PRELIMINARY INSTRUCTION MANUAL

TYPE 5T1A TIMING UNIT

This is a preliminary instruction manual. It is not complete, and it may contain minor errors. We will send you the permanent instruction manual just as soon as it is ready. Be sure to complete and send in the attached card so that we can send the manual directly to the user of the instrument.

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SECTION 1

GENERAL DESCRIPTION

Introduction

The Type 5T1A Timing Unit is a sampling-type timing plug-in unit for use with the Tektronix Type 661 Oscilloscope, and '4' Series sampling plug-in units. The Type 5T1A can receive trigger signals either through a front-panel connector (externally supplied) or through interconnecting wiring from vertical sampling units which have provisions for internal trigger takeoff. Trigger signals must bear a fixed time relationship to the signals to be displayed by the sampling unit.

The Type 5T1A has 16 calibrated equivalent-time sweep rates. Any sweep rate may be continuously increased to about 3X faster than the calibrated rate. A 7-position TIME EXPANDER switch allows any portion of the display to be expanded with a constant dot density. A front-panel control selects the number of samples per centimeter of horizontal deflection. A single-display circuit allows the operator to start a single horizontal sweep.

The triggering circuit will operate either on negative-going or positive-going signals. Trigger threshold is adjustable over a ±200-millivolt range for either positive-going or negative-going signals. Trigger source may be selected internally from the sampling unit, externally through a front-panel connector on the Type 5T1A, or internally from the Type 661 Amplitude/Time Calibrator. The trigger circuit may also be free-run at its maximum repetition rate. The repetition rate of the trigger circuit is determined by the setting of the SWEEP TIME/CM switch and the RECOVERY TIME control.

The RECOVERY TIME control provides a range of trigger recovery times, allowing the operator to adjust for jitter-free triggering.

A TIME POSITION control provides a variable time delay for time-positioning the signal display in the TIME EXPANDER switch X1 position. In the expanded positions, the TIME POSITION control moves the time "window" anywhere within the original range displayed in the X1 position of the TIME EXPANDER switch.

Operating Characteristics

Sweep Time/Cm -- Sweep rates in 16 calibrated steps of equivalent time from 1 nsec/cm to 100 μsec/cm in a 1, 2, 5, 10 sequence. An uncalibrated variable control provides a continuous range up to 3X the calibrated rate between steps. A variable control extends the fastest rate to about 1/3 nsec/cm. All calibrated rates better than 3% accuracy.

Samples/Cm -- 5, 10, 20, 50, and 100, ±3% accuracy; also 1000 and timed sweep, with an unmagnified display.

Sweep Mode -- Repetitive or single display.

Trigger Source -- External, internal, free run, and calibrator. Sensitive to positive-going or negative-going slope.

Triggering Threshold -- Continuously variable over a ±200-mv range.

Trigger Sensitivity -- Internal or External: 5 mv external for a 1 nsec pulse. (Internal level is determined by output of sampling unit trigger-takeoff circuit.)

Recovery Time -- Variable from about 10 to about 13 μsec on sweep rates faster than 0.2 μsec/cm; longer on slower sweep rates.

Time Expansion -- Provides X1, X2, X5, X10, X20, X50, and X100 expansion of sweep rate selected with a constant number of samples/cm. Expansion may be selected to fall anywhere in basic time-base range, determined by SWEEP TIME/CM switch setting.

Time Position -- Provides continuously variable time display window. Time position range is controlled by the TIME EXPANDER and SWEEP TIME/CM switches. Table 1-1 lists the ranges as a function of control settings.

Time Jitter -- Less than 30 psec (picoseconds), or 10^{-4} X (fast ramp duration), whichever is greater, in 100-μsec through 2-nsec/cm sweep rates. Less than 10 psec at 1 nsec/cm sweep rate.

External trigger "kickout" is less than 5 mv.

TABLE 1-1

Time Range of TIME POSITION Control

SWEEP TIME/CM Switch Setting	TIME EXPANDER Switch Setting		
	X1	X2	X5, X10, X20, X50, X100
100, 50, or 20 μSEC	100 μsec	500 μsec	1000 μsec
10, 5, or 2 μSEC	10 μsec	50 μsec	100 μsec
1, .5, or 2 μSEC	1 μsec	5 μsec	10 μsec
.1 μSEC, 50 nSEC, or 20 nSEC	0.1 μsec	0.5 μsec	1 μsec
10, 5, or 2 nSEC	100 nsec	100 nsec	200 nsec
1 nSEC	10 nsec	10 nsec	20 nsec

SECTION 2

OPERATING INSTRUCTIONS

Introduction

The operating instructions are divided into three parts. First is a description of front-panel controls and connectors. Second is a discussion of methods of triggering the Type 5T1A. Third is a discussion of the controls.

Because the Type 5T1A is part of a system, we suggest that you also familiarize yourself with the information in the Type 661 Instruction Manual and for the '4' Series sampling unit used. Familiarize yourself with the operation of the system by displaying the Amplitude/Time Calibrator and Delayed Pulse signals available from the Type 661. We also suggest that you read the booklet "Sampling Notes", Tektronix publication number 061-557.

The Type 5T1A requires a trigger signal with a definite time relation to the signal to be displayed. These trigger signals may be obtained internally, when a sampling unit with internal trigger takeoff provisions is used. They may also be externally fed to the Type 5T1A through a front-panel connector. The Timing Unit may be triggered by either positive- or negative-going signals of 5-to 250-millivolts peak-to-peak amplitude.

FUNCTION OF FRONT-PANEL CONTROLS AND CONNECTORS

SWEEP TIME/CM .... The SWEEP TIME/CM switch sets the equivalent time/horizontal cm of display when the VARIABLE control is in the CALIBRATED position.

VARIABLE	The uncalibrated VARIABLE control permits up to 3X decrease in sweep time/cm between sweep ranges. Control can extend the 1-nsec/cm range to about 1/3 nsec/cm.
SAMPLES/CM	Establishes the number of dots (samples) per horizontal centimeter of the crt display. The TIMED position allows a constant rate of horizontal deflection, with sweep rate adjustable from 8 sec/cm to approximately 5 sec/cm.
TIME EXPANDER	Expands a portion of the sweep to a full-width display. Samples/cm in the display remain constant.
TIME POSITION	Allows movement of the time-display window. Allows time-expanded sweep window to present any part of display seen in X1. Positioning range shown in Table 1-1.
SWEEP MODE	Establishes NORMAL (repetitive) or SINGLE DISPLAY condition. Spring return START position starts the single display.
TRIGGERING SOURCE	Permits selection of triggering signals from the sampling unit internally, or from the EXTERNAL TRIGGER INPUT connector. A third position places the sweep-sampling

system in a free-run mode at which time stable displays may be obtained from the Type 661 Delayed Pulse generator, or from a system that has been triggered by the delayed pulse.

TRIGGERING POLARITY .... Permits starting the display on a negative-polarity pulse (-), or on a positive-polarity pulse (+). A CAL position permits triggering on the Type 661 Amplitude/Time Calibrator signal, internally connected. The CAL position is useful when displaying small signals from the Amplitude/Time Calibrator.

EXTERNAL TRIGGER INPUT ...... A nominally 50 Ω, ac-coupled, external trigger input connector. Mates with General Radio Type 874 connectors. Allows direct connection of the Type 5T1A to the triggering signal when the signal is less than the required 40 mv for internal triggering. Signals from 5 to 250 mv will permit proper operation of the timing unit. For proper triggering on slow-rise signals, 10-mv/µsec minimum rate of change is required. See Fig. 2-1.

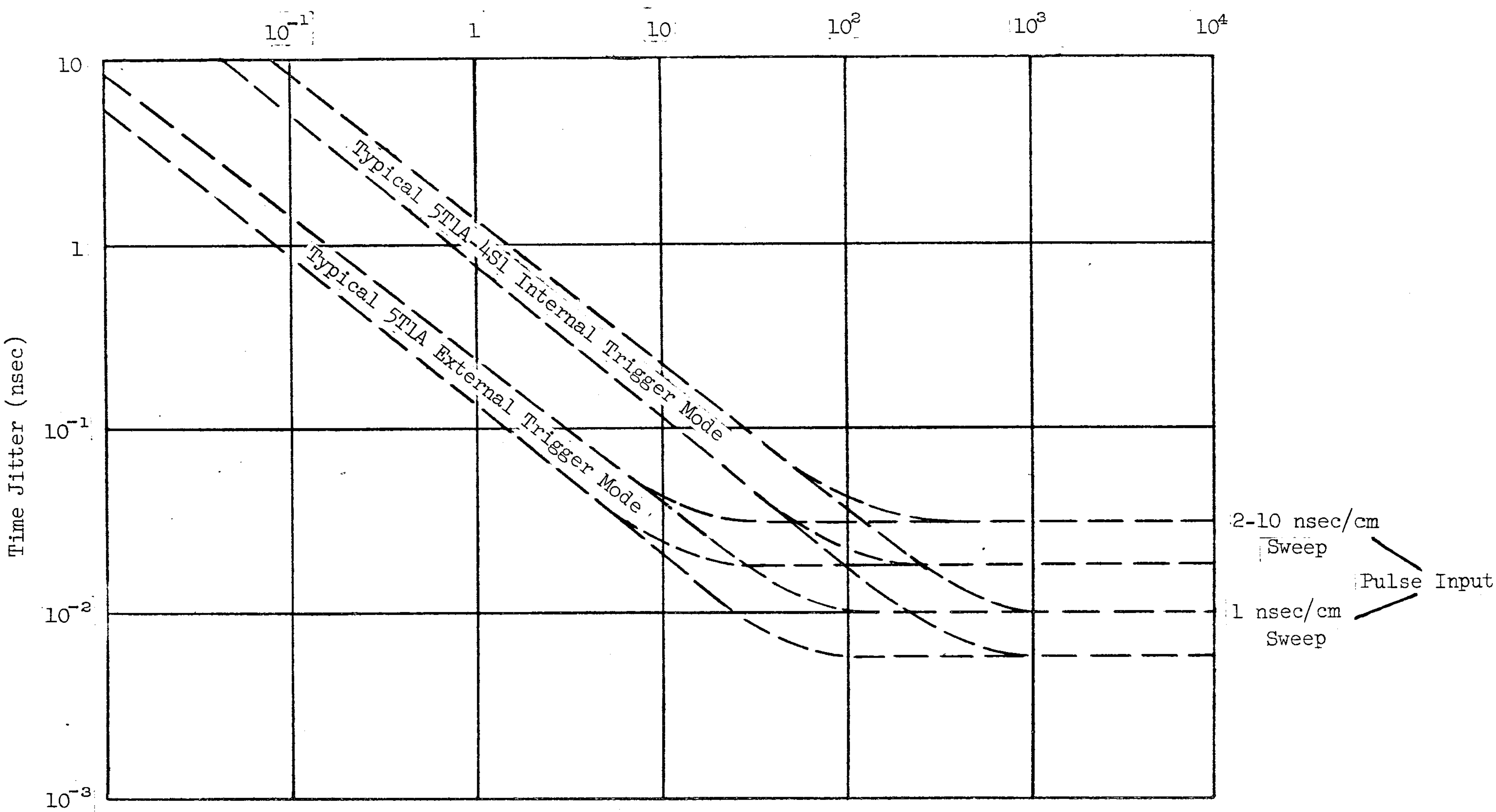


Fig. 2-1. Type 5T1A Triggering jitter as a function of trigger signal

TRIGGERING THRESHOLD .... The Type 5T1A trigger system is sensitive to signals exceeding 5 mv. The THRESHOLD control determines the signal level needed to trigger the system. Setting the triggering POLARITY control in the + position and the THRESHOLD control fully clockwise will hold off the triggering system for normal amplitude positive trigger signals. Turning the THRESHOLD control counterclockwise permits proper triggering as the trigger-to-threshold voltage difference is brought to zero. Triggering occurs as the extreme positive portion of the triggering signal reaches the threshold voltage. Turning the THRESHOLD control further counterclockwise will finally produce a free-running sweep, at the condition when the trigger signal base-line level reaches the threshold voltage. The same conditions exist when the POLARITY switch is at - and the THRESHOLD control is turned in the + direction.

RECOVERY TIME .... The RECOVERY TIME control is in the circuit that locks out the trigger circuit for a definite recovery time after each sample has been taken. It is normally left in the MIN. position. Turning the control clockwise will then increase the lock-out period after each sample. With adjustable lock-out time, it is usually possible to adjust for a clean display if an irregular display is caused by the triggering signal persisting or a second trigger arriving at the same time the lock-out is released.

Installation

Before installing the Type 5T1A, be sure the Type 661 POWER and SCALE ILLUM. control is in the POWER OFF position. If the Type 5T1A is installed when the power is on, damage may result.

Pull out the lock bar located at the bottom of the Type 661 timing plug-in unit compartment. Insert the Type 5T1A in the plug-in compartment, and press it firmly in place so that the connectors mate. When placed properly, the Type 5T1A front panel will be tight against the Type 661 front panel, and the lock will move to about a 45° angle with the front-panels. Press the lock bar firmly against the front panel.

NOTE

The Delayed Pulse generator of the Type 661 Oscilloscope must be readjusted for each Type 5T1A unit used. See the Calibration section of this manual for procedure.

TRIGGERING CONSIDERATIONS

The Type 5T1A may be triggered from either internal trigger signals, when a sampling unit with trigger takeoff provisions is used, or from an external source. The Type 661 Amplitude/Time Calibrator may also be internally connected to trigger the Type 5T1A. The trigger pulse must be related in time, and have a repeitition rate equal to or less than that of the signal displayed. It must also meet amplitude and timing requirements, as discussed in the following paragraphs.

Internal Source

When a sampling unit is used that has internal trigger-takeoff circuitry and vertical-signal delay following the trigger takeoff, such as the Type 4S1, the signal itself may be used to trigger the Type 5T1A. The signal sent from the sampling unit must be at least 5 mv, determined by the ratio of input signal to the division of signal by the sampling unit. The Type 4S1, for example, provides a trigger signal about 1/8 the amplitude of the input signal, thus the input signal must be at least 40 millivolts for internal triggering. The internal trigger signal is ac or dc coupled into the Type 5T1A and is controlled by the sampling unit. Placing the Type 5T1A SOURCE switch in the INT. position connects the internal trigger from the sampling unit. The Type 4S1 provides vertical signal delay following the trigger-takeoff circuit which allows the signal that triggers the Type 5T1A to be displayed.

The Type 661 Delayed Pulse may be used to trigger a circuit under test. The Delayed Pulse generator is driven by the trigger circuit of the Type 5T1A, and delivers about a -400-mv pulse. The pulse appears about 40 nsec after the trigger circuit has operated, allowing the sampling unit to view the delayed pulse. To obtain the delayed pulse, place the triggering SOURCE switch in the FREE RUN position. Repetition rate of the pulse is determined by the repetition rate of the Type 5T1A trigger circuit, controlled by the trigger-holdoff circuit. This rate may be varied by use of the RECOVERY TIME control.

When the Type 5T1A is used with a sampling unit having a delay line, such as the Type 4S1, the Delayed Pulse from the Type 661 must be viewed with the SWEEP TIME/CM switch in the 2 nSEC or slower sweep rate position. In the 1 nSEC sweep rate position, the signal delay of the sampling unit places normal input signals in the TIME POSITION control range, which is 10 to 20 nsec at this sweep rate. To view the Delayed Pulse on a signal-delaying sampling unit at a 1-nsec or faster sweep rate, place the SWEEP TIME/CM control in the 2 nSEC position and use the TIME EXPANDER switch to increase the sweep rate. This allows at least 100 nsec of TIME POSITION control range, and delays the sweep sufficiently to display the Delayed Pulse.

External Source

When a sampling unit without signal delay (such as the Type 4S2) is used, and external trigger signal must be supplied to the Type 5T1A EXTERNAL TRIGGER INPUT connector. External triggering also may be used instead of internal triggering when a sampling unit such as the Type 4S1 is used. Placing the SOURCE switch in the EXT. position connects the EXTERNAL TRIGGER INPUT connector through an ac-coupling circuit and through an isolation stage to the trigger circuit.

The Type 5T1A must be triggered at least 35 nsec before the signal reaches the sampling gate of the sampling unit. The TIME POSITION control allows an extra delay in operation, added to the 35 nsec requirement. Thus, the time window after triggering that is displayed may be moved a considerable distance in time, allowing flexibility in test setup. Remember that as little as 8 inches of RG-8A/U cable can insert an extra nsec of delay.

There are two methods of triggering the Type 5T1A before the signal arrives at the sampling-unit sampling gate. The first is to pretrigger the Type 5T1A by using a pulse generator that triggers the system, and some time later triggers the circuit under test. The second is to insert some delay in the signal connections to the sampling unit so that the signal will arrive at the sampling gate after the Type 5T1A is triggered (occurs internally in Type 4S1). The following are some examples of each method:

Pretriggering

This method may be used when the circuit under test can be triggered, producing the signal to be displayed some finite time after it has been triggered. Typical circuits of this sort are blocking oscillator and avalanche transistor circuits. A suitable pretrigger generator is a Tektronix Type 111 Pretrigger Pulse Generator. The Type 111 supplies a trigger signal to the Type 5T1A, and some time later, supplies a trigger signal for the circuit under test. The system should be adjusted so that the time between the pretrigger signal sent to the Type 5T1A and the trigger sent to the circuit under test is 35 to 50 nsec, minus the time delay in the circuit under test between triggering and signal output.

When using the pretriggering technique, remember that any time jitter between the pretrigger and the signal sampled will be displayed as time-jitter.

Signal Delay

This method is suitable for circuits which cannot be triggered by some external means. A suitable delay line for most applications is the Tektronix Type 113 Delay Cable, which provides a 60-nsec delay with a risetime under 0.1 nsec.

When the input signal must be used to trigger the Type 5T1A, a suitable arrangement must be made to split the signal so that it may also drive the trigger circuit of the Type 5T1A.

A suitable transformer-type trigger takeoff is the Tektronix CT-1 Nanosecond Current Transformer. This unit does not require an input circuit of any specific impedance. Its output is 5 mv/ma. Since the current in the input circuit follows ohm's law, the output of the CT-1 may be quickly calculated from the following equation:

$$E_{out} = \frac{5E_{sig}}{Z}$$

where: E_{out} = 5T1A output in millivolts

E_{sig} = signal amplitude (ac) in millivolts

Z = characteristic impedance of the signal circuit

The CT-1 output impedance is 50 Ω - suitable for direct connection to the Type 5T1A EXTERNAL TRIGGER INPUT connector. Remember that the input to the Type 5T1A must be in the 5-to 250-mv range of the trigger circuit.

A Tektronix VP-1 Voltage Pickoff unit may also be used as a trigger signal source. The Type VP-1 works with either a Tektronix P6034 or P6035 Probe. When using the VP-1, the effect of the P6034 or P6035 on the system impedance must be considered, as well as the output voltage which will arrive at the EXTERNAL TRIGGER INPUT connector.

An impedance matched "T" with 16.7 Ω in all 3 legs will divide an input signal into 2 equal, 1/2 amplitude signals; one for a 50 Ω vertical input to the sampling unit and one for the timing unit. Thus, a 10-mv signal will provide 5 mv for viewing and 5 mv for triggering.

The Type 110 allows transformer-type trigger takeoff from a 50 Ω system. 98% of the signal passes through the signal system for viewing, while a trigger signal 20% of the signal voltage is provided by the unit for use in triggering the Type 5T1A. The Type 110 has a dynamic range versatility which will allow most signals from a 50 Ω source to be used in triggering the Type 5T1A. When the Type 110 is used, be sure the trigger takeoff output fed to the Type 5T1A is within the 5-to 250-mv range of the trigger circuit. The pulse generator section of the Type 110 may be used to trigger a circuit under test. Typical test setups using the Type 110 are shown in the Type 110 Instruction Manual.

Trigger Signal Repetition Rate

The Tektronix Type 280 Trigger Countdown unit can be used to reduce the repetition rate of trigger signals with frequencies (or repetition rates) up to 5 gc (50×10^6 to 5×10^9 trigger signals/second) for more stable triggering. The trigger signal is fed to the Type 280, and the output from the FAST RISE OUTPUT connector is connected to the Type 5T1A EXTERNAL TRIGGER INPUT connector.

Adjusting Triggering POLARITY and THRESHOLD

The Type 5T1A POLARITY switch selects triggering on either positive-going (+) or negative-going (-) signals. The THRESHOLD control can select the voltage point, (within a ±20-mv range) where the trigger circuit will actually operate. Once the signal voltage passes the threshold point set by the THRESHOLD control, the trigger circuit can free-run until the signal voltage once again drops below the threshold point. The maximum repetition rate of the trigger circuit is controlled by a trigger holdoff circuit, and may be increased about 30% by the RECOVERY TIME control.

Set the POLARITY switch at + to trigger on positive-going signals; at - to trigger on negative-going signals. The THRESHOLD control can set the triggering threshold anywhere over a ±200-mv range. Adjustment should start with the THRESHOLD control in the same polarity region for which the POLARITY switch is set (+ for +, - for -). The THRESHOLD control should be adjusted toward the opposite polarity region. Set the THRESHOLD control so that stable minimum-jitter triggering occurs. If the THRESHOLD control is moved too far toward the opposite polarity region, multiple triggering may occur, and multiple traces may be displayed on the crt. Turning the THRESHOLD control further will cause the trigger circuit to free-run, and the display will be meaningless. During these adjustments, the RECOVERY TIME control should be set to MIN., allowing the trigger circuit to operate at the highest possible repetition rate. Experimenting with the THRESHOLD control and a signal display from the Type 661 Amplitude/Time Calibrator with the POLARITY switch set to CAL. will help you use the THRESHOLD control properly.

"False" Display

It is possible to obtain a "false" display on the crt when using a low sampling density, and when the sweep rate selected is such that several cycles of signal will be displayed on the crt. To illustrate, connect a 100-mv, 10-μsec/cycle signal from the Type 661 Amplitude/Time Calibrator to the Type 5T1A. Set the Type 5T1A SWEEP TIME/CM control to 100 μSEC, the SAMPLES/CM control to 5, the triggering SOURCE switch to CAL., and the TIME EXPANDER switch to X1. You should obtain about a 2-cycle display on the crt, although, by calculation, you should obtain 10 cycles/cm. Now move the SAMPLES/CM switch to 1000 and observe the display in each position between 5 and 1000 samples/cm. You should see, with 1000-samples/cm density, the calculated 10 cycles/cm. The reason for the false display with the lower sampling densities is that there are not enough samples taken to trace the outline of each cycle. The samples seen in the false displays lie on the true curve, but are insufficient to display its outline. The effect is similar to the plotting of a graph with insufficient information points. Check for false displays by moving the SAMPLES/CM control to another position. If the outline of the display is correct, the samples will remain the same in both positions. Increasing the sweep rate with a constant number of samples/cm decreases equivalent sweep time between samples, and allows a lower sampling density to provide a proper display.

Recovery Time

The recovery time of the trigger-recognition circuit is controlled by the holdoff circuit. The recovery time is dependent on the time required for fast-ramp operation, or the 100-kc maximum repetition rate, whichever is greater. If the duty factor of the trigger signal is long, in relation to the repetition rate of the Type 5T1A, multiple triggering may occur. The RECOVERY TIME control can often be used to improve triggering under these circumstances. This control should be set to MIN. for initial adjustments. If multiple triggering is obtained, the RECOVERY TIME control may be adjusted to provide proper triggering. The best setting for the control is determined by experiment. The RECOVERY TIME control can increase recovery time by about 30%.

OBTAINING A DISPLAY

1. Set the TRIGGERING SOURCE switch for the same polarity as the trigger signal.
2. Select a sweep time/cm long enough to permit viewing the signal. If unknown, start at 10 nsec/cm.
3. Set the SAMPLES/CM switch to 5. This can be increased to a larger number if a more continuous trace is desired.

4. Turn the TIME POSITION control fully clockwise. It can later be set to bring the desired signals in view on the crt. Set the TIME EXPANDER switch to X1.
5. Set the RECOVERY TIME control to MIN.
6. Set the THRESHOLD control to hold off the sweep (cw +, ccw -). Turn the control toward zero for proper triggering.
7. If triggering difficulties occur, establish whether the trouble is due to: (a) too low or too high trigger amplitude, (b) too high a trigger-signal repetition rate, (c) too low a rate of rise (or fall) of trigger-signal voltage, or (d) interference due to recovery time. The cause can usually be found by operating the SWEEP TIME/CM switch, THRESHOLD, and RECOVERY TIME controls. Inability to hold off the sweep with the THRESHOLD control indicates too large a trigger signal. Use an input attenuator to reduce amplitude. If advancing the THRESHOLD control causes the sweep to free-run before obtaining a stable display, either amplitude or rate-of-change is too low. If the problem is high repetition rate, and moving the RECOVERY TIME control does not stabilize a display, an external trigger-countdown unit such as Tektronix Type 280 may be needed. If the signal has a low rate of rise (for example, sinewaves below about 50 kc), a faster-rising trigger signal is needed. (Dc triggering is available internally only. See sampling unit instruction manual.) If confused triggering results in the form of multiple

traces, try operating the RECOVERY TIME control.

ADJUSTING THE SYSTEM FOR BEST VIEWING

Once you have obtained a display and located the signal you wish to view on the crt, you may adjust for increased resolution by expanding the portion of the display you wish to study and by increasing sampling density.

1. To expand the portion you wish to display, increase the sweep rate with the SWEEP TIME/CM switch. This is the best method since time-jitter is held to a minimum. The TIME POSITION control may be used to position the signal onto the crt. Another method is to use the TIME EXPANDER switch and then to position the portion you wish to observe with the TIME POSITION control. The TIME EXPANDER switch allows you to position signals occurring over a relatively large period of time compared with the length of the time window actually displayed.

3. To increase sampling density, increase the number of samples/cm with the SAMPLES/CM switch. Note that increased sampling density provides smoothing of the trace. When using smoothing, check for sufficient dot transient response by moving the SAMPLES/CM switch to the next higher density and checking for transient information that was not present on the display. Generally, the best setting for the SAMPLES/CM switch is for the highest density with reasonable display repetition rate.

Timed Operation

This includes using the timed sweep and single display features. To use the timed sweep, set the SAMPLES/CM switch to TIMED. This should be done after the system is set up to display the desired signal. With the SAMPLES/CM switch in TIMED, the system is no longer dependent on trigger repetition rate for display sweep, but will display a signal linearly over a period of time. The rate at which the display moves across the crt may be adjusted by use of the front-panel screwdriver adjustment immediately under the SAMPLES/CM switch.

The timed sweep may be used when signals from the Type 661 vertical-signal output connectors are used to drive a clock-type recorder. The timed sweep allows the sweep rate (of the display) to be synchronized with the rate at which the recorder operates.

SECTION 3

CIRCUIT DESCRIPTION

The Type 5T1A Timing Unit is used with '4' Series sampling units in the Type 661 Oscilloscope. The Timing Unit is triggered by signals with a fixed time relationship to repetitive identical signals displayed on the crt. The sampling technique allows resolution of repetitive identical signal-voltage changes occurring at fractional nanosecond (less than 10^{-9} second) rates with a broad bandpass for resolution of signals approaching dc.

The function of the Type 5T1A is to control the time at which the sampling unit takes the sample, and to simultaneously provide the display oscilloscope with a horizontal deflection signal. The horizontal deflection signal represents the time that elapses after the Type 5T1A is triggered before the sample is taken. By taking a series of samples, each one occurring a little later after triggering than the last, the display constructs a representation of the repetitive signals that were sampled.

The Type 5T1A has three major functional sections shown in simplified block diagram, Fig. 3-1. First is the trigger recognition and regeneration circuit, which triggers the operation of the remainder of the unit, and in turn must be triggered by a signal time-related to that displayed. Second is the fast ramp and comparator circuit. The fast ramp is a voltage fall with a constant calibrated slope. This voltage is fed to the comparator and compared with another voltage which represents the amount of horizontal deflection. The comparator provides a pulse output trigger to the sampling unit when the voltages are equal. Thus, the horizontal-deflection voltage level fed to the comparator represents a calibrated interval of time following the operation of the trigger circuit.

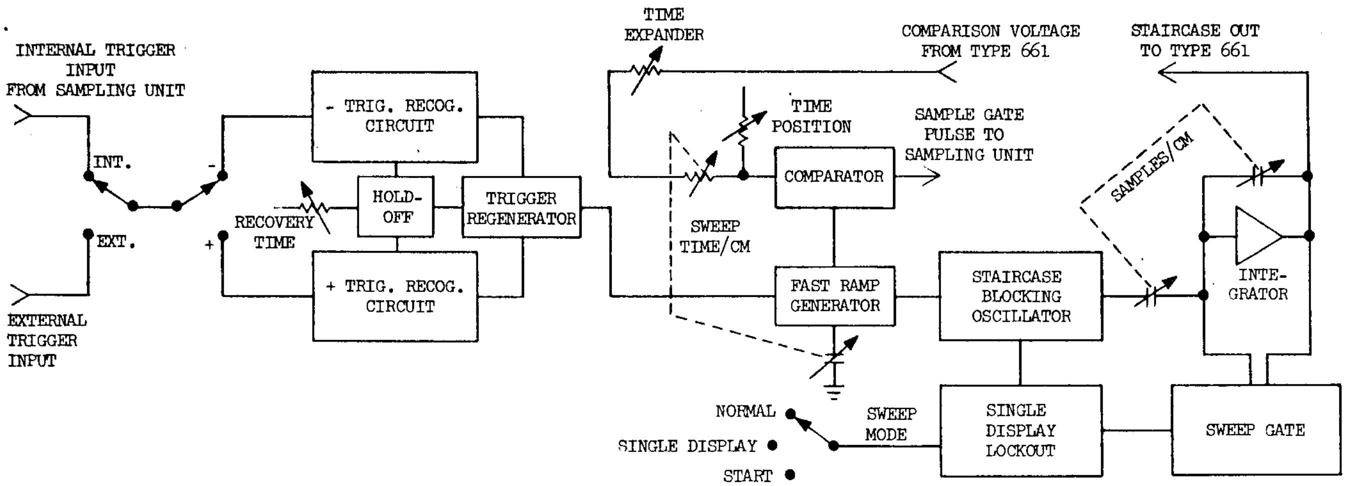


Fig. 3-1. Type 5T1A simplified block diagram.

Third is the staircase generator. When the Type 5T1A provides the horizontal deflection (Type 661 HORIZONTAL DISPLAY control in a SWEEP MAGNIFIER position), the staircase generator provides the horizontal deflection signal. The staircase steps one voltage increment after each sample is taken. When enough increments are stepped over, and a full display sweep is completed (about 10 1/2 cm), the staircase resets and repeats the display. The size of each increment is controlled by the SAMPLES/CM switch determining the density (in equivalent time) of the samples.

The system may be triggered by an external 5 to 250 mv signal through a front-panel connector. Internal triggering from the signal applied to the sampling unit is also possible when the sampling unit used has a trigger takeoff circuit (such as the Type 4S1). Trigger circuit threshold may be set by a front-panel control.

The trigger recognition and regeneration circuit must receive trigger signals having a fixed time relation to the signal to be displayed. This circuit provides an output pulse to the time base (fast ramp) and the Type 661 Delayed Pulse generator for each trigger signal that operates the circuit. The holdoff circuit allows the trigger recognition circuit to operate only when the system is prepared for a new sample (never more often than about every 10 microseconds).

The trigger-recognition circuit triggers a fast-ramp voltage-rundown circuit. The fast-ramp circuit generates a voltage with a constant calibrated slope. Because the slope of the ramp is constant, some given time after triggering is equivalent to the time required for the fast-ramp voltage to travel from its starting point to a specific voltage. Thus, if the ramp slope is -5 volts/μsec, the equivalent voltage for 2 μsec is -10 volts. In the Type 5T1A, the fast-ramp slope is controlled by the SWEEP TIME/CM switch. The total voltage change of the fast ramp, representing full-scale horizontal deflection on the crt, is selected by the SWEEP TIME/CM and TIME EXPANDER switches.

The Type 5T1A is provided with a staircase generator which advances a voltage increment after each run of the fast ramp. The staircase output voltage is normally fed to the Type 661 horizontal amplifier. When the Type 661 HORIZONTAL DISPLAY switch is in a SWEEP MAGNIFIER position, the staircase voltage is supplied to the comparator portion of the fast-ramp circuit. When the fast ramp has run from its starting voltage to the comparison voltage fed to the comparator, the comparator initiates a pulse, which is sent to the sampling plug-in unit. The staircase voltage, which represents time after the trigger has occurred, is also fed to the horizontal display circuit of the Type 661. The horizontal deflection caused by the staircase voltage represents the time it takes the ramp voltage to run down to the same voltage as the staircase level. The voltage increments of each step of the staircase voltage determine the equivalent time-spacing between samples.

When the Type 661 HORIZONTAL DISPLAY switch is in the EXT. HORIZ. INPUT positions, the staircase voltage is not used. Instead, the deflection caused by the external horizontal input voltage determines the time after triggering when samples are taken. The Type 5T1A must be triggered in the same manner as it was when the staircase was used to provide horizontal deflection. The position of the trace on the crt, determined by the horizontal input signal, determines the time after triggering when a sample will be taken. Thus, if the left graticule edge represents a specific time T_0, and the SWEEP TIME/CM switch is set at 10 nSEC, the vertical deflection at the fifth graticule mark will represent the signal at the input occurring 50 nsec after T_0. Note that the input voltage to the external horizontal circuit of the Type 661 and Type 5T1A system always represent time when displayed on the crt.

Manual scan also provides a display of equivalent time. With the SWEEP TIME/CM switch at 10 nSEC, scanning the crt with the HORIZONTAL POSITION controls will cover an equivalent time from T_0 to $(T_0 + 100)$ nsec.

A time-expander circuit allows the system to view only a portion of the fast-ramp rundown time, displaying this time as a full 10 cm display. The expanded time portion of the turndown is determined by the TIME EXPANDER switch and TIME POSITION control. The TIME EXPANDER switch determines the length (difference in voltage between beginning and end) of the fast-ramp rundown portion used. The TIME POSITION control sets the dc level of the portion used, effectively shifting the time scanned. Notice that magnifying the signal with the TIME EXPANDER switch allows a portion of the signal to be viewed with a constant number of samples/cm. The Type 661 SWEEP MAGNIFIER switch allows a portion of the signal to be viewed, with a decrease in the number of samples/centimeter (constant time/dot) in the crt display. A combination of the two magnification methods may be used.

Trigger Recognition Circuits

Two trigger-recognition circuits are used. One responds to positive-trigger information, and one responds to negative-trigger information. The trigger-recognition circuit used is selected by POLARITY switch SW10B. When the POLARITY switch is in the CAL. position, the signal from the Type 661 Amplitude/Time Calibrator is fed to the negative-trigger recognition circuit. The trigger-recognition circuits are similar except that they use opposite input and supply voltage polarities. The external trigger information is inverted by T2 before being fed to the trigger-recognition circuits. Isolation amplifier Q4 isolates the external trigger input from the trigger-recognition circuits.

The trigger source is selected by SOURCE switch SW10A. Trigger signals may be internally supplied by the sampling unit if the sampling unit has a trigger takeoff circuit. They may also be supplied from an external source. External triggering is necessary when the sampling unit has no provisions for trigger takeoff or when low amplitude signals are being sampled. The SOURCE switch selects the trigger source, and feeds the signals to the POLARITY switch which directs the signals to one of the trigger-recognition circuits. When the SOURCE switch is in the FREE RUN position, a bias is applied to the trigger-recognition circuit selected by the POLARITY switch, causing the trigger-recognition circuit to free-run. The THRESHOLD control sets the level (over a ±200 mv range) at which triggering occurs, and the + and - positions of the POLARITY switch set the direction in which the signal must move to cause triggering.

Assume TRIGGERING SWITCHES SW10A and SW10B are set to - INT as shown on the Trigger and Holdoff schematic. The THRESHOLD control is set far enough into the - region to hold off the trigger circuit. Assume also that the trigger circuits are ready to retrigger. D25 rests at its low state, near the switching point. D25 receives bias current from two sources. One is through R20, R21, R22, and L25. In addition, D35 is already in the high state, and current is supplied through R33. D25 is ready to trigger. If we move the THRESHOLD control to its + region, the small additional current supplied through the THRESHOLD control switches D25 to its high state. This sends a positive pulse to T65 through C60 and R60. The other end of the drive winding of

T65 is connected to +19 volts through C61, R61, R47, R48, R49, and through R19 and the POLARITY switch. The connection through POLARITY switch SW10B locks out positive trigger-recognition circuit D45 and D55.

The pulse from D25, through the drive winding of regenerator transformer T65, causes enough additional current to flow in the circuit of D65 to switch D65 to its high state. After the pulse, D65 switches back to its low state. The regenerated output is taken from D65 through C65 and used to trigger the fast-ramp circuit. A negative gate signal is supplied by Q73 and D72 for use by the Type 661 Delayed Pulse generator. This gate circuit is driven by a separate winding on T65. D72 starts the delayed pulse and Q73 ends it.

The positive pulse at D25 is also fed to the emitter of holdoff driver Q104, starting operation of the holdoff circuit. The holdoff assures that the sampling cycle does not repeat before the system is prepared to take another sample. The circuit will not retrigger until D35 is turned to the high state and Q84 and Q94 are turned off. Under the free-running conditions described, D25 will retrigger immediately after D35 switches to its high state, which occurs after Q84 and Q94 are turned off.

With normal trigger operation, D25 will not have sufficient bias to switch to its high state until a trigger signal is received. THRESHOLD control R16 determines the signal level needed to trigger D25 to its high state. Trigger signals are fed either from the external or the internal trigger inputs, depending on the setting of SOURCE switch SW10A.

Operation of the positive trigger-recognition circuit is similar to that of the negative circuit. D45 is the recognition diode, and D55 is the recovery diode. The negative trigger-recognition circuit is locked out by -19 volts through POLARITY switch SW10A, and R17. The holdoff circuit is driven when D45 switches to the high state and sends a signal to the base of Q104. D55 is switched to the low state by the collector of Q84. D45 and D55 are connected opposite in polarity to D25 and D35. Note that the negative trigger-recognition circuit actually operates on positive-going signals, and the positive trigger-recognition circuit operates on negative-going signals. This is because trigger signals provided to the Type 5T1A are inverted before being fed to the trigger-recognition circuits.

Operation of the trigger-recognition circuits in FREE RUN is similar to the operation described previously. The input is driven by either +19 volts, in the - POLARITY, or -19 volts in the + POLARITY position.

Holdoff

The holdoff circuit prevents the trigger-recognition circuit from operating after a trigger has been received and recognized until the remainder of the system is ready to take a new sample. The holdoff period is required to allow the fast ramp to run for a time equivalent to 10 cm of display; then reset, or to limit the system repetition rate to 100 kc, whichever time is longer. The holdoff period is variable; 1.3:1 from the MAX. to the MIN. position of the front-panel RECOVERY TIME control. This may be adjusted to aid stable triggering if the triggering input frequency and the holdoff repetition rate are equal.

The holdoff circuit consists of two bistable multivibrators and a Miller integrator. Each bistable multivibrator drives a transistor which shunts supply current from one pair of the trigger-recognition circuit tunnel diodes. The output of the Miller integrator is also fed to a gate which switches both multivibrators. Recognition tunnel-diode multivibrator Q115-Q125 drives Q94. Recovery-diode multivibrator Q165-Q175 drives Q84. Miller integrator Q144 drives Q154 and gate D144. Tunnel diodes D25 and D45 are the recognition diodes, and D35 and D55 are the recovery diodes. Q104 drives the holdoff circuit.

When a trigger signal is received and recognized (assume the same conditions as for the trigger-recognition circuit discussion), D25 switches to the high state. This causes the emitter of Q104 to go positive, forward biasing the transistor. The collector voltage of Q104 rises, forward biasing Q115. The collector of Q115 drops, turning Q125 off. The same collector voltage drop at Q115 causes D92 to become forward biased, shunting the current source for D25 and causing D25 to return to its low state.

When Q125 turns off, its collector voltage rises, and current is supplied through R132 and RECOVERY TIME control R136, forward biasing Q144. This causes a voltage drop at the collector of Q144 which was clamped by Q154 at +19 volts. The collector drop of Q144 is fed back to its base through C145 and C146, preventing any large voltage swing at the base of Q144. Thus, the current through R132 and R136 that is charging C145 and C146 remains essentially constant. The value of C145 determines the rate of voltage fall at the collector of Q144, and is selected by the SWEEP TIME/CM switch for the desired holdoff time. As soon as the collector voltage of Q144 begins to fall, Q154 becomes back-biased, and its collector voltage drops to ground.

When the collector of Q144 reaches ground, D144 is forward biased which lowers the base voltage of Q165, turning it off and raising its collector voltage. C166 and R166 couple this collector voltage rise to Q175, turning it on. The collector of Q175 drops, forward biasing D82 and Q84. When Q84 is turned on, it shunts the current source for D35, returning D35 to the low state.

The collector voltage rise at Q165 is also coupled through D164, C164, and R164, to the base circuit of Q125, turning Q125 on. The collector voltage of Q125 drops, and this drop, coupled through C126 and R126, turns Q115 off. The collector voltage of Q115 rises, back biasing D92 and Q94, and restoring the current source to D25. Note, however, that D35 is in the low state, and that no current is available to D25 through R35. Thus, D25 remains in the low state, and cannot be triggered yet.

When Q125 is turned on, its collector voltage drops, and C145 and C146 discharge through R132 and R136. The voltage falls at the base of Q144 which decreases the collector current, causing the collector voltage to rise. This rise is fed back through C145 and C146, and the collector voltage of Q144 runs back up at a rate proportional to the total capacitance of C145 and C146. When the collector voltage of Q144 reaches +19 volts, Q154 becomes forward biased. This clamps the collector voltage of Q144 at +19 volts. When Q154 becomes forward biased, its collector voltage rises, forward biasing Q165. The collector voltage of Q165 drops, and this drop, coupled through C166 and R166, turns Q175 off. The collector voltage clamps the base of Q144, through D146, from going below the collector voltage of Q165. D164 is back biased, preventing the drop at the collector of Q165 from operating multivibrator Q115-Q125.

The collector voltage rise of Q175 back biases D82, and turns Q84 off. This restores the operating current to D35, and D35 immediately switches to the high state. With D35 in the high state, D25 receives additional current through R33, and is ready to be retriggered to initiate a new sampling cycle.

Fast Ramp

The fast-ramp circuit consists of a comparison-voltage amplifier, a ramp generator, and a pulse-forming comparator. The output of the ramp generator is a voltage fall with a constant calibrated slope used as an internal time base. The comparison voltage is received either from the staircase generator or externally through the Type 661. In the manual scan mode, the comparison voltage is supplied by the Type 661. For this discussion, assume that the Type 661 HORIZONTAL DISPLAY control is in the X1 position unless otherwise stated.

The comparison and fast-ramp voltages are fed to the pulse-forming comparator. When the two voltages are just equal, the comparator circuit generates a pulse used to drive the sampler in the '4' Series sampling unit. A pulse from the comparator circuit also drives the staircase generator, causing it to advance one step. The fast-ramp circuit operates each time a trigger output signal is fed to it from the trigger circuit. As the staircase voltage advances, step by step, the fast-ramp voltage must become greater, and thus will run a little longer with each succeeding run-down before the comparator circuit generates a pulse. The fast-ramp voltage represents the real time on which the system reconstructs the signal.

Ramp Generator

Q261 is a constant-current supply. Before a trigger signal is received from the trigger circuit, D255 is in the high state and holds Q254 on. Current from Q261 passes through Q254 and holds C260 near ground voltage. D255 is held in the high state by current through R244. Current through R244 also provides base current for Q254, and Q254 conducts the current supplied by Q261.

Q261 receives a constant base voltage from the -19-volt supply through decoupling filter R260 and C260. Q261 emitter current, which comes from the -100-volt supply, passes through R265 and R267 which drop about 81 volts. This determines the current through Q261. Current supplied by the transistor is determined by emitter current, and is little affected by any change in collector voltage.

The trigger circuit sends a positive pulse which causes Q244 to conduct more current. The collector voltage of Q244 rises to ground, and switches D255 to its low state, turning

Q254 off. After the trigger pulse passes, Q254 remains cut off, held by D255 which remains in the low state. Q261 collector current now flows through ramp-slope capacitor C260, whose value is selected by SWEEP TIME/CM switch SW260. Before the beginning of the fast-ramp rundown, comparator diode D270 is back biased, and all current from Q261 is fed to C260. The ramp voltage runs down until D270 becomes forward biased. Collector current from Q261 is now fed through D270 and Q276, and the collector voltage of Q276 drops. D275 switches to the high state.

Before D275 switches, the voltage on either side of D276 is about zero volts. When the current from Q261 passes through Q276, it causes a step at D275, quickly switching D275 to the high state. Because D276 was not conducting, it appears as an open circuit as D275 switches.

When D275 switches, D276 becomes back biased. Because it is a tunnel diode, D276 conducts current easily, coupling the step caused by the switching of D275 to D285. This causes D285 to switch. When D285 switches, a step is fed to T284, which is a doubling transformer. The output of T284 forward biases Q284, causing the collector voltage of Q284 to rise. This gate, which appears at the collector of Q284, is connected directly through interconnecting cables to the '4' Series sampling unit. The gate is also sent, through isolation resistance network R285, R286, and R287, to the stairstep generator, where it is used to advance the stairstep one step. When the current through T284 (fed from R288 and R289) rises, D285 is switched back to the low state.

The fast ramp is reset by the comparator pulse. When D275 changes to the high state, D256 conducts, and changes D255 to the high state. Q254 now conducts the current supplied by Q261 and discharges C260. RAMP RECOVERY control R254 sets the maximum current through Q254 to a safe value commensurate with speedy ramp recovery.

Because the fast ramp is triggered by the incoming signal (or in a fixed time relationship to it), the instant, in real time, when the comparator pulse is sent to the sampling unit is determined by the comparison voltage. This determines the time the fast ramp must take to run down before the comparator pulse is sent to the sampling unit.

The rate of fall of the fast-ramp voltage, except the 1 nsec/cm rate, is determined by C260. Five capacitors allow five rates of fall or ramp slope (in volts/μsec) over the range above 1 nsec/cm. The 1 nsec/cm sweep rate is set by C263 and circuit stray capacitance. With C260 disconnected, C263 remains in the collector circuit of Q261 at all sweep rates, but is a small fraction of the circuit capacitance in sweep rates slower than 1 nsec/cm.

The effective portion of the fast-ramp voltage used is determined by the range of comparison voltage fed to the base of comparator transistor Q276. In the .1 μSEC position of the SWEEP TIME/CM switch, the effective ramp length is 10 volts; in the 50 nSEC position, 5 volts; and in the 20 nSEC position, 2 volts. (These voltages are true with the TIME EXPANDER switch in X1.) In each of these three positions, the slope of the ramp voltage is the same.

The voltage fed to comparator transistor Q276 is determined by the current fed to the operational amplifier preceding it; Q223 and Q234. Because Q223 is an emitter follower, the amplifier is current driven. Because Q234 is collector loaded, the output is a voltage output. Feedback resistor R231 determines the characteristics of the amplifier. There are three sources of current for Q223; from DELAY ZERO control R220 fed through R223 (this is a calibration adjustment); from the TIME POSITION control circuit, and from the Type 661 HORIZONTAL DISPLAY switch. When the HORIZONTAL DISPLAY switch is in any of the SWEEP MAGNIFIER switch positions, the staircase voltage is fed to the comparator circuit through two attenuator networks. One network, R214 and R215, always looks like a constant impedance at the input to the attenuator, but divides the current fed to Q223. Table 3-1 lists the positions of the SWEEP TIME/CM switch and the current attenuation introduced in each position. The SWEEP TIME/CM switch controls the values of R214 and R215. Table 3-1 also lists the resulting comparison voltage output equal to 10 cm of horizontal deflection. This voltage is seen at the base of Q276.

A second attenuator, R208 and R209, may be cascaded ahead of R214 and R215. R208 and R209 are controlled by the TIME EXPANDER switch, and are used to introduce further current division, above that introduced by R214 and R215. When R208 and R209 are switched into the circuit, the input continues to look like a constant impedance, and the current source for the comparator circuit is subjected only to a constant load impedance regardless of the settings of the

SWEEP TIME/CM and TIME EXPANDER switches.

The range of the TIME POSITION control depends on both the SWEEP TIME/CM and the TIME EXPANDER switch settings. This control is a variable current supply, and its range of operation (in time) depends on the voltage shift it can impose on the comparison voltage. Table 3-1 shows the voltages of the fast-ramp duration in SWEEP TIME/CM switch settings. Table 1-1 shows the range of the TIME POSITION control in time according to SWEEP TIME/CM and TIME EXPANDER switch settings. The voltage ranges over which the TIME EXPANDER control can shift the comparison voltage limits are as follows:

(a) All SWEEP TIME/CM switch settings slower than 10 nsec/cm, and TIME EXPANDER switch at X1: 1 volt.

(b) 10 nsec/cm through 1 nsec/cm sweep rates and TIME EXPANDER switch at X1: 5 volts.

(c) All SWEEP TIME/CM switch settings and TIME EXPANDER switch at X2: 5 volts.

(d) All SWEEP TIME/CM switch settings and TIME EXPANDER switch at X5, X10, X20, X50, or X100: 10 volts.

The voltage at the base of Q223 is controlled by INVERTER INPUT ZERO control R225. This control is set so that the base of Q223 is at zero volts dc, allowing proper operation of the current sources feeding Q223.

Staircase Generator

With the Type 661 HORIZONTAL DISPLAY switch in the SWEEP MAGNIFIER positions, the staircase generator provides a staircase voltage for the comparison circuit of the fast ramp. The staircase generator is triggered by the fast-ramp

TABLE 3-1

SWEEP TIME/CM Switch

SWEEP TIME/CM Switch Setting	Fast Ramp Slope	Attenuator Ratio	Duration of Fast Ramp Voltage = 10 cm Sweep
100 μSEC	0.01 volt/ μsec	X1	10 volts
50 μSEC		X2	5 volts
20 μSEC		X5	2 volts
100 μSEC	0.1 volt/ μsec	X1	10 volts
5 μSEC		X2	5 volts
2 μSEC		X5	2 volts
1 μSEC	1.0 volt/ μsec	X1	10 volts
.5 μSEC		X2	5 volts
.2 μSEC		X5	2 volts
.1 μSEC	10 volts/ μsec	X1	10 volts
50 nSEC		X2	5 volts
20 nSEC		X5	2 volts
10 nSEC	50 volts/ μsec	X2	5 volts
5 nSEC		X4	2.5 volts
2 nSEC		X10	1 volt
1 nSEC	500 volts/ μsec	X2	5 volts

comparator pulse, and steps one step for each comparison pulse fed to it. The voltage increment of each step is determined by the SAMPLES/CM switch. When the staircase has stepped over a voltage equivalent to the sweep length, a reset circuit returns the staircase voltage and a new trace begins. In the TIMED position of the SAMPLES/CM switch, the staircase generator is allowed to run up linearly in a smooth runup. A single-sweep lockout circuit may be selected by SWEEP MODE switch SW325. A single sweep is obtained by preventing the staircase from starting until the SWEEP MODE switch is set to START. The staircase will then step through one display cycle, return, and be locked out until the SWEEP MODE switch is set to START again.

The staircase circuit includes gate circuit Q335-Q345, single display lockout D325-Q324, blocking oscillator Q300, and step integrator V361-V373.

Assume that the gating circuit is allowing a staircase voltage run, and that the SWEEP MODE switch is in NORMAL with Q335 and Q345 conducting. Note that Q335 is a PNP transistor, and that Q345 is NPN. The circuit operates with both transistors turned on or turned off simultaneously. The collector circuit of each transistor is connected to the base of the other, and the circuit has two stable states. Its operation will be discussed later. With both Q335 and Q345 conducting, disconnect diodes D352 and D353 are back biased, allowing staircase capacitor C360 to be charged by the staircase step integrator as pulses arrive from the blocking oscillator.

A pulse from the fast-ramp comparator passes through C30 into the blocking oscillator circuit. The pulse sends current through the collector winding of T300. The trigger current induces a current in the base winding of T300 which turns on blocking oscillator transistor Q300. Normal blocking oscillator saturation follows. D306 completes the base-winding circuit of T300. The negative emitter-output signal of Q300 is fed through C358 (SAMPLES/CM switch SW358) to the step integrator. The amplitude of the pulse fed to C358 is controlled by R304, the internal SAMPLES/CM control.

Saturation occurs, and the blocking oscillator starts its backswing. D300 becomes forward biased and current passes through D300 instead of the collector winding of T300.

The negative pulse passed through C358 back biases D361, and forward biases D360. The pulse energy is fed directly to C360 and the grid of V361. V361 and associated circuit is a Miller integrator. The pulse energy starts to charge C360, and lowers the grid voltage of V361 which allows plate voltage to rise. This rise is coupled to the grid of cathode follower V373B. The cathode of V373B is coupled to C360 via C378 and D378. The rise of V373B cathode voltage raises the voltage to C360. The result is that the voltage of the V361 grid side of C360 remains nearly constant. The amount of charge given C360 is proportional to the capacitance of C358, which is controlled by SAMPLES/CM switch SW358. In the TIMED position of the SAMPLES/CM switch, current through R355 and R356 causes C360 to charge in a linear ramp. C360 is paralleled by C361 in the SAMPLES/CM switch 1000 and TIMED positions, decreasing the staircase (or ramp) voltage slope for a given amount of charge fed through C358.

A positive feedback loop keeps the plate current of V361 constant over the output range to improve linearity and response time. The cathode voltage of V373B is fed through Zener diode D377 and C377 to the grid of V373A. As C360 charges, the grid voltage of V373A rises. The cathode of V373A follows the grid and keeps the current through R371 and V361 essentially constant.

The staircase voltage at the cathode of V373B is fed through a resistance divider to pin 22 of P4 and to the Type 661 HORIZONTAL DISPLAY switch. The voltage at pin 24 of P4 runs from about 0 to 50 volts. Dc level of the output is set by DC LEVEL control R381. This voltage is fed back to the comparator of the Type 5T1A as a comparison voltage when the Type 661 HORIZONTAL DISPLAY switch is in any of the SWEEP MAGNIFIER positions.

Staircase Gating Circuit

The unattenuated output signal is fed from C360 to the gating circuit. This signal passes through R346, D345, R345, and R344 to the base circuit of Q335. As the staircase voltage rises, the base of Q335 is moved toward cutoff. SWP LENGTH control R345 determines the amount of signal sent to Q335. When the base current approaches about 0.1 ma, the transistor turns off, and its collector voltage falls from 0 to -18 volts. This fall is coupled through R332 and C332 to the base of Q345 where the voltage drops from -18 to -20 volts. Q345 turns off, and its collector voltage raises from -18 to 0 volts. The grid of V361 is at about -0.9 volts, and D353 becomes forward biased. This raises the grid voltage of V361, since a current path is established through D353 to the +19-volt supply. The step integrator circuit now runs down and discharges C360 until D352 becomes forward biased, and state of clamped equilibrium exists. When the Miller step-integrator circuit has discharged C360, D345 becomes back biased, and a current path no longer exists between the integrator circuit and the base of Q335. This prevents the staircase voltage from turning Q335 and Q345 back on.

The pulses from the blocking-oscillator circuit are fed through Q324 to switch the gate back on to start the next staircase output. C303 transmits each negative pulse through

R324 to D325 and the emitter of Q324. Each pulse switches D325 to the high state and forward biases Q324, which causes the emitter of Q324 to fall from 6.3 volts to zero. At the end of each blocking oscillator pulse, D325 switches back to the low state, and Q324 turns off. The negative pulse at the collector of Q324 is transmitted through C322 and R336 to the base of Q335. The first pulse received after D345 becomes back biased and C345 has discharged allows Q335 to conduct, raising its collector to ground, and allowing Q345 to conduct. C345 is paralleled by C346 in the SAMPLES/CM switch TIMED and 1000 positions which lengthens the holdoff time before Q335 can be turned back on. The collector of Q345 drops back to about -18 volts, back biasing D352 and D353, and the step integrator is free to run up again until the feedback path from the integrator to the base of Q335 stops the run-up.

Blanking mixer Q314 is driven by the gate circuit, and by the blocking oscillator to provide blanking signals to the Type 661. When the gate is in the off state (neither Q335 or Q345 conducting), Q314 is turned on through R331. When the gate is in the on state, (staircase run-up permitted) the collector voltage of Q335 turns off Q314 and permits each pulse from the blocking oscillator to turn on Q314 for the duration of the pulse. The collector circuit of Q314 is completed in the Type 661. Whenever Q314 is forward biased, collector current flows, and crt blanking occurs. Thus, the crt beam is off whenever deflection is occurring.

A single sweep is obtained by moving SWEEP MODE switch SW325 to the SINGLE SWEEP position. R325 is connected, by

SW325, to the -19-volt supply, and holds D325 in the high state. With D325 held in the high state, Q324 remains in conduction, and the negative pulse necessary to switch the gate transistors back into conduction is blocked. This locks the staircase at zero output. When the SWEEP MODE switch is moved to the START position, the junction of R310 and C310, which was at -19 volts, is grounded. C310 sends a positive pulse through R312 and R315 to D325, causing it to switch back to the low state momentarily, turning Q324 off. D325 switches back to the high state with the next pulse from blocking oscillator Q335, and allows the staircase generator to generate one display. At the end of the single sweep, Q335 is turned back off in the normal manner, and the SWEEP MODE switch must be set to START to obtain the next staircase output.

SECTION 4

CALIBRATION

General

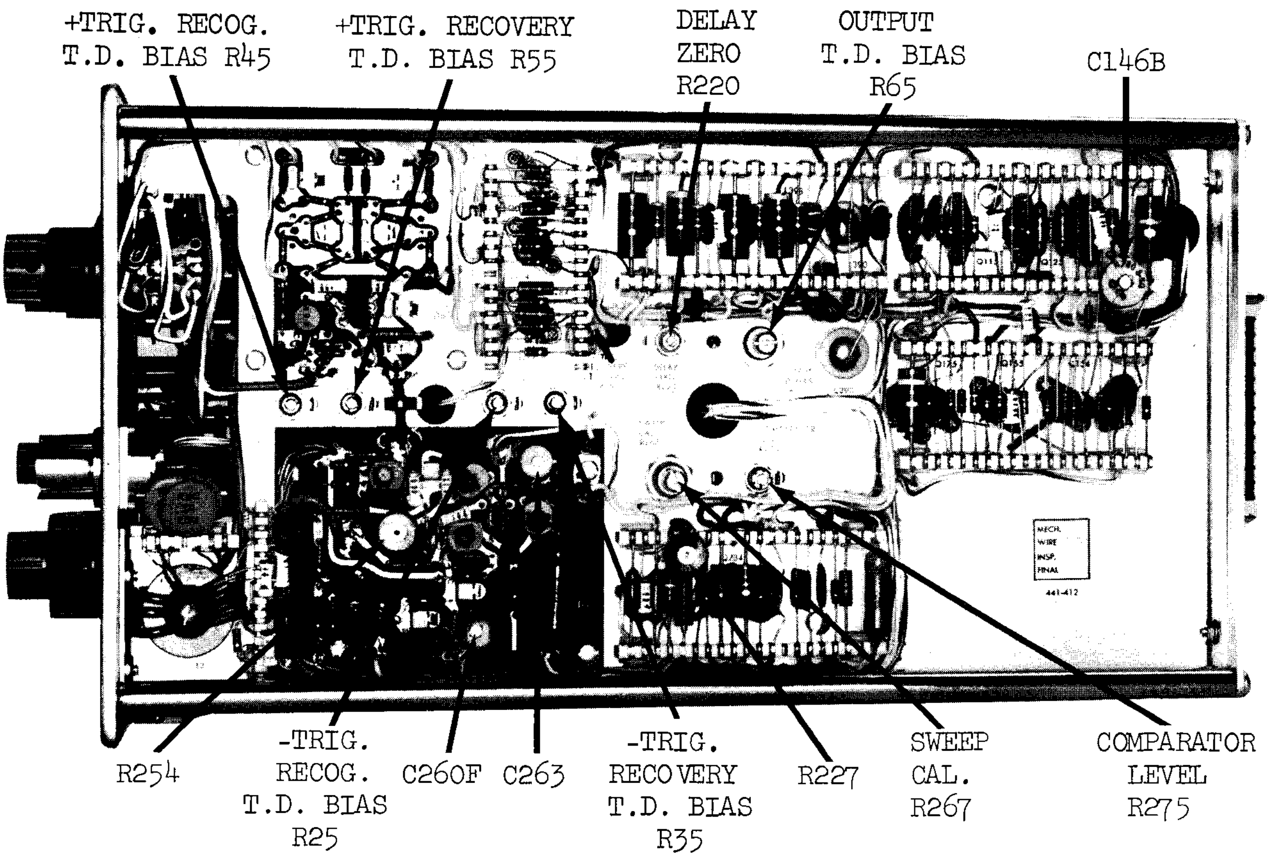
The Type 5T1A is a stable instrument, and should operate properly with a minimum of care. The instrument should be recalibrated at least once every 6 months or 500 hours of operation, whichever comes first. For best results, the steps in this calibration procedure should be followed in the order they appear.

Tunnel diodes used in the Type 5T1A should not be handled unless necessary. Do not connect probes directly to tunnel-diode bodies. When tunnel diodes are marked with a color code, it will appear on the anode side. The cathode side has a small external disc. Locations of internal controls and tunnel diodes are shown in Figure 4-1.

Preset internal controls to midrange only if the Type 5T1A has undergone repairs, or is known to be seriously out of calibration.

Equipment Required

1. Tektronix Type 661 Oscilloscope.
2. Tektronix '4' Series sampling unit.
3. Volt-ohm-milliammeter, dc resistance 5000 ohms/volt, or better.
4. Time-mark generator, Tektronix Type 180A, or equivalent.
5. Test oscilloscope, dc to 15-mc bandpass, sensitivity capable of displaying 400-mv signal, Tektronix Type 531A with Type K Plug-In Unit or equivalent.



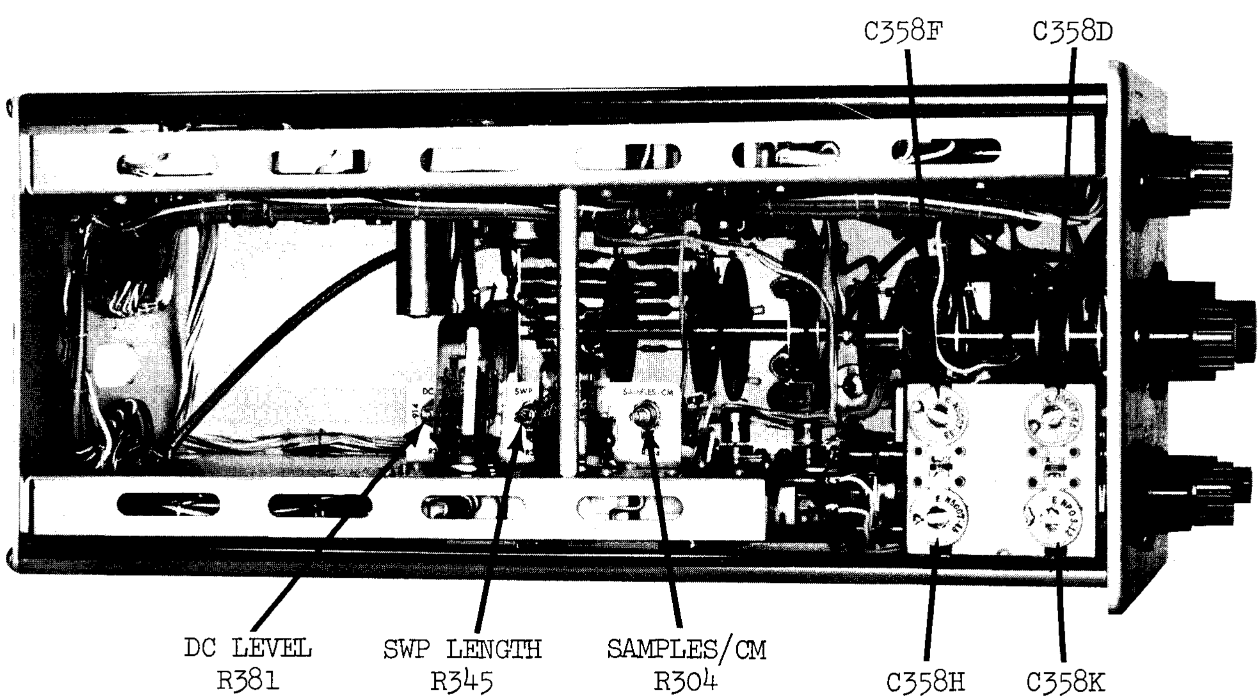


Fig. 4-1. Type 5T1A internal adjustment locations.

6. 30-cm air line, General Radio part number 874L30, or equivalent.

7. Pulse generator, Tektronix Type 111, or equivalent.

Procedure

1. Check Resistance to Ground at Power Plug

   With common lead of test meter grounded, the following resistances are typical: (This check necessary only after repair.)

Pin	Power Supply Voltage	Ohms
15	300	40 k
17	100	80 k
5	-100	10 k
3	-19	150 Ω
18	10	10 Ω

2. Preset Front-Panel Controls

   Install plug-in units in Type 661 Oscilloscope.

   Turn on power and set front-panel controls as follows:

5T1A

SWEEP TIME/CM	10 nSEC
VARIABLE	CALIBRATED
SWEEP MODE	NORMAL
TIME POSITION	Clockwise
SOURCE	EXT.
POLARITY	NEG.
RECOVERY TIME	MIN.

661

HORIZONTAL DISPLAY	F MANUAL SCAN
AMPLITUDE/TIME CALIBRATOR	OFF
HORIZONTAL POSITION	Centered

Sampling Unit

Dc Offset	Zero Volts
Mv/Cm	200
Vertical Position	Centered

Test Oscilloscope

Time/Cm	10 μsec
Volts/Cm	0.5

3. 0 Threshold

   Connect the dc voltmeter between the center terminal of the THRESHOLD control (potentiometer nearest the front panel) and ground. Adjust THRESHOLD control for zero volts on the meter. The dot on the control knob should be aligned with the 0 on the front panel; if not, loosen and reposition the knob.

4. - Threshold

   Connect the test oscilloscope probe to the junction of L25 and the anode of D25. Set -TRIG. RECOVERY T.D. BIAS R35 fully clockwise, and adjust -TRIG. RECOG. T.D. BIAS R25 for a stable display.

5. + Threshold

   Connect the test oscilloscope probe to the junction of L45 and the anode of D45. Set +TRIG. RECOVERY T.D. BIAS R55 fully clockwise, and adjust +TRIG. RECOG. T.D. BIAS R45 for a stable display.

6. Output Tunnel-Diode Bias

   Connect the test oscilloscope probe to the junction of C65 and the anode of D65. Adjust OUTPUT T.D. BIAS R65 for a stable display. The display should be about a +0.4-volt, 0.3-μsec pulse, and should disappear when the THRESHOLD control is turned fully clockwise.

7. Ramp Recovery

Connect the test oscilloscope probe to the junction of Q244 collector and D255 cathode. Adjust R254 for a stable +0.4-volt, 50-nsec pulse. You may have to adjust COMPARATOR LEVEL R275 for a stable display. All values are approximate.

8. Comparator Level

Connect the test oscilloscope probe to the collector of Q284. Adjust COMPARATOR LEVEL R275 for a stable +5.5-to +6-volt pulse, about 750 nsec wide at the top. This is the fast-ramp pulse to the sampling unit. A similar pulse (3v) should appear at the opposite end of R285 (560 Ω resistor). Set Type 661 HORIZONTAL DISPLAY switch to X1; a sweep should appear on the crt. Remove test probe.

This is a preliminary adjustment. If the sweep is not on the crt, check the staircase generator circuit for proper operation.

9. Threshold Sensitivity

With a trace on the crt, adjust -TRIG. RECOG. T.D. BIAS R25 so that the sweep free-runs as near the 0 position as possible when the THRESHOLD control is turned clockwise. Adjust -TRIG. RECOVERY T.D. BIAS R35 so that the sweep stops within 5° to the ~~right~~ LEFT of the 0 position.

With a trace on the crt, adjust +TRIG. RECOG. T.D. BIAS R45 so that the sweep free-runs as near the 0 position as possible when the THRESHOLD control is turned counterclockwise. Adjust +TRIG. RECOVERY T.D. BIAS R55 so that the sweep stops within 5° to the ~~left~~ RIGHT of the 0 position.

10. Lockout Time

Apply a 0.1-μsec/cycle, 100-mv signal from the Type 661 Amplitude/Time Calibrator to the Type 5T1A EXTERNAL TRIGGER INPUT connector. Adjust the THRESHOLD control to trigger the Type 5T1A. Touch the test oscilloscope probe to the junction of C65 and the anode of D65, and adjust C146B for 9.5 to 10 μsec between pulses.

11. Delayed-Pulse Generator Bias

Connect the test oscilloscope probe to the emitter of Q73. Adjust DELAYED PULSE GEN. BIAS R990 (located on the right side of the Type 661) until a -0.4-to -0.5-volt pulse appears on the crt. Repetition rate should be the same as that of output tunnel diode D65. This adjustment may require resetting OUTPUT T.D. BIAS R65 to maintain the stability of D65. Connect a cable from the Type 661 DELAYED PULSE 50 Ω connector to the vertical input connector. The pulse at Q73 should be stable when connecting and disconnecting cable.

12. Sweep Length

Adjust SWP LENGTH R345 for a 10.5-cm sweep length. Connect the test oscilloscope probe to the center terminal of the VARIABLE SWEEP TIME/CM control (potentiometer at rear of SWEEP TIME/CM switch wafer). A 52.5 ±1 volt, peak ac, staircase voltage should appear on the crt.

13. Sweep Rate

Set the SWEEP TIME/CM switch to 1 μSEC, and apply 1-μsec markers from the time-mark generator. Adjust SWEEP CAL R267 for 1 mark/cm between 1st and 9th major graticule divisions. Timing should be within 2% on all ranges from 20 nsec/cm to 100 μsec/cm. Check to see that the VARIABLE SWEEP TIME/CM control provides a 3:1 sweep-timing range.

14. Check Time Expander

With the SWEEP TIME/CM switch set to 1 μsec, check all ranges of the TIME EXPANDER switch with the TIME POSITION control at midrange. Locate the proper midrange point by setting the TIME POSITION control fully counterclockwise, and then turning clockwise to midrange. Also, recheck with 1-μsec time marks in the X1 position. Accuracy must be ±1.5% between 1st and 9th major graticule divisions.

15. Sweep Delay and Registration

Preset controls as follows:

<u>5T1A</u>

DC LEVEL (R381)	Counterclockwise
DELAY ZERO (R220)	Clockwise
SAMPLES/CM	100
TRIGGERING	INT +
SWEEP TIME/CM	2 μSEC
TIME EXPANDER	X1
TIME POSITION	Clockwise

<u>661</u>

AMPLITUDE/TIME CALIBRATOR	1000 mv, 1 μsec/cycle
SWEEP MAGNIFIER	X5

Connect output of Type 661 Amplitude/Time Calibrator to the sampling unit. Display a sinewave by adjusting THRESHOLD, RECOVERY TIME, COMPARATOR LEVEL R275, and Type 661 POSITION controls.

Adjust R275 and R254 for best corner transition-to-sine curve. Dots should be continuous. Connect the test oscilloscope probe to the base of Q223, with test oscilloscope set for 50 mv/cm, dc coupled. Adjust the test oscilloscope for a 0-volt dc reference level. Adjust R225, for 0 volt dc (same as reference level). Turn SWEEP TIME/CM switch to the 2, 1, and .5 μSEC positions. Adjust DELAY ZERO R220 so that the sinewave starts at the same place on the crt at each position of the SWEEP TIME/CM switch. Set the SWEEP TIME/CM switch to 1 μSEC. Adjust DC LEVEL R381 to remove the straight line of dots preceding the start of the sinewave. Disregard any dots that may appear at other dc levels.

Apply a 2-nsec pulse from the pulse generator to the sampling unit. Pretrigger the Type 5T1A from the pulse-generator pretrigger output through the EXTERNAL TRIGGER INPUT connector. Set the SWEEP TIME/CM switch to 1 nSEC, and locate the pulse-generator output on the second major vertical graticule division where it crosses the horizontal centerline. Insert the 30-cm air line in the signal connection to the sampling unit, and adjust C263 so that the pulse now lies on the third major vertical graticule division where it crosses the horizontal centerline. Remove the air line and reposition the pulse (with the Type 661 positioning controls) so that it again crosses the second major vertical graticule division. Recheck the adjustment by reinserting the air line. Repeat this procedure until inserting the 30-cm air line causes a 1-cm signal delay.

Apply a 50-mc signal from the time-mark generator to the sampling unit. Set the SWEEP TIME/CM switch to 10 nSEC and adjust C260F for 1 cycle/2 cm. Apply a 20-to 30-nsec pulse from the pulse generator to the sampling unit. The pulse should remain on the crt through all the SWEEP TIME/CM switch positions from 2 nSEC to 2 μSEC. Use the TIME EXPANDER switch to increase resolution, and make it easier to locate the pulse on the slower sweep rates. Make the final adjustment of DELAY ZERO R220 to position the pulse at the same starting point as when the TIME POSITION control is set fully clockwise.

16. Sweep Timing

Apply a 50-mc sinewave from the time-mark generator to the sampling unit. Set the SWEEP TIME/CM switch to 10 nSEC and adjust C260F for 1 cycle/2 cm.

17. Time Position

Apply a 10-mc sinewave from the time-mark generator to the sampling unit. Set the SWEEP TIME/CM switch to 10 nSEC. Set the TIME POSITION control fully clockwise, and the TIME EXPANDER witch to X1. Turn the TIME POSITION control fully counterclockwise.

Check delay range according to the following table:

SWEEP TIME/CM Switch Setting	Input Frequency	TIME EXPANDER Switch Setting	Delay Range
10 nSEC	10 mc	X1	greater than 100 nsec
10 nSEC	10 mc	X2	greater than 100 nsec
10 nSEC	10 mc	X5	greater than 200 nsec
100 nSEC	10 mc	X1	greater than 100 nsec
100 nSEC	10 mc	X2	greater than 500 nsec
100 nSEC	1 mc	X5	greater than 1000 nsec

18. Samples/Cm

Set the SOURCE switch to FREE RUN, SAMPLES/CM switch to 5, SWEEP TIME/CM switch to 1 μSEC, and Type 661 HORIZONTAL DISPLAY switch to X1. Adjust SAMPLES/CM R304 for 5 dots/cm; 1 dot exactly at each minor division between the 1st and 9th major graticule divisions. Linearity must be ±0.5 mm.

Apply a 350-mv pulse from the pulse generator to the sampling unit. Adjust the SOURCE switch and THRESHOLD control to trigger the Type 5T1A. Adjust the pulse-generator repetition rate for 100 kc with the RECOVERY TIME control at MIN. Change the pulse-generator repetition rate to 50 cps. The samples (dots)/cm should not change more than ±1%. Return SOURCE switch to FREE RUN. Make the following preliminary adjustments for the samples (dots)/cm:

Type 661 HORIZONTAL DISPLAY Switch Setting	SAMPLES/CM Switch Setting	Adjust	Dots/Cm
X10	10	C358D	1
X20	20	C358F	1
X50	50	C358H	1
X100	100	C358K	1

Set the SAMPLES/CM switch to 5, Type 661 HORIZONTAL DISPLAY switch to X1, and SWEEP TIME/CM switch to 20 nSEC. Apply a 5-mc sinewave from the time-mark generator to the sampling unit. Adjust the THRESHOLD control to trigger the Type 5T1A for a good sinewave display. Then set the SWEEP TIME/CM switch to 1 μSEC. A single row of dots should appear on the crt. Now set the time-mark generator for 1-μsec markers. With the TIME POSITION control near its fully counterclockwise position, adjust SAMPLES/CM R304 and SWEEP CAL. R267 for a single level row of dots on the rise of 1-μsec markers (use TIME POSITION control). A dot should occur at exactly the 2nd and 10th major graticule divisions in a nearly level line across the crt. Set the time-mark generator for 50-mc sinewaves, and use the following table for the final samples/cm adjustments. Adjust for straightest possible line, or better than table.

SAMPLES/CM Switch Setting	Adjust	Rows of Dots	Maximum Number of Cycles or Crossovers
10	C358D	1	2.5 cycles
20	C358F	2	5 crossovers
50	C358H	1	2.5 cycles
100	C358K	2	5 crossovers

19. Times Mode

Set the SAMPLES/CM switch to TIMED. Set R357 (front panel) fully clockwise. Set the SOURCE switch to FREE RUN. Set the time-mark generator for 1-sec marks. Fewer than ten marks should occur between each two major graticule divisions (sweep rate faster than 5 sec/cm). Set R357 fully counterclockwise; sweep should stop.

20. Single Display

Turn the SWEEP MODE switch from SINGLE DISPLAY to START; only one sweep should occur.

SECTION 5

PARTS LIST AND SCHEMATICS

ELECTRICAL PARTS

Values are fixed unless marked Variable.

Ckt. No.	Tektronix Part Number	Description				S/N Range
		BULBS				
B319	150-002	Neon, NE-2				

CAPACITORS

Tolerance ±20% unless otherwise indicated.
Tolerance of all electrolytic capacitors are as follows (with exceptions):

3V - 50V = -10%,+250%
51V - 350V = -10%,+100%
351V - 450V = -10%,+50%

Ckt. No.	Tektronix Part Number	Description				S/N Range
C1	283-002	.01 µf	Disc Type	500 v		
C2	283-002	.01 µf	Disc Type	500 v		
C3	283-002	.01 µf	Disc Type	500 v		
C4	283-003	.01 µf	Disc Type	150 v		
C5	281-557	1.8 pf	Cer.	500 v		
C7	281-544	5.6 pf	Cer.	500 v	10%	
C8	281-534	3.3 pf	Cer.	500 v	±.25 pf	
C9	283-003	.01 µf	Disc Type	150 v		
C10	283-010	.05 µf	Disc Type	50 v		
C20	283-026	.2 µf	Disc Type	25 v		

CAPACITORS (Cont'd.)

C21	281-580	470 pf	Cer.		500 v	10%
C30	283-026	.2 µf	Disc Type		25 v	
C40	283-026	.2 µf	Disc Type		25 v	
C50	283-026	.2 µf	Disc Type		25 v	
C60	281-504	10 pf	Cer.		500 v	10%
C61	281-504	10 pf	Cer.		500 v	10%
C65	281-549	68 pf	Cer.		500 v	10%
C75	283-000	.001 µf	Disc Type		500 v	
C110	283-010	.05 µf	Disc Type		50 v	
C120	283-010	.05 µf	Disc Type		50 v	
C126	281-519	47 pf	Cer.		500 v	10%
C140	283-002	.01 µf	Disc Type		500 v	
C145A	283-012	.1 µf	Disc Type		100 v	
C145B	283-010	.05 µf	Disc Type		50 v	
C145D	283-003	.01 µf	Disc Type		150 v	
C145E	283-001	.005 µf	Disc Type		500 v	
C145G	283-000	.001 µf	Disc Type		500 v	
C145H	283-032	470 pf	Disc Type		500 v	5%
C146A	281-512	27 pf	Cer.		500 v	10%
C146B	281-022	8-50 pf	Cer.	Var.		
C155	283-000	.001 µf	Disc Type		500 v	
C160	283-010	.05 µf	Disc Type		50 v	
C164	281-511	22 pf	Cer.		500 v	10%

CAPACITORS (Cont'd.)

C166	281-523	100 pf	Cer.	350 v	
C200	283-026	.02 µf	Disc Type	25 v	
C201	283-026	.02 µf	Disc Type	25 v	
C202	283-002	.01 µf	Disc Type	500 v	
C225	283-000	.001 µf	Disc Type	500 v	
C231	281-518	47 pf	Cer.	500 v	
C232	283-002	.01 µf	Disc Type	500 v	
C241	283-000	.001 µf	Disc Type	500 v	
C242	281-543	270 pf	Cer.	500 v	10%
C254	281-550	120 pf	Cer.	500 v	10%
C261	283-026	.2 µf	Disc Type	25 v	
C260A)		1 µf)			
C260B)		.1 µf)			
)	*295-065	)	Timing Series	Matched within 1%	
C260C)		.01 µf)			
C260D)		.001 µf)			
C260E	283-591	150 pf	Mica	500 v	5%
C260F	281-022	8-50 pf	Cer. Var.		
C263	281-061	5.5-18 pf	Cer. Var.		
C270	281-518	47 pf	Cer.	500 v	
C274	283-028	.0022 µf	Disc Type	50 v	
C288	283-000	.001 µf	Disc Type	500 v	
C300	283-067	.001 µf	Disc Type	200 v	10%
C301	290-107	25 µf	Littl-Lytics	25 v	
C302	283-003	.01 µf	Disc Type	150 v	
C303	281-551	390 pf	Cer.	500 v	10%

CAPACITORS (Cont'd.)

C305	283-000	.001 µf	Disc Type		500 v	
C309	281-504	10 pf	Cer.		500 v	10%
C310	283-003	.01 µf	Disc Type		150 v	
C322	281-551	390 pf	Cer.		500 v	10%
C332	281-523	100 pf	Cer.		350 v	
C335	283-003	.01 µf	Disc Type		150 v	
C341	283-024	.1 µf	Disc Type		30 v	
C342	283-000	.001 µf	Disc Type		500 v	
C345	283-004	.02 µf	Disc Type		150 v	
C346	285-623	.47 µf	PTM		100 v	
C358A	283-581	510 pf	Mica		300 v	5%
C358C	283-580	220 pf	Mica		500 v	5%
C358D	281-012	7-45 pf	Cer.	Var.		
C358E	283-579	100 pf	Mica		500 v	5%
C358F	281-012	7-45 pf	Cer.	Var.		
C358G	283-578	27 pf	Mica		500 v	5%
C358H	281-012	7-45 pf	Cer.	Var.		
C358J	281-542	18 pf	Cer.		500 v	10%
C358K	281-007	3-12 pf	Cer.	Var.		
C360	*291-019	.01 µf	Polystyrene		500 v	5%

CAPACITORS (Cont'd.)

C361	285-576	1 µf	PTM	100 v	10%
C362	283-012	.1 µf	Disc Type	100 v	
C365	283-003	.01 µf	Disc Type	150 v	
C370	283-000	.001 µf	Disc Type	500 v	
C373	283-000	.001 µf	Disc Type	500 v	
C374	283-001	.005 µf	Disc Type	500 v	
C377	285-572	.1 µf	PTM	200 v	
C378	285-572	.1 µf	PTM	200 v	
C390	290-015	100 µf	EMT	25 v	
C391	283-026	.2 µf	Disc Type	25 v	
C396	290-026	5 µf	EMT	25 v	
C397	290-015	100 µf	EMT	25 v	
C398	283-026	.2 µf	Disc Type	25 v	

DIODES

D7	152-008	Germanium	T12G	
D25	152-043	Tunnel	1N3129	20 MA
D35	152-043	Tunnel	1N3129	20 MA
D45	152-043	Tunnel	1N3129	20 MA
D55	152-043	Tunnel	1N3129	20 MA
D65	152-043	Tunnel	1N3129	20 MA
D72	152-026	Germanium	Q6-100	
D82	152-008	Germanium	T12G	
D92	152-008	Germanium	T12G	
D122	152-061	Silicon	6061	

DIODES (Cont'd.)

D132	152-008	Germanium	T12G	
D144	152-008	Germanium	T12G	
D146	152-045	Silicon	6045	
D147	152-008	Germanium	T12G	
D164	152-008	Germanium	T12G	
D234	152-076	Zener	OAZ10	
D255	152-074	Tunnel	1N3128	5 MA
D256	152-071	Silicon	ED2007	
D270	152-071	Silicon	ED2007	
D271	152-008	Germanium	T12G	
D272	152-058	Stabistor	SG22	
D275	152-073	Tunnel	10 MA	
D276	152-077	Back	BD1	1 MA
D285	152-043	Tunnel	1N3129	20 MA
D300	152-025	Germanium	1N634	
D306	152-025	Germanium	1N634	
D324	152-071	Silicon	ED2007	
D325	152-074	Tunnel	1N3128	5 MA
D336	152-025	Germanium	1N634	
D337	152-025	Germanium	1N634	
D345	152-045	Silicon	6045	
D352	152-045	Silicon	6045	
D353	152-045	Silicon	6045	
D360	152-045	Silicon	6045	
D361	152-045	Silicon	6045	

DIODES (Cont'd.)

D362	152-045	Silicon	6045
D377	152-069	Zener	1M75Z10
D378	152-069	Zener	1M75Z10
D420	152-066	Silicon	1N3194
D421	152-066	Silicon	1N3194
D422	152-066	Silicon	1N3194

INDUCTORS

L25	*108-182	.3 μh
L35	*108-182	.3 μh
L45	*108-182	.3 μh
L55	*108-182	.3 μh
L300	*108-200	40 μh
L390	*120-261	Toroid 5T
L398	*120-261	Toroid 5T

RESISTORS

Resistors are fixed, composition, ±10% unless otherwise indicated.

R3	316-121	120 Ω	1/4 w
R4	317-201	200 Ω	1/10 w
R5	316-222	2.2 k	1/4 w
R6	317-510	51 Ω	1/10 w
R7	317-510	51 Ω	1/10 w
R8	316-152	1.5 k	1/4 w
R9	317-510	51 Ω	1/10 w

RESISTORS (Cont'd.)

R10	302-101	100 Ω	1/2 w		
R11	302-101	100 Ω	1/2 w		
R12	302-470	47 Ω	1/2 w		
R14	316-472	4.7 k	1/4 w		
R15	302-223	22 k	1/2 w		
R16+	311-299	100 k		Var.	THRESHOLD
R17	316-472	4.7 k	1/4 w		
R18	302-470	47 Ω	1/2 w		
R19	316-472	4.7 k	1/4 w		
R20	307-023	4.7 Ω	1/2 w		
R21	305-621	620 Ω	2 w		5%
R22	301-471	470 Ω	1/2 w		5%
R24	316-561	560 Ω	1/4 w		
R25	311-171	5 k		Var.	TRIG. RECOG. T.D. BIAS
R27	315-750	75 Ω	1/4 w		5%
R28	315-750	75 Ω	1/4 w		5%
R29	316-103	10 k	1/4 w		
R30	307-023	4.7 Ω	1/2 w		
R31	305-471	470 Ω	2 w		5%
R32	301-361	360 Ω	1/2 w		5%
R33	316-560	56 Ω	1/4 w		
R34	316-681	680 Ω	1/4 w		

+Concentric with R136. Furnished as a unit.

RESISTORS (Cont'd.)

R35	311-171	5 k		Var.	TRIG RECOVERY T.D. BIAS
R40	307-023	4.7 Ω	1/2 w		
R41	305-621	620 Ω	2 w		5%
R42	301-471	470 Ω	1/2 w		5%
R44	316-561	560 Ω	1/4 w		
R45	311-171	5 k		Var.	TRIG. RECOG. T.D.BIAS
R47	315-750	75 Ω	1/4 w		5%
R48	315-750	75 Ω	1/4 w		5%
R49	316-103	10 k	1/4 w		
R50	307-023	4.7 Ω	1/2 w		
R51	305-471	470 Ω	2 w		5%
R52	301-361	360 Ω	1/2 w		5%
R53	316-560	56 Ω	1/4 w		
R54	316-681	680 Ω	1/4 w		
R55	311-171	5 k		Var.	TRIG. RECOVERY T.D. BIAS
R60	316-101	100 Ω	1/4 w		
R61	316-101	100 Ω	1/4 w		
R65	311-004	200 Ω		Var.	OUTPUT T.D. BIAS
R66	306-391	390 Ω	2 w		
R67	307-053	3.3 Ω	1/2 w		5%
R73	315-510	51 Ω	1/4 w		5%
R74	316-122	1.2 k	1/4 w		
R75	316-122	1.2 k	1/4 w		
R83	316-472	4.7 k	1/4 w		

RESISTORS (Cont'd.)

R93	316-472	4.7 k	1/4 w			
R101	316-181	180 Ω	1/4 w			
R103	316-181	180 Ω	1/4 w			
R110	316-220	22 Ω	1/4 w			
R115	301-752	7.5 k	1/2 w			5%
R116	316-393	39 k	1/4 w			
R117	316-683	68 k	1/4 w			
R120	316-220	22 Ω	1/4 w			
R122	302-222	2.2 k	1/2 w			
R125	309-317	7.45 k	1/2 w		Prec.	1%
R126	316-473	47 k	1/4 w			
R127	316-154	150 k	1/4 w			
R132	309-317	7.45 k	1/2 w		Prec.	1%
R133	309-154	30 k	1/2 w		Prec.	1%
R136+	311-299	5 k		Var.		RECOVERY TIME
R140	316-100	10 Ω	1/4 w			
R144	306-154	150 k	2 w			
R145	316-560	56 Ω	1/4 w			
R147	302-222	2.2 k	1/2 w			
R154	315-472	4.7 k	1/4 w			5%
R155	316-271	270 Ω	1/4 w			
R157	316-223	22 k	1/4 w			
R160	316-220	22 Ω	1/4 w			
R164	316-473	47 k	1/4 w			
R165	316-472	4.7 k	1/4 w			

+Concentric with R16. Furnished as a unit.

RESISTORS (Cont'd.)

R166	316-393	39 k	1/4 w			
R167	316-683	68 k	1/4 w			
R175	315-472	4.7 k	1/4 w			5%
R176	316-393	39 k	1/4 w			
R177	316-104	100 k	1/4 w			
R200	316-100	10 Ω	1/4 w			
R201	316-100	10 Ω	1/4 w			
R202	316-100	10 Ω	1/4 w			
R208B	318-012	25 k	1/8 w		Prec.	1%
R208C	318-001	100 k	1/8 w		Prec.	1%
R208D	318-016	225 k	1/8 w		Prec.	1%
R208E	321-450	475 k	1/8 w		Prec.	1%
R208F	318-121	1.225 meg	1/8 w		Prec.	1%
R208G	319-073	2.475 meg	1/4 w		Prec.	1%
R209B	321-356	49.9 k	1/8 w		Prec.	1%
R209C	321-337	31.6 k	1/8 w		Prec.	1%
R209D	321-331	27.4 k	1/8 w		Prec.	1%
R209E	321-329	26.1 k	1/8 w		Prec.	1%
R209F	321-328	25.5 k	1/8 w		Prec.	1%
R209G	321-328	25.5 k	1/8 w		Prec.	1%
R211+	*311-295	10 k		Var.	WW	VARIABLE
R212	309-159	5 k	1/2 w		Prec.	1%
R213A	318-074	11.8 k	1/8 w		Prec.	1%
R213B	318-010	5.03 k	1/8 w		Prec.	1%

+Concentric with SW211. Furnished as a unit.

RESISTORS (Cont'd.)

R214A	309-193	25 k	1/2 w		Prec.	1%
R214B	309-389	50 k	1/2 w		Prec.	1%
R214C	309-376	125 k	1/2 w		Prec.	1%
R214D	309-389	50 k	1/2 w		Prec.	1%
R214E	309-260	100 k	1/2 w		Prec.	1%
R214F	309-162	250 k	1/2 w		Prec.	1%
R214G	309-389	50 k	1/2 w		Prec.	1%
R215B	309-389	50 k	1/2 w		Prec.	1%
R215C	309-037	31.1 k	1/2 w		Prec.	1%
R215D	309-389	50 k	1/2 w		Prec.	1%
R215E	309-375	33.3 k	1/2 w		Prec.	1%
R215F	309-339	27.4 k	1/2 w		Prec.	1%
R215G	309-389	50 k	1/2 w		Prec.	1%
R216	309-168	78 k	1/2 w		Prec.	1%
R217A,B	311-394	2 x 10 k		Var.	TIME POSITION	
R218	318-074	11.8 k	1/8 w		Prec.	1%
R219A	309-181	2.5 k	1/2 w		Prec.	1%
R219B	302-223	22 k	1/2 w			
R220	311-125	50 k	.2 w	Var.	DELAY ZERO	
R223	309-049	150 k	1/2 w		Prec.	1%
R225	311-303	200 Ω		Var.	INVERTER INPUT ZERO	
R227	309-200	11.76 k	1/2 w		Prec.	1%
R229	301-393	39 k	1/2 w			5%
R231	309-159	5 k	1/2 w		Prec.	1%
R232	316-100	10 Ω	1/4 w			

RESISTORS (Cont'd.)

R233	304-334	330 k	1 w			
R234	303-153	15 k	1 w			5%
R237	316-101	100 Ω	1/4 w			
R240	316-562	5.6 k	1/4 w			
R241	316-122	1.2 k	1/4 w			
R242	315-510	51 Ω	1/4 w			5%
R243	316-124	120 k	1/4 w			
R244	315-133	13 k	1/4 w			5%
R254	311-393	1 k		Var.		RAMP RECOV.
R261	316-100	10 Ω	1/4 w			
R260A	301-510	51 Ω	1/2 w			5%
R260F	316-100	10 Ω	1/4 w			
R263	315-510	51 Ω	1/4 w			5%
R264	315-181	180 Ω	1/4 w			5%
R265	308-273	6.5 k	5 w		WW	3%
R267	311-395	2.5 k		Var.		SWEEP CAL.
R270	316-101	100 Ω	1/4 w			
R271	318-084	10 k	1/8 w		Prec.	1%
R272	316-103	10 k	1/4 w			
R274	316-122	1.2 k	1/4 w			
R275	311-060	1 k		Var.		COMPARATOR LEVEL
R285	316-561	560 Ω	1/4 w			
R286	316-152	1.5 k	1/4 w			
R287	316-332	3.3 k	1/4 w			
R288	307-057	5.1 Ω	1/2 w			5%

RESISTORS (Cont'd.)

R289	308-067	750 Ω	5 w		WW	5%
R303	301-152	1.5 k	1/2 w			5%
R304	311-170	20 k		Var.		SAMPLES/CM CAL.
R305	302-270	27 Ω	1/2 w			
R306	301-472	4.7 k	1/2 w			5%
R308	316-223	22 k	1/4 w			
R309	302-393	39 k	1/2 w			
R310	302-105	1 meg	1/2 w			
R312	317-910	91 Ω	1/10 w			5%
R314	317-910	91 Ω	1/10 w			5%
R315	301-102	1 k	1/2 w			5%
R319	302-474	470 k	1/2 w			
R322	301-332	3.3 k	1/2 w			5%
R323	302-101	100 Ω	1/2 w			
R324	301-222	2.2 k	1/2 w			5%
R325	301-472	4.7 k	1/2 w			5%
R330	301-274	270 k	1/2 w			5%
R331	302-393	39 k	1/2 w			
R332	301-103	10 k	1/2 w			5%
R333	301-272	2.7 k	1/2 w			5%
R334	302-104	100 k	1/2 w			
R335	302-101	100 Ω	1/2 w			
R336	301-472	4.7 k	1/2 w			5%
R337	302-393	39 k	1/2 w			
R340	301-123	12 k	1/2 w			5%

RESISTORS (Cont'd.)

R341	302-270	27 Ω	1/2 w			
R342	301-512	5.1 k	1/2 w			5%
R343	301-332	3.3 k	1/2 w			5%
R344	301-473	47 k	1/2 w			5%
R345	311-170	20 k		Var.		SWP LENGTH
R346	302-101	100 Ω	1/2 w			
R349	316-223	22 k	1/4 w			
R356	311-157	100 k		Var.		TIMED
R357	309-095	10 meg	1/2 w		Prec.	1%
R358	301-102	1 k	1/2 w			5%
R362	303-223	22 k	1 w			5%
R364	316-101	100 Ω	1/4 w			
R365	302-101	100 Ω	1/2 w			
R370	316-101	100 Ω	1/4 w			
R371	301-393	39 k	1/2 w			5%
R372	316-101	100 Ω	1/4 w			
R373	316-101	100 Ω	1/4 w			
R374	316-101	100 Ω	1/4 w			
R375	303-273	27 k	1 w			5%
R376	305-153	15 k	2 w			5%
R377	301-124	120 k	1/2 w			5%
R381	311-125	50 k	.2 w	Var.		STAIRCASE DC LEVEL
R382	309-090	50 k	1/2 w		Prec.	1%
R383	309-090	50 k	1/2 w		Prec.	1%
R384	309-115	1 k	1/2 w		Prec.	1%

RESISTORS (Cont'd.)

R386	316-101	100 Ω	1/4 w
R393	306-330	33 Ω	2 w
R394	306-330	33 Ω	2 w
R395	304-101	100 Ω	1 w
R420	302-275	2.7 meg	1/2 w

SWITCHES

	Unwired	Wired		
SW10A)	260-438	*262-452	Rotary	TRIGGERING (Source)
SW10B)			Rotary	TRIGGERING (Polarity)
SW210	260-527	*262-552	Rotary	TIME EXPANDER
SW211+	*311-295			
SW260	260-528	*262-553	Rotary	SWEEP TIME/CM
SW325)	260-526	*262-554	Rotary	SWEEP MODE
SW358)			Rotary	SAMPLES/CM

TRANSFORMERS

T2	*120-262	Toroid 1T
T65	*120-263	Toroid 3T
T284	*120-264	Toroid 3T
T300	*120-265	Toroid 7T

TRANSISTORS

Q4	151-027	2N700
Q73	151-068	2N636
Q84	151-065	2N1991
Q94	151-065	2N1991
Q104	151-031	2N1517

+Concentric with R211. Furnished as a unit.

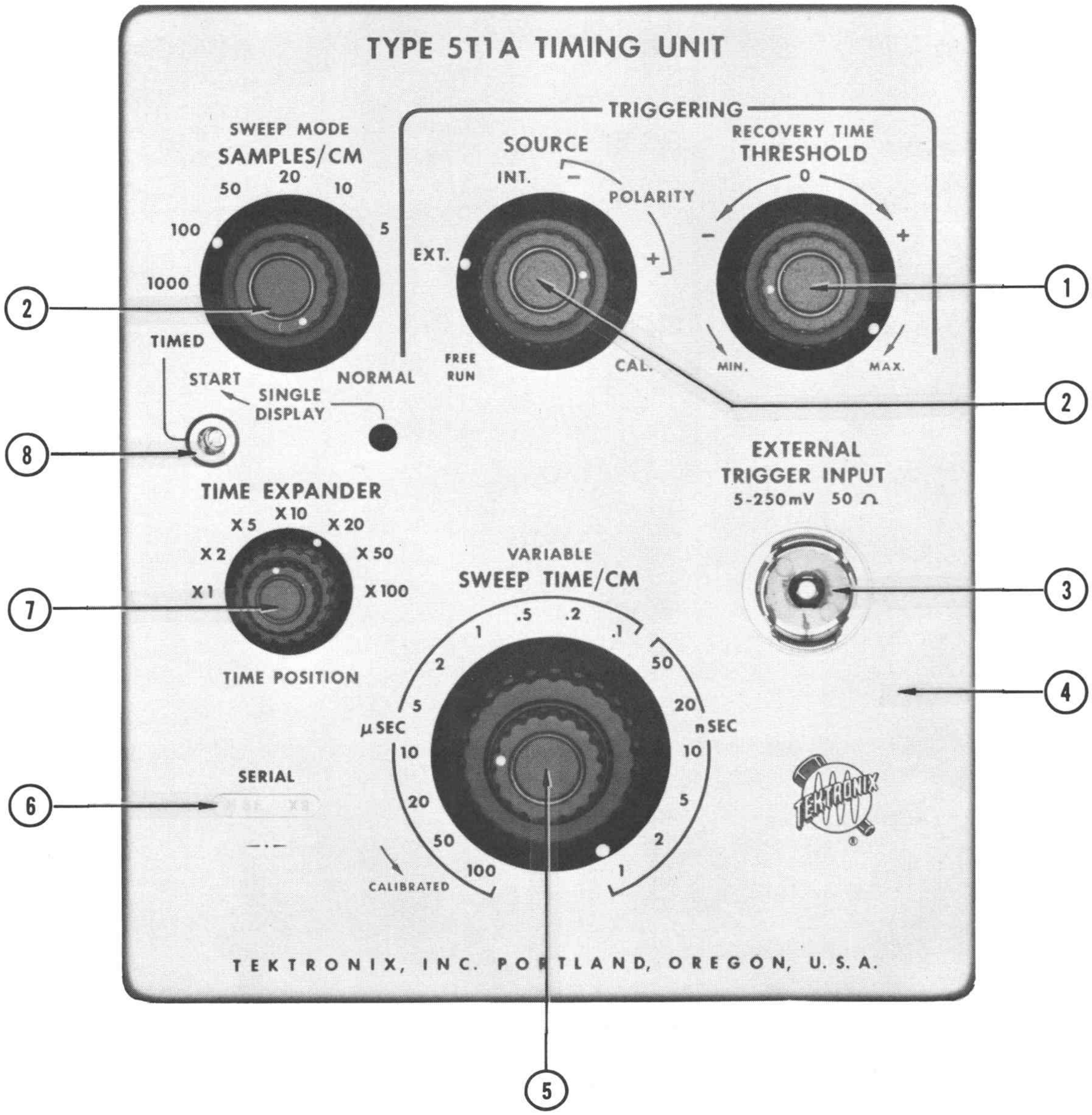
TRANSISTORS (Cont'd.)

Q115	151-072	2N1308	
Q125	151-072	2N1308	
Q144	151-072	2N1308	
Q154	151-071	2N1305	
Q165	151-072	2N1308	
Q175	151-072	2N1308	
Q223	151-103	Planar Silicon	
Q234	151-087	J3138	
Q244	151-123	2N976	
Q254	151-123	2N976	
Q261	151-108	Tek 151-108	
Q276	151-108	Tek 151-108	
Q284	151-123	2N976	
Q300	*153-511	OC170	checked
Q314	151-054	2N1754	
Q324	151-068	2N636	
Q335	151-031	2N1517	
Q345	151-040	2N1302	

ELECTRON TUBES

V361	154-215	6688/E180F
V373	154-187	6DJ8/ECC88

FRONT


TYPE 5T1A TIMING UNIT
TRIGGERING
SWEEP MODE
SAMPLES/CM
50 20 10
100 5
1000
TIMED
START
SINGLE
DISPLAY
NORMAL
SOURCE
INT.
POLARITY
EXT.
FREE RUN
CAL.
RECOVERY TIME
THRESHOLD
0
MIN.
MAX.
EXTERNAL
TRIGGER INPUT
5-250mV 50 Ω
TIME EXPANDER
X5 X10 X20
X2 X50
X1 X100
TIME POSITION
VARIABLE
SWEEP TIME/CM
1 .5 .2 .1
2 50
5 20
μSEC nSEC
10 10
20 5
50 2
100 1
CALIBRATED
SERIAL
TEKTRONIX
TEKTRONIX, INC. PORTLAND, OREGON, U. S. A.
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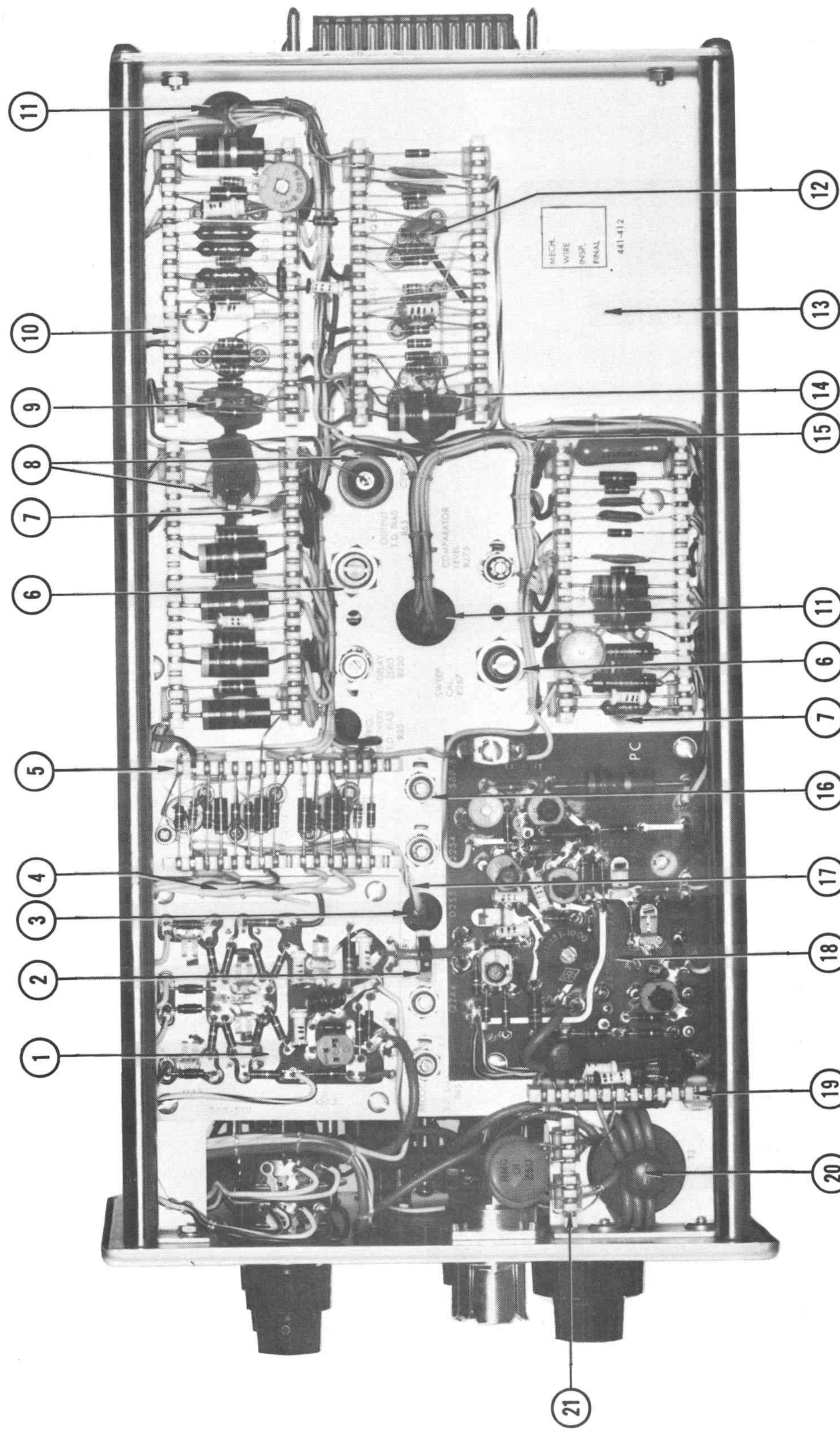
FRONT

Ref.	Part No.	Quan.	Description
1.	366-146	1	Knob, Charcoal
	366-032	1	Knob, Small Red
	210-413	1	Nut
	210-840	1	Washer
	210-012	1	Lockwasher
2.	366-142	2	Knob, Charcoal
	366-031	2	Knob, Small Red
	210-413	2	Nut
	210-840	2	Washer
	210-012	2	Lockwasher
3.	132-001	1	Nut Coupling
	132-002	1	Sleeve, Outer Conductor
	132-007	1	Snap Ring
	132-016	1	Retaining Nut
	132-026	1	Outer Transition
	132-027	1	Inner Transition
	132-028	1	Insulator
	132-029	1	Inner Conductor
	166-221	1	Tube, Alum., Ferrule
	132-040	1	Adapter, Panel
	211-038	4	Screw, Adapter to Subpanel
4.	333-753	1	Panel, Front
	006-105	1	Cover, Front Panel
	387-783	1	Plate, Subpanel
5.	366-144	1	Knob, Large Charcoal
	366-038	1	Knob, Small Red
	210-413	1	Nut
	210-840	1	Washer
	210-012	1	Lockwasher
6.	334-679	1	Tag, Metal Serial
7.	366-175	1	Knob, Charcoal
	366-140	1	Knob, Small Red
	210-413	1	Nut
	210-840	1	Washer
	210-012	1	Lockwasher
8.	358-054	1	Bushing, Banana Jack
	210-011	1	Lockwasher
	210-471	1	Nut, Spacer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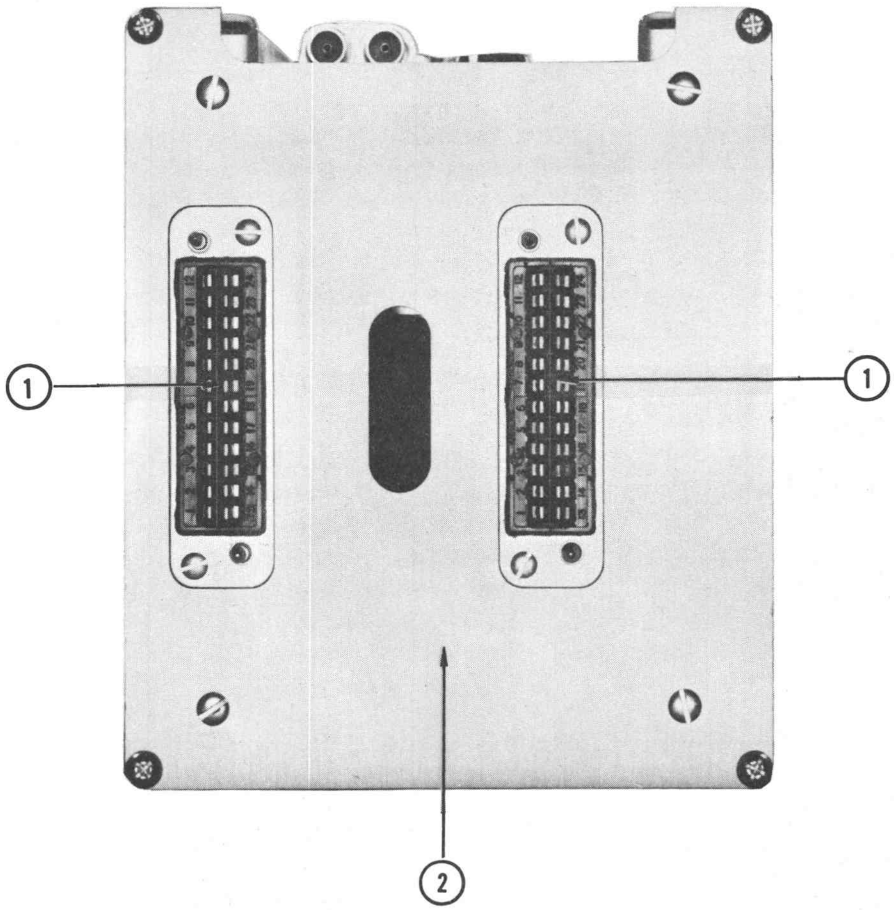
RIGHT SIDE

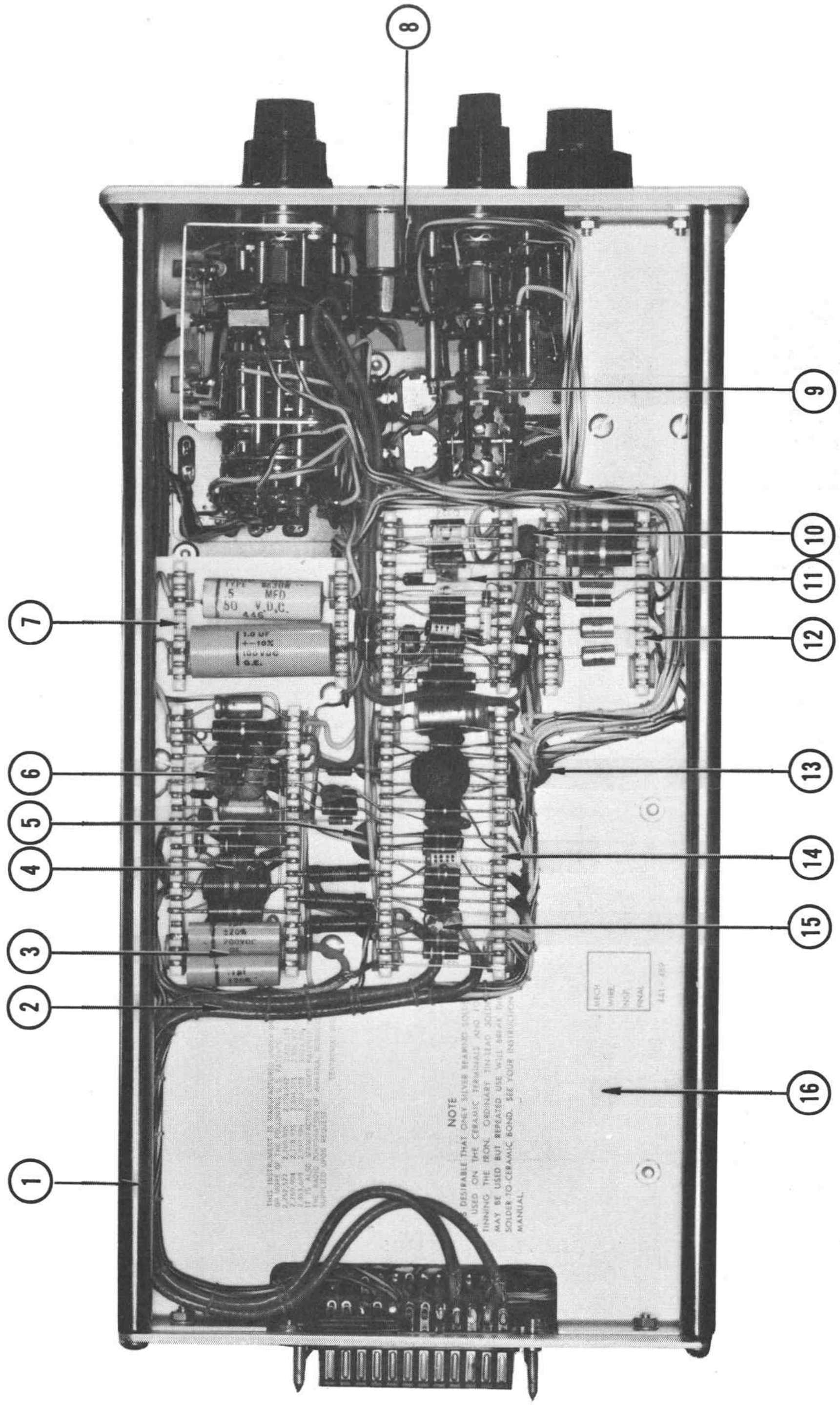
Ref.	Part No.	Quan.	Description
1.	670-029	1	Etched Circuit Board, Trigger
		Includes:	
		136-062	Socket, Transistor
		352-041	Holder, Tunnel Diode
	211-008	4	Screw, Circuit Board to Chassis
2.	426-121	1	Mount, Toroid
	361-007	1	Spacer
3.	348-003	1	Grommet
4.	179-599	1	Cable, Harness, Etched Board
5.	124-146	2	Ceramic Strip, 16 Notch
	361-007	4	Spacer
6.	210-413	2	Nut, Pot Mounting
	210-840	2	Washer
7.	348-031	3	Grommet, Plastic Snap-in
8.	354-068	2	Ring, Capacitor Securing
9.	210-204	1	Solder Lug
	213-044	1	Screw
10.	124-145	8	Ceramic Strip, 20 Notch
	361-007	16	Spacer
11.	348-005	2	Grommet
12.	136-095	11	Socket, Transistor
	213-113	22	Screw, Socket to Chassis
13.	441-412	1	Chassis, Ramp Amp
	211-538	3	Screw, Chassis to Subpanel
	211-507	2	Screw, Chassis to Rear Plate
	210-006	3	Lockwasher
	210-407	3	Nut
14.	210-201	1	Solder Lug
	213-044	1	Screw
15.	179-774	1	Cable, Harness, Ramp Amp Chassis
16.	210-223	4	Solder Lug, Mini. Pot (not shown)
17.	179-639	1	Cable, Harness, Pot

RIGHT SIDE (Cont.)

Ref.	Part No.	Quan.	Description
18.	670-030	1	Etched Circuit Board, Fast Ramp
		Includes:	
		136-062	Socket, Transistor
		352-041	Holder, Tunnel Diode
	211-008	4	Screw, Circuit Board to Chassis
	210-204	1	Solder Lug
19.	124-147	1	Ceramic Strip, 13 Notch
	361-007	2	Spacer
20.	211-040	1	Screw, Nylon
	210-810	1	Washer, Fiber
	385-107	1	Rod, Nylon, Core Mounting
	211-011	1	Screw, Rod to Chassis
21.	124-149	1	Ceramic Strip, 7 Notch
	361-007	2	Spacer



Ref.	Part No.	Quan.	Description
1.	131-149	2	Connector, Plug-in
	211-008	4	Screw
	210-004	3	Lockwasher
	210-201	1	Solder Lug
	210-406	4	Nut
2.	387-598	1	Plate, Rear Frame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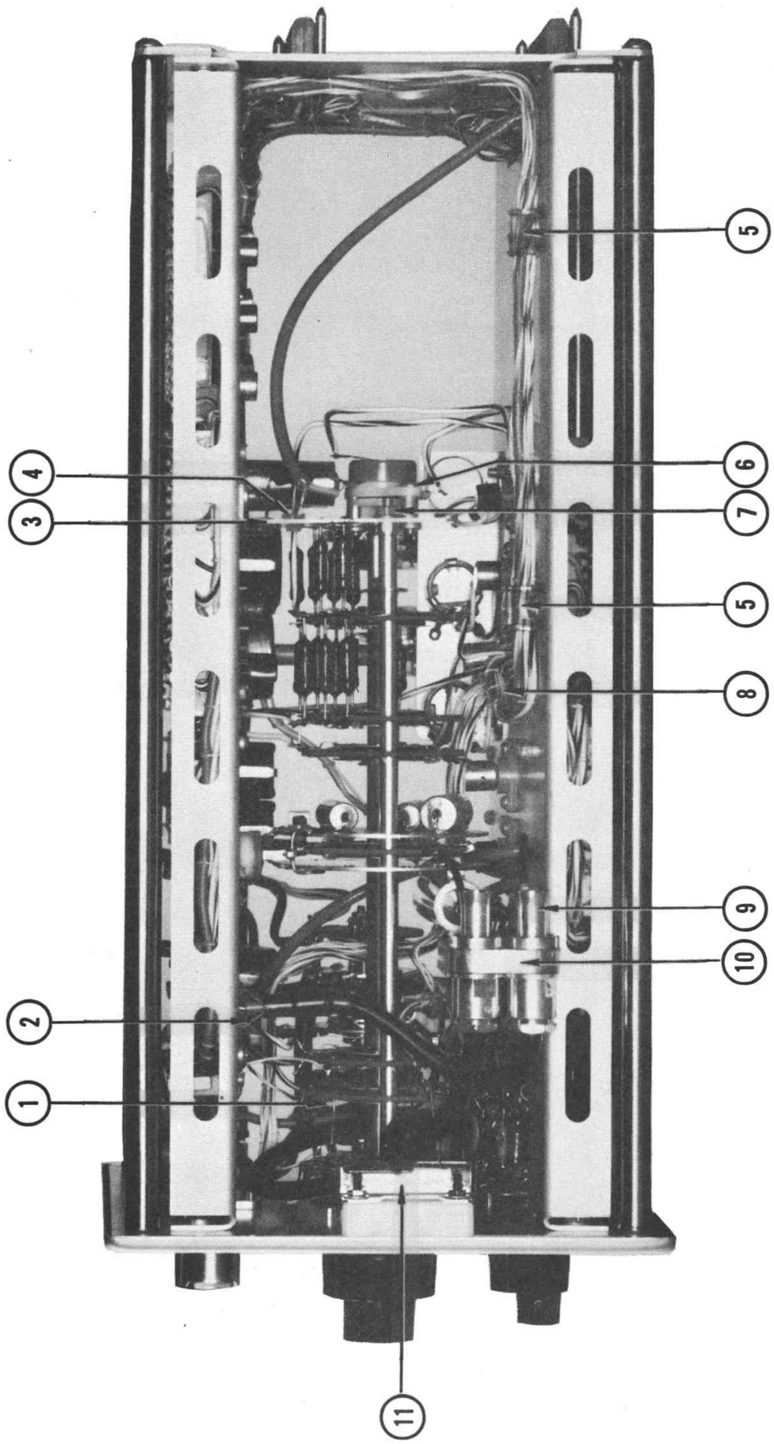
LEFT SIDE

Ref.	Part No.	Quan.	Description
1.	384-566	4	Rod, Frame
	212-044	4	Screw, Rod to Rear Plate
2.	179-772	1	Cable, Harness, Stair-Step Chassis
3.	210-201	1	Solder Lug
	213-044	1	Screw
4.	136-014	1	Socket, Tube
	213-044	2	Screw
5.	348-003	3	Grommet
6.	136-085	1	Socket, Tube W/shield
	213-044	2	Screw
7.	124-148	2	Ceramic Strip, 9 Notch
	361-007	4	Spacer
8.	352-008	1	Holder, Neon
	211-031	1	Screw, Holder to Subpanel
	210-406	2	Nut
9.	210-413	2	Nut, Pot
	210-012	1	Lockwasher
10.	348-002	2	Grommet
11.	136-127	1	Socket, Tunnel Diode Holder
12.	124-147	4	Ceramic Strip, 13 Notch
	361-007	8	Spacer
13.	348-005	1	Grommet
14.	124-145	4	Ceramic Strip, 20 Notch
	361-007	8	Spacer
15.	136-095	5	Socket, Transistor
	213-113	10	Screw, Socket to Chassis
16.	441-489	1	Chassis, Stairstep
	211-559	2	Screw, Chassis to Subpanel
	211-507	2	Screw, Chassis to Rear Plate
	210-006	4	Lockwasher
	210-407	4	Nut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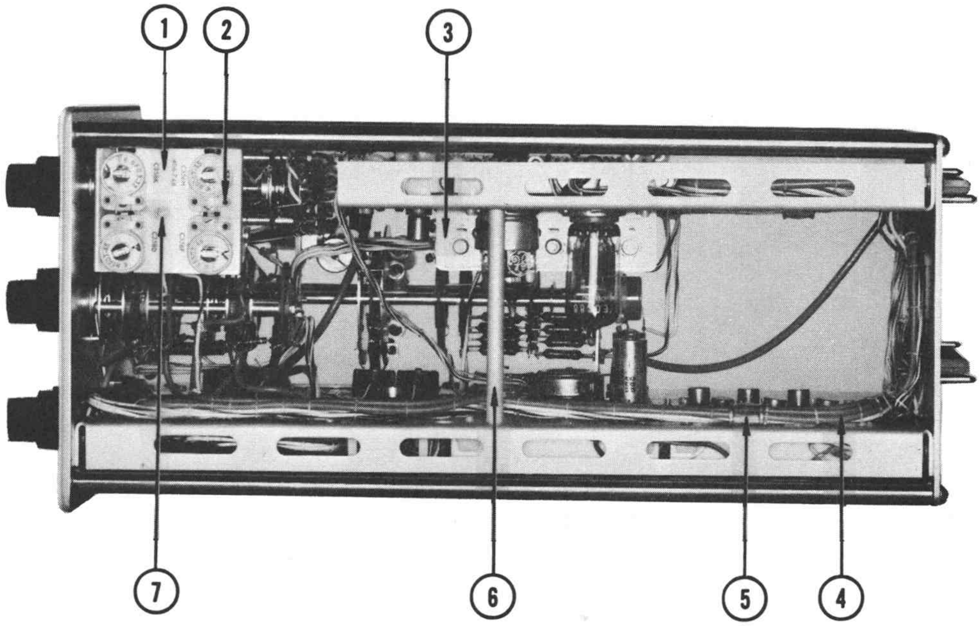
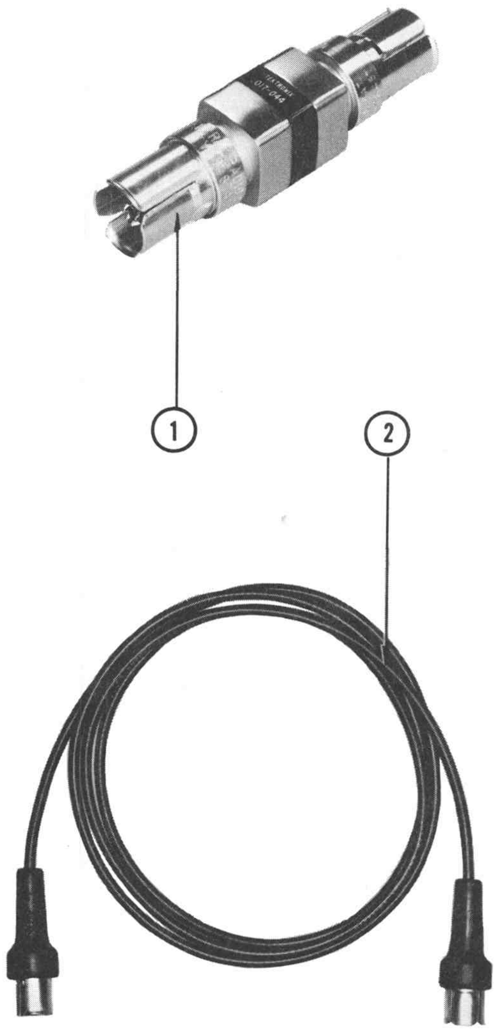
BOTTOM

Ref.	Part No.	Quan.	Description
1.	166-204	1	Tube, Coax. Adapter
	132-117	1	Ferrule
2.	166-240	1	Tube, Coax. Adapter
	132-117	1	Ferrule
3.	406-747	1	Bracket, Sweep Speed Switch
	211-504	2	Screw, Bracket to Chassis
4.	348-031	1	Grommet, Plastic Snap-in
5.	343-042	2	Clamp, Cable
	211-507	2	Screw, Clamp to Chassis
	210-803	2	Washer
	210-006	2	Lockwasher
	210-407	2	Nut
6.	211-014	2	Screw, Pot Mounting
	166-025	2	Tube, Aluminum Spacer
7.	210-449	2	Nut, Bracket to Switch
	210-006	2	Lockwasher
8.	179-773	1	Cable, Harness, Sweep Time/CM
9.	131-221	2	Connector, Bulkhead Jack
	358-172	2	Bushing, Connector
10.	426-150	1	Mount, Connector
	211-511	2	Screw, Mount to Bracket
	406-779	1	Bracket, Mount Support (not shown)
	211-507	2	Screw, Bracket to Chassis
	210-006	4	Lockwasher
	210-407	4	Nut
11.	214-222	1	Spring Striker
	361-029	1	Spacer, Spring Striker
	211-082	2	Screw, Spring Striker to Subpanel
	210-004	2	Lockwasher
	210-406	2	Nut



Ref.	Part No.	Quan.	Description
1.	406-748	1	Bracket, Capacitor Mounting
	211-008	4	Screw, Bracket to Switch
	210-004	4	Lockwasher
	210-406	4	Nut
2.	214-153	4	Fastener, Capacitor
3.	406-914	1	Bracket, Pot Mounting
	211-507	2	Screw, Bracket to Chassis
4.	179-640	1	Cable, Harness, Connecting
5.	343-042	1	Clamp, Cable
	211-507	1	Screw, Clamp to Chassis
	210-803	1	Washer
	210-006	1	Lockwasher
	210-407	1	Nut
6.	384-135	1	Rod, Spacer
	211-507	2	Screw, Rod to Chassis
7.	131-180	2	Connector, Stand-off
	358-135	2	Bushing, Teflon



Ref.	Part No.	Quan.	Description
1.	017-044	2	Attenuator, 50 Ω, 10X (see pub. no. 061-762 for parts breakdown)
2.	017-501	1	Cable, 50 Ω, 10 N sec. (see pub. no. 061-765 for parts breakdown)


590