INSTRUCTION MANUAL

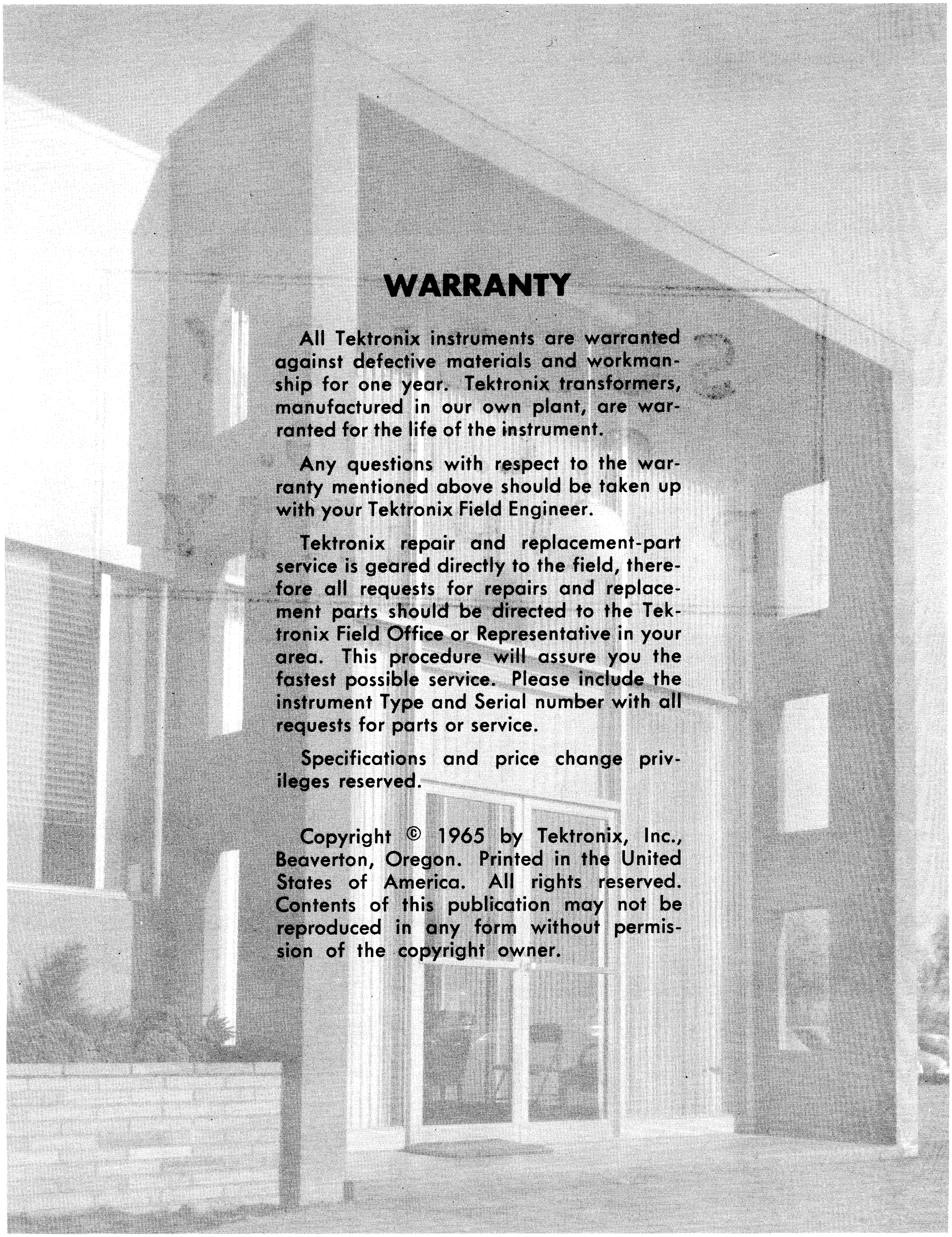
Serial Number 424

N610 TYPE

5T3

TIMING UNIT

Tektronix, Inc.
S.W. Millikan Way ● P. O. Box 500 ● Beaverton, Oregon ● Phone MI 4-0161 ● Cables: Tektronix



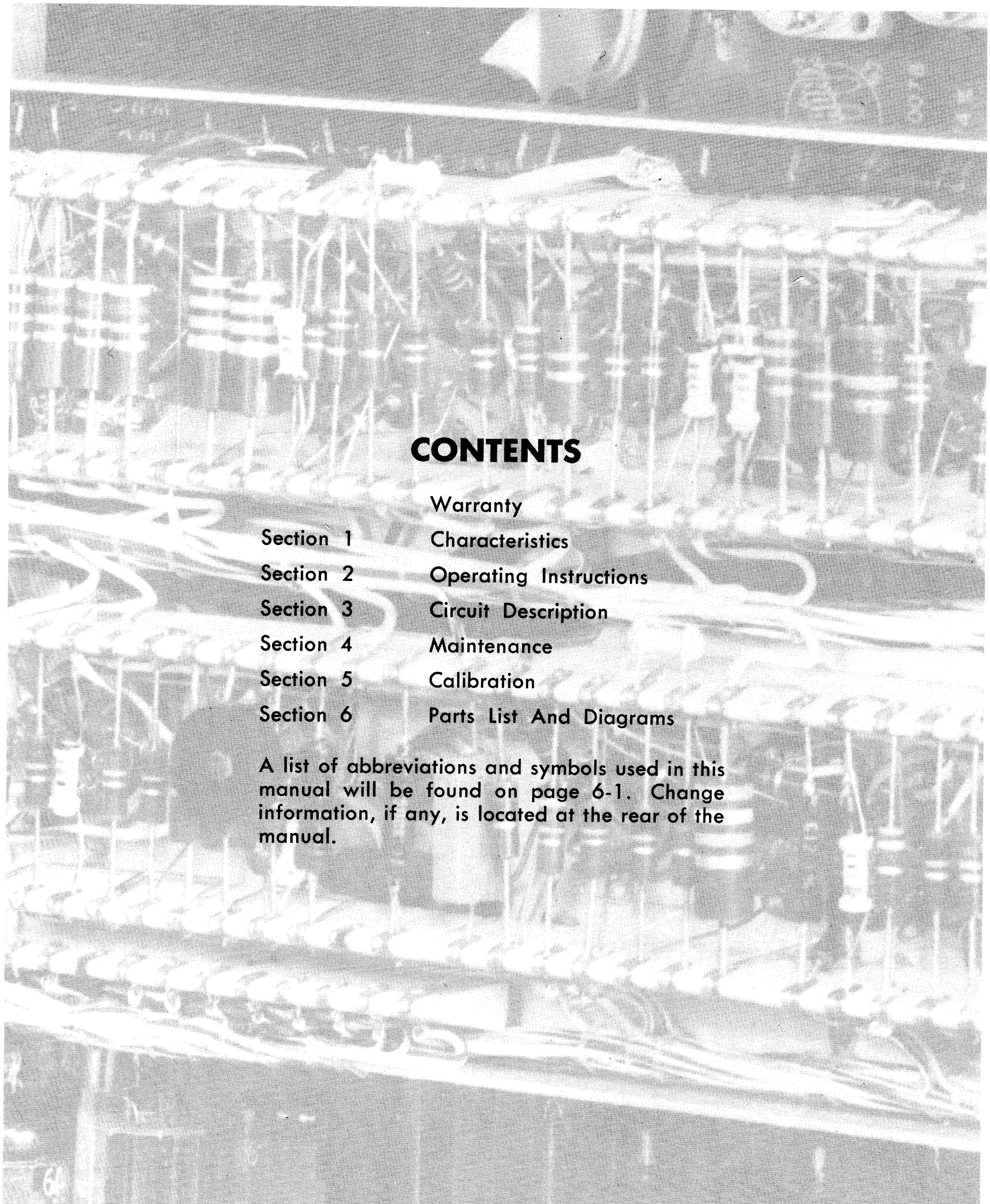
WARRANTY

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.

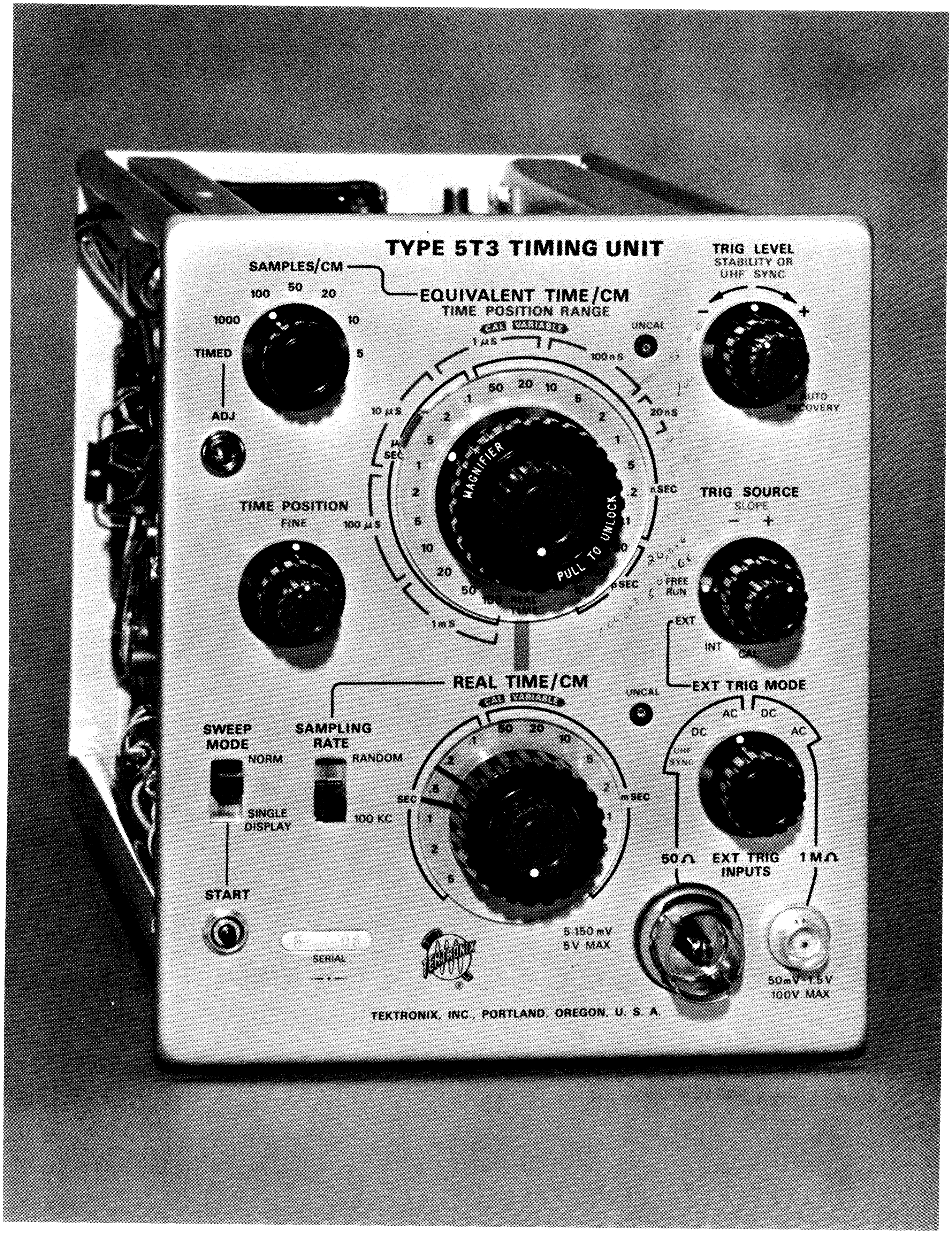
Tektronix repair and replacement-part service is geared directly to the field, therefore all requests for repairs and replacement parts should be directed to the Tektronix Field Office or Representative in your area. This procedure will assure you the fastest possible service. Please include the instrument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

Specifications and price change privileges reserved.



CONTENTS

A list of abbreviations and symbols used in this manual will be found on page 6-1. Change information, if any, is located at the rear of the manual.


TYPE 5T3 TIMING UNIT
SAMPLES/CM
EQUIVALENT TIME/CM
TIME POSITION RANGE
CAL VARIABLE
UNCAL
TIMED
ADJ
TRIG LEVEL
STABILITY OR
UHF SYNC
AUTO
RECOVERY
MAGNIFIER
PULL TO UNLOCK
REAL TIME
TIME POSITION
FINE
TRIG SOURCE
SLOPE
FREE
RUN
EXT
INT
CAL
EXT TRIG MODE
REAL TIME/CM
SWEEP
MODE
NORM
SINGLE
DISPLAY
SAMPLING
RATE
RANDOM
100 KC
START
SERIAL
UHF
SYNC
50Ω EXT TRIG 1MΩ
INPUTS
5-150 mV
5V MAX
50mV-1.5V
100V MAX
TEKTRONIX, INC., PORTLAND, OREGON, U. S. A.

Type 5T3

SECTION 1
CHARACTERISTICS

General Description

The Type 5T3 Timing Unit is a wide-range time-base plug-in unit for use with the Type 661 Sampling Oscilloscope. Twenty-two calibrated equivalent-time sweep rates and fourteen calibrated real-time sweep rates provide accurate crt displays from 5 seconds per centimeter to 10 picoseconds per centimeter. The equivalent sweep rates faster than 1 nanosecond per centimeter are provided by a direct-reading magnifier. Variable sweep rate controls provide uncalibrated sweep rates between the calibrated steps and extend the fastest equivalent sweep rate to about 4 picoseconds per centimeter.

A Schmitt-type bistable trigger circuit provides triggering from dc to 500 megacycles from either internal or external sources. External triggering may be taken from either a 50 Ω source or a high-impedance source. A synchronizing circuit operated through the 50 Ω external trigger input extends the triggering capability of the Type 5T3 from 500 megacycles to above 5 gigacycles.

This wide range of sweep and triggering rates enables the sampling oscilloscope to display low-frequency signals, as well as repetitive high-frequency signals with risetimes in the picosecond range. In addition to repetitive-sweep displays, a triggered single sweep mode is provided for all sweep rates. In the equivalent-time range, a front-panel control positions the start of the crt "time window" for convenient viewing.

EQUIVALENT-TIME SWEEP

Sweep Rates

100 μsec/cm to 1 nsec/cm, unmagnified, in 16 calibrated steps. Sequence is 1, 2, 5; accuracy within ±3%[1]. A direct-reading magnifier provides up to 100× magnification with no increase in dot spacing. Using the magnifier, the fastest calibrated sweep rate is 10 psec/cm. The magnified display is expanded from the left edge of the screen.

An uncalibrated variable control provides sweep rates between the calibrated steps, increasing the sweep speed up to at least 2.5 times from the calibrated position, and extends the fastest magnified rate to about 4 psec/cm.

Sweep Modes

Repetitive (NORM) or single-display, selected by front-panel switch. START button arms single display circuit. Next trigger starts the sweep.

Display Samples/Cm

5, 10, 20, 50, 100 and 1000 when the oscilloscope magnifier is at ×1 position. With the SAMPLES/CM switch in the TIMED position, sweep is continuous at a rate adjustable from 0.5 to greater than 5 sec/cm.

Display Time Positioning

1 msec to 20 nsec, depending on the sweep rate and magnification. TIME POSITION and FINE controls delay the start of the display time window over the range indicated on the blue Time Position Range scale. Total width of observable time is equal to the Time Position Range setting plus the time width of one screen diameter.

Blanking

Sweep retrace and interdot blanking internally dc-coupled to oscilloscope blanking circuit.

REAL-TIME SWEEP

Sweep Rates

5 sec/cm to 0.2 msec/cm in 14 calibrated steps. Function only with EQUIVALENT TIME/CM switch at REAL TIME position. Sequence is 1, 2, 5, 10; accuracy within ±3%. An uncalibrated variable control provides sweep rates between the calibrated steps, increasing the sweep speed up to at least 2.5 times from the calibrated position, and extends the fastest real-time sweep rate to about 80 μsec/cm.

Sweep Modes

Repetitive (NORM) or single display. START button arms single display circuit. Next trigger starts the sweep. The same controls are used for both equivalent-time mode and real-time mode.

Sampling Rates

100 KC—A precise clock rate set by an oscillator circuit. Frequency is adjusted to within 1% of 100 kc.

RANDOM—Approximate 80-kc rate frenquency-modulated with 60 cps signal. Maximum period between samples is 15 μsec; minimum period is 10 μsec. Random rate is provided to break up false sampling displays.

Blanking

Sweep retrace and interdot blanking internally dc-coupled to oscilloscope blanking circuit.

TRIGGERING

Trigger Sources

Internal from sampling plug-in unit or oscilloscope calibrator, and external through 50 Ω or 1 MΩ External Trig-

[1] **Excluding slight non-linearity at start of sweep with TIME POSITION and FINE controls fully clockwise.**

ger Inputs. All trigger sources are disconnected in the FREE RUN position of the TRIG SOURCE switch. When the sweep is in free run, the oscilloscope delayed pulse will present a stable display on the crt screen.

Trigger Slope

Positive-going (+) or negative-going (—) from all sources except 50 Ω UHF sync. The UHF synchronizer circuit operates on the positive-going portion of the input waveform in UHF Sync mode.

Trigger Coupling

Dc or ac from all sources except Calibrator and 50 Ω UHF sync. Ac only from these two sources. Internal signal source may be ac-coupled in the sampling unit.

Trigger Characteristics

Internal (from sampling unit with trigger takeoff)

Operating Range—Dc to approximately 500 Mc when dc-coupled.

Signal Requirements— ±5 mv to ±150 mv from sampling unit. Input to sampling unit must be large enough to provide this amount of trigger output to the Type 5T3 (e.g., the Type 4S1 must have a 40-mv input to provide 5-mv output).

Calibrator

Operating Range—100 kc to 100 Mc, internally connected to 100-mv oscilloscope calibrator signal.

External 50 Ω Input

Input Impedance—Nominally 50 ohms, regardless of input coupling.

Operating Ranges—Dc to 500 Mc at DC position; approximately 500 kc to 500 Mc at AC position; 500 Mc to 5 Gc at UHF SYNC.

Signal Requirements— ±5 mv to ±150 mv. Maximum short-duration overload is ±5 volts.

External 1 MΩ Input

Input RC (approximate)—1 megohm paralleled by 30 pf.

Operating Range—Dc to 20 Mc at DC position; approximately 160 cps to 20 Mc at AC position.

Signal Requirements— ±50 mv to ±1.5 volts. Maximum short-duration overload is ±100 volts.

Trigger Holdoff Duration

Minimum of 10 μsec on equivalent Time Position Ranges of 20 nsec, 100 nsec and 1 μsec; 4 times the Time Position Range switch setting on slower equivalent-time sweep rates.

Minimum of 10 μsec on all real-time sweep rates.

Equivalent-Time Trigger Jitter

Bistable TD Trigger or Auto Recovery (with pulse input)

Less than or equal to 30 psec of jitter when triggered on a 50-mv pulse applied to the 50 Ω External Trigger Input or applied from the sampling unit to the Type 5T3[1]. (Input pulse duration is 2 nsec, risetime is 1 nsec or less and repetition rate is 100 kc.)

Less than or equal to 300 psec of jitter when triggered with a 5-mv pulse of the same shape applied to the External Trigger Input or applied from the sampling unit to the Type 5T3.

Auto Recovery (with sine-wave input)

Less than or equal to 70 psec of jitter at 500 Mc when triggered with a 50-mv signal applied to the 50 Ω External Trigger Input or applied from the sampling unit to the Type 5T3.

Less than or equal to 300 psec of jitter at 500 Mc when triggered with a 5-mv signal applied to the 50 Ω External Trigger Input or applied from the sampling unit to the Type 5T3.

External UHF Sync

Less than or equal to 30 psec of jitter at 2 Gc with a 10-mv signal applied through the 50 Ω External Trigger Input, or 70 psec with a 5-mv signal applied (using the 20-nsec Time Position Range).

Less than or equal to 30 psec of jitter at 5 Gc with a 50-mv signal applied, or 70 psec with a 10-mv signal applied.

Equivalent-Time Display Jitter

Less than or equal to 30 psec on the 20-nsec Time Position Range; 40 psec on the 100 nsec Time Position Range, and 0.02% of the ramp duration on all other Time Position Ranges, when triggered internally with a 50-mv fast-rise signal applied from the sampling unit to the Type 5T3[1] (signal risetime less than 1 nsec).

Real-Time Display Jitter

Less than or equal to 1 μsec when triggered internally on the 100-mv, 100-kc calibrator waveform.

Less than or equal to 10 μsec when triggered through the 1 MΩ External Trigger Input from a 200-mv, 1-kc square-wave signal.

MECHANICAL CHARACTERISTICS

Construction

Aluminum-alloy chassis frame and anodized front panel. Epoxy laminate etched-wiring boards.

[1] See Internal Trigger Characteristics.

Dimensions

Height—7 inches; width—5⅞ inches; depth—14½ inches.

STANDARD ACCESSORIES

Information on accessories for use with this instrument is included at the rear of the mechanical parts list.

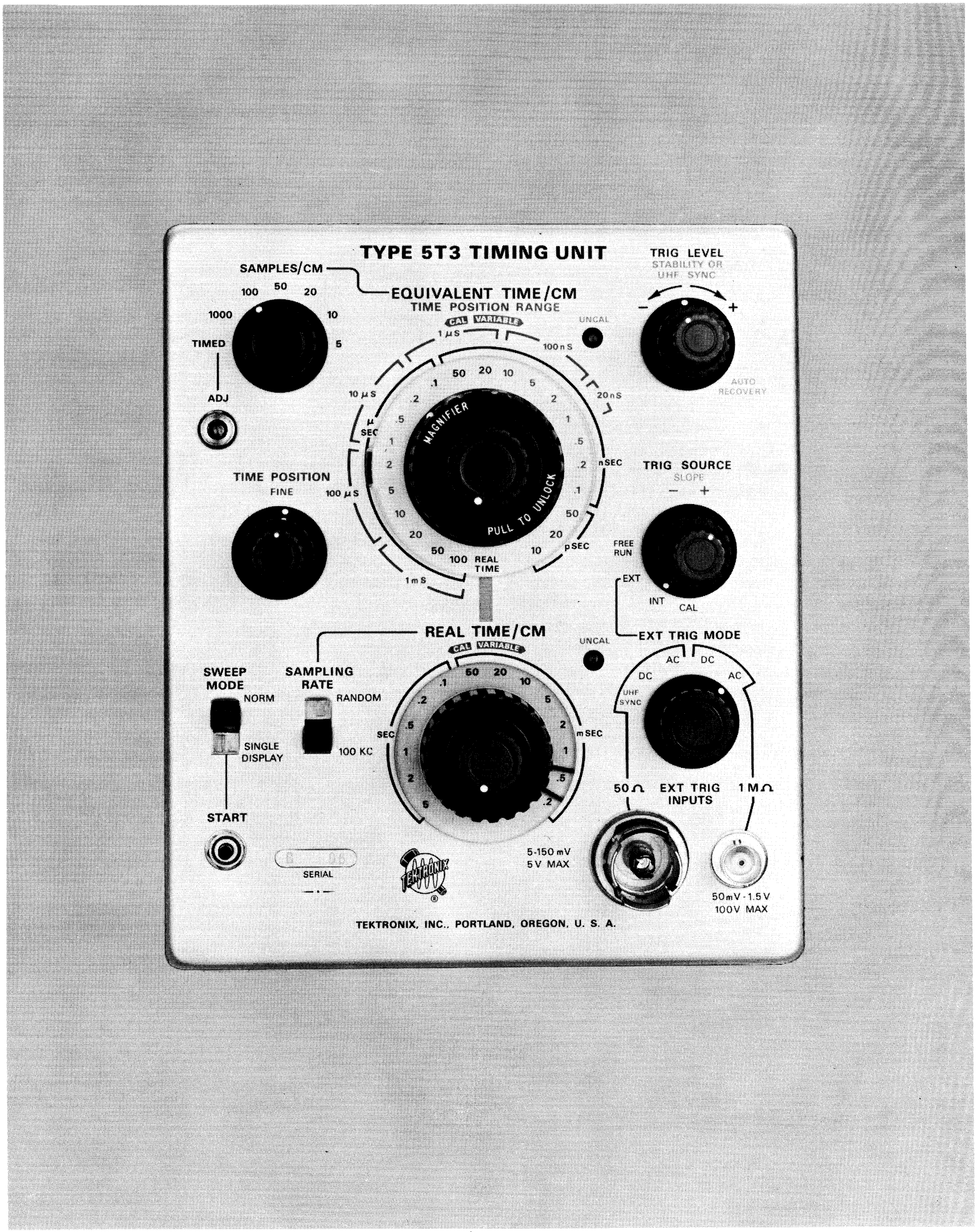


Fig. 2-1. Front-panel controls and connectors on the Type 5T3.

SECTION 2
OPERATING INSTRUCTIONS

General Information

To make full use of the Type 5T3, the operating modes that are possible and the operating control functions must be known. This section provides the basic information required for operation of the Type 5T3, including functions of the front-panel controls and connectors, triggering modes and use of the Type 5T3 for making time measurements.

Basic Definitions

Equivalent Time Sampling. In equivalent-time sampling, one triggering event is required for taking one sample and displaying one dot. A staircase generator and a real-time "fast" ramp are employed so each sample is taken a little later along the waveform than the preceding sample, with respect to the initiating triggering event. The amount of delay time difference between samples, combined with the number of samples displayed per cm, gives the equivalent sweep time per cm. Thus, an equivalent-time display with 100 samples per cm (or 1000 samples per display) required 1000 input triggering events, all alike, for a single display of the complete picture. If the input events are arriving at a low-repetition rate, the sweep speed of the display may be very slow, even though the equivalent sweep rate may be quite fast.

Real-Time Sampling. In real-time sampling, the time between samples is set by a sampling-rate oscillator, and the display rate as seen on the crt screen is the true time per cm. Two real-time sampling rates are provided in the Type 5T3—100 kc and random. The random rate can be used to break up a false display[1] whenever the uniform 100-kc sampling rate produces such a presentation. A good example of a false display in real-time mode is seen by displaying the oscilloscope Amplitude/Time Calibrator 10 μsec/cycle (100 kc) wavefrom and using a 100-kc sampling rate. The display is that of the beat frequency of the calibrator and the sampling-rate oscillators. This is demonstrated in the First-Time Operation procedure. Switching the sampling rate to RANDOM breaks up the false display and reveals the 100-kc envelope.

Installation

CAUTION

Always turn off the oscilloscope power before inserting or removing the plug-in unit.

To install the Type 5T3 in the timing plug-in unit of the oscilloscope, first pull outward on the locking latch at the bottom of the compartment until the latch is perpendicular to the oscilloscope front panel. Next insert the Type 5T3 in the plug-in compartment and push it in as far as possible. The plug-in unit front panel will be against the oscilloscope panel and the latch will be at about a 45° angle if the unit has been inserted far enough. Complete the operation by pressing the locking latch firmly against the front panel.

To remove the plug-in unit, first turn off the oscilloscope power, then pull the locking latch outward until it is perpendicular to the front panel. The unit may then be withdrawn from the oscilloscope.

NOTE

Whenever the Type 5T3 is transferred from one oscilloscope to another, the Delayed Pulse Bias adjustment of the oscilloscope must be checked, as described later in this section.

Cooling

The Type 5T3 receives adequate cooling from the fan in the indicator oscilloscope. The temperature of ambient air should not exceed 122° F.

FUNCTIONS OF CONTROLS AND CONNECTORS

All controls and connectors required for operation of the Type 5T3 are located on the front panel of the instrument (see Fig. 2-1).

The following tabulation briefly describes the functions of these controls and connectors. Further information, if required, is included under appropriate headings later in this section. The type of display desired and the nature of the triggering source will determine the settings of the front-panel controls.

Sweep and Triggering[1]

SWEEP MODE Switch	Selects either repetitive (NORM) or single-sweep mode of display presentation. START pushbutton arms sweep circuit so next trigger initiates single-sweep presentation.
START Push-button	Arms single-display circuit when button is pressed while SWEEP MODE switch is set at SINGLE DISPLAY. Next trigger starts single sweep. Subsequent sweeps are held off. Button must be released completely to rearm single-sweep circuit.
TRIG LEVEL Control	In triggered mode, selects triggering signal level that starts triggered circuit operation. Does not function in UHF Sync mode.

[1] See "Operating Information" later in this section.

[1] These controls function at all sweep rates.

STABILITY OR UHF SYNC Control: Adjusts bistable trigger circuit hysteresis levels for best sampling display; switches circuit to auto recovery mode. In auto recovery mode, adjusts trigger circuit to synchronize on high-frequency signal. In UHF Sync mode, adjusts UHF oscillator to synchronize on externally-applied UHF signal.

TRIG SOURCE Switch: Selects triggering signal from one of 3 sources—external, internal or calibrator. Also permits free-run operation of triggering circuit. Calibrator signal connected internally at CAL position provides 100-mv amplitude to trigger circuit whenever the calibrator is turned on.

SLOPE Switch: Selects either positive-going or negative-going slope of triggering signal to trigger sweep and sampling circuits.

EXT TRIG MODE Switch: Selects source of externally-applied triggering signal from either 50 Ω EXT TRIG INPUT or 1 MΩ EXT TRIG INPUT connector when TRIG SOURCE switch is set to EXT. Selects either ac or dc input coupling or UHF Sync mode. Always use dc-coupling for low-frequency signals.

EXT TRIG INPUT Connectors: Permit application of external signals for triggering sampling operation. Triggering signal must be time-related to vertical input signal. For equivalent-time mode, one trigger is required for each sample; for real-time mode, one trigger is required for each sweep. Be sure to attenuate signal if its amplitude (dc plus peak ac) exceeds maximum limit stated on front panel.

Equivalent Time[1]

EQUIVALENT TIME/CM MAGNIFIER Switch: Operates with TIME POSITION RANGE switch to select display equivalent sweep rate. Calibrated steps range from 100 µsec to 10 psec/cm. Also magnifies time display up to ×100 in 6 steps. White dot on MAGNIFIER knob always indicates display equivalent sweep rate. Calibrated only when Equivalent Time/Cm VARIABLE control is at CAL position. Actual sweep rate also depends on triggering signal repetition rate and on display dot density. See "First-Time Operation" and "Equivalent-Time Magnification" later in this section for use of magnification and time positioning. Switches instrument to Real Time sampling operation when set fully counterclockwise to REAL TIME position.

Equivalent Time/Cm VARIABLE Control: Varies equivalent sweep rate continuously between steps of EQUIVALENT TIME/CM switch. Extends fastest equivalent sweep rate (10 psec/cm) to about 4 psec/cm. Equivalent Time/Cm UNCAL neon is lit when VARIABLE control is not in CAL position (fully counterclockwise). Turn control clockwise to increase sweep rate from that indicated by EQUIVALENT TIME/CM switch. Always set VARIABLE control to CAL position for making time measurements from display.

TIME POSITION RANGE Switch: Indicates time range through which TIME POSITION controls can move start of display "time window". Range is read on blue TIME POSITION RANGE scale, as indicated by blue tab on clear skirt.

TIME POSITION and FINE Controls: Position start of crt "time window" through range indicated on TIME POSITION RANGE switch. Fully clockwise position of each control provides minimum sampling delay.

SAMPLES/CM Switch: Selects number of samples (dots) displayed per cm of horizontal displacement. Sampling rate is calibrated only when oscilloscope Horizontal Display switch is at Sweep Magnifier ×1 position. When sweep is magnified, dot density is divided by magnification factor. When external or manual horizontal deflection is used, dot density is not calibrated. In the TIMED position, sweep rate is linear, adjustable from 0.5 to 5 cm/sec with the timed ADJ control.

[1] **These controls function only for equivalent-time sweep rates (100 µs to 10 ps/cm).**

Real Time[1]

REAL TIME/CM Switch: Selects display sweep rate from 14 calibrated steps ranging from 5 sec to 0.2 msec/cm. Sweep rate is calibrated only when VARIABLE (Real Time/Cm) control is at CAL position.

Real Time/Cm VARIABLE Control: Varies sweep rate continuously between steps of REAL TIME/CM switch. Extends fastest real-time sweep rate (0.2 msec/cm) to about 80 µsec/cm. Real Time/Cm UNCAL neon is lit when VARIABLE control is not in CAL position (fully counterclockwise). Be sure control is at CAL position when making time measurements.

SAMPLING RATE Switch: Selects either a 100-kc (100 KC) or a basic 80-kc rate with 60 cps modulation (RANDOM) for real-time sampled displays. Use the random mode if "false" displays occur at multiples of 100 kc.

Oscilloscope Front Panel

Delayed Pulse Output Connector: Provides a —400-mv output pulse approximately 40 nsec after the oscilloscope delayed pulse generator has been triggered by the Type 5T3 trigger circuit. This al-

[1] **These controls function only for real-time sweep rates (5 sec to 0.2 msec/cm) with EQUIVALENT TIME/CM switch set to REAL TIME position.**

	lows the system to view the delayed pulse when the Type 5T3 is free running.
Vertical Signal Output Connectors	Provide vertical channel outputs of 200 mv per centimeter of display. Permit external triggering through 1 MΩ EXT TRIG INPUT from the oscilloscope display in real-time mode. (Not useable for triggering in equivalent-time mode.)

FIRST-TIME OPERATION

The following demonstration illustrates the basic operation of the Type 5T3. Additional information is given later in this section for displaying other signals and for triggering from other sources.

1. Be sure oscilloscope power is turned off before inserting plug-in units.

2. Install the Type 5T3 in the timing unit compartment of a Type 661 Oscilloscope.

3. Install a 4-Series sampling unit in the sampling unit compartment of the oscilloscope.

4. Turn on the oscilloscope and allow 2 or 3 minutes warm up.

5. Connect the oscilloscope Amplitude/Time Calibrator output signal to the vertical input of the sampling unit. Use a 50 Ω coaxial cable or a sampling probe and adapter.

6. Set controls as follows:

Type 5T3

EQUIVALENT TIME/CM	.2 μSEC (MAGNIFIER engaged with TIME POSITION RANGE)
Equivalent Time/Cm VARIABLE	CAL (counterclockwise at detent)
Equivalent Time SAMPLES/CM	20
TIME POSITION	Clockwise
Time Position FINE	Centered
SWEEP MODE	NORM
REAL TIME/CM	.5 mSEC
Real Time/Cm VARIABLE	CAL (counterclockwise at detent)
Real Time SAMPLING RATE	100 KC
TRIG LEVEL	Clockwise
STABILITY OR UHF SYNC	Clockwise (but not at AUTO RECOVERY detent)
TRIG SOURCE	FREE RUN
SLOPE	+
EXT TRIG MODE	1 MΩ AC

Type 661

Horizontal Display	Sweep Magnifier ×1
Position and Vernier	Centered
Amplitude/Time Calibrator	1000 mV Amplitude, 1 μSec/Cycle
Intensity	Set for normal trace brightness
Focus and Astigmatism	Centered

Sampling Unit

Millivolts/Cm	200
Millivolts/Cm Variable	Calibrated
Mode	Set to channel with input signal
Vertical Position	Centered
Display	Normal
DC Offset	Set to center the display
Smoothing	Set for unity loop gain (see "Loop Gain Adjustment" following)
Triggering	Set to channel with input signal, AC

7. Reset the TRIG SOURCE switch to CAL.

8. Center the STABILITY OR UHF SYNC control.

9. Turn the TRIG LEVEL control through its full range of rotation and note that there is only one portion of the range in which the sweep will run. Set the control near the clockwise end of that region.

10. Turn the STABILITY OR UHF SYNC control through its range of rotation. Note the range of adjustment that provides stable triggering. Set the control near the counterclockwise end of the range in which the sweep will run.

11. Adjust the oscilloscope Focus and Astigmatism controls for the smallest dots possible, with equal horizontal and vertical dimensions of the dots.

12. Reset the SAMPLES/CM switch to 100 and the EQUIVALENT TIME/CM switch to .5 μSEC. The TIME POSITION RANGE switch will turn with the EQUIVALENT TIME/CM switch, but will still be set in the 10 μS range, read on the blue TIME POSITION RANGE scale around the switch as indicated by the blue tab on the clear skirt.

13. Adjust the oscilloscope horizontal Position control so the trace starts at the left edge of the graticule.

14. Adjust the TIME POSITION and FINE controls so the display starts near the top of a positive-going slope on the waveform (see Fig. 2-2).

15. Pull out on the gray Equivalent Time/Cm MAGNIFIER knob and turn it clockwise 1 position. (The TIME POSITION RANGE switch should not turn.) The display is now magnified 2 times. The sweep rate of the magnified display is read at the white dot directly from the black EQUIVALENT TIME/CM scale. Note that the time magnification takes place following the starting point of the display.

16. Turn the MAGNIFIER knob clockwise one more position. The display is now magnified 5 times.

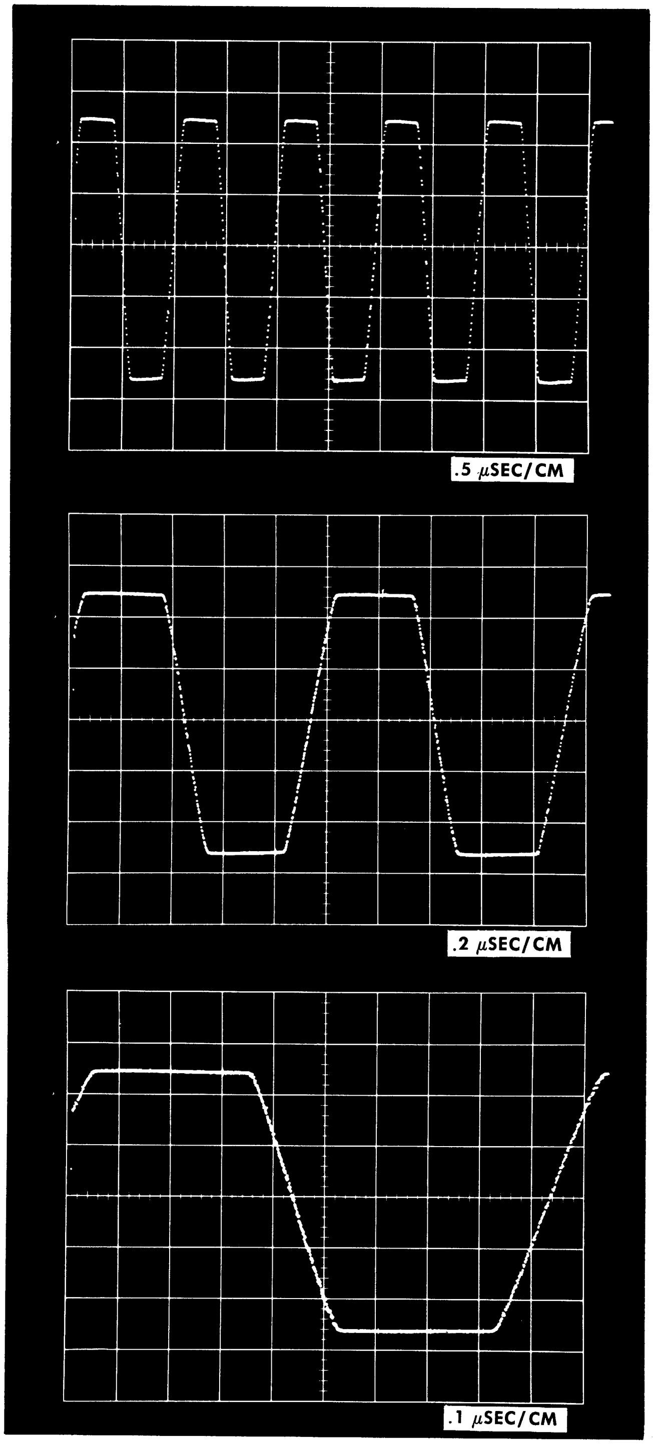


Fig. 2-2. Triggered calibrator waveform illustrating equivalent-time magnification. Time expansion occurs about the left edge of the display.

17. Turn the MAGNIFIER knob counterclockwise to the .5 μSEC position again. It will automatically engage with the TIME POSITION switch. (It is not necessary to pull on the MAGNIFIER knob except when disengaging it.)

18. At this equivalent sweep rate of 0.5 μsec/cm, the full width of the crt screen represents a time duration of 5 μsec. Set the TIME POSITION and FINE controls fully counterclockwise. Observe the display while slowly turning the TIME POSITION and FINE controls fully clockwise. The operation moves the left edge of the display "time window" through the amount of time indicated on the TIME POSITION RANGE scale (10 μsec). Thus the total range of observable time is 15 μsec — 10 μsec of the time positioning plus the 5 μsec of the screen diameter.

19. Turn the EQUIVALENT TIME/CM switch to 5 μSEC. (This will set the TIME POSITION RANGE switch to 100 μS.)

20. Pull out on the MAGNIFIER knob and turn it clockwise 3 positions. The display is the same as the previous display, though now it is a 5-μsec/cm sweep rate magnified 10 times.

21. Slowly turn the TIME POSITION and FINE controls from the fully counterclockwise position to the fully clockwise position. Note that the range of observable time is now 105 μsec — 100 μsec from the TIME POSITION RANGE and 5 μsec from the screen width.

22. Disconnect the Calibrator signal from the vertical input.

23. Set the EQUIVALENT TIME/CM and TIME POSITION RANGE switches to the REAL TIME position.

24. Set the sampling unit Millivolts/Cm switch to 20.

25. Set the Type 5T3 TRIG SOURCE switch to FREE RUN.

26. Connect a 1-kc square-wave signal to the sampling unit input. (Be sure the signal amplitude does not exceed the input limit of the sampling unit.)

27. Adjust the amplitude of the input signal to provide from 3 to 5 cm of deflection.

28. Connect a patch cord from the oscilloscope Vertical Signal Output (of the channel with the 1-kc signal) to the 1 MΩ EXT TRIG INPUT connector on the Type 5T3.

29. Set the TRIG SOURCE switch to EXT.

30. Center the STABILITY OR UHF SYNC control.

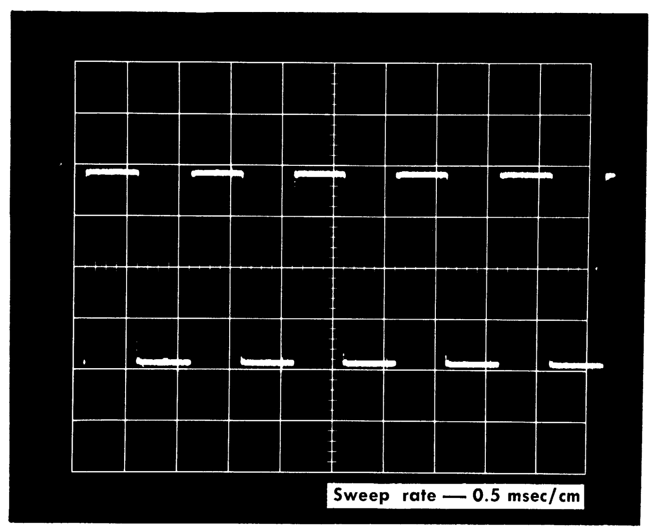


Fig. 2-3. Triggered 1-kc square-wave display in real-time mode. Each cm of display height provides 200 mv of signal at oscilloscope Vertical Signal Output.

31. Set the TRIG LEVEL control near the clockwise end of the range in which the trace will run.

32. Adjust the STABILITY OR UHF SYNC control for the best possible triggering. If all positions provide equally good triggering, set the control near the counterclockwise end of the range in which the sweep will run. Fig. 2-3 shows the triggered 1-kc display. Note that stable triggering on this 60- to 100-millivolt signal is provided conveniently by the Vertical Signal Output. 200 millivolts of output amplitude is provided for each centimeter of display height. Thus the 3- to 5-cm display provides 600 mv to 1 volt to the external trigger input.

33. Set the SLOPE switch to —.

34. This time, due to the polarity reversal, set the TRIG LEVEL near the counterclockwise end of the range in which the trace will run.

35. Adjust the STABILITY OR UHF SYNC control for the best possible triggering. If all positions provide equally good triggering, set the control near the counterclockwise end of the range in which the trace will run. The 1-kc waveform should now be triggered on the negative-going portion of the square-wave signal. Note that (in this frequency range) the STABILITY OR UHF SYNC control is set to approximately the same counterclockwise position for either + or — slope.

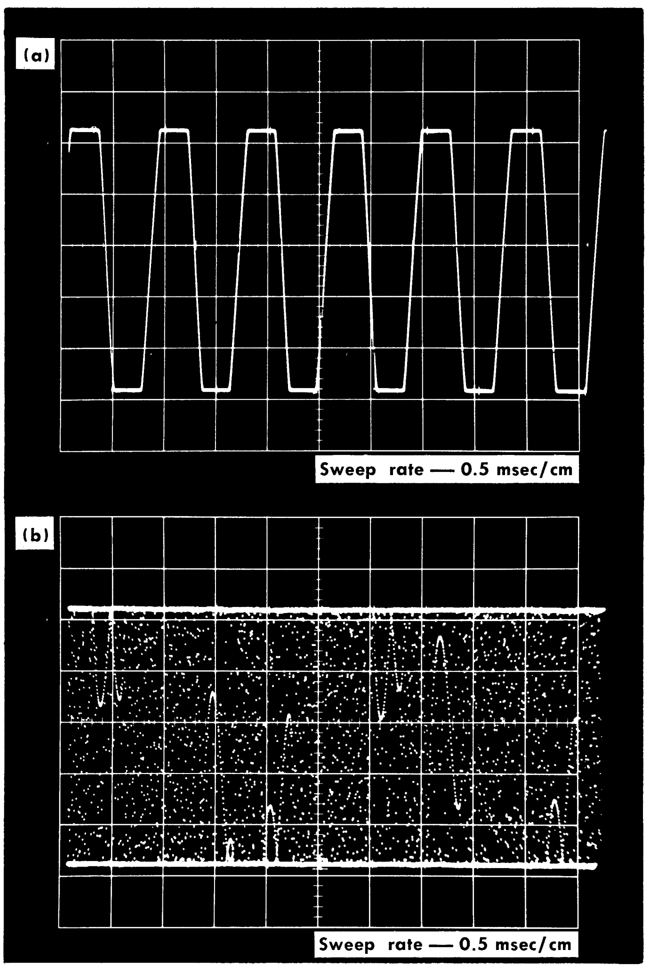


Fig. 2-4. Use of the SAMPLING RATE switch for breaking up false displays in real-time mode: (a) false display of 1 Mc calibrator signal with switch at 100 KC; (b) same signal with switch at RANDOM.

36. Disconnect the square-wave signal.

37. Set the sampling unit Millivolts/Cm switch to 200.

38. Set the Type 5T3 SLOPE switch to + and the REAL TIME/CM switch to 2 mSEC.

39. Connect the Amplitude/Time Calibrator signal to the sampling unit input again.

40. Set the cailbrator for a 10 μsec/cycle output frequency.

41. Trigger the display. This is a false display of the calibrator signal, resulting from the beat-frequency relationship between the 100-kc calibrator signal and the 100-kc sampling rate.

42. Set the REAL TIME/CM switch to 5 mSEC. The false display will remain.

43. Set the Real Time SAMPLING RATE switch to RANDOM. This will break up the waveform, revealing that the display was false (see Fig. 2-4).

44. This completes the brief demonstration of basic functions. Remove the input signal and the patch cord.

TRIGGERING NOTES

General Information

Selection of the triggering mode will depend primarily on the characteristics of the triggering signal. Several factors must be considered — frequency of the applied signal, amplitude and source impedance of the signal, and the type of sampling unit used for viewing the signal.

For triggered operation, the Type 5T3 requires an input triggering signal that is time-related to the vertical input signal to be displayed. Triggering signals may be obtained externally from a trigger probe connected to a test device, from a pulse generator that is pulsing the test device, or from the same signal that is applied to the vertical input. If the sampling unit used with the oscilloscope has internal trigger takeoff, internal triggering may be taken from the input signal through the sampling unit. If internal triggering is used, the amplitude of the input signal must be sufficient to provide at least 5 mv of signal to the Type 5T3. (For a Type 4S1 Sampling Unit, this requires a 40-mv input signal.) When connecting any input signal to either the Type 5T3 or to the sampling unit, be sure that the signal amplitude does not exceed the operating voltage limits of the input.

If a device under test is pulsed with the oscilloscope Delayed Pulse Output, the response signal from the test device will present a stable display on the oscilloscope crt when the Type 5T3 is set to free run.

Triggering Modes

The Type 5T3 Timing Unit is equipped with a tunnel-diode trigger sytem that possesses the wide bandwidth trig-

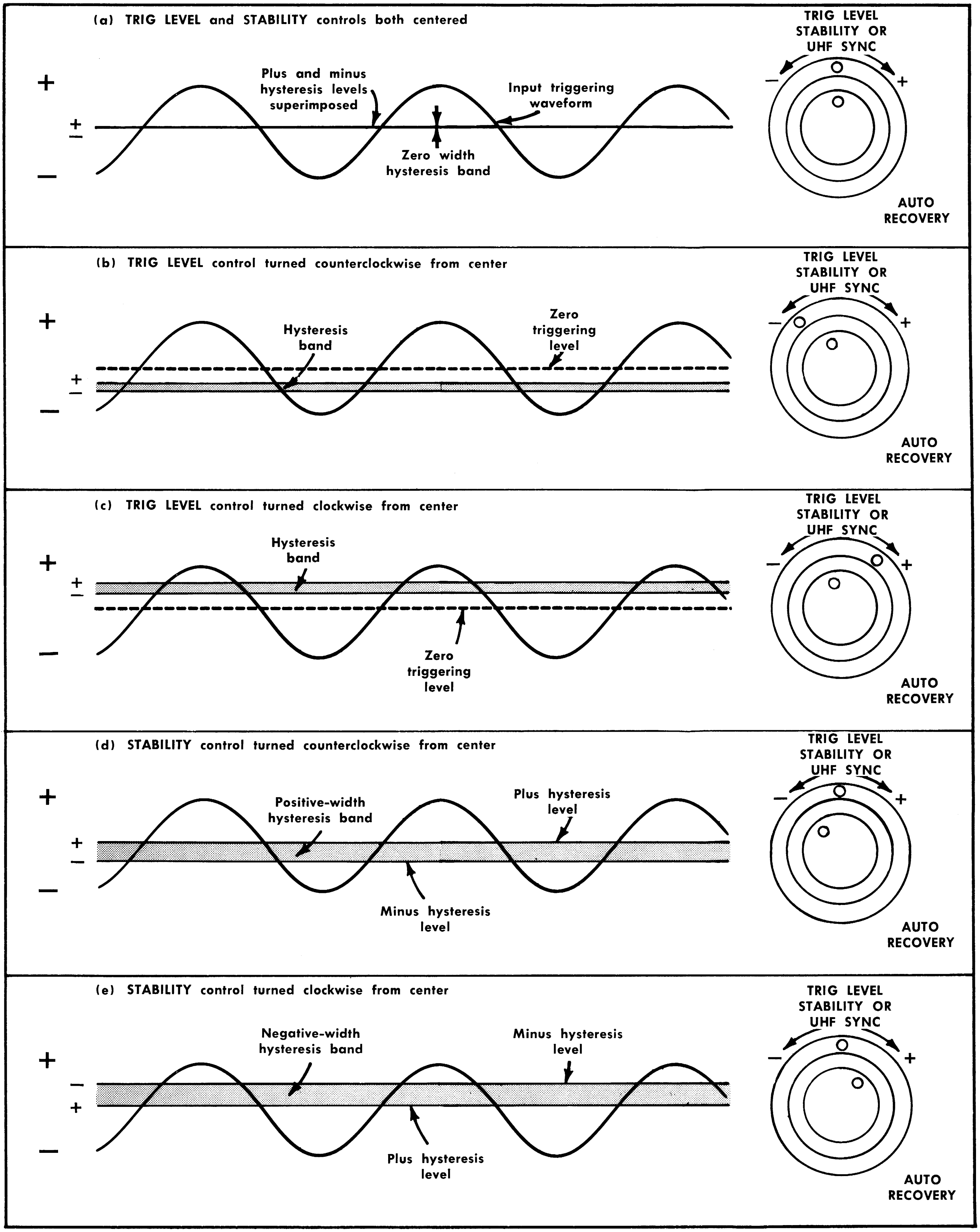


Fig. 2-5. Schmitt-type triggering functions of TRIG LEVEL and STABILITY OR UHF SYNC controls (with SLOPE switch at +).

gering capabilities of low-capacitance tunnel diodes, while retaining many of the characteristics of a standard Schmitt trigger circuit.[1] Three basic modes of triggering are possible with this system: Schmitt-type bistable triggering; auto recovery mode with triggering similar to that used in many contemporary sampling timing systems; and UHF Sync mode that eliminates the need for an external high-frequency countdown device.

SCHMITT-TYPE TRIGGERING

For triggering signals from dc to approximately 1 Gc, the bistable trigger circuit operated in the manner of a Schmitt trigger circuit recognizes both positive-going and negative-going excursions of the input triggering signal. The setting of the SLOPE switch determines which slope of the signal arms the trigger circuit and which slope causes the circuit to produce an output. The TRIG LEVEL control determines the triggering signal voltage level that causes a trigger recognition to be made, and the STABILITY OR UHF SYNC control determines the sensitivity of the trigger recognition circuit.

Fig. 2-5 illustrates the terms used in the following discussion of the triggering controls. The SLOPE switch is considered to be in the + position during the discussion, except where otherwise noted. Since the SLOPE switch causes inversion of the triggering signal prior to the time it is applied to the trigger circuit, the same considerations apply with regard to the — position of the SLOPE switch, except that the positive-going slope and the negative-going slope of the input triggering signal are exchanged.

Normally a triggering level of zero volts is obtained with a "straight up" position of the TRIG LEVEL control, and a zero width of the Schmitt hysteresis band[1] is obtained with a "straight up" position of the STABILITY OR UHF SYNC control. This condition is shown in Fig. 2-5a.

If the TRIG LEVEL control is turned counterclockwise (—) from the center position, the level of the hysteresis band is moved in the negative (—) direction on the waveform. If the control is moved in the clockwise (+) direction, the level of the hysteresis band is moved in a positive (+) direction on the waveform. Fig. 2-5b and c illustrate this.

If the STABILITY OR UHF SYNC control is turned counterclockwise from the center position, the minus (—) level of the band is moved in a negative direction with respect to the plus (+) hysteresis level (see Fig. 2-5d). The hysteresis band formed when the plus and minus hysteresis levels are in this relationship is called a "positive-width" hysteresis band in the following discussion.

If the STABILITY OR UHF SYNC control is turned clockwise from the center position, the minus (—) level is moved in a positive direction with respect to the plus (+) level (see Fig. 2-5e). The hysteresis band formed when the two hysteresis levels are related in this way is called a "negative-width" hyteresis band. In either of these cases, the farther the STABILITY OR UHF SYNC control is turned from the center position, the wider the hysteresis band becomes.

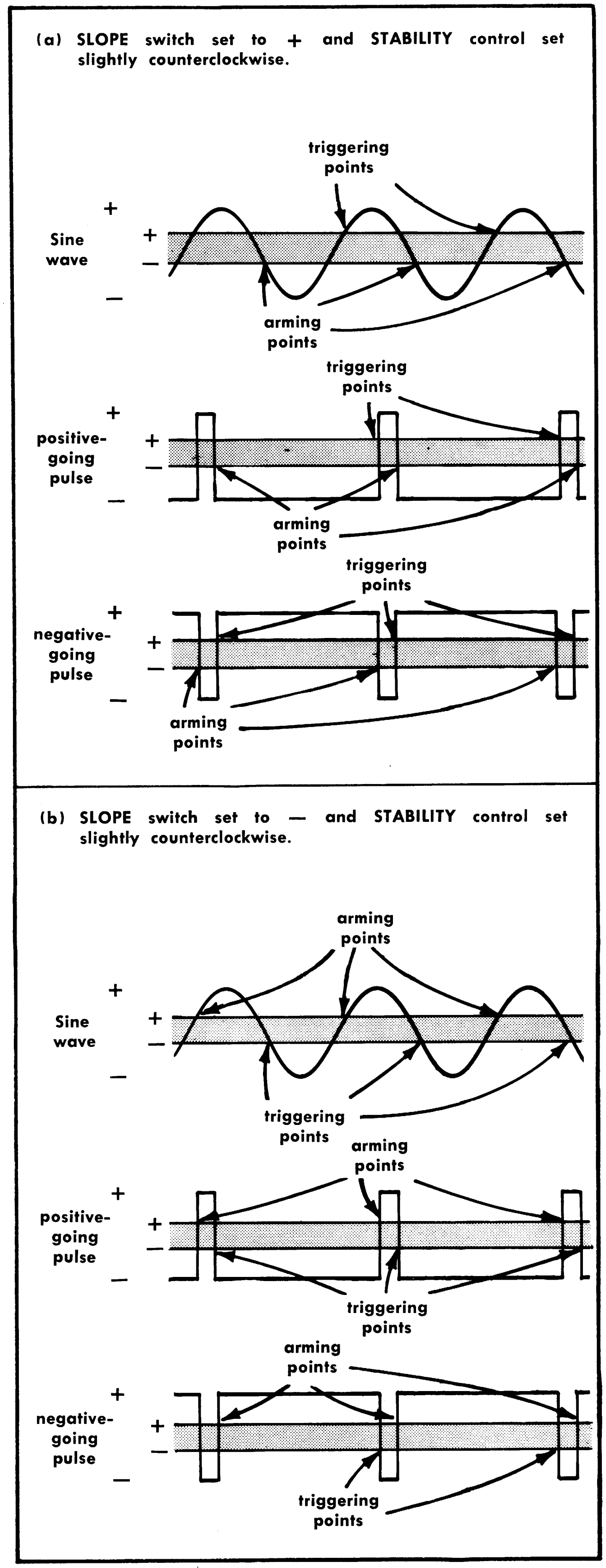


Fig. 2-6. Conditions required for trigger recognition with a positive-width hysteresis band.

[1] Pulse and Digital Circuits, J. Millman and H. Taub, McGraw-Hill 1956, pp 164-172.

Positive-Width Schmitt Triggering. Normal Schmitt-type operation of the bistable trigger circuit is accomplished with the STABILITY OR UHF SYNC control set counterclockwise from center, producing a positive-width hysteresis band. In this mode, the following important conditions must exist:

1. For a trigger recognition to take place on the positive-going slope of the input triggering waveform, the SLOPE switch must be set to the + position and the triggering signal excursion must pass first to a voltage that is negative with respect to the minus hysteresis level, then to a voltage that is positive with respect to the plus hysteresis level. Fig. 2-6a illustrates this operation. Note that for a sine wave and for a positive-going pluse, the circuit is armed by the negative-going portion of the preceding cycle of the waveform, but that for a negative-going pulse the negative-going portion of the same cycle arms the trigger circuit. When triggering on a negative-going pulse in this manner, the minimum pulse duration at the 50% level is about 2 nsec.

2. For a trigger recognition to take place on the negative-going slope of the input triggering waveform, the SLOPE switch must be set to the — position and the triggering signal excursion must pass first to a voltage that is positive with respect to the plus hysteresis level, then to a voltage that is negative with respect to the minus hysteresis level. Fig. 2-6b illustrates this operation. In this case, for either a sine wave or for a positive-going pulse, the trigger is armed by the positive-going portion of the **same** cycle of the waveform, and for a negative-going pulse the trigger is armed on the positive-going portion of the preceding cycle of the waveform. The minimum duration of 2 nsec applies to the positive-going pulse in this case.

No trigger recognition will be made if the positive-width hysteresis band is too wide or if the band is displaced by the TRIG LEVEL setting so the signal level does not coincide with the hysteresis band at all, or coincides with only a portion of it. Fig. 2-7 illustrates these conditions.

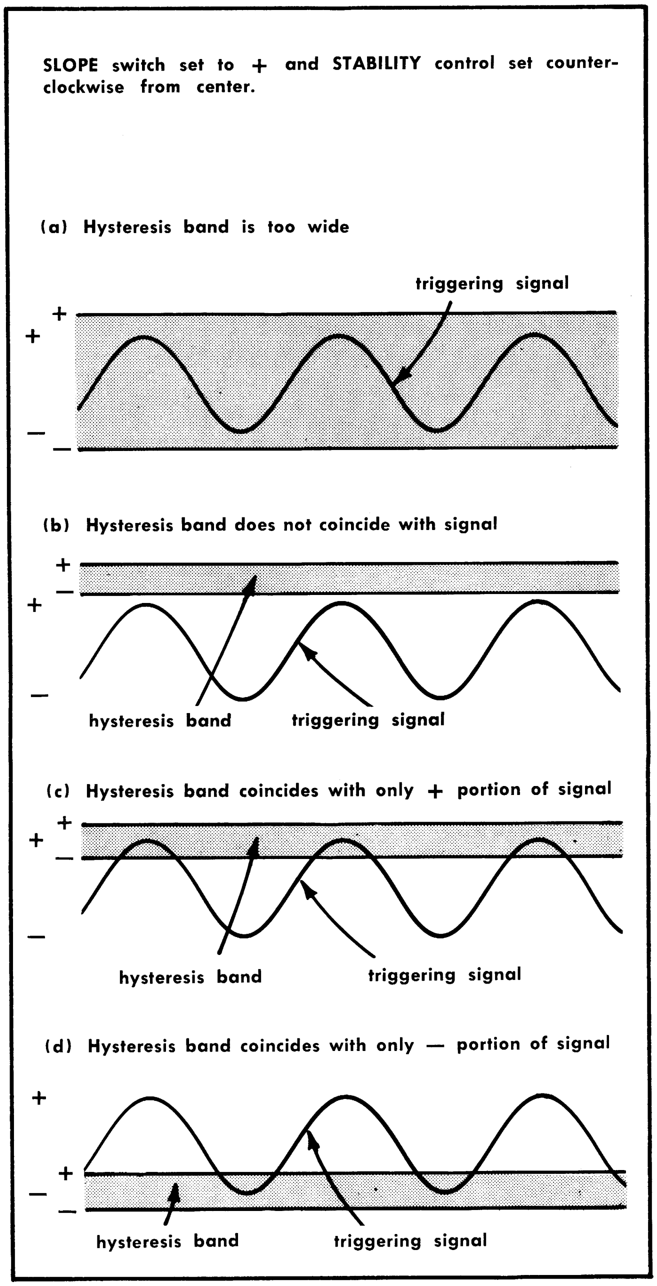


Fig. 2-7. Conditions under which no trigger recognition will occur, with a positive-width hysteresis band.

Negative-Width Triggering. Normally, whenever the trigger input voltage lies in the negative-width hysteresis band, the trigger circuit tends to free run (see Fig. 2-8a and b). If the STABILITY OR UHF SYNC control is turned fully clockwise, the free-running band is quite wide. If the control is turned toward the center position, the free-running band becomes narrower, giving a smaller free-run range of adjustment for the TRIG LEVEL control. When the STABILITY OR UHF SYNC control is set counterclockwise from center (positive-width band), free-run conditions are never present and an input triggering signal is required to make the circuit operate.

Under certain conditions, negative-width triggering is possible with the bistable trigger circuit in the Type 5T3. This is accomplished by setting the STABILITY OR UHF SYNC control clockwise from center and adjusting the TRIG LEVEL control so the triggering signal passes through only one level of the hysteresis band (see Fig. 2-9). The signal must pass through the plus hysteresis level if the SLOPE switch is set to +, and through the minus hysteresis level if the switch is set to —. Note that the same conditions exist as were required for positive-width triggering: the positive-going triggering signal passes to a voltage that is positive with respect to the plus hysteresis level and to a voltage that is negative with respect to the minus hysteresis level. In this case, both conditions exist at the same time in the negative-width band, and the signal does not need to pass through the minus level. For a — position of the SLOPE switch, similar conditions exist when a negative-going pulse crosses only the minus hysteresis level. This type of triggering can be used on very narrow pulses, but will cause the circuit to free run if the signal voltage stays in the negative-width band for very long (see Fig. 2-8c).

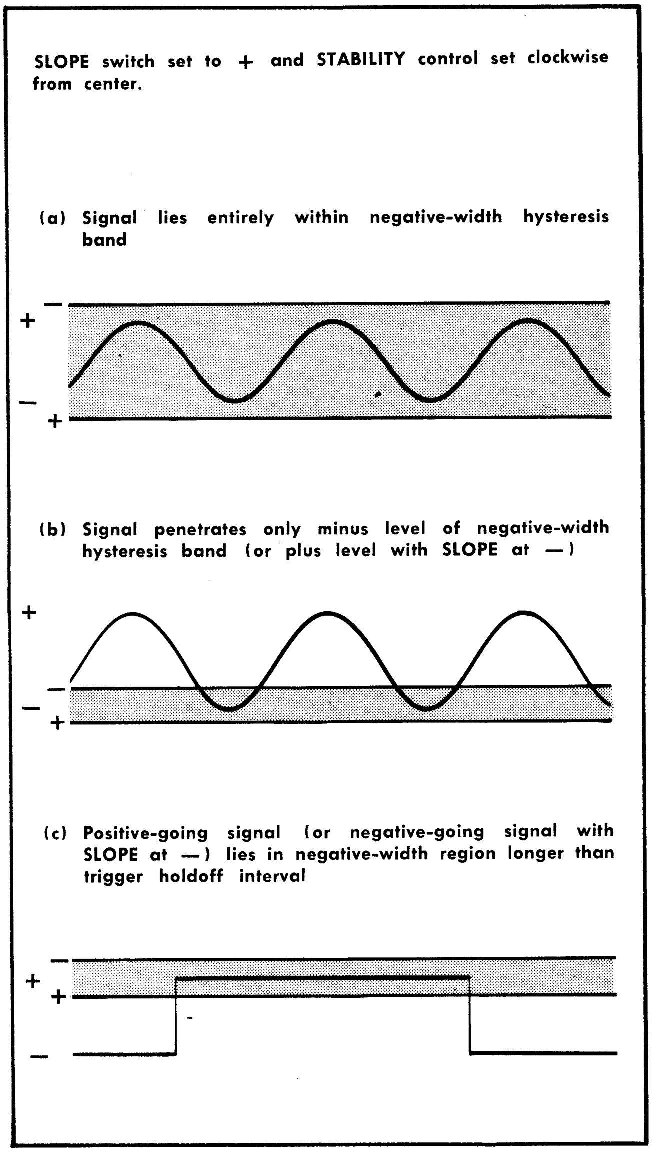


Fig. 2-8. Conditions under which the trigger will free run, with negative-width hysteresis band.

AUTO RECOVERY MODE

In auto recovery mode, the trigger circuit operation is modified to permit the circuit to be triggered by a pulse input signal or to synchronize on a high-frequency input signal. With the STABILITY OR UHF SYNC control set fully clockwise to the AUTO RECOVERY detent position, the Schmitt-type trigger action is essentially disabled and the circuit is set for a wide negative-width hysteresis band.

For narrow pulse input signals ($<$ 1 μsec width and $<$ 1% duty factor) from dc to 10 Mc, the circuit is triggerable on the negative-width hysteresis band as described previously under "Schmitt-Type Triggering". For signals from 10 Mc to 500 Mc, the circuit synchronizes on the input signal to trigger the Type 5T3 at a lower frequency. Internal, external and calibrator triggering sources may be used in this mode, with triggering on the leading edge in either + or — slope.

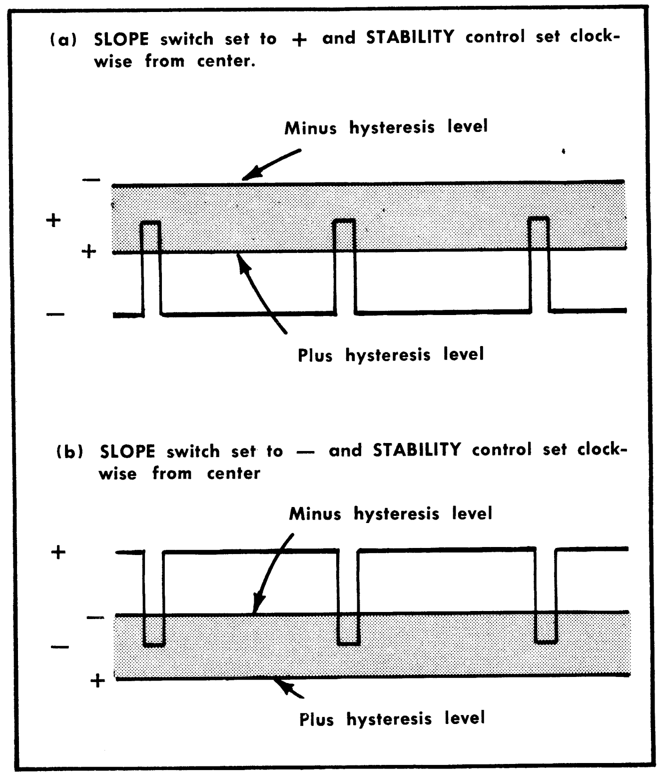


Fig. 2-9. Triggering on narrow pulses with a negative-width hysteresis band.

UHF SYNC MODE

In the UHF Sync mode, only the 50 Ω EXT TRIG INPUT is used. A direct high-quality signal path is made to a special high-frequency tunnel-diode countdown circuit, with no intervening isolation transistor stages to limit the bandpass. The UHF Sync circuit is ac-coupled, with a low-frequency 30%-down point of approximately 1 Gc (usable down to 500 Mc or lower). The frequency of the UHF synchronizing circuit is controlled by the STABILITY OR UHF SYNC control.

Special Considerations for Real-Time Triggering

In general, the operation of the triggering controls is the same for real-time sampling as it is for equivalent-time sampling. A more counterclockwise setting of the STABILITY OR UHF SYNC control is usually required, however, for triggering on small signals.

When samples are taken by the sampling unit, there may sometimes be a tendency for the trigger circuit to operate, due to the energy radiated by the sampling circuits.

For triggering on small signals in real-time mode, the oscilloscope Vertical Signal Outputs provide a very convenient triggering source. For each centimeter of deflection on the crt, 200 mv of signal amplitude is provided at the output jack. By setting the TRIG SOURCE switch to EXT and the EXT TRIG MODE switch to 1 MΩ AC or DC, a patch cord connected between the Vertical Signal Ouput jack of the channel with the vertical signal and the 1 MΩ EXT TRIG INPUT will provide very stable triggering. This method of triggering was demonstrated in the First-Time Operation procedure. The fact that the sampling channels are continually taking samples when operating in real-time mode permits this triggering source to be available at the Vertical Signal Output connectors. This source is not available in equivalent-time mode, however, since a triggering event is required **before** the sampling channel can operate.

Triggering Controls

Operation of the triggering controls depends on the particular triggering mode being used and the type of input signal applied. Table 2-1 outlines the use of the triggering controls.

Triggering Sources

The TRIG SOURCE switch selects the input triggering signal from one of the EXT TRIG INPUTS, from the sampling unit trigger takeoff circuit, or from the oscilloscope calibrator. The frequency and amplitude characteristics of these sources are summarized in Table 2-2.

Internal Sources. The oscilloscope calibrator and the sampling unit trigger takeoff circuits are connected internally to the Type 5T3 trigger circuit. With the TRIG SOURCE switch set to INT (if the sampling unit has a trigger takeoff circuit), a portion of the vertical input signal is taken off for triggering. The amplitude of the input signal must be large enough so the portion taken off is 5 mv or more. For example, the input to a Type 4S1 Sampling Unit must be 40 mv to provide the 5 mv to the Type 5T3, since the amplitude of the takeoff signal is $\frac{1}{8}$th the amplitude of the input signal.

When the TRIG SOURCE switch is set to CAL, a 100-mv calibrator signal of the selected frequency is sent to the Type 5T3. The amplitude of this internally-connected signal is 100 mv, regardless of the amplitude at the calibrator output connector. This source is convenient for triggering the display when viewing the calibrator waveform (especially if the signal amplitude is small) and avoids the necessity of an external trigger connection when using a sampling unit without trigger takeoff.

TABLE 2-1

Use of Triggering Controls

Triggering	Signal	SLOPE	TRIG SOURCE	EXT TRIG MODE	STABILITY OR UHF SYNC	TRIG LEVEL
Schmitt-type	Calibrator (Type 661)	+ or —	CAL or INT[1]	Non-operating	Adjust for moderate sensitivity (counterclockwise from center)	Adjust to position triggering level at desired level on input signal
	Sine wave	+ or —	INT[1]	Non-operating		
			EXT	50 ΩAC or DC 1 MΩAC or DC		
	+Pulse	+	INT[1]	Non-operating		
			EXT	50 ΩAC or DC 1 MΩAC or DC		
	—Pulse	—	INT[1]	Non-operating		
			EXT	50 ΩAC or DC 1 MΩAC or DC		
Auto Recovery Mode	Calibrator (Type 661)	+ or —	CAL or INT[1]	Non-operating	AUTO RECOVERY position	Adjust to synchronize circuit with input signal
	Sine wave	+ or —	INT[1]	Non-operating		
			EXT	50 ΩAC or DC 1 MΩAC or DC		
	+Pulse	+	INT[1]	Non-operating		
			EXT	50 ΩAC or DC 1 MΩAC or DC		
	—Pulse	—	INT[1]	Non-operating		
			EXT	50 ΩAC or DC 1 MΩAC or DC		
UHF Sync Mode	Sine wave	Non-operating	EXT	50 Ω UHF SYNC	Adjust to synchronize circuit with input signal	Non-operating

[1] **Operates only with sampling unit that has trigger takeoff.**

TABLE 2-2
Trigger Selection Guide

Source & Coupling	Frequency	Suggested Connections	Amplitude
EXT 1 MΩ AC		BNC/Banana Patch Cord[2]	0.3-8 cm of display
		~50 Ω Coax Cable[3 4] (BNC)	
		P6028 1X Probe (BNC)	
EXT 1 MΩ DC	to DC	P6006 10X Probe (BNC)	
		P6007 100X Probe (BNC)	
CAL (AC)		(Internal)	
EXT 50 Ω AC		50 Ω Coax Cable[3 5] (GR)	
		P6034 10X Probe[6]	
EXT 50 Ω DC	to DC	P6035 100X Probe[6]	
		50 Ω Coax/Adapter/CT-3	
INT AC[1]		(at Type 4S1 Input:)	(at Signal Source:)
		50 Ω Coax Cable[3] (GR)	
INT DC[1]	to DC	P6034 10X Probe	
		P6035 100X Probe	
UHF SYNC (AC)		50 Ω Coax Cable[3] from GR T-connector[7]	
			1 mv, 10 mv, 100 mv, 1 v, 10 v, 100 v
Sweep Modes			
Real Time	to 5 sec/cm		
Equiv. Time	to 10 psec/cm		
Triggering Modes			
Schmitt-type	to DC		
Auto Recovery	pulses		
UHF Sync			
	100 cps, 1 kc, 10 kc, 100 kc, 1 Mc, 10 Mc, 100 Mc, 1 Gc, 10 Gc		

Tektronix Part Numbers of Suggested Connecting Devices:

CT-3 Current Takeoff	017-0060-00
VP-1 Voltage Pickoff	017-0073-00
2-nsec Coax Cable (GR)	017-0505-00
5-nsec Coax Cable (GR)	017-0502-00
10-nsec Coax Cable (GR)	017-0501-00
~ 50 Ω Coax Cable (BNC)	012-0057-00
BNC/Banana Patch Cord	012-0090-00
P6034 10X Probe (GR)	010-0110-00
P6035 100X Probe (GR)	010-0111-00
P6028 1X Probe (BNC)	010-0074-00
P6006 10X Probe (BNC)	010-0127-00
P6007 100X Probe (BNC)	010-0150-00

[1] Applicable only to sampling units with trigger takeoff.

[2] Triggering signal taken from oscilloscope Vertical Signal Output, in real-time operation only.

[3] With no attenuation. External attenuators may be used for larger signals.

[4] Connected directly or from a CT-3.

[5] Use impedance-matching device if source impedance is other than 50 Ω.

[6] Signal may be obtained from 50 Ω system with VP-1.

[7] Reduce reflections with T-attenuators.

External Sources. When a sampling unit without signal delay or tigger takeoff is used, an external triggering signal must be supplied to the Type 5T3. The frequency and source impedance of the input triggering signal determines whether the 50 Ω or the 1 MΩ EXT TRIG INPUT should be used. In general, the 1 MΩ Input is used in conjunction with real-time sampling displays and the 50 Ω Input is used with equivalent-time displays. See Table 2-2 for the relationships between sweep mode, triggering mode and trigger input selection.

In order to view the signal that triggers the Type 5T3, triggering must take place at least 35 nsec before the input signal reaches the sampling gate of the vertical unit. This time interval may be provided either by pretriggering the Type 5T3 before generating the pulse to be applied to the vertical input, or by taking the triggering signal from the input signal, then delaying the signal in its path to the sampling gate.

When the circuit under test can be operated by an input pulse, pretrigger the Type 5T3 from the pulse generator. The signal delay between the pretrigger and the output pulse should be about 35 nsec plus about one-half the reading on the blue TIME POSITION RANGE scale, minus the delay time of the test device. This positions the response signal pulse on the crt screen when the TIME POSITION control is centered, and allows the display to be examined in detail.

For circuits that cannot be tested by external pulsing, a trigger signal may be picked off and the signal may then be delayed with coaxial cables to produce the trigger-to-sample delay required. If any time delay is added to the path of the trigger signal, an equal amount of delay must be added to the input signal path. Keep in mind that any cable used in the vertical input signal path will degrade the high-frequency portions of the signal. It is advisable to keep signal delay at a minimum since the high-frequency attenuation increases as the square of the cable length increase.

Several types of connecting devices are available for connecting the external triggering signal to the Type 5T3. These include coaxial cables, attenuator probes, voltage pickoff devices and transformer-matched Ts. Some of these are suggested in Table 2-2 for the various trigger coupling modes.

For connecting the oscilloscope Vertical Signal Output to the 1 MΩ connector, as described previously, an unshielded patch cord is sufficient. This triggering source is available only for triggering in real-time mode.

When the oscilloscope delayed pulse is used to pulse a test device, the trigger circuit is in effect its own trigger source. Usually the trigger circuit is operated in free-run mode for viewing the delayed pulse signal, but if a particular repetition rate of the delayed pulse is desired, the Type 5T3 can be externally triggered at the desired rate.

Triggering Signal Coupling

Either ac- or dc-coupling is provided for the 1 MΩ and 50 Ω EXTERNAL TRIGGER INPUTS. Only ac-coupling is provided for the UHF Sync and internal calibrator sources. The internal triggering signal coupling is dc in the Type 5T3, but may be either ac- or dc-coupled in the sampling unit.

In general, ac-coupling of the input triggering signal is preferred, to avoid offsetting the triggering level. However, none of these couplings will tolerate a very large dc offset. If the triggering signal has a large dc component with the ac signal, avoid trouble by using a coupling capacitor at the input to the Type 5T3. Be sure to take this capacitance into consideration when determining the low-frequency cutoff.

Ac-coupling cannot be used very far below the lower-frequency 30%-down point of the particular coupling. For the following three sources, use dc-coupling below the indicated 30%-down frequencies:

1 MΩ AC External Input.................160 cps
INT (from Type 4S1)....................350 kc
50 Ω AC External Input..................500 kc

The 30%-down frequency, and thus the lower usable frequency, of the 50 Ω UHF Sync External Input is about 1 Gc. The internal calibrator ac-coupling has a low-frequency cutoff point well below the lowest frequency available (100 kc).

Triggering Difficulties

The incorrect use of triggering controls and incorrect coupling to the signal source are the most common causes of apparent triggering problems. Sometimes, however, the cause of difficulty may arise from the misadjustment of a calibration control or the malfunction of a circuit component.

Always check switch and control settings and triggering signal input connections if an apparent problem occurs. Table 2-3 provides information that may aid in alleviating certain possible triggering difficulties.

TABLE 2-3

Possible Sources of Triggering Problems

Symptoms	Conditions	Suggestions
No triggering	INT triggering	Applies only to sampling units with trigger takeoff. Use external triggering for other units. Check sampling unit Triggering switch for correct channel.
	Low-frequency triggering signal	Dc-coupling of triggering signal is required below low-frequency cutoff of ac-coupling.[1]
	Vertical Signal Output Source	Can be used only for triggering when using real-time sampling. Check that correct output channel is connected to 1 MΩ EXT TRIG INPUT.
	Extended from oscilloscope	Triggering signal cable is required from Type 5T3 to oscilloscope for internal triggering.
Free-running sweep	General	Check TRIG SOURCE switch setting. Check STABILITY OR UHF SYNC control setting. Check OUTPUT TD BIAS calibration.
	Equivalent time only	Check COMP LEVEL (Registration) calibration.

Ⓐ

TABLE 2-3 *(Cont'd)*
Possible Sources of Triggering Problems

Symptoms	Conditions	Suggestions
No sweep	General	Check that SWEEP MODE switch is at NORM. Check that TRIG SOURCE switch is set correctly. Check that STABILITY OR UHF SYNC control is set correctly. Check OUTPUT TD BIAS calibration.
	Equivalent Time only	Check COMP LEVEL (Registration) calibration.
	Extended from oscilloscope	Sampling-pulse cable is required between Type 5T3 and oscilloscope.
Display Jitter	General	Check that ac- or dc-coupling is correct.[1] Use larger triggering signal. Check trigger circuit calibration.
	Low-amplitude real-time signal	Use oscilloscope Vertical Signal Output of the corresponding channel.
	Delayed Pulse signal	Check that oscilloscope calibrator is turned off.

[1] See "Triggering Signal Coupling".

OPERATING INFORMATION

Loop Gain Adjustment

To present a correct display on the crt screen, the dot transient response of the sampling unit must be correct. That is, the loop gain of the unit must be set so each displayed dot accurately represents the signal level at the time the sample was taken. The Smoothing control of the sampling unit adjusts this response. For particularly noisy signals, it may sometimes be desirable to operate the system with decreased loop gain. If this is done, however, the transient response will be decreased unless a high dot density is used.

Sampling-Probe Units. For sampling units with direct-sampling probes, loop gain depends partially on the source impedance of the signal being observed. One convenient method of setting the Smoothing control is as follows:

1. With a display on the crt (nearly any display will do), set the Smoothing control for a slight amount of smoothing (less than unity gain). A convenient signal to use is the 0.1 μsec/cycle calibrator waveform, with the TRIG SOURCE switch set to INT.

2. Adjust the Type 5T3 STABILITY OR UHF SYNC and TRIG LEVEL controls for a double-triggered display (see Fig. 2-10). If a double-triggered display (two traces) is not possible, obtain a multiple-triggered display.

3. Adjust the Smoothing control so each of the double-triggered waveforms has the normal triggered waveshape and amplitude. This is the point of unity gain.

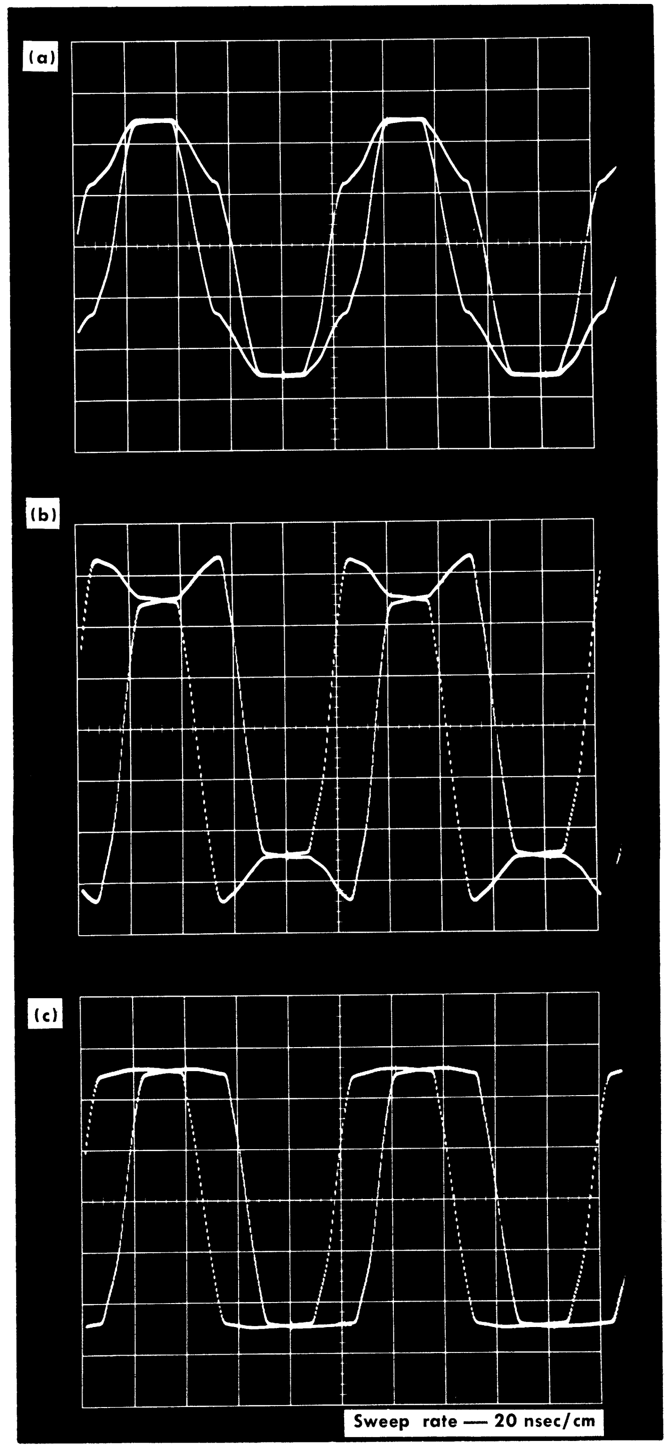


Fig. 2-10. Double-triggered display of .1 μSec/Cycle calibrator waveform for setting Smoothing (loop gain) control: (a) less than unity loop gain; (b) greater than unity; (c) adjusted to the point of unity gain.

If loop gain is greater than unity, the display will be excessively noisy. If loop gain is less than unity, the display amplitude will decrease for sine waves, and the rising portion of fast pulses will be rolled off when using a low dot density.

50 Ω Sampling Units. Normally the loop gain of a 50 Ω system is set for correct response with the Smoothing control set to Normal. However, this setting may be incorrect by several percent, depending on the Timing Unit used. To check for correct response, use the procedure given for sampling-probe units.

If the loop gain is found to be greater than 1, adjust the Smoothing control for correct dot transient response. If loop gain is less than 1, the sampling bridge adjustments must be recalibrated. See the calibration section of the sampling unit instruction manual for the recalibration procedure.

NOTE

For use with the Type 5T3, you may wish to deliberately set the gain to slightly greater than unity. It can then be reduced with the sampling unit Smoothing control for best response.

"False" Displays

As demonstrated in the First-Time Operation procedure, it is possible to obtain a false sampling display when the sweep rate is set so the time between samples is close to an integral multiple of the period of the waveform displayed.

The demonstration was of a real-time mode false display, but a similar display may be obtained in equivalent-time mode. In either case, the false display appears as a waveform of much lower frequency than the input signal and is caused by sampling at such a slow rate that the sampling occurs on widely-spaced portions of the signal. Each sample represents the correct amplitude at the instant of sampling, but there are not enough samples to trace out the correct waveform.

In real-time mode, a false display is eliminated by using a random sampling rate. In equivalent-time mode, the false display can be eliminated by increasing the dot density of the display with the SAMPLES/CM switch. In either mode, if the display is found to be a false one, the sweep speed may be increased to provide a correct presentation of the input signal.

Selecting Dot Density

In equivalent-time mode, selection of the dot density that will produce the best display depends on both the equivalent sweep rate and the repetition rate of the input signal. If the input repetition rate is low, the trace progresses very slowly across the screen when the dot density is high. In general, the best setting of the SAMPLES/CM switch is the one that produces the highest dot density possible with a reasonable display repetition rate.

If smoothing is used for reducing noise on the displayed waveform, the dot density must be sufficiently high to allow the sampling circuits to follow the input signal closely. If the shape of the displayed waveform changes when the SAMPLES/CM switch is changed to a higher setting, the display is being modified by the combination of smoothing and low dot density.

Sweep Calibration Check

Since the Type 5T3 depends on the indicator oscilloscope for its input dc voltages, it may require slight readjustment when it is transferred from one oscilloscope to another. Whenever this is done, be sure to check the real-time and equivalent-time sweep calibration as described in Section 5.

Magnification

Equivalent-Time Mode. A ×100 direct-reading time magnifier is built into the EQUIVALENT TIME/CM switch. Use of the magnifier allows the operator to widen the "time window" by a factor of 10 or 100 on most equivalent sweep rates, and to increase the display sweep rate up to 100 times from the fastest unmagnified rate. Dot spacing in the display is not increased by the time magnification. This means that the number of samples taken per unit equivalent time is increased by the magnification factor. When the display is magnified in this manner, expansion occurs about the left edge of the screen, regardless of the TIME POSITION control setting.

Fig. 2-11 shows the time magnifier controls on the EQUIVALENT TIME/CM switch. Set the controls as follows for magnification:

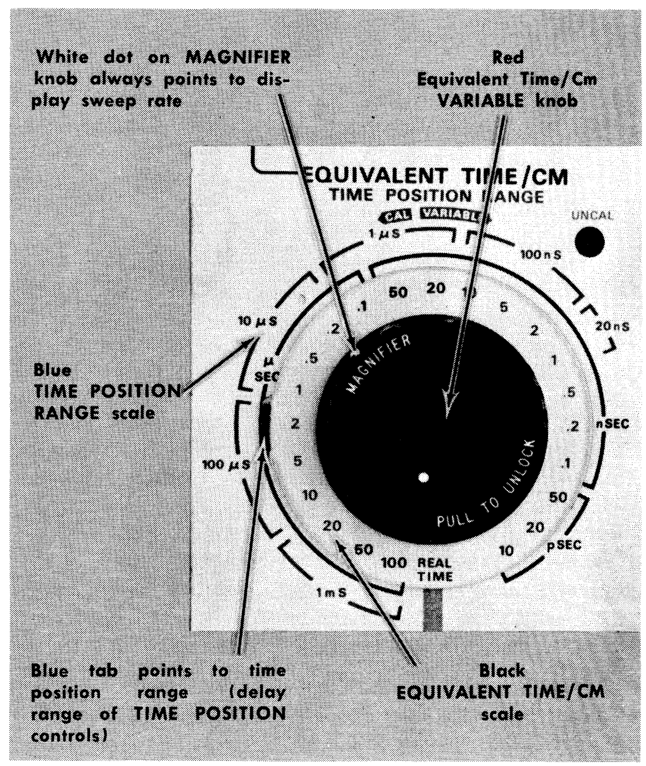


Fig. 2-11. Use of the Equivalent Time MAGNIFIER for expanding the display. As shown, the unit is set for ×10 magnification with a display sweep rate of 0.2 µsec/cm and a crt "time window" positioning range of 100 µsec.

1. With the EQUIVALENT TIME/CM MAGNIFIER knob and the TIME POSITION RANGE switch engaged, set the sweep rate to the desired unmagnified display. (White dot and blue tab should be together.)

2. Position the display with the TIME POSITION and FINE controls so the portion of interest is near the left edge of the screen.

3. Pull out the gray MAGNIFIER knob and turn it clockwise for the desired amount of magnification. Six powers of magnification are available — 2, 5, 10, 20, 50 and 100. If the MAGNIFIER knob is turned clockwise farther than the ×100 position, it will pull the TIME POSITION RANGE switch with it.

4. Reposition the FINE control slightly, if necessary.

Up to 2½ times more time magnification (uncalibrated) with no decrease in dot density can be obtained with the Equivalent Time/Cm VARIABLE control. Display expansion with the VARIABLE control also takes place about the left edge of the screen.

In addition to the time magnification provided by the Type 5T3, sweep magnification is also provided by the oscilloscope. If the display is magnified with the oscilloscope sweep magnifier, however, the spacing between dots is increased by the magnification factor and the display is on the screen only during the portion of the sweep that would be at the center of the screen in the unmagnified display. (The sweep is expanded about the center of the screen.) When using the oscilloscope magnifier with equivalent-time displays, the TIMED position of the SAMPLES/CM switch may be used to obtain a continuous bright display during the time that the display is on the screen.

Real-Time Mode. Display magnification in real-time mode must be provided by the oscilloscope sweep magnifier. In many cases, however, the same effect is obtained by increasing the sweep rate. This method of expanding the display is preferred to sweep magnification whenever possible, since sweep magnification extends the sweep beyond the ends of the crt screen, thus reducing the repetition rate and the brightness of the display.

If the portion of the display that you wish to expand is not at a triggering point on the waveform or if it does not follow a triggering point closely, it will be necessary to use the oscilloscope Sweep Magnifier and horizontal Position control in order to view the display in detail.

Delayed Pulse Output

The oscilloscope Delayed Pulse Generator is pulsed by the Type 5T3 trigger circuit. The resulting output pulse from the oscilloscope thus occurs a short time after the trigger circuit has operated. If the output pulse is then connected to the vertical input of the sampling unit, or if it is used to pulse a test device and the response signal is connected to the vertical input, a stable display will be presented on the crt whenever the sweep is running.

NOTE

Be sure to turn off the oscillscope Amplitude/Time Calibrator whenever using the Delayed Pulse or setting the Delayed Pulse Bias.

Delayed Pulse Bias Adjustment. Whenever the timing unit is changed, the oscilloscope Delayed Pulse Bias control must be readjusted for correct operation of the Delayed Pulse Generator. The following procedure uses the oscilloscope display for setting the adjustment:

1. Connect the Delayed Pulse output directly to the sampling unit input through a 50 Ω coaxial cable or a sampling probe and adapter.

2. Set the EQUIVALENT TIME/CM switch to .1 μSEC and the TRIG SOURCE switch to FREE RUN.

3. Set the sampling unit Millivolts/Cm switch to 100.

4. Adjust the TIME POSITION control and the vertical positioning controls to display both the negative-going and positive-going portions of the pulse. The display should be similar to that shown in Fig. 2-12.[1]

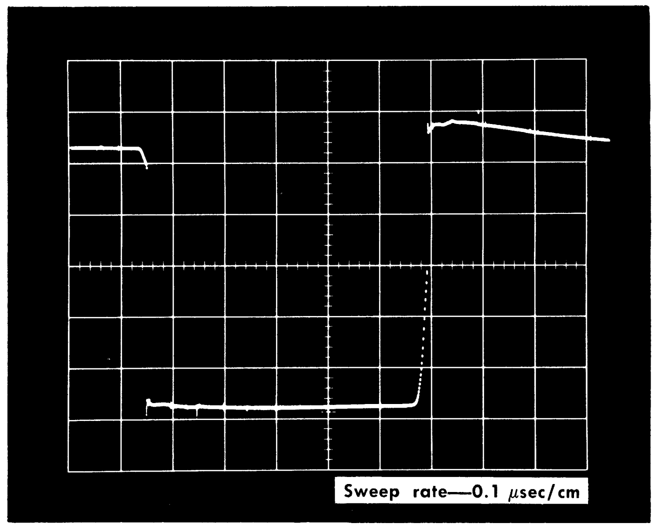


Fig. 2-12. Crt display for oscilloscope Delayed Pulse Bias adjustment.

5. If the display is not correct or is not stable, remove the right side panel of the oscilloscope and adjust the Delayed Pulse Bias control.

External Sweep and Manual Scan

No provision is made for an external sweep input through the Type 5T3. However, the oscilloscope used with the Type 5T3 does provide for driving the crt scan with an externally applied signal. The oscilloscope also allows the screen to be scanned manually with the Horizontal Position control. In either case, the Type 5T3 must still provide the strobe pulses to the sampling unit.

In equivalent-time mode, the Type 5T3 also provides the time base of the display. In this mode, any signal applied to the vertical input is displayed at an equivalent sweep rate set by the EQUIVALENT TIME/CM switch. In real-time mode, the signal applied to the horizontal input provides the display sweep base, just as in any non-sampling oscilloscope.

[1] **If the sampling unit has no internal delay line, set the EQUIVALENT TIME/CM switch to 10 nSEC to view the falling portion and to 20 nSEC to view the rise.**

Single Display

In real-time mode, the single-display feature may be used for viewing or photographing a non-repetitive waveform or a slow-moving sweep. In equivalent-time mode, the input waveform must be repetitive in order to produce an intelligible display, but a single-display presentation is still available for photographing a slow-moving sweep.

To use single display in either real-time or equivalent-time mode:

1. Set up the triggering controls with the SWEEP MODE switch at NORM.

2. Set the SWEEP MODE switch to SINGLE DISPLAY. The sweep will be held off until the START button is pressed.

3. Press the START button. The single-display circuit is armed and ready to produce a sweep when the first trigger pulse arrives.

4. Release the START button. This allows the single-display circuit to be reset following the first trigger. The START button must be released to its normal position before it can be pressed again for another single-display presentation.

Timed Sweep

The oscilloscope in which the Type 5T3 is used provides vertical and horizontal outputs for driving pen recorders and other external devices. For using these outputs in equivalent-time mode, it is usually desirable to have a ramp sawtooth output rather than a staircase output, since the staircase may not be linear in real time. The TIMED position of the Equivalent Time SAMPLES/CM switch provides such an output signal, still referenced to the equivalent-time sweep.

Timed Sweep Adjustment. The range of display sweep rates available with the Timed sweep is from more than 5 sec/cm to less than 0.5 sec/cm. To set the Timed ADJ control for some calibrated rate (e.g., 5 sec/cm), use the following procedure:

1. Connect a time-mark or signal generator to the vertical unit input.
2. Set the EQUIVALENT TIME/CM to approximately 50 nSEC.
3. Set the signal generator for a convenient output repetition rate (1 second/cycle could be used in this example).
4. Trigger the Type 5T3 either externally or internally, as desired.
5. Adjust the Timed ADJ control with a small screwdriver for the proper crt display (in this case 5 markers/cm).

Digital Readout

A modification kit is available for converting the Type 5T3 to digital readout operation. All switching contacts required for the modification and all input and output connections to the etched-wiring boards are already built into the Type 5T3. Contact your Tektronix Field Office or Field Engineer for further information.

BASIC APPLICATIONS

General Information

The displayed waveform on the oscilloscope crt screen is normally a plot of voltage per unit time. Voltage is displayed in the vertical direction and time is represented as horizontal deflection. The Type 5T3 can be used for making accurate time measurements of the input signals. In addition to time-interval and frequency measurements, comparison measurements can also be made of phase and time relationships between two vertical input signals.

Time Interval Measurement

The calibrated sweep rates of the Type 5T3 make any horizontal displacement on the crt screen represent a specific interval of time. Thus the time interval between any two displayed events can be measured directly from the the crt screen.

Set the sweep rate with the EQUIVALENT TIME/CM or REAL TIME/CM switch so the part of the waveform containing the two points of interest is spread over a large portion of the screen. All measurements must be made with the VARIABLE sweep rate control in the CAL position (at counterclockwise detent).

To make a time measurement between two points on a waveform:

1. Measure the horizontal distance in centimeters on the graticule between the two points of interest. Be sure the VARIABLE control is at CAL.

2. Multiply the number of centimeters of horizontal deflection by the sweep rate indicated on the EQUIVALENT TIME/CM or REAL TIME/CM switch.

Fig. 2-13 illustrates an example of time interval measurement. Assuming the EQUIVALENT TIME/CM switch to be set a 1 nSEC/CM, the horizontal deflection of 2.1 cm is multiplied by 1 nsec/cm to obtain the time interval of 2.1 nsec. Basic sweep accuracy of the Type 5T3 is within ±3% at all sweep rates.

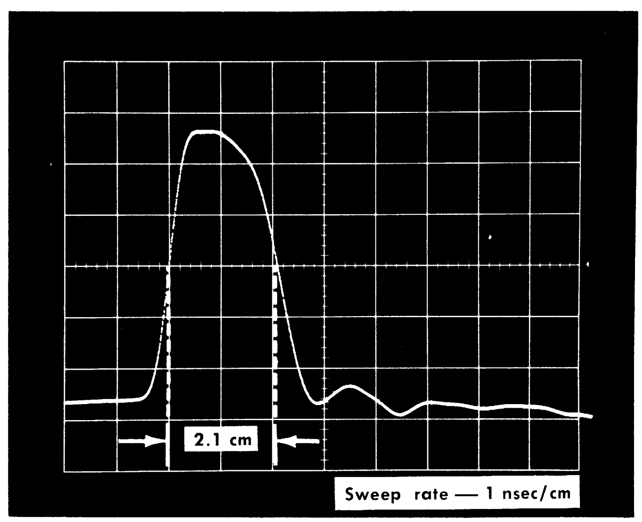


Fig. 2-13. Time interval measurement.
Example: 2.1 cm x 1 nsec/cm = 2.1 nsec time interval.

The same procedure can be used for making time-comparison measurements between time-related events on two input signals.

Ⓐ

Risetime Measurement

The risetime of a pulse or signal is measured with the time interval method. Unless otherwise specified, the risetime is measured between the 10% and 90% levels of the signal rise. To measure the risetime of a pulse:

1. Set the EQUIVALENT TIME/CM or REAL TIME/CM switch so the rise will cover several centimeters horizontally. Leave the VARIABLE control at CAL position.

2. Position the pulse rise near the center of the crt screen.

3. Set the vertical sampling unit Millivolts/Cm switch and VARIABLE control to produce some even number of centimeters of deflection on the crt screen.

4. Measure the horizontal distance between the 10% level and the 90% level on the pulse rise. See Table 2-4 for the vertical deflection to be used in the measurement.

TABLE 2-4

Risetime Deflection Guide

Total Cm of Deflection	Deflection Between 10% and 90% Points
4 cm	3.2 cm
5 cm	4.0 cm
6 cm	4.8 cm
7 cm	5.6 cm
8 cm	6.4 cm

For example, if the horizontal distance between the 10% and 90% points is 4.8 cm (see Fig. 2-14), and the EQUIVALENT TIME/CM switch is set to .1 nSEC/CM, the risetime of the pulse is 4.8 cm times 0.1 nsec/cm, or 0.48 nsec (480 psec).

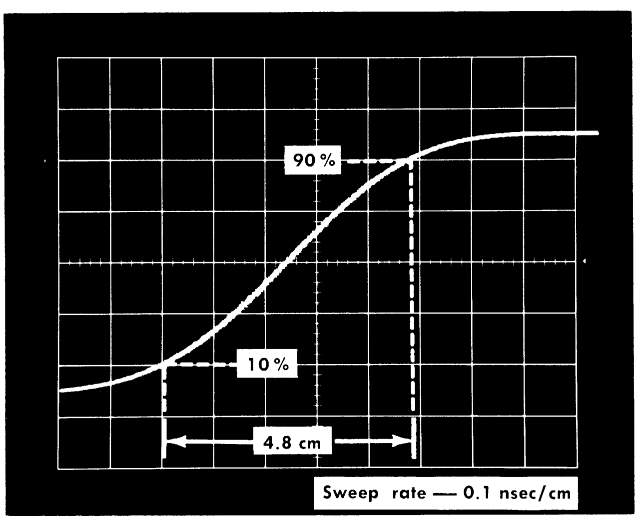


Fig. 2-14. Risetime measurement. Example: 4.8 cm x 0.1 nsec/cm = 480 psec.

Frequency Measurements

Since the frequency of any repetitive signal is equal to the reciprocal of its period (time interval of 1 cycle), the frequency can be calculated directly from the time interval of one cycle (see Fig. 2-15). If, for example, the period of a recurrent waveform is measured to be 105 nsec, the frequency of the signal is 1/105 nsec, or 9.5 Mc.

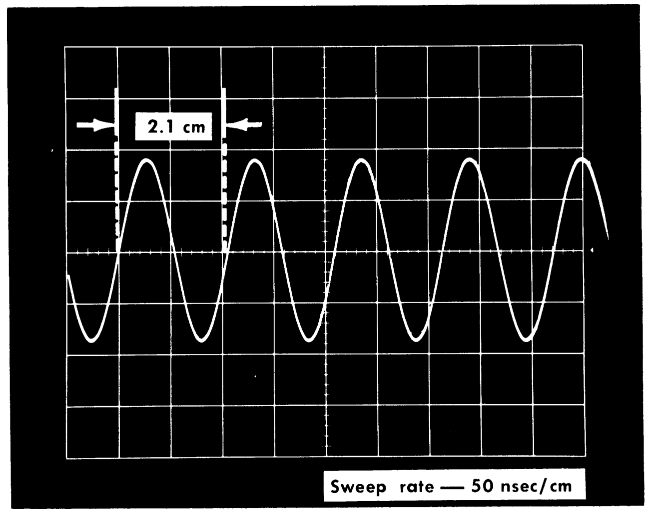


Fig. 2-15. Frequency measurement using the relationship $f = \frac{1}{\text{period}}$. Example: $f = \frac{1}{2.1 \times 50\ \text{nsec}} = 9.5 \times 10^6 = 9.5$ Mc.

Another method of determining frequency that is usually easier and faster to use is obtained by dividing the average number of cycles displayed per centimeter by the sweep rate of the display. Determine the frequency as follows:

1. Set the EQUIVALENT TIME/CM or REAL TIME/CM switch to display several cycles of the waveform on the crt screen. Be sure the VARIABLE control is in CAL position.

2. Count the number of cycles displayed on the 10 cm of the graticule (see Fig. 2-16).

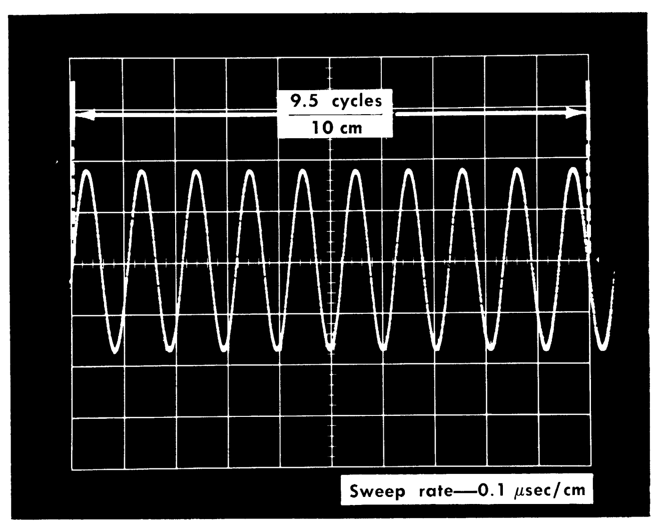


Fig. 2-16. Frequency measurement using average number of cycles/cm. Example: $\frac{9.5\ \text{cycles/10 cm}}{0.1\ \mu\text{sec/cm}} = \frac{0.95}{0.1}$ cycles/μsec = 9.5 Mc.

3. Divide the number of cycles by 10 to obtain the average number of cycles per centimeter.

4. Divide the average number of cycles/cm by the setting of the EQUIVALENT TIME/CM or REAL TIME/CM switch to obtain the frequency.

For example, with a sweep rate of 0.1 μsec/cm, if the number of cycles displayed is exactly 9.5, first divide the 9.5 cycles by 10 cm giving 0.95 cycles/cm. The frequency is then 0.95 cycles/cm divided by the 0.1 μsec/cm sweep rate, or 9.5 Mc.

Phase Measurement

One complete cycle of a sinusoidal waveform is considered to be 360 degrees. Phase angle measurements are commonly used for comparing input and output signals from amplifiers, etc. Dual-trace operation of the vertical sampling unit is used to display the phases simultaneously on the crt screen. X-Y operation of the sampling unit may also be used for determining phase relationships. See the sampling unit manual for this method.

To retain the exact relationship between the signals at their sources, the signals should be applied to the vertical inputs through identical lengths of coaxial cable. Triggering of the dual-trace display may be taken either from one of the input signals or from an external signal.

For phase angle measurements, it is usually convenient to first calibrate the sweep in degrees of phase angle per centimeter of display. For instance, if the display sweep rate is adjusted with the EQUIVALENT TIME/CM or REAL TIME/CM and VARIABLE controls so one cycle of the waveform covers 8 centimeters of the graticule, each centimeter then corresponds to 45 degrees and the display is calibrated at 45°/cm. The use of 45°/cm is suggested because it produces a large display and also calibrates the sweep at 1 quadrant (90°) for every 2 centimeters.

The relative amplitude of the signals does not affect the phase measurement as long as each signal is vertically centered on the horizontal centerline. However, it is often easier to read the phase difference if the display amplitudes have been adjusted to be the same.

To measure the phase angle between two input signals:

1. Set the sampling unit Triggering switch to the channel with the reference signal, or connect an external reference triggering signal to the Type 5T3.

2. Adjust the sweep rate with the EQUIVALENT TIME/CM or REAL TIME/CM and VARIABLE controls so 1 cycle of the reference waveform covers 8 cm of the graticule, to calibrate the sweep at 45°/cm.

3. Position both waveforms to center on the horizontal graticule centerline.

4. Adjust the TRIG LEVEL control or TIME POSITION control so the reference waveform starts slightly below the centerline.

5. Measure the horizontal distance between corresponding points on the two waveforms (see Fig. 2-17).

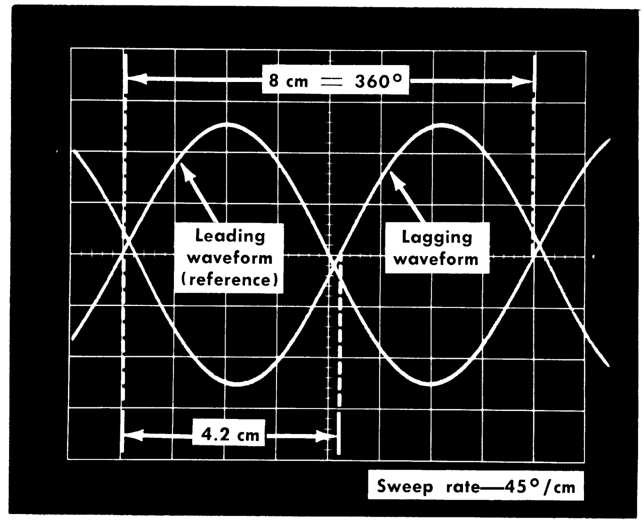


Fig. 2-17. Dual trace display with sweep calibrated at 45°/cm. Example: 4.2 cm x 45°/cm = 189°.

6. Multiply the horizontal distance by the calibrated sweep rate (45°/cm) to obtain the phase angle in degrees.

For example, if the time interval between corresponding points is 4.2 cm, the phase difference is 4.2 cm times 45°/cm, or 189°.

The "leading" waveform is generally considered to be the one to the left in the crt display, though this may not be the reference waveform. If the second waveform lies to the left, it leads the reference signal by the phase angle; if it lies to the right, it lags the reference signal. In the illustration, the second signal lags the reference waveform by 189°.

Ⓐ

SECTION 3
CIRCUIT DESCRIPTION

The Type 5T3 Timing Unit is designed to operate as part of the Tektronix Type 661 Sampling Oscilloscope system. This section of the manual presents a brief description of the basic sampling processes in equivalent-time mode and in real-time mode, then gives more detailed descriptions of the various circuits.

BASIC SAMPLING PROCESSES

Sampling oscilloscopes are designed primarily to be used for viewing high-frequency or fast-rise repetitive waveforms. Most modern sampling systems accomplish this by taking samples from many different cycles of the input signal, then reconstructing the waveform in "equivalent time" on the crt screen.

In addition to equivalent-time sampling, the Type 5T3 incorporates a real-time sampling mode that permits viewing of low-frequency and non-repetitive signals at sweep rates below the practical lower limit of equivalent-time sampling.

Equivalent-Time Mode

The equivalent-time portions of the sampling system are shown in the simplified block diagram in Fig. 3-1. The vertical channel uses an input gate that can take quick samples of the input signal and a memory circuit that remembers the previous sample level until another sample is taken. The horizontal sweep is produced by a staircase voltage that advances one step each time a new sample is to be displayed. In triggered operation, one excursion of the input triggering signal actuates the trigger circuit, which then initiates one cycle of the sampling process to produce one dot of the crt display. Each displayed sample requires a separate triggering event.

The trigger circuit starts the operation of the fast ramp and arms the sweep to start. When the fast ramp rundown voltage becomes equal to the existing staircase feedback voltage, the comparator triggers the regenerator circuit. In turn, the regenerator pulses the sampling circuit and the staircase generator. The sampling circuit then takes a quick sample of the signal level at the input, while the staircase generator advances one step. The sampling memory output is applied to the vertical amplifier and the new staircase output level is applied to the horizontal amplifier. As soon as the sample is taken, a dot is displayed on the crt screen at a level proportional to the input signal level at the moment it was sampled. The dot then remains stationary on the screen until a new sample is taken.

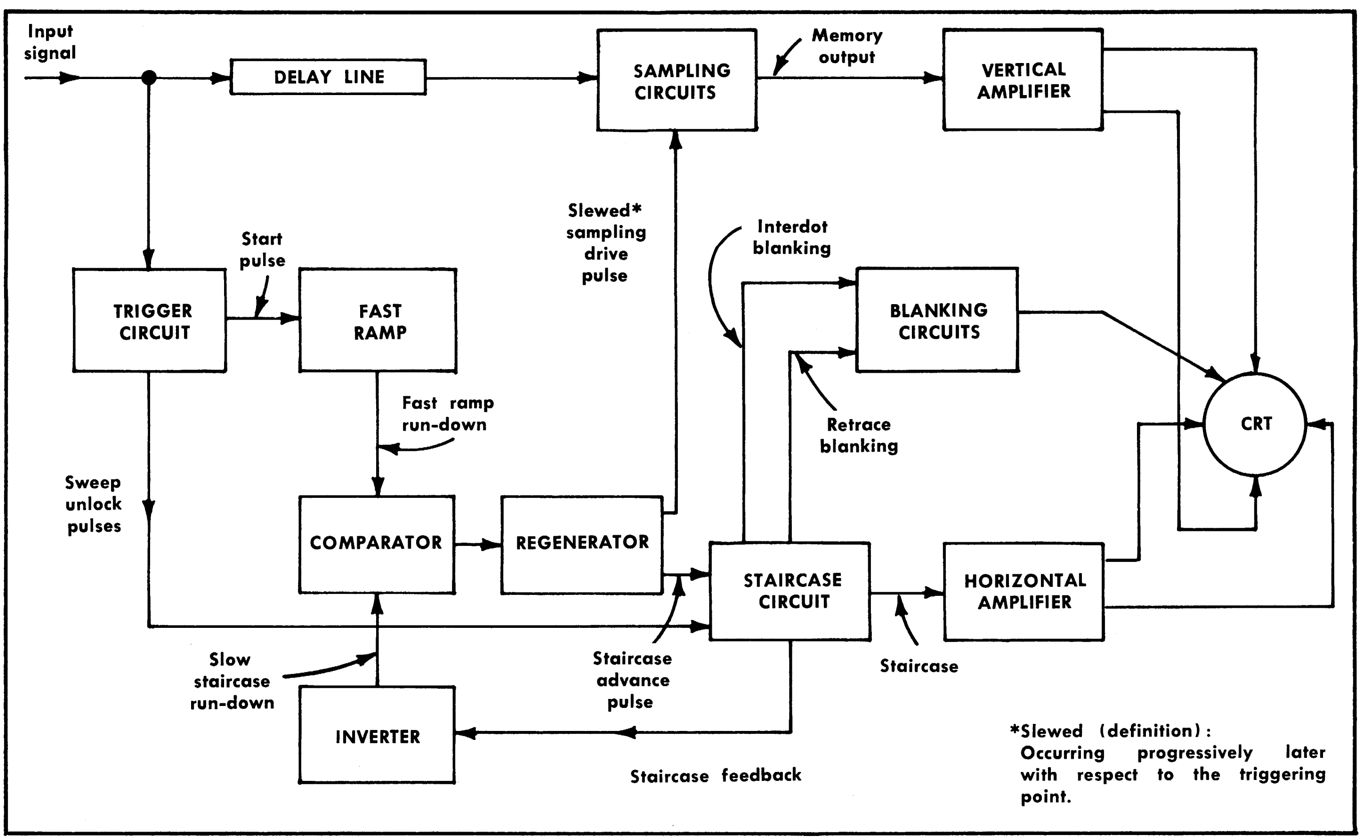


Fig. 3-1. Simplified block diagram of Sampling System with Type 5T3 in equivalent-time mode.

Each subsequent triggering event initiates the same series of sampling events, but since the staircase feedback voltage moves down one step each time, the fast ramp has to run down slightly farther each time before a comparison pulse is produced. In this way, the sampling event is delayed by successively longer intervals and the samples are taken successively later along the waveform with respect to the triggering point. Each time a sample is taken, the crt is blanked momentarily while the dot position on the crt screen moves horizontally by one increment, and to a new vertical level. Since the sampling channel is an error-sensing circuit, the vertical position of the dot will change only if the input voltage level changes between samples.

Fig. 3-2 illustrates the development of an equivalent-time display from a repetitive square-wave signal. Note that the sampling operation is triggered each time at the same point on the triggering waveform, but that the sample is taken progressively later on the waveform, due to the longer delay between the triggering event and the sampling event. In an equivalent-time display, no two samples are taken on the same cycle of the input waveform; though, if the waveform is of a very high frequency, several cycles may occur between samples, due to the inherent recovery time of the trigger circuit.

Real-Time Mode

Fig. 3-3 is a simplified block diagram showing the system components that function in real-time mode. The sampling operation performed by the sampling unit is identical to that performed in equivalent time, and some of the sweep and triggering functions remain the same. In real-time mode, however, the sampling process and the staircase advance are not initiated by the trigger circuit, but rather by a real-time clock circuit.

In real-time mode, since the waveforms to be viewed are relatively slow moving, samples are taken at a rapid rate continuously along the waveform, rather than from different cycles of the signal. The crt display is thus made up of a series of dots that actually follows the changes of the input waveform. Only one trigger is required per sweep (as in a conventional non-sampling oscilloscope), rather than one trigger per samples (as in equivalent-time mode).

The real-time clock circuit operates whenever the instrument is set for real-time operation. Each cycle of the clock sends a gate pulse to the staircase generator and a sampling drive pulse through the regenerator to the sampling channel. The dots on the crt screen are produced at a constant rate and the crt display progresses at the selected real-time sweep rate. Thus the sweep rate and the sampling rate determine the dot spacing on the crt screen. For example, a sweep rate of 1 sec/cm and a sampling rate of 100 kc produces a display of 100,000 dots per sweep.

CIRCUIT ANALYSIS

During the following analysis of the various circuits of the Type 5T3, refer to the block diagrams in the text for the general operation of each circuit, and refer to the particular schematic diagram at the rear of this manual for the detailed analysis.

Tunnel Diodes

Since several circuits in the instrument use tunnel diodes as switching devices, the basic operating characteristics of these components are described in general here, rather than in the description of each circuit.

These diodes are specially manufactured to have voltage-current characteristics similar to the 10-ma curve shown in Fig. 3-4. As current through the diode is increased from

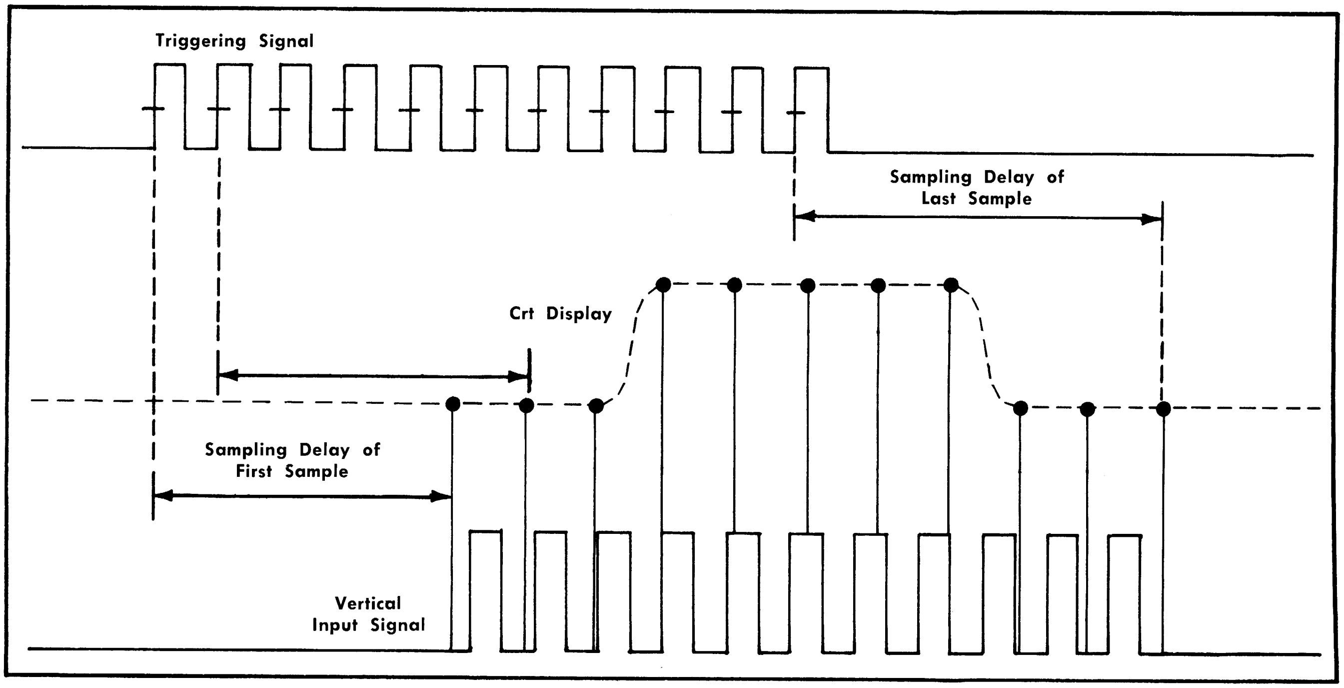


Fig. 3-2. Formation of crt display in equivalent-time mode.

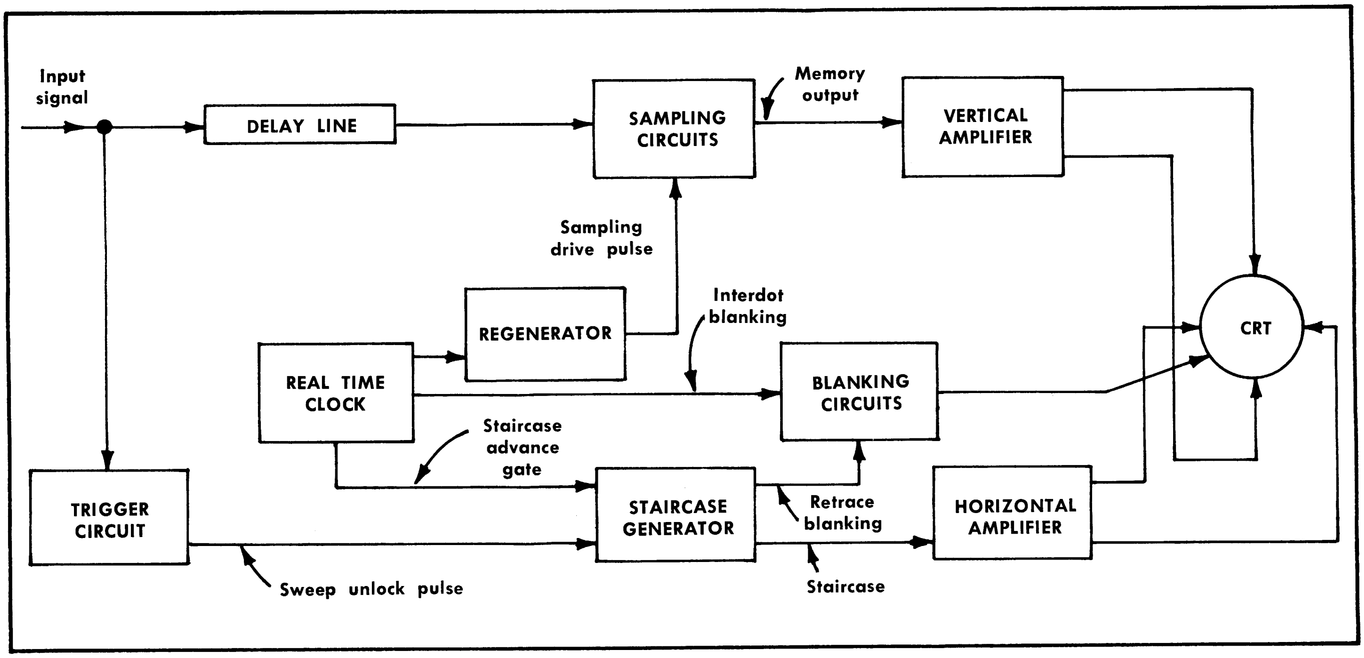


Fig. 3-3. Simplified block diagram of Sampling System with Type 5T3 in real-time mode.

zero to the 10-ma point, the voltage across it increases slowly to about 75-100 millivolts. This is called the low-voltage state of the diode. Any further increase in current then causes an abrupt voltage increase to about 500 millivolts. The diode is then in its high-voltage state. The fast voltage pulse that occurs as the diode switches to its high-voltage state is the pulse that is used as a trigger. Once the diode has switched to its high-voltage state, current through it must be decreased to about 2 ma to make it switch back to the low-voltage state. When it is switched back to the low-voltage state, the transition is also very fast and the resulting voltage pulse may also be used as a trigger or reset pulse.

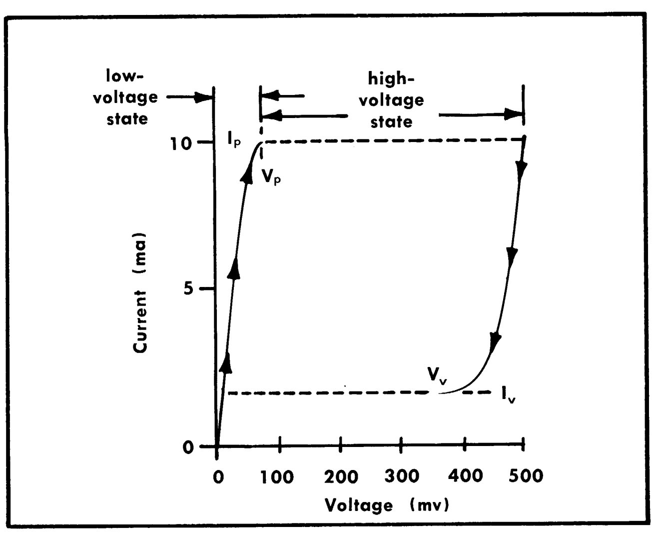


Fig. 3-4. Typical switching characteristics of a 10-ma tunnel diode.

External Trigger Circuit

The external trigger circuit consists of the two external trigger inputs (50 Ω and 1 MΩ), an isolation cathode-follower for the 1 MΩ input and a wide-band external trigger amplifier. Triggering signals that are applied in UHF Sync mode of operation are connected directly to the trigger circuit. All other triggering signals applied to the external trigger inputs are processed by the external trigger amplifier circuit.

50 Ω INPUT

The 50 Ω input circuit presents a constant impedance of 50 ohms at the input connector, regardless of the internal coupling used. The 50 Ω AC or DC positions of the EXT TRIG MODE switch permit triggering from external 50-ohm sources up to a frequency of 500 Mc. The lower frequency limit of the AC position is about 500 kc. In addition to these, a 50 Ω UHF SYNC position of the switch connects the input directly to a monostable tunnel diode in the trigger circuit for synchronizing on input signals up to 5 Gc. In this mode, no trigger isolation amplifiers are used, allowing a great increase in bandwidth but also allowing a considerable amount of external kickout from the tunnel diode.

In the UHF Sync mode, the input is terminated by R187, R183 and R184. In the 50 Ω AC and DC positions, R49 and R57 provide the termination. When the EXT TRIG MODE switch is set to either of the 1 MΩ positions, R53 terminates the 50 Ω input.

1 MΩ INPUT

A high-impedance input circuit is provided at the 1 MΩ AC or DC positions of the EXT TRIG MODE switch for use with low- and intermediate-frequency external triggering signals (up to 20 Mc). Input impedance remains a constant

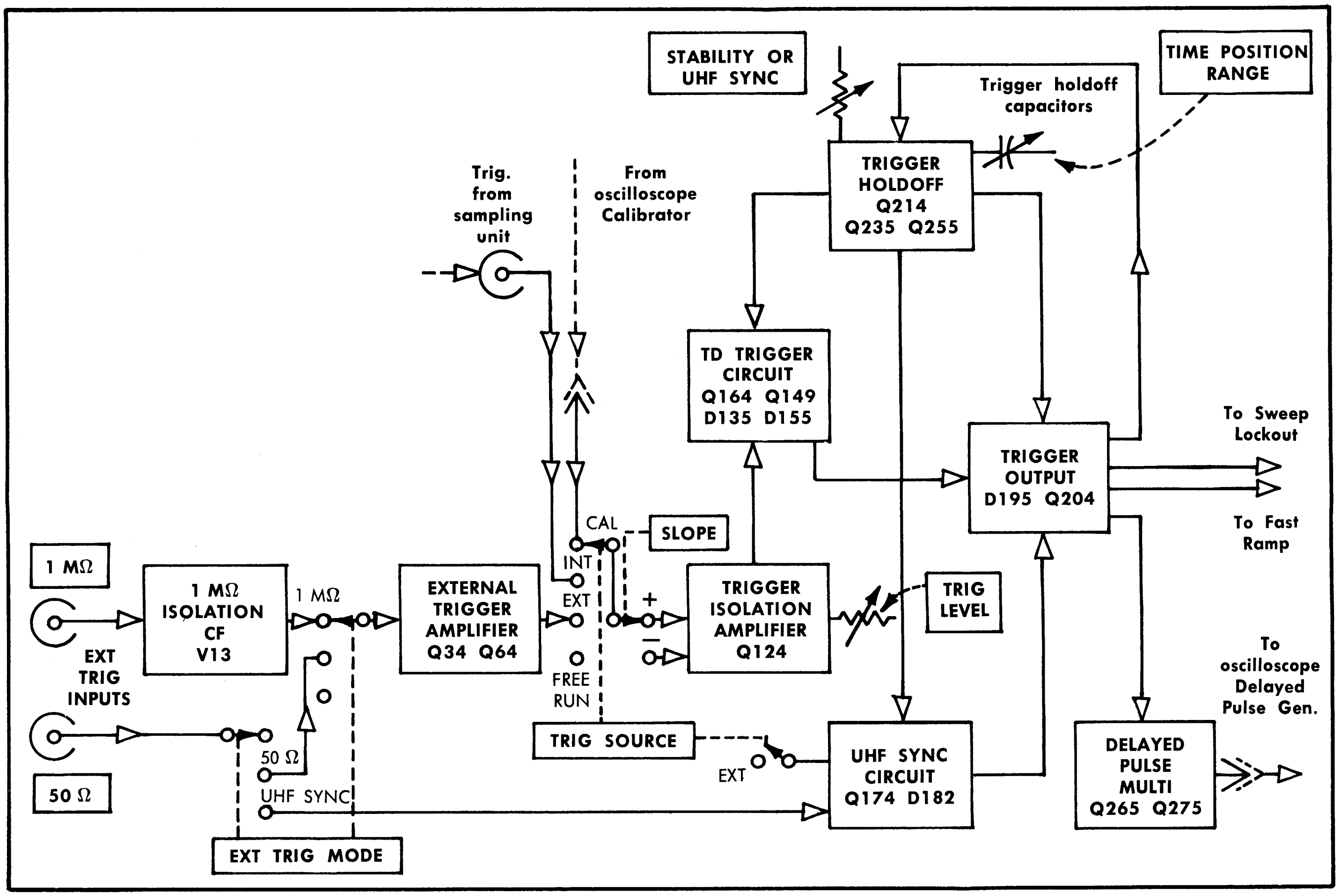


Fig. 3-5. Block diagram of External Trigger Input and Trigger circuits.

1 megohm, set by R5 in the grid circuit of V13. When set to the 1 MΩ AC position, the lower-frequency limit is approximately 160 cps.

1 MΩ ISOLATION CF

In addition to isolating the 1 MΩ input from the trigger circuits, the circuit of cathode-follower V13 also provides an impedance transformation from 1 megohm at the input to about 1 kilohm at its output to the external trigger amplifier. Further impedance transformation is provided by the amplifier circuit.

Input signals of from 50 millivolts to 1½ volts are applied through the 1 MΩ input to the grid of V13. Excessively large signals are clipped by diodes D5 and D7. Gain through the cathode follower is slightly less than one. When the EXT TRIG MODE switch is set to one of the 1 MΩ positions, a 10× attenuator is formed by R15 and R20, providing most of the impedance transformation to 1 kilohm. The 1 MΩ ZERO adjustment (R10) is set so that when there is no signal applied to the 1 MΩ input, the output of the external trigger amplifier to the trigger circuit is zero volts.

EXTERNAL TRIGGER AMPLIFIER

The transistor pair, Q34 and Q64, constitute a wideband inverter amplifier for the external trigger input circuits. Basic frequency response of the circuit is from dc to 500 Mc with a gain of one.

There are two input paths to the amplifier, one at the base of Q34 and the other at the emitter of Q64. Transistor Q64 is used as a common-base amplifier for high-frequency signals and as a degenerative common-emitter amplifier for low frequencies. Transistor Q34 is used as a simple emitter follower.

When the EXT TRIG MODE switch is set to one of the 1 MΩ positions, the signal is applied from V13 to the base of Q34. The primary of transformer T55 is shorted and the emitter of Q64 is, in effect, terminated in 50 ohms. In this case, only the low-frequency common emitter character of Q64 is used. Thus with a collector load of 50 ohms and an emitter resistance of 50 ohms, a voltage inversion is obtained with a gain of one through the amplifier.

When the EXT TRIG MODE switch is set to one of the 50 Ω positions, V13 is no longer connected to the amplifier. In the 50 Ω DC position, a signal applied to the 50 Ω EXT TRIG INPUT connector passes through the EXT TRIG MODE switch to T55. The high-frequency components of the signal are inverted in the transformer and connected through a coax directly to the emitter of Q64. The low-frequency portion of the signal passes through the primary of T55 to the base of Q34. Fifty-ohm signals applied to the 50 Ω EXT TRIG INPUT connector are thus amplified by a factor of one through one or the other of the two paths. Crossover frequency from low-frequency to high-frequency operation occurs at about 3 Mc.

In the 50 Ω AC position of the EXT TRIG MODE switch, the dc connection to the base of Q34 is disconnected and C45 is tied to ground in parallel with C49. In this position, only the high-frequency information coupled through T55 is applied to Q64, and the low-frequency cutoff is about 500 kc.

TRIGGER SOURCE AND SLOPE SWITCHES

The TRIG SOURCE switch (SW80) is designed to provide a 50-ohm termination for each input triggering signal not connected to the trigger circuit. The three inputs provided to the switch are the oscilloscope calibrator (CAL), internal (INT) from the sampling unit and external (EXT) from the external trigger amplifier or UHF Sync circuit.

The internal connection from the sampling unit is dc-coupled in the Type 5T3, but may be ac-coupled in the sampling unit. In the CAL position of the TRIG SOURCE switch, a 100-mv signal from the oscilloscope calibrator is connected to the trigger circuit. The amplitude of this calibrator signal remains the same, regardless of the amplitude at the calibrator output. The signal is applied through T90 and is ac-coupled only.

The SLOPE switch (SW95) applies input triggering signals to the base and emitter of the trigger isolation amplifier, Q124. In addition, it permits polarity reversal of the voltages connected to the TRIG LEVEL control (shown on the Trigger schematic diagram). In the positive position of the SLOPE switch, signals are applied directly to the emitter of Q124 with no inversion. In this mode, the base of Q124 is held at ground by R99. In the negative polarity (—), however, Q124 is connected to operate as an inverter amplifier. The dc-coupled signal is applied to the base of the transistor and an inverted signal is ac-coupled to the emitter through transformer T97. At high frequencies the dc-coupled signal is shorted to ground through C99 and the primary signal path is through T97. At lower frequencies, the ac-coupling of T97 becomes less effective, while the dc-coupling to the base of Q124 becomes more effective.

Trigger Circuit

The trigger circuit is composed of several smaller circuits —a trigger isolation amplifier, a bistable tunnel-diode trigger circuit, a trigger output tunnel-diode circuit, a monostable tunnel-diode UHF Sync circuit, a trigger holdoff multivibrator, a delayed pulse multivibrator and several switching transistors. Output signals from the trigger circuit are provided for starting the fast ramp circuitry and the staircase generator and for pulsing the delayed pulse generator in the oscilloscope.

When the triggering controls are set for triggered operation, a triggering signal applied to the input isolation amplifier causes the bistable TD circuit to initiate the operation of the rest of the trigger circuit. The bistable TD circuit delivers a pulse to the output tunnel diode which then starts the fast ramp. In addition, the output tunnel diode turns on the transistor in the trigger output circuit, starting the operation of the trigger holdoff and sending an unlock pulse to the sweep gate in the horizontal sweep generator. The trigger holdoff prevents the trigger circuit from operating again until after the holdoff period by cutting off bias current from the bistable TD circuit. At the end of the holdoff period, current is restored to this circuit making it sensitive to the input triggering signal.

If the UHF Sync mode is used, the UHF Sync tunnel diode synchronizes on the input signal then triggers the output tunnel diode to initiate the output pulses. The holdoff circuit also controls the bias current for the UHF Sync circuit.

TRIGGER ISOLATION AMPLIFIER

When the SLOPE switch is set to +, the trigger isolation amplifier (Q124) operates as a common-base amplifier. Positive-going signals applied to the emitter decrease current through the transistor, decreasing current through the recognition tunnel diode (D135) in the TD trigger circuit. When the SLOPE switch is set to —, the triggering signal is applied to the base of Q124 and the inverted signal is applied to the emitter. The negative-going portion of the triggering signal then decreases current through D135 to arm the trigger circuit.

The TRIG LEVEL control in the emitter circuit of Q124 sets the dc current through the transistor. This determines the input signal level that will cause the trigger circuit to operate. The TRIG LEVEL ZERO adjustment (R120) is set to center the range of the TRIG LEVEL control, and the TRIG BAL control (R103) adjusts the emitter voltage level to zero with no signal applied.

BISTABLE TD TRIGGER AND TRIGGER OUTPUT

Since the bistable tunnel-diode trigger circuit and the trigger output circuit operate so closely as a unit, they will be discussed together here. The bistable tunnel-diode circuit is formed by D135, D155 and Q149. Transistor Q164 is a current switch for this circuit. Output tunnel diode D195 and transistor Q204 form the trigger output circuit. The current source for both circuits is the 19-volt switch (Q214) operated by the holdoff circuit.

All of the current that passes through D135 and D155 also flows through Q164. Since diodes D135 and D155 are connected to a common current source, an increase in current through D135 (caused by a current increase in Q124) is accompanied by a decrease in current through D155. Similarly, a current decrease in D135 is accompanied by a current increase in D155. The STABILITY OR UHF SYNC control (R170) adjusts current through Q164 to set the bias on D135 and D155 for triggered, synchronizing or free-running operation.

In the quiescent state, output tunnel diode D195 is biased near the triggering point by current through R210 (OUTPUT TD BIAS), and output transistor Q204 is not conducting.

Schmitt-Type Triggering. The bistable TD trigger circuit is reset at the completion of each holdoff cycle and if it is set for triggered operation, the circuit is ready to accept another triggering event. At this time, recognition tunnel diode D135 and recovery tunnel diode D155 are both biased in their low-voltage states, with D155 near its switching point and D135 well below its switching point. Transistor Q149, which is connected in shunt with D135, has a saturation characteristic such that its emitter-to-collector impedance is very high when the emitter-to-collector voltage is below 100 mv, and very low when the voltage is greater than 100 mv. The base-to-emitter junction is normally forward biased with a quiescent current of approximately 0.5 ma, so that whenever the emitter-to-collector voltage exceeds 100 mv, the transistor will saturate. With D135 in its low state, however, the voltage applied across Q149 is below the 100-mv saturation voltage and the transistor is held out of conduction.

Heater current for V13 and V583 (Horiz. Sweep Generator) flowing through the low-impedance path of D157, R152, R149-R150 and R155 holds the cathode of D155 near +6.2 volts and produces a drop of approximately 250 mv across R149-R150, setting the anode voltage of D147. With both D135 and D155 in the low-voltage state, the anode of D146 is at a less positive voltage than the anode of D147; therefore D146 is reverse biased and D147 is conducting all of the current that passes through R146.

If the input triggering signal causes current to increase through isolation amplifier Q124 (and thus through D135), no switching will occur because the current increase will not raise the bias on D135 above its switching point. When the input voltage excursion causes a current decrease through D135, the resulting current increase through D155 switches D155 to its high-voltage state. The positive-going voltage pulse that appears at the anode of D155 is applied directly to the anode of D135 and through the network of C140, R144 and LR133 to the anode of D135. This raises the level of both the anode and cathode of the tunnel diode, forward biasing D146 and switching current from D147 to D146 and D135. The increased current through D135 biases this diode up near its switching point, but since current is decreasing through Q124, D135 will not switch at this time. The next excursion of the input signal that increases the current through Q124 and D135 (corresponding to a positive-going excursion with the SLOPE switch set to +) causes D135 to switch to its high-voltage state. The resulting negative-going pulse at its cathode is inverted by T135 and applied through C190 and R195 to the anode of D195, the trigger output tunnel diode.

When recognition tunnel diode D135 switches to its high-voltage state, it also applies several hundred millivolts across Q149 and LR133. Initially most of this voltage appears across LR133, but as the field in the inductor begins to break down, more of the voltage appears across Q149. As this transistor saturates, it shorts out D135, automatically resetting the tunnel diode to its low-voltage state.

The positive-going pulse from the bistable TD trigger circuit switches D195 to its high-voltage state. As D195 switches, the positive-going pulse at its anode is sent to the fast ramp circuit and also is applied to the base of Q204, causing the transistor to conduct. As Q204 turns on, it sends a negative gate pulse to the sweep gate circuit and also reverse biases D227 to start the operation of the trigger holdoff circuit. As Q204 becomes saturated, it diverts enough current from Q164 to turn off that transistor. Thus, with the main current source removed from the bistable TD circuit, D135 is held in its low-voltage state, D155 is reset to its low state and D146 is turned off, restoring current through D147.

The holdoff multivibrator turns off Q214 at the halfway point of the holdoff period, causing D195 to reset to its low-voltage state and turn off Q204. Transistor Q164 does not turn on again though, since the current source through Q214 has been cut off. At the end of the holdoff period when Q214 is turned on again, current is reestablished through Q164 and the bistable TD trigger circuit can again be armed and triggered by the input triggering signal.

Auto Recovery Mode. When the STABILITY OR UHF SYNC control (R170) is switched to the AUTO RECOVERY detent position, C207 is connected to ground, delaying the rearming of D195. With R170 set to this position, current through Q164 sets the bias on D155 slightly above its switching level, so that at the end of each holdoff period, D155 is switched immediately and arms D135 without waiting for a negative excursion of the input signal. If the TRIG LEVEL is set so that D135 is then switched to its high-voltage state, D135 and Q149 will operate as a free-running multivibrator for a few cycles until D195 reaches its triggerable bias level. The repetition rate of this free-running circuit is adjusted by controlling current through D135 with the TRIG LEVEL control. The circuit can thus be adjusted to synchronize on a high-frequency input signal (10-500 Mc) and send a series of small fast triggers to D195.

As the bias on D195 reaches the triggerable level, the first of the small triggers that is able to raise the diode above the switching level switches it to its high-voltage state to produce an output pulse. The normal holdoff interval follows the output pulse, then D155 is reset and D135 and D149 again synchronize on the input triggering signal.

In auto recovery mode, if the TRIG LEVEL is set for triggered operation rather than free run, D135 is rearmed at the end of the holdoff period and is then repeatedly triggered by negative-going excursions of the input signal until one of the triggers is able to switch D195.

Whether free running or triggered, the auto recovery mode operates best on short fast pulses and high-fequency sine waves, but not very well on long pulses or square waves.

Free Run Mode. For triggered operation, R210 (OUTPUT TD BIAS) sets the bias current through D195. However, when the TRIG SOURCE switch is set to FREE RUN position, in addition to disconnecting all triggering sources, the TRIG SOURCE switch also shorts across R210. The resulting increase in bias current causes D195 to be retriggered as soon as the holdoff period has ended, without waiting for a signal from the bistable TD circuit.

UHF SYNC TD CIRCUIT

Diode D182 is the UHF Sync tunnel diode oscillator circuit, capable of synchronizing on input signals from 500 Mc to more than 5 Gc. The tunnel diode receives bias current from the stability control circuit when Q174 is turned on at the end of the holdoff period with the TRIG SOURCE set to EXT. Diode D182, L178 and R179 constitute a free-running oscillator circuit whose frequency is controlled by the adjustable bias current through the STABILITY OR UHF SYNC control. Maximum repetition rate of the circuit is about 50 Mc. The frequency of the oscillator can be adjusted so it will synchronize with a very high-frequency signal applied from the 50 Ω EXT TRIG INPUT through R183, R184 and the capacitance built into the etched-wiring board. In this mode, the OUTPUT TD BIAS control is shorted out, as in FREE RUN mode, and C207 is connected to ground, as in AUTO RECOVERY mode, to retard the recovery of D195. Under these conditions, the series of small fast triggers applied to the output tunnel diode (D195) causes the diode to switch as soon as one of the small triggers raises the diode above the triggering level following holdoff.

As soon as D195 switches and starts the operation of the holdoff circuit, Q174 is turned off and is held off until after the holdoff period has again ended.

TRIGGER HOLDOFF MULTIVIBRATOR

While Q204 is turned off, prior to receiving a trigger from D195, both transistors in the trigger holdoff circuit (Q235 and Q255) are turned on, holding Q214 in saturation. D227 is conducting current through the path from —100 volts to +19 volts. Diodes D228 and D233 are reverse biased, so the voltage on the holdoff capacitors connected to the junction between the diodes is held at about +12 volts by current through R230 and R233.

When a trigger is received and D195 turns Q204 on, D227 is reverse biased and the current from the —100-volt supply turns on D228 and flows into the holdoff capacitors (C230 and capacitors C660, C662 and C664 on the TIME POSITION RANGE switch). The capacitors begin a rundown toward the —100 volts, but when the voltage at the junction between R248 and R249 reaches approximately ground level, D250 turns on and transistor Q255 is turned off. The positive-going voltage at the collector of Q255 then turns off Q235 and Q214. When Q214 turns off, it resets the triggering circuits as described previously and the holdoff period is at its halfway point.

The reset of D195 turns off Q204 and current is reestablished through D227, turning off D228. Current through D233, which was forward biased when Q235 turned off, allows the holdoff capacitors to begin a runup toward the +100-volt supply. When the voltage at the emitter of Q235 reaches about +12 volts, Q235 turns back on, turning on Q255 and Q214 and turning off D233. Q214 then rearms the trigger circuits making them ready for another triggering event.

Minimum duration of the holdoff cycle is slightly longer than 10 μsec for all the fast equivalent sweep rates, with only C230 connected to the circuit. For slower sweep rates, larger holdoff capacitors are connected through the TIME POSITION RANGE switch to retard the holdoff rundown and runup. The holdoff interval is always slightly longer than the maximum excursion of the fast ramp.

DELAYED PULSE MULTIVIBRATOR

Normally, transistors Q265 and Q275 in the delayed pulse multivibrator are turned on. In this state, very little current flows into or out of the delayed pulse generator circuit in the oscilloscope. When a trigger pulse is received and D195 turns Q204 on, a voltage pulse is developed across the secondary of T224, sending a drive signal to the delayed pulse multivibrator. The positive portion of the pulse is applied through D263 to the base of Q275, turning off Q275 and Q265 and sending a 15-ma negative-going current pulse to the delayed pulse generator circuit in the oscilloscope. If the bias on the delayed pulse tunnel diode is set correctly, this diode is switched to its high-voltage state, producing the Delayed Pulse output.

When transistors Q275 and Q265 turned off at the beginning of the pulse, C275 began to charge up toward +19

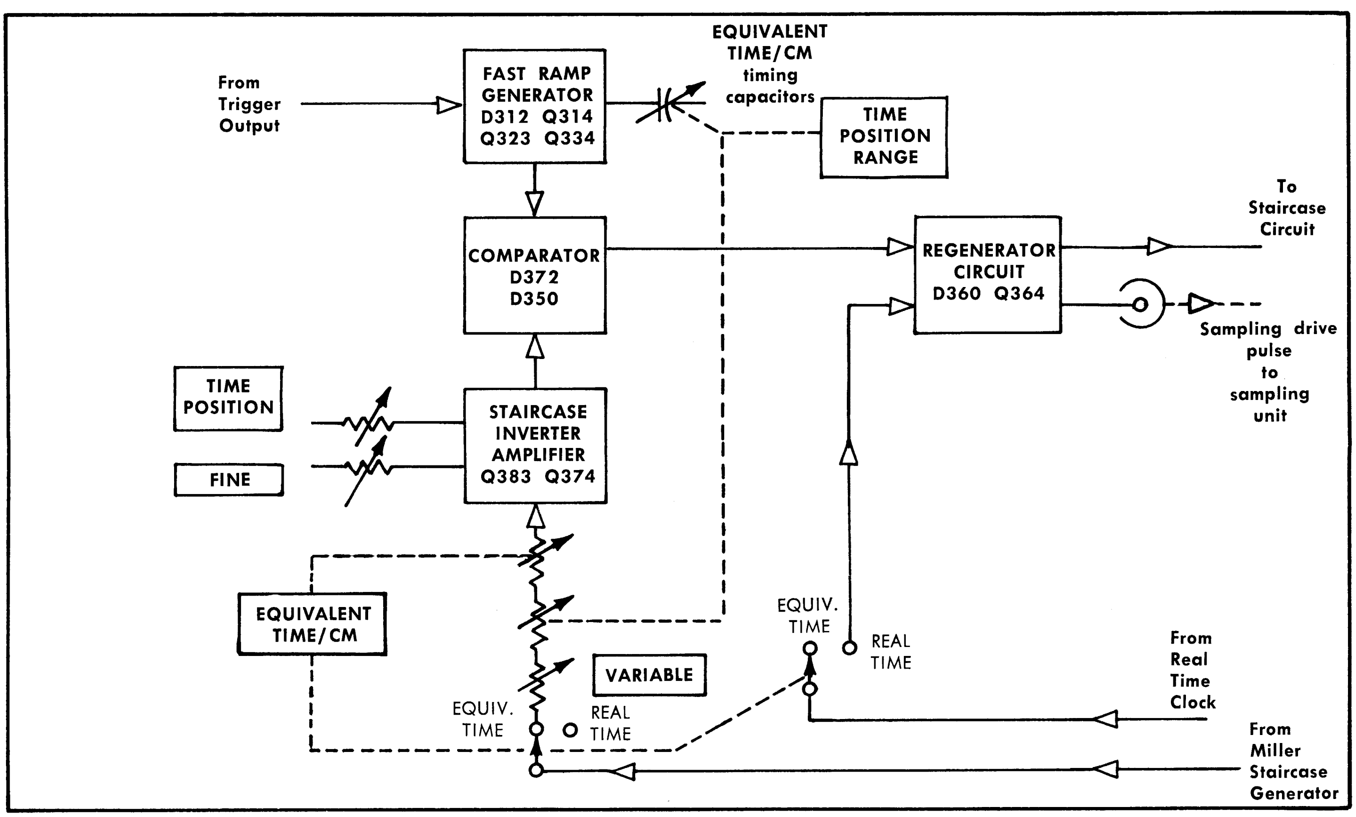


Fig. 3-6. Block diagram of Fast Ramp circuit.

volts through R275. When C275 has charged up to approximately 7 volts, D260 turns on and current through R263 turns on Q275, causing the multivibrator to regenerate into saturation. C275 is then discharged through the multivibrator and a positive-going current pulse is sent to the delayed pulse tunnel diode in the oscilloscope to reset it to its low state.

Fast Ramp

The fast ramp diagram includes four main circuits—a staircase inverter amplifier, a fast ramp generator, a comparator and a regenerator.

In equivalent-time mode, these circuits operate to generate the slewed sample drive pulses and the staircase advance pulses that allow the sampling event to progress along the waveform. Feedback voltage from the Miller staircase generator is applied through magnification attenuators to the staircase inverter amplifier. The output of this amplifier is thus an inverter staircase that follows the waveform of the horizontal sweep voltage. Each time the fast ramp generator is triggered, it runs down rapidly until its output voltage is equal to the existing level at the output of the staircase inverter amplifier. When these two voltages become equal, the comparator produces an output pulse that triggers the regenerator circuit. The regenerator then turns on, sending time-oriented pulses to the sampling unit and to the staircase driver circuit to initiate a single sampling event and staircase advance.

In real-time mode, the inverter amplifier is turned off, preventing the comparator from generating output pulses. Clock pulses from the real-time clock circuit then operate the regenerator circuit to pulse the sampling unit. Pulses from the regenerator circuit to the horizontal sweep generator, however, do not advance the staircase, since the staircase driver circuit is disabled in real-time mode.

STAIRCASE INVERTER AMPLIFIER

The staircase inverter amplifier, composed of Q383 and Q374, is an operational amplifier with a gain determined by the ratio of feedback resistor R383 to the input resistor selected by the EQUIVALENT TIME/CM switch. The 52.5-volt staircase voltage is applied to the input through the TIME POSITION RANGE and EQUIVALENT TIME/CM switches. When the Equivalent Time/Cm MAGNIFIER switch is locked to the TIME POSITION RANGE switch, a 1, 2, 5 magnification sequence is obtained for any particular time position range as the switches are turned. This is accomplished by changing the 1-, 2-, 5-step series resistors (R722, R724 and R726) that serve as the input resistors to the inverter amplifier. (These resistors are shown on the Equivalent Time/Cm Switch schematic diagram.) In addition, when the Equivalent Time/Cm MAGNIFIER knob is pulled out and turned clockwise, two attenuators may be connected to the input of the inverter amplifier to change the amplitude of the applied signal. The attenuators consist of R701, R702 and R705 (a 10× attenuator); and R710, R712 and R715 (a 100× attenuator). The greater the attenuation applied to the input of the staircase inverter amplifier (or the smaller the amplification factor), the smaller the staircase inverter output excursion becomes and the less equivalent time there is between samples. This produces the effect of magnifying the display, though the dot density of the display remains unchanged. The Equivalent Time/Cm VARIABLE control R650 can also change the gain of the amplifier, since it is a series input resistor. On the fastest sweep rates, R669 and R666 provide increased attenuation for further magnification.

The TIME POSITION and FINE controls (R395A and B) determine the dc level at which the output staircase waveform starts. The range of these controls can cause the starting level to move a total of 7.5 volts. By moving the entire staircase waveform up or down, the TIME POSITION controls cause all the samples to be delayed or advanced by the same amount of time, and therefore have the effect of moving the "time window" of the crt screen along the waveform.

The INVERTER DC LEVEL adjustment (R376) adjusts the input level of the amplifier to match the output level of the staircase start, so that no current will flow in the input resistors until the staircase begins its excursion. The TIME POSITION ZERO adjustment (R390) is set so the comparison events begin as soon as the sweep starts.

In equivalent-time mode, when the oscilloscope Horizontal Display switch is set to one of the external or manual sweep positions, the externally applied signal instead of the staircase is applied through the EQUIVALENT TIME/CM switch to produce the comparison voltage. Since the input current to the inverter amplifier is still proportional to the horizontal deflection voltage, the horizontal position of each dot on the crt screen is still referenced to time.

In real-time mode, with the EQUIVALENT TIME/CM switch set to REAL TIME, the input to the staircase inverter amplifier is tied to +19 volts through R720, driving the output down until it is stopped at —19 volts by D385. Since the maximum excursion of the fast ramp generator is about 17 volts, D372 never turns on and D350 never switches. As a result, these circuits are disabled in real-time mode.

FAST RAMP GENERATOR

Before arrival of a trigger from the trigger output circuit, Q314 is operating as a non-saturated clamp transistor with its base at about —0.4 volt and its collector at about —2 volts. Q323 is a common-base amplifier supplying current both to the base of Q314 and to tunnel diode D312. The diode is held in its high state by the current through Q323. Current is drawn by Q314 from the —19-volt supply through D328 and from Q334, the ramp current-source transistor.

When the trigger output tunnel diode switches to its high state, D312 is switched to its low state, quickly turning off Q314 and clamp diode D328. The 7.5 ma of current that Q314 had been drawing from Q334 and R340 (TIMING CURRENT) is switched into the ramp timing capacitors through the comparator circuit. The ramp capacitors (C350 A-K) then begin charging at a linear rate toward —100-volts. The particular rate of the ramp rundown is determined by the capacitor selected by the EQUIVALENT TIME/CM switch. On the fastest sweep rates, the ramp slope is 7.5 volts in 20 nsec, produced by C343 and the inherent capacitance in the circuit.

The ramp voltage continues its rundown until a comparison is made with the staircase inverter output by D372, and the comparator switches.

At the beginning of the fast-ramp operation, when Q314 and D328 turned off, the current that had been flowing through D328 was switched into Q323 and D312, bringing D312 up near its switching point. When D195 in the trigger output circuit returns to its low state halfway through the trigger holdoff period, D312 switches back to its high-voltage state, and Q314 and D328 turn back on.

COMPARATOR

The bias on tunnel diode D350 is determined by the current division between R345 and R347 in series with D350, and is adjusted by R345 (COMP LEVEL) to be very close to its switching point when the fast ramp rundown approaches the staircase inverter level. When D372 becomes forward biased, the additional current through D350 and D372 causes D350 to switch to its high-voltage state, sending an output pulse through T350 to the regenerator.

At the fastest sweep rate there is no arming current for D350, but the increased current through D372 at the time of comparison switches D350 approximately 1 nsec after comparison starts.

REGENERATOR

In equivalent-time mode, the comparison pulse applied through T350 switches D360 to its high state, turning on Q364. As Q364 is turned on, a positive-going pulse is sent to the sampling unit and to the staircase driver in the horizontal sweep generator. D360 resets automatically following the pulse and Q364 turns off.

In real-time mode, the comparator circuit is not operating, and the regenerator circuit is operated by negative-going gate pulses from the real-time clock. Each clock pulse applied through R360 causes D360 to switch to its high state and Q364 to turn on.

Horizontal Sweep Generator

GENERAL

The horizontal sweep circuit includes a sweep lockout, a sweep gate multivibrator, a staircase driver amplifier, a

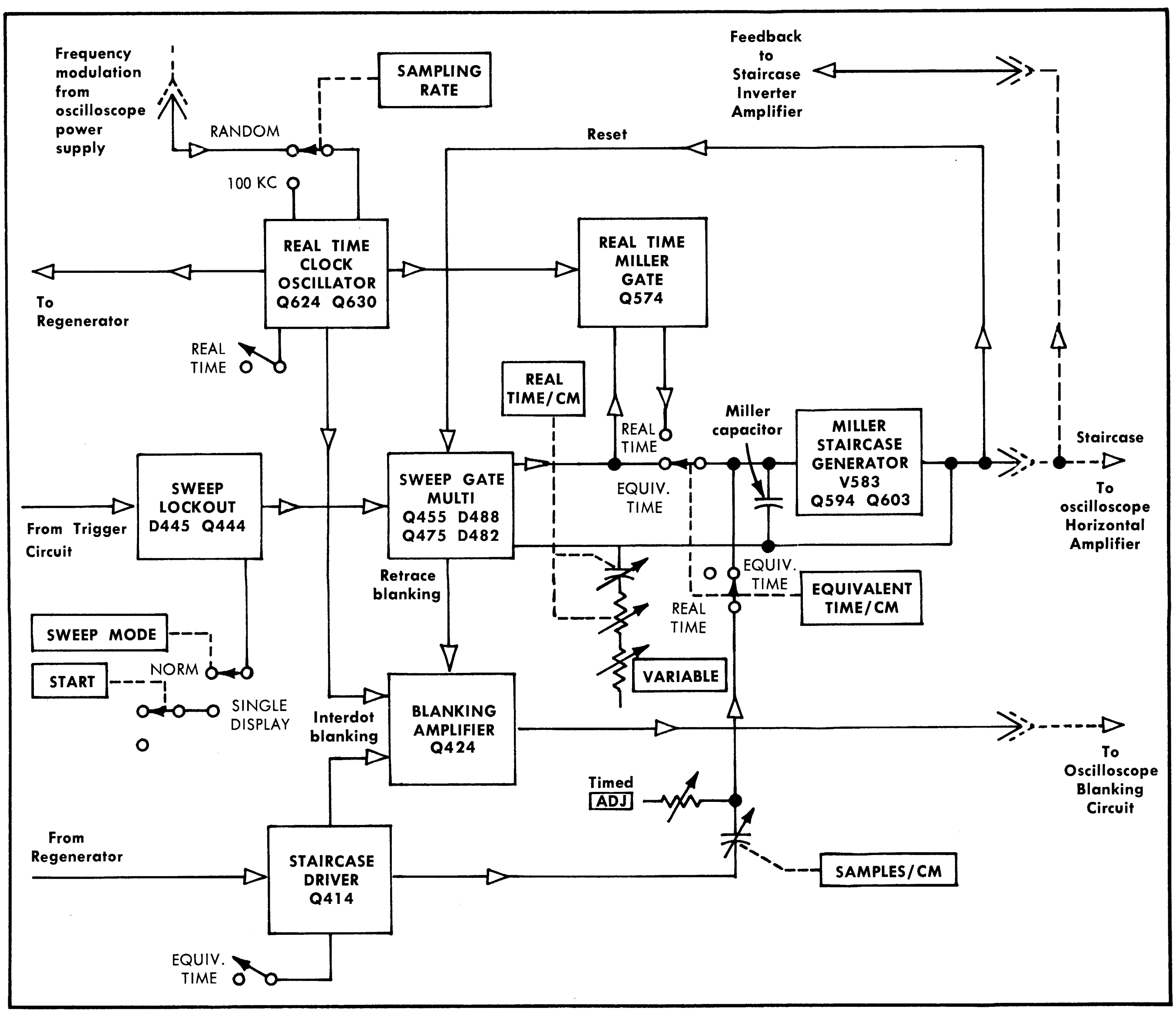


Fig. 3-7. Block diagram of Horizontal Sweep Generator.

real-time clock oscillator and gate, a Miller staircase generator and a blanking amplifier. Switching is provided by the Equivalent Time/Cm, the Real Time/Cm, the Time Position Range and the Samples/Cm switches.

Equivalent-Time Mode. Each time the trigger circuit sends a start pulse to the fast ramp circuit to initiate the sampling sequence, it also pulses the sweep lockout in the horizontal sweep circuit. If the sweep gate has been reset, the lockout circuit switches the gate so the sweep starts as soon as the first sample pulse is received. Further trigger pulses applied to the sweep gate through the sweep lockout have no effect until the gate has been reset following completion of the sweep. When triggered, the sweep gate disconnects the Miller staircase capacitors from the discharge path through the disconnect diodes, allowing pulses from the staircase driver to charge up the Miller capacitors.

Following comparison, the regenerator circuit sends a sample drive pulse to the sampling unit and a staircase-advance pulse to the staircase driver at the input to the Miller circuit. The staircase driver in turn sends pulses to the Miller staricase generator and to the blanking amplifier. The amount of charge in the pulses applied to the Miller staircase generator is determined by the capacitors connected into the circuit by the front-panel SAMPLES/CM switch. The step-by-step increase in the charge on the Miller capacitors produces the staircase output voltage.

The staircase output drives the oscilloscope horizontal amplifier for horizontal deflection of the crt beam and also provides the feedback comparison voltage for advancing the sample delay so the sample will be taken later each time with respect to the trigger. When the staircase output reaches a certain value (set by the SWEEP LENGTH control), it resets the sweep gate circuit, causing the Miller capacitors to discharge, and the circuit is ready to start another sweep with the next input trigger pulse.

Real-Time Mode. Whenever the EQUIVALENT TIME/CM switch is set to the REAL TIME position, the real-time clock oscillator operates. Output pulses from the oscillator are sent to the regenerator circuit to strobe the sampling unit, to the Miller circuit to step the staircase, and to the blanking amplifier. The real-time clock gate remains non-conducting while the sample is displayed. When the gate is pulsed by the clock, all the charge that has built up on the real-time capacitors is transferred through the gate to the Miller capacitors, producing an output step. The output of the circuit thus remains a staircase, but the size of each step is proportional to the amount of time elapsed since the previous step. Operation of the sweep lockout, the sweep gate and the blanking amplifier is essentially the same as for equivalent-time operation.

Single Display. When the SWEEP MODE switch is set to SINGLE DISPLAY and the START button pressed, the sweep lockout circuit permits a single trigger pulse to initiate a full sweep of the crt display, but locks out subsequent trigger pulses.

Blanking. During the time that a sample drive pulse is applied to the Miller circuit to step the staircase voltage, a pulse is also applied to the blanking amplifier, causing it to blank the crt while the voltage step is taken. This is called interdot blanking. During retrace of the sweep, while the sweep gate circuit is being reset, the gate circuit also applies a voltage to the blanking amplifier to blank the crt. This provides retrace blanking.

SWEEP LOCKOUT

Pulses from the collector of Q204 in the trigger circuit are sent through Q444 in the sweep lockout circuit to switch the sweep gate. Quiescently, with the SWEEP MODE switch set to NORM, Q444 is cut off and its collector is at about 6.5 volts. Each negative trigger pulse applied through C440 and R440 to the emitter of Q444 turns the transistor on rapidly, producing a fast 6-volt negative pulse at the collector. The pulse is sent through C446 and R448 to the sweep gate circuit. At the end of each pulse from the trigger circuit, the emitter of Q444 returns to ground and the transistor turns off. The positive-going collector pulse as Q444 turns off is shorted to ground through D448.

A single sweep of the crt is obtained when the SWEEP MODE switch (SW435) is set to SINGLE DISPLAY and the START button (SW430) is pressed. With the SWEEP MODE switch at NORM, the cathode of D445 is connected to ground through R431 and R435 and the diode is normally turned off. When the switch is set to SINGLE DISPLAY, the cathode is connected to a negative voltage from the voltage divider R438, R435 and R431. The diode is still in its low-voltage state, but is biased up near its switching point. The first negative trigger received from the trigger circuit switches D445 to its high-voltage state while Q444 sends the negative pulse to the sweep gate in the usual manner. Following the end of the trigger pulse, however, the emitter of Q444 is held below ground, keeping the transistor turned on. With Q444 turned on, negative pulses cannot be transmitted through the transistor to the sweep gate. As soon as the sweep gate has reset, the sweep is locked out and the staircase output is locked at zero.

In addition to setting the bias on D445, the SWEEP MODE switch in SINGLE DISPLAY position connects a voltage across C430, charging it to approximately 19 volts. If the START button is pressed, the negative side of the capacitor is connected to ground, causing a positive pulse to be applied to the cathode of D445 and the emitter of Q444. The diode switches momentarily to its low-voltage state and Q444 turns off. As soon as C430 has discharged, D445 returns to its triggerable bias point. The next pulse from the trigger circuit turns on Q444, initiating a single sweep of the display, and switches D445 back to its high-voltage state. Releasing the START button again connects C430 to —19 volts. This has no effect on either D445 or Q444, but it allows C430 to recharge, to be ready to initiate another single display.

At the end of the single sweep, the sweep gate resets and is ready to be switched, but with Q444 held in the conducting state, subsequent sweeps are locked out until the START button is pressed again.

SWEEP GATE

The sweep gate circuit (Q455-Q475) is a bistable multivibrator that operates with both transistors turned on during the sweep and both transistors turned off during the retrace. At the end of the retrace period, just prior to a new sweep, the voltage at the base of Q455 returns to a level slightly above ground, holding the transistor in cutoff. With the SWEEP MODE switch set to NORM, negative pulses are continuously being applied from the sweep lockout circuit to the sweep gate through C446 and R448. The first negative pulse that is able to foward-bias the base-emitter junction of Q455 turns on the transistor, switching the multivibrator. The collector of Q455 goes positive, turning on Q475. The collector of Q475 then goes negative and the regenerative action of the circuit causes both transistors to saturate. The negative voltage at the collector of Q475 reverse-biases D482 and D488, disconnecting the Miller circuit from the sweep gate, allowing the sweep to progress as the staircase capacitors charge.

The output signal from the Miller circuit is applied to the sweep gate circuit through R610, D610, R611 and R612 (SWEEP LENGTH). As the staircase voltage rises, more current is drawn through the sweep length network, diverting current from the base of Q455. R612 is adjusted so when the staircase output voltage reaches 52.5 volts, Q455 will be turned off. The negative step at the collector of Q455 turns on the blanking amplifier transistor and turns off Q475, allowing its collector to go positive. This positive-going collector voltage forward biases D488 and the staircase capacitors begin to discharge. The resulting rise on the grid of V583 operates through the Miller circuit, causing the staircase output voltage to drop quickly to near ground voltage. When the negative-going output forward-biases D482, the diode conducts and a state of clamped equilibrium exists. D488 remains forward biased and conducting current away from the grid of V583 until the sweep gate is triggered and switches again.

When the output voltage drops during the discharge of the staircase capacitor, D610 becomes reverse biased, disconnecting the sweep gate from the staircase output. C611, which had charged up to the staircase voltage, discharges through the SWEEP LENGTH control circuit, setting the holdoff time of the staircase. The current source is restored to the base of Q455 as C611 discharges; however, Q455 is held in cutoff by the current through D455 and R450. The next negative trigger from the sweep lockout will trigger the sweep gate to initiate a new sweep.

STAIRCASE DRIVER

In equivalent-time mode, Q414 serves as a constant-voltage pulse source for driving the samples/cm capacitors and the blanking amplifier. Capacitively-coupled positive pulses are applied from the regenerator circuit to the base of Q414, turning on the transistor and delivering negative pulses through R421 to C560 (SAMPLES/CM). The size of each pulse is set by SAMPLES/CM CAL adjustment R415. The amount of charge applied through D565 to the Miller grid circuit is determined by the particular capacitance value selected by the front-panel SAMPLES/CM switch.

In real-time mode, the emitter current supply for Q414 is disconnected and the circuit is inoperative.

REAL-TIME CLOCK AND MILLER GATE

The real-time clock oscillator consists of a blocking oscillator (Q630) and a transistor that provides current (Q624) to the blocking oscillator. When the SAMPLING RATE switch (SW615) is set to the 100 KC position, Q624 is operated as a 100-kc oscillator. In this mode, sufficient current is supplied from the collector of Q624 during oscillation peaks to completely charge C632 from +19 volts to below ground. When the emitter voltage of Q630 becomes slightly negative, D635 turns on, forward-biasing the base-emitter junction of Q630. This transistor turns on, starting the blocking oscillator action that produces a large output pulse across each output winding of T635. The blocking oscillator pulses are sent to the regenerator circuit, the blanking amplifier (Q424) and the real-time Miller gate (Q574). When the backswing has ended, C632 is charged back up to +19 volts.

When Q574 is momentarily saturated by the blocking oscillator pulse, the charge on the real-time timing capacitors is transferred to the Miller capacitor C495, causing the staircase output to make a step.

In the RANDOM POSITION of the SAMPLING RATE switch, Q624 is connected as a dc current source that can charge C632 from +19 volts to a point slightly below ground in about 12.5 μsec. This current to C632 is frequency-modulated by 60 cps hum from the oscilloscope heater circuit. Thus the oscillation period of Q630 in random mode varies by about $\pm 5\%$. The purpose of the modulation is to break up false displays that might occur as a result of viewing signals that are multiples of 100 kc.

MILLER STAIRCASE GENERATOR

In equivalent-time mode, the negative output pulses from the staircase driver circuit are sent through R421, C560, D565 and R570 to the Miller capacitors (C493 and C495) and the grid of V583. The amount of the charge delivered to the capacitors is determined by the value of C560.

When the sweep gate circuit is holding off the sweep, the energy of the stepping pulses is sent through D488 and dissipated. As soon as the sweep gate has switched and disconnected D482 (the discharge path), the pulse energy starts to charge up the Miller capacitors. In this mode (equivalent-time), Q574 is shorted out by the EQUIVALENT TIME/CM switch. The voltage on the grid of V583 begins to drop and the voltage on the cathode follows. An amplified positive signal is produced at the collector of Q594 and coupled to the output. This signal, applied to the output side of the Miller capacitors keeps the grid of the tube nearly stationary and each energy pulse applied to the grid appears as a charge on C493 and C495.

The staircase voltage output, which runs from zero to 52.5 volts, is sent through the EQUIVALENT TIME/CM switch to the staircase inverter amplifier, to the sweep gate to reset the gate, and to the oscilloscope horizontal amplifier to produce the horizontal deflection of the crt beam.

When enough pulses have been received to raise the charge on the Miller capacitors to the required staircase amplitude, the sweep gate is switched, causing the disconnect diodes to discharge the Miller capacitors, and the staircase recovers to produce another sweep.

During positive excursions, the output emitter follower, Q603, is turned on to provide the necessary current at the output. During reset, D597 turns on to reset the base of the staircase near zero volts. R585 (STAIRCASE ZERO) adjusts the output level so the staircase does start at zero volts.

In real-time operation, the real-time timing capacitors C488, C486, C490 and C493 are used to produce a ramp sawtooth waveform at the emitter of Q574. In this mode, Q574 is not shorted out, but is gated on by the blocking oscillator pulses from the real-time clock. The particular combination of capacitors and resistors selected by the REAL TIME/CM switch then produces a linear ramp as the capacitors charge from the —100-volt supply. When Q574 is pulsed on, the charge is transferred to C495 to produce the real-time staircase step. Each step made in real-time mode is proportional to the real time elapsed between the previous sample and the new one.

BLANKING AMPLIFIER

The blanking amplifier (Q424) is driven by the staircase driver, the real-time clock and the sweep gate to provide blanking signals to the oscilloscope. The collector of Q455 in the sweep gate circuit is connected through R457 to the base of Q424, and one winding of T635 in the real-time clock is connected through D458 and R458 to the base of the transistor. While the staircase is being generated, the voltage applied to Q424 from the sweep gate circuit is set slightly positive so the blanking amplifier will be turned off except when a negative pulse is applied from the staircase driver (through R420 and C420) or from the real-time clock. During retrace, while the Miller capacitor is being discharged and the horizontal deflection voltage is returning the crt beam to the left side of the screen, the negative voltage from the sweep gate keeps Q424 turned on.

The collector circuit of Q424 is completed in the oscilloscope, so that whenever the transistor is turned on, current through it produces blanking of the crt. Thus, no sample dot is displayed on the screen while the dot position is changing or while the beam is retracing to the left side of the crt.

SECTION 4
MAINTENANCE

This section of the manual contains maintenance and troubleshooting suggestions for the Type 5T3. Illustrations are included for locating the circuit components mounted on the etched-wiring boards.

PREVENTIVE MAINTENANCE

Preventive maintenance consists of cleaning, visual inspection, lubrication and recalibration. Preventive maintenance preformed on a regular basis helps prevent instrument failure and improves reliability of the instrument. The severity of the environment will determine the frequency of maintenance.

Cleaning

The Type 5T3 should be cleaned as often as operating conditions require. The side panels of the oscilloscope provide partial protection against dust accumulating in the interior of the instrument, but a certain amount of dust is brought in by circulating air. Operation without the side panels in place requires more frequent cleaning. If the Type 5T3 is stored on a shelf when not in use, cover it with a cloth or piece of plastic to keep dust out of the instrument.

To clean the interior, blow off any accumulated dust with dry, low-velocity air. Do not use a high-velocity compressed air stream, as this may damage some of the small components. Any remaining dust or dirt in the interior may be removed with a small cloth or cotton-tipped applicator dampened with isopropanol or a mild solution of water and detergent.

CAUTION

Do not clean any plastic materials with organic chemical solvents such as benzene, acetone or denatured ethyl alcohol. These may damage the plastics. (Isopropanol is safe to use.)

The front panel of the instrument may be cleaned with a soft cloth dampened with a mild solution of water and detergent. Abrasive cleaners should not be used.

Lubrication

The reliability of potentiometers, rotary switches and other moving parts can be increased by keeping them properly lubricated. Use a cleaning-type lubricant on shaft bushings, interconnecting plug contacts and switch contacts. Lubricate switch detents with a heavier grease. A lubrication kit containing the necessary lubricating materials and instructions is available from Tektronix. Order by Tektronix Part Number 003-0342-00.

Visual Inspection

The Type 5T3 should be inspected occasionally for possible defects such as damaged connectors, improperly seated pin connectors, transistors or Nuvistors, frayed cable shields and heat-damaged components.

The corrective procedures for most visible defects are obvious. Particular care must be taken, however, if heat-damaged parts are located. Overheating usually indicates other trouble in the instrument. For this reason, the cause of the overheating should be located and corrected before operating the instrument.

Transistor and Nuvistor Checks

Periodic checks of the transistors and Nuvistors used in the Type 5T3 are not recommended. The best check of performance is the actual operation of the component in its circuit. However, if a circuit malfunction occurs, the transistors and Nuvistors in the circuit should be checked as described in the troubleshooting procedure.

Recalibration

To ensure that the Type 5T3 is operating correctly and accurately, it should be checked and recalibrated after each 500 hours of operation, and at least once every 6 months. Complete calibration instructions are given in Section 5. In some cases, minor troubles not apparent during normal use may be revealed or corrected by recalibration.

CORRECTIVE MAINTENANCE

Corrective maintenance generally consists of component replacement and instrument repair. Special techniques or procedures required to replace parts of this instrument are described here.

Replacement Parts

Standard Parts. All electrical and mechanical part replacements for the Type 5T3 can be obtained through your local Tektronix Field Office or representative. However, many of the standard electronic components can be obtained locally in less time than is required to order them from the factory. Before purchasing or ordering replacement parts, consult the Parts List in Section 6 of this manual for the required characteristics.

NOTE

When obtaining replacement parts, remember that the physical size and shape of a component may affect its performance, especially at high frequencies. Replace components only with identical parts unless it is known that a different component will not adversely affect the instrument operation.

Special Parts. In addition to the standard electronic components, some special components and parts are used in the Type 5T3. These parts are manufactured by or for Tektronix, or are selected by Tektronix to meet specific performance requirements. Each of these special parts is indicated in the Parts List by an asterisk preceding the part number. In addition, most of the mechanical parts used in this instrument have been manufactured by Tektronix. Order all special parts directly from your Tektronix Field Office or representative.

Ordering Parts

When ordering replacement parts from Tektronix, always include the following information:

1. A complete description of the part as given in the Parts List. If it is an electrical part, also give the circuit number.

2. The instrument type (Type 5T3).

3. The instrument Serial Number.

Soldering Techniques

Etched-Wiring Boards. Use ordinary 60/40 tin-lead solder with a 35- to 40-watt pencil-type soldering iron. A hotter type of iron may separate the etched-wiring material from the laminate base. The tip of the iron should be clean and properly tinned for quick heat transfer to the solder joints. The following technique is suggested for replacing a component on an etched-wiring board.

Removal:

1. Grip one lead with a pair of long-nose pliers. (If the component is known to be defective, the leads may be cut close to the component body for individual removal.)

2. Touch the tip of the soldering iron to the lead at the solder connection (see Fig. 4-1). When the solder begins to melt, pull the lead out gently. A clean hole should be left in the board. If not, the hole can be opened by reheating the solder and quickly inserting a pointed tool or toothpick into the hole.

3. Remove each of the other leads in the same manner.

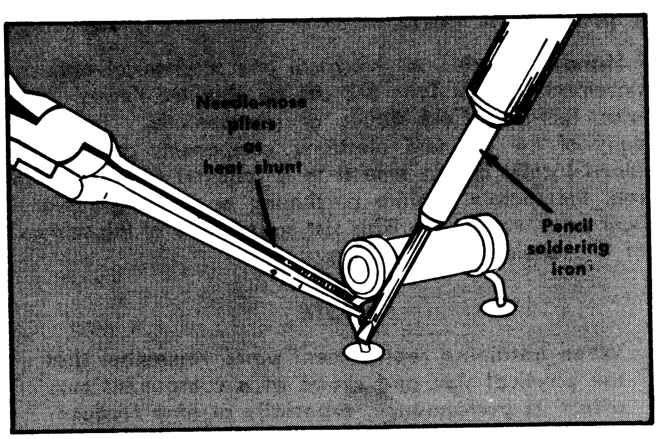


Fig. 4-1. Apply soldering iron to the heat-shunted lead when removing a component from an etched-wiring board.

Installation:

1. Bend the leads of the new component to match the holes in the board.

2. Insert the leads into the board and position the component properly with respect to the board.

3. Heat-shunt each lead by holding it with long-nose pliers while applying a small amount of solder to the connection on the reverse side of the board.

4. Clip off the excess lead length.

5. Clean the area around the solder connection with a flux-remover solvent. Be careful not to remove any information printed on the etched-wiring board.

Metal Terminals. When soldering to metal terminals such as connector jacks and switch terminals, ordinary 60/40 tin-lead solder can be used. The soldering iron should have a 40- to 75-watt rating and a 1/8th inch chisel-shaped tip.

Observe the following precautions:

1. Apply only enough heat to make the solder flow freely.

2. If the leads of small components are being soldered to the terminals, be sure to heat-shunt the leads with long-nose pliers.

3. Apply only enough solder to form a solid connection. Excess solder may impair the function of the part.

4. If excess wire extends beyond the completed solder joint, clip it off and remove it from the instrument. Loose wire ends in the instrument may cause shorting.

Replacement Procedures

Etched-Wiring Board Removal. If one of the etched-wiring boards is damaged and cannot be repaired, or if one of the built-in capacitors in the anode circuit of D182 is damaged, the board will need to be replaced. When replacing a defective board, the entire assembly including the soldered-on components should be replaced. Part numbers for the replacement board assemblies are given in the mechanical Parts List. Nearly all electrical connections to the boards are made with pin connectors or mini-jack coax connectors. The exceptions to this are the 3 bus wires from the Equivalent Time/Cm switch and two wires from the Timing Current control to the Trigger and Fast Ramp board. The following procedure is suggested for replacing one of the etched-wiring boards.

Removal:

1. Disconnect all pin connectors and coax mini-jack connectors from the board.

2. Remove all screws holding the board to the chassis frame.

3. If the Trigger and Fast Ramp board is being replaced, heat-shunt and unsolder the 2 bus wires from the Timing Current control. Cut the 3 bus wires connecting the board to the Equivalent Time/Cm switch.

4. Lift the etched-wiring board out of the instrument. Do not force or bend it.

5. Unsolder and remove the cut sections of bus wire from the board and the Equivalent Time/Cm switch.

Installation:

1. Reverse the order of removal to install a new etched-wiring board.

2. Replace the bus wires between the board and the Equivalent Time/Cm switch.

3. Connect the pin connectors to the board as shown in Figs. 4-2 or 4-3. Replace the pin connectors carefully so they mate correctly with the pins.

Rotary Switches. Individual parts or sections of rotary switches are normally not replaced separately. If a switch is defective, the entire assembly should be replaced. Order the switch either with or without the associated components wired in place. Part numbers are given in the electrical Parts List.

Tag the leads and switch contacts with corresponding identification tags as the leads are disconnected, then use the old switch as a model for installing the new one. When soldering the leads to the new switch, do not let the solder flow beyond the rivet on the switch terminal. Spring tension of the switch contact will be destroyed by excess solder.

TROUBLESHOOTING

This portion of the Maintenance section is provided to aid in locating and correcting trouble in the Type 5T3 if trouble develops. Information contained in the circuit description, the calibration section and the schematic diagrams is also helpful when troubleshooting the instrument.

Troubleshooting Aids

Diagrams. Circuit schematic diagrams are given on fold-out pages in Section 6. The circuit numbers and electrical values of all components, as well as significant voltages and waveforms, are shown on the circuit diagrams. All front-panel and internal control names are given and all pin connectors and coax connectors are labeled on the diagrams. The components in each separate circuit are assigned related circuit numbers so they can be easily located on the diagrams. When referring to the voltages and waveforms that are shown, be sure to note the test conditions under which they were obtained.

The sections of rotary switches are coded on the diagrams to indicate the physical positions of the switch contacts. The sections are numbered from the front panel to the rear of the assembly. The letters F and R indicate whether the front or rear of the section is used to perform the particular switching function. For example, 3R refers to the rear side of the third switching section.

Etched-Wiring Boards. The circuit numbers of many important components are labeled on the etched-wiring boards. Connecting pins and coax jacks are also marked. Figs. 4-2 and 4-3 show the physical locations of all components mounted on the circuit boards and show the connections to the pins and jacks.

Wiring Color-Code. All insulated wire in the Type 5T3 is color-coded for convenience in circuit tracing. Signal-carrying leads are identified with one or two colored stripes. Voltage-supply leads are coded with three stripes to indicate the approximate voltage carried by the lead, using the standard EIA resistor color code. The code is read starting with the widest stripe and proceeding in order of decreasing width. A white background indicates a positive voltage and a tan background indicates a negative voltage. As an example, coding on the +100-volt lead is brown (widest stripe), black and brown (narrowest stripe), on a white background.

Resistor Color-Code. Some metal-film resistors, identifiable by their gray body color, are used in this instrument. Color-coding of metal-film resistors is the same as that of composition resistors, using the EIA code, except that 3 significant figures and a multiplier are indicated, instead of only 2 significant figures and a multiplier.

Troubleshooting Techniques

The following procedure is arranged in a sequence to check operational troubles before proceeding with extensive troubleshooting. If the trouble is not located by the checks, the remaining steps will aid in location of the defective parts. Follow the replacement procedures described earlier in this section when replacing any defective parts.

Check Control Settings. Incorrect control settings can indicate trouble that does not exist. For example, incorrect setting of the Triggering controls may appear as defective trigger or sweep circuits. If there is any question about the correct function and use of a control, refer to the Operating Instructions section of this manual.

Check Associated Equipment. Before troubleshooting the Type 5T3, be sure that the equipment used with it is operating correctly. Check that input cables are not defective. If another Timing Unit is available, substitute it in the oscilloscope and check that the oscilloscope and sampling unit are all right. Check the power-supply voltages of the oscilloscope with the Type 5T3 out of the oscilloscope, then again with the Type 5T3 installed.

CAUTION

Turn off power while removing or inserting the plug-in unit.

Check Instrument Calibration. The procedure given in the Calibration section of this manual provides a step-by-step check of the various circuits and usually will indicate

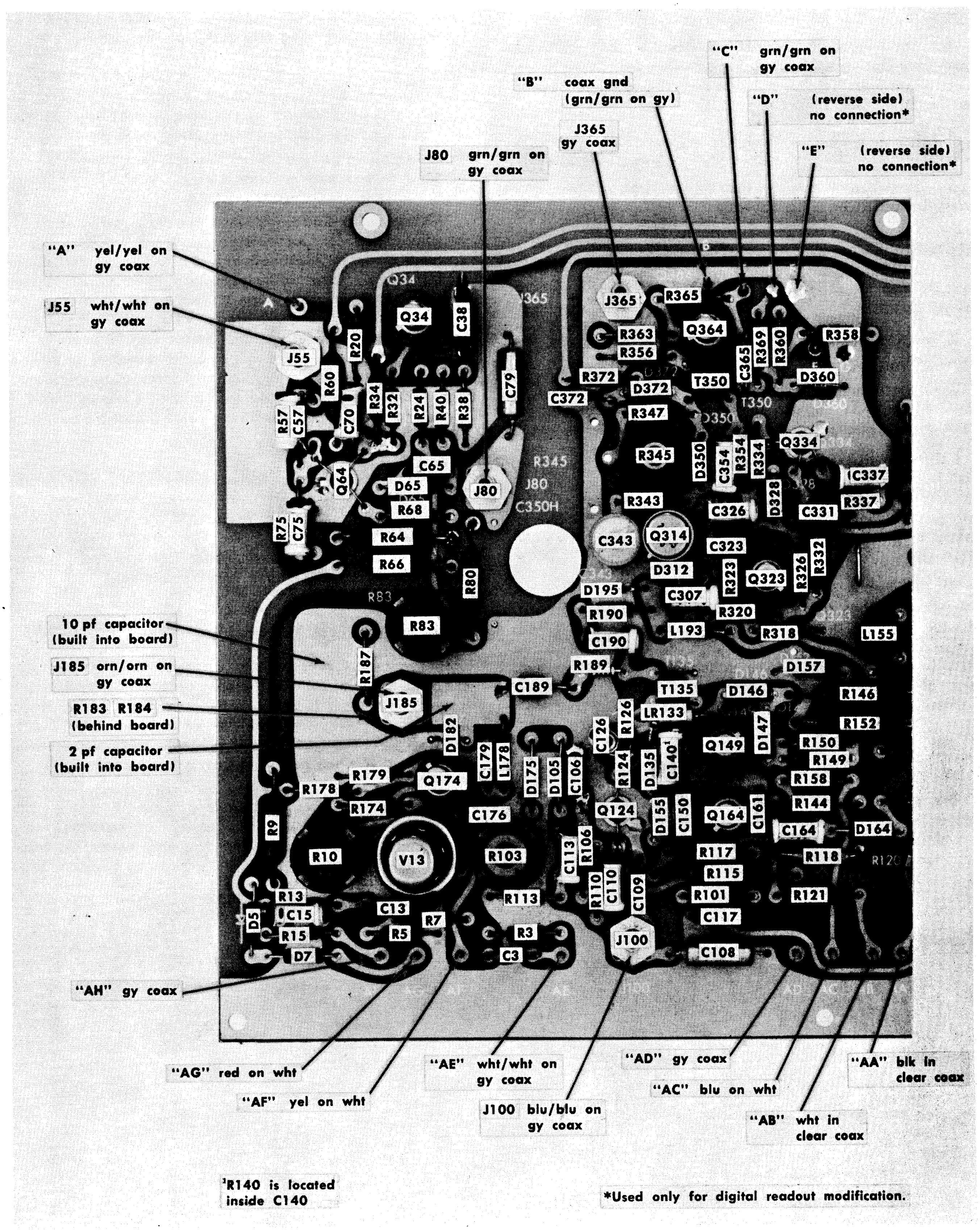


Fig. 4-2a. Circuit components and pin-connector wiring code on Trigger and Fast Ramp etched-wiring board (front half).

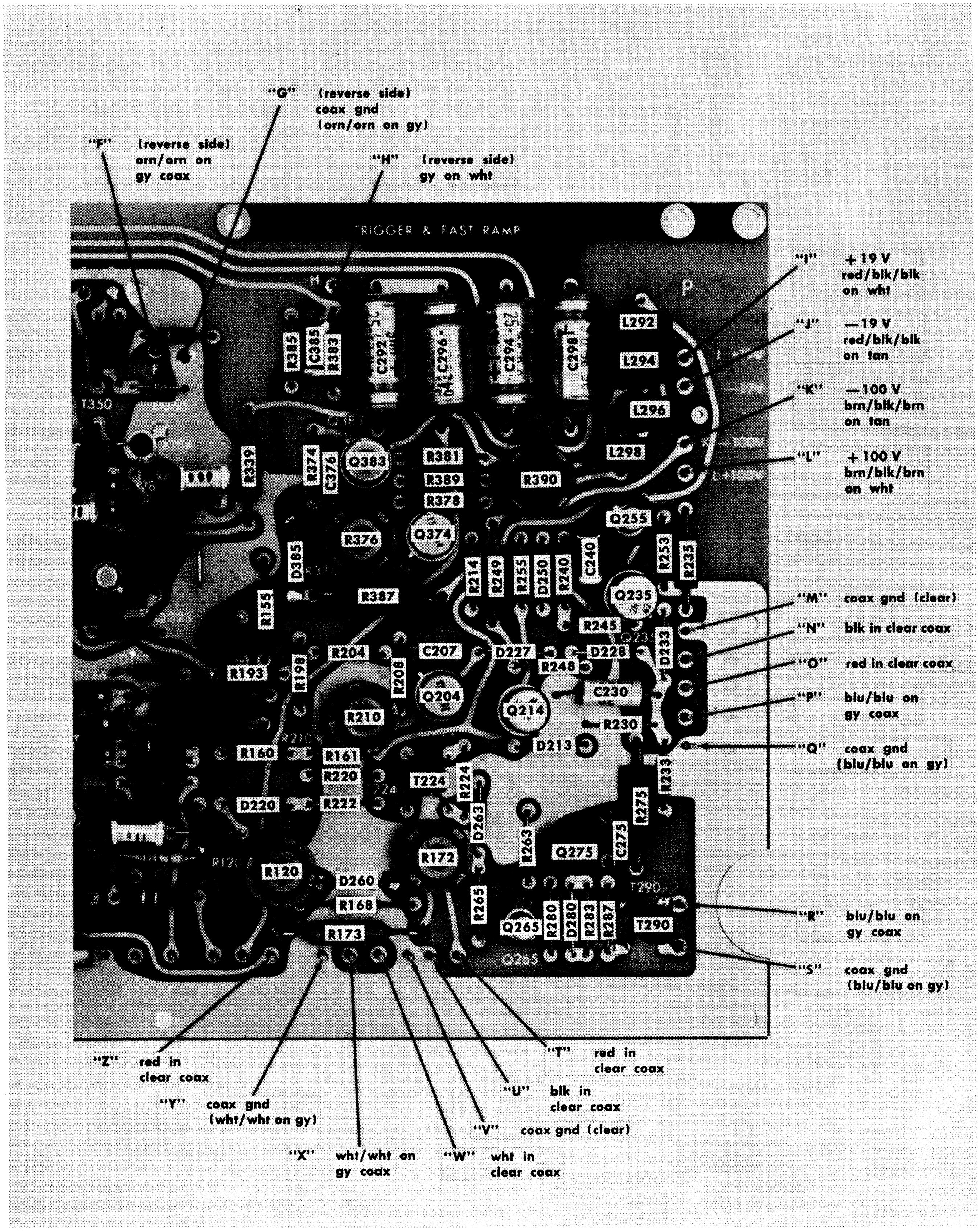


Fig. 4-2b. Circuit components and pin-connector wiring code on Trigger and Fast Ramp etched-wiring board (rear half).

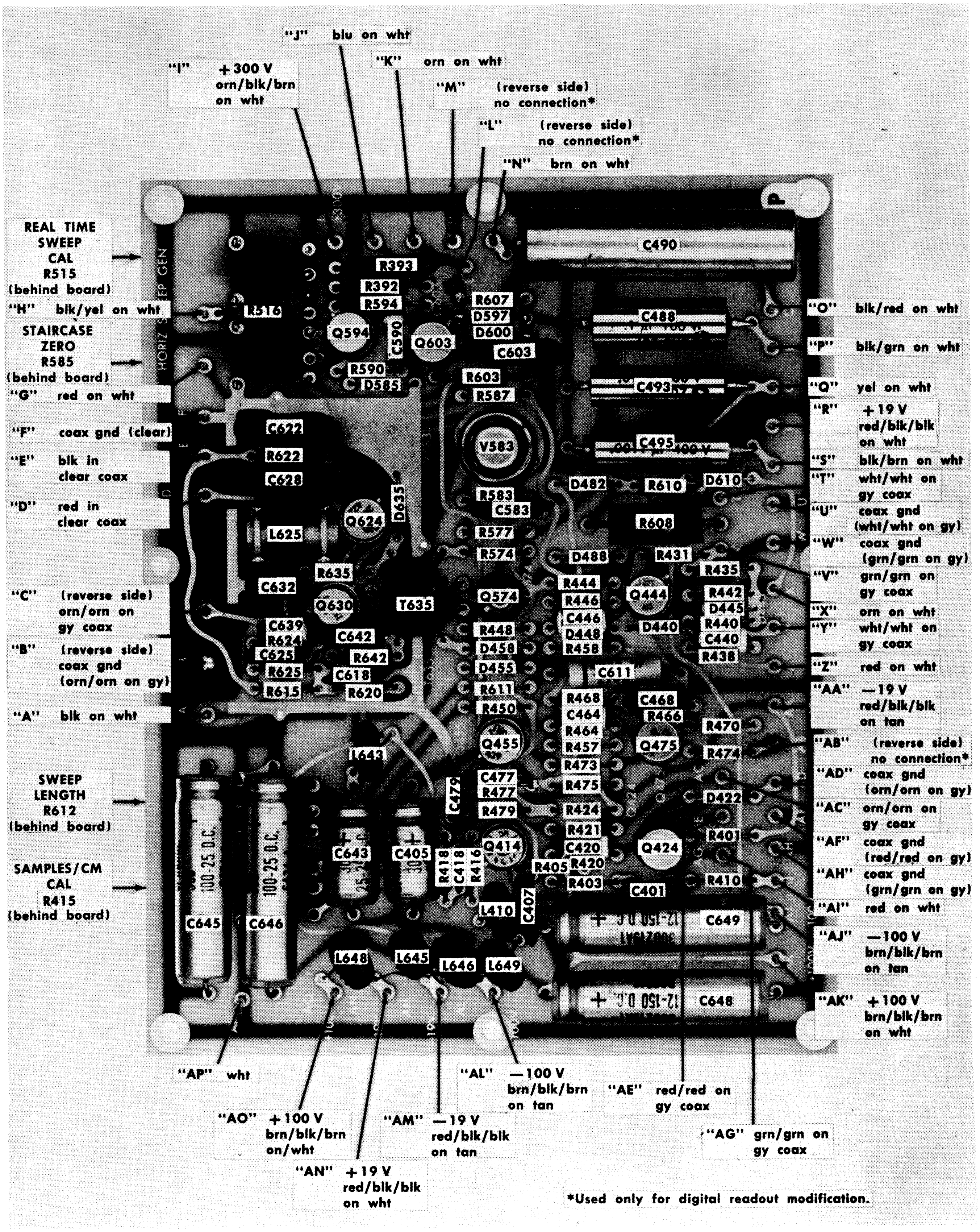


Fig. 4-3. Circuit component locations and pin-connector wiring code on Horizontal Sweep Generator etched-wiring board.

the location of the trouble. The indicated trouble may only be the result of a misadjustment and may be corrected by calibration. If individual calibration steps are performed out of sequence, remember that any change in adjustment settings will affect subsequent steps of the procedure.

Isolate the Trouble to a Circuit. If the trouble has not been corrected or isolated to a particular circuit with the preceding steps, make the following checks if possible:

a. Check for the correct resistance readings at the plug-in unit power connector as indicated in Table 4-1. The power plug (P4) is the plug nearest the center of the oscilloscope.

TABLE 4-1

Power Plug Resistance Checks[1]

Pin[2]	Resistance to ground (±20%). 2nd reading with leads reversed.
2	0
3	100 Ω - 350 Ω
5	6 kΩ - 12 kΩ
8	1.5 MΩ
9	0
10	1.7 kΩ - 900 Ω
11	15 kΩ
12	0
15	19 kΩ
17	7.5 kΩ - 8.5 kΩ
18	70 Ω - 80 Ω
20	1.5 MΩ
21	8 MΩ - 30 Ω
22	1.8 kΩ - 1.0 kΩ
24	3 kΩ - 16 kΩ

[1] **Type 5T3 disconnected from oscilloscope.**
[2] **All other pins have infinite resistance to ground.**

b. Check the etched-wiring board connectors for loose or incorrect connections. The correct connections are shown in Figs. 4-2 and 4-3. In some cases, the detachable pin connectors may aid you in locating the source of trouble by disconnecting a circuit from the rest of the instrument.

c. Check for voltages and waveforms with the instrument turned on. Typical voltages and waveforms are given on the schematic diagrams. Voltage measurements should be made with a 20,000 ohms/volt dc voltmeter, accurate within 3% on all ranges. Insulate the test prods to prevent accidental shorting. Check for waveforms with a 30-Mc test oscilloscope and a 10× probe (approximately 10-megohm input resistance). The Type 5T3 may be operated on a plug-in extension cable (Tektronix Part Number 012-0064-00) and Gremar strobe cable (Tektronix Part Number 012-0070-00) for checking the unit in detail. Two Gremar cables are needed to check internal triggering.

Check the Circuit Visually. After isolating the trouble to a particular circuit, check the circuit for damaged parts or broken connections. Often a visual inspection can indicate the source of trouble.

Check Individual Components. Components that are soldered in place can be checked most easily by disconnecting one end. This eliminates incorrect measurements due to the effects of surrounding circuitry.

Transistors and Nuvistors: Most circuit failures are caused by the failure of an active component due to normal aging and use. The recommended method of checking a transistor or Nuvistor is by direct substitution, since static testers do not indicate the circuit performance of a component. A dynamic tester such as a Tektronix Type 570 or 575 characteristic-curve display oscilloscope may also be useful for checking a transistor or Nuvistor that is suspected of being defective. Before installing a replacement, be sure that the circuit voltages are not abnormal. If replacement is made without checking the circuit, the new component may be damaged by a defective circuit. After replacing a transistor or Nuvistor, check the calibration of the affected circuit or circuits.

Diodes: Ordinary semiconductor diodes can be checked for an open or shorted condition by measuring the resistance between terminals. With an ohmmeter scale using an internal source of 3 volts or less, the resistance should measure very high in one direction and very low with the leads reversed.

CAUTION

Do not use an ohmmeter scale that uses a high-voltage source. If the junction breakdown voltage is exceeded, the reading will not be correct and the diode may be damaged. Do not check tunnel diodes with an ohmmeter.

Resistors: Check resistor values with an ohmmeter. The tolerance permitted for each resistor used in the instrument is given in the Parts List. It is usually unnecessary to replace a resistor unless the value is far out of tolerance.

Inductors: Check inductors for an open condition with an ohmmeter. Shorted or partially shorted inductors may sometimes be found by checking the circuit waveforms. An inductance meter is required to determine the exact value.

Capacitors: A leaky or shorted capacitor can be detected by checking it with an ohmmeter set to a high scale. (Do not exceed the voltage rating of the capacitor.) The resistance reading should be infinite after the capacitor is charged. An open capacitor can be detected with a capacitance meter or by trying to pass an ac signal through it.

NOTES

SECTION 5
CALIBRATION

GENERAL INFORMATION

A complete verification and calibration procedure for the Type 5T3 is provided in this section. This procedure checks the instrument to the performance characteristics given in Section 1.

Specialized calibration equipment is used wherever applicable to provide the quickest and most accurate calibration. If this equipment is not available, substituted equipment must equal or exceed the requirements listed below under "Equipment Required". If the equipment does not meet these requirements, the Type 5T3 cannot be calibrated to the accuracy given. In such cases, the difference between the accuracy of the equipment used and the specified equipment accuracy must be added to the tolerances listed in the calibration steps.

This procedure may be used to make only the calibration adjustments by performing those steps entitled "Adjust . . . . . ◐". The symbol ◐ is provided to locate the "Adjust" steps.

In addition, a calibration outline is included at the end of the procedure. This outline can be used as a guide for quick calibration by an experienced calibrator, or as a checklist to verify correct calibration and operation of the Type 5T3. The step numbers correspond to the steps in the calibration procedure.

Any maintenance that is needed should be performed before proceeding with the calibration. Troubles which become apparent during calibration should also be corrected before proceeding. Maintenance procedures are given in Section 4 of this manual.

The following procedure is arranged in a sequence that allows the Type 5T3 to be calibrated with the least interaction of adjustments. Each step contains complete information for performing that step. If desired, some of the steps may be performed out of sequence or may be performed individually. However, since some adjustments affect the calibration of other circuits, it may be necessary to check some of the subsequent steps of the procedure. The steps that may be affected by an adjustment are listed under "Interaction" at the end of the adjustment step.

Equipment Required

The following (or equivalent) equipment is required for a complete calibration of the Type 5T3. The equipment is illustrated in Figs. 5-1 and 5-2.

1. Sampling Oscilloscope, Tektronix Type 661. Compatible with Tektronix 4-Series Sampling Units and 5-Series Timing Units. Amplitude/Time Calibrator accurately calibrated at 100 Mc.

2.[1] Sampling Unit, Tektronix Type 4S1. Risetime ≤ 350 psec; 50-ohm vertical inputs.

3.[2] Sampling Unit, Tektronix Type 4S2. Risetime ≤ 100 psec; 50-ohm vertical inputs.

4. Test Oscilloscope, Tektronix Type 545B with Type 1A1 Plug-In Unit. Bandpass from dc to at least 30 Mc; deflection factors from 10 volts/cm to 0.005 volt/cm; sweep rates from 10 msec/cm to at least 2 μsec/cm; ac and dc vertical input coupling; voltage and timing accuracy within $\pm 3\%$; 1-kc calibrator output waveform. Single vertical input channel is used.

5. Time-Mark Generator, Tektronix Type 180A. Time markers from 5 sec to 1 μsec; sine waves of 5 Mc; 10 Mc and 50 Mc; accuracy within 0.1%.

6. Pretrigger Pulse Generator, Tektronix Type 111. Output pulses of 2-nsec duration, 100-kc repetition rate, risetime less than 1 nsec and amplitude greater than 1 volt; capable of operating in a 50-ohm system.

7. Oscillator Power Supply (e.g., General Radio Type 1201-B). Compatible with oscillators requiring a power supply.

8. Oscillator, 500-Mc (e.g., General Radio Type 1209-B). Required only for high-frequency triggering check. Sine wave output with peak-to-peak amplitude of at least 2 volts into 50 ohms; accuracy within $\pm 3\%$.

9.[2] Oscillator, 2-Gc (e.g., General Radio Type 1218-A). Sine wave output with peak-to-peak amplitude of at least 2 volts into 50 ohms; amplitude within $\pm 3\%$.

10.[2] Oscillator, 5-Gc (e.g., Polarad Model 1107). Sine wave output with power amplitude of at least 1 mw; amplitude within $\pm 3\%$.

11.[2] Bolometer (e.g., Hewlett-Packard Type 431-C). Characteristic impedance 50 ohms; maximum sensitivity at least 6 μw; accuracy within $\pm 3\%$.

12. Dc Voltmeter (e.g., Simpson Model 262 Multimeter). Low-voltage scales. Full-scale accuracy within $\pm 3\%$. Used only for zero-voltage checks. Dc-coupled test oscilloscope may be substituted.

13. 10× Probe for test oscilloscope. Tektronix P6006 Probe recommended. Tektronix part number 010-0127-00 (BNC) or 010-0125-00 (UHF).

14. 10-nsec coaxial cable (RG-58A/U) with GR 50-ohm connectors. Standard accessory with Type 5T3. Tektronix part number 017-0501-00.

15. One 5-nsec coaxial cable (RG-8A/U) with GR 50-ohm connectors. Two are required for UHF Sync triggering check. Tektronix part number 017-0502-00.

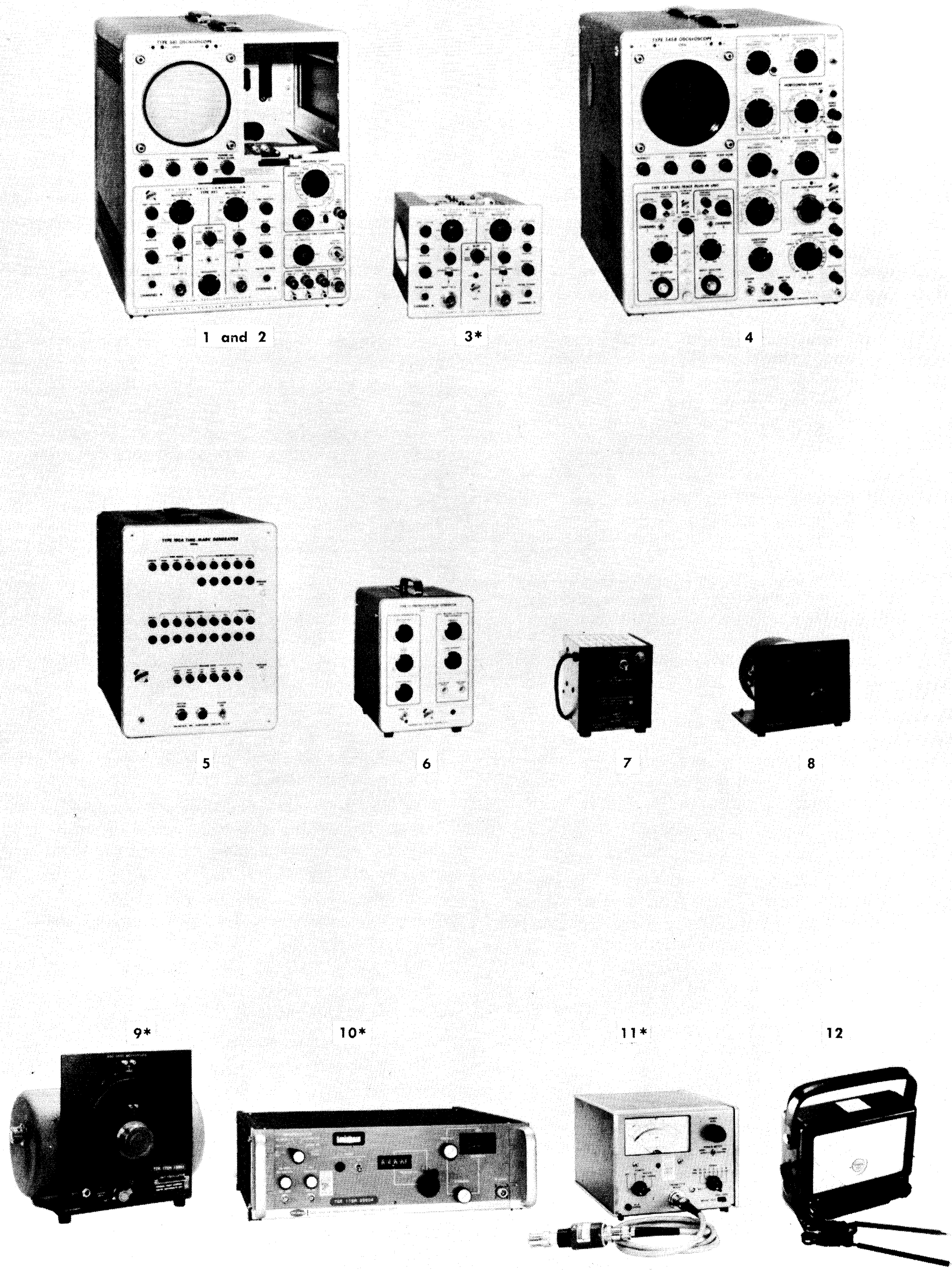
16. 42-inch coaxial cable for connecting to time-mark generator and test oscilloscope calibrator. Tektronix part number 012-0057-00 (BNC) or 012-0001-00 (UHF).

17. Variable attenuator with GR 50-ohm connectors. Tektronix part number 067-0511-00. Fixed attenuators, as required, may be substituted.

18. Two 2× T-attenuators. 50-ohm characteristic impedance; GR 50-ohm connectors. Tektronix part number 017-0046-00.

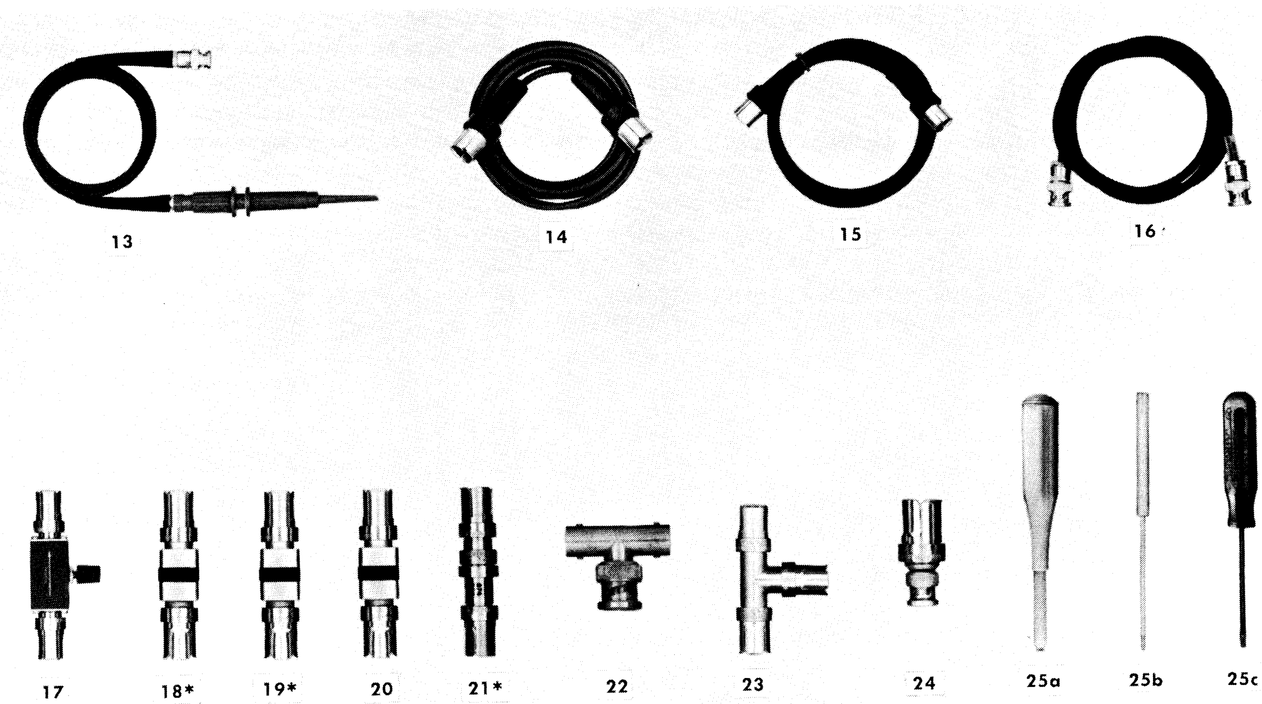
---

[1]If a 4-Series sampling unit without trigger takeoff is used, external triggering must be provided for the Type 5T3, and the internal triggering checks must be omitted.
[2]Required only for UHF Sync Triggering check.



*Required only for UHF Sync triggering check.

Fig. 5-1. Recommended calibration equipment.



*Required only for UHF Sync triggering check.

Fig. 5-2. Small calibration equipment and tools.

19.[2] One 5× T-attenuator. 50-ohm characteristic impedance; GR 50-ohm connectors. Tektronix part number 017-0045-00.

20. Two 10× T-attenuators. 50-ohm characteristic impedance; GR 50-ohm connectors. Standard accessory with Type 5T3. Tektronix part number 017-0044-00.

21.[2] General Radio 10× T-attenuator. 50-ohm characteristic impedance. General Radio part number 874-G20.

22. BNC T-connector. Required only for external triggering check. Tektronix part number 103-0030-00.

23. GR T-connector. 50-ohm characteristic impedance. Required only for high-frequency and UHF triggering checks. Tektronix part number 017-0069-00.

24. Connector adapter. GR/BNC plug. Tektronix part number 017-0064-00.

25. Adjustment tools (see Fig. 5-2):

a. Plastic screwdriver-type tool. Shaft length 1½ inches. Tektronix part number 003-0000-00.

b. Plastic coil-adjustment tool. Separate handle and small hex tip. Required only for adjusting 100-kc real-time clock. Tektronix part number 003-0307-00 for handle; 003-0310-00 for tip.

c. Pocket-type screwdriver. Blade width less than ⅛-inch.

26. Connector adapters as required for adapting between connector types:

[2] Required only for UHF Sync Triggering check.

a. GR/UHF jack. Tektronix part number 017-0022-00.

b. GR/UHF plug. Tektronix part number 017-0023-00.

c. GR/BNC jack. Tektronix part number 017-0063-00.

d. GR/BNC plug. Tektronix part number 017-0064-00.

Preliminary Setup

1. Remove the right side panel of the Type 661 Oscilloscope.

2. Install the Type 5T3 in the timing unit compartment of the Type 661 and a Type 4S1 Sampling Unit in the sampling unit compartment.

3. Connect the Type 661 Oscilloscope and the other test instruments to the power line.

4. Turn on the instruments and allow at least 5 minutes warm up before beginning the procedure.

5. Connect the 10× probe to the test oscilloscope vertical input connector.

CALIBRATION PROCEDURE

A test equipment setup picture is shown for each major group of adjustments or checks. Beneath each setup picture is a complete list of front-panel control settings. Any control that has been changed from the setting at the end of the previous step is given in bold type.

Throughout the procedure, except where noted, the EQUIVALENT TIME/CM MAGNIFIER knob is locked to the TIME POSITION RANGE switch. Only one channel of the sampling unit is utilized in the procedure—Channel A will be assumed.

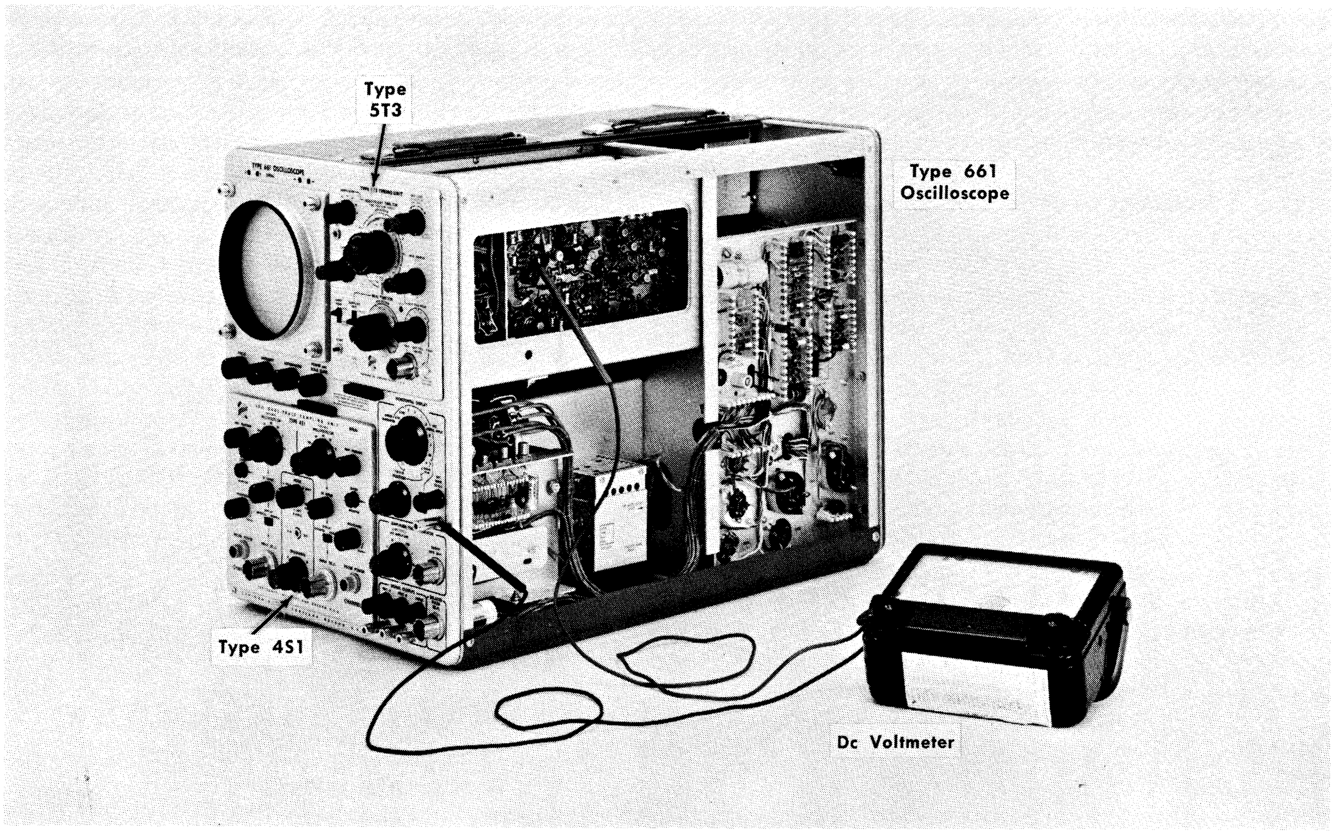


Fig. 5-3. Test equipment setup for steps 1 through 6.

Type 5T3

EQUIVALENT TIME/CM	50 μSEC
Equivalent Time/Cm VARIABLE	CAL
Equivalent Time SAMPLES/CM	100
TIME POSITION	Centered
Time Position FINE	Centered
SWEEP MODE	NORM
REAL TIME/CM	.2 mSEC
Real Time/Cm VARIABLE	CAL
Real Time SAMPLING RATE	100 KC
TRIG LEVEL	Clockwise
STABILITY OR UHF SYNC	Clockwise (not at detent)
TRIG SOURCE	FREE RUN
SLOPE	+
EXT TRIG MODE	50 Ω DC

Type 661

Horizontal Display	×1
Position and Vernier	Centered
Amplitude/Time Calibrator	Off
Intensity	Set for normal brightness
Focus and Astigmatism	Adjusted for sharp focus

Type 4S1

Millivolts/Cm	100
Millivolts/Cm Variable	Calibrated
Mode	A Only
Vertical Position	Centered
Display	Normal
DC Offset	Set to center the trace
Smoothing	Set for unity gain
Triggering	A DC

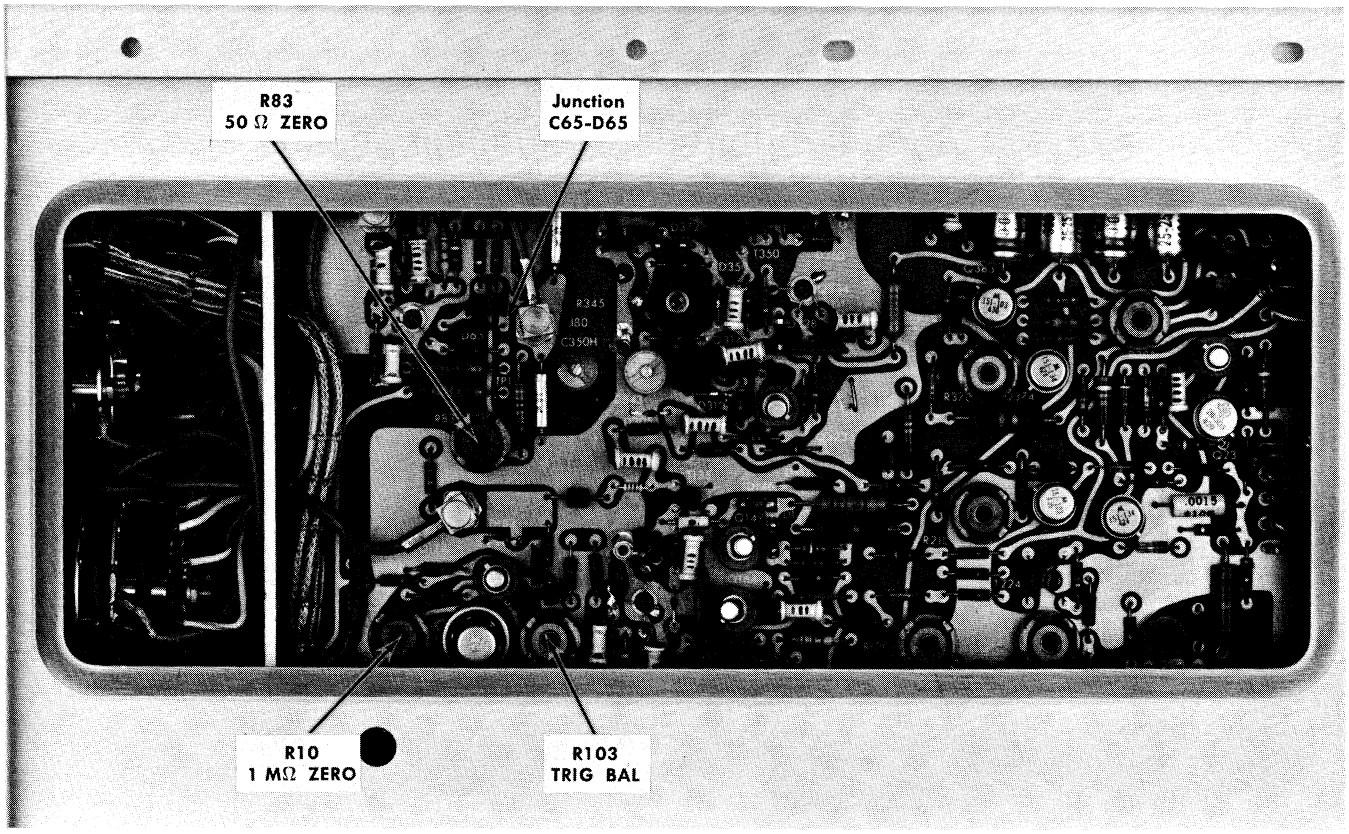


Fig. 5-4. Test point and controls for external trigger adjustments.

1. Adjust External Trigger Zero Levels

a. Test equipment setup is shown in Fig. 5-3.

b. Reset the TRIG SOURCE switch to CAL.

c. Install a GR 10× T-attenuator on the 50 Ω EXT TRIG INPUT connector.

d. Connect the common lead of the dc voltmeter to the Type 661 Oscilloscope chassis ground.

e. Touch the other meter lead to the junction of C65 and D65. See Fig. 5-4 for the location of the test point.

f. **Check** for a meter reading of zero volts.

g. **Adjust** R83 (50 Ω ZERO) if the reading is not correct.

h. Remove the 10× T-attenuator from the 50 Ω EXT TRIG INPUT connector.

i. Set the EXT TRIG MODE switch to 1 MΩ DC.

j. Touch the voltmeter lead to the junction of C65 and D65.

k. **Check** for a meter reading of zero volts.

l. **Adjust** R10 (1 MΩ ZERO) if the reading is not correct. See Fig. 5-4 for the location of R10.

2. Adjust Trigger Balance

a. Center the front-panel TRIG LEVEL control.

b. Turn R120 (TRIG LEVEL ZERO) fully counterclockwise. See Fig. 5-5 for the location of R120.

c. Touch the voltmeter lead to the emitter of Q124 (see Fig. 5-5).

d. **Check** for a meter reading of zero volts.

e. **Adjust** R103 (TRIG BAL) if the reading is not correct.

f. Remove the meter lead from the test point and disconnect the meter common lead from chassis ground.

g. **Interaction:** The Trigger Level Zero (step 4) must be readjusted.

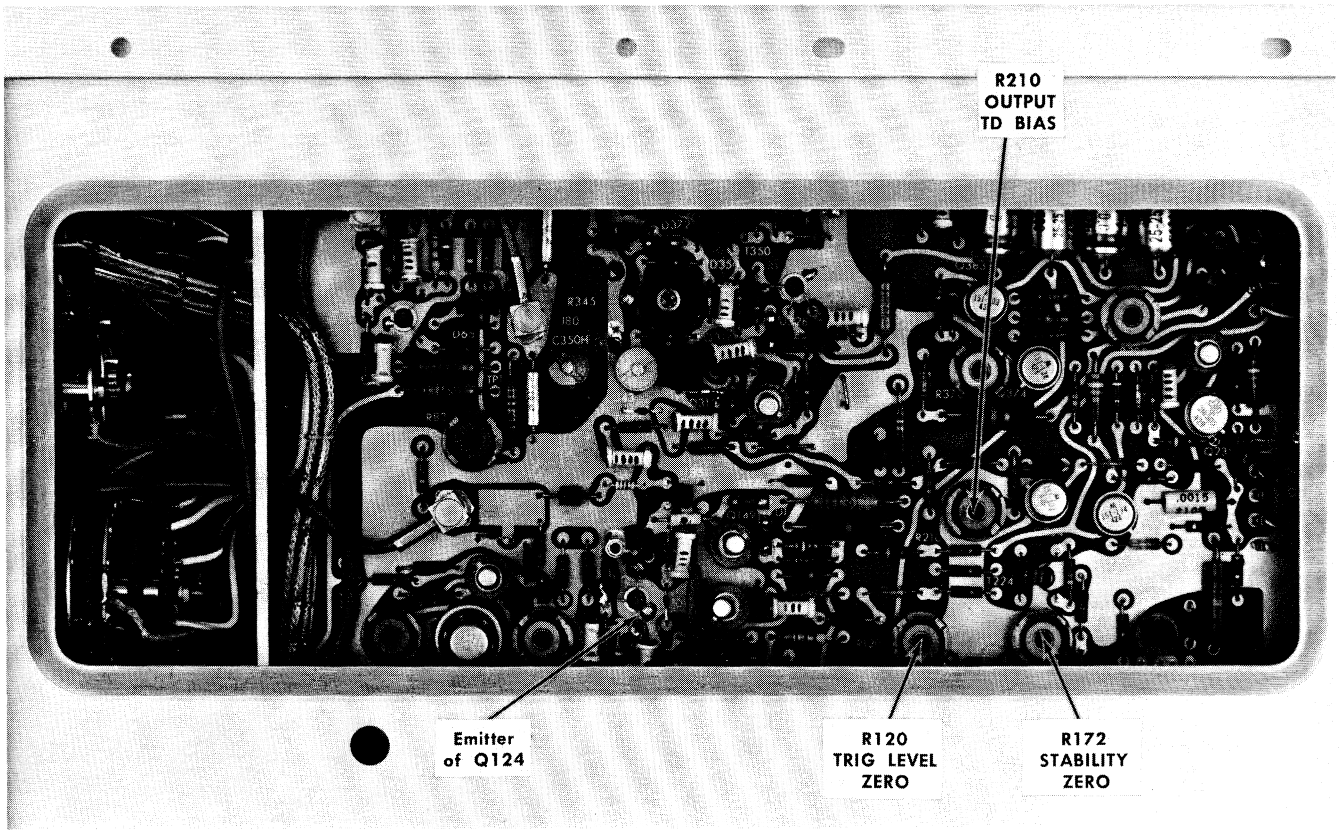


Fig. 5-5. Test point and controls for trigger adjustments.

3. Adjust Output TD Bias

a. Turn the front-panel TRIG LEVEL control fully clockwise.

b. Turn R210 (OUTPUT TD BIAS) clockwise until the trace free runs. The location of R210 is shown in Fig. 5-5.

c. **Adjust** R210 counterclockwise just past the point where the sweep stops.

4. Adjust Trigger Level Zero

a. Turn the STABILITY OR UHF SYNC control fully clockwise to the AUTO RECOVERY detent position.

b. Center the TRIG LEVEL control.

c. **Adjust** R120 (TRIG LEVEL ZERO) so the sweep just runs (not quite a free run).

d. Set the SLOPE switch to —. The sweep should just barely run. If not, readjust R120 slightly so the sweep will barely operate with the SLOPE switch in either the + or — position. Readjust the front-panel TRIG LEVEL control as needed to obtain the desired operation.

e. **Check** the position of the TRIG LEVEL knob under the conditions just described. If the white index dot is not straight up, loosen the knob and reposition it.

f. Leave the SLOPE switch at + position.

5. Adjust Stability Zero

a. Set the STABILITY OR UHF SYNC control slightly clockwise from center.

b. Adjust the TRIG LEVEL control so the trace free runs.

c. Turn the STABILITY OR UHF SYNC control through the midpoint of its range (top center).

d. **Check** that the sweep begins to free run when the STABILITY OR UHF SYNC control is just clockwise from center and stops free running when the control is just counterclockwise from center.

e. **Adjust** R172 (STABILITY ZERO) if the operation of the control is not correct. The location of R172 is shown in Fig. 5-5.

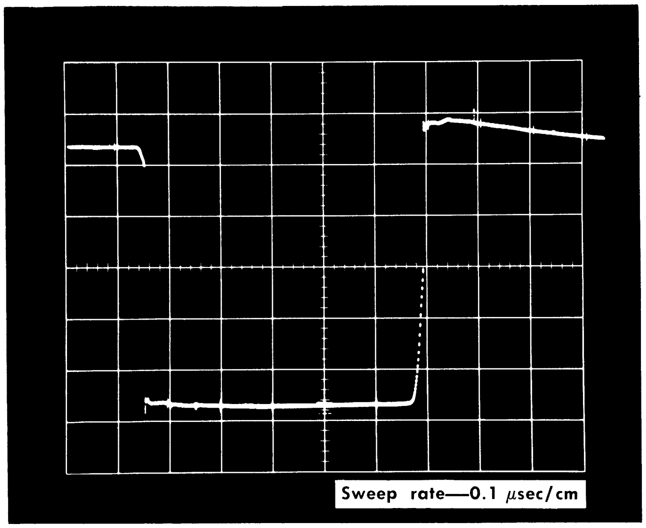


Fig. 5-6 Typical waveform for checking Delayed Pulse Bias adjustment.

6. Adjust Delayed Pulse Bias

a. Connect the Type 661 Oscilloscope Delayed Pulse output to the sampling unit vertical input.

b. Set the EQUIVALENT TIME/CM switch to .1 μSEC.

c. Set the TRIG SOURCE switch to FREE RUN.

d. Turn the TIME POSITION and FINE controls fully clockwise.

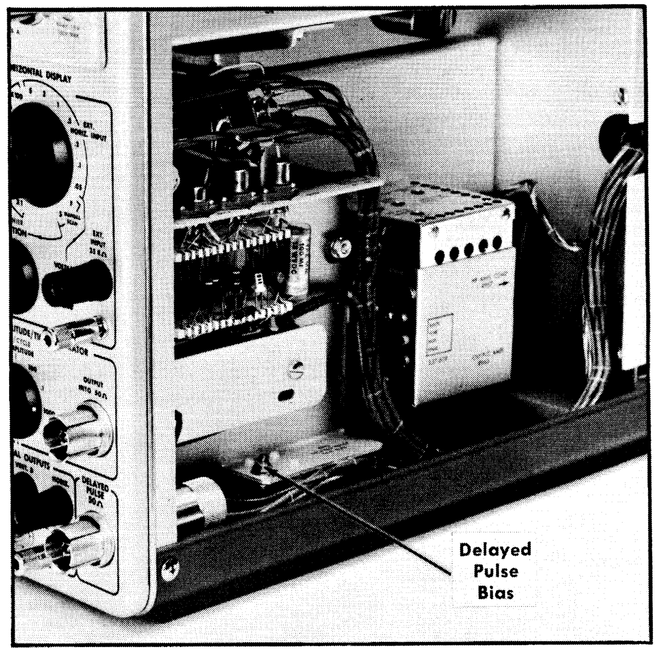


Fig. 5-7. Location of oscilloscope Delayed Pulse Bias adjustment.

e. **Check** the Delayed Pulse waveform for a shape similar to that shown in Fig. 5-6. Both the fall and the rise of the pulse should be stable.

f. **Adjust** the oscilloscope Delayed Pulse Bias control (see Fig. 5-7) if the display is not correct.

g. Disconnect the Delayed Pulse signal.

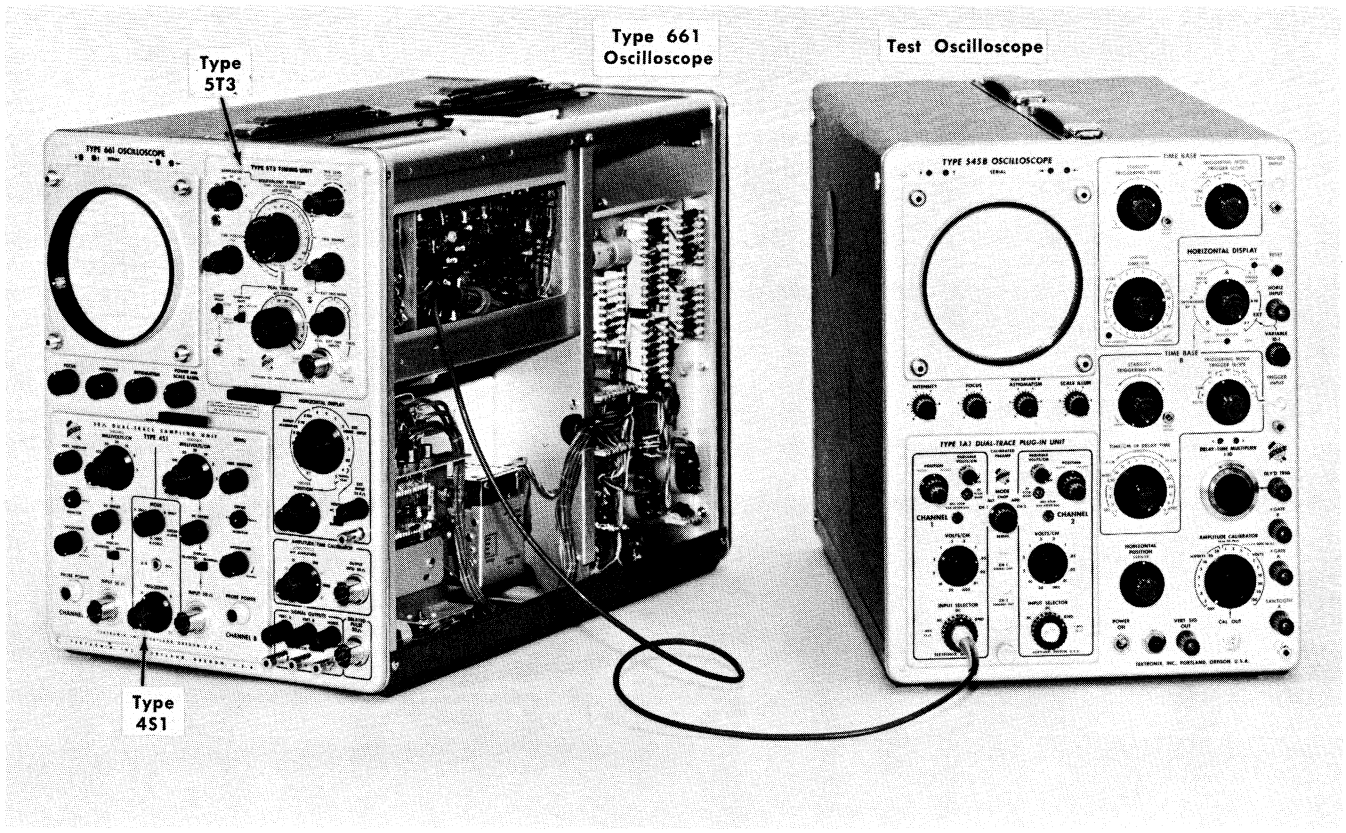


Fig. 5-8. Test equipment setup for steps 7 through 9.

Type 5T3

EQUIVALENT TIME/CM	.1 μSEC
Equivalent Time/Cm VARIABLE	CAL
Equivalent Time SAMPLES/CM	100
TIME POSITION	**Centered**
Time Position FINE	**Centered**
SWEEP MODE	NORM
REAL TIME/CM	.2 mSEC
Real Time/Cm VARIABLE	CAL
Real Time SAMPLING RATE	100 KC
TRIG LEVEL	**Clockwise**
STABILITY OR UHF SYNC	**Clockwise**
TRIG SOURCE	FREE RUN
SLOPE	+
EXT TRIG MODE	1 MΩ DC

Type 661

Horizontal Display	×1
Amplitude/Time Calibrator	Off

Type 4S1

Millivolts/Cm	**200**
Millivolts/Cm Variable	Cal
Mode	A Only
Vertical Position	Centered
Display	Normal
DC Offset	Centered
Smoothing	Unity gain
Triggering	**A AC**

Test Oscilloscope

Sweep Mode	Triggered
Sweep Rate	10 μSec/Cm
Vertical Deflection Factor	0.5 Volts/Cm
Input Coupling	DC

Ⓐ

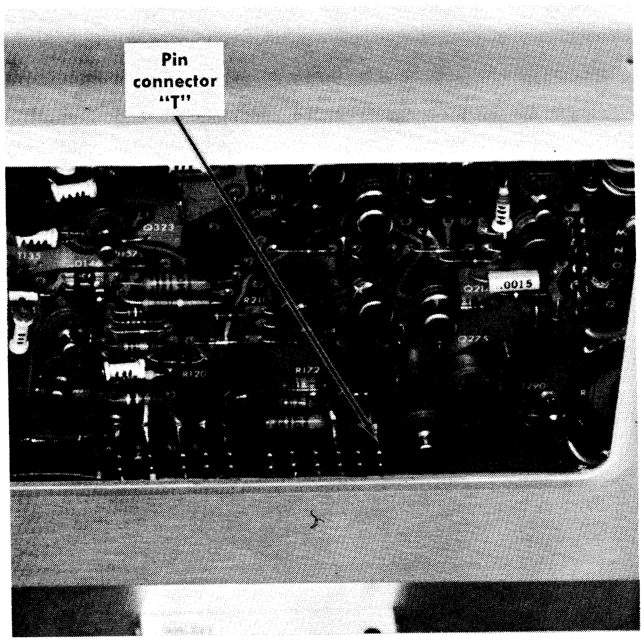


Fig. 5-9. Test point for checking trigger holdoff waveform.

7. Check Trigger Holdoff

a. Test equipment setup is shown in Fig. 5-8.

b. Connect the test probe to pin connector "T" on the Fast-Ramp etched-wiring board (see Fig. 5-9).

c. Trigger the test oscilloscope.

d. Turn the Type 5T3 EQUIVALENT TIME/CM switch to each position from 1 nSEC to .1 μSEC.

e. **Check** for a holdoff waveform with a minimum holdoff period of 10 μsec on these sweep rates. A typical holdoff waveform is shown in Fig. 5-10.

f. **Check** the holdoff time on equivalent-time sweep rates from 0.2 to 100 μsec as indicated in Table 5-1.

g. Set the EQUIVALENT TIME/CM switch to REAL TIME.

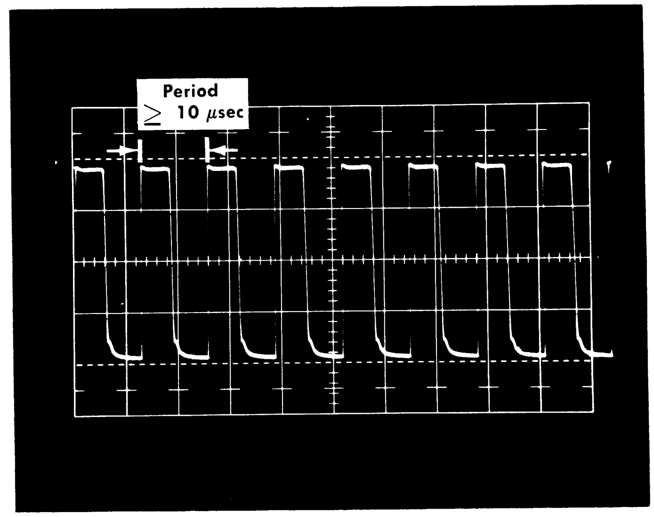


Fig. 5-10. Typical free run trigger holdoff waveform at pin connector "T", at all sweep rates except 0.2 through 100 μsec.

h. Set the test oscilloscope sweep rate to 10 μsec/cm.

i. Turn the REAL TIME/CM switch through all of its positions.

j. **Check** for a minimum holdoff period of 10 μsec on all real-time sweep rates.

k. Remove the probe from the test point.

TABLE 5-1

Holdoff Interval Check

EQUIVALENT TIME/CM	Test Sweep Rate	Display (Max. No. of Cycles)
.1 μSEC to 1 nSEC	10 μSec/Cm	10
.2 μSEC to 1 μSEC	50 μSec/Cm	12.5
2 μSEC to 10 μSEC	.5 mSec/Cm	12.5
20 μSEC to 100 μSEC	5 mSec/Cm	12.5

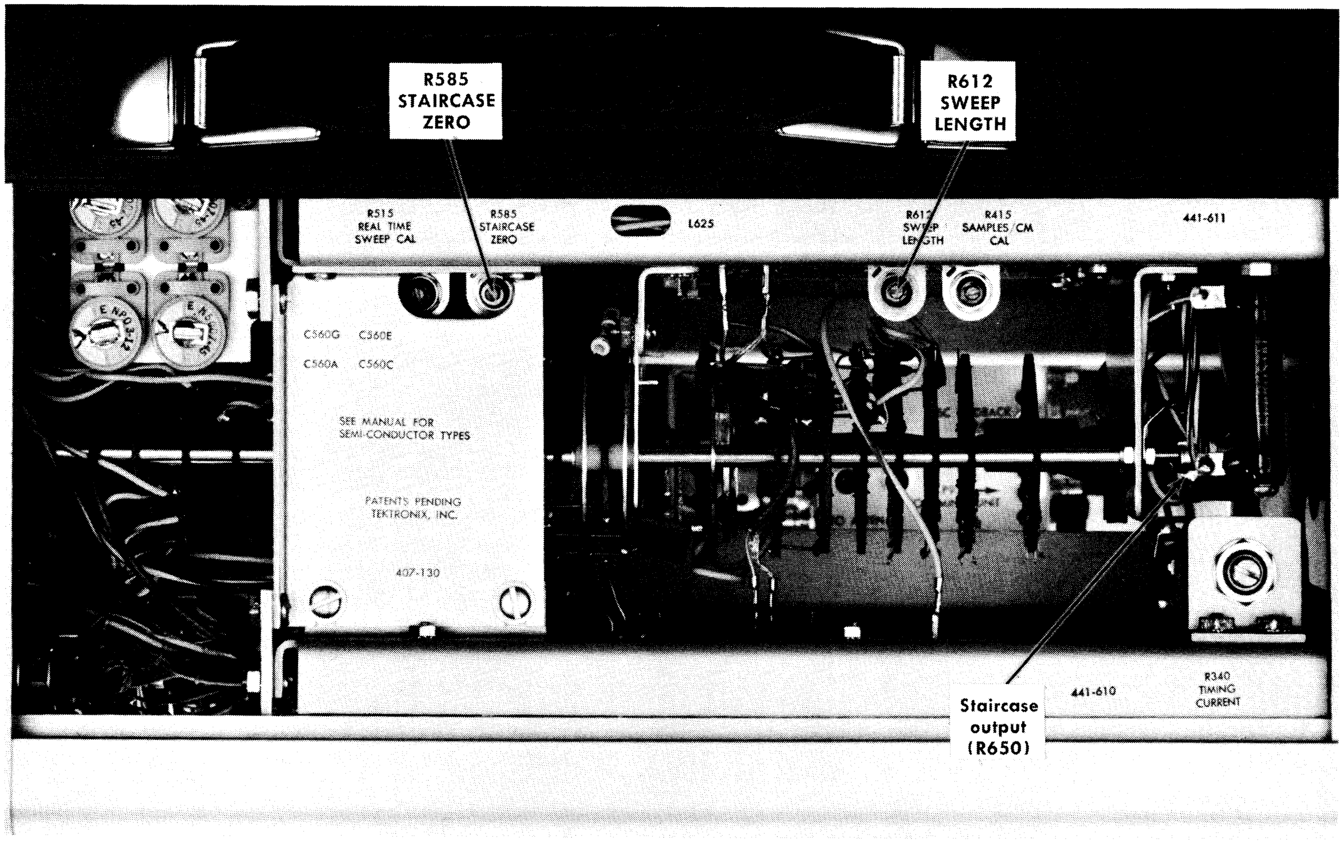


Fig. 5-11. Top view of Type 5T3 showing staircase adjustments and test points.

8. Adjust Staircase Zero

a. Set the Type 5T3 SWEEP MODE switch to SINGLE DISPLAY.

b. Set the EQUIVALENT TIME/CM switch to 2 μSEC.

c. Adjust the test oscilloscope trace for a dc zero reference level.

d. Connect the probe to the staircase output on R650 (Equivalent Time/Cm VARIABLE) shown in Fig. 5-11.

e. Set the test oscilloscope for a sweep rate of 0.5 msec/cm and a vertical deflection factor of 0.005 volts/cm.

f. **Check** for a waveform similar to Fig. 5-12, with its base at zero volts (reference level).

g. **Adjust** R585 (STAIRCASE ZERO) if the bottom of the waveform is not at zero volts.

h. **Interaction:** Check sweep length adjustment (step 9). Check equivalent-time registration (step 19).

9. Adjust Sweep Length

a. Leave the probe tip connected to R650.

b. Set the test oscilloscope input for 1 volt/cm and a sweep rate of 2 msec/cm.

c. Set the Type 5T3 SWEEP MODE switch to NORM and the EQUIVALENT TIME/CM switch to 50 nSEC.

d. **Check** for a staircase amplitude of 51 to 55 volts, measured from the zero reference level just set (see Fig. 5-13). (Be sure the vertical gain of the test oscilloscope is calibrated at that voltage.)

e. **Adjust** R612 (SWEEP LENGTH) for a staircase amplitude of 52.5 volts if it was not within the 51- to 55-volt range. See Fig. 5-11 for the location of R612. The length of the sweep on the crt of the Type 661 should be 10.5 cm if the staircase amplitude is 52.5 volts. If not, the oscilloscope horizontal amplifier is not calibrated correctly.

f. Disconnect the test probe.

Ⓐ

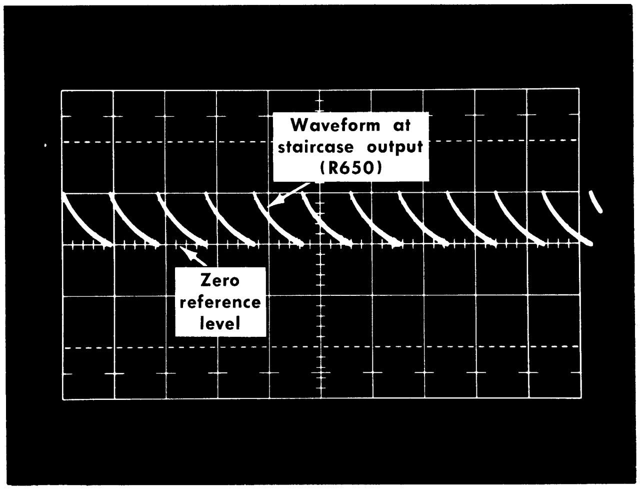


Fig. 5-12. Typical waveform at the staircase output on R650 for checking STAIRCASE ZERO adjustment (R585).

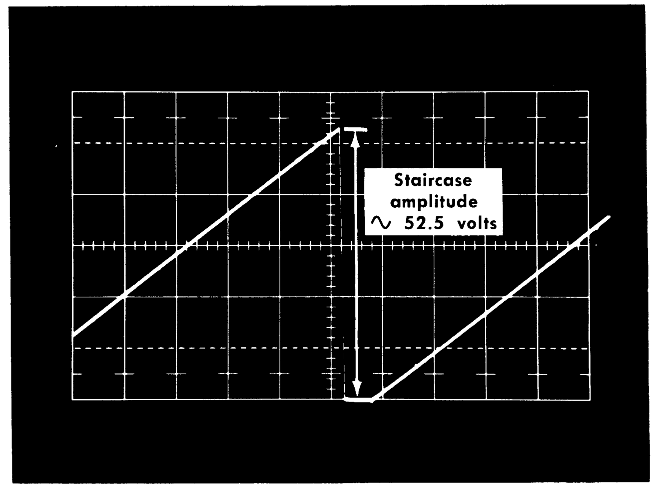


Fig. 5-13. Staircase waveform for setting SWEEP LENGTH control (R612).

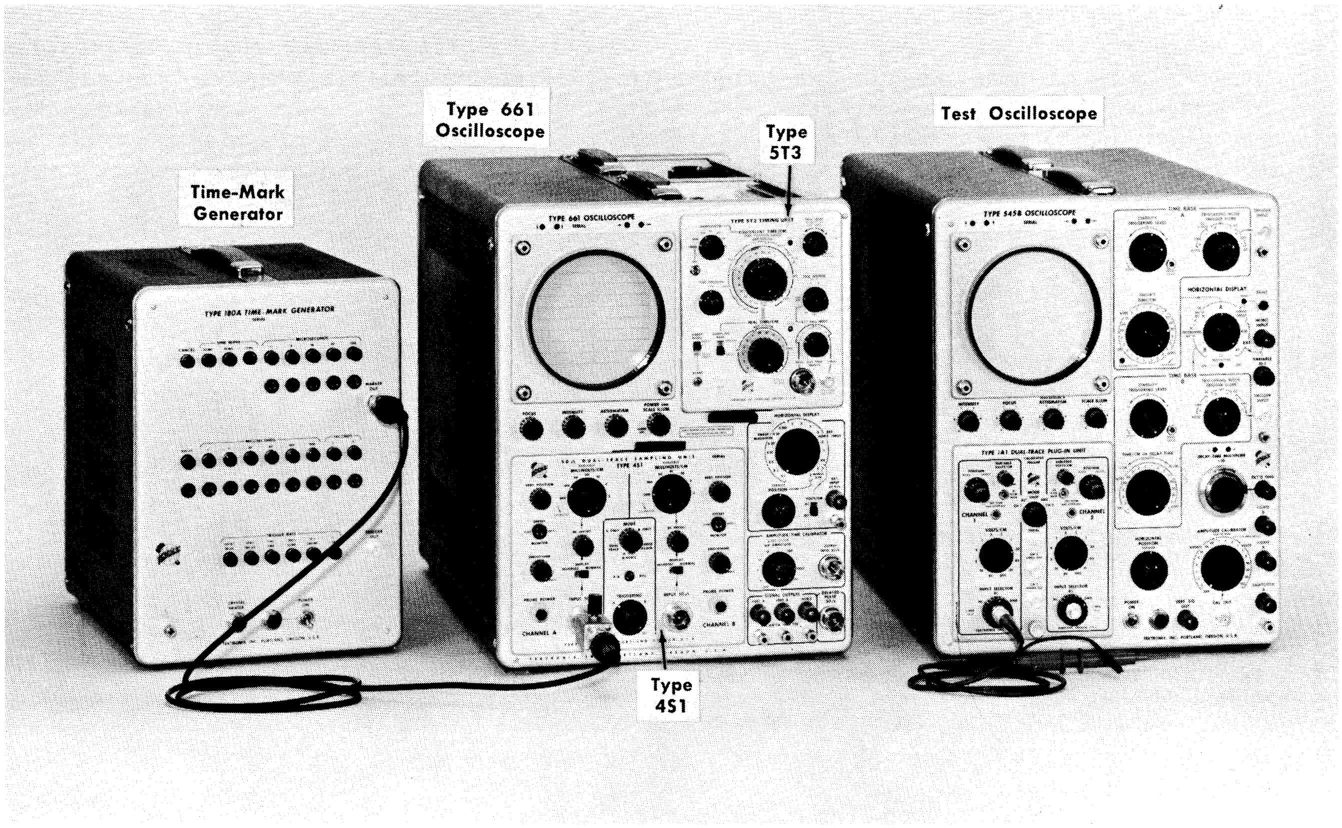


Fig. 5-14. Test equipment setup for steps 10 through 14.

Type 5T3

EQUIVALENT TIME/CM	**REAL TIME**
Equivalent Time/Cm VARIABLE	CAL
Equivalent Time SAMPLES/CM	100
TIME POSITION	Centered
Time Position FINE	Centered
SWEEP MODE	NORM
REAL TIME/CM	**1 mSEC**
Real Time/Cm VARIABLE	CAL
Real Time SAMPLING RATE	100 KC
TRIG LEVEL	Clockwise
STABILITY OR UHF SYNC	Clockwise
TRIG SOURCE	**INT**
SLOPE	+
EXT TRIG MODE	1 MΩ DC

Type 661

Horizontal Display	×1
Amplitude/Time Calibrator	Off

Type 4S1

Millivolts/Cm	**50**
Millivolts/Cm Variable	Calibrated
Mode	A Only
Vertical Position	Centered
Display	Normal
DC Offset	Centered
Smoothing	Unity gain
Triggering	A AC

Test Oscilloscope

Sweep Mode	Triggered
Sweep Rate	**2 μSec/Cm**
Vertical Deflection Factor	**0.2 Volts/Cm**
Vertical Input Coupling	DC

10. Adjust Real Time Sweep Cal ⓿

a. Test equipment setup is shown in Fig. 5-14.

b. Connect the output of the time-mark generator through the variable attenuator to the vertical input of the sampling unit.

c. Set the time-mark generator for 1 msec time markers.

d. Adjust the triggering controls for a stable display of the waveform.

e. Adjust the attenuator for about 4 cm of deflection.

f. **Check** for a display of 1 time mark/cm (±3%) over the center 8 cm of the graticule. See Fig. 5-15.

g. **Adjust** R515 (REAL TIME SWEEP CAL) if the display is not correct. The location of R515 is shown in Fig. 5-16.

h. **Interaction:** Check real-time sweep rates (step 11).

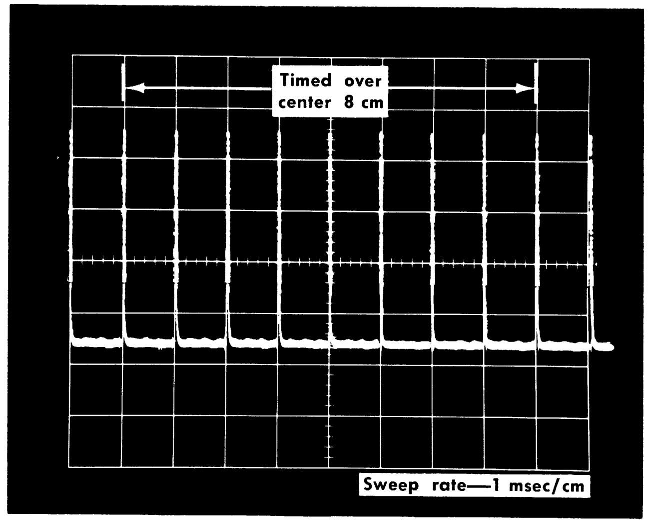


Fig. 5-15. Typical time-mark waveform for Real Time Sweep Cal check.

11. Check Real Time Sweep Rates

a. Leave the time-mark signal connected to the vertical input.

b. **Check** the other real-time sweep rates as indicated in Table 5-1. If timing is not within 3% on all sweep rates, R515 (REAL TIME SWEEP CAL) may require a slight readjustment (see step 10).

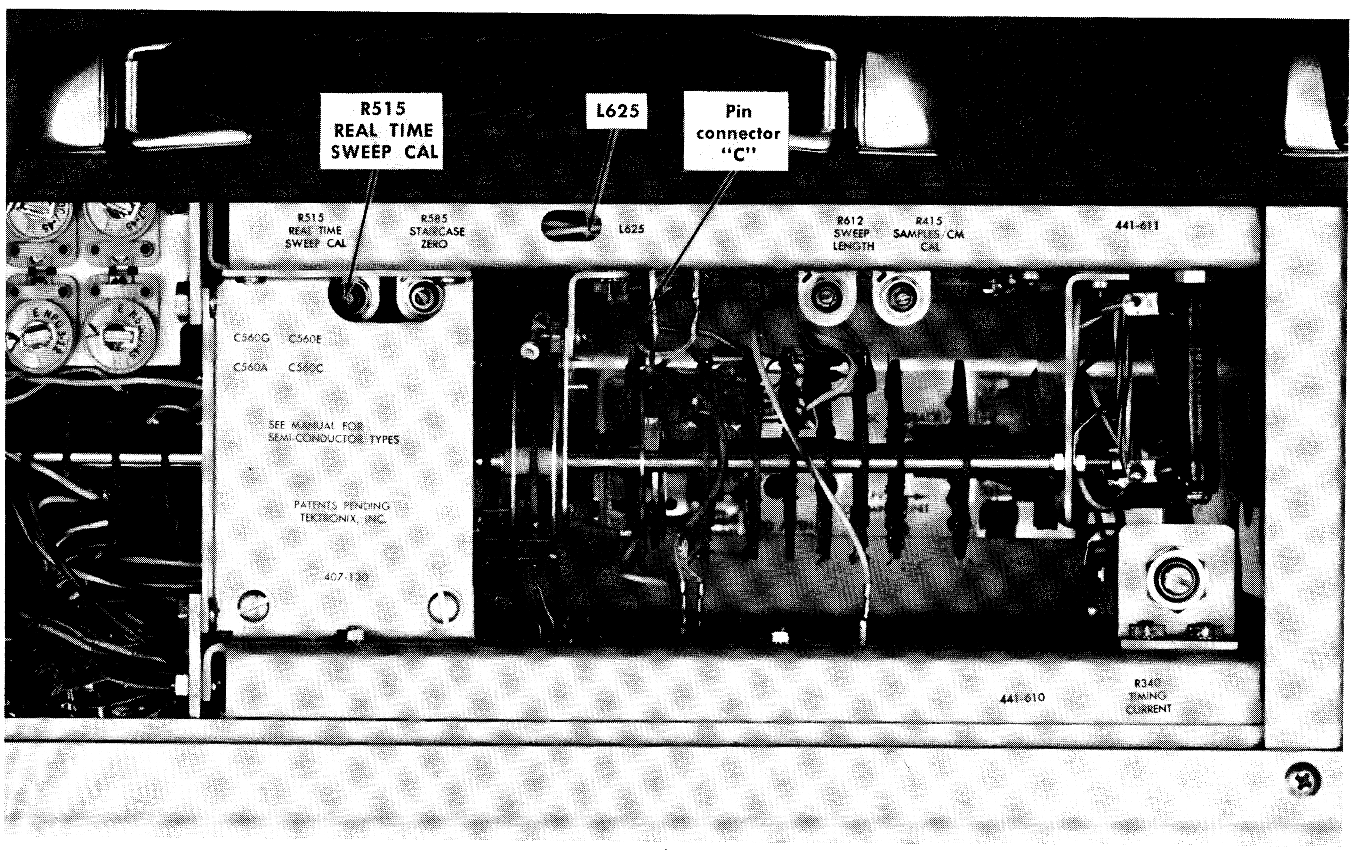


Fig. 5-16. Real-time sweep calibration and clock adjustments.

TABLE 5-2

Real Time Sweep Rate Check

REAL TIME/CM	Time-Mark Signal	Display (Marks/Cm)
.2 mSEC	100 μsec	2
.5 mSEC	500 μsec	1
1 mSEC	1 msec	1
2 mSEC	1 msec	2
5 mSEC	5 msec	1
10 mSEC	10 msec	1
20 mSEC	10 msec	2
50 mSEC	50 msec	1
.1 SEC	100 msec	1
.2 SEC	100 msec	2
.5 SEC	500 msec	1
1 SEC	1 sec	1
2 SEC	1 sec	2
5 SEC	5 sec	1

12. Check Real Time/Cm Variable

a. Leave the time-mark signal connected to the vertical input.

b. Set the time-mark generator for 1 msec time markers.

c. Set the REAL TIME/CM switch to 1 mSEC.

d. Turn the Real Time/Cm VARIABLE control fully clockwise and observe the display expansion.

e. **Check** that the control has an effective range of 2.5 (or more) to 1 (see Fig. 5-17). The distance between markers in the display should be 2.5 cm or greater.

f. **Check** that the UNCAL neon is lit whenever the VARIABLE control is not in the CAL detent position (fully counterclockwise).

g. Return the VARIABLE control to CAL.

13. Adjust Real Time Clock

a. Leave the time-mark signal connected to the vertical input.

b. Set the TRIG SOURCE switch to FREE RUN.

c. Set the time-mark generator for a 10 μsec marker output (100 kc repetition rate).

d. Set the REAL TIME/CM switch to about 20 mSEC.

e. Observe the free running time-mark signal on the crt screen.

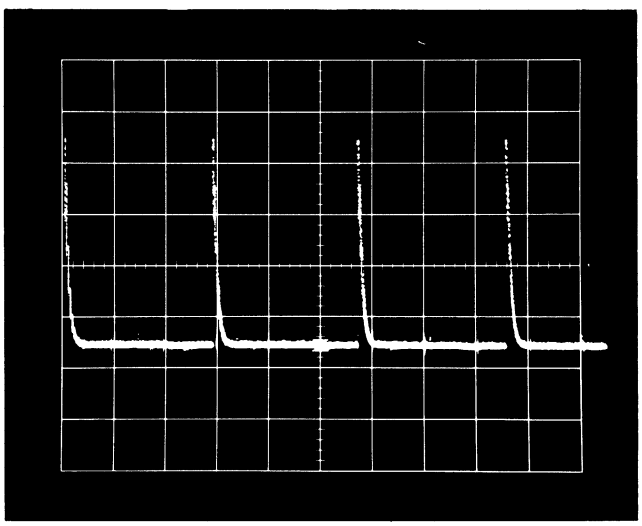


Fig. 5-17. Typical 1-msec marker waveform with REAL TIME/CM switch at 1 mSEC and Real Time/Cm VARIABLE fully clockwise.

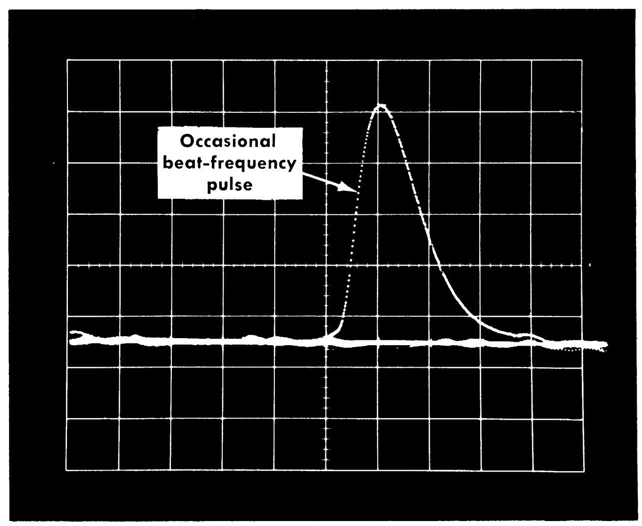


Fig. 5-18. Typical waveform for checking real-time clock oscillator. Waveform shows beat frequency of 10 μsec markers with 100-kc sampling rate.

f. **Check** for a straight line display with occasional wide marker pulses (see Fig. 5-18). The crt display is a beat-frequency waveform representing the difference between the 100-kc marker rate and the 100-kc oscillator rate.

g. **Adjust** L625 (see Fig. 5-16) if the display is not approximately correct. The more widely the pulses are spaced, the closer the frequency is to 100 kc.

14. Check Random Rate

a. Connect the test probe to pin connector "C" on the sweep circuit etched-wiring board. See Fig. 5-16 for the location of pin "C".

b. Set the SAMPLING RATE switch to RANDOM.

c. **Check** for a maximum period of 15 μsec or less and a minimum period of 10 μsec or more (see Fig. 5-19).

d. Disconnect the test probe.

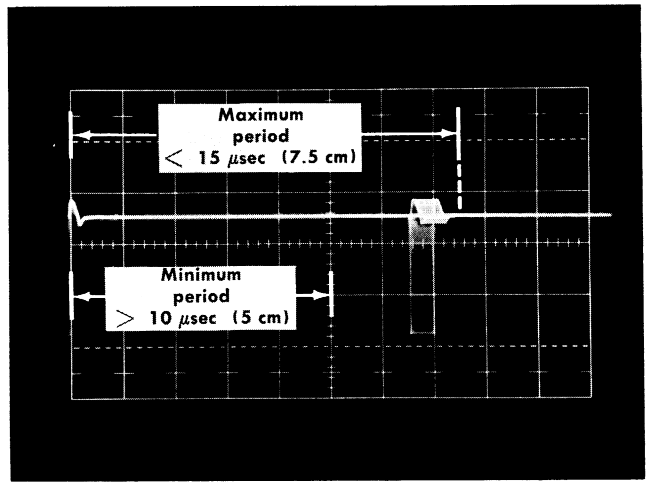


Fig. 5-19. Typical real-time oscillator output with SAMPLING RATE switch at RANDOM.

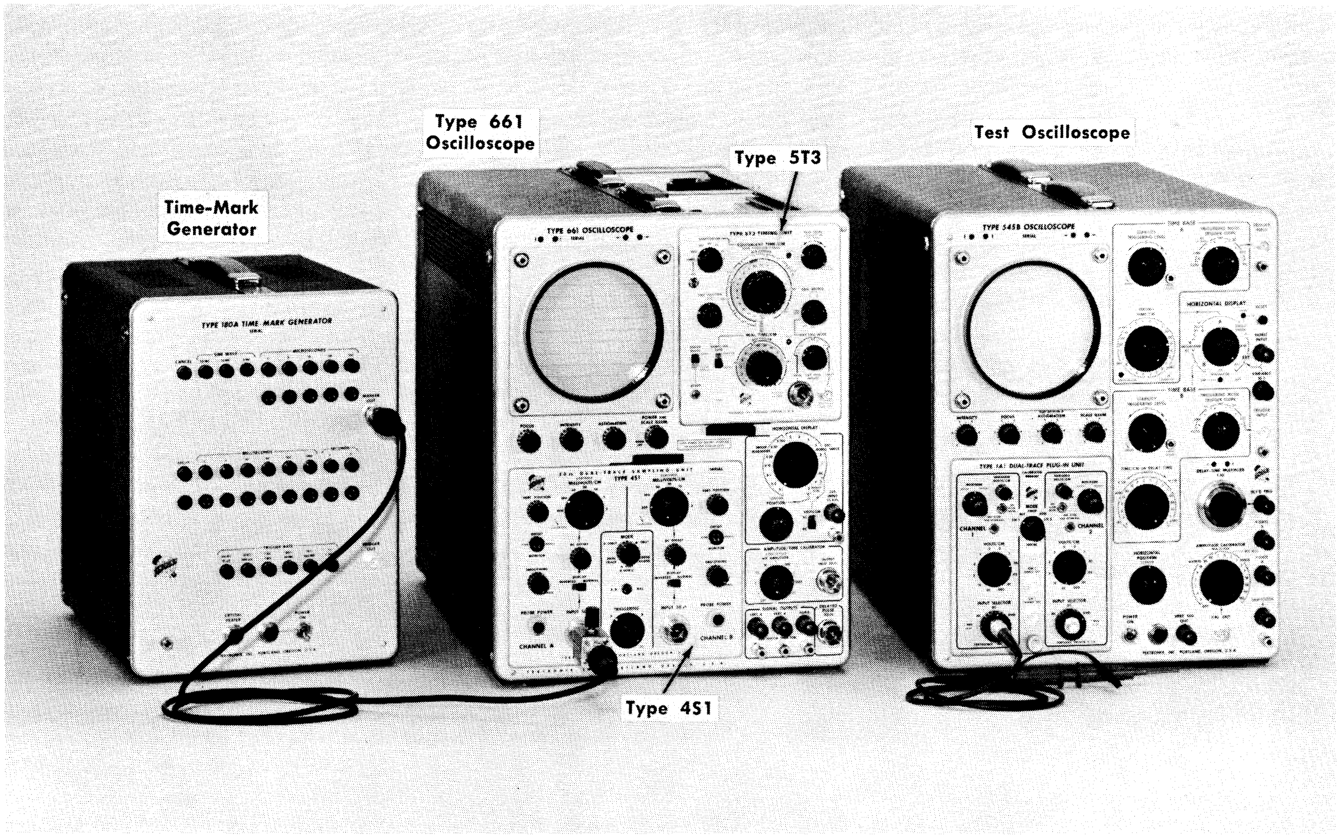


Fig. 5-20. Test equipment setup for steps 15 through 18.

Type 5T3

EQUIVALENT TIME/CM	**1 μSEC**
Equivalent Time/Cm VARIABLE	CAL
Equivalent Time SAMPLES/CM	100
TIME POSITION	Centered
Time Position FINE	Centered
SWEEP MODE	NORM
REAL TIME/CM	**1 mSEC**
Real Time/Cm VARIABLE	CAL
Real Time SAMPLING RATE	**100 KC**
TRIG LEVEL	**Clockwise**
STABILITY OR UHF SYNC	**Clockwise**
TRIG SOURCE	**INT**
SLOPE	+
EXT TRIG MODE	1 MΩ DC

Type 661

Horizontal Display	×1
Amplitude/Time Calibrator	Off

Type 4S1

Millivolts/Cm	**100**
Millivolts/Cm Variable	Calibrated
Mode	A Only
Vertical Position	Centered
Display	Normal
DC Offset	Centered
Smoothing	Unity gain
Triggering	A AC

Test Oscilloscope

Sweep Mode	Triggered
Sweep Rate	2 μSec/Cm
Vertical Deflection Factor	0.2 Volts/Cm
Input Coupling	DC

Ⓐ

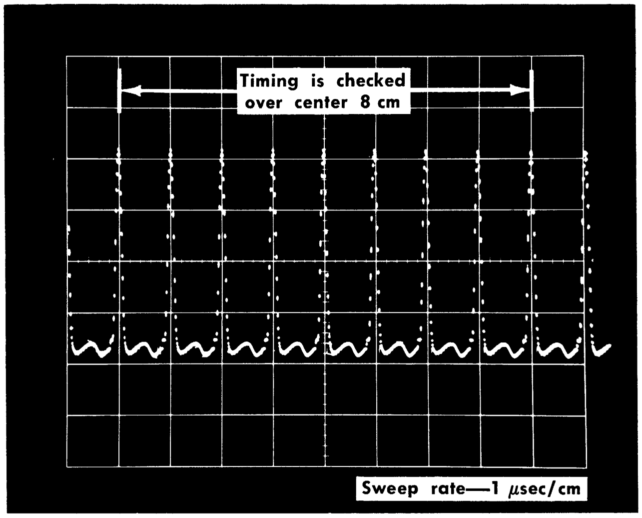


Fig. 5-21. 1-μsec marker waveform for TIMING CURRENT (R340) adjustment.

15. Adjust Equivalent Time Sweep Calibration

a. Test equipment setup is shown in Fig. 5-20.

b. Leave the time-mark signal connected through the variable attenuator to the vertical input.

c. Set the time-mark generator for a 1 μsec marker output.

d. Adjust the triggering controls for a stable display.

e. Adjust the variable attenuator for about 4 cm of deflection.

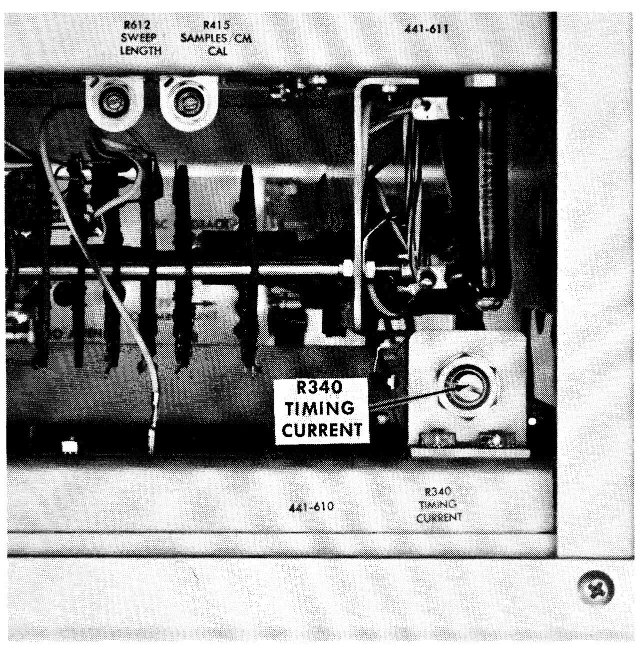


Fig. 5-22. Location of equivalent-time sweep calibration adjustment (TIMING CURRENT R340) on top of Type 5T3.

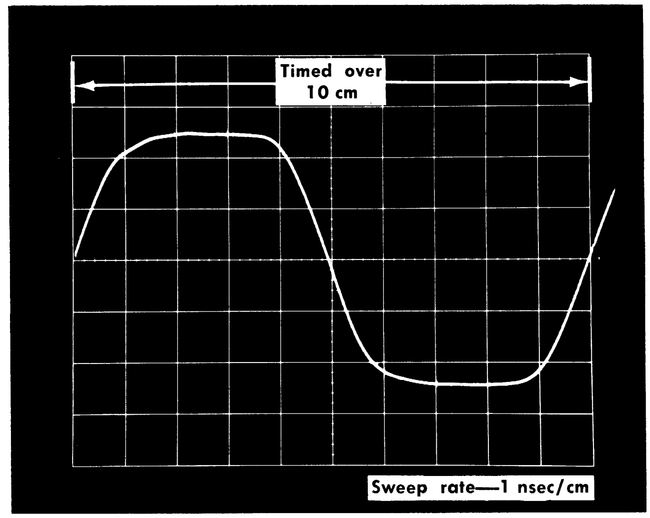


Fig. 5-23. Oscilloscope calibrator waveform for checking 1-nsec equivalent-time sweep rate.

f. **Check** for exactly 1 cycle/cm (see Fig. 5-21).

g. **Adjust** R340 (TIMING CURRENT) if the display is not correct. The location of R340 is shown in Fig. 5-22.

h. **Interaction:** Affects equivalent-time registration and all equivalent-time sweep rates (steps 19 and 20).

i. Disconnect the time-mark signal and the variable attenuator.

16. Adjust 1 and 10 nSec Ramp Timing

a. Connect the oscilloscope Amplitude/Time Calibrator output to the sampling unit vertical input.

b. Set the Calibrator for a 1000-mv, 0.01-μSec/Cycle output.

c. Set the EQUIVALENT TIME/CM switch to 1 nSEC.

d. Set the sampling unit Millivolts/Cm switch to 200.

e. Adjust the triggering controls for a stable display.

f. Position the waveform with the TIME POSITION control so the rising portion of the waveform crosses the edges of the graticule (see Fig. 5-23).

g. **Check** for a display of 1 cycle/10 cm.

h. **Adjust** C343 (see Fig. 5-24) if the display is not correct.

i. Set the EQUIVALENT TIME/CM switch to 10 nSEC.

j. **Check** for a display of 1 cycle/cm over the center 8 cm of the graticule.

k. **Adjust** C350H (see Fig. 5-24) if the display is not correct.

17. Adjust Samples/Cm

a. Reconnect the time-mark signal to the sampling unit input through the variable attenuator.

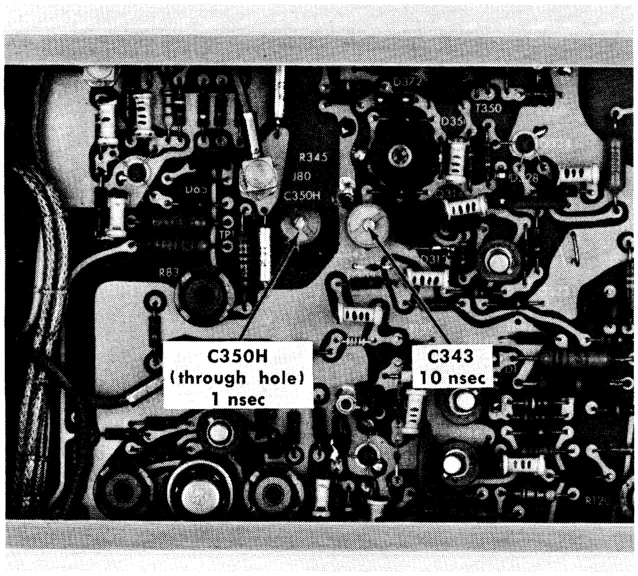


Fig. 5-24. 1-nsec and 10-nsec fast ramp timing adjustments.

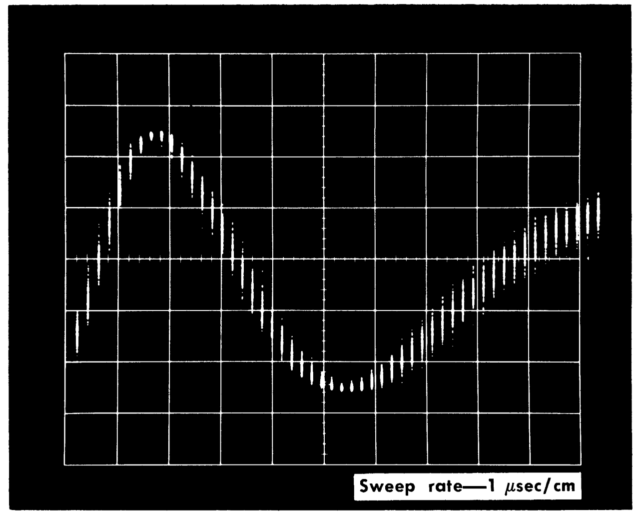


Fig. 5-25. Typical false sampling display with SAMPLES/CM CAL (R415) set within 0.5%.

b. Set the time-mark generator for a 50-Mc sine-wave output.

c. Set the EQUIVALENT TIME/CM switch to 20 nSEC.

d. Adjust the variable attenuator for about 4 cm of deflection.

e. Trigger the display.

f. Set the Type 5T3 SAMPLES/CM switch to 5 and the EQUIVALENT TIME/CM switch to 1 μsec.

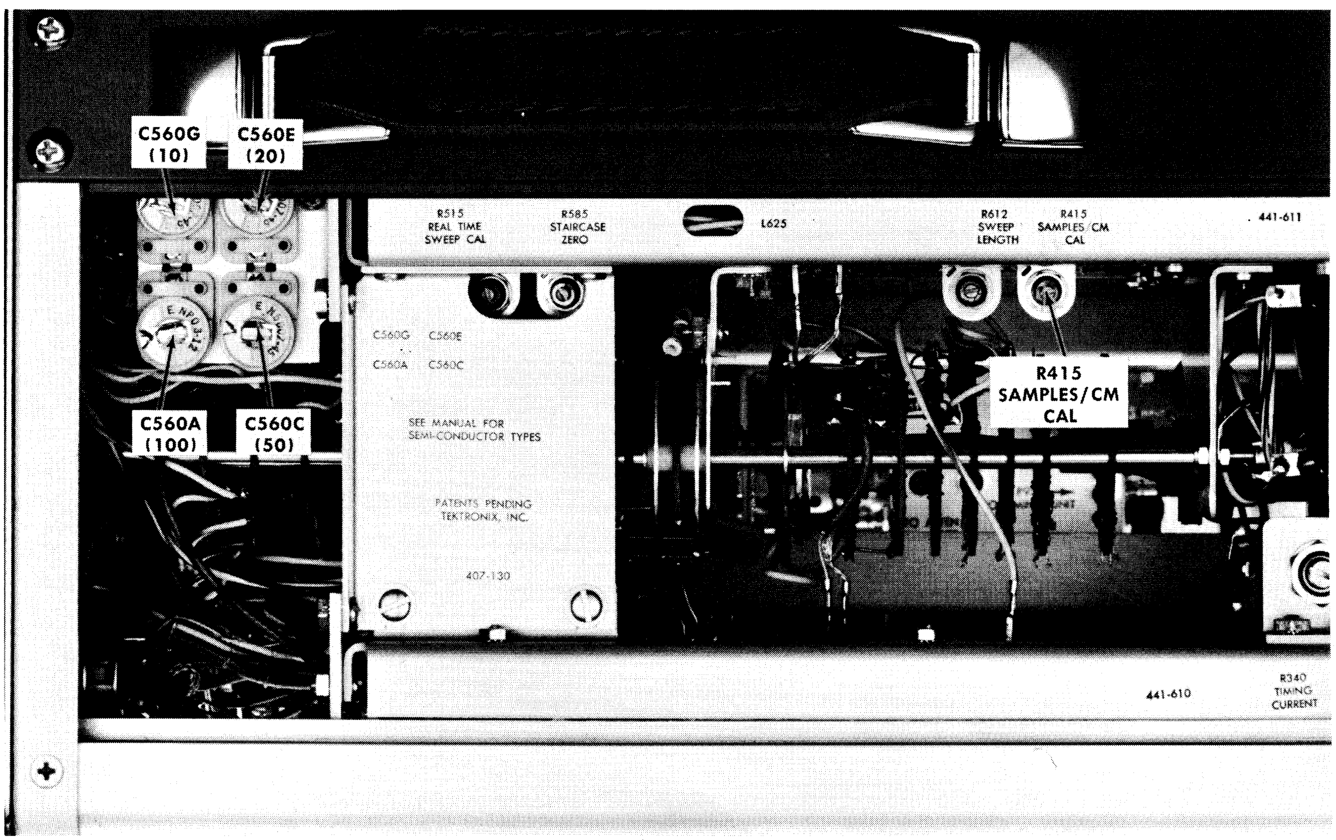


Fig. 5-26. Samples/Cm adjustments on top of Type 5T3.

g. **Check** for a false display similar to that shown in Fig. 5-25. If the number of cycles in the display is less than 2.5, the dot spacing is adjusted within 0.5%. Required accuracy is within ±3%.

h. **Adjust** R415 (SAMPLES/CM CAL) if 0.5% accuracy is desired and the display is not as illustrated. Fig. 5-26 shows the adjustments for this step.

i. **Check** for crt displays as listed in Table 5-3 with the SAMPLES/CM switch set at the 10, 20, 50 and 100 positions.

j. **Adjust** the capacitors listed in the table if 0.5% accuracy is desired and crt displays are not as indicated.

TABLE 5-3

Samples/Cm Adjustments

SAMPLES/CM Switch	Maximum Cycles or Crossovers	Rows of Dots	Adjust
10	2.5	1	C560G
20	5	2	C560E
50	2.5	1	C560C
100	5	2	C560A

18. Check Timed Control

a. Leave the time-mark signal applied to the vertical input of the sampling unit.

b. Set the EQUIVALENT TIME/CM switch to 50 nSEC.

c. Set the SAMPLES/CM switch to TIMED.

d. Set the TRIG SOURCE switch to FREE RUN.

e. Set the time-mark generator for 1 second markers.

f. Adjust the variable attenuator for about 2 cm of deflection.

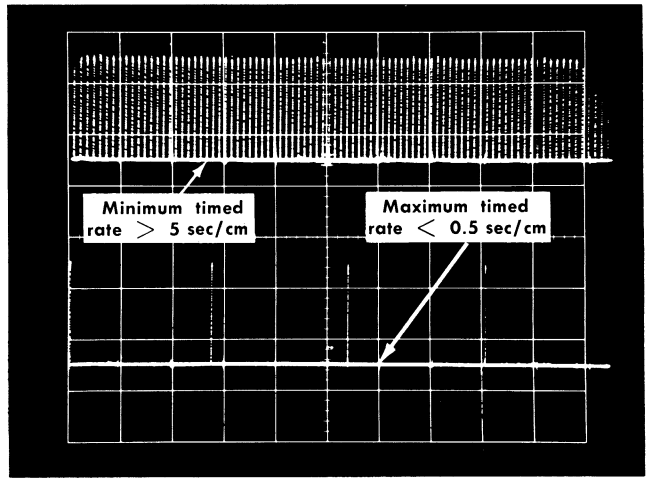


Fig. 5-27. Double exposure showing maximum and minimum sweep rates with Timed ADJ control set fully counterclockwise and fully clockwise.

g. With a small screwdriver, set the front-panel Timed ADJ control fully counterclockwise.

h. **Check** for an equivalent sweep rate of 5 (or more) seconds per cm (5 or more markers per cm). A typical display is shown in Fig. 5-27.

i. Turn the ADJ control fully clockwise.

j. **Check** for an equivalent sweep rate of 0.5 (or less) second per cm (1 marker per 2 or more cm).

k. Leave the ADJ control set fully clockwise, or set it for some calibrated rate if you desire.

l. Disconnect the time-mark generator signal and the variable attenuator.

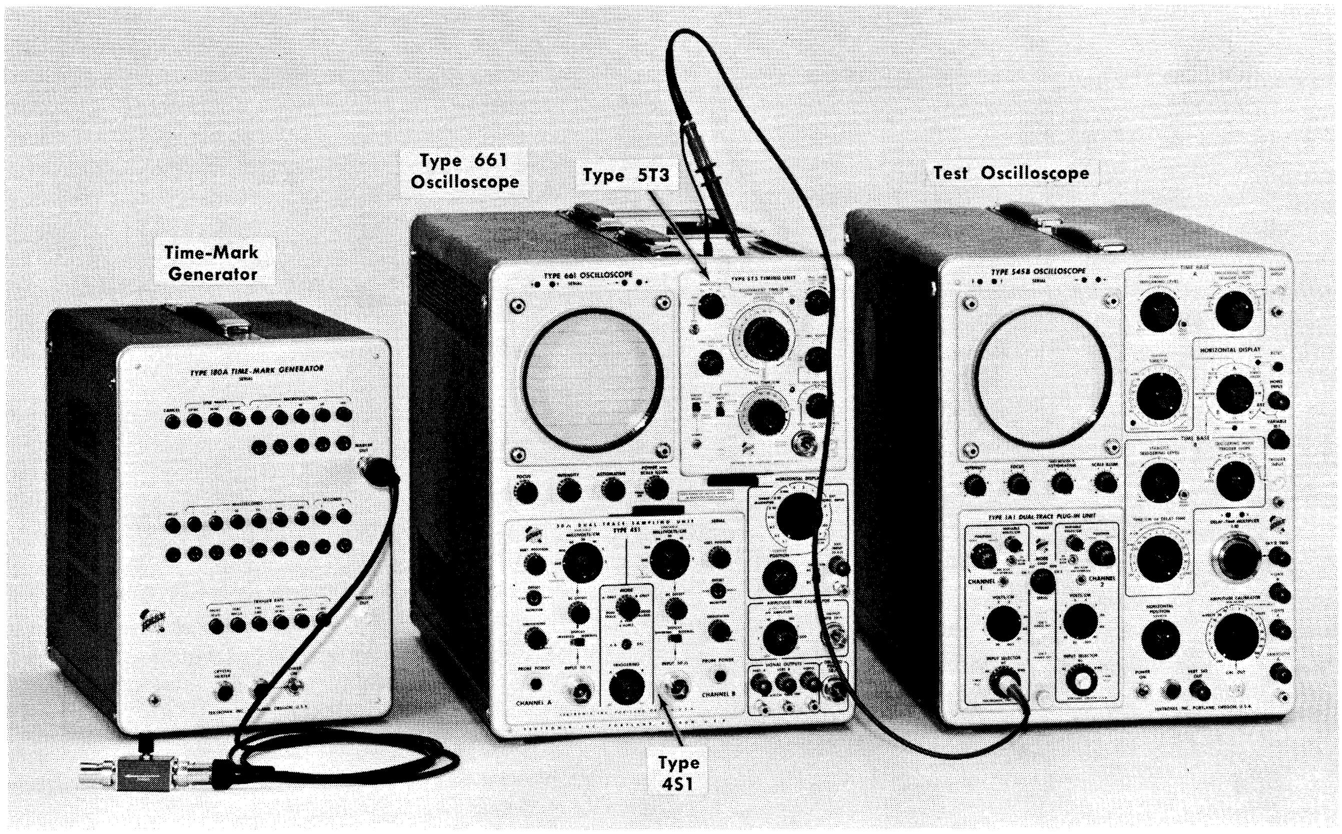


Fig. 5-28. Test equipment setup for steps 19 through 24.

Type 5T3

EQUIVALENT TIME/CM	**2 μSEC**
Equivalent Time/Cm VARIABLE	CAL
Equivalent Time SAMPLES/CM	**50**
TIME POSITION	**Clockwise**
Time Position FINE	**Clockwise**
SWEEP MODE	**SINGLE DISPLAY**
REAL TIME/CM	1 mSEC
Real Time/Cm VARIABLE	CAL
Real Time SAMPLING RATE	100 KC
TRIG LEVEL	**Clockwise**
STABILITY OR UHF SYNC	**Clockwise**
TRIG SOURCE	FREE RUN
SLOPE	+
EXT TRIG MODE	1 MΩ DC

Type 661

Horizontal Display	×1
Amplitude/Time Calibrator	**1000 mv, 10 μSec/Cycle**

Type 4S1

Millivolts/Cm	**200**
Millivolts/Cm Variable	Calibrated
Mode	A Only
Vertical Position	Centered
Display	Normal
DC Offset	Centered
Smoothing	Unity gain
Triggering	A AC

Test Oscilloscope

Sweep Mode	Triggered
Sweep Rate	**0.5 mSec/Cm**
Vertical Deflection Factor	**0.005 Volts/Cm**
Vertical Input Coupling	DC

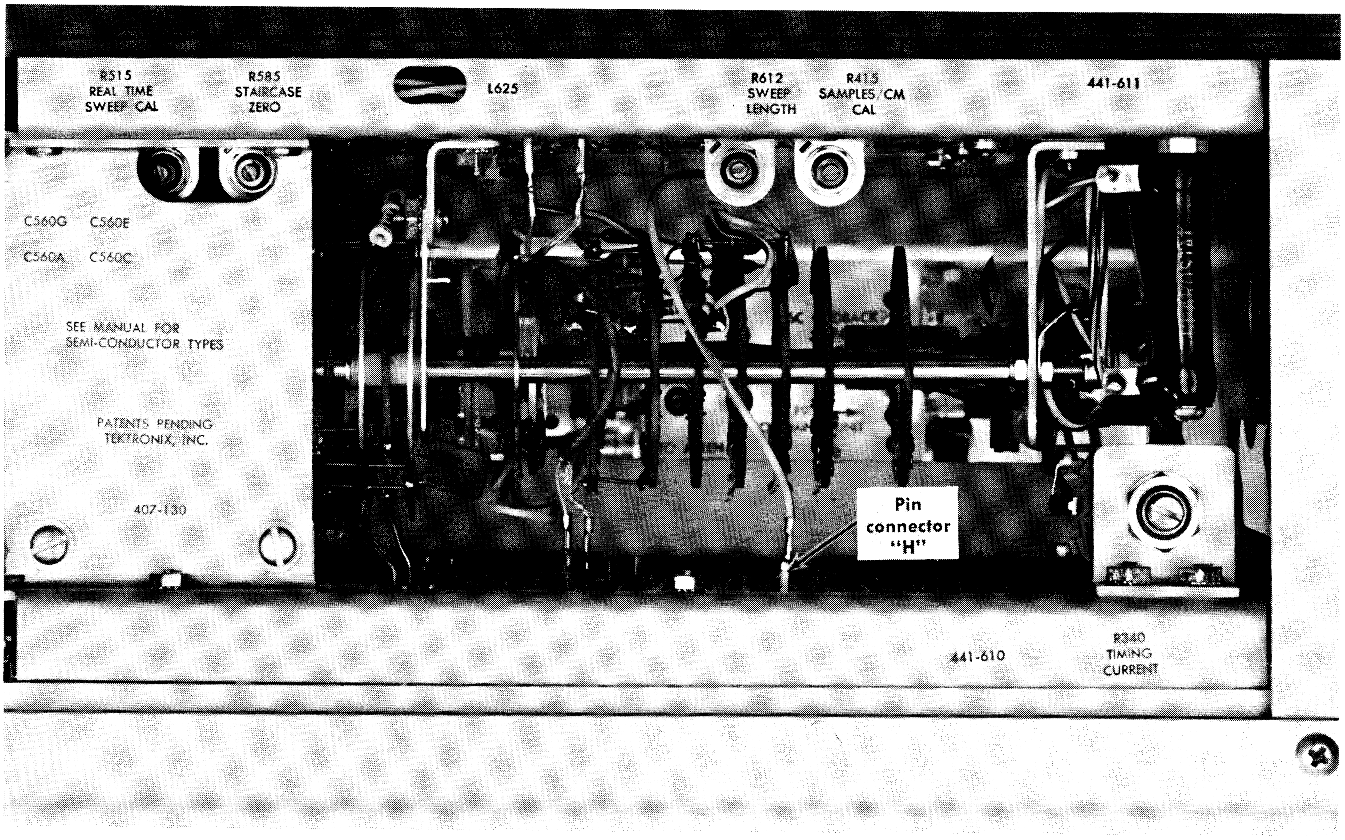


Fig. 5-29. Location of inverter input at pin connector "H".

19. Adjust Equivalent Time Registration ⓘ

(If staircase zero adjustment (step 8) has not been checked previously, check it before performing this step.)

Inverter DC Level

a. Test equipment setup is shown in Fig. 5-28.

b. Set the test oscilloscope for a dc zero reference level.

c. Connect the test probe to pin connector "H". The location of pin "H" is shown in Fig. 5-29.

d. **Check** for a reading of zero volts (reference level) at the top of the waveform (see Fig. 5-30).

e. **Adjust** R376 (INVERTER DC LEVEL) if the top of the waveform is not at zero volts. See Fig. 5-31 for the location of R376.

f. Remove the test probe.

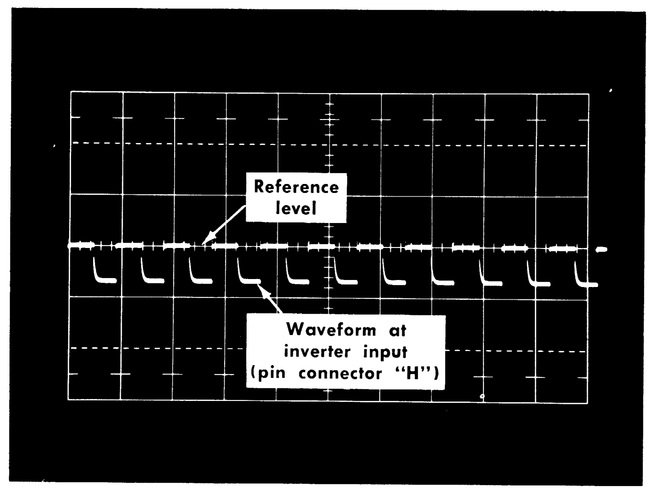


Fig. 5-30. Waveform for checking inverter input zero.

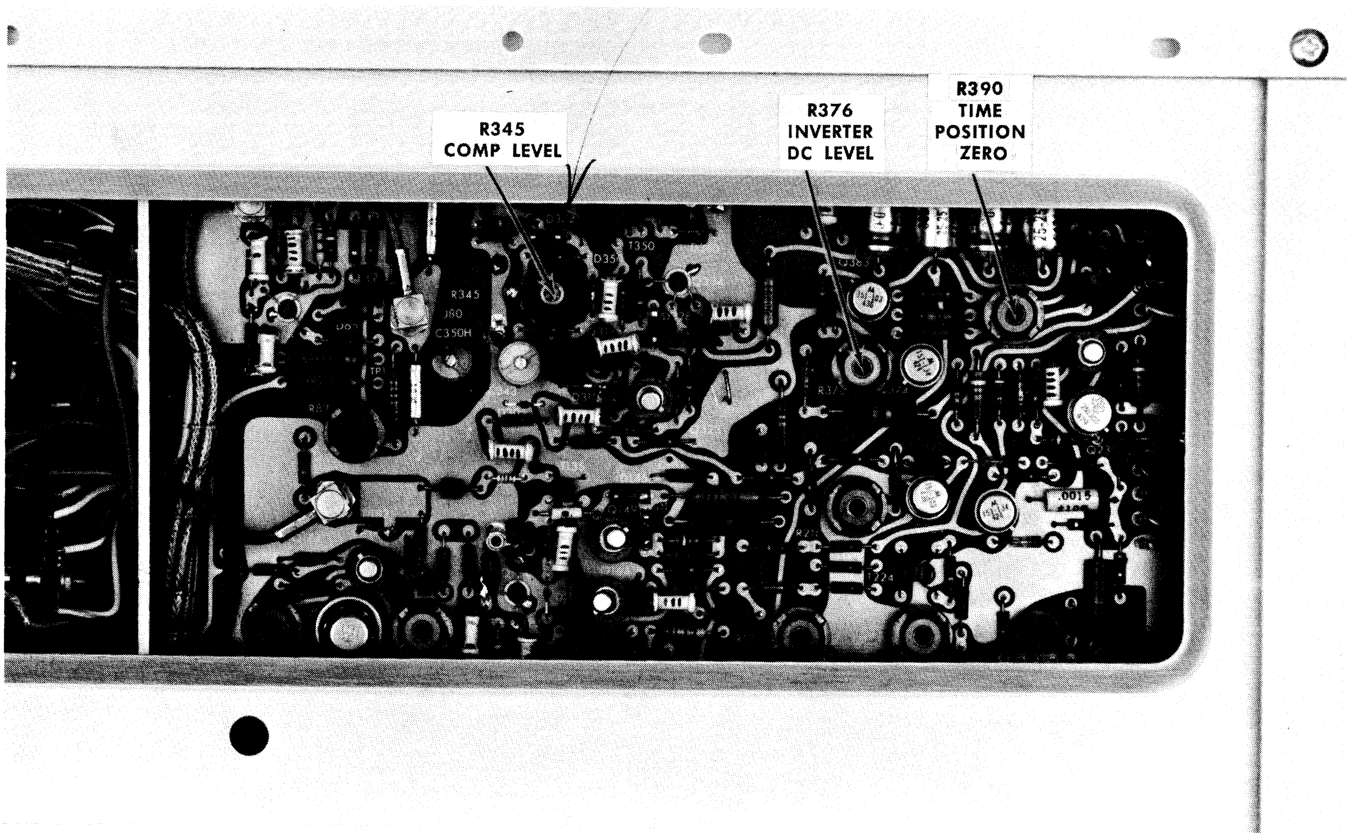


Fig. 5-31. Equivalent-time sweep registration controls.

Comparator Level

g. Connect the Type 661 Amplitude/Time Calibrator output to the sampling unit vertical input.

h. Set R390 (TIME POSITION ZERO) fully counterclockwise. See Fig. 5-31 for the location of R390.

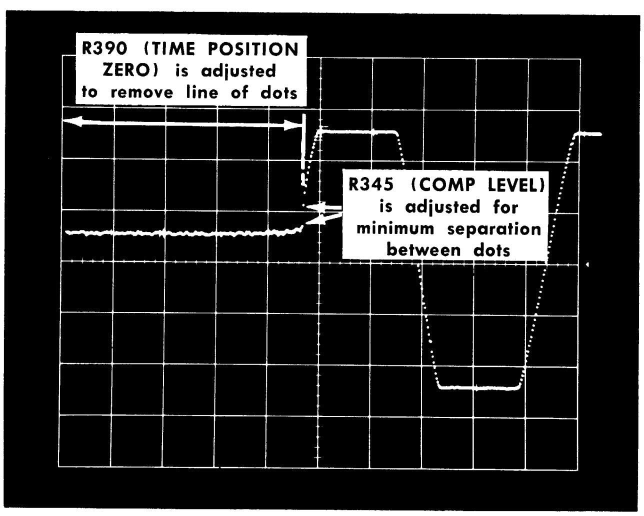


Fig. 5-32. Waveform for adjusting equivalent-time registration.

i. Set the TRIG SOURCE switch to INT and the SWEEP MODE switch to NORM.

j. Trigger the Type 5T3 and observe the beginning portion of the crt display on the Type 661. There should be a straight line of dots preceding the calibrator waveform.

k. Set the triggering controls so the waveform rise begins on a positive slope near the center of the screen (see Fig. 5-32).

l. Observe the point of transition between the straight line and the calibrator waveform.

m. **Adjust** R345 (COMP LEVEL) for the best possible transition from the line to the waveform. See Fig. 5-31 for the location of R345. With R345 adjusted correctly, it is set near the clockwise end of the range that will allow the sweep to run. If the control is turned too far clockwise, the waveform will disappear.

Time Position Zero

n. Observe the straight line preceding the calibrator waveform.

o. **Adjust** R390 (TIME POSITION ZERO) to remove the line of dots.

p. Turn the EQUIVALENT TIME/CM switch between the 2 and 1 μSEC positions. The waveform should start at approximately the same level (within 1 cm) in both positions of the switch.

q. Disconnect the calibrator signal.

Ⓐ

20. Check Equivalent Time Sweep Rates

a. Set the SAMPLES/CM switch to 100.

b. Center the TIME POSITION and FINE controls.

c. Connect the time-mark generator through the variable attenuator to the vertical input of the sampling unit.

d. Set the time-mark generator as indicated in Table 5-4.

e. **Check** the equivalent-time sweep rates as given in the table. Timing is checked over the center 8 cm of the graticule (see Fig. 5-33). Adjust the amplitude as required. (The 10, 5, 2 and 1 nSEC positions of the EQUIVALENT TIME/CM switch were checked by step 16.) Timing accuracy should be within 3% on all sweep rates. If not, R340 (TIMING CURRENT) may need to be readjusted slightly (see step 15). If the timing current is changed, also check steps 16, 17 and 19.

TABLE 5-4

Equivalent Time Sweep Rate Checks

EQUIVALENT TIME/CM	Time-Mark Signal	Display
20 nSEC	50 Mc sine wave	1 cycle/cm
50 nSEC	10 Mc	1 cycle/2 cm
.1 μSEC	10 Mc	1 cycle/cm
.2 μSEC	5 Mc	1 cycle/cm
.5 μSEC	1 μsec marker	1 mark/2 cm
1 μSEC	1 μsec	1 mark/cm
2 μSEC	1 μsec	2 marks/cm
5 μSEC	5 μsec	1 mark/cm
10 μSEC	10 μsec	1 mark/cm
20 μSEC	10 μsec	2 marks/cm
50 μSEC	50 μsec	1 mark/cm
100 μSEC	100 μsec	1 mark/cm

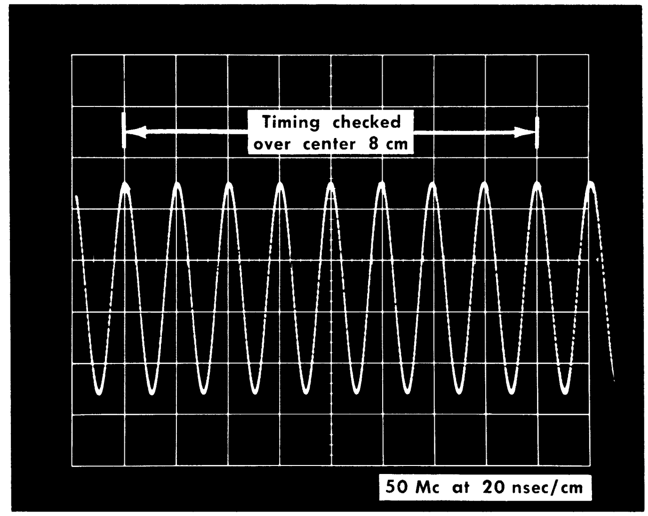


Fig. 5-33. Typical waveform for checking equivalent-time sweep timing and linearity.

21. Check Equivalent Time Variable

a. Leave the time-mark signal connected to the vertical input.

b. Set the EQUIVALENT TIME/CM switch to 1 μSEC.

c. Set the time-mark generator for an output of 1 μsec markers.

d. Trigger the display

e. Turn the Equivalent Time/Cm VARIABLE control fully clockwise and observe the display expansion.

f. **Check** for an effective range of 2.5 (or more) to 1. Distance between the markers should be 2.5 cm or greater.

g. **Check** that the UNCAL neon is lit whenever the VARIABLE control is not in the CAL position (fully counterclockwise).

h. Return the VARIABLE control to CAL.

22. Check Equivalent Time Magnifier

a. Leave the time-mark signal connected to the vertical input.

b. Set the EQUIVALENT TIME/CM switch to 2 μSEC.

c. The time-mark generator should be set for a 1-μsec marker output.

d. Pull out on the gray EQUIVALENT TIME/CM MAGNIFIER knob and turn it clockwise 1 position (to 1 μSEC). The TIME POSITION RANGE switch should remain at 100 μS.

e. **Check** for correct magnification (±3%) on each setting of the MAGNIFIER knob from 1 μSEC to 20 nSEC, as indicated in Table 5-5. Timing is checked over the center 8 cm. Accuracy of the sweep rates from .5 nSEC to 10 pSEC is checked by this procedure, since these sweep rates are determined by the timing and the magnifier.

f. Turn the MAGNIFIER knob back to the 2 μSEC position to again lock it to the TIME POSITION RANGE switch.

TABLE 5-5

Equivalent Time Magnifier Check

MAGNIFIER	Time-Mark Signal	Display
1 μSEC	1 μsec marker	1 mark/cm
.5 μSEC	1 μsec	1 mark/2 cm
.2 μSEC	5 Mc sine wave	1 cycle/cm
.1 μSEC	10 Mc	1 cycle/cm
50 nSEC	10 Mc	1 cycle/2 cm
20 nSEC	10 Mc	1 cycle/5 cm

23. Check Single Display

a. Leave the time-mark signal connected to the vertical input.

b. Set the EQUIVALENT TIME/CM switch to 1 μSEC.

c. Set the time-mark generator for a 1-μsec marker output.

d. Set the STABILITY OR UHF SYNC control slightly counterclockwise from center and trigger the display with the TRIG LEVEL control.

e. Set the SWEEP MODE switch to SINGLE DISPLAY. After completion of the sweep, the trace will be held off.

f. Set the time-mark generator for no output.

g. Press the START button. The sweep will remain off.

h. Set the time-mark generator for 1-μsec markers. A single triggered sweep will occur.

i. Press the START button. A single triggered sweep will occur.

j. Set the SWEEP MODE switch to NORM.

24. Check Fast Ramp Linearity

a. Leave the time-mark signal connected to the sampling unit vertical input.

b. Set the EQUIVALENT TIME/CM switch to 20 μSEC.

c. Pull out on the gray MAGNIFIER knob and turn it to 5 μSEC.

d. Set the time-mark generator for 5 μsec markers.

e. Center the FINE control. This setting allows for the inherent nonlinearity at the start of the fast ramp.

f. **Check** for a display of 1 mark/cm with the TIME POSITION control set fully counterclockwise and again with the control fully clockwise. Timing should be within ±3% at each end of the time-position range.

g. Set the oscilloscope Amplitude/Time Calibrator to .01 μSec/Cycle.

h. Check each range of the TIME POSITION RANGE switch, from 100 μS to 20 nS, as indicated in Table 5-6. Leave the FINE control centered at all times during these checks. For the 100 nS and 20 nS ranges, remove the time-mark signal and connect either the oscilloscope Amplitude/Time Calibrator signal or a 500-Mc sine-wave signal to the vertical input. If available, the 500-Mc signal is preferred.

i. Disconnect the input signal.

TABLE 5-6

Fast Ramp Linearity Check

TIME POSITION RANGE	EQUIVALENT TIME/CM	Input Signal	Display
1 mS	5 μSEC	5 μsec marker	1 mark/cm
100 μS	.5 μSEC	1 μsec marker	1 mark/2 cm
10 μS	50 nSEC	10 Mc sine wave	1 cycle/2 cm
1 μS	10 nSEC	50 Mc sine wave	1 cycle/2 cm
100 nS	2 nSEC	.01 μSec/Cycle 500 Mc sine wave	1 cycle/5 cm 1 cycle/cm
20 nS	1 nSEC	.01 μSec/Cycle 500 Mc sine wave	1 cycle/10 cm 1 cycle/2 cm

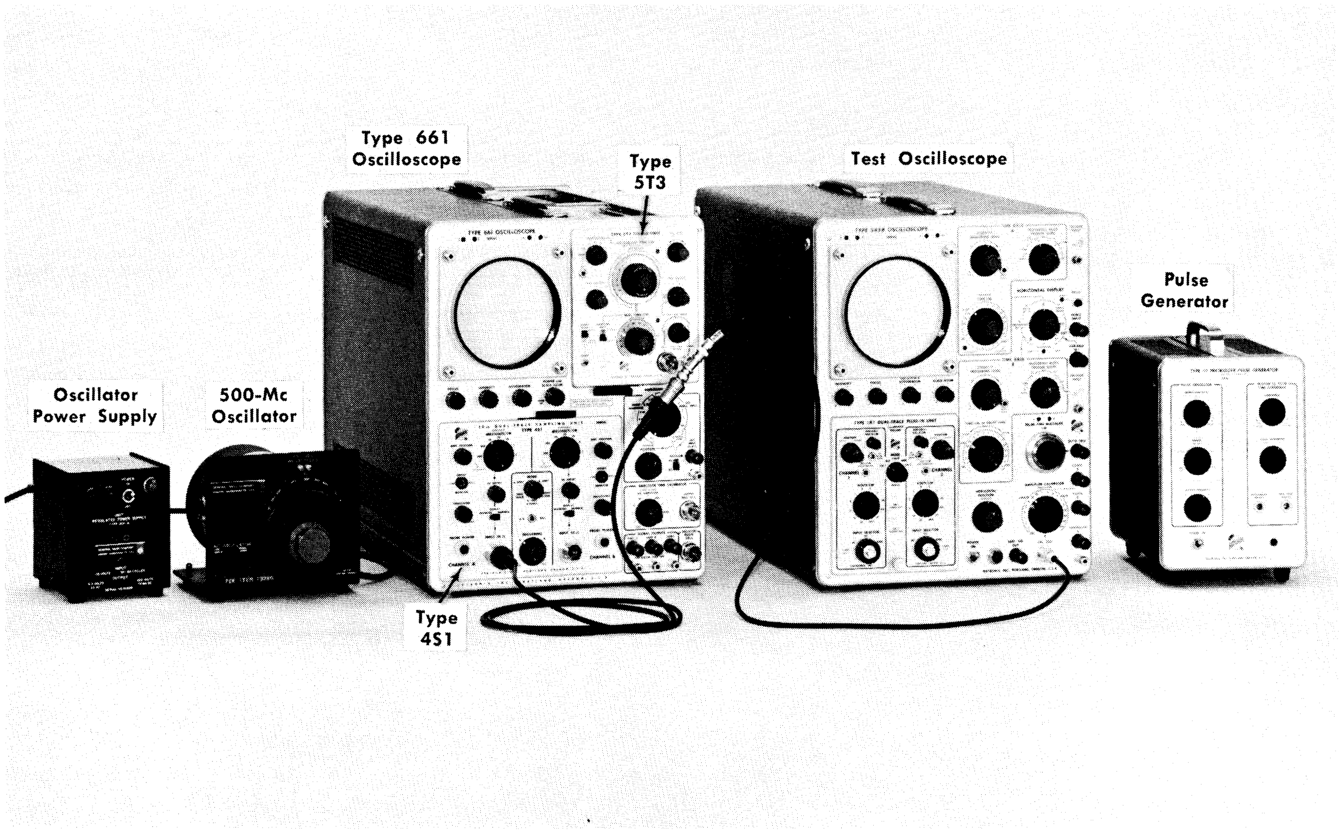


Fig. 5-34. Test equipment setup for steps 25 through 28.

Type 5T3

EQUIVALENT TIME/CM	**REAL TIME**
Equivalent Time/Cm VARIABLE	CAL
Equivalent Time SAMPLES/CM	100
TIME POSITION	**Centered**
Time Position FINE	**Centered**
SWEEP MODE	NORM
REAL TIME/CM	**.5 mSEC**
Real Time/Cm VARIABLE	CAL
Real Time SAMPLING RATE	100 KC
TRIG LEVEL	**Clockwise**
STABILITY OR UHF SYNC	**Clockwise**
TRIG SOURCE	**EXT**
SLOPE	+
EXT TRIG MODE	1 MΩ AC

Type 661

Horizontal Display	×1
Amplitude/Time Calibrator	**1000 mv, 10 μSec/Cycle**

Type 4S1

Millivolts/Cm	**50**
Millivolts/Cm Variable	Cal
Mode	A Only
Vertical Position	Centered
Display	Normal
DC Offset	Centered
Smoothing	Unity gain
Triggering	A AC

25. Check Real Time Display Jitter

NOTE

If the sampling unit is not set for unity gain (or less) for this step and the remainder of the calibration procedure, vertical display noise will cause incorrect jitter readings.

 Ⓐ

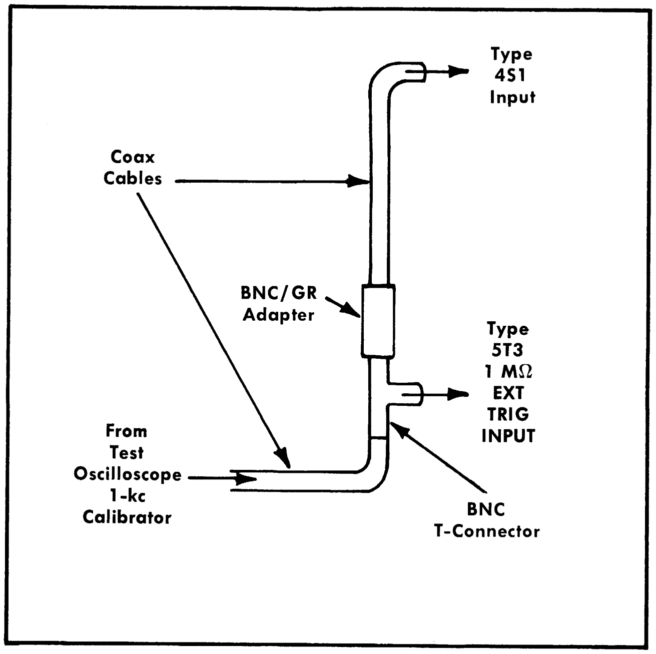


Fig. 5-35. Signal connections for checking real-time display jitter.

a. Test equipment setup is shown in Fig. 5-34.

b. Connect a 200-mv 1-kc square-wave signal to the Type 5T3 1 MΩ EXT TRIG INPUT and to the vertical input of the sampling unit as shown in Fig. 5-35. The test oscilloscope calibrator may be used for the signal source.

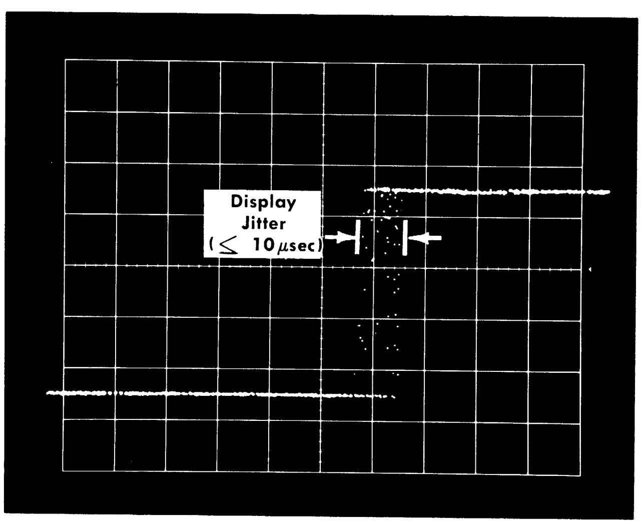


Fig. 5-36. Typical crt display for checking real-time display jitter on a 1-kc square wave.

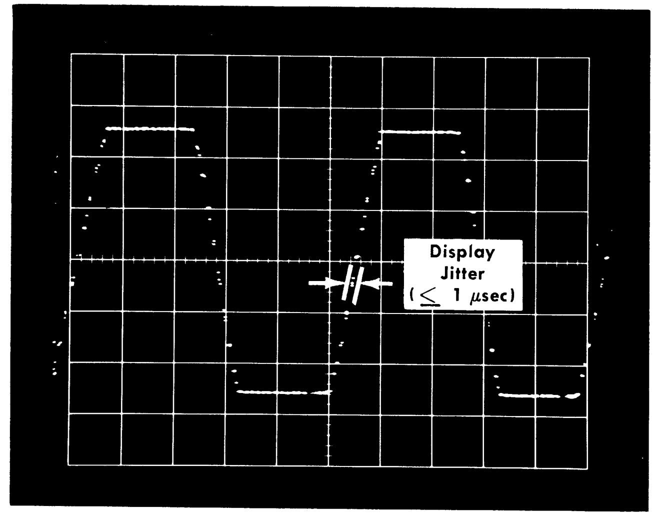


Fig. 5-37. Typical crt display for checking real-time display jitter on internal calibrator.

c. Trigger the display.

d. Set the Type 661 Oscilloscope Sweep Magnifier to ×50. (This makes the display sweep rate 10 μsec/cm.)

e. Position the second rise of the waveform to the center of the crt screen.

f. Set the SAMPLING RATE switch to RANDOM.

g. **Check** the horizontal thickness of the trace for the amount of time jitter. This should not exceed 10 μsec (see Fig. 5-36).

h. Disconnect the 1-kc calibrator signal and the T-connector.

i. Connect the Type 661 Oscilloscope Amplitude/Time Calibrator output to the vertical input of the sampling unit.

j. Set the REAL TIME/CM switch to .2 mSEC.

k. Set the TRIG SOURCE switch to CAL.

l. Set the sampling unit Millivolts/Cm switch to 200.

m. Set the oscilloscope Sweep Magnifier switch to ×100. (This makes the display sweep rate 2 μsec/cm.)

n. Trigger the display.

o. With the sampling unit DC Offset and the oscilloscope horizontal Position controls, position the rise of the second cycle of the waveform at the center of the crt.

p. **Check** the horizontal thickness of the trace for the amount of time jitter. This should not exceed 1 μsec (see Fig. 5-37).

26. Check Equivalent Time Display Jitter

a. Leave the Amplitude/Time Calibrator signal connected to the vertical input.

b. Set the EQUIVALENT TIME/CM switch to 20 μSEC.

c. Set the oscilloscope Sweep Magnifier to ×1.

d. Set the Amplitude/Time Calibrator for a 1-μsec/cycle output frequency.

e. Set the sampling unit Millivolts/Cm switch to 200.

f. Pull out on the MAGNIFIER knob and turn the EQUIVALENT TIME/CM switch to .2 μSEC.

g. Trigger the display.

h. With the Time Position FINE control, position the most vertical portion of the waveform rise on the center of the crt screen.

i. Set the sampling unit Millivolts/Cm switch to 50.

j. **Check** the horizontal thickness of the trace for time jitter on the 1 mS TIME POSITION RANGE. See Table 5-7 for maximum jitter characteristics.

k. **Check** the display jitter also on the 100 μS, 10 μS and 1 μS positions of the TIME POSITION RANGE switch, as listed in Table 5-7. Fig. 5-38 shows a typical waveform for checking equivalent-time display jitter.

l. Disconnect the calibrator signal from the vertical input.

m. Turn off the oscilloscope calibrator.

TABLE 5-7

Equivalent Time Display Check

TIME POSITION RANGE	EQUIVALENT TIME/CM	Calibrator	Display Jitter (max)
1 mS	.2 mSEC	1 μSEC	≤ 200 nsec
100 μS	20 nSEC	1 μSEC	≤ 20 nsec
10 μS	2 nSEC	.1 μSEC	≤ 2 nsec
1 μS	.2 nSEC	.01 μSEC	≤ 200 psec

27. Check Equivalent Time Triggering

a. Install the variable attenuator and a 10× T-attenuator on the sampling unit vertical input.

b. Connect the pulse generator output pulse to the attenuators on the input.

c. Set the repetition rate of the pulse generator to 100 kc. Do not use an external charge line with the Type 111.

d. Set the TRIG SOURCE switch to INT.

e. Set the TIME POSITION RANGE switch to 100 nS and the EQUIVALENT TIME/CM switch to 1 nSEC.

f. Set the sampling unit Millivolts/Cm switch to 100.

g. Trigger the display.

h. Adjust the variable attenuator for a pulse amplitude of 400 mv into the sampling unit.

i. Pull out on the MAGNIFIER knob and set the EQUIVALENT TIME/CM switch to 50 pSEC.

j. Adjust the TIME POSITION control and the sampling unit DC Offset control to position the 50% level of the pulse rise at the center of the crt screen.

k. Set the sampling unit Millivolts/Cm switch to 10.

l. **Check** the horizontal thickness of the trace for time jitter of the display. This should not exceed 40 psec (see Fig. 5-38).

m. Set the TIME POSITION RANGE switch to 20 nS and the EQUIVALENT TIME/CM switch to 50 pSEC.

n. **Check** the display for time jitter. This should not exceed 30 psec.

o. Connect a second 10× T-attenuator in series with the attenuators at the sampling unit input.

p. Set the EQUIVALENT TIME/CM switch to 1 nSEC.

q. Trigger the display.

r. Adjust the variable attenuator for an amplitude of 40 mv.

s. Pull out on the MAGNIFIER knob and set it to .5 nSEC.

t. Position the 50% level of the pulse rise at the center of the crt screen.

u. Set the sampling unit Millivolts/Cm switch to 2.

v. **Check** the trace for triggering jitter. This should not exceed 300 psec.

w. Disconnect the pulse generator signal, the variable attenuator and the 10× T-attenuators from the vertical input.

28. Check Auto Recovery Triggering

a. Connect a 500-Mc oscillator signal to the Type 5T3 50 Ω EXT TRIG INPUT and to the sampling unit vertical input as shown in Fig. 5-39.

b. Set the sampling unit Millivolts/Cm switch to 100.

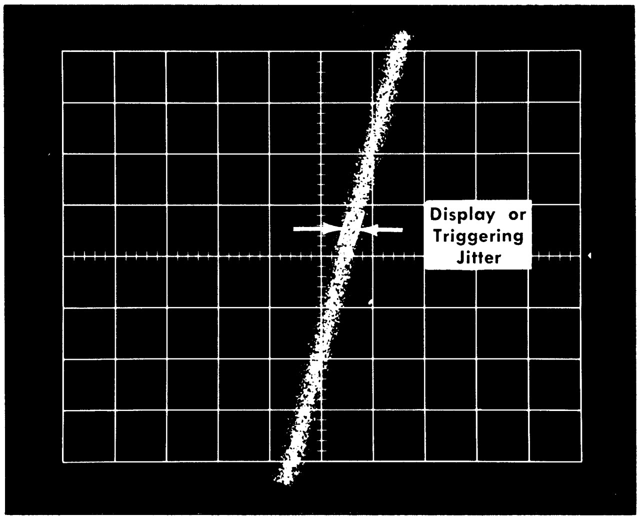


Fig. 5-38. Typical crt display for checking equivalent-time display jitter or triggering jitter.

c. Set the EXT TRIG MODE switch to 50 Ω AC. (The TRIG SOURCE switch should still be at INT.)

d. Set the EQUIVALENT TIME/CM switch to 1 nSEC.

e. Adjust the oscillator output and the variable attenuator to produce 4 cm of deflection (50 mv to the Type 5T3 from the sampling unit).

f. Switch the STABILITY OR UHF SYNC control to the AUTO RECOVERY detent position.

g. Trigger the display with the TRIG LEVEL control.

h. Pull out on the MAGNIFIER knob and set it to .1 nSEC.

i. With the TIME POSITION control position the most vertical portion of the waveform rise at the center of the crt screen.

j. Set the sampling unit Millivolts/Cm switch to 10.

k. **Check** the trace for time jitter. This should not exceed 70 psec (see Fig. 5-38).

l. Set the sampling unit Millivolts/Cm switch to 100.

m. Adjust the variable attenuator to produce 5 cm of deflection on the crt screen (50 mv at the 50 Ω EXT TRIG INPUT).

n. Set the TRIG SOURCE switch to EXT.

o. Trigger the display.

p. Position the waveform rise at the center of the crt.

q. Set the sampling unit Millivolts/Cm switch to 10.

r. **Check** the display for time jitter. This should not exceed 70 psec.

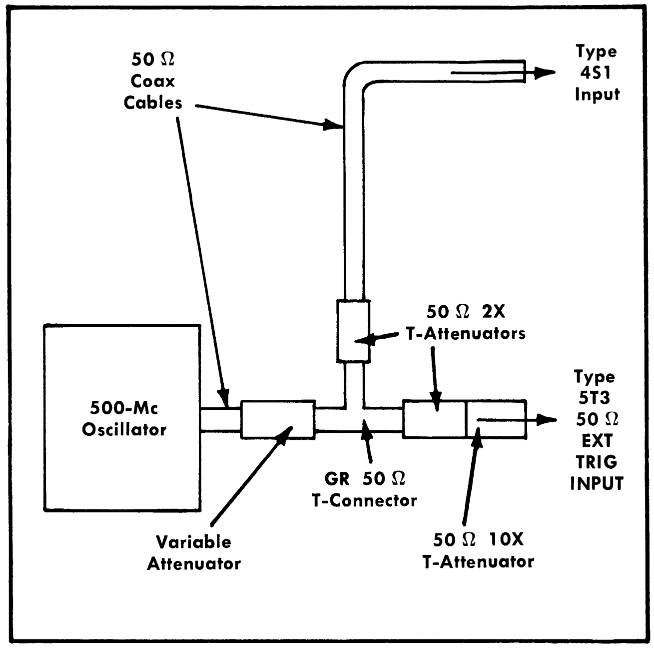


Fig. 5-39. Connections for 500 Mc high-frequency Auto Recovery triggering check.

s. Set the TRIG SOURCE switch to INT.

t. Insert a 10× T-attenuator in the signal path at the output of the 500-Mc oscillator.

u. Set the EQUIVALENT TIME/CM switch to .5 nSEC.

v. Trigger the display with the TRIG LEVEL control.

w. Adjust the variable attenuator to produce 4 cm of deflection on the crt screen (5 mv internally to the Type 5T3).

x. Set the sampling unit Millivolts/Cm switch to 2.

y. **Check** the display for time jitter. This should not exceed 300 psec.

z. Set the sampling unit Millivolts/Cm switch to 10.

aa. Adjust the variable attenuator to produce 5 cm of deflection (5 mv at the 50 Ω EXT TRIG INPUT).

bb. Set the TRIG SOURCE switch to EXT.

cc. Trigger the display.

dd. Center the rising portion of the waveform.

ee. Set the sampling unit Millivolts/Cm switch to 2.

ff. **Check** the display for time jitter. This should not exceed 300 psec.

gg. Disconnect the oscillator signal and remove the attenuators, connectors and cables.

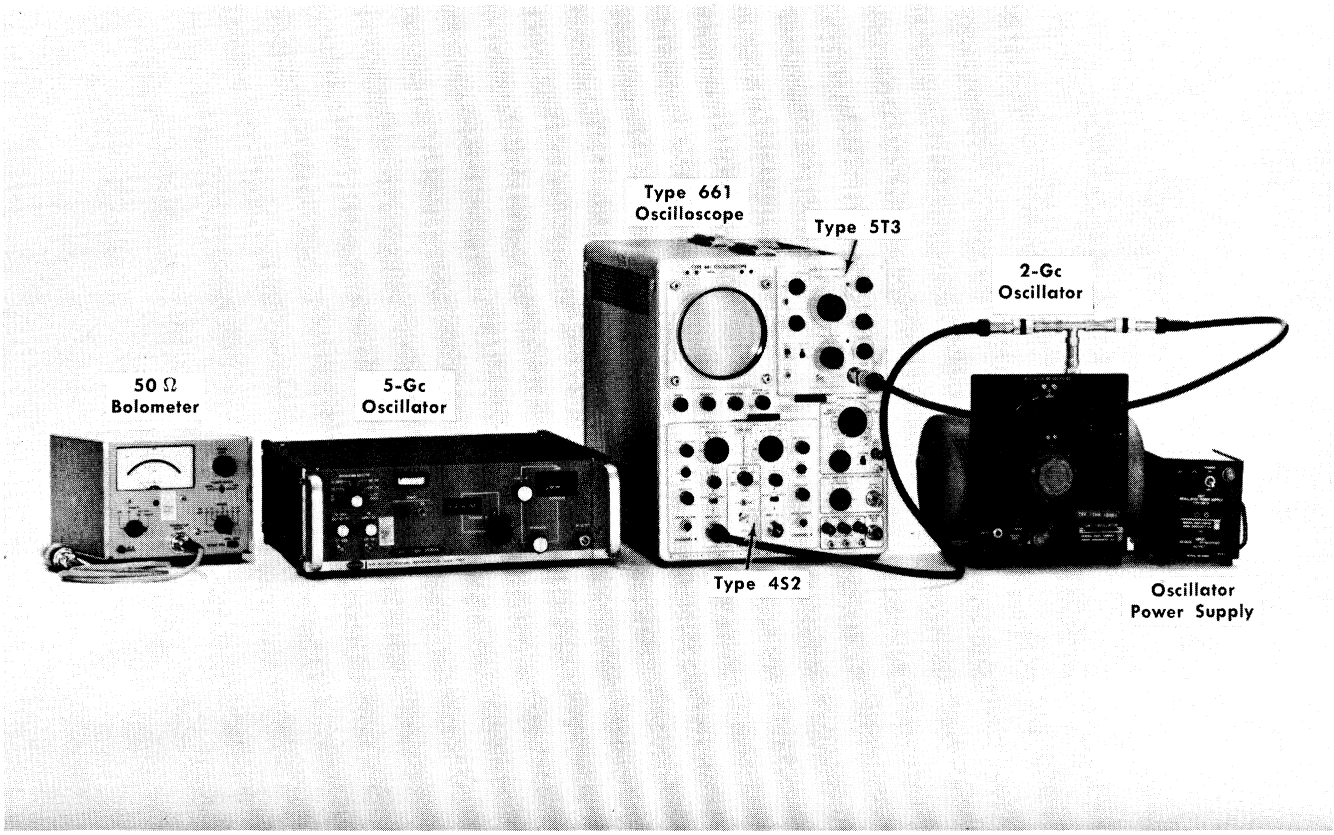


Fig. 5-40. Test equipment setup for step 29.

Type 5T3

EQUIVALENT TIME/CM	**50 pSEC**
TIME POSITION RANGE	20 nS
Equivalent Time/Cm VARIABLE	CAL
Equivalent Time SAMPLES/CM	100
TIME POSITION	Centered
Time Position FINE	Centered
SWEEP MODE	NORM
REAL TIME/CM	Any Position
Real Time/Cm VARIABLE	CAL
Real Time SAMPLING RATE	100 KC
TRIG LEVEL	**Centered**
STABILITY OR UHF SYNC	AUTO RECOVERY
TRIG SOURCE	EXT
SLOPE	+
EXT TRIG MODE	**50 Ω UHF SYNC**

Type 661

Horizontal Display	×1
Position and Vernier	Centered
Amplitude/Time Calibrator	Off

Type 4S2

Millivolts/Cm	**20**
Millivolts/Cm Variable	Calibrated
Mode	A Only
Vertical Position	Centered
Display	Normal
DC Offset	Centered
Smoothing	Unity gain

29. Check UHF Sync Triggering

a. Test equipment setup is shown in Fig. 5-40.

b. Turn off the oscilloscope.

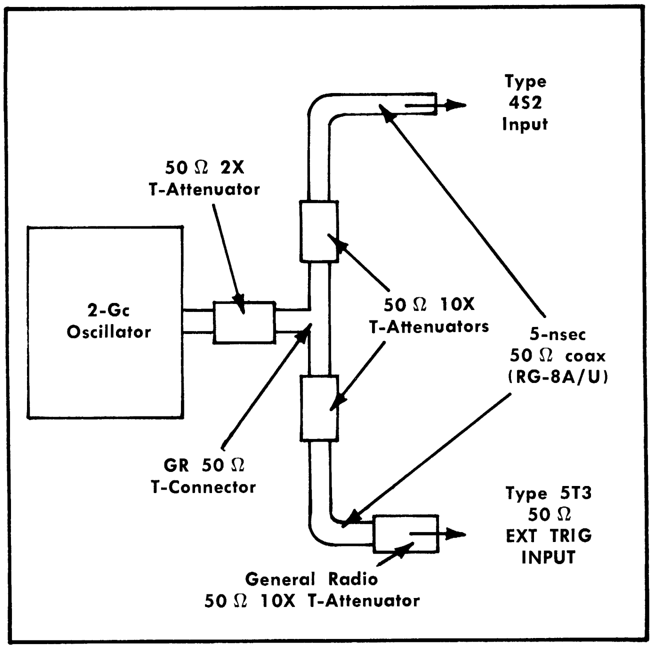


Fig. 5-41. Signal connections for 2-Gc UHF Sync check.

c. Remove the Type 4S1 Sampling Unit and insert the Type 4S2 Sampling Unit.

d. Turn on the oscilloscope. Allow 5 minutes for warm up.

e. Connect a 2-Gc oscillator signal to the sampling unit vertical input and to the Type 5T3 50 Ω EXT TRIG INPUT as shown in Fig. 5-41.

f. Set the oscillator output to produce 5 cm of deflection (100 mv to the vertical unit; 10 mv to the 50 Ω EXT TRIG INPUT).

g. Trigger the display with the STABILITY OR UHF SYNC control.

h. Center a rising portion of the waveform on the crt screen.

i. Set the sampling unit Millivolts/Cm switch to 5.

j. **Check** the display for time jitter. This should not exceed 30 psec (see Fig. 5-42).

k. Replace the 2× T-attenuator with a 5× T-attenuator in the test setup.

l. Set the sampling unit Millivolts/Cm switch to 10.

m. Set the 2-Gc oscillator output amplitude to produce 5 cm of deflection on the crt screen.

n. Set the EQUIVALENT TIME/CM switch to .1 nSEC.

o. Trigger the display.

p. Center a rising portion of the waveform on the crt screen.

q. Set the sampling unit Milivolts/Cm switch to 5.

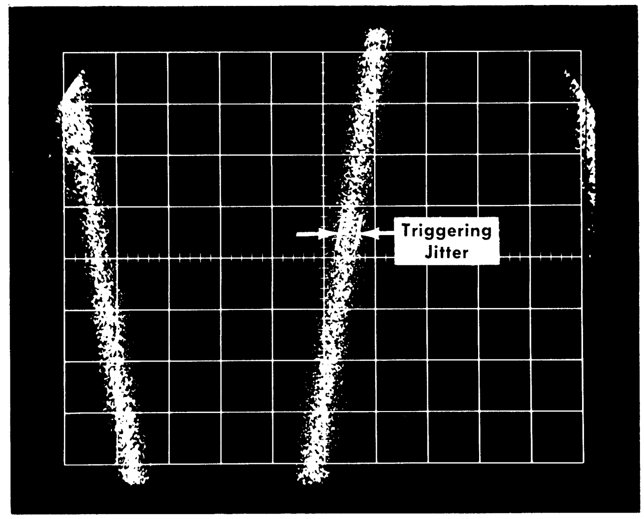


Fig. 5-42. Typical crt display for checking UHF Sync triggering jitter. Measure only effective horizontal thickness, not maximum random excursions.

r. **Check** the display for time jitter. This should not exceed 70 psec.

s. Disconnect the 2-Gc oscillator and connect the 5-Gc oscillator as shown in Fig. 5-43.

t. Set the oscillator amplitude to present 50 mv of signal (peak-to-peak) at the Type 5T3 50 Ω EXT TRIG INPUT connector. Measure this amplitude with a bolometer (17.7 mv rms = 6.24 μw in 50 ohms) by temporarily disconnecting the attenuator from the 50 Ω EXT TRIG INPUT connector as shown in Fig. 5-43. The display cannot be used to determine the signal amplitude.

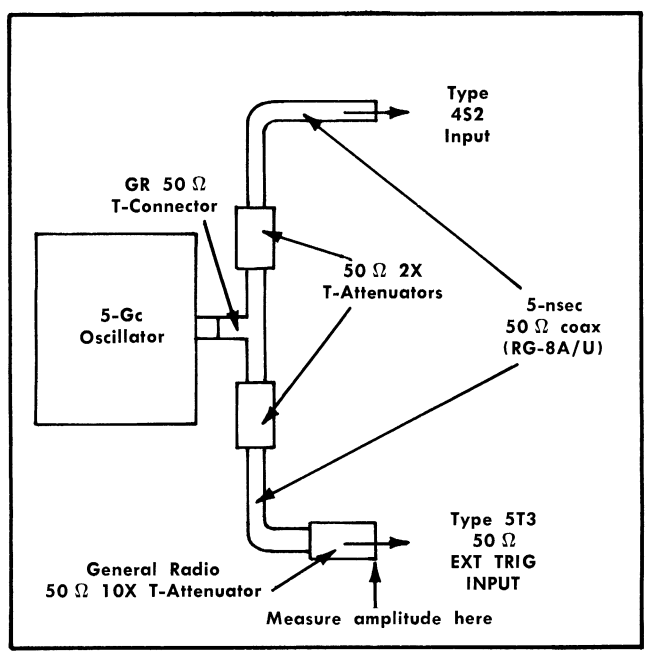


Fig. 5-43. Signal connections for 5-Gc UHF Sync check.

u. Set the EQUIVALENT TIME/CM switch to 50 pSEC.

v. Trigger the display.

w. Center a rising portion of the waveform on the crt screen.

x. Set the sampling unit Millivolts/Cm switch to 10.

y. **Check** the display for time jitter. This should not exceed 30 psec (see Fig. 5-42).

z. Disconnect the coax from the 10× T-attenuator on the 50 Ω EXT TRIG INPUT connector.

aa. Connect a 5× T-attenuator on the end of the cable.

bb. Set the output amplitude of the 5-Gc oscillator for 100 mv peak-to-peak as measured at the output of the 5× T-attenuator (35.4 mv rms = 25 µw in 50 ohms).

cc. Connect the 5× T-attenuator to the 10× attenuator on the 50 Ω EXT TRIG INPUT.

dd. Trigger the display.

ee. Set the sampling unit Millivolts/Cm switch to 2S.

ff. **Check** the display for time jitter. This should not exceed 70 psec.

gg. Disconnect the test setup.

CALIBRATION OUTLINE

This calibration outline is provided to serve as a quick calibration guide for those familiar with the procedure. It may also be used as a verification and calibration record. The step number and titles are the same as those used in the procedure.

Type 5T3 Serial No. __________ Calibration Date ________

☐ 1. Adjust External Trigger Zero Levels.
Zero volts at external trigger output.

☐ 2. Adjust Trigger Balance.
Zero volts at trigger input.

☐ 3. Adjust Output TD Bias.
Bias level just short of free run.

☐ 4. Adjust Trigger Level Zero.
Trigger Level operation set to center.

☐ 5. Adjust Stability Zero.
Stability operation set to center.

☐ 6. Adjust Delayed Pulse Bias.
Stable operation of delayed pulse generator.

☐ 7. Check Trigger Holdoff.
≥10 µsec on 1 µS, 100 nS and 20 nS ranges.
≥4-times time position range on other equivalent time ranges.
≥10 µsec on all real time rates.

☐ 8. Adjust Staircase Zero.
Base of staircase output at zero.

☐ 9. Adjust Sweep Length.
Approximately 52.5 volts (51-55 volts).

☐ 10. Adjust Real Time Sweep Calibration.
Correct timing within ±3% at 1 msec/cm.

☐ 11. Check Real Time Sweep Rates.
Within ±3% at all real-time sweep rates.

☐ 12. Check Real Time/Cm Variable.
At least 2.5 times increase in display sweep speed.

☐ 13. Adjust Real Time Clock
Within ±1% of 100 kc.

☐ 14. Check Random Rate.
Oscillator period between 10 µsec and 15 µsec.

☐ 15. Adjust Equivalent Time Sweep Calibration.
Correct timing within ±3% at 1 µsec/cm.

☐ 16. Adjust 1 and 10 nSec Ramp Timing.
Within ±3% at 1 nsec/cm and 10 nsec/cm.

☐ 17. Adjust Samples/Cm.
Correct dot spacing at 1 µsec/cm.

☐ 18. Check Timed Control.
Timed sweep from ≤ 0.5 to ≥ 5 sec/cm.

☐ 19. Adjust Equivalent Time Registration.
Zero volts at inverter input.
Correct comparator bias current.
Correct comparison (time position) starting level.

☐ 20. Check Equivalent Time Sweep Rates.
Within ±3% at all equivalent-time sweep rates.

☐ 21. Check Equivalent Time Variable.
At least 2.5 times increase in display sweep speed.

☐ 22. Check Equivalent Time Magnifier.
Correct timing within ±3% from 2 µsec/cm.

☐ 23. Check Single Display.
Triggerable single sweep operation.

☐ 24. Check Fast Ramp Linearity.
±3% at any time position, excluding first portion of ramp. (Excluded portions: 15% of 20 nS; 10% of 100 nS; 4% of 1 µS; 1.5% of 10 µS, 100 µS and 1 mS).

☐ 25. Check Real Time Display Jitter.
≤10 µsec on 1-kc 200-mv square wave;
≤1 µsec on 100-kc 100-mv clipped sine wave.

☐ 26. Check Equivalent Time Display Jitter.
≤0.02% of time position range at 1 mS, 100 µS, 10 µS and 1 µS;
≤0.04% of time position range at 100 nS;
≤0.15% of time position range at 20 nS.

☐ 27. Check Equivalent Time Triggering.
≤30 psec trigger jitter on a 2-nsec 50-mv pulse (400-mv at sampling unit input);
≤300 psec trigger jitter on a 2-nsec 5-mv pulse (40-mv at sampling unit input).

☐ 28. Check Auto Recovery Triggering.
≤70 psec trigger jitter on 50-mv 500-Mc sine wave (400-mv at sampling unit input);
≤300 psec trigger jitter on 5-mv 500-Mc sine wave (40-mv at sampling unit input).

☐ 29. Check UHF Sync Triggering.
≤30 psec trigger jitter on 10-mv 2-Gc sine wave;
≤70 psec trigger jitter on 5-mv 2-Gc sine wave;
≤30 psec trigger jitter on 50-mv 5-Gc sine wave;
≤70 psec trigger jitter on 5-mv 5-Gc sine wave.

SECTION 6
PARTS LIST and DIAGRAMS

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix Field Office.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number including any suffix, instrument type, serial number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix Field Office will contact you concerning any change in part number.

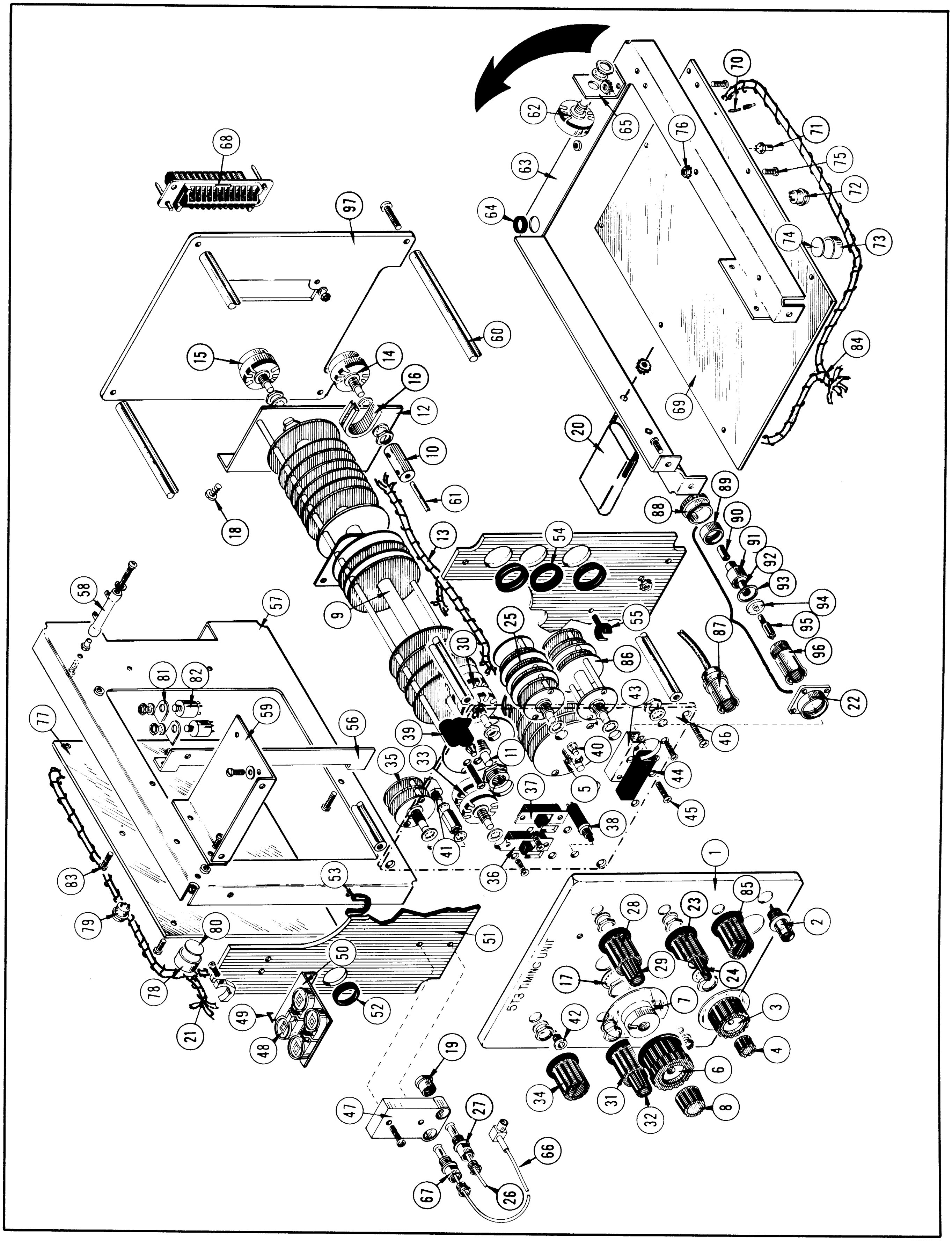
ABBREVIATIONS AND SYMBOLS

a or amp	amperes
BHS	binding head steel
C	carbon
cer	ceramic
cm	centimeter
comp	composition
cps	cycles per second
crt	cathode-ray tube
CSK	counter sunk
dia	diameter
div	division
EMC	electrolytic, metal cased
EMT	electroyltic, metal tubular
ext	external
f	farad
F & I	focus and intensity
FHS	flat head steel
Fil HS	fillister head steel
g or G	giga, or 10^9
Ge	germanium
GMV	guaranteed minimum value
h	henry
hex	hexagonal
HHS	hex head steel
HSS	hex socket steel
HV	high voltage
ID	inside diameter
incd	incandescent
int	internal
k or K	kilohms or kilo (10^3)
kc	kilocycle
m	milli, or 10^{-3}
mc	megacycle
mm	millimeter
meg or M	megohms or mega (10^6)
met.	metal
μ	micro, or 10^{-6}
n	nano, or 10^{-9}
Ω	ohm
OD	outside diameter
OHS	oval head steel
p	pico, or 10^{-12}
PHS	pan head steel
piv	peak inverse voltage
plstc	plastic
PMC	paper, metal cased
poly	polystyrene
Prec	precision
PT	paper tubular
PTM	paper or plastic, tubular, molded
RHS	round head steel
rms	root mean square
sec	second
Si	silicon
S/N	serial number
t or T	tera, or 10^{12}
TD	toroid
THS	truss head steel
tub.	tubular
v or V	volt
Var	variable
w	watt
w/	with
w/o	without
WW	wire-wound

SPECIAL NOTES AND SYMBOLS

X000	Part first added at this serial number.
000X	Part removed after this serial number.
*000-000	Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, or reworked or checked components.
Use 000-000	Part number indicated is direct replacement.
(screwdriver symbol)	Internal screwdriver adjustment.
(box symbol)	Front-panel adjustment or connector.

EXPLODED VIEW



Ⓑ

EXPLODED VIEW

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	Q T Y.	DESCRIPTION
1	333-0889-00			1	PANEL, front, 5T3
2	131-0106-00			1	CONNECTOR, BNC
3	366-0208-00			1	KNOB, gray—REAL TIME/CM
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
4	366-0081-00			1	KNOB, red—CAL VARIABLE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
5	262-0708-00			1	SWITCH, wired—REAL TIME/CM
	- - - - - -			-	switch includes:
	260-0668-00			1	SWITCH, unwired—REAL TIME/CM
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0012-00			1	LOCKWASHER, internal, 3/8 x 1/2 inch
	210-0413-00			1	NUT, hex, 3/8-32 x 1/2 inch
	210-0840-00			1	WASHER, .390 ID x 9/16 inch OD
6	366-0293-00			1	KNOB, gray—EQUIVALENT TIME/CM
	- - - - - -			-	knob includes:
	213-0022-00			2	SCREW, set, 4-40 x 3/16 inch, HSS
7	331-0155-00			1	DIAL, window, plexiglas
	- - - - - -			-	dial includes:
	213-0022-00			2	SCREW, set, 4-40 x 3/16 inch, HSS
8	366-0038-00			1	KNOB, red—CAL VARIABLE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
9	262-0705-00			1	SWITCH, wired—EQUIVALENT TIME/CM
	- - - - - -			-	switch includes:
	260-0667-00			1	SWITCH, unwired—EQUIVALENT TIME/CM
10	376-0008-00			1	COUPLING, alum., 7/8 inch long x 1/2 inch diameter
	- - - - - -			-	coupling includes:
	213-0005-00			2	SCREW, set, 8-32 x 1/8 inch HSS
11	384-0354-00			1	ROD, extension, 1/8 inch diameter x 11.160 inch long
12	407-0131-00			1	BRACKET, switch mounting
	- - - - - -			-	mounting hardware: (not included w/bracket alone)
	210-0006-00			1	LOCKWASHER, internal, #6
	210-0202-00			1	LUG, solder, SE #6
	210-0449-00			2	NUT, hex, 5-40 x 1/4 inch
13	179-0972-00			1	CABLE HARNESS, switch
	131-0371-00			-	CONNECTOR, pin
14	- - - - - -			1	POT
	- - - - - -			-	mounting hardware: (not included w/pot alone)
	210-0013-00			1	LOCKWASHER, internal, 3/8 x 11/16 inch
	210-0840-00			1	WASHER, .390 ID x 9/16 inch OD
	210-0413-00			1	NUT, hex, 3/8-32 x 1/2 inch

EXPLODED VIEW *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
- -	- - - - - -			-	SWITCH ASSEMBLY *(cont'd)*
15	- - - - - -			1	POT
	- - - - - -			-	mounting hardware: (not included w/pot alone)
	210-0012-00			1	LOCKWASHER, internal, 3/8 x 1/2 inch
	210-0413-00			2	NUT, hex, 3/8-32 x 1/2 inch
	376-0014-00			1	COUPLING, pot
16	358-0215-00			1	BUSHING, black plastic
17	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0049-00			1	LOCKWASHER, internal, 5/8 inch
	210-0579-00			1	NUT, hex, 5/8-24 x 3/4 inch
18	211-0507-00			4	SCREW, 6-32 x 5/16 inch BHS
	210-0803-00			2	WASHER, 6L x 3/8 inch
	210-0457-00			2	NUT, keps, 6-32 x 5/16 inch
19	358-0172-00			2	BUSHING, rod, 7/16-28 threads
20	- - - - - -			1	CAPACITOR
	- - - - - -			-	mounting hardware: (not included w/capacitor)
	210-0457-00			2	NUT, keps, 6-32 x 5/16 inch
21	179-0971-00			1	CABLE HARNESS, horizontal sweep generator
	- - - - - -			-	cable harness includes:
	131-0371-00			32	CONNECTOR, pin
22	132-0040-00			1	ADAPTER, panel
	- - - - - -			-	mounting hardware: (not included w/adapter)
	211-0038-00			4	SCREW, 4-40 x 5/16 inch FHS phillips
23	366-0175-00			1	KNOB, charcoal—TRIG SOURCE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS
24	366-0189-00			1	KNOB, small red—SLOPE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS
25	262-0706-00			1	SWITCH, wired—TRIG SOURCE
	- - - - - -			-	switch includes:
	260-0669-00			1	SWITCH, unwired—TRIG SOURCE
	175-0372-00			1	CABLE, w/right angle connector (14 inches)
	175-0373-00			1	CABLE, w/right angle connector (12 1/2 inches)
26	175-0331-00			1	CABLE, assembly, w/connectors
	- - - - - -			-	cable includes:
27	131-0393-00			1	CONNECTOR, coaxial cable
	- - - - - -			-	mounting hardware: (not included w/switch)
	361-0008-00			1	SPACER, nylon, 5/32 inch
	210-0865-00			2	WASHER, fiber, shouldered
	210-0413-00			1	NUT, hex, 3/8-32 x 1/2 inch
28	366-0138-00			1	KNOB, gray—TRIG LEVEL
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS

EXPLODED VIEW *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	QTY.	DESCRIPTION
29	366-0319-00			1	KNOB, red—STABILITY OR UHF SYNC
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
30	- - - - - -			-	POT
	- - - - - -			-	mounting hardware: (not included w/pot)
	210-0012-00			1	LOCKWASHER, internal, 3/8 x 1/2 inch
	210-0840-00			1	WASHER, flat, .390 ID x 9/16 inch OD
	210-0413-00			1	NUT, hex, 3/8-32 x 1/2 inch
31	366-0138-00			1	KNOB, gray—TIME POSITION
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
32	366-0319-00			1	KNOB, red—FINE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
33	- - - - - -			-	POT
	- - - - - -			-	mounting hardware: (not included w/pot)
	210-0012-00			1	LOCKWASHER, internal, 3/8 x 1/2 inch
	210-0840-00			1	WASHER, flat, .390 ID x 9/16 inch OD
	210-0413-00			1	NUT, hex, 3/8-32 x 1/2 inch
34	366-0173-00			1	KNOB, gray—SAMPLES/CM
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
35	262-0704-00			1	SWITCH, wired—SAMPLES/CM
	- - - - - -			-	switch includes:
	260-0666-00			1	SWITCH, unwired—SAMPLES/CM
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0840-00			1	WASHER, flat, .390 ID x 9/16 inch OD
	210-0413-00			1	NUT, hex, 3/8-32 x 1/2 inch
36	260-0447-00			1	SWITCH—SWEEP MODE
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0406-00			2	NUT, hex, 4-40 x 5/16 inch, FHS
37	260-0447-00			1	SWITCH—SAMPLING RATE
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0406-00			2	NUT, hex, 4-40 x 3/16 inch
38	260-0689-00			1	SWITCH, push button—START
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0046-00			1	LOCKWASHER, internal, .400 OD x .261 ID
	210-0940-00			1	WASHER, flat mini pot
	210-0583-00			1	NUT, hex, 1/4-32 x 5/16 inch
39	352-0067-00			2	HOLDER, neon, single
	- - - - - -			-	mounting hardware for each: (not included w/holder)
	211-0031-00			1	SCREW, 4-40 x 1 inch, FHS
	210-0406-00			2	NUT, hex, 4-40 x 3/16 inch

EXPLODED VIEW *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	QTY.	DESCRIPTION
40	378-0541-00			2	FILTER, lens, neon indicator light
41	- - - - - -			-	POT
	- - - - - -			-	mounting hardware: (not included w/pot)
	210-0471-00			1	NUT, mini pot, 1/4-32 x 5/16 x 19/32 inch long
	210-0046-00			2	LOCKWASHER, internal, 1/4 inch
42	358-0054-00			1	BUSHING, banana jack, 1/4-32 x 13/32 inch
43	214-0222-00			1	SPRING, striker, 1 11/32 x 15/32 inch
44	361-0029-00			1	SPACER, latch spring, delrin
	- - - - - -			-	mounting hardware: (not included w/spring and spacer)
45	211-0106-00			2	SCREW, 4-40 x 5/8 inch, FHS
	210-0586-00			2	NUT, keps, 4-40 x 1/4 inch
46	386-0146-00			1	PLATE, alum., front sub-panel
47	426-0150-00			1	MOUNT, line connector
	- - - - - -			-	mounting hardware: (not included w/mount)
	211-0511-00			2	SCREW, 6-32 x 1/2 inch, BHS
	210-0457-00			2	NUT, keps, 6-32 x 5/16 inch
48	- - - - - -			4	CAPACITOR, trimmer
	- - - - - -			-	mounting hardware for each: (not included w/capacitor)
49	214-0153-00			1	FASTENER, snap, double pronged, delrin
50	407-0133-00			1	BRACKET, alum., trimmer
	- - - - - -			-	mounting hardware: (not included w/bracket)
	211-0507-00			1	SCREW, 6-32 x 5/16 inch, BHS
	211-0510-00			1	SCREW, 6-32 x 3/8 inch, BHS
	210-0457-00			2	NUT, keps, 6-32 x 5/16 inch
51	386-0145-00			1	PLATE, bulkhead
	- - - - - -			-	plate includes:
	211-0094-00			4	SCREW, 4-40 x 1/2 inch, THS phillips
52	348-0064-00			1	GROMMET, 5/8 inch, plastic
53	358-0215-00			1	BUSHING, plastic, 2 1/32 x 5/8 x 3/16 inch
54	348-0050-00			3	GROMMET, 3/4 inch, plastic
55	352-0086-00			5	HOLDER, toroid
56	407-0132-00			1	BRACKET, alum., switch support
	- - - - - -			-	mounting hardware: (not included w/bracket)
	211-0507-00			2	SCREW, 6-32 x 5/16 inch, BHS
	210-0457-00			2	NUT, keps, 6-32 x 5/16 inch
57	441-0611-00			1	CHASSIS, left, horizontal sweep generator
	- - - - - -			-	mounting hardware: (not included w/chassis)
	211-0507-00			3	SCREW, 6-32 x 5/16 inch, BHS
	210-0457-00			1	NUT, keps, 6-32 x 5/16 inch

EXPLODED VIEW *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
58	------			1	RESISTOR
	------			-	mounting hardware: (not included w/resistor)
	211-0507-00			1	SCREW, 6-32 x 5/16 inch, BHS
	210-0478-00			1	NUT, hex, alum., 5/16 x 21/32 inch
	210-0601-00			1	EYELET, brass, tapered barrel
	211-0553-00			1	SCREW, 6-32 x 1 1/2 inches, RHS
59	407-0130-00			1	BRACKET, alum., chassis support
	------			-	mounting hardware: (not included w/bracket)
	211-0507-00			6	SCREW, 6-32 x 5/16 inch, BHS
	210-0803-00			2	WASHER, flat, 6L x 3/8 inch
	210-0457-00			4	NUT, keps, 6-32 x 5/16 inch
60	384-0615-00			4	ROD, spacer, 13 1/4 inches long
	------			-	mounting hardware for each: (not included w/rod)
	212-0044-00			1	SCREW, 8-32 x 1/2 inch, RHS
61	384-0351-00			1	ROD, extension, 1/8 x 10.938 inches
62	------			-	POT
	------			-	mounting hardware: (not included w/pot)
	210-0013-00			1	LOCKWASHER, internal, 3/8 x 11/16 inch
	210-0840-00			1	WASHER, flat, .390 ID x 9/16 inch OD
	210-0413-00			1	NUT, hex, 3/8-32 x 1/2 inch
63	441-0610-00			1	CHASSIS, right, trigger & fast ramp
	------			-	mounting hardware: (not included w/chassis)
	211-0507-00			5	SCREW, 6-32 x 5/16 inch, BHS
	210-0457-00			3	NUT, keps, 6-32 x 5/16 inch
64	348-0063-00			1	GROMMET, 1/2 inch, plastic
65	406-0109-00			1	BRACKET, pot
	------			-	mounting hardware: (not included w/bracket)
	211-0507-00			2	SCREW, 6-32 x 5/16 inch, BHS
	210-0457-00			2	NUT, keps, 6-32 x 5/16 inch
66	175-0332-00			1	CABLE, coax. assembly, w/connector
	------			-	cable includes:
67	131-0393-00			1	CONNECTOR, coaxial cable
68	131-0149-00			1	CONNECTOR, 24-pin
	------			-	mounting hardware: (not included w/connector)
	210-0586-00			2	NUT, keps, 4-40 x 1/4 inch
	211-0008-00			2	SCREW, 4-40 x 1/4 inch, BHS

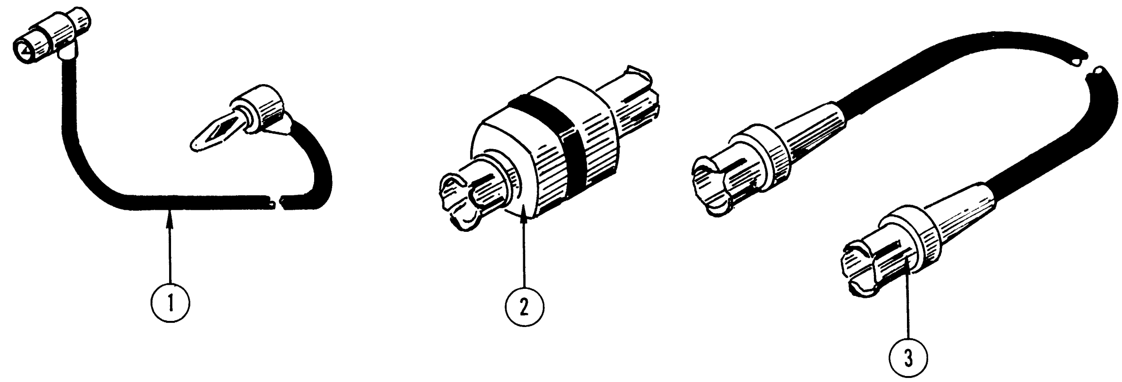
EXPLODED VIEW *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
69	670-0071-00			1	ASSEMBLY, TRIGGER & FAST RAMP CIRCUIT BOARD (wired)
	- - - - - -			-	assembly includes:
	388-0626-00			1	BOARD, etched circuit
	- - - - - -			-	board includes:
70	214-0506-00			34	PIN, straight
	344-0108-00			8	CLIP, diode
71	131-0391-00			5	CONNECTOR, coaxial
72	136-0183-00			15	SOCKET, transistor
73	136-0125-00			1	SOCKET, 5 pin
74	387-0603-00	100	249X	1	PLATE, insulator
	- - - - - -			-	mounting hardware: (not included w/assembly)
75	211-0097-00	100	329	5	SCREW, 4-40 x 5/16 inch, PHS, phillips
	211-0008-00	100	329	1	SCREW, 4-40 x 1/4 inch, BHS
	211-0116-00	330		6	SCREW, sems, 4-40 x 5/16 inch, PHB, phillips
76	210-0586-00			5	NUT, keps, 4-40 x 1/4 inch
77	670-0070-00			1	ASSEMBLY, HORIZONTAL SWEEP GENERATOR CIRCUIT BOARD (wired)
	- - - - - -			-	assembly includes:
	388-0625-00			1	BOARD, etched circuit
	- - - - - -			-	board includes:
	214-0506-00			42	PIN, straight
78	136-0125-00			1	SOCKET, Nuvistor
79	136-0183-00			10	SOCKET, transistor
80	387-0603-00	100	249X	1	INSULATOR, Nuvistor
81	387-0794-00			4	PLATE, pot
82	- - - - - -			4	POT
	- - - - - -			-	mounting hardware for each: (not included w/pot)
	210-0583-00			1	NUT, hex, 1/4-32 x 5/16 inch, mini pot
	210-0940-00			1	WASHER, plain, mini pot
	- - - - - -			-	mounting hardware: (not included w/assembly)
83	211-0008-00	100	329	6	SCREW, 4-40 x 1/4 inch, BHS
	211-0116-00	330		6	SCREW, sems, 4-40 x 5/16 inch, PHB, phillips
84	179-0970-00			1	CABLE HARNESS, trigger & fast ramp
	- - - - - -			-	cable harness includes:
	131-0371-00			38	CONNECTOR, straight pin
85	366-0173-00			1	KNOB, charcoal—EXT TRIG MODE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch HSS

EXPLODED VIEW *(Cont'd)*

REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
86	262-0707-00			1	SWITCH, wired—EXT TRIG MODE
	- - - - - - -			-	switch includes:
	260-0670-00			1	SWITCH, unwired—EXT TRIG MODE
	175-0374-00			1	CABLE, with connector, 11½ inches
	175-0375-00			1	CABLE, with connector, 4 inches
87	175-0333-00			1	CABLE, external trigger, assembly
	- - - - - - -			-	cable assembly includes:
88	132-0121-00			1	NUT, retaining
89	132-0001-00			1	NUT, coupling
90	166-0221-00			1	FERRULE
91	132-0115-00			1	TRANSITION, outer
92	132-0116-00			1	TRANSITION, inner
93	132-0007-00			1	RING, snap
94	132-0028-00			1	INSULATOR
95	132-0029-00			1	CONDUCTOR, inner
96	132-0002-00			1	SLEEVE, outer conductor
	- - - - - - -			-	mounting hardware: (not included w/switch)
	361-0008-00			1	SPACER, nylon, $5/32$ inch
	210-0865-00			2	WASHER, fiber, shouldered
	210-0413-00			1	NUT, hex, $3/8$-32 x $1/2$ inch
97	387-0598-00			1	PLATE, rear

STANDARD ACCESSORIES



REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	DISC.	QTY.	DESCRIPTION
1	012-0090-00			1	PATCH CORD, BNC to banana, black, $17^{3}/_{4}$ inches long
2	017-0044-00	100	319	2	ATTENUATOR, 10×, 50 Ω
	017-0078-00	320		2	ATTENUATOR, 10×, 50 Ω
3	017-0501-00			1	CABLE, 10 nsec delay, 50 Ω, RG58/AU
	070-0470-00			2	MANUAL, instruction (not shown)

ELECTRICAL PARTS

Values are fixed unless marked Variable.

Ckt. No.	Tektronix Part No.	Description				S/N Range

Bulbs

B518	150-0025-00	Neon	NE-2E	UNCAL	
B650	150-0025-00	Neon	NE-2E	UNCAL	

Capacitors

Tolerance ±20%, unless otherwise indicated.

C1	283-0078-00	0.001 μf	Cer	500 v	
C3	283-0000-00	0.001 μf	Cer	500 v	
C13	283-0081-00	0.1 μf	Cer	25 v	
C15	281-0601-00	7.5 pf	Cer	500 v	±0.5 pf
C20	290-0134-00	22 μf	EMT	15 v	
C38	283-0092-00	0.03 μf	Cer	200 v	
C45	283-0002-00	0.01 μf	Cer	500 v	
C49	283-0000-00	0.001 μf	Cer	500 v	
C57	281-0501-00	4.7 pf	Cer	500 v	±1 pf
C65	283-0023-00	0.1 μf	Cer	10 v	
C70	281-0523-00	100 pf	Cer	350 v	
C75	281-0593-00	3.9 pf	Cer		10%
C79	290-0167-00	10 μf	EMT	15 v	
C80	290-0134-00	22 μf	EMT	15 v	
C99	283-0000-00	0.001 μf	Cer	500 v	
C106	283-0599-00	98 pf	Mica	500 v	5%
C108	290-0167-00	10 μf	EMT	15 v	
C109	283-0000-00	0.001 μf	Cer	500 v	
C110	281-0501-00	4.7 pf	Cer	500 v	±1 pf
C113	281-0593-00	3.9 pf	Cer		10%
C117	283-0026-00	0.2 μf	Cer	25 v	
C120	283-0000-00	0.001 μf	Cer	500 v	
C122	283-0000-00	0.001 μf	Cer	500 v	
C126	281-0525-00	470 pf	Cer	500 v	
C140	281-0518-00	47 pf	Cer	500 v	
C150	283-0092-00	0.03 μf	Cer	200 v	
C161	283-0000-00	0.001 μf	Cer	500 v	
C164	281-0543-00	270 pf	Cer	500 v	10%
C176	283-0000-00	0.001 μf	Cer	500 v	
C179	283-0000-00	0.001 μf	Cer	500 v	
C189	281-0537-00	0.68 pf	Cer	500 v	
C190	281-0523-00	100 pf	Cer	350 v	
C207	283-0000-00	0.001 μf	Cer	500 v	
C230	285-0626-00	0.0015 μf	PTM	100 v	10%

Capacitors *(Cont'd)*

Ckt No.	Tektronix Part No.	Description					S/N Range
C240	281-0523-00	100 pf	Cer		350 v		
C275	283-0000-00	0.001 μf	Cer		500 v		
C292	290-0107-00	25 μf	EMT		25 v	+75%—10%	
C294	290-0107-00	25 μf	EMT		25 v	+75%—10%	
C296	290-0107-00	25 μf	EMT		25 v	+75%—10%	
C298	290-0107-00	25 μf	EMT		25 v	+75%—10%	
C307	281-0523-00	100 pf	Cer		350 v		
C323	283-0051-00	0.0033 μf	Cer		100 v	5%	
C326	281-0523-00	100 pf	Cer		350 v		
C331	283-0026-00	0.2 μf	Cer		25 v		
C337	281-0504-00	10 pf	Cer		500 v	10%	
C343	281-0091-00	2-8 pf	Cer	Var			
C350A	*295-0084-00	1 μf	Timing Capacitor				
C350B	*295-0084-00	0.1 μf	Timing Capacitor				
C350C	*295-0084-00	0.01 μf	Timing Capacitor				
C350D	*295-0084-00	0.001 μf	Timing Capacitor				
C350E	281-0523-00	100 pf	Cer		350 v		
C350F	281-0523-00	100 pf	Cer		350 v		
C350G	283-0602-00	53 pf	Mica		300 v	5%	
C350H	281-0063-00	9-35 pf	Cer	Var			
C350J	283-0059-00	1 μf	Cer		25 v		
C354	281-0518-00	47 pf	Cer		500 v		
C365	283-0000-00	0.001 μf	Cer		500 v		
C372	283-0000-00	0.001 μf	Cer		500 v		
C376	283-0000-00	0.001 μf	Cer		500 v		
C385	281-0523-00	100 pf	Cer		350 v		
C401	283-0000-00	0.001 μf	Cer		500 v		
C405	290-0107-00	25 μf	EMT		25 v	+75%—10%	
C407	283-0002-00	0.01 μf	Cer		500 v		
C418	283-0000-00	0.001 μf	Cer		500 v		
C420	281-0504-00	10 pf	Cer		500 v	10%	
C430	283-0003-00	0.01 μf	Cer		150 v		
C440	281-0551-00	390 pf	Cer		500 v	10%	
C446	281-0551-00	390 pf	Cer		500 v	10%	
C464	281-0523-00	100 pf	Cer		350 v		
C468	283-0002-00	0.01 μf	Cer		500 v		
C477	283-0000-00	0.001 μf	Cer		500 v		
C479	283-0081-00	0.1 μf	Cer		25 v		
C486	*295-0083-00	10 μf	Timing Capacitor				
C488	*295-0083-00	0.1 μf	Timing Capacitor				
C490	*295-0083-00	1 μf	Timing Capacitor				
C493	*295-0083-00	0.01 μf	Timing Capacitor				
C495	*295-0083-00	0.0011 μf	Timing Capacitor				
C520	290-0149-00	5 μf	EMT		150 v		
C522	285-0623-00	0.47 μf	PTM		100 v		
C524	285-0629-00	0.047 μf	PTM		100 v		
C560A	281-0007-00	3-12 pf	Cer	Var			

Capacitors *(Cont'd)*

Ckt No.	Tektronix Part No.	Description					S/N Range
C560B	281-0558-00	18 pf	Cer		500 v		
C560C	281-0012-00	7-45 pf	Cer	Var			
C560D	285-0002-00	27 pf	Glass		500 v	5%	
C560E	281-0012-00	7-45 pf	Cer	Var			
C560F	285-0003-00	100 pf	Glass		500 v	5%	
C560G	281-0012-00	7-45 pf	Cer	Var			
C560H	285-0004-00	220 pf	Glass		500 v	5%	
C560J	285-0001-00	510 pf	Glass		500 v	1%	
C565	285-0598-00	0.01 μf	PTM		100 v	5%	
C583	283-0081-00	0.1 μf	Cer		25 v		
C590	281-0523-00	100 pf	Cer		350 v		
C603	283-0057-00	0.1 μf	Cer		200 v		
C611	285-0566-00	0.022 μf	PTM		200 v	10%	
C614	283-0059-00	1 μf	Cer		25 v		
C618	283-0002-00	0.01 μf	Cer		500 v		
C622	283-0593-00	0.01 μf	Mica		100 v	1%	
C625	283-0059-00	1 μf	Cer		25 v		
C628	283-0593-00	0.01 μf	Mica		100 v	1%	
C632	283-0594-00	0.001 μf	Mica		100 v	1%	
C639	281-0504-00	10 pf	Cer		500 v	10%	
C642	283-0002-00	0.01 μf	Cer		500 v		
C643	290-0107-00	25 μf	EMT		25 v	+75%—10%	
C645	290-0215-00	100 μf	EMT		25 v		
C646	290-0215-00	100 μf	EMT		25 v		
C648	290-0200-00	12 μf	EMT		150 v	+75%—10%	
C649	290-0200-00	12 μf	EMT		150 v	+75%—10%	
C660	290-0276-00	0.68 μf	EMT		35 v	10%	
C662	285-0686-00	0.068 μf	PTM		100 v	10%	
C664	285-0685-00	0.0068 μf	PTM		100 v	10%	

Diodes

D5	*152-0185-00	Silicon	Replaceable by 1N3605
D7	*152-0185-00	Silicon	Replaceable by 1N3605
D65	152-0034-00	Silicon	1N753 0.4 w, 6.2 v, 10%
D105	*152-0185-00	Zener	Replaceable by 1N3605
D135	*153-0020-00	Tunnel	Selected TD253B
D146 } D147 }	*152-0207-00	Tek GaAs	Selected (1 pair)
D155	152-0177-00	Tunnel	TD253B 10 MA
D157	152-0034-00	Zener	1N753 0.4 w, 6.2 v, 10%
D164	*152-0185-00	Silicon	Replaceable by 1N3605
D175	*152-0185-00	Silicon	Replaceable by 1N3605
D182	152-0177-00	Tunnel	TD253B 10 MA
D195	152-0177-00	Tunnel	TD253B 10 MA

Diodes *(Cont'd)*

Ckt. No.	Tektronix Part No.	Description		S/N Range
D213	152-0008-00	Germanium		
D220	152-0008-00	Germanium		
D227	152-0008-00	Germanium		
D228	*152-0185-00	Silicon	Replaceable by 1N3605	
D233	*152-0185-00	Silicon	Replaceable by 1N3605	
D250	152-0008-00	Germanium		
D260	152-0008-00	Germanium		
D263	*152-0185-00	Silicon	Replaceable by 1N3605	
D280	*152-0185-00	Silicon	Replaceable by 1N3605	
D312	152-0125-00	Tunnel	Selected TD3A 4.7 MA	
D328	*152-0206-00	Tek GaAs	Selected	
D350	152-0125-00	Tunnel	Selected TD3A 4.7 MA	
D360	152-0125-00	Tunnel	Selected TD3A 4.7 MA	
D372	*152-0206-00	Tek GaAs	Selected	
D385	152-0008-00	Germanium		
D422	152-0008-00	Germanium		
D440	152-0071-00	Germanium	ED2007	
D445	152-0093-00	Tunnel	1N31716 4.7 MA	
D448	152-0008-00	Germanium		
D455	152-0008-00	Germanium		
D458	152-0008-00	Germanium		
D482	152-0008-00	Germanium		
D488	*152-0165-00	Silicon	Selected from 1N3579	
D565	*152-0165-00	Silicon	Selected from 1N3579	
D566	*152-0185-00	Silicon	Replaceable by 1N3605	
D567	*152-0185-00	Silicon	Replaceable by 1N3605	
D585	152-0008-00	Germanium		
D597	*152-0185-00	Silicon	Replaceable by 1N3605	
D600	*152-0185-00	Silicon	Replaceable by 1N3605	
D610	*152-0185-00	Silicon	Replaceable by 1N3605	
D635	*152-0185-00	Silicon	Replaceable by 1N3605	

Connectors

J1	131-0106-00	Connector, Chassis mtd, coax, 1 contact, female
P3	131-0149-00	Connector, Chassis mtd, 24 contact, male
P4	131-0149-00	Connector, Chassis mtd, 24 contact, male
J8	131-0393-00	Connector, Coax
J9	131-0393-00	Connector, Coax
J55	131-0391-00	Connector, Coax †
J80	131-0391-00	Connector, Coax †
J100	131-0391-00	Connector, Coax †
J185	131-0391-00	Connector, Coax †
J365	131-0391-00	Connector, Coax †

† Mounted on etched-wiring board.

Inductors

Ckt. No.	Tektronix Part No.	Description			S/N Range
L50	Use 276-0517-00	Core, Powder Iron			
L53	Use 276-0517-00	Core, Powder Iron			
L55	276-0535-00	Core, Toroid			
L85	276-0535-00	Core, Toroid			
L94	276-0535-00	Core, Toroid			
L95	276-0535-00	Core, Toroid			
LR133	*108-0325-00	0.5 μh (wound on a 100 Ω resistor)			
L155	*120-0250-00	Toroid, 5T			
L176	276-0507-00	Core, Ferramic Suppressor			
L178	Use *108-0181-01	0.2 μh			
L193	Use *108-0170-01	0.5 μh			
L292	*120-0398-00	Toroid, 15T			
L294	*120-0398-00	Toroid, 15T			
L296	*120-0398-00	Toroid, 15T			
L298	*120-0398-00	Toroid, 15T			
L307	276-0507-00	Core, Ferramic Suppressor			
L310	276-0507-00	Core, Ferramic Suppressor			
L365	276-0535-00	Core, Toroid			
L410	*120-0398-00	Toroid, 15T			
L625	*114-0179-00	500-800 μh	Var	Core 276-506	
L643	*120-0398-00	Toroid, 15T			
L645	*120-0250-00	Toroid, 5T			
L646	*120-0398-00	Toroid, 15T			
L648	*120-0398-00	Toroid, 15T			
L649	*120-0398-00	Toroid, 15T			

Transistors

Q34	*151-0133-00	Selected from 2N3251
Q64	*151-0138-00	Replaceable by 2N2857
Q124	*151-0138-00	Replaceable by 2N2857
Q149	*153-0533-00	Selected 2N2501
Q164	*151-0133-00	Selected from 2N3251
Q174	*151-0133-00	Selected from 2N3251
Q204	*151-0103-00	Replaceable by 2N2219
Q214	*151-0134-00	Replaceable by 2N2905
Q235	151-0071-00	2N1305
Q255	*151-0108-00	Replaceable by 2N2501
Q265	*151-0108-00	Replaceable by 2N2501
Q275	151-0089-00	2N962
Q314	*153-0532-00	Selected 2N1195
Q323	*151-0108-00	Replaceable by 2N2501
Q334	*151-0138-00	Replaceable by 2N2857

Transistors *(Cont'd)*

Ckt. No.	Tektronix Part No.	Description	S/N Range
Q364	*151-0083-00	Selected from 2N964	
Q374	*151-0134-00	Replaceable by 2N2905	
Q383	*151-0103-00	Replaceable by 2N2219	
Q414	*151-0136-00	Replaceable by 2N3053	
Q424	151-0063-00	2N2207	
Q444	151-0040-00	2N1302	
Q455	151-0071-00	2N1305	
Q475	151-0040-00	2N1302	
Q574	*151-0108-00	Replaceable by 2N2501	
Q594	*151-0096-00	Selected from 2N1893	
Q603	*151-0096-00	Selected from 2N1893	
Q624	151-0040-00	2N1302	
Q630	*151-0103-00	Replaceable by 2N2219	

Resistors

Resistors are fixed, composition, ±10% unless otherwise indicated.

R3	315-0104-00	100 k	1/4 w			5%
R5	315-0105-00	1 meg	1/4 w			5%
R7	315-0101-00	100 Ω	1/4 w			5%
R9	322-0280-00	8.06 k	1/4 w		Prec	1%
R10	311-0496-00	2.5 k		Var		1 MΩ ZERO
R13	315-0101-00	100 Ω	1/4 w			5%
R15	315-0912-00	9.1 k	1/4 w			5%
R20	315-0102-00	1 k	1/4 w			5%
R24	315-0105-00	1 meg	1/4 w			5%
R32	315-0390-00	39 Ω	1/4 w			5%
R34	321-0269-00	6.19 k	1/8 w		Prec	1%
R38	315-0752-00	7.5 k	1/4 w			5%
R40	315-0821-00	820 Ω	1/4 w			5%
R49	301-0510-00	51 Ω	1/2 w			5%
R53	301-0510-00	51 Ω	1/2 w			5%
R57	315-0390-00	39 Ω	1/4 w			5%
R60	322-0603-00	2.51 k	1/4 w		Prec	1%
R64	308-0301-00	10 k	3 w		WW	1%
R66	322-0249-00	3.83 k	1/4 w		Prec	1%
R68	315-0510-00	51 Ω	1/4 w			5%
R75	315-0510-00	51 Ω	1/4 w			5%
R80	322-0603-00	2.51 k	1/4 w		Prec	1%
R83	311-0496-00	2.5 k		Var		50 Ω ZERO
R87	315-0101-00	100 Ω	1/4 w			5%
R88	315-0101-00	100 Ω	1/4 w			5%

Resistors *(Cont'd)*

Ckt. No.	Tektronix Part No.	Description					S/N Range
R90	315-0101-00	100 Ω	1/4 w			5%	
R91	315-0101-00	100 Ω	1/4 w			5%	
R94	315-0101-00	100 Ω	1/4 w			5%	
R95	315-0101-00	100 Ω	1/4 w			5%	
R99	301-0510-00	51 Ω	1/2 w			5%	
R101	315-0103-00	10 k	1/4 w			5%	
R103	311-0442-00	250 Ω		Var		TRIG BAL	
R106	315-0103-00	10 k	1/4 w			5%	
R110	315-0390-00	39 Ω	1/4 w			5%	
R113	315-0510-00	51 Ω	1/4 w			5%	
R115	323-0234-00	2.67 k	1/2 w		Prec	1%	
R117	321-0143-00	301 Ω	1/8 w		Prec	1%	
R118	321-0268-00	6.04 k	1/8 w		Prec	1%	
R120	311-0463-00	5 k		Var		TRIG LEVEL ZERO	
R121	321-0285-00	9.09 k	1/8 w		Prec	1%	
R122†	311-0533-00	100 k		Var		TRIG LEVEL	
R124	315-0101-00	100 Ω	1/4 w			5%	
R126	315-0201-00	200 Ω	1/4 w			5%	
R140	317-0101-00	100 Ω	1/10 w			5%	
R144	321-0414-00	200 k	1/8 w		Prec	1%	
R146	323-0335-00	30.1 k	1/2 w		Prec	1%	
R149	307-0111-00	3.6 Ω	1/4 w			5%	
R150	307-0105-00	3.9 Ω	1/4 w			5%	
R152	303-0620-00	62 Ω	1 w			5%	
R155	307-0058-00	5.6 Ω	1/2 w			5%	
R158	315-0102-00	1 k	1/4 w			5%	
R160	315-0241-00	240 Ω	1/4 w			5%	
R161	315-0562-00	5.6 k	1/4 w			5%	
R168	321-0241-00	3.16 k	1/8 w		Prec	1%	
R170†	311-0533-00	20 k		Var		STABILITY OR UHF SYNC	
R172	311-0442-00	250 Ω		Var		STABILITY ZERO	
R173	323-0158-00	432 Ω	1/2 w		Prec	1%	
R174	315-0103-00	10 k	1/4 w			5%	
R178	315-0302-00	3 k	1/4 w			5%	
R179	315-0100-00	10 Ω	1/4 w			5%	
R183	317-0680-00	68 Ω	1/10 w			5%	
R184	317-0680-00	68 Ω	1/10 w			5%	
R187	315-0510-00	51 Ω	1/4 w			5%	
R189	317-0510-00	51 Ω	1/10 w			5%	
R190	315-0510-00	51 Ω	1/4 w			5%	
R193	315-0330-00	33 Ω	1/4 w			5%	
R198	315-0101-00	100 Ω	1/4 w			5%	
R204	315-0751-00	750 Ω	1/4 w			5%	
R208	315-0751-00	750 Ω	1/4 w			5%	
R210	311-0462-00	1 k		Var		OUTPUT TD BIAS	

† R122, R170 and SW170 furnished as a unit.

Resistors *(Cont'd)*

Ckt No.	Tektronix Part No.		Description				S/N Range
R214	315-0823-00	82 k	1/4 w			5%	
R220	315-0222-00	2.2 k	1/4 w			5%	
R222	315-0201-00	200 Ω	1/4 w			5%	
R224	315-0101-00	100 Ω	1/4 w			5%	
R230	316-0825-00	8.2 meg	1/4 w				
R233	316-0475-00	4.7 meg	1/4 w				
R235	301-0393-00	39 k	1/2 w			5%	
R240	315-0102-00	1 k	1/4 w			5%	
R245	315-0391-00	390 Ω	1/4 w			5%	
R248	315-0102-00	1 k	1/4 w			5%	
R249	301-0393-00	39 k	1/2 w			5%	
R253	315-0153-00	15 k	1/4 w			5%	
R255	315-0912-00	9.1 k	1/4 w			5%	
R263	315-0102-00	1 k	1/4 w			5%	
R265	315-0202-00	2 k	1/4 w			5%	
R275	303-0102-00	1 k	1 w			5%	
R280	315-0102-00	1 k	1/4 w			5%	
R283	315-0510-00	51 Ω	1/4 w			5%	
R287	315-0510-00	51 Ω	1/4 w			5%	
R289	304-0122-00	1.2 k	1 w				
R290	308-0023-00	10 k	10 w		WW	5%	
R318	315-0202-00	2 k	1/4 w			5%	
R320	315-0163-00	16 k	1/4 w			5%	
R323	315-0471-00	470 Ω	1/4 w			5%	
R326	315-0562-00	5.6 k	1/4 w			5%	
R332	315-0100-00	10 Ω	1/4 w			5%	
R334	315-0101-00	100 Ω	1/4 w			5%	
R337	315-0100-00	10 Ω	1/4 w			5%	
R339	308-0212-00	10 k	3 w		WW	5%	
R340	311-0474-00	2 k		Var		TIMING CURRENT	
R343	315-0750-00	75 Ω	1/4 w			5%	
R345	311-0441-00	200 Ω		Var		COMP LEVEL	
R347	315-0750-00	75 Ω	1/4 w			5%	
R350A	315-0240-00	24 Ω	1/4 w			5%	
R350B	315-0240-00	24 Ω	1/4 w			5%	
R350C	315-0240-00	24 Ω	1/4 w			5%	
R350D	315-0240-00	24 Ω	1/4 w			5%	
R350E	315-0240-00	24 Ω	1/4 w			5%	
R350F	315-0240-00	24 Ω	1/4 w			5%	
R350G	315-0240-00	24 Ω	1/4 w			5%	
R354	315-0391-00	390 Ω	1/4 w			5%	
R356	315-0200-00	20 Ω	1/4 w			5%	
R358	315-0392-00	3.9 k	1/4 w			5%	
R360	315-0202-00	2 k	1/4 w			5%	
R363	315-0510-00	51 Ω	1/4 w			5%	

Resistors *(Cont'd)*

Ckt No.	Tektronix Part No.		Description			S/N Range
R365	315-0561-00	560 Ω	¼ w			5%
R369	315-0822-00	8.2 k	¼ w			5%
R372	315-0390-00	39 Ω	¼ w			5%
R374	315-0393-00	39 k	¼ w			5%
R376	311-0442-00	250 Ω		Var		INVERTER DC LEVEL
R378	321-0297-00	12.1 k	⅛ w		Prec	1%
R381	321-0373-00	75 k	⅛ w		Prec	1%
R383	321-0613-00	5.03 k	⅛ w		Prec	1%
R385	315-0510-00	51 Ω	¼ w			5%
R387	303-0153-00	15 k	1 w			5%
R389	321-0401-00	147 k	⅛ w		Prec	1%
R390	311-0465-00	100 k		Var		TIME POSITION ZERO
R392	301-0205-00	2 meg	½ w			5%
R393	323-0419-00	226 k	½ w		Prec	1%
R395A, R395B	311-0272-00	2 x 5 k		Var		TIME POSITION FINE
R401	315-0102-00	1 k	¼ w			5%
R403	315-0510-00	51 Ω	¼ w			5%
R405	315-0102-00	1 k	¼ w			5%
R410	315-0200-00	20 Ω	¼ w			5%
R415	311-0448-00	20 k		Var		SAMPLES/CM CAL
R416	315-0152-00	1.5 k	¼ w			5%
R418	315-0270-00	27 Ω	¼ w			5%
R420	315-0393-00	39 k	¼ w			5%
R421	315-0510-00	51 Ω	¼ w			5%
R424	316-0274-00	270 k	¼ w			
R431	315-0910-00	91 Ω	¼ w			5%
R433	301-0105-00	1 meg	½ w			5%
R435	315-0102-00	1 k	¼ w			5%
R438	315-0472-00	4.7 k	¼ w			5%
R440	315-0102-00	1 k	¼ w			5%
R442	315-0101-00	100 Ω	¼ w			5%
R444	315-0103-00	10 k	¼ w			5%
R446	315-0512-00	5.1 k	¼ w			5%
R448	315-0472-00	4.7 k	¼ w			5%
R450	315-0393-00	39 k	¼ w			5%
R457	315-0393-00	39 k	¼ w			5%
R458	315-0101-00	100 Ω	¼ w			5%
R464	315-0103-00	10 k	¼ w			5%
R466	315-0272-00	2.7 k	¼ w			5%
R468	315-0101-00	100 Ω	¼ w			5%
R470	315-0104-00	100 k	¼ w			5%
R473	315-0123-00	12 k	¼ w			5%
R474	315-0223-00	22 k	¼ w			5%
R475	315-0332-00	3.3 k	¼ w			5%
R477	315-0512-00	5.1 k	¼ w			5%

Resistors *(Cont'd)*

Ckt No.	Tektronix Part No.	Description					S/N Range
R479	315-0270-00	27 Ω	1/4 w			5%	
R502	323-0696-00	121 k	1/2 w		Prec	1/2%	
R505	323-0697-00	301 k	1/2 w		Prec	1/2%	
R507	323-0698-00	604 k	1/2 w		Prec	1/2%	
R509	323-0656-00	1.5 meg	1/2 w		Prec	1/2%	
R510	323-0656-00	1.5 meg	1/2 w		Prec	1/2%	
R512	323-0699-00	1.21 meg	1/2 w		Prec	1/2%	
R515	311-0448-00	20 k		Var		REAL TIME SWEEP CAL	
R516	301-0303-00	30 k	1/2 w			5%	
R517	301-0104-00	100 k	1/2 w			5%	
R518†	311-0274-00	100 k		Var		REAL TIME/CM VARIABLE	
R520	301-0104-00	100 k	1/2 w			5%	
R550	311-0110-00	100 k		Var		TIMED ADJ	
R551	301-0125-00	1.2 meg	1/2 w			5%	
R555	301-0222-00	2.2 k	1/2 w			5%	
R567	316-0825-00	8.2 meg	1/4 w				
R570	315-0330-00	33 Ω	1/4 w			5%	
R574	315-0102-00	1 k	1/4 w			5%	
R577	315-0101-00	100 Ω	1/4 w			5%	
R583	315-0101-00	100 Ω	1/4 w			5%	
R585	311-0328-00	1 k		Var		STAIRCASE ZERO	
R587	315-0103-00	10 k	1/4 w			5%	
R590	315-0101-00	100 Ω	1/4 w			5%	
R594	301-0334-00	330 k	1/2 w			5%	
R603	301-0202-00	2 k	1/2 w			5%	
R607	315-0101-00	100 Ω	1/4 w			5%	
R608	305-0223-00	22 k	2 w			5%	
R610	315-0101-00	100 Ω	1/4 w			5%	
R611	315-0473-00	47 k	1/4 w			5%	
R612	311-0448-00	20 k		Var		SWEEP LENGTH	
R614	301-0154-00	150 k	1/2 w			5%	
R615	315-0163-00	16 k	1/4 w			5%	
R620	315-0912-00	9.1 k	1/4 w			5%	
R622	315-0331-00	330 Ω	1/4 w			5%	
R624	315-0392-00	3.9 k	1/4 w			5%	
R625	315-0153-00	15 k	1/4 w			5%	
R635	315-0102-00	1 k	1/4 w			5%	
R642	315-0101-00	100 Ω	1/4 w			5%	
R650††	311-0523-00	10 k		Var		EQUIVALENT TIME/CM VARIABLE	
R652	301-0104-00	100 k	1/2 w			5%	

† Furnished as a unit with SW518.

†† Furnished as a unit with SW650.

Resistors *(Cont'd)*

Ckt. No.	Tektronix Part No.	Description				S/N Range
R655	301-0472-00	4.7 k	½ w		5%	
R666	321-0692-00	49.9 k	⅛ w	Prec	½%	
R669	321-0689-00	24.9 k	⅛ w	Prec	½%	
R701	321-0687-00	7.77 k	⅛ w	Prec	½%	
R702	321-0700-00	169 k	⅛ w	Prec	¼%	
R705	321-0697-00	18.9 k	⅛ w	Prec	½%	
R710	321-0699-00	23.2 k	⅛ w	Prec	¼%	
R712	321-0701-00	187 k	⅛ w	Prec	¼%	
R715	321-0698-00	1.89 k	⅛ w	Prec	¼%	
R720	315-0472-00	4.7 k	¼ w		5%	
R722	321-0690-00	34 k	⅛ w	Prec	½%	
R724	321-0693-00	68.1 k	⅛ w	Prec	½%	
R726	321-0694-00	169 k	⅛ w	Prec	½%	
R730	321-0693-00	68.1 k	⅛ w	Prec	½%	
R732	321-0691-00	42.7 k	⅛ w	Prec	½%	

Switches

	Unwired	Wired		
SW20	260-0670-00	*262-0707-00	Rotary	EXT TRIG MODE
SW80 } SW95 }	260-0669-00	*262-0706-00	Rotary	TRIG SOURCE SLOPE
SW170†	311-0533-00			AUTO RECOVERY
SW430	260-0689-00		Push Button	START
SW435	260-0447-00		Slide	SWEEP MODE
SW518††	311-0274-00			REAL TIME UNCAL
SW525	260-0668-00	*262-0708-00	Rotary	REAL TIME/CM
SW555	260-0666-00	*262-0704-00	Rotary	SAMPLES/CM
SW615	260-0447-00		Slide	SAMPLING RATE
SW650†††	311-0523-00			EQUIVALENT TIME UNCAL
SW665 } SW725 }	260-0667-00	*262-0705-00	Rotary	TIME POSITION RANGE EQUIVALENT TIME/CM

Transformers

T55	*120-0376-00	Toroid, 5T bifilar
T90	*120-0375-00	Toroid, 6T 2 windings
T97	*120-0372-00	Toroid, 5T bifilar
T135	*120-0373-00	Toroid, 4T
T224	*120-0374-00	Toroid, 2T-4T

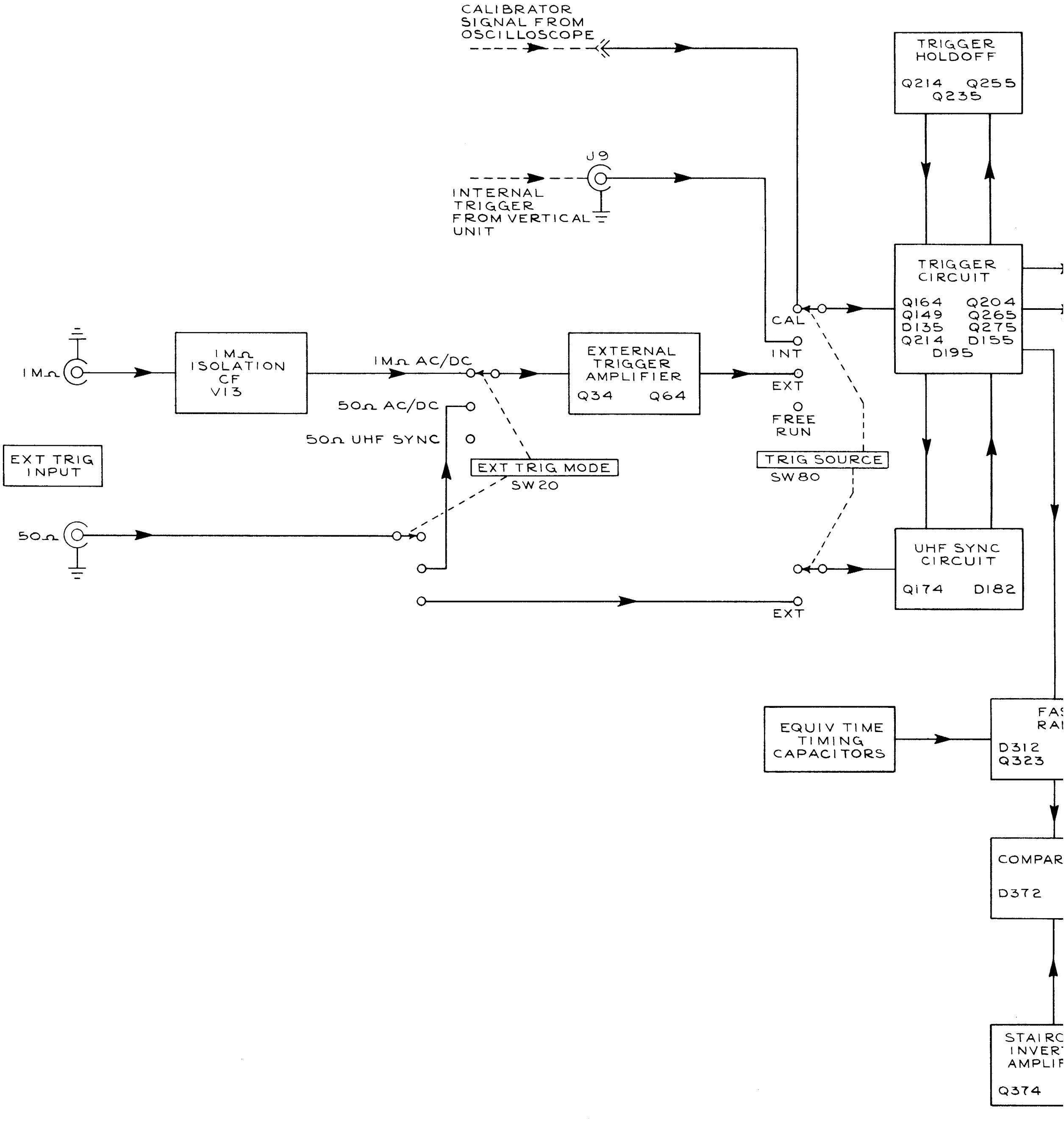
†Furnished as a unit with R122 and R170.
††Furnished as a unit with R518.
†††Furnished as a unit with R650.

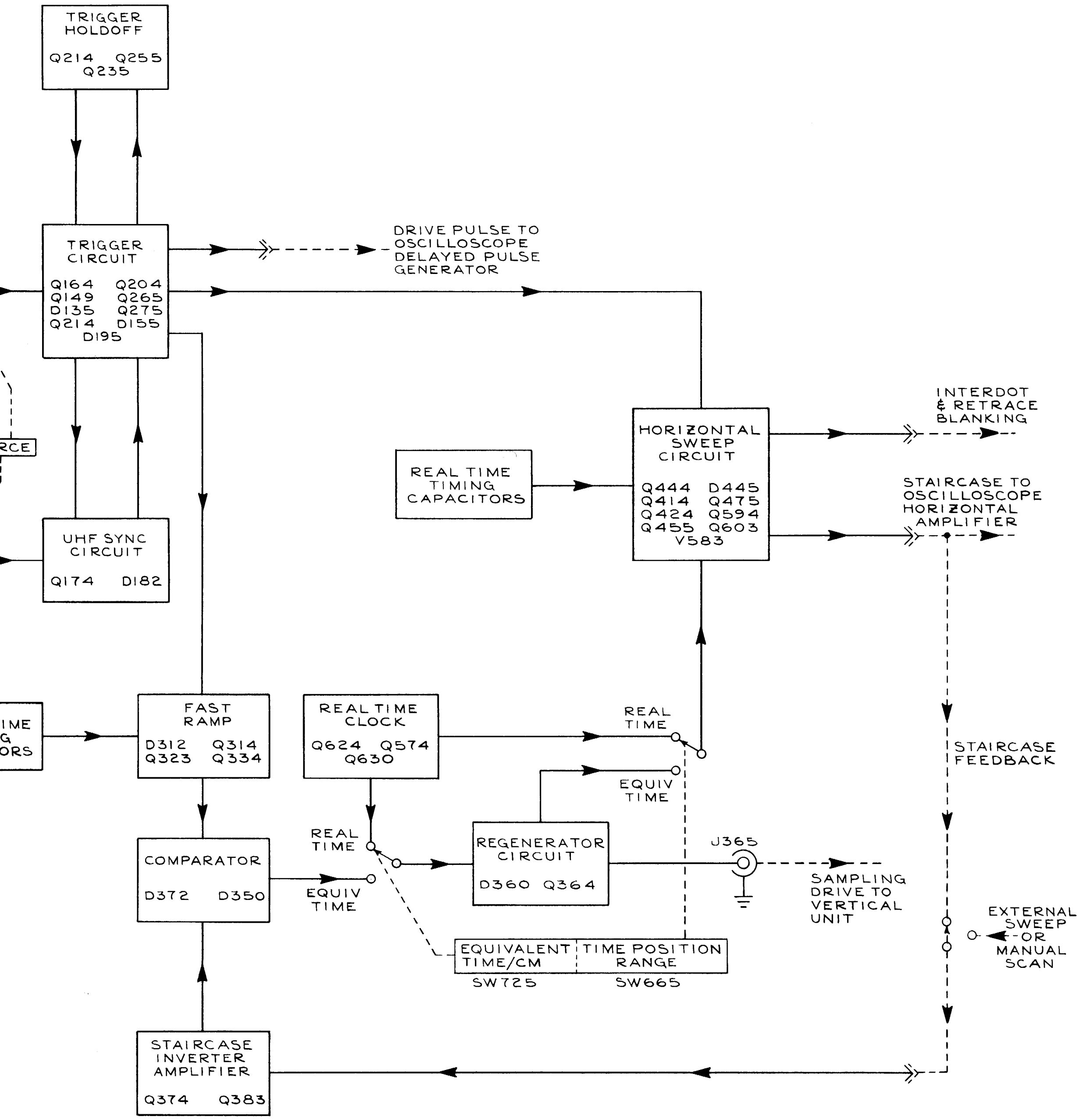
Transformers *(Cont'd)*

Ckt. No.	Tektronix Part No.	Description	S/N Range
T290	*120-0325-00	Toroid, bifilar	
T350	*120-0374-00	Toroid, 2T-4T	
T635	*120-0371-00	Toroid, 4 windings	

Electron Tubes

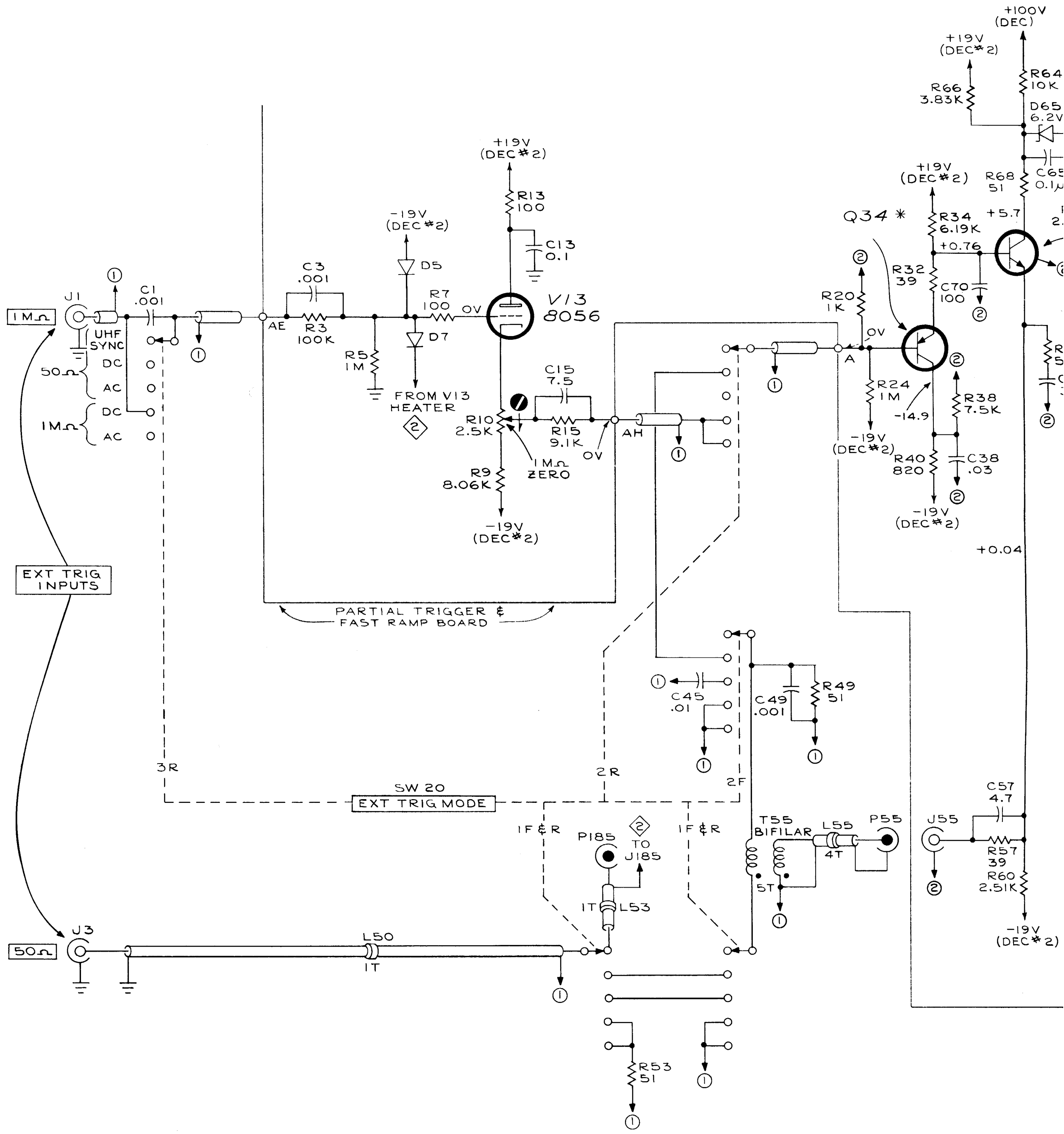
V13	154-0417-00	8056	
V583	154-0417-00	8056	


CALIBRATOR SIGNAL FROM OSCILLOSCOPE
TRIGGER HOLDOFF
Q214 Q255 Q235
J9
INTERNAL TRIGGER FROM VERTICAL UNIT
TRIGGER CIRCUIT
Q164 Q204 Q149 Q265 D135 Q275 Q214 D155 D195
CAL
INT
EXT
FREE RUN
1MΩ
1MΩ ISOLATION CF V13
1MΩ AC/DC
EXTERNAL TRIGGER AMPLIFIER
Q34 Q64
50Ω AC/DC
50Ω UHF SYNC
EXT TRIG MODE
SW20
TRIG SOURCE
SW80
EXT TRIG INPUT
50Ω
UHF SYNC CIRCUIT
Q174 D182
EXT
EQUIV TIME TIMING CAPACITORS
FAS RA
D312 Q323
COMPAR
D372
STAIRC INVERT AMPLIF
Q374



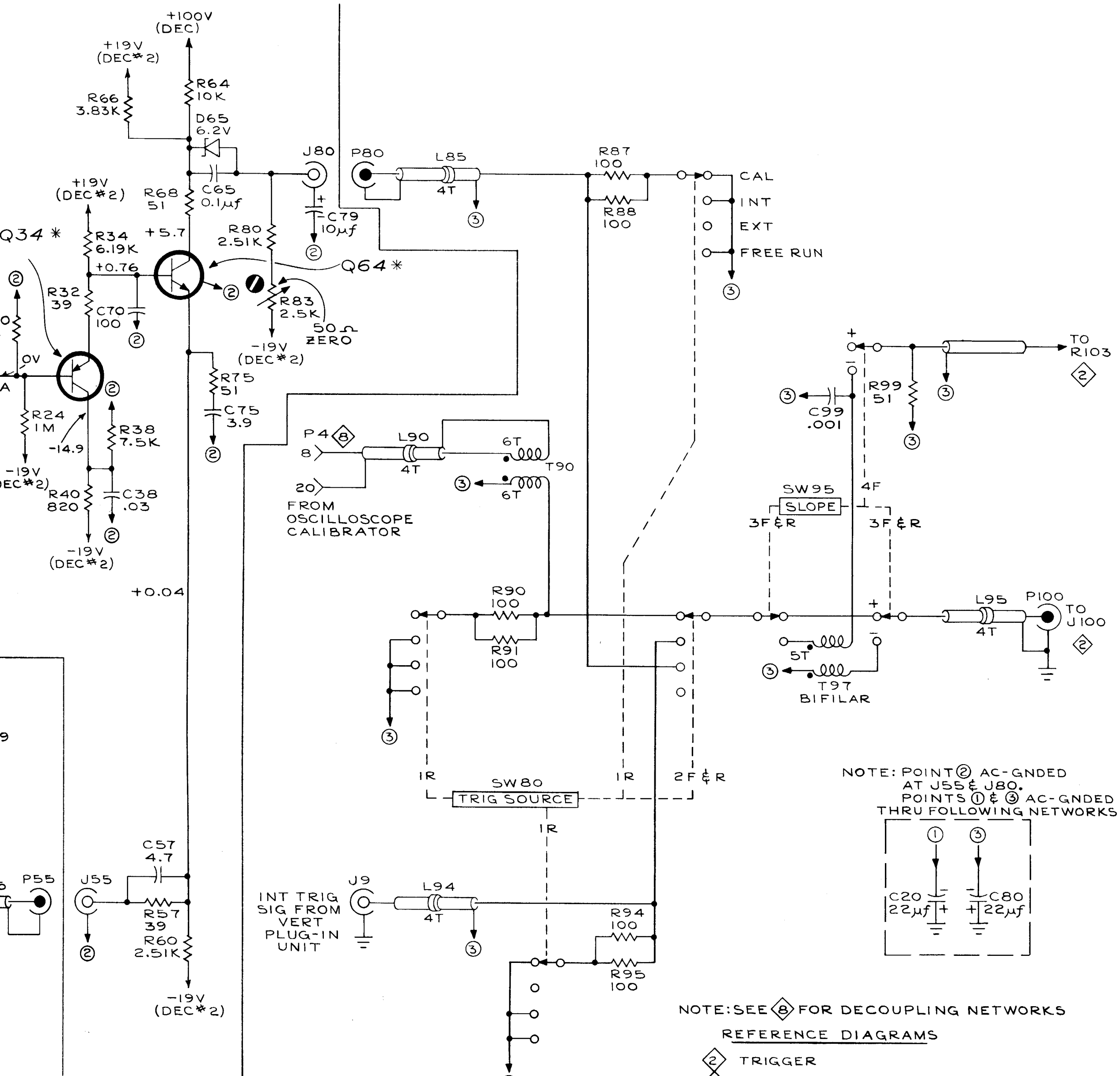
A

BLOCK DIAGRAM
PLM
365



TYPE 5T3 TIMING UNIT

A



NOTE: SEE ⑧ FOR DECOUPLING NETWORKS

REFERENCE DIAGRAMS

② TRIGGER

⑧ INTERCONNECTING PLUG

* DENOTES SPECIAL PART. SEE PARTS LIST.

VOLTAGE READINGS on this diagram obtained under test conditions given on Trigger diagram.

A EXT TRIGGER INPUT & TRIGGER SWITCHING ①

PLM 265

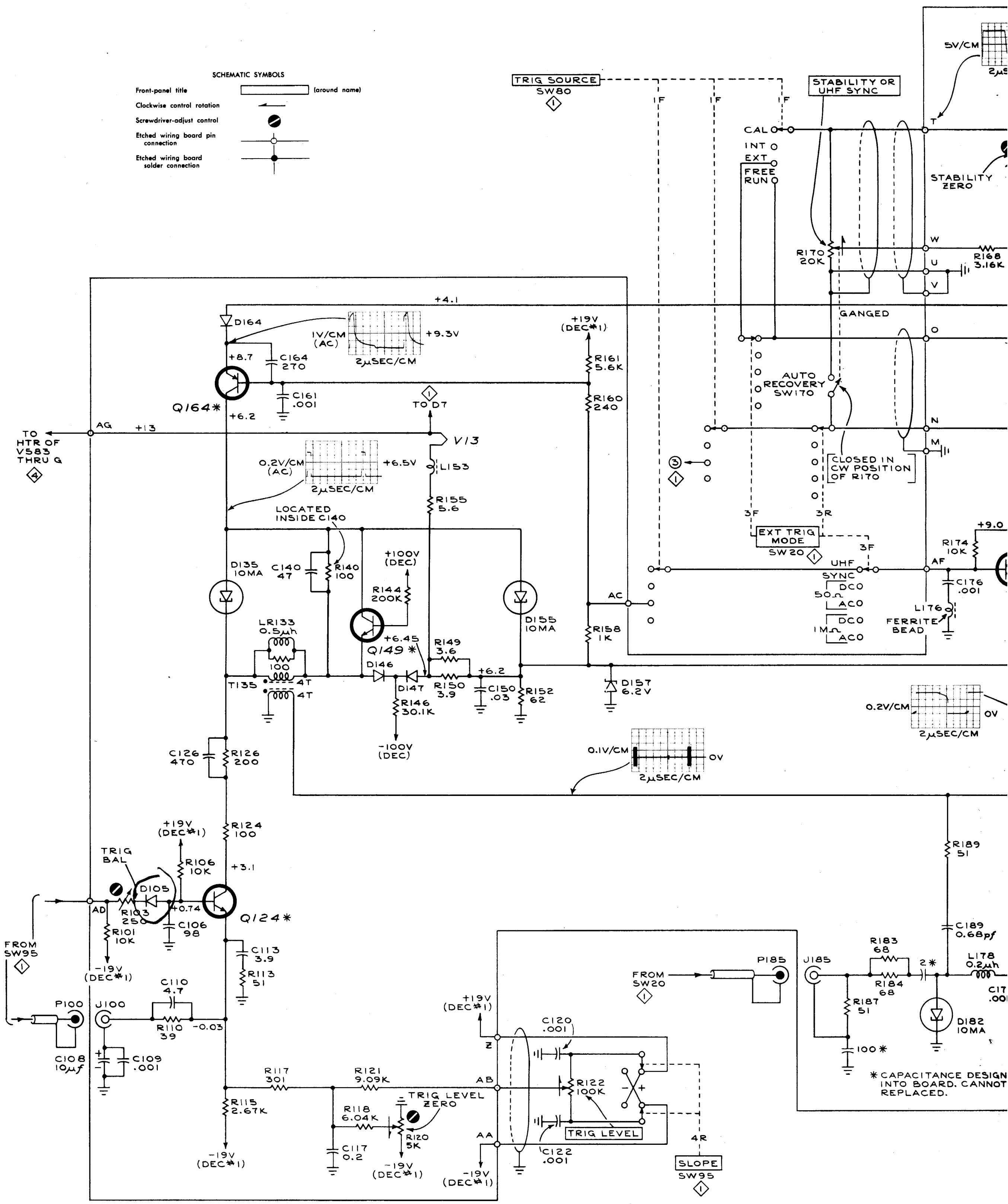
TEST CONDITIONS

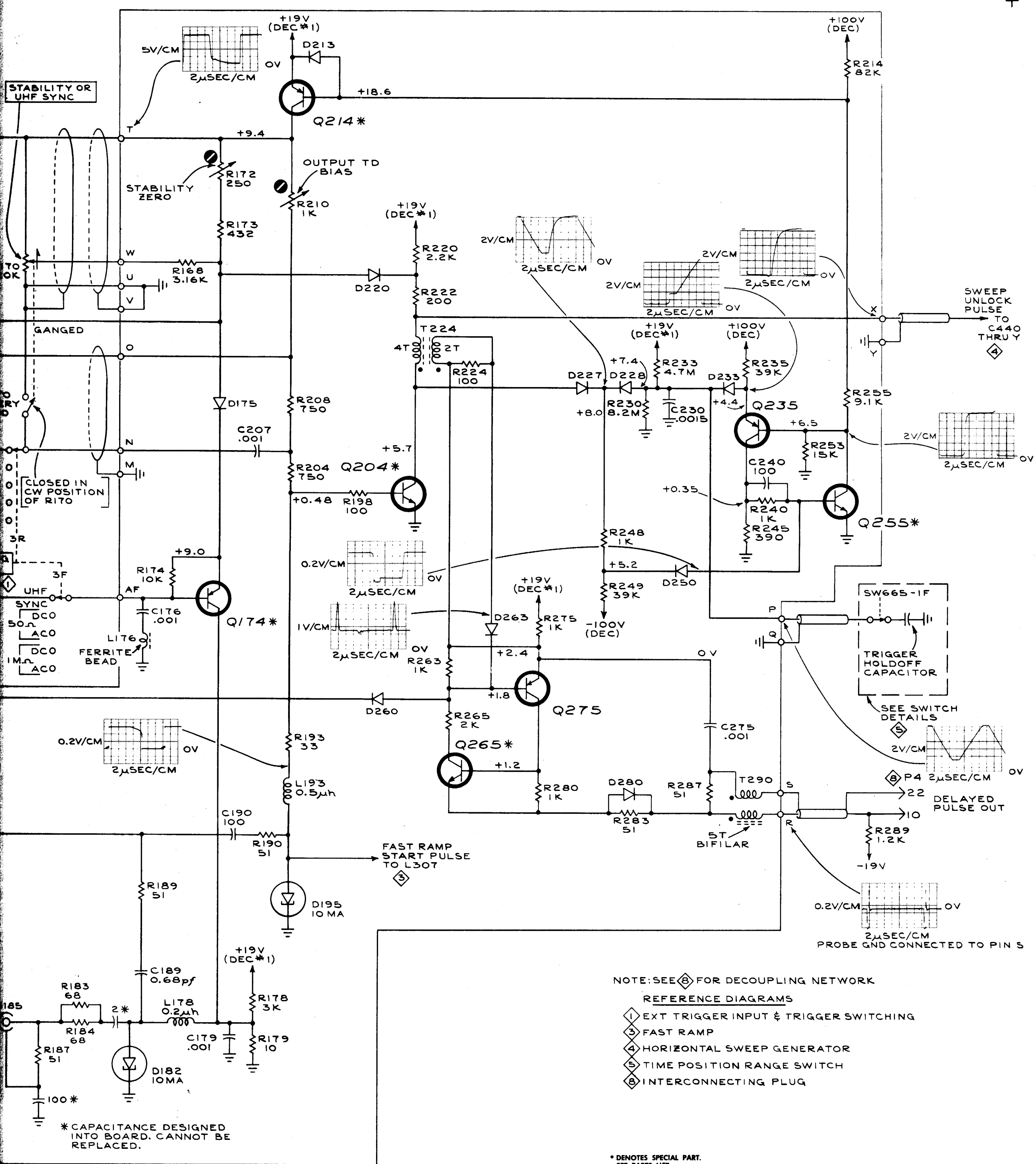
Typical waveforms and voltage measurements (shown in blue) were obtained under the following conditions unless otherwise noted on the specific diagrams:

Type 5T3 Installed in Type 661 Oscilloscope	
Dc Voltmeter Sensitivity	20,000 ohms/volt
Test Oscilloscope Bandpass	Dc to 30 Mc
Test Probe Ground Lead	Connected to Chassis
Type 661 Horiz Display	Sweep Magnifier X1
Amplitude/Time Calibrator	Off
Vertical Input Signal	None
External Triggering Signal	None
Type 5T3 Control Settings:	
EQUIVALENT TIME/CM	50 nSEC (locked with TIME POSITION RANGE)
Equiv. Time/Cm VARIABLE	CAL
Equiv. Time SAMPLES/CM	100
TIME POSITION	Centered
Time Position FINE	Centered
SWEEP MODE	NORM
Real Time SAMPLING RATE	100 KC
REAL TIME/CM	1 mSEC
Real Time/Cm VARIABLE	CAL
EXT TRIG MODE	1MΩ DC
TRIG SOURCE	INT
SLOPE	+
STABILITY OR UHF SYNC	AUTO RECOVERY
TRIG LEVEL	Counterclockwise

Voltage readings are given in volts dc. Voltage measurements taken in any particular instrument may vary somewhat from those given, due to normal differences in component characteristics.

⟨4⟩ HORIZ. SWEEP GENERATOR
⟨5⟩ TIME POSITION RANGE SW.
⟨2⟩ TRIGGER
⟨3⟩ FAST RAMP


SCHEMATIC SYMBOLS
Front-panel title
(around name)
Clockwise control rotation
Screwdriver-adjust control
Etched wiring board pin connection
Etched wiring board solder connection
TRIG SOURCE
SW80
CAL
INT
EXT
FREE RUN
STABILITY OR UHF SYNC
5V/CM
STABILITY ZERO
R170 20K
R168 3.16K
GANGED
AUTO RECOVERY SW170
CLOSED IN CW POSITION OF R170
EXT TRIG MODE
SW20
UHF SYNC
50Ω
DCO
ACO
1MΩ
R174 10K
+9.0
C176 .001
L176
FERRITE BEAD
+4.1
D164
1V/CM (AC)
2μSEC/CM
+9.3V
+8.7
C164 270
Q164*
+6.2
C161 .001
+19V (DEC*1)
R161 5.6K
R160 240
TO D7
TO HTR OF V583 THRU G
AG
+13
V13
L153
0.2V/CM (AC)
+6.5V
R155 5.6
LOCATED INSIDE C140
D135 10MA
C140 47
R140 100
+100V (DEC)
R144 200K
Q149*
+6.45
D155 10MA
AC
R158 1K
LR133 0.5μh
100
R149 3.6
D146
D147
R150 3.9
+6.2
C150 .03
R152 62
D157 6.2V
T135
4T
R146 30.1K
-100V (DEC)
0.2V/CM
0V
C126 470
R126 200
0.1V/CM
R189 51
R124 100
TRIG BAL
R106 10K
+3.1
D105
R103 250
+0.74
C106 98
Q124*
AD
R101 10K
-19V (DEC*1)
FROM SW95
C113 3.9
R113 51
C189 0.68pf
R183 68
R184 68
L178 0.2μh
P100
J100
C110 4.7
R110 39
-0.03
C108 10μf
C109 .001
FROM SW20
P185
J185
R187 51
100*
D182 10MA
C120 .001
R117 301
R121 9.09K
AB
R122 100K
TRIG LEVEL ZERO
R118 6.04K
R120 5K
C117 0.2
R115 2.67K
AA
C122 .001
TRIG LEVEL
4R
SLOPE
SW95
*CAPACITANCE DESIGN INTO BOARD. CANNOT REPLACED.



NOTE: SEE ⑧ FOR DECOUPLING NETWORK

REFERENCE DIAGRAMS

- ① EXT TRIGGER INPUT & TRIGGER SWITCHING
- ③ FAST RAMP
- ④ HORIZONTAL SWEEP GENERATOR
- ⑤ TIME POSITION RANGE SWITCH
- ⑧ INTERCONNECTING PLUG

* CAPACITANCE DESIGNED INTO BOARD. CANNOT BE REPLACED.

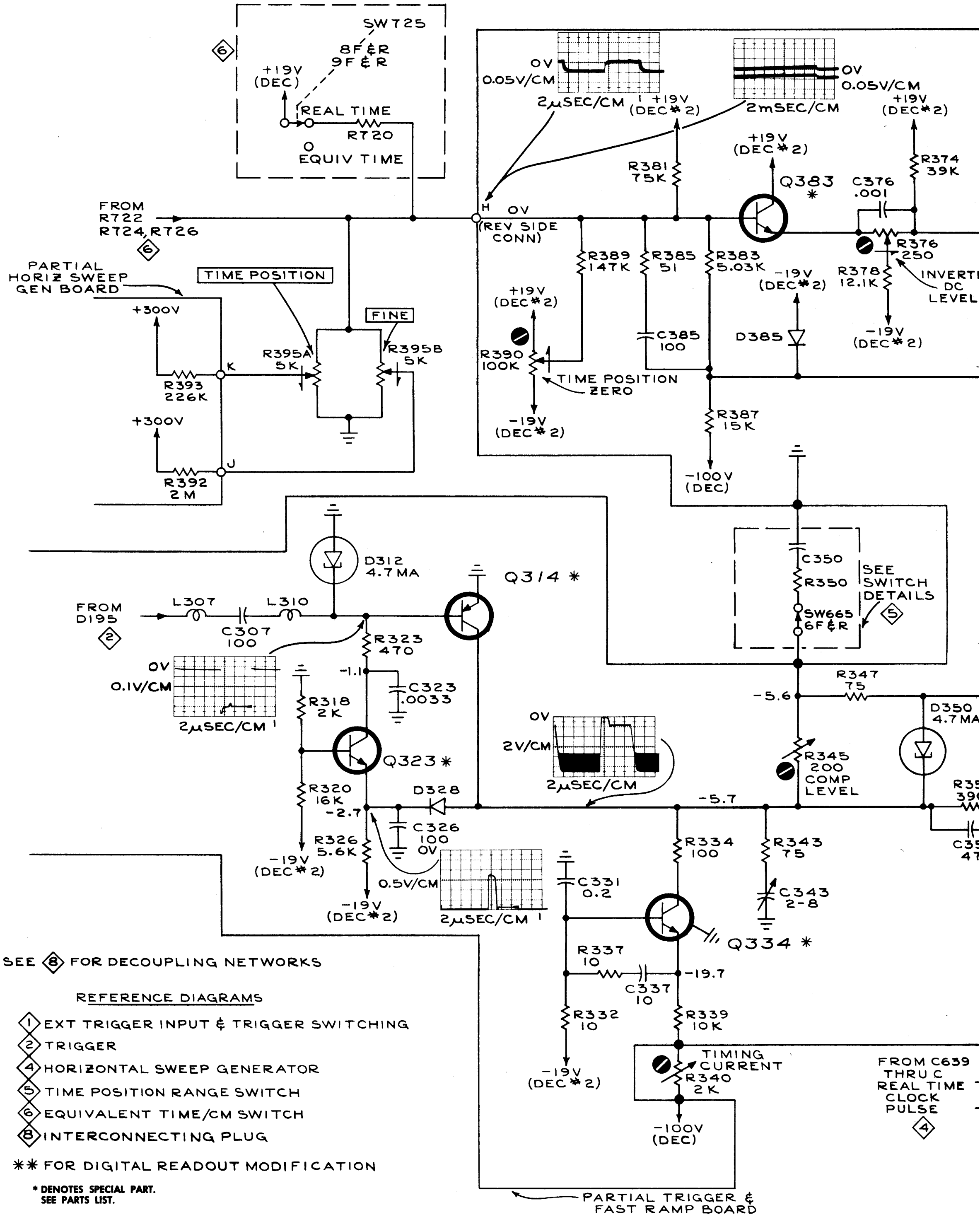
* DENOTES SPECIAL PART. SEE PARTS LIST.

WAVEFORMS and VOLTAGE READINGS on this diagram obtained under test conditions given on left side of this diagram.
Test oscilloscope +EXT triggered on signal at pin "T" on Trigger board.

A1

TRIGGER ②
PLM
765

② TRIGGER



NOTE: SEE ⑧ FOR DECOUPLING NETWORKS

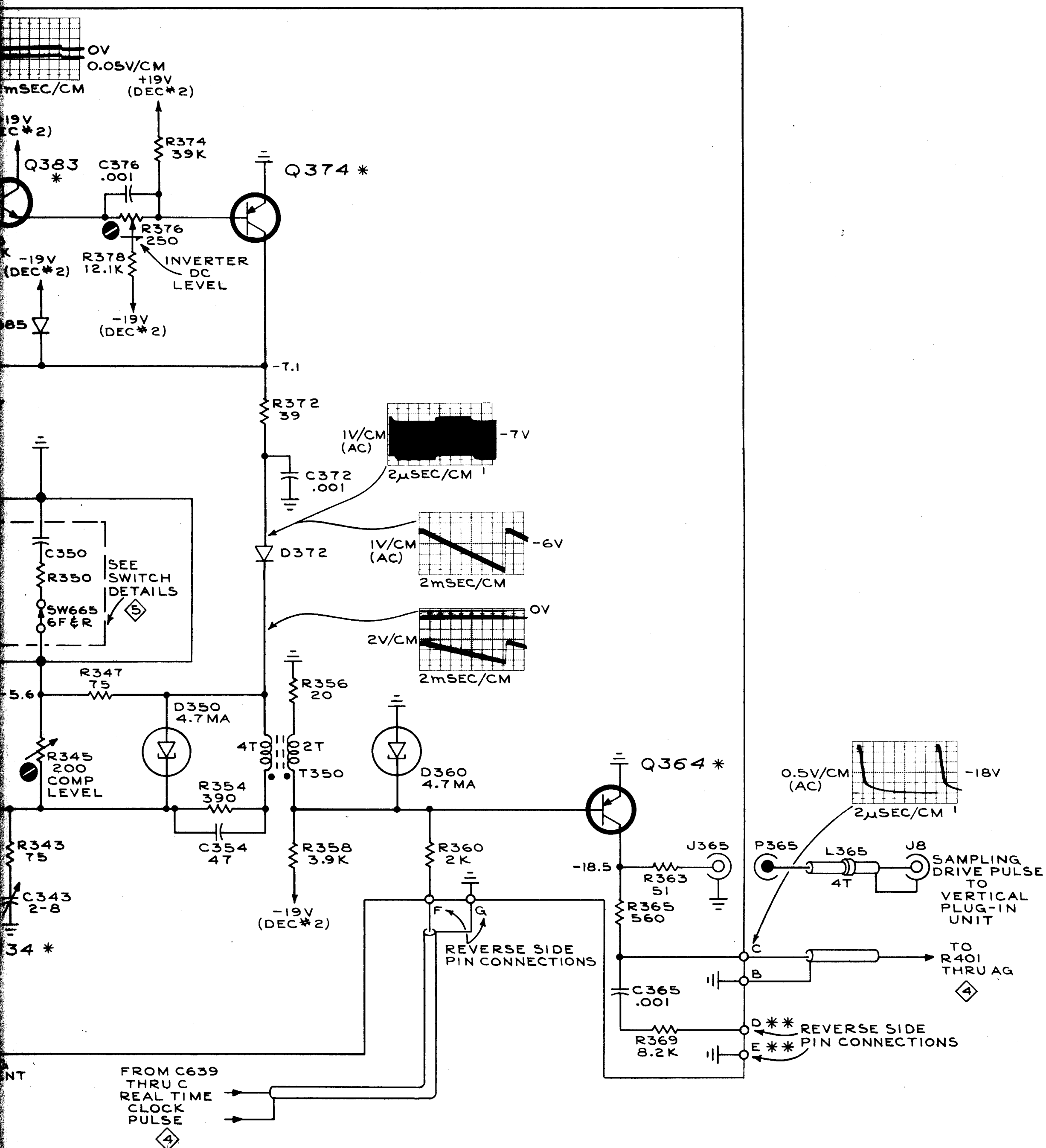
REFERENCE DIAGRAMS

① EXT TRIGGER INPUT & TRIGGER SWITCHING
② TRIGGER
④ HORIZONTAL SWEEP GENERATOR
⑤ TIME POSITION RANGE SWITCH
⑥ EQUIVALENT TIME/CM SWITCH
⑧ INTERCONNECTING PLUG

** FOR DIGITAL READOUT MODIFICATION

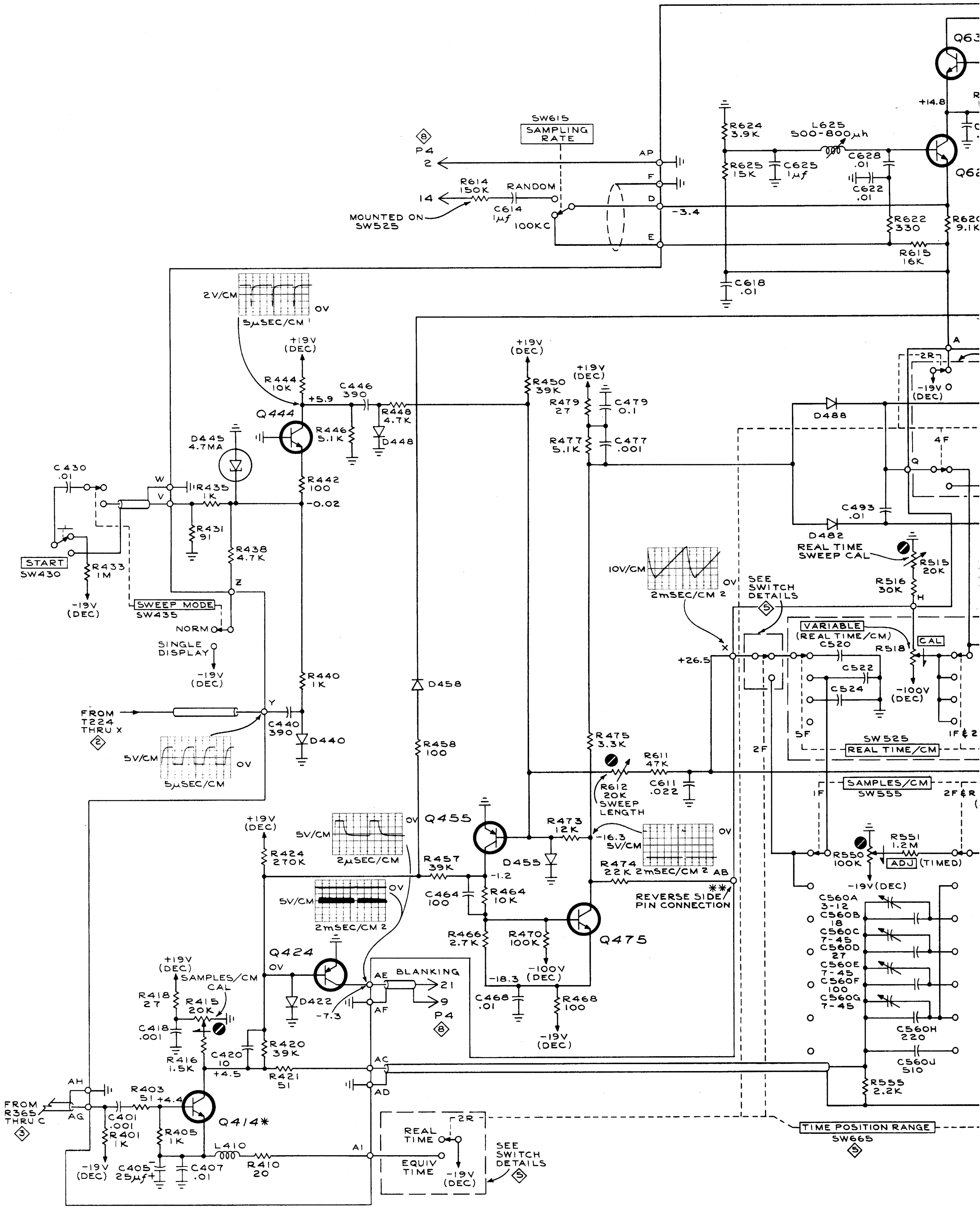
* DENOTES SPECIAL PART. SEE PARTS LIST.

WAVEFORMS and VOLTAGE READINGS on this diagram obtained under test conditions given on Trigger diagram.
[1]Test oscilloscope —EXT triggered on signal at collector of Q314.



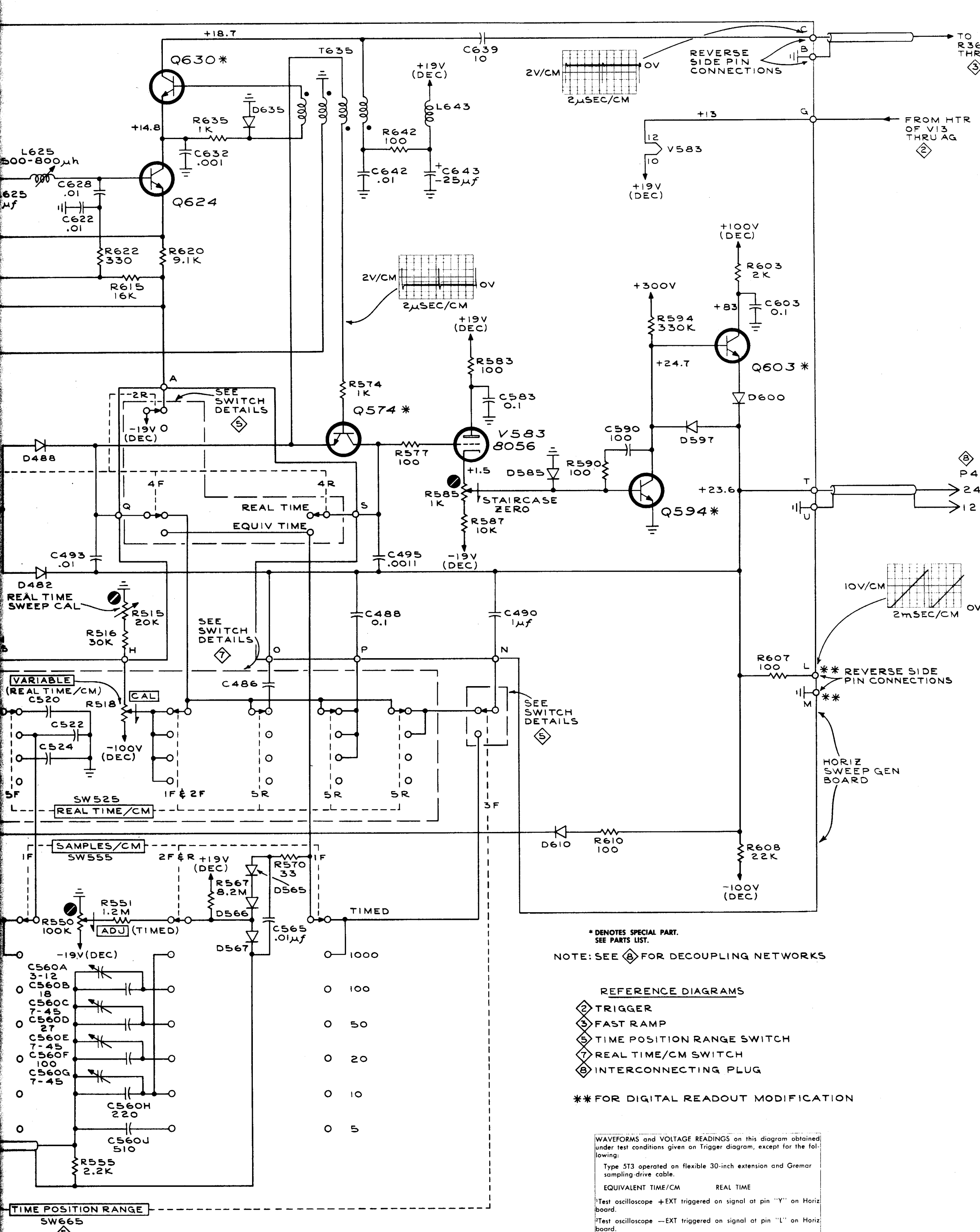
A

FAST RAMP ③
PLM
265



TYPE 5T3 TIMING UNIT

A



* DENOTES SPECIAL PART. SEE PARTS LIST.

NOTE: SEE 8 FOR DECOUPLING NETWORKS

REFERENCE DIAGRAMS

2 TRIGGER
3 FAST RAMP
5 TIME POSITION RANGE SWITCH
7 REAL TIME/CM SWITCH
8 INTERCONNECTING PLUG

** FOR DIGITAL READOUT MODIFICATION

WAVEFORMS and VOLTAGE READINGS on this diagram obtained under test conditions given on Trigger diagram, except for the following:

Type 5T3 operated on flexible 30-inch extension and Gremar sampling-drive cable.

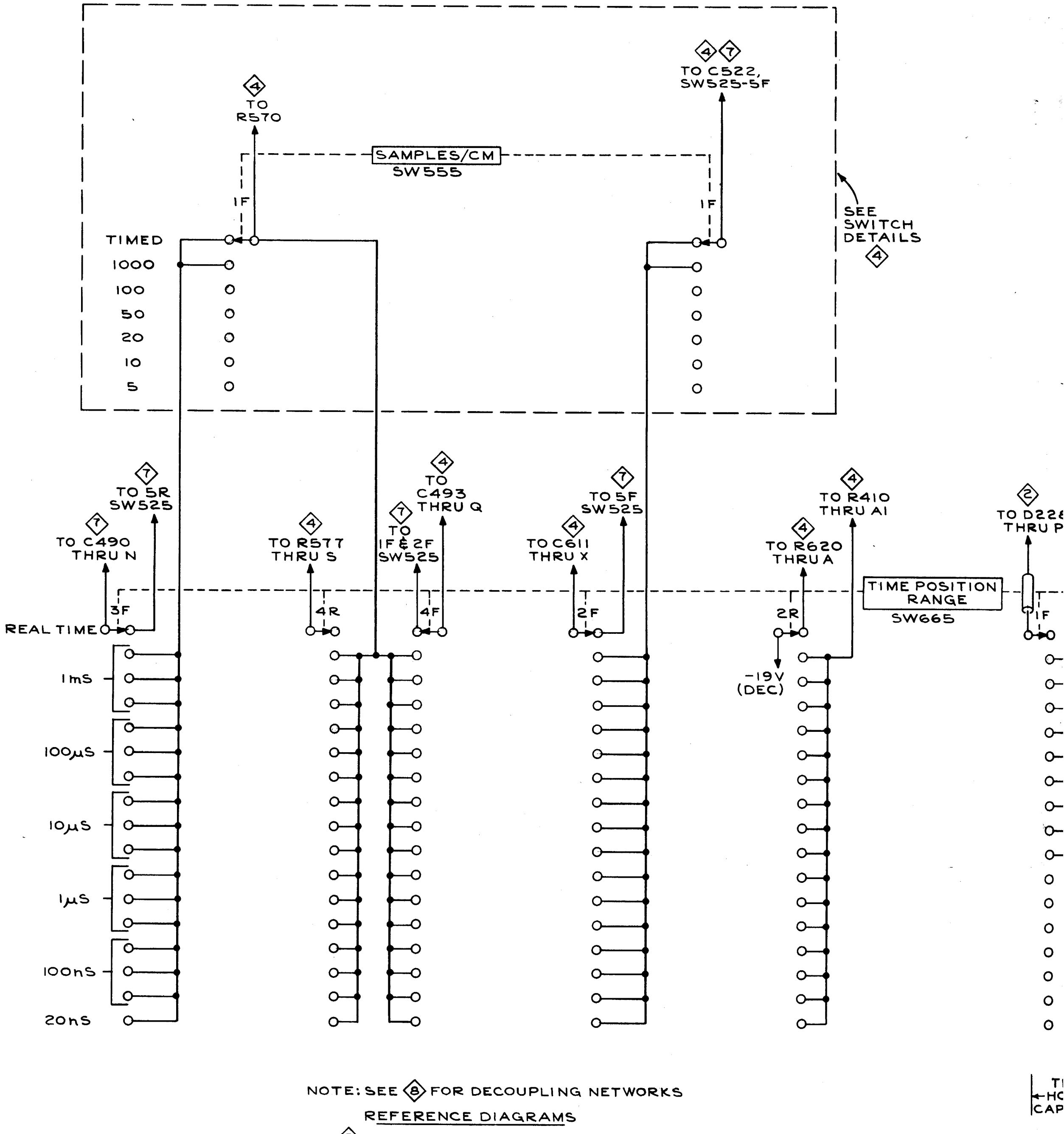
EQUIVALENT TIME/CM REAL TIME

[1]Test oscilloscope +EXT triggered on signal at pin "Y" on Horiz board.

[2]Test oscilloscope —EXT triggered on signal at pin "L" on Horiz board.

A

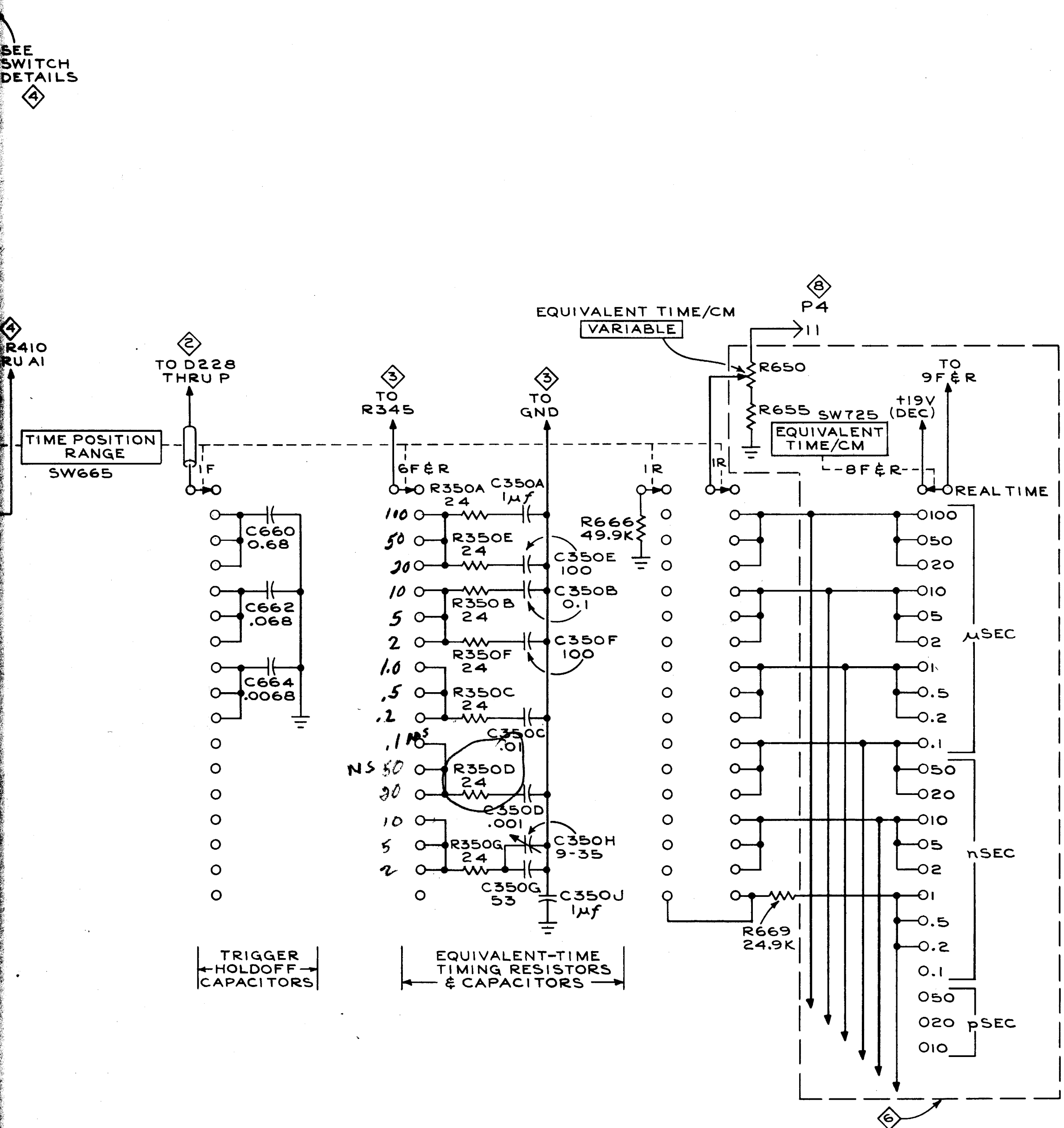
HORIZONTAL SWEEP GENERATOR 4



NOTE: SEE ⑧ FOR DECOUPLING NETWORKS

REFERENCE DIAGRAMS

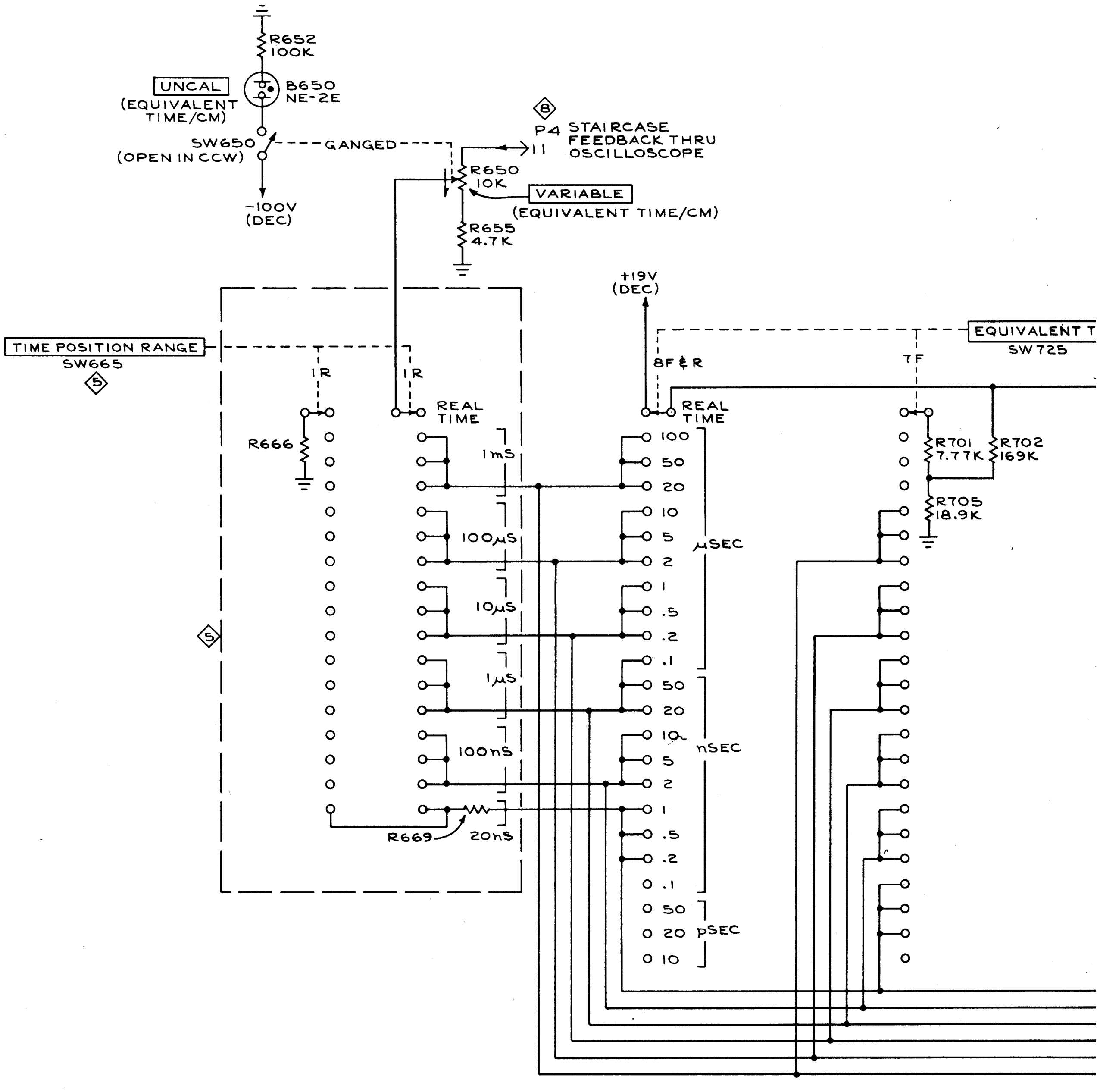
- ② TRIGGER
- ③ FAST RAMP
- ④ HORIZONTAL SWEEP GENERATOR
- ⑥ EQUIVALENT TIME/CM SWITCH
- ⑦ REAL TIME/CM SWITCH
- ⑧ INTERCONNECTING PLUG



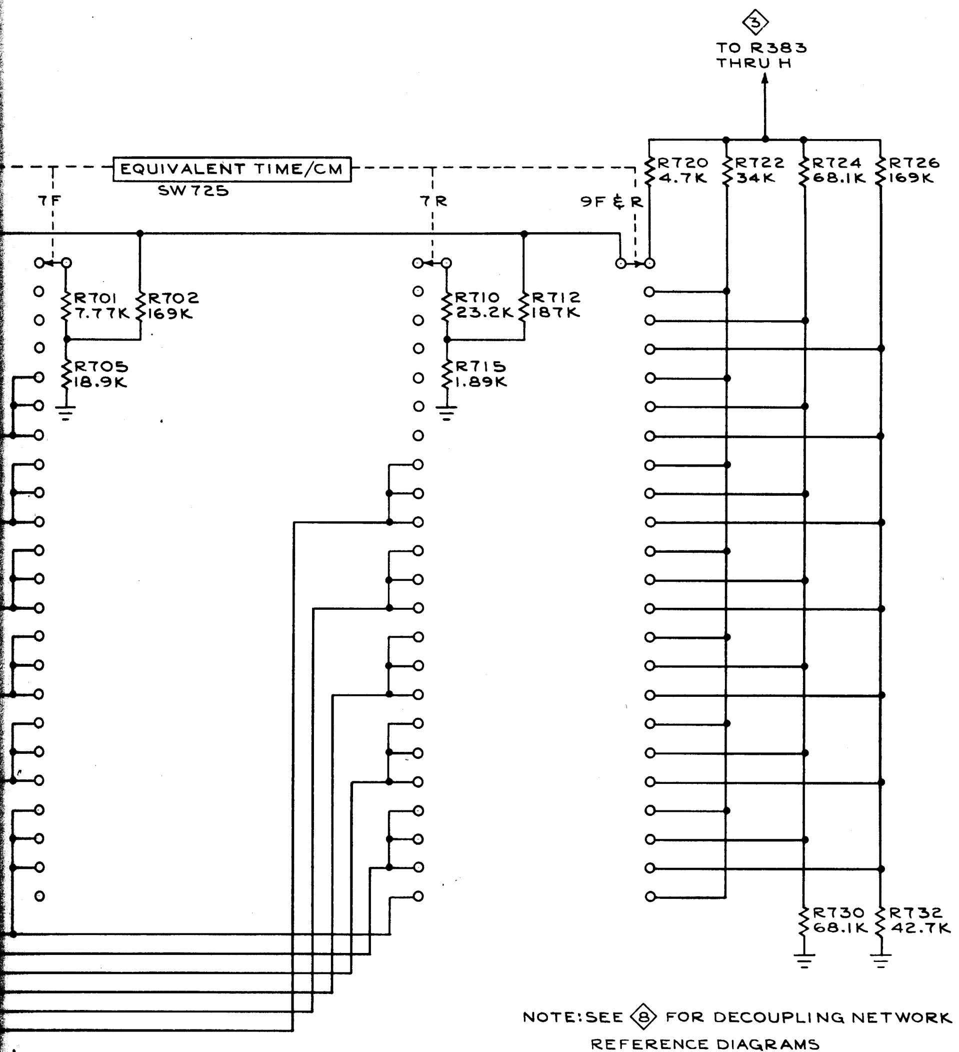
A

TIME POSITION RANGE SWITCH ⑤

PLM
465


R652
100K
UNCAL
(EQUIVALENT TIME/CM)
B650
NE-2E
SW650
(OPEN IN CCW)
GANGED
-100V
(DEC)
P4
11
STAIRCASE FEEDBACK THRU OSCILLOSCOPE
R650
10K
VARIABLE
(EQUIVALENT TIME/CM)
R655
4.7K
+19V
(DEC)
TIME POSITION RANGE
SW665
1R
1R
8F & R
7F
EQUIVALENT T
SW725
REAL TIME
REAL TIME
R666
R701
7.77K
R702
169K
R705
18.9K
1mS
100μS
10μS
1μS
100nS
20nS
R669
100
50
20
10
5
2
1
.5
.2
.1
μSEC
50
20
10
5
2
1
.5
.2
.1
nSEC
50
20
10
pSEC

A



NOTE: SEE ⟨8⟩ FOR DECOUPLING NETWORK

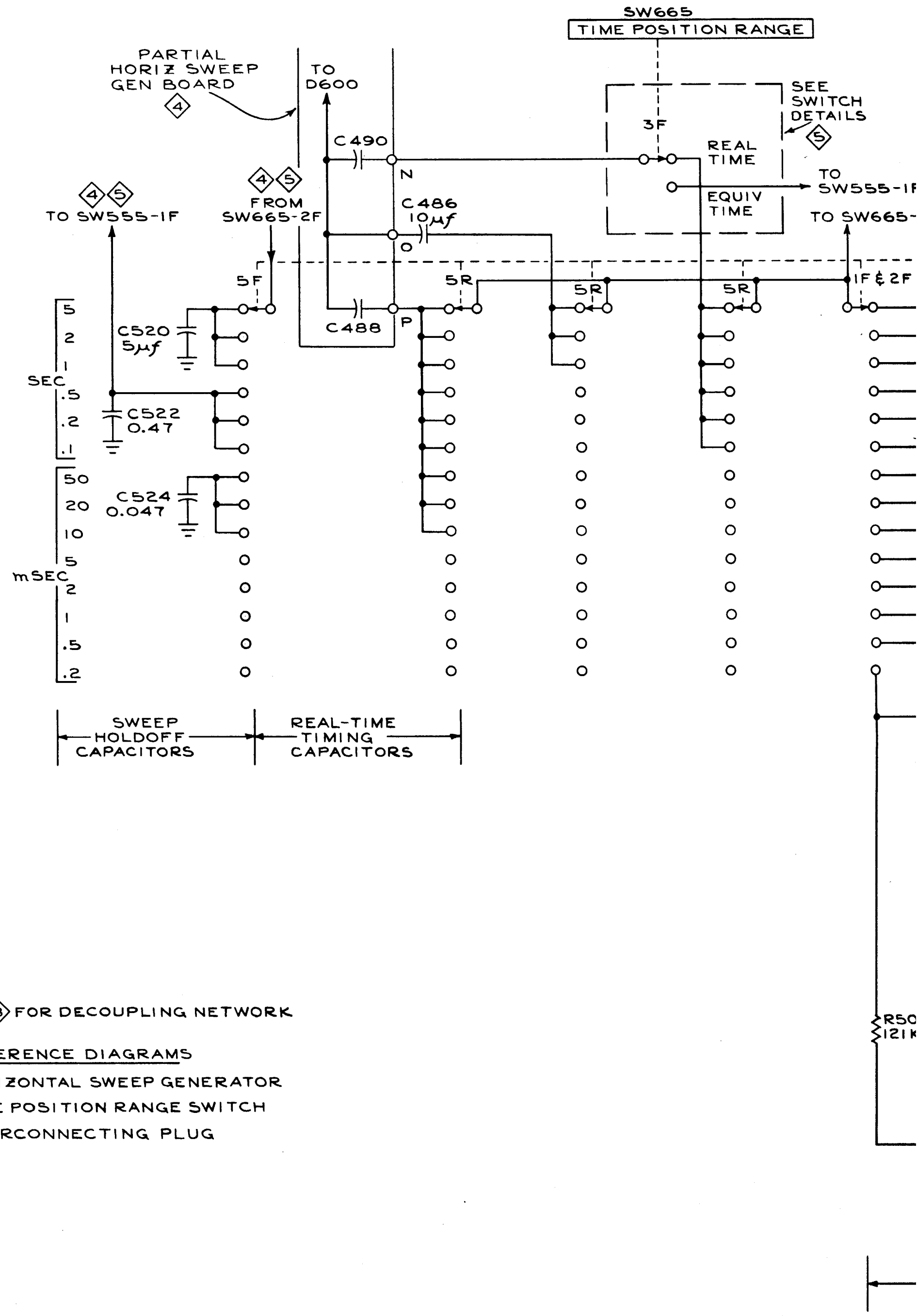
REFERENCE DIAGRAMS

⟨3⟩ FAST RAMP
⟨5⟩ TIME POSITION RANGE SWITCH
⟨8⟩ INTERCONNECTING PLUG

A

EQUIVALENT TIME/CM SWITCH ⟨6⟩

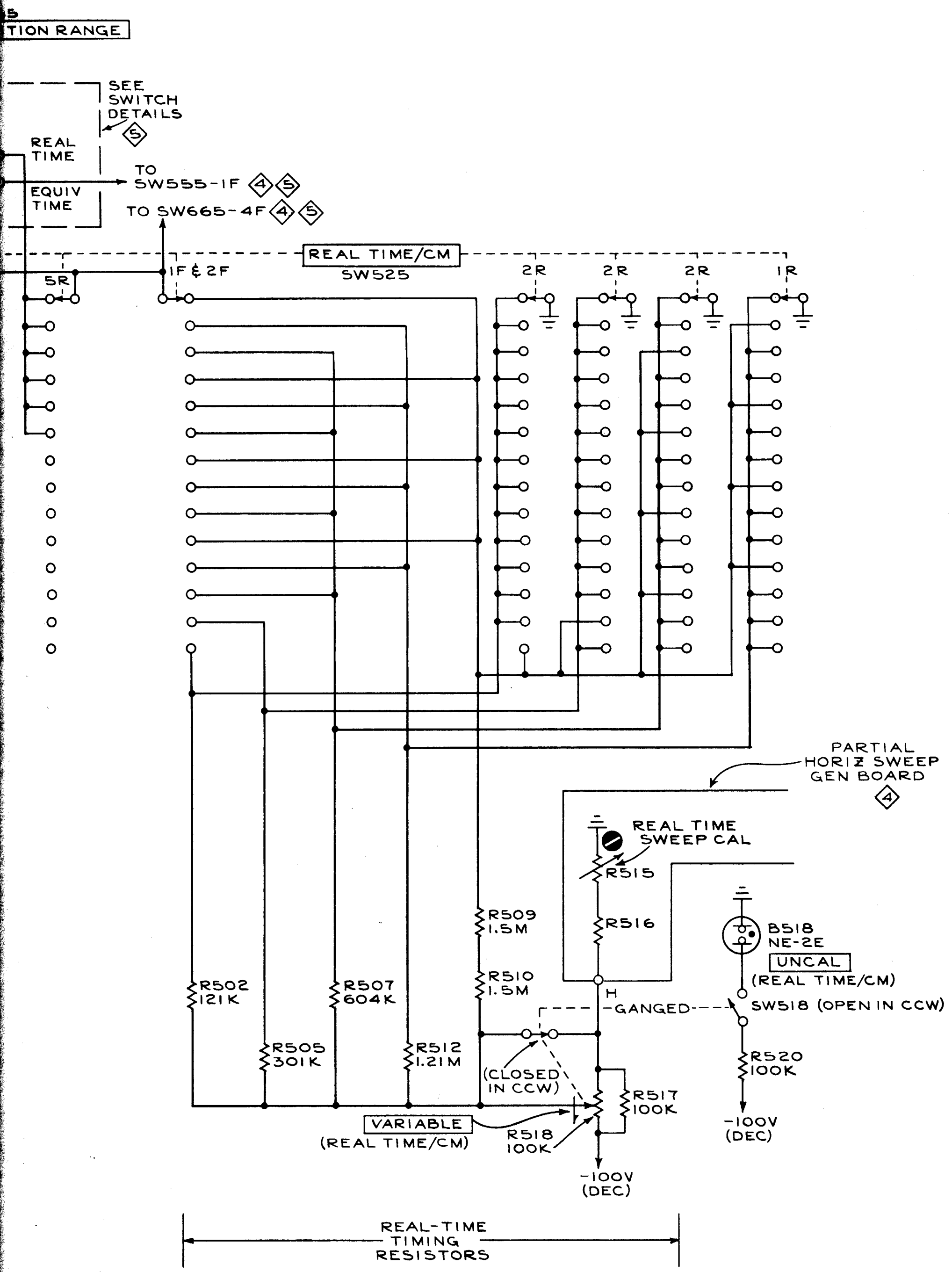
PLM
465



NOTE: SEE 8 FOR DECOUPLING NETWORK

REFERENCE DIAGRAMS

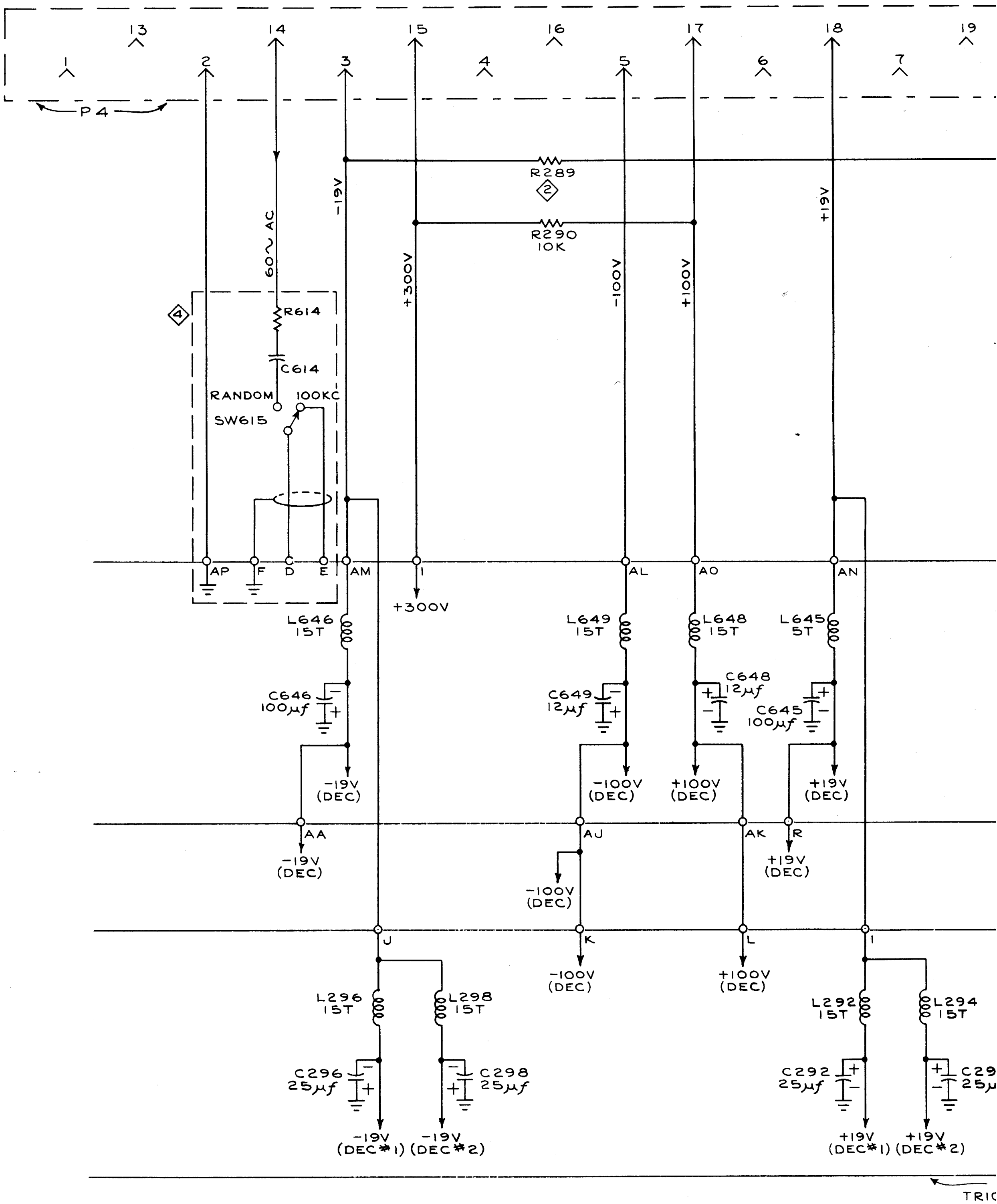
4 HORIZONTAL SWEEP GENERATOR
5 TIME POSITION RANGE SWITCH
8 INTERCONNECTING PLUG



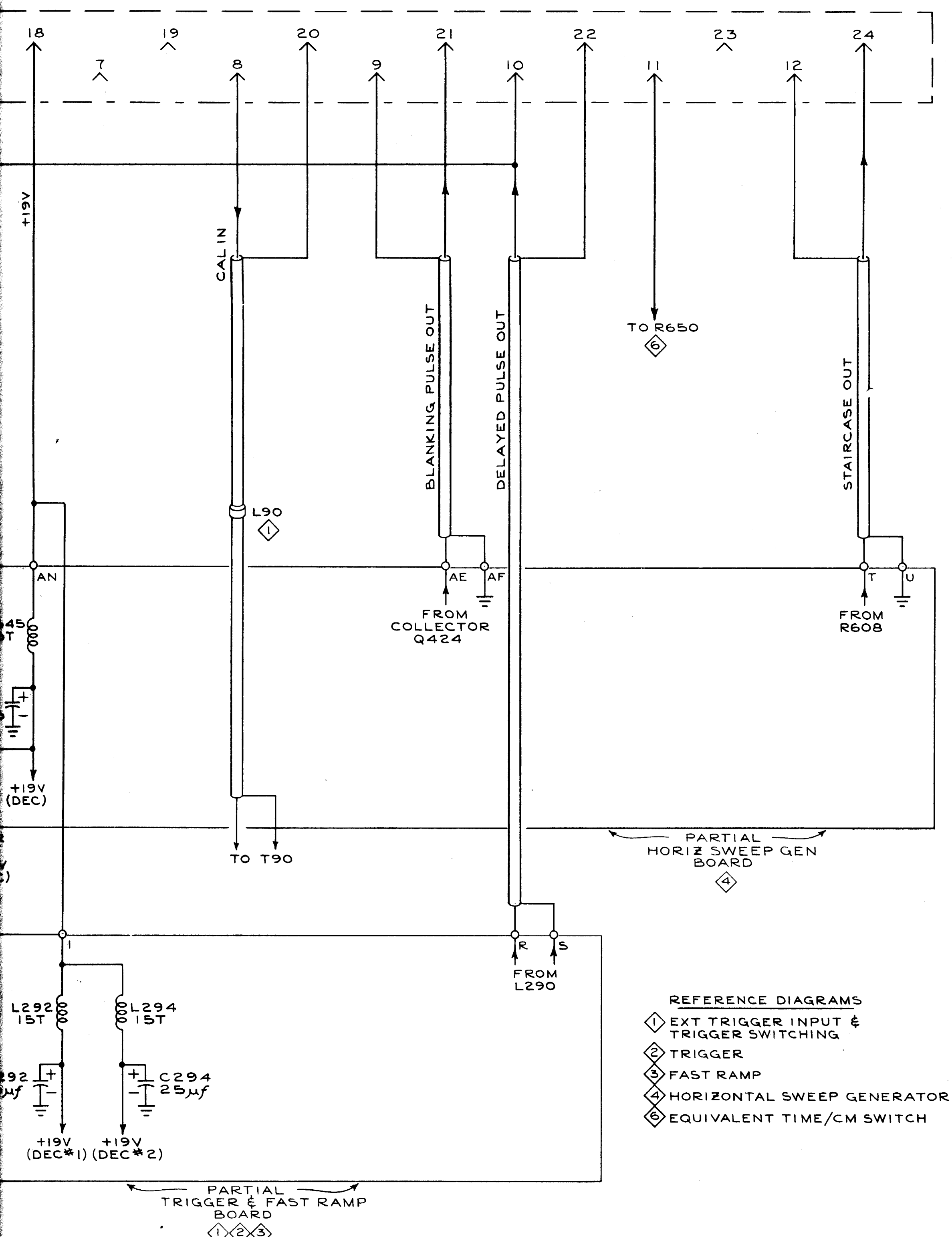
A

REAL TIME/CM SWITCH 7

PLM
365



TYPE 5T3 TIMING UNIT A



A

INTERCONNECTING PLUG ⟨8⟩

PLM
365

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.