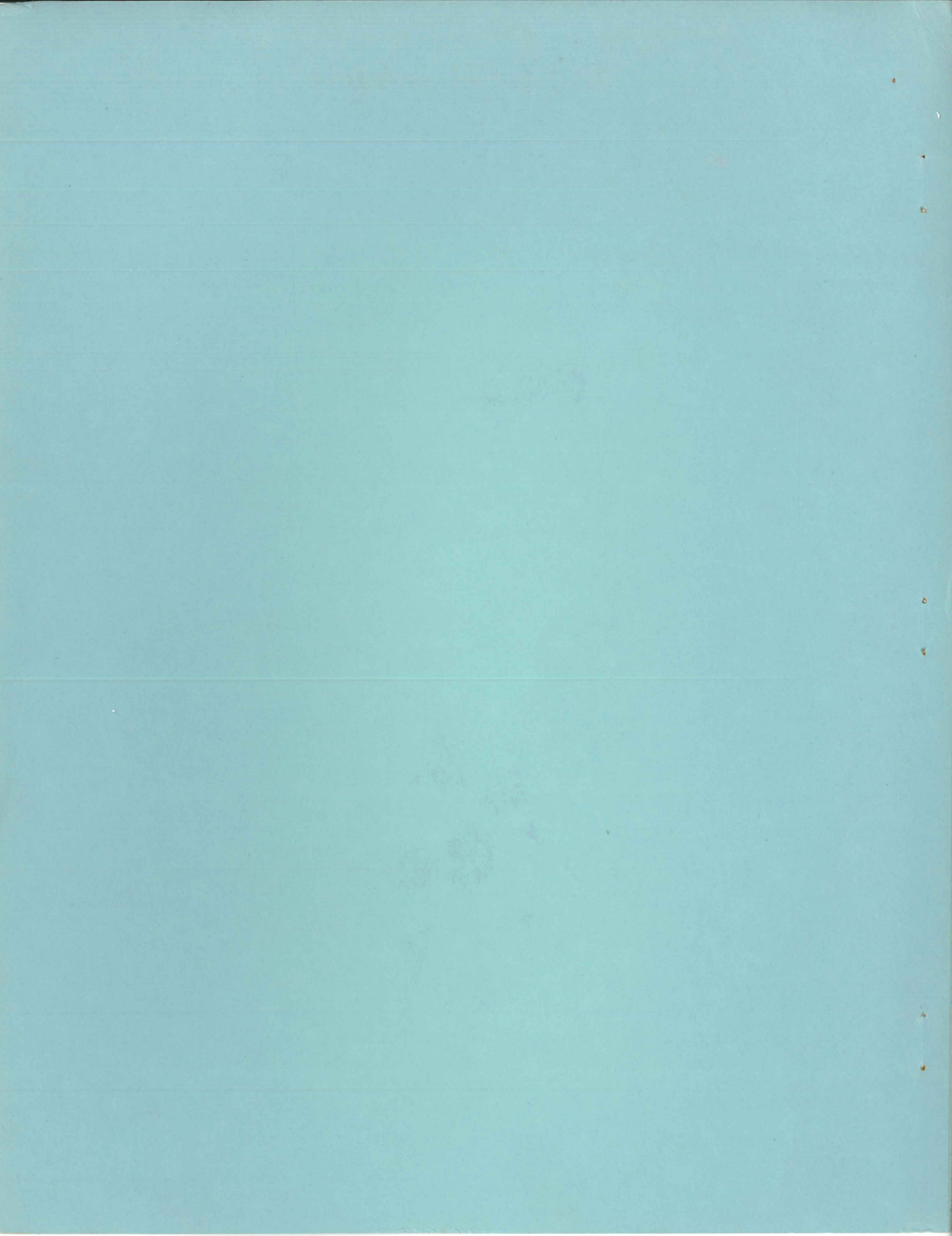


TYPE 519
Cathode-Ray
Oscilloscope

OPERATING INSTRUCTIONS



TEKTRONIX, INC.
PO Box 500 Beaverton, Oregon



Specifications

Section 1

General Information

The Tektronix Type 519 Oscilloscope is a wide-band laboratory type instrument designed expressly for the observation and measurement of high-frequency phenomena. Fast linear sweeps, high crt accelerating potential, high sensitivity, wide-band trigger system, and extreme bandwidth permit single-shot photographic recording of fractional nanosecond signals. An internal delay line in the vertical channel of the instrument eliminates the need for adjusting cable lengths. Since the length of the delay line remains constant, the bandwidth of the Type 519 also remains constant.

The Type 519 incorporates an adjustable repetition rate fast-rise pulse generator and a fast-rise calibration-step generator which can supply waveforms to check the calibration of the oscilloscope itself or drive external devices. These generators meet most requirements to complete a test setup.

VERTICAL-DEFLECTION SYSTEM

Vertical Deflection Factor--With Type T519A CRT, nominally 10 volts per cm.

Passband--With Type T519A CRT, dc to 1 gigacycle* (3db down).

Risetime--With Type 519A CRT, less than 0.35 nanosecond.

Input Impedance--125 ohms.

Maximum Allowable Input Power to Vertical Channel--1.8 watts (+or- 15 volts dc or rms).

Maximum Allowable Peak Signal Amplitude-- +or- 100 volts.

Internal Signal Delay--45 nanoseconds, fixed.

Voltage Standing Wave Ratio--Nominally 1.2:1 from dc to 1 gigacycle.*

*Gigacycle = 10^9 cps.

TRIGGER

Triggering Signal Sources--Internal from +or- applied signals, internal from the Rate Generator, internal from the Calibration-Step Generator, and External.

External Triggering Signal Requirements--Pulse amplitude: 20 millivolts. Pulse duration: 1 nanosecond or longer. Maximum permissible external triggering signal: +or- 10 volts peak.

Internal Triggering Signal Requirements--Pulse amplitude: sufficient signal to produce a 2 trace-width deflection on the screen. Duration: 1 nanosecond or longer. Repetition rate: 0 to 1 gigacycle.

Countdown--Triggering circuits count down from triggering signal frequencies higher than 400 kc. Sine-wave trigger requirements: 0.1 mc to 1000 mc (1 gc), 20 mv peak-to-peak external trigger input or 150 mv peak-to-peak signal to vertical input.

Pulse Amplitude or Sync--Single control adjusts pulse triggering level or high-frequency sync. An additional control provides vernier sync.

Delay--0 to 35 nanoseconds sweep-start delay. Permits sweep to display a selected time interval.

TIME BASE

Sweep Rates--Nine ranges: 2, 5, 10, 20, 50, 100, 200, 500, and 1000 nanoseconds (1 microsecond) per centimeter.

Accuracy--Typically within 2% of indicated rate on all ranges except the 2 nanosecond range which is within 3%. These tolerances apply to all ranges except for the first 2 nanoseconds or 2 mm (whichever is larger) portion of any of the above rates.

Single - Sweep--Normal or single sweeps selected by front panel switch and reset by push-button.

+ Trigger Output--1-volt into 50 ohms upon triggering.

Delayed +Gate--1-volt pulse into 50 ohms at start of sweep; hence, time-dependent upon setting of sweep-delay control.

RATE GENERATOR

Risetime--Less than 0.8 nanosecond.

Pulse Repetition Rate--3 pps to 30 kc, continuously variable.

Pulse Duration--10 nanoseconds.

Output Impedance--50 ohms.

Amplitude--Approximately +15 volts.

CALIBRATION-STEP GENERATOR

Risetime--approximately 0.1 nanosecond.

Step Repetition Rate--Adjustable 250 to 1000 cps, normally operated at reed-switch resonant frequency near 750 cps.

Output Impedance--125 ohms.

Amplitude--Into 125 ohms, 0 to 10 volts. Into 50 ohms through T125/T50 adapter, 0 to 1 volt. Voltages applied to both impedances are continuously variable and calibrated. Uncalibrated voltages up to 50 volts into 125Ω.

Polarity--The output polarity can be selected by a front-panel switch.

CATHODE-RAY TUBE

Type--T519A

Phosphors--Type P11 phosphor standard (recommended for single - shot photographic recording of fastest sweep rate). Other phosphors available on special request.

Usable Viewing Area--Two centimeters, vertical, six centimeters horizontal.

Accelerating Voltage--24 kv.

Spot Diameter--0.004 inch at normal intensity.

Deflection--Electrostatic. Traveling-wave vertical deflection system with conventional horizontal deflection plates.

CONSTRUCTION AND POWER REQUIREMENTS

Construction--single-unit construction with light-weight aluminum-alloy chassis and four-piece vinyl-finish cabinet. Side panels, top and bottom panels are separately removable.

Ventilation--Filtered forced air with protective thermal cut-out insures safe operating temperatures.

Dimensions -- Approximately 22-1/4" high, 14-3/4" wide, and 25-1/4" long.

Net Weight--Approximately 99 pounds.

Power Requirements--105 to 125 or 210 to 250 volts, 50 to 60 cycles, 650 watts.

ACCESSORIES

1 -- 125Ω Termination (017-007)

1 -- 125Ω Adapter T50/T125 (017-008)

2 -- 125Ω Insertion Units (017-013)

1 -- 125Ω Adapter N50/N125 (017-015)

1 -- 125Ω Adapter T50/N125 (017-017)

1 -- 125Ω Coupling Capacitor (017-018)

1 -- 125Ω 1 KMC Ringing Crt (017-019)

1 -- 125Ω 1 nsec Delay Cable (017-507)

1 -- 125Ω 2 nsec Delay Cable (017-508)

1 -- 125Ω 5 nsec Delay Cable (017-509)

1 -- 125Ω 10 nsec Delay Cable (017-510)

1 -- Set of spare miscellaneous cable connector parts consisting of:

Double Button Assy. (017-032)

Panel Adapter Assy. (017-033)

125Ω Cable Connector (017-035)

2 Spare Reed Switches (260-362)	1 -- 3-conductor Power Cord	(161-010)
1 -- Viewing Hood (includes attached bezel)	1 -- Power Cord Adapter	(013-013)
1 -- Accessory Box	1 -- Instruction Manual	

Operating Information

Section 2

Introduction

The Type 519 Oscilloscope is a high sweep rate laboratory instrument designed for observing, measuring, and photographically recording phenomena in the nanosecond (millimicrosecond) region. However, before the instrument can be successfully applied in actual use, it is

important to have an understanding of the operation of each control and its function. This section of the Operator's Manual is intended to provide this understanding and other basic information. A brief description of each of the front-panel controls follows. Front-panel lettering is shown in Fig. 2-1.

FUNCTION OF CONTROLS

CRT

SCALE ILLUM.	Adjusts the brightness of the graticule markings.
ASTIGMATISM	Used in conjunction with the FOCUS control to obtain a round spot and a sharply focused trace.
INTENSITY	Adjusts the brightness of the trace.
FOCUS	Used in conjunction with the ASTIGMATISM control to focus the oscilloscope display.
Graticule Control	A knurled knob located below the center of the graticule permits graticule to be moved down when not used.

TIME BASE

NANOSEC/CM	Selects the time-base rates.
DELAY	Sets the delay time duration. Delays start of sweep with respect to trigger signal input.
NORMAL-SINGLE SWEEP	Selects either normal or single-sweep operation.

RATE GENERATOR

CYCLES/SEC	Selects the significant figures for the RATE GENERATOR output frequency.
MULTIPLIER	Multiplier for the CYCLES/SEC control. Should be set to OFF position when Rate Generator is not being used.

CALIBRATION-STEP GENERATOR

RANGE	Selects either of two full-scale amplitudes of the calibrator step, a variable pulse amplitude, or a standby condition. Should be set to STANDBY position when Calibration-Step Generator is not being used.
VARIABLE	Permits the step waveform to be preset to an arbitrary desired amplitude up to about 50 volts.
VOLTS	Sets the output voltage amplitude of the calibration-step waveform.
POLARITY	Selects either positive- or negative-going output step waveform.
REED SWITCH	
DRIVE	Adjusts reed-switch magnetic excitation or permits single closure.
FREQUENCY	Controls frequency of the reed-switch magnetic excitation to reduce multiple contact bounces.

TRIGGER

PULSE AMPLITUDE OR SYNC*	Rejects triggers below selected amplitude or adjusts synchronization.
VERNIER SYNC	Used in conjunction with PULSE AMPLITUDE or SYNC control to synchronize the sweep.
FUNCTION*	Permits choices of triggered or synchronized displays, depending upon nature of input signals.
GAIN*	Selects proper gain for the triggering signal.
TRIGGER SOURCE	Selects the triggering signal source and polarity.

*Also see TRIGGER OPERATION section of front-panel, Fig. 2-1.

POSITIONING

VERTICAL	Adjusts the vertical position of the trace.
AXIS ROTATION	Aligns the trace parallel to the horizontal centerline.
HORIZONTAL	Adjusts the horizontal position of the trace.

POWER

DIM ADJ.	Used to adjust brightness of adjacent pilot light after 45 seconds warm-up.
ON	Main power switch.

PRELIMINARY INSTRUCTIONS

Cooling

A blower maintains safe operating temperature in the Type 519 Oscilloscope by drawing air through a filter and circulating it over the components. Therefore, the instrument must be placed so that the air intake and cabinet ventilating holes are not blocked. The air filter must be kept clean to permit adequate air flow.

A thermal cutout switch will disconnect the dc power if air flow is restricted or ambient temperature is too high. DC power will return when the temperature drops to a safe value. The pilot lamp will increase to full brightness in event of loss of dc power. The blower continues to cool the interior and reduces the time the thermal switch remains open.

Power Requirements

The regulated power supplies in the Type 519 Oscilloscope will operate with line voltages from 105 to 125 volts (117 nominal) or from 210 to 250 volts (234 nominal). The line voltage for which your instrument is wired at the factory is indicated on a metal tag fastened to the rear panel near the power receptacle. Power wiring may be changed for either 117- or 234-volt operation in compliance with the information given in Fig. 2-2.

The power transformer is wound with two 117-volt primaries which can be connected in parallel for 117-volt operation or in series for 234-volt operation. Since the blower motor is connected across only one of the transformer primaries, no change in the motor lead connections is required. When power wiring is changed, the voltage indicated on the metal tag should be covered with another tag which conforms to the new operating voltage.

For maximum dependability and long life, the line voltage applied to the Type 519 Oscilloscope should be near the design center (117 or 234 volts). If the line voltage exceeds the operating limits or has a poor waveform (distorted sine-wave peaks), unstable power supply operation may result. Observe for proper line voltage and waveform before checking for other causes of unstable operation.

Fuse Requirements

When the Type 519 Oscilloscope is connected for 117-volt operation, use a 7-amp slow-blowing type fuse. When the instrument is connected for 234-volt operation, use a 4-amp slow-blowing type fuse.

Time Delay

A time delay relay used in the Type 519 delays operation of the instrument for approximately 45 seconds after the power switch is operated. The relay allows a brief tube-warmup period before the dc operating voltages are applied. When the ac-power pilot light dims, the instrument is ready for use.

If the ac power is interrupted for only an instant, the normal 45-second delay will occur before the instrument returns to full operation.

Dim Adjustment

The DIM ADJ. control is a screwdriver adjustment which controls the brightness of the ac-power pilot light after the 45-second delay period. The control may be adjusted to any desired setting. Normally, it is adjusted to a setting which will reduce glare from the pilot light when waveform observations are being made in a darkened room.

FIRST-TIME OPERATION

To place the Type 519 in operation for the first time, the following procedure is suggested:

1. Set the front-panel controls as follows:

POWER	Off
DIM ADJ.	Centered
FOCUS	Centered
INTENSITY	Fully counterclockwise
ASTIGMATISM	Centered
SCALE ILLUM.	Centered
DELAY	Min.
NANOSEC/CM	5

MULTIPLIER	X1000
CYCLES/SEC	10
CALIBRATION- STEP GENERATOR controls	Standby
TRIGGER SOURCE	RATE GEN.
GAIN	NORMAL
FUNCTION	PULSE
VERNIER SYNC	centered
PULSE AMPLI- TUDE or SYNC	Fully counterclockwise
VERTICAL	Centered
HORIZONTAL	Fully clockwise

2. Connect the power cord to the rear of the instrument and to the source of power. The line voltage for which the instrument is wired at the factory is indicated near the power cord receptacle.
3. Set the POWER switch to ON.
4. Allow about .45 seconds for the pilot lamp to suddenly dim, indicating that dc-operating voltages are applied and the instrument is ready for use.
5. Advance the INTENSITY control until a visible spot appears near the left center of the screen.

CAUTION

Do not turn the intensity so high that a bright glow surrounds the spot. Excessive undeflected brightness may damage the screen in a few seconds.

6. Adjust the FOCUS and ASTIGMATISM controls in conjunction with each other to produce a small round spot.
7. Advance the PULSE AMPLITUDE or SYNC control fully clockwise to obtain a horizontal sweep trace across the screen. Readjust the INTENSITY control for suitable trace brightness.

8. Rotate the HORIZONTAL positioning control to position the start of the trace at the left side of the graticule.
9. Adjust the AXIS ROTATION control until the trace is parallel to the horizontal centerline of the graticule.
10. Connect a T50/N125 adapter to the + RATE 50Ω connector so that the 50-ohm fittings match.
11. Connect a 2-nsec 125-ohm cable from the 125-ohm end of the adapter to the SIGNAL 125Ω connector.
12. Rotate the PULSE AMPLITUDE or SYNC control slowly counterclockwise until a stable display of the Rate Generator pulse is obtained. Center the waveform vertically using the VERTICAL positioning control.
13. Adjust the FOCUS, INTENSITY, and ASTIGMATISM controls until a sharp trace with adequate intensity is obtained. These controls are slightly interdependent and will require readjustment to obtain the best trace.

An external signal and/or trigger may now be applied to the input connectors. If external triggers are used, set the TRIGGER SOURCE switch to + or - EXT.

CRT CONTROLS AND GRATICULE

Intensity

The INTENSITY control is used to adjust the brightness of the oscilloscope display. Thus, compensation can be made for changes in brightness resulting from changes in the triggering rate or time-base rate. The INTENSITY control is rotated clockwise to increase brightness and counterclockwise to decrease brightness. Care must be taken when using the INTENSITY control that the brightness is not turned up to the point where the phosphor on the face of the cathode-ray tube (crt) becomes permanently damaged. The intensity of the beam should never be turned up to the point where a bright halo forms around a stationary spot.

Focus and Astigmatism

The FOCUS and ASTIGMATISM controls operate collectively to permit a sharp, clearly defined spot or trace to be obtained. The proper setting of the ASTIGMATISM control is obtained by rotating the FOCUS control fully clockwise, setting the PULSE AMPLITUDE or SYNC control fully counterclockwise, and setting the INTENSITY control high enough so the spot is visible (it may be necessary to adjust the POSITIONING controls). Then adjust the ASTIGMATISM control to obtain the most circular spot possible. The FOCUS control is then adjusted to reduce the spot diameter as much as possible. This method of spot adjustment is made with no input signal applied to the SIGNAL 125 Ω input connector. Also, the ambient light in the room should be kept low or the viewing hood should be used so the spot can be observed at a low intensity level.

Another method for adjusting the spot size would be to couple a 10-volt step waveform from either the RATE GENERATOR or the CALIBRATION-STEP GENERATOR to the SIGNAL 125 Ω connector. When the step waveform is displayed on the screen, the FOCUS control is adjusted to narrow the trace during the rising portion of the waveform. The ASTIGMATISM control is used to narrow the trace along the horizontal portion of the same waveform. Since the two controls interact, repeat the procedure to obtain a sharply-defined trace in both the vertical and horizontal direction.

Graticule

The disappearing graticule used with the Type 519 Oscilloscope is accurately marked with 6 horizontal and 2 vertical 1-centimeter divisions. The markings on the horizontal centerline are 5 millimeters apart; those on the vertical centerline are 2 millimeters apart. The graticule markings allow time and voltage measurements to be made from the oscilloscope screen.

To make the graticule disappear for a clear view of the screen, loosen the knurled knob located just below the graticule and slide it downward the full length of the slot. Tighten the knob. To make the graticule reappear, reverse the process.

The graticule cover and mask assembly is held securely in place by four slotted graticule nuts and is provided with hinge fittings for mounting the viewing hood. In addition, the hinge fittings allow quick removal of the viewing hood so that a Tektronix Model C12 or Model C19 camera may be mounted. The Model C19 camera is especially designed to photograph the fast sweeps of the Type 519 Oscilloscope. When the camera is not being used, it can be unlatched and swung away from the crt screen.

Graticule Illumination

The graticule is illuminated by two lamps located at the top edge of the graticule. The SCALE ILLUM. control, located below the oscilloscope screen, is rotated clockwise to increase the illumination of the graticule markings and counterclockwise to decrease the illumination.

Camera Jack

A camera jack, marked 6.3V CAMERA, provides a 6.3-volt source for use with the Type C19 camera. When the camera plug is inserted in the jack, the SCALE ILLUM control and oscilloscope graticule lights are automatically disconnected. The 6.3-volt source is utilized by the camera to project a virtual image graticule on the face of the crt. During projection of the image graticule, the oscilloscope graticule should be dropped out of view.

POSITIONING

Two controls, VERTICAL and HORIZONTAL, are used to allow the trace to be positioned to the desired point on the oscilloscope screen. A third positioning control, AXIS ROTATION, is used to align the trace with the horizontal centerline of the graticule.

The VERTICAL position control has sufficient range to allow the trace to be positioned completely off the top or bottom of the screen or to any intermediate point. The trace moves up when the control is rotated clockwise and down when the control is rotated counterclockwise.

The HORIZONTAL position control causes the trace to move to the right when it is rotated in the clockwise direction and to the

left when it is rotated counterclockwise. The total horizontal positioning range of the control is about 2 centimeters.

The AXIS ROTATION control is a screw-driver adjustment located between the VERTICAL and HORIZONTAL controls. This adjustment permits the trace to be rotated about an axis through the center of the screen. The control is adjusted to align the trace parallel to the horizontal centerline.

VERTICAL-DEFLECTION SYSTEM

Input Signal Connection

The electrical signal to be observed is applied externally through a 125-ohm coaxial cable to the SIGNAL 125 Ω connector. The signal passes internally first through a trigger-energy takeoff, then through a 45-nsec delay cable to the distributed vertical deflection plates of the crt. The signal causes the spot to be deflected vertically. The spot traces out the signal waveform on the screen as the spot is deflected horizontally by the horizontal sweep circuits. The vertical size of the displayed waveform is adjusted to a suitable amplitude by inserting external attenuators or an amplifier in series with the signal-carrying cable. Or, if the CALIBRATION-STEP GENERATOR is being used as the signal source, the vertical amplitude of the waveform can be adjusted by means of the CALIBRATION-STEP GENERATOR front-panel controls.

The vertical sensitivity of the Type 519 Oscilloscope is the same as the sensitivity of the crt mounted in the instrument. Each crt for the Type 519 is measured for sensitivity and risetime at the factory. These measurements are then clearly recorded on the crt face mask. The sensitivity measurement can be checked at any time by using the CALIBRATION-STEP GENERATOR.

To check the measurement, connect a 125-ohm cable from the OUTPUT 125 Ω connector to the SIGNAL 125 Ω connector. Set the (CALIBRATION-STEP GENERATOR) RANGE switch to 10V TO 125 Ω and rotate the VOLTS control to 10.00. Adjust the oscilloscope front-panel controls for a stable presentation of the step waveform. Rotate the VOLTS control counterclockwise until that portion of the waveform located 2 nsec after the rise is exactly one

centimeter high. The exact vertical sensitivity in volts per centimeter can now be read directly from the VOLTS dial.

For example, if the VOLTS dial shows a reading of 8.70, the vertical deflection factor is 8.7 volts per centimeter.

When connecting the oscilloscope to any signal source, the connections should be made directly through 125-ohm cables or through suitable impedance matching devices to the SIGNAL 125 Ω connector. If the signal amplitude is too great, it will be necessary to attenuate the signal to a usable level before applying it to the SIGNAL 125 Ω connector. This can be done by inserting a 125 Ω attenuator (or known attenuation factor) between the signal source and the SIGNAL 125 Ω connector. Attenuators may be used individually or may be "stacked" (connected in series).

If the signal amplitude is too low to produce sufficient vertical deflection, an external amplifier can be inserted between the signal source and the SIGNAL 125 Ω connector. However, if the amplifier does not provide the correct input and output impedance, or has limited bandwidth, signal waveform errors may result. In addition, if the amplifier stages do not operate linearly the signal will not be reproduced faithfully on the crt.

In general, to obtain an accurate waveform display and to prevent unwanted reflection of high-frequency waveforms or of fast-rise pulses, all cables should be terminated in their characteristic impedances.

Delaying the Signal

The Type 519 Oscilloscope contains a fixed signal-delay line which permits the sweep to be well under way before displaying the leading edge of an input signal. By means of the fixed signal-delay line, the input signal is purposely delayed 45 nanoseconds before arriving at the vertical deflection plates. This amount of delay allows sufficient time for the trigger circuits to process the trigger signal and start the sweep.

The DELAY control delays the start of the sweep from 0 to 35 nanoseconds. Within this range of time, the DELAY control can be used to select the display time and thus apparently position the waveform horizontally on the screen.

For triggered sweep operation with externally-derived trigger signals, the time relationship of the external trigger signal to the input signal must fall within the adjustment range of the DELAY control. If, for example, too much delay is introduced by using long cables to couple the trigger signal to the EXTERNAL TRIGGER 125Ω connector, the input signal will arrive at the vertical deflection plates before the sweep is triggered. The input waveform, having arrived early, will not be displayed on the screen. To offset external delay of this type, shorten the external trigger cable, if possible. If this is not possible, cable can be added in series with the signal-carrying cable, but only at the expense of bandwidth.

The delay provided by a typical 125-ohm cable such as one of the RG-63/U cables (shipped with the oscilloscope) is approximately 1.2 nsec per foot. If any portion of the input waveform is displayed on the screen, the amount of delay which must be added or subtracted to display the waveform properly on the screen can be determined by the sweep rate and the number of divisions that the display must be moved. If the display must be moved to the right, less delay in the trigger cable is required.

When 30 megacycle or higher repetition-rate signals of identical shape and amplitude are being displayed, the DELAY control will always permit display of the complete waveform. If all waveforms are uniform, it is not important which is displayed. The internal delay line may be bypassed by direct connections to the crt if desired, at the sacrifice of internal triggering from the signal.

TRIGGER

Triggering (or Synchronizing) the Sweep

In most cases it is desirable for a repetitive waveform to appear stationary on the oscilloscope screen so that the characteristics of the waveform can be examined in detail. As a necessary condition for this type of display, the start of the horizontal sweep must be related to the input waveform. In the Type 519 Oscilloscope this is accomplished either by triggering or synchronizing the sweep with the displayed waveform or with another waveform bearing a definite time relationship to the displayed wave-

form. More information about the horizontal sweep is given in the Time Base portion of this manual.

The following paragraphs outline the various triggering controls in the TRIGGER section on the front panel, in the order normally encountered. Briefly, the order would be to set the TRIGGER SOURCE switch first, GAIN switch second, and FUNCTION switch third. Lastly, the PULSE AMPLITUDE or SYNC control is adjusted to obtain a stable display for "triggered" sweep operation. For "synchronized" sweep operation, both the PULSE AMPLITUDE or SYNC and VERNIER SYNC controls may be adjusted to obtain a stable display.

Selecting the Trigger Source

The sweep can be either triggered or synchronized (depending upon the setting of the FUNCTION switch) from the following waveform sources: (1) displayed waveform, (2) externally-derived waveform, (3) Calibration-Step Generator waveform, or (4) Rate Generator waveform. Trigger source selection is made by means of the TRIGGER SOURCE switch. Each trigger source has advantages for certain applications.

(1) Displayed Waveform. Triggering from the displayed waveform is the method most commonly used. The displayed waveform to be used as a trigger is selected when the TRIGGER SOURCE switch is set to either the +INT. or -INT. position. Internal triggering is convenient since no external triggering signal connections are required. A displayed pulse waveform that produces at least two trace-widths of vertical deflection is sufficient for reliable triggering.

(2) Externally-Derived Waveform. To trigger the sweep from some external waveform, connect the triggering waveform to the EXTERNAL TRIGGER 125Ω input connector. The external triggering waveform must be at least 20 millivolts in amplitude, with a time duration of 1 nanosecond or more. The maximum amplitude should not exceed +or- 2 volts peak except when the GAIN switch is set to X.2. In the X.2 position the external trigger should not exceed +or- 10 volts. Larger triggers may be attenuated externally. When an external triggering

signal is connected to the EXTERNAL TRIGGER 125 Ω connector, the TRIGGER SOURCE switch must be set to either +EXT. or -EXT.

External triggering provides definite advantages over other methods of triggering in certain cases. With external triggering, the triggering signal usually remains constant in amplitude and shape (depending upon the source). Also, time and phase relationships between waveforms at different points in the circuit can be seen. If, for example, the external triggering signal is derived from the waveform at the input to a device under test, it is possible to observe the shaping, jitter, amplification, or delay of the signal through the device without resetting the oscilloscope triggering controls for each observation.

(3) Calibration-Step Generator Waveform. In the +CAL or -CAL. positions of the TRIGGER SOURCE switch, the triggering signal is obtained internally from the CALIBRATION-STEP GENERATOR. The signal is derived through the use of a trigger pickoff circuit inserted near the termination of the generator. Therefore, it is necessary to keep in mind that the controls which set the output amplitude of the CALIBRATION-STEP GENERATOR also affect the amplitude of the triggering signal available at the +CAL. and -CAL. positions of the TRIGGER SOURCE switch. These two positions of the TRIGGER SOURCE switch are used when observing a waveform which is related to the output waveform of the CALIBRATION - STEP GENERATOR. It is then possible to observe and actually measure shaping, jitter, amplification, or delay at any point in the device under test. In addition, the requirement for a minimum signal height and duration can be circumvented.

(4) Rate Generator Waveform. The RATE GEN. position of the TRIGGER SOURCE switch provides triggering signals which can be varied to cover a continuous repetition-rate range from 3 cps to 30 kc. These signals can then be used to trigger the sweep at a known repetition rate within the above range. To select the RATE GENERATOR trigger, set the TRIGGER SOURCE switch to RATE GEN. Then set the MULTIPLIER switch and CYCLES/SEC control to the desired repetition rate.

Selecting the Trigger Polarity

The horizontal sweep can be triggered on either the rising (+slope) or falling (-slope) portion of the triggering waveform as determined by the position of the TRIGGER SOURCE switch.

In many applications the triggering polarity is important since triggering on one of the slopes will make it possible to observe the start of a pulse in pulse measurement applications. If the wrong slope is selected it may not be possible to observe the desired portion of the waveform. In many other cases, however, such as high-frequency repetitive waveforms, the triggering polarity is not important.

Selecting the Trigger Gain

A four-position GAIN switch permits incoming trigger signals to be attenuated or amplified as necessary for proper operation of the PULSE AMPLITUDE or SYNC control. The four gain settings are: X.2, NORMAL, X5, and X20. To aid in determining which GAIN switch setting to use for reliable triggering, Table 2-1 is included. Additional discussion will be found in the PULSE AMPLITUDE or SYNC control description.

Selecting the Trigger Function

Three functions or modes of operation are provided in the Type 519 Oscilloscope to cover a wide range of triggering conditions. They are: PULSE, SYNC, and HF SYNC.

Each of the triggering functions is designed to provide stable triggering from a certain type of waveform. For many applications, however, more than one function will trigger well. For applications where more than one function works well, the triggering function used is simply a matter of choice.

To determine the best trigger function to use for a particular application, it is best to have some understanding of all three before making a selection

Table 2-1

TRIGGER SOURCE Switch Setting	Approximate GAIN Switch Settings			
	X.2	NORMAL	X5	X20
RATE GEN.		Always use this setting		
+ or -CAL.*		8v to 50v	5v to 25v	0.5v to 8v
+ or -EXT.	1v to 10v (peak)	0.2v to 2v (peak)	0.1v to 0.5v	0.02v to 1v
+ or -INT.**	10v (pulse) to 100v (pulse)	2v to 20v (pulse)	1v to 5v	0.1v to 1.5v

Used for small amplitude triggers up to 200 mc.

*CALIBRATION-STEP GENERATOR output step amplitudes are listed. Approximately 2.5% of the step amplitude is coupled to the +CAL. and -CAL. positions of the TRIGGER SOURCE switch.

**Voltage ranges of signals applied to the SIGNAL 125 Ω connector are given. Approximately 12.5% of the signal amplitude is picked off and coupled to the +INT. and -INT. positions of the TRIGGER SOURCE switch.

The PULSE function permits choice of a free-running sweep or a stable sweep which can be triggered by signals at random or uniform repetition rates up to 50 mc. The upper repetition-rate limit varies, depending upon the regularity of the pulse period. The PULSE function when used in conjunction with the SINGLE SWEEP switch permits photographic recording of single events at any setting of the NANOSEC/CM switch.

The SYNC trigger function permits stable displays of waveforms occurring at a constant repetition rate up to approximately 200 mc. To make use of this function, the FUNCTION switch is placed in the SYNC position. The PULSE AMPLITUDE or SYNC control is used as a coarse synchronization control; the VERNIER SYNC control is used as a fine synchronization control to "lock in" the waveform to be observed.

The HF SYNC trigger function permits the sweep to be synchronized with high frequency signals from approximately 100 mc to 2 gigacycles. To use the high-frequency synchronization mode of operation, the FUNCTION switch

is placed in the HF SYNC position. The PULSE AMPLITUDE or SYNC and the VERNIER SYNC controls are used in conjunction with each other to lock the waveform.

Triggering or Synchronizing the Sweep

The last controls which are usually operated in the TRIGGER section of the front panel are the PULSE AMPLITUDE or SYNC control and its companion, VERNIER SYNC. These controls, as their names imply, are used for two functions: pulse amplitude selection and synchronization, depending upon the setting of the FUNCTION switch.

If the FUNCTION switch is set to the PULSE position, the PULSE AMPLITUDE (or SYNC) control is used for triggered sweep operation. The PULSE AMPLITUDE (or SYNC) control sets the minimum level at which a trigger can initiate the sweep. All triggers below the set level are rejected. In order for the control to operate properly within its rotational range, sufficient amplitude triggers must be available as explained earlier under Selecting the Trigger Gain. Triggering on small signals is best just before the arrow.

If the FUNCTION switch is set to either the SYNC or the HF SYNC positions, the (PULSE AMPLITUDE or) SYNC control is used for making the coarse synchronization adjustment. Final adjustment may be made with the VERNIER SYNC control. The sweep repetition rate will synchronize to the same frequency as the triggering signal or at some sub-multiple frequency.

In actual operation the VERNIER SYNC control is normally set at midrange until the coarse adjustment is made, then the VERNIER SYNC control is adjusted to obtain a stable display.

TIME BASE

Horizontal Sweep

The Type 519 Oscilloscope graphically presents instantaneous signal voltage versus time. The signal voltage produces a vertical deflection of the trace; time is represented through horizontal deflection. It is necessary for the spot formed by the electron beam to be deflected horizontally at a known rate. With this condition any horizontal distance on the screen represents a definite known period of time. The trace formed by the deflection of the spot across the screen is known as the horizontal sweep. Since the horizontal deflection of the spot bears a definite relationship to time and provides the means for making time measurements from the screen, the horizontal sweep is also known as the time base.

The settings of the NANOSEC/CM switch accurately determine the time-base rate. The time-base rates of the switch range from 2 nanoseconds per centimeter to 1000 nanoseconds (1 μ sec) per centimeter in 9 accurately calibrated steps.

Extreme care has been taken in design of the sweep generator to provide long-term stability of sweep calibrations and linearity.

Single Sweep Operation

The Type 519 Oscilloscope permits a single-sweep presentation to be obtained and eliminates all subsequent sweeps so the signal can be clearly recorded without confusion resulting from multiple traces. The single-sweep feature is selected by placing the NORMAL-SINGLE

SWEEP switch in the SINGLE SWEEP position. The RESET button must be actuated to 'arm' the time-base and permit a single-trigger event.

When the FUNCTION switch is placed in the PULSE position and the PULSE AMPLITUDE or SYNC control is set fully clockwise (past the RECURRENT arrow or line), a single sweep runs immediately each time the RESET button is depressed.

When the PULSE AMPLITUDE or SYNC control is set for triggered sweep operation, the single sweep does not occur when the RESET button is depressed. Instead, the READY lamp lights to indicate that the sweep is armed and ready to be triggered. When a trigger is received, the sweep runs once and the READY light goes out. Each time the RESET button is depressed the procedure is repeated.

When the FUNCTION switch is placed either in the SYNC or HF SYNC position, a single sweep runs immediately each time the RESET button is depressed regardless of the settings of the PULSE AMPLITUDE or SYNC control.

Synchroscope Operation

In the usual oscilloscope application, the sweep is triggered or synchronized by the input waveform. However, in some applications it may be more desirable to reverse the process and drive an external circuit from the oscilloscope. In this 'synchroscope' application, the sweep is caused to free run or to be triggered by the RATE GENERATOR. The output signal from either the + TRIGGER 50 Ω , the DELAYED + GATE or the + RATE 50 Ω connector is used to initiate the input waveform (see Fig. 2-3).

The sweep can be made to free run with any setting of the FUNCTION switch. If the PULSE position of the FUNCTION switch is used, the PULSE AMPLITUDE or SYNC control must be rotated fully clockwise past the RECURRENT arrow. The number of free-running sweeps per second is determined by the settings of the NANOSEC/CM switch (refer to Table 2-2).

TABLE 2-2

NANOSEC/CM Switch Settings	SWEEP REPETITION RATES (RECURRENT rates)
2	Adjusted to 400 kc
5	200 kc nominal
10	100 kc "
20	50 kc "
50	20 kc "
100	10 kc "
200	5 kc "
500	2 kc "
1000	1 kc "

In addition to providing the means for initiating an applied waveform, a recurrent sweep also provides a convenient reference trace on the oscilloscope screen without requiring an input signal. The trace can then be positioned to any desired point on the oscilloscope screen or can be used to establish a zero-voltage reference line.

Delayed Trigger

A delayed triggering pulse can be obtained from the DELAYED +GATE 50 Ω connector of the oscilloscope any time from approximately 0 to 35 nanoseconds after the trigger is accepted. The trigger pulse bears a fixed relation to the time of sweep start. The delayed triggering pulse can be used to initiate action at approximately the time of sweep start.

RATE GENERATOR

The output pulse from a transistor operating in the avalanche mode is coupled to the RATE GEN. position of the TRIGGER SOURCE switch and to the +RATE 50 Ω connector. The pulse risetime is less than 0.8 nanosecond, amplitude is nominally +15 volts, and duration is 10 nanoseconds. Calibration of the RATE GENERATOR is in cycles per second times a multiplier. To select a desired rate for triggering the sweep from the RATE GENERATOR set the TRIGGER SOURCE switch to RATE GEN. Then set the CYCLES/SEC dial to the significant figures and the MULTIPLIER dial to multiply by 1, 10, 100, or 1000 times. Any frequency between 3 cps and 30 kc can be selected within an accuracy of 10%.

Since the sweep can be triggered at the repetition rate set by the RATE GENERATOR from 3 cps up to 30 kc, this feature can be used for applications similar to those described previously under the headings "Selecting the Trigger Source", and "Synchroscope Operation". When the RATE GENERATOR is not used, it can be turned off by placing the MULTIPLIER switch in the OFF position.

CALIBRATION-STEP GENERATOR

Step Waveform

Step waveform from the CALIBRATION-STEP GENERATOR is generated by discharging a charged coaxial line into an external load through a magnetically-closed dry-reed switch. The physical length of the charged line determines the duration of the output step waveform. In the Type 519, with no external charge line added, the step duration is equal to twice the transit time of the built-in 1.5-nsec charge line. Transit time of the charge line is defined as the time required for a signal to pass from one end of the line to the other. For the 1.5-nsec charge line then, the duration of the output pulse is 3 nsec.

An additional charge line (cable) may be added to the Charge Line Connector located next to the Trigger Takeoff (see Fig. 2-4). When an additional charge line is added, the Line Charging Network and the Charging Source Voltage are disconnected. Then they are reconnected to the open end of the charge line.

The Line Charging Network performs two purposes: (1) Reduces effective reed switch capacitance and (2) provides an energy coupling source for the charge line.

(1) The reed switch presents a capacitive load across its contacts just before closure, at which time the pulse is generated. This load bleeds off energy from the charge cable and results in a lower voltage pulse than the indicated charging voltage. This is minimized by adding a 125 Ω terminating resistor and a large energy source in the form of a capacitor behind the reed switch. This capacitor is large enough to supply this energy without loss of amplitude. The 47-k resistor recharges the capacitor before the next pulse comes along. This causes the trailing edge of the pulse to

have an rc decay of approximately 0.4 μ sec (see Fig. 2-5).

(2) The Line Charging Network provides a means for coupling the energy source to the charge line. The energy source is a dc voltage controlled by the front-panel VARIABLE, RANGE, VOLTS, and POLARITY controls.

Polarity

Step polarity, either positive or negative, is controlled by the POLARITY switch. The polarity of the step is the same as the polarity of the charge voltage.

Amplitude

Step amplitude is dependent upon the amount of charging voltage used. The charge voltage obtained from the charging source is 2 times the peak pulse voltage present at the OUTPUT 125 Ω connector when driving an external 125-ohm load. The peak pulse voltage reading is accurately indicated by the settings of the RANGE and VOLTS control.

When the VOLTS control is set to 10.00 the RANGE switch permits a choice of two full-scale step amplitudes, 10 volts or 1 volt. When the RANGE switch is placed in the 10V (TO 125 Ω) position, 10 volts into a 125-ohm impedance is obtained. When the RANGE switch is set in the 1V (TO 50 Ω) position, a T50/T125 adapter must be connected to the OUTPUT 125 Ω connector to obtain a 1-volt amplitude step into a 50 ohm load.

The scale of the VOLTS control, when used with either of the two above RANGE switch positions, indicates the step amplitude. The VOLTS control is the 0 to 1 multiplier for the two ranges.

When the RANGE switch is set to the VARIABLE position, the step amplitude may be preset by the VARIABLE control to any uncalibrated amplitude from 0 to approximately 50 volts when driving a 125-ohm impedance. To determine the amplitude of the step for any setting of the VARIABLE control, apply the step waveform from the OUTPUT 125 Ω connector through a 125-ohm cable to the SIGNAL 125 Ω connector. Measure the amplitude of the vertical deflection in centimeters and multiply the distance measured by the sensitivity of the oscilloscope.

Adjusting the Drive and Frequency

Two convenient front-panel controls, DRIVE and FREQUENCY, control the movement of the dry reed switch. These controls are adjusted in conjunction with each other to cause the reed to make-and-break contact reliably.

To adjust the two controls, they must first be preset fully counterclockwise. Then advance the DRIVE control until the reed vibrates (makes a buzzing sound). Advance the FREQUENCY control until the reed fails to operate and then rotate the control slightly counterclockwise to start the reed operating again. Rotate the DRIVE control counterclockwise while rotating the FREQUENCY control back and forth to find the resonant frequency of the reed. The resonant frequency is found when the drive is decreased to a point where the reed will vibrate in one small rotational area of the FREQUENCY control range. For optimum operation the DRIVE and FREQUENCY controls are then adjusted in conjunction with each other to obtain the most stable waveform at the resonant frequency of the reed. When adjusting the DRIVE control, use enough drive to get a solid closure of the reed contacts. The resonant frequency of most reeds is usually within the range of 700 to 800 cps.

NOTE

To extend the life of the reed switch when the CALIBRATION-STEP GENERATOR is not being used, set the RANGE control to STANDBY.

ACCESSORIES

A number of accessories are included with the Type 519 Oscilloscope. Those which require more information pertaining to their use are described in this portion of the manual.

(1) 125 Ω Termination

The 125 Ω Termination (Fig. 2-6) is supplied as a replacement for the T519A crt termination. The unit can be used to terminate any 125-ohm cable, tuned stub, or other similar applications.

(2) 125Ω Adapter T50/T125*

This adapter (Fig. 2-7) is commonly known as a minimum loss attenuator. Designed to match a 50-ohm line to a 125-ohm line, the attenuator presents minimum loss and no reflection. It contains a network composed of a shunt and a series resistor. Though the attenuator presents a correct impedance match in either direction, the insertion loss (43.5%) is greater than the N50/N125 adapter which is described next.

(3) 125Ω Adapter N50/N125*

Also called an unterminated adapter connector, this accessory (Fig. 2-8) is straight-thru connector which connects a 50-ohm line directly to a 125-ohm line. This unit is used for pulse applications. If a pulse is applied to the 50-ohm end of the adapter, the pulse amplitude is 1.425 times greater at the 125-ohm end than if it had been terminated with 50 ohms. Since it is not a constant-impedance unit, it should not be used for terminating high-frequency continuous-wave signal sources. When it is used, the abrupt discontinuity inherent in the unit causes a reflection to occur which may interfere with the waveform on display unless certain precautionary measures are taken.

To prevent a reflection from occurring on the displayed waveform, make the combined electrical length of the 50-ohm cable and the adapter equal to or more than $T/2$, where T is the length of the pulse to be observed. This accessory is not generally used to handle a signal traveling in the reverse direction.

(4) 125Ω Adapter T50/N125*

This adapter is usually called a 50-ohm termination adapter and the internal circuitry is shown in Fig. 2-9. In actual use the 83.3-ohm resistor is shunted by the 125-ohm input impedance of the oscilloscope. The combined resistances present a total shunt impedance of 50-ohms to the signal source.

The adapter is designed to handle pulse or continuous-wave signals originating from a 50-ohm source. Maximum signal voltages can then be applied to the input of the Type 519 Oscilloscope with minimum loss.

This pad terminates the 50-ohm system so no reflections occur at this pad. Any possible reflections would have to originate at the end of the vertical deflection system. The vertical deflection system has 45 nsec of delay before it is terminated in 125-ohms, therefore any mismatch reflection would occur 90 nsec from the start of the pulse. The reflection is relatively small because the VSWR of the vertical system is 1.25 or better.

*The letter "T" in the adapter type means "Terminated"; "N" means "Not terminated".

(5) 125Ω Insertion Unit

This unit is a hollow coax connector with access holes located on each side of the cylinder to permit small components to be mounted inside. A snap-on sleeve cover permits adequate shielding of components and minimum discontinuity in the line. The unit can be used for making attenuators, filters, impedance matching circuits, testing devices, and many other networks.

(6) 125Ω Coupling Capacitor

The 125Ω Coupling Capacitor connector contains a silvered-ceramic, wafer-type capacitor connected in series with the inner conductor. The conductors are butt-soldered to the capacitor (see Fig. 2-10).

This unit is normally used for ac-coupling high-frequency signals with minimum reflections to the Type 519 Oscilloscope. Low-frequency signals and dc are blocked. Its characteristics are:

Coupling Capacitance: 0.01 μ f, GMV.

Voltage Rating: 400 volts.

Reflection Loss: Negligible

(7) 125Ω 1 KMC Ringing Circuit

The 125Ω 1 KMC Ringing Circuit is a Sweep Calibrator which is used to make periodic sweep calibration checks of the 2- and 5-nanosec/cm sweep rates.

To use the Sweep Calibrator, set the CALIBRATION-STEP GENERATOR Range switch to VARIABLE. Rotate the VARIABLE control

fully clockwise. Adjust, if necessary, the DRIVE and FREQUENCY controls for stable reed operation. Set the POLARITY switch to +. Connect a 2-nsec 125-ohm cable from the OUTPUT 125Ω connector to the Sweep Calibrator. Connect the other end of the Sweep Calibrator to the SIGNAL 125Ω connector.

Set the TRIGGER SOURCE switch to +CAL., GAIN switch to NORMAL and the FUNCTION switch to PULSE. Set the NANOSEC/CM switch to 2. Adjust the PULSE AMPLITUDE or SYNC control for a stable display of the ringing waveform. Use the DELAY control to position the waveform horizontally. The amplitude of the waveform is typically about 0.2 cm to 0.3 cm. Sweep timing is correct when two cycles per centimeter are aligned with the graticule markings, starting one centimeter from the start of the sweep. If sweep timing is not accurate, remove the left-side panel from the instrument and adjust the 2 nSEC control (R732A) for a correctly-timed display.

Set the NANOSEC/CM switch to 5. Exactly five sine-waves per centimeter should be displayed if sweep-rate timing is correct, starting 1 cm from the start of the sweep. If not, adjust the 5 nSEC control (R732B) for correct sweep timing.

(8) 125Ω Delay Cables

Different length cables are supplied for use in coupling the signal and/or trigger to the appropriate input connectors on the front panel of the Type 519 Oscilloscope. The loss per foot of cable when used with the Type 519 is 0.6 db at 1 gigacycle. The delay time marked on each cable is the time required for a signal to travel from one end of the cable to the other.

(9) 125Ω Cable Connector Parts

(a) Double Button Assembly. Used for replacing a defective insert in any of the 125-ohm front-panel connectors or cable connectors.

(b) Panel Adapter Assembly. Replacement for any of the front-panel 125-ohm connectors.

(c) 125Ω Cable Connector. Replacement for any of the cable connectors.

(10) Reed Switch

Two spare reed switches are included as replacements for the reed switch used in the CALIBRATION-STEP GENERATOR. To replace the reed switch proceed as follows:

Remove the four mounting screws which hold the OUTPUT 125Ω connector to the front panel. Grasp the connector and pull straight out from the front panel to extract the attached coax tube assembly. The complete assembly is about 18" long and contains the reed switch (see Fig. 2-11). Take apart and remove the OUTPUT 125Ω connector to expose the location of the reed switch. Grip the metal end of the reed switch with long-nosed pliers and pull the reed switch out.

To install the replacement reed switch, remove the 125-ohm double button assembly from the conductor sleeve. Connect the button center conductor to one end of the reed switch to serve as a holder. Plug the other end of the reed switch into the center conductor located inside the tube. Look through the small hole in the side of the tube to see that the switch and conductor are properly connected. Align the slots in the connector parts. Screw the connector fittings together to complete the assembly. Insert the assembly through the front panel while holding the OUTPUT 125Ω connector in correct upright position (similar to the position of the flanges of the EXTERNAL TRIGGER 125Ω connector) so the connector at the far end will match correctly. Mount the OUTPUT 125Ω connector securely to the front panel with the four screws.

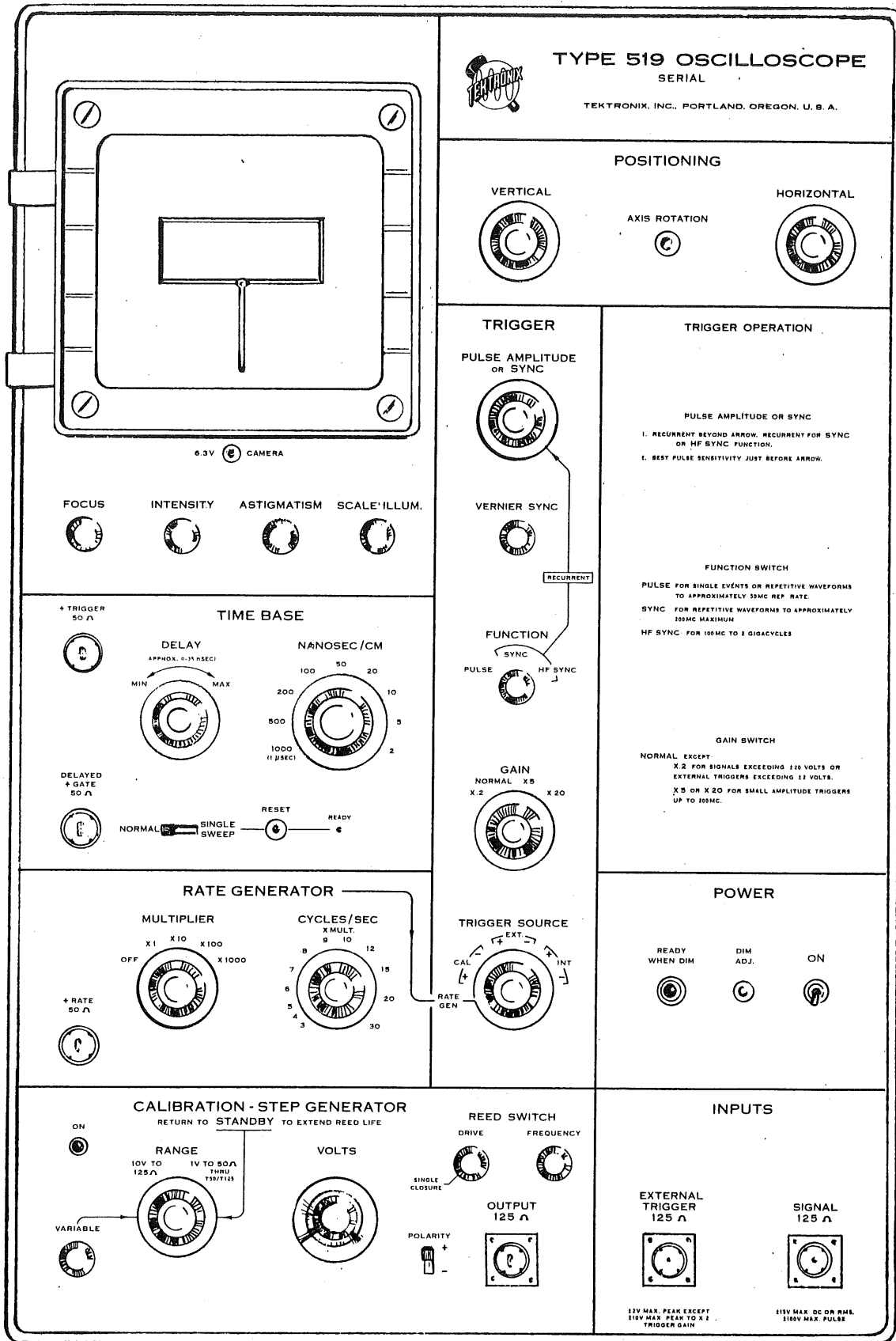
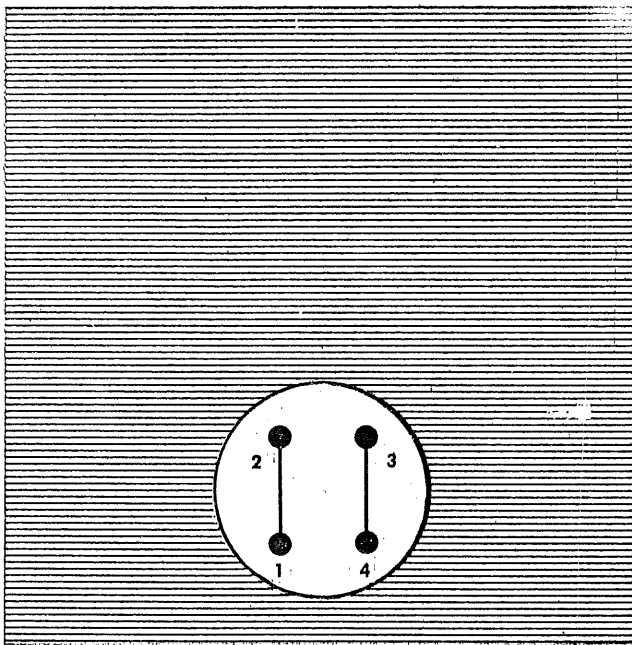
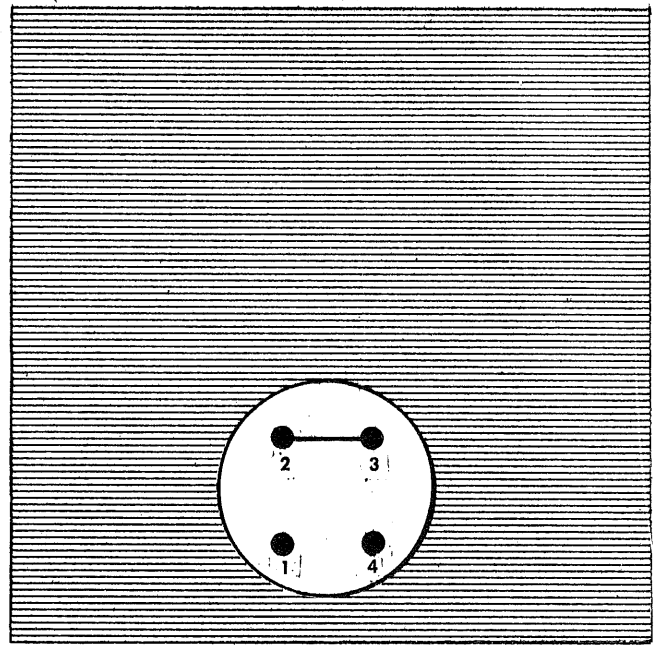


Fig. 2-1. The Type 519 Oscilloscope.



117-VOLT OPERATION



234-VOLT OPERATION

Fig. 2-2. For 117-volt operation terminal 1 of the power transformer (T601) is connected to terminal 2, and terminal 3 is connected to terminal 4. For 234-volt operation, terminal 2 is connected to terminal 3.

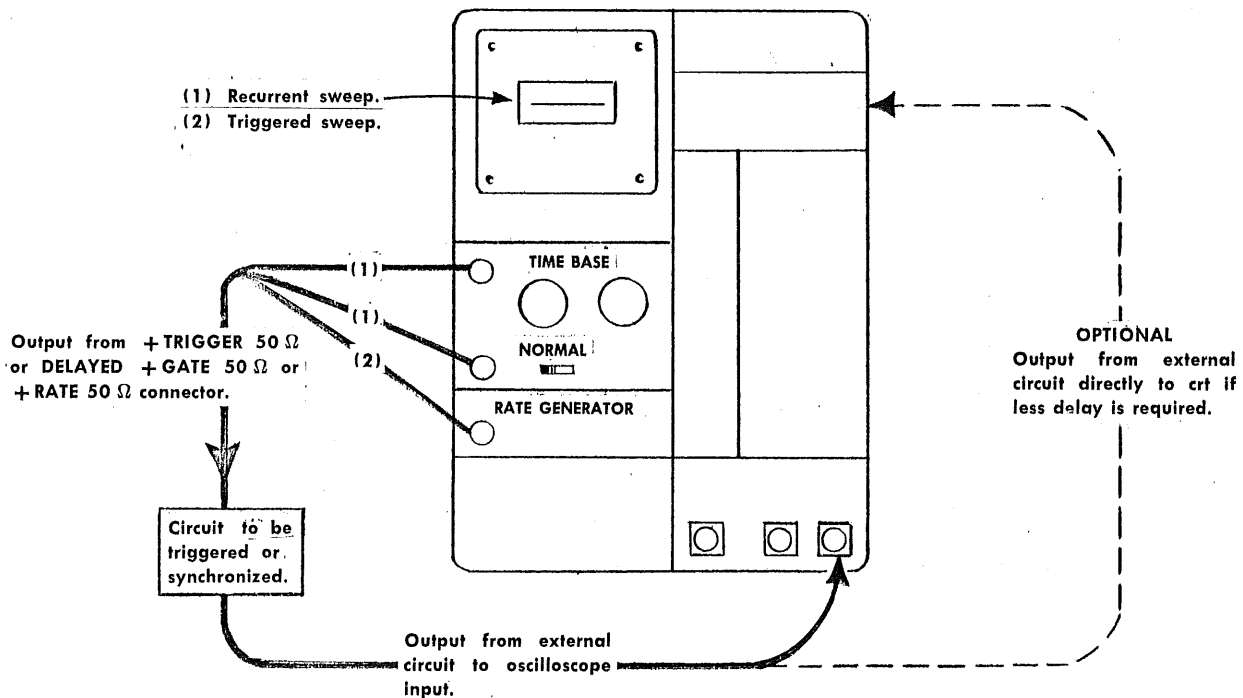


Fig. 2-3. Using the +Trigger, the Delayed +Gate, or the +Rate waveforms to drive an external circuit. For (1) PULSE AMPLITUDE or SYNC control is set past the arrow to RECURRENT. For (2) TRIGGER SOURCE switch is set to RATE GEN., and FUNCTION switch to PULSE; the PULSE AMPLITUDE or SYNC control is set for triggered sweep operation.

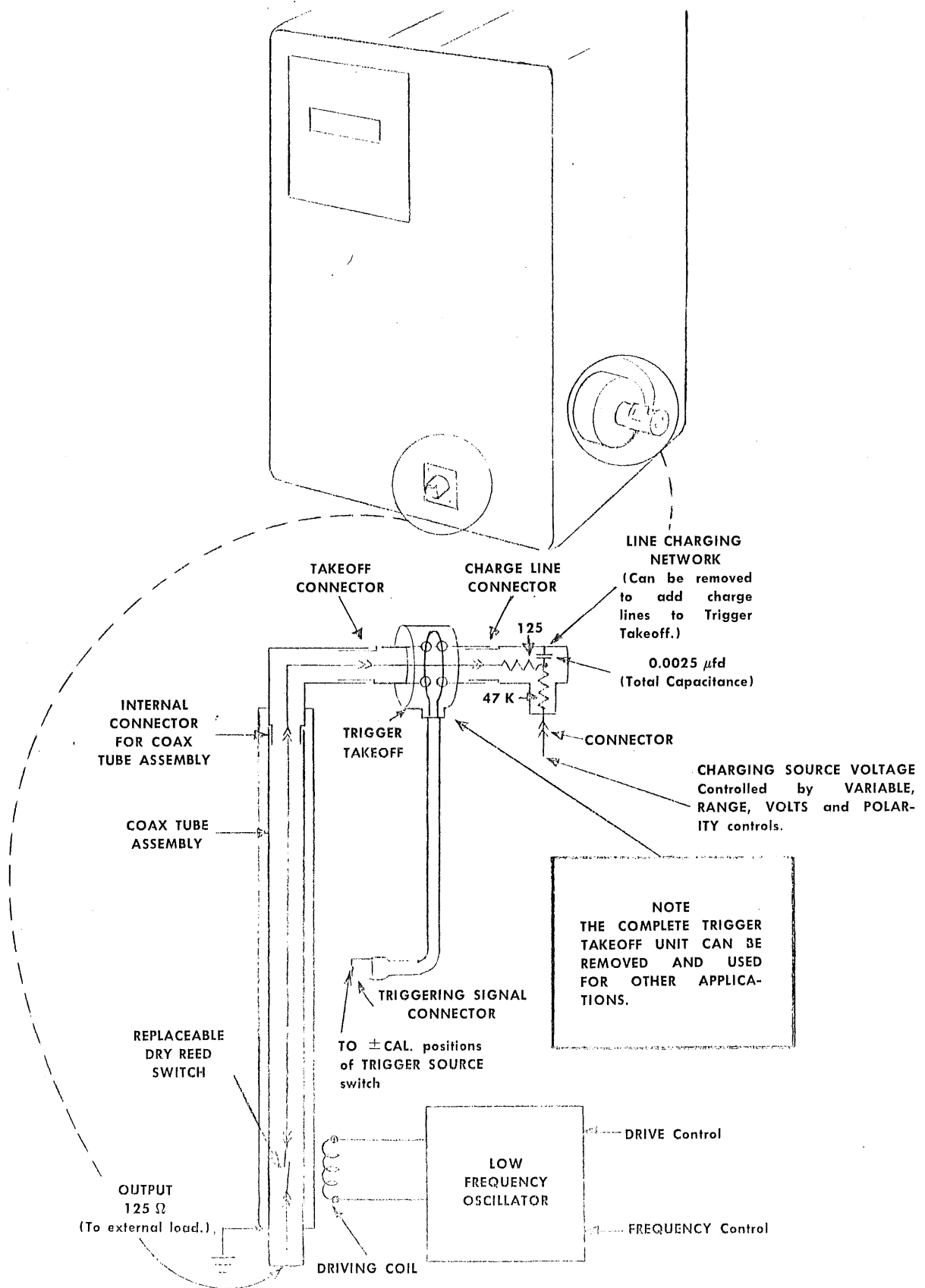


Fig. 2-4. Drawing of the CALIBRATION-STEP GENERATOR.

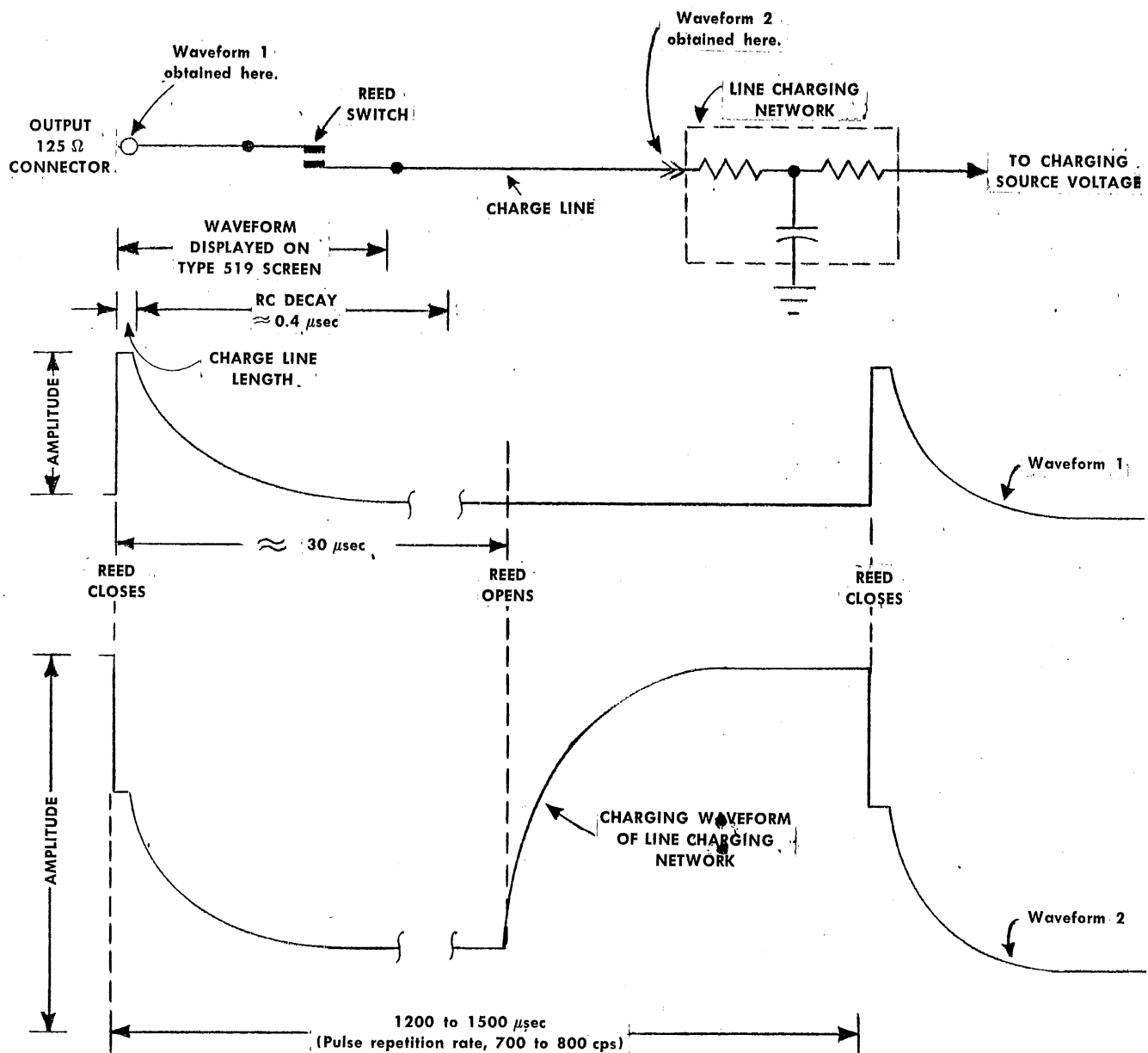


Fig. 2-5. Time relationship of waveforms obtained from the CALIBRATION-STEP GENERATOR.

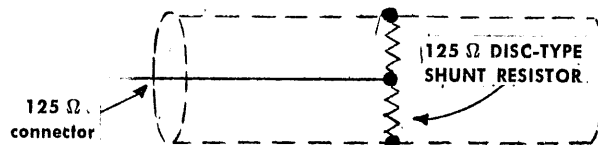


Fig. 2-6. Construction of the 125 Ω Termination.

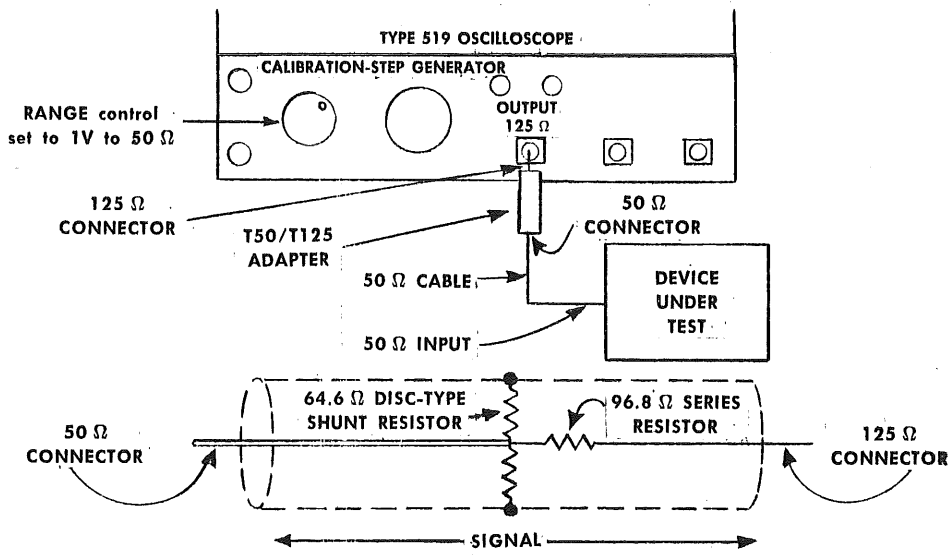


Fig. 2-7. Construction of the T50/T125 Adapter and a typical application.

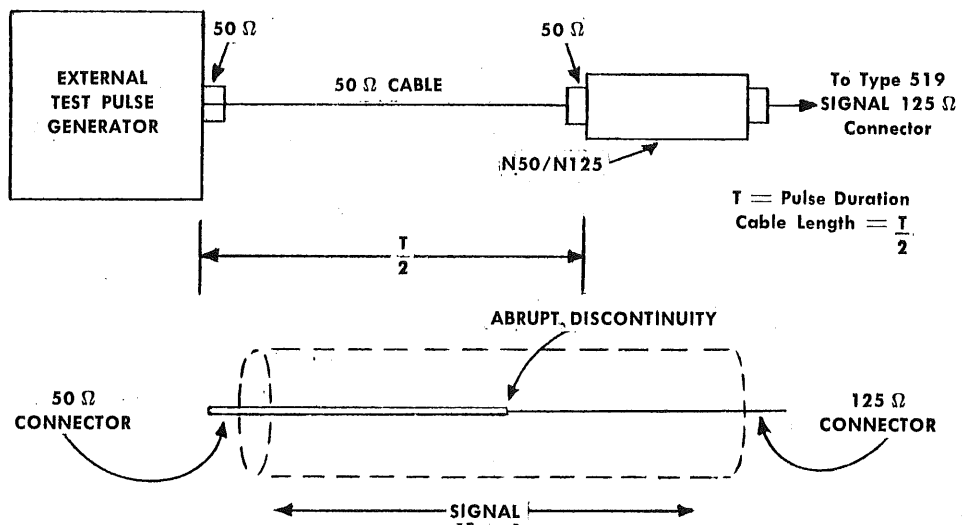


Fig. 2-8. Construction of the N50/N125 Adapter and a typical application.

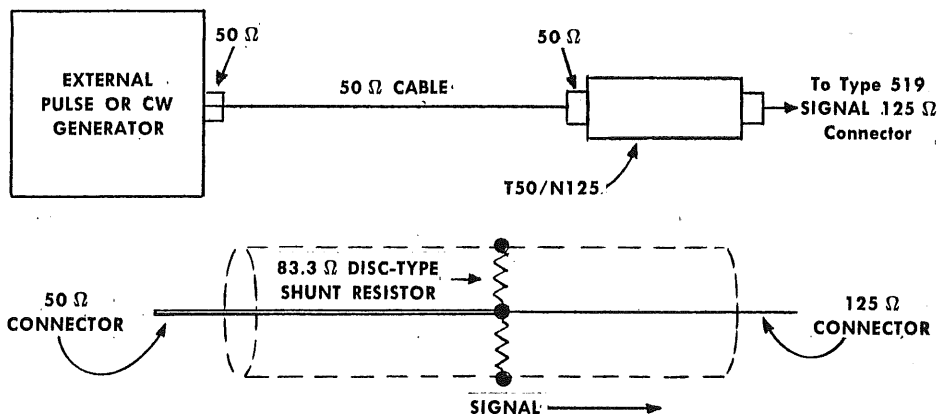


Fig. 2-9. Construction of the T50/N125 Adapter and a typical application.

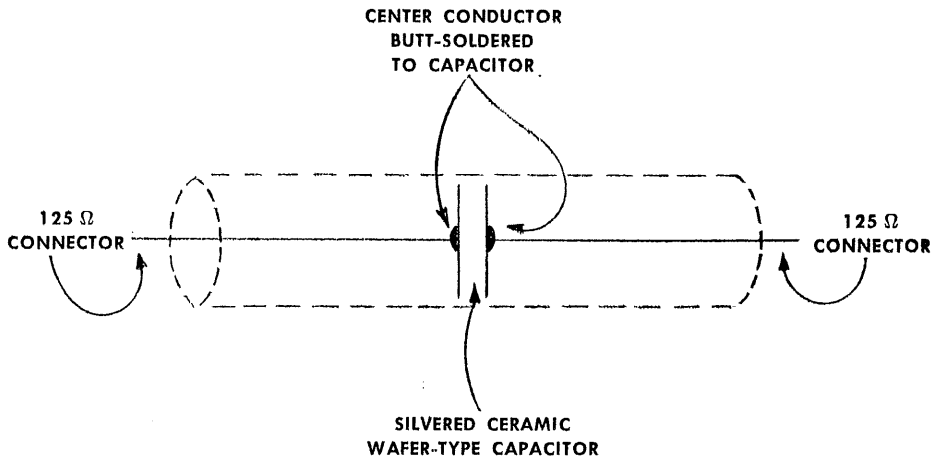


Fig. 2-10. Construction of the 125 Ω Coupling Capacitor.

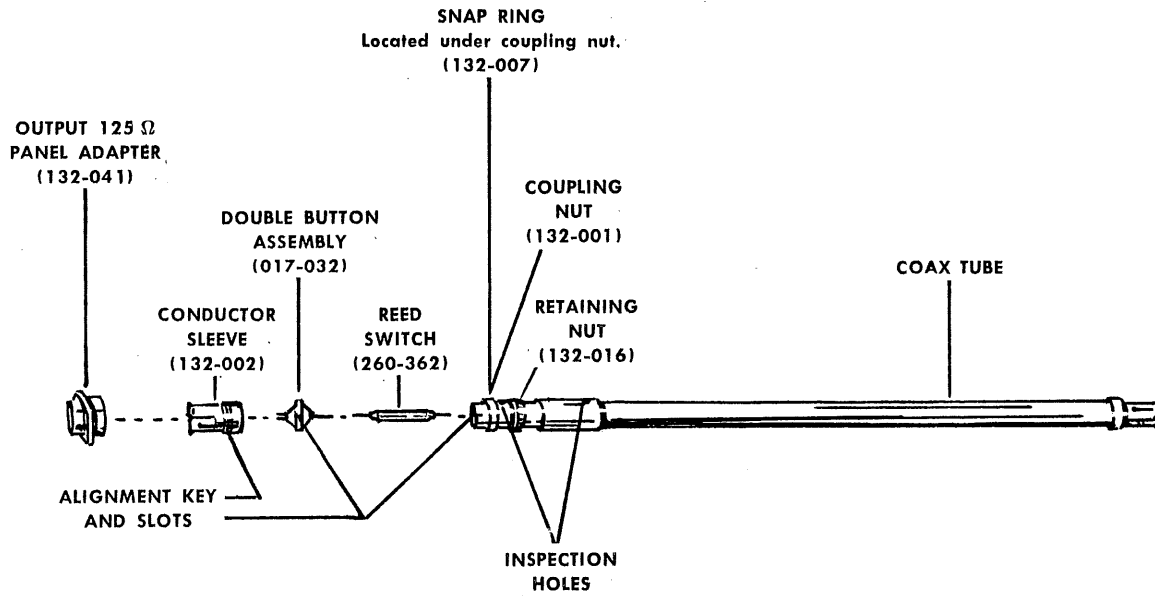
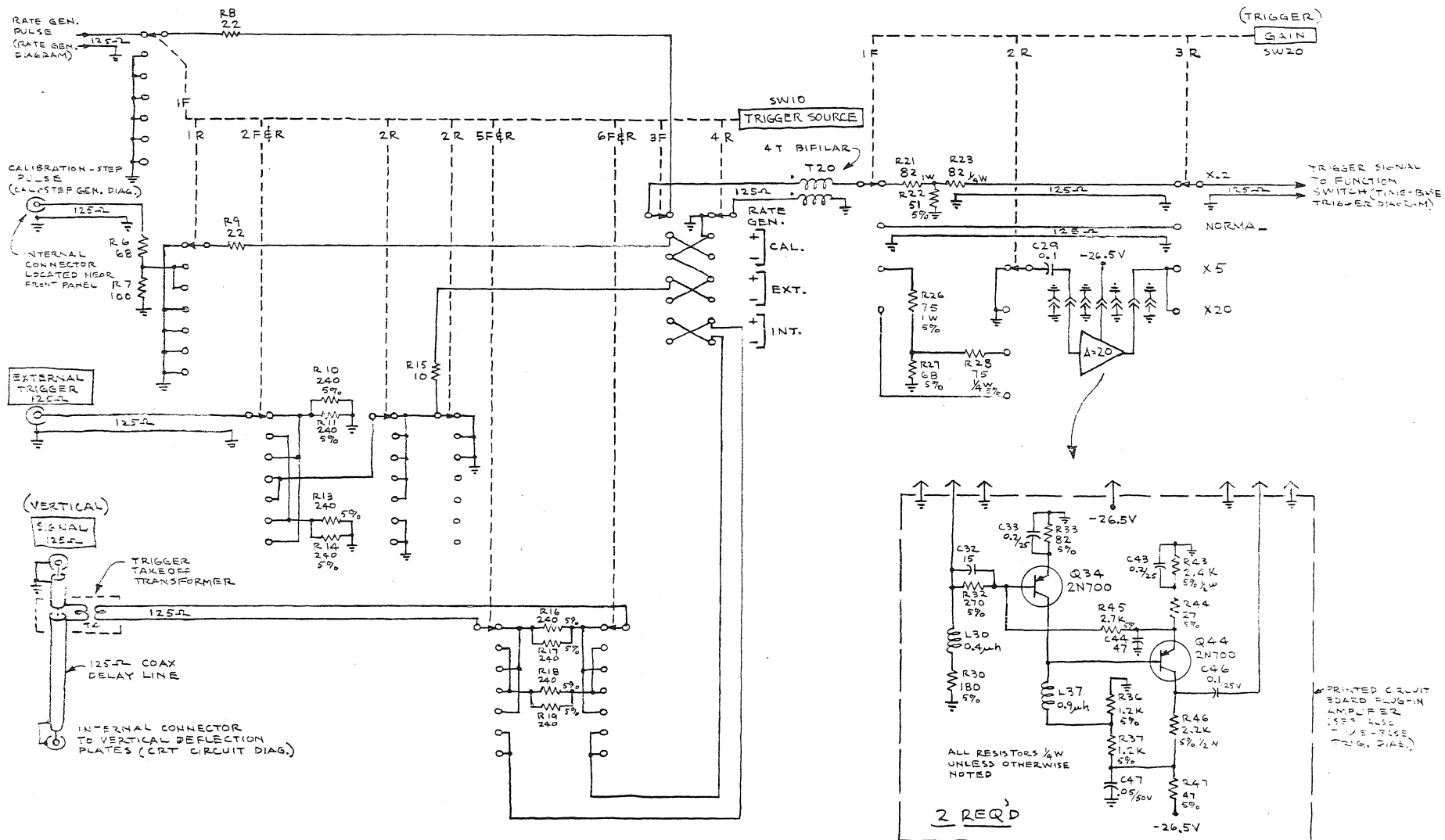
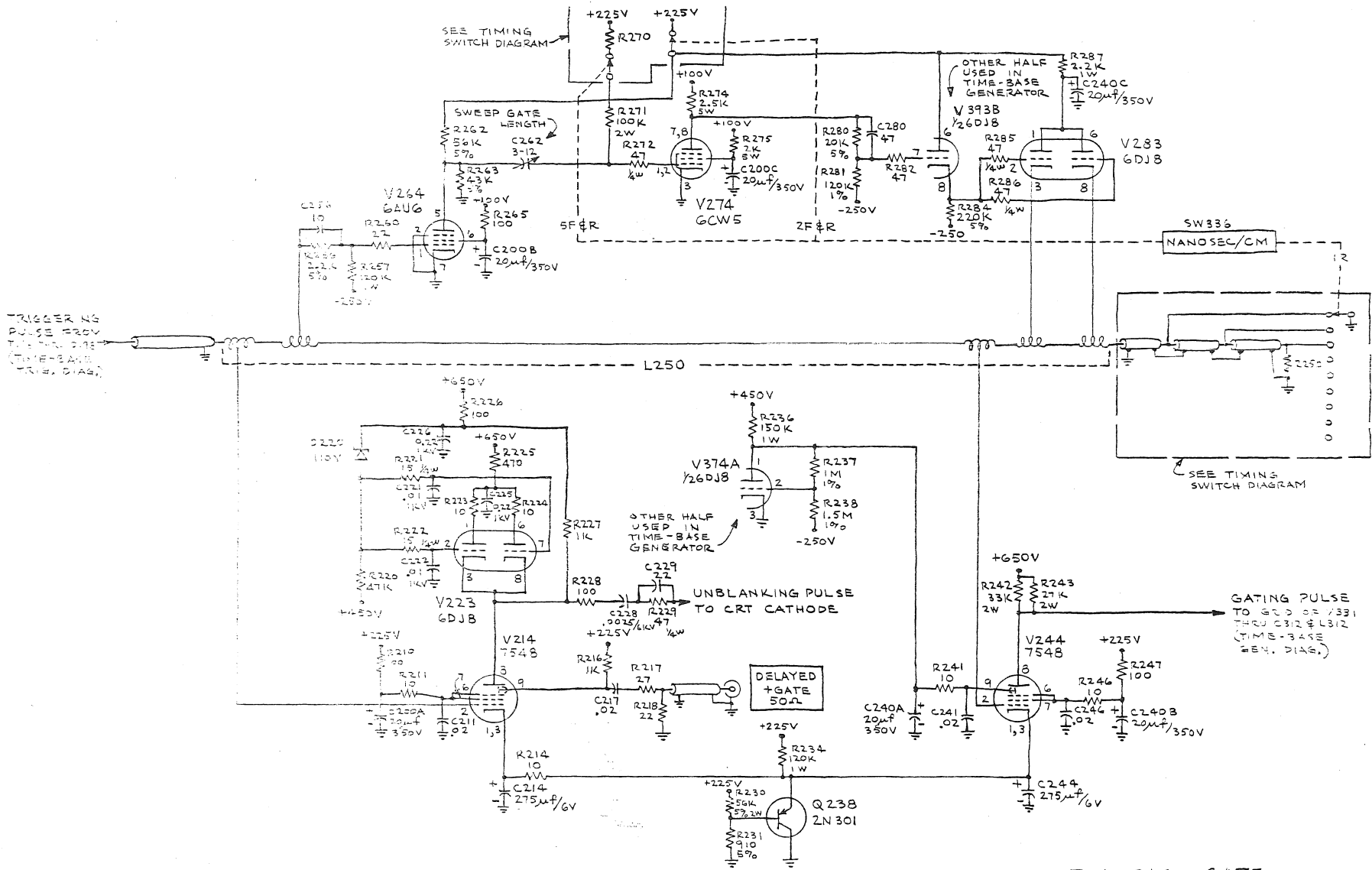


Fig. 2-11. Exploded view of the coax tube assembly. The Snap Ring, Coupling Nut, and Retaining Nut are not removed from the tube when replacing the reed switch.



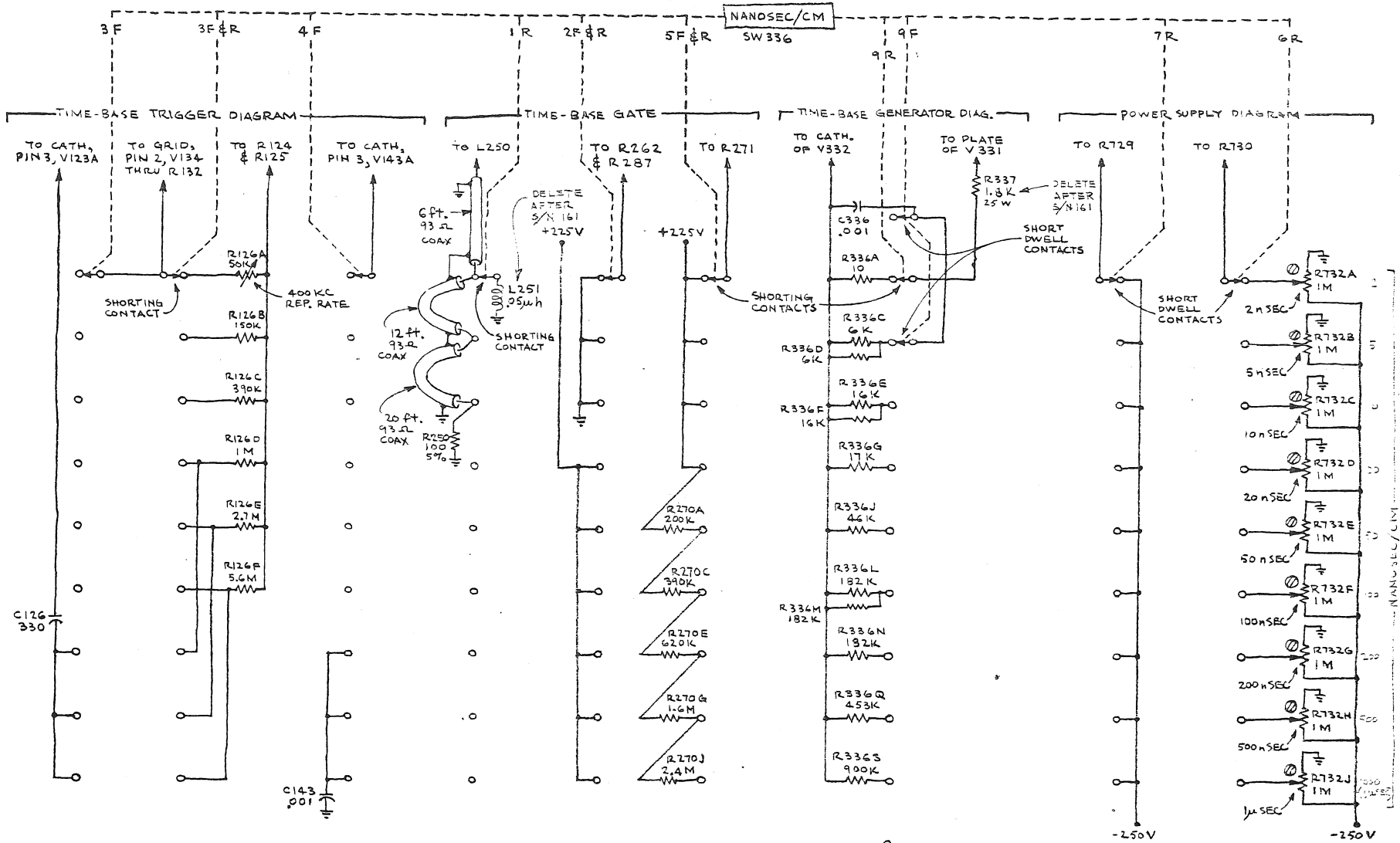
TYPE 519 OSCILLOSCOPE

TRIGGER SWITCH & VERTICAL DELAY LINE



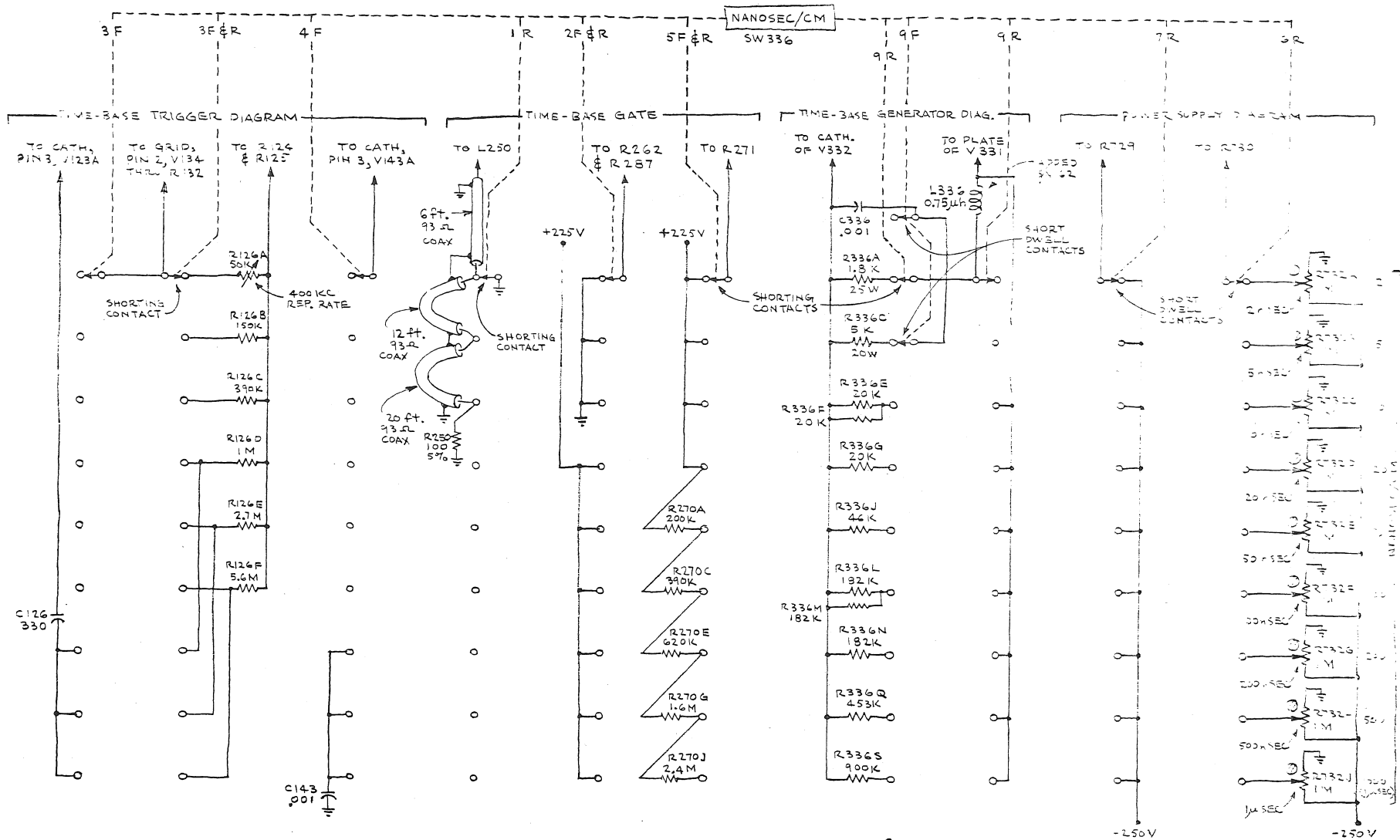
TYPE 519 OSCILLOSCOPE

TIME-BASE GATE & UNBLANKING



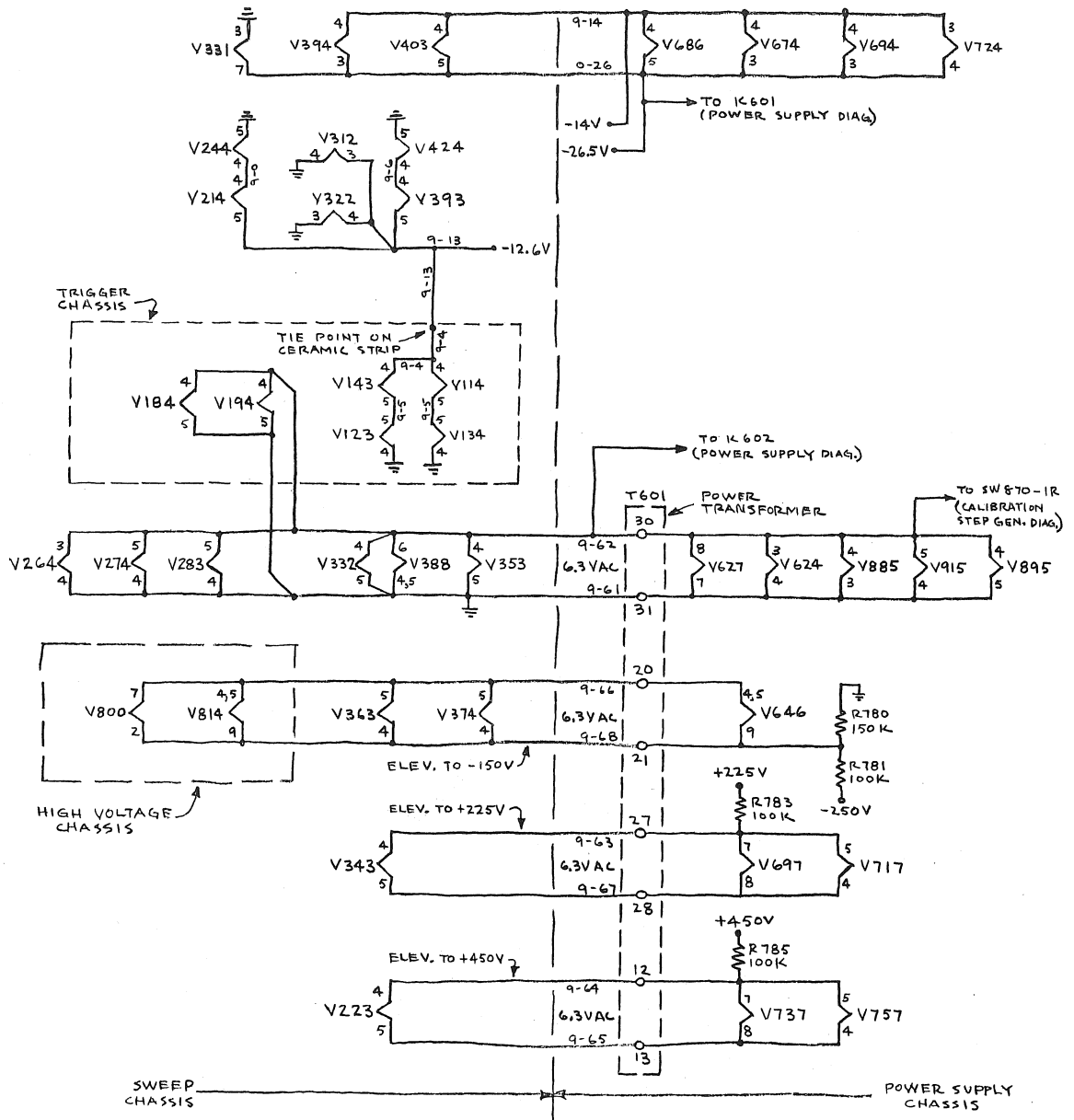
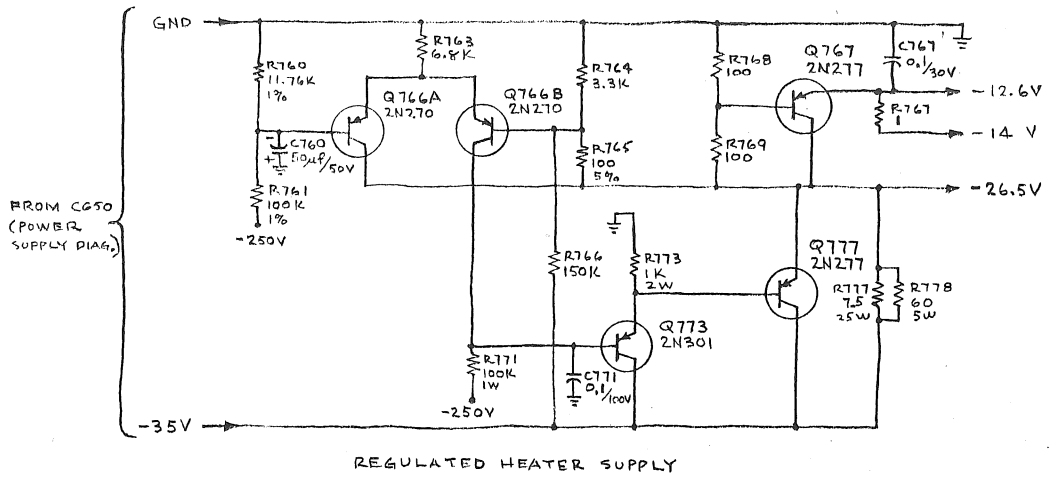
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TYPE 519 OSCILLOSCOPE

TIMING SWITCH

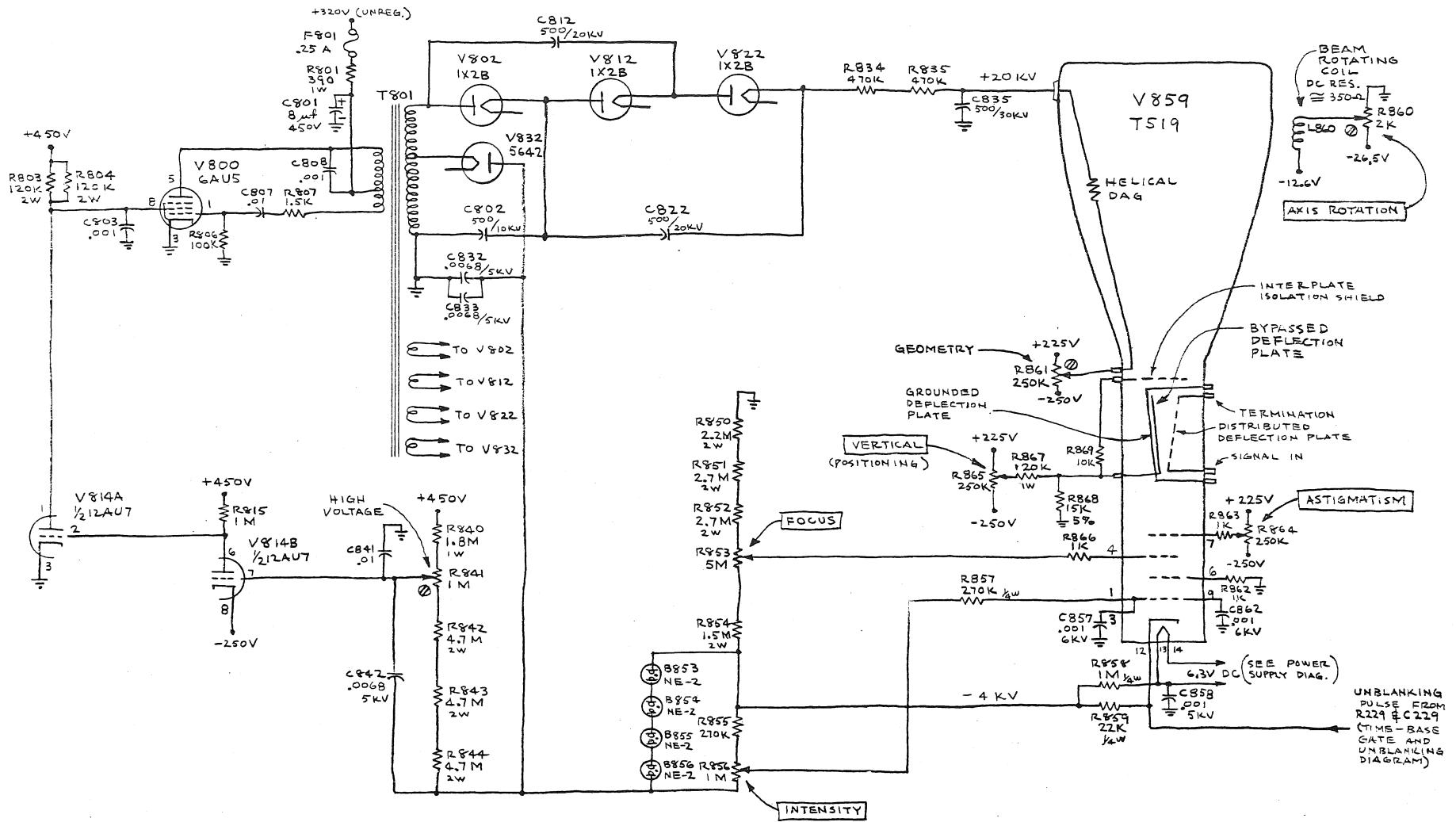


S/N 162
 TYPE 519 OSCILLOSCOPE

TIMING SWITCH

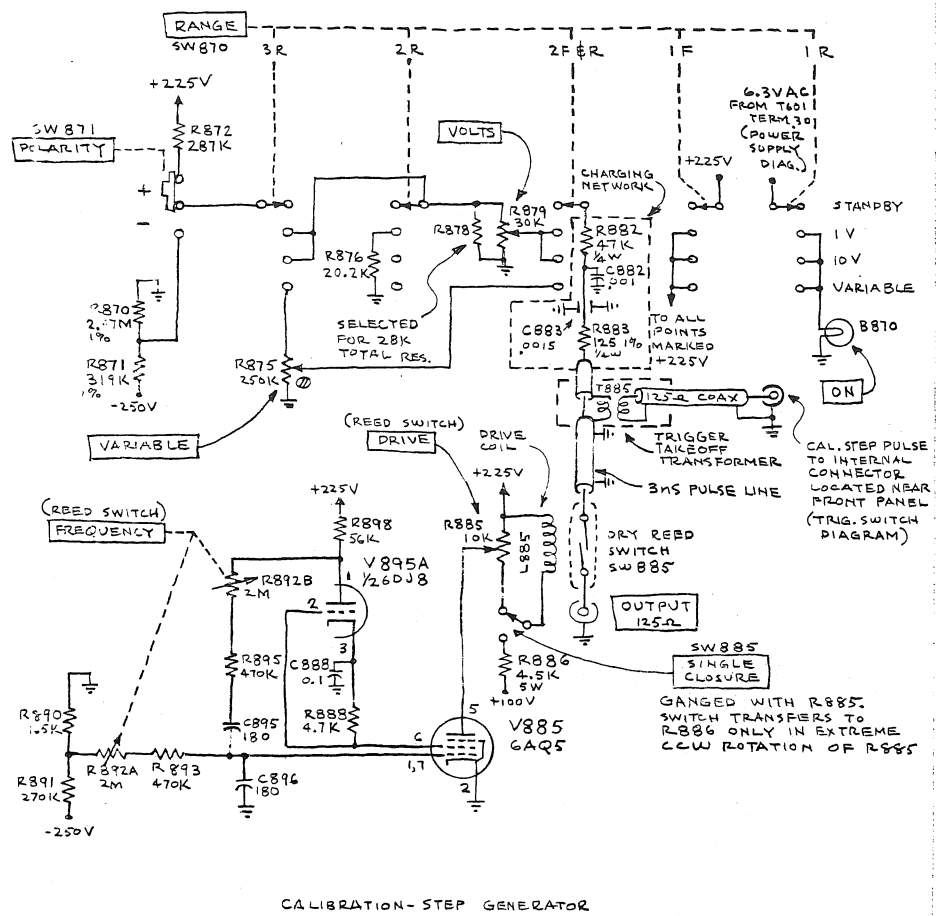


TYPE 519 OSCILLOSCOPE



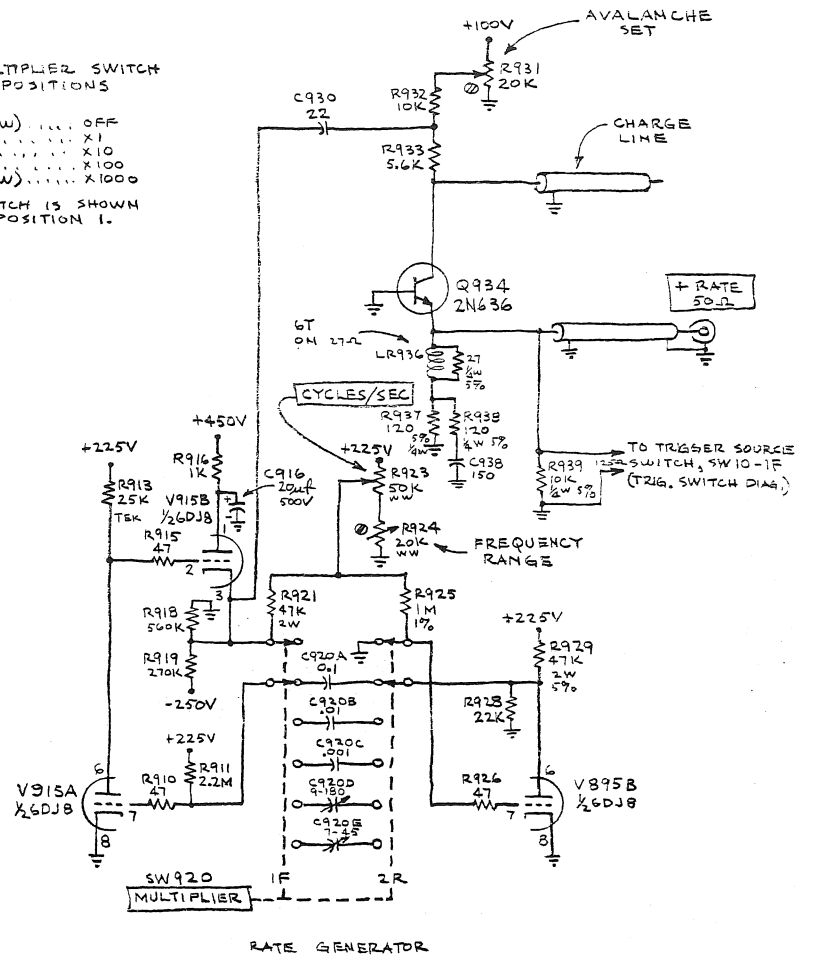
TYPE 519 OSCILLOSCOPE

CRT CIRCUIT



TYPE 519 OSCILLOSCOPE

MULTIPLIER SWITCH POSITIONS
 1 (CCW) OFF
 2 X1
 3 X10
 4 X100
 5 (CW) X1000
 SWITCH IS SHOWN IN POSITION 1.



CALIBRATION-STEP GENERATOR & RATE GENERATOR