch is in the HF SYNC position. This knob also serves as an attenuation control for horizontal deflection voltages when the HORIZONTAL DISPLAY switch is in the EXT. position.
HORIZONTAL DISPLAY	Three position switch. In NORMAL position the sweep rates indicated in black numbers on the TIME/CM scale apply. When the HORIZONTAL DISPLAY switch is in the 5X MAG. position, blue numbers on the TIME/CM scale apply, and that part of the display which originally occupied the center two centimeters of the graticule is expanded to occupy the entire graticule length. In the EXT. position of the HORIZONTAL DISPLAY switch, horizontal-deflection voltage is to be supplied externally by way of the HORIZ. INPUT connector.
TIME/CM	Twenty-four position switch to control the horizontal sweep rate. Read the black numbers when the HORIZONTAL DISPLAY switch is in the NORMAL position, and the blue numbers when the HORIZONTAL DISPLAY switch is in the 5X MAG. position.
VARIABLE	Red VARIABLE control provides continuous coverage between ranges of the TIME/CM switch. The UNCALIBRATED light will light as soon as the VARIABLE control is turned from the CALIBRATED position (full right).
HORIZONTAL POSITION	Positions trace horizontally.
VERNIER	Fine positioning control.
SQUARE-WAVE CALIBRATOR (black knob)	The SQUARE-WAVE CALIBRATOR (black knob) switch selects any one of nine output amplitudes. When the red SQUARE-WAVE CALIBRATOR control is in the MILLIVOLTS position nine millivolt ranges are available, and the switch markings should be read as millivolt amplitudes.
SQUARE-WAVE CALIBRATOR (red knob)	The SQUARE-WAVE CALIBRATOR (red knob) switch selects one of three positions. In addition to the OFF position two output amplitude positions, volts and millivolts, are available.

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SINGLE SWEEP	A two position switch to select either single sweep or normal operation of the sweep circuits.	SAWTOOTH OUT	Connector supplying a positive-going sawtooth having a peak value of about +150 volts. The rising part of the sawtooth coincides with the oscilloscope horizontal sweep, when the HORIZONTAL DISPLAY switch is in the NORMAL or the 5X MAG. position. The rate at which the sawtooth rises is controlled by the TIME/CM controls.
RESET	The RESET button prepares the sweep circuits for operation on the first triggering signal received after the button has been depressed.		
FOCUS	Controls sharpness of spot or trace.	+GATE OUT	Connector supplying a positive-going rectangular wave having a maximum 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.
SCALE ILLUM.	Controls graticule-scale illumination.		
INTENSITY	Controls the brightness of the display.		
ASTIGMATISM	When operated in conjunction with the FOCUS this control enables the operator to adjust the spot or display for satisfactory focus at any point on the screen.	CAL. OUT	Coaxial connector for supplying square-wave output voltage from the calibrator at 1000 cps $\pm 30\%$.
TRIGGER INPUT	Coaxial connector for accepting an external triggering signal for the time base when the TRIGGER SLOPE switch is in the +EXT. or —EXT. positions.	CRT. CATH.	Connector at the rear of the cabinet for accepting beam-intensity-modulation voltage. Capacitively coupled. This connector should be jumpered to the GND. connector when not in use.
HORIZ. INPUT	Connector for accepting an externally derived horizontal-deflection signal.		

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

The vertical-deflection system is shown in the upper half of the Block Diagram. The blocks labeled "Plug-ins" represents Tektronix plug-in preamplifiers. Power and signal connections to the plug-ins are made through multiple-contact interconnecting sockets. Output from these units is push-pull at low impedance.

Main-Unit Amplifier

The main-unit Vertical Amplifiers amplify the signals and drive the delay lines which terminate in the vertical-deflection plates. The trigger pickoff circuits obtain samples of the vertical signals for triggering the sweep.

Delay Line

The balanced delay lines add 0.2 microsecond of delay to the signals 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-Pickoff Amplifiers

The trigger signals from the vertical-amplifiers are amplified by the Trigger-Pickoff amplifiers. The amplified signals are coupled at low impedance to the time-base triggering circuits through the Trigger-Pickoff CF's.

Trigger-Input Amplifier

The time-base triggering signal is selected with the TRIGGER SLOPE switch from one of four sources: the Upper-Beam vertical amplifier, the Lower-Beam vertical amplifier, the

power line, or the TRIGGER INPUT connector. The selected triggering signal is amplified by the Trigger-Input Amplifier and coupled to the Schmitt Trigger. The Schmitt Trigger square-wave output is differentiated to sharp negative-going pulses suitable for triggering the Sweep-Gating Multivibrator.

Sweep-Gating Multivibrator

The Sweep-Gating Multivibrator turns on the Miller Runup 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 Schmitt Trigger trips the multivibrator, which thereafter stays in the second state until the time-base generator reverts it to its quiescent state.

Miller Runup Circuit

The Miller Runup is a Miller integrator that produces a positive-going sawtooth about 150 volts peak-to-peak. The Time-Base Generator turns itself off when it reaches a prescribed level by transmitting a signal through the holdoff circuits to the Sweep Gating Multivibrator. The output waveform is coupled to the horizontal-deflection system through the HORIZONTAL DISPLAY switch. The signal is also connected to a front-panel connector through a cathode follower.

Holdoff Circuit

The holdoff circuit transmits the time-base turn-off signal to the Sweep-Gating 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 Miller Runup 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 time-base generator into push-pull output at low impedance at the level required to sweep the beam across the crt

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screen. The amplifier gain can be increased 5 times for sweep magnification. The horizontal-positioning control operates in this circuit.

Unblanking

The Sweep-Gating Multivibrator generates a positive-gating unblanking pulse at the same time it turns on the Miller Run-up. The positive pulse is transmitted through a floating high-negative-voltage supply to the control grid of the crt. The pulse is also coupled to the front-panel +GATE OUT connector through a cathode follower.

Sync. Amplifier

The pulses generated by the Sweep-Gating Multivibrator are amplified by the Sync. Amplifier for connection through the plug-in connector to the switching circuits in a Tektronix dual-trace plug-in. This circuit is only in operation when the plug-in dual-trace feature is used.

External Sweep Amplifier

The External Sweep Amplifier provides a means of using external sweep voltage. Choice of internal or external sweep can be made by means of the HORIZONTAL DISPLAY switch.

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

As can be seen by a quick examination of the Block Diagram and Vertical Amplifier schematics, the Upper-Beam and Lower-Beam vertical-deflection systems are identical. Therefore, the description that follows will be confined to the Upper-Beam Vertical Amplifier. The description applies equally well to both amplifiers.

The dc-coupled push-pull, Upper-Beam Vertical Amplifier provides the necessary gain to drive the Delay Line and one set of vertical-deflection plates in 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. V1223A, and the Indicator Amplifier and lamps, V1084A and B1083, and V1223B and V1227, 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 preamplifier'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 V1033B and V1043B. 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 crt 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 Compensations

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 COMP. control, is connected between the two networks to adjust for the proper amount of compensation.

Beam-Position Indicators

The beam-position indicators B1083 and B1227, 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 (TRIGGER SLOPE switch at + or — LOWER BEAM or at + or — UPPER BEAM), 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 the Trigger Pickoff C.F. V1223A.

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, non-inductive, distributed resistors. The 600 ohms total resistance in each is "tapered", or distributed, in steps. The largest segment of the terminating resistance 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 circuit 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 four sources, as determined by the setting of the TRIGGER SLOPE switch SW10. When the switch is in the + or — EXT. positions, an external signal is employed in the development of the triggering pulse. When the switch is in the + or — LOWER positions the signal displayed by the LOWER-BEAM plug-in is used to develop the triggering pulse. Similarly, when the switch is in the + or — UPPER positions, the signal displayed by the UPPER-BEAM plug-in is used. 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., UPPER, LOWER 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., LOWER, UPPER or LINE range), the grid of V24A is connected to the signal 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 four 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,

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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 a 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-Input Amplifier.

Triggering Mode

The TRIGGERING MODE switch SW30 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 Schmitt Trigger.

In the AC SLOW and AC LF REJECT modes, capacitor C10 removes the dc component of the triggering signal; the Trigger Input stage is still dc-coupled to the Schmitt Trigger, however, the AC LF REJECT 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 changes.

In the AUTOMATIC mode the Schmitt Trigger 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 0.01 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 LF REJECT 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 a triggering signal, the sweep generates a baseline 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 submultiple 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 Time-Base Trigger produces a square-wave 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, V145 and 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 V183B-V133B, the Hold-Off Capacitor C180 and the Hold-Off Resistor R181-R180.

Sweep-Gating Multivibrator

The Sweep-Gating Multivibrator operates as a bistable multivibrator. In the quiescent state V135A is conducting and its plate is down. This cuts off V145 through V135B and the divider R141-R143, and the common cathode resistor R144. With V145 cutoff, its plate is clamped about 3 volts below ground by the conduction of diodes V152 (A & B) through R147 and R148. Conduction of 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 circuits 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 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 V145 is the conducting tube. As V145 conducts its plate drops, cutting off the On-Off Diodes V152. Any spiking that may 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 C150, 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, R160L, varies the sweep rate over a $2\frac{1}{2}$ to 1 range. Switch SW160-6F 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 Sweep 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 Sweep Length control. This will increase the voltage at the grid and cathode of V183B 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 V145 cutoff. The voltage at the plate of V145 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 in 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 waveform except for 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

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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 beams return rapidly to their starting points.

Hold-Off Circuit

The Hold-Off Circuit prevents the Time-Base Generator from being triggered during the retrace interval. That is, the Hold-Off circuit 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 V183B, as a result of the rise in voltage at the cathode of V183B. 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 (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 that 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 a point that the discharge of the Hold-Off Capacitor C180 can switch the multi. Adjusted in this 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, an internal screwdriver adjustment labeled Preset Stability, 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 red SINGLE SWEEP switch is in the IN 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. 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 SINGLE SWEEP 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 (ccw) the grid of V135A will be pulled down causing 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 holdoff 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 where 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. Placing the HORIZONTAL DISPLAY switch in the EXT. position adds R145 to the Sweep-Gating Multivibrator cathode circuit making the circuits insensitive to trigger pulses.

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

Synchronizing pulses for dual-trace plug-in preamplifiers are supplied by V154. When V145 cuts off, a sharply differentiated positive pulse is developed at its screen. This pulse, coupled to the grid of V154, produces a negative trigger at the plate. This trigger then switches the multivibrator in the dual-trace unit employed for alternate sweeps.

HORIZONTAL AMPLIFIER

The dc-coupled Horizontal Amplifier consists of a cathode-follower input stage, an external-sweep amplifier, and a cathode-follower output stage. The gain of the amplifier is controlled by negative feedback from the cathodes of the Output C.F. stage to the grid of the Driver C.F. stage. The amount of negative feedback, and hence the gain of the amplifier, is determined by the setting of the HORIZONTAL DISPLAY switch.

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. V343B. The small time-constant network R343-C343 improves the start of the waveform at the faster sweep speeds. The two positioning controls HORIZONTAL POSITION R333 and VERNIER R330 affect the beam position by alternating the dc level at the grid of V343B. The voltage and resistance values in the positioning circuits are such that the VERNIER can move the spot about 1 centimeter while the HORIZONTAL POSITION control can move the spot about 10 centimeters when the HORIZONTAL DISPLAY switch is in the NORMAL position. Because the voltage changes are coupled through the Horiz. Position CF, an adjustment of the positioning controls does not alter the attenuation of the divider network.

Driver CF

In the NORMAL position of the HORIZONTAL DISPLAY switch, the gain of the amplifier is reduced by a factor of five by a feedback loop between the cathode circuit of V364B and the grid circuit of V343A. This loop consists of R355 shunted by C355, and R349 and R350 shunted by C350. The amount of feedback, and hence the gain of the amplifier, is adjusted by means of R349, the Sweep Cal. control. When the HORIZONTAL DISPLAY switch is turned to 5X MAG. or EXT. the feedback loop is removed.

The Norm. Mag. Regis control, R358, adjusts the voltage at the grid of V343A to equal the voltage at the grid of V343B when the spot is in the center of the screen and the HORIZONTAL DISPLAY switch is in the NORMAL position. This insures that the portion of the waveform within the center two graticule divisions, when the HORIZONTAL DISPLAY switch is in the NORMAL position, will be expanded the full length of the graticule when the HORIZONTAL DISPLAY switch is turned to the 5X MAG. position.

Output Stage

The output Amplifier stage V364A-V384A operates as a conventional push-pull plate-loaded amplifier. The Mag. Gain control, R374, determines the amount of degeneration in the cathode circuit and hence the gain of the stage. The control is used to set the gain of the amplifier when the HORIZONTAL DISPLAY switch is in the 5X MAG. position; that is, when the feedback loop is removed from the circuit. Capacitor C372 is used to vary the gain of the stage at high sweep rates.

The cathode followers V364B-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 C364 and C384 improve the response of 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 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 V364B. This permits the cathode of V364B, 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 during the retrace.

Because the plate current of a pentode is fairly constant over a large range of plate voltage, the cathode current of V364B will remain nearly constant even though its cathode falls about 150 volts during the trace portion of the negative sweep waveform.

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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 V384, in C392 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 HORIZONTAL INPUT couples an externally-derived signal to the Horizontal Amplifier circuit when the HORIZONTAL DISPLAY switch is in the EXT. position. A preamplifier stage V314 is also connected into the circuit.

The Ext.-Sweep Amplifier, V314, operates as a cathode-coupled amplifier. V314B is the cathode-follower and V314A is the grounded-grid stage. The EXT. HORIZ. INPUT ATTEN. (ganged with the STABILITY control) provides a means for alternating the input signal.

POWER SUPPLY

Plate and filament power for the tubes in the Type 551 is furnished by power transformers T601, T602 and T750. The primaries have 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 V619. This tube, which has a constant voltage drop establishes a fixed potential of about —87 volts at the grid of V616A, one-half of a difference amplifier. The grid voltage for the other half of the difference amplifier, V616B, is obtained from a divider consisting of R628, R627 and R262. The —150 ADJ. control R627 determines the percentage of total voltage that appears at the grid of V616B 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 V616B and V604 and applied to the grids of the series tubes V637A and V637B. 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 C611 and C625 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 V604 through R606. The phase of the amplified

ripple voltage at the plate of V604 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 V654) the voltage of a point near ground potential obtained from the divider R658-R657 connected between the +100-volt bus and the regulated —150-volt supply. Any error voltage that exists is amplified and inverted in polarity by V654 and coupled to the series tubes V657A and V657B to prevent the output voltage from changing. Capacitor V658 improves the ac gain of this circuit.

A small sample of the unregulated bus ripple appears at the screen of V654 through R653. This produces a ripple component at the grid of the series tubes V657A and —B 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. The same circuit also improves the regulation in the presence of line-voltage variations.

+225-Volt Supply

Rectified voltage from terminals 13 and 14 of the power transformer is added to the voltage supplying the +100-volt regulator to furnish power for the +225-volt regulator. This supply is regulated by comparing to ground (the grid of V686B) the voltage of a point near ground obtained from the divider R688-R686 connected between the +225-volt bus and the regulated —150-volt supply. Any error voltage that exists between the grids of the difference amplifier (V686) is amplified in both V686 and V674, and coupled to the series tubes V687A and V687B. The change in voltage at the cathodes of V687, 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 +330 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 9 and 10 of T602 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 R721-R722 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. Note that instead of any two series tubes, this supply has four. This is necessary because of the additional current requirements.

+500-Volt Supply

Rectified voltage from terminals 20 and 21 of T602 is added to the regulated side of the +350-volt supply to furnish power for the +50-volt regulator. This supply is regulated by comparing to the regulated +350-volts the voltage of a point near +350 obtained from the divider R744-R743 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 K600 delays the application of dc voltages to the amplifier tubes in the instrument for almost 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

CRT Control Circuits

The Type T57 CRT used in the Type 551 has two electron guns and two sets of vertical-deflection plates. The horizontal-deflection plates are common to both guns. As a result, many of the crt control circuits are duplicated to provide the necessary adjustments and controls for each beam.

The INTENSITY control, R853, varies the voltage at the grids of both electron guns to control the beam currents simultaneously. The internal Intensity Adj. control is provided in one of the grid circuits so that both beam currents will be the same for a given setting of the INTENSITY control. The ASTIGMATISM control, R846, varies the voltage at the astigmatism anode of both guns to focus the crt beams in both dimensions simultaneously. The Geom. Adj., R842, varies the field the beams encounter as they emerge from the deflection systems to control the linearity at the extremes of deflection.

The ganged FOCUS controls vary the voltage supplied to the electron gun beam-forming plates and hence the shape of the electron beam. The Focus Adj. control provides for the slight voltage change necessary to bring both beams into focus on the crt screen for a given setting of the FOCUS control. The Horiz. Beam Regis. control varies the field the beam encounters as it emerges from the horizontal-deflection plates. In this way, an adjustment is provided to insure the vertical alignment of the start of both traces.

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 V822 provides -1350 volts for the crt cathode. A half-wave voltage-tripler circuit, V832, V842 and V852 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 R802-C802.

A floating half-wave rectifier V864 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 V814A)

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 output 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 V814A. The error signal will be amplified by V814A and V814B; the output of V814B 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 grids and cathodes of the crt. The unblanking pulses from the Time-Base Generator are transmitted to the crt grids through the cathode follower V183A 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, isolation networks composed of R860, C857 and C855 are employed. By this arrangement the fast leading edge of the unblanking pulse is coupled through C857 and C855 to the grids of the crt. For short-duration unblanking pulses, at the faster 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 R860. This pulls up the floating supply and holds the grids at the unblanked potential for the duration of the blanking pulse.

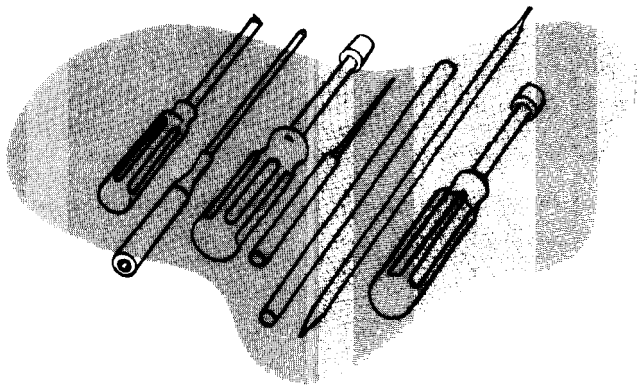
CALIBRATOR

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 V875 connected so as to switch the cathode follower V334A between two operating states—cutoff and conduction.

During the negative portion of the Multivibrator waveform the grid of V334A is driven well below cutoff and its cathode rests at ground potential. During the positive portion of the waveform V875A is cutoff and its plate rests slightly below +100 volts. The voltage at the plate V875A, when this tube is cutoff, is determined by the setting of the CAL. ADJ. control R879, part of a divider connected between +100 volts and ground.

Cathode-follower V334A has a precision, tapped divider for its cathode resistor. When the CAL. ADJ. control is properly adjusted, the cathode of V334A is at +100 volts when V875A is cutoff. By means of the tapped divider R885 through R893 and a second 1000/1 divider R896-R897, output voltages from .2 millivolts to 100 volts, in steps, are available. C884, connected between the cathode of V334A and ground, corrects the output waveform for a slight overshoot.

NOTES



SECTION 5

MAINTENANCE

PREVENTIVE MAINTENANCE

Air Filter

The Type 551 Oscilloscope is cooled by air drawn into the instrument through a washable filter constructed of adhesive-coated aluminum wool. If this filter is allowed to become dirty, it will restrict the flow of air and may cause the instrument to overheat. You should inspect, and clean if necessary, the filter every three or four months. If the filter is damaged, you should replace it as soon as possible to prevent dust being drawn into the instrument.

To remove the loose dirt in the filter, rap the filter gently on a hard surface. Then wash the filter briskly from the dirty side with hot water or, if necessary, with hot soapy water. After rinsing and drying thoroughly, coat the filter with "Handi-Koter" or "Filtercoat", products of the Research Products Corporation. These products are generally available from air-conditioner suppliers.

Fan Motor

To protect the fan motor bearings, they should be lubricated every three or four months with a few drops of light machine oil.

Visual Inspection

You should visually inspect the entire oscilloscope every few months for possible circuit defects. These defects may include loose or broken connections, damaged binding posts, improperly seated tubes, scorched wires or resistors, missing tube shields, or broken terminal strips. For most of these troubles, the remedy is apparent, but particular care must be taken when scorched components are detected. Scorched parts are often the result of other, less apparent, defects in the circuit. Therefore, it is essential that you determine the cause of overheating before replacing scorched parts in order to prevent damage to the new components.

Recalibration

The Type 551 Oscilloscope is a stable instrument, and will provide many hours of trouble-free operation. To insure the reliability of measurements obtained with the Type 551, we suggest that you recalibrate the instrument after each 500

hours of operation (or every six months if used intermittently). A complete step-by-step procedure for recalibrating the instrument is presented in the Recalibration Procedure section of this manual.

REPLACING COMPONENTS

The procedures required for replacing most of the components in the Type 551 are obvious. Detailed instructions are therefore not required. Other parts, however, can best be replaced if a definite procedure is followed. Instructions for the removal of some of these parts are contained in the following paragraphs. Because of the nature of the instrument, replacing certain parts will require a recalibration of the oscilloscope. Refer to Section 6 for recalibration procedures.

Removing Side and Bottom Panels

The panels of the Type 551 Oscilloscope are held in place by small screwhead fasteners. To remove the side panels,



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use a screwdriver to rotate the fasteners approximately two turns counterclockwise; then pull the upper portion of the panels outward from the carrying handles. To remove the bottom panel, lay the instrument on its side, rotate the fasteners approximately two turns counterclockwise, and pull off the panel. To prevent damage to the finish of the side panels, you should remove them first, before laying the instrument on its side to remove the bottom panel.

Replacing the Cathode-Ray Tube

To remove the cathode-ray tube, first disconnect the tube socket and all leads connected to the neck of the tube. Loosen the tube clamp at the base of the crt and remove the graticule cover. Pull the crt straight out through the front panel. When the new crt is in place, the leads may be properly connected to the neck of the tube by following the color code information provided on the tube shield. After replacing the crt, it will be necessary to recalibrate the oscilloscope.

Replacing Switches

Methods for removal of defective switches are, for the most part, obvious and only a normal amount of care is required. Single wafers are normally not replaced on the switches used in the Type 551 and if one wafer is defective, the entire switch should be replaced. Switches may be ordered from Tektronix either wired or unwired as desired.

Tube Replacements

Care should be taken both on preventive and corrective maintenance that tubes are not replaced unless they are actually causing a definite circuit malfunction. Many times during routine maintenance it will be necessary for you to remove tubes from their sockets. It is important that these tubes be returned to the same sockets unless they are actually defective. Replacing or switching tubes will many times necessitate recalibration of the instrument. If tubes do require replacement, it is recommended that they be replaced by previously checked high-quality tubes. Low-noise tubes used in the instrument should be replaced by equivalent tubes.

Soldering and Ceramic Strips

Many of the components in your Tektronix instrument are mounted on ceramic terminal strips. The notches in these strips are lined with a silver alloy. Repeated use of excessive heat, or use of ordinary tin-lead solder will break down the silver-to-ceramic bond. Occasional use of tin-lead solder will not break down the bond if excessive heat is not applied.

If you are responsible for the maintenance of a large number of Tektronix instruments, or if you contemplate frequent parts changes, we recommend that you keep on hand a stock of solder containing about 3% silver. This type of solder is used frequently in printed circuitry and should be read-

ily available from radio-supply houses. If you prefer, you can order the solder directly from Tektronix in one-pound rolls. Order by Tektronix part number 251-514.

Because of the shape of the terminals on the ceramic strips it is advisable to use a wedge-shaped tip on your soldering iron when you are installing or removing parts from the strips. Be sure and file smooth all surfaces of the iron which will be tinned. This prevents solder from building up on rough spots where it will quickly oxidize.

When removing or replacing components mounted on the ceramic strips you will find that satisfactory results are obtained if you proceed in the manner outlined below.

1. Use a soldering iron of about 75-watt rating.
2. Tin only the first 1/16 to 1/8 inch of the tip. For soldering to ceramic terminal strips tin the iron with solder containing about 3% silver.
3. Apply one corner of the tip to the notch where you wish to solder.
4. Apply only enough heat to make the solder flow freely.
5. Do not attempt to fill the notch on the strip with solder; instead, apply only enough solder to cover the wires adequately and to form a slight fillet on the wire.

In soldering to metal terminals (for example, pins on a tube socket) a slightly different technique should be employed. Prepare the iron as outlined above, but tin with ordinary tin-lead solder. Use only enough heat to allow the solder to flow freely along the wire so that a slight fillet will be formed.

General Soldering Considerations

When replacing wires in terminal slots clip the ends neatly as close to the solder joint as possible. In clipping the ends of wires take care the end removed does not fly across the room as it is clipped.

Occasionally you will wish to hold a bare wire in place as it is being soldered. A handy device for this purpose is a short length of wooden dowel. In soldering to terminal pins mounted in plastic rods it is necessary to use some form of "heat sink" to avoid melting the plastic. A pair of long-nosed pliers makes a convenient tool for this purpose.

Ceramic Strips

Two distinct types of ceramic strips have been used in Tektronix instruments. The earlier type mounted on the chassis by means of #4-40 bolts and nuts. The later type is mounted with snap-in plastic fittings.

To replace ceramic strips which bolt to the chassis, screw a #4-40 nut onto each mounting bolt, positioning the bolt so that the distance between the bottom of the bolt and the ceramic strip equals the height at which you wish to mount the strip above the chassis. Secure the nuts to the bolts with a drop of red glyptal. Insert the bolts through the holes in the chassis where the original strip was mounted, placing a

#4-40 lockwasher between each nut and the chassis. Place a second set of #4-40 lockwashers on the protruding ends of the bolts, and fasten them firmly with another set of #4-40 nuts. Place a drop of red glyptal over each of the second set of nuts after fastening.

Mounting Later Ceramic Strips

To replace ceramic strips which mount with snap-in plastic fittings, first remove the original fittings from the chassis. Assemble the mounting post on the ceramic strip. Insert the nylon collar into the mounting holes in the chassis. Carefully force the mounting posts into the nylon collars. Snip off the portion of the mounting post which protrudes below the nylon collar on the reverse side of the chassis.

NOTE

Considerable force may be necessary to push the mounting rods into the nylon collars. Be sure that you apply this force to the upper ends of the mounting rods rather than to the ceramic strip.

ORDERING REPLACEMENT PARTS

Standard Parts

Replacement for all parts used in the Type 551 Oscilloscope can be purchased directly from Tektronix at current net prices. However, since most of the components are standard electronic parts, they can generally be obtained locally in less time than required to obtain them from the factory. Before ordering or purchasing parts, be sure to consult the parts list to determine the tolerance required. The parts list gives the values, tolerances and Tektronix part numbers of all components used in the instrument.

Special Parts

In addition to the standard parts discussed in the previous paragraph, special parts are also used. These parts are manufactured, or specially selected by Tektronix, or are made especially for Tektronix by other manufacturers. Special parts are so designated in the parts list. These parts and all mechanical parts should be ordered from Tektronix since they will normally be difficult or impossible to obtain from other sources.

Since the production of your instrument, some of the Tektronix-manufactured components may have been superseded by improving components. The part number of these new components will not be listed in your manual. If you order a Tektronix-manufactured part, and it has been superseded by an improved component, the new part will be shipped in place of the part ordered. Your local Tektronix Field Engineering Office has knowledge of these changes and may call you if a change in your purchase order is necessary.

Replacement information sometimes accompanies the improved component to aid in its installation.

NOTE

Always include the instrument TYPE and SERIAL NUMBER in any correspondence concerning your instrument.

TROUBLESHOOTING

INITIAL PROCEDURES

This section is included to provide you with information about the Type 551 Oscilloscope that will enable you to more efficiently troubleshoot the instrument in the event of equipment failure. During troubleshooting work, you should correlate information contained in this section with information obtained from other sections of this manual. We have not attempted to give detailed step by step procedures for finding the cause of specific troubles, but rather have attempted to outline a general troubleshooting guide. This guide provides a means for determining the probable defective circuit or part from the symptoms observed rather than from detailed voltage or resistance measurements.

Trouble Isolation

Although the Type 551 Oscilloscope is a complex instrument, it can conveniently be thought of as consisting of a number of interrelated basic circuits as shown on the block diagram contained in the diagram section of the manual. Each of these basic circuits performs a specific part of the overall circuit operation required to place a display on the face of the crt. If any one of these circuits should fail, a definite symptom of this failure will be apparent. By investigating the possible causes of this symptom by means of systemized circuit checks, it is possible to determine which circuit or circuits are at fault. After determining which circuit is defective, additional checks will isolate the trouble to a particular part.

Before proceeding with troubleshooting of the instrument, make sure that any apparent trouble is actually due to a malfunction within the oscilloscope, and not due to improper control settings. Instructions for the operation of the instrument are contained in the "Operating Instructions" section of this manual. If, after reviewing the Operating Instructions, you determine that control settings are not at fault, you should next check the calibration of the suspected circuit according to the procedures contained in the "Recalibration Procedure" section of the manual. A calibration check will not only correct any troubles due to improper calibration, but will often also aid in isolating the faulty stage in cases where an actual trouble does exist. After checking control settings and calibration, if the trouble still exists, you should then go to a more detailed troubleshooting analysis. Specific troubleshooting procedures are given later in this section.

Schematic Diagrams

Separate schematic diagrams of each circuit are contained in the back of this manual together with a block diagram

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which provides an overall picture of instrument operation. The reference designation of each electronic component of the instrument is shown on the circuit diagrams as well as important voltages and waveforms. The following chart lists the reference designations associated with each circuit.

All numbers less than 100.....	Time-Base Trigger
100 series.....	Time-Base Generator and Timing Switch
300 series.....	Horizontal Amplifier
600 and 700 series.....	Low-Voltage Power Supply
800 series.....	CRT Circuit and Calibrator
1000 and 2000 series.....	Upper- and Lower- Beam Vertical Amplifiers

Switch wafers shown on the schematic diagrams are coded to indicate the position of the wafer on the actual switches. The number portion of the code refers to the wafer number on the switch assembly, wafers being numbered from the front of the switch to the rear, and the letters F and R indicate whether the front or the rear of the wafer is used to perform the particular switching function. Photographic details of these switches are also shown on the same fold-out page as the corresponding schematic diagram. These photographs are provided as parts-location guides.

Color Coding

All wiring used in the Type 551 Oscilloscope is color coded to facilitate circuit tracing. In addition, primary power, filament, and regulated power-supply output leads are distinguished by specific color codes. All regulated power-supply output leads follow the standard RETMA code. The -150 volt bus wire is coded brown-green-brown; the $+100$ volt bus is coded brown-black-brown; the $+225$ volt bus is coded red-red brown; the $+350$ volt bus is coded orange-green-brown; and the $+500$ bus is coded green-black-brown. The widest stripe is the first-digit color.

INITIAL PROCEDURES

As mentioned previously, the first checks that should be made in the event of an apparent trouble are for proper control settings and correct calibration. The next check for any type of trouble should be for proper operation of the regulated power supplies. Correct operation of every circuit in the oscilloscope depends on proper output voltages from the regulated power supplies. Due to the circuit configuration employed in the Type 551, it is possible for an incorrect power-supply voltage to affect one circuit more than the others. When all but one circuit in the oscilloscope is functioning properly, there is a tendency to over-look the power supply as a source of the trouble and to concentrate on the circuit where the trouble apparently exists. In cases of this type, valuable time can be saved by checking the power

supplies first. If the output and ripple voltages of the regulated power supplies are correct, use the trouble symptoms and the following Circuit Isolation information to locate the defective circuit.

When working on the instrument with the power on, you should work with only one hand at a time, being careful that the other hand does not touch the metal frame of the instrument. If possible, stand on an insulated surface, and use insulated tools and probes.

TROUBLE ANALYSIS and CIRCUIT ISOLATION

This portion of the Troubleshooting Procedure lists most of the troubles that can be caused by a circuit failure in the Type 551 Oscilloscope. It also describes checks that can be made to isolate the faulty circuit or circuits. In some cases, simple front-panel checks can determine which circuit is defective, but in other cases internal checks and measurements are required.

Upper or Lower Beam Not Visible On CRT

The inability to display either the upper or lower beam on the crt may be due to an unbalance in the corresponding vertical amplifier or to a defect in the crt circuit.

To determine which circuit is at fault, short the applicable vertical-deflection plates together at the neck of the crt. Be careful that the pins are not shorted to the crt shield. If the beam returns to the crt face, the trouble is due to an unbalanced vertical amplifier. If the beam does not reappear, the trouble is located in the crt circuit.

If an unbalanced vertical amplifier is indicated, move the shorting strap back, across correspondingly opposite sides of the vertical amplifier until you reach a point where the beam is not returned to the crt screen. The stage immediately following this point will be the one producing the unbalance. In making these checks with a shorting strap, be doubly sure that you are shorting together correspondingly opposite points such as the Distributed Amplifier grid lines or the control grids of V1033 and V1043. Serious damage can result if other than opposite points are shorted together.

If a faulty crt circuit is indicated, check the voltages in the circuits peculiar to the inoperative beam. A convenient method of checking these voltages is to compare them with the voltages in the circuits associated with the operative beam.

Neither Beam Visible on CRT

If a spot or trace is not produced by either beam, turn the instrument off and remove the leads connected to the crt horizontal-deflection plates (making sure that the metal ends do not touch the chassis). Turn the instrument back on and, after warmup, adjust the VERTICAL POSITION controls on the plug-in units. If the spots now appear, on the crt, either the Horizontal Amplifier or the Time-Base Generator is causing the trouble. If the spots do not appear you can suspect a faulty crt or crt circuit.

To isolate the trouble to either the Horizontal Amplifier or Time-Base Generator, reconnect the leads to the horizon-

tal-deflection plates and turn the HORIZONTAL DISPLAY switch to the EXT. position. If the spot now reappears, the Horizontal Amplifier is in balance, and the trouble is being caused by an inoperative condition in the Time-Base Generator. To troubleshoot this circuit, turn the HORIZONTAL DISPLAY switch to the NORMAL position, and turn the STABILITY control to the free-running (full right) position. Next, turn the TIME/CM switch through its range. If a sweep or trace appears for some positions of the switch, but not others, the trouble will be occurring in the components associated with the Timing Switch.

If no trace appears in any position of the TIME/CM switch, replace the tubes in the Time-Base Generator one at a time. Make sure that all tubes found to be good are returned to their original sockets. If this does not reveal the source of the trouble, the voltages throughout the circuit can be checked. In particular, check to see that the STABILITY control varies the voltage at the grid of V125. Neon lamp B167 is an important part of the Time-Base circuit; check to see that it is not burned out.

It is important that you understand the operation of the Time-Base Generator before proceeding with any extensive investigation of the circuit. For this reason we suggest that you thoroughly study that portion of the Circuit Description that pertains to this circuit.

If no spot appeared on the crt when the HORIZONTAL DISPLAY switch was turned to the EXT. position, the Horizontal Amplifier is causing the trouble. The faulty stage in this circuit can be isolated by shorting together correspondingly-opposite sides of the amplifier and checking for a spot or trace on the crt.

Insufficient or No Vertical Deflection

If there is some vertical deflection on the crt, but not enough to correspond to the calibrated value, the Vertical Amplifier can be investigated for insufficient gain. If there is only a slight deficiency in the deflection, as will usually be the case, the amplifier can generally be recalibrated for gain. Refer to the Recalibration Procedure for this. However, if the amplifier cannot be recalibrated, or if the decrease in gain is more pronounced, it will be necessary to check the tubes and circuit components.

Insufficient or No Horizontal Deflection

If there is insufficient horizontal deflection on the crt, the circuit at fault can be either the Time-Base Generator or the Horizontal Amplifier.

The operation of the Time-Base Generator can be checked from the front panel. Set the HORIZONTAL DISPLAY switch to NORMAL, the TIME/CM switch to .5 SEC., and adjust the STABILITY control for a free running sweep (full right). Connect a voltmeter between the SAWTOOTH OUT connector and ground. If the voltage varies between zero and +150 volts, as the Miller circuit runs up and back, the Time-Base Generator is operating properly. No voltage at this jack indicates an inoperative Time-Base circuit.

If the voltage reading at the SAWTOOTH OUT connector is low, you can suspect marginal tubes in the Time-Base gen-

erator or a misadjustment of the Sweep Length control. Consult the Recalibration Procedure for information on adjusting this control.

If a voltmeter indicates the proper reading at the SAWTOOTH OUT connector, the Horizontal Amplifier will be the circuit at fault. There are two gain adjustments in this circuit: the SWP CAL, R349 and the MAG. GAIN, R375. Any adjustment of these controls, however, will also affect the sweep timing. Be sure to refer to the Recalibration Procedure before making any adjustments in the Horizontal Amplifier.

Nonlinear Time-Base

The linearity of the horizontal-deflection circuit can be checked by connecting a marker-generator to the VERTICAL INPUT connector and adjusting the Time-Base controls for a stationary display. If the displayed markers are not equally spaced across the graticule, a nonlinear horizontal sawtooth, at the horizontal deflection plates, is indicated. This can be caused by non-linear amplification in the Horizontal Amplifier, or by non-linear operation of the Time-Base Generator.

If another oscilloscope is available, the linearity of the Time Base Generator can be checked by observing the sawtooth available at the SAWTOOTH OUT connector. If the slope of the trace portion of the sawtooth is constant, the Time-Base Generator is producing a linear sawtooth and the nonlinearity is being produced in the Horizontal Amplifier. If the slope of the trace is not constant, however, the nonlinearity is being produced by the Time-Base Generator.

Improper Time-Base Calibration

If the timing of the horizontal sweep appears to be improper, check to see if this is occurring in all positions, or just in certain positions, of the TIME/CM switch. If the timing appears to be off in all positions of the switch, the Horizontal Amplifier will probably be out of adjustment. Two adjustments, the SWP CAL, R349 and the MAG. GAIN, R375, affect the timing at all sweep rates. Refer to the Recalibration Procedure for the adjustment of these controls.

If the timing is off in just one setting, or in just one group of settings, of the TIME/CM switch, one (or more) of the components associated with the Timing Switch have probably changed in value. There are three variable capacitors associated with this switch: C160A, C160C, and C160E. These capacitors are additional timing adjustments at the faster sweep rates (μ SEC range). These capacitors should be adjusted only if the timing in the μ SEC range appears to be off.

Improper Triggering

If you cannot obtain a stable display of the displayed waveforms, the trouble is probably in:

- The Trigger-Pickoff Amplifier in the vertical amplifier,
- The Time-Base Trigger, or
- The Time-Base Generator circuit.

The operation of the Trigger-Pickoff Amplifiers can be checked as follows. Connect an external triggering signal

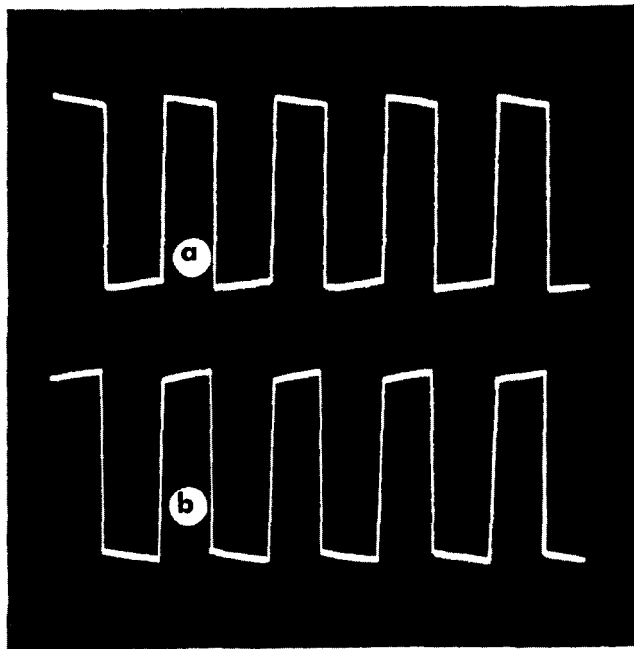


Fig. 5-1. 50-cps square-wave displays illustrating two types of low-frequency distortion.

(preferably the input-signal waveform) to the TRIGGER INPUT connector. Set the black TRIGGER SLOPE knob to EXT. (+ or -). Try to adjust the controls for stable triggering. If you can trigger the sweep in this manner, you can suspect the Trigger-Pidkoff Amplifier as the faulty stage.

If the waveform cannot be triggered in either the INT. or Ext. positions of the TRIGGER SLOPE switch, some circuit in either the Time-Base Trigger or Time-Base Generator is not operating properly. The Time-Base Generator can be eliminated if the trace can be turned off and on with the STABILITY control.

Waveform Distortion

Waveform distortion can be divided into two categories: (a) low-frequency distortion illustrated in Fig. 5-1, and (b) high-frequency distortion illustrated in Fig. 5-2. Any low-frequency distortion apparent in the waveform will be produced by the plug-in preamplifier. The main Vertical Amplifier is dc-coupled; therefore its response is flat down to dc. NOTE: Low-frequency distortion can also be produced by an

improperly adjusted probe. Refer to "Use of Probes", page 3-8.

High-frequency distortion is produced in the Vertical Amplifiers or Delay Lines. Generally, this will appear at the front corner of a step function.

Insufficient high-frequency peaking, which limits the rise-time and consequently the bandwidth, will produce the rounded-corner type of distortion illustrated in Fig. 5-2 (a). Tubes are often a cause of this type of distortion. Shorted, or partially shorted, peaking coils are another common source.

The overshoot condition, illustrated in Fig. 5-2 (b), is the result of excessive high-frequency peaking, and is produced by improperly adjusted peaking coils. The "wrinkle" condition, shown in Fig. 5-2 (c), is produced by an improperly adjusted Delay Line. Refer to the Recalibration Procedure for the Delay Line tuning procedure.

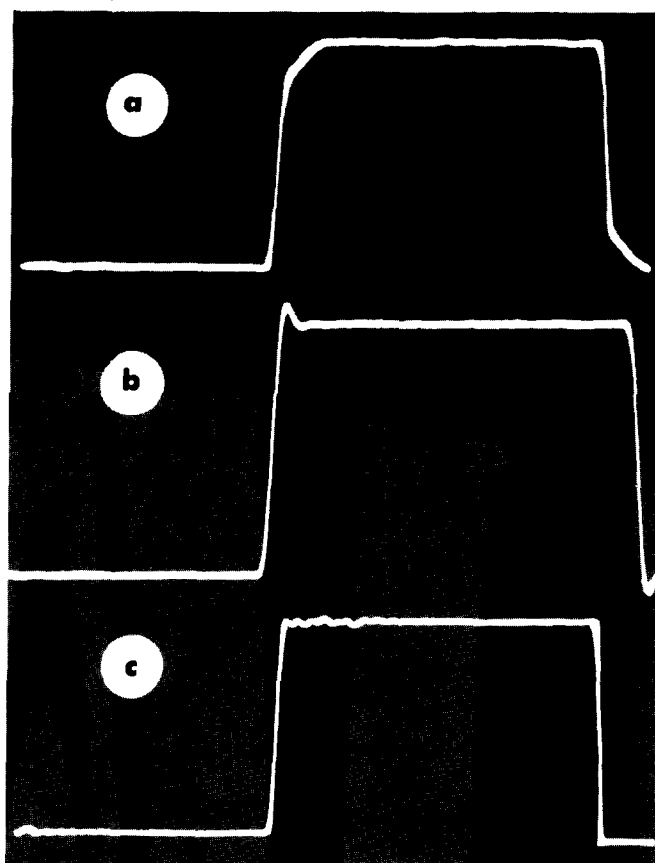


Fig 5-2. 450-kc square-wave displays illustrating three types of high-frequency distortion.

PARTS LIST *and* DIAGRAMS

<p>ABBREVIATIONS</p> <table> <tr> <td>Cer.</td><td>Ceramic</td><td>n</td><td>Nano or 10^{-9}</td></tr> <tr> <td>Comp.</td><td>Composition</td><td>Ω</td><td>ohm</td></tr> <tr> <td>EMC</td><td>Electrolytic, metal cased</td><td>p</td><td>Pico or 10^{-12}</td></tr> <tr> <td>f</td><td>Farad</td><td>PTB</td><td>Paper, "Bathtub"</td></tr> <tr> <td>G</td><td>Giga, or 10^9</td><td>PMC</td><td>Paper, metal cased</td></tr> <tr> <td>GMV</td><td>Guaranteed minimum value</td><td>Poly.</td><td>Polystyrene</td></tr> <tr> <td>h</td><td>Henry</td><td>Prec.</td><td>Precision</td></tr> <tr> <td>K or k</td><td>Kilohms or kilo (10^3)</td><td>PT</td><td>Paper Tubular</td></tr> <tr> <td>M/Cer.</td><td>Mica or Ceramic</td><td>T</td><td>Terra or 10^{12}</td></tr> <tr> <td>M or meg</td><td>Megohms or mega (10^6)</td><td>v</td><td>Working volts DC</td></tr> <tr> <td>μ</td><td>Micro, or 10^{-6}</td><td>Var.</td><td>Variable</td></tr> <tr> <td>$\mu\mu$</td><td>Micromicro or 10^{-12}</td><td>w</td><td>Watt</td></tr> <tr> <td>m</td><td>milli or 10^{-3}</td><td>WW</td><td>Wire-wound</td></tr> </table>				Cer.	Ceramic	n	Nano or 10^{-9}	Comp.	Composition	Ω	ohm	EMC	Electrolytic, metal cased	p	Pico or 10^{-12}	f	Farad	PTB	Paper, "Bathtub"	G	Giga, or 10^9	PMC	Paper, metal cased	GMV	Guaranteed minimum value	Poly.	Polystyrene	h	Henry	Prec.	Precision	K or k	Kilohms or kilo (10^3)	PT	Paper Tubular	M/Cer.	Mica or Ceramic	T	Terra or 10^{12}	M or meg	Megohms or mega (10^6)	v	Working volts DC	μ	Micro, or 10^{-6}	Var.	Variable	$\mu\mu$	Micromicro or 10^{-12}	w	Watt	m	milli or 10^{-3}	WW	Wire-wound
Cer.	Ceramic	n	Nano or 10^{-9}																																																				
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<p>SPECIAL NOTES AND SYMBOLS</p> <p>+ and up</p> <p>† Approximate serial number.</p> <p>X000 Part first added at this serial number.</p> <p>000X Part removed after this serial number.</p> <p>* 000-000 Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, also reworked or checked components.</p> <p>(Mod. w/) Simple replacement not recommended.</p> <p>Modify to value for later instruments and change other parts to match.</p>																																																							



MANUFACTURERS OF CATHODE-RAY OSCILLOSCOPES

HOW TO ORDER PARTS

Replacement parts are available through your local Tektronix Field Office.

Improvements in Tektronix instruments are incorporated as soon as available. Therefore, when ordering a replacement part it is important to supply the part number including any suffix, instrument type, serial number, plus a modification number where applicable.

If the part you have ordered has been improved or replaced, your local Field Office will contact you if there is a change in part number.

PARTS LIST

Bulbs

			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
B347		Neon, Type NE-2	150-002
B386		Neon, Type NE-2	150-002
B394		Neon, Type NE-2	150-002
B397		Neon, Type NE-2	150-002
B751		Incandescent, Type 47	150-001
B752		Incandescent, Type 47	150-001
B837	X3680-up	Neon, Type NE-2	150-002
B1083		Neon, Type NE-2	150-002
B1227		Neon, Type NE-2	150-002
B2083		Neon, Type NE-2	150-002
B2227		Neon, Type NE-2	150-002

Capacitors

Values fixed unless marked variable.

Tolerances $\pm 20\%$ unless otherwise indicated.

C1		4.7 pf	Cer.	500 v	281-501
C6		4.7 pf	Cer.	500 v	281-501
C10		.001 μf	PTM	600 v	285-501
C11		100 pf	Cer.	350 v	281-523
C15		.001 μf	Cer.	500 v	283-000
C20		.001 μf	Cer.	500 v	283-000
C27		47 pf	Cer.	500 v	281-518
C32		.01 μf	PTM	400 v	285-510
C37		.005 μf	Cer.	500 v	283-001
C42		22 pf	Cer.	500 v	281-510
C116		.001 μf	Cer.	500 v	283-000
C117		.005 μf	Cer.	500 v	283-001
C121		270 pf	Cer.	500 v	281-543
C124		8 pf	Cer.	500 v	281-503
C129		.005 μf	Cer.	500 v	283-001
C131		27 pf	Cer.	500 v	281-513
C135	X2159-up	8 pf	Cer.	500 v	281-503
C138		.005 μf	Cer.	500 v	283-001
C141	101-2158	12 pf	Cer.	500 v	281-506
	2159-up	8 pf	Cer.	500 v	281-503
C149		.005 μf	Cer.	500 v	283-001
C150		82 pf	Cer.	500 v	281-528
C160A		3-12 pf	Cer.	Var. 500 v	281-007
C160B		82 pf	Cer.	500 v	283-534
C160C		4.5-25 pf	Cer.	Var. 500 v	281-010

5%

Capacitors (continued)

							Tektronix Part Number
C160D		82 pf	Cer.		500 v	5%	283-534
C160E		4.5-25 pf	Cer.	Var.	500 v		281-010
C160F		.001 μ f	Mylar			$\pm 1/2$	291-008
C160G		.01 μ f					
C160H		.1 μ f			Mylar Timing Series	$\pm 1/2$	*291-007
C160J		1 μ f					
C160K	X3800-up	270 pf	Cer.		500 v		281-543
C165		82 pf	Cer.		500 v		281-528
C167		.001 μ f	Cer.		500 v		283-000
C180A		180 pf	Mica		500 v	10%	283-509
C180B		.0022 μ f	PTM		400 v	5%	285-543
C180C		.022 μ f	PTM		400 v		285-515
C180D		.1 μ f	PTM		400 v		285-526
C180E		.1 μ f	PTM		400 v		285-526
C181	101-923	39 pf	Cer.		500 v		281-517
	924-up	22 pf	Cer.		500 v		281-511
C191		.001 μ f	Cer.		500 v		283-000
C195	101-3379	12 pf	Cer.		500 v		281-506
	3380-up	15 pf	Cer.		500 v		281-509
C198		.005 μ f	Cer.		500 v		283-001
C330	X2159-up	.005 μ f	Cer.		500 v		283-001
C334	101-2158X	.01 μ f	Cer.		500 v		283-002
C340		4.5-25 pf	Cer.	Var.	500 v		281-010
C343	101-2158	12 pf	Cer.		500 v		281-505
	2159-up	4.7 pf	Cer.		500 v		281-501
C347	X1970-up	.001 μ f	Cer.		500 v		283-000
C350		3-12 pf	Cer.	Var.	500 v		281-009
C351	X2159-up	.005 μ f	Cer.		500 v		283-001
C355		1.5 pf	Cer.		500 v		281-526
C364		3-12 pf	Cer.	Var.	500 v		281-009
C372		9-180 pf	Mica	Var.	500 v		281-023
C381		6.25 μ f	EMT		300 v		290-000
C384		3-12 pf	Cer.	Var.	500 v		281-009
C390		.047 μ f	PTM		400 v		285-519
C392		4.7 pf	PTM		500 v		281-501
C394	X457-up	.005 μ f	Cer.		500 v		283-001
C600		.02 μ f	Cer.		150 v		283-004
C611		.01 μ f	PTM		400 v		285-510
C616		.01 μ f	PTM		400 v		285-510
C625		.01 μ f	PTM		400 v		285-510
C631	101-2357	2 x 40 μ f	EMC		350 v		290-027
C631	2358-up	2 x 40 μ f	EMC		250 v		290-040
C641	101-2357	125 μ f	EMC		450 v		290-045
C641	2358-up	125 μ f	EMC		350 v		290-044
C658		.01 μ f	PTM		400 v		285-510
C665		2 x 200 μ f	EMC		250 v		290-082
C677		.01 μ f	PTM		400 v		285-510
C688		.01 μ f	PTM		400 v		285-510
C692	X2358-up	.02 μ f	Cer.		600 v		283-006
C695		125 μ f	EMC		450 v		290-045

Capacitors (continued)

Tektronix
Part Number

C700		2 x 100 μ f	EMC	350 v	290-081
C701		2 x 100 μ f	EMC	350 v	290-081
C702	X2358-up	.02 μ f	Cer.	600 v	283-006
C721	101-2357	.01 μ f	PTM	400 v	285-510
C721	2358-up	.01 μ f	PTM	600 v	285-511
C742	X2358-up	.02 μ f	Cer.	600 v	283-006
C744		.01 μ f	PTM	400 v	285-510
C747		2 x 40 μ f	EMC	450 v	290-042
C751 ABC		10-10-10 μ f	EMC	450 v	290-033
C755		.005 μ f	Cer.	500 v	283-001
C756		.005 μ f	Cer.	500 v	283-001
C760		.005 μ f	Cer.	500 v	283-001
C761		.005 μ f	Cer.	500 v	283-001
C765		.005 μ f	Cer.	500 v	283-001
C770		.005 μ f	Cer.	500 v	283-001
C781	X457-up	.01 μ f	Cer.	500 v	283-002
C784		.01 μ f	Cer.	500 v	283-002
C800		.001 μ f	PTM	600 v	285-501
C802		.047 μ f	PTM	400 v	285-519
C805		.01 μ f	PTM	400 v	285-510
C806		.001 μ f	PTM	600 v	285-501
C807		2 x 20 μ f	EMC	450 v	290-037
C812		.02 μ f	Cer.	600 v	Use 283-006
C814	101-2219	.0068 μ f	PTM	3000 v	285-508
C814	2220-up	.01 μ f	Cer.	2000 v	283-011
C821	101-2060	470 pf	PTM	10,000 v	Use 281-556
	2061-up	500 pf	Cer.	10,000 v	281-556
C822	101-2219	.0068 μ f	PTM	3000 v	285-508
	2220-up	.01 μ f	Cer.	2000 v	283-011
C823	101-2069	.0068 μ f	PTM	5000 v	Use 283-034
	2070-up	.005 μ f	Cer.	4000 v	283-034
C824	101-2060	470 pf	PTM	10,000 v	Use 281-556
	2061-up	500 pf	Cer.	10,000 v	281-556
C825	101-2060	470 pf	PTM	10,000 v	Use 281-556
	2061-up	500 pf	Cer.	10,000 v	281-556
C828	101-2060	.015 μ f	PTM	3000 v	285-513
	2061-up	.01 μ f	Cer.	2000 v	283-011
C837	X3680-up	.01 μ f	Discap	2000 v	283-011
C839	101-2060	.015 μ f	PTM	3000 v	285-513
	2061-up	.01 μ f	Cer.	2000 v	283-011
C850	101-2219	.0068 μ f	PTM	3000 v	285-508
	2220-up	.01 μ f	Cer.	2000 v	283-011
C851	101-2060	.015 μ f	PTM	3000 v	285-513
	2061-up	.01 μ f	Cer.	2000 v	283-011
C854	X3090-up	470 pf	Cer.	500 v	281-525
C855	101-2060	.015 μ f	PTM	3000 v	285-513
	2061-up	.01 μ f	Cer.	2000 v	283-011
C856	X2130-up	.01 μ f	Cer.	2000 v	283-011
C857	101-2060	.015 μ f	PTM	3000 v	285-513
	2061-up	.01 μ f	Cer.	2000 v	283-011
C858	X2130-up	.01 μ f	Cer.	2000 v	283-011
C862	X3090-up	.1 μ f	Cer.	100 v	283-012
C865		.005 μ f	Cer.	500 v	283-001
C866	X3090-up	.005 μ f	Cer.	500 v	283-001
C871		330 pf	Mica	500 v	283-518

10%

Capacitors (continued)

					Tektronix Part Number
C875	330 pf	Mica		500 v	283-518
C884	27 pf	Cer.		500 v	281-513
C897	.001 μ f	Cer.		500 v	283-000
C1003	2 x 20 μ f	EMC		450 v	290-036
C1005A	40 μ f	EMC		475 v	290-063
C1005B	20 μ f				
C1005C	10 μ f				
C1007	.1 μ f	PTM		400 v	285-526
C1013	.005 μ f	Cer.		500 v	283-001
C1029	.001 μ f	Cer.		500 v	283-000
C1031	.005 μ f	Cer.		500 v	283-001
C1039	.001 μ f	Cer.		500 v	281-536
C1043	.005 μ f	Cer.		500 v	283-001
C1049	.001 μ f	Cer.		500 v	281-536
C1052	.001 μ f	Cer.		500 v	283-000
C1054	.005 μ f	Cer.		500 v	283-001
C1056	150 pf	Cer.		500 v	281-524
C1062	.001 μ f	Cer.		500 v	283-000
C1075	8-50 pf	Cer.	Var.	500 v	281-022
C1077	8-50 pf	Cer.	Var.	500 v	281-022
C1078	.7-3 pf	Tub.	Var.	500 v	281-027
C1085	.005 μ f	Cer.		500 v	283-001
C1093	4 x 75 μ f	EMC		150 v	290-071
C1102	.001 μ f	Cer.		500 v	283-000
C1104	.7-3 pf	Tub.	Var.	500 v	281-027
C1105	150 pf	Cer.		500 v	281-524
C1106	150 pf	Cer.		500 v	281-524
C1112	.001 μ f	Cer.		500 v	283-000
C1122	.001 μ f	Cer.		500 v	283-000
C1124	.7-3 pf	Tub.	Var.	500 v	281-027
C1126	150 pf	Cer.		500 v	281-524
C1132	.001 μ f	Cer.		500 v	283-000
C1142	.001 μ f	Cer.		500 v	283-000
C1144	.7-3 pf	Tub.	Var.	500 v	281-027
C1146	150 pf	Cer.		500 v	281-524
C1152	.001 μ f	Cer.		500 v	283-000
C1162	.001 μ f	Cer.		500 v	283-000
C1164	.7-3 pf	Tub.	Var.	500 v	281-027
C1166	150 pf	Cer.		500 v	281-524
C1172	.001 μ f	Cer.		500 v	283-000
C1182	.001 μ f	Cer.		500 v	283-000
C1184	.7-3 pf	Tub.	Var.	500 v	281-027
C1186	150 pf	Cer.		500 v	281-524
C1192	.001 μ f	Cer.		500 v	283-000
C1202	.001 μ f	Cer.		500 v	283-000
C1204	.7-3 pf	Tub.	Var.	500 v	281-027
C1205	150 pf	Cer.		500 v	281-524
C1208	.005 μ f	Cer.		500 v	283-001
C1212	.001 μ f	Cer.		500 v	283-000

Capacitors (continued)

Tektronix
Part Number

C1223		.001 μ f	Cer.		500 v		283-000
C1228		.005 μ f	Cer.		500 v		283-001
C1299	X678-up	.7-3 pf	Tub.	Var.	500 v		281-027
C1300	X678-up	.7-3 pf	Tub.	Var.	500 v		281-027
C1301-C1350		.7-3 pf	Tub.	Var.	500 v	(50)	281-027
C1360-C1375		1.5 pf	Cer.		500 v		(16) 281-529
C1380-C1383		.68 pf	Cer.		500 v	$\pm .136$ pf	(4) 281-537
C2003		2 x 20 μ f	EMC		450 v		290-036
C2005A		40 μ f	EMC		475 v		290-063
C2005B		20 μ f					
C2005C		10 μ f					
C2007		.1 μ f	PTM		400 v		285-526
C2013		.005 μ f	Cer.		500 v		283-001
C2029		.001 μ f	Cer.		500 v		283-000
C2031		.005 μ f	Cer.		500 v		283-001
C2039		.001 μ f	Cer.		500 v	± 100 pf	281-536
C2043		.005 μ f	Cer.		500 v	± 100 pf	283-001
C2049		.001 μ f	Cer.		500 v		281-536
C2052		.001 μ f	Cer.		500 v		283-000
C2054		.005 μ f	Cer.		500 v		283-001
C2056		150 pf	Cer.		500 v		281-524
C2062		.001 μ f	Cer.		500 v		283-000
C2075		8-50 pf	Cer.	Var.	500 v		281-022
C2077		8-50 pf	Cer.	Var.	500 v		281-022
C2078		.7-3 pf	Tub.	Var.	500 v		281-027
C2085		.005 μ f	Cer.		500 v		283-001
C2093		4 x 75 μ f	EMC		150 v		290-071
C2102		.001 μ f	Cer.		500 v		283-000
C2104		.7-3 pf	Tub.	Var.	500 v		281-027
C2105		150 pf	Cer.		500 v		281-524
C2106		150 pf	Cer.		500 v		281-524
C2112		.001 μ f	Cer.		500 v		283-000
C2122		.001 μ f	Cer.		500 v		283-000
C2124		.7-3 pf	Tub.	Var.	500 v		281-027
C2126		150 pf	Cer.		500 v		281-524
C2132		.001 μ f	Cer.		500 v		283-000
C2142		.001 μ f	Cer.		500 v		283-000
C2144		.7-3 pf	Tub.	Var.	500 v		281-027
C2146		150 pf	Cer.		500 v		281-524
C2152		.001 μ f	Cer.		500 v		283-000
C2162		.001 μ f	Cer.		500 v		283-000
C2164		.7-3 pf	Tub.	Var.	500 v		281-027
C2166		150 pf	Cer.		500 v		281-524
C2172		.001 μ f	Cer.		500 v		283-000
C2182		.001 μ f	Cer.		500 v		283-000
C2184		.7-3 pf	Tub.	Var.	500 v		281-027
C2186		150 pf	Cer.		500 v		281-524
C2192		.001 μ f	Cer.		500 v		283-000
C2202		.001 μ f	Cer.		500 v		283-000
C2204		.7-3 pf	Tub.	Var.	500 v		281-027
C2205		150 pf	Cer.		500 v		281-524

Capacitors (continued)						Tektronix Part Number
C2208		.005 μ f	Cer.	500 v		283-001
C2212		.001 μ f	Cer.	500 v		283-000
C2223		.001 μ f	Cer.	500 v		283-000
C2228		.005 μ f	Cer.	500 v		283-001
C2301-C2350		.7-3 pf	Tub.	Var.	500 v	(50) 281-027
C2359	X1970-up	1 pf	Cer.	500 v	± 0.2 pf	281-538
C2360-C2375		1.5 pf	Cer.	500 v		(16) 281-529
C2380-C2383		.68 pf	Cer.	500 v		(4) 281-537

Fuses

F601	101-931	4 amp	3 AG, Slo-Blo (117 V operation)			159-027
		2 amp	3 AG, Slo-Blo (234 V operation)			159-023
	932-up	8 amp	3 AG, Slo-Blo (117 V operation)			159-035
		4 amp	3 AG, Slo-Blo (234 V operation)			159-027
F602		6 amp	3 AG, Fast-Blo (117 V operation)			159-013
		3 amp	3 AG, Slo-Blo (234 V operation)			159-005
F1054	X3180-up	.15 amp	Fast-Blo (150 ma)			159-049
F2054	X3180-up	.15 amp	Fast-Blo (150 ma)			159-049

Diodes

D131	X2159-up	Germanium Diode				152-008
D162		Germanium Diode				152-008
D172		Germanium Diode				152-008
D642 A,B,C,D	X2358-up	Silicon Diode				152-047
D662 A,B,C,D	X2358-up	Silicon Diode				152-047
D692A,B	X2358-up	Silicon Diode				152-047
D702 A,B	X2358-up	Silicon Diode				152-047
D712	X2358-up	Silicon Diode				152-047
D742 A,B,C,D	X2358-up	Silicon Diode				152-047

Inductors

L133	101-2158X	88 μ h	Fixed			*108-022
LR149		1 mh	Fixed	(on 3.3 k resistor)		*108-058
L770	X3080-up	Core Ferramic Suppressor				276-507
L765	X3080-up	Core Ferramic Suppressor				276-507
L1014	101-596	1.7-3.7 μ h	Var.			*114-088
	597-up	1.8-3.9 μ h	Var.	core	276-506	*114-112
L1015	X922-up	.45 μ h	Fixed			*108-062
L1024	101-596	1.7-3.7 μ h	Var.	core	276-506	*114-088
	597-up	1.8-3.9 μ h	Var.	core	276-506	*114-112
L1025	X922-up	.45 μ h	Fixed			*108-062
L1033	X3080-up	Core Ferramic Suppressor				276-507
L1036	101-596	.5-1 μ h	Var.	core	276-506	*114-087
	597-up	.3-.55 μ h	Var.	core	276-506	*114-111
L1046	101-596	.5-1 μ h	Var.	core	276-506	*114-087
	597-up	.3-.55 μ h	Var.	core	276-506	*114-111
L1064	101-769	14 μ h	Fixed			*108-134
	770-up	8.4 μ h	Fixed			*108-157
L1071		.3-.5 μ h	Var.	core	276-506	*114-092
L1073		.3-.5 μ h	Var.	core	276-506	*114-092
L1103		Grid Line 6 section				*108-145
L1104		Plate Line 7 section				*108-139
L1113		Grid Line 6 section				*108-145
L1114		Plate Line 7 section				*108-139
L1300	X678-up	1.2-2.4 μ h	Var.	core	276-506	*114-114
L1301	X678-up	1.2-2.4 μ h	Var.	core	276-506	*114-114

Inductors (continued)

Tektronix
Part Number

L1302	X678-up	1.2-2.4 μ h	Var.	core 276-506	*114-114
L1303	X678-up	1.2-2.4 μ h	Var.	core 276-506	*114-114
L1304	101-1609	Delay Line 30 section			Use *108-177
	1610-up	Delay Line 30 section			*108-177
L1305	101-1609	Delay Line 30 section			Use *108-177
	1610-up	Delay Line 30 section			*108-177
L1334	101-1609	Delay Line 20 section			Use *108-176
	1610-up	Delay Line 20 section			*108-176
L1335	101-1609	Delay Line 20 section			Use *108-176
	1610-up	Delay Line 20 section			*108-176
L1354		.9-1.6 μ h	Var.	core 276-506	*114-038
L1355		.9-1.6 μ h	Var.	core 276-506	*114-038
L2014	101-596	1.7-3.7 μ h	Var.	core 276-506	*114-088
	597-up	1.8-3.9 μ h	Var.	core 276-506	*114-112
L2015	X922-up	.45 μ h	Fixed		*108-062
L2024	101-596	1.7-3.7 μ h	Var.	core 276-506	*114-088
	597-up	1.8-3.9 μ h	Var.	core 276-506	*114-112
L2025	X922-up	.45 μ h	Fixed		*108-062
L2033	X3080-up	Core Ferramic Suppressor			276-507
L2036	101-596	.5-1 μ h	Var.	core 276-506	*114-087
	597-up	.3-.55 μ h	Var.	core 276-506	*114-111
L2046	101-596	.5-1 μ h	Var.	core 276-506	*114-087
	597-up	.3-.55 μ h	Var.	core 276-506	*114-111
L2064	101-769	14 μ h	Fixed		*108-134
	770-up	8.4 μ h	Fixed		*108-157
L2071		.3-.5 μ h	Var.	core 276-506	*114-092
L2073		.3-.5 μ h	Var.	core 276-506	*114-092
L2103		Grid Line 6 Section			*108-145
L2104		Plate Line 7 Section			*108-139
L2113		Grid Line 6 Section			*108-145
L2114		Plate Line 7 Section			*108-139
L2304	101-1609	Delay Line 20 Section			Use *108-176
	1610-up	Delay Line 20 Section			*108-176
L2305	101-1609	Delay Line 20 Section			Use *108-176
	1610-up	Delay Line 20 Section			*108-176
L2334	101-1609	Delay Line 30 Section			Use *108-177
	1610-up	Delay Line 30 Section			*108-177
L2335	101-1609	Delay Line 30 Section			Use *108-177
	1610-up	Delay Line 30 Section			*108-177
L2354		.9-1.6 μ h	Var.	core 276-506	*114-038
L2355		.9-1.6 μ h	Var.	core 276-506	*114-038
L2356		.9-1.6 μ h	Var.	core 276-506	*114-038
L2357		.9-1.6 μ h	Var.	core 276-506	*114-038

Resistors

Resistors are Fixed, Comp., $\pm 10\%$ unless otherwise indicated.

R1	1 meg	$\frac{1}{2}$ w			302-105
R2	390 k	$\frac{1}{2}$ w			302-394
R3	50 k		Var.	Int. Trig. DC Level Adj.	311-023
R4	100 k	$\frac{1}{2}$ w			302-104
R6	1 meg	$\frac{1}{2}$ w			302-105
R7	390 k	$\frac{1}{2}$ w			302-394
R8	50 k		Var.	DC Level Adj. Int. Trig.	311-023
R9	100 k	$\frac{1}{2}$ w			302-104
R12	1 meg	$\frac{1}{2}$ w			302-105
R13	100 k	$\frac{1}{2}$ w			302-104

Resistors (continued)

						Tektronix Part Number
R15		470 k	1/2 w			302-474
R17†		100 k		Var.	TRIG. LEVEL	311-099
R18		22 k	1/2 w			302-223
R19		470 k	1/2 w			302-474
R20	101-2158	470 k	1/2 w			302-474
	2159-up	56 k	1/2 w			302-563
R21	101-2158X	56 k	1/2 w			302-563
R23		33 k	2 w			306-333
R24		39 k	2 w			306-393
R25		47 Ω	1/2 w			302-470
R26		47 Ω	1/2 w			302-470
R27		4.7 k	1 w			304-472
R29		4.7 k	1 w			304-472
R32		47 k	1/2 w			302-473
R33		47 k	1/2 w			302-473
R34		47 Ω	1/2 w			302-470
R35	101-2158	22 k	2 w			306-223
	2159-up	18 k	1 w			304-183
R37		500 Ω		Var.	Trig. Sens.	311-005
R38	101-2158	22 k	2 w			306-223
	2159-up	18 k	1 w			304-183
R39		100 k	2 w	Var.	Trig. Level Centering	311-026
R40	101-2158	100 k	1/2 w			302-104
	2159-up	120 k	1/2 w			302-124
R41		2.7 meg	1/2 w			302-275
R42		100 k	1/2 w			302-104
R44	101-2158	2.7 k	1/2 w			302-272
	2159-up	1.5 k	1/2 w			302-152
R45	X457-2158X	1 meg	1/2 w			302-105
R46	101-2158	1 k	1/2 w			302-102
	2159-up	680 Ω	1/2 w			302-681
R47		47 Ω	1/2 w			302-470
R48		1.5 k	1/2 w			302-152
R49	X2159-up	1 meg	1/2 w			302-105
R110†		500 k		Var.	STABILITY	311-099
R111		100 k		Var.	Preset Stability	311-026
R114		470 k	1/2 w		5%	301-474
R115		100 k	1/2 w		5%	301-104
R116	101-2158	200 k	1/2 w		5%	301-204
	2159-up	180 k	1/2 w		5%	301-184
R118		10 meg	1/2 w			302-106
R121		100 Ω	1/2 w			302-101
R122		22 k	1/2 w			302-223
R124		100 k	1/2 w		5%	301-104
R125		50 k	0.1 w	Var.	Lockout Level Adj.	311-078
R126		300 k	1/2 w		5%	301-304

†R17 concentric w/R110, R310 & SW310. Furnished as a unit.

Resistors (continued)

Tektronix
Part Number

R127		100 Ω	$\frac{1}{2}$ w					302-101
R128		12 k	$\frac{1}{2}$ w					302-123
R129		10 k	$\frac{1}{2}$ w					302-103
R130		22 k	2 w					306-223
R131		1 k	$\frac{1}{2}$ w					302-102
R132		47 Ω	$\frac{1}{2}$ w					302-470
R133	101-2158X	3.3 k	1 w	Matched w/in $\pm 2\frac{1}{2}\%$ each other				*312-569
R134	101-2158X	2.7 k						
R135	X2159-up	6 k	3 w	3 k tap	mica plate	1%		*310-555
R136	101-2158X	56 k	1 w			5%		303-563
R137		47 Ω	$\frac{1}{2}$ w					302-470
R138		47 Ω	$\frac{1}{2}$ w					302-470
R141	101-2158	39 k	$\frac{1}{2}$ w	Matched w/in 5% each other				*312-570
R143	101-2158	33 k						
R141	2159-up	33 k	1 w			Prec.	1%	310-070
R143	2159-up	30 k	1 w			Prec.	1%	310-072
R144		8 k	5 w			WW	5%	308-053
R145		1 meg	$\frac{1}{2}$ w					302-105
R146		100 Ω	$\frac{1}{2}$ w					302-101
R147		1 k	$\frac{1}{2}$ w					302-102
R148		47 k	$\frac{1}{2}$ w					302-473
R150		270 Ω	$\frac{1}{2}$ w					302-271
R152		36 k	$\frac{1}{2}$ w				5%	301-363
R153		1 meg	$\frac{1}{2}$ w					302-105
R154		10 k	$\frac{1}{2}$ w					302-103
R155		1 meg	$\frac{1}{2}$ w					302-105
R156		1.8 meg	$\frac{1}{2}$ w					302-185
R160A		100 k	$\frac{1}{2}$ w			Prec.	1%	309-045
R160B		200 k	$\frac{1}{2}$ w			Prec.	1%	309-051
R160C		500 k	$\frac{1}{2}$ w			Prec.	1%	309-003
R160D		1 meg	$\frac{1}{2}$ w			Prec.	1%	309-014
R160E		2 meg	$\frac{1}{2}$ w			Prec.	1%	309-023
R160F		5 meg	$\frac{1}{2}$ w			Prec.	1%	309-087
R160G		10 meg	1 w			Prec.	1%	310-107
R160H		10 meg	1 w			Prec.	1%	310-107
R160J		30 meg	2 w			Prec.	1%	310-505
R160K		10 k	$\frac{1}{2}$ w					302-103
R160L	101-346	20 k		Var.				311-083
	347-up	20 k		Var.				311-108
R160V	X2070-up	1 meg	$\frac{1}{2}$ w			WW	TIME/CM	302-105
R163		100 k	$\frac{1}{2}$ w					302-104
R164		22 k	2 w					306-223
R165		22 k	2 w					306-223
R166		22 k	2 w					306-223
R167		1.5 meg	$\frac{1}{2}$ w					302-155
R168		47 k	$\frac{1}{2}$ w					302-473
R170		47 Ω	$\frac{1}{2}$ w					302-470
R172		47 Ω	$\frac{1}{2}$ w					302-470
R173		470 Ω	$\frac{1}{2}$ w					302-471
R174		8 k	5 w			WW	5%	308-053

Resistors (continued)

							Tektronix Part Number
R176		2 k	2 w	Var.		Sweep Length	311-008
R178		4 k	5 w		WW	5%	308-051
R180A		470 k	1/2 w				302-474
R180B		4.7 meg	1/2 w				302-475
R181		4.7 meg	1/2 w				302-475
R183		100 Ω	1/2 w				302-101
R191		100 k	1 w				304-104
R193		100 k	1 w				304-104
R195		47 k	1/2 w				302-473
R196	101-3379	100 k	1/2 w				302-104
R196	3380-up	110 k				5%	301-114
R197		100 Ω	1/2 w				302-101
R198	101-2158	47 Ω	1/2 w				302-470
	2159-up	47 Ω	1/4 w				316-470
R199		4.7 k	1 w				304-472
R310†		100 k		Var.		Ext. Sw. Atten.	311-099
R311		1 k	1/2 w				302-102
R314		22 k	2 w				306-223
R316		47 Ω	1/2 w				302-470
R318		33 k	2 w				306-333
R330†	101-2158	500 k		Var.		VERNIER	311-048
	2159-up	200 k		Var.		VERNIER	311-149
R331	101-2158	4.7 meg	1/2 w				302-475
	2159-up	12.1 meg	1/2 w		Prec.	1%	309-268
R333†	101-2158	500 k		Var.		HORIZ. POS.	311-048
	2159-up	100 k		Var.		HORIZ. POS.	311-149
R334	101-2158	560 k	1/2 w				302-564
	2159-up	3.5 meg	1/2 w		Prec.	1%	309-086
R335	101-2158X	100 Ω	1/2 w				302-101
R338	101-2158X	470 k	1/2 w				302-474
R340	101-2158	1 meg	1/2 w		Prec.	1%	309-014
	2159-up	1.5 meg	1/2 w		Prec.	1%	309-017
R341	101-2158X	1.23 meg	1/2 w		Prec.	1%	309-016
R343	101-2158	680 Ω	1/2 w				302-681
	2159-up	2.2 k	1/2 w				302-222
R344		100 Ω	1/2 w				302-101
R346		100 k	1 w				304-104
R347		100 k	1/2 w				302-104
R349		50 k		Var.		Sweep Cal.	311-078
R350	101-2889	111 k	1/2 w		Prec.	1%	Use 309-091
R350	2890-up	120 k	1/2 w		Prec.	1%	309-091
R351		100 Ω	1/2 w				302-101
R353		100 k	1/2 w				302-104
R355		400 k	1 w		Prec.	1%	310-094
R356		400 k	1 w		Prec.	1%	310-094
R357		22 k	1/2 w				302-223
R358		20 k		Var.		Norm/Mag. Regis.	311-018
R363		47 Ω	1/2 w				302-470
R364		25 k	5 w	(6 k tap)	Prec.	1%	310-506
R366		47 Ω	1/2 w				302-470
R372		2.2 k	1 w				304-222
R373		6 k	5 w		WW	5%	308-052
R374		2.2 k	1 w				304-222
R375		2 k				Mag. Gain	311-008

†R330 & R333 are concentric. Furnished as a unit.

‡R310 concentric w/R17, R110 & SW110. Furnished as a unit.

Resistors (continued)

					Tektronix Part Number	
R381		100 Ω	$\frac{1}{2}$ w			302-101
R383		47 Ω	$\frac{1}{2}$ w			302-470
R384		6-30 k	5 w	Prec.	1%	310-507
R386		100 Ω	$\frac{1}{2}$ w			302-101
R387		39 k	2 w			306-393
R388		39 k	2 w			306-393
R390		390 Ω	$\frac{1}{2}$ w			302-391
R391		47 Ω	$\frac{1}{2}$ w			302-470
R392		2.2 k	$\frac{1}{2}$ w			302-222
R394		470 k	$\frac{1}{2}$ w			302-474
R395	101-162	470 k	$\frac{1}{2}$ w			302-474
	163-up	820 k	$\frac{1}{2}$ w			302-824
R396	101-162	470 k	$\frac{1}{2}$ w			302-474
	163-up	820 k	$\frac{1}{2}$ w			302-824
R397		470 k	$\frac{1}{2}$ w			302-474
R600	X127-up	12 Ω	1 w			304-120
R603		150 k	$\frac{1}{2}$ w			302-154
R604		68 k	$\frac{1}{2}$ w			302-683
R605	101-2357	12 k	1 w			304-123
R605	2358-up	12 k	$\frac{1}{2}$ w			302-123
R606		18 k	1 w			304-183
R607	101-2357	120 k	$\frac{1}{2}$ w			302-124
R607	2358-up	220 k	$\frac{1}{2}$ w			302-224
R610		2.2 meg	$\frac{1}{2}$ w			302-225
R611		3.3 meg	$\frac{1}{2}$ w			302-335
R613		33 k	$\frac{1}{2}$ w			302-333
R615		100 k	$\frac{1}{2}$ w			302-104
R618		100 k	$\frac{1}{2}$ w			302-104
R620		470 k	$\frac{1}{2}$ w			302-474
R622		1 k	$\frac{1}{2}$ w			302-102
R623		100 k	$\frac{1}{2}$ w			302-104
R626		50 k	1 w			310-086
R627		10 k		Var.	Prec. WW	1% —150 Adj.
R628		68 k	1 w		Prec.	1%
R636		1 k	$\frac{1}{2}$ w			310-054
						302-102
R637		1.5 meg	$\frac{1}{2}$ w			302-155
R639		1.5 k	25 w		WW	5%
R641	101-2357	10 Ω	1 w			308-040
R641	2358-up	10 Ω	2 w			304-100
R642	101-2357	10 Ω	1 w			306-100
						304-100
R642	2358-up	10 Ω	2 w			306-100
R643		150 k	1 w			304-154
R651		39 k	$\frac{1}{2}$ w			302-393
R652	101-2357	47 k	$\frac{1}{2}$ w			302-473
R652	2358-up	120 k	$\frac{1}{2}$ w			302-124
R653	101-2357	470 k	$\frac{1}{2}$ w			302-474
R653	2358-up	820 k	$\frac{1}{2}$ w			302-824
R655		1.5 meg	$\frac{1}{2}$ w			302-155
R656		1 k	$\frac{1}{2}$ w			302-102
R657		490 k	1 w	Prec.	1%	310-057

Resistors (continued)

						Part Number Tektronix
R658		333 k	1 w	Prec.	1%	310-056
R659	X166-up	6 k	5 w	WW	5%	308-052
R664		82 k	1 w			304-823
R665		10 Ω	1 w			304-100
R666	X2358-up	10 Ω	1 w			304-100
R668		400 Ω	20 w	WW	5%	308-029
R671		56 k	$\frac{1}{2}$ w			302-563
R672		270 k	$\frac{1}{2}$ w			302-274
R673	101-2357	1 meg	$\frac{1}{2}$ w			302-105
R673	2358-up	1.2 meg	$\frac{1}{2}$ w			302-125
R674		1.5 meg	$\frac{1}{2}$ w			302-155
R676		2.2 meg	$\frac{1}{2}$ w			302-225
R677		1.5 meg	$\frac{1}{2}$ w			302-155
R679		82 k	$\frac{1}{2}$ w			302-823
R680		1 k	$\frac{1}{2}$ w			302-102
R681		1.5 k	25 w	WW	5%	308-040
R682		180 k	$\frac{1}{2}$ w			302-184
R684		1 k	$\frac{1}{2}$ w			302-102
R685	101-2357	2.2 meg	$\frac{1}{2}$ w			302-225
R685	2358-up	120 k	$\frac{1}{2}$ w			302-124
R686		220 k	1 w	Prec.	1%	310-055
R688		333 k	1 w	Prec.	1%	310-056
R695		10 Ω	2 w			306-100
R696		220 k	1 w			304-224
R697	X2358-up	10 Ω	2 w			306-100
R700		220 k	1 w			304-224
R701	101-2357	10 Ω	1 w			304-100
R701	2358-up	18 Ω	2 w			306-180
R702	101-2357	10 Ω	1 w			304-100
R702	2358-up	18 Ω	2 w			306-180
R703	X2358-up	18 Ω	2 w			306-180
R711	101-2357	47 k	$\frac{1}{2}$ w			302-473
R711	2358-up	56 k	$\frac{1}{2}$ w			302-563
R712	101-2357	390 k	$\frac{1}{2}$ w			302-394
R712	2358-up	560 k	$\frac{1}{2}$ w			302-564
R714		1 meg	$\frac{1}{2}$ w			302-105
R716		1.5 meg	$\frac{1}{2}$ w			302-155
R717		100 k	$\frac{1}{2}$ w			302-104
R720	101-2357	2.2 meg	$\frac{1}{2}$ w			302-225
	2358-up	150 k	$\frac{1}{2}$ w			302-154
R721	101-2789	236 k	1 w	WW	1%	308-083
	2790-up	237 k	1 w	Prec.	1%	310-124
R722	101-2789	100 k	$\frac{1}{2}$ w	WW	1%	Use 309-334
	2790-up	100 k	$\frac{1}{2}$ w	Prec.	1%	309-334
R723		1 k	$\frac{1}{2}$ w			302-102
R724		1 k	$\frac{1}{2}$ w			302-102
R725		1 k	$\frac{1}{2}$ w			302-102
R726	101-2357	2.4 k	25 w	WW	5%	308-041
	2358-up	2 k	25 w	WW	5%	308-065
R727	101-2357	2.4 k	25 w	WW	5%	308-041
R727	2358-up	2 k	25 w	WW	5%	308-065
R728	101-2357	2.4 k	25 w	WW	5%	308-041

Resistors (continued)

Tektronix
Part Number

R728	2358-up	2 k	25 w	WW	5%	308-065
R729	101-2357	2.4 k	25 w	WW	5%	308-041
R729	2358-up	2 k	25 w	WW	5%	308-065
R731		27 k	1/2 w			302-273
R732		120 k	1/2 w			302-124
R734	101-2357	180 k	1/2 w			302-184
R734	2358-up	150 k	1/2 w			302-154
R736		1 meg	1/2 w			302-105
R741	101-2357	10 Ω	2 w			306-100
R741	2358-up	10 Ω	1 w			304-100
R743		720 k	1 w	Prec.	1%	310-059
R744		220 k	1 w	Prec.	1%	310-055
R745		1 k	1/2 w			302-102
R747		82 k	1 w			304-823
R748		150 k	1 w			304-154
R751		50 Ω		Var.	SCALE ILLUM.	311-055
R755		100 k	1/2 w			302-104
R760		100 k	1/2 w			302-104
R775		150 k	1/2 w			302-154
R780		150 k	1/2 w			302-154
R781		100 k	1/2 w			302-104
R784		10 Ω	1/2 w			302-100
R800		56 k	2 w			306-563
R802		1 k	1/2 w			302-102
R805		100 k	1/2 w			302-104
R806		1 k	1/2 w			302-102
R807		390 Ω	2 w			306-391
R809		470 k	1/2 w			302-474
R811		2 meg	2 w	Var.	H.V. ADJ.	311-042
R812		2.2 meg	1/2 w			302-225
R813		4.7 meg	1/2 w			302-475
R814		4.7 meg	1/2 w			302-475
R815		4.7 meg	1/2 w			302-475
R821		1 meg	1/2 w			302-105
R822		10 k	1/2 w			302-103
R826		5.6 meg	2 w			306-565
R827		2 x 2 meg		Var.	FOCUS	311-107
R828		1 meg	1/2 w			302-105
R831		5.6 meg	2 w			306-565
R832		2 meg		Var.	Focus Adj.	311-043
R837	X3680-up	1 meg	1/2 w			302-105
R838		27 k	1/2 w			302-273
R839		1 meg	1/2 w			302-105
R841		100 k	2 w	Var.	Vert. Defl. Plates Shield Volts	311-026
R842		100 k	2 w	Var.	Geom. Adj.	311-026
R844	101-215X	100 k		Var.	Horiz. Beam Register	311-026
	X2032-up	50 k	2 w	Var.	Horiz. Beam Register	311-023
R846		50 k		Var.	ASTIGMATISM	311-023
R850		47 k	1/2 w			302-473
R851		3.3 meg	2 w			306-335
R852		3.3 meg	2 w			306-335
R853	101-1259	2 meg		Var.	INTENS.	311-043
	1260-up	5 meg		Var.	INTENS.	311-121

Resistors (continued)

					Tektronix Part Number	
R854	X3090-up	33 k	$\frac{1}{2}$ w			302-333
R855		2.2 meg	$\frac{1}{2}$ w			302-225
R856		2.2 meg	$\frac{1}{2}$ w			302-225
R857	101-665	2.2 meg	$\frac{1}{2}$ w			302-225
	666-up	1.2 meg	$\frac{1}{2}$ w			302-125
R858	101-665	1 meg	$\frac{1}{2}$ w			302-105
	666-up	1.2 meg	$\frac{1}{2}$ w			302-125
R859		2 meg		Var.	Int. Adj.	311-043
R860	101-2129	100 k	$\frac{1}{2}$ w			302-104
	2130-up	33 k	$\frac{1}{2}$ w			302-333
R861	X3090-up	1.8 meg	$\frac{1}{2}$ w			302-185
R862	X3090-up	1.8 meg	$\frac{1}{2}$ w			302-185
R863		68 k	2 w			306-683
R864		100 Ω	$\frac{1}{2}$ w			302-101
R865		47 Ω	$\frac{1}{2}$ w			302-470
R866	X3090-up	8.2 k	$\frac{1}{2}$ w			302-822
R870		150 k	$\frac{1}{2}$ w			302-154
R871	101-2158	3.3 meg	$\frac{1}{2}$ w			302-335
	2159-up	3.9 meg	$\frac{1}{2}$ w			302-395
R872		1 k	$\frac{1}{2}$ w			302-102
R874		68 k	$\frac{1}{2}$ w			302-683
R875		2.7 meg	$\frac{1}{2}$ w			302-275
R876		1 k	$\frac{1}{2}$ w			302-102
R878		33 k	1 w			304-333
R879		10 k		Var.	Cal. Adj.	311-016
R880	101-2158	100 k	$\frac{1}{2}$ w			302-104
	2159-up	68 k	$\frac{1}{2}$ w			302-683
R882	101-2158X	1.5 meg	$\frac{1}{2}$ w			302-155
R883		100 Ω	$\frac{1}{2}$ w			302-101
R885		9.5 k	$\frac{1}{2}$ w		Prec. 1%	309-121
R886		6.375 k	$\frac{1}{2}$ w		Prec. 1%	309-119
R887		2.1 k	$\frac{1}{2}$ w		Prec. 1%	309-117
R888		1.025 k	$\frac{1}{2}$ w		Prec. 1%	309-116
R889		610 Ω	$\frac{1}{2}$ w		Prec. 1%	309-113
R890		200 Ω	$\frac{1}{2}$ w		Prec. 1%	309-073
R891		100 Ω	$\frac{1}{2}$ w		Prec. 1%	309-112
R892		60 Ω	$\frac{1}{2}$ w		Prec. 1%	309-067
R893		40 Ω	$\frac{1}{2}$ w		Prec. 1%	309-066
R896		100 k	$\frac{1}{2}$ w		Prec. 1%	309-045
R897		100 Ω	$\frac{1}{2}$ w		Prec. 1%	309-112
R898		100 Ω	$\frac{1}{2}$ w		Prec. 1%	309-112
R899		.25 Ω	1 w		WW	*308-090
R1003		100 Ω	1 w			304-101
R1005		100 Ω	1 w			304-101
R1007		47 Ω	$\frac{1}{2}$ w			302-470
R1008		47 Ω	$\frac{1}{2}$ w			302-470
R1009		100 Ω	1 w			304-101
R1010		167 Ω	5 w		WW 5%	308-104
R1011		27 Ω	$\frac{1}{2}$ w			302-270
R1013		910 Ω	2 w		5%	305-911
R1014	101-921	500 Ω	$\frac{1}{2}$ w		Prec. 2%	*310-515
	922-up	500 Ω	$\frac{1}{2}$ w		Prec. 1%	309-179
R1016	101-291	4 k	5 w		WW 5%	308-051
	292-up	3 k	5 w		WW 5%	308-062
R1017	101-291	12 k	8 w		WW 5%	308-069
	292-up	10 k	8 w		WW 5%	308-126

Resistors (continued)

Tektronix
Part Number

R1018		330 Ω	$\frac{1}{2}$ w				302-331
R1019		470 k	$\frac{1}{2}$ w				302-474
R1021		27 Ω	$\frac{1}{2}$ w				302-270
R1024	101-921	500 Ω	$\frac{1}{2}$ w		Prec.	2%	*310-515
	922-up	500 Ω	$\frac{1}{2}$ w		Prec.	1%	309-179
R1026		330 Ω	$\frac{1}{2}$ w				302-331
R1027	101-4609	200 Ω	2 w	Var.		Gain Adj.	311-004
R1027	4610-up	200 Ω	2 w			Gain Adj.	*311-333
R1029		470 k	$\frac{1}{2}$ w				302-474
R1031	101-291	4.7 k	1 w				304-472
	292-up	2.2 k	1 w				304-222
R1033	101-596	1.5 k	5 w		WW	5%	308-061
	597-up	2.5 k	5 w		WW	5%	308-127
R1036		27 k	2 w				306-273
R1039	101-596	39 Ω	$\frac{1}{2}$ w				302-390
	597-up	33 Ω	$\frac{1}{2}$ w				302-330
R1046		27 k	2 w				306-273
R1049	101-596	39 Ω	$\frac{1}{2}$ w				302-390
	597-up	33 Ω	$\frac{1}{2}$ w				302-330
R1052		470 k	$\frac{1}{2}$ w				302-474
R1053	101-1609X	50 Ω		Var.		Astig. Bal.	311-055
R1054		167 Ω	5 w		WW	5%	308-104
R1055		4.5 k	5 w		WW	5%	308-066
R1062		470 k	$\frac{1}{2}$ w				302-474
R1064	101-769X	2 k	1 w			5%	303-202
R1071		600 Ω }	5 w	Matched to $\frac{1}{2}$ % each other			*312-587
R1073		600 Ω }					
R1075		220 Ω	$\frac{1}{4}$ w				316-221
R1077		47 Ω	$\frac{1}{4}$ w				316-470
R1078		150 Ω	$\frac{1}{4}$ w				316-151
R1080		120 k	$\frac{1}{2}$ w				302-124
R1081	101-2158X	330 k	$\frac{1}{2}$ w				302-334
R1083	101-162	330 k	$\frac{1}{2}$ w				302-334
R1083	163-up	390 k	$\frac{1}{2}$ w				302-394
R1084		680 k	$\frac{1}{2}$ w				302-684
R1085		1 meg	$\frac{1}{4}$ w				316-105
R1090	101-3119	8.2 k	Selected				316-822
R1090	3120-up	6.8 k	Selected				316-682
R1091		250 k	2 w	Var.		D.C. Shift Comp.	311-061
R1092		47 k	$\frac{1}{2}$ w				302-473
R1093	X3180-up	56 k	1 w		Comp.	10%	304-563
R1094		68 k	1/10 w				307-006
R1095	101-3119	8.2 k	Selected				316-822
R1095	3120-up	6.8 k	Selected				316-682
R1097		47 k	$\frac{1}{2}$ w				302-473
R1099		68 k	1/10 w				307-006
R1102		470 k	$\frac{1}{2}$ w				302-474
R1105		4.5 k	5 w		WW	5%	308-066
R1112		470 k	$\frac{1}{2}$ w				302-474
R1122		470 k	$\frac{1}{2}$ w				302-474
R1125		4.5 k	5 w		WW	5%	308-066
R1132		470 k	$\frac{1}{2}$ w				302-474
R1142		470 k	$\frac{1}{2}$ w				302-474
R1145		4.5 k	5 w		WW	5%	308-066
R1152		470 k	$\frac{1}{2}$ w				302-474
R1162		470 k	$\frac{1}{2}$ w				302-474

Resistors (continued)

						Tektronix Part Number	
R1165		4.5 k	5 w	WW	5%	308-066	
R1172		470 k	1/2 w			302-474	
R1182		470 k	1/2 w			302-474	
R1185		4.5 k	5 w	WW	5%	308-066	
R1192		470 k	1/2 w			302-474	
R1202		470 k	1/2 w			302-474	
R1205		4.5 k	5 w	WW	5%	308-066	
R1206		360 Ω	1/2 w		5%	301-361	
R1208		12 k	8 w	WW	5%	308-069	
R1212		470 k	1/2 w			302-474	
R1216		360 Ω	1/2 w		5%	301-361	
R1218		1 k	5 w	WW	5%	308-106	
R1221		100 Ω	1/2 w			302-101	
R1223	101-596	2.7 k	2 w			306-272	
	597-up	4.7 k	2 w			306-472	
R1224		30 k	10 w	WW	5%	308-027	
R1227	101-162	330 k	1/2 w			302-334	
	163-up	390 k	1/2 w			302-394	
R1228		1 meg	1/4 w			316-105	
R1301-R1308		1 k	1/2 w			(8) 302-102	
R2003		100 Ω	1 w			304-101	
R2005		100 Ω	1 w			304-101	
R2007		47 Ω	1/2 w			302-470	
R2008		47 Ω	1/2 w			302-470	
R2009		100 Ω	1 w			304-101	
R2010		167 Ω	5 w	WW	5%	308-104	
R2011		27 Ω	1/2 w			302-270	
R2013		910 Ω	2 w		5%	305-911	
R2014	101-921	500 Ω	1/2 w	Prec.	2%	310-515	
	922-up	500 Ω	1/2 w	Prec.	1%	309-179	
R2016	101-291	4 k	5 w	WW	5%	308-051	
	292-up	3 k	5 w	WW	5%	308-062	
R2017	101-291	12 k	8 w	WW	5%	308-069	
	292-up	10 k	8 w	WW	5%	308-126	
R2018		330 Ω	1/2 w			302-331	
R2019		470 k	1/2 w			302-474	
R2021		27 Ω	1/2 w			302-270	
R2024	101-921	500 Ω	1/2 w	Prec.	2%	310-515	
	922-up	500 Ω	1/2 w	Prec.	1%	309-179	
R2026		330 Ω	1/2 w			302-331	
R2027		200	2 w	Var.	Gain Adj.	Use *311-333	
R2029		470 k	1/2 w			302-474	
R2031	101-291	4.7 k	1 w			304-472	
	292-up	2.2 k	1 w			304-222	
R2033	101-596	1.5 k	5 w	WW	5%	308-061	
	597-up	2.5 k	5 w	WW	5%	308-127	
R2036		27 k	2 w			306-273	
R2039	101-596	39 Ω	1/2 w			302-390	
	597-up	33 Ω	1/2 w			302-330	
R2046		27 k	2 w			306-273	
R2049	101-596	39 Ω	1/2 w			302-390	
	597-up	33 Ω	1/2 w			302-330	

Resistors (continued)

Tektronix
Part Number

R2052		470 k	$\frac{1}{2}$ w				302-474
R2054		167 Ω	5 w		WW	5%	308-104
R2055		4.5 k	5 w		WW	5%	308-066
R2062		470 k	$\frac{1}{2}$ w				302-474
R2064	101-769X	2 k	1 w			5%	303-202
R2071		600 Ω	5 w	Matched to $\frac{1}{2}$ % each other			*312-587
R2073		600 Ω					
R2075		220 Ω	$\frac{1}{4}$ w				316-221
R2077		47 Ω	$\frac{1}{4}$ w				316-470
R2078		150 Ω	$\frac{1}{4}$ w				316-151
R2083	101-162	330 k	$\frac{1}{2}$ w				302-334
	163-up	390 k	$\frac{1}{2}$ w				302-394
R2084		680 k	$\frac{1}{2}$ w				302-684
R2085		1 meg	$\frac{1}{4}$ w				316-105
R2090		6.8 k	Selected				316-682
R2091		250 k	2 w	Var.		D.C. Shift	311-061
R2092		47 k	$\frac{1}{2}$ w				302-473
R2093	X3180-up	56 k	1 w		Comp.	10%	304-563
R2094		68 k	1/10 w				307-006
R2095		6.8 k	Selected				316-682
R2097		47 k	$\frac{1}{2}$ w				302-473
R2099		68 k	1/10 w				307-006
R2102		470 k	$\frac{1}{2}$ w				302-474
R2105		4.5 k	5 w		WW	5%	308-066
R2112		470 k	$\frac{1}{2}$ w				302-474
R2122		470 k	$\frac{1}{2}$ w				302-474
R2125		4.5 k	5 w		WW	5%	308-066
R2132		470 k	$\frac{1}{2}$ w				302-474
R2142		470 k	$\frac{1}{2}$ w				302-474
R2145		4.5 k	5 w		WW	5%	308-066
R2152		470 k	$\frac{1}{2}$ w				302-474
R2162		470 k	$\frac{1}{2}$ w				302-474
R2165		4.5 k	5 w		WW	5%	308-066
R2172		470 k	$\frac{1}{2}$ w				302-474
R2182		470 k	$\frac{1}{2}$ w				302-474
R2185		4.5 k	5 w		WW	5%	308-066
R2192		470 k	$\frac{1}{2}$ w				302-474
R2202		470 k	$\frac{1}{2}$ w				302-474
R2205		4.5 k	5 w		WW	5%	308-066
R2206		360 Ω	$\frac{1}{2}$ w			5%	301-361
R2208		12 k	8 w		WW	5%	308-069
R2212		470 k	$\frac{1}{2}$ w				302-474
R2216		360 Ω	$\frac{1}{2}$ w			5%	301-361
R2218		1 k	5 w		WW	5%	308-106
R2221		100 Ω	$\frac{1}{2}$ w				302-101
R2223	101-596	2.7 k	2 w				306-272
	597-up	4.7 k	2 w				306-472
R2224		30 k	10 w		WW	5%	308-027
R2227	101-162	330 k	$\frac{1}{2}$ w				302-334
	163-up	390 k	$\frac{1}{2}$ w				302-394
R2228		1 meg	$\frac{1}{4}$ w				316-105
R2301-R2308		1 k	$\frac{1}{2}$ w				(8) 302-102

Rectifiers

			Tektronix Part Number
SR640	101-2357X	5-250 ma plates per leg	*106-045
SR660	101-2357X	5-500 ma plates per leg	*106-013
SR690	101-2357X	4-500 ma plates per leg	*106-046
SR700	101-2357X	5-500 ma plates per leg	*106-048
SR740	101-2357X	5-100 ma plates per leg	*106-047

Relays

K600	101-126	15-sec. Time Delay	148-009
	127-up	45-sec. Time Delay	148-002
K601	101-2357	6 volt 4 pole 2PDT; 2PST	148-004
K601	2358-up	Holding Relay	148-011

Switches

			Unwired	Wired
SW10	101-2158	2 sec. 8 pos., front: TRIGGER SLOPE	*260-204	*262-148
SW10	2159-up	2 sec. 8 pos., front: TRIGGER SLOPE	*260-204	*262-279
SW30	101-2158	3 sec. 5 pos., rear: TRIGGERING MODE	*260-204	*262-148
SW30	2159-up	3 sec. 5 pos., rear: TRIGGERING MODE	*260-204	*262-279
SW110		STABILITY W/R17, R110 and R310	311-099	
SW117		Single-pole single-throw: RESET	260-017	
SW160	101-923	5 sec. 24 pos., rotary: TIME/CM	*260-203	Use *050-005
	924-up	5 sec. 24 pos., rotary: TIME/CM	*260-230	*262-188
SW340		3 sec. 7 pos., rotary: HORIZONTAL DISPLAY and SINGLE SWEEP	*260-205	*262-149
SW601		SPST, toggle: POWER ON	260-199	
SW870		SPTT: VOLTS MILLIVOLTS OFF and		
SW880		2-wafer, 7-pos., rotary: SQUARE WAVE CALIBRBATOR	*260-177	*262-132
TK601	101-799	Thermal Cutout 128°	Use 260-120	
	800-2357	Thermal Cutout 137°	260-120	
	2358-up	Thermal Cutoff 133°	260-208	
TK750		Thermal Cutout 133°	260-208	

Transformers

T601	101-2357	L.V. Plate	*120-098
	2358-up	L.V. Plate	*120-128
T602	101-126	L.V. Heater	*120-099
	127-2357	L.V. Heater	*120-106
	2358-up	L.V. Heater	*120-127
T750		Indicator Heater	Use *120-235
T801		H.V. Transformer	*120-036

Electron Tubes

V24	101-2158	6BQ7A	154-028
	2159-up	6DJ8	154-187
V45	101-2158	6U8	154-033
	2159-up	6DJ8	154-187
V125		6AU6	154-022

Electron Tubes and Semiconductors (continued)

				Tektronix Part Number
V133	101-2158	6BQ7A		154-028
	2159-up	6DJ8		154-187
V135	101-2158	6BQ7A		154-028
	2159-up	6DJ8		154-187
V145		12BY7		154-047
V152		6AL5		154-016
V154		6AU6		154-022
V161		6CL6		154-031
V173	101-2158	6BQ7A		154-028
	2159-up	6DJ8		154-187
V183	101-2158	6BQ7A		154-028
	2159-up	6DJ8		154-187
V193	101-2158	6BQ7A		154-028
	2159-up	6DJ8		154-187
V314	101-2158	6BQ7A		154-028
	2159-up	6DJ8		154-187
V334	101-2158	6BQ7A		154-028
	2159-up	12AU7		154-041
V343	101-2158	6BQ7A		154-028
	2159-up	6DJ8		154-187
V364	101-2158	6BQ7A	Selected	*157-022
	2159-up	6DJ8		154-187
V384	101-2158	6BQ7A	Selected	*157-022
	2159-up	6DJ8		154-187
V394		6CL6		154-031
V604		6AU6		154-022
V616		12AX7		154-043
V619		5651		154-052
V637		6080		154-056
V654		6AU6		154-022
V657		6080		154-056
V674		6AU6		154-022
V686		12AX7		154-043
V687		6080		154-056
V714		6AU6		154-022
V717		6080		154-056
V727		6080		154-056
V734		6AU6		154-022
V737		12B4		154-044
V747		12B4		154-044
V800		6AU5GT		154-021
V814		12AU7		154-041
V822		5642		154-051
V832		5642		154-051
V842		5642		154-051
V852		5642		154-051
V859	101-2031	T551P2	CRT	Use 050-026 w/154-252A
	2032-up	T5511P2		154-252A
V862		5642		154-051
V875	101-2158	6U8		154-033
	2159-up	6AU6		154-022
V1014*		12BY7A	Selected	*157-053
V1024*		12BY7A	Selected	*157-053

Electron Tubes and Semiconductors (continued)

				Tektronix Part Number
V1033	101-596	6BQ7A		154-028
	597-up	6DJ8		154-187
V1043	101-596	6BQ7A		154-028
	597-up	6DJ8		154-187
V1054		8136/6DK6		154-367
V1064		8136/6DK6		154-367
V1084	101-1095	6BQ7A		154-028
	1096-up	6DJ8		154-187
V1104-V1214		8136/6DK6		(12) 154-367
V1223	101-596	6BQ7A		154-028
	597-up	6DJ8		154-187
V2014**		12BY7A	Selected	*157-053
V2024**		12BY7A	Selected	*157-053
V2033	101-596	6BQ7A		154-028
	597-up	6DJ8		154-187
V2043	101-596	6BQ7A		154-028
	597-up	6DJ8		154-187
V2054		8136/6DK6		154-367
V2064		8136/6DK6		154-367
V2104-V2214		8136/6DK6		(12) 154-367
V2223	101-596	6BQ7A		154-028
	597-up	6DJ8		154-187

* V1014 and V1024 are furnished as a unit.

** V2014 and V2024 are furnished as a unit.

Type 551 Mechanical Parts List

	Tektronix Part Number
ADAPTER BINDING POST	013-004
ADAPTER POWER CORD 3 WIRE TO 2 WIRE	103-013
ANGLE FRAME TOP LEFT	122-019
ANGLE FRAME 20 ⁷ / ₁₆ BOTTOM (101-2294)	122-039
ANGLE FRAME 14 ³ / ₈ BOTTOM (101-2294)	122-042
ANGLE FRAME 14 ³ / ₈ TOP	122-043
ANGLE FRAME 14 ³ / ₈ BOTTOM BLUE VINYL (2295-up)	122-067
ANGLE FRAME 20 ⁷ / ₁₆ BOTTOM BLUE VINYL (2295-up)	122-072
BAR ³ / ₁₆ x ¹ / ₂ x 1 ³ / ₄ W/2 8-32 TAPPED HOLES	381-073
BAR EXT. TOP SUPPORT 14 ³ / ₈ " (101-1176)	381-087
BAR ³ / ₈ x ³ / ₈ x 9 ⁵ / ₈ TAPPED 8-32 ONE END W/TWO ³ / ₁₆ HOLES	381-103
BAR EXT.TOP SUPPORT (IND.) (1177-2294)	381-121
BAR EXT. TOP SUPPORT (POWER) (1177-2294)	381-127
BAR EXT. TOP SUPPORT (IND.) BLUE VINYL (2295-up)	381-149
BAR EXT. TOP SUPPORT (POWER) BLUE VINYL (2295-up)	381-152
BASE, CRT ROTATOR (1820-up)	432-022
BOLT, SPADE STEEL	214-013
BRACKET, ALUM., .080 x 1 ¹ / ₂ x 4 ¹ / ₂ x ⁵ / ₈ (101-2357X)	406-128
BRACKET PLASTIC MOLDED COIL MTNG.	406-175
BRACKET SP. PHOS. BRONZE CRT SPRING	406-239
BRACKET NYLON MLD. COAX INSUL.	406-244
BRACKET PHOS. BRONZE GROUND CLIP	406-245
BRACKET ALUM. 1 x ³ / ₄ x 1 ¹ / ₁₆ D. L.	406-293
BRACKET POWER TRANSFORMER SUPPORT	406-294
BRACKET 5 POT	406-296
BRACKET 2 POT	406-297
BRACKET 7 POT	406-298
BRACKET ALUM. .080 x 1 x 4 ³ / ₄ x ⁵ / ₈ (101-2357X)	406-304
BRACKET TIME/CM. SWITCH (101-923)	406-316
BRACKET D. L. TERM.	406-319
BRACKET CRT SUPPORT	406-332
BRACKET HORIZ. DISP. SW.	406-333
BRACKET TIME/CM. SW. (924-up)	406-416

Mechanical Parts List *(continued)*

		Tektronix Part Number
BRACKET CAL. SUPPORT	(101-2158)	406-291
BRACKET CAL. SUPPORT	(2159-up)	406-543
BUSHING HEX $\frac{3}{8}$ -32 x $1\frac{13}{32}$		358-029
BUSHING NYLON FOR 5-WAY BINDING POST		358-036
CABLE HARNESS V.A. "A"	(101-1609)	179-161
CABLE HARNESS SWEEP	(101-2158)	179-162
CABLE HARNESS SWEEP	(2159-up)	179-391
CABLE HARNESS F & I #1		179-163
CABLE HARNESS F & I #2		179-164
CABLE HARNESS V.A. "B"	(101-1609)	179-194
CABLE HARNESS V.A. SWEEP		179-195
CABLE HARNESS V.A. 110 V		179-195
CABLE HARNESS V.A. "A"	(1610-up)	179-378
CABLE HARNESS V.A. "B"	(1610-up)	179-379
CABLE HARNESS 110 V POWER SUPPLY	(101-2357)	179-165
CABLE HARNESS 110 V POWER SUPPLY	(2358-up)	179-422
CABLE HARNESS POWER SUPPLY	(101-2357)	179-160
CABLE HARNESS POWER SUPPLY	(2358-up)	179-423
CAM, NYLON $\frac{3}{8}$ "		401-004
CAP, FUSE		200-015
CHASSIS D.L. HORIZ. 10"		441-100
CHASSIS D. L. HORIZ. $8\frac{1}{8}$ "		441-114
CHASSIS D. L. VERT, $12\frac{1}{4}$ "		441-115
CHASSIS D. L. VERT.		441-137
CHASSIS F & I		441-163
CHASSIS D. L. HORIZ. #2 (B760)		441-164
CHASSIS D. L. HORIZ. #2 (761)		441-165
CHASSIS D. L. VERT. #2		441-166
CHASSIS VERT. AMP.		441-168
CHASSIS SWEEP	(101-2158)	441-170
CHASSIS SWEEP	(2159-up)	441-297
CHASSIS POWER	(101-2357)	441-172
CHASSIS POWER	(2358-up)	441-313
CLAMP CABLE $\frac{1}{8}$ PLASTIC		343-001

Mechanical Parts List *(continued)*

	Tektronix Part Number
CLAMP CABLE $\frac{3}{16}$ PLASTIC	343-002
CLAMP CABLE $\frac{1}{2}$ PLASTIC	343-006
CLAMP CABLE $\frac{3}{8}$ PLASTIC	343-013
CLAMP STN. STL. (101-1819)	343-034
CLAMP #20 WIRE	343-043
CONNECTOR CHASSIS MNT. 16 CONT. FEMALE (INDICATOR)	131-018
CONNECTOR CHASSIS MNT. 83 IRTY	131-038
CONNECTOR CHASSIS MNT. 83 IRTY (CAL OUT) COAX	131-064
CONNECTOR CHASSIS MNT. 16 CONT. MALE (POWER)	131-077
CONNECTOR CHASSIS MNT. 16 CONT. FEMALE SOCKET (POWER)	131-078
CONNECTOR CABLE 31" ANODE	131-086
CONNECTOR CHASSIS MNT. 3 COND. (158-2399)	131-093
CONNECTOR CHASSIS MNT. 3 COND. W/3SE6 (101-157)	131-094
CONNECTOR CHASSIS MNT. 3 WIRE MALE (2400-up)	131-150
COUPLING, POT WIRE STEEL	376-014
COVER GRATICULE	200-025
COVER CRT ANODE	200-112
EYELET, TAPERED BARREL	210-601
FAN $5\frac{1}{2}$ " BLADE	369-001
FAN 7" BLADE	369-007
FILTER AIR 10 x 10 x 1	378-011
FILTER AIR 7 x 7 x 1	378-015
FILTER LIGHT PLEXI 5"	378-514
GRATICULE, 5"	331-045
GROMMET RUBBER $\frac{1}{4}$	348-002
GROMMET RUBBER $\frac{5}{16}$	348-003
GROMMET RUBBER $\frac{3}{8}$	348-004
GROMMET RUBBER $\frac{1}{2}$	348-005
GROMMET RUBBER $\frac{3}{4}$	348-006
GROMMET RUBBER $\frac{5}{8}$	348-012
HANDLE LEATHER (101-1176)	367-001
HANDLE FABRIC BLUE VINYL (1177-up)	367-011
HOLDER NYLON NEON DOUBLE MOLDED	352-006
HOLDER NYLON NEON SINGLE MOLDED	352-008

Mechanical Parts List *(continued)*

	Tektronix Part Number
HOLDER FUSE	352-010
HOLDER NYLON FOR COIL FORM $\frac{3}{16} \times \frac{3}{4}$	352-015
HOLDER NYLON FOR COIL FORM $\frac{3}{16} \times \frac{9}{16}$ W/O PIN	352-016
HOLDER NYLON FOR COIL FORM $\frac{3}{16} \times \frac{9}{16}$ W/PIN	352-017
HOUSING AIR FILTER (WRINKLE) IND. (101-2294)	380-008
HOUSING AIR FILTER (WRINKLE) POW. (101-2294)	380-009
HOUSING AIR FILTER (VINYL) POW. (2295-up)	380-016
HOUSING AIR FILTER (VINYL) IND. (2295-up)	380-018
JEWEL, LIGHT PILOT	378-518
KNOB SM. RED $\frac{3}{16}$ INSERT HOLE (1820-up)	366-032
KNOB SM. BLK. $\frac{1}{4}$ INSERT HOLE	366-033
KNOB SM. RED $\frac{3}{16}$ HOLE PART WAY (101-2158)	366-039
KNOB SM. RED $\frac{1}{8}$ HOLE PART WAY (2159-up)	366-038
KNOB LRG. BLK. $\frac{17}{64}$ HOLE THRU (101-2158)	366-046
KNOB LRG. BLK. $\frac{1}{4}$ HOLE THRU (2159-up)	366-040
KNOB LRG. BLK. .250 HOLE THRU	366-058
LOCKWASHER INT. #4	210-004
LOCKWASHER EXT. #6	210-005
LOCKWASHER INT. #6	210-006
LOCKWASHER EXT. #8	210-007
LOCKWASHER INT. #8	210-008
LOCKWASHER INT. #10	210-010
LOCKWASHER POT INT. $\frac{3}{8} \times \frac{1}{2}$	210-012
LOCKWASHER POT INT. $\frac{3}{8} \times \frac{11}{16}$	210-013
LOCKWASHER NO. 5 SPRING	210-017
LUG SOLDER SE4	210-201
LUG SOLDER SE6 W/2 WIRE HOLES	210-202
LUG SOLDER SE6 LONG	210-203
LUG SOLDER DE6	210-204
LUG SOLDER SE8	210-205
LUG SOLDER SE10 LONG	210-206
LUG SOLDER POT PLAIN $\frac{3}{8}$	210-207
LUG SOLDER #10 NON-LOCKING	210-224
MOTOR, FAN	147-001

Mechanical Parts List *(continued)*

	Tektronix Part Number
MOUNT FAN MOTOR 5½"	426-046
MOUNT FAN MOTOR 7"	426-047
NUT CAP HEX 8-32 x 5/16	210-402
NUT HEX 4-40 x 3/16	210-406
NUT HEX 8-32 x 1/4	210-407
NUT HEX 8-32 x 5/16	210-409
NUT HEX 10-32 x 5/16	210-410
NUT HEX 3/8-32 x 1/2	210-413
NUT HEX 15/32-32 x 9/16	210-414
NUT KNURLED, GRATICULE 3/8-24 x 9/16 x 3/16	210-424
NUT HEX 3/8-32 x 1/2 x 5/8	210-444
NUT HEX 10-32 x 3/8 x 1/8	210-445
NUT HEX 5-40 x 1/4	210-449
NUT HEX 1/4-28 x 3/8 x 3/32	210-455
NUT KEPS 6-32 x 5/16	210-457
NUT KEPS 8-32 x 11/32	210-458
NUT HEX 8-32 x 1/2 x 23/64 25 W RES.	210-462
NUT SWITCH 12 SIDED	210-473
NUT HEX 6-32 x 5/16 5-10 W RES.	210-478
NUT 21/32 x 21/2, TAPPED 6-32 BOTH ENDS, CRT ROTATOR SECURING	210-503
NUT HEX 10-32 x 3/8 x 1/8	210-564
PANEL FRONT IND.	333-321
PANEL FRONT POWER	333-552
PLATE BAKELITE H. V.	386-358
PLATE BRASS CONNECTING	386-374
PLATE CAB. SIDE LEFT (101-272)	386-564
PLATE CAB. BOTTOM (INDICATOR) (101-2294)	386-597
PLATE P. I. HOUSING BOTTOM	386-610
PLATE P. I. HOUSING LEFT	386-611
PLATE P. I. HOUSING RIGHT	386-614
PLATE SUB-PANEL FRONT (INDICATOR)	386-637
PLATE REAR OVERLAY (101-2294)	386-653
PLATE P. I. HOUSING BACK	386-654
PLATE P. I. HOUSING TOP	386-655

Mechanical Parts List (continued)

Tektronix
Part Number

PLATE SUB-PANEL REAR (INDICATOR)	386-658
PLATE CAB. BOTTOM (POWER SUPPLY) (101-2294)	386-662
PLATE SUB-PANEL FRONT (POWER SUPPLY)	386-712
PLATE CAB. SIDE LEFT & RIGHT (101-272)	386-716
PLATE CAB. SIDE LEFT (INDICATOR) (273-2294)	286-736
PLATE REAR OVERLAY (POWER) (101-2294)	386-748
PLATE SUB-PANEL REAR (POWER)	386-749
PLATE P. I. HOUSING TOP	386-752
PLATE CAB. SIDE RIGHT (101-272)	386-754
PLATE CAB. SIDE LEFT & RIGHT (POWER) (273-2294)	386-775
PLATE CAB. SIDE RIGHT (IND.) (273-2294)	386-782
PLATE TEXTOLITE $7\frac{1}{2} \times 12\frac{1}{4}$ D. L.	386-948
PLATE TEXTOLITE $2\frac{1}{4} \times 8\frac{1}{8}$ D. L.	386-949
PLATE TEXTOLITE $12\frac{9}{32} \times 8\frac{1}{8}$ D. L.	386-955
PLATE TEXTOLITE $1\frac{1}{2} \times 1\frac{5}{32}$ D.L.	386-956
PLATE TEXTOLITE $1\frac{1}{8} \times 2$ W/8 EYELETS	386-963
PLATE TEXTOLITE $1 \times 5\frac{1}{16}$ PLATE LINE	386-964
PLATE CAB. BOTTOM BLUE VINYL (2295-up)	387-061
PLATE CAB. SIDE R & L BLUE VINYL (POWER) (2295-up)	387-063
PLATE CAB. BOTTOM BLUE VINYL (2295-up)	387-064
PLATE CAB. SIDE LEFT BLUE VINYL (2295-up)	387-077
PLATE CAB. SIDE RIGHT BLUE VINYL (IND.) (2295-up)	387-081
PLATE REAR OVERLAY BLUE VINYL (2295-up)	387-082
PLATE REAR OVERLAY BLUE VINYL (POWER) (2295-up)	387-083
PLUG, CRT CONTACT	134-031
POST CONNECTING CERAMIC $\frac{1}{2}$ " (101-1219)	129-009
POST BINDING (355-503 & 200-072)	129-020
POST BINDING 5-WAY STEM & CAP ASS'Y (101-989)	129-030
POST CONNECTING CERAMIC $\frac{3}{4}$ " (101-1219)	129-034
POST BINDING 5-WAY STEM & CAP ASS'Y (FLUTED) (990-up)	129-036
RING FAN $5\frac{3}{4}$ ID WITH MTNG. EARS	354-051
RING FAN $7\frac{3}{8}$ ID WITH MTNG. EARS	354-053
RING LOCKING SWITCH	354-055
RING ROTATING (101-1819)	354-066

Mechanical Parts List *(continued)*

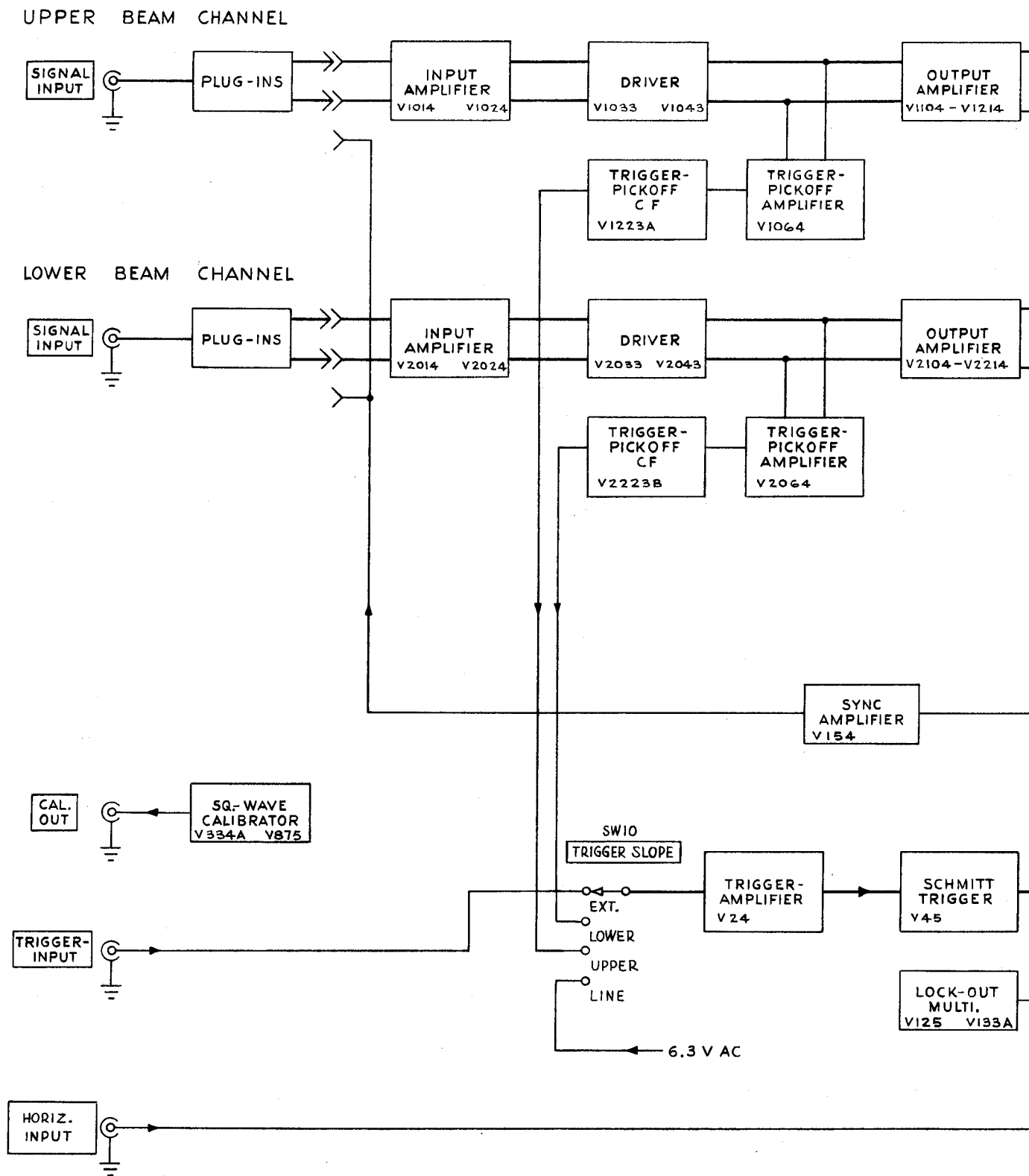
		Tektronix Part Number
RING SECURING	(1820-4199)	354-178
RING SECURING	(4200-up)	354-178
RING CLAMPING	(1820-up)	354-079
RING CLAMPING	(354-079 & 210-502)	354-103
ROD SPACING	$\frac{1}{4} \times 3\frac{1}{8}$ TAPPED 6-32 BOTH ENDS	384-135
ROD EXTENSION	$\frac{1}{8} \times 8\frac{7}{16}$	384-162
ROD MTNG. POST	$\frac{1}{4} \times \frac{3}{4}$ TAPPED 4-40 THRU W/1 #48 HOLE (101-3059)	384-532
ROD NYLON	$\frac{5}{16} \times 1\frac{1}{4}$ TAPPED 6-32 BOTH ENDS	385-018
ROD NYLON	$\frac{5}{16} \times 1\frac{9}{16}$ TAPPED 6-32 BOTH ENDS	385-090
ROD HEX	$\frac{3}{8} \times 2\frac{3}{4}$ TAPPED 6-32 & 10-24 (101-1633)	385-102
ROD HEX	$\frac{3}{8} \times 2\frac{3}{4}$ TAPPED 6-32 & 8-32 (101-2357)	385-103
ROD DELRIN	$\frac{5}{16} \times 1\frac{5}{16}$ (3060-up)	385-135
ROD HEX	$\frac{3}{8} \times 2\frac{3}{4}$ TAPPED 6-32 & 10-32 (2358-up)	385-140
SCREW	4-40 $\times \frac{1}{4}$ BHS	211-008
SCREW	4-40 $\times \frac{5}{16}$ BHS	211-011
SCREW	4-40 $\times \frac{3}{8}$ BHS	211-013
SCREW	4-40 $\times \frac{5}{8}$ RHS	211-016
SCREW	4-40 $\times \frac{3}{8}$ FHS	211-025
SCREW	4-40 $\times 1$ FHS	211-031
SCREW	4-40 $\times \frac{5}{16}$ PAN HS W/LOCKWASHER	211-033
SCREW	4-40 $\times \frac{1}{2}$ BH NYLON	211-036
SCREW	4-40 $\times \frac{5}{16}$ FHS, PHILLIPS	211-038
SCREW	6-32 $\times \frac{3}{16}$ BHS	211-503
SCREW	6-32 $\times \frac{1}{4}$ BHS	211-504
SCREW	6-32 $\times \frac{5}{16}$ BHS	211-507
SCREW	6-32 $\times \frac{3}{8}$ BHS	211-510
SCREW	6-32 $\times \frac{1}{2}$ BHS	211-511
SCREW	6-32 $\times \frac{5}{8}$ BHS	211-513
SCREW	6-32 $\times \frac{3}{4}$ BHS	211-514
SCREW	6-32 $\times \frac{5}{8}$ FHS, 100°	211-522
SCREW	6-32 $\times 1\frac{3}{4}$ BHS	211-530
SCREW	6-32 $\times \frac{5}{16}$ PAN HS W/LOCKWASHER	211-534
SCREW	6-32 $\times \frac{3}{8}$ TRUSS HS, PHILLIPS	211-537
SCREW	6-32 $\times \frac{5}{16}$ FHS, 100°, CSK, PHILLIPS	211-538
SCREW	6-32 $\times \frac{1}{4}$ FHS, 100°, CSK, PHILLIPS	211-541

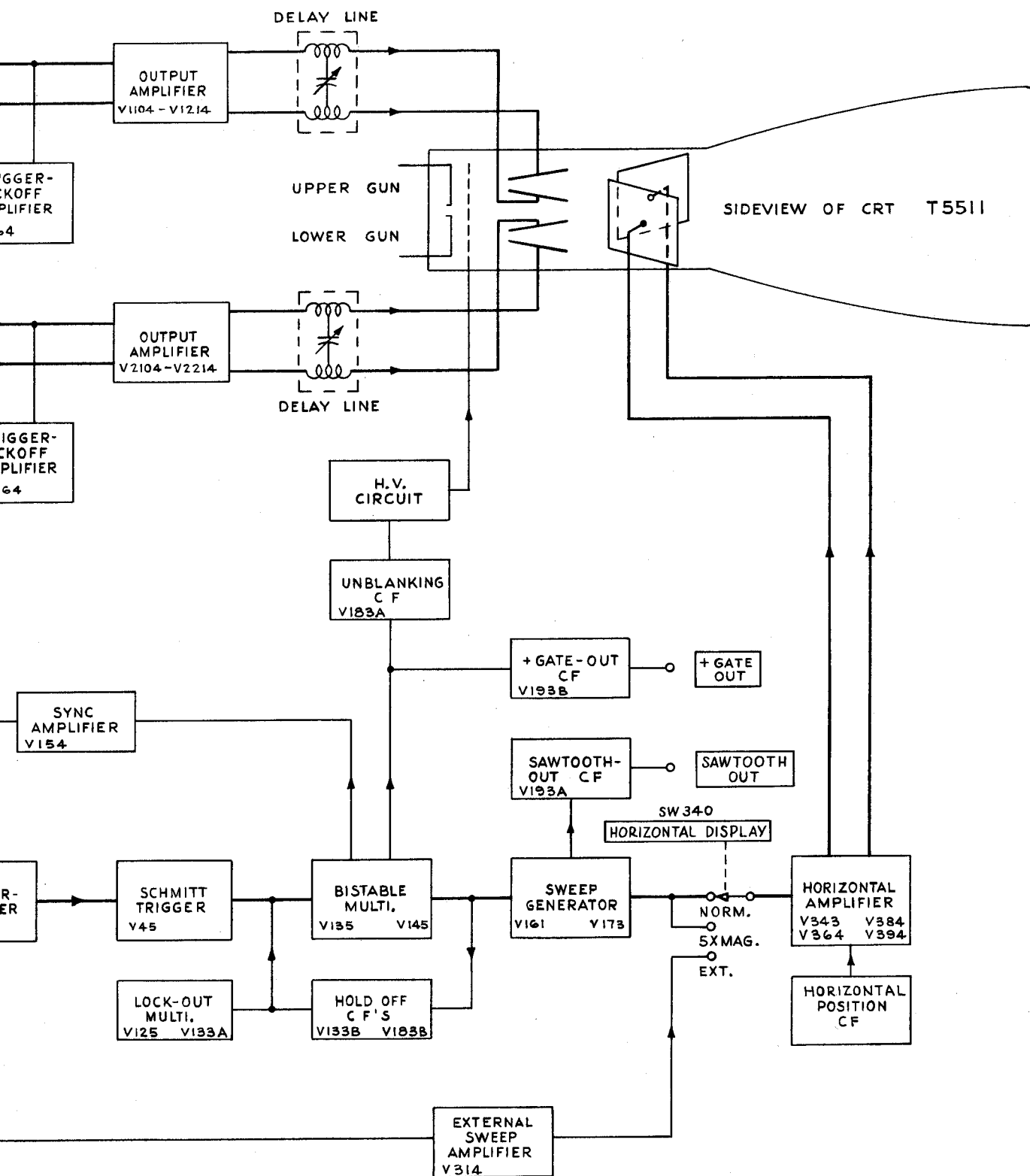
Mechanical Parts List *(continued)*

	Tektronix Part Number
SCREW 6-32 x $\frac{5}{16}$ RHS	211-543
SCREW 6-32 x $1\frac{1}{2}$ RHS, PHILLIPS	211-553
SCREW 6-32 x $\frac{3}{8}$ FHS, 100°, PHILLIPS	211-559
SCREW 6-32 x 1 RHS	211-560
SCREW 6-32 x $\frac{3}{8}$ HEX SOC FH CAP	211-561
SCREW 6-32 x $\frac{1}{4}$ TRUSS HS, PHILLIPS	211-565
SCREW 8-32 x $\frac{5}{16}$ BHS	212-004
SCREW 8-32 x $\frac{5}{8}$ BHS	212-010
SCREW 8-32 x $\frac{3}{8}$ BHS	212-023
SCREW 8-32 x $3\frac{3}{4}$ RHS	212-027
SCREW 8-32 x $1\frac{1}{4}$ RHS	212-031
SCREW 8-32 x $1\frac{3}{4}$ FIL HS	212-037
SCREW 8-32 x $\frac{3}{8}$ TRUSS HS	212-039
SCREW 8-32 x $\frac{3}{8}$ FHS 100°, PHILLIPS	212-040
SCREW 8-32 x $4\frac{3}{4}$ RHS	212-547
SCREW THREAD CUTTING 4-40 x $\frac{3}{8}$ FHS	213-012
SCREW THREAD CUTTING 4-40 x $\frac{1}{4}$ PHS, PHILLIPS	213-035
SCREW THREAD CUTTING 6-32 x $\frac{3}{8}$ TRUSS HS, PHILLIPS	213-041
SCREW THREAD CUTTING 5-32 x $\frac{3}{16}$ PAN HS, PHILLIPS	213-044
SCREW THREAD CUTTING 4-40 x $\frac{5}{16}$ PHS, PHILLIPS	213-045
SCREW THREAD CUTTING 6-32 x $\frac{5}{16}$ PHS, PHILLIPS	213-054
SCREW THREAD FORMING 6-32 x $\frac{3}{8}$ THS	213-104
SHIELD SOCKET	337-005
SHIELD TUBE	337-009
SHIELD SWEEP AMPLIFIER	337-157
SHIELD 5" GRATICULE LIGHT	337-187
SHIELD 5" CRT	337-199
SHIELD CAL. SW.	337-203
SHIELD H. V. (SILK-SCREENED) (101-2049)	337-208
SHIELD H. V. (SILK-SCREENED) (2050-up)	337-287
SHIELD F & I	337-216
SHIELD TUBE $\frac{1}{2}$ " W/SPRING	337-272
SHOCKMOUNT	348-008
SOCKET GRATICULE LAMP	136-001

Mechanical Parts List *(continued)*

	Tektronix Part Number
SOCKET STM7G	136-008
SOCKET STM8G	136-011
SOCKET STM9G	136-015
SOCKET STM14	136-019
SOCKET LIGHT JEWEL	136-025
SOCKET TIP JACK BLACK NYLON	136-037
SOCKET 7 PIN TUBE	136-044
SPACER INSULATING $\frac{3}{8} \times \frac{3}{8}$ (101-1219)	361-001
SPACER NYLON MOLDED $\frac{1}{16}$ (1220-up)	361-007
SPACER NYLON MOLDED $\frac{3}{16}$ (1220-up)	361-008
SPACER NYLON MOLDED $\frac{5}{16}$ (1220-up)	361-009
SPOOL, ASSEMBLY OF MOLDED NYLON	214-210
STRAP, MOUNTING	346-001
STRIP FELT	124-068
STRIP CERAMIC $\frac{3}{4} \times 3$ NOTCHES, CLIP MOUNTED	124-087
STRIP CERAMIC $\frac{3}{4} \times 4$ NOTCHES, CLIP MOUNTED	124-088
STRIP CERAMIC $\frac{3}{4} \times 7$ NOTCHES, CLIP MOUNTED	124-089
STRIP CERAMIC $\frac{3}{4} \times 9$ NOTCHES, CLIP MOUNTED	124-090
STRIP CERAMIC $\frac{3}{4} \times 11$ NOTCHES, CLIP MOUNTED	124-091
STRIP CERAMIC $\frac{3}{4} \times 1$ NOTCH, CLIP MOUNTED	124-100
STUD STEEL 10-32 $\times \frac{7}{16}$, W/#44 HOLE THRU	355-044
STUD STEEL 10-32 $\times \frac{3}{16} \times 3\frac{1}{4}$ (1820-up)	355-049
TAG VOLTAGE RATING (50-60 CYCLE)	334-649
TAG VOLTAGE RATING (50-800 CYCLE)	334-650
WASHER STEEL 6L $\times \frac{3}{8} \times .032$	210-803
WASHER STEEL 8S $\times \frac{3}{8} \times .032$	210-804
WASHER BRASS CENTERING 20 W RES.	210-808
WASHER BRASS CENTERING 25 W RES.	210-809
WASHER FIBER #10	210-812
WASHER RUBBER	210-816
WASHER STEEL .390 $\times \frac{9}{16} \times .020$	210-840
WASHER STEEL $\frac{9}{64} \times \frac{1}{2} \times \frac{1}{32}$	210-867
WASHER RUBBER (FOR FUSE HOLDER)	210-873
WASHER STEEL .470 $\times 2\frac{1}{32} \times .030$	210-902
WASHER WAVY	210-914



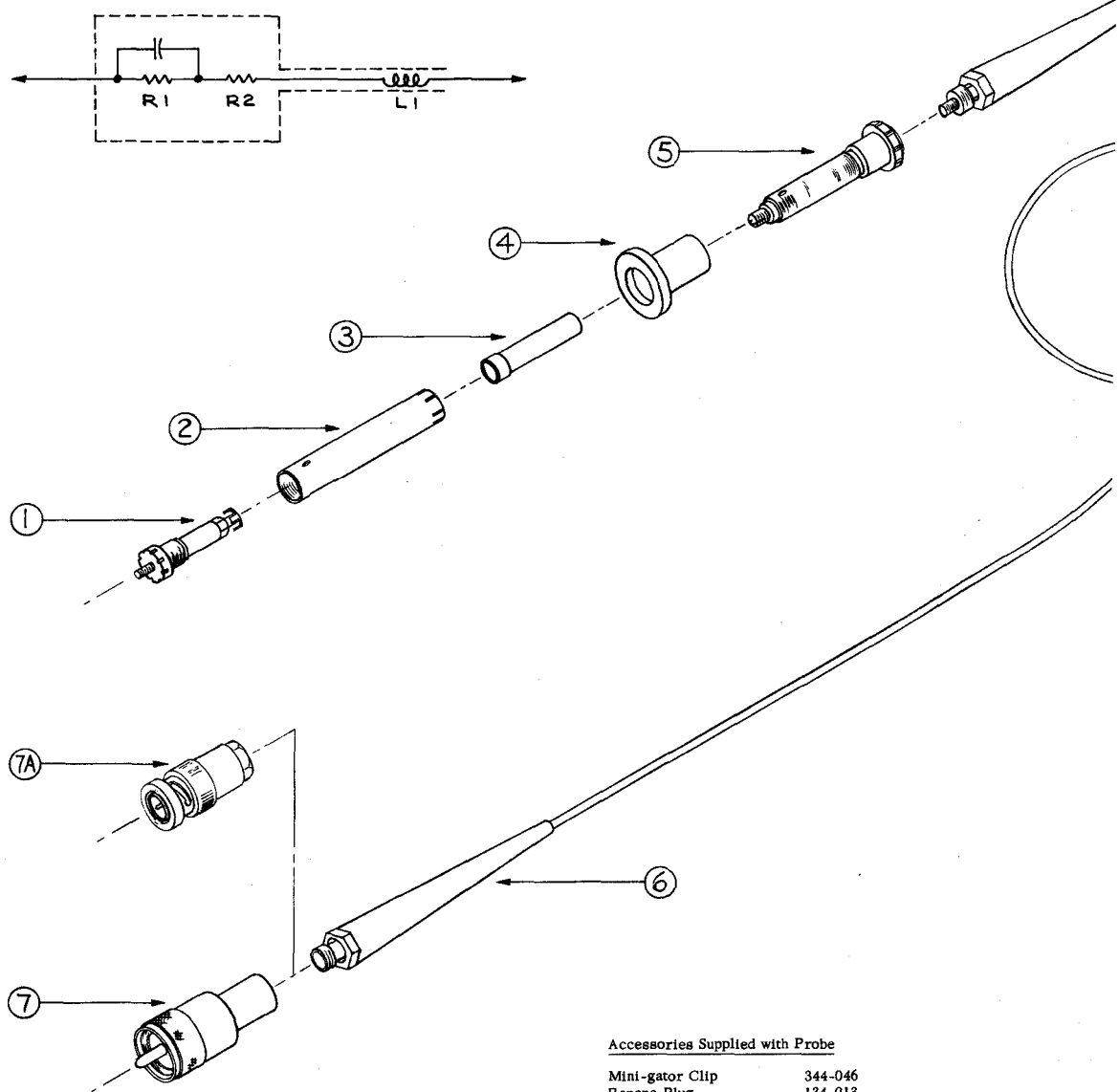
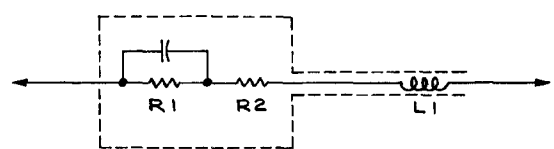


9-22-62

JR

AA₂

BLOCK DIAGRAM

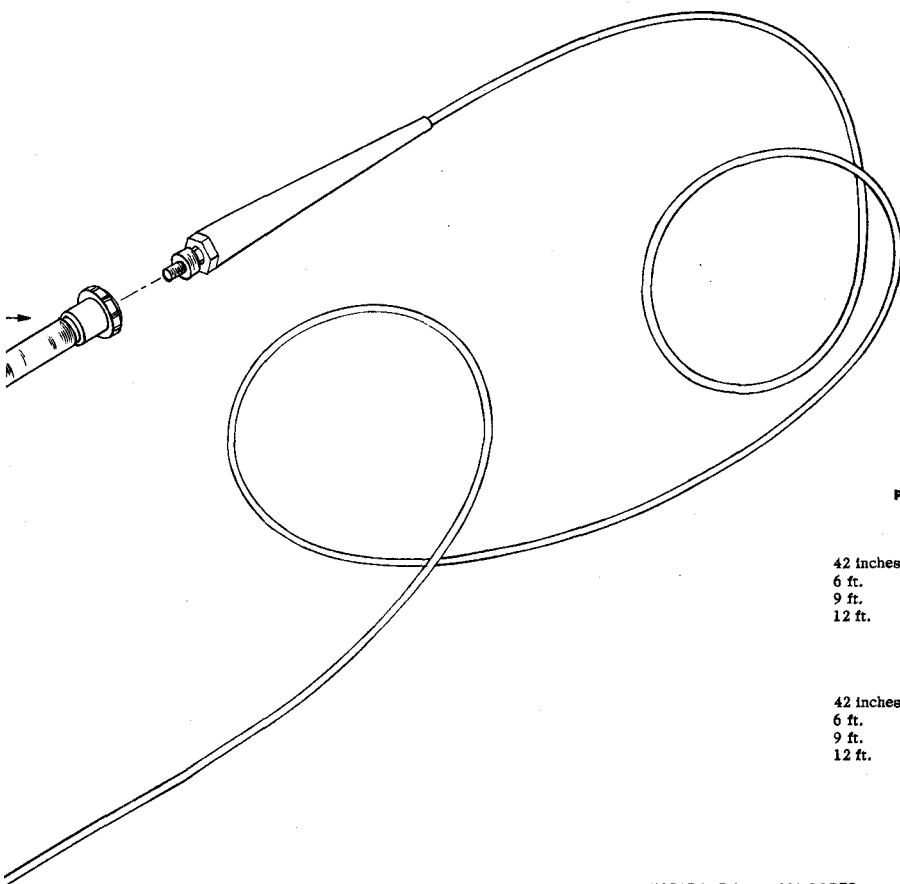


Accessories Supplied with Probe

Mini-gator Clip	344-046
Banana Plug	134-013
Probe Holder	352-024
Hook Tip	206-105
BNC Tip	206-015
Spring Tip	206-060
Pincer Tip	013-027
5 inch Ground Strap	175-124
12 inch Ground Strap	175-125

Accessories That May be Purchased

BNC to Probe Adaptor	013-020
Spring Tip without Shank	206-061
Pinjack Tip, Insulated	206-054
Insert Tip	206-052
Pinjack Tip	206-045
Straight Tip	206-104
18 inch Ground Strap	175-184



PROBES THIS SHEET COVERS

P6000

42 inches	Tektronix Part No.	010-020
6 ft.		010-030
9 ft.		010-035
12 ft.		010-041

P6003

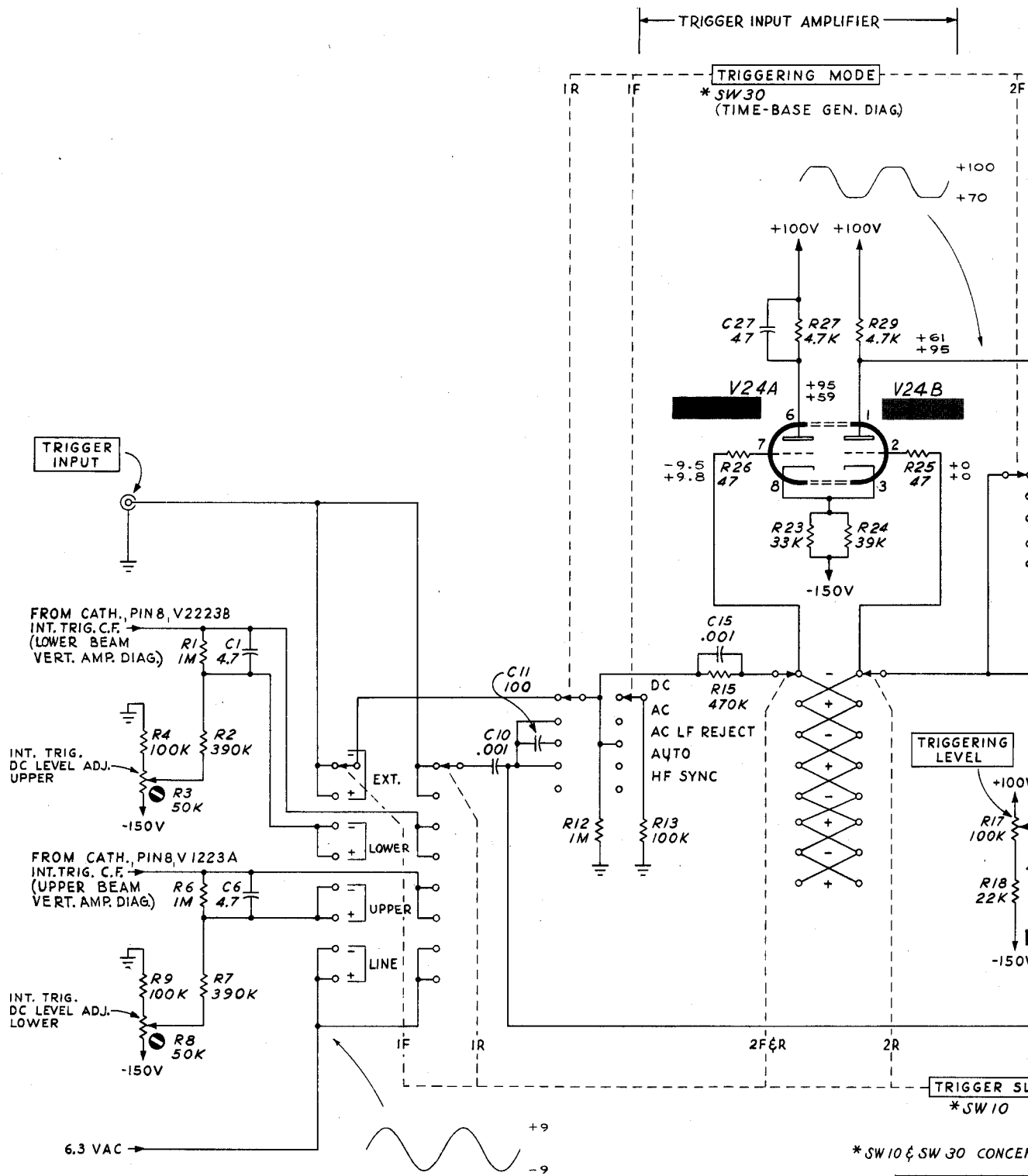
42 inches	Tektronix Part No.	010-027
6 ft.		010-031
9 ft.		010-045
12 ft.		010-046

TABLE I ELECTRICAL PARTS

Ckt. No.	Cable Length	Value	Description	Tektronix Part No.
L1	42 inches only	.5 μ h	Fixed	108-211
R1	All Lengths	9 meg	1/2 w Fixed Prec. 2%	309-232
R2	6ft., 9ft., 12 ft		Selected	

TABLE II MECHANICAL PARTS

Item No.	Probe Type	Cable Length	Part Title	Tektronix Part No.
1	P6000/P6003	42 inches	Nose Assembly	206-014
		6 ft.		206-014
		9 ft.		206-068
		12 ft.		206-056
2	P6000/P6003	42 inches	Probe Body	204-021
		6 ft.		204-021
		9 ft.		204-021
		12 ft.		204-057
3	P6000/P6003	42 inches	Thermo-fit and Sleeve Assembly	166-212
		6 ft.		166-214
		9 ft.		166-219
		12 ft.		166-216
4	P6000	42 inches	Locking Ring	105-022
	P6003	42 inches		105-028
	P6000	6 ft.		105-024
	P6003	6 ft.		105-025
	P6000	9 ft.		105-029
	P6003	9 ft.		105-033
	P6000	12 ft.		105-030
	P6003	12 ft.		105-034
5	P6000/P6003	All Lengths	Assembly Base Bushing	358-121
6	P6000	42 inches	Cable Assembly	175-159
	P6003	42 inches		175-162
	P6000	6 ft.		175-165
	P6003	6 ft.		175-168
	P6000	9 ft.		175-171
	P6003	9 ft.		175-174
	P6000	12 ft.		175-177
	P6003	12 ft.		175-180
7	P6000	All Lengths	Connector, UHF	131-058
7A	P6003	All Lengths	Connector, BNC	131-185

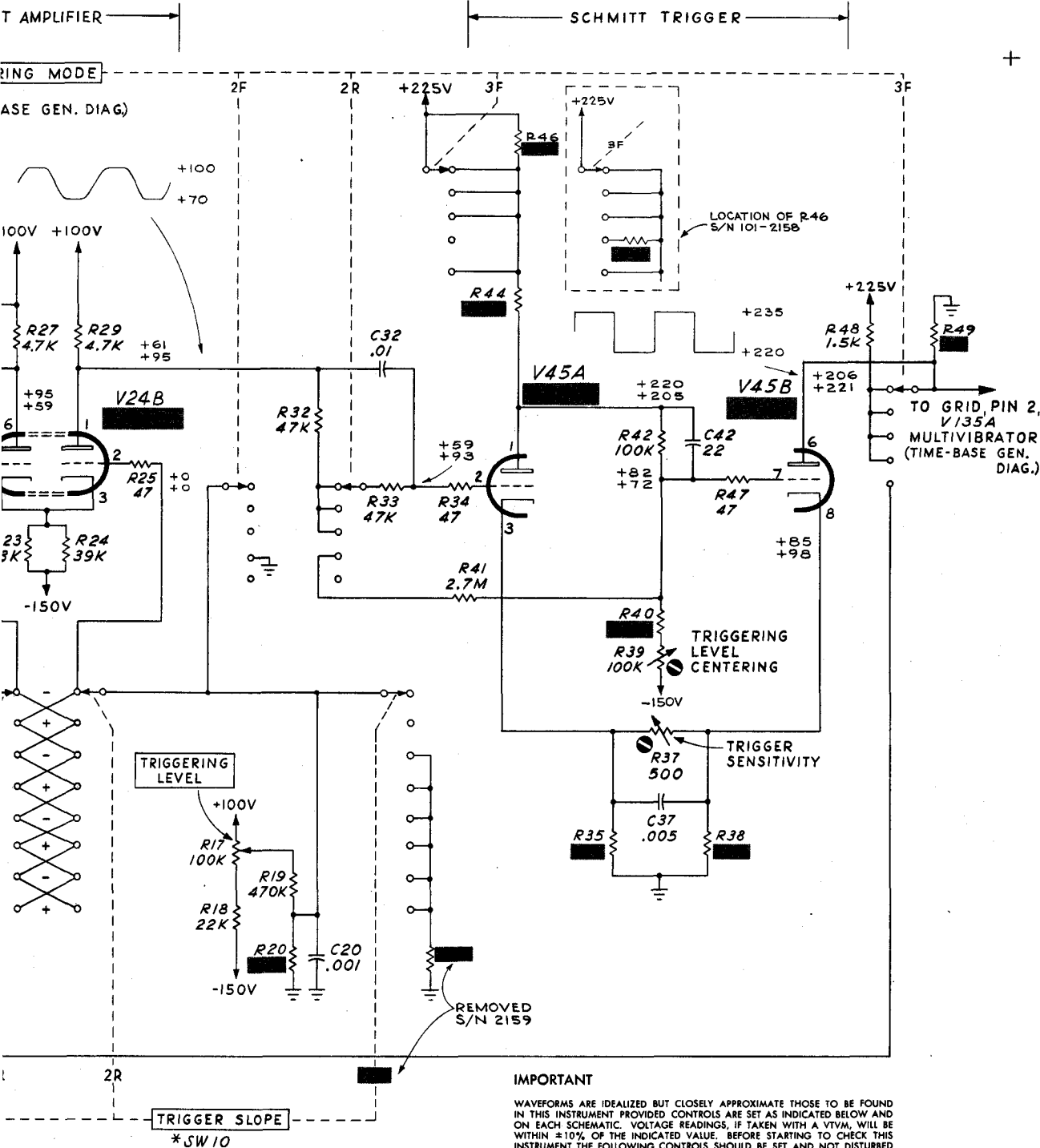


WAVEFORMS AND
WERE OBTAINED WITH CO
TRIGGERING LEVEL
FOR WAVEFORMS
FOR UPPER VOLTAGE RE
FOR LOWER VOLTAGE R
SEE ALSO IMPORTANT

551

TYPE 551 OSCILLOSCOPE

AA₂



IMPORTANT

WAVEFORMS ARE IDEALIZED BUT CLOSELY APPROXIMATE THOSE TO BE FOUND IN THIS INSTRUMENT PROVIDED CONTROLS ARE SET AS INDICATED BELOW AND ON EACH SCHEMATIC. VOLTAGE READINGS, IF TAKEN WITH A VTVM, WILL BE WITHIN $\pm 10\%$ OF THE INDICATED VALUE. BEFORE STARTING TO CHECK THIS INSTRUMENT THE FOLLOWING CONTROLS SHOULD BE SET AND NOT DISTURBED UNLESS OTHERWISE NOTED ON SCHEMATICS BEING USED. RETURN CONTROLS TO THE POSITIONS LISTED BELOW BEFORE MOVING TO THE NEXT SCHEMATIC.

AMPLITUDE CALIBRATOR	OFF
HORIZONTAL DISPLAY	NORMAL
VARIABLE TIME/CM	CW
TIME/CM	1 mSEC
TRIGGER MODE	AC
TRIGGER LEVEL	CENTERED
TRIGGER SLOPE	+LINE
STABILITY	PRESET

*SW 10 & SW 30 CONCENTRIC

WAVEFORMS AND VOLTAGE READINGS

WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:

TRIGGERING LEVEL	CENTERED
FOR WAVEFORMS	
FOR UPPER VOLTAGE READINGS	CCW
FOR LOWER VOLTAGE READINGS	CW

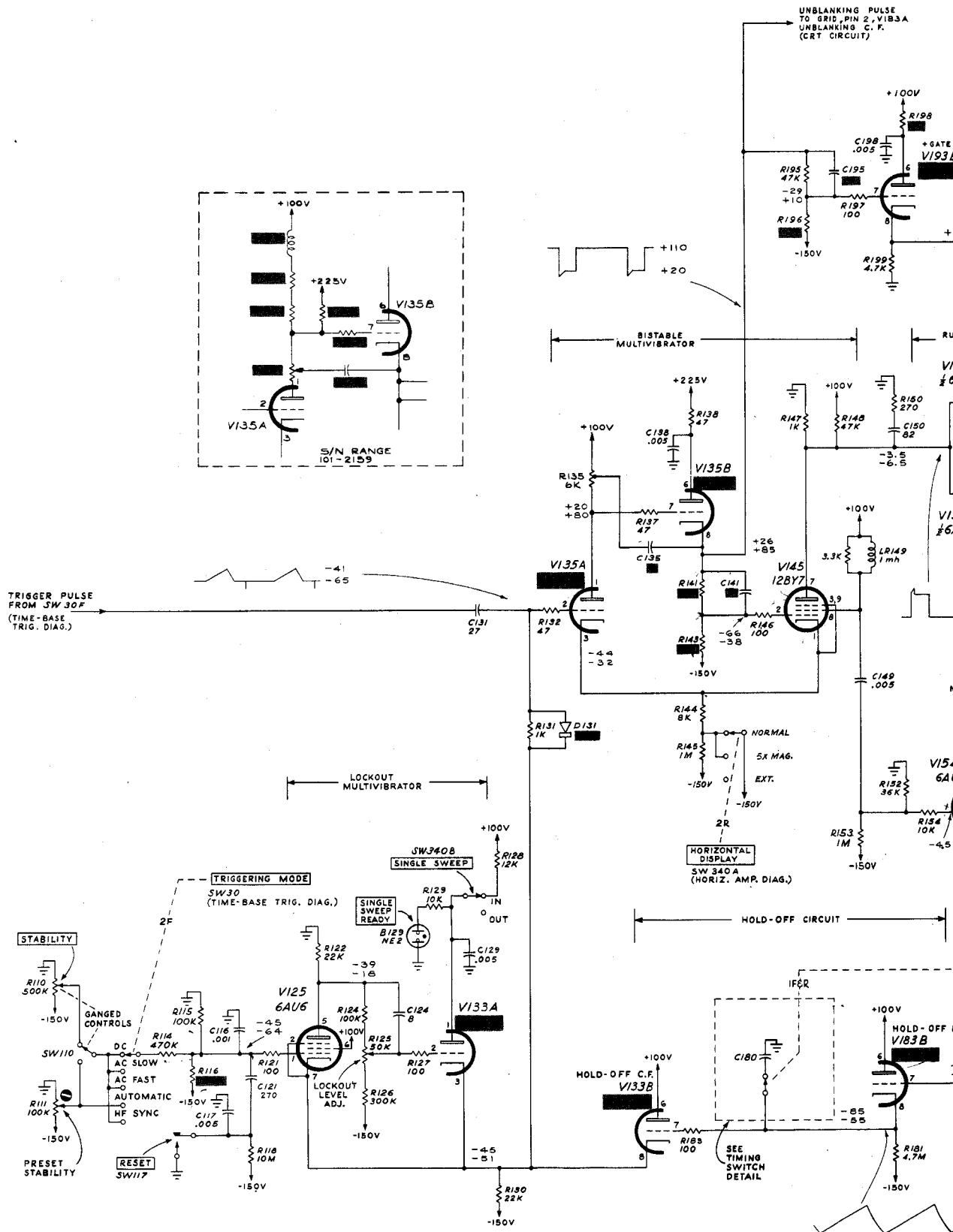
SEE ALSO IMPORTANT NOTE ON THIS DIAGRAM

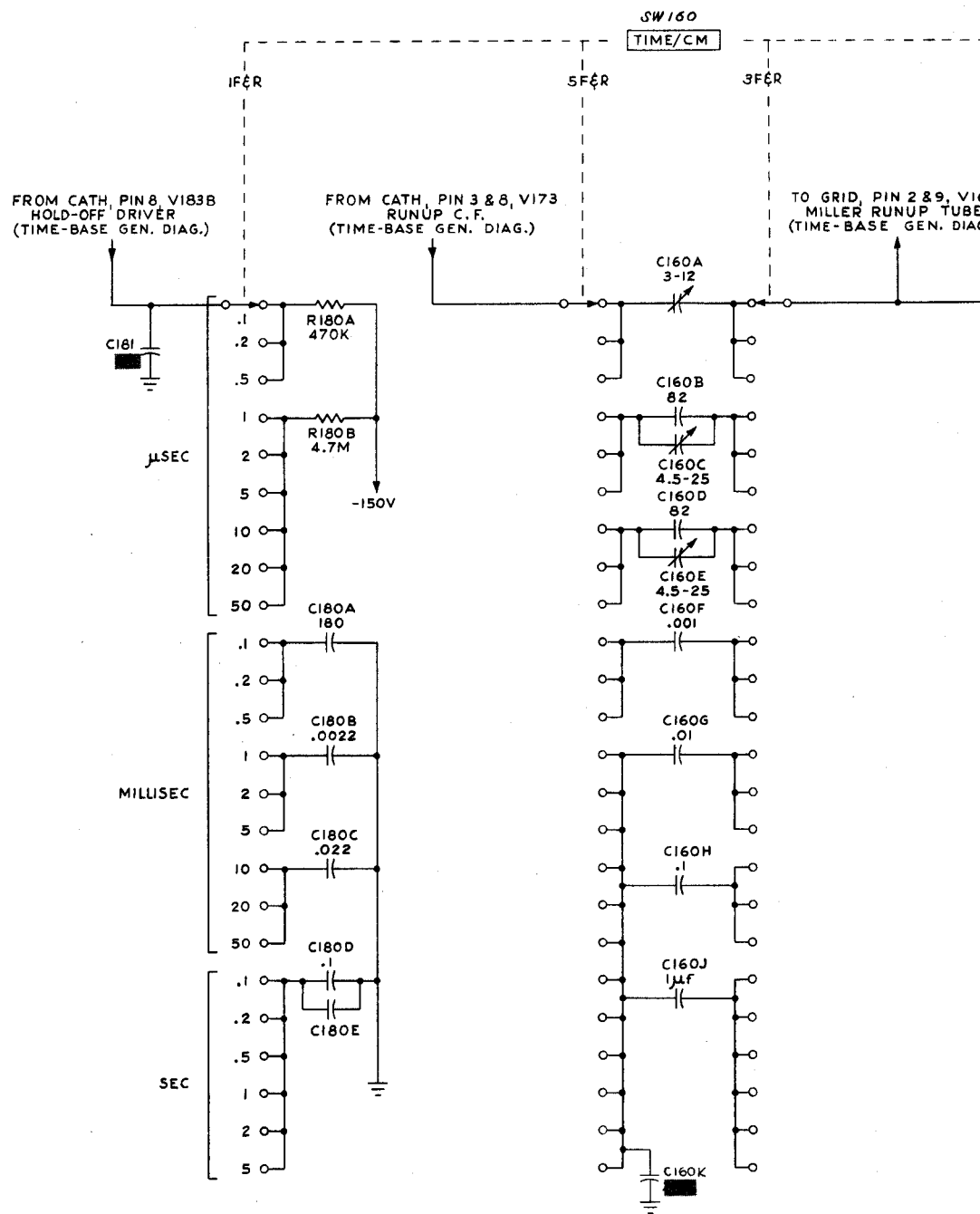
581 A TIME-BASE TRIGGER

9-6-62 JF

TIME-BASE TRIGGER

AA₂



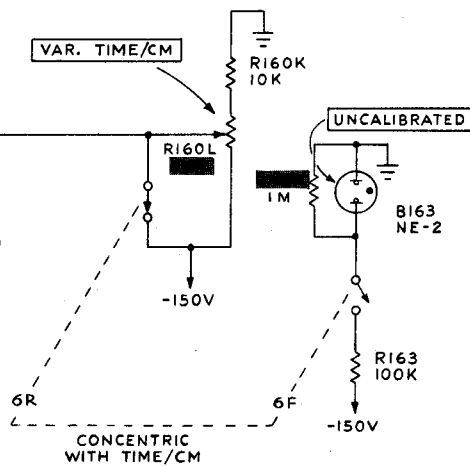
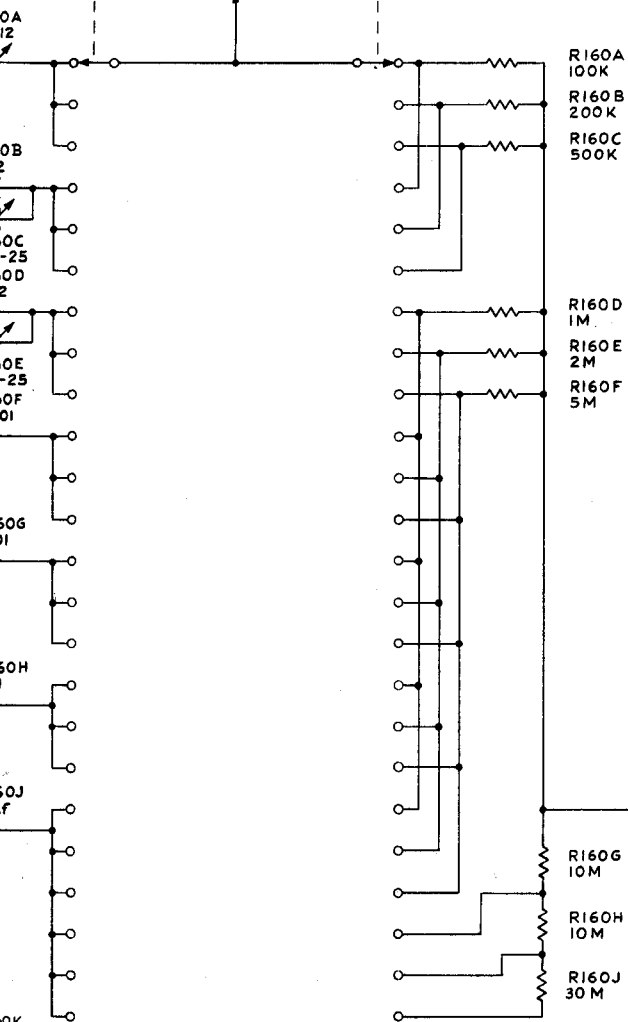


TYPE 551 OSCILLOSCOPE

50
CM

3F6R 4F6R

TO GRID, PIN 2 & 9, V161
MILLER RUNUP TUBE
(TIME-BASE GEN. DIAG.)

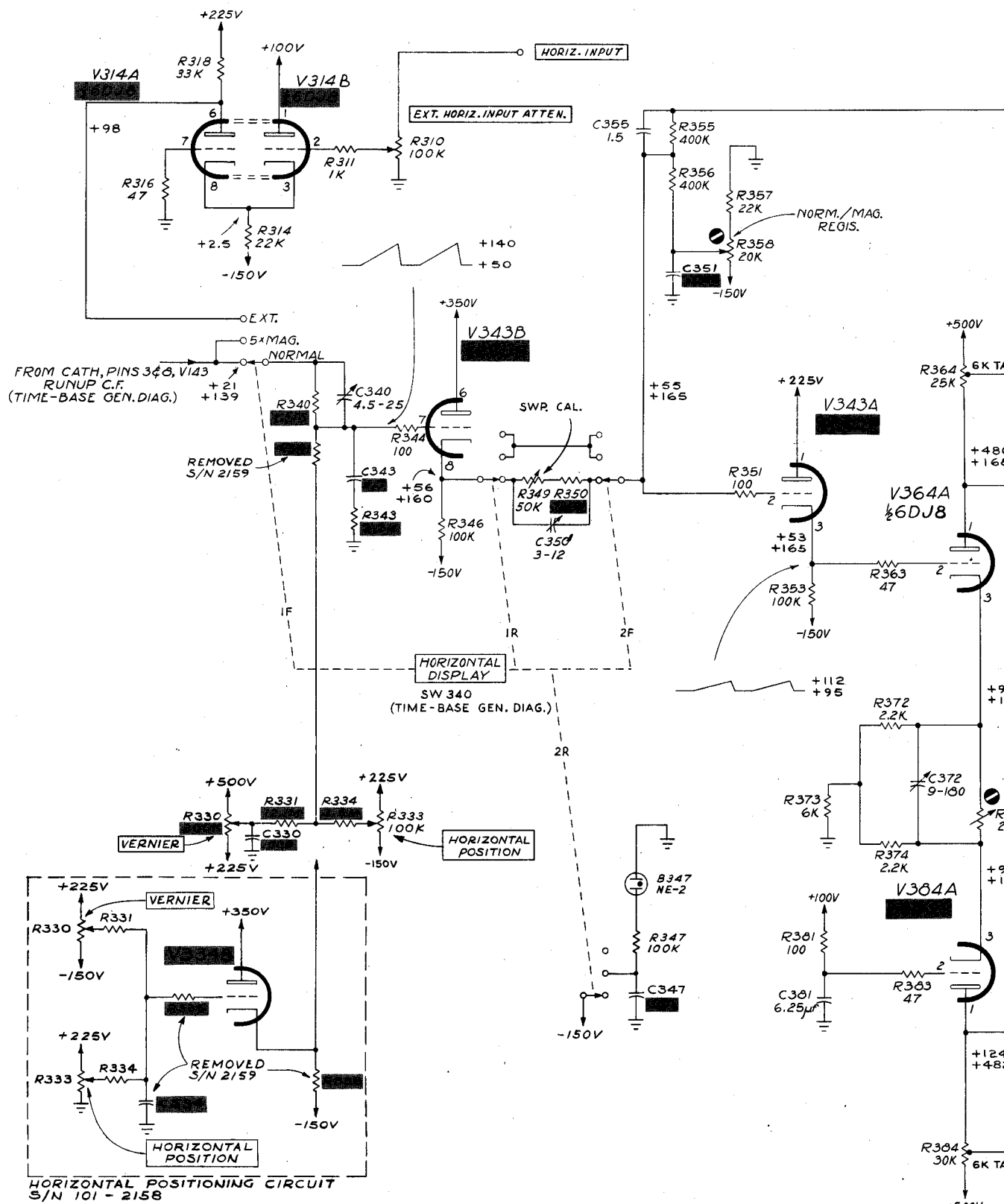


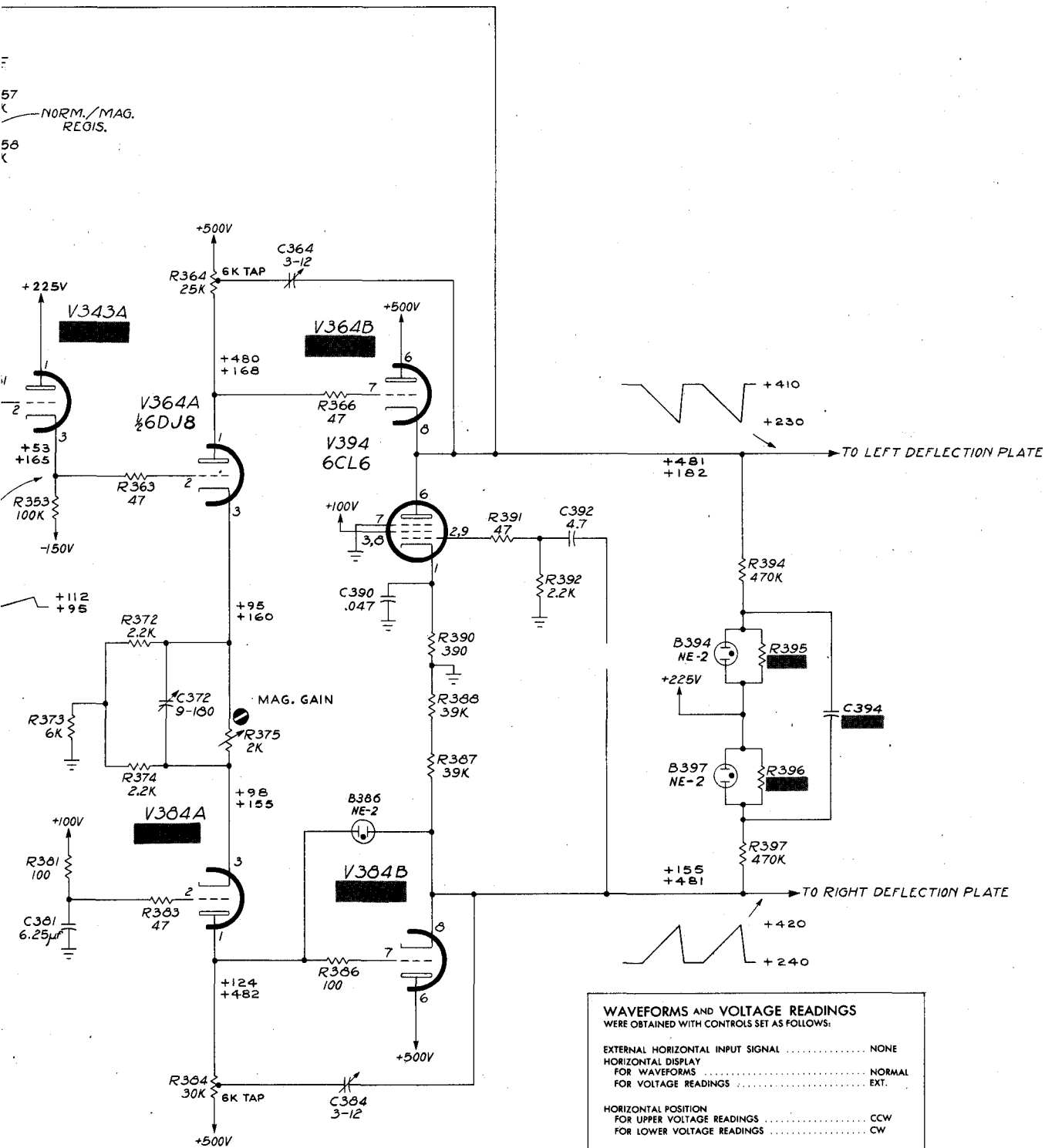
SEE PARTS LIST FOR EARLIER
VALUES AND S/N CHANGES OF
PARTS MARKED WITH RED
TINT BLOCKS

9-6-62
JR

TIMING SWITCH

AB₁





WAVEFORMS AND VOLTAGE READINGS
WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:

EXTERNAL HORIZONTAL INPUT SIGNAL NONE
HORIZONTAL DISPLAY
FOR WAVEFORMS NORMAL
FOR VOLTAGE READINGS EXT.

HORIZONTAL POSITION
FOR UPPER VOLTAGE READINGS CCW
FOR LOWER VOLTAGE READINGS CW

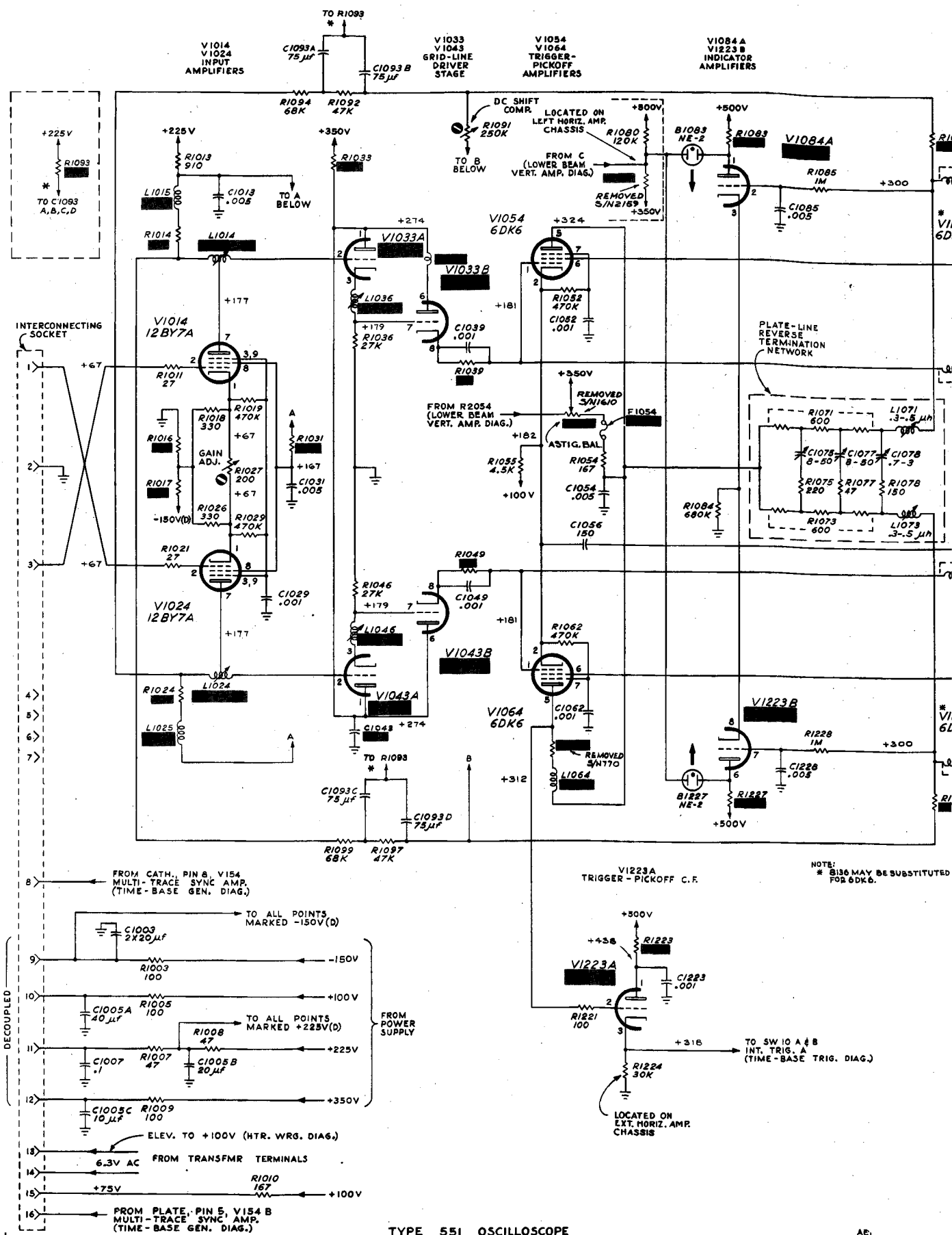
SEE ALSO IMPORTANT NOTE ON TIME-BASE TRIGGER DIAGRAM

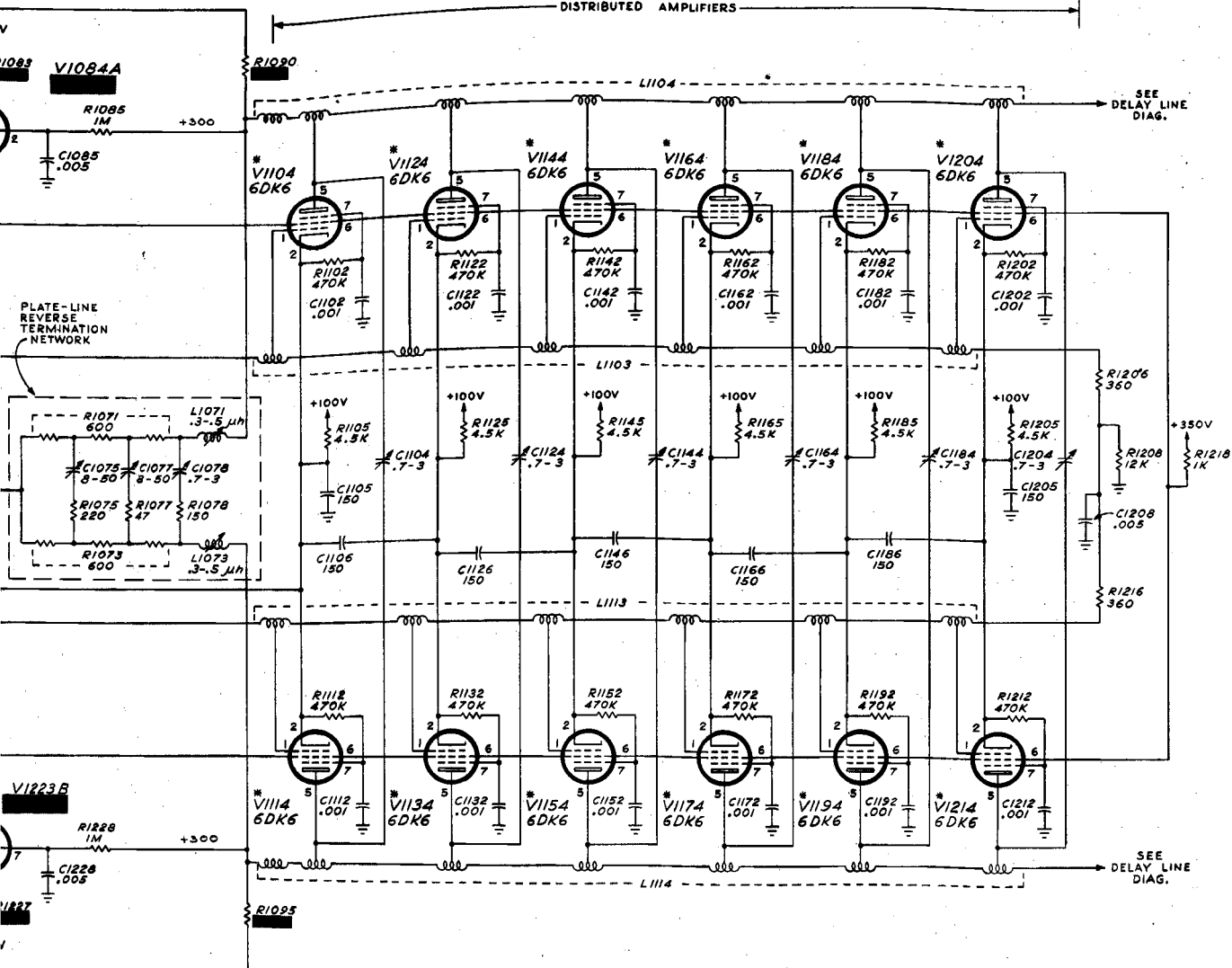
SEE PARTS LIST FOR EARLIER
VALUES AND S/N CHANGES OF
PARTS MARKED WITH RED
TINT BLOCKS

9-27-62 J/R

AB₄

HORIZONTAL AMPLIFIER





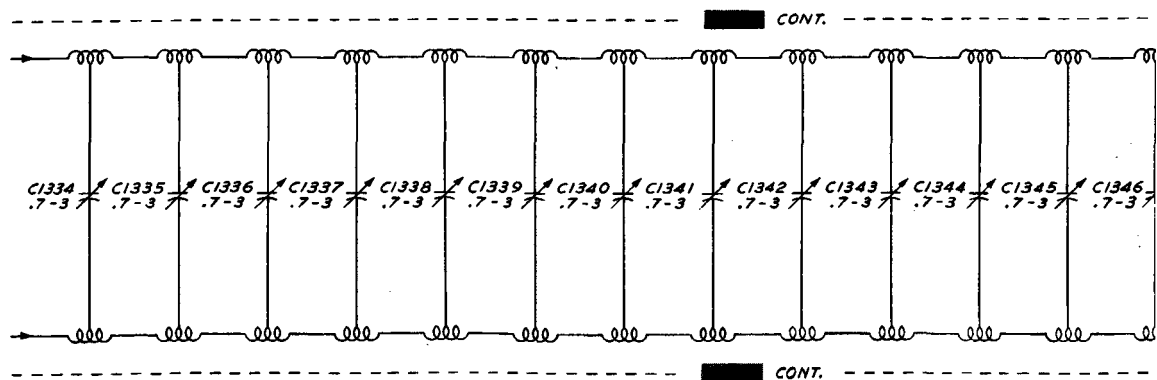
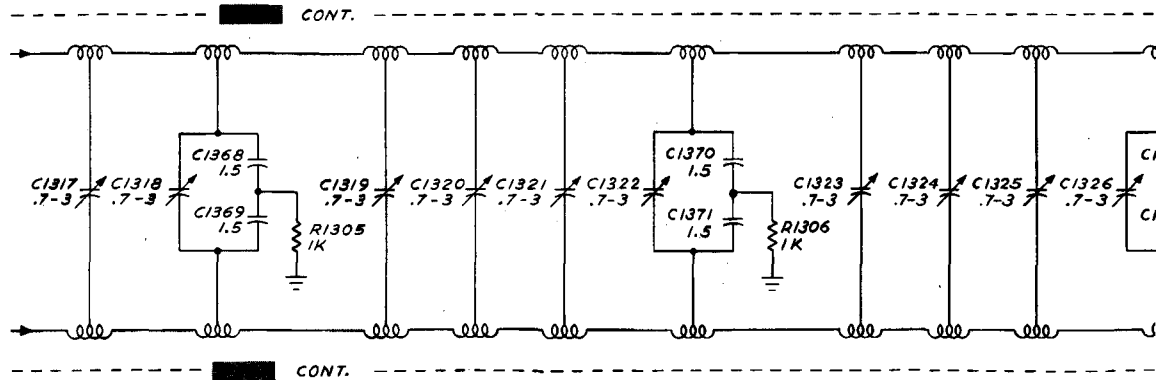
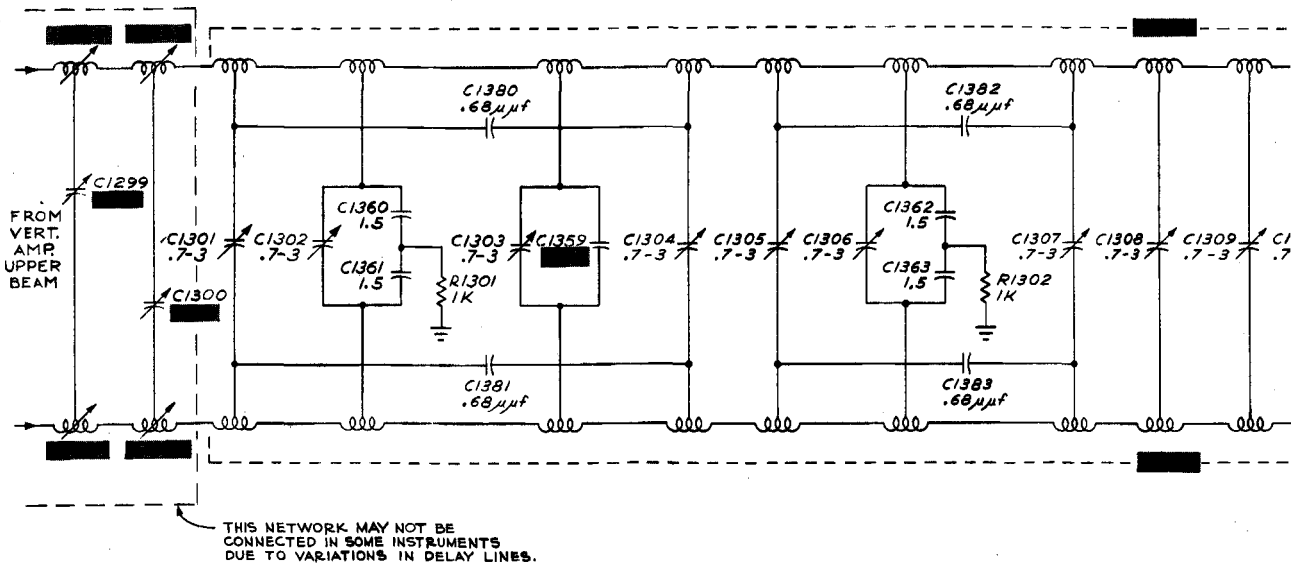
TO SW 10 A #8
INT. TRIG. A
(TIME-BASE TRIG. DIAG.)

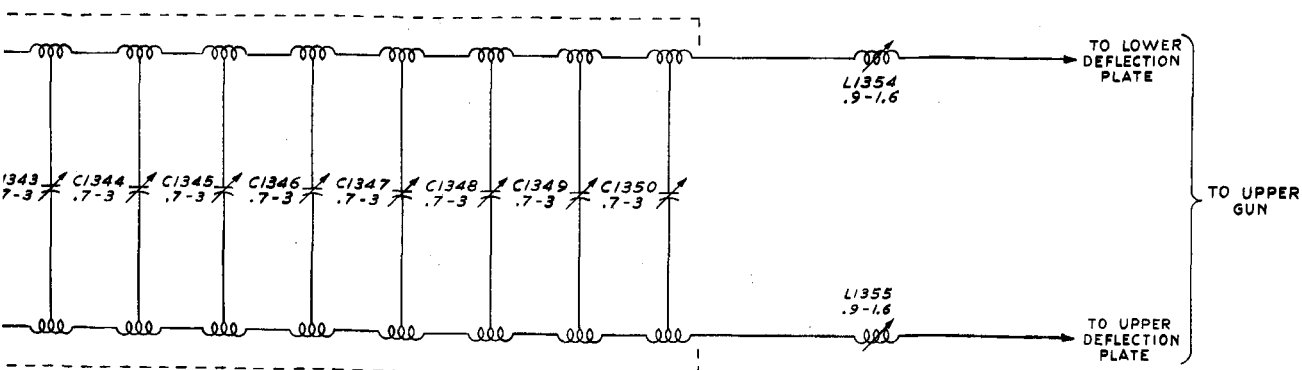
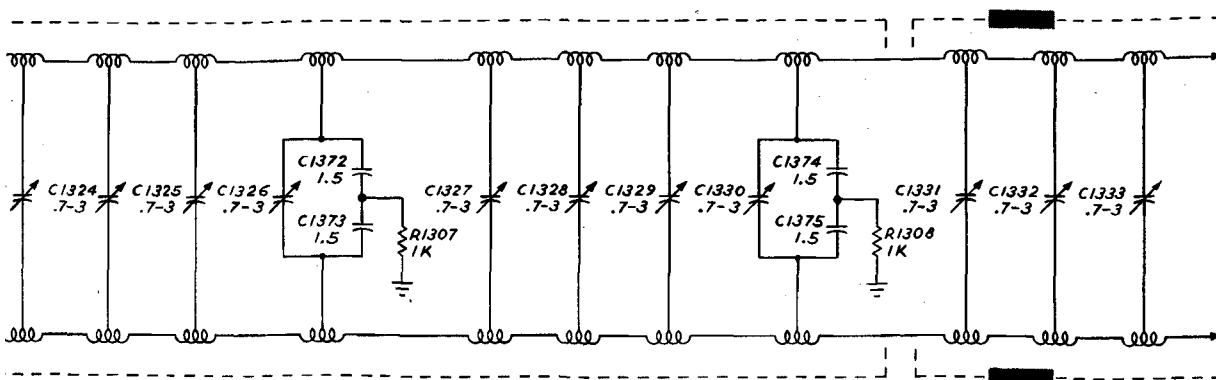
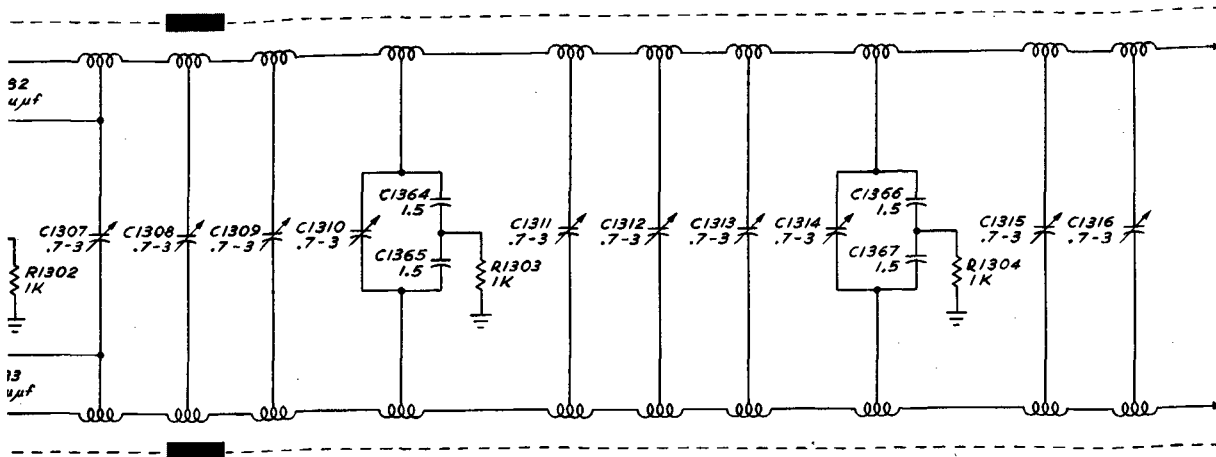
SEE PARTS LIST FOR EARLIER
VALUES AND S/N CHANGES OF
PARTS MARKED WITH RED
TINT BLOCKS

8-10-62

JR

UPPER BEAM
VERTICAL AMPLIFIER





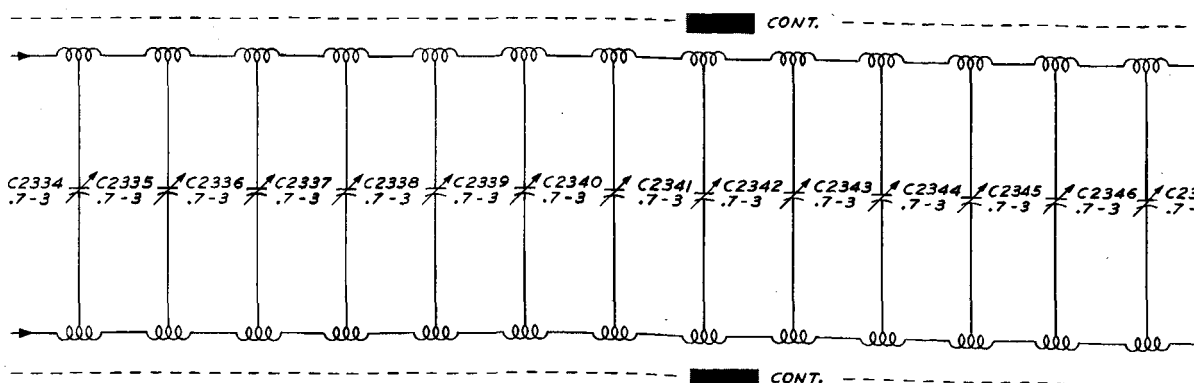
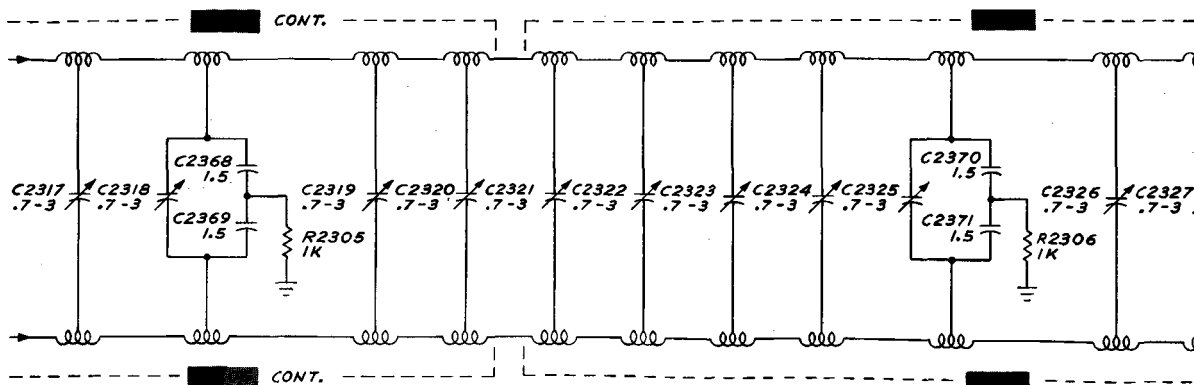
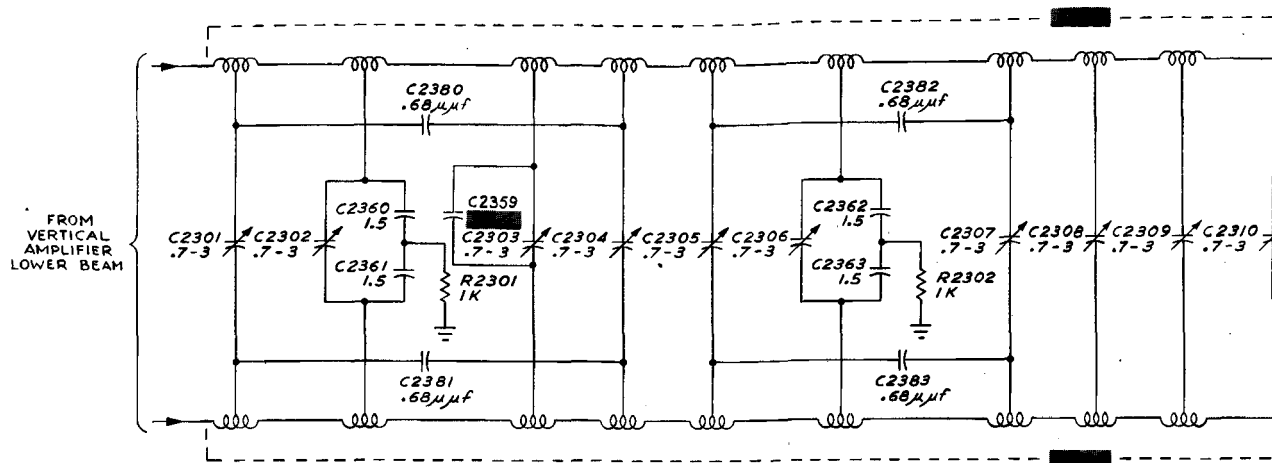
SEE PARTS LIST FOR EARLIER
VALUES AND S/N CHANGES OF
PARTS MARKED WITH RED
TINT BLOCKS

9-23-62
JR
GAB

UPPER BEAM

DELAY LINE NETWORK

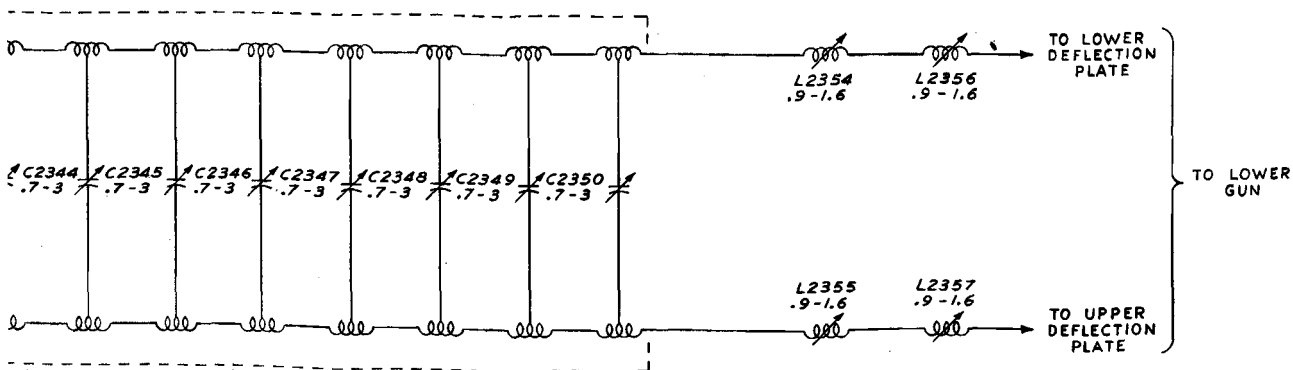
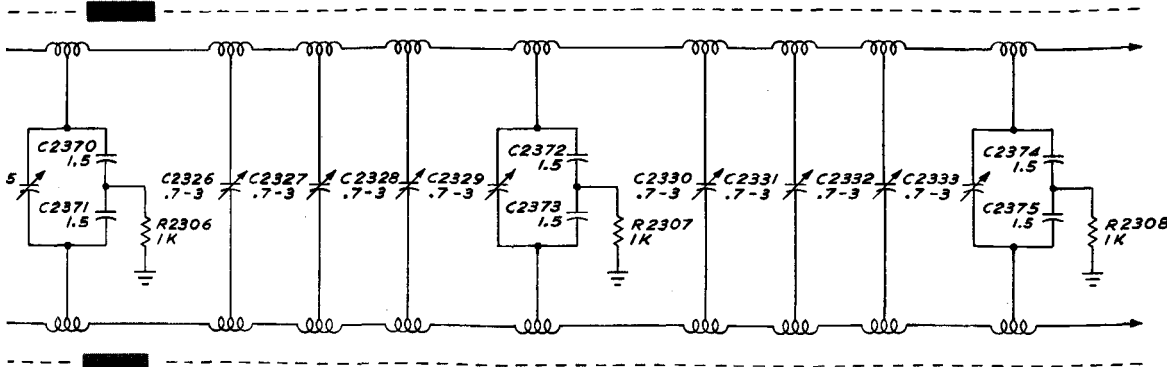
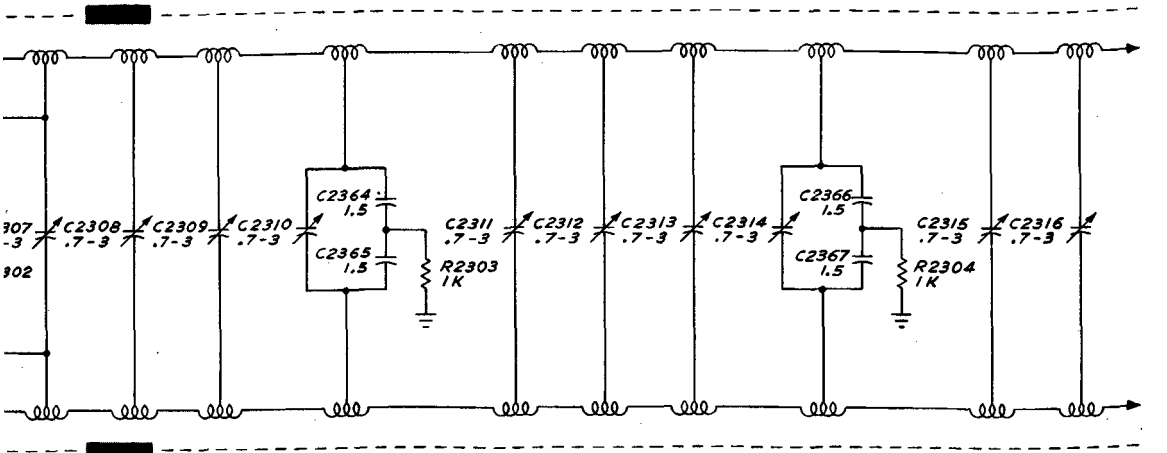
AA₂



TYPE 551 OSCILLOSCOPE

AA₁

+

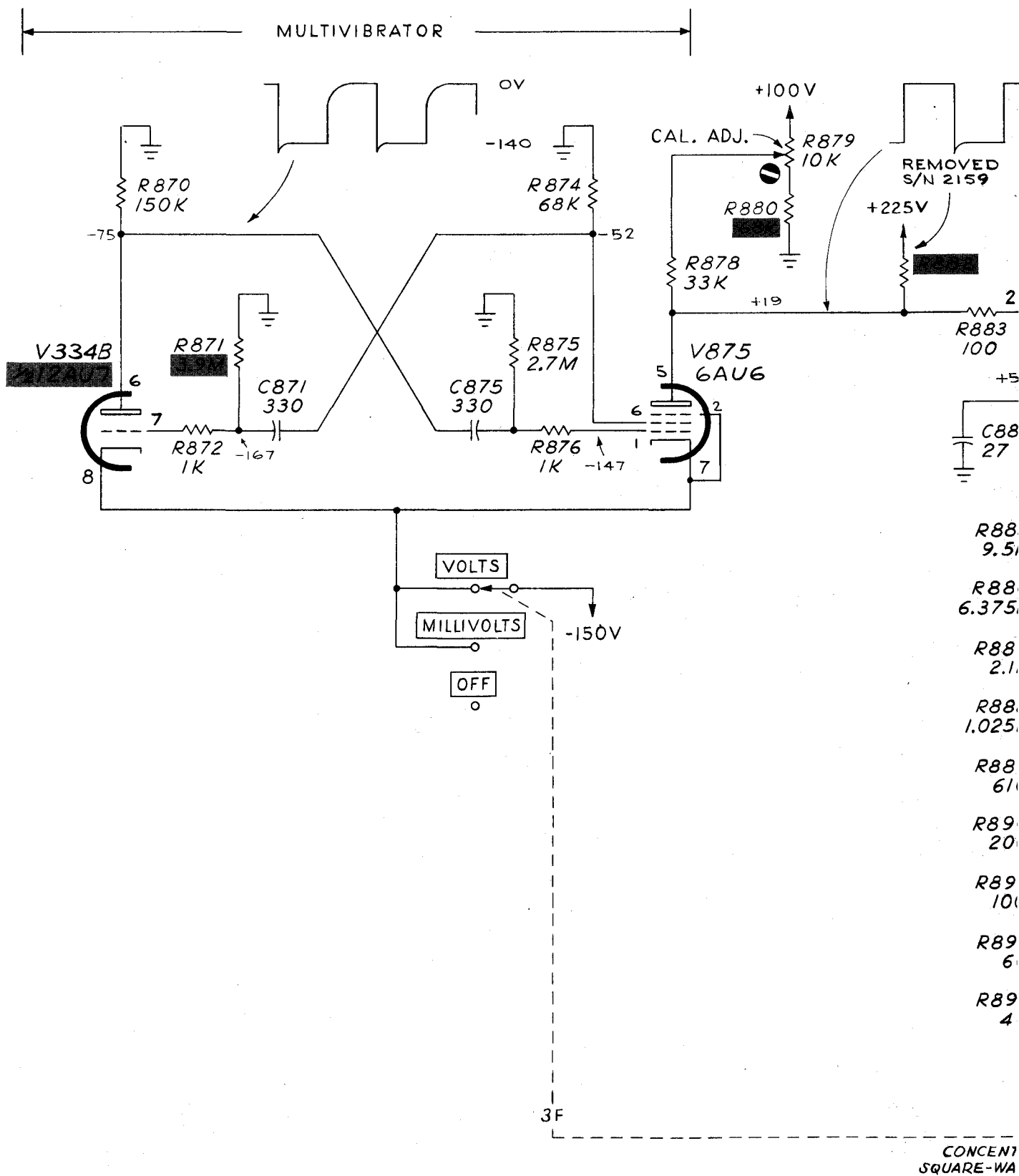


SEE PARTS LIST FOR EARLIER
VALUES AND S/N CHANGES OF
PARTS MARKED WITH RED
TINT BLOCKS

9-7-62 JR

LOWER BEAM
DELAY LINE NETWORK

AA,

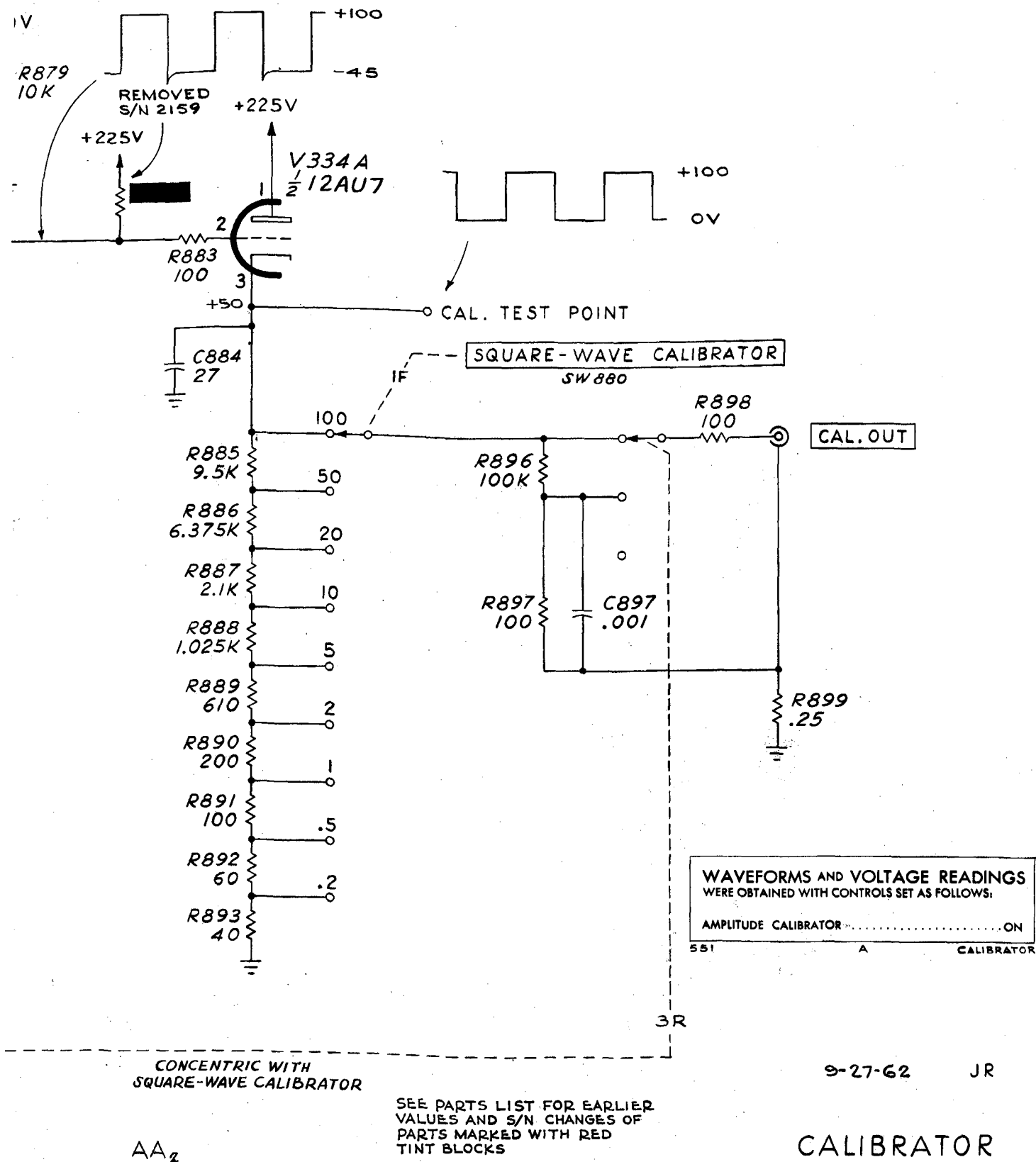


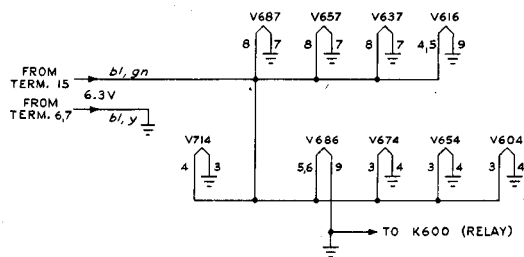
+ TYPE 551 OSCILLOSCOPE

AA₂

+

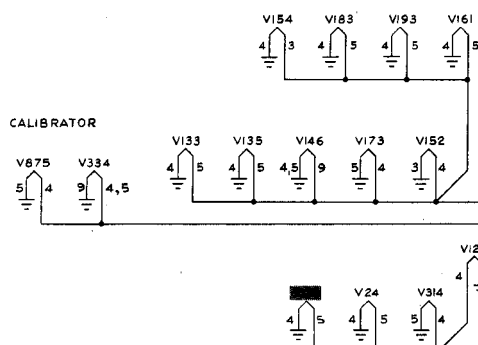
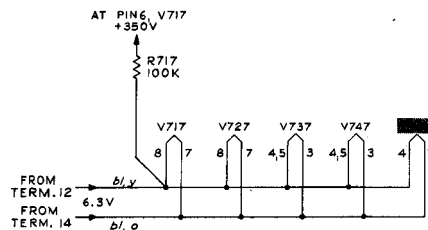
CAL. C.F.



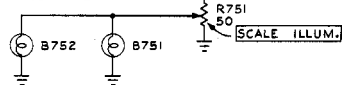


COMMON GND
AT PIN 7, V657

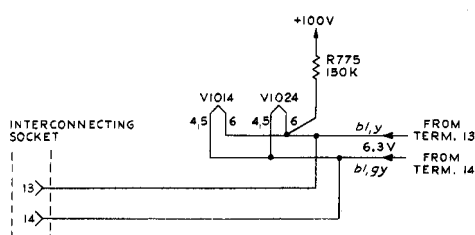
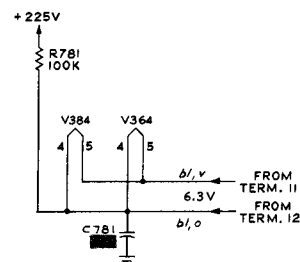
POWER SUPPLY



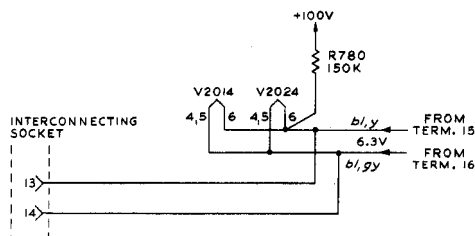
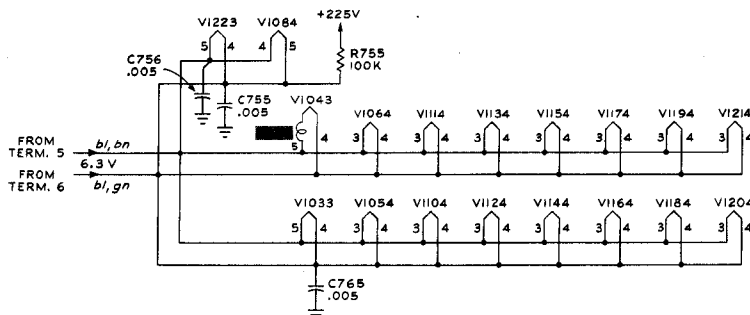
GRATICULE LIGHTS



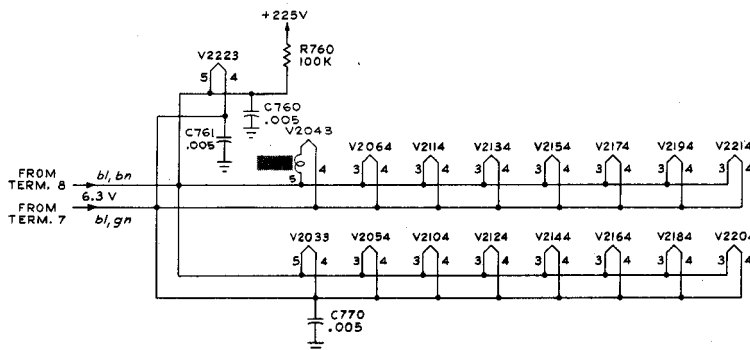
SWEEP



INTERCONNECTING
SOCKET



INTERCONNECTING
SOCKET



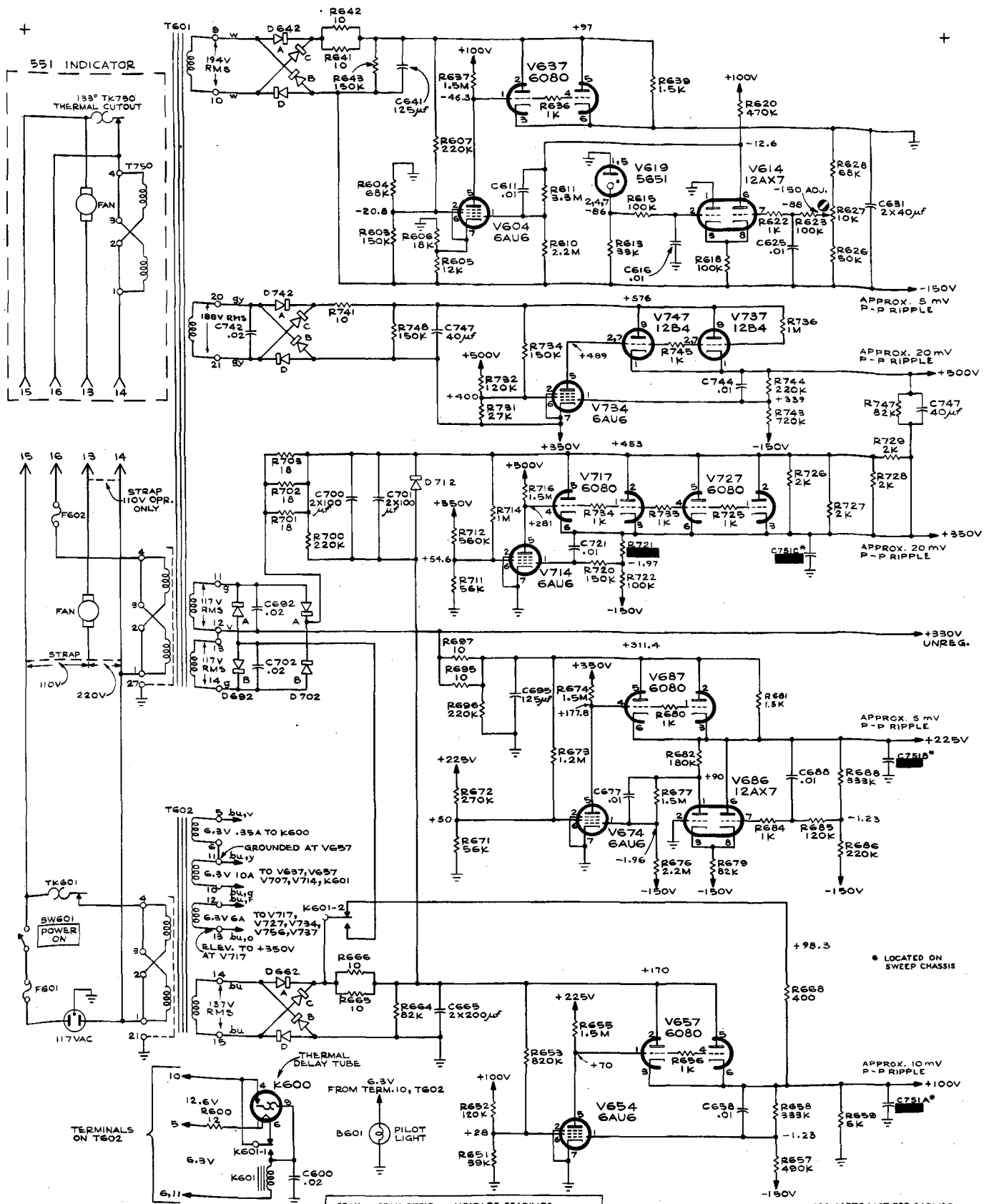
VERTICAL AMPLIFIERS

TYPE 551 OSCILLOSCOPE

HEATER WIRING

S/N 2358 UP

9-7-62
JR



TYPE 551 OSCILLOSCOPE

PEAK TO PEAK RIPPLE AND VOLTAGE READINGS
WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:

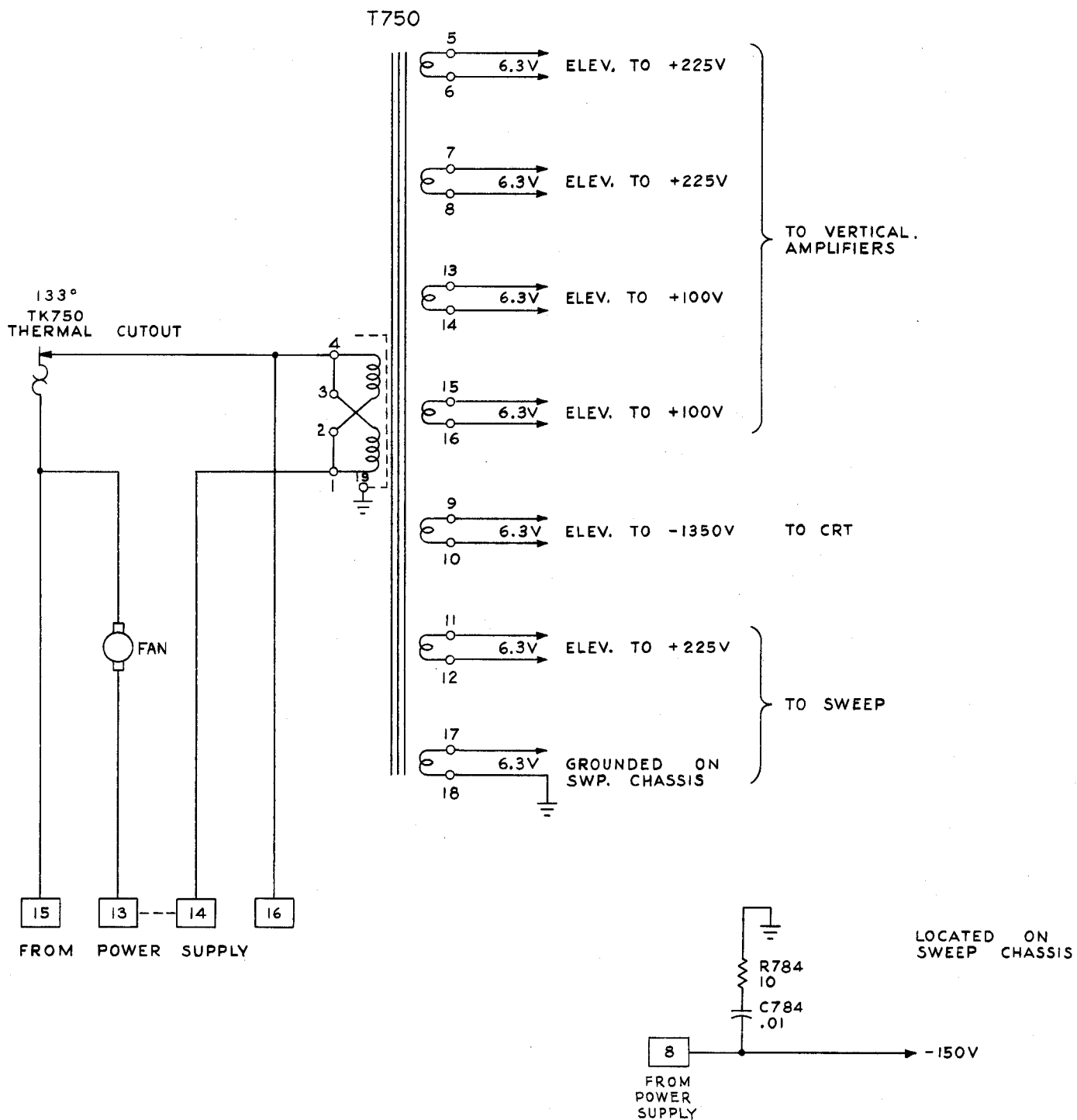
VERTICAL INPUT SIGNAL	NONE
TRIGGER INPUT SIGNAL	NONE
LINE VOLTAGE	117 VAC
STABILITY (BOTH TIME BASES)	CW, BUT NOT SWITCHED TO PRESET

SEE ALSO IMPORTANT NOTE ON TIME BASE TRIGGER DIAGRAM.

LV POWER SUPPLY

S/N 2858 & UP

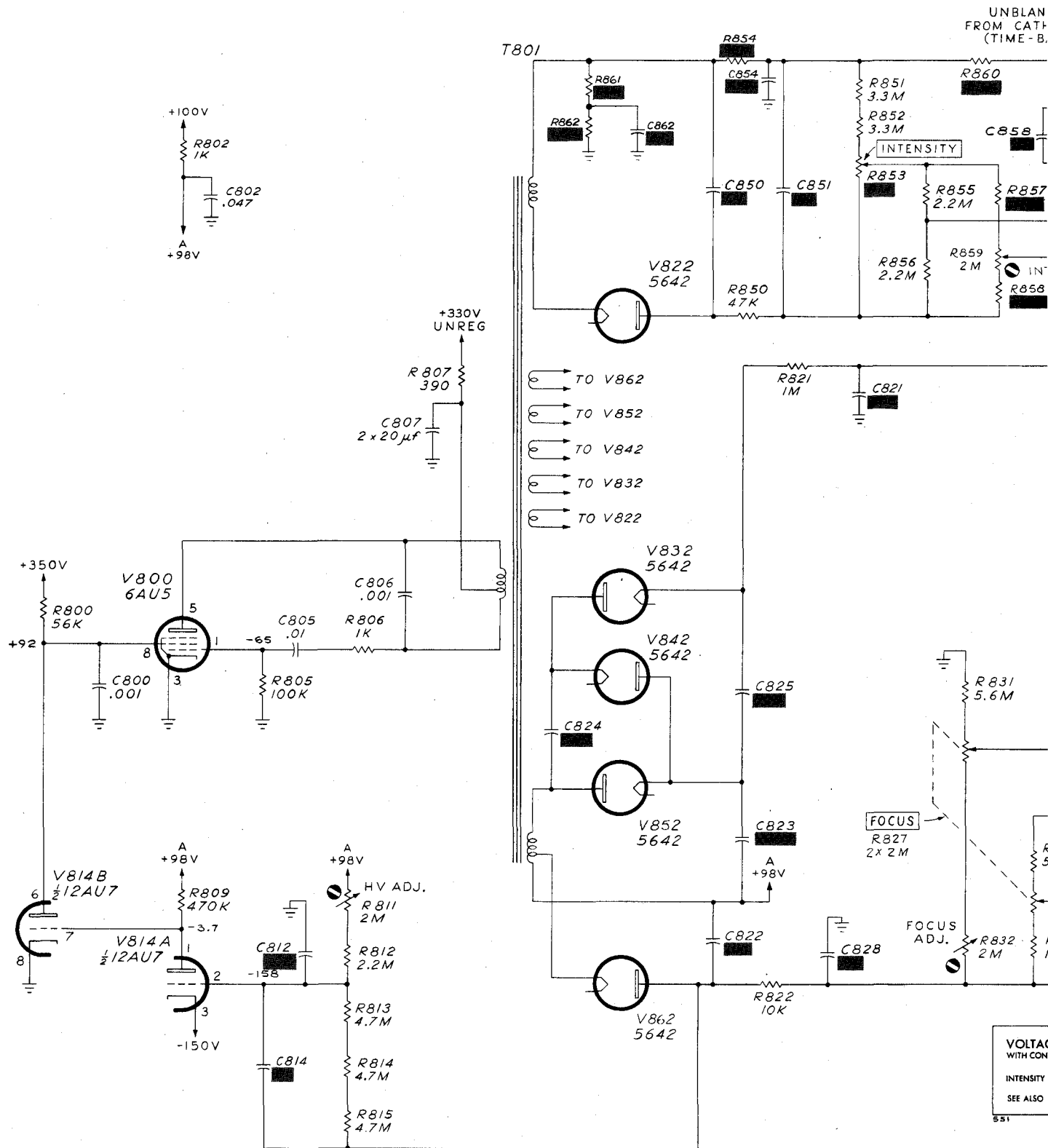
SEE PARTS LIST FOR EARLIER
VALUES AND S/N CHANGES OF
PARTS MARKED WITH RED
TINT BLOCKS



9-10-62 JR

TYPE 551 OSCILLOSCOPE

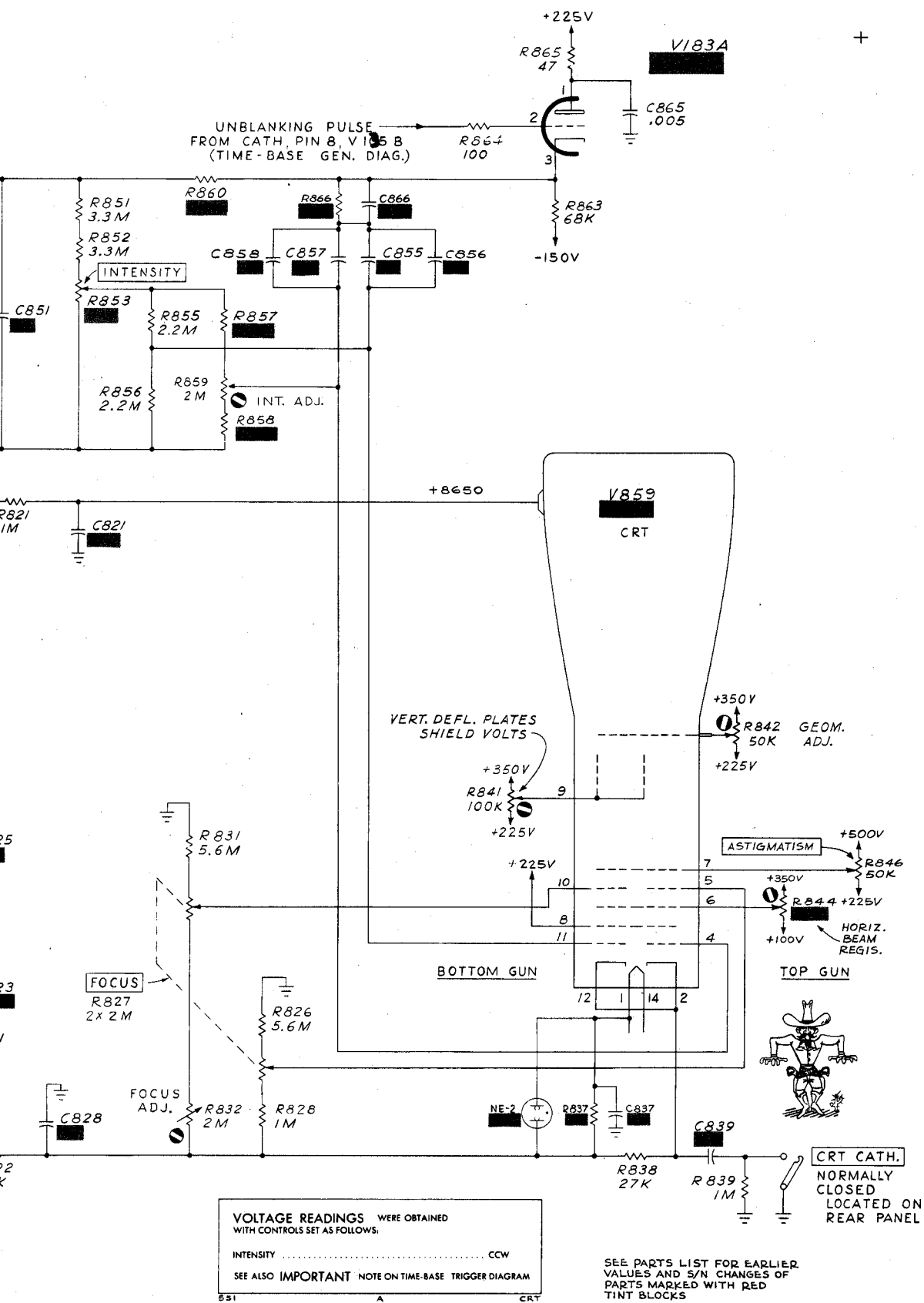
AA₁ INDICATOR HEATER SUPPLY



+ TYPE 551 OSCILLOSCOPE

AD₂

VOLTA
WITH CON
INTENSIT
SEE ALSO



JR
09-21-62

CRT CIRCUIT

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages. If it does not, your manual is correct as printed.

TYPE 551
Direct Replacement

HANDLE, ASSEMBLY, INDICATOR	should read	381-204
HANDLE, ASSEMBLY, PWR SUPPLY	should read	381-207

TYPE 551

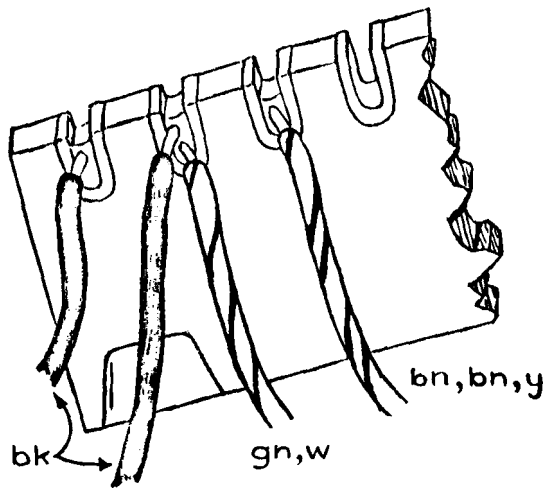


Fig. 2. Shows fan connection for 234V operation.

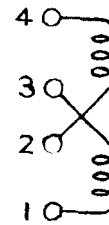


Fig. 1. Transformer connections.

To convert the Type 551 indication and power supply units for operation on 234 V nominal line voltage:

1. Remove the straps between terminals 1 and 2, 3 and 4 on all three of the transformers (2 in Power Supply and 1 in Indicator).
2. Remove the strap between terminals 13 and 14 of the inter-connecting plug on the Power Supply.
3. Looking at the bottom of the Power Supply unit from the rear. Move the right-hand fan lead from the third slot to the second slot in the ceramic strip. This movement in the Power Supply unit will convert the fan motors of both units for operation on 234 volts.
4. Place straps between terminals 2 and 3 on the transformers. Remember to do all three of the transformers.
5. Put in the correct value fuses as called out in the parts list of the manual.

TYPE 551

Correction to Calibration Procedure Pg 6-5

8a. From the Time Mark Generator apply 1 msec time markers to both the Upper and Lower Beam vertical INPUT connectors. With the display triggered, adjust the Horiz Beam Regis until the markers on the Lower Beam coincide with those of the Upper Beam.

27. Checking both Vertical Amplifiers for Equal Delay Time

Set the controls as follows:

TRIGGERING MODE	AC
TRIGGER SLOPE	LOWER-
HORIZONTAL DISPLAY	5X MAG
TIME/CM	.1 μ sec

Plug-in controls should be set to the most sensitive volts/cm position and the input AC coupled. Two Type 'P' plug-in's may be used for this check.

Apply a fast rise square wave to Upper and Lower Beam vertical INPUT connectors. This type of waveform may be obtained from a Tektronix Type 107 or 105 Square Wave Generator. When using the Square Wave Generator set the output frequency at approximately 500 kc.

Display approximately 2 cm of vertical signal on the crt. Now with the positioning controls position the two waveforms until they are superimposed. If the leading edges of the two waveforms are parallel to each other, but more than 1 mm separates them a section of delay line may be added to the Upper Beam delay line, to increase its delay, to more closely match that of the Lower Beam.

TYPE 551
MOD 6402 - Tent S/N 5080 (53)

R823	Add	2 x 250k	Pot	Var	311-356
R826	Change to	3.9m	2w	10%	306-395
R828	Change to	680k	1/2w	10%	302-684
R829	Add	15m	2w	10%	306-156
R830	Add	15m	2w	10%	306-156
R831	Change to	3.9m	2w	10%	306-395
R851	Change to	4.7m	2w	10%	306-475
R852	Change to	4.7m	2w	10%	306-475
R853	Change to	1m	Pot	Var	311-041
R855	Change to	1m	1/2	10%	302-105
R857	Change to	1m	1/2	10%	302-105
B852	Add	Bulb, neon		NE23	150-027
B853	Add	Bulb, neon		NE23	150-027
C833	Add	.02	150v	Cer	283-004
C834	Add	.01	500v	Cer	283-068
C835	Add	.01	500v	Cer	283-068
C836	Add	.02	150v	Cer	283-004
Q833	Add	Transistor	2N398A		151-055
Q843	Add	Transistor	2N398A		151-055

As per schematics attached.

TYPE 551
MOD 6402 - Tent S/N 5080

On instruments with S/N above 5080, some circuit changes were made in the CRT system. These changes consist of the addition of a HORIZONTAL SENSITIVITY BALANCE control and the necessary circuitry to provide individual control of the cathode voltages to compensate for slight differences in the horizontal deflection sensitivity of the two halves of the CRT.

The HORIZONTAL SENSITIVITY BALANCE control will permit optimum registration of the two traces. The control range is $\pm 1\frac{1}{2}$ mm. Note that the edge focus and geometry are not changed by this modification.

To check the registration, insert time markers from a 180 TIME MARK GENERATOR into both channels of the 551, superimposing the two traces. If registration does not occur, adjust as shown in the CALIBRATION section of this manual.

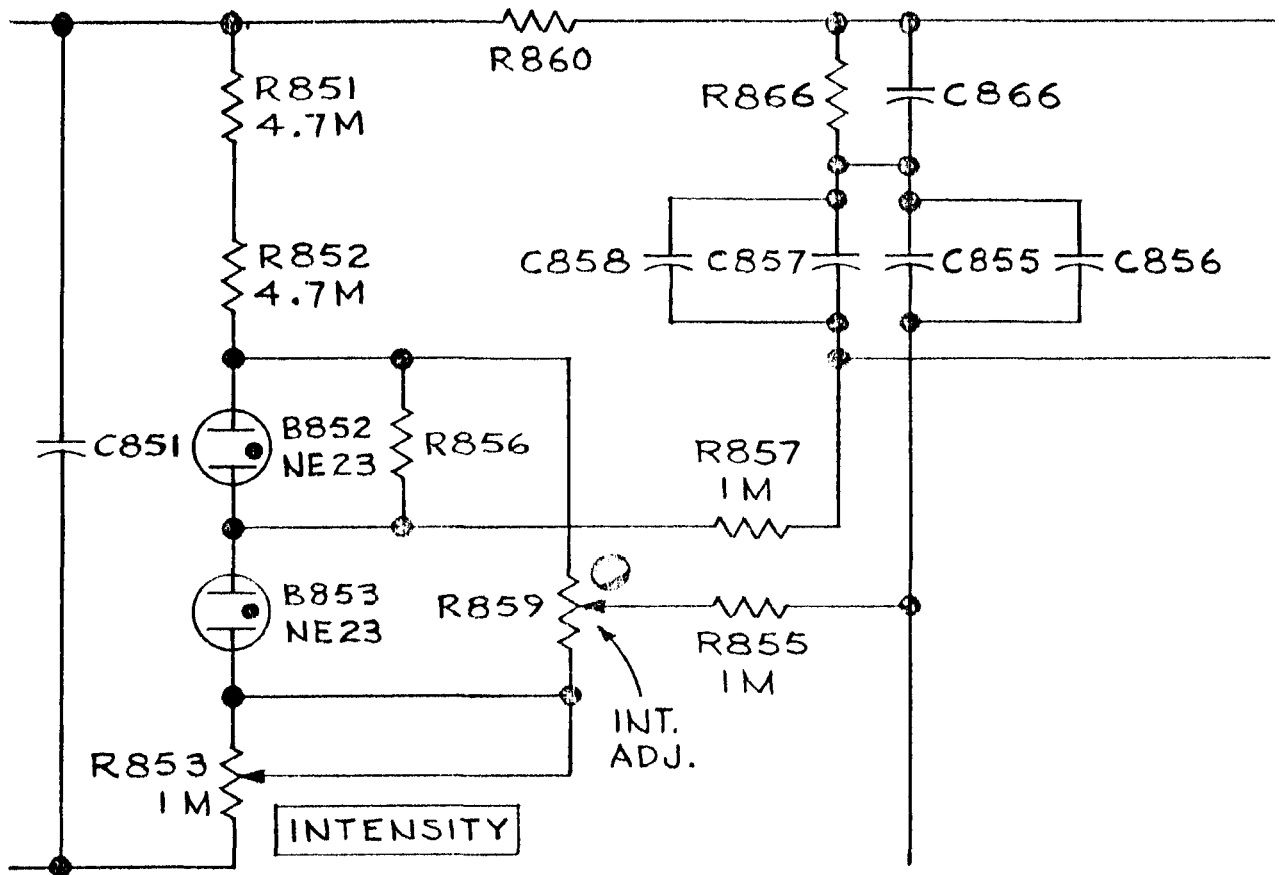
CALIBRATION PROCEDURE

1. Set the HORIZONTAL SENSITIVITY BALANCE control to mid range.
2. Set the INTENSITY and INTENSITY BALANCE for low but equal intensity.
3. Adjust the FOCUS and ASTIGMATISM controls for optimum sharpness.
4. If the lower beam is short, the cathode of the lower beam must move in a positive direction so turn the HORIZ. SENS. BAL. control CCW.

If the lower beam is long, the cathode of the lower beam must move in a negative direction so move the HORIZ. SENS. BAL. control CW.

Now the HORIZ. SENS. BAL. control should give you the last half mm of adjustment you need to give good registration of the two traces. You will note that the HORIZ. SENS. BAL. control moves one trace one way and the other in the opposite direction.

There is an interaction between the INTENSITY BALANCE, HORIZONTAL SENS. BAL. and focus controls. It may be necessary to repeat the sequence of adjustment until the two traces match in timing, focus and intensity.



PARTIAL DIAGRAM - 551 CRT CIRCUIT
MOD 6402

12-18-62

K4XL's BAMA

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