TEKTRONIX®

TYPE 1S2
SAMPLING UNIT
S/N 1990—UP

INSTRUCTION MANUAL

Tektronix, Inc.
P.O. Box 500
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Serial Number ____________________

070-0889-00

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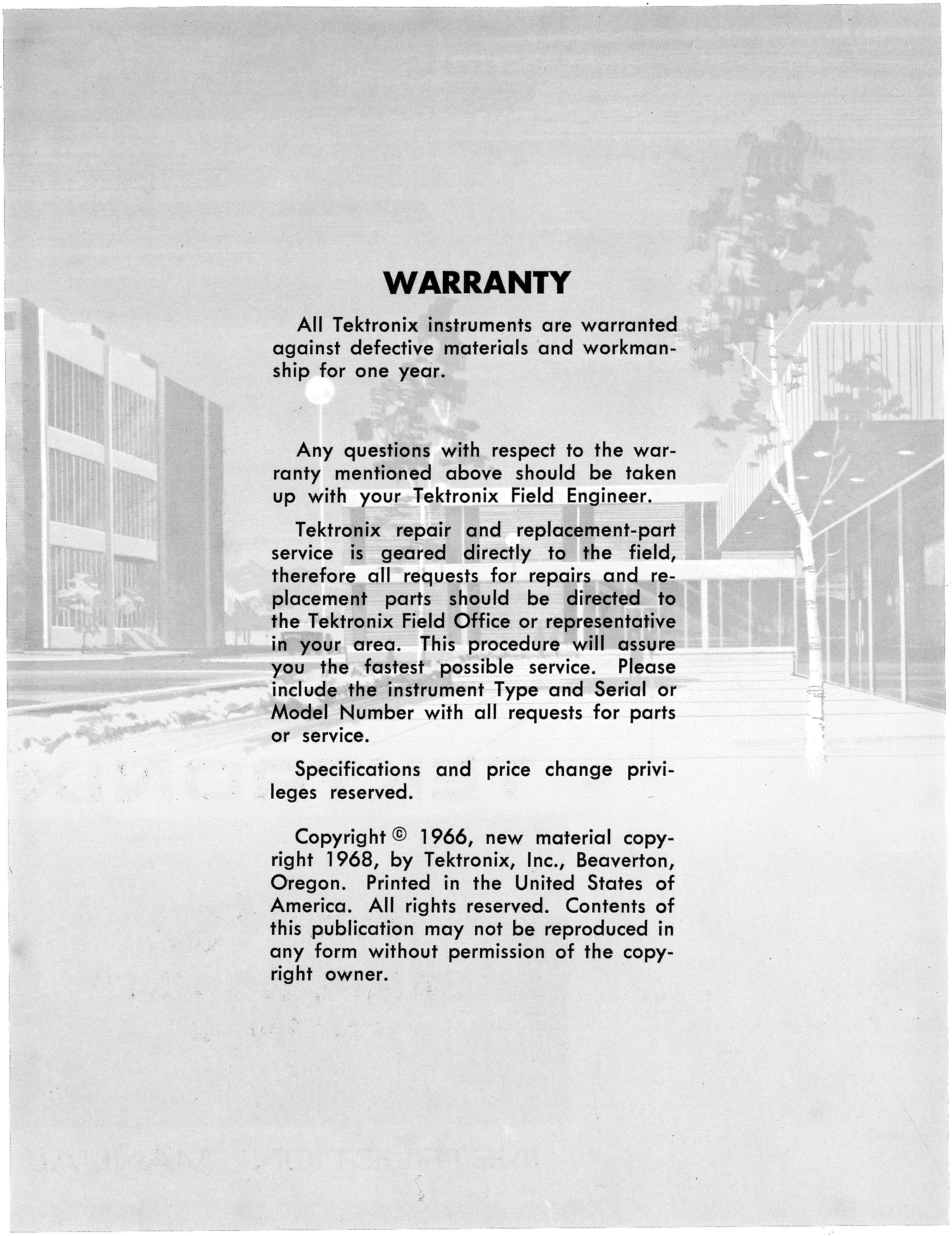


WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year.

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

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

Specifications and price change privileges reserved.

CONTENTS

Abbreviations and symbols used in this manual are based on, or taken directly from, IEEE Standard 260 "Standard Symbols for Units", MIL-STD-12B and other standards of the electronics industry. Change information, if any, is located at the rear of this manual.

Fig. 1-1. Type 1S2 Sampling Unit.

SECTION 1
CHARACTERISTICS

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

The Tektronix Type 1S2 Sampling Unit is a DC to 3900 MHz multiple purpose sampling plug-in unit. It will operate in any Tektronix 500-series Oscilloscope that will accept 1-series or letter-series plug-in units. The Type 1S2 provides both the vertical and the horizontal information to the oscilloscope during equivalent-time sampling.

Normal signal sampling operation or special coaxial cable Time Domain Reflectometry (TDR) testing are the main features of the Type 1S2. The sampler step-response 10% to 90% risetime is 90 picoseconds (ps) or less in a 50 Ω environment. The sampler is a two-connector through-signal channel for viewing signals within a 50 Ω transmission line, or at the end of a terminated 50 Ω transmission line. Unterminated sampler through-channel DC resistance is approximately 5000 Ω, useful during low frequency real-time sampling operation.

The vertical channel is calibrated for either volts or reflection coefficient (ρ) in seven steps from 0.005 to 0.5 in a 1-2-5 sequence. A Variable control can either increase or decrease these deflection factors for complete coverage between calibrated deflection factors. Minimum uncalibrated deflection factors are: approximately 0.002 Volts/div or 0.002 ρ/div.

The horizontal axis of the display is calibrated for either Time or Distance in three major ranges and 21 steps from 100 ps/div to 1000 ns/div Time, and from 1 cm/div to 100 meters/div Distance. Time or Distance units/div are displayed by an illuminated readout panel for ease of interpreting the display. The illuminated panel Units lamps are turned off whenever the Magnifier Variable control is not at its CAL detent position. Maximum uncalibrated sweep rates with the Range control at .1 μs—10 m and Magnifier at ×100 are: ≤28.75 ps/div Time and ≤0.275 cm/div Distance.

Distance calibration is dependent upon the position of a Dielectric switch that provides correct horizontal deflection factors for the different propagation velocities of AIR, solid TFE, or solid POLYETHYLENE dielectrics. Other dielectrics that cause intermediate propagation velocities can be tested after the operator adjusts the front panel variable PRESET dielectric control so the horizontal units/div match the particular line being tested.

The horizontal units/div are automatically set to Time whenever the Type 1S2 is operated as a normal sampling plug-in unit.

Two internal step-function pulse generators provide a selectable test signal during TDR operation. One provides a 0.25-volt 50 ps 10% to 90% risetime pulse and the other provides a 1.0-volt 1 ns 10% to 90% risetime pulse, each at a source impedance of 50 Ω. Other TDR features include a two-position RESOLUTION switch, signal-related vertical OFFSET (positioning) voltage and time related horizontal POSITION control that indicates the Time or Distance Position of the time window start as a percentage of the unmagnified ten division time window. These controls (OFFSET and POSITION), allow accurate slide-back measurements of both the magnitude and location of TDR signals.

Critical analysis of any TDR display is possible through the use of either a storage oscilloscope or a photograph. Storage displays are obtained by using the Type 1S2 in a Tektronix Type 549 Storage Oscilloscope. Permanent record photographs of CRT displays are possible with any one of several Tektronix Oscilloscope Cameras.

Modes of Operation

The two general operating modes of the Type 1S2 are as a Time Domain Reflectometer and as a normal signal sampling oscilloscope. Four display modes perform for both general operating modes. (1) Normal repetitive sweeps for general CRT viewing. (2) Single Sweep, where the desired display can be caused to traverse the CRT horizontally once, without repeating until required. (3) Manual scan; the display is converted to a single spot that can be moved horizontally at a hand operated rate convenient to the operator. And (4) External scan; the display is a single spot (as in Manual Scan) that is caused to traverse the horizontal axis at a rate set by any external drive signal. (The oscilloscope main frame time-base Sawtooth Out signal can be connected to the external input to sweep the display at very slow rates.)

Vertical and Horizontal output signals permit the Type 1S2 to drive X-Y or Y-T recorders. Or, the recorder can control the CRT scan rate (through the EXT INPUT) and the Type 1S2 Vertical output signal will then control the pen recorder Y axis. Output signal jacks have a 10 kΩ output impedance.

ELECTRICAL CHARACTERISTICS

The following characteristics apply over an ambient temperature range of 0° C to +50° C, except as otherwise stated. These characteristics apply only after the Type 1S2 has been properly mated to the oscilloscope and after a warm-up time of at least 20 minutes. A procedure for mating the Type 1S2 to each oscilloscope can be found in the Operating Instructions (Section 3) of this manual.

VERTICAL SYSTEM

General Characteristics	Performance Requirement	Supplemental Information
Risetime 10% to 90% (sampling operation)	Not more than 90 ps from +15° C to +35° C.	Internal adjustment may be required between 0° C to +15° C and +35° C to +50° C. Use Cal Procedure Step 34 using setup of Step 26.
Risetime 10% to 90% (TDR operation)	Not more than 140 ps from +15° C to +35° C.	Measured t_r of reflection from shorted end of 20 cm air line driven by 0.25 V Pulser. Adjustment may be required as above.
THRU SIGNAL CHANNEL 50 Ω Loop Impedance (Z_o)		Nominally 50 Ω
Input Signal Range	Signals between +2 V and —2 V limits may be displayed at any deflection factor (Vertical Units/Div switch setting). Safe overload is ±3 V if Thru Signal Channel is coupled directly to the EXT TRIG INPUT connector; ±5 V if not.	
Reflections from within THRU SIGNAL CHANNEL	Not more than 10%.	Displayed during first 500 ps after 0.25-V Pulser incident step, during TDR operation.
Noise (tangential) (sampling mode operation)	Not more than 2 mV.	Ignores occasional +5% and —5% peaks. RESOLUTION Sw at NORMAL.
Deflection Factors	0.005 to 0.5 units/div in seven calibrated steps.	Steps in a 1-2-5 sequence, either VOLTS or ρ.
Accuracy	Within 3% of indicated deflection when VARIABLE control is at CAL detent position.	Viewed at CRT.
Variable units/div	Counterclockwise rotation from CAL position changes vertical deflection factor to at least 2 times the units/div setting; clockwise rotation changes deflection factor to 40% or less of the units/div setting.	Counterclockwise rotation increases deflection factor (decreases sensitivity); clockwise rotation decreases deflection factor (increases sensitivity).
OFFSET Controls Voltage Range	Not less than —2 V to +2 V.	Referred to the input.
×1 OFFSET OUTPUT Voltage Range	Not less than —2 V to +2 V.	
×1 OFFSET OUTPUT Voltage Accuracy	±1% of full scale. (Referred to any fixed vertical display position).	Through 10 kΩ. Accuracy valid into infinite impedance voltmeter. (1 MΩ meter causes —1% error to Performance Requirement tolerance.)
VERT OUTPUT Jack voltage accuracy (referred to input)	$\frac{\text{Input Signal}}{\text{UNITS/DIV Sw}}$ = VERT OUTPUT (volts) ±1%.	Maximum output, ±10 Volts. (Variable Units/Div control does not affect VERT OUTPUT signal referred to input).
Deflection Factor (referred to CRT display)		1 volt per displayed division when VARIABLE is at CAL.
Source resistance		10 kΩ, ±1% resistor.

HORIZONTAL SYSTEM

POSITION Range Accuracy	±1% of full scale.	Maximum range is between 9.90 and 9.96.
Magnifier VARIABLE Range	Not less than a 2.5:1 increase in sweep rate from the CAL position.	
HORIZ OUTPUT Jack 1 V/DIV Accuracy	Within 2%.	Relationship of time to volts, not related to CRT display.
Source resistance		10 kΩ, ±5% resistor.
Horizontal Units/Div TIME	1000 ns/div to 100 ps/div in 21 steps, in a 1-2-5 sequence.	
Accuracy	Within 3%; except 100 ns ramp with ×50 and ×100 magnifier, within 5%.	Related to CRT display when oscilloscope Ext Horiz set for 1 volt/div, ±1%.

HORIZONTAL SYSTEM *(cont)*

General Characteristics	Performance Requirement	Supplemental Information
DISTANCE	100 meters/div to 1 cm/div in 21 steps in a 1-2-5 sequence.	Observed as not more than 140 ps risetime from shorted end of 20 cm air line while pulser feeds THRU SIGNAL Sampler through the 10 inch GR Connector Cable.
Accuracy		Dependent upon dielectric material in line tested.
DIELECTRIC Switch propagation velocities and accuracy.	AIR: 1 × c, ±3%. Solid TFE: 0.695 × c, ±3%. Solid POLYETHYLENE: 0.659 × c, ±3%.	Related to speed of light, c, where c = 30.0 cm/ns.
PRESET (Variable dielectric range).	From 1 × c, to between 0.6 and 0.65 × c.	
EXT HORIZ Jack Input horizontal deflection factor.	Variable from less than 2 volts/div to more than 15 volts/div.	
Maximum input voltage	150 volts combined DC plus AC peak.	

SAMPLING MODE TRIGGERING

External Triggering Trigger Jitter		
Sine Waves: 350 kHz, 500 mV peak to peak.	Not more than 100 ns.	EXT TRIG Operation.
100 MHz, 500 mV peak to peak.	Not more than 100 ps.	EXT TRIG Operation.
Pulses: 1 ns risetime 80 mV step pulse	Not more than 100 ps.	EXT TRIG Operation, for both positive and negative pulses.
Sine Waves: 5 GHz	Not more than 30 ps.	UHF SYNC Operation, tested according to Step 15 of the Performance Check procedure in this manual.
Maximum input voltage to EXT TRIG connector.	+3 or —3 volts DC and combined AC peak.	

1.0 V, 1 ns, PULSE SOURCE

Pulse 10% to 90% risetime	Not more than 1.1 ns from +15° C to +35° C.	Observed by terminated THRU SIGNAL Sampler through the 10 inch GR Connector Cable. .25 V, 50 ps, PULSE SOURCE (Pulse 10% to 90% risetime)
Display aberrations (Pulse Flatness Deviation)	Not more than + and — 2.5% after pulse display reaches 100%.	When display system is as above and termination is GR 874-W50B supplied with the Type 1S2.
Pulser source impedance		Nominally 50 Ω, not tested.
Pulse amplitude into 50 Ω	From 0.9 to 1.0 volt.	
Displayed jitter	Not more than 20 ps.	When display system is as above.

.25 V, 50 ps, PULSE SOURCE

Pulse 10% to 90% risetime	Not more than 55 ps from +15° C to +35° C.	Observed as not more than 140 ps risetime from shorted end of 20 cm air line while pulser feeds THRU SIGNAL Sampler through the 10 inch GR connector cable. Adjustments may be required to Vertical System per Step 34 of Cal Procedure between 0° C to +15° C and +35° C to +50° C.
Display aberrations (Pulse Flatness Deviation)	Not more than + and — 7% in the first 500 ps after pulse display reaches 100%. Not more than + and — 3% P-P after the above 500 ps.	When displayed as above.

.25 V, 50 ps, PULSE SOURCE (cont)

General Characteristics	Performance Requirement	Supplemental Information
Pulser source impedance		Nominally 50 Ω. Not tested.
Pulse amplitude into 50 Ω	From 230 to 260 mV.	Typically 250 mV.
Displayed jitter	Not more than 20 ps.	When display system is as above.

POWER LINE VOLTAGE

Line voltage range	Will operate over an RMS line voltage range as stated for the Tektronix oscilloscope in which the Type 1S2 is operated.	Does not apply when plug-in extenders are used. May not operate correctly at low line voltage limits due to voltage drop in an extender.

ENVIRONMENTAL CHARACTERISTICS

Storage

Temperature— —40° C to +65° C.

Altitude—to 50,000 feet.

Operating

Operating temperature—0° C to +50° C.

0° C to +15° C and +35° C to +50° C possible by special adjustment.

Operating Altitude—Up to 15,000 feet.

MECHANICAL CHARACTERISTICS

	Height	7 inches	Approximate
Dimensions—	Width	5⅞ inches	dimensions
	Length	11 inches	including knobs and connectors.

Weight—8 pounds.

Construction—aluminum alloy chassis.

Finish—anodized and silk screened front panel.

Accessories

An illustrated list of the accessories supplied with the Type 1S2 will be found at the end of the Mechanical Parts List pullout pages following the schematic diagrams.

SECTION 2
TIME DOMAIN REFLECTOMETRY THEORY AND THE TESTING OF COAXIAL TRANSMISSION LINES

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

This section of the manual contains general and detailed descriptions of Time Domain Reflectometry (TDR) analysis of coaxial transmission lines. The section begins with a comparison between two test methods, sine wave testing and step function testing of transmission lines. Sine wave testing is known as frequency domain reflectometry (FDR) and step function testing is known as TDR. The FDR-TDR comparison is followed by a basic description of TDR testing principles; reflections from capacitors and inductors; reflections from resistive discontinuities; coaxial cable response to a step signal; and finally special applications.

This section, combined with the Operating Instructions of Section 3 should provide the experienced electronics technician with adequate information to effectively use the Tektronix Type 1S2 Sampling Unit.

A TDR system can measure lumped resistance and reactance as well as characteristic impedance within a transmission line. Measurement is by analysis of signals reflected from a step function signal sent into the line. TDR measurements provide such information as a function of distance from the transmission line input terminals, and in particular, show multiple discontinuities individually.

FDR-TDR Comparison

Frequency domain reflectometers, the slotted line and bridges, drive and observe the input terminals of a transmission line as a function of frequency. They do not locate discontinuities on a distance basis. As a result, measurement techniques and the unique advantages of such devices differ from those of TDR.

A pure resistance measured by either time domain or frequency domain devices will appear as an infinitely long lossless transmission line. Thus, a perfectly terminated short length of lossless line will yield the same information to both kinds of testing, and neither test system can locate the termination. However, if the termination includes a small inductive or capacitive reactance, both systems will indicate its presence, but the TDR system will show where in the line the reactance is located.

The following comparisons of TDR and frequency domain (FDR) devices are supported by four specific examples and illustrations.

1. FDR measures Standing Wave Ratio directly, but a TDR display can speed FDR testing by locating resonant frequencies of resonant networks prior to FDR testing.

2. TDR locates discrete discontinuities and permits analysis of their value. But FDR will indicate two different resonant discontinuities which may be located very close together when TDR may not.

3. FDR measures an antenna standing wave ratio directly while TDR will not. But TDR will locate faults more quickly and identify the type of fault more rapidly than will FDR, should a change in SWR indicate problems. The time domain display will validate a transmission line to an antenna, while frequency domain reflectometry cannot, unless the antenna is disconnected and the transmission line terminated.

4. TDR can locate small changes in transmission line surge impedance (such as a too-tight clamp holding a flexible line) while FDR will show whether or not the standing wave ratio is acceptable.

5. Both test systems will quantitatively evaluate single discrete reactances, with a higher degree of accuracy possible with FDR.

6. Both TDR and FDR have advantages, each being very valuable in its own way. Thus, the two systems complement each other and both aid where observations and measurements are required.

TDR vs FDR Measurements

A one pF discrete capacitor inserted in parallel with a transmission line will produce almost no TDR indication if the step pulse has a risetime of 1 nanosecond. The same capacitor will produce a significant reflection if the step pulse has a risetime of 150 picoseconds. A FDR test will produce a large standing wave ratio at the series resonant frequency determined by the capitance and its lead inductance. Such a discontinuity would require considerable time for proper FDR testing due to the numerous frequency test points, but with a fast rise TDR system the capacitance and resonant frequency can be quickly determined.

Fig. 2-1 shows waveforms and SWR curves of first a single capacitor and then two capacitors inserted in parallel with a transmission line. Note that the FDR measurement on the right side of the figure plainly shows the two resonant circuits of the two closely spaced small capacitors, while the TDR display at the left shows two resonant frequencies, but not in a manner to permit separation of the two capacitors.

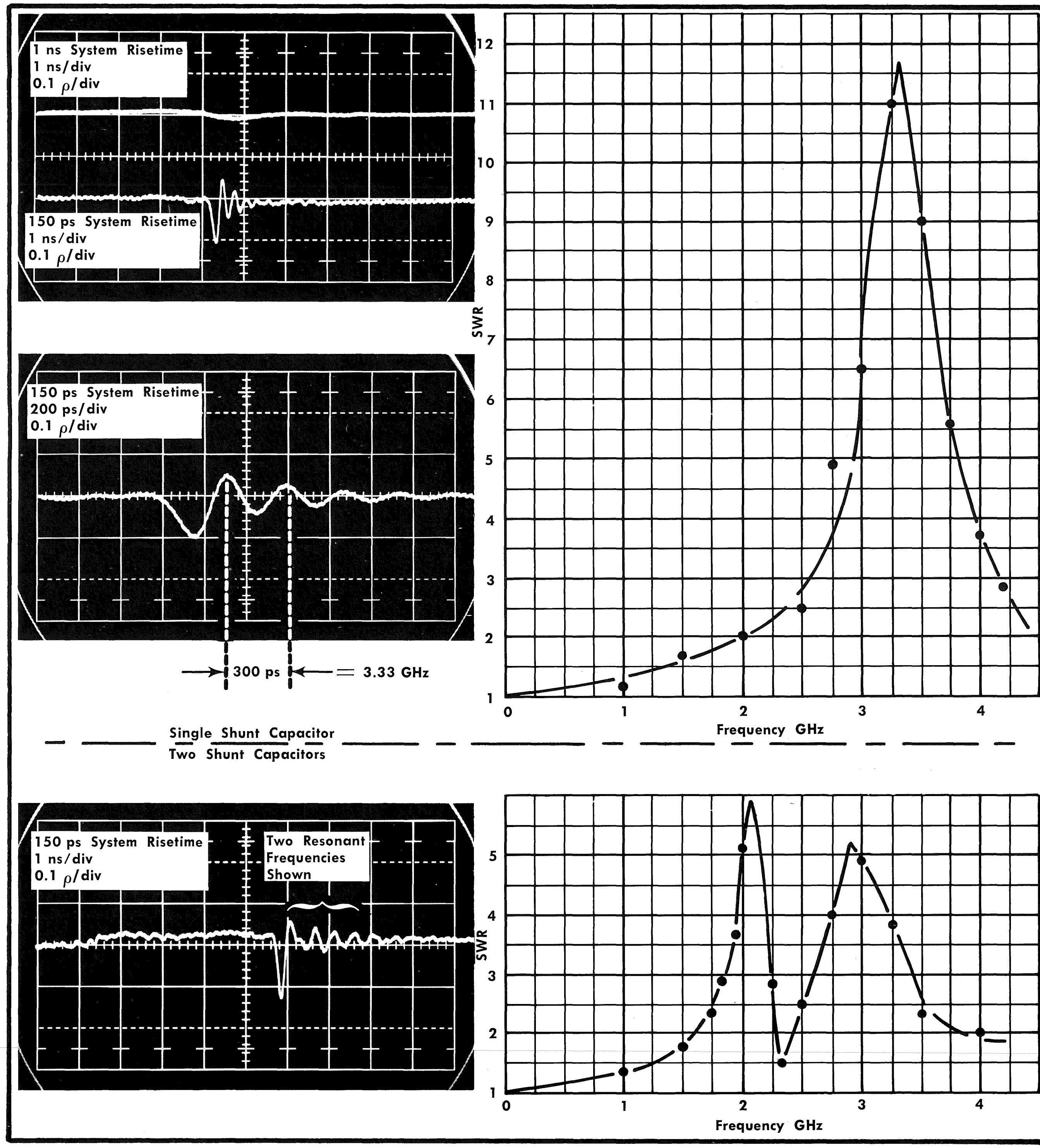


Fig. 2-1. Two examples of discrete shunt capacitors.

The single capacitor of this example was made of $1/4$ inch wide strip copper, $5/8$ inch long, with one end soldered to the side of a component insertion unit (Tektronix Part No. 017-0030-00) and the other end near the center conductor. The insertion unit was modified to have a continuous center conductor using three inner transition pieces (Tektronix Part No. 358-0175-00). One of the inner transition pieces was shortened to fit between the two mounted end pieces, and then soldered in place. The second capacitor (resonant at 2.1 GHz) was a 0.5 to 1.5 pF piston trimmer with a total lead length of about $5/16$ inch, and it was adjusted to about 1.2 pF. The piston capacitor was soldered in place in parallel with

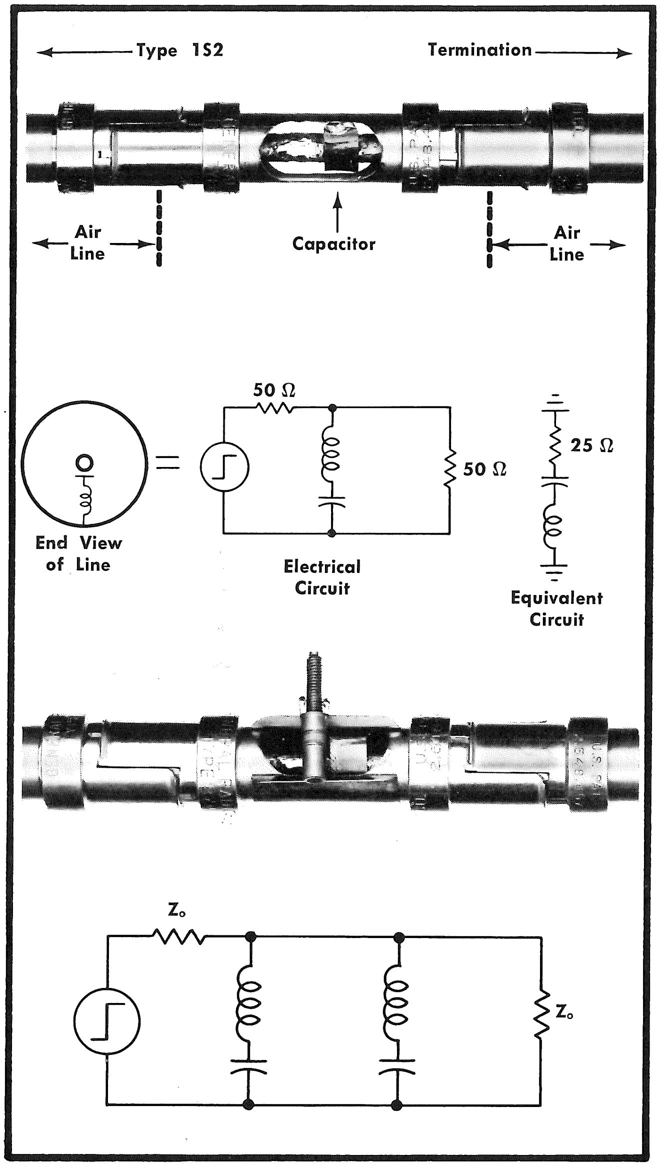


Fig. 2-2. Capacitors measured in Fig. 2-1.

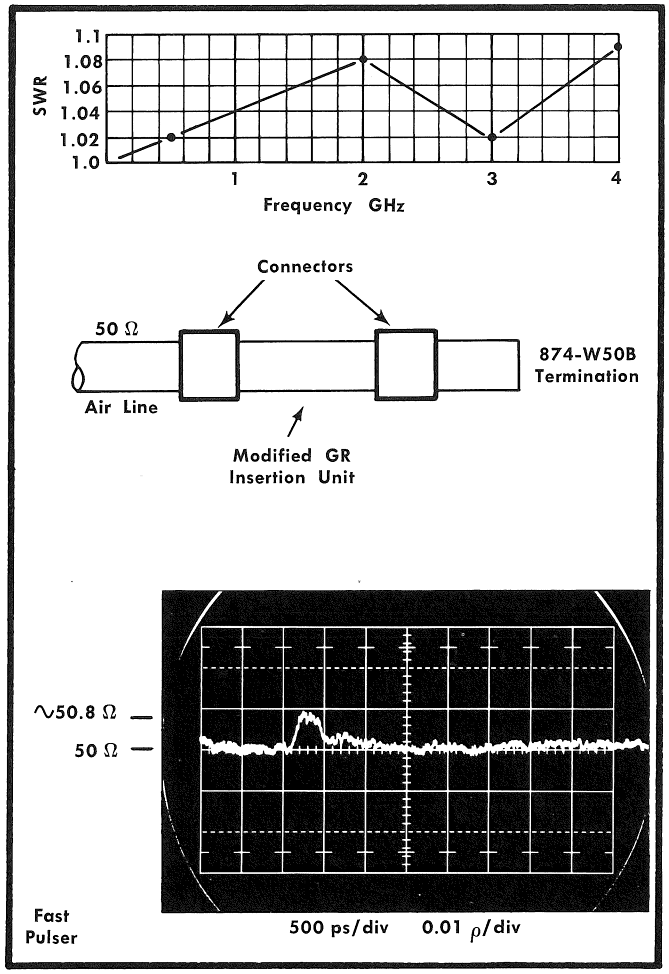


Fig. 2-3. Modified (through-connected) Tektronix Insertion unit for testing small components in parallel with 50 Ω line.

the strip copper capacitor about 1/8 inch away. It is obvious from both testing methods that neither capacitor was critically damped by the characteristic impedance of the transmission line. The physical and equivalent circuit of the single shunt capacitor is shown in Fig. 2-2. The single capacitor test was made with a shield in place completely covering both openings.

Fig. 2-3 shows the ability of TDR to locate an off-impedance point in a transmission line, and quickly resolve its value. The same through-connected insertion unit used in example number 1 was tested without any component inserted in it. The shield was in place for both TDR and FDR testing.

The TDR display of Fig. 2-3 shows the increased surge impedance due to the increased diameter of the outer conductor at the two cutout access slots. Such a TDR display will permit rather rapid correction to be made to the center conductor diameter if one desires to make a truly constant impedance through the length of the insertion unit.

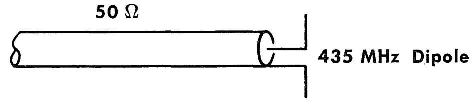
The SWR curve shows some changes from a constant impedance transmission line, but does not help to locate an aberration if it is inside a continuous piece of cable. Either FDR or TDR would help one to make the unit have a constant impedance if such a unit were being designed.

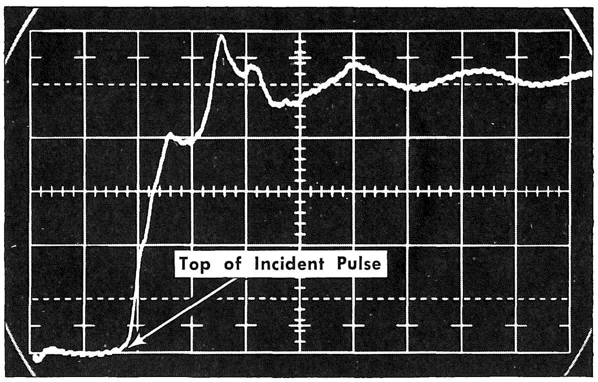
Fig. 2-4 shows two TDR and two SWR plots of a simple dipole antenna. The TDR waveforms at the left were photographed first, quickly locating the two radiating resonant frequencies and permitting a saving in time for the FDR testing. The SWR curves permit a direct evaluation of the antenna radiation resistance ($\frac{R_L}{Z_o} = \frac{V_{max}}{V_{min}}$ if R_L is purely resistive), while the TDR display tells only the transmission line quality and the radiating resonant frequencies of the nonshorting type antenna. An antenna design engineer could use the SWR data and FDR test equipment to test a compensating network to be located at the antenna to minimize standing waves in the transmission line. The TDR system cannot be used for such design assistance.

Fig. 2-5 shows both TDR and FDR tests of a General Radio Type 874-K series blocking capacitor. The upper TDR display permits direct calculation of the series capacitance, in this case approximately 6.2 nanofarads (0.0062 μF).

TDR shows open circuit

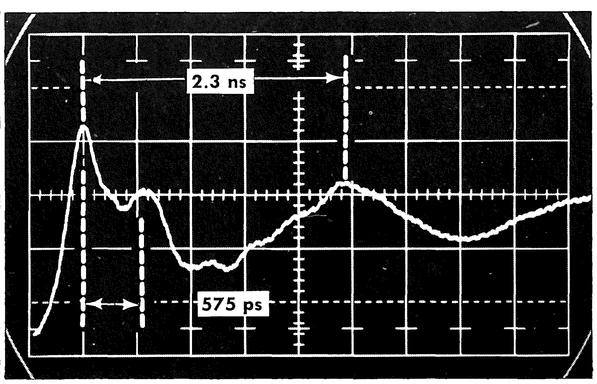
SWR shows acceptable antenna radiation resistance





1 ns/div   0.2 ρ/div

(0.25-V Pulser)

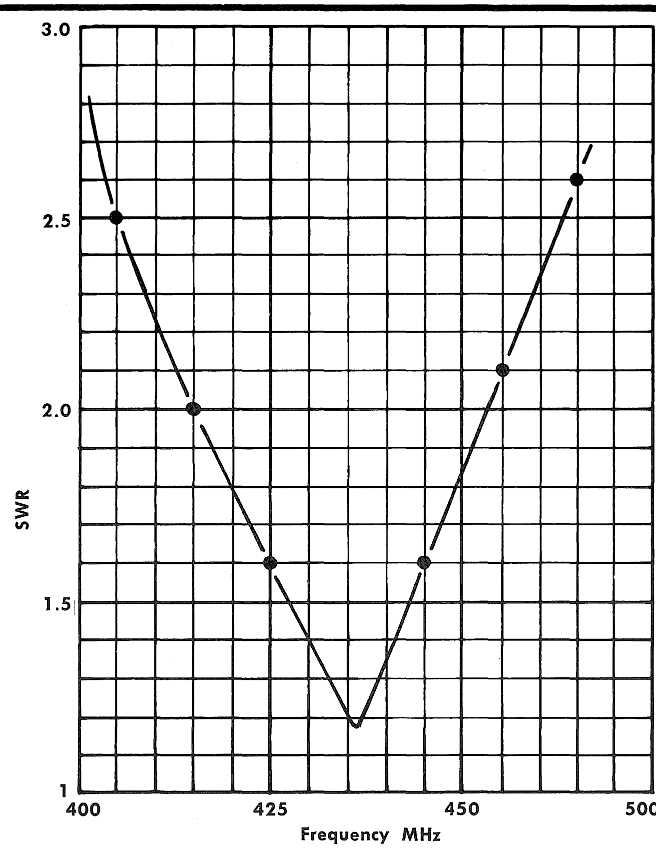


500 ps/div   0.1 ρ/div

Antenna resonant frequencies seen by TDR:

(Fundamental) $F = \frac{1}{2.3 \times 10^{-9}} = 435$ MHz

(Fourth Harmonic) $F = \frac{1}{575 \times 10^{-12}} = 1740$ MHz



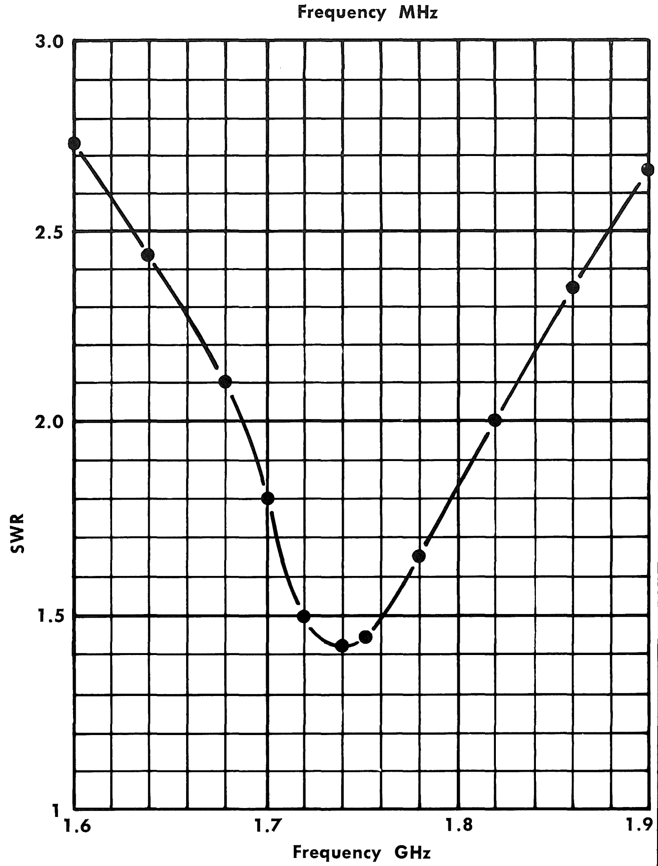


Fig. 2-4. Two plots of 435 MHz dipole antenna.

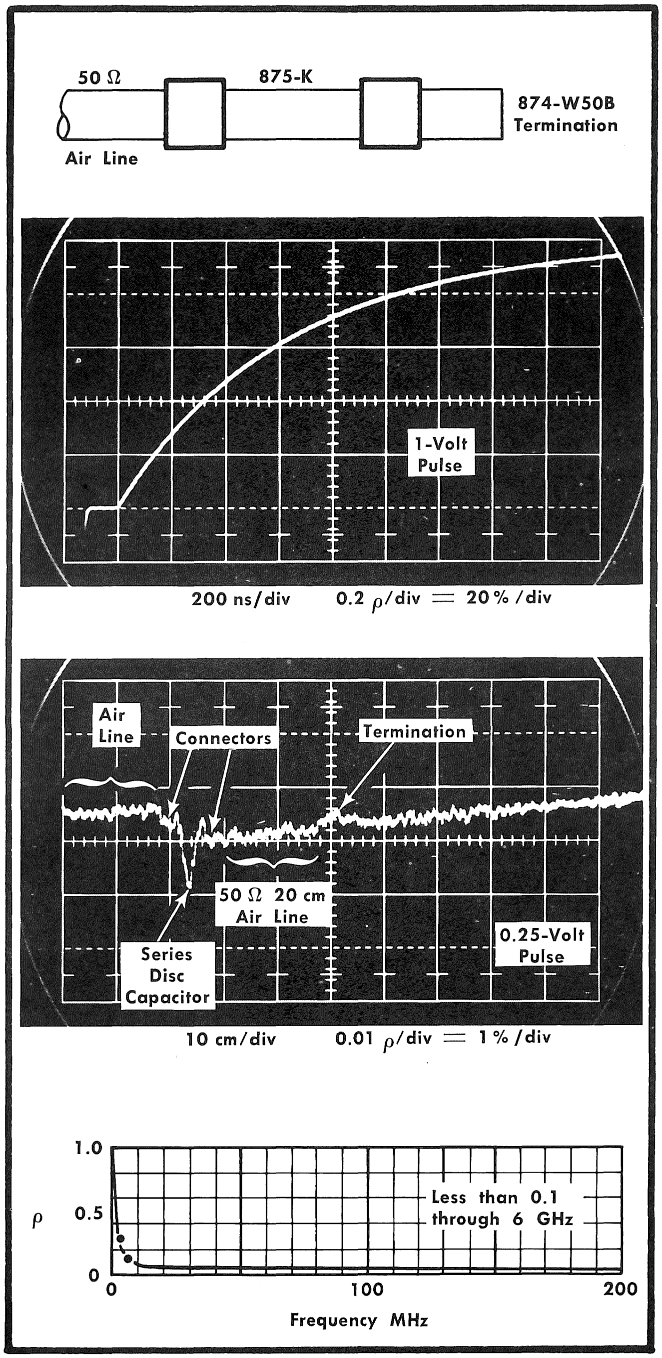


Fig. 2-5. Series blocking capacitor: General Radio Type 874-K.

The SWR curve shows that the series capacitor does not upset the transmission line significantly except for low frequencies. The middle TDR waveform shows the change in surge impedance due to the physical shape of the series capacitor. Note that the disc capacitor reduces the transmission line surge impedance to approximately 49 ohms for only a very short period of time. The same display also permits the precise location of adjacent discontinuities that affect the high frequency performance. The combined TDR and FDR data tells more about the series capacitor unit than either testing method does alone.

Basic Approach to TDR

Time Domain Reflectometry can be understood most easily if its operation is first compared with a DC circuit.

DC Analogy

Fig. 2-6 shows three simple circuits that can be related to transmission lines and TDR. Fig. 2-6A is the diagram of an ordinary resistance voltage divider, where the voltage across R_2 is $E_{R2} = \frac{R_2}{R_1 + R_2} \times E$ of the battery. (1)

Fig. 2-6B substitutes R_{line} (or Z_o) for R_2, and substitutes R_g (generator resistance) for R_1. It is assumed the battery has zero internal resistance and that R_g is an inserted series generator resistance. If the battery is 1 volt and if $R_g = R_{line}$, then a voltmeter across R_{line} will indicate 0.5 volt when the switch is closed.

Fig. 2-6C indicates a pair of zero resistance wires of same length physically connecting R_{line} to the battery and switch. A voltmeter across R_{line} will still indicate 0.5 volt when the switch is closed.

Adding the Time Dimension

Fig. 2-7 substitutes a step generator for the battery and switch of Fig. 2-6. The generator has zero source resistance so R_g is again added in series with the generator. The generator and R_g drive a finite length transmission line that has a characteristic impedance of Z_o. The transmission line has output terminals that permit connecting a load R_L. An oscilloscope voltmeter measures the voltage signal(s) at the input end of the transmission line.

Assume that no load resistance is connected to the transmission line output terminals ($R_L = \infty$) and that $R_g = Z_o$ (Z_o acts exactly as if it were the DC resistor R_{line} of Fig. 2-6). As the zero impedance step generator applies its 1-volt step signal to R_g, the oscilloscope voltmeter indicates 0.5 volt. The oscilloscope voltmeter will continue to indicate a 0.5 volt signal until the wave has traveled down the line to the open end, doubled in amplitude due to no current into $R_L = \infty$, and reflected back to the generator end of the line. The oscilloscope finally indicates a signal of 1 volt after the measurable period of time required for the step signal to travel down and back the finite length of open ended transmission line.

Reflection Signal Amplitudes

Fig. 2-8 shows TDR oscilloscope (voltmeter) displays related to the value of R_L vs the value of the transmission line Z_o. Apply resistance values of 50 Ω to R_g and Z_o, and 75 Ω to R_L of Fig. 2-7. By formula (1), the oscilloscope display of the reflection amplitude will be 0.6 volt. The actual reflection, however, is only 0.1 volt added to the 0.5-volt incident step.

Reflection Coefficient

A somewhat more convenient method of handling signal reflections than has just been suggested, is to consider the reflection as having been added to or subtracted from the incident pulse. Thus the reflection amplitude is not measured from zero volts, but is referenced to the incident signal amplitude. This permits establishing a ratio between the incident and reflected signals which is called the reflection coefficient, rho (ρ). The value of ρ is simply the reflected pulse ampli-

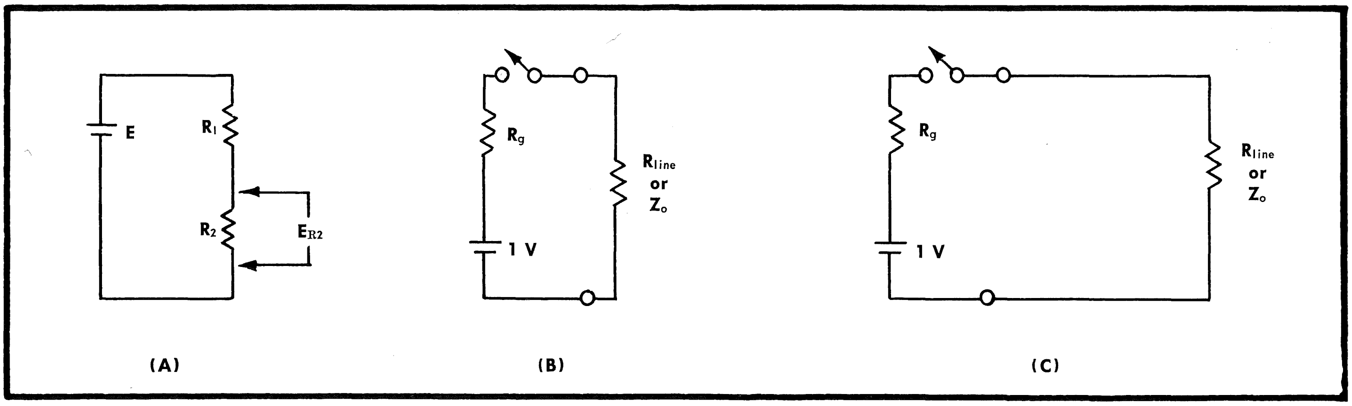


Fig. 2-6. Circuits showing DC analogy of TDR.

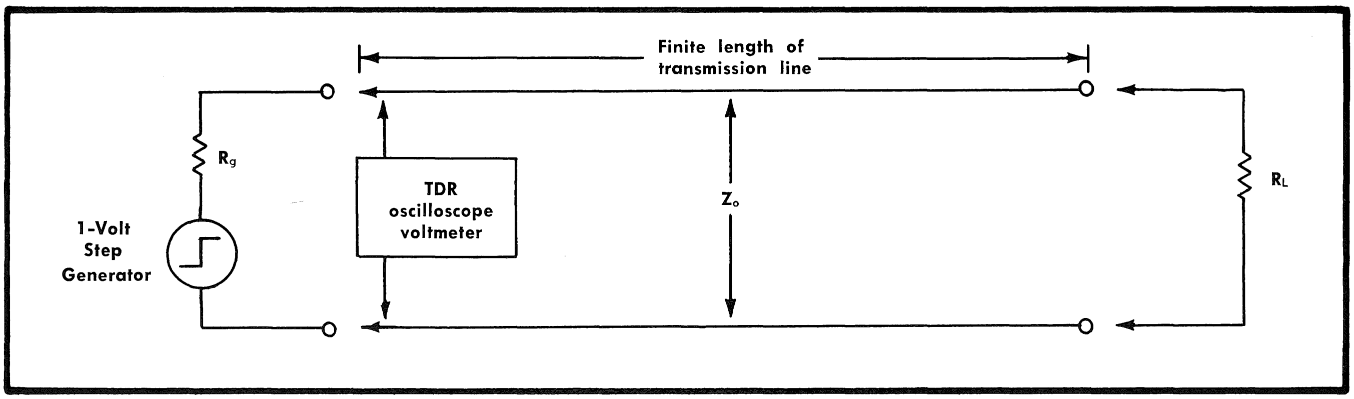


Fig. 2-7. Adding the time dimension to the circuit of Fig. 2-6.

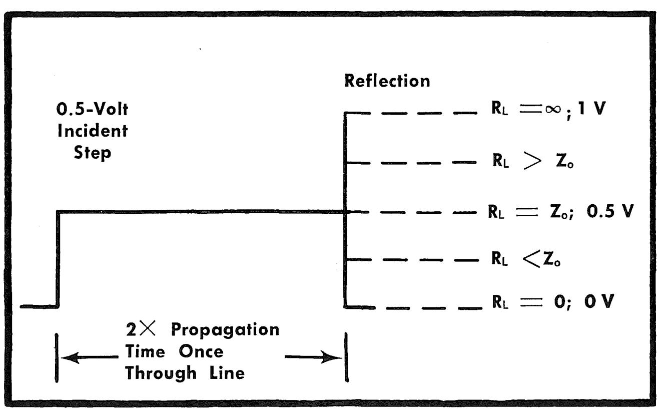


Fig. 2-8. Oscilloscope voltmeter displays for circuit of Fig. 2-7, dependent upon value of R_L vs Z_o.

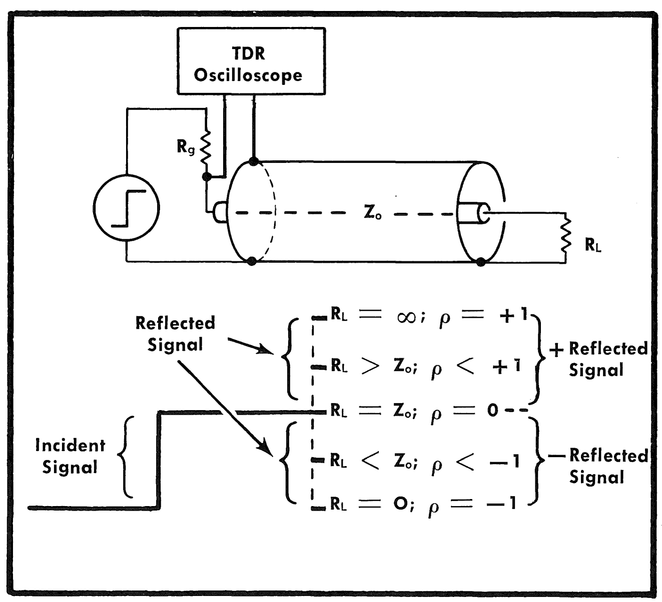


Fig. 2-9. TDR oscilloscope displays for various values of R_L vs Z_o.

tude (the display total amplitude minus the incident pulse amplitude) divided by the incident pulse amplitude. Fig. 2-9 shows the two parts of the display appropriately labeled to identify the incident and reflected signals.

When $\rho = 0$, the transmission line is terminated in a resistance equal to its characteristic impedance Z_o. If the line is terminated in $R_L > Z_o$, then ρ is positive. If the line is terminated in $R_L < Z_o$, then ρ is negative. The dependence of ρ on the transmission line load is

$$\rho = \frac{R_L - Z_o}{R_L + Z_o} \qquad (2)$$

If ρ is known, R_L can be found by rearranging formula (2);

$$R_L = Z_o \left(\frac{1+\rho}{1-\rho}\right) \qquad (3)$$

Formula (3) applies to any display that results from a purely resistive load. The load shown in Fig. 2-9 is assumed to be at the end of a lossless coaxial transmission line.

Substituting 50 Ω for Z_o in formula (3), calculations for small values of ρ show that each division of reflected signal is approximately equal to a certain number of ohms. Table 2-1 lists the ohms per division for vertical deflection factors of 0.005 ρ, 0.01 ρ and 0.02 ρ. Or, for R_L values near 50 Ω, you may use the approximation formula

$$R_L \approx 50 + 100\,\rho.$$

This approximation formula has an error of $\leq$ 2.2% for absolute values of $\rho \leq 0.1$ and an error of $\leq$ 8% for absolute values of $\rho \leq 0.2$.

R_L for reflections with ρ up to essentially +1 or −1 can be quickly determined using the graph of Fig. 2-10. Fig. 2-10 is based upon a transmission line surge impedance of 50 Ω just prior to the discontinuity that causes the reflection signal. The graph of Fig. 2-10 may be photographically reproduced without special permission from Tektronix.

TABLE 2-1

R_L Approximations For Reflection Coefficients of 0.005, 0.01 and 0.02 Related to a 50 Ω Transmission Line

ρ/div	Ω/div	Error/div
0.005	½	~0.016 Ω
0.01	1	~0.066 Ω
0.02	2	~0.2 Ω

REFLECTIONS FROM CAPACITORS AND INDUCTORS

Contrary to frequency domain measurements, TDR response to a reactance is only momentary. Thus either an inductor or a capacitor located in a transmission line will give only a short duration response to the TDR incident pulse. Analysis of large reactances is relatively simple and makes use of time constant information contained in the reflection display. Small reactances are not so simple to evaluate quantitatively, so will be treated separately.

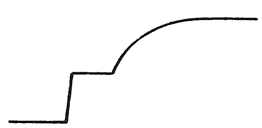
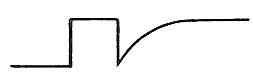
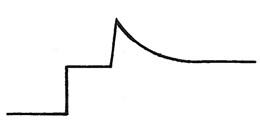
Large Reactances

The difference between a "large" and a "small" reactance is not a fixed value of capacitance or inductance, but is instead related to the TDR display. If the displayed reflection includes a definite exponential curve that lasts long enough for one time constant to be determined, the reactance is considered "large".

Discrete (single) capacitors connected in series or parallel with a transmission line start to charge at the instant the incident pulse arrives. Inductors start to conduct current at the arrival of the incident pulse. Both forms of reactance cause an exponentially changing reflection to be sent back to the TDR unit. When a capacitor is fully charged, the TDR unit indicates an open circuit. When an inductor is fully "charged" (current through it has reached its stable state), the TDR unit indicates a short circuit. The TDR unit will indicate an inductor's series DC resistance if its value is significant in relation to Z_o. The general form of reflection and long term effect upon the TDR display by both inductors and capacitors is listed in Table 2-2 and Table 2-3.

TABLE 2-2

Single Capacitor or Inductor TDR Displays Related to Terminated Transmission Lines

Reactance	In Series with Line	In Parallel with Line	Line Impedance at Reactance
CAPACITOR			SERIES: 2 Z_o PARALLEL: $\frac{Z_o}{2}$
INDUCTOR			SERIES: 2 Z_o PARALLEL: $\frac{Z_o}{2}$

Finding One Time Constant

In practice, TDR reactance displays usually contain aberrations of the desired pure exponential reflection. Such aberrations prevent finding the normal 63% one time-constant point of the curve accurately. (The aberrations are due to either the environment around the reactance, i.e. stray inductance in series with a capacitor, or stray capacitance in parallel with an inductor, or secondary system reflections.) However, accurate time constant information can be obtained from less than a complete exponential curve. The principle used requires that a "clean" portion of the display must exist. The "clean" portion used must include the right-hand "end" of the displayed curve (a capacitor is then fully charged, or an inductor current has stopped changing). The "end" of the curve will appear on the display to be parallel

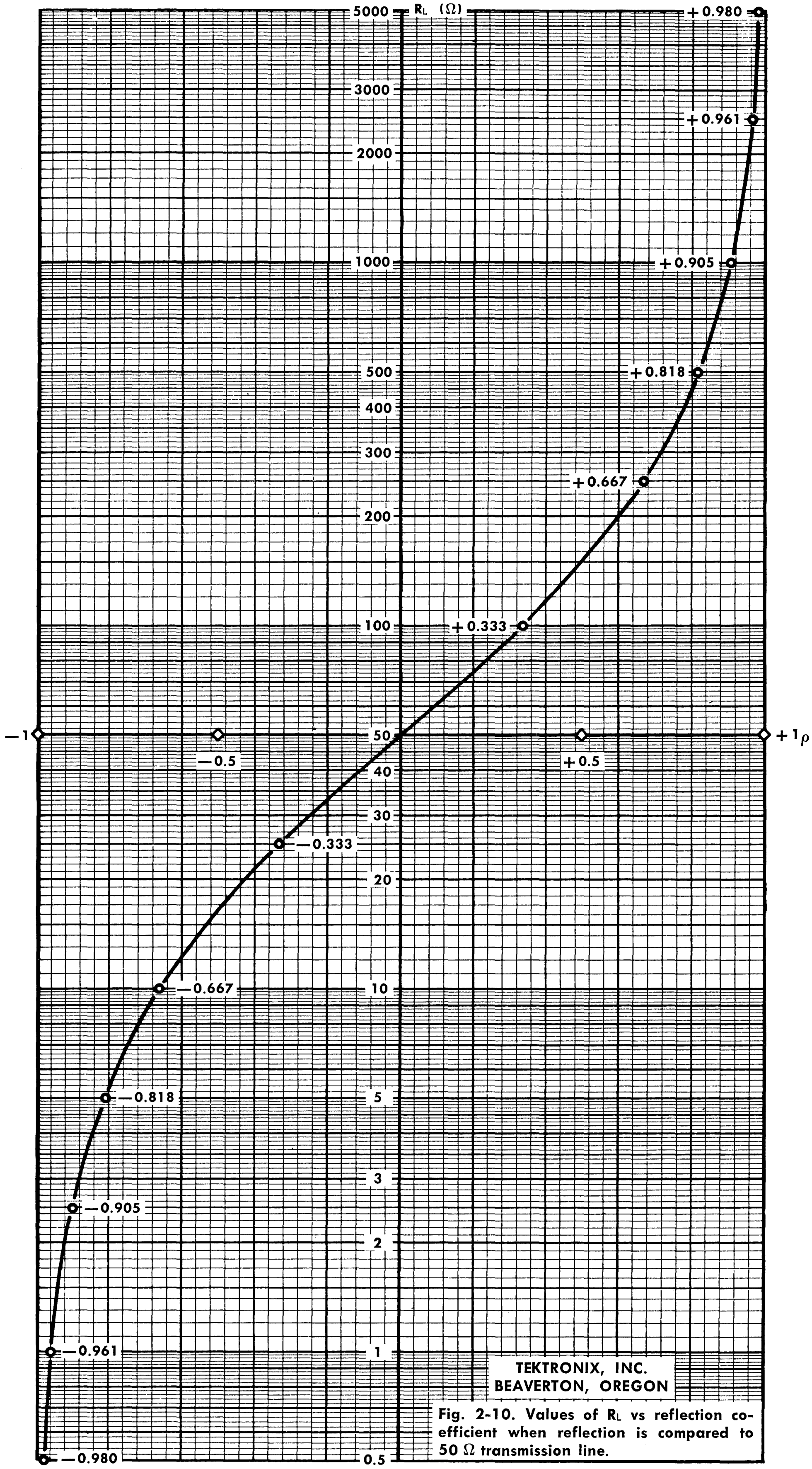
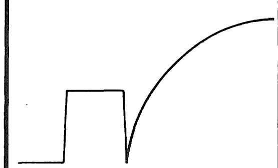
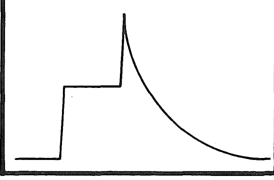


Fig. 2-10. Values of RL vs reflection coefficient when reflection is compared to 50 Ω transmission line.

TABLE 2-3

Single Capacitor or Inductor TDR Displays when Connected Across End of Transmission Line

Reactance	Display	Line Impedance at Reactance
CAPACITOR		Z_o
INDUCTOR		Z_o

to a horizontally scribed graticule line. Thus, aberrations that exist at the beginning of the curve can be ignored.

Fig. 2-11 shows the first example of obtaining valid time-constant information from less than a full 100% exponential curve. The technique is to choose any "clean" portion of the display that includes the "end" of the exponential curve and find the half-amplitude point. The time duration from the beginning of any new 100% curve section to its 50% amplitude point is always equal to 69.3% of one time constant. Thus, the time duration for a 50% change divided by 0.693 is equal to one time constant.

Fig. 2-11 shows the TDR displays of a capacitor placed in series with a transmission line center conductor (2 Z_o environment). Fig. 2-11A waveforms comprise a double exposure with the left curve taken while the Type 1S2 RESOLUTION switch was at NORMAL and the right curve taken when the switch was at HIGH. Both curves give sufficient information to measure one time constant. Note that the top of the incident pulse is indefinite (in the displays) due to the sweep rate and short length of cable used between the Type 1S2 and the capacitor. Such a display does not have a definite beginning of the normal 100% exponential curve. This prevents 63% of the total curve from being read directly from the display. (It is also quite possible for lead inductance to cause a capacitor to ring. When a TDR display shows capacitor ringing, the ringing can sometimes be reduced by: 1. using the slower 1-Volt pulser, and/or 2. changing the transmission line environment to place a lower value Z_o in parallel with the capacitor.)

The double exposure of Fig. 2-11B shows a full exponential curve beginning in the vicinity of 1 division from the graticule bottom. Then the same curve has been time-expanded for easier reading. The indefinite beginning of the 500 ns/DIV exponential curve prevents finding one time constant by measuring the time of 63% of the total curve amplitude. The new arbitrarily chosen 100% amplitude portion of the curve begins at the graticule center horizontal line and extends (off the right of the graticule) to the top graticule line. Three divisions were chosen for the new 100% exponential curve, with the 100% and 50% points marked. Then, dividing the

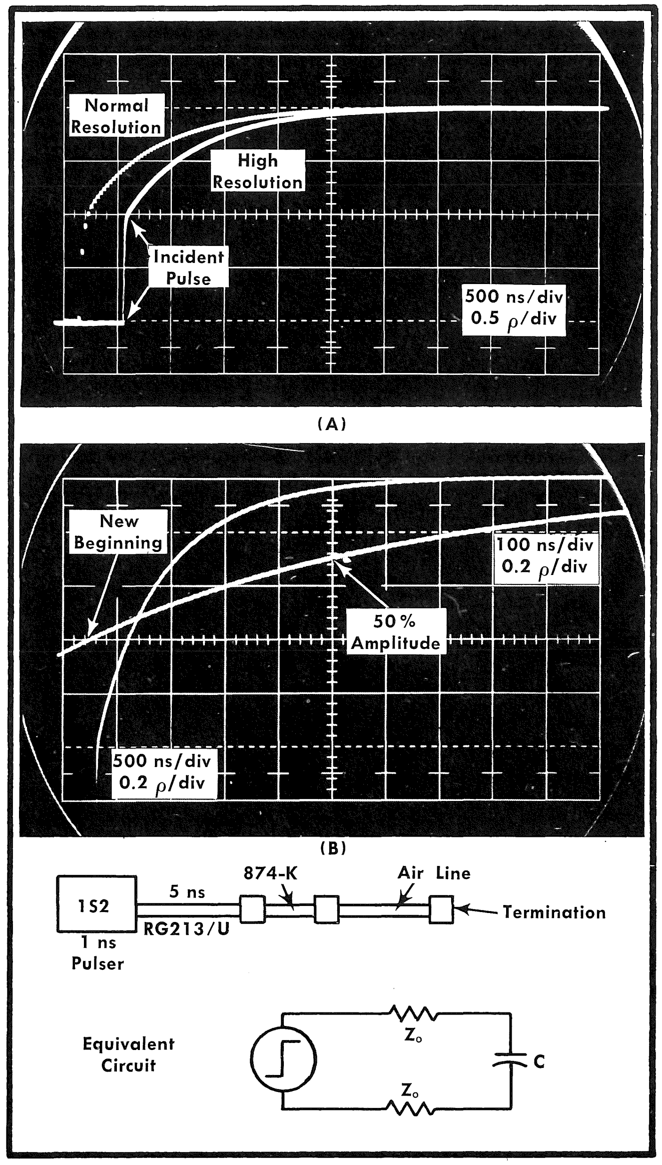


Fig. 2-11. Exponential curves and circuit of 6.5 nF capacitor in series with terminated transmission line.

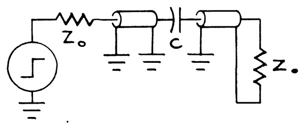
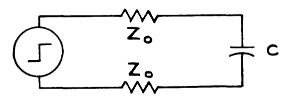
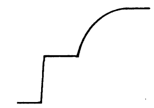
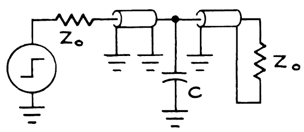
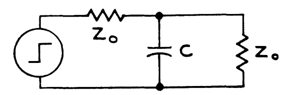
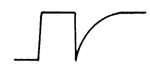
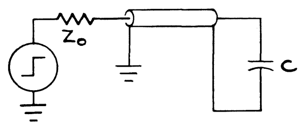
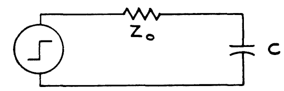
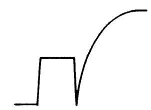
time for the 50% amplitude change by 0.693 gives a total one time-constant time value of 650 ns. Since the equivalent circuit shows 2 Z_o in series with the capacitor, its value is found by formula (4) (Table 2-4) to be 6.5 nanofarads.

Large Capacitors

The difference between a "large" and a "small" capacitor is not a fixed value of capacitance, but is instead related to the TDR display. If the display includes a definite exponential curve that lasts long enough to permit one RC time constant to be determined, the capacitor value can be found by using a normal RC time constant formula. The actual formula varies according to the equivalent circuit in which the capacitor is located. Table 2-4 lists the possible configurations and their related formulae.

TABLE 2-4

"Large" Capacitor Circuits and Formulae

Circuit		Equivalent Circuit	Formula	Display
Series with terminated line			$C = \frac{1}{2}\frac{TC}{Z_o}$ (4)	
Parallel with terminated line			$C = \frac{1\ TC}{Z_o/2}$ (5)	
Across line end			$C = \frac{1\ TC}{Z_o}$ (6)	

Where C = Farads; TC = Time Constant; Z_o = Line Surge Impedance.

The first example of "large" capacitance measurement was given under the previous heading Finding One Time Constant. The large value of capacitor used is easy to measure and usually causes only one aberration to the exponential curve. That aberration is the indefinite curve beginning.

Moving A Reflection Aberration

When testing small capacitors that still produce a usable exponential curve, it may be difficult to get accurate time constant data when there are reflections within the system.

For example, a 100 pF discap was soldered into a General Radio Radiating Line section (Fig. 2-12). The 1-Volt pulser was used; re-reflections from the pulser distort the exponential curve at the arrow of Fig. 2-12A. The re-reflection is moved to the right just outside the time window by placing a 20 ns signal delay RG213/U cable between the pulser and the sampler. The acceptable waveform is shown in Fig. 2-12B. Fig. 2-12C is a double exposure that shows first how the "end" of the exponential curve is set to a graticule line. Then the display is time expanded to 500 ps/DIV (leaving the vertical position as adjusted) and the new arbitrary 100% exponential curve is chosen and marked. The capacitor's value taken from the time expanded curve of Fig. 2-12C and using the formula (5) is 104 pF ($1.8 \times 10^{-9}/0.693 \div 25 = 1.04 \times 10^{-10} = 104$ pF). Note that the vertical ρ factor was changed for Fig. 2-12C in order to make the time constant measurement from a clean section of the curve near its end.

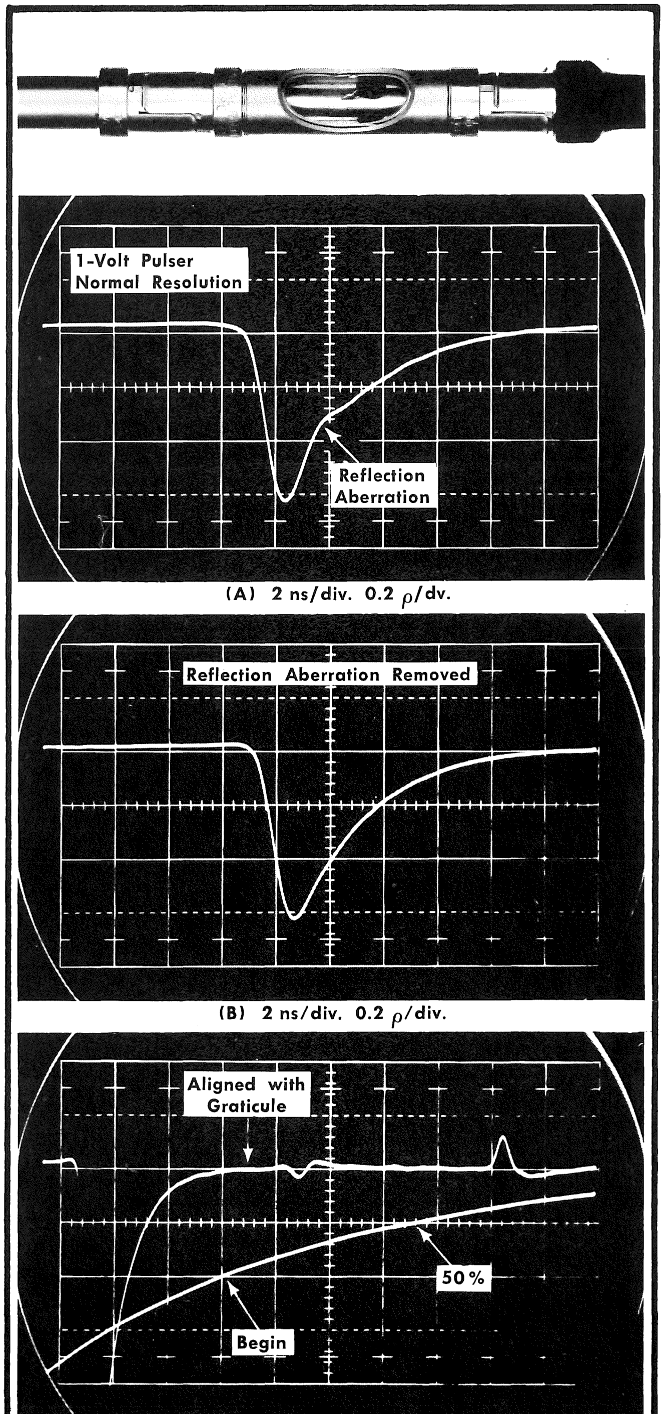
Large Inductors

The difference between "large" and "small" inductors follows the same general display limits as large or small capacitors. A "small" inductor in series with a transmission line center conductor will give a display that does not permit normal time-constant analysis. The same inductor in parallel with a terminated transmission line may give a display that does allow normal time-constant analysis.

Ringing in the exponential TDR display is often observed when measuring inductors. It is usually caused by distributed capacitance across the coil that has not been adequately damped by transmission line surge impedance. Since an inductor with stray capacitance will ring unless adequately damped, and inductor in parallel with a transmission line ($Z_o/2$ environment) will be less likely to ring than the same inductor in series with a line (2 Z_o environment).

Fig. 2-13 shows waveforms taken of the reflections from a seven turn 3/8 inch diameter coil. The coil was connected across the end of a 50 Ω transmission line (Z_o environment). Fig. 2-13A was made using the Type 1S2 0.25-Volt fast pulser at High Resolution. The ringing makes it impossible to obtain an accurate time constant measurement from the display. Fig. 2-13B was made using the Type 1S2 1-Volt pulser at Normal Resolution. Here the slower risetime incident pulse does not excite the ringing, and in addition the time averaging of fast changes by Normal Resolution operation permits a time constant to be measured. Ringing could also have been reduced by a $Z_o/2$ environment by placing a termination across the inductor, or placing the inductor at a convenient mid-point of a long time.

The triple exposure of Fig. 2-13B includes three curves: #1, the total reflected signal at 10 ns/div and 0.5 ρ/div; #2, increased vertical deflection and the exponential curve end positioned one division below the graticule center horizontal line; and #3, the #2 curve time expanded to 1 ns/div for measurement of the L/R time constant. The new 100% to 50% amplitude time duration of curve #3 is shown as 3¾ns. 3.75/0.693 = 5.41 ns for 1 time constant. Since the coil is at the end of a 50 Ω transmission line, the inductance is calculated by formula (9) of Table 2-5 to be 270.5 nH (L = $50 \times (5.41 \times 10^{-9}) = 2.705 \times 10^{-7} = 270.5$ nH).

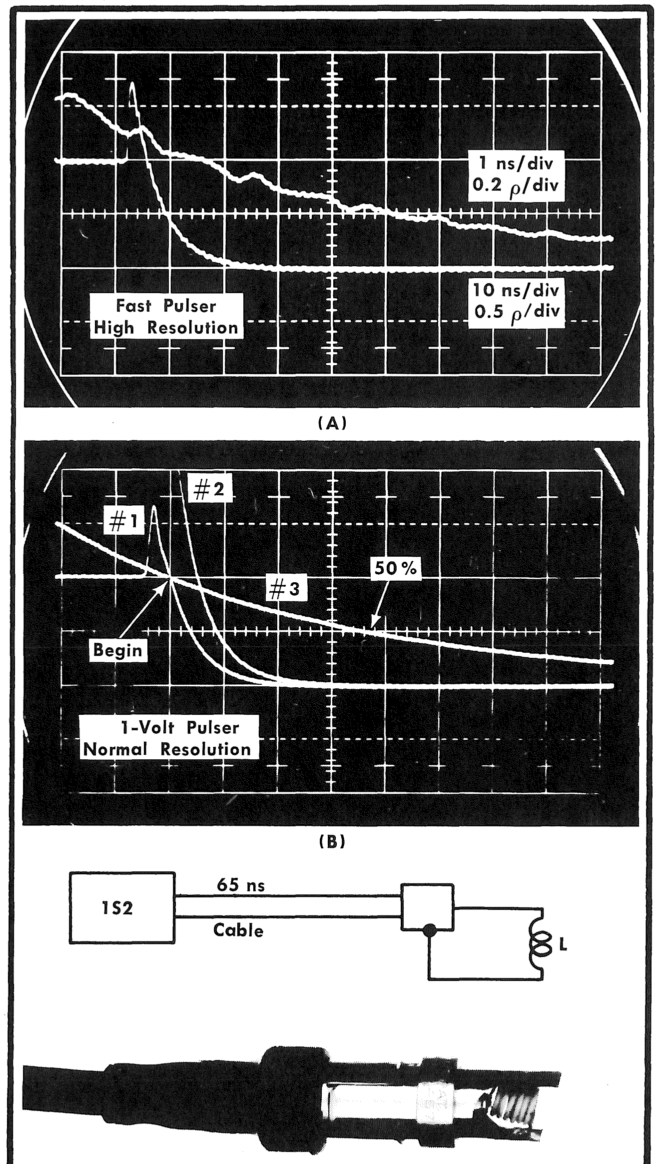


(A) 2 ns/div. 0.2 ρ/dv.

(B) 2 ns/div. 0.2 ρ/div.

(C) 500 ps/div. 0.1 ρ/div.

Fig. 2-12. Example of moving display reflection aberrations to obtain a "clean" exponential curve.



(A)

(B)

(C)

Fig. 2-13. Seven turn coil across end of 50 Ω line.

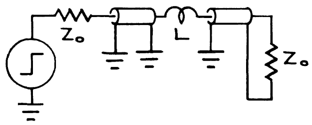
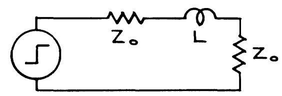
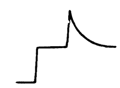
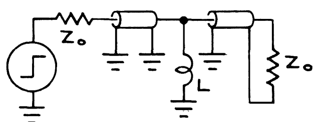
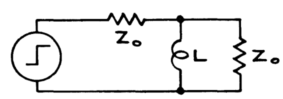
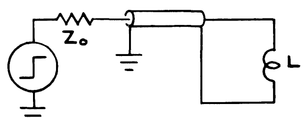
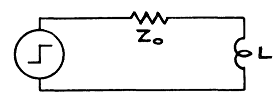
Small Reactances

"Small" reactances are here defined as series-connected inductors and shunt-connected capacitors that cause TDR reflections without apparent time constant reaction to the incident pulse. Some small reactances are capable of being "charged" (capacitor voltage is stable; inductor current is stable) at a rate faster than the 0.25-Volt pulser incident pulse rate of rise. If the TDR display has no exponential section, normal RC and L/R calculations cannot be made. All small reactances generate TDR reflections with less than $+1\rho$ or -1ρ.

Small discrete capacitors with leads always include stray series inductance of a significant amount. Fig. 2-1 and associated discussion is an example of such a capacitor with inductive leads. Small shunt capacitors without leads may be produced by either an increase in a coaxial cable center conductor diameter or a reduction of its outer conductor diameter. Leadless capacitors are sometimes treated as a small reduction in Z_0 rather than as a capacitor. Usually, such small capacitors are considered capacitance when the section of reduced Z_0 line is so short physically that no level portion can be seen in the TDR display.

TABLE 2-5

"Large" Inductor Circuits and Formulae

Circuit		Equivalent Circuit	Formula	Display
Series with terminated line			**(7)** $L = 2\, Z_o \times 1\ TC$	
Parallel with terminated line			**(8)** $L = \frac{Z_o}{2} \times 1\ TC$	
Across line end			**(9)** $L = Z_o \times 1\ TC$	

Small series inductors rarely have sufficient parallel (stray) capacitance to be significant in the TDR display. However, the coaxial environment around such a small inductor does affect the TDR display. Small series inductors without capacitive strays are sometimes caused by changes in diameter of a coaxial cable: decreased center conductor diameter, or increased outer conductor diameter. This form of inductor is usually treated as a small increase in Z_o rather than as an inductor. Usually, such inductors are considered to be inductance when the section of increased Z_o line is so short physically that no level portion can be seen in the TDR display.

Assumptions that Permit Analysis of Small Reactances

The usual TDR system does not have the required characteristics for accurately measuring small reactances. Yet small reactances can be measured provided the following assumptions are made regarding the TDR system:

1. That the actual TDR system may be adequately described by a model having a simple ramp as the pulse source and a lossless transmission line with an ideal sampler;

2. That the rounded "corners" of the actual pulse source may be ignored;

3. That the transmission line high frequency losses classed as "skin effect" or "dribble up" are not significant. ("Dribble up" is explained under Measuring Technique in connection with Fig. 2-17);

4. That the sampler is non-loading, non-distorting and of infinitesimal risetime;

5. That parasitic (stray) reactances are insignificant.

The formula for small series inductance and small shunt capacitance in a transmission line contain factors for (1) the system risetime at the spatial location of the reactance, (2) the observed reflection coefficient, and (3) the transmission line surge impedance.

The system risetime may be measured from the display by placing either an open circuit or a short circuit at the spatial location of the reactance.

The value for a small series inductor can calculated using the formula

$$L = 2.5\ \alpha\ Z_o\ t_r \qquad (10)$$

where L is in henries, Z_o is in ohms, t_r is the system 10% to 90% risetime in seconds, and α (as in formulas above and below) is a dimensionless coefficient related to the observed reflection coefficient ρ by either the graph or Fig. 2-14, or formula (11).

$$\rho = \alpha\,(1 - \varepsilon^{-\frac{1}{\alpha}}) \qquad (11)$$

A small shunt capacitor's value can be calculated using the formula

$$C = \frac{2.5\ \alpha\ t_r}{Z_o} \qquad (12)$$

where C is in farads, and the other units are as in formula (10).

Small Series Inductor

Fig. 2-15 is an example of TDR displays from a small inductor (1¾ turn) placed in parallel with a 50 Ω line at (A), and in series with the 50 Ω line at (B). Calculations were made on Fig. 2-15A first because the display is a clean exponential that permits L/R time constant analysis. Waveforms #1 and #2 of Fig. 2-15A show first the full exponential decay through five CRT divisions, then at #2 the waveform was postioned vertically so the exponential end is at —1 division. Waveform #3 used the same vertical calibration, but was time expanded to obtain the new 100% to 50% time duration.

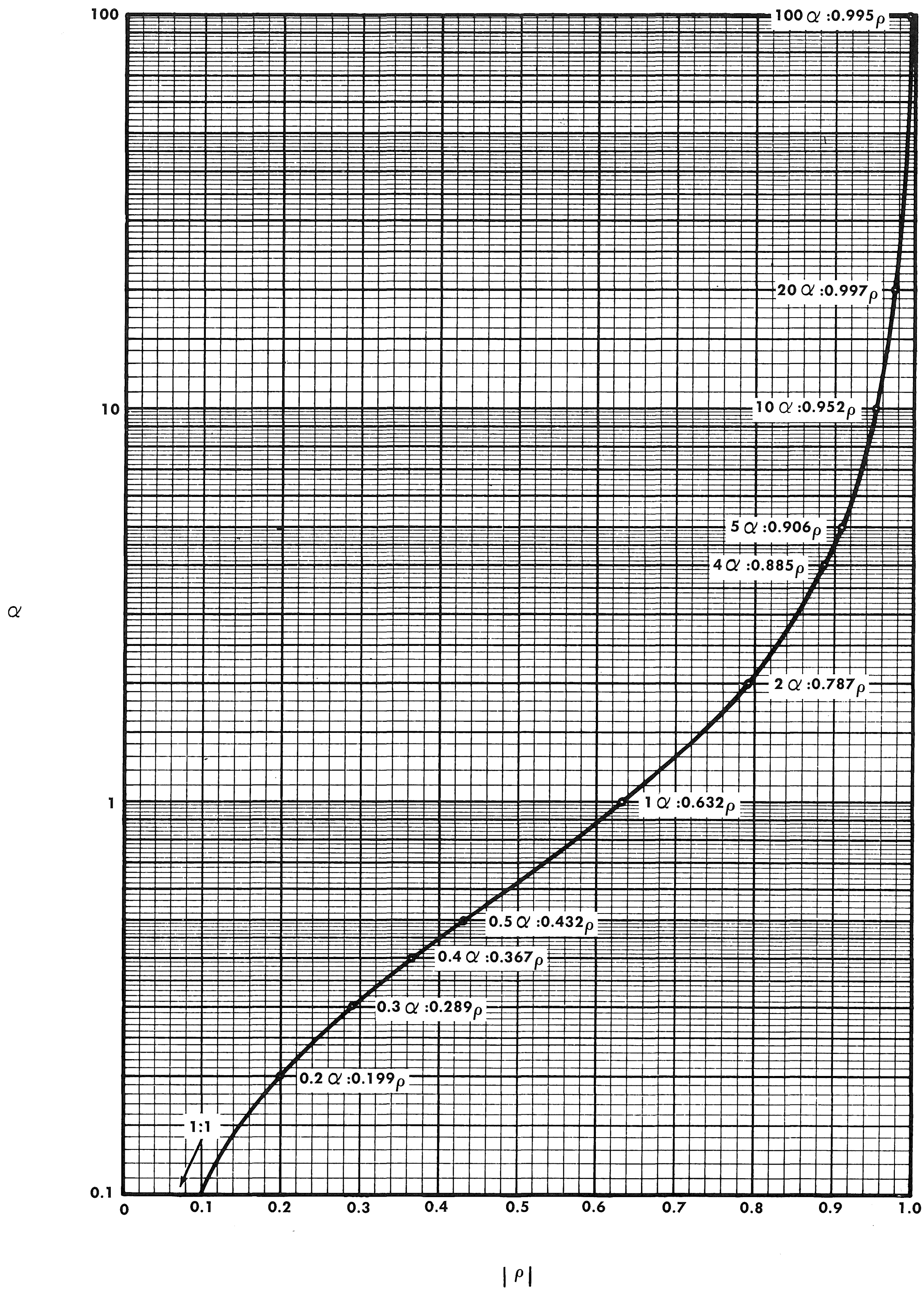


Fig. 2-14. Graph for conversion of small reactance observed ρ to α for use in formulae (10) and (12).

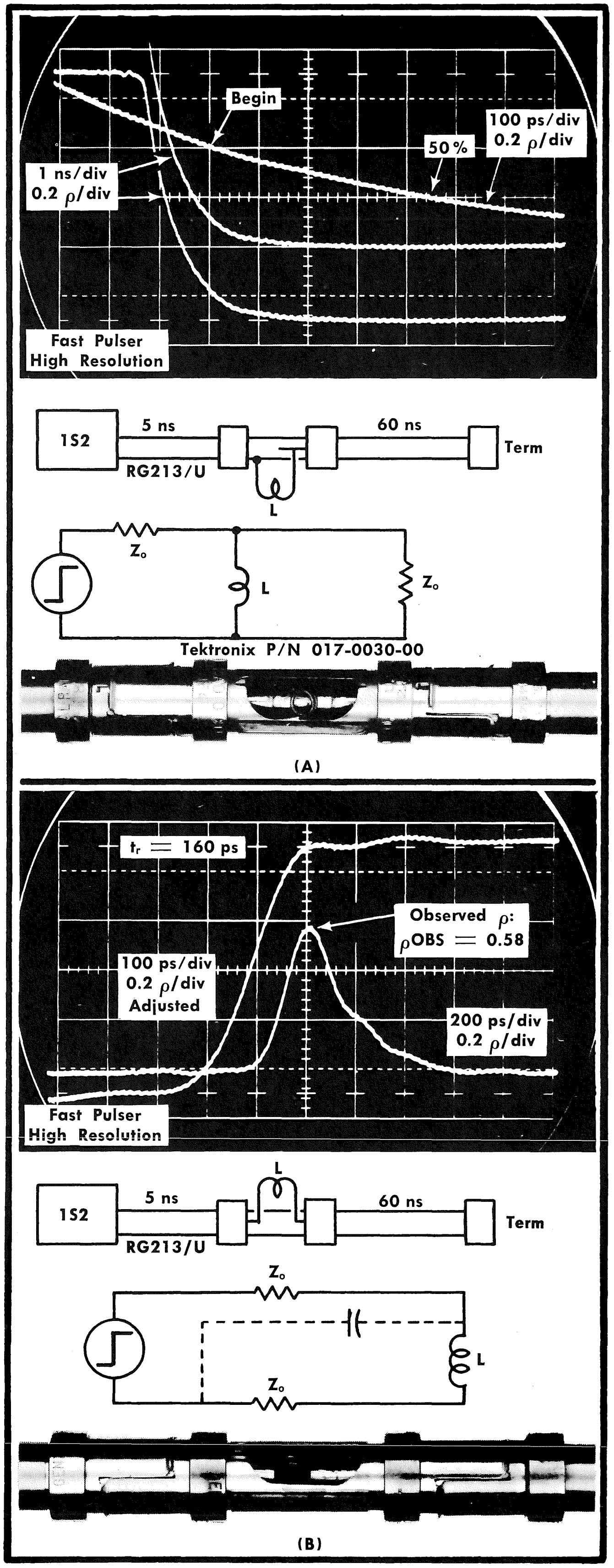


Fig. 2-15. (A) 1¾ turn coil in parallel, (B) same coil in series, with 50 Ω coaxial line.

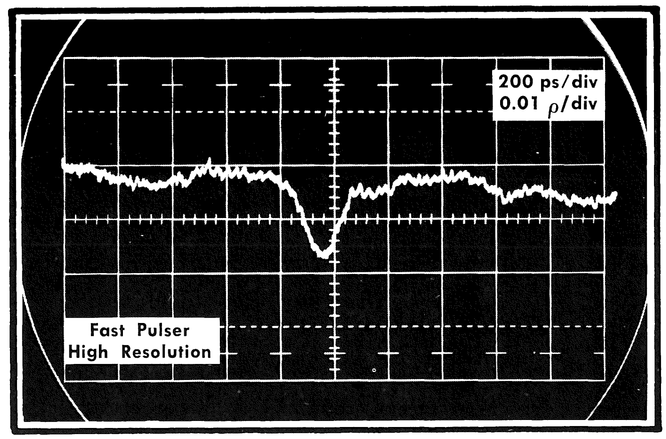


Fig. 2-16. Shunt capacitor, ≈0.085 pF, caused by compressing RG8A/U coaxial cable with pliers.

The time duration of the 50% amplitude change section of the exponential curve is 450 ps. This time divided by 0.693 produces a one time-constant time duration of 650×10^{-12} seconds. Then from formula (8), the value of the inductor is 16.22 nH (1.622×10^{-8} H).

The waveform of Fig. 2-15B has an observed deflection coefficient of +0.58. From the graph of Fig. 2-14, 0.58 ρ is equal to 0.82 α. The risetime of the system was found to be 160 ps by disconnecting the insertion unit in which the inductor was located and measuring the reflection signal risetime. These figures placed into formula (11) give a value for the series inductor of 16.4 nH (1.64×10^{-8} H). This correlates very well with the previous parallel measurement.

Small Shunt Capacitor

Fig. 2-16 is an example of a small shunt capacitor placed across a 50 Ω coaxial cable by compressing the cable outer diameter. Since the cable (RG8A/U) has normal impedance variations along its length, the peak reflection from the capacitor can only be approximated. Assuming a ρ of —1 division in Fig. 2-16, then by formula (12), the capacitance is approximately 0.085 picofarads.

The Type 1S2 is useful for observing similar small discontinuities along transmission lines. In particular, high quality cable connectors can be evaluated for their ability to maintain a constant impedance where two cables are mated. Or, the quality of production installation of high quality connectors to flexible cable can easily evaluated.

Measuring Technique

The measurement of the small series inductor of Fig. 2-15B is explained here to point out necessary techniques for measuring small reactances.

In evaluating small reactances with the TDR system, we have assumed the driving pulse to be a linear ramp; therefore, the ramp risetime must be determined for each change in the test system. The words "dribble up" refer to the characteristic of a coaxial cable to transport a step signal with distortion. The time required for the cable output signal to reach 100% of the step signal input amplitude is many times longer than the interval needed for the output signal to change from 0% to 50%. If we consider that the small reactance receives a pure ramp signal, then the rounded corners of the output pulse must be ignored.

Fig. 2-17 shows the degradation of the Type 1S2 incident signal pulse by two different lengths of RG8A/U coaxial cable. Fig. 2-17A is the reflection from an open cable 96 cm long, (192 cm signal path) and Fig. 2-17B is the reflection from an open cable 550 cm long (1100 cm signal path). The upper waveform in each case was made with the Type 1S2 VERTICAL UNITS/DIV control set to 0.5 ρ/DIV, calibrated. The lower waveform in each case was made with the Type 1S2 vertical VARIABLE control advanced slightly clockwise to approximate a deflection factor of 0.5 ρ/DIV for just the ramp portion of the waveform. In each case the signal continues to rise after the initial step, but Fig. 2-17B shows the "dribble up" characteristic very plainly. The lower waveform of Fig. 2-17A and B does not permit an accurate measurement of the system risetime because the waveforms as shown are not large enough. However, the upper waveforms of Fig. 2-18A and B are large enough to permit a reasonable measurement of the 10% to 90% risetime of the ramp that drives the small inductor. It is also obvious from Fig. 2-18A and B that the series inductor peak reflection is truly caused by just the ramp portion of the driving signal and not by the "dribble up" portion.

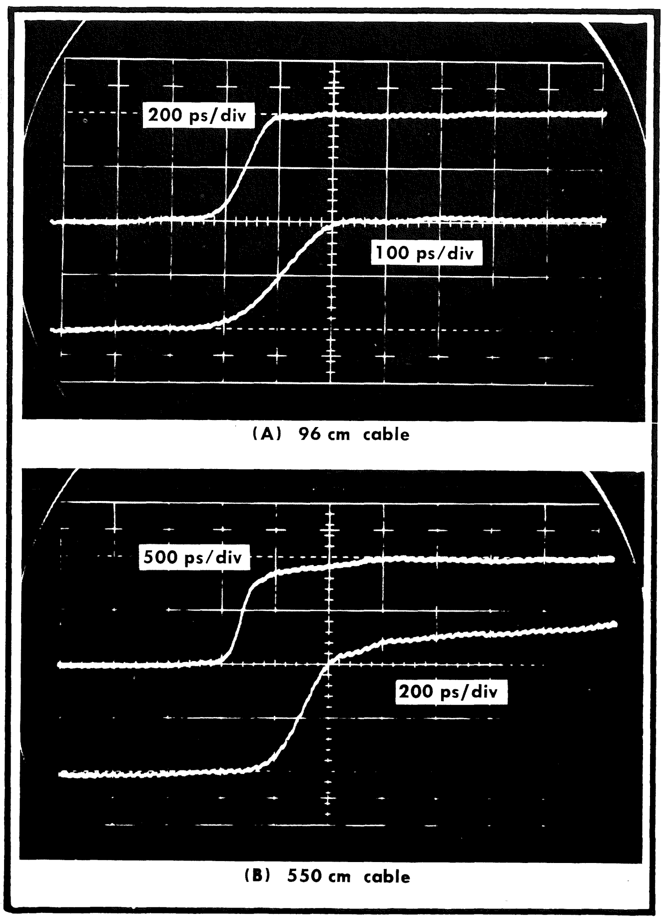


Fig. 2-17. "Dribble up" characteristics of two lengths of RG8A/U.

Calculations made from Fig. 2-18A and B using formula (11) and the curve of Fig. 2-14, indicate the series coil has an inductance of 16.40 nH at Fig. 2-18A and inductance of 16.51 nH at Fig. 2-18B. (Fig. 2-18A: $L = (2.5)(0.82)(50)(1.60 \times 10^{-8}) = 1.64 \times 10^{-8}$ H.) (Fig. 2-18B: $L = (2.5)(0.66)(50)(2.0 \times 10^{-8}) = 1.651 \times 10^{-8}$ H.) This indicates that an inductor in series with a coaxial transmission line can be accurately measured so long as the risetime of the ramp portion of the incident signal can be measured. Fig. 2-18B indicates that a cable of RG8A/U a bit longer than 550 cm might make it difficult to measure the ramp risetime from the display. If a cable has sufficient length to prevent a reasonable display to measure the ramp 10% to 90% risetime, the small series inductor cannot be measured.

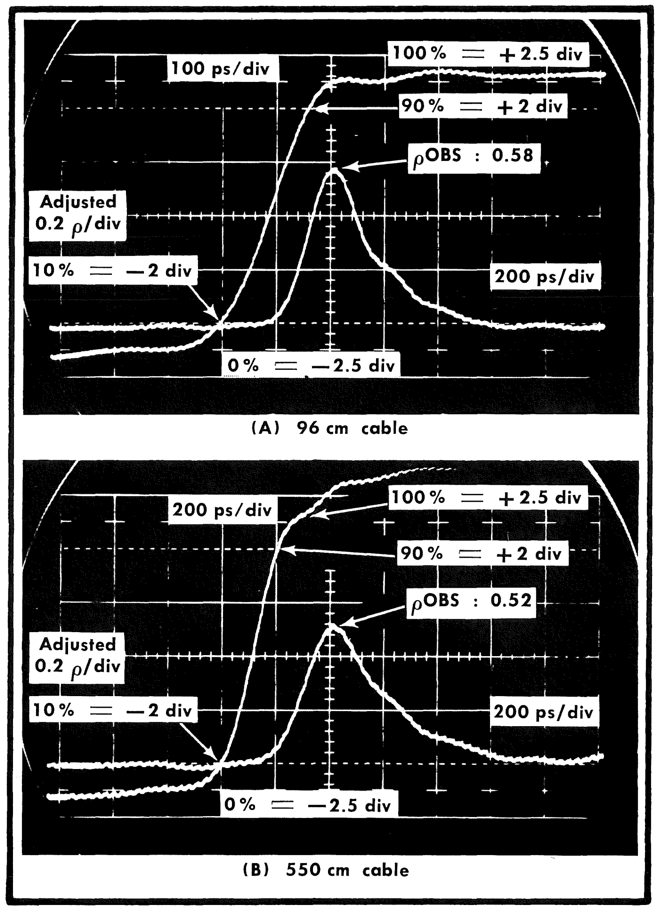


Fig. 2-18. Small series inductor measured 96 cm and 550 cm away from Type 1S2 in RG8A/U coaxial cable.

Calculations of cable risetime will not permit small inductor measurements because the Type 1S2 vertical ρ/DIV calibration must be adjusted in each case. Once the vertical gain has been increased to measure the ramp risetime, the same new adjusted vertical ρ/DIV setting is used for measuring the observed ρ from the series inductor. If the cable is long enough to make it impossible to "see" the top of the ramp, the inductor cannot be measured. The same limitations apply when measuring small shunt capacitors.

Locating Small Reactances

The discussion of small reactances has thus far assumed that the TDR operator has access to all the cable between the TDR unit and the reactance being measured. This is, of course, not always the case. When a long length of cable indicates a fault, the reflected signal has not only been reduced in amplitude, it has also been smeared in time. The discontinuity is then located in time, closely related to the approximate 10% amplitude point on the beginning edge of the display rather than, as might be expected, at the peak of the reflection.

REFLECTIONS FROM RESISTIVE DISCONTINUITIES

Two types of reflections occur from two types of resistive discontinuity. They are a step reflection, or a continuously changing reflection. A resistance in series with a transmission line causes a positive reflection. A resistance in parallel with a transmission line causes a negative reflection. Discrete single resistors cause a step reflection, while distributed resistance causes a continuously changing reflection. The discrete resistor reflections are shown in ideal form in Fig. 2-19, and the distributed resistance reflections are shown in ideal form in Fig. 2-20.

Fig. 2-20 has been exaggerated by showing the distributed resistance beginning at a particular point in the line. Normally, such series or shunt distributed resistance will be found in the total length of line tested by TDR.

All four forms of resistance reflections are an indication of signal losses between the input and output ends of the transmission line. The single resistor discontinuities can occur due to discrete components or may indicate a loose connector with added series resistance. Such discontinuities can be physically located by special use of the POSITION control as suggested in Section 3 Operating Instructions under Function of Front Panel Controls and Connectors. Distributed losses are usually part of the particular line being tested and the TDR display can be of value for quantitative analysis of resistance per unit of line length.

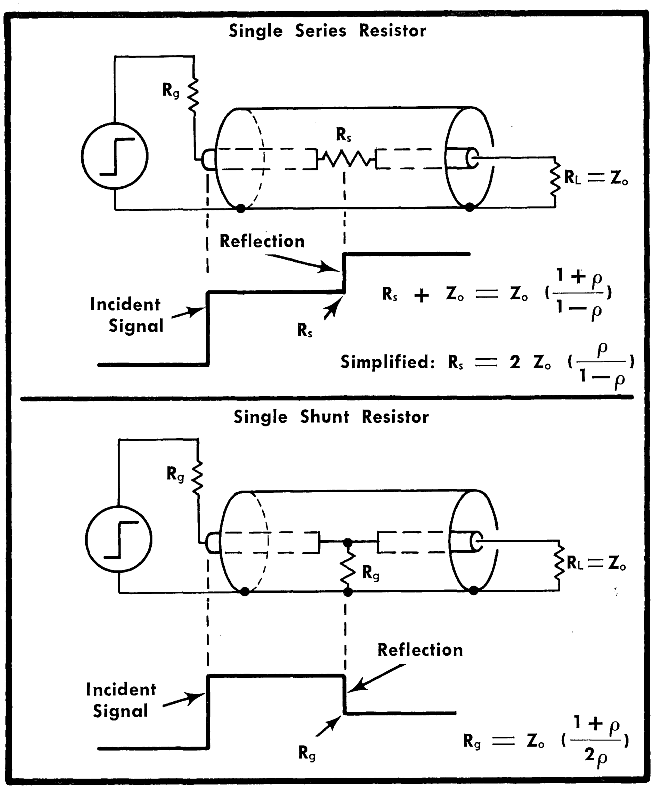


Fig. 2-19. Single resistor discontinuities.

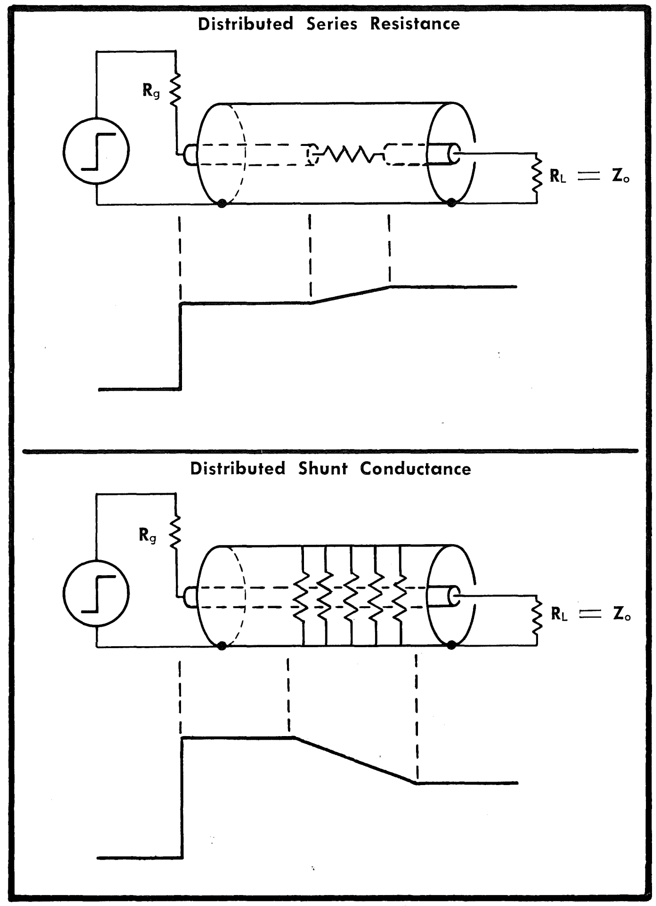


Fig. 2-20. Distributed resistance reflections.

No reflection should occur from a properly fabricated matched attenuator. Therefore, a TDR unit will not indicate losses when matched attenuators are used.

Distributed Resistance Examples

The examples of distributed resistance reflections that follow deal with the normal characteristics of transmission lines. Both small diameter lossy cables and moderate diameter quality cables are discussed.

Small, Lossy Cables

A small diameter 50 Ω transmission line (such as ⅛ inch diameter cable) will have sufficient DC resistance to mask "skin effect" losses. The DC resistance in its center conductor will cause a nearly exponential changing reflection. See Fig. 2-21A. As the incident signal propagates down the line away from the TDR unit, the small series resistance causes small reflections to return to the TDR unit. If you mentally integrate the line into small sections of series resistance, you can then understand the continuous return of energy to the input end of the line. Each reflected energy "bit" is additionally attenuated on its way back to the TDR unit. This return attenuation is the factor that prevents the display from being a linear ramp, converting it into a nearly exponential reflection. (Note the curve of the reflection between the incident signal plus step and the termination of Fig. 2-21A).

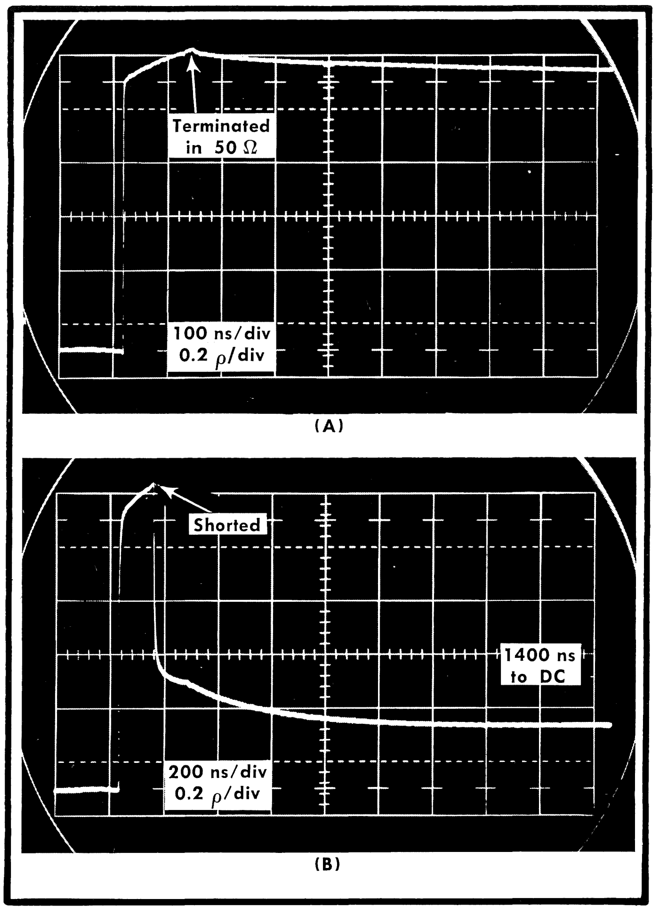


Fig. 2-21. Waveforms of 1/8 inch diameter lossy 50 Ω cable.

Another way of expressing the effect of the nearly exponential reflection is to say that the transmission line input surge impedance changes with time. Fig. 2-21A shows the line surge impedance to be essentially 50 Ω at the beginning of the exponential reflection and to be approximately 64 Ω after 130 ns ($+0.12\,\rho = 64\,\Omega$).

The long nearly exponential decay after the termination of Fig. 2-21A is related to high frequency losses and the previously described "dribble up". The negative reflection occurs at the termination because the 50 Ω termination was driven by approximately 64 Ω. If the long exponential decay after the termination were expanded vertically, it would follow the rules for distortion to pulses by coaxial cables described with Fig. 2-25.

If the small diameter cable is shorted at its end instead of terminated, the TDR display will appear similar to Fig. 2-21B. A lossless line would have a full $-1\,\rho$ after the short, but the small lossy cable not only has attenuation of the signal to the short, but attenuation of the reflected signal back to the TDR unit. Again, the long nearly exponential curve after the short is caused by the cable distorting the reflected step signal.

Fig. 2-21B also allows measuring the total cable DC resistance between the TDR unit and the short circuit of Fig. 2-21B. The vertical distance between the incident pulse peak level and the right end flat portion of the reflected signal is due strictly to the cable DC resistance. In this case, -3.8 divisions $= -0.76\,\rho$ which is equal to 6.5 Ω (from curve of Fig. 2-10). (A bench multimeter type ohmmeter indicated 6.8 ohms for the same cable.)

Quality Cables

A quality cable, such as RG8A/U (52 Ω), RG213/U (50 Ω) or RG11/U (75 Ω) will exhibit similar characteristics to the small lossy cable just described, but the cable must be much longer to obtain a similar display of series resistance. Fig. 2-22A and B show the same rising type of waveform caused by center conductor series resistance in RG213/U. Fig. 2-22C shows the residual DC resistance of the line when shorted. Fig. 2-22D is a time and voltage expansion of the (A) and (B) waveforms to show a possible use for the Type 1S2 in troubleshooting cable fabricating equipment.

Fig. 2-23 shows the same series resistance characteristics for RG11/U cable. However, instead of terminating the cable end, the series resistance was measured first with the end open, and then with the end shorted. Note the difference in slope of the waveform (apparent change in resistance) after the signal has traveled to the indicated line end. The change in slope is due to distortion of the originally flat incident pulse by traveling through the cable once. As the non-flat signal reaches the cable end, its reflection back through the cable is altered a second time. The net result is an obvious distortion to the true resistive slope of the reflected "bits" of the distributed series resistance during the 2nd half of the reflection. This example is given to show the desirability of properly terminating any line section in which you wish to measure its total distributed series resistance. (Conditions leading to this changing slope phenomenon are described by H. H. Skilling on page 397 of his text "Electronic Transmission Lines", McGraw-Hill, 1951.) Each of the three waveform pictures of Fig. 2-23 is a double exposure with the lower waveform showing the normal Type 1S2 response to a termination resistance at (A) and (B) and a short circuit at (C).

COAXIAL CABLE RESPONSE TO A STEP SIGNAL

Coaxial cables have a step-function response that distorts the original signal. The distortion is caused by cable losses of several types which are frequency dependent. The longer the cable length, the greater the distortion. Response to a step signal can be evaluated by placing the cable in a TDR system, or by placing it between a fast rise pulser and a fast risetime sampler. (When a cable is tested by a TDR

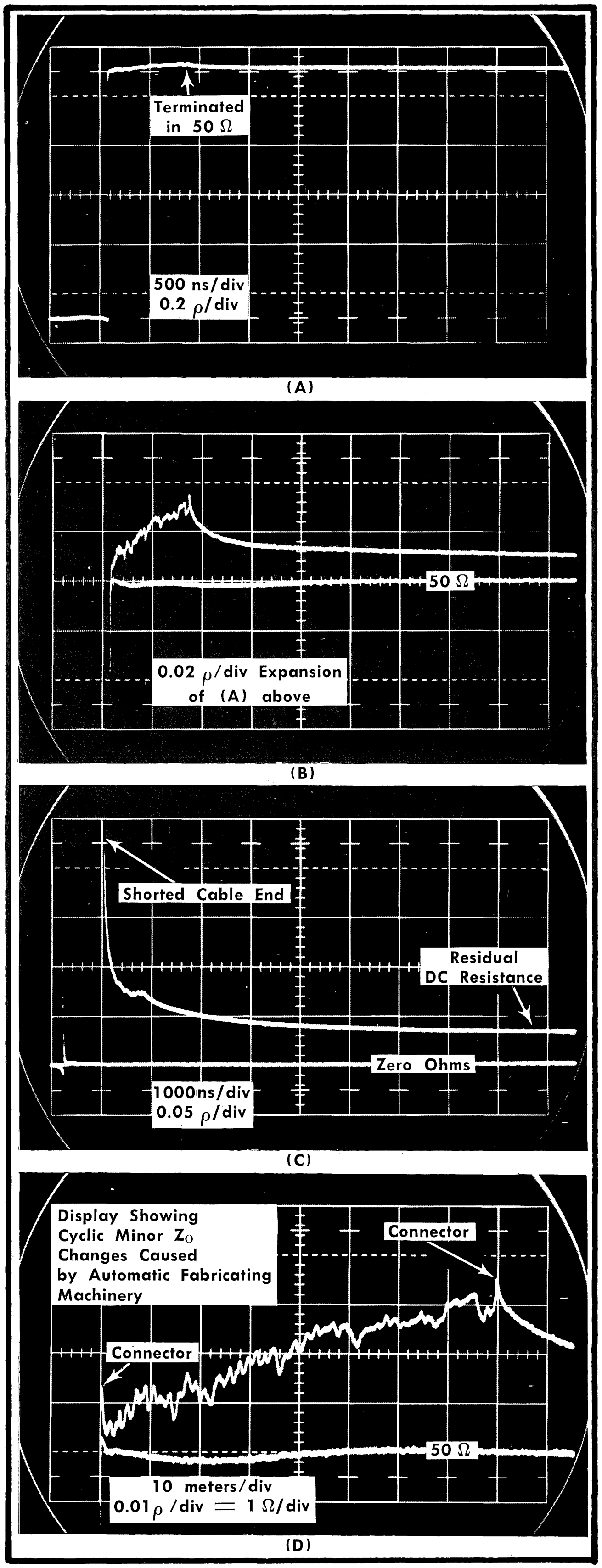


Fig. 2-22. Quality RG213/U cable resistance and ΔZ_o characteristics. (Cable tested 260 feet long.)

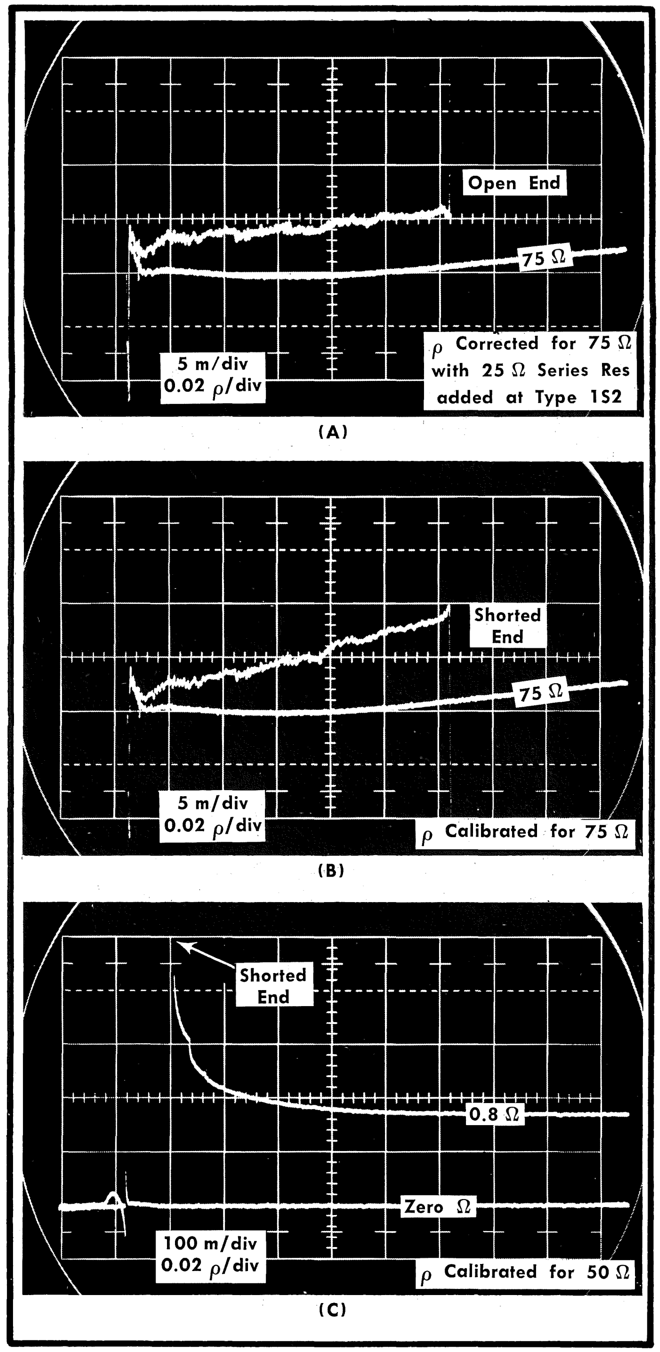


Fig. 2-23. Quality RG11/U cable resistance and ΔZ_o characteristics. (Cable tested was 100 feet long.)

device, the signal traverses the line twice; when a cable is placed between a pulser and a sampler, the signal traverses the line once.)

Studies in the past that considered skin effect losses only[1] have indicated that some types of coaxial cables have a step-function response with decibel attenuation that varies as the square root of the frequency. Based upon this assumption (of skin effect losses only), the step response time from 0% to 50% will increase by a factor of 4 through a cable whose length is twice that of a previous test. Such is not the case in practice as seen by use of the Type 1S2. Other forms of losses due to the dielectric material between inner and outer conductors, radiation from lines whose outer conductor is braided, and reflection losses from surface variations of the conductors, are discussed in detail in an article by N. S. Nahman[2]. Nahman considers several techniques which are useful in analyzing the transient behavior of coaxial cables that have these forms of high frequency losses.

Long Cables

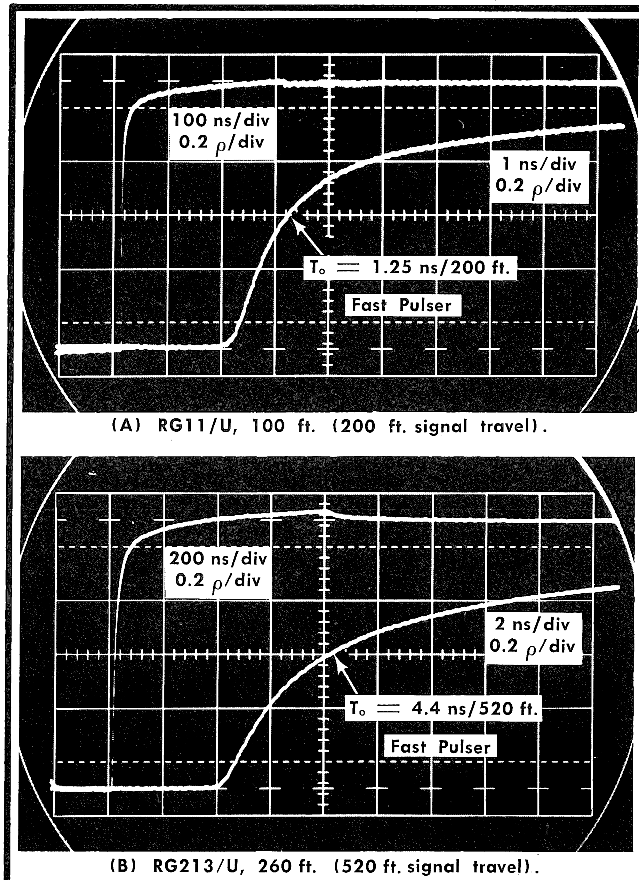
Distortion to pulse signals in coaxial cables is most easily evaluated (visually displayed on a CRT) when the cable is long. A long cable is here defined as one that exhibits significant losses in the system in which it is used. The tests shown in Fig. 2-24 where made on a 100 foot section of RG11/U and a 260 foot section of RG213/U. In each case the signal traversed the line twice in a normal TDR manner. The cable far end was left an open circuit so that a return signal of $+1\ \rho$ could be observed. This gives the same effect as having sent the Type 1S2 signal through a line twice as long.

The term T_o, shown in Fig. 2-24, is the length of time between the 0% amplitude and 50% amplitude points along the step rise of the cable output signal. 0% to 50% is chosen because it contains the fastest part of the transition and because it is easy to read. The usual practice of measuring risetime from 10% to 90% is perfectly valid if the display has an adequate rate of rise at the 90% point. The cables tested for Fig. 2-24 have a 10% to 90% risetime that lasts about 18 times longer than T_o. Fig. 2-24 shows plainly that the step response of a coaxial cable does not have the familiar Gaussian shape. For this reason the risetime of systems containing long coaxial cables cannot be calculated using the square root of the sum of the squares of the individual unit risetimes.

The length of time required for the output signal to rise to 100% of the input signal is many times longes than T_o. This distortion is called "dribble up" as first discussed earlier under Measuring Technique when measuring a small series inductor in a transmission line. Fig. 2-25A is a double exposure using the 260 foot length of RG213/U connected between the Type 1S2 1-Volt pulser and the terminated Thru Signal Sampler. Both traces were made at 100 ns/div. The upper trace at 0.2 ρ/DIV and the lower trace at 0.05 ρ/DIV. The lower trace leads us to believe that the output pulse reaches 100% amplitude sometime between 4000 and 5000 ns after the initial step rise. More exact measurements can be made by comparing the cable output with the Type 1S2 no-cable response as shown in Fig. 2-25B. Here both traces were made at 1000 ns/DIV and 0.02 ρ/DIV with an intentional small vertical repositioning. When the two traces become a constant distance apart, you can be relatively certain the cable output signal has reached 100% amplitude. Fig. 2-25B indicates a possibility that the output signal had not completely reached 100% amplitude even after 8000 ns (8 μs).

[1]**R. L. Wigington and N. S. Nahman, "Transient analysis of coaxial cables considering skin effect," Proc. IRE, vol. 45, pp. 166-174; February 1957. Q. Kerns, F. Kirsten and C. Winningstad, "Pulse Response of Coaxial Cables," Counting Notes, File No. CC2-1, Rad. Lab., University of California, Berkely, Calif.; March, 1956. Revised by F. Kirsten; Jan. 15, 1959.**

[2]**N. S. Nahman, "A Discussion on the Transient Analysis of Coaxial Cables Considering High-Frequency Losses," IRE Transactions On Circuit Theory, vol. CT-9, No. 2, pp. 144-152; June, 1962.**



(A) RG11/U, 100 ft. (200 ft. signal travel).

(B) RG213/U, 260 ft. (520 ft. signal travel).

Fig. 2-24. RG11/U and RG213/U distortion to a step signal. Waveforms are reflections from cable open end.

Short Cables

Even though information just given on Long Cables is true for any length cable, a physically short cable can be treated as if it were Gaussian. A short cable will have a T_o sufficiently faster than the Type 1S2 fast pulser 10% to 90% risetime, that the long slow rise ("dribble up") of Fig. 2-25 will not be evident. Under these short cable conditions, it is reasonable to assume the bandpass upper limit of a cable and its system can be approximated from the 10% to 90% risetime display. A display of 10% to 90% risetime in 100 picoseconds then approximates a sine wave upper frequency 70% amplitude of: $0.35/(1 \times 10^{-10}) = 3500$ MHz.

Large Diameter Transmission Lines

Use of the Type 1S2 0.25-Volt fast risetime pulser should be limited to use on lines whose outer conductor inner diameter is less than about one-quarter wavelength at 3500 MHz. Normal signal propagation mode in transmission lines is TEM, but will change to a waveguide mode, TE_{11}, if too

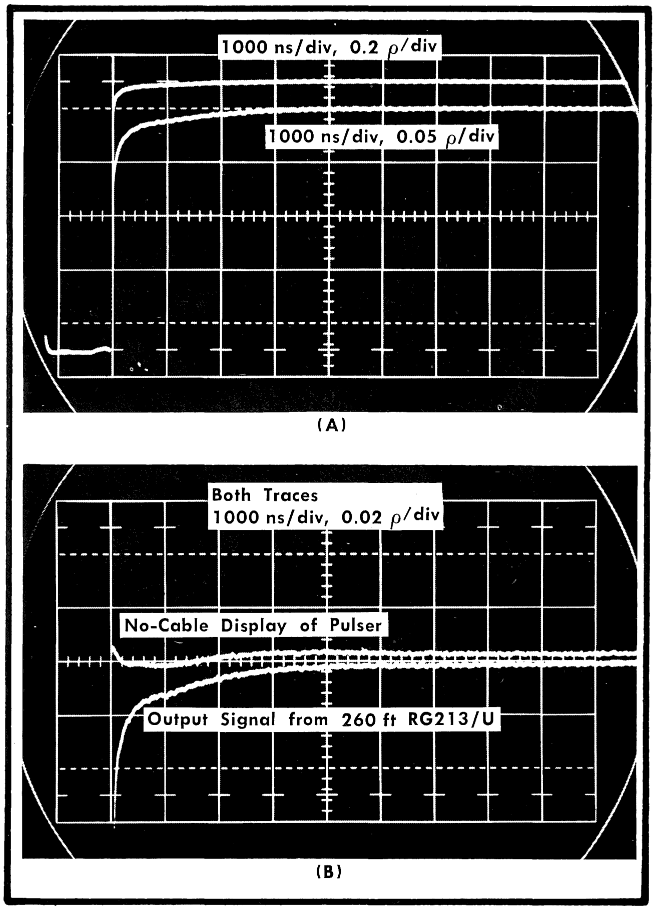


Fig. 2-25. "Dribble up" output signals from 260 ft. RG213/U.

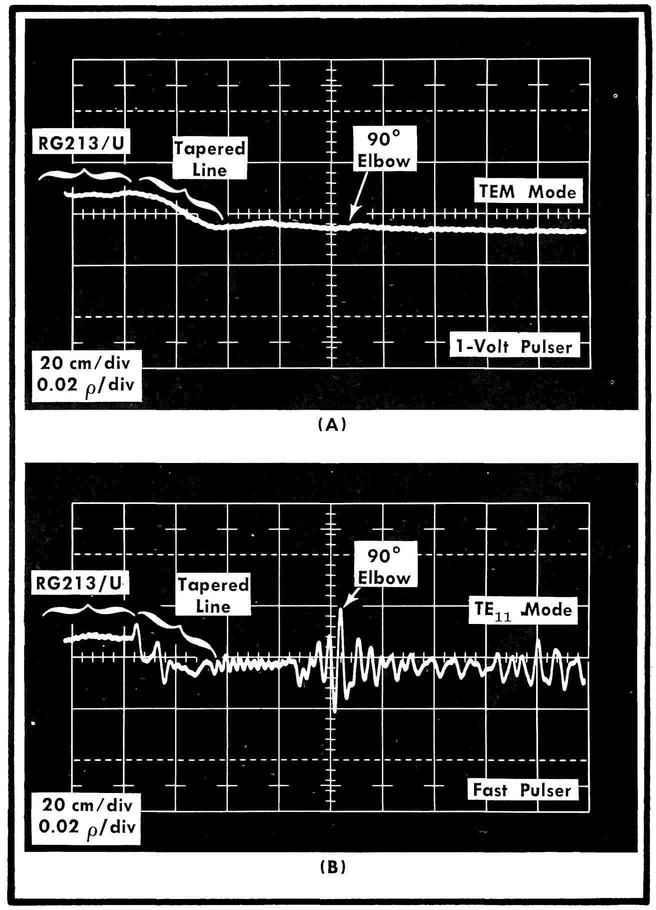


Fig. 2-26. Propagation mode change in large diameter transmission line when driven by the Type 1S2 fast pulser.

high a frequency is used. Fig. 2-26 shows both modes of propagation in a transmission line 3⅛ inch in diameter. Fig. 2-26A picture was taken using the Type 1S2 1-Volt pulser. Fig. 2-26B picture was taken using the Type 1S2 0.25-Volt fast pulser. The line elements were the same in each case; 1) a short section of RG213/U cable between the Type 1S2 and a tapered line section; 2) the tapered line section; and 3) a section of 3⅛ inch diameter rigid air line with a 90° elbow in the display time window. The numerous aberrations of Fig. 2-26B are due to a change in propagation mode when the signal arrived at the 90° elbow. The resulting multiple reflections are of no value to the operator testing the line.

CAUTION

Long lengths of stored coaxial cable can develop large electrostatic voltage charges unless there is a permanent connection between the inner and outer conductor. Always short the cable end to remove any such electrostatic charge before connecting the Type 1S2.

SPECIAL APPLICATIONS

General

Much of the previous portion of this section deals with using the Type 1S2 as a Time Domain Reflectometer. Many more uses can be made of the unit in a TDR mode, limited only by the measurement needs of the user. Use of the Type 1S2 as a normal sampling plug-in (with 3.9 GHz 70% amplitude response) will be discussed in Section 3 Operating Instructions. Listed below are suggestions of other TDR applications not yet described.

Signal Generator Output Impedance

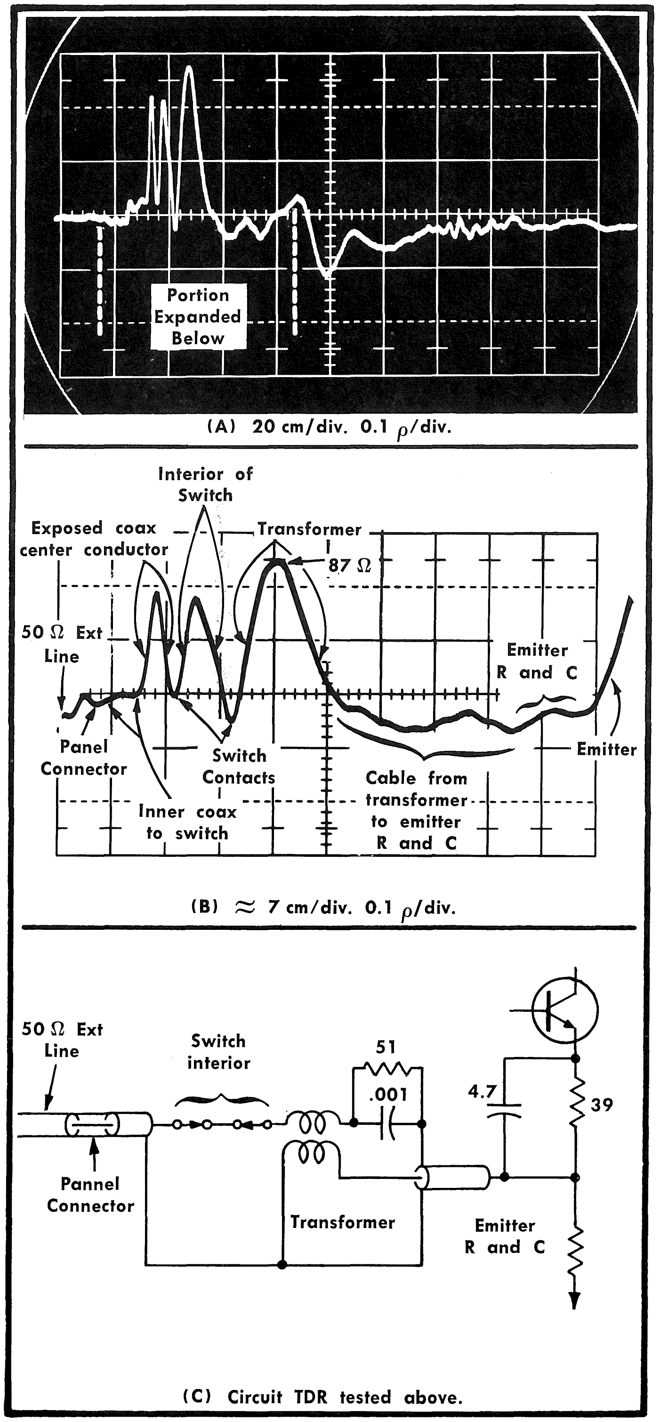
The Type 1S2 can be connected to the output terminal of a signal generator to measure its output impedance. If the generator output signal can be turned off while keeping the output circuit active, a clean TDR display can be obtained.

Broadband Amplifier Input Impedance

Fig. 2-27 shows two pictures of a broadband amplifier input circuit. Fig. 2-27A includes the active emitter circuit of the input common-base transistor amplifier. Fig. 2-27B includes the parts between the input connector and the transistor emitter. The power was off when Fig. 2-27B photo was taken to show the transistor emitter spatial location accurately.

Circuit Board Lead Impedance

Fig. 2-28A shows changes in surge impedance of leads along an etched circuit board. (The board reverse side was fully plated.) The major dip is due to a right angle corner while the minor dip is due to a rounded corner.



(A) 20 cm/div. 0.1 ρ/div.

(B) ≈ 7 cm/div. 0.1 ρ/div.

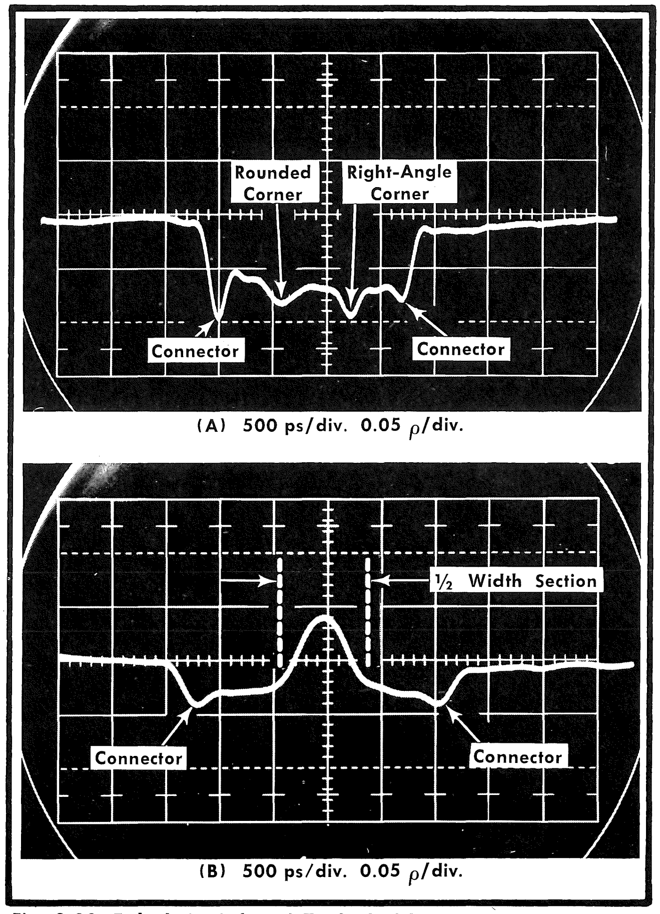
(C) Circuit TDR tested above.

Fig. 2-27. TDR view of broadband amplifier input circuit.

Changes in surge impedance due to a change in lead width are also plainly seen by TDR. Fig. 2-28B shows an inductive section of line when the physical width of the line was reduced one half for a length of about 1.25 inches.

Frequency Compensation of Lossy Cables

A lossy coaxial cable connected between one of the Type 1S2 pulsers and the sampler (terminated) permits a view of the cable output signal. Fig. 2-29 shows the same lossy cable described earlier with Fig. 2-21. A double exposure shows at the top how the cable distorts the 1-Volt pulser while the



(A) 500 ps/div. 0.05 ρ/div.

(B) 500 ps/div. 0.05 ρ/div.

Fig. 2-28. Etched circuit board Z_o checked by TDR.

lower waveform is flatter due to a simple RC compensation network placed between the pulser and the cable. The TDR unit will permit testing such compensation networks.

Evaluation of Ferrite Beads and Cores

Ferrite beads and cores can be evaluated using the Type 1S2. Simple inductors wound on toroid ferrite cores are represented by an equivalent circuit which is essentially an inductance in parallel with a resistance. The resistance results from core losses and may be typically as low as 10 to 30 ohms/(turn)^2. Both the resistance and inductance characteristics of ferrites can be seen in a TDR display.

Fig. 2-30 shows two displays and the special adapter jig used to test a ferrite bead. The adapter jig is made from one half of a Tektronix Insertion Unit (Part No. 017-0030-00). The end of the center piece was flattened and a formed piece of #10 copper wire soldered in place with a ferrite bead included. Thus, there is only a small diameter change of the 50 center conductor (pip in both displays) and one turn through the ferrite center. (Use smaller wire for smaller beads.)

Fig. 2-30A shows the basic display. L/R time-constant analysis is similar to that of Fig. 15 and formula (8) of Table 5, except the core R is in parallel with the driving line Zo.

Fig. 2-30B shows the ferrite bead resistance as —0.16 ρ, or 36 Ω. (The 36 Ω is read directly from the curve of Fig. 2-10.) The resistance value of a core is read by finding the curve knee (as marked in Fig. 2-30B) where the inductance effect becomes obvious. The positive pip is ignored.

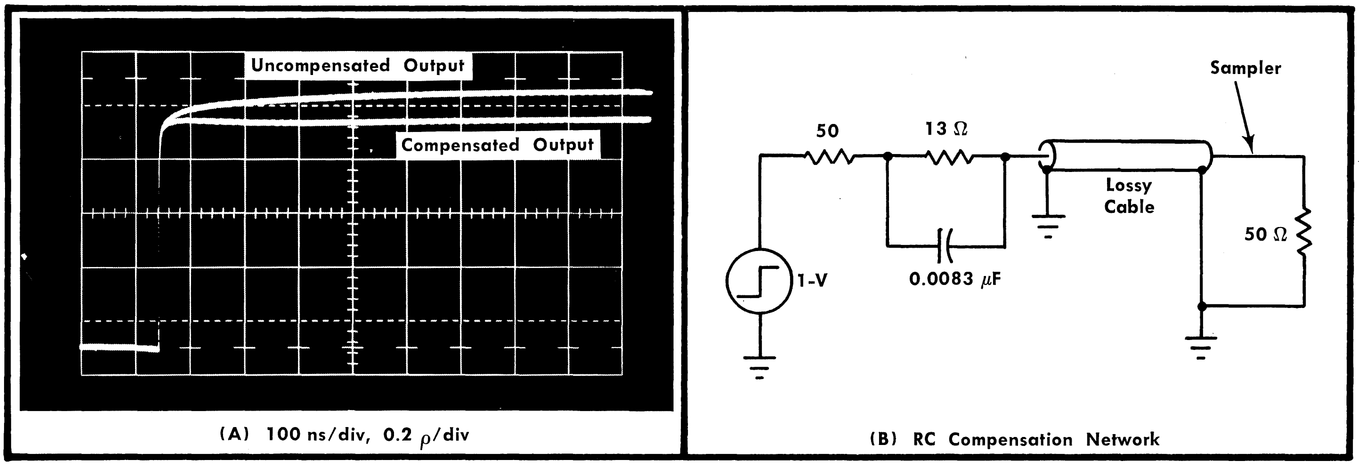


Fig. 2-29. Simple frequency compensation for lossy coaxial cable.

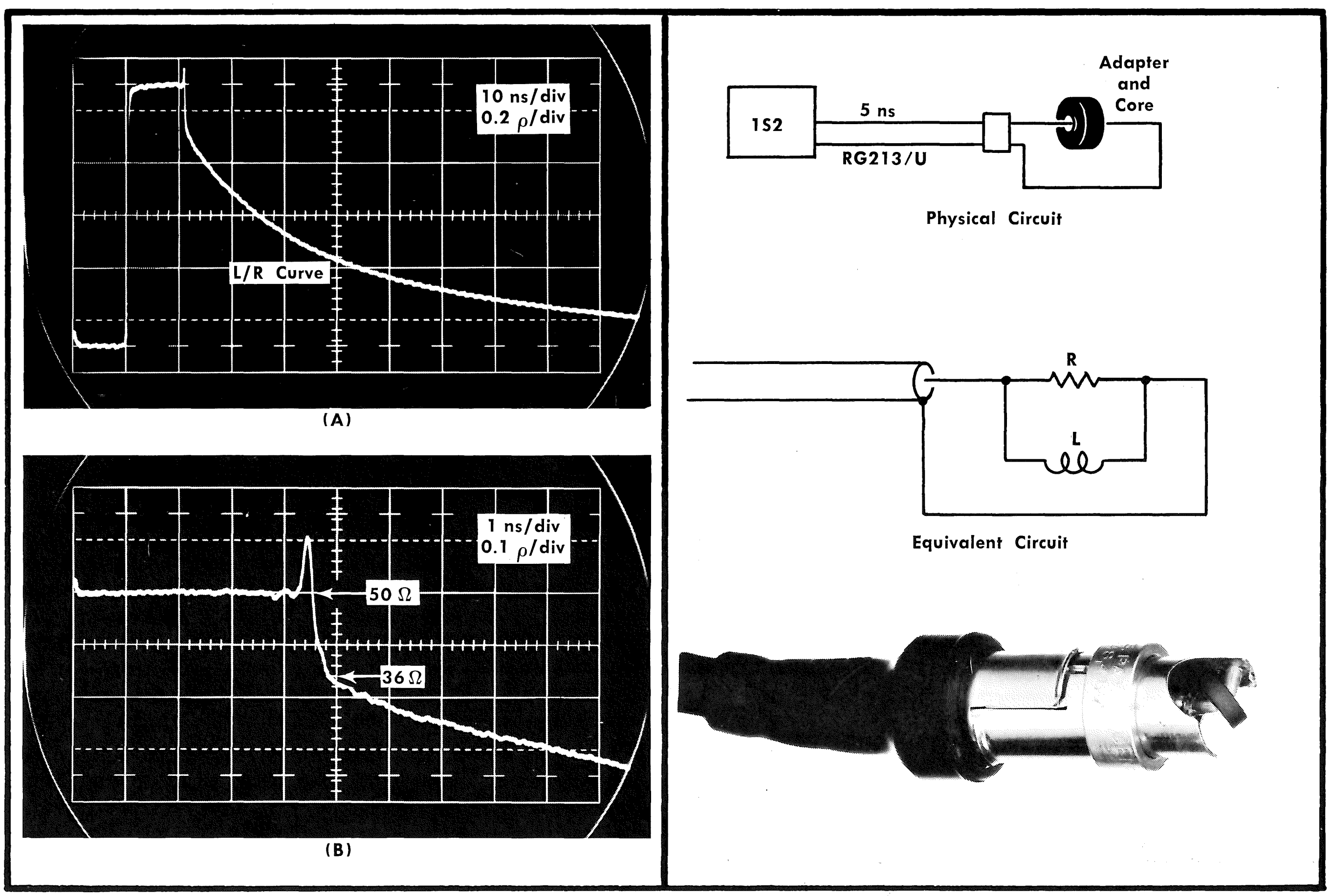


Fig. 2-30. Evaluation of a ferrite core.

SECTION 3
OPERATING INSTRUCTIONS

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

The Type 1S2 Sampling Unit is both a Time Domain Reflectometer and a normal sampling oscilloscope plug-in unit with upper frequency response of 3.9 GHz (70% amplitude response). The unit may be operated in Tektronix 530/540/550 and 580 (with Type 81 adapter) series Oscilloscopes. This section deals with details of operation of the Type 1S2.

PRELIMINARY INSTRUCTIONS

Since the Type 1S2 Sampling Unit is part of a complete oscilloscope system, we suggest that you be familiar with the oscilloscope main frame into which the Type 1S2 is placed. Some oscilloscopes require that the AC power be turned off before plug-in unit insertion or removal, others do not.

Installing the Type 1S2 in the Oscilloscope

With the oscilloscope power off, gently slide the Type 1S2 fully into the plug-in unit compartment. Press it firmly into the rear connector before tightening the gray locking screw. When certain that the rear connectors are properly mated, turn the gray locking screw (bottom center of panel) several turns clockwise until it is obvious the unit cannot slip forward.

To remove the Type 1S2, disconnect any cables, turn off the oscilloscope power, turn the gray locking screw counterclockwise until obviously free of the threads, and gently pull the unit forward and out of the plug-in compartment.

MATING THE TYPE 1S2 TO THE OSCILLOSCOPE

The Type 1S2 is calibrated to operate in any 500-series Tektronix oscilloscope that has its external horizontal system set for 1 V/div. Two adjustments must be made each time that the Type 1S2 is placed into another oscilloscope: (1) the oscilloscope external horizontal deflection sensitivity and (2) the Type 1S2 VERT GAIN control. Two methods are available for each adjustment. One method uses an external accurate voltage source, the other method uses only the Type 1S2 and its accessories.

NOTE

The external accurate voltage source is the only method acceptable if the Type 1S2 specifications are being checked. The "self-contained" procedure is given as a convenience to those without the required accurate voltage source readily available.

Equipment Required to Check Type 1S2 Specifications

1. An accurate voltage source that provides 5 volts DC or low frequency AC to an accuracy of $\pm 1\%$ with a source impedance $\leq 1\ k\Omega$.

2. An accurate voltage source that provides no less than 0.5 or more than 2.0 volts $\pm 1\%$ into 50 Ω, DC or greater than 100 kHz AC. If AC, an external trigger source with amplitude between 50 mV and 1 volt. Tektronix Type 284 recommended.

3. The GR 874 W50B termination supplied with the Type 1S2.

Procedure Using External Voltage Sources

1. Install the Type 1S2 into the oscilloscope. Turn the oscilloscope Intensity control fully counterclockwise and turn on the AC power.

Set the oscilloscope controls:

Horizontal Display	External ×10 or ×1, for 1 V/div
Time Base Triggering Circuits	No triggers or sweeps
Horizontal Position	Midscale
CRT Cathode Selector (rear panel)	Chopped Blanking

Set the Type 1S2 controls:

OFFSET	Midrange
VERTICAL UNITS/DIV	.5
Vertical Units VARIABLE	CAL detent
ρ—VOLTS	VOLTS
POSITION	0.00
DISPLAY MODE	NORMAL
HORIZONTAL UNITS/DIV	TIME
MODE (lower right side)	EXT TRIG
TRIGGER SENS	Fully Clockwise
MAGNIFIER	×1
Magnifier VARIABLE	CAL
RANGE	.1 μs—10 m if vertical voltage source is DC, to appropriate time/div range if AC
DIELECTRIC	AIR

2. After 20 minutes warm up, connect the 5 volt source to the oscilloscope External Horizontal Input connector.

Slowly turn up the Intensity control while turning the Horizontal Position control back and forth through about half its range. As soon as the horizontal scan limits are seen, the display position and intensity can be properly adjusted.

Adjust the External Variable gain control (sometimes labeled VAR 10-1) for a horizontal deflection of 1 CRT division per volt.

3. Connect the Type 1S2 HORIZ OUTPUT banana jack to the oscilloscope External Horizontal Input connector. A patch cord is provided for this purpose with the Type 1S2 accessories.

There should now be a sweep. Position its beginning to the graticule left edge.

4. Connect the 50 Ω termination to one of the THRU SIGNAL CHANNEL 50 Ω connectors. Connect the vertical voltage source to the other thru channel connector and the triggering signal to the EXT TRIG INPUT connector. If there is no special provision for an external trigger signal from the voltage source, limit the voltage to 1 volt or less and connect it to the EXT TRIG INPUT connector through the THRU SIGNAL 50 Ω connectors. This is done by using the 10 inch GR Connector Cable between the top THRU Signal connector and the Ext Trig Input connector, and feeding the lower Thru Signal connector. (The Thru Signal Channel approximate 5 kΩ DC resistance will not significantly upset the voltage source accuracy if the voltage source is truly calibrated to drive 50 Ω).

5. If using a Tektronix Type 284, set the Period switch to 1 μs and the Square Wave Amplitude switch to 1.0 V.

Set the Type 1S2 controls:

RANGE	1 μs/100 m
MAGNIFIER	×1
VARIABLE	CAL

Adjust the TRIGGER SENS control for a stable display.

6. Adjust the Type 1S2 VERT GAIN control until the CRT display indicates that the deflection factor is correct for the particular voltage source used.

Equipment Required for Self Contained Setup Procedure

1. Two GR 90° elbows.
2. Patch cord from Type 1S2 HORIZ OUTPUT banana jack to oscilloscope external horizontal input connector.
3. 20 cm long air line, GR874-L20.
4. 5 ns signal delay RG213/U coaxial cable with GR connectors.

All of these parts are supplied with the Type 1S2.

Self Contained Setup Procedure

This procedure uses the TDR features of the Type 1S2 to set the oscilloscope horizontal gain and the Type 1S2 VERT GAIN controls. This procedure is NOT to be used unless you are certain the Type 1S2 is properly calibrated and in good working order. Instrument specifications are not to be tested by the use of this setup procedure.

1. Install the Type 1S2 into the oscilloscope. Turn the oscilloscope Intensity control fully counterclockwise and turn on the AC power.

Set the oscilloscope controls:

Horizontal Display	External ×10
Time Base Triggering Circuits	No triggers or sweeps
Horizontal Position	Midscale
CRT Cathode Selector (rear panel)	Chopped Blanking

Set the Type 1S2 controls:

OFFSET	Midrange
VERTICAL UNITS/DIV	.5
Vertical Units VARIABLE	CAL detent
ρ—VOLTS	ρ
POSITION	Fully clockwise
DISPLAY MODE	NORMAL
HORIZONTAL UNITS/DIV	DISTANCE
MODE (lower right side)	INT PULSE .25 V—50 ps
MAGNIFIER	×20
Magnifier VARIABLE	CAL detent
RANGE	.1 μs—10 m
DIELECTRIC	AIR
TRIGGER SENS	Any position

2. Make the following connections.

Install a patch cord between the Type 1S2 HORIZ OUTPUT banana jack and the oscilloscope external input connector.

Join the 0.25-Volt Pulser and the lower Thru Channel connectors using the 10 inch GR Connector Cable.

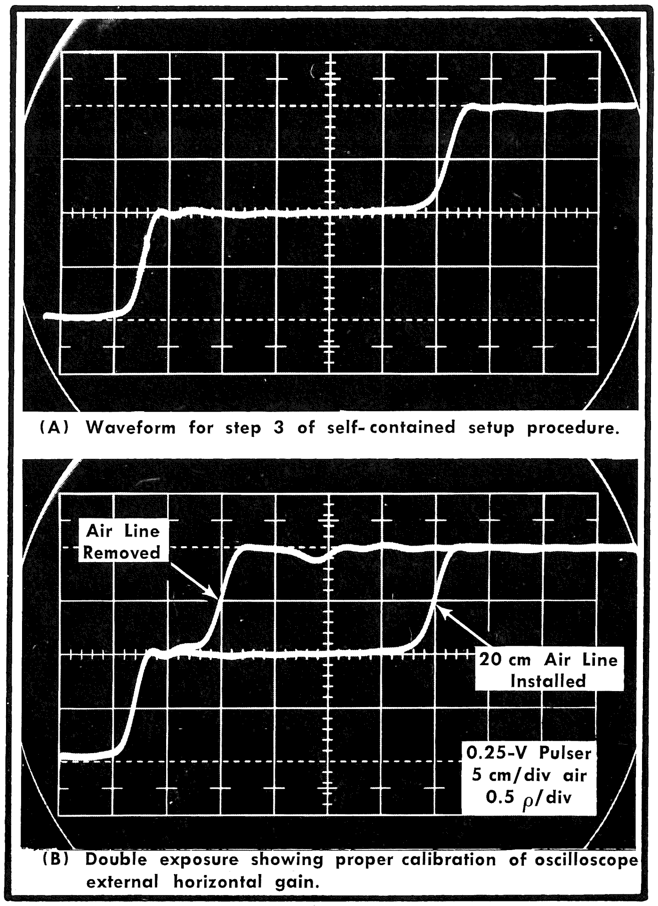
Install a 20 cm air line (GR874-L20) to the upper Thru Channel connector.

3. After 20 minutes warm up, turn up the oscilloscope Intensity control. If there is no pulse display with the controls as set, use a small bit screwdriver and adjust the STABILITY control located next to the pulser in use. Proper adjustment of the STABILITY control is shown in Fig. 3-3B. There will be some time positioning of the incident pulse as the STABILITY control is adjusted. If the pulse moves off the left side of the CRT with the POSITION control at 0.00 and the MAGNIFIER control at ×100, use the Calibration Procedure step 26 or 30 to correct the problem. Final adjustment of the STABILITY control should produce minimum time jitter of the incident pulse and little or no change in trace level just before the transition begins. Once the STABILITY control is correctly set, and the display is similar to Fig. 3-1A, set the oscilloscope external horizontal gain control (sometimes labeled VAR 10-1) for a sweep length of 10.5 divisions.

4. Proper final adjustment of the oscilloscope external horizontal gain control is achieved when the TDR reflection moves exactly 4 divisions horizontally with, and then without, the 20 cm air line installed. Fig. 3-1B is a double exposure showing how the open end reflection of the air line, and then the open end reflection from the Thru Channel connector

are exactly 4 divisions apart. It is essential that the 20 cm air line be fully mated with the Thru Channel connector. Accurate timing, as shown in Fig. 3-1 can be accomplished by careful adjustment of the oscilloscope horizontal gain control and Vernier Horizontal Position control, and the Type 1S2 POSITION control at the time the 20 cm air line is installed.

5. Change the Type 1S2 RANGE switch to 1 μs—100 m, the RESOLUTION switch to HIGH and the DIELECTRIC switch to POLYETHYLENE. Remove the 20 cm air line and install a 5 ns signal delay RG213/U coaxial cable to the Thru Signal connector.



(A) Waveform for step 3 of self-contained setup procedure.

(B) Double exposure showing proper calibration of oscilloscope external horizontal gain.

Fig. 3-1. Self-contained timing setup waveforms, steps 3 and 4.

Adjust the POSITION control for a display horizontal position similar to that shown in Fig. 3-2.

Adjust the Type 1S2 VERT GAIN screwdriver adjust control until the portions of the display marked in Fig. 3-2 are even with graticule lines 4 divisions apart vertically. The portions of the display indicated by Fig. 3-2 arrows provide the most accurate points for making this adjustment; no reflections appear at those points. This method excludes the cable characteristics from adding any error to the VERT GAIN adjustment.

FIRST TIME TDR OPERATION

The self contained setup procedure is actually a TDR operation. If you adjusted the oscilloscope horizontal gain and the Type 1S2 vertical gain with external references, perform the self contained setup procedure as your first time TDR operation.

Note in Fig. 3-1 and Fig. 3-2 that two different lengths of coaxial line were tested. The information to be gained from either figure is the line length, and that it was open at the "load" end. Also, from Fig. 3-2, the waveform shows that the line used has a characteristic impedance slightly greater than 50 Ω. If it had been exactly 50 Ω, there would have been no deflection greater than 4 divisions between the 3rd the 5th distance graticule lines. Changes in temperature may require either the 1.0 V or the .25 V pulser STABILITY control to be readjusted. If there is no pulse, or if there is pulse jitter, repeat step 3 of the Self Contained Setup Procedure just completed above and refer to Fig. 3-3.

When operating with the .25 V pulser and the vertical units per division is expressed in ρ units, risetime measurements of reflected signals requires there be at least 14 segments in the display transition. Most displays will show no segments, but should they be visible, there must be at least 14 in the transition (or ramp portion of the display) in order to make a valid risetime measurement.

Understanding TDR Displays

Section 2 of this manual deals with many TDR applications and principles. Refer to that material for better understanding of your various TDR displays.

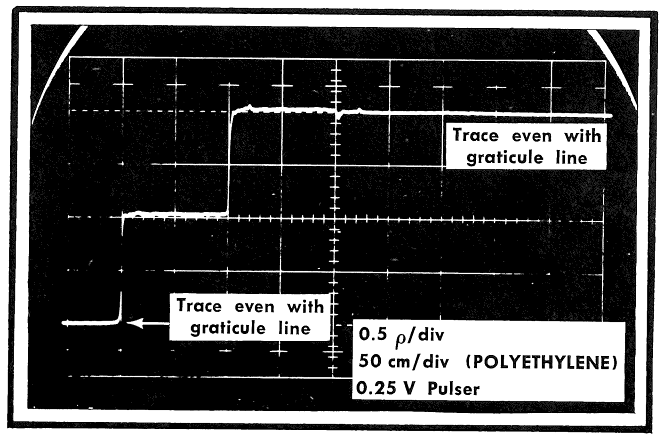


Fig. 3-2. Proper display when settinng VERT GAIN control in self-contained procedure, step 5.

75 OHM TDR MEASUREMENTS

TDR measurements can be made in 75 ohm transmission lines by special use of the Type 1S2. The following discussion and Fig. 3-4 outline the method for correcting the vertical calibration to obtain direct reading reflection coefficient data.

If a 75 ohm line is connected directly to the Type 1S2 (in TDR mode), reflections from discontinuities will be reflected by the 50 Ω mismatch at the sampler. Fig. 3-4A and B waveforms were taken when a 75 Ω cable with approximately 13 ns signal delay was connected directly to the Thru Signal sampler. No re-reflections show in (A) because the time window did not include them. Re-reflections in (B) add only

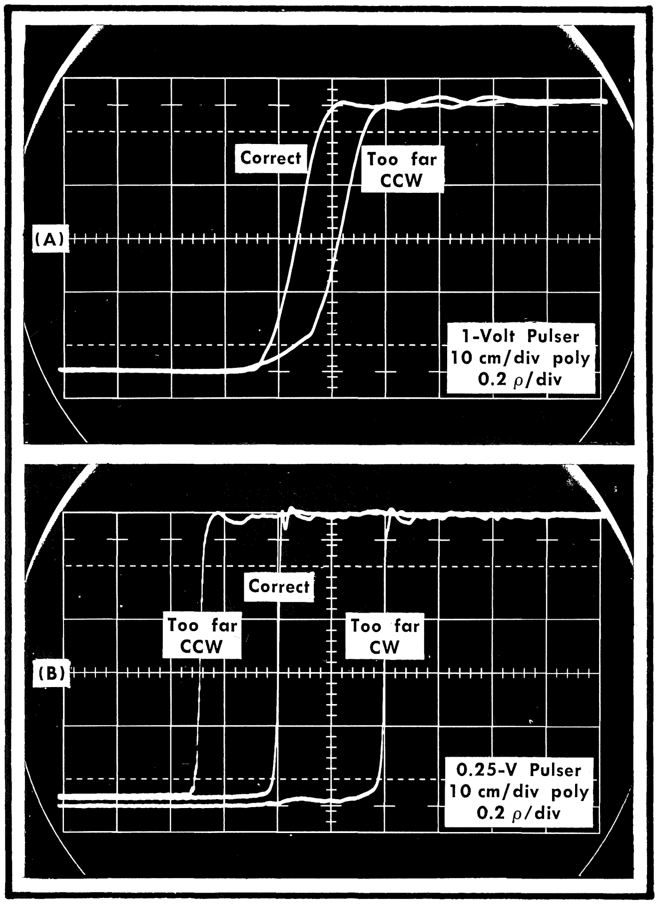


Fig. 3-3. Incident pulse displays (into 50 Ω line) while adjusting STABILITY controls.

confusion. However, there is nothing wrong with this hookup because the re-reflections can be placed out of sight past the time window, providing the line's electrical length is known.

Fig. 3-4C was taken when a 25 Ω resistor was placed in series between the Type 1S2 and the 75 Ω line. Note that no major re-reflections are now evident, just the small negative pip due to the environment around the 25 Ω resistor. (The 25 Ω resistor was two 50 Ω 1% deposited film ½ watt resistors in parallel inside a Tektronix Insertion Unit in series with the center conductor. Insertion Unit, Tektronix Part No. 017-0030-00.)

ρ Correction

All waveforms of Fig. 3-4 show a corrected deflection factor to obtain direct reading reflection coefficient data. The incident pulse is ignored, and the Vertical Units/Div VARIABLE control adjusted clockwise until the open end reflection of +1ρ spans the correct number of vertical divisions to agree with the VERTICAL UNITS/DIV switch. A short at the cable end will cause an equal amplitude —1ρ reflection, again ignoring the incident pulse.

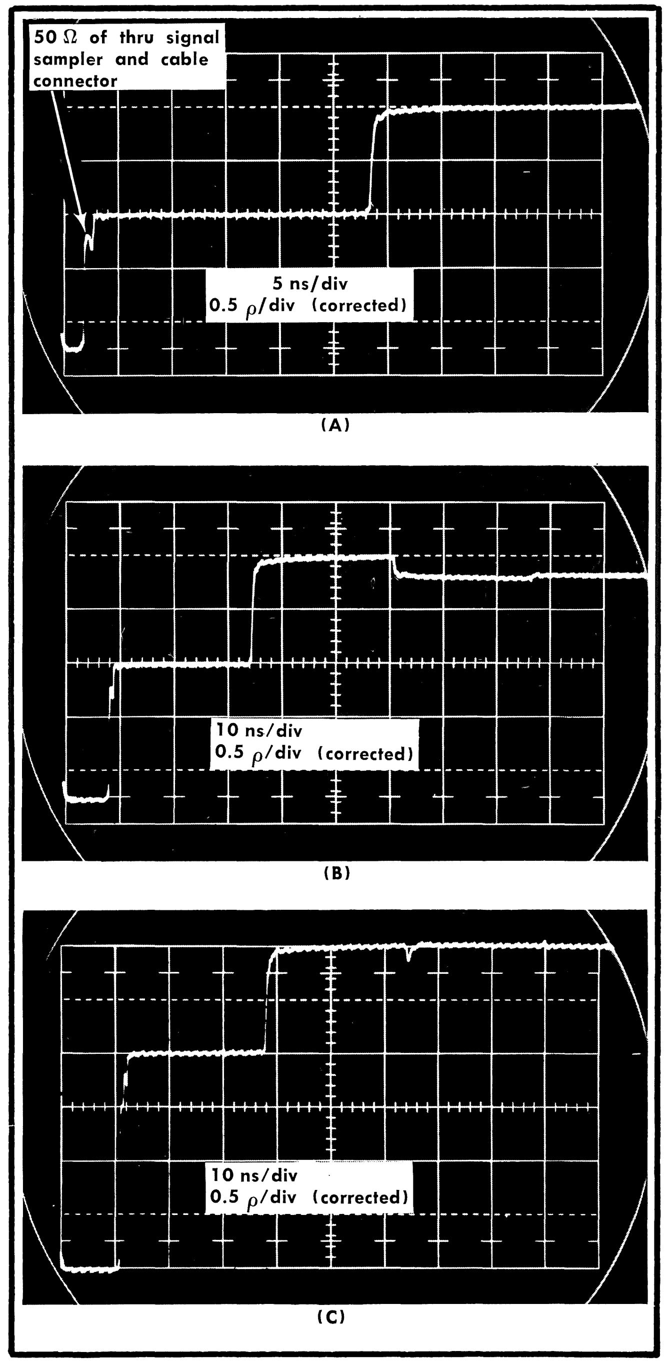


Fig. 3-4. ρ correction for 75 Ω lines.

Resistive reflections can now be analyzed through use of formulae (2) and (3) found in Section 2. Reactive discontinuities can also be evaluated using the proper formulae from Section 2.

Front Panel Layout

The Type 1S2 front panel is arranged in two basic parts. The left side and top-center controls deal primarily with the oscilloscope vertical display. The right side and mid-center controls deal primarily with the oscilloscope horizontal display and the TDR pulser source. The readout window relates entirely to the horizontal units per CRT division.

The two part layout is followed in the descriptions of controls and connectors below. The description begins with the VERTICAL UNITS/DIV control and, moving counterclockwise around the front panel, ends with the POSITION control.

Function of Front Panel Controls and Connectors

VERTICAL UNITS/DIV — A seven position switch that selects the display units per division in a 1, 2, 5 sequence from .005 to .5. The actual units are either ρ or VOLTS depending upon the lower right side MODE switch and the ρ—VOLTS switch. The vertical units/div will be only VOLTS when the MODE switch is at either UHF SYNC or EXT TRIG for normal sampling oscilloscope operation. The vertical units/div can be either ρ or VOLTS when the MODE switch is at either INT PULSE position.

Vertical Units VARIABLE Control — A variable control that gives continuous coverage between all VERTICAL UNITS/DIV switch positions. The VARIABLE control normally rests at its center CAL position. Counterclockwise rotation increases the vertical deflection factor (instrument is less sensitive). Clockwise rotation reduces the vertical deflection factor (instrument is made more sensitive). The control changes the vertical deflection factor to at least 2 times the units/div setting; clockwise rotation changes deflection factor to 40% or less of the units/div setting.

ρ—VOLTS Switch — Two position slide switch that selects the vertical units/div when the lower right side MODE switch is at either INT PULSE position. This switch is inoperative and the VOLTS lamp is lighted when the MODE switch is at either UHF SYNC or EXT TRIG.

VERT GAIN (Screwdriver adjust) — Variable control that permits the Type 1S2 output vertical signal to properly match the oscilloscope main-frame amplifier sensitivity. Set the VERT GAIN control each time the Type 1S2 is first placed in a different oscilloscope. (See the First Time Operation Instructions in this section.)

OFFSET Controls — Positions the display vertically and provides a 1:1 signal-related front panel voltage for accurate slideback measurement of voltage or reflection coefficient.

×1 OFFSET OUTPUT Jack (±2 V, 10 kΩ) — Pin jack external connection from the OFFSET circuit. Total voltage deviation available, ±2 volts at 10 kΩ output impedance. Voltage accuracy related to any one fixed vertical display point is ±1% into an infinite impedance voltmeter.

RESOLUTION Switch — Changes sampling display resolution (dot density and smoothing) by selecting one of two horizontal sweep rates. NORMAL resolution selects a sweep rate with slight flicker giving a continuous display. HIGH resolution selects a slow sweep rate that takes about two seconds per sweep.

DISPLAY MODE Switch — Four position switch that controls the Type 1S2 horizontal mode of operation.

- **NORMAL** — Horizontal scanning (sweep) is repetitive as controlled internally for TDR or normal sampling equivalent time displays.
- **SINGLE SWEEP** — Turns off the repetitive sweep when MODE switch is placed in this position. Permits one sweep to occur when the associated START button is pressed. Single sweep operation is valuable when photographing displays (or using storage oscilloscope displays). Photographs or stored oscilloscope displays allow the most accurate measurement analysis, and photographs are most easily made using the Single Sweep feature.
- **MAN** — CRT spot can be manually moved (or left stationary). Spot movement is by hand rotation of the MANUAL SCAN red knob that is concentric with the DISPLAY MODE switch. Manual movement of the CRT spot scans the equivalent time display at any hand controlled rate convenient to the operator.
- **EXT HORIZ (150 V MAX)** — CRT spot can be made to scan the equivalent time display by application of an external positive-going ground referenced voltage to the associated INPUT jack. External signal can be attenuated by the EXT HORIZ ATTEN control (which is also the MANUAL SCAN control). Allows display scan rate to be set by such devices as self-scanning paper graph recorders. (Use the VERT OUTPUT jack to drive a recorder vertical pen position.) Input resistance is 100 kΩ to 20 kΩ depending upon position of EXT HORIZ ATTEN control.

EXT HORIZ ATTEN—MANUAL SCAN Control — Red knob concentric with DISPLAY MODE switch; operative when the DISPLAY MODE switch is at either MAN or EXT HORIZ position. Positions the spot horizontally across the CRT during manual scan operation.

Allows high voltage externally applied scanning signals to be attenuated for proper external control of the display horizontal axis.

EXT HORIZ INPUT (150 V MAX) — Banana jack for connection of external scanning voltage as stated above.

THROUGH SIGNAL CHANNEL 50 Ω (GR 874 connectors) — Two connectors of the through-signal sampling circuit. Allow monitoring of voltage signal on a 50 Ω transmission line without interrupting the signal flow. When operating as a reflectometer, one PULSE SOURCE connector is attached (via elbows or cable) to one sampler connector, and the line under test is attached to the other sampler connector. When operating as a normal sampling unit, signal is attached to one connector and a 50 Ω termination is attached to the other connector. Has approximately 5 kΩ to ground DC input resistance when not terminated.

PULSE SOURCE 50 Ω (GR 874 connectors) — Two connectors that are the two pulser output connectors. The 1.0 V—1 ns connector serves as the external trigger input connector when the Type 1S2 is operated as a normal sampling unit.

1.0 V—1 ns EXT TRIG INPUT Connector — Dual function connector. When the associated MODE switch white dot points to this connector, it provides a positive-going, ground referenced 1.0-Volt, 1 ns risetime step transition pulse. Pulser output impedance is 50 Ω. The pulse duration is longer than twice the time of the longest time window of each of the three ranges. (Pulse trailing edge cannot be observed on Type 1S2.) The pulser can be used as a generator to drive other equipment.

When the associated MODE switch is at either UHF SYNC or EXT TRIG, the connector is the EXT TRIG INPUT circuit.

NOTE

The 1.0V pulser is not recommended for use as the pulse source for TDR displays when the RANGE switch is at 0.1 μs-10 m. Instead, the .25 V pulser is recommended. See the discussion on Choice Of Pulser later in this section.

STABILITY — A screwdriver-adjusted control that sets the operating bias on a tunnel diode in the 1.0 V pulser. Allows correction of pulser operation changes due to temperature deviations. Proper adjustment is described earlier under First Time TDR Operation. See Fig. 3-3.

.25 V—50 ps Connector — When the associated MODE switch white dot points to this connector, it provides a positive-going, ground referenced 0.25-volt, 50 ps risetime step transition pulse. Pulser output impedance is 50 Ω. Pulse duration is longer than twice the time of the longest time window of each of the three ranges. (Pulse trailing edge cannot be observed on Type 1S2). The pulser can be used to drive other equipment.

CAUTION

Never permit a signal greater than 1 volt to enter back into the .25 V—50 ps connector. Greater than 1 volt DC or instantaneous AC can damage the pulse source.

The connector is inactive when the associated MODE switch is at any other position.

NOTE

The .25 V pulser is not recommended for use as the pulse source for TDR displays when the RANGE switch is at 10 μs-1 km. Instead, the 1.0 V pulser is recommended. See the discussion on Choice of Pulser later in this section.

STABILITY — A screwdriver adjusted control that sets the operating bias on a tunnel diode in the .25 V pulser. Allows pulser operation changes due to changes in temperature to be corrected. Proper adjustment is described earlier under First Time TDR Operaion. See Fig. 3-3.

VERT OUTPUT Banana Jack 1 V/DIV, 10 kΩ — Provides a DC coupled voltage reproduction of the displayed signal. Output amplitude is 1 volt for each vertical division of display. Output impedance is 10 kΩ. Output voltage is nominally zero volts when both the signal and the ×1 OFFSET OUTPUT are zero volts.

HORIZ OUTPUT Banana Jack 1 V/DIV, 10 kΩ — Provides sawtooth sweep signal for horizontal deflection of either an oscilloscope or an X-Y recorder horizontal deflection. Output amplitude is 1 volt for each horizontal division of display. Output impedance is 10 kΩ. Output voltage is zero volts near the scan mid-point. Display device must have sensitivity of one division per volt.

MODE Switch (Lower right side) — Four position switch that controls the Type 1S2 operation as either a TDR unit or normal sampler unit.

INT PULSE — Selects TDR operation and one of the two pulsers.

UHF SYNC — Selects normal sampling operation with stable synchronization of displays for signals to over 5 GHz. CRT always has a trace with or without trigger signal.

EXT TRIG — Selects normal sampling operation with stable + or — triggered displays from external trigger signals. Trigger signals must be time related to vertical signals that are connected to the through-sampler. See Section 1 for trigger signal amplitude and polarity limits.

UHF SYNC OR TRIGGER SENS Control — Red knob concentric with MODE switch just described.

When MODE switch is at UHF SYNC, this control alters the internal trigger circuit free-run rate. Control then allows internal trigger circuits to properly synchronize with UHF trigger signals.

When MODE switch is at EXT TRIG, this control has a dead zone over about 10° of its rotation when the white dot is at the top. Counterclockwise rotation permits proper triggering from positive-going trigger signals. Clockwise rotation permits proper triggering from negative-going trigger signals. Rotation in either direction from the dead zone increases the trigger circuit sensitivity to a point where the trigger circuits free run before either end of rotation is reached.

The remaining controls to be described all relate to the horizontal equivalent time sweep rate and the relation of the CRT time window to the total range of each RANGE control position. Time and distance data for all possible control positions are presented in tabular form. Tables 3-2 and 3-3 may be photographically reproduced for operator convenience without special permission from Tektronix, Inc.

HORIZONTAL UNITS/DIV — Two position switch that selects the horizontal display DISTANCE or TIME units/div and the readout panel units. When at DISTANCE: display indicates one-way signal travel through test line. When at TIME: display indicates round-trip signal travel time. DIELECTRIC switch operates only when HORIZONTAL UNITS/DIV switch is set to DISTANCE.

RANGE Switch (DISTANCE or TIME) — Three position switch that sets the basic display distance or time limits. Each position indicates the total POSITION control range.

Table 3-2 lists the relationships between the RANGE switch and the POSITION control.

Table 3-3 lists the relationships between the RANGE and MAGNIFIER controls when the POSITION control is at full scale (9.90).

DIELECTRIC Switch — Red knob concentric with RANGE switch. Alters the horizontal DISTANCE units/div to match the propagation velocity of the transmission line under test. The control is inoperative during TIME units/div operation. Table 3-1 lists significant velocity of propagation figures for three dielectric materials.

TABLE 3-1

Coaxial Transmission Line Signal Velocity of Propagation (V_p) Compared to the Speed of Light (c)

Transmission Line Dielectric	V_p
Air	$1.0 \times c = 30$ cm/ns[1]
TFE[2]	$0.695 \times c = 20.85$ cm/ns
Polyethylene[2]	$0.659 \times c = 19.77$ cm/ns

[1]cm × 0.3937 = Inches.

[2]Solid, not foamed dielectric material.

PRESET (Screwdriver Adjust) — A variable control of the sweep rate during DISTANCE operation. Allows distance to be measured for transmission lines with a dielectric other than AIR, solid TFE or solid POLYETHYLENE. The PRESET control affects the distance sweep rate only when the DIELECTRIC switch is at PRESET. Total range of the control extends from the equivalent of AIR to a sweep rate slightly slower than for solid Polyethylene.

MAGNIFIER Switch — Magnifies the display horizontally by altering the equivalent TIME or DISTANCE sweep rate ×1 to ×100 in a 1, 2, 5 sequence. Digital readout of display horizontal units/div changes with MAGNIFIER switch, RANGE switch and HORIZONTAL UNITS/DIV switch.

Magnifier VARIABLE — Red knob concentric with the MAGNIFIER switch. Clockwise rotation (only) away from CAL position speeds up the equivalent time sweep rate $\geq$2.5:1 over the calibrated rate. Thus maximum uncalibrated sweep rates with RANGE at .1 μs—10 m and MAGNIFIER at ×100 are: $\leq$28.75 μs/div TIME and $\leq$0.275 cm/div DISTANCE. The center panel readout numerals remain lighted, but the units lamps go out when the VARIABLE control is not at its detent CAL position. The POSITION control is no longer calibrated when the magnifier VARIABLE is not at CAL.

POSITION (DISTANCE or TIME) — Ten turn control that time-positions the display time-window horizontally. In particular, controls the point within the RANGE at which the time-window begins.

Indicates the TIME or DISTANCE position of time-window start as a percentage of the ×1 ten division time window duration (duration listed in Table 3-3 to right of each MAGNIFIER ×1 setting).

Provides accurate slideback TIME or DISTANCE measurements between two points along the RANGE, referenced to any fixed horizontal point on the CRT display. (Slideback measurements ignore all horizontal amplifier gain tolerances and possible CRT non-linearities.)

For each RANGE selected, and with the POSITION control set to 0.00, the TDR incident pulse leading edge will be positioned one major graticule division to the right of the trace beginning.

POSITION control full scale setting will be between 9.90 and 9.96.

Table 3-2 lists the POSITION control units per revolution for each setting of the RANGE switch. Table 3-3 lists the Range end, which is the maximum round trip TIME or one way DISTANCE that can be displayed.

The POSITION control is capable of locating discontinuities by slideback method within a time tolerance of ±1% of full scale. This is true providing the 0.25-volt pulser is used, and the reflection from the open sampler (no line connected) and from the discontinuity can respectively be positioned to the same horizontal position on the CRT. (The ±1% tolerance does not apply to distance measurements due to variations in dielectric constant among various cables.)

TABLE 3-2

POSITION Control Units Per Revolution
Referenced to RANGE Switch Setting

RANGE Switch	POSITION Control Units			
	ONE REVOLUTION (0.1 of full scale)		0.1 REVOLUTION (0.01 of full scale)	
	TIME	DISTANCE	TIME	DISTANCE
10 μs/1 km	1000 ns	100 m	100 ns	10 m
1 μs/100 m	100 ns	10 m	10 ns	1 m
.1 μs/10 m	10 ns	100 cm	1 ns	10 cm

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TABLE 3-3

Full-Scale Time and Distance Units
Related to RANGE and MAGNIFIER Controls

RANGE Switch setting	MAGNIFIER setting	Time Window (10 div total)		Range End[3] POSITION: 9.90	
		TIME	DISTANCE[4]	TIME	DISTANCE
10 μs/1 km	×1	10 μs	1000 m (3,281 ft)	19.9 μs	1990 m (6,529.2 ft)
	×2	5 μs	500 m (1,640.5 ft)	14.9 μs	1490 m (4,888.7 ft)
	×5	2 μs	200 m (656.2 ft)	11.9 μs	1190 m (3,904.4 ft)
	×10	1 μs	100 m (328.1 ft)	10.9 μs	1090 m (3,576.3 ft)
	×20	.5 μs	50 m (164.05 ft)	10.4 μs	1040 m (3,402.25 ft)
	×50	.2 μs	20 m (65.62 ft)	10.1 μs	1010 m (3,313.8 ft)
	×100	.1 μs	10 m (32.81 ft)	10.0 μs	1000 m (3,281.0 ft)
1 μs/100 m	×1	1000 ns	100 m	1990 ns	199 m (652.9 ft)
	×2	500 ns	50 m	1490 ns	149 m (488.9 ft)
	×5	200 ns	20 m	1190 ns	119 m (390.4 ft)
	×10	100 ns	10 m	1090 ns	109 m (357.6 ft)
	×20	50 ns	5 m (16.4 ft)	1040 ns	104 m (341.2 ft)
	×50	20 ns	2 m (6.56 ft)	1010 ns	101 m (331.4 ft)
	×100	10 ns	1 m (3.28 ft)	1000 ns	100 m (328.1 ft)
.1 μs/10 m	×1	100 ns	10 m	199 ns	19.9 m (65.3 ft)
	×2	50 ns	5 m	149 ns	14.9 m (48.9 ft)
	×5	20 ns	2 m	119 ns	11.9 m (39 ft)
	×10	10 ns	1 m	109 ns	10.9 m (35.7 ft)
	×20	5 ns	50 cm (18.685 in)	104 ns	10.4 m (34.1 ft)
	×50	2 ns	20 cm (7.874 in)	101 ns	10.1 m (33.1 ft)
	×100	1 ns	10 cm (3.937 in)	100 ns	10 m (32.8 ft)

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Beaverton, Oregon, U.S.A.

[3]Figures in this column are maximum round-trip TIME and maximum one-way DISTANCE that can be observed by the Type 1S2.

[4]Meters × 3.281 = Feet.
cm × 0.3937 = Inches.

Choice of Pulser

The Type 1S2 contains two different pulse sources to meet the wide needs of various reflectometer applications. The faster risetime of the .25 V pulser provides better resolution for the analysis of short discontinuities located close to the instrument. The greater amplitude of the 1.0 V provides better resolution for the analysis of long transmission lines due to their inherent losses.

In addition to choice of pulse source, resolution of the Type 1S2 depends upon the setting of various front-panel controls such as RANGE, ρ-VOLTS and RESOLUTION. The most limited case occurs when using the .25 V pulse source, 10 μs-1 km range, ρ-volts switch at ρ and RESOLUTION switch at NORMAL. In this case the display of a transmission line discontinuity must cover at least one horizontal graticule division in order for 100% of the reflection amplitude to be displayed. Such a display may be considerably improved by any one or combination of the following steps which a particular application may permit:

1. Use the 1.0 V pulse source (if the 1.0 ns risetime does not itself become the resolution limit).
2. Use the shortest RANGE setting consistent with the requirements of sweep rate and time/distance position range.
3. Use the VOLTS setting of the ρ-VOLTS switch.
4. Use the HIGH setting of the RESOLUTION switch.
5. Use the MAN setting of the DISPLAY MODE switch.

Use of the Type 1S2 as a Synchroscope

Either pulse source may be used to drive the input of a transmission line, amplifier or other circuit under test while its output is monitored by the signal channel. AC coupling should be used if the test circuit applies any DC voltage back to the pulse source. Other signals coupled back from the test circuit may cause faulty operation of the .25 V pulse source, as it is a direct-coupled tunnel diode.

FIRST TIME EQUIVALENT TIME SAMPLING OPERATION

The Type 1S2 must be mated to the oscilloscope before normal sampling operations can begin. Perform one of the previous procedures for mating the Type 1S2 to the oscilloscope.

NOTE

Equivalent time sampling operation requires that the lower right side MODE switch be at either EXT TRIG or UHF SYNC, and that the HORIZONTAL UNITS/DIV switch be set to TIME. The horizontal equivalent time sweep rate is read directly from the center-panel illuminated readout panel.

Triggering Signals

The Type 1S2 must be externally triggered to obtain equivalent time sampling displays. For fast rise pulses, the trigger signal must arrive at the EXT TRIG INPUT connector in advance of the signal to the Thru Channel sampler connector. The trigger lead time for fast events is at least 30 ns +1/10 of the RANGE control time setting before the test signal reaches the sampler connector. It is the trigger lead time that allows the Type 1S2 to display the leading edge of the test signal. Sine waves or closely spaced repetitive signals do not require that the trigger signal arrive in advance of the test signal.

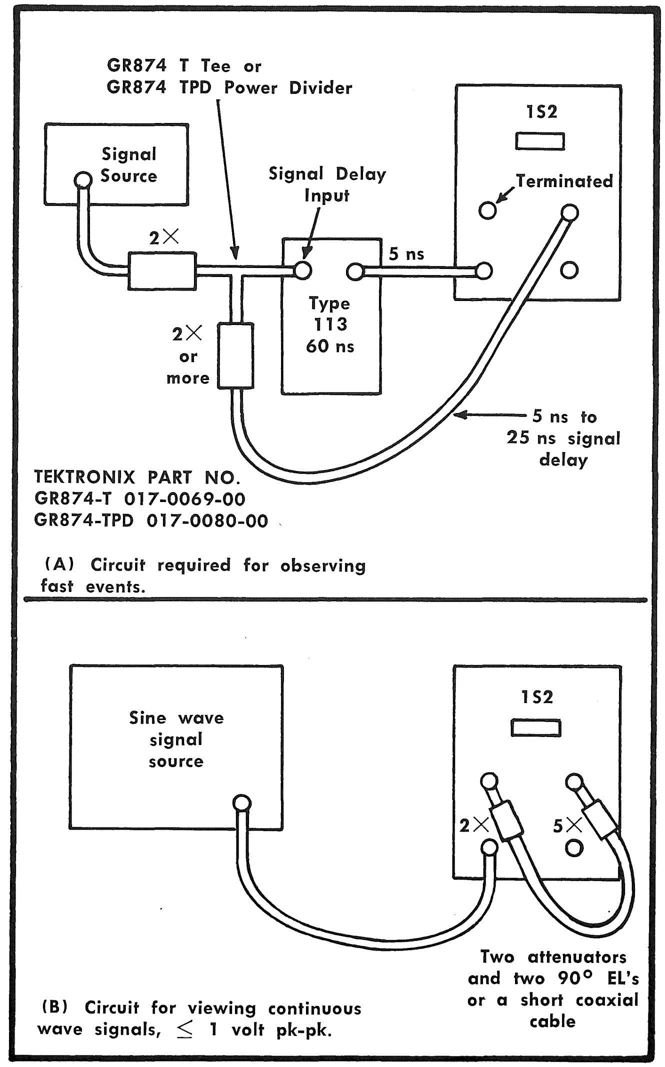


Fig. 3-5. Methods of obtaining trigger signals for equivalent time sampling.

Two methods of obtaining triggering signals from a signal source are shown in Fig. 3-5. The attenuators may not be required if the Tee of Fig. 3-5A is the GR Power Divider. Their function is to minimize reflections when using the GR 874 T, which is not required with the Power Divider. In any case, it is always important to consider the use of attenuators in order to maintain correct signal levels to both the Thu Signal sampler and the EXT TRIG INPUT connector. Fig. 3-5B shows a simple method of signal and trigger set-up when viewing displays of continous wave signals. The 2× and 5× GR connector attenuators supplied with the Type 1S2 present a very clean termination to the signal. (The 50 Ω termination within the EXT TRIG INPUT connector causes significant reflections of signals.) The total of 10× attenuation will prevent good triggering characteristics on low level signals, and then less attenuation must be used. If no attenuation is used, the input signal amplitude must not exceed ±3 volts DC and combined AC peak.

The signal delay cable of Fig. 3-5A should not distort the test signal, and therefore must be of the highest quality. The Tektronix Type 113 Delay Cable suggested, plus a 5 ns delay section of RG213/U cable between it and the terminated Thru Signal sampler, changes the Type 1S2 10% to 90% step signal risetime from 90 ps to approximately 230 ps. Additional slowing of the risetime must be accounted for by any other cables between the signal source and the signal delay input.

It is suggested that the first equivalent time sampling operation be of a sine wave signal without the need for either signal delay or UHF SYNC.

Valid Displays

Equivalent time sampling of sine wave signals produce accurate time and amplitude displays when the sweep rate is such that there is no more than one complete cycle per major graticule division. A sweep rate that causes the display to have two cycles per major graticule division causes a significant reduction in amplitude, but still permits accurate time measurements.

Accurate pulse amplitude or risetime measurements require that the display transition include at least one half a major graticule division. If the sweep rate produces a transition that occurs in less than one half a major graticule division, the risetime and amplitude measurements may both be in error.

Some displays may appear segmented in a step transition or slope of a sine wave. When this occurs, there must be at least 17 segments in the transition (or ramp portion of the display) in order to permit accurate time and amplitude measurements.

Lowest Measurable Frequency

The lowest sine wave frequency for which one complete cycle can be displayed is 100 kHz. One cycle of 50 kHz can be observed by use of the time POSITION control when only ½ cycle is displayed in 10 horizontal divisions. For lower frequencies, change to real time sampling described briefly below.

REAL TIME SAMPLING

Signals from DC to sine-waves of up to about 5 kHz can be displayed by real time sampling operation of the Type 1S2. Any sine-wave above 2 kHz will present a display with an attenuated amplitude. Between 2 kHz and 5 kHz, the time per cycle can still be measured. Above about 5 kHz, the display segments prevent interpretation of either time or amplitude of any real time display.

Real Time Sampling Procedure

1. The Type 1S2 requires no triggering signals to operate in the real time sampling mode. The only connection required is that of the input signal. The input impedance can be either the normal 50 Ω terminated value using a termination on one of the Thru Channel connectors, or approximately 5 kΩ when no termination is used.

2. The real time sampling mode sweep is controlled by the oscilloscope main frame. Set the oscilloscope HORIZONTAL DISPLAY switch for normal internal sweep operation. Set the oscilloscope triggering controls for normal internal DC or AC coupled triggering. The sweep rate range for acceptable displays can include the slowest sweep rate up to 0.5 ms/div.

3. The Type 1S2 must operate with a free running trigger circuit, TRIGGER SENS control fully clockwise; the MODE switch at UHF SYNC or EXT TRIG; the DISPLAY MODE switch must be at either EXT HORIZ or MAN; the RANGE switch must be at either 1 μs—100 m or .1 μs—10 m; and the RESOLUTION switch must be at NORMAL. The following controls no longer affect the display; POSITION, DIELECTRIC, MAGNIFIER and its VARIABLE, HORIZONTAL UNITS/DIV, EXT HORIZ ATTEN—MANUAL SCAN and the ρ—VOLTS switch.

4. The VERTICAL UNITS/DIV switch is now a VOLTS/DIV switch and the OFFSET controls now vertically position the display.

5. Apply a signal and adjust the oscilloscope controls in the normal manner. Select the horizontal sweep rate with the oscilloscope TIME/CM control, and the triggering with the oscilloscope triggering controls.

SECTION 4
CIRCUIT DESCRIPTION

Change information, if any, affecting this section will be found at the rear of the manual.

This section of the manual contains an electrical description of each circuit in the Type 1S2 Plug-In. A detailed block diagram is given for each main section in the following description. A complete block diagram is located in the Diagrams section. The complete block diagram shows the relationship between the major circuits of the instrument.

Refer to the numbered schematic diagrams in the manual to identify components in this description.

VERTICAL SYSTEM

The Type 1S2 Vertical System is a single channel, error sampled feedback system with a maximum calibrated sensitivity of 5 millivolts per division and a risetime of less than 90 ps. The Vertical system features a thru channel signal path which allows sampling to occur either before or after the test circuit. The error sampling feedback system consists of the sampling bridge, preamp, attenuator, AC amp, memory gate, memory and feedback attenuator, with offset capabilities. The memory gate driver and avalanche circuit are driven by the sampler comparator from the horizontal circuitry. A snap-off diode provides strobe pulses to the sampling bridge, and is driven by an avalanche transistor. The inter dot blanking amplifier is driven by the memory gate driver.

Variable gain and Vertical gain calibration are accomplished in the drive circuitry to the Vertical Output source follower Q393. Retrace blanking for the Vertical output comes from Q724 in the Horizontal Sweep circuitry through the Blanking Amplifier.

Sampler Circuit Schematic ⟨1⟩

The avalanche, snap-off, sampling bridge, source follower and blow-by circuits are located on the Sampler board. See Fig. 4-1. The avalanche circuit converts the slewed pulse from the Sampler comparator circuit to a very fast pulse to drive the Snap-off diode into cutoff. From J135, the slewed pulse is transformer coupled by T135 to the base of the Avalanche transistor Q134. Q134 quiescent collector voltage is determined by the Q133 emitter-follower voltage as set by the Avalanche Volts control R131. This voltage sets the amplitude of the signal to drive the snap-off circuit, and assures the normal avalanche action of Q134 when driven by the slewed pulse signal.

When avalanche transistor Q134 is turned on, the negative pulse at the collector is coupled through C134 and through transformer T144. Q143 determines the snap-off diode current and thus the snap-off diode stored charge. When the charge of the snap-off diode is removed by the drive waveform and the fast-rising transition to the off state is shaped by two clip lines to give narrow pulses of opposite polarity through R148 and R149 to the sampling diodes D110 and D111. The bridge diodes are back biased from the bridge volts circuit through R110, R111, R117 and R118. The pulses momentarily forward bias D110 and D111 to allow signal through the bridge to the preamp.

For SN 1990 through 2999, T114 is used to couple the narrow pulses of opposite polarity to the sampling diodes D110 and D111. The bridge diodes are back biased from the bridge volts circuit through R117, R118 and T114. R148 reduces reflections in the clip lines after the sample is taken.

Q115 is operating as a source follower with high input impedance and low output impedance to couple the error signal to the Preamplifier circuit. The error signal is the voltage difference between the feedback voltage (coupled through the Bridge Volts circuit) and a portion of the input signal coupled by the sampling bridge.

Preamp Circuit Schematic ⟨2⟩

The Preamplifier consists of Q154 and Q164 operational amplifier, and Q163 emitter follower output. The input signal from the source follower Q115 is amplified by the Preamplifier and AC coupled to the vertical attenuator and to the input circuit of the AC Amplifier. Fig. 4-2 shows a block diagram of the Preamplifier.

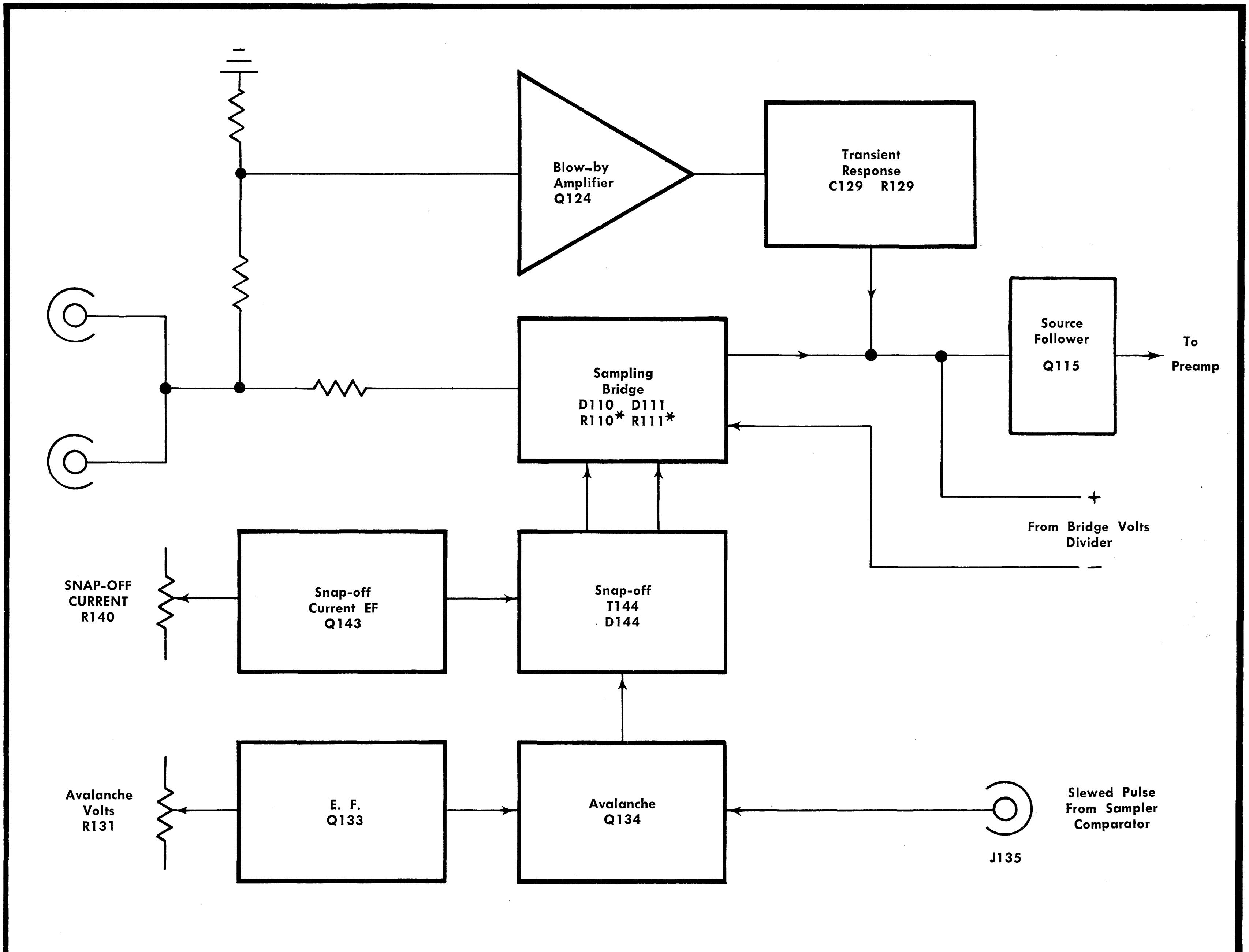
The input signal at Q154 base is inverted and amplified at Q154 collector. Q154 collector drives Q164 base to provide an inverted signal at Q164 collector. Negative feedback through R164 to Q154 emitter determines the overall gain. The feedback permits high amplification of fast signals due to the voltage-divider ratio of R164 and R163 with C163 and DOT RESPONSE control R168. R168 allows the AC gain of the amplifier to be adjusted. The DC gain of the amplifier is set by R164 and R157.

Low output impedance for positive and negative excursions is provided by emitter follower Q163. The signal at Q164 collector drives the base of Q163. C166 and R162 maintain Q163 base-emitter junction conduction for fast positive excursions.

AC Amplifier (Fig. 4-2)

The AC Amplifier is an AC coupled inverting operational amplifier consisting of Q184 and Q193. The amplifier provides part of the overall forward gain and drives the Memory gate circuit. The input circuit consists of the forward attenuator and a high frequency filter R175, R176 and C175 connected to the low impedance base circuit of Q184. The low-impedance Q193 emitter follower output circuit is capacitively coupled through R199 and C199 to the memory gate circuit.

The DC or low frequency gain is determined by R196, R197 and C196 in the feedback path.



*Denotes R110 and R111 are replaced by T114 for SN 1990 through 2999.

Fig. 4-1. Sampler circuit.

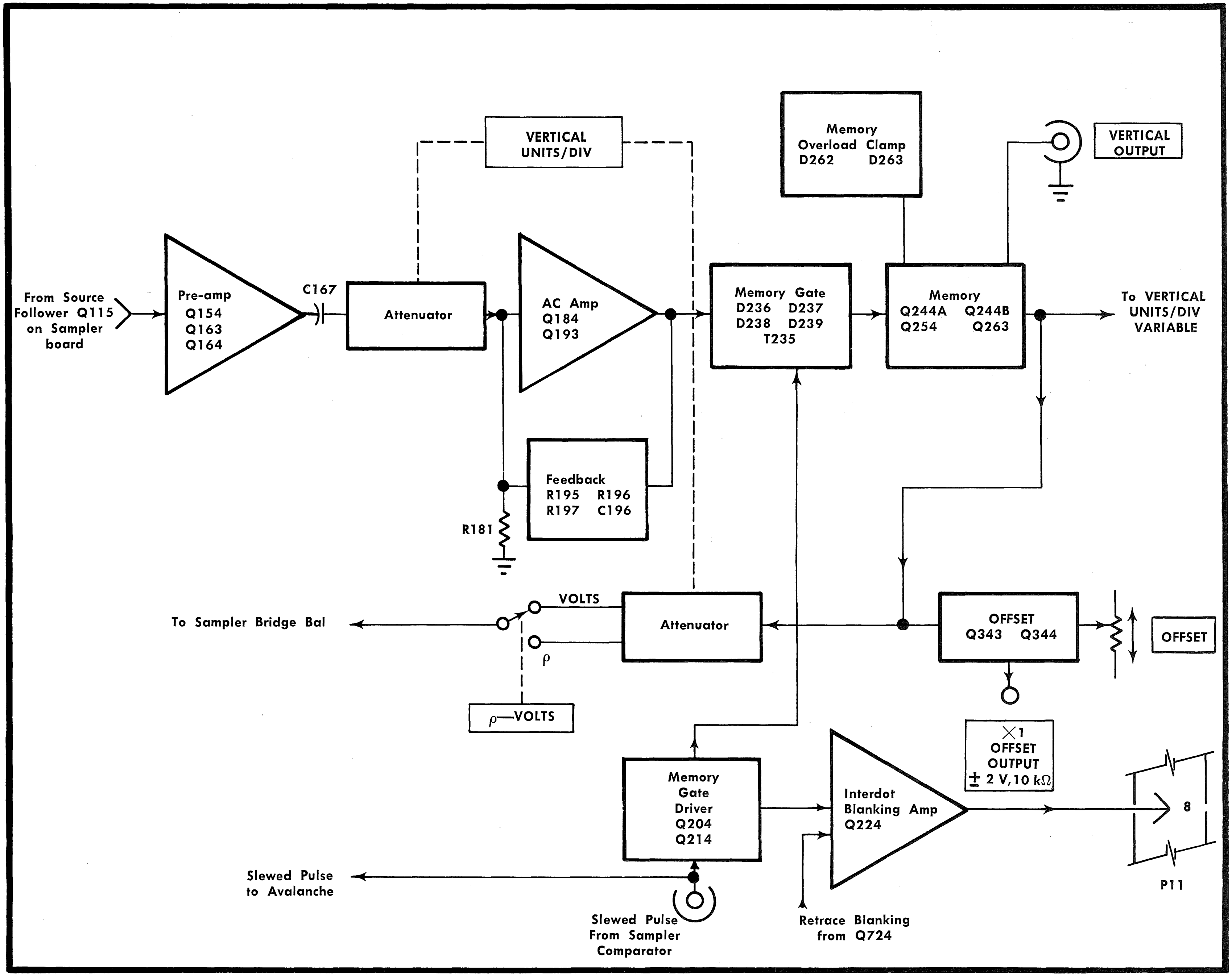


Fig. 4-2. Preamp and Memory.

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Memory Gate and Memory Gate Drive Schematic ⟨2⟩

The memory gate circuits consists of the gate diodes D236, D237, D238 and D239 along with the biasing circuitry R230, D230, R233, and R232 and transformer T235. T235 is driven by 0.33 μs duration pulse from the Memory Gate Driver circuit. The memory gate allows a high impedance coupling between the AC Amplifier and the Memory Amplifier except for the 0.33 μs when it is driven by the Memory Gate Driver at the time of each sample.

A slewed pulse from the Sampler Comparator circuits drives both the Avalanche, and the Memory Gate Driver circuits at the same time. The Memory Gate Driver circuit is a monostable multi that turns the Memory Gate on for about 0.33 μs and drives the interdot blanking amplifier.

The memory gate diodes are reverse biased by the voltage of the Zener diode D230. This 5 volt zener is balanced to ground by R230 and R233. This sets the voltage at D236 cathode at +2.5 volts, and D238 anode at —2.5 volts. The gate diodes are forward biased by the 0.33 μs Memory Gate Driver signal through T235. Due to the balanced action of T235 the output to Q244A gate is held at virtual ground by charge contained in C240 between samples when no error signal is applied from the AC Amplifier. The forward-biased gate diodes conduct the error signal to C240 and the input to the memory amplifier Q244A gate.

Memory Schematic ⟨2⟩

The memory amplifier stores the amplified error signal until the next sample by charging C260, provides an output through the feedback attenuator to the sampling bridge as a comparison level for the next sample, and provides a vertical display level to the vertical signal output and to the vertical channel of the oscilloscope.

The memory amplifier circuit consists of Q244, Q254, and Q263. The circuit is an unusually high input impedance, low output impedance integrating operational amplifier. The dual field effect transistor Q244 temperature-balances the input of the memory and provides memory gate balancing capability through Q244B gate as set by the Memory Gate Bal control. Q263 emitter follower provides a low impedance output drive through L268.

The memory gate conducts the signal to C240 and the amplifier input, Q244A gate. Q244 amplifies the signal and drives Q254 base from Q244B drain current path through R244. Q254 collector circuit drives the base of Q263 emitter follower, charging the memory capacitor C260 positively or negatively depending upon the input signal.

This memory has a diode clamping network at its output to stop the memory should it be overloaded and to prevent it from ever reaching saturation or cutoff. This is accomplished by diodes D262 and D263 and resistors R261, R262, R263 and R264. This circuit is turned on when the memory output exceeds the reference voltage of the divider. Thus all of the charge that is presented to the input of the memory during an overload condition is absorbed through the diodes to the output emitter follower. When the signal has been removed, the memory will be ready to accept the next signal.

Offset and Vertical Output Schematic ⟨3⟩

The Offset circuitry consists of Q343 and Q344. The main purpose of this transistor pair is to provide a very low impedance and provide a variable plus or minus voltage at the junction of R327 and R328. The offset range potentiometer, R396, sets the gate voltage of Q393B and acts as a vertical position control. The OFFSET circuitry, when positioned to zero volts, may not give center-screen operation. Therefore the Offset Range becomes a position control, to get the trace to the middle of the CRT graticule. Q393B is one half of the source follower output pair that drives the vertical system of the main frame. The VARIABLE and vertical gain calibration circuitry is connected between the Memory and Q393A gate divider resistors including R384, R385, R386, R387, and the Var Bal control R388. The divider resistors with C384 connected to Q393A gate provide a low pass filter. In the HIGH position, RESOLUTION switch SW750 connects C385 to the divider resistors and provides an additional low pass filter circuit.

The output of the Memory is calibrated against the 1 kΩ impedance across the series resistors, R351, R352, R353 and R356. When switching between pulse generators, a change in gain of about 4:1 is needed without changing the accuracy of the attenuator of the feedback loop. By changing the tap on the 1 kΩ impedance feeding back to the bridge, the Memory output can be effectively made four times larger for the .25 Volt Pulser and 1.05 times larger for the 1 Volt Pulser by selecting either R351 or R353.

Blanking Amplifier Schematic ⟨3⟩

The Blanking Amplifier circuit (Q379) deflects the beam off the CRT screen when driven by the Retrace Blanking Amplifier circuit (Q724). Q379 base voltage is initially set by current in the divider R377 and R378. This base voltage sets the current in Q379 and R379 at about 1 mA. This 1 mA current path divides equally with about 0.5 mA in D393-R394 and about 0.5 mA in D392. See Fig. 4-3 for a block diagram presentation of the Blanking Amplifier circuitry.

The negative retrace blanking pulse caused by increased current in R374 and Q724 is coupled through D376 to Q379 base, decreasing the current in Q379 and R379. D393 anode voltage goes in the positive direction. D392 cathode voltage also goes positive, with the result that D392 is back biased. D396 and D397 conduct, which limits D393 anode voltage rise to about 1.2 volts above the voltage at Q393B source. This 1.2 volt signal is connected to the vertical amplifier in the oscilloscope. With a deflection factor of 0.1 V/cm, the trace is deflected off screen. The beam is held off the screen for the duration of the retrace blanking signal.

ρ—Volts Selection Schematic ⟨3⟩

The ρ—VOLTS lights are controlled by the ρ—VOLTS switch in the vertical section and the MODE switch in the horizontal section. The positions of these two switches determine the actual vertical calibration of the sampling loop in either ρ or volts.

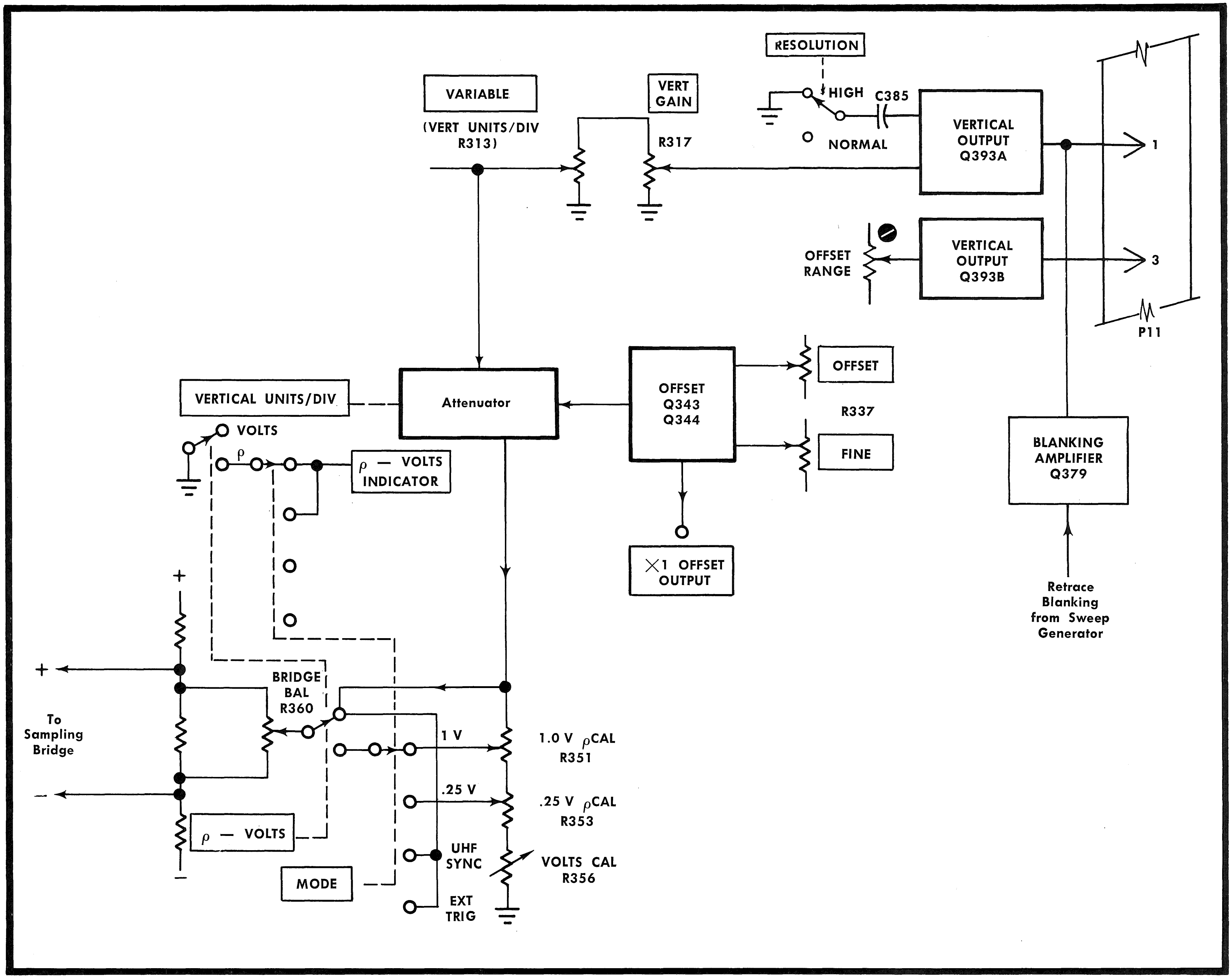

Fig. 4-3. Offset and Vertical Output.

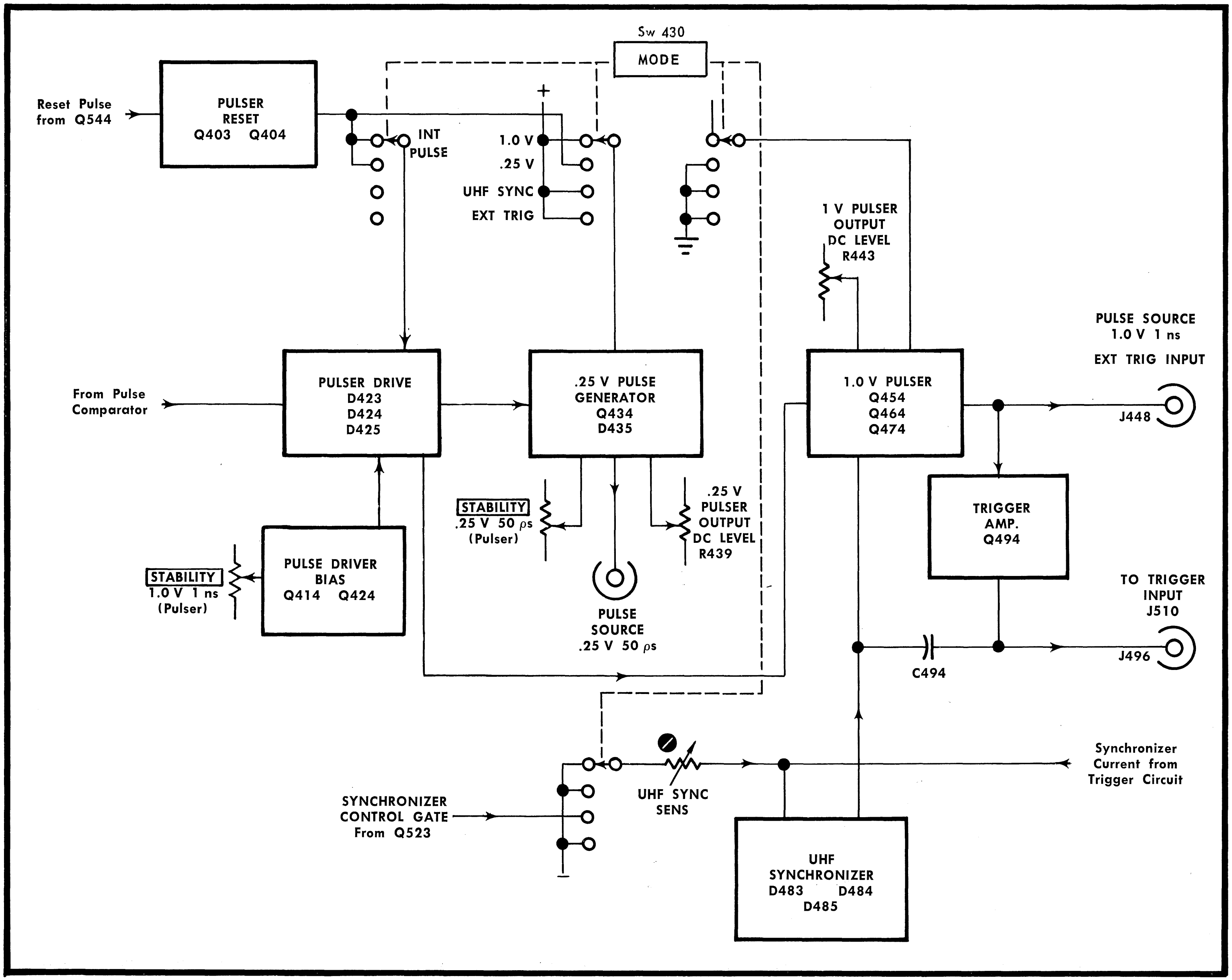

Fig. 4-4. Pulse Generators.

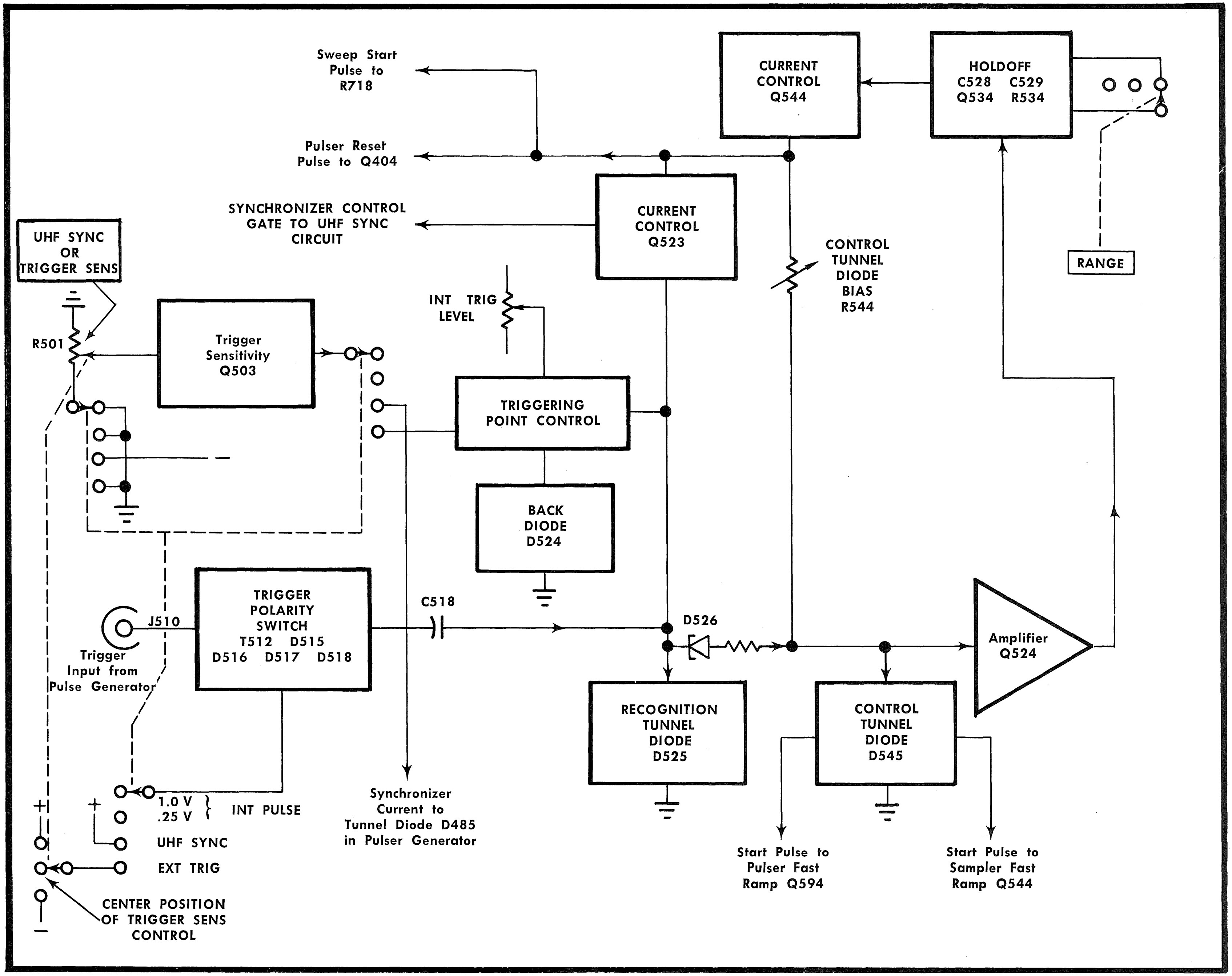

Fig. 4-5. Trigger circuits.

Pulser Generator Schematic ⟨4⟩

The pulse generator circuitry consists of two pulsers, a 1 ns 1 volt pulse and a 50 ps .25 volt pulse. Also contained on this board (Fig. 4-4) is the UHF synchronizing and trigger input circuitry. The pulser drive circuitry consists of D423, D424 and D425. Q414 and Q424 comprise the bias circuitry for D425, the 100 mA tunnel diode. The pulse from the comparator circuit on the horizontal board turns on tunnel diode D423. D423 pulse is capacitively coupled to the 0.25 V Pulse Generator through C427. Then D423, through tunnel diode D424 (used as a back diode) turns on D425, which controls the 1.0 V pulse generator. The pulser reset circuitry Q403 and Q404 is used to turn off the current sources of both the 100 mA tunnel diode, D425, and the 50 mA tunnel diode, D435. Thus, they are both returned to their low state so they can be again turned on by the pulse from the comparator circuitry.

When the .25 volt Pulse Generator is being used, the forward current for D435 is adjusted to just below peak value in the emitter circuit of common base amplifier Q434. When tunnel diode D423 is triggered on, the signal is coupled through C427 to the emitter of Q434, turning on D435. L435, R435, R434, R436 and C436 shape the tunnel diode waveform on the front corner. R438 and R439 set the zero level of the beginning of the .25 volt pulse. R437, in series with the tunnel diode D435 circuitry, determines the pulser output impedance. The temperature compensation circuit for tunnel diode D435 consists of R427, R428, R429 and R430. TD Temp Comp control R428 permits adjustment for the effects of temperature on D435.

When the MODE switch is set to the 1 VOLT PULSE position, the .25 Volt Pulser is disabled. Q454 and Q464 comprise the 1 Volt Pulser. R455 and R465 determine the emitter currents of transistors Q454 and Q464, and resistors R444, R445 and R442 and variable R443 determine the collector currents for Q454 and Q464. R443, the 1 V Pulser Output DC Level control allows the collector current to be adjusted so that the output quiescent level can be set to zero. The 93 Ω cable and L445-R447 determine the termination and front corner characteristics of the 1 Volt Pulser. R454 and R464 are required to prevent oscillation of the transistor pair and reduce ringing on the front corner of the 1 volt pulse. Tunnel diode D425 provides the drive that turns off the transistor pair. The bases of the transistor pair are referred to —5 volts by D484 in the UHF Sync biasing circuitry. Q474 provides the long time constant turnoff of Q454 and Q464. Thus, a fast turnoff is provided by the tunnel diode and a slower turnoff by Q474.

In the triggered mode, the 100 mA tunnel diode D425 and the pulse generators are all turned off. The 1.0 V pulser output connector becomes the trigger input. The trigger signal path is through R490 to the emitter of grounded base stage Q494. The collector of this stage is connected to J496 and is thus cabled to the horizontal trigger circuitry.

High frequency trigger signals applied to the external trigger input are coupled through the collector-to-base capacitance of Q454 and Q464 to the anode of D485. Tunnel diode D485, with D483, L483 and biasing, form a UHF synchronizer. The repetition rate at which the UHF synchronizer will operate is determined by adjusting the biasing on the UHF Synchronizer circuitry (R480 and R481) and then adjusing the TRIGGER SENSITIVITY knob on the MODE switch. The output from the UHF Synchronizer tunnel diode is coupled through C494 and connected to the trigger line that goes to the horizontal circuitry via J496.

HORIZONTAL SYSTEM

Trigger Circuit Schematic ⟨5⟩

The trigger circuit (see Fig. 4-5) provides a triggering signal to the ramps at a rate of approximately 100 kHz (about 15 kHz in the 10 μs position of the RANGE switch) when the Type 1S2 is being operated in the TDR mode. When the Type 1S2 is being operated in a triggered mode, the Trigger circuit is armed at rates up to 100 kHz (lower rates in 10 μs range) to allow a triggered operation.

Trigger signals are coupled in through J510, transformer T512 and diodes D515, D516, D517 and D518 through R518 and C518 to D525, the recognition tunnel diode. Transformer T512 and the diodes D515, D516, D517 and D518 form a trigger polarity switching circuit. This scheme permits inverting the incoming signal when necessary, to apply a positive-going leading edge to D525. When SW501, ganged with the TRIGGER SENSITIVITY control, connects a positive voltage to decoupling resistor R515, diodes D517 and D516 are turned on, connecting the transformer T512 in the non-inverting mode. When a negative voltage is switched to R515, diodes and D515 and D518 are turned on, connecting the transformer in an inverting mode. When the trigger circuit is in an armed mode ready to accept a signal, D525 and D545 are both in the armed state, Q524 is cut off and Q523 and Q544 are turned on. Q523 controls the current to D525, and Q544 controls the current to D545.

When the trigger arrives, tunnel diode D525 goes to its high state. The positive signal is coupled to D545 (and differentiated) by C526-D526, causing D545 to switch to its high voltage state. This starts the timing ramp. When D545 goes to its high state, it turns on Q524. When Q524 turns on, it immediately shuts off Q523, thereby removing any current to D525 and preventing D525 from being triggered again. Additionally, when Q524 turns on, it turns off Q534. This permits the current through R534 to charge C528 until Q544 turns off, about one-third of the way through the holdoff cycle. When Q544 turns off, the current to D545 is turned off, resetting D545 to the low state. When D545 goes to the low state, Q524 turns off, permitting the current through R528 to charge C528 until Q534 turns on, turning on Q544 and re-arming the tunnel diodes.

Trigger sensitivity is controlled by R501 operating through emitter follower Q503. This emitter follower provides a varying voltage for controlling the current through R488 to the UHF Synchronizer circuit or varying the current through R509 into D525. When the MODE switch SW430 is set to either pulser or UHF SYNC, no current is pulled out through R509. R523 is set so that the current through L525 to D525 will not only arm D525, but trigger it as well. In this manner, when Q503 is not switched in, the trigger circuit will free run by the self-triggering action of D525. When operated in a triggered mode, Q503 pulls current out of D525, allowing the triggering point to be controlled by the setting of the TRIGGER SENSITIVITY control. Normally, R544 sets the D545 just short of its free running point. In addition to its primary function of controlling D545, Q544 (the trigger circuit) provides logic which starts the horizontal sweep and resets the

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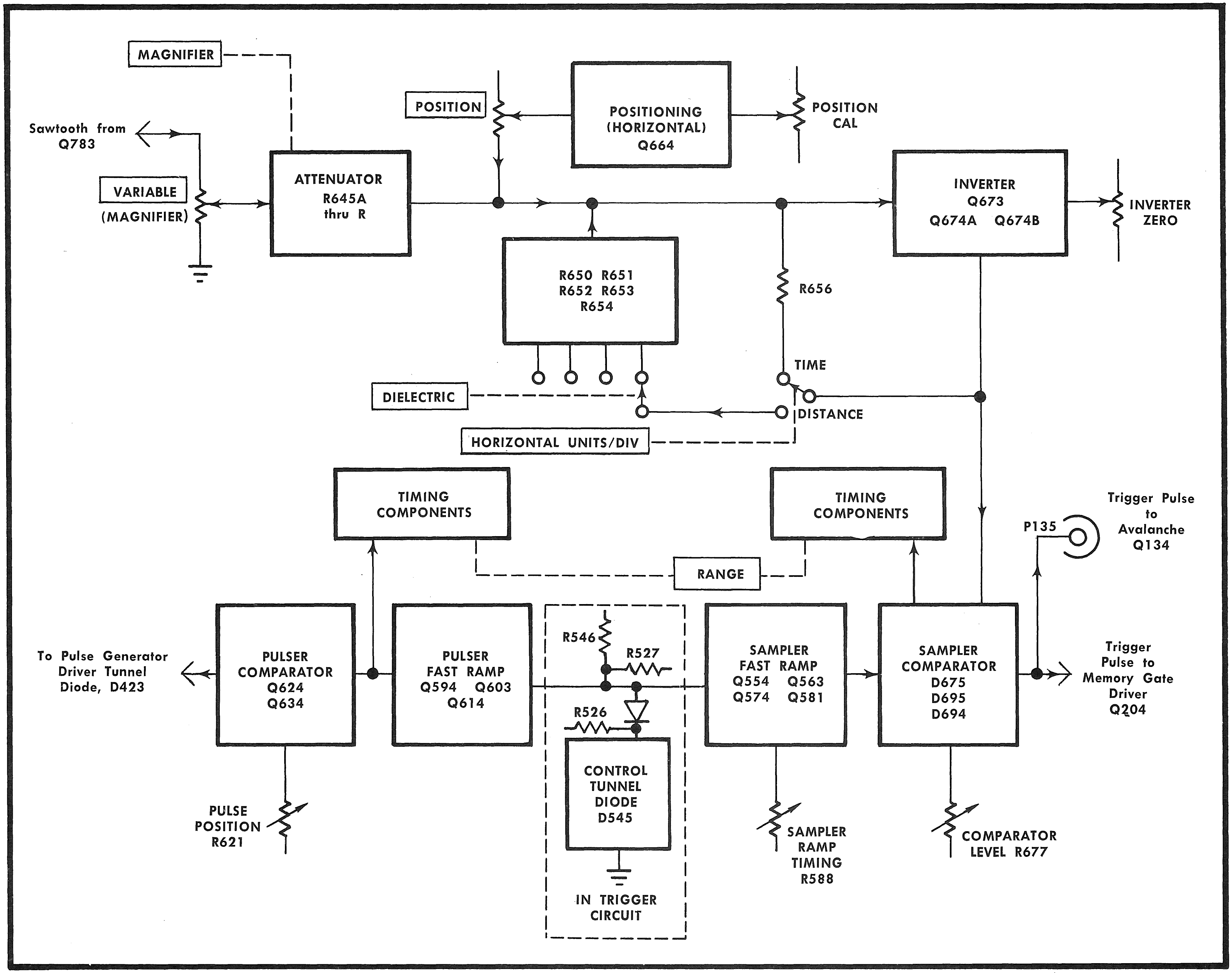


Fig. 4-6. Fast Ramp.

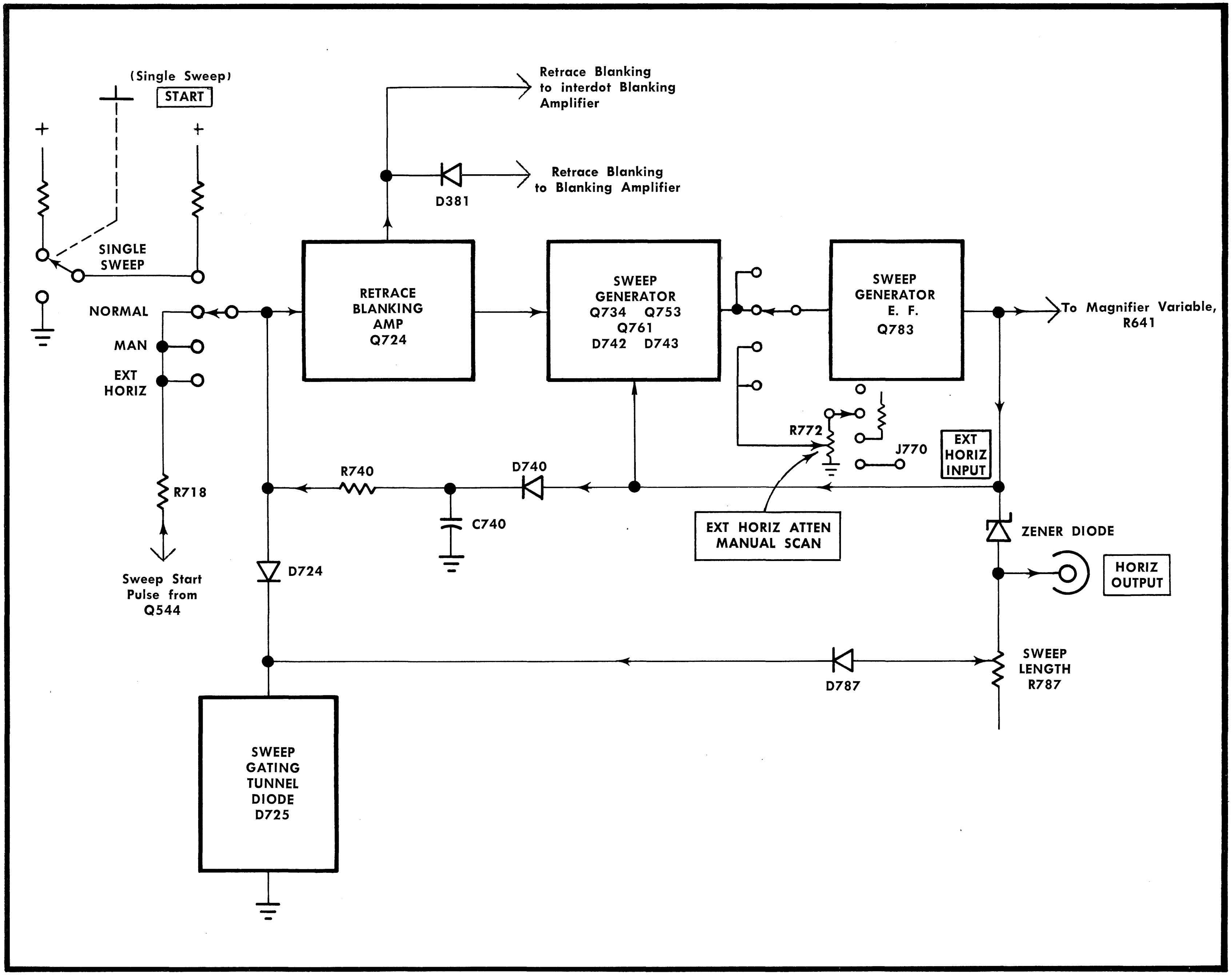


Fig. 4-7. Sweep Generator.

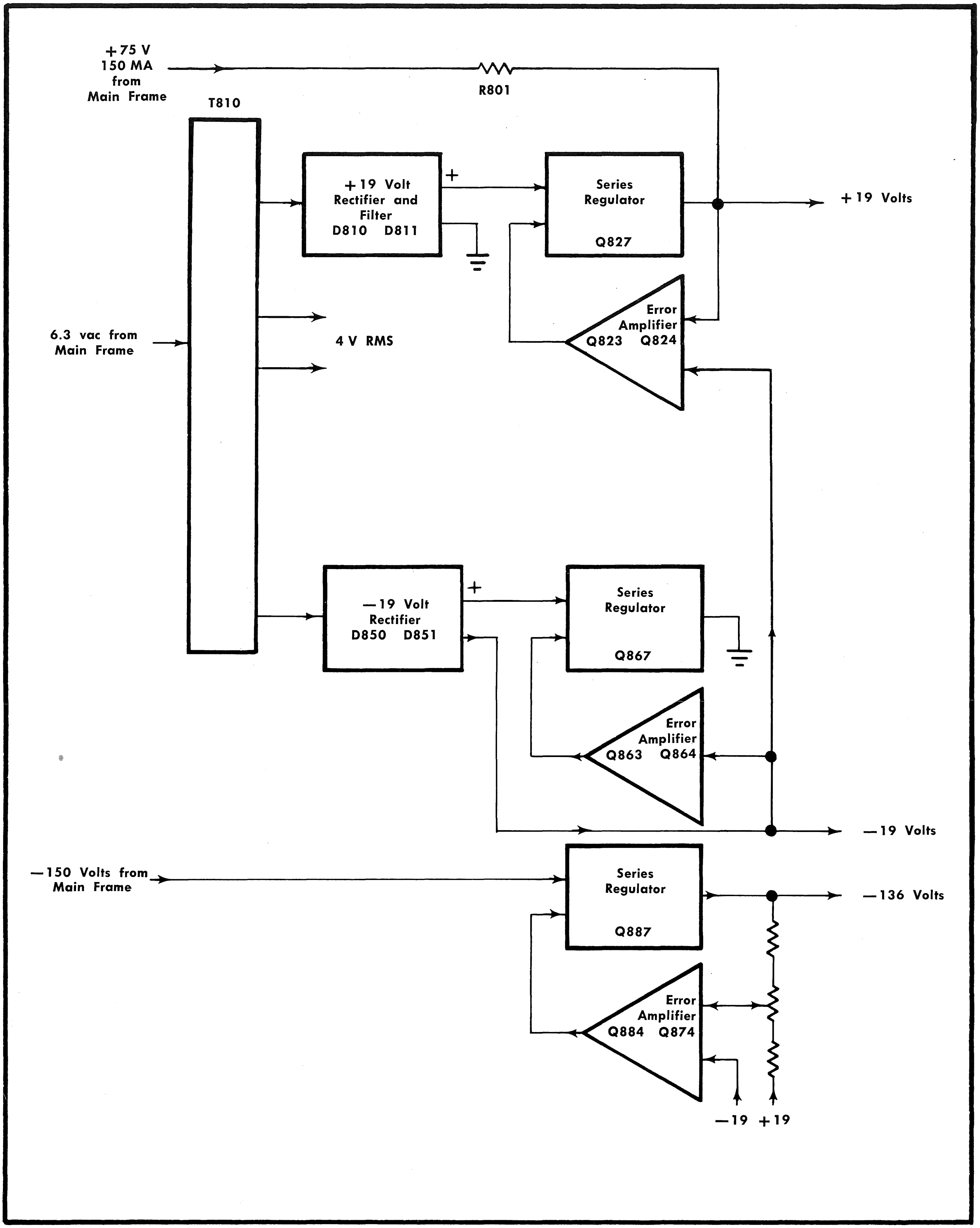


Fig. 4-8. Power Supplies.

pulser circuits when they are being used. At the emitter of Q523 is a signal which turns on D485 (the synchronizer tunnel diode) so that it will start when D525 is armed, and turns it off when D525 is triggered to start the fast ramp.

Fast Ramp Schematic ⟨6⟩

The fast ramps time both the sampler section and the pulser operation in the Type 1S2. When D545 is turned on, two ramps are started; the pulser timing ramp and the sampler timing ramp. The pulser timing ramp determines when the pulse will appear on the CRT screen, when Pulsers are used. The sampler timing ramp sets the unmagnified time per division, and the postion range of the sampler timing section.

Quiescently, Q554 is off, allowing the current through Q563 to turn on Q574, clamping the ramp charging current determined by Q581. As Q574 sets near its saturated level, D563 regulates the current through Q563 to prevent Q574 from going completely into saturation. When D545 goes to the high state, it starts the fast ramp by turning on Q554, which reduces the base voltage of Q574 to approximately ground and turns off Q574. This allows the current through Q581 to charge the timing capacitor, C585B C, E or G negatively until the capacitor reaches a voltage approximately equal to the output of the inverter, approximately 1 volt below the emitter of Q673. At this time D675, which was armed by the capacitor charging current, is triggered by the current added by the conduction of Q673. When D675 switches to the high state, a signal is generated in T675, amplified by D695 and Q694, providing a trigger signal to the avalanche pulse generator and memory gate driver. When D545 is returned to its low state by the trigger holdoff logic, Q544 turns off, permitting Q574 to turn on. This returns the ramp to its clamped state, switching D675 to its low state.

When D545 goes to its high state, it turns on Q594 in the pulser timing ramp. In a manner analogous to the sampler timing section, Q614 is turned off permitting the pulser timing ramp to start operating. The capacitor charge negatively with the charging current path out of timing capacitor C615C, D, E, F, G or H through R616 and R618. The ramp runs down until the emitter of Q624 is pulled negative enough to turn the transistor on. When Q624 turns on, its collector pulls down, turning on Q634. As the collector of Q634 rises, C636 couples regenerative feedback to the base of Q624. The collector output is coupled to D423, a tunnel diode in the Pulser circuit.

Inverter Amplifier Schematic ⟨6⟩

Transistors Q674A and Q674B form the differential input to an operational amplifier whose output is Q673. The gain of this operational amplifier is determined by resistors R652, R653, R654, R656 and/or R658, depending on switch settings. The ten volt sweep of the horizontal ramp drives through the MAGNIFIER divider resistors, R645A through R to set the drive current to this operational amplifier, the output of which sets a comparison voltage against which the fast ramp compares. The output level of this operational amplifier is controlled by R664, the POSITION control. A calibrated current flow through the collector of Q664 is set by R661. The percentage of this current, which is driven into the low impedance of the amplifier, can be set quite linearly with the rotation of R664, the 10 turn POSITION control. This permits the display to be shifted in time by a calibrated amount.

Sweep Generator Schematic ⟨7⟩

The sweep generator provides a voltage ramp ranging from —1 to +9 volts, the output of which drives the ten divisions of sweep across the face of the CRT and provides the current which, through the comparator, scans the time range desired on the fast ramp. The sweep generator output is quiescently locked at the —1 volt level (reset position) until a trigger signal is received from the trigger circuit which will unlatch the sweep generator and allow a trace to run across the CRT screen. Initially, D725, Q724 and Q734 are on. Fig. 4-7 provides a block diagram of the Sweep Generator. Current in R742 forward biases D743 and D742. Q753 is connected as a differential comparator with Q753B base set by the divider R756 and R757.

In the NORMAL and SINGLE SWEEP position of the DISPLAY MODE switch, Q753, Q761, and Q783 circuits operate as an operational amplifier setting the output voltage to the VARIABLE Magnifier circuit at about —1 volt. Current path from Q544 in the trigger circuit through R718, R720, D724 and D725 holds D725 in its high state. When Q544 in the trigger circuit cuts off, current is reduced in R718 and D725 turns off. Q724 turns off, and its collector goes up. This returns the trace which had been pulled off during the reset operation, and turns off Q734. When the collector of Q734 goes down, the gating diodes D742 and D743 are turned off, allowing Q753A base voltage to start toward the —19 volt supply. Q753B collector goes negative, driving Q761 base. This allows Q761 collector to rise. This drives Q783 emitter follower, which results in a linear rise of voltage at the upper end of the timing capacitor C750. A current is coupled to Q753 base through C750 in a direction to correct for the base's attempt to go negative. This action holds Q753 base voltage virtually constant, so a constant current charges C750 with a current path through R751 and/or R750 as selected by the RESOLUTION switch SW750. Q783 emitter voltage rises until the voltage at the Sweep Length control R787 passes about —0.7 volts, turning on D787. D725 turns on and resets the sweep. C740 charges through R741 and D740 during the sweep. When the sweep is reset, D740 is back biased and C740 slowly discharges through R740, providing a holdoff time for D725.

Power Supplies Schematic ⟨8⟩

The Type 1S2 contains two sets of rectifier diodes and three regulators (see Fig. 4-8). From interconnecting pins 13 and 14 of P11 from the Oscilloscope main frame, 6.3 volts is supplied to transformer primary T810. The secondary provides power for —19 V and +19 V supplies and 4 VAC for operation of the readout lamps.

+19-Volt Supply. T810 secondary terminal pins, 7, 8, and 9 supply power to the full wave rectifier D810-D811 producing about 30 volts DC across C812.

The regulator circuit consists of a comparator amplifier Q824, an emitter follower Q823 and a series regulator transistor Q827. Q824 compares the voltage from the precision divider R826 and R828 with the voltage at D821 cathode.

Q824 collector current path through R820 to +100 V provides the base voltage for Q823 emitter follower. Q823 emitter drives Q827 series regulator. C822 prevents high frequency oscillations. C829 reduces high-frequency output impedance. The +75-Volt supply connected at pin 15 of P11 adds about 150 mA to the +19 volt supply through R801.

—19-Volt Supply. T801 secondardy terminal pins 3, 4 and 5 supply power to the full wave rectifiers D850-D851, producing about 30 volts DC across C852.

The regulator circuit consists of a comparator amplifier Q864, emitter follower Q863 and a series regulator transistor Q867. Q864 compares the voltage from the divider consisting of R66, R868 and control (for —19 volts) through D862, with D861 cathode voltage. Q864 collector current path through R860 to +19 volts provides the base voltage to Q863 emitter follower. Q863 emitter drives Q867 series regulator. R862 provides current for temperature compensating diode D862. C862 prevents high frequency oscillations. C869 reduces the high-frequency output impedance. R861 provides current for D861.

—136-Volt Supply The —150 volt supply from the oscilloscope through pin 9 of P11 is regulated to —136 volts by the regulator circuit consisting of a comparison transistor Q874, an amplifier transistor Q884, and a series regulator transistor Q887.

Q874 compares the voltage from the divider R888, R886 and R887 (—136 V) with D870 anode voltage. Q874 collector current path through R874 provides the base voltage to Q884. Q884 drives Q887 series regulator.

The maximum current that Q887 can conduct is restricted by its emitter resistor Q885 and Zener diode D885. In addition, the maximum current the amplifier transistor Q884, can conduct is limited by the resistor R883, in Q884 emitter circuit. D871 protects the base-emitter junction of Q874. If the supply is shorted, D883 is back biased preventing excessive current in Q884.

Readout Switching Schematic ⟨9⟩

The Readout Switching circuit provides the proper lamp indications for numerical value as well as appropriate units for a lighted readout of the Horizontal Units/Div. The proper Horizontal Units/Div are displayed for every combination of RANGE, UNITS/DIV and MAGNIFIER switch positions with the MAGNIFIER VARIABLE in the CAL position. With the MAGNIFIER VARIABLE in other than the CAL position, the unit lamp will not be lighted. 4 V RMS from T801 terminal pins 9 and 10 provides power for the lighted readout with terminal pin 9 common to all lamps.

NOTES

SECTION 5
MAINTENANCE

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

This section of the manual contains maintenance information for use in preventive maintenance, corrective maintenance or troubleshooting of the Type 1S2.

PREVENTIVE MAINTENANCE

General

Preventive maintenance consists of cleaning, visual inspection, lubrication, etc. Preventive maintenance performed on a regular basis will help prevent instrument failure and will improve reliability of this instrument. The severity of the environment to which the Type 1S2 is subjected will determine the frequency of maintenance.

Cleaning

The Type 1S2 should be cleaned as often as operating conditions require. Accumulation of dirt in the instrument can cause overheating and component breakdown. Dirt on components acts as an insulating blanket and prevents efficient heat dissipation. It also provides an electrical conduction path.

The top and bottom covers of the Type 540 series instrument into which the Type 1S2 fits, provide protection against dust in the interior of the instrument. Operating without the covers in place will require more frequent cleaning.

CAUTION

Avoid the use of chemical cleaning agents which might damage the plastics used in this instrument. Some chemicals to avoid are benzene, toluene, xylene, acetone or similar solvents.

Exterior. Loose dust accumulated on the outside of the Type 1S2 can be removed with a soft cloth or small paint brush. The paint brush is particularly useful for dislodging dirt on and around the front-panel controls. Dirt which remains can be removed with a soft cloth dampened in a mild solution of water and detergent. Abrasive cleaners should not be used.

Interior. Dust in the interior of the instrument should be removed occasionally due to its electrical conductivity under high-humidity conditions. The best way to clean the interior is a blow off the accumulated dust with dry, low-velocity air. Remove any dirt which remains with a soft paint brush or a cloth dampened with a mild detergent and water solution. A cotton-tipped applicator is useful for cleaning in narrow spaces or for cleaning ceramic terminal strips and circuit boards.

Lubrication

The reliability of potentiometers, rotary switches and other moving parts can be increased if they are kept properly lubricated. Use a cleaning-type lubricant (such as Tektronix Part No. 006-0218-00) on switch contacts. Lubricate switch detents with a heavier grease (such as Tektronix Part No. 006-0219-00). Potentiometers should be lubricated with a lubricant which will not affect electrical characteristics (such as Tektronix Part No. 006-0220-00). Do not over lubricate. A lubrication kit containing the necessary lubricants and instructions is available from Tektronix. Order Tektronix Part No. 003-0342-00.

Visual Inspection

The Type 1S2 should be inspected occasionally for such defects as broken connections, improperly seated transistors, damaged circuit boards and heat-damaged parts.

The remedy for most visible defects is obvious; however, care must be taken if heat-damaged parts are located. Overheating is usually only a symptom of trouble. For this reason, it is essential to determine the actual cause of overheating before the heat-damaged part is replaced; otherwise, the damage may be repeated.

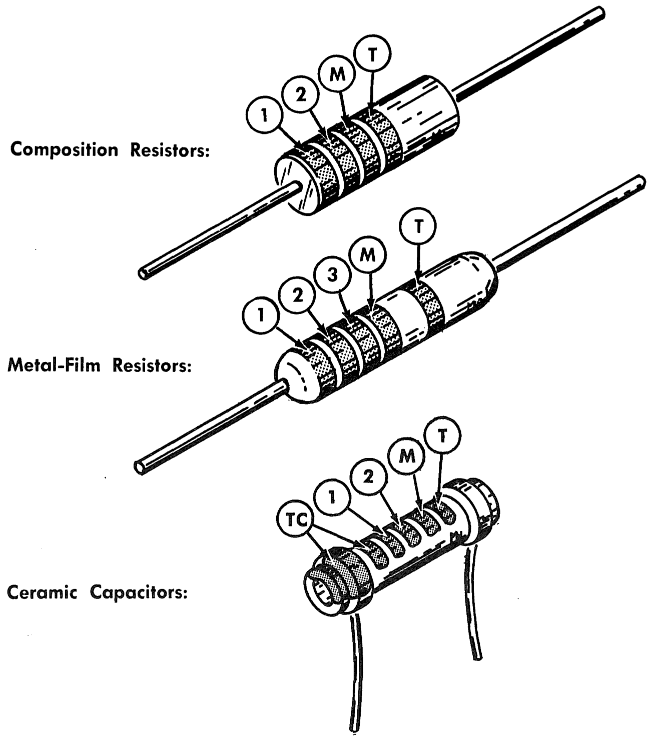
Recalibration

To assure accurate measurements, check the calibration of this instrument after each 500 hours of operation or once every six months.

Parts Identification

Identification of Switch Wafers. Wafers of switches shown on the circuit diagrams are numbered from the first wafer located behind the detent section of the switch to the last wafer. The letters F and R indicate whether the front or the rear of the wafer is used to perform the particular switching function. For example, the designation 2R printed by a switch section on a schematic identifies the switch section as being on the rear side of the second wafer when counting back from the front panel.

Wiring Color Code. The wiring in the Type 1S2 is color coded to facilitate circuit tracing. In the case of power supply leads, the color code indicates the voltage carried, with the widest stripe denoting the first significant figure. Table 5-1 lists the color combinations and the voltages indicated by the colors.



(1) (2) and (3) —1st, 2nd and 3rd significant figures;
(M) —multiplier; (T) —tolerance;
(TC) —temperature coefficient.

Resistor and Capacitor Color Code

Color	Significant Figures	Multiplier		Tolerance	
		Resistors	Capacitors	Resistors	Capacitors
Silver	- - -	10^{-2}	- - -	±10%	- - -
Gold	- - -	10^{-1}	- - -	±5%	- - -
Black	0	1	1	- - -	±20% or 2 pF*
Brown	1	10	10	±1%	±1% or 0.1 pF*
Red	2	10^2	10^2	±2%	±2%
Orange	3	10^3	10^3	±3%	±3%
Yellow	4	10^4	10^4	±4%	+100% −0%
Green	5	10^5	10^5	±0.5%	±5% or 0.5 pF*
Blue	6	10^6	10^6	- - -	- - -
Violet	7	- - -	- - -	- - -	- - -
Gray	8	- - -	10^{-2}	- - -	+80% −20% or 0.25 pF*
White	9	- - -	10^{-1}	- - -	±10% or 1 pF*
(none)	- - -	- - -	- - -	±20%	±10% or 1 pF*

*For capacitance of 10 pF or less.

NOTE: (T) and/or (TC) color code for capacitors depends upon manufacturer and capacitor type. May not be present in some cases.

Fig. 5-1. Resistor and ceramic capacitor color code.

All leads that clip to the permanently mounted circuit boards are color coded. The color code of each lead and the pin lettering is shown in parts location figures later on in this section.

Resistor Coding. The Type 1S2 uses a number of very stable metal film resistors identified by their gray background color and color coding.

If the resistor has three significant figures with a multiplier, the resistor will be EIA color coded. If it has four significant figures with a multiplier, the value will be printed on the resistor. For example, a 333 kΩ resistor will be color coded, but a 333.5 kΩ resistor will have its value printed on the resistor body.

TABLE 5-1

Power Supplies Wire Color Coding

Supply	Color Code
+350	Orange/Green/Brown on White
+225	Red/Red/Brown on White
+100	Brown/Black/Brown on White
+19	Red/Black/Black on White
−19	Red/Black/Black on Tan
−136	Brown/Black/Brown on Tan

The color-coding sequence is shown in Fig. 5-1.

Capacitor Marking. The capacitance values of common disc capacitors and small electrolytics are marked in microfarads on the side of the component body. The white ceramic capacitors used in the Type 1S2 are color coded in picofarads using a modified EIA code (see Fig. 5-1).

Diode Color Code. The cathode end of each glass-enclosed diode is indicated by a stripe, a dot or a series of stripes. For normal silicon or germanium diodes the stripes also indicate the type of diode, using the resistor color-code system (e.g., 6165 indicates the type of diode with Tektronix Part No. 152-0165-00). The cathode and anode ends of metal-encased diodes can be distinguished by the diode symbol marked on the body or by the flared end of the anode.

Parts Replacement

All parts used in the Type 1S2 can be purchased directly through your Tektronix Field Office or Representative. However, replacements for standard electronic items can generally be obtained locally in less time than is required to obtain them from Tektronix. Replacements for the special parts used in the assembly of the Type 1S2 should be ordered from Tektronix since these parts are either manufactured or selected by Tektronix to satisfy a particular requirement. Before purchasing or ordering, consult the Electrical Parts List to determine the value, tolerance and ratings required.

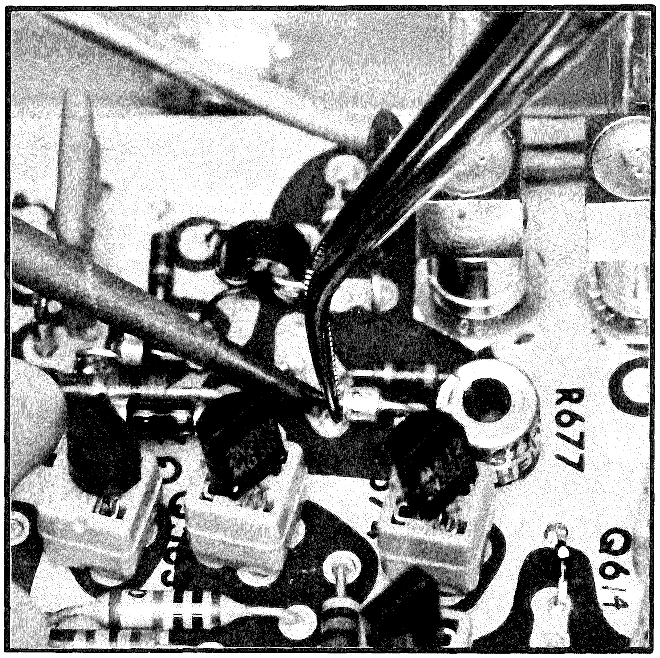


Fig. 5-2. Tunnel diode removal.

NOTE

When selecting the replacement parts, it is important to remember that the physical size and shape of a component may affect its performance at high frequencies. Parts orientation and lead dress should duplicate those of the original part since many of the components are mounted in a particular way to reduce or control stray capacitance and inductance. After repair, portions of the instrument may require recalibration.

Rotary Switches. Individual wafers or mechanical parts of rotary switches are normally not replaced. If a switch is defective, replace the entire assembly. The availability of replacement switches, either wired or unwired, is detailed in the Electrical Parts List.

Circuit Boards. Use ordinary 60/40 solder and a 35- to 40-watt pencil type soldering iron on the circuit boards. The tip of the iron should be clean and properly tinned for best heat transfer to the solder joint. A higher wattage soldering iron may separate the etched wiring from the base material.

Replacement of Tunnel Diodes. Grasp the TD lead between the body of the TD and the circuit board with a small pair of tweezers. See Fig. 5-2.

Touch the tip of the soldering iron to the TD lead where it enters the circuit board. Do not lay the iron tip directly on the circuit board. Gently but firmly pull the TD lead from the hole in the circuit board. If removal of the diode does not leave a clean hole, apply a sharp object such as a toothpick or pointed tool while reheating the solder. Avoid using too much heat.

To place the new TD, bend the leads and trim to fit just through the board. Tin each lead while using the tweezers as a heat sink. Place the TD leads in the holes. Apply a small amount of solder, if necessary, to assure a good bond. Use the tweezers as a heat sink and use only enough heat for a good connection.

Replacement of other soldered-in components. Grip the component lead with long-nose pliers. Touch the soldering iron to the lead at the solder connection. Do not lay the iron directly on the board, as it may damage the board. Refer to Fig. 5-3.

When the solder begins to melt, pull the lead out gently. This should leave a clean hole in the board. If not, the hole can be cleaned by reheating the solder and placing a sharp object such as a toothpick or pointed tool into the hole to clean it out.

Bend the leads of the new component to fit the holes in the board. If the component is replaced while the board is mounted in the instrument, cut the leads so they will just protrude through the board.

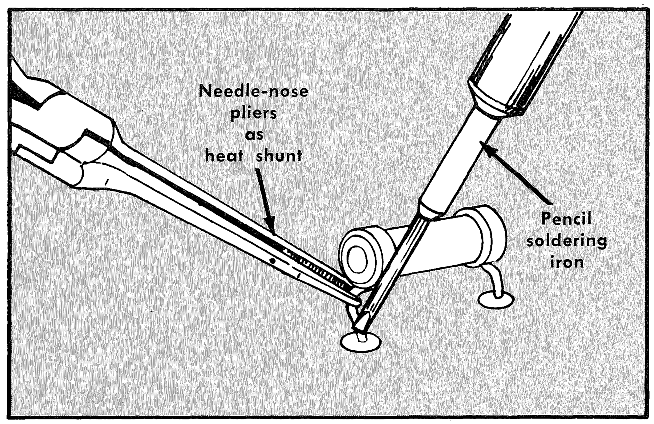


Fig. 5-3. Apply the soldering iron to the heat-shunted lead when removing a component from a circuit card.

Pre-tin the leads of the component by applying the soldering iron and a small amount of solder to each (heat-shunted) lead. Insert the leads into the board until the component is firmly seated against the board. If it does not seat properly, heat the solder and gently press the component into place.

Apply the iron and a small amount of solder to the connection to make a firm solder joint. To protect heat-sensitive components, hold the lead between the component body and the solder joint with a pair of long-nose pliers or other heat sink.

Clip the excess lead that protrudes through the board.

Clean the area around the soldered connection with a flux-remover solvent to maintain good environmental characteristics. Be careful not to remove information printed on the board.

Leadless Capacitors. There are leadless ceramic capacitors soldered directly to the sampler circuit boards. Care must be taken when replacing these capacitors as they are easy to crack. The type of solder used must be high quality, with good cold-flow characteristics. Thus, do not use 50/50 solder, but 60-40 or 62-38 solder when replacing the leadless capacitors.

Use only enough solder to obtain a good full-flow joint. Excess solder on either side of the capacitor can lead to a short circuit.

Readout Panel Lamps. The horizontal units/div readout panel lamps are operated at low current for longest lifetime. Yet, they will need to be replaced occasionally. Replacement requires removal of the circuit board to which they are soldered. Removal is explained below as part of the section on Subassembly Removal.

Metal Terminals. When soldering metal terminals (e.g., switch terminals, potentiometers, etc.), ordinary 60-40 solder can be used. The soldering iron should have a 40- to 75-watt rating with a $1/8$ inch wide chisel-shaped tip.

Observe the following precautions when soldering metal terminals:

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

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

3. If a wire extends beyond the solder point, clip off the excess.

4. Clean the flux from the solder joint with a flux-remover solvent to maintain good environmental characteristics.

Removal and Replacement of Sampling Diodes. The Sampling Bridge Diodes are mounted in a plastic holder that slides into a cutout in the edge of the Sampler circuit board. Removal and/or replacement of the diodes is most easily made with a pair of forceps, such as the Xcelite No. 42H, or equivalent. Fig. 5-4 shows a plastic diode holder assembly being removed from the circuit board.

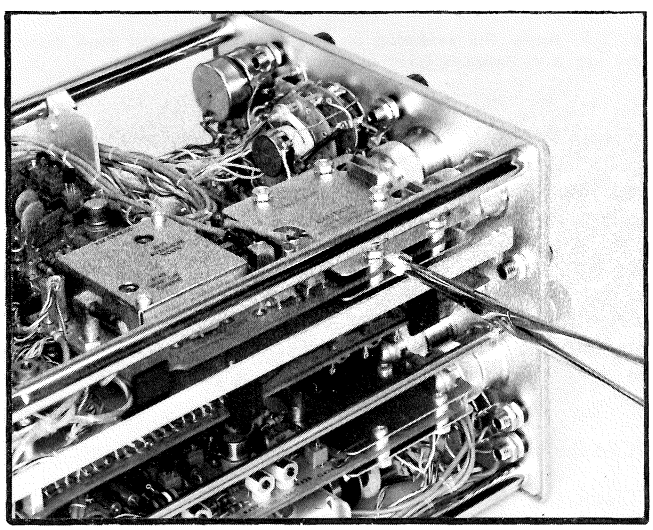


Fig. 5-4. Plastic sampling diode assembly removal.

Subassembly Removal

Circuit Board Replacement. If a circuit board is damaged and cannot be repaired, the entire assembly including all soldered-on components should be replaced. The part number given in the Mechanical Parts List is for the completely-wired board.

Procedure for replacing circuit boards follows:

Most connections to the circuit boards are made with solder. Some, however are made with pin connectors.

Most of the components mounted on the circuit boards can be replaced without removing the boards from the instrument. Observe soldering precautions given under Soldering Techniques in this section. However, if the underside of the board must be reached or if the board must be moved to gain access to other areas of the instrument, only the mounting screws need be removed. The interconnecting wires allow the board to be moved out of the way or turned over without unsoldering the leads.

The Sampler board and the Pulse Generator boards require special procedures for removal and replacement. The procedure is as follows:

Sampler Board Removal. Remove the two 12 sided nuts that secure the GR connectors to the front panel. A special Tektronix tool is available for removing the 12 sided nuts. Order: 12 sided nut wrench, Tektronix Part No. 003-0459-00.

Remove the two cables from the jacks, J115 and J135.

Remove the five leads, A, B, C, and the two strobe pulse leads, that are attached to the circuit board with solderless pin connectors.

Spread the two clips that hold the rear of the board in place.

Lift the rear of the board away from the chassis and slide the whole assembly away from the front panel, then lift the circuit board away from the chassis. Do not force or bend the circuit board.

Pulse Generator Board Removal. All of the connections to the Pulse Generator board are soldered pin type connections or Subminax cable connectors. To remove the board from the instrument, disconnect the leads from the circuit board. Remove the 12 sided nuts from the panel connectors. Spread the clips which hold the rear of the board and lift the end of the board free of the mounting clips. Slide the board away from the front panel and free of the instrument. Do not force or bend the circuit board.

Parts Replacement on Sampler and Pulse Generator Boards

Removal of Shields. Replacement of components under the shields on these boards requires special handling. The shields, GR connectors and circuit board make up a precision assembly.

Remove the circuit board from the instrument, as per removal instructions.

Loosen, but do not remove, the five nuts, with captive washers.

Loosen the knurled nuts on the GR connectors. See Fig. 5-5. This frees the shield fingers from the notches in the connector sleeves. Rotate the notched connector sleeves 90° and slide the connector assembly away from the circuit board.

Carefully remove the nuts and bolts from the assembly, while preventing any motion of the shields that might disturb the leads to the shield mounted capacitors. (Resistor leads under the shields.)

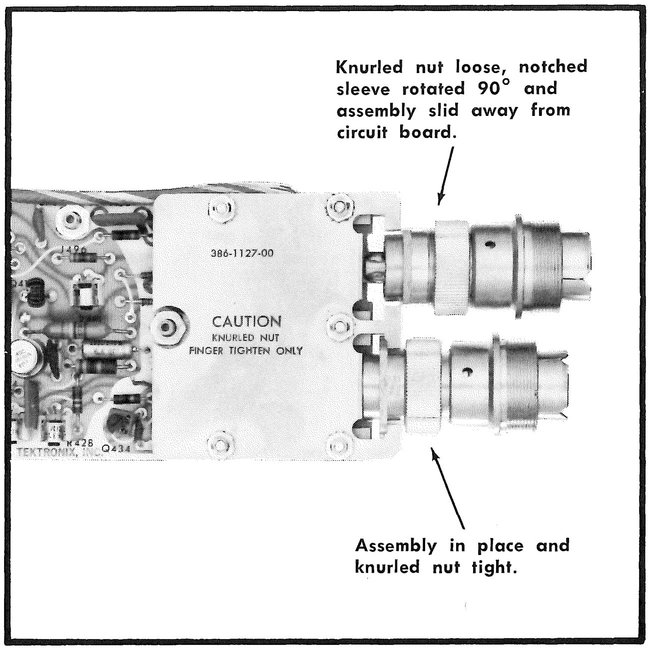


Fig. 5-5. GR connector assembly attached to Pulser board.

Heat the center capacitor terminal (on the Sampler board only) with the soldering iron tip and pull the shield away from the board. Turn the circuit board over and remove the other shield in a similar manner.

Should it become necessary to replace R104, R105, R106 or R107, do not let solder flow onto the area to which contact is made by the Sampling Diodes. See Fig. 5-6.

Color of the leads and position of transformers T114 and T144 must be observed when replacing either of them. These transformers must be installed correctly for the circuit to function.

Replacement of Shields. The parts must be reassembled properly to maintain the 50 Ω impedance through the transistion from the GR connector to the circuit board. Failure to follow this procedure results in poor ground connection, poor displays and pulse flatness deviations.

Clean out the center terminal on the shield mounted capacitors (Sampler board only) so that the resistor lead, Fig. 5-7, will slide freely into the hole.

Carefully place the shield-mounted capacitor center hole over the resistor lead and hold in place while placing a couple of bolts through the shield and circuit board.

Place the opposite shield over the bolts just placed, aligning the capacitor center hole over the resistor lead.

Place nuts on the two bolts but do not tighten. Place the remaining bolts in the holes and attach the nuts, but do not tighten.

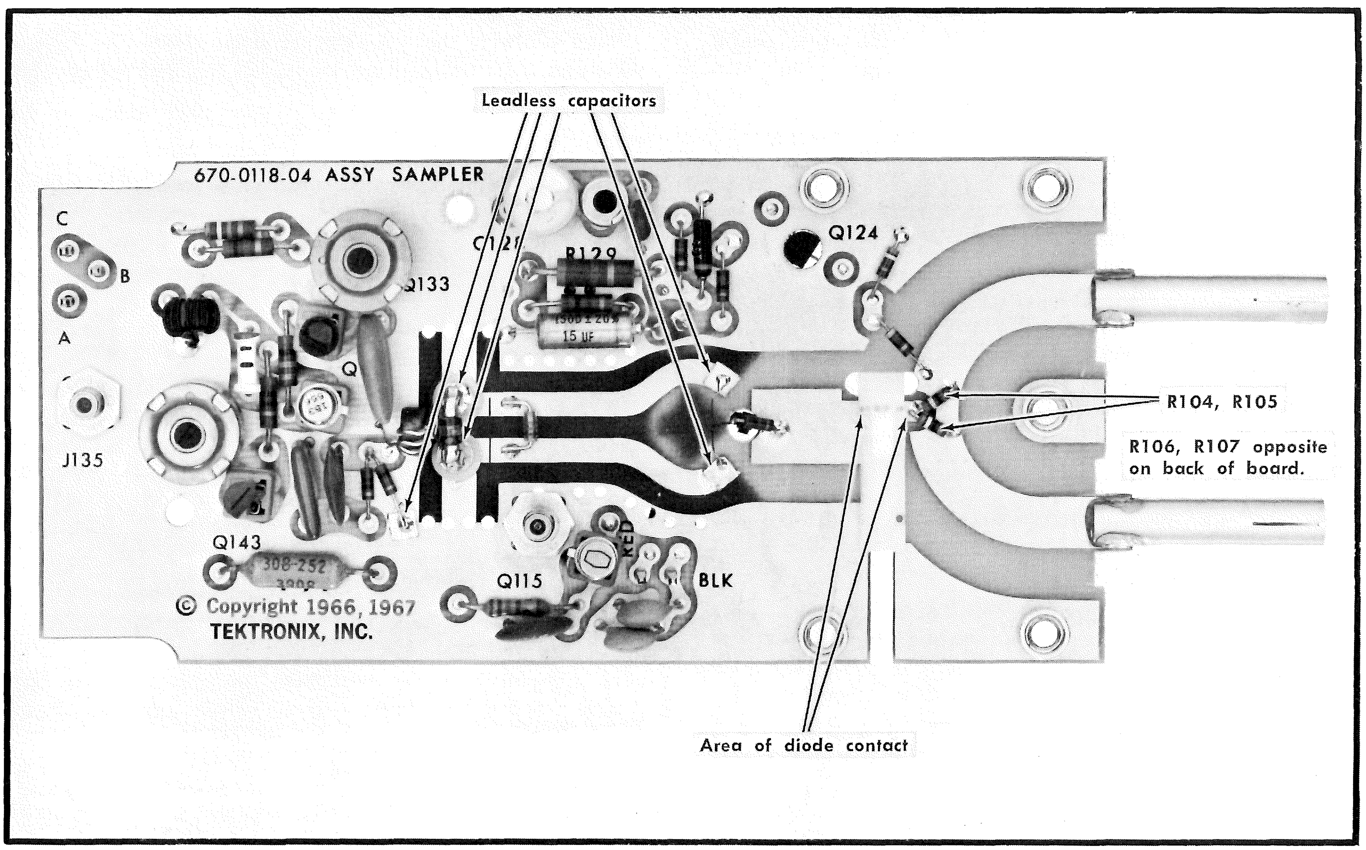


Fig. 5-6. R104, R105, R106, R107 soldering and sampling diode clips.

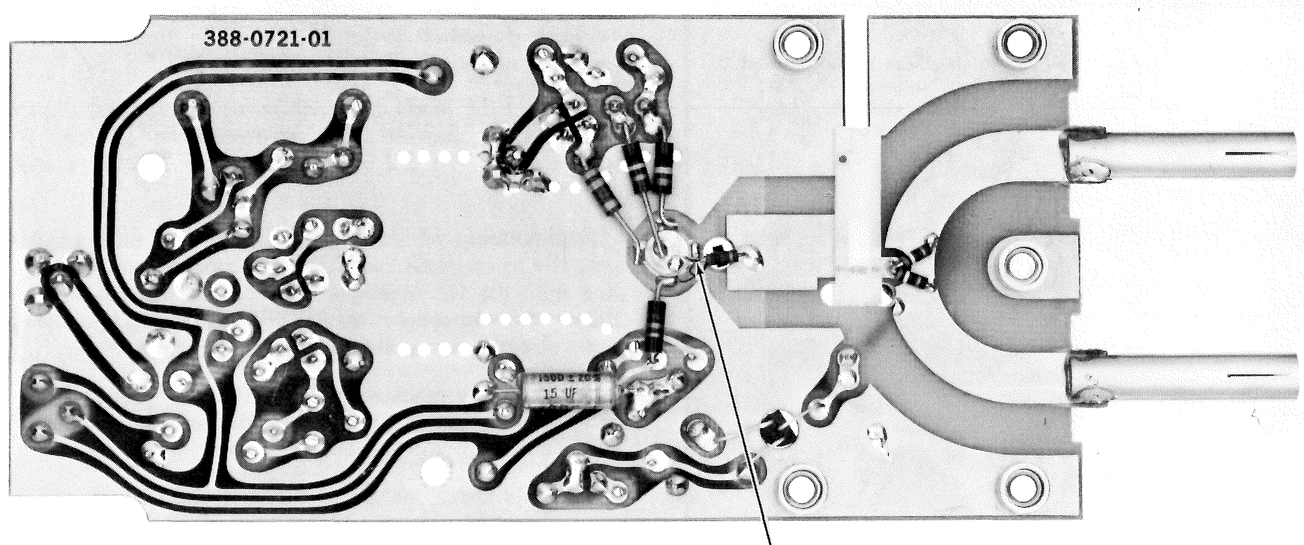


Fig. 5-7. Sampler board resistor lead (shield replacement).

Slide the GR connector assemblies onto the circuit board center conductors, rotating the notched sleeves so that each sleeve slides between a set of shield fingers.

Rotate the notched sleeves 90° and mate the notches with the shield fingers.

Press the shields firmly against the notched sleeves and tighten the knurled nuts (Finger Tight Only).

Tighten the 5 nuts that hold the shields in place.

Solder the capacitor leads into place on both shields.

Replacing Sampling and Pulse Generator Boards in the Instrument. Slide the GR connectors through the holes in the front panel and push the rear of the circuit board down into the mounting clips.

Replace the 12 sided nuts on the front panel and tighten.

Replace the leads on the connectors. Be certain the metal clip which snaps over the barrel of connector P420 is spring pressure-connected to the pulse generator metal shield.

Replacing Readout Incandescent Lamps. To remove the readout circuit board, use a 1/4 inch open-end wrench with a 90° end. Remove the 6-32 nuts from the captive bolts; lift the board free of the captive bolts and the board can then be brought out the instrument left side.

Lamp removal and replacement requires a pair of tweezers and a small soldering iron. Withdraw the burned-out lamp. To install the new lamp, cut the leads to proper length, and then bend then into the same shape as found in the original lamp.

After soldering the new lamp in place, check that there is no excess solder to short between a hot terminal and ground.

Position the lamp the same as all other lamps in the assembly.

Place the board back onto the captive bolts and replace the 1/4 inch nuts.

TROUBLESHOOTING

Introduction

The following information is provided to facilitate troubleshooting of the Type 1S2 if trouble develops. Information contained in other sections of this manual should be used along with the following information to aid in locating the defective component.

Troubleshooting Aids

Diagrams. Circuit diagrams are given on foldout pages in Section 10. The circuit number and electrical value of each component in this instrument are shown on the diagrams. Important voltages and waveforms are also shown on the diagrams.

Component Numbering. The circuit number of each electrical part is shown on the circuit diagram. Each main circuit is assigned a series of circuit numbers. Table 5-2 lists the main circuits in the Type 1S2 and the series of circuit numbers

TABLE 5-2

Circuit Numbers on Schematics	Circuit
101-149	Sampler
150-199 200-299	Preamp and Memory
300-399	Offset and Output
400-499	Pulse Generator
500-549	Trigger
550-599 600-699	Fast Ramp
700-799	Sweep Generator
800-899	Power Supply
900-999	Readout Switching

assigned to each. For example, using Table 5-2, a resistor numbered R652 is identified as being located in the Fast Ramp Circuit.

Troubleshooting Techniques

This troubleshooting procedure is arranged in an order which checks the simple trouble possibilities before proceeding with extensive troubleshooting. The first few checks assure proper connection, operation and calibration. If the trouble is not located by these checks, the remaining steps aid in locating the defective component. When the defective component is located, it should be replaced following the replacement procedures given in this section.

1. Check Associated Equipment. Before proceeding with troubleshooting of the Type 1S2 check that the equipment used with the Type 1S2 is operating correctly. Check that the signal is properly connected and that the interconnecting cables are not defective. Also, check the power source.

2. Check Control Settings. Incorrect control settings can indicate a trouble that does not exist. For example, incorrect setting of the MAGNIFIER VARIABLE control appears as an uncalibrated sweep; incorrect setting of the TRIGGER SENS control appears as defective sweep or trigger circuit; incorrect setting of the Vertical Units/Div VARIABLE control appears as incorrect gain, etc. If there is any question about the correct function or operation of any control, see the Operating Instructions section of this manual.

3. Check Instrument Calibration. Check the calibration of the instrument, or the affected circuit if the trouble exists in one circuit. The indicated trouble may only be a result of misadjustment or may be corrected by calibration. Complete instructions are given in the Calibration section of this manual.

CAUTION

It is important not to adjust any power supply voltages unless a total calibration effort is planned. Changing power supply voltages alters the whole instrument calibration. Other steps of the Calibration Procedure can be performed in any sequence unless otherwise stated.

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

a. Check for the correct resistance readings at the interconnecting plug terminals, as indicated in Table 5-3.

If the resistance values at the interconnecting plug are equal or higher than stated in Table 5-3, proceed with the next step.

TABLE 5-3

Interconnecting Plug Resistance Checks
Type 1S2 disconnected from Oscilloscope

Pin Number	Resistance to Ground
1	12 kΩ
2	Gnd
3	10 kΩ
4	Inf
5	Inf
6	Inf
7	Inf
8	8 kΩ
9	6.5 kΩ
10	19 kΩ
11	35 kΩ
12	90 kΩ
13	Inf
14	Inf
15	400 Ω
16	100 kΩ

b. Connect the Type 1S2 to the oscilloscope in which it will normally operate. Use the flexible cable extension, Tektronix Part No. 012-0038-00. Turn on the instrument and allow at least 5 minutes warm-up time.

Check the power supply voltages. Proper test points are shown in Fig. 5-8.

Incorrect operation of all circuits often indicates trouble in the power supplies. Check first for correct adjustment of the individual supplies. However, a defective component elsewhere in the instrument can appear as a power-supply trouble and may also affect the operation of other circuits.

Table 5-4 lists the tolerances of the power supplies in the Type 1S2. If a power-supply voltage is within the listed tolerance, the supply can be assumed to be working correctly. If outside the tolerance, the supply may be misadjusted or operating incorrectly. Use the procedure given in the Calibration section to adjust the power supplies.

TABLE 5-4

Type 1S2 Power Supply Tolerances

Power Supply	Tolerance
+350-Volt	Typically +349 volts[1]
+225-Volt	Typically +224 volts[1]
+100-Volt	Typically +98 volts[1]
+19-Volt	±3% (limits: +18.43 to +19.57)
—19-Volt	±3% (limits: —18.43 to —19.57)
—136-Volt	±3% (limits: —131.92 to —139.08)
—150-Volt	Typically —145 volts[1]

[1]Value is based upon a series decoupling resistor within the oscilloscope. If voltage is significantly less (several volts) examine the associated decoupling resistor network in the oscilloscope.

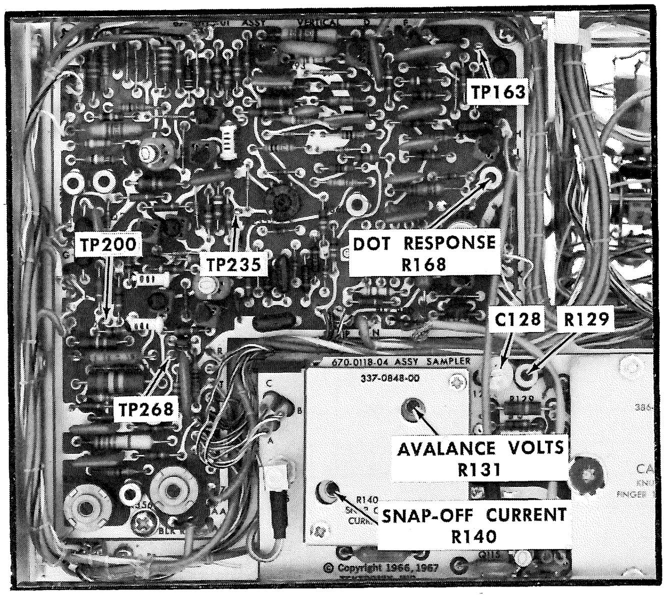


Fig. 5-8. Power supply test points.

c. Check for circuit voltages and waveforms. Typical voltages and waveforms, given on the schematic diagrams, were obtained under the test conditions listed on the left page of the Sampler circuit diagram.

NOTE

Voltages and waveforms given on the diagrams are not absolute and may vary slightly between instruments. To obtain operating conditions similar to those used to take these readings, see the first schematic page.

Transistor Checks

Transistors should not be replaced unless they are actually defective. Transistor defects usually take the form of the transistor opening, shorting or developing excessive leakage.

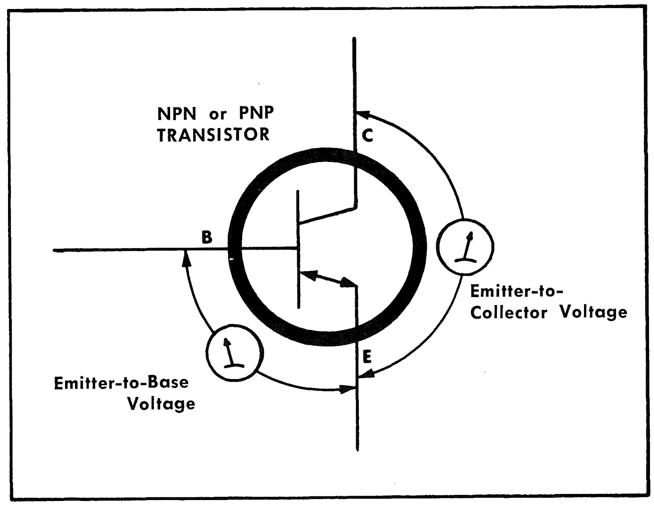


Fig. 5-9. In-circuit voltage checks NPN or PNP transistors.

To check a transistor for these and other defects, use a transistor curve display instrument such as a Tektronix Type 575. However, if a good transistor checker is not readily available, a defective transistor can be found by signal-tracing, by making in-circuit voltage checks, by measuring the transistor forward-to-back resistance using proper ohmmeter resistance ranges, or by using the substitution method. The location of all transistors is shown in the parts location figures later in this section.

To check transistors using a voltmeter, measure the emitter-to-base and emitter-to-collector voltages and determine if the voltages are consistent with the normal resistances and currents in the circuit (see Fig. 5-9).

To check a transistor using an ohmmeter, know your ohmmeter ranges, the currents they deliver, and the internal battery voltage(s). If your ohmmeter does not have sufficient resistance in series with its internal voltage source, excessive current will flow through the transistor under test. Excessive current and/or high internal source voltage may permanently damage the transistor.

NOTES

NOTE

As a general rule, use the R × 1 k range where the current is usually limited to less than 2 mA and the internal voltage is usually 1½ volts. You can quickly check the current and voltage by inserting a multimeter between the ohmmeter leads and measuring the current and voltage for the range you intend to use.

When you know which ohmmeter ranges will not harm the transistor, use those ranges to measure the resistance with the ohmmeter connected both ways as given in Table 5-5.

TABLE 5-5

Transistor Resistance Checks

Ohmmeter Connections[2]	Resistance Reading That Can Be Expected Using the R × 1 k Range
Emitter-Collector	High readings both ways (about 60 kΩ to around 500 kΩ).
Emitter-Base	High reading one way (about 200 kΩ or more). Low reading the other way (about 400 Ω to 2.5 kΩ).
Base-Collector	High reading one way (about 500 kΩ or more). Low reading the other way (about 400 Ω to 2.5 kΩ).

[2]Test prods from the ohmmeter are first connected one way to the transistor leads and then the test prods are reversed (connected the other way). Thus, the effects of the polarity reversal of the voltage applied from the ohmmeter to the transistor can be observed.

If there is doubt about whether the transistor is good, substitute a new transistor; but first, be certain the circuit voltages applied to the transistor are correct before making the substitution.

When checking transistors by substitution, be sure that the voltages on the transistor are normal before making the substitution. If a transistor is substituted without first checking out the circuit, the new transistor may immediately be damaged by some defect in the circuit.

CAUTION

Be careful when making measurements on live circuits. The small size and high density of components used in this instrument result in close spacing. An inadvertent movement of the test probes, or the use of oversized probes may short between circuits.

Diode Checks

A diode can be checked for an open or shorted condition by measuring the resistance between terminals. With an ohmmeter scale having an internal source of about 1.5 volts, the resistance should be very high in one direction and very low when the leads are reversed. Do not check the sampling diodes with an ohmmeter. Change sampling diodes any time you cannot properly adjust the Blowby compensation, step 35 of the Calibration Procedure.

CAUTION

Do not use an ohmmeter scale that has a high internal current. High currents may damage the diode. Do not measure tunnel diodes with an ohmmeter; use a dynamic tester (such as Tektronix Type 575 Transistor-Curve Tracer).

Field Effect Transistors

Field Effect transistors in the Type 1S2 should not be tested with an ohmmeter. Rather, if you suspect one of the dual FET's, pull the unit out of the socket, rotate it 180° and re-insert it. A bad FET will change balance problems and slash. The leads are arranged in a manner to permit the unit to be installed with the guide pin either straight up or straight down. Q244 should be replaced if during a calibration procedure, the MEMORY GATE BAL control cannot be properly adjusted.

Actual condition of an FET can be checked using a Tektronix Type 575 Transistor Curve Tracer. Follow the lead identification of Fig. 5-10 when making connections at the curve tracer sockets.

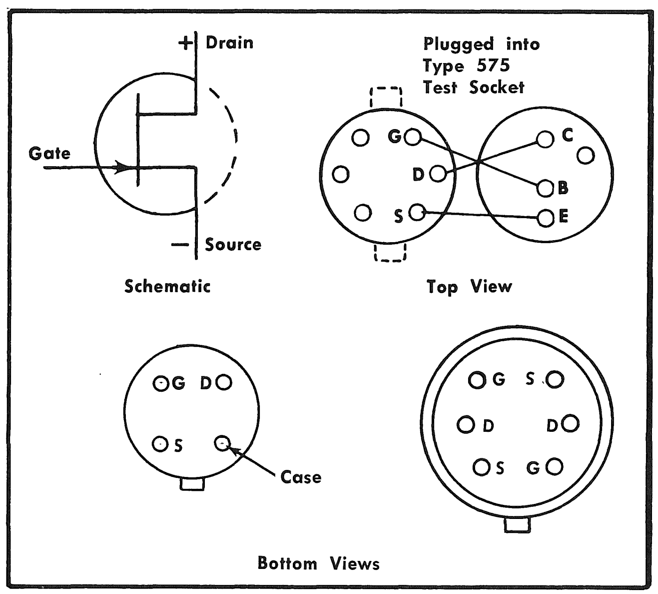


Fig. 5-10. Pin arrangement in dual FET used in Type 1S2.

Set the curve tracer controls:

COLLECTOR SWEEP Controls

PEAK VOLTS RANGE	200
POLARITY	+ (NPN)
PEAK VOLTS Control	Fully counterclockwise
DISSIPATION LIMITING RESISTOR	2K

VERTICAL Controls

CURRENT OR VOLTAGE	1 COLLECTOR MA
POSITION	Spot at lower left corner of graticule

HORIZONTAL Controls	
VOLTS/DIV	10 COLLECTOR VOLTS
POSITION	Spot at lower left corner of graticule
BASE STEP GENERATOR Controls	
REPETITIVE/OFF/SINGLE FAMILY	REPETITIVE
STEPS/FAMILY	Fully counterclockwise
POLARITY	—
STEPS/SEC	120 (up)
SERIES RESISTOR	Optional
STEP SELECTOR	.2 MA PER STEP
Sloping Panel Controls	
Center rotary switch	EMITTER GROUNDED

Connect a 1000 Ω (1% or 5%) ½ watt resistor between the B and E binding posts on whichever side of the sloping panel you plan to test the FET. This resistor develops a voltage bias for the Gate lead at 1 volt per mA base step current.

Since the leads of the FET are short, you can avoid bending them (with a chance of breakage) by building an adapter out of a spare transistor socket and wire leads to the sloping panel binding posts. Follow Fig. 5-10 when making connections.

Major Circuit and Parts Locations

The remainder of this section includes photograph of sections of the Type 1S2. Major circuit areas are identified. All components mounted on circuit boards are identified by circuit numbers. All circuit board connections are identified by pin number or color code.

NOTES

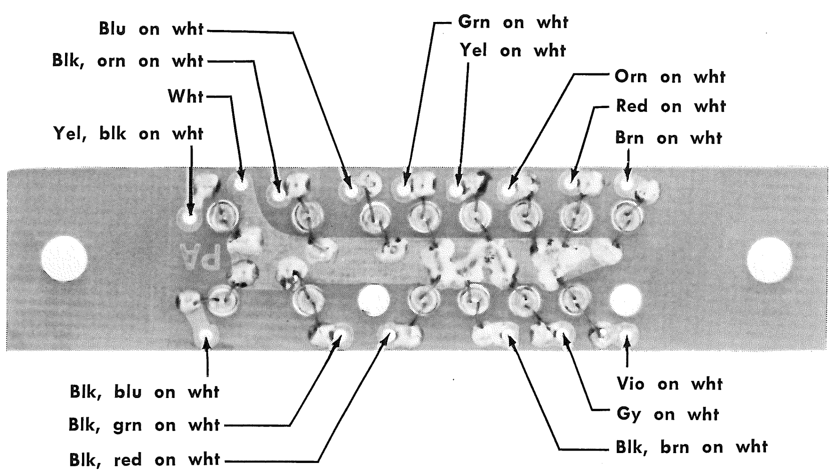


Fig. 5-11. Readout circuit board assembly.

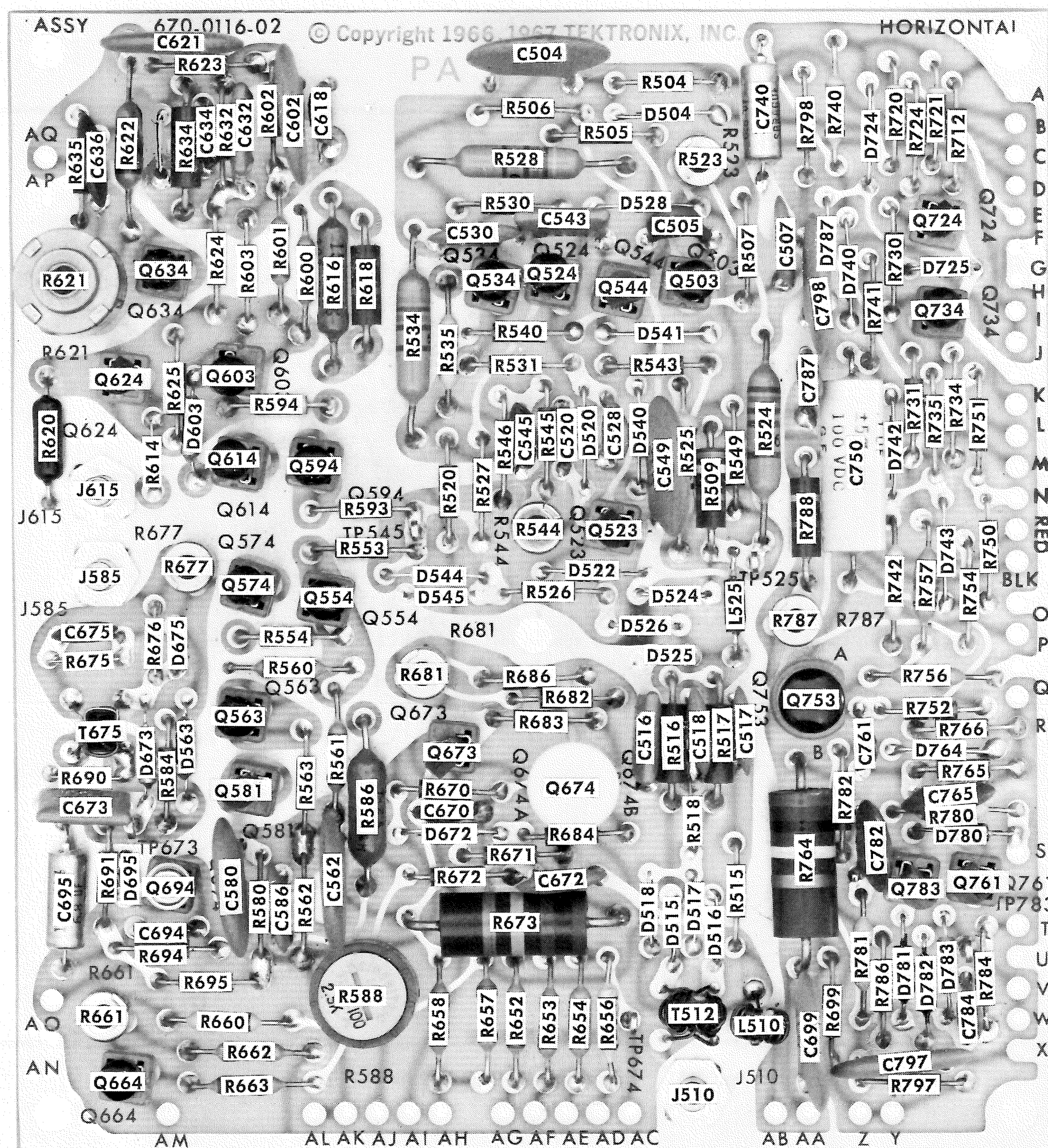


Fig. 5-12A. Horizontal circuit board assembly.

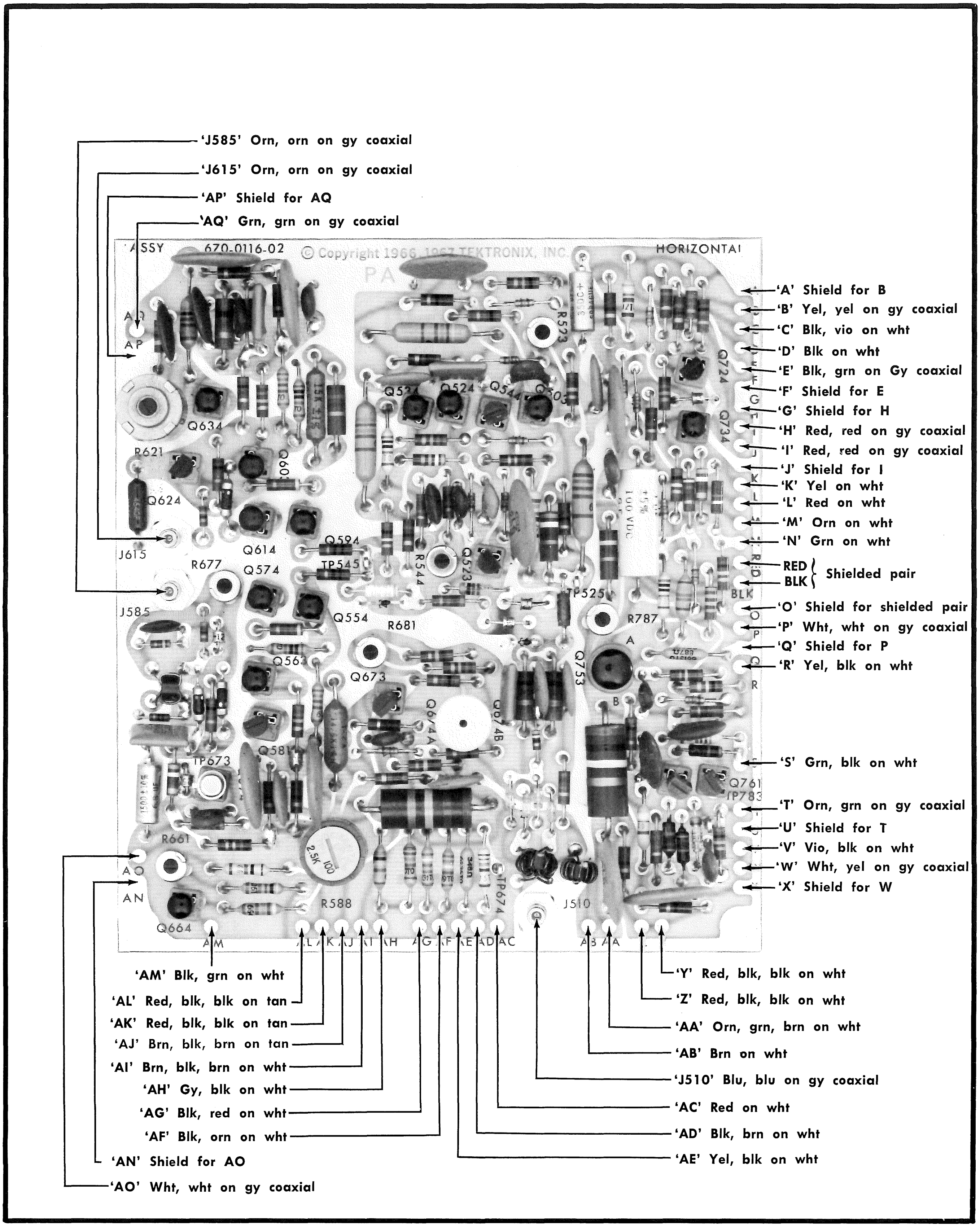
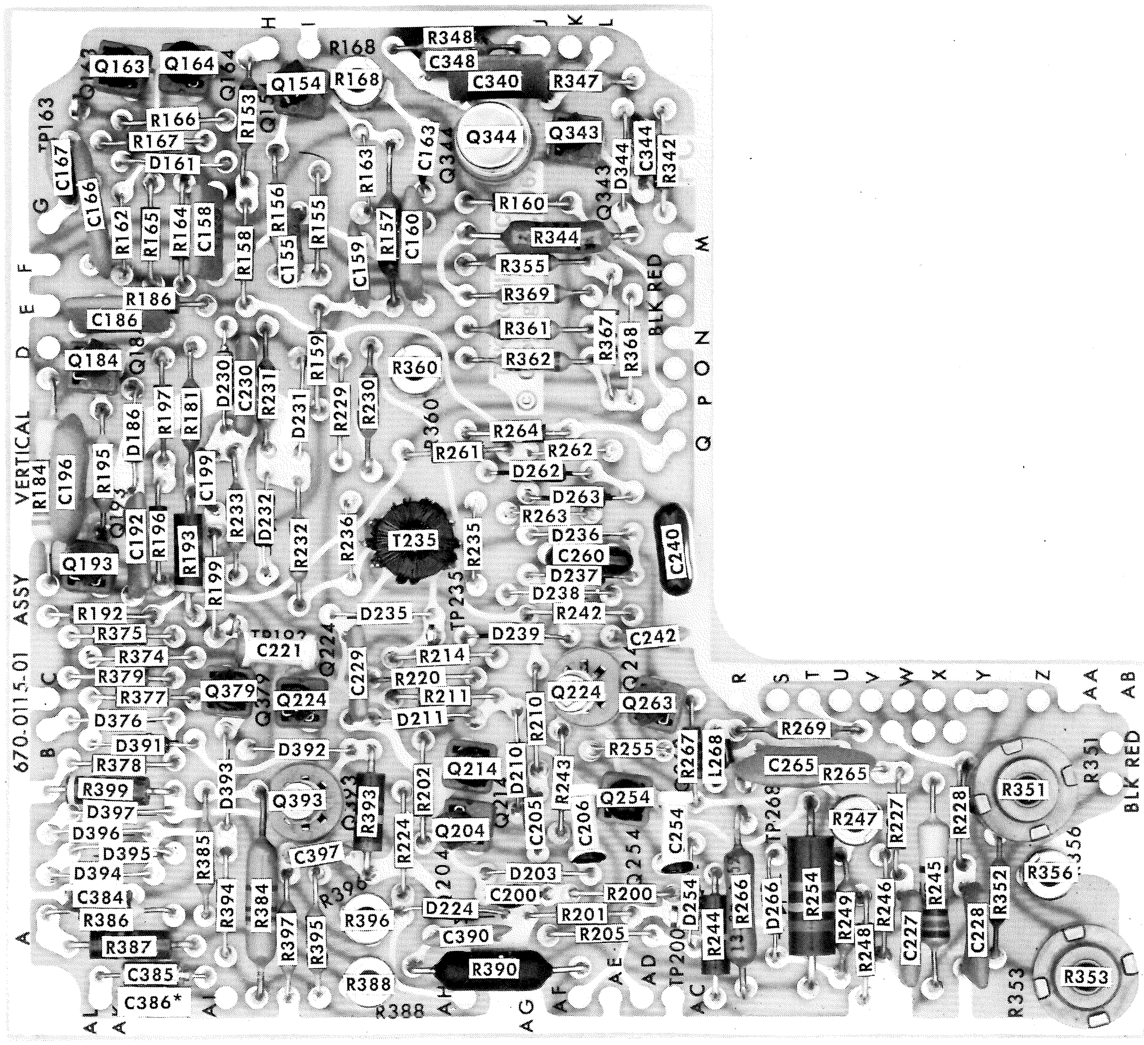


Fig. 5-12B. Horizontal circuit board assembly.



*Added at SN 3000-up.

Fig. 5-13A. Vertical circuit board assembly.

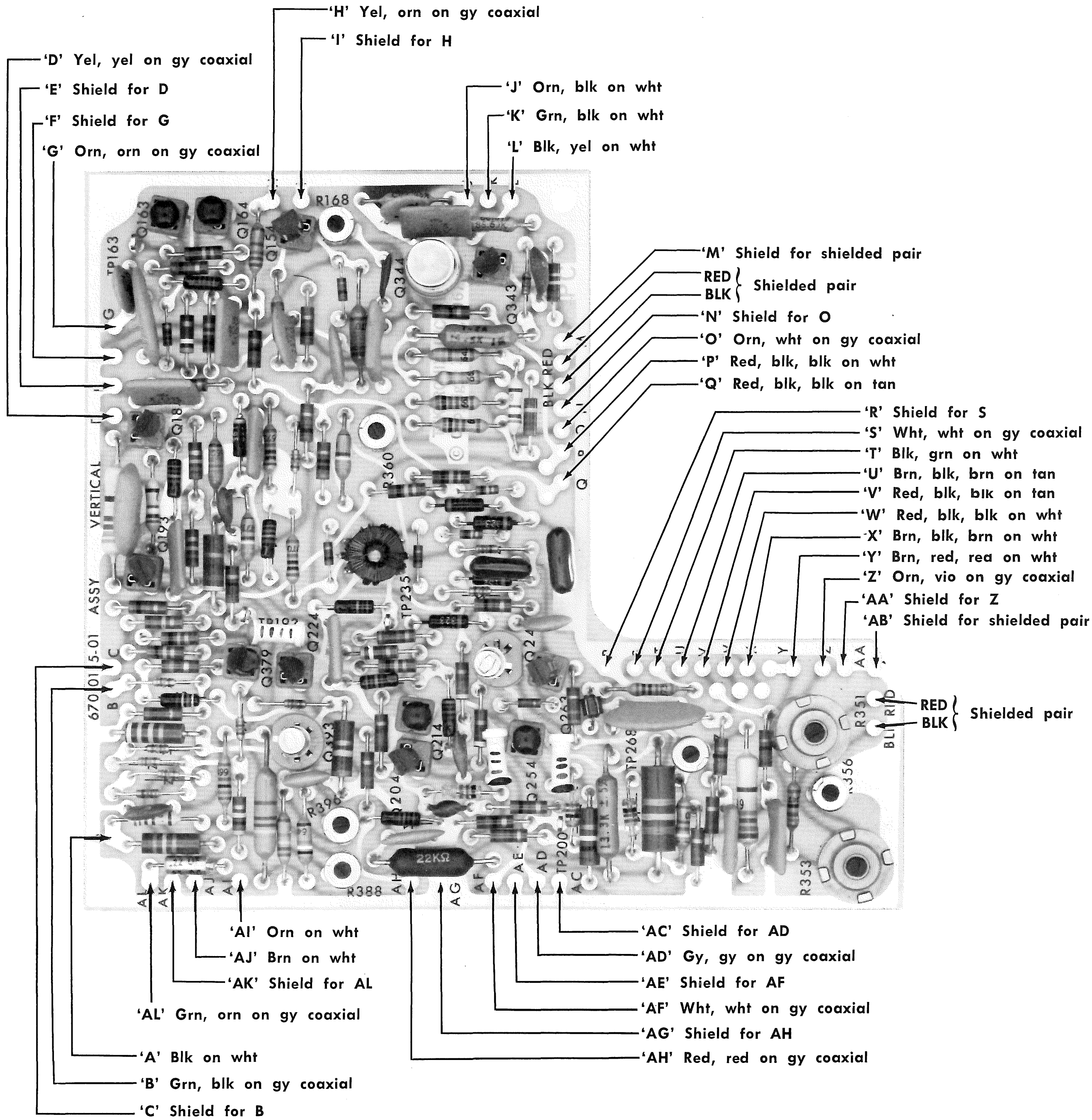


Fig. 5-13B. Vertical circuit board assembly.

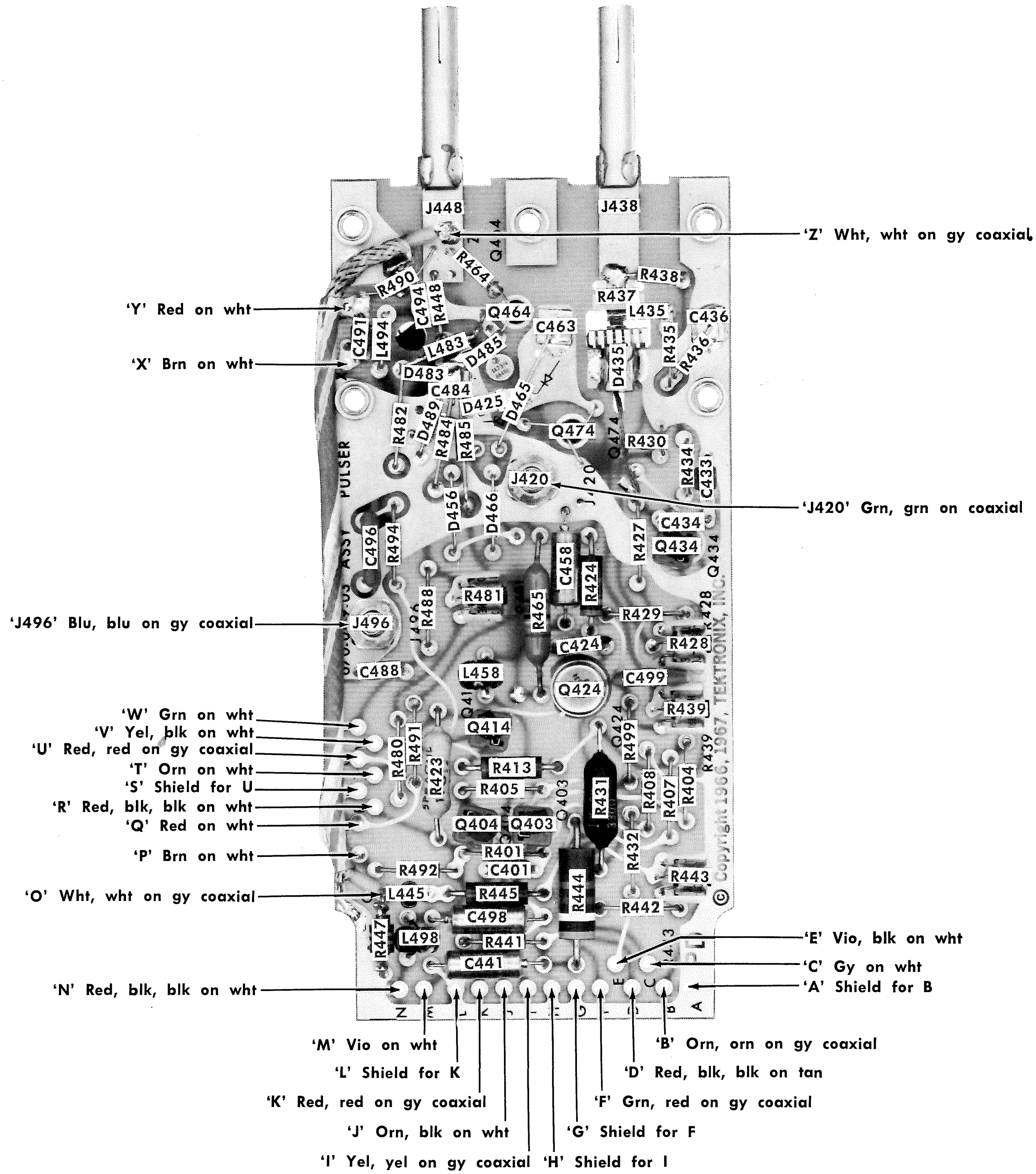


Fig. 5-14A. Pulser circuit board assembly (front).

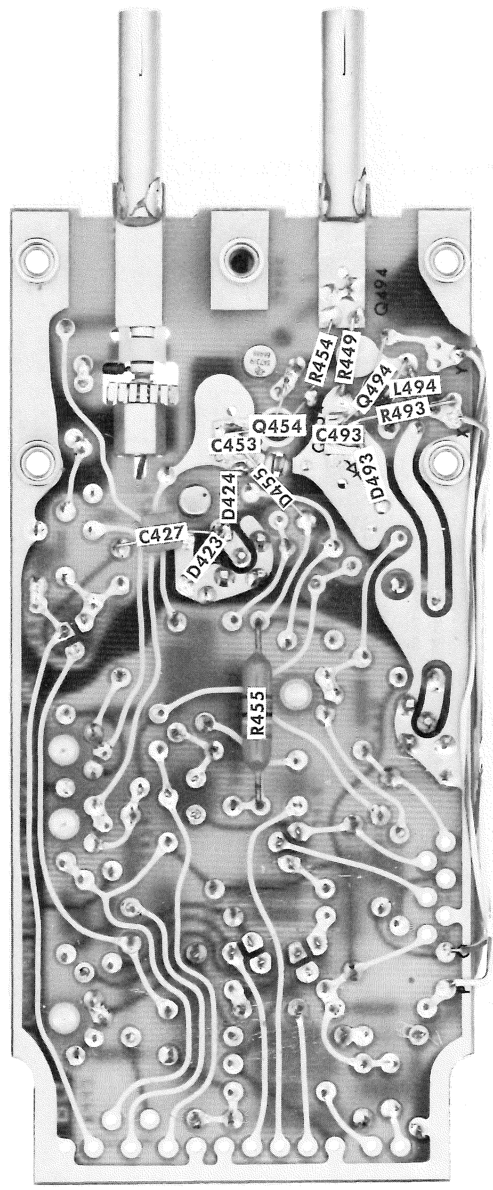


Fig. 5-14B. Pulser circuit board assembly (back).

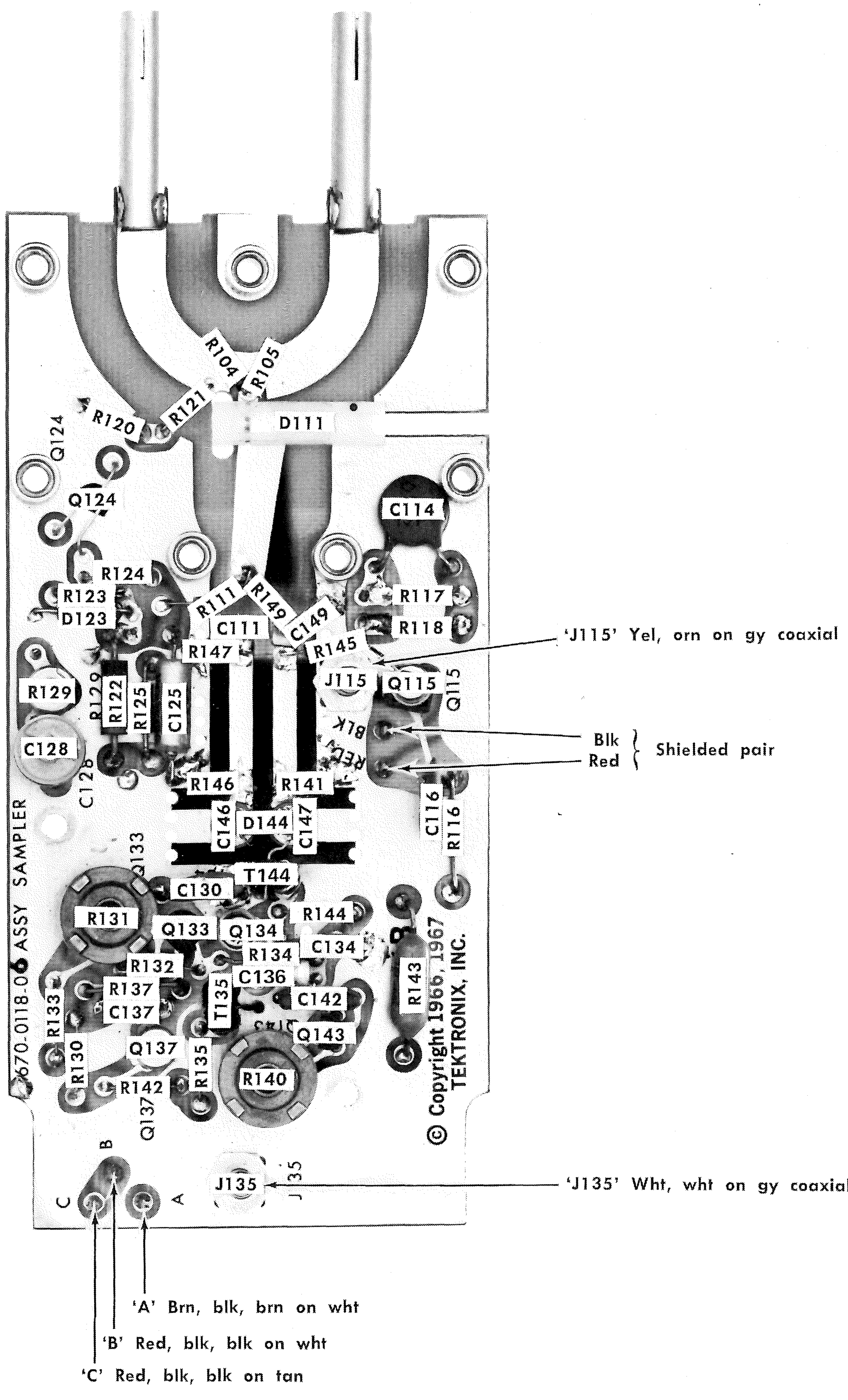


Fig. 5-15A. Sampler circuit board assembly (front) for SN 3000 and up.

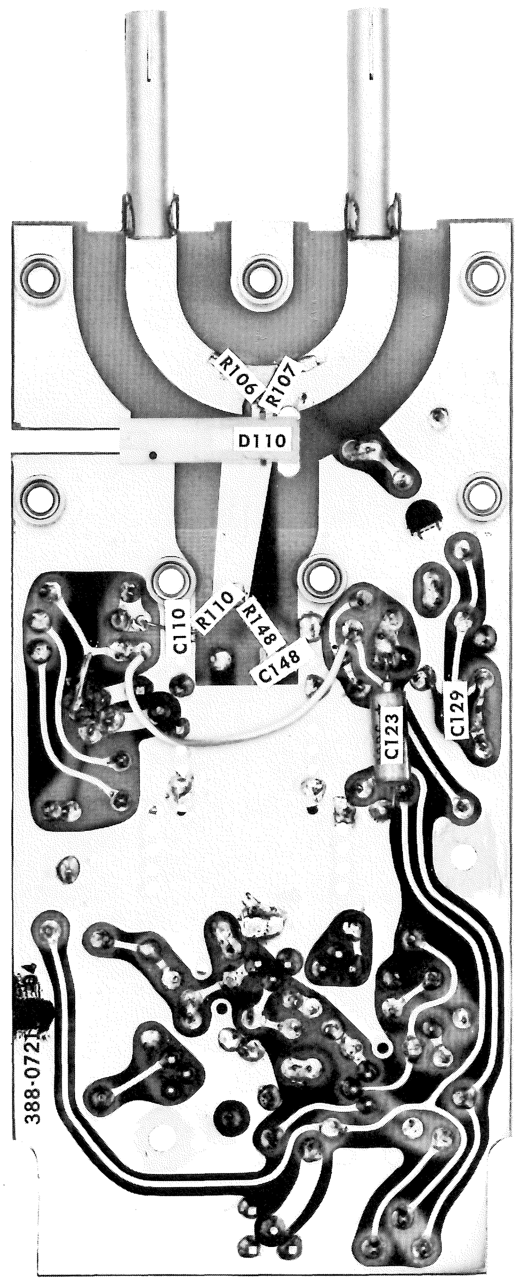


Fig. 5-15B. Sampler circuit board assembly (back) for SN 3000 and up.

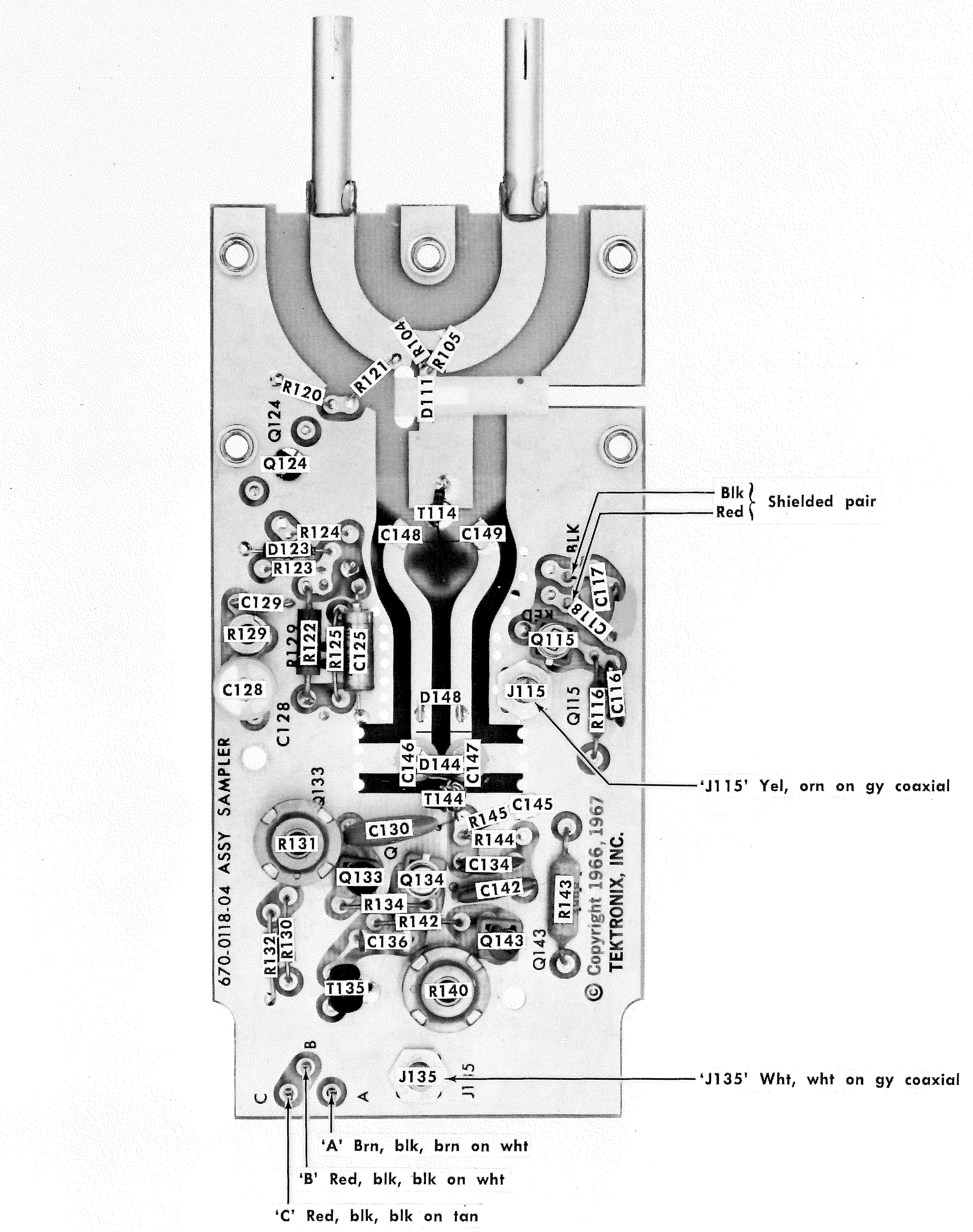


Fig. 5-15C. Sampler circuit board assembly (front) SN 1989-2999.

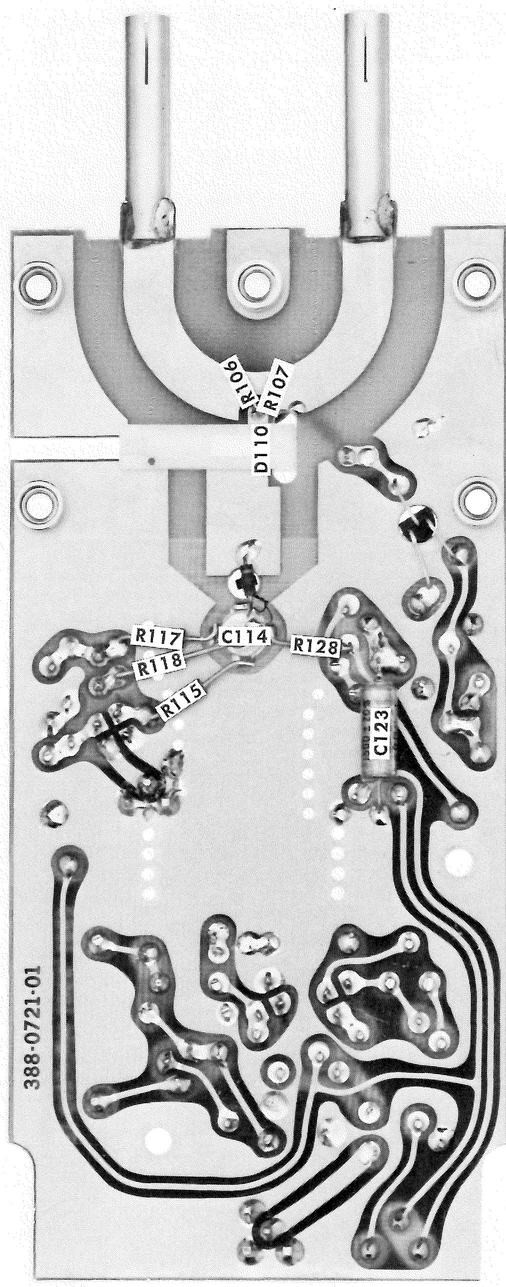


Fig. 5-15D. Sampler circuit board assembly (back) SN 1989-2999.

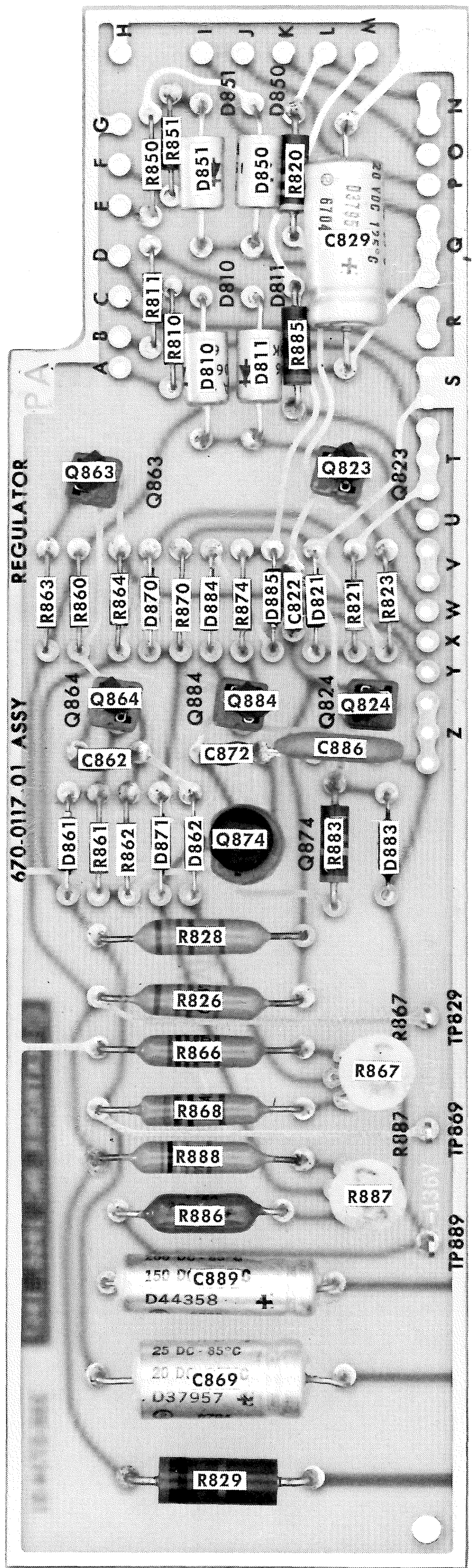


Fig. 5-16A. Regulator circuit board assembly.

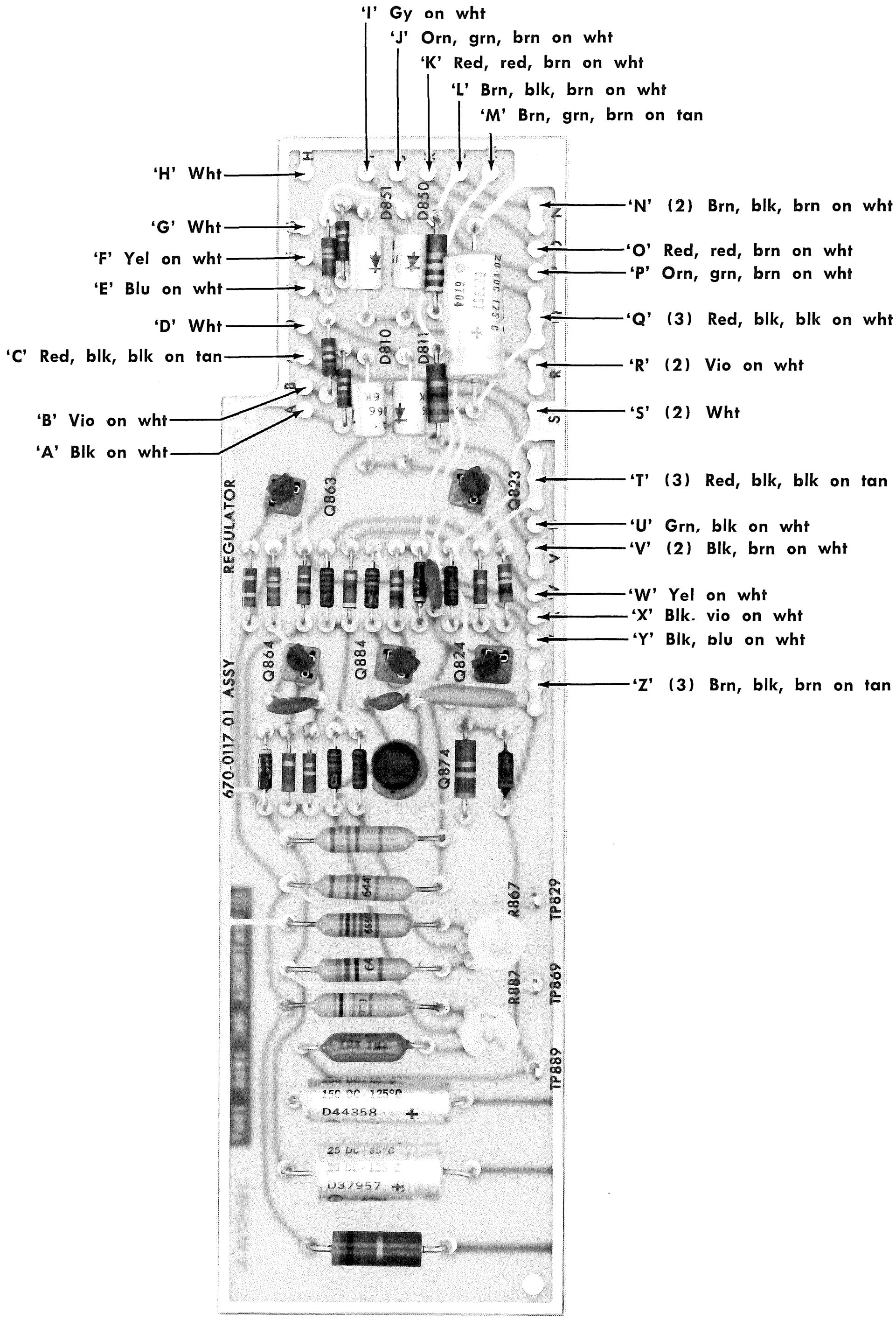


Fig. 5-16B. Regulator circuit board assembly.

NOTES

SECTION 6
PERFORMANCE CHECK

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

This section of the manual provides a means of rapidly checking the performance of the Type 1S2. It is intended to check the calibration of the instrument without the need for performing the complete Calibration Procedure. The Performance Check does not provide for the adjustment of any internal controls. Failure to meet the requirements given in this procedure indicates the need for internal checks or adjustments, and the user should refer to the Calibration Procedure in this manual.

Recommended Equipment

The following equipment is recommended for a complete performance check. Specifications given are the minimum necessary to perform this procedure. All equipment is assumed to be calibrated and operating within the original specifications of the recommended equipment.

For the most accurate and convenient performance check, special calibration fixtures are used in this procedure. These calibration fixtures are available from Tektronix, Inc. Order by part number through your local Tektronix Field Office or representative.

1. Test Oscilloscope. Bandwidth DC to 20 MHz; minimum deflection factor, 1 mV/div; DC comparison voltage for accurate DC voltage measurements; Tektronix Type 545B with a W Plug-In Unit is recommended.

2. Indicator Oscilloscope, Tektronix Type 547, for use with the Type 1S2.

3. 50 Ω Amplitude Calibrator, voltage range, .012 to 2.0 volts square wave; accuracy, ±0.25%, modified as per instruction in Section 7. Tektronix Calibration Fixture 067-0508-00.

4. Time-Mark Generator. Marker outputs, 10 ns to .1 μs. Tektronix Type 184 Time-Mark Generator is recommended.

5. Constant Amplitude Signal Generator. Frequencies, 350 kHz and 100 MHz; amplitude, 500 mV. Tektronix Type 191 Constant Amplitude Signal Generator is recommended.

6. Sine Wave Generator. Frequency range to 5 GHz. Output amplitude, 500 mV. Output impedance, 50 Ω The Polarad Model 1107 is recommended.

7. Amplitude Calibrator. Amplitude accuracy, ±0.25%; amplitude range, 2.0 volts to 100 volts. Repetition range, 1 kHz. Tektronix Calibration Fixture, 067-0502-00 is recommended.

8. Pulse Generator, such as the Tektronix Type 284 Pulse Generator used in this procedure. Pulse risetime ≤70 ps, at approximately 200 mV amplitude into 50 Ω, with a trigger signal available at least 70 ns in advance of the fast pulse. (If your Type 284 Leadtime switch is labeled 5 ns-50 ns, order modification kit, Tektronix Part No. 040-0487-00.)

9. Delay Cable. Impedance, 50 Ω; delay, 60 ns. Tektronix Type 113 Delay Cable is recommended.

10. Tee connector, GR874-T, Tektronix Part No. 017-0069-00.

11. Tee Power Divider. Impedance, 50 Ω; GR874-TPD, Tektronix Part No. 017-0082-00 is recommended.

12. Air Line. Impedance, 50 Ω; length, 20 cm; GR874-L20, Tektronix Part No. 017-0084-00.

13. Variable Attenuator. Tektronix Calibration Fixture 067-0511-00.

14. Termination. Impedance, 50 Ω; GR874-W50B, Tektronix Part No. 017-0081-00.

15. 10 inch GR Connector Cable. Impedance, 50 Ω; Tektronix Part No. 017-0513-00. (1 furnished with instrument.)

16. Probe, 1×, Tektronix P6028 is recommended.

17. Probe, 10× for use with the Type W Plug-In Unit. Tektronix P6023 is recommended.

18. Cable, impedance, 50 Ω; delay 2 ns. Tektronix Part No. 017-0505-00.

19. Cable, impedance, 50 Ω; delay 5 ns. Tektronix Part No. 017-0502-00 (two required).

20. Patch cord. Length, 18 inches; banana terminals on both ends. Tektronix Part No. 012-0054-00.

21. Patch cord. Length, 18 inches; banana terminal at one end, BNC on the other. Tektronix Part No. 012-0091-00.

22. Adapter, BNC female to GR. Tektronix Part No. 017-0063-00, and BNC male to GR, Tektronix Part No. 017-0064-00.

23. Adapter. BNC to Clip-lead. Tektronix Part No. 103-0076-00, and banana tip (probe adapter) for banana jack connection, Tektronix Part No. 134-0013-00.

24. Cable. Impedance, 50 Ω; BNC connectors on both ends. Tektronix Part No. 012-0057-01.

25. Attenuators. Impedance, 50 Ω; attenuation, 5×, Tektronix Part No. 017-0079-00; attenuation, 10×, Tektronix Part No. 017-0078-00; attenuator 2×, Tektronix Part No. 017-0080-00.

26. Short circuit termination, type GR874 WN, Tektronix Part No. 017-0087-00.

PERFORMANCE CHECK PROCEDURE

General

In the following procedure, test equipment connections or control settings should not be changed except as noted. If only a partial check is desired, refer to the preceding step(s) for setup information.

The following procedure uses the equipment listed under Recommended Equipment. If substitute equipment is used, control setting or setup must be altered to meet the requirements of the equipment used.

Preliminary Procedure

a. Plug the Type 1S2 into the plug-in compartment in the Type 547 Oscilloscope. Switch the Type 547 Power switch to ON. Allow a 20 minute warm up.

b. Set the Type 1S2 controls as follows:

OFFSET	Midrange
FINE	Midrange
VERTICAL UNITS/DIV	.5
VARIABLE	CAL
DISPLAY MODE	NORMAL
MANUAL SCAN	Clockwise
MODE	EXT TRIG
MAGNIFIER	×1
VARIABLE	CAL
RANGE	10 μs, 1 km
POSITION	0.00
HORIZONTAL UNITS/DIV	TIME
ρ—VOLTS	VOLTS
RESOLUTION	NORMAL
DIELECTRIC	AIR
UHF SYNC OR TRIGGER SENS	Clockwise

c. Switch the Type 547 Oscilloscope Horizontal Display to Ext, ×10.

d. Connect the Standard Amplitude Calibrator to the Type 547 Oscilloscope as follows:

Connect a 50 Ω cable with BNC connectors to the Standard Amplitude Calibrator Output.

Connect a BNC female to Clip lead Adapter to the end of the 50 Ω cable.

Connect the red clip lead to the Type 547 Horizontal Input and black clip lead to ground.

Switch the Standard Amplitude Calibrator Mode to ⊓⊔ and the Amplitude switch to 5 volts.

Observe a horizontal deflection on the Type 547 CRT.

Position the display to the center of the graticule area.

Adjust the Type 547 Variable 10-1 to place the dots exactly 5 cm apart.

NOTE

Once the Type 547 Variable 10-1 control is set as just mentioned, be careful not to move it again during the balance of this procedure.

e. Disconnect the clip lead adapter.

f. Connect a patch cord from the Type 1S2 HORIZ OUTPUT to the Type 547 Horiz Input.

1. Check Deflection Factor Accuracy

Requirement: Accuracy within ±3% of that indicated on the VERTICAL UNITS/DIV switch.

a. Connect a 50 Ω, 5 ns cable between the Type 1S2 upper THRU SIGNAL CHANNEL 50 Ω and the 50 Ω Amplitude Calibrator.

b. Connect a 50 Termination to the lower THRU SIGNAL CHANNEL 50 Ω connector.

c. Connect a 50 Ω GR to BNC female Adapter to the Type 1S2 EXT TRIG INPUT.

d. Connect a 50 Ω cable with BNC connectors between the GR to BNC Adapter and the 50 Ω Amplitude Calibrator Trigger Output.

e. Set the 50 Ω Amplitude Calibrator Output Amplitude to 2.0 volts.

f. Check for 4 divisions of display, ±3%. (4 divisions, ±0.6 minor divisions.)

g. Check the remaining positions of the VERTICAL UNITS/DIV switch, while switching the 50 Ω Amplitude Calibrator voltages. Table 6-1 shows the equipment settings, desired display and accuracy.

TABLE 6-1

50 Ω Amplitude Calibrator	1S2 VERTICAL UNITS/DIV	Divisions of display	Tolerance %
2.0	.5	4	3
1.2	.2	6	3
.6	.1	6	3
.3	.05	6	3
.12	.02	6	3
.06	.01	6	3
.03	.005	6	3

2. Check Vertical Units/div Variable

Requirement: Counterclockwise rotation decreases sensitivity by at least 0.5:1. Clockwise rotation increases sensitivity by at least 2.5:1.

a. Switch the VERTICAL UNITS/DIV switch to .5.

b. Switch the 50 Ω Amplitude Calibrator Volts to 1.2.

c. Rotate the VERTICAL UNITS/DIV VARIABLE fully counterclockwise.

d. Display amplitude should be less than or equal to 1.2 divisions (ratio, 0.5:1).

e. Rotate the VERTICAL UNITS/DIV VARIABLE fully clockwise.

f. Display amplitude should be at least 6.0 divisions (ratio, 1:2.5).

g. Return the VERTICAL UNITS/DIV VARIABLE to CAL.

3. Check Offset Accuracy

a. Switch the VERTICAL UNITS/DIV to .005.

b. Set the following Type W controls:

Input A selector	DC
Input Atten	R = infinity
Display	A-Vc
mV/CM	50
Vc Range	—11
Comparison Voltage	0.00

c. Set the Test Oscilloscope controls as follows:

Triggering Mode	AC
Stability	Clockwise
Horizontal Display	A
Time/cm	10 μs
Horizontal Position	Midrange

d. Connect a 1× Probe to the Type W Input A.

e. Connect the 1× Probe tip to the Type 1S2 OFFSET connector.

f. Vertically position the top of the display on the Type 547 Oscilloscope to the graticule center horizontal line with the Type 1S2 OFFSET controls.

g. Adjust the Type W Position control to position the Test Oscilloscope trace to the graticule center line.

h. Rotate the Type 1S2 OFFSET and FINE controls to position the bottom of the trace to the Type 547 graticule center line. Some adjustment of the Type 547 Horizontal Position control may be necessary to make the baseline of the Type 1S2 signal appear within the graticule as the display is positioned upward.

i. Rotate the Type W Voltage Comparison outer dial to 1.

j. Rotate the Type W Comparioson Voltage inner knob until the trace is positioned to the Test Oscilloscope center line.

k. Read the voltage directly from the Type W Comparison dials.

l. The voltage should be 1.2 volts, ±1% (1.188 to 1.212 V).

4. Check ×1 Offset Output Range

Requirement: At least + and —2 Volts.

a. Rotate the Type 1S2 OFFSET and FINE controls fully clockwise.

b. Switch the Type W Input A selector switch to Gnd.

c. Rotate the Type W Voltage Comparison dials to 0.00.

d. Vertically position the trace on the Test Oscilloscope to the graticule center horizontal line, using the Type W Position control.

e. Switch the Type W Input A selector to DC.

f. Rotate the Type W Comparison Voltage outer dial to 2.

g. Rotate the inner dial to position the Test Oscilloscope trace to graticule center.

h. The Comparison Voltage dial should indicate at least 2.00 (2 volts).

i. Rotate the Type 1S2 OFFSET and FINE controls fully counterclockwise.

j. Switch the Type W Vc Range to +11.

k. Adjust the Type W Comparison Voltage inner dial to position the Test Oscilloscope trace to the graticule center.

l. The Comparison Voltage dial should indicate at least 2.0 volts.

m. Set the Type W Input Atten switch to 1 before removing the probe tip from the Type 1S2.

5. Check Vertical Output Accuracy

Requirement:

$$\frac{\text{Signal Input}}{\text{VERT UNITS/DIV}} = \text{Vertical Output (volts)} \pm 1\%.$$

a. Set the Type 1S2 VERTICAL UNITS/DIV to .5.

b. Set the 50 Ω Amplitude Calibrator Volts to 2.0.

c. Reset the Type W controls as follows:

Comparison Voltage	0.00
Vc Range	—1.1
Input Atten	1
mV/cm	50
Input A selector	DC

d. Connect the 10× Probe tip to the Type 1S2 VERT OUTPUT connector.

e. Set the Test Oscilloscope controls as follows:

Time/cm	10 ms
Trigger Slope	+ Int
Stability	Stable Display
Triggering Level	Stable Display

f. Vertically position the top of the Test Oscilloscope display to the graticule center horizontal line, using the Type W Position control and 1S2 OFFSET control.

g. Rotate the Type W Comparison Voltage outer dial to 4 and the inner dial to vertically position the bottom of the Test Oscilloscope display to the graticule center line.

h. Read the voltage from the Comparison Voltage dials. The Comparison Voltage dials should indicate.

$$\frac{\text{Signal in}}{\text{Vert Units/div}} = \frac{2.0 \text{ Volts}}{.5} = 4.0 \text{ volts out}$$

6. Check Vertical Output Deflection Factor

Requirement: 1 Volt per displayed division, referred to Type 547 CRT.

a. Check the display on the Type 547 Oscilloscope for 4 divisons of vertical amplitude.

b. Observe 1 volt of display vertically on the Test Oscilloscope for each division of display on the Type 547 CRT. (4 volts indicated on the Type W Comparison Voltage scale for 4 divisions of display on the Type 547.)

7. Check Horizontal Position Range Accuracy

Requirement: Accuracy within ±1% of reading for full POSITION dial rotation.

a. Set the Type 1S2 controls as follows:

POSITION	0.00
MAGNIFIER	×10

b. Connect the Type 1S2 lower THRU SIGNAL CHANNEL 50 Ω to a 5 ns, 50 Ω cable.

c. Connect the 50 Ω, 5 ns cable to the Type 184 Time-Mark Generator Marker Output using a GR to BNC male adapter.

d. Connect the 10 inch GR Connector Cable between the Type 1S2 upper THRU SIGNAL CHANNEL 50 Ω and EXT TRIG INPUT connectors.

e. Set the Time-Mark Generator Marker Output to 1 μs.

f. Rotate the Type 1S2 POSITION control to bring a time mark horizontally to the 1 cm vertical graticule line.

g. Note the reading on the POSITION control.

h. Rotate the POSITION control to place the next time mark to the 1 cm graticule line.

i. Again note the POSITION control reading.

j. The difference in the two readings should be 100 minor divisions, ±10 minor divisions of the POSITION control. (10 minor divisions equals 1% of full 1000 minor divisions of POSITION control.)

k. Check for accuracy of the remainder of the POSITION control as outlined in the above steps. (Position each mark in turn to the 1 cm graticule line and check the POSITION control for accuracy.)

8. Check Magnifier Variable Range

Requirement: Not less than a 2.5:1 increase in sweep rate from CAL position.

a. Switch the Type 1S2 MAGNIFIER to ×20.

b. Switch the Time-Mark Generator Marker Selector to .1 μs.

c. Position a marker to the Type 547 1 cm vertical graticule line. This places the second displayed marker at the 3 cm graticule line.

d. Rotate the Type 1S2 MAGNIFIER VARIABLE fully clockwise.

e. Check for not less than 5 divisions between markers. Reposition the display as necessary.

f. Return the MAGNIFIER VARIABLE to CAL.

9. Check Horizontal Output Accuracy

Requirement: 1 Volt/division

a. Set the Type 1S2 MAGNIFIER to ×1.

b. Set the Time-Mark Generator Marker Selector to 1 μs.

c. Connect a 10× Probe to the Type W Input A.

d. Connect a 10× Probe tip to one terminal of the patch cord which connects the Type 1S2 HORIZ OUTPUT to the Type 547 Ext Horiz Input.

e. Set the Type W controls as follows:

Input Atten	1
Vc Range	+11
mV/cm	50
Comparison Voltage	0.00

f. Set the Test Oscilloscope controls as follows:

Time/cm	.1 s
Trigger Slope	+ Int

g. Position the bottom of the Test Oscilloscope display to the graticule center line.

h. Rotate the Comparison Voltage outer dial to 1.

i. Rotate the Comparison Voltage inner dial to position the top of the display to the Test Oscilloscope graticule center horizontal line.

j. The Comparison Voltage dials should indicate 10.4, ±2%.

k. Remove the 10× Probe from the Type 1S2 HORIZ OUTPUT connector.

10. Check Horizontal Timing Accuracy

Requirement: Within ±3% over total length of sweep.

a. Position a marker to the Type 547 Oscilloscope graticule 1 cm vertical line, using the Type 1S2 POSITION control.

b. Measure the displacement of each of the markers from its respective graticule line. Each marker must coincide, within 3%, with a graticule line from the 1 cm to the 9 cm graticule lines. See Fig. 6-1.

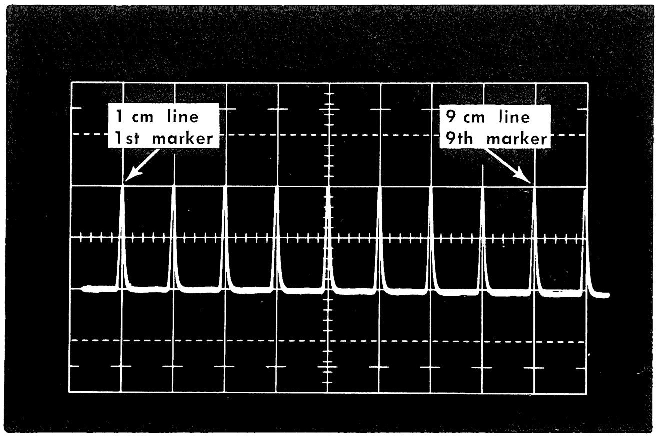


Fig. 6-1. Typical CRT display of time marks.

11. Check Dielectric Accuracy

Requirement: AIR, 1, ±3%

POLYETHYLENE, 0.659, ±3%

TFE, 0.695, ±3%

PRESET Range, 0.6-0.65 to 1

a. Switch the Type 1S2 RANGE switch to 1 μs—100 m.

b. Set the Time-Mark Generator Marker Selector to .1 μs.

c. Observe 1 marker per horizontal division.

d. Switch the Type 1S2 HORIZONTAL UNITS/DIV to DISTANCE.

e. Check for 8.73 to 9.27 divisions between the marker at the 1 cm graticule line and the sixth marker from the 1 cm graticule line.

f. Set the Time-Mark Generator Selector to 50 ns.

g. Adjust the Type 1S2 UHF SYNC OR TRIGGER SENS control for a stable display on the Type 547 Oscilloscope CRT.

h. Adjust the Type 1S2 MAGNIFIER VARIABLE for exactly 1 cycle per graticule division.

i. Switch the Type 1S2 DIELECTRIC switch to TFE.

j. Position a sine wave crest to the 1 cm graticule line with the Type 1S2 POSITION control.

k. Measure the distance between the crest at the 1 cm graticule line and the twelfth crest from the 1 cm graticule line. The distance should lie between 8.1 and 8.6 divisions.

l. Switch the Type 1S2 DIELECTRIC switch to POLYETHYLENE.

m. Position a sine wave crest to the 1 cm graticule line, using the Type 1S2 POSITION control.

n. Measure the distance between the crest at the 1 cm graticule line and the twelfth crest from the 1 cm graticule line. The distance measured should lie between 7.7 and 8.15 divisions.

o. Switch the Type 1S2 DIELECTRIC switch to PRESET.

p. Rotate the Type 1S2 PRESET control fully counterclockwise.

q. Check the display for 1 cycle of sine wave per graticule line.

r. Rotate the Type 1S2 DIELECTRIC PRESET control fully clockwise.

s. Measure the distance between the crest at the 1 cm graticule line and the twelfth crest from the 1 cm graticule line. The distance measured should lie between 7.2 and 7.8 divisions.

t. Remove the 50 Ω, 5 ns cable from the Type 184 Time-Mark Generator Output.

u. Reset HORIZONTAL UNITS/DIV to TIME.

v. Reset MAGNIFIER VARIABLE to CAL.

12. Check External Horizontal Deflection Factor

Requirement: Less than 2 Volts/div to greater than 15 Volts/div.

a. Set the Type 1S2 controls as follows:

DISPLAY MODE	EXT HORIZ
EXT HORIZ ATTEN	Clockwise

b. Connect a 50 Ω cable with BNC connectors to the Standard Amplitude Calibrator output.

c. Connect a Clip-lead to BNC adapter to the 50 Ω cable.

d. Connect the red clip lead to a banana tip and the banana tip to the Type 1S2 EXT HORIZ INPUT.

e. Connect the black clip-lead to the Type 1S2 Ground terminal.

f. Set the Standard Amplitude Calibrator Amplitude to 2 Volts.

g. Check for a horizontal deflection of more than 1 division.

h. Rotate the EXT HORIZ ATTEN counterclockwise.

i. Switch the Standard Amplitude Calibrator to 100 V.

j. Check for a horizontal deflection or less than 1.5 division.

13. Check Trigger Jitter (External)

Requirement: Less than 100 ns (350 kHz at 500 mV), less than 100 ps (100 MHz at 500 mV).

a. Connect a 50 Ω, 5× Attenuator to the Type 1S2 lower THRU SIGNAL CHANNEL 50 Ω connector.

b. Connect a 50 Ω, 5 ns cable between the 50 Ω, 5× attenuator and the Type 191 Constant Amplitude Signal Generator Output.

c. Connect a 50 Ω, 2 ns cable between the Type 1S2 upper THRU SIGNAL CHANNEL 50 Ω and the EXT TRIG INPUT.

d. Set the Constant Amplitude Signal Generator controls as follows:

Frequency Range	.35-.75 MHz
Variable	.35
Amplitude Range	.5-5 V
Amplitude	25

e. Set the Type 1S2 controls as follows:

VERTICAL UNITS/DIV	.1
MAGNIFIER	×1
DISPLAY MODE	NORMAL
HORIZONTAL UNITS/DIV	TIME
RANGE	10 μs

f. Adjust the Type 1S2 UHF SYNC OR TRIGGER SENS control for a stable display.

g. Adjust the Constant Amplitude Signal Generator for a 5 division display on the Type 547 Oscilloscope CRT.

h. Switch the Type 1S2 VERTICAL UNITS/DIV to .005.

i. Switch the Type 1S2 MAGNIFIER to ×50.

j. Locate the display on the Type 547 CRT using the Type 1S2 POSITION control.

k. Check for not more than 100 ns (5 divisions) of horizontal jitter.

l. Reset the Type 1S2 controls as follows:

VERTICAL UNITS/DIV	.1
MAGNIFIER	×1
RANGE	.1 μs

m. Reset the Type 191 Constant Amplitude Signal Generator controls as follows:

Frequency Range	42-100
Variable	100

n. Position the trace as necessary, using the Type 1S2 OFFSET and POSITION controls.

o. Adjust the Type 1S2 UHF SYNC OR TRIGGER SENS control for a stable display.

p. Observe 5 divisions of display (vertically).

q. Switch the Type 1S2 VERTICAL UNITS/DIV to .005.

r. Switch the Type 1S2 MAGNIFIER to ×100, locating the trace if necessary with the Type 1S2 POSITION control.

s. Check for not more than 100 p (1 division) of horizontal jitter.

14. Check Trigger Jitter (80 mV pulse input)

Requirement: Less than 100 ps.

a. Connect a Variable Attenuator to the Pulse Output connector of the Type 284 Pulse Generator.

b. Connect a GR Tee connector to the Variable Attenuator.

c. Connect a GR Tee Power Divider to the GR Tee connector.

d. Connect a 5 ns cable from the Tee Power Divider to the Delay Cable and a 5 ns cable from the Delay Cable to the lower THRU SIGNAL CHANNEL 50 Ω connector.

e. Connect a 20 cm Air Line with a GR Short Circuit to the GR Tee connector.

f. Connect a 5 ns cable from the GR Tee Power Divider to the Type 1S2 EXT TRIG INPUT connector.

g. Connect a 50 Ω Termination to the Type 1S2 upper THRU SIGNAL CHANNEL 50 Ω connector.

h. Set the Type 1S2 controls as follows:

VERTICAL UNITS/DIV	.2
RANGE	.1 μs
MODE	EXT TRIG
POSITION	0.00
OFFSET	Midrange
MAGNIFIER	×1

i. Adjust the UHF SYNC OR TRIGGER SENS for a stable display.

j. Adjust the Variable Attenuator to produce 4 divisions of display.

k. Switch the VERTICAL UNITS/DIV to .005.

l. Switch the MAGNIFIER to ×100.

m. Position the leading edge of the display to the graticule area, using the Type 1S2 POSITION control.

n. Check for not more than 100 ps (1 division) of horizontal jitter.

15. Check Trigger Jitter (5 GHz Sine Wave)

Requirement: Less than 30 ps.

a. Install the GR 50 Ω Termination in the upper THRU SIGNAL CHANNEL 50 Ω connector.

b. Connect a 50 Ω 5 ns cable from the Sine-Wave Generator Output connector to the GR Tee Power Divider.

c. Connect the GR Tee Power Divider to the Type 1S2 lower THRU SIGNAL CHANNEL 50 Ω connector and a 50 Ω 2 ns cable from the GR Tee Power Divider to the EXT TRIG INPUT connector.

d. Adjust the Sine Wave Generator Frequency to 5 GHz.

e. Set the Type 1S2 VERTICAL UNITS/DIV to .1.

f. Set the Type 1S2 MAGNIFIER to ×1.

g. Adjust the Sine Wave Generator Output Amplitude for 3 divisions of display on the Type 547 CRT.

h. Adjust the Type 1S2 UHF SYNC OR TRIGGER SENS control for a stable display.

i. Switch the Type 1S2 VERTICAL UNITS/DIV to .005.

j. Switch the Type 1S2 MAGNIFIER to ×100.

k. Reposition the display as necessary, using the Type 1S2 POSITION control, to display the leading edge of the waveform.

l. Check the display for not more than 30 ps (about 1/3 division) of horizontal jitter.

16. Check 1.0 Volt Pulser Risetime

Requirement: Not more than 1.1 ns.

a. Set the Type 1S2 controls as follows:

VERTICAL UNITS/DIV	.2
MAGNIFIER	×10
MODE	INT PULSE, 1.0 V
POSITION	0.00

b. Connect the 10 inch GR Connector Cable between the Type 1S2 upper THRU SIGNAL CHANNEL 50 Ω and the PULSE SOURCE 1.0 V connectors.

c. Connect a 50 Ω Termination to the lower THRU SIGNAL CHANNEL 50 Ω connector.

d. Switch the Type 1S2 ρ—VOLTS selector to ρ.

e. Measure the risetime from 10% to 90% amplitude points.

NOTE

Align the trace to the horizontally scribed graticule line on the oscilloscope being used as an indicating instrument. Adjust the Trace Rotation control (mechanical CRT rotation on instruments that do not have internal graticule) for correct trace alignment.

f. Measured risetime should be equal to or less than 1.1 ns. See Fig. 6-2.

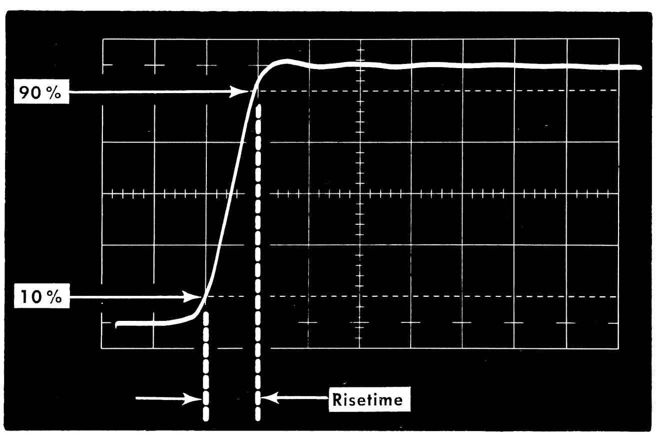


Fig. 6-2. Typical CRT display of 1.0 V Pulser risetime.

17. Check 1.0 Volt Pulse Flatness Deviation

Requirement: Less than + and —2.5% (1 1/4 cm) within the first 10 ns following the leading edge. + and —1% (0.5 cm) after the first 10 ns following the leading edge.

a. Set the Type 1S2 VERTICAL UNITS/DIV to .02.

b. Position the top of the display to the Type 547 graticule area.

c. Position the trace horizontally, using the Type 1S2 POSITION control, to place the top of the display (the final steady state value following the flatness deviations) to the graticule center line.

d. Set the Type 1S2 MAGNIFIER switch to ×5 and reposition the trace horizontally to observe the aberrations.

e. Check the display for aberrations not more than 2.5% (1 1/4 division) above or below the graticule center line during the first 10 ns, 5 divisions, of display.

f. Check for not more than 1% flatness deviations (1/2 division) above or below the graticule center line after the first 10 ns, 5 division.

18. Check 1.0 Volt Pulser Amplitude

Requirement: 0.9 to 1.0 volt.

a. Set the Type 1S2 controls as follows:

VERTICAL UNITS/DIV	.2
VARIABLE	CAL
RANGE	10 μs, 1 km
ρ—VOLTS	VOLTS

b. Switch the Test Oscilloscope Time/cm to 5 ms.

c. Connect the 10× Probe tip to the Type 1S2 VERT OUTPUT jack.

d. Vertically position the bottom of the display on the Test Oscilloscope to the graticule center line, using the Type W Position control.

e. Switch the Type W Range to +1.1.

f. Switch the Type W outer Comparison Voltage dial to 4.

g. Rotate the inner Comparison Voltage dial to position the top of the display to the Test Oscilloscope center graticule line.

h. Read the voltage from the Comparison Voltage dials. Comparison Voltage dial reading, times the probe attenuation factor of 10, times the VERTICAL UNITS/DIV setting equals Pulser amplitude. For example, Comparison Voltage reading of .48 volts times probe attenuation of 10, times VERTICAL UNITS/DIV of .2 equals .96 volts.

i. Switch the Type 1S2 ρ—VOLTS switch to ρ.

j. Check for 5 divisions of display on the Type 547 CRT.

19. Check 1.0 Volt Pulser Jitter

Requirement: Less than 20 ps.

a. Reset the Type 1S2 controls as follows:

VERTICAL UNITS/DIV	.005
MAGNIFIER	×100
RANGE	.1 μs

b. Adjust the Type 1S2 OFFSET and POSITION controls as necessary to display the rising portion of the display.

c. Check for not more than 20 ps for horizontal jitter (1 minor division).

20. Check .25 Volt Pulser Flatness Deviation

Requirement: Less than + and —7% flatness deviation following the leading edge. Less than + and —3% flatness deviation after the first 500 ps following the leading edge.

a. Set the Type 1S2 ρ—VOLTS switch to ρ and MODE switch to INT PULSE, .25 V.

b. Move the end of the 10 inch GR Connector Cable from the PULSE SOURCE 1.0 V connector to the .25 V connector.

c. Switch the Type 1S2 VERTICAL UNITS/DIV to .02.

d. Position the top of the display to the Type 547 graticule area, using the Type 1S2 OFFSET and POSITION controls.

e. Position the trace horizontally, using the Type 1S2 POSITION control, to place the top of the display (the final steady state value following the flatness deviations) to the graticule center line.

f. Reposition the trace horizontally to observe the flatness deviations.

g. Check the display for flatness deviation not more than 7% (3.5 divisions) above or below the graticule center line during the first 500 ps (5 divisions) of display.

h. Check for not more than 3% flatness deviation above or below the graticule center line after the first 500 ps (5 divisions).

21. Check .25 Volt Pulser Amplitude

Requirement: 230 mV to 260 mV.

a. Reset the Type 1S2 controls as follows:

VERTICAL UNITS/DIV	.05
ρ—VOLTS	VOLTS

b. Set the Type W Comparison Voltage to 0.00.

c. Position the bottom of the Test Oscilloscope display to the graticule center line, using the Type W Position control.

d. Rotate the Comparison Voltage dials to position the top of the display to the Test Oscilloscope graticule center line.

e. Read the Comparison Voltage dials.

f. Comparison Voltage dial reading times VERTICAL UNITS/DIV setting equals Pulse amplitude. For example: Comparison voltage reading, 4.93 × VERTICAL UNITS/DIV, setting, .05 equals .246 V pulse amplitude.

g. Switch the Type 1S2 ρ—VOLTS switch to ρ.

h. Check for 5 divisions of display on the Type 547 graticule.

22. Check .25 Volt Pulser Jitter

Requirement: Less than 20 ps.

a. Reset the Type 1S2 controls as follows:

VERTICAL UNITS/DIV	.005
MAGNIFIER	×100

b. Display the rising edge of the display and check for not more than 20 ps of horizontal jitter (1 minor division).

23. Check Risetime (Sampling Configuration)

Requirement: Risetime must be less than 90 ps from the 10% to 90% amplitude points. Risetime will appear on the CRT in relation to the pulse risetime. The risetime of the Type 284 is less than 70 ps so the displayed risetime, computed by formula $TR = (TRO^2 + TRE^2)^{1/2}$, will appear as less than 114 ps.

a. Set the Type 1S2 controls as follows:

MODE	EXT TRIG
MAGNIFIER	×1
VERTICAL UNITS/DIV	.05

b. Connect the Type 284 Pulse Generator Pulse Output to a 20 cm Air Line.

c. Connect the 20 cm Air Line to the lower THRU SIGNAL CHANNEL 50 Ω connector.

d. Connect a 50 Ω Termination to the upper THRU SIGNAL CHANNEL 50 Ω connector.

e. Connect a 50 Ω, 5 ns cable from the Pulse Generator Trigger output to the 1S2 EXT TRIG INPUT with a GR to BNC male adapter.

f. Adjust the Pulse Generator TD Bias and the Type 1S2 UHF SYNC OR TRIGGER SENS for a stable display. (UHF SYNC OR TRIGGER SENS toward counterclockwise end of rotation, positive slope).

g. Adjust the Type 1S2 VERTICAL UNITS/DIV VARIABLE for 5 cm of display amplitude.

h. Position the display as necessary on the Type 547 CRT, using the Type 1S2 POSITION and OFFSET controls. See NOTE in step 16e.

i. Measure the time between the 10% and 90% amplitude points. Measured time should be less than 114 ps.

24. Check Risetime (TDR Configuration)

Requirement: Risetime must be 140 ps from the 10% to 90% amplitude points on the falling portion of the pulse.

a. Connect a 20 cm Air Line to the upper THRU SIGNAL CHANNEL 50 Ω connector.

b. Connect a Short Circuit Termination to the open end of the 20 cm Air Line.

c. Connect the 10 inch GR Connector Cable between the lower THRU SIGNAL 50 Ω connector and the PULSE SOURCE .25 V connector.

d. Set the Type 1S2 MODE switch to .25 V INT PULSE.

e. Switch the Type 1S2 VERTICAL UNITS/DIV to .2.

f. Position the display to show the reflected portion of the display.

g. Switch the Type 1S2 MAGNIFIER to ×100.

h. Adjust the Type 1S2 OFFSET and POSITION controls as necessary to center the display in the graticule area. See NOTE in Step 16e.

i. Measure the risetime between the 10% and 90% amplitude points on the reflected portion of the pulse. Measured risetime should be 140 ps. See Fig. 6-3.

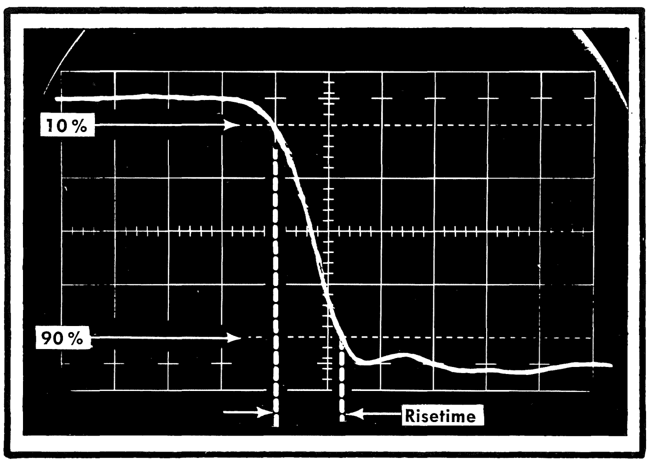


Fig. 6-3. Typical CRT display of risetime (TDR configuration).

25. Check Internal Reflections

Requirement: Less than 10% of the relected pulse amplitude.

a. Switch the Type 1S2 MAGNIFIER to ×10.

b. Switch the Type 1S2 VERTICAL UNITS/DIV to .1.

c. Position the top of the reflected pulse to the graticule center line using the Type 1S2 OFFSET control.

d. Position the start of the reflected pulse to approximately the 1 cm graticule line.

e. Check the flatness deviation after approximately 4 ns following the leading edge.

f. Flatness deviation should be less than 10% of the reflected pulse amplitude.

26. Check Tangential Noise

Requirement: Less than 2 mV, measured tangentially.

NOTE

When making a visual noise reading from a sampling display, the eye interprets a noise value which is neither the RMS nor the peak to peak value. Since most observers agree that the displayed noise value is approximately 3 times the RMS value, the Tangential Noise here defined is 3 times the RMS value. (The measurement technique given produces acceptable agreement between various operators as to the instruments noise value.)

a. Using the indicator oscilloscope Amplitude Calibrator as a signal source, connect its output to the Type 1S2 Thru Signal Channel using the following items. At the Calibrator output, a BNC 50 Ω coaxial cable, then a BNC to GR coaxial adapter, a 5× GR attenuator, a 10× GR attenuator and the special variable attenuator feeding the Type 1S2 input. Place the 50 Ω termination onto the other Thru Signal Channel connector.

b. Set the Type 1S2 controls:

EXT HORIZ ATTEN	about 9 o'clock
DISPLAY MODE	EXT HORIZ
(Turn down the oscilloscope intensity)	
RESOLUTION	NORMAL
RANGE	Either 1 μs or .1 μs
Trigger MODE	UHF SYNC
ρ - VOLTS	VOLTS
VERTICAL UNITS/DIV	.005
VARIABLE	CAL
OFFSET	For centered trace

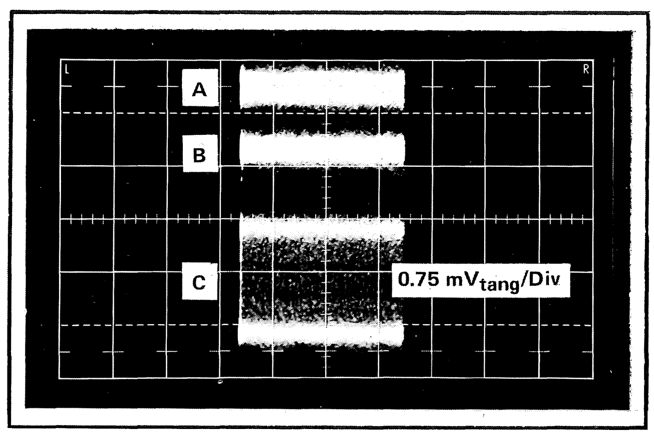


Fig. 6-4. Noise check waveforms, Step 26.

c. Connect a double banana plug 18' patch cord from the oscilloscope Sawtooth A connector to the Type 1S2 Ext Horiz INPUT.

d. Set the indicator oscilloscope controls:

Horizontal Display	×1 (no change)
Time Base A Stability	Fully Clockwise
Time Base A Time/CM	.2 mS
Amplitude Calibrator	.1 V Into 50 Ω
Position	Centered display

The instrument should now have a shortened trace clearly displaying any sampling circuit noise. If not, adjust the OFFSET and Intensity and Horizontal Position controls for a display similar to Part A or Part B or Fig. 6-4.

e. Adjust the Variable Attenuator control for maximum signal amplitude. The display will now be two traces spaced slightly, similar to Fig. 6-4A.

Adjust the Variable Attenuator control to reduce the signal amplitude until the two traces just appear to be one trace, as shown in Fig. 6-4B.

Remove the 10× attenuator from the signal path (be careful not to change the Variable Attenuator control setting) and reconnect the 5× attenuator to the Variable Attenuator. The display will now be similar to Fig. 6-4C, from which the tangential noise can be read.

The display has a tangential noise deflection of 0.75 mV/Div. Maximum trace separation can be 2.66 major divisions. The example shown in Fig. 6-4C is just 2 major divisions, or a tangential noise of 1.5 mV.

Determining Tangential Noise Deflection Factor

The noise display of Fig. 6-4 has a noise deflection factor based upon the signal amplitude, the Type 1S2 vertical deflection factor in mV, the fact that the final trace separation is twice the RMS noise, and that the tangential noise is then 3 times the RMS noise. The square wave signal amplitude that makes two traces appear as one sets the trace separation at twice the RMS noise. The procedure used here then permits a noise deflection factor to be determined by dividing the input mV/div deflection factor by 2 (trace separation is 2X the RMS noise) and then dividing by 10 (the signal amplitude change complement).

f. If the tangential noise is outside the required limits, the Type 1S2 requires adjustment of either or both the Avalanche Volts control (R131) or the Dot Response control (R168). See Step 34 of the Calibration Procedure.

g. Return the DISPLAY MODE switch to NORMAL.

27. Check Horizontal Units/Div Readout Lamp Operation

Requirement: Proper lamp operation of each combination of DISTANCE-TIME, RANGE and MAGNIFIER positions.

RANGE	10 μs-1 km		1 μs-100 m		.1 μs-10 m	
MAGNIFIER	DISTANCE	TIME	DISTANCE	TIME	DISTANCE	TIME
×1	100 m	1000 ns	10 m	100 ns	100 cm	10 ns
×2	50 m	500 ns	5 m	50 ns	50 cm	5 ns
×5	20 m	200 ns	2 m	20 ns	20 cm	2 ns
×10	10 m	100 ns	1 m	10 ns	10 cm	1 ns
×20	5 m	50 ns	50 cm	5 ns	5 cm	500 ps
×50	2 m	20 ns	20 cm	2 ns	2 cm	200 ps
×100	1 m	10 ns	10 cm	1 ns	1 cm	100 ps

TIME and DISTANCE units will be extinguished when MAGNIFIER VARIABLE is out of the CAL position.

SECTION 7
CALIBRATION

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

This calibration procedure can be used either for complete calibration of the Type 1S2 to return it to original performance, or as an operational check of instrument performance. Completion of every step in this procedure returns the Type 1S2 to original factory performance standards. If it is desired to merely touch up the calibration, perform only those steps entitled Adjust . . .

NOTE

The Adjust . . . steps provide a check of instrument performance before the adjustment is made. To prevent recalibration of other circuits when performing a partial calibration, readjust only if the listed tolerance is not met.

General Information

Any needed maintenance should be performed before preceeding with calibration. Troubles which become apparent during calibration should be corrected using the techniques given in the Maintenance section of the Instruction Manual.

This procedure is arranged in a sequence which allows this instrument to be calibrated with the least interaction of adjustments and reconnection of equipment. If desired, the steps may be performed out of sequence or a step may be done individually. However, some adjustments affect the calibration of other circuits within the instrument. In this case, it will be necessary to check the operation of other parts of the instrument. When a step interacts with others, the steps which need to be checked will be noted.

The location of test points and adjustments is shown in each step. Waveforms which are helpful in determining the correct adjustment or operation are also shown.

Where references are made to divisions of deflection, the indication will be major divisions.

The oscilloscope used with the Type 1S2 is referred to as the Indicator Oscilloscope and the oscilloscope used to observe waveforms and voltages is referred to as the Test Oscilloscope.

All Type 1S2 controls are written in all capitals. Other controls have the first letter capitalized only.

RECOMMENDED EQUIPMENT

(see Fig. 7-1 and Fig. 7-2)

General

The following equipment, or its equivalent, is required for complete calibration of the Type 1S2. Specifications given are the minimum necessary for accurate calibration of this instrument. All test equipment is assumed to be correctly calibrated and operating within the original specifications. If equipment is substituted, it must meet or exceed the specifications of the recommended equipment.

Special Test Equipment

For the quickest and most accurate calibration, special calibration fixtures are used where necessary. All calibration fixtures listed under Equipment Required can be obtained from Tektronix, Inc. Order by part number through your local Tektronix Field Office or representative.

1. Indicator Oscilloscope for use with the Type 1S2, Tektronix Type 547.

2. If a Type W is not used with the Test Oscilloscope, a precision voltmeter is required that will measure +19 V, —19 V, and —136 V within ±0.25%, such as a John Fluke Model 825B.

3. Test Oscilloscope. Bandwidth, DC to 20 MHz; minimum deflection factor, .001 volts/div; high gain differential comparator with + and — comparison voltages to 11 V; accuracy within 0.3%. Tektronix Type 545B with Type W Plug-In Unit.

4. Sine-Wave Generator. Frequency range to ;5 GHz output impedance, 50 Ω, output amplitude, at least 500 mV; The Polarad Type 1107 is recommended.

5. 50 Ω Amplitude Calibrator, voltage range .012 V to 2.0 V square wave, modified as per instructions later in this section; Tektronix Calibration Fixture 067-0508-00.

6. Time-Mark Generator. Marker outputs, 10 ns to 1 μs. Trigger outputs provided. The Tektronix Type 184 Time-Mark Generator is recommended.

7. Sine-Wave Generator. Frequencies, 350 kHz to 100 MHz; output amplitude 2.5 volts. Tektronix Type 191 Constant Amplitude Signal Generator is recommended.

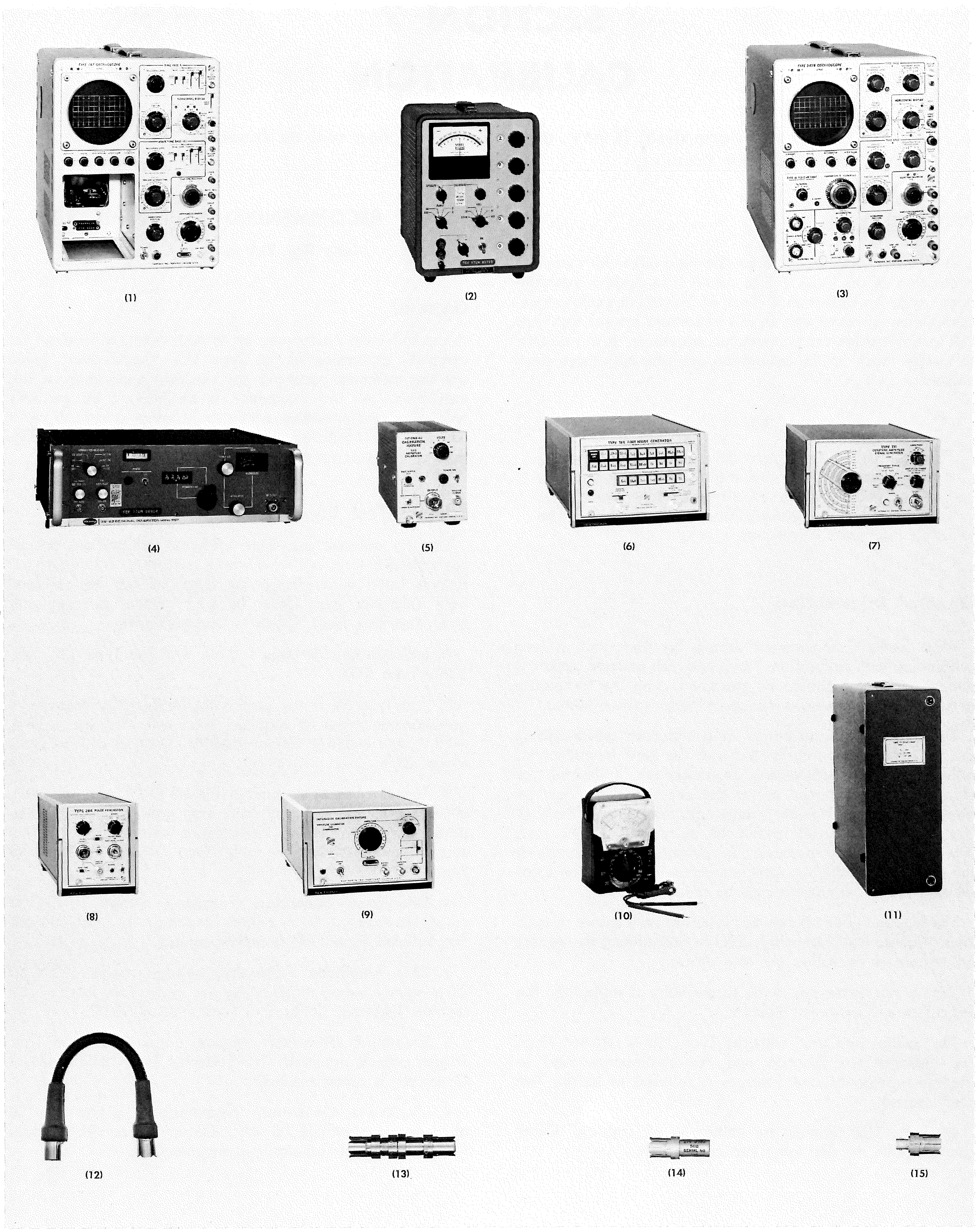


Fig. 7-1. Recommended calibration equipment, items 1 through 15.

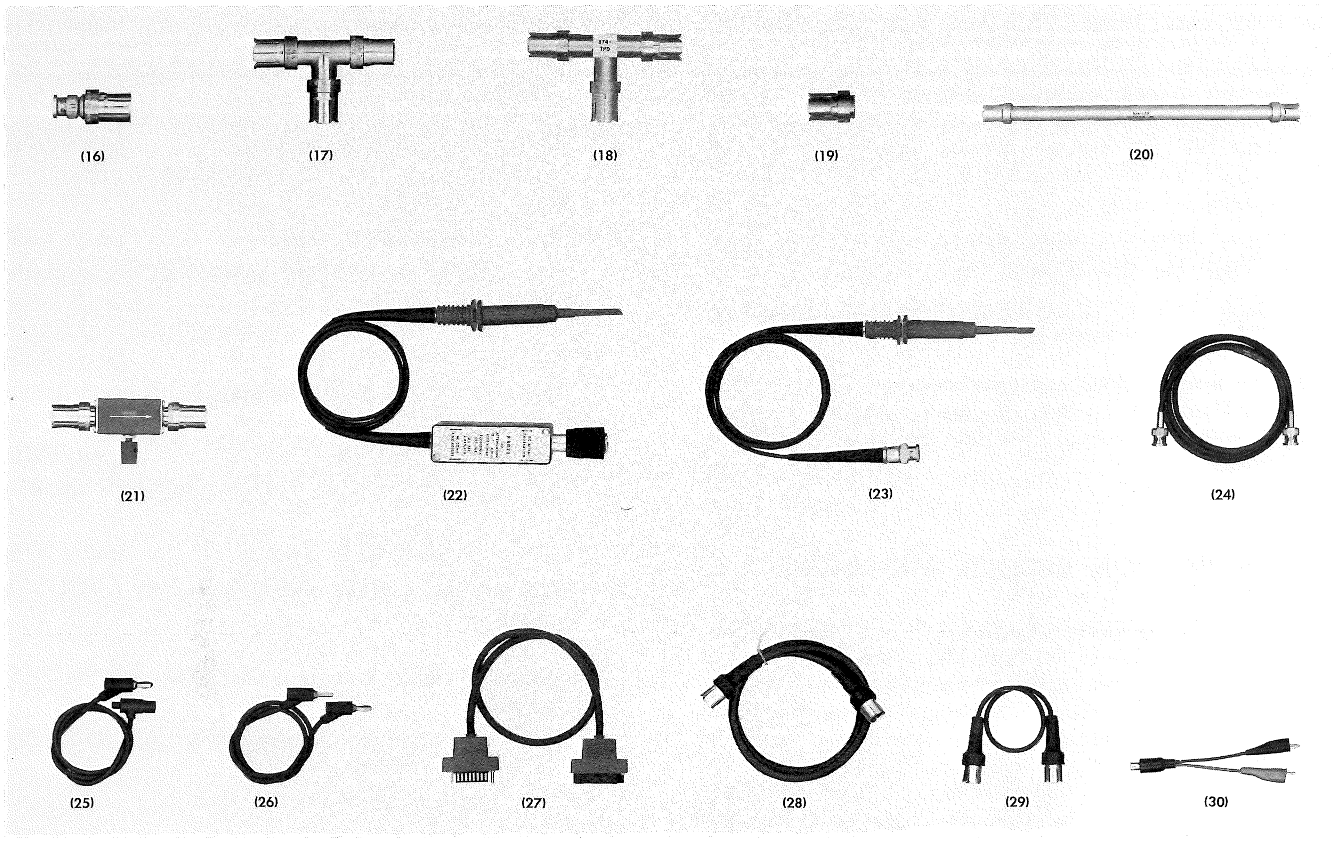


Fig. 7-2. Recommended calibration equipment, items 16 to 30.

8. Fast Rise Pulse Generator. Risetime requirement ≤70 ps; minimum output amplitude, 0.2 volts; output impedance, 50 Ω; trigger output, available at least 70 ns ahead of fast pulse. Tektronix Type 284 Pulse Generator (If your Type 284 Leadtime switch is labeled 5 ns-50 ns, order modification kit, Tektronix Part No. 040-0487-00.)

9. Amplifier Calibrator. Amplitude accuracy within one quarter of one percent; signal amplitude 5 volts and 100 volts (square wave); repetition rate, 1 kHz. Tektronix Calibration Fixture 067-0502-00 is recommended.

10. Voltohmeter. Ohms ranges, ×1 to ×100 k; DC voltage ranges, 0.6 volts to 350 volts. Triplett Model 630 is recommended.

11. Cable, delay. Impedance, 50 Ω; delay, 60 ns; connectors, GR. Tektronix Type 113 Delay Cable is recommended.

12. 10-inch GR Cable, Tektronix Part No. 017-0513-00. (Supplied with the Type 1S2.) Alternate item: Two 90° GR elbows, Tektronix Part No. 017-0070-00.

13. Attenuators. Impedance, 50 Ω; attenuation, 10×, Tektronix Part No. 017-0078-00; attenuation 5×, Tektronix Part No. 017-0079-00; attenuation 2×, Tektronix Part No. 017-0080-00.

14. Termination. Impedance, 50 Ω; connectors, GR type 874, GR874-W50B. Tektronix Part No. 017-0081-00.

15. Adapter. Impedance, 50 Ω; GR to BNC female. Tektronix Part No. 017-0063-00

16. Adapter. Impedance, 50 Ω; GR to BNC male. Tektronix Part No. 017-0064-00.

17. Tee connector, GR874-T, Tektronix Part No. 017-0069-00.

18. T Power Divider. Impedance, 50 Ω; connectors, GR. GR874-TPD. Tektronix Part No. 017-0082-00 is recommended.

19. Short Circuit Termination, GR Type 874 WN, Tektronix Part No. 017-0087-00.

20. Air Line. Impedance, 50 Ω; length, 20 cm; connectors, GR. GR874-L20. Tektronix Part No. 017-0084-00.

21. Attenuator, variable. 100 Ω with GR connectors. Tektronix Part No. 067-0511-00.

22. Probe. 10× for use with the Type W Plug-In. Tektronix P6023 is recommended for the most accurate measurements with the Type W Plug-In. Tektronix Part No. 010-0167-00.

23. Probe. 1× for use with Type W Plug-In. Tektronix P6028, Tektronix Part No. 010-0074-00.

24. Cable, 42-inch; impedance, 50 Ω; connectors, ;BNC Tektronix Part No. 012-0057-01.

25. Patch cord. Length, 18 inches. Banana terminal on one end, BNC on the other. Tektronix Part No. 012-0091-00.

26. Patch cord. Length, 18 inches. Banana terminals on both ends. Tektronix Part No. 012-0031-00.

27. Flexible plug-in extension. For use in operating the Type 1S2 Plug-In outside of the Type 547 Oscilloscope. Tektronix Part No. 012-0038-00. Vertical interference will be present unless the wire connecting pins 8 is replaced with a shielded lead.

28. Cable. 50 Ω, 5 ns delay, with GR type 874 connectors. Tektronix Part No. 017-0502-00. (Three required.)

29. Cable, 50 Ω, 2 ns delay, with GR type 874 connectors. Tektronix Part No. 017-0505-00.

30. Clip lead to BNC connector adapter, Tektronix Part No. 013-0076-00. A banana tip (probe adapter) is useful for banana jack connection, Tektronix Part No. 134-0013-00 (not shown).

CALIBRATION RECORD AND INDEX

This Abridged Calibration Procedure is provided to aid in checking the operation of the Type 1S2. It may be used as a calibration guide by the experienced calibrator, or it may be used as a calibration record. Since the step numbers and titles used here correspond to those used in the complete Calibration Procedure, the following procedure serves as an index to locate a step in the complete Calibration Procedure. Characteristics are those listed in the Characteristics section of the Instruction Manual.

Type 1S2 Serial No. ____________________

Calibration Date ____________________

☐ 1. Check or Adjust Power Supplies (page 7-9)
Adjust —19 V, —136 V, check +19 V; Check ripple.

☐ 2. Adjust Control Tunnel Diode Bias (page 7-9)
Correct operation, see Calibration Procedure.

☐ 3. Adjust Int Trig Level (page 7-9)
See Calibration Procedure.

☐ 4. Adjust UHF Sync Sensitivity (page 7-9)
See Calibration Procedure.

☐ 5. Check Manual Scan Operation (page 7-10)
MANUAL SCAN range, at least 7 volts
POSITION range, at least 7 volts

☐ 6. Adjust Sweep Duration (page 7-10)
Sweep Start at —1.0 volts ±0.1 volt
Sweep Amplitude, 10.4 volts

☐ 7. Check Single Sweep (page 7-10)
Observe a ramp each time SINGLE SWEEP button is depressed.

☐ 8. Adjust Inverter Zero (page 7-11)
Adjust INVERTER ZERO for 0 volts across PRESET control.

☐ 9. Adjust Comparator Firing Level (page 7-12)
Correct firing point. See Calibration Procedure.

☐ 10. Check Memory Gate Width (page 7-12)
340 ±30 ns pulse width, between 50% amplitude points

☐ 11. Measure Bridge Volts (page 7-15)
Between 4.8 and 6 volts difference

☐ 12. Adjust Bridge Balance (page 7-15)
No level change with Vertical UNITS/DIV rotation

☐ 13. Adjust Memory Gate Balance (page 7-15)
No change at VERT OUTPUT jack as ρ-VOLTS is changed

☐ 14. Adjust Variable Balance and Offset Range (page 7-15)
No trace shift while rotating VERTICAL UNITS/DIV throughout its range
Vertically centered trace.

☐ 15. Adjust Volts Cal (page 7-15)
1 volt signal at VERT OUTPUT for each division of display.

☐ 16. Adjust Vertical Gain (page 7-16)
Set to exactly 4.0 divisions of display

☐ 17. Check Vertical Units/div Accuracy (page 7-16)
Within ±3% of indicated units/div

☐ 18. Check Vertical Units/div Variable (page 7-16)
Range, less than 1.2 divisions (ratio .5 to 1) greater than 6.0 divisions (ratio, 1 to 2.5)

☐ 19. Check Offset Accuracy and Range (page 7-16)
Accuracy, within ±1%
Range, more than + and —2 Volts

☐ 20. Adjust Sampler Ramp and Timing (page 7-17)
Correct timing. See Calibration Procedure.

☐ 21. Check Magnifier Accuracy (page 7-18)
MAGNIFIER ACCURACY, within ±2%

☐ 22. Check Magnifier Variable Range (page 7-18)
Range, more than 2.5 to 1

☐ 23. Adjust Position Cal (page 7-19)
See Calibration Procedure.

☐ 24. Check Incremental Accuracy of Position Control (page 7-19)

Within ±1% of indicated at each major division of POSITION control

☐ 25. Check Dielectric Accuracy (page 7-19)

AIR, 1

TFE, 0.695, ±3%

POLYETHYLENE, 0.659, ±3%

PRESET range, 0.6-0.65 to 1

☐ 26. Adjust 1.0 V Pulser Stability and Pulse Start Level (page 7-21)

Adjust 1.0 V, 1 ns STABILITY for positive step.

Adjust PULSER DC OUTPUT LEVEL for pulse start and baseline at same DC level.

☐ 27. Check 1.0 V Pulser Risetime (page 7-22)

Measured risetime ≤1.1 ns from 10% to 90% amplitude points.

☐ 28. Adjust 1.0 V ρ CAL and Check Pulser Amplitude (page 7-22)

See Calibration Procedure.

Pulser amplitude, 0.9 to 1.0 volts

☐ 29. Check 1.0 V Pulser Jitter (page 7-22)

Jitter less than 20 ps

☐ 30. Adjust .25 V Pulser Stability and Pulse Start Level (page 7-23)

Adjust .25 V, 50 ps STABILITY for positive step.

Adjust PULSER OUTPUT DC LEVEL for pulse start and baseline at same DC level.

☐ 31. Adjust Pulse Position (page 7-23)

See Calibration Procedure.

☐ 32. Adjust .25 V Cal and Check Pulse Amplitude (page 7-24)

See Calibration Procedure.

Pulser Amplitude, 230 mV to 260 mV

☐ 33. Check .25 V Pulser Jitter (page 7-24)

Jitter, less than 20 ps

☐ 34. Check System Risetime (page 7-24)

Measured risetime, ≤140 ps from 10% to 90% amplitude points

☐ 35. Adjust Transient Response (page 7-25)

Optimum flat top and best corner

See Calibration Procedure.

☐ 36. Check 1.0 V Pulse Flatness Deviation (page 7-26)

Not more than 2.5% during the first 10 ns

Not more than 1% after the first 10 ns

☐ 37. Check .25 V Pulse Flatness Deviation (page 7-26)

Not more than 7% during first 500 ps

Not more than 3% after first 500 ps

☐ 38. Check Sampler Risetime (page 7-27)

≤114 ps with Type 284 Pulse Generator

☐ 39. Check Internal Reflections (page 7-28)

Flatness deviation after 4 ns less than 10% reflected pulse amplitude.

☐ 40. Check Vertical Balance (page 7-28)

Repeat steps 12 and 13

☐ 41. Check Tangential Noise (page 7-29)

Noise Amplitude, less than 2 mV

☐ 42. Check Ext Horizontal (page 7-30)

Sensitivity range, less than 2 V/div to more than 15 V/div

☐ 43. Check Manual Scan (Visual) (page 7-30)

More than 10 cm of spot travel

☐ 44. External Trigger Jitter (page 7-30)

Less than 100 ns at 350 kHz and 500 mV

Less than 100 ps at 100 MHz and 500 mV

☐ 45. Check UHF Sync Jitter (page 7-32)

Less than 30 ps at 5 GHz

☐ 46. Check Trigger Jitter (Pulse Input) (page 7-33)

Less than 100 ps with 50 mV pulse

☐ 47. Check Horizontal Units/Div Readout Lamps (page 7-34)

All lamps operating properly

NOTES

CALIBRATION PROCEDURE

General

In the following calibration procedure, a test equipment setup is shown for each major setup change. Complete control settings are listed following the picture. To aid in locating individual controls which have been changed during complete calibration, these control names are printed in bold type. If only a partial calibration is performed, start with the nearest setup preceding the desired portion.

NOTE

When performing a complete recalibration, best performance will be provided if each adjustment is made to the exact setting, even if the Check is within the allowable tolerance.

The following procedure uses the equipment listed under Equipment Required. If substitute equipment is used, control settings or setup must be altered to meet the requirements of the equipment used.

Modification of the 50 Ω Amplitude Calibrator, 067-0508-00

If the instrument you are using has a repetition rate of 20 kHz, modification is required for use in this Calibration Procedure.

This modification consists of changing C25 from a .005 μF discap to a .0033 μF discap.

Fig. 7-3A shows C25 on the schematic diagram.

Fig. 7-3B shows the physical location of C25, connected between the emitters of Q15 and Q25.

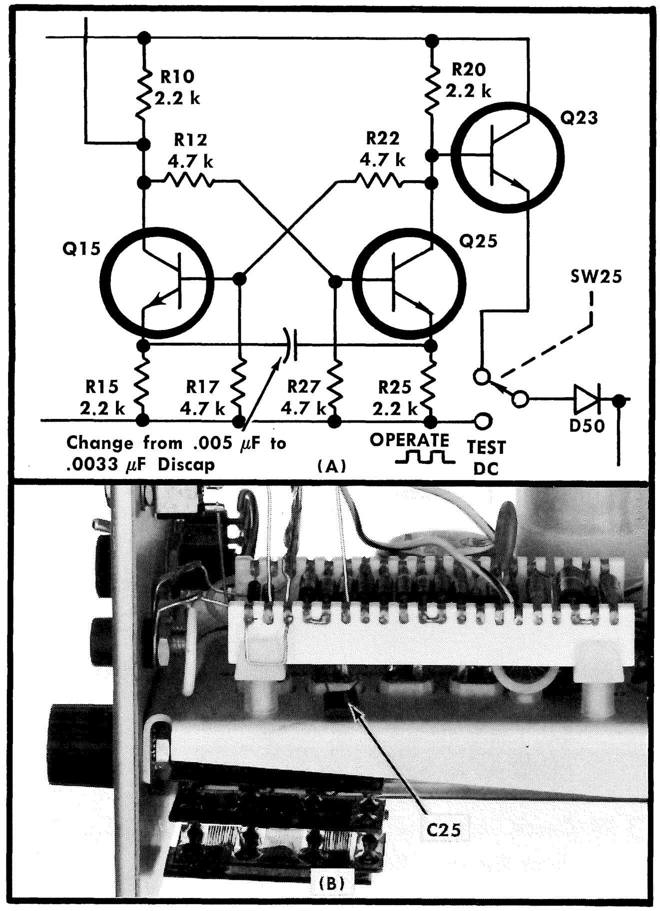


Fig. 7-3. Location of C25 in the 067-0508-00 Calibration Fixture. (A) Circuit location (B) Physical location.

NOTES

Preliminary Procedure

1. Plug the Flexible Extender into the connector in the Indicator Oscilloscope.

2. Plug the Type 1S2 into the connector on the Flexible Extender.

3. Pull out the white plunger at top-rear of the Type 547 plug-in compartment.

4. Turn the Type 547 Intensity control counterclockwise.

5. Turn the power switch to ON.

6. Insert the Type W into the Test Oscilloscope and apply power.

7. Allow a 20 minute warm up.

NOTES

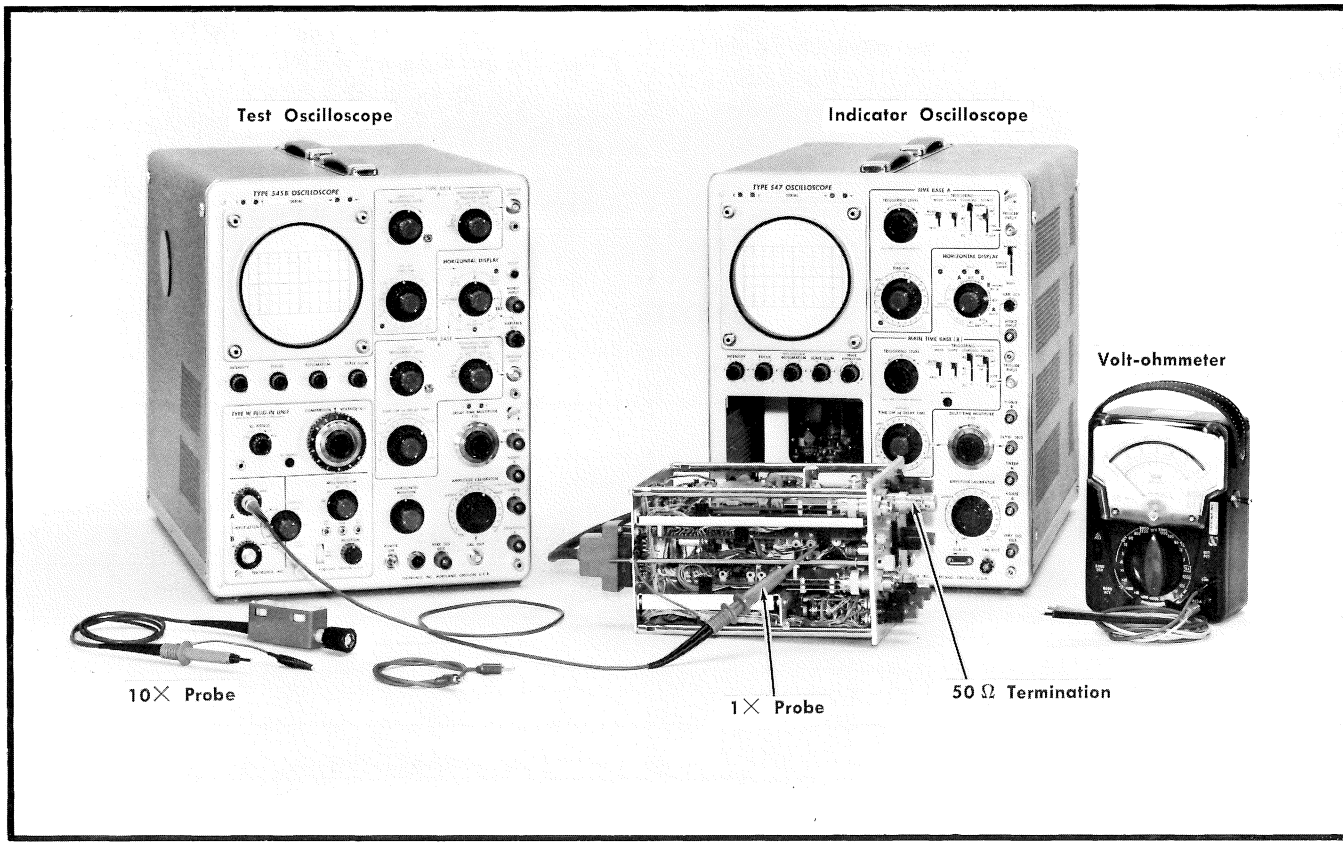


Fig. 7-4. Initial equipment setup for steps 1 through 10.

Control Settings

Type 1S2

OFFSET	Midrange
FINE	Midrange
VERTICAL UNITS/DIV	.5
VARIABLE	CAL
DISPLAY MODE	MAN
MANUAL SCAN	Clockwise
MODE	EXT TRIG
UHF SYNC OR TRIGGER SENS	Midrange
MAGNIFIER	×1
RANGE	10 μs, 1 km
POSITION	0.00
HORIZONTAL UNITS/DIV	TIME
ρ—VOLTS	VOLTS
RESOLUTION	NORMAL

Indicator Oscilloscope

Horizontal Display	Ext, ×10
Variable 10-1	Midrange

Test Oscilloscope

Horizontal Display	A
Triggering Mode	AC
Trigger Slope	+Line
Trigger Level	Stable Display
Stability	Stable Display
Time/cm	1 ms
Variable	Calibrated
Sweep Magnifier	Off

Type W Plug-In

Display	A-Vc
Input Atten	10
Millivolts/cm	50
Variable	Calibrated
Comparison Voltage	1900
Vc Range	+11
Input A selector	GND
Position	Trace centered

1. Check or Adjust Power Supplies

a. Use the equipment setup as shown in Fig. 7-4. Connect the 1× probe to test point TP829, +19 VOLTS. Power Supply test points and adjustments are shown in Fig. 7-5.

b. Set the Type W Input Selector to DC and check that the trace is at the centerline, with a Comparison Voltage setting within the limits 1843 and 1957 (+19 volts ±3%).

c. Connect the 1× probe to test point TP869, —19 VOLTS, and set the Vc Range to —11.

d. Check that trace is centered with a Comparison Voltage setting within the limits 1843 to 1957 (—19 volts ±3%). If the Comparison Voltage reading is more than 1957 or less than 1843, adjust R867, —19 V, for a setting of 1900.

e. Set the Type W Input Atten to 100 and Comparison Voltage to 1360. Connect the 1× probe to test point TP889, —136 VOLTS.

f. Check that trace is centered with a Comparison Voltage setting between 1319 and 1401 (—136 volts ±3%). If Comparison Voltage reads more than 1401 or less than 1319, adjust R887 —136 V for a setting of 1360.

g. Set the test oscilloscope Time/cm switch to 10 ms and the Type W Input Coupling to AC, the Vc Range to 0, the Input Atten to 1 and the Millivolts/cm to 5.

h. Check the —136 VOLTS, test point TP889, for not more than 1 division of ripple (5 mV).

i. Set the Type W Millivolts/cm switch to 10 and connect the 1× probe to the —19 VOLTS test point, TP869. Check for not more than 1 division of ripple (10 mV).

j. Move the 1× probe to the +19 VOLTS test point, TP289, and check for not more than 1 division of ripple (10 mV).

k. Remove the 1× probe.

2. Adjust Control Tunnel Diode Bias

a. Set the Type 1S2 DISPLAY MODE to NORMAL and the UHF SYNC OR TRIGGER SENS control fully clockwise. Connect a patch cord from the HORIZ OUTPUT jack to the Indicator Oscilloscope Horiz Input jack and set the Variable 10:1 control for a trace approximately 10.4 cm long. If the Type 1S2 vertical is not operating, connect the 10× probe to the Type W Input A connector and to TP525 (See Fig. 7-6). This will produce a free-running trace on the Test Oscilloscope.

b. Set the UHF SYNC OR TRIGGER SENS control to midrange (white dot straight up). This should extinguish the trace.

c. Adjust R544, CONTROL TD BIAS, clockwise until a trace again appears on the Indicator Oscilloscope or Test Oscilloscope, whichever is being used for this step.

d. Set the CONTROL TD BIAS about 30° counterclockwise from the free-run trace position. Adjustment of INT TRIG LEVEL, Step 3, interacts with this adjustment.

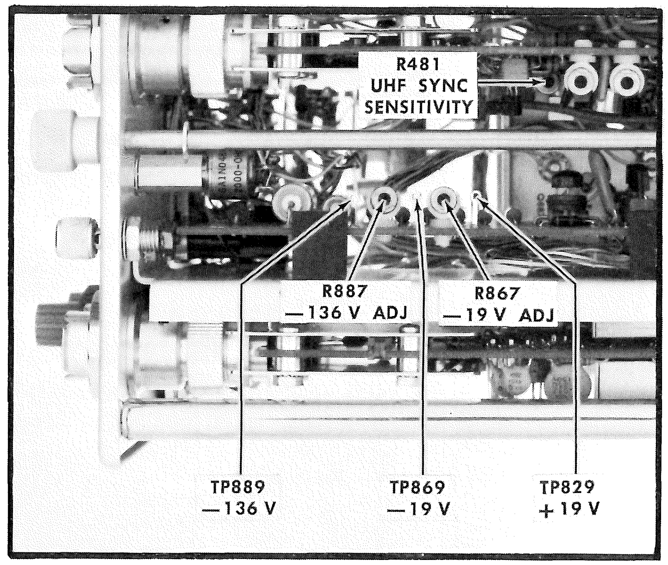


Fig. 7-5. Location of Power Supply test points, adjustments and UHF SYNC SENSITIVITY control, bottom view of Type 1S2.

3. Adjust Internal Triggering Level

a. Connect the 10× probe to the Type W Input A connector and connect the probe tip to TP525, see Fig. 7-6.

b. Set the Test Oscilloscope Time/cm to 0.2 μs, Trigger Slope to + Int and the Type W Millivolts/cm switch to 5.

c. Set the Type 1S2 UHF SYNC OR TRIGGER SENS control fully counterclockwise and adjust the Test Oscilloscope Triggering Level and Stability controls for a stable display.

d. Adjust INT TRIG LEVEL, R523 (Fig. 7-6) for a display similar to Fig. 7-7, showing approximately 8 to 12 peaks with 10 peaks nominal.

e. Turn the UHF SYNC OR TRIGGER SENS control fully clockwise and check that the display has the same number of peaks; change the RANGE switch to 1 μs, 100 m and check for the same number of peaks. This adjustment may require a touch-up of the CONTROL TD BIAS adjustment, step 2, and resultant repetition of this step.

4. Adjust UHF Sync Sensitivity

a. Set the Type 1S2 MODE switch to UHF SYNC and turn the UHF SYNC OR TRIGGER SENS control fully counterclockwise.

b. Check that any rotation of the UHF SYNC OR TRIGGER SENS control will produce a change in time (period) of the peaks on the test oscilloscope display, or an increase in the number of peaks.

c. Adjust R481, UHF SYNC SENSITIVITY, Fig. 7-5, for a change in test oscilloscope peak period as the UHF SYNC OR TRIGGER SENS control is turned from the counterclockwise stop.

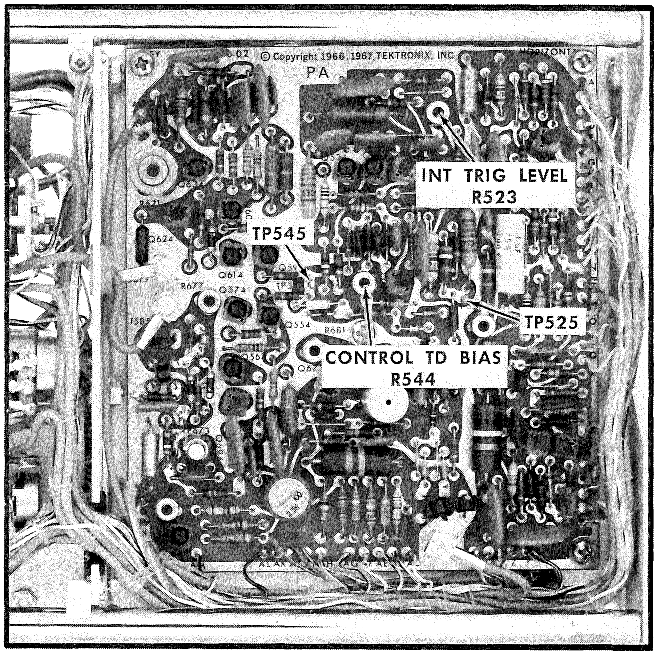


Fig. 7-6. Location of controls on Horizontal circuit board for steps 2 and 3.

5. Check Manual Scan Operation

a. Set the Type 1S2 DISPLAY MODE switch to MAN.

b. Set the Type W Millivolts/cm switch to 50 and the Input A selector switch to DC. Rotate the Test Oscilloscope Stability control fully clockwise.

c. Connect the 10× Probe tip to test point TP673, shown in Fig. 7-8, and rotate the MANUAL SCAN control fully counterclockwise.

d. Position the trace on the Test Oscilloscope CRT to the graticule center horizontal line, using the Type W Position control.

e. Rotate the Type 1S2 MANUAL SCAN control clockwise.

f. Switch the Type W Vc Range to —1.1 and rotate the Type W Comparison Voltage dials to again position the trace to the Test Oscilloscope graticule center line.

g. Read at least 7 volts from the Type W Comparison Voltage dials.

h. Rotate the MANUAL SCAN control and the POSITION control fully counterclockwise.

i. Rotate the Type W Comparison Voltage dials to position the trace to the Test Oscilloscope graticule center line.

j. Read at least 7 volts from the Type W Comparison Voltage dials.

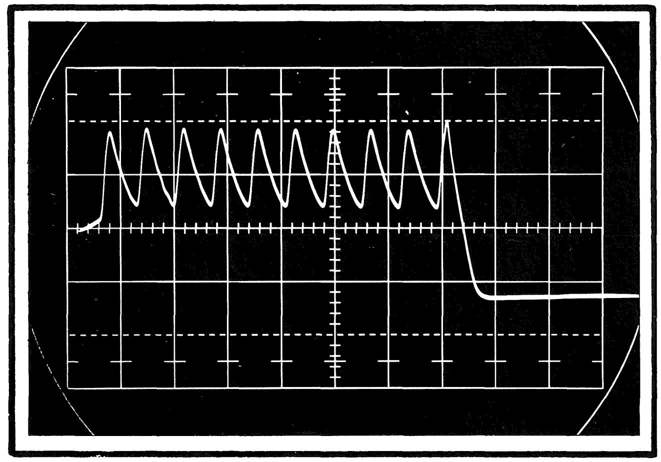


Fig. 7-7. Typical CRT display of waveform at TP525, steps 3 and 4.

6. Adjust Sweep Duration

a. Set the Type 1S2 DISPLAY MODE switch to NORMAL.

b. Set the Test Oscilloscope Time/cm switch to 5 ms and the Type W Input A selector switch to GND.

c. Connect the 10× Probe tip to the center arm of the MAGNIFIER VARIABLE control, R641, shown in Fig. 7-9.

d. Position the Test Oscilloscope trace to the graticule center line using the Type W Position control.

e. Set the Type W Comparison Voltage dials to 000, the Input A selector switch to DC and the Vc Range switch to —1.1.

f. Rotate the Type W Comparison Voltage dials to position the test oscilloscope trace to the center line. Check that the dial is between 0.9 and 1.1 (—1 ±0.1 volt).

g. Set the Type W Comparison Voltage to 940 and the Vc Range switch to +1.1.

h. Adjust the SWEEP LENGTH control, R787, shown in Fig. 7-8, to bring the top of the test oscilloscope display to the center graticule line.

i. Set the Type W Input Atten switch to 10, Comparison Voltage to 000, Vc Range to 0 and the test oscilloscope Trigger Slope to —Int.

j. Obtain a stable display and check that the ramp duration is approximately 12 ms; Fig. 7-10.

7. Check Single Sweep

a. Set the Type 1S2 RESOLUTION switch to HIGH and set the Test Oscilloscope Time/cm to .2 s.

b. Set the Test Oscilloscope Stability and Triggering Level controls for a stable display on the CRT. Check that the duration of the ramp portion of the waveform is approximately .8 second (4 cm).

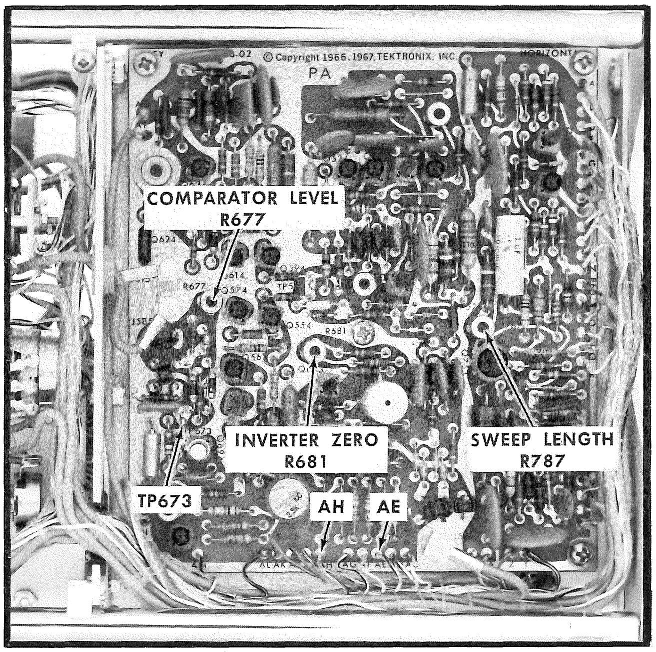


Fig. 7-8. Horizontal circuit board control locations.

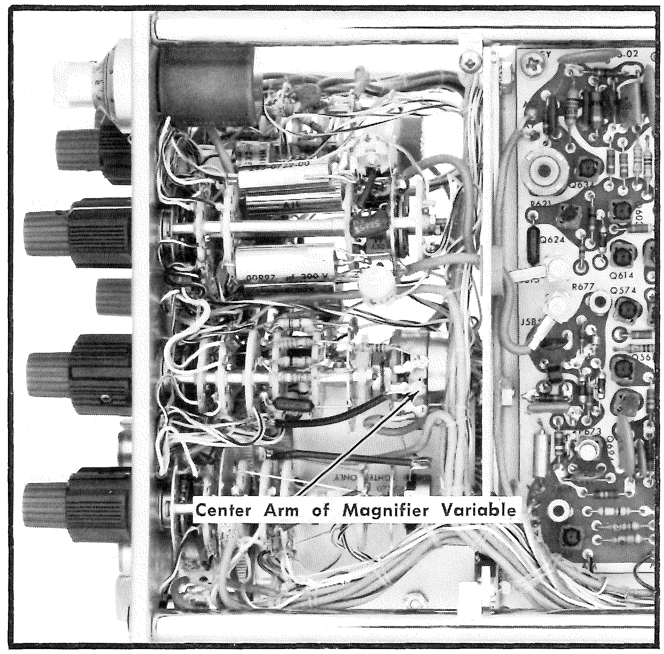


Fig. 7-9. Location of control R641 for steps 6 and 8.

c. Set the Test Oscilloscope Time/cm switch to .5 s and set the Type 1S2 DISPLAY MODE switch to SINGLE SWEEP.

d. Depress the SINGLE SWEEP START button. As soon as the sweep starts on the Test Oscilloscope CRT, depress the SINGLE SWEEP START again and check for a sawtooth on the Test Oscilloscope CRT. A sawtooth should appear each time the START button is depressed.

8. Adjust Inverter Zero

a. Change the following Type 1S2 controls:

DISPLAY MODE	NORMAL
MANUAL SCAN	Fully clockwise
MODE	EXT TRIG
UHF SYNC OR TRIGGER SENS	Fully counterclockwise
MAGNIFIER	×100
VARIABLE	Clockwise
HORIZONTAL UNITS/DIV	DISTANCE
RESOLUTION	NORMAL
DIELECTRIC	PRESET
PRESET	Fully clockwise

b. Connect the 50 Ω Termination to the Type 1S2 UPPER THRU SIGNAL CHANNEL 50 Ω connector.

c. Position the trace start to the 1 cm line on the CRT.

d. Connect a short clip lead between the Type 1S2 chassis ground and the center arm of the MAGNIFIER VARIABLE control.

e. Connect a DC Voltmeter (range set to .6 volts) across the PRESET control, R650 (front panel).

NOTE

Terminals AE and AH on the bottom edge, see Fig. 7-8, of the Horizontal Circuit board are connected to the PRESET control terminals.

f. Adjust the INVERTER ZERO control, R681 (Fig. 7-8), for a reading of zero volts on the meter.

g. Remove the ground strap from the MAGNIFIER VARIABLE center arm and ground.

h. Rotate the MAGNIFIER VARIABLE control counterclockwise to the CAL position.

i. Remove the meter leads from the Type 1S2.

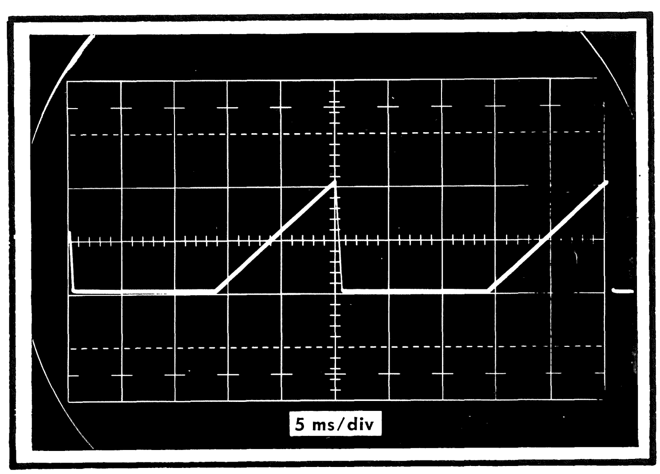


Fig. 7-10. Typical CRT display of ramp duration for step 6.

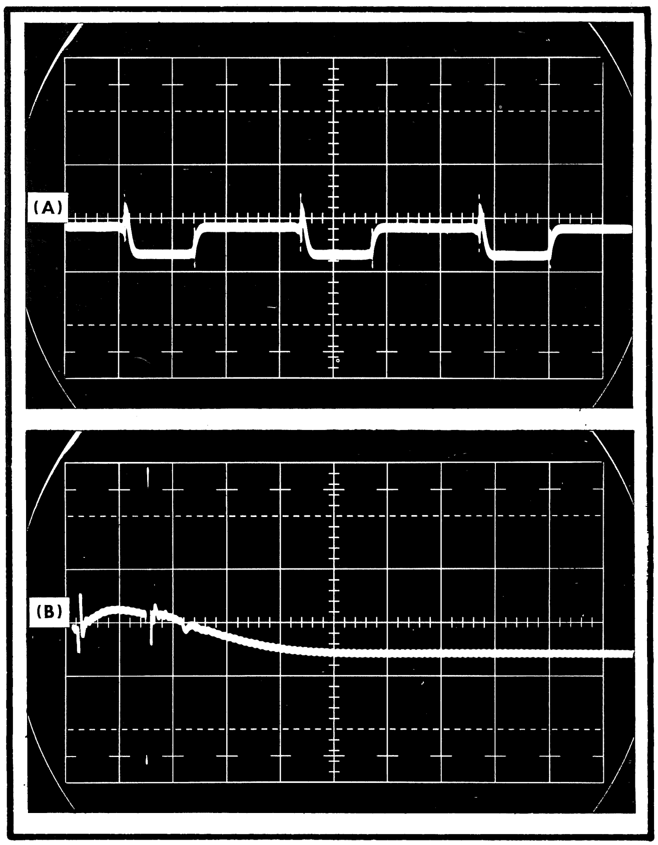


Fig. 7-11. Typical CRT displays for adjustment of Comparator Firing Level. (A) 20 μs/cm and (B) 1 μs/cm.

9. Adjust Comparator Firing Level

a. Change the following Type 1S2 controls:

DISPLAY MODE	MANUAL
MANUAL SCAN	Fully counterclockwise
RANGE	1 km, 10 μs
HORIZONTAL UNITS/DIV	TIME

b. Connect the 10× probe tip to test point TP673, Fig. 7-8, and connect the 1× Probe from the Test Oscilloscope Trigger In to test point TP545, Fig. 7-6.

c. Set the Type W Input A selector to AC, Input Atten to 1 and the Millivolts/cm switch to 2.

d. Set the test oscilloscope Trigger Slope to + Ext and the Time/cm to 20 μs. Obtain a stable display.

e. Turn the COMPARATOR LEVEL control R677 (shown in Fig. 7-8), clockwise until a spike appears as shown in Fig. 7-11A.

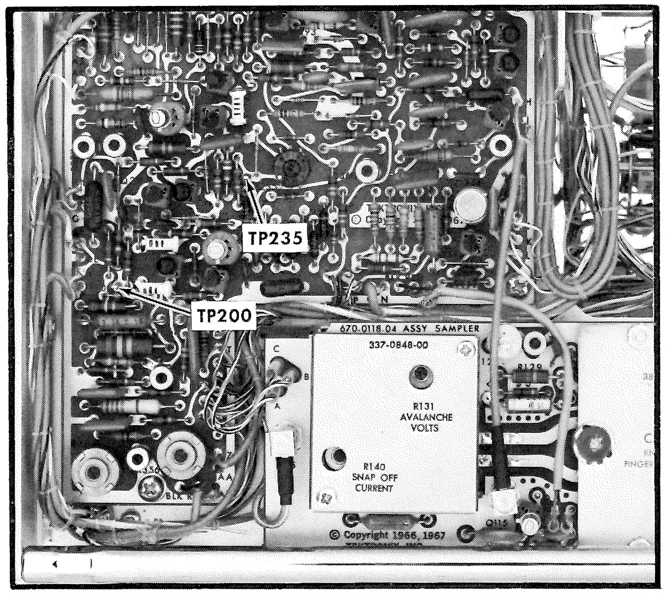


Fig. 7-12. Location of test points TP200 and TP235, Vertical Circuit board assembly.

f. Continue turning R677 until the spike appears to jump to the left, then turn R677 counterclockwise until the spike jumps to the right. Set R677 approximately 10° farther counterclockwise. The spike should be on the down (right) side of the display. Set the Time/cm to 1 μs and the MAGNIFIER to ×10 for a more obvious test oscilloscope display, as shown in Fig. 7-11B.

g. Remove both probes from the Type 1S2.

10. Check Memory Gate Width

a. Set the Type W Millivolts/cm switch to 1 and the Input Atten switch to 10.

b. Set the Type 1S2 DISPLAY MODE switch to NORMAL.

c. Connect the 10× Probe tip to test point TP200; see Fig. 7-12. Set the Test Oscilloscope Time/cm to .1 μs and the Trigger Slope to + Int.

d. Observe a spike, as shown in Fig. 7-13, of about 3 volts positive peak.

e. Move the 10× Probe from TP200 to TP235.

f. Check the waveform at the 50% amplitude points for a pulse width of 340 ns ±30 ns (3.1 to 3.7 cm). See Fig. 7-14.

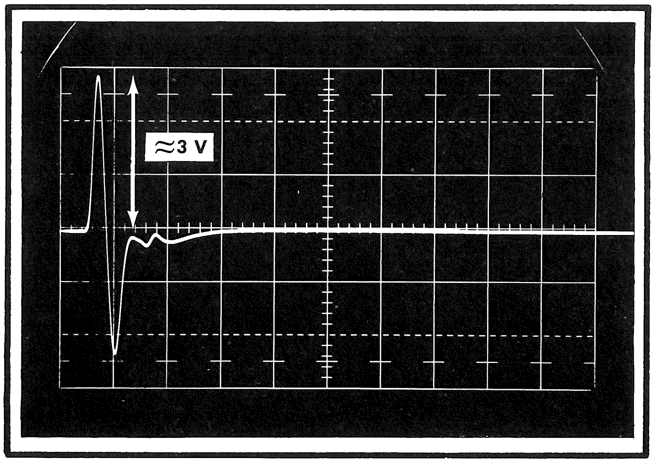


Fig. 7-13. Typical CRT display of waveform at TP200.

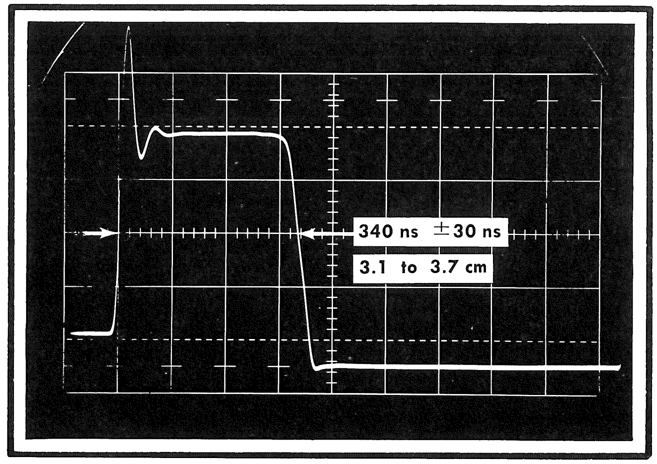


Fig. 7-14. Typical CRT display for measurement of Memory Gate Width.

NOTES

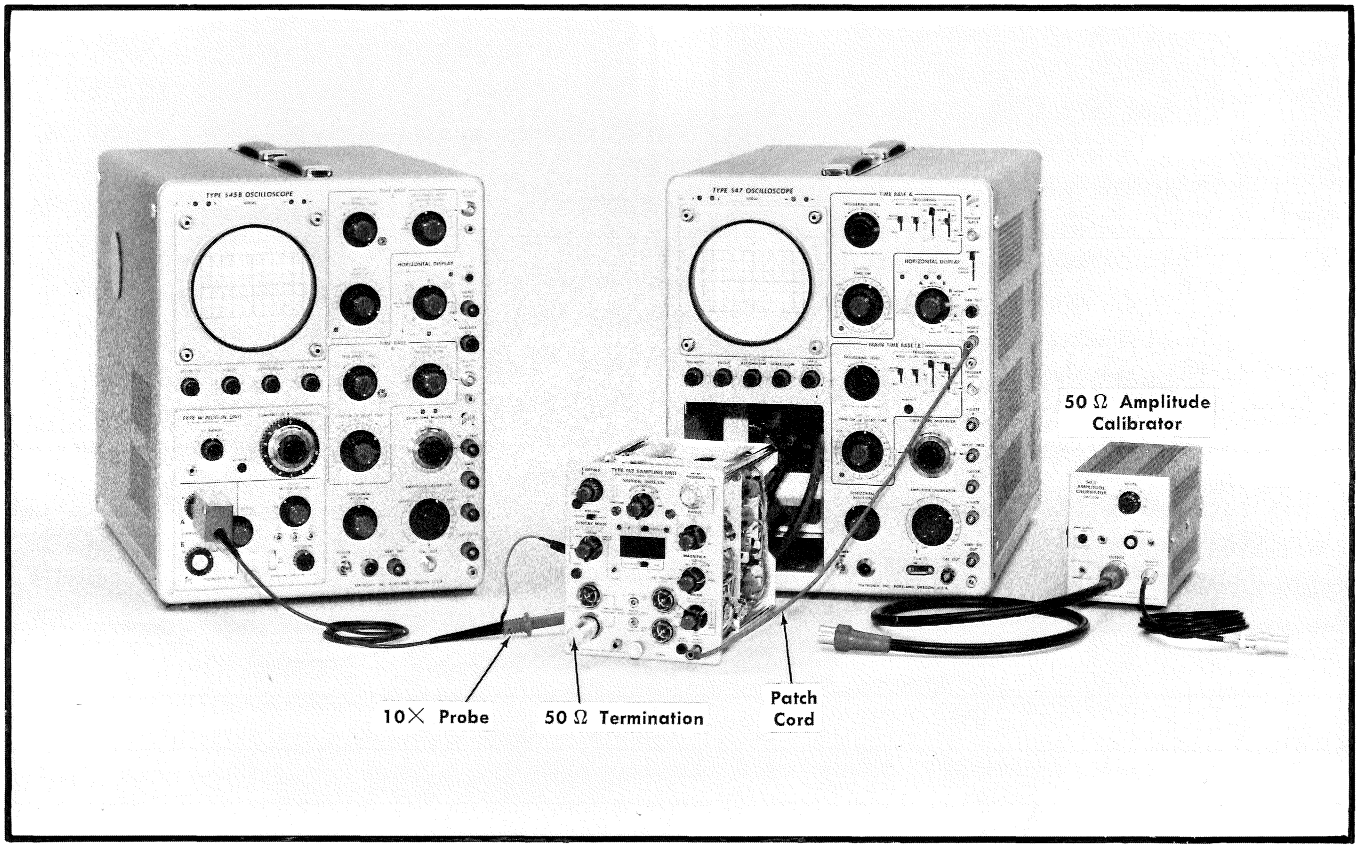


Fig. 7-15. Initial equipment setup for steps 11 through 19.

Control Settings

Type 1S2

OFFSET	Midrange
FINE	Midrange
VERTICAL UNITS/DIV	.5
VARIABLE	CAL
DISPLAY MODE	NORMAL
MANUAL SCAN	Clockwise
MODE	.25 V INT PULSE
UHF SYNC OR TRIGGER SENS	Midrange
MAGNIFIER	×1
RANGE	10 μs, 1 km
POSITION	0.00
HORIZONTAL UNITS/DIV	TIME
ρ—VOLTS	VOLTS
RESOLUTION	NORMAL

Indicator Oscilloscope

Horizontal Display	Ext, ×10
Variable 10-1	As set

Test Oscilloscope

Horizontal Display	A
Triggering Mode	AC
Trigger Slope	+ Int
Triggering Level	Clockwise
Stability	Clockwise
Time/cm	2 μs
Variable	Calibrated
Sweep Magnifier	Off

Type W Plug-In

Display	A-Vc
Input Atten	10
Millivolts/cm	20
Variable	Cal
Comparison Voltage	0.00
Vc Range	0
Input A selector	Gnd
Position	Midrange

11. Measure Bridge Volts

a. Use the equipment as shown in Fig. 7-15. Connect the 10× Probe to the + Bridge Volts lead; see Fig. 7-16.

b. Center the Test Oscilloscope trace with the Type W Position control and set the Input A selector switch to DC.

c. Note the amount of trace shift.

d. Connect the 10× Probe to the — Bridge Volts lead and note the trace shift.

e. Check that the total trace shift is more than 2.4 cm and less than 3 cm (voltage difference greater than 4.8 V and less than 6 V between the red and black leads).

12. Adjust Bridge Balance

a. Set the Type W Input Atten switch to 1 and the Millivolts/cm switch to 5.

b. Connect the 10× Probe to the ×1 OFFSET OUTPUT jack and set the OFFSET controls for zero volts at the jack.

c. Connect the 10× Probe to test point TP268, the Memory Output, and center the test oscilloscope trace. Set the Type W Millivolts/cm switch to 10.

d. Preliminary adjustments: Set the AVALANCHE VOLTS control, R131, counterclockwise from the free run position; set the SNAP OFF CURRENT control, R140, clockwise at the first stable trace level from a counterclockwise position.

e. Rotate the VERTICAL UNITS/DIV switch to .005 and adjust the BRIDGE BALANCE control R360, shown in Fig. 7-16 for no level change on the test oscilloscope.

13. Adjust Memory Gate Balance

a. Connect the 10× Probe to the ×1 OFFSET OUTPUT jack and set the OFFSET controls for zero volts at the jack.

b. Move the 10× Probe to test point TP268, Memory Output. Set the Type W Input Atten switch to 10.

c. Adjust the Type 1S2 MEMORY GATE BALANCE control R247, shown in Fig. 7-16, for no trace shift on the test oscilloscope as the ρ—VOLTS switch is changed between ρ and VOLTS.

14. Adjust Variable Balance and Offset Range

a. Connect the 10× Probe to test point TP268, Memory Output, and check for zero volts, as shown by a vertically centered trace on the Test Oscilloscope.

b. Observe the trace on the Indicator Oscilloscope and adjust the OFFSET RANGE control, R396 shown in Fig. 7-16, to center the trace vertically on the CRT graticule.

c. Rotate the VERTICAL UNITS/DIV VARIABLE control throughout its range and adjust the VARIABLE BALANCE control, R388 shown in Fig. 7-16, for no trace shift on the Indicator Oscilloscope CRT graticule.

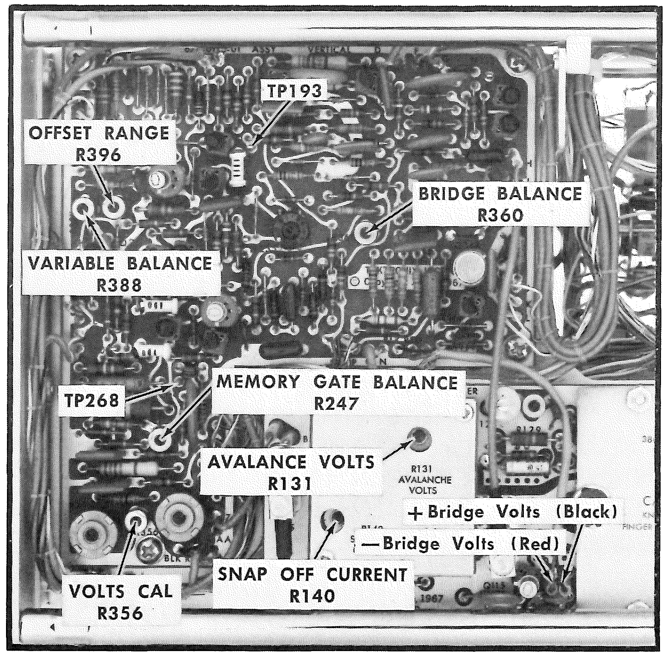


Fig. 7-16. Location on Vertical circuit board of controls and test points.

d. Readjust the OFFSET RANGE control, R396, to vertically center the trace on the Indicator Oscilloscope graticule.

e. Connect the 10× Probe to the ×1 OFFSET OUTPUT jack.

15. Adjust Volts Cal

a. Set the Type 1S2 MODE switch to EXT TRIG; set the Type W Vc Range switch to —1.1 and the Input A selector to GND; set the Test Oscilloscope Time/cm switch to 10 ms, the Triggering Level control to midrange, and center the trace with the Type W Position control.

b. Set the Type W Input A selector to DC and position the Test Oscilloscope trace to graticule center with the Type 1S2 OFFSET controls.

c. Connect the 50 Ω Amplitude Calibrator to the Type 1S2 as follows:

5 ns coaxial cable from the Calibrator Output connector to the upper THRU SIGNAL CHANNEL 50 Ω connector. Connect the 50 Ω Termination to the lower THRU SIGNAL CHANNEL 50 Ω connector.

50 Ω coaxial cable with BNC connectors and a BNC to GR adapter from the Trigger Output connector to the EXT TRIG INPUT connector.

d. Set the 50 Ω Amplitude Calibrator Amplitude switch to 2.0 volts and the Test-Operate switch to Operate.

e. Move the 10× Probe to the VERT OUTPUT jack and set the Type W Millivolts/cm switch to 10 and the Input A selector to GND.

f. Trigger the Type 1S2 on either + slope or — slope so that a vertical transition (up or down) is closest to the vertical centerline.

g. Set the Type W Position control for a centered trace on the Test Oscilloscope graticule, then set the Comparison Voltage to 400 and the Input A selector to DC.

h. Adjust the VOLTS CAL control, R356 shown in Fig. 7-16, to position the bottom of the display at the Test Oscilloscope graticule center line (4 volts of signal amplitude at the VERT OUTPUT jack.)

i. Remove the 10× Probe from the VERT OUTPUT jack.

16. Adjust Vertical Gain

a. Adjust the Type 1S2 UHF SYNC OR TRIGGER SENS control for a stable display on the Indicator Oscilloscope CRT.

b. Position the display vertically to the center of the graticule area.

c. Rotate the front panel VERT GAIN control to set the display amplitude to exactly 4 divisions.

17. Check Vertical Units/Div Accuracy

a. Check each of the switch positions of the Type 1S2 VERTICAL UNITS/DIV. Table 7-1 shows switch settings and correct deflection for each position.

TABLE 7-1

50 Ω Amplitude Calibrator	1S2 VERTICAL UNITS/DIV	Divisions of deflection	Tolerance %
2.0	.5	4	0
1.2	.2	6	3
.6	.1	6	3
.3	.05	6	3
.12	.02	6	3
.06	.01	6	3
.03	.005	6	3

18. Check Vertical Units/Div VARIABLE

a. Set the Type 1S2 VERTICAL UNITS/DIV to .5.

b. Set the 50 Ω Amplitude Calibrator volts to 1.2.

c. Rotate the VERTICAL UNITS/DIV VARIABLE fully counterclockwise.

d. Observe not more than 1.2 divisions of display on the Test Oscilloscope CRT.

e. Rotate the VERTICAL UNITS/DIV VARIABLE through CAL fully clockwise.

f. Observe not less than 6.0 divisions of display.

19. Check Offset Accuracy and Range

a. Set the VERTICAL UNITS/DIV switch to .05.

b. Connect the 10× Probe tip to the Type 1S2 ×1 OFFSET jack.

c. Switch the Type W Plug-In Input A Selector switch to Gnd and the Comparison Voltage to zero.

d. Set the Test Oscilloscope trace to the graticule center horizontal line with the Type W Position Control.

e. Set the Type W Input A Selector to DC.

f. Apply 1.2 volts from the 50 Ω Amplitude Calibrator.

g. Adjust the OFFSET and FINE controls to position the zero level of the 1.2 volt test voltage to the graticule center line of the Indicator Oscilloscope.

h. Measure the OFFSET OUTPUT level with the test oscilloscope Type W Unit.

i. Position the top of the 1.2 volt test signal to the Indicator Oscilloscope graticule center line with the OFFSET controls.

j. Measure the new OFFSET OUTPUT with the Type W Unit. The total voltage change in OFFSET OUTPUT should be 1.2 ±0.012 volts.

k. Rotate the Type 1S2 OFFSET and FINE controls fully clockwise and measure the offset voltage with the Type W Unit. Read at least —2.0 volts.

l. Rotate the Type 1S2 OFFSET and FINE CONTROLS fully counterclockwise and measure the offset voltage with the Type W. Read at least +2.0 volts.

m. Disconnect the 50 Ω Amplitude Calibrator from the Type 1S2.

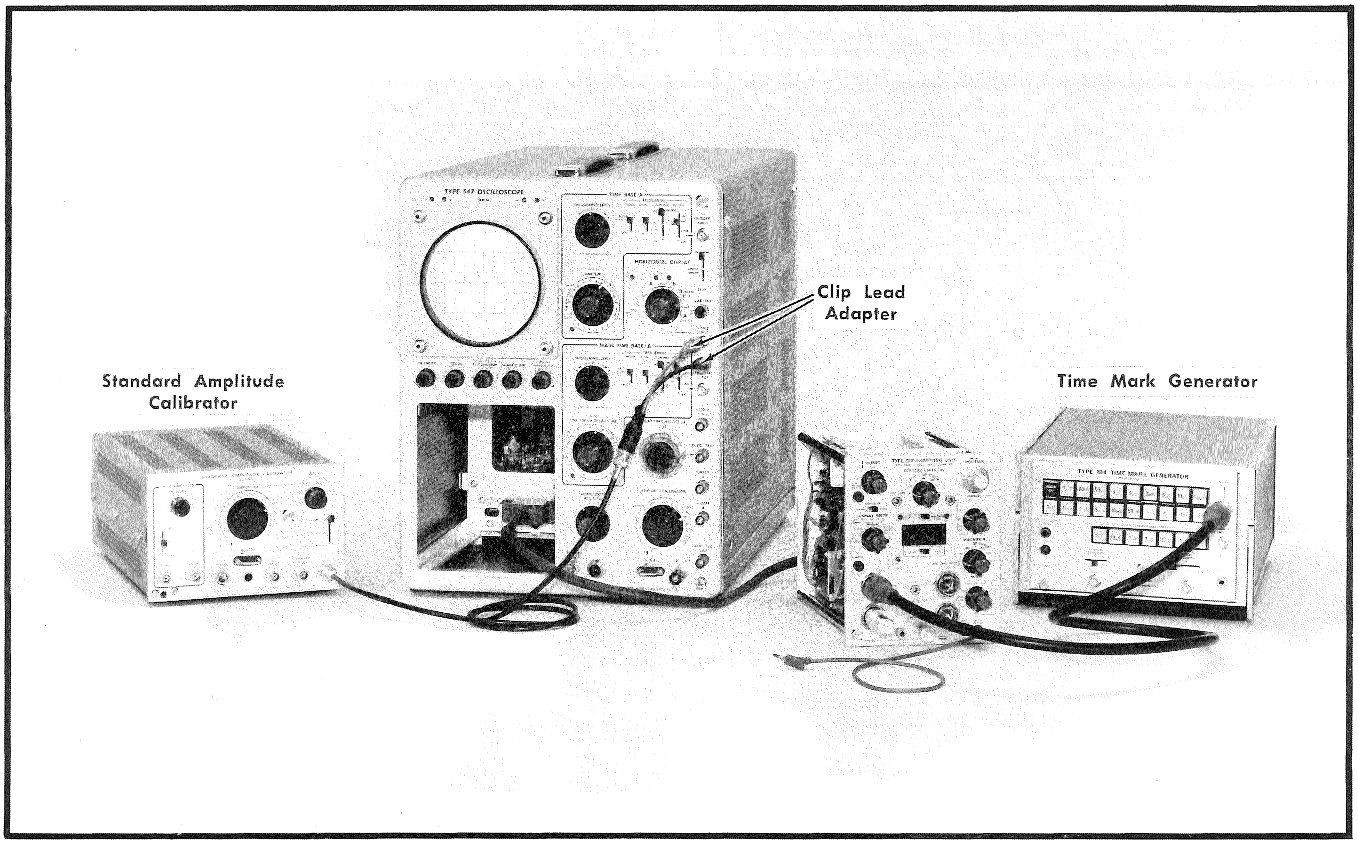


Fig. 7-17. Initial equipment setup for steps 20 through 25.

Control Settings

Type 1S2

OFFSET	Midrange
FINE	Midrange
VERTICAL UNITS/DIV	.5
VARIABLE	CAL
DISPLAY MODE	NORMAL
MANUAL SCAN	Clockwise
MODE	EXT TRIG
UHF SYNC OR TRIGGER SENS	Clockwise
MAGNIFIER	×1
VARIABLE	CAL
RANGE	10 μs, 1 km
POSITION	0.00
HORIZONTAL UNITS/DIV	TIME
ρ—VOLTS	VOLTS
RESOLUTION	HIGH

Indicator Oscilloscope

Horizontal Display	Ext, ×10
Variable, 10-1	As set

Standard Amplitude Calibrator

Mode	⊓⊔
Amplitude	5 volts
Output Selector Switch	Calibrator Output (UP)

Time-Mark Generator

Marker Selector	1 μs
Trigger Selector	1 μs
H. F. Selector	Off
Marker Amplifier	Off

20. Adjust Sampler Ramp and Timing

a. Preliminary equipment setup is shown in Fig. 7-17. Parts b through e accurately set the horizontal gain of the Indicator Oscilloscope.

b. Connect a 50 Ω coaxial cable with BNC connectors from the Standard Amplitude Calibrator Output connector to the Indicator Oscilloscope Horiz Input and Ground through a BNC to Clip-lead adapter.

c. Adjust the Horizontal Position control and observe two dots as shown in Fig. 7-18.

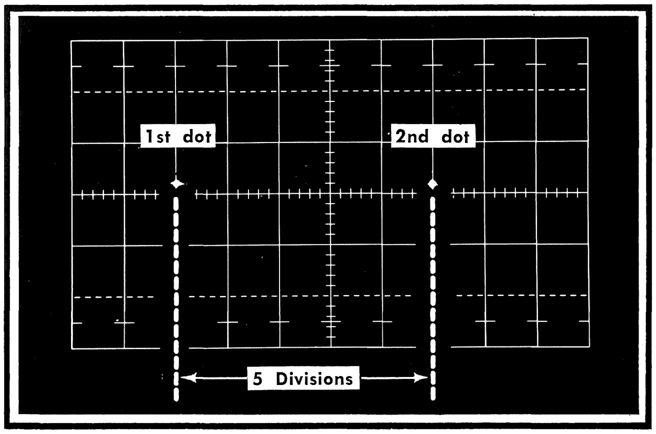


Fig. 7-18. Typical CRT display for calibrating Oscilloscope Ext Horizontal.

d. Adjust the 10-1 Variable control on the Indicator Oscilloscope for exactly 5 divisions between dots. Position the dots horizontally to the center area of the graticule.

e. Disconnect the Standard Amplitude Calibrator.

NOTE

Do not move the Variable 10-1 control during the timing adjustments which follow.

f. Reconnect the patch cord from the Type 1S2 HORIZ OUTPUT jack to the Indicator Oscilloscope Horiz Input jack.

g. Connect a 5 ns coaxial cable from the Time Mark Generator Marker Output through a BNC male adapter to the Type 1S2 upper THRU SIGNAL CHANNEL 50 Ω connector.

h. Connect a 50 Ω coaxial cable from the Time Mark Generator Trigger Output connector to the Type 1S2 EXT TRIG INPUT connector through a BNC female to GR adapter.

i. Connect a 50 Ω Termination to the lower THRU SIGNAL CHANNEL 50 Ω connector.

j. Repeat step 9, Adjust Comparison Firing Level, R677. Return the DISPLAY MODE switch to NORMAL.

k. Set the RESOLUTION switch to HIGH and adjust the UHF SYNC OR TRIGGER SENS control for a stable display.

l. Adjust SAMPLER RAMP TIMING, R588 shown in Fig. 7-20, for 1 marker/division on the graticule, check timing over the center 8 divisions. See Fig. 7-19.

m. Set the RESOLUTION switch to NORMAL, the RANGE switch to .1 μs, 10 m and the Time Mark Generator for the 10 ns signal.

n. Obtain a stable display and adjust C585B, Fig. 7-21, for 1 cycle per division.

o. Set the RANGE switch to 1 μs, 100 m and the Time Mark Generator for .1 μs markers.

p. Check for 1 marker/division within ±3%.

21. Check Magnifier Accuracy

a. Equipment setup remains as in step 20. Set the RANGE switch to 10 μs, 1 km, the RESOLUTION switch to HIGH and the Time Mark Generator for 1 μs markers.

b. Check the MAGNIFIER positions. Refer to Table 7-2 for settings and the display to be expected.

TABLE 7-2

Type 184 Marker Selector	Type 1S2 Range	Magnifier	Marks/ div
1 μs	10 μs	×1	1
.5 μs	10 μs	×2	1
.1 μs	10 μs	×5	2
.1 μs	10 μs	×10	1
50 ns	10 μs	×20	1
20 ns	10 μs	×50	1
10 ns	10 μs	×100	1

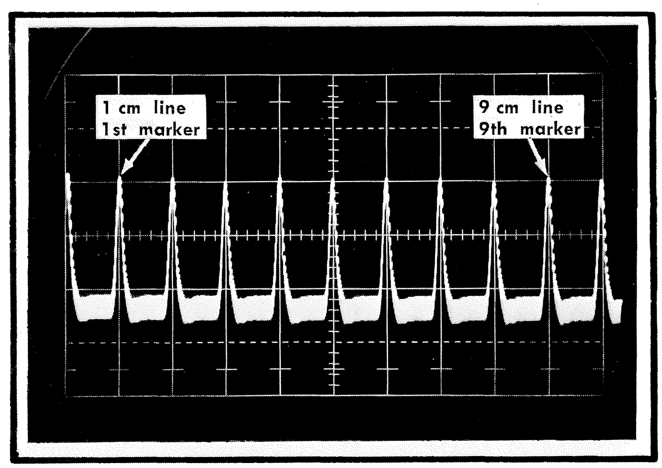


Fig. 7-19. Typical CRT display of time marks for adjusting timing.

22. Check Magnifier Variable Range

a. Set the Time Mark Generator to .1 μs markers and the Type 1S2 RANGE switch to 1 μs, 100 m, MAGNIFIER to ×1.

b. Rotate the MAGNIFIER VARIABLE control fully clockwise.

c. Check the display for at least 2.5 divisions between the first and third markers; see Fig. 7-22.

d. Set the MAGNIFIER VARIABLE to CAL.

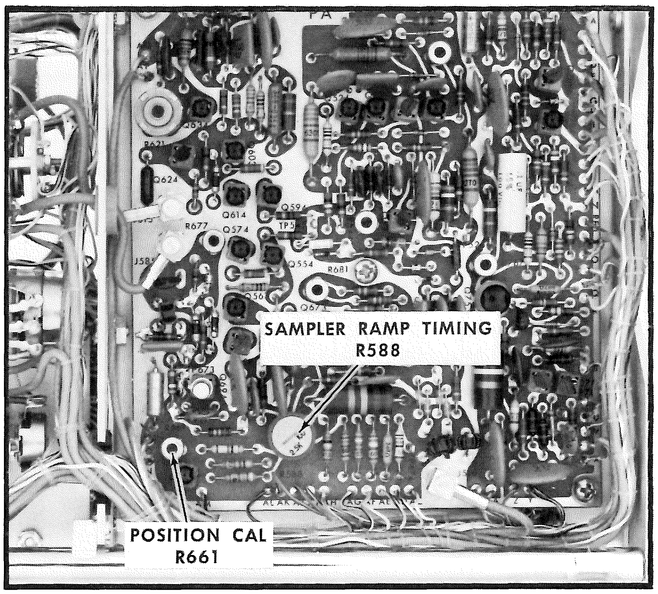


Fig. 7-20. Location of SAMPLER RAMP TIMING control, R588, and POSITION CAL, R661, on Horizontal circuit board.

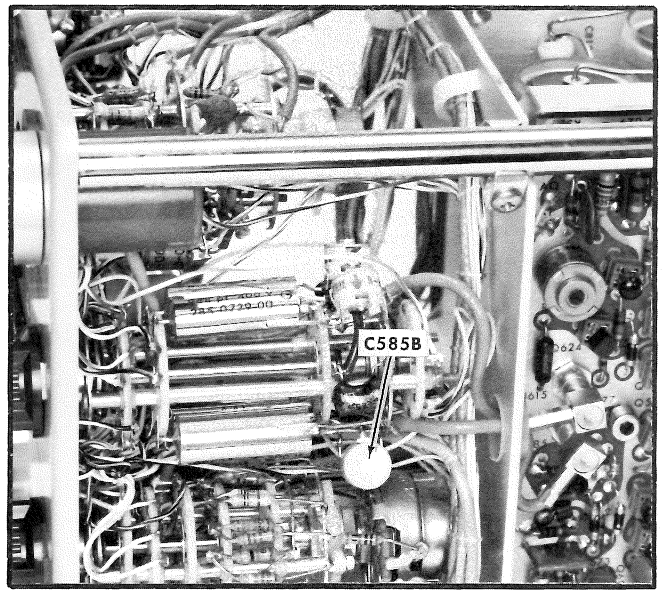


Fig. 7-21. Location of C585B for step 20.

23. Adjust Position Cal

a. Set the RANGE switch to 10 μs, 1 km.

b. Set the Time Mark Generator Marker Selector to 5 μs and the Trigger Selector to 10 μs.

c. Adjust the UHF SYNC OR TRIGGER SENS for a stable display on the Indicator Oscilloscope CRT.

d. Rotate the Type 1S2 POSITION control to position the first time mark to the 1 cm vertical graticule line. See Fig. 7-23.

e. Note the Type 1S2 POSITION dial reading.

f. Turn the Type 1S2 POSITION control 5 divisions counterclockwise and adjust the POSITION CAL control, R661, to place the time mark behind the 1 cm graticule line.

g. Repeat steps d through f until the markers line up with the 1 cm graticule mark with 5 divisions difference in the POSITION control settings. (There is some interaction between the POSITION control and R661.)

24. Check Incremental Accuracy of Position Control

a. Set the Time Mark Generator Marker Selector to 1 μs. Readjust the UHF SYNC OR TRIGGER SENS control if necessary for a stable display.

b. Set the Type 1S2 POSITION control fully clockwise.

c. Turn the Type 1S2 POSITION control counterclockwise until a time mark coincides with the 1 cm vertical graticule line.

d. Note the POSITION dial reading.

e. Continue turning the POSITION control and note the dial reading when the next marker coincides with the 1 cm graticule mark.

f. Note the POSITION dial reading. The dial reading should be the original setting plus 1 major division (outer dial), ±10 minor divisions (inner dial).

g. Turn the POSITION control and check the dial reading as each of the time marks coincides with the 1 cm graticule mark. Each reading should fall within the 10 minor divisions of the inner dial.

25. Check Dielectric Accuracy

a. Test equipment setup remains as in step 24.

b. Set the Time Mark Generator Selector to .1 μs and Trigger Selector to 1 μs.

c. Set the RANGE switch to 1 μs-100 m, DIELECTRIC switch to AIR and RESOLUTION switch to NORMAL.

d. Observe 1 marker per horizontal division on the Indicator Oscilloscope CRT.

e. Set the HORIZONTAL UNITS/DIV to DISTANCE.

f. Check for 8.73 to 9.27 divisions between the marker at the 1 cm graticule line and the sixth marker from the 1 cm graticule line.

g. Set the Time Mark Generator Marker Selector to 50 ns.

h. Adjust the UHF SYNC OR TRIGGER SENS control for a stable display.

i. Adjust the MAGNIFIER VARIABLE for exactly 1 cycle per graticule division. See Fig. 7-24.

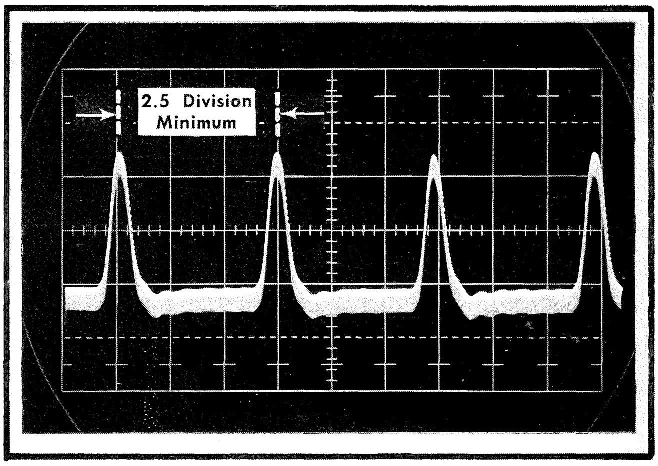


Fig. 7-22. Typical CRT display of time marks for checking Magnifier Variable range.

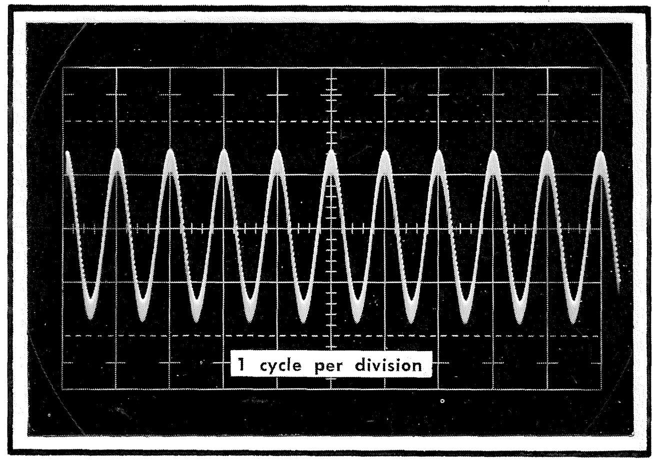


Fig. 7-24. Typical CRT display for checking Dielectric accuracy, step 25.

j. Set the DIELECTRIC switch to TFE.

k. Position a sine wave crest to the 1 cm graticule line with the Type 1S2 POSITION control.

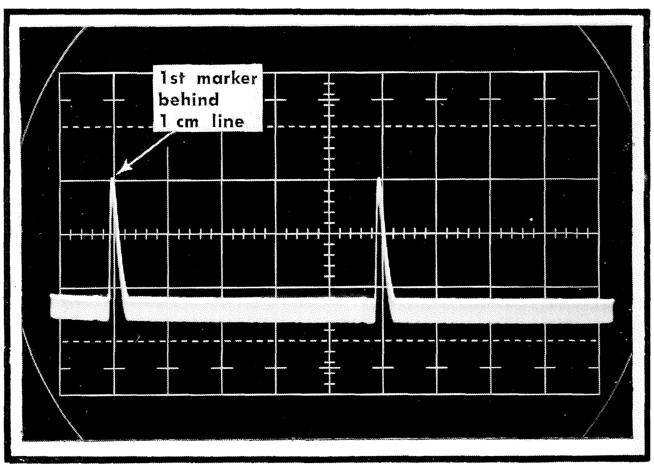


Fig. 7-23. Typical CRT display of time marks for adjusting Position Cal.

l. Measure the distance between the crest at the 1 cm graticule line and the twelfth crest from the 1 cm graticule line. The distance should lie between 8.1 and 8.6 divisions.

m. Set the DIELECTRIC switch to POLYETHYLENE.

n. Position a sine wave crest to the 1 cm graticule line, using the Type 1S2 POSITION control.

o. Measure the distance between the crest at the 1 cm graticule line and the twelfth crest from the 1 cm graticule line. The distance measured should be between 7.7 and 8.15 divisions.

p. Set the DIELECTRIC switch to PRESET.

q. Rotate the PRESET control fully counterclockwise.

r. Check the display for 1 cycle of sine wave per graticule line.

s. Rotate the DIELECTRIC PRESET control fully clockwise.

t. Measure the distance between the crest at the 1 cm graticule line and the twelfth crest from the 1 cm graticule line. The distance measured should lie between 7.2 and 7.8 divisions.

u. Disconnect the Time Mark Generator from the Type 1S2.

NOTES

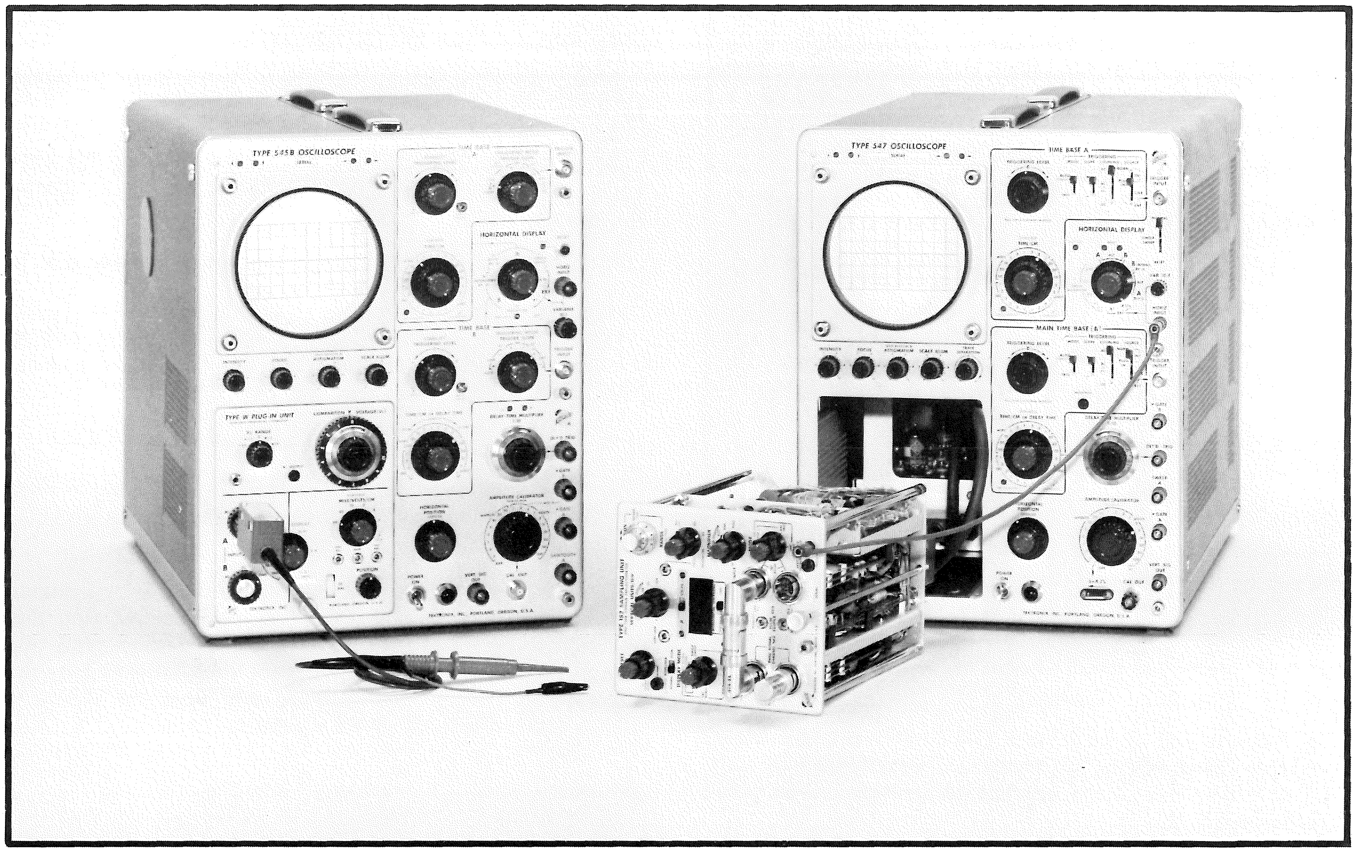


Fig. 7-25. Initial equipment setup for steps 26 through 37.

Control Settings

Type 1S2

OFFSET	Midrange
FINE	Midrange
VERTICAL UNITS/DIV	.2
VARIABLE	CAL
DISPLAY MODE	NORMAL
MANUAL SCAN	Clockwise
MODE	INT PULSE, 1 V
UHF SYNC OR TRIGGER SENS	As set in step 25
MAGNIFIER	×100
VARIABLE	CAL
RANGE	1 μs, 100 m
POSITION	0.00
HORIZONTAL UNITS/DIV	TIME
ρ—VOLTS	ρ
RESOLUTION	NORMAL

Indicator Oscilloscope

Horizontal Display	Ext, ×10
Variable 10-1	As previously set

Type W Plug-In

Display	A-Vc
Input Atten	1
Millivolts/cm	50
Variable	Cal
Comparison Voltage	0.00
Vc Range	0
Input A selector	Gnd
Position	Midrange

26. Adjust 1 Volt Pulse Stability and Pulse Start Level

a. Test equipment setup is shown in Fig. 7-25.

b. Connect the 10 inch GR Connector Cable between the Type 1S2 1 VPULSE SOURCE, 50 Ω and THRU SIGNAL CHANNEL, 50 Ω.

c. Connect a 50 Ω Termination, GR Type 874-W50B to the bottom THRU SIGNAL CONNECTOR, 50 Ω connector on the Type 1S2.

d. Adjust the front panel STABILITY 1.0 V 1 ns, R411, for a positive step. R621, PULSE POSITION, may be adjusted to place the pulse on the CRT graticule area (step 41).

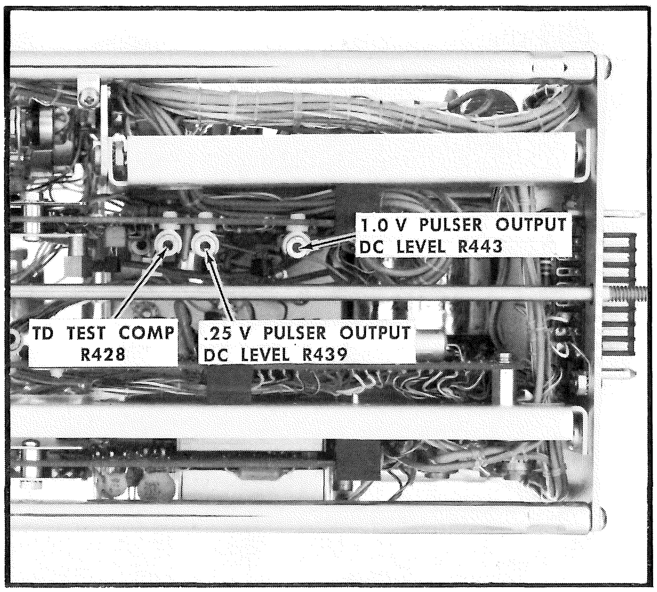


Fig. 7-26. Location of Pulser adjustments, bottom of Type 1S2.

e. Pull one end of the 10 inch GR Connector Cable out of the Type 1S2 connector far enough to break the signal path, and note the level of the baseline as seen on the Indicator Oscilloscope CRT.

f. Adjust the Type 1S2 1.0 Volt PULSER DC OUTPUT LEVEL, R443 (Fig. 7-26), while alternately connecting and disconnecting the signal, to set the pulse start at the same level as the baseline.

27. Check 1.0 Volt Pulser Risetime

a. Test equipment setup remains as in step 26.

b. Reset the Type 1S2 controls as follows:

VERTICAL UNITS/DIV	.2
MAGNIFIER	×100

c. Set the VARIABLE VERTICAL UNITS/DIV control for a 5 division display.

d. Check for a risetime of ≤1.1 ns as measured from the 10% to 90% amplitude points. See Fig. 7-27.

e. Set the VARIABLE control to CAL.

28. Adjust 1.0 Volt ρ Cal and Check Pulser Amplitude

a. Test equipment setup remains as in step 27.

b. Set the Type W Plug-In A selector to Gnd and connect the 10× Probe tip to the Type 1S2 VERT OUTPUT connector.

c. Set the Test Oscilloscope trace to the graticule center line using the Type W Position control.

d. Set the Type W Input A selector DC and the Vc Range to +1.1.

e. Rotate the Type 1S2 OFFSET control to bring the base line of the display on the Test Oscilloscope to the horizontal graticule center line.

f. Rotate the Type W Comparison Voltage outer dial to 5.00.

g. Adjust the Type 1S2 1.0 V ρ CAL, R351, Fig. 7-28 to position the top of the display to the Test Oscilloscope center line.

h. Switch the Type 1S2 ρ—VOLTS switch to VOLTS.

i. Rotate the Type W Comparison Voltage dials to position the top of the Test Oscilloscope display to the graticule center line.

j. The Type W Comparison Voltage dial reading should fall between 4.5 and 5.0 volts. (Comparison Voltage dial reading times the VERTICAL UNITS/DIV setting gives the signal amplitude. For example, 4.65 Volts, indicated by the Comparison Voltage dial ×.2 as read from the VERTICAL UNITS/DIV switch equals 0.93 Volts.)

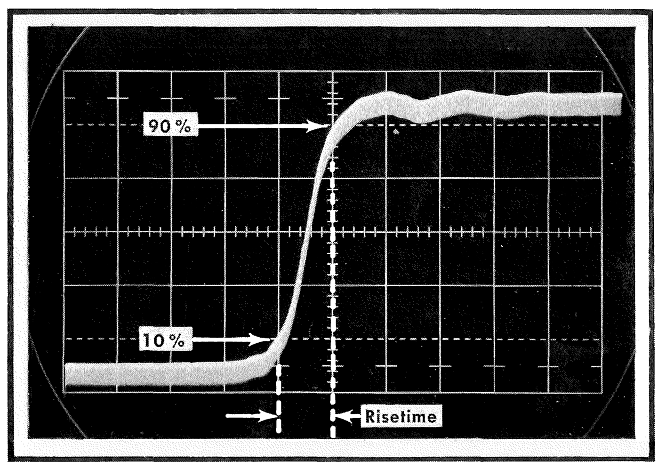


Fig. 7-27. Typical CRT display of 1.0 V Pulser risetime for step 27.

29. Check 1.0 Volt Pulser Jitter

a. Test equipment setup remains as in step 28.

b. Reset the Type 1S2 controls as follows:

VERTICAL UNITS/DIV	.005
MAGNIFIER	×100
RANGE	.1 μs

c. Center the display with the OFFSET controls.

d. Check for not more than 20 ps (1 minor division) of horizontal jitter.

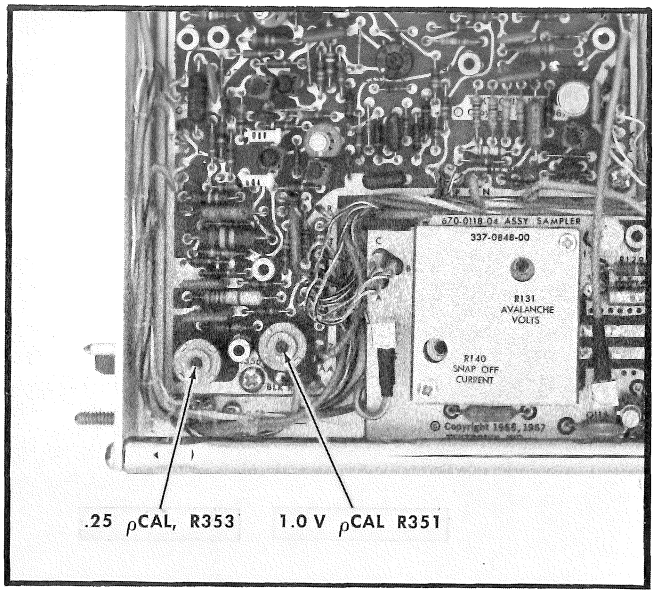


Fig. 7-28. Location of Pulser controls, Vertical circuit board.

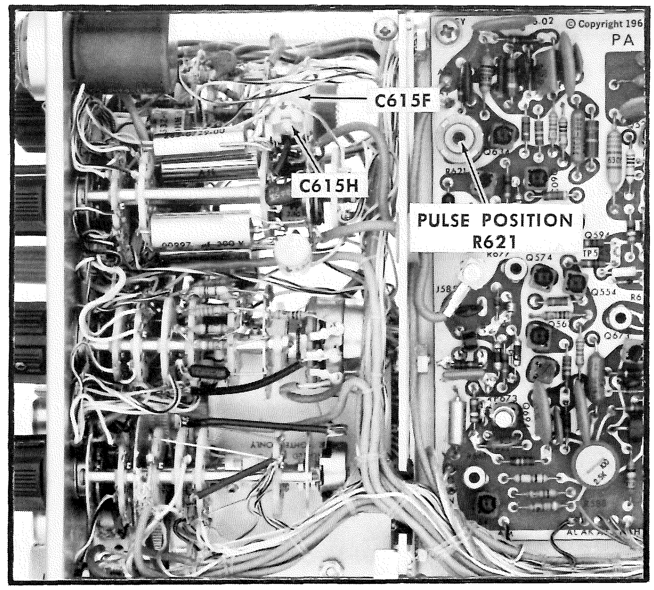


Fig. 7-29. Locations of C615F, C615H and PULSE POSITION, R621, control.

30. Adjust .25 Volt Pulser Stability and Pulse Start Level

a. Test equipment setup remains as in step 29.

b. Reset the Type 1S2 controls as follows:

MAGNIFIER	×10
MODE	.25 V
VERTICAL UNITS/DIV	.2
ρ—VOLTS	ρ

c. Set the OFFSET controls for a trace on the Indicator Oscilloscope CRT.

d. Move the end of the 10 inch GR Connector Cable connected to the Type 1S2 1.0 V PULSE SOURCE 50 Ω connector to the .25 V PULSE SOURCE 50 Ω connector.

e. Center the step with the Type 1S2 POSITION control.

f. Adjust the .25 V 50 ps STABILITY control, front panel, for a positive step on the Indicator Oscilloscope CRT. Set the control halfway between positions where the step disappears.

g. Pull one end of the 10 inch GR Connector Cable out of the Type 1S2 connector far enough to break the signal path and note the level of the baseline on the Indicator Oscilloscope CRT.

h. Adjust the Type 1S2 PULSER OUTPUT DC LEVEL, R439 (Fig. 7-26), while alternately connecting and disconnecting the signal to set the pulse start at the same level as the baseline.

NOTE

Proceed to the next step unless the .25 Volt Pulser signal moves rapidly across the CRT during warm-up or after several hours operation.

i. Warm the plates behind the INT PULSE connector for about 10 or 15 seconds with a hot air blower (not listed in Equipment Required), then adjust the TD TEMP COMP control, R428, to return the pulse display to the CRT.

j. Cool the plates to normal operating temperature and adjust the STABILITY control, part h.

k. Repeat parts i and j once more.

31. Adjust Pulse Position

a. Set the Type 1S2 VERTICAL UNITS/DIV switch to .05, POSITION dial to .000, and the MAGNIFIER switch to ×100.

b. Position the start of the display on the CRT graticule to the zero cm vertical graticule line, using the Indicator Oscilloscope Horizontal Position control.

c. Adjust the PULSE POSITION control, R621 (Fig. 7-29), to horizontally position the start of the pulse rise to the 1 cm graticule line.

d. Set the RANGE switch to 1 μs, 100 m.

e. Adjust C615F (see Fig. 7-29), to horizontally position the start of the pulse rise to the 1 cm graticule line.

f. Set the RANGE switch to .1 μs, 10 m.

g. Adjust C615H, (see Fig. 7-29) to horizontally position the start of the pulse to the 1 cm graticule line.

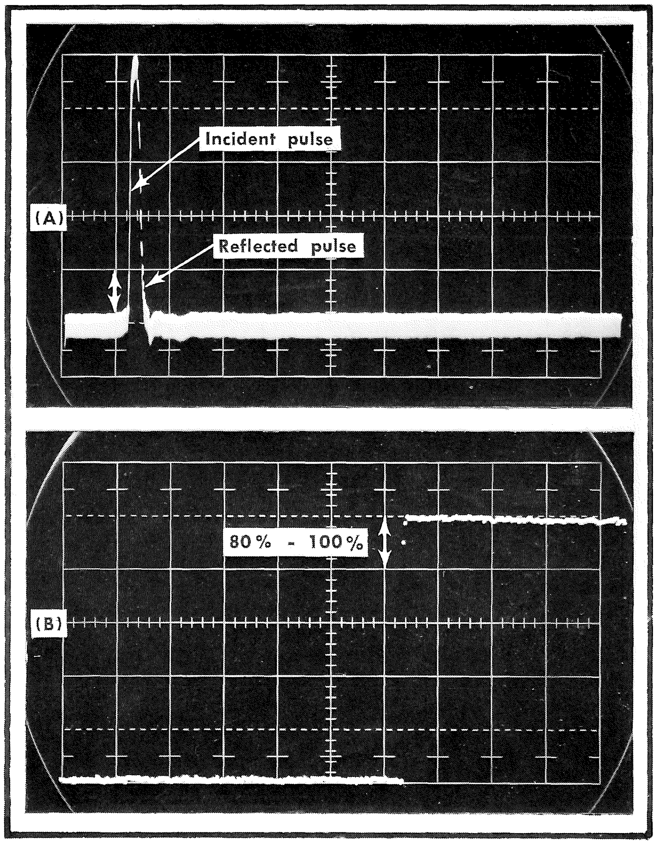


Fig. 7-30. (A) Incident and reflected pulses, and Avalanche Volts adjustment and (B) Test Oscilloscope display for Dot Response adjustment.

32. Adjust .25 Volt ρ CAL

a. Test equipment setup remains as in step 30. Connect the 10× Probe to the VERT OUTPUT jack.

b. Set the Type W Input A selector to Gnd, Comparison Voltage to 000 and adjust the Type W Position control to place the Test Oscilloscope trace to the graticule horizontal center line.

c. Switch the Type W Input A selector switch to DC.

d. Adjust the Type 1S2 OFFSET control to position the baseline of the Test Oscilloscope display to the graticule center line.

e. Rotate the Type W Comparison Voltage outer dial to 5.0 and set the Type W Vc Range to +1.1.

f. Adjust the Type 1S2 .25 Volt ρ CAL, R353 (Fig. 7-28), to position the top of the Test Oscilloscope display to the graticule center line.

g. Set the Type 1S2 ρ—VOLTS switch to VOLTS and the VERTICAL UNITS/DIV to .05.

h. Set Comparison Voltage to 000 and repeat part "d".

i. Rotate the Type W Comparison Voltage dials to position the top of the Test Oscilloscope display to the graticule center line.

j. Read the Comparison Voltage dials. The indication should fall between .6 and 5.2 Volts. (Pulser amplitude may be calculated as follows: Comparison Voltage dial indication X VERTICAL UNITS/DIV equal Pulser amplitude. For example, if the Comparison Voltage dials indicate 4.73 Volts; 4.73 X .05 = .236 Volts.)

k. Remove the 10× Probe.

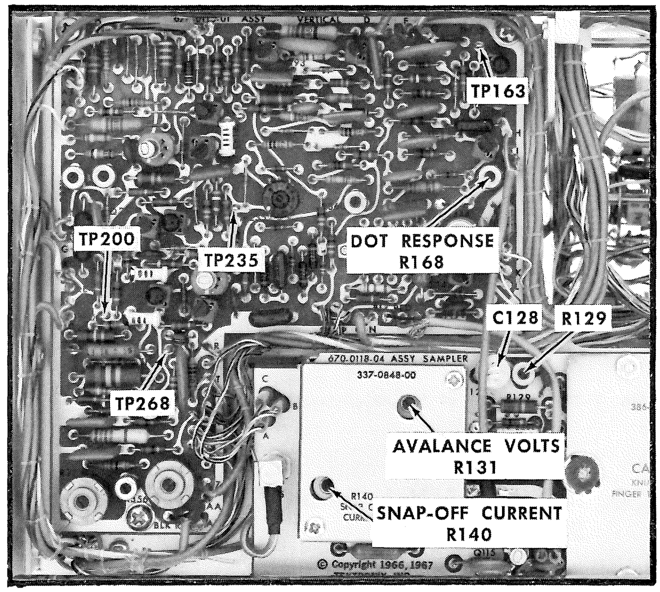


Fig. 7-31. Location of adjustments on Vertical circuit board for steps 34 and 35.

33. Check .25 Volt Pulser Jitter

a. Test equipment setup remains as in step 32. Center the display vertically with the OFFSET controls.

b. Reset the Type 1S2 controls as follows:

VERTICAL UNITS/ DIV	.005
MAGNIFIER	×100

c. Center the display with the 1S2 POSITION control.

d. Check for not more than 20 ps (1 minor division) of pulse jitter.

34. Check System Risetime

a. Test equipment setup remains as in step 33. Remove the 50 Ω Termination.

b. Connect a 20 cm Air Line to the upper THRU SIGNAL CHANNEL 50 Ω connector.

c. Connect a GR-874 WN Short Circuit Termination to the open end of the 20 cm Air Line.

d. Set the Type 1S2 Magnifier to ×1.

e. Position the trace with the Type 1S2 POSITION control to show both the incident and reflected portions of the waveform. See Fig. 7-30.

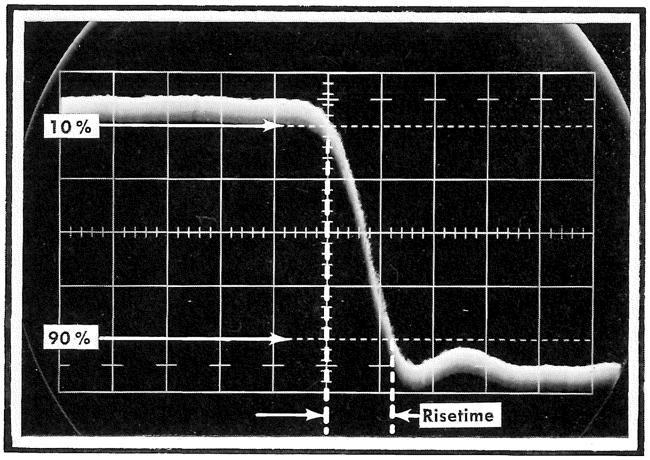


Fig. 7-32. Typical CRT display of system risetime for step 34.

f. Adjust the AVALANCHE VOLTS control (R131) for maximum separation between the pulse base line and the first dot of the vertical transition; this is counterclockwise of the free run setting.

g. Switch the Type 1S2 MAGNIFIER to ×100.

h. Position the reflected portion of the waveform to the graticule area using the Type 1S2 OFFSET and POSITION controls.

i. Readjust the Type 1S2 SNAP-OFF CURRENT control (R140), for the shortest risetime as measured from the 10% to the 90% amplitude points on the reflected portion of the pulse. See Fig. 7-31.

j. Measured risetime should be ≤140 ps.

NOTE

If either AVALANCHE VOLTS or SNAPOFF CURRENT requires adjustment, the DOT RESPONSE may require adjustment also.

k. Set the Test Oscilloscope Time/div switch to 2 ms, the Type W Input Atten switch to 10 and the Millivolts/cm switch to 10. Connect the 10× probe tip to test point TP268, the Memory Output.

l. Remove the 20 cm Air Line and install the 50 Ω termination to the upper THRU SIGNAL CHANNEL 50 Ω connector.

m. Set the RANGE switch to 10 μs, 1 km and adjust the Test Oscilloscope Triggering controls for a stable display similar to Fig. 7-30B.

n. Adjust the DOT RESPONSE control, R168, so the first dot is at least 80% or not more than 100% of the total amplitude as shown in Fig. 7-30B.

35. Adjust Transient Response

a. Test equipment setup remains as in step 34.

b. Move the end of the 10 inch GR Connector Cable connected to the Type 1S2 .25 V PULSE SOURCE 50 Ω connector to the 1.0 V PULSE SOURCE 50 Ω connector.

c. Set the Type 1S2 MAGNIFIER switch to ×1, RANGE switch to 1 μs, 100 m, ρ—VOLTS switch to ρ and the MODE switch to 1.0 V INT PULSE.

d. Set the VERTICAL UNITS/DIV switch to .2 and move the OFFSET controls to place the top of the waveform to the center of the CRT.

e. Adjust C128 and R129 for optimum flat top. Set the VERTICAL UNITS/DIV switch to .02, keeping the top of the waveform at the center of the CRT with the OFFSET controls, for the final adjustment. See Fig. 7-33.

f. Set the RESOLUTION switch to HIGH and the RANGE switch to 10 μs, 1 km.

g. Check the waveform for optimum flat top.

NOTES

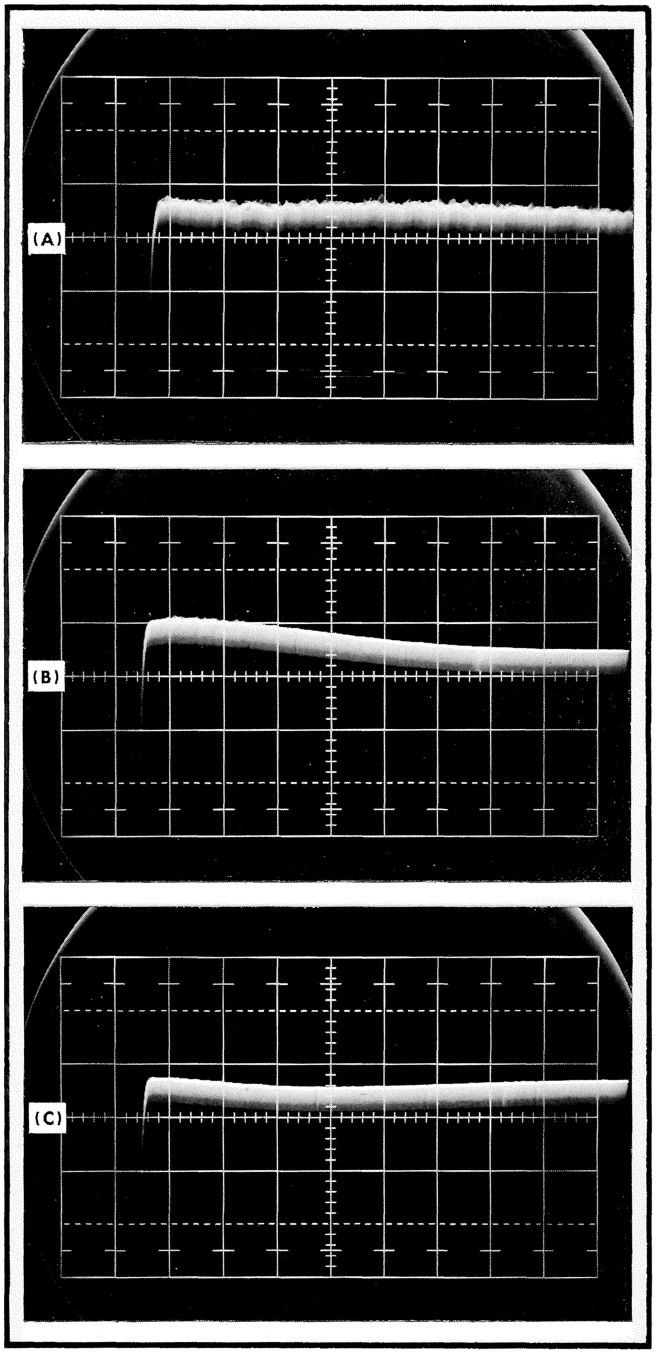


Fig. 7-33. Typical CRT displays for adjusting blow-by, transient response. (A) Correct display at .02 VERTICAL UNITS/DIV and (B) Incorrect setting of C128 at .2 and (C) Incorrect setting of R129 at .2.

36. Check 1.0 Volt Pulser Flatness Deviation

a. Test equipment setup remains as in step 35. Change the Type 1S2 controls as follows:

MAGNIFIER	×100
VERTICAL UNITS/DIV	.01
RANGE	1 μs,100 m

b. Move the OFFSET controls to place the top of waveform on the CRT. Establish the 100% level by turning the Type 1S2 POSITION control 3 or more turns and note the level.

c. Check the waveform for flatness deviation as follows: equal to or less than + or —2.5% (2.5 divisions) during the first 10 ns following the leading edge.

d. Check the waveform for flatness deviation equal to or less than 1% (1 division) after the first 10 ns following the leading edge.

37. Check .25 Volt Pulser Flatness Deviation

a. Move the end of the 10 inch GR Connector Cable connected to the Type 1S2 1.0 V PULSE SOURCE 50 Ω connector to the .25 V PULSE SOURCE 50 Ω connector.

b. Set the Type 1S2 MODE switch to INT PULSE .25 V, the RANGE to .1 μs, 10 m, and the VERTICAL UNITS/DIV switch to .05.

c. Position the top of the Indicator Oscilloscope display to the graticule area with the OFFSET controls. Establish the 100% level by turning the Type 1S2 POSITION control 3 or more turns and note the level.

d. Check the waveform flatness deviation for less than + and — 7% (1.4 divisions) during the first 500 ps following the leading edge.

e. Set the VERTICAL UNITS/DIV switch to .02.

f. Check the waveform flatness deviation for less than + and — 3% (1.5 division) after the first 500 ps following the leading edge.

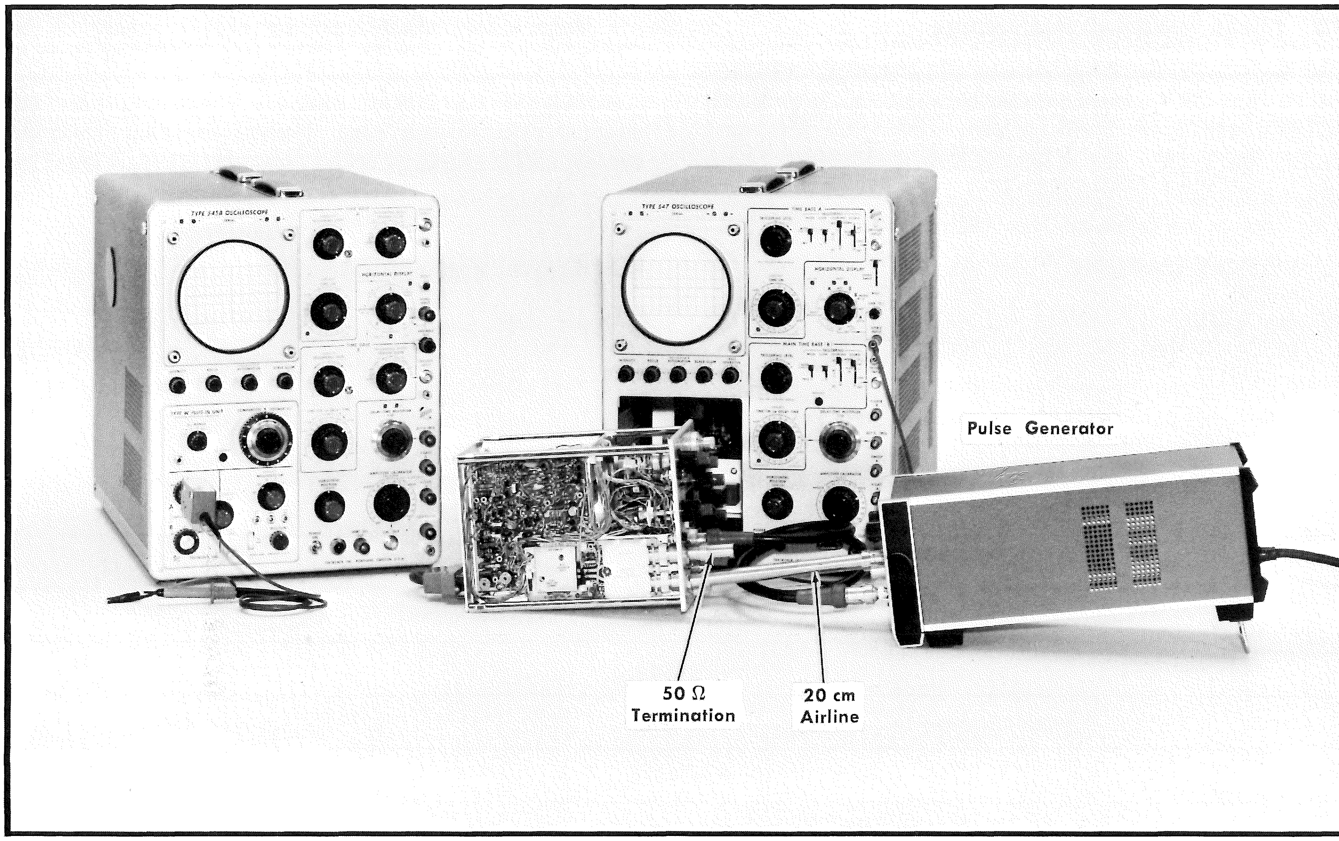


Fig. 7-34. Test equipment setup for step 38.

Control Settings

Type 1S2

OFFSET	Midrange
FINE	Midrange
VERTICAL UNITS/DIV	.05
VARIABLE	CAL
DISPLAY MODE	NORMAL
MANUAL SCAN	Clockwise
MODE	EXT TRIG
MAGNIFIER	×100
VARIABLE	CAL
RANGE	.1 μs, 10 m
UHF SYNC OR TRIGGER SENS	Counterclockwise
POSITION	0.00
HORIZONTAL UNITS/DIV	TIME
RESOLUTION	NORMAL
ρ—VOLTS	VOLTS
DIELECTRIC	AIR

Type 547 Oscilloscope

Horizontal Display	Ext, ×10
Variable 10-1	As previously set

Pulse Generator

Mode	Pulse Output

38. Check Sampler Risetime

a. Test equipment setup is shown in Fig. 7-34. Connect the Fast Rise Pulse Generator with the risetime of ≤70 ps to the lower THRU SIGNAL CHANNEL 50 Ω connector through a 50 Ω 20 cm Air Line. Connect the 50 Ω Termination to the upper THRU SIGNAL CHANNEL 50 Ω connector.

b. Connect the Pulse Generator Trigger Out to the EXT TRIG INPUT connector through a 50 Ω 5 ns coaxial cable and BNC male to GR adapter.

c. Position the trace on the Indicator Oscilloscope CRT with the Type 1S2 POSITION and OFFSET controls.

d. Adjust the UHF SYNC OR TRIGGER SENS control and the Pulse Generator TD Bias control for the fastest step with minimum time jitter. Adjust the VARIABLE VERTICAL UNITS/DIV control for 5 cm step amplitude.

e. Measure the risetime between the 10% and 90% amplitude points. Measured risetime should be ≤114 ps.

f. Disconnect the Pulse Generator and set the VARIABLE VERTICAL UNITS/DIV control to CAL.

39. Check Internal Reflections

a. Test equipment setup remains as in step 38. Connect the 10 inch GR Connector Cable between the .25 V PULSE SOURCE and lower THRU SIGNAL CHANNEL 50 Ω connectors and connect the 20 cm Air Line to the upper THRU SIGNAL CHANNEL 50 Ω connector.

b. Change the following Type 1S2 controls:

VERTICAL UNITS/DIV	.05
MODE	INT PULSE, .25 V
MAGNIFIER	×10
RESOLUTION	HIGH
ρ—VOLTS	ρ

c. Position the reflected portion of the display to the CRT graticule area with the OFFSET and POSITION controls.

d. Measure the flatness deviation about 4 ns after the reflected pulse leading edge. Flatness deviation should be less than 10% of the reflected pulse amplitude, 2 cm.

40. Check Vertical Balance

Repeat step 12, Adjust Bridge Balance, and step 13, Adjust Memory Gate Balance. Do not readjust AVALANCHE VOLTS or SNAPOFF CURRENT.

NOTES

Control Settings

Type 1S2

OFFSET	Midrange
FINE	Midrange
VERTICAL UNITS/DIV	.005
VARIABLE	CAL
DISPLAY MODE	NORMAL
MANUAL SCAN	Clockwise
MODE	EXT TRIG
UHF SYNC OR TRIGGER SENS	Counterclockwise
RANGE	10 μs, 1 km
POSITION	0.00
HORIZONTAL UNITS/ DIV	TIME
RESOLUTION	NORMAL
DIELECTRIC	AIR
ρ—VOLTS	VOLTS
MAGNIFIER	×1

Indicator Oscilloscope

Horizontal Display	Ext, ×10
Variable 10-1	As previously set

50 Ω Amplitude Calibrator

Volts	.12
Test-Operate	Operate

Variable Attenuator

Amplitude control	Midrange

41. Check Tangential Noise

Requirement: Less than 2 mV, measured tangentially.

NOTE

When making a visual noise reading from a sampling display, the eye interprets a noise value which is neither the RMS nor the peak to peak value. Since most observers agree that the displayed noise value is approximately 3 times the RMS value, the Tangential Noise here defined is 3 times the RMS value. (The measurement technique given produces acceptable agreement between various operators as to the instruments noise value.)

a. Using the indicator oscilloscope Amplitude Calibrator as a signal source, connect its output to the Type 1S2 Thru Signal Channel using the following items. At the Calibrator output, a BNC 50 Ω coaxial cable, then a BNC to GR coaxial adapter, a 5× GR attenuator, a 10× GR attenuator and the special variable attenuator feeding the Type 1S2 input. Place the 50 Ω termination onto the other Thru Signal Channel connector.

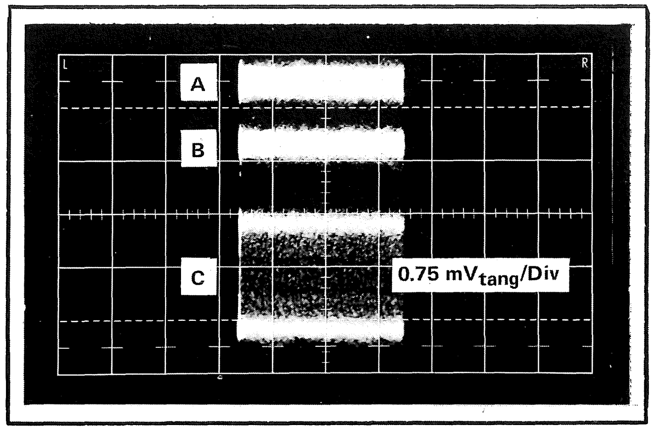


Fig. 7-35. Noise check waveform, Step 41.

b. Set the Type 1S2 connector.

EXT HORIZ ATTEN	about 9 o'clock
DISPLAY MODE	EXT HORIZ
(Turn down the osciloscope intensity)	
RESOLUTION	NORMAL
RANGE	Either the 1 μs or .1 μs
Trigger MODE	UHF SYNC
ρ - VOLTS	VOLTS
VERTICAL UNITS/DIV	.005
VARIABLE	CAL
OFFSET	For centered trace

c. Connect a double banana plug 18' patch cord from the oscilloscope Sawtooth A connector to the Type 1S2 Ext Horiz INPUT.

d. Set the indicator oscilloscope controls:

Horizontal Display	×1 (no change)
Time Base A Stability	Fully clockwise
Time Base A Time/Cm	.2 ms
Amplitude Calibrator	.1 V Into 50 Ω
Position	Centered display

The instrument should now have a shortened trace clearly displaying any sampling circuit noise. If not, adjust the OFFSET and Intensity and Horizontal Position controls for a display similar to Part A or Part B or Fig. 7-35.

e. Adjust the Variable Attenuator control for maximum signal amplitude. The display will now be two traces spaced slightly, similar to Fig. 7-35A.

Adjust the Variable Attenuator control to reduce the signal amplitude until the two traces just appear to be one trace, as shown in Fig. 7-35B.

Remove the 10× attenuator from the signal path (be careful not to change the Variable Attenuator control setting) and reconnect the 5× attenuator to the Variable Attenuator. The display will now be similar to Fig. 7-35C, from which the tangential noise can be read.

The display has a tangential noise deflection factor of 0.75 mV/Div. Maximum trace separation can be 2.66 major divisions. The example shown in Fig. 7-35C is just 2 major divisions, or a tangential noise of 1.5 mV.

Determining Tangential Noise Deflection Factor

The noise display of Fig. 7-35 has a noise deflection factor based upon the signal amplitude, the Type 1S2 vertical deflection factor in mV, the fact that the final trace separation is twice the RMS noise, and that the tangential noise is then 3 times the RMS noise. The square wave signal amplitude that makes two traces appear as one sets the trace separation at twice the RMS noise. The procedure used here then permits a noise deflection factor to be determined by dividing the input mV/div deflection factor by 2 (trace separation is 2× the RMS noise), multiplying by 3 (tangential noise is 3 times the RMS noise) and then dividing by 10 (the signal amplitude change complement).

f. If the tangential noise is outside the required limits, the Type 1S2 requires readjustment of either or both the the Avalanche Volts control (R131) or the Dot Response control (R168). See Step 34 of the Calibration Procedure.

g. Return the DISPLAY MODE switch to NORMAL.

42. Check Ext Horiz

a. Install the Type 1S2 in the Indicator Oscilloscope. Turn the power off, remove the flexible extension, and place the Type 1S2 in the oscilloscope. Turn the power on and wait about 5 minutes before proceeding.

b. Connect a 50 Ω coaxial cable with a BNC to clip lead adapter from the Standard Amplitude Calibrator Output connector to the Type 1S2 EXT HORIZ INPUT (with banana tip for probe) and to ground.

c. Observe two dots on the CRT, separated by at least 1 cm.

d. Rotate the Type 1S2 EXT HORIZ ATTEN fully counterclockwise.

e. Switch the Standard Amplitude Calibrator Amplitude control to 100 volts.

f. Check for not more than 1.5 cm spacing between the dots, if there are two dots.

g. Disconnect the Calibrator signals.

43. Check Manual Scan (Visual)

a. Test equipment setup remains as in step 43.

b. Set the Type 1S2 DISPLAY MODE to MANUAL SCAN and rotate the MANUAL SCAN control fully counterclockwise.

c. Position the dot on the CRT to the 0 cm vertical graticule line using the Indicator Oscilloscope Horizontal Position control.

d. Rotate the MANUAL SCAN control fully clockwise.

e. The dot should move to the right past the 10th cm graticule line.

44. Check External Trigger Jitter

a. Set the Type 1S2 controls as follows:

VERTICAL UNITS/DIV	.1
DISPLAY MODE	NORMAL
RANGE	10 μs, 1 km

b. Set the Constant Amplitude Signal Generator as follows:

Frequency Range	.35-.75 MHz
Variable	.35
Amplitude Range	.5 to 5 V
Amplitude	25

c. Connect a 50 Ω 5 ns coaxial cable with 5× attenuator from the Constant Amplitude Signal Generator to the lower THRU SIGNAL CHANNEL 50 Ω connector.

d. Connect a 50 Ω 2 ns coaxial cable from the upper THRU SIGNAL CHANNEL 50 Ω connector to the EXT TRIG INPUT connector.

e. Set the Constant Amplitude Signal Generator Amplitude controls for 5 vertical divisions of display on the CRT and adjust the UHF SYNC OR TRIGGER SENS control for a stable display.

f. Set the VERTICAL UNITS/DIV switch to .005 and the MAGNIFIER to ×10.

g. Position the single rising portion of the waveform to the graticule area using the Type 1S2 POSITION control.

h. Check for not more than 100 ns (1 division) or horizontal jitter.

i. Set the Constant Amplitude Signal Generator Frequency Range switch to 42-100 and rotate the Frequency Variable to 100.

j. Set the RANGE to .1 μs, 10 m and adjust the UHF SYNC OR TRIGGER SENS as necessary for a stable display on the CRT.

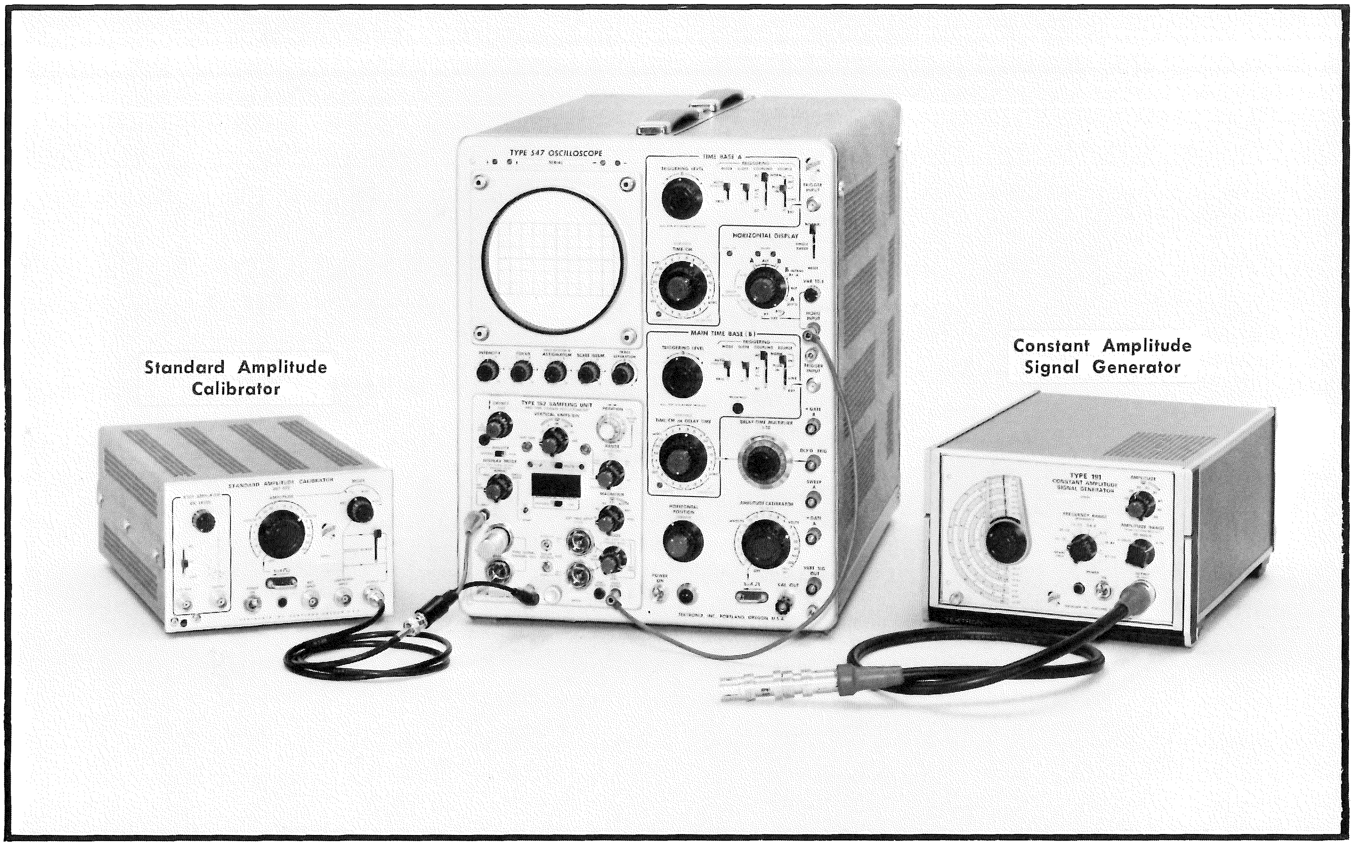


Fig. 7-36. Initial equipment setup for steps 42, 43 and 44.

k. Switch the VERTICAL UNITS/DIV to .005 and the MAGNIFIER to $\times$100, repositioning the trace as necessary, using the Type 1S2 POSITION control, to keep the display centered.

l. Check the display on the CRT for not more than 100 ps (1 division) of horizontal jitter.

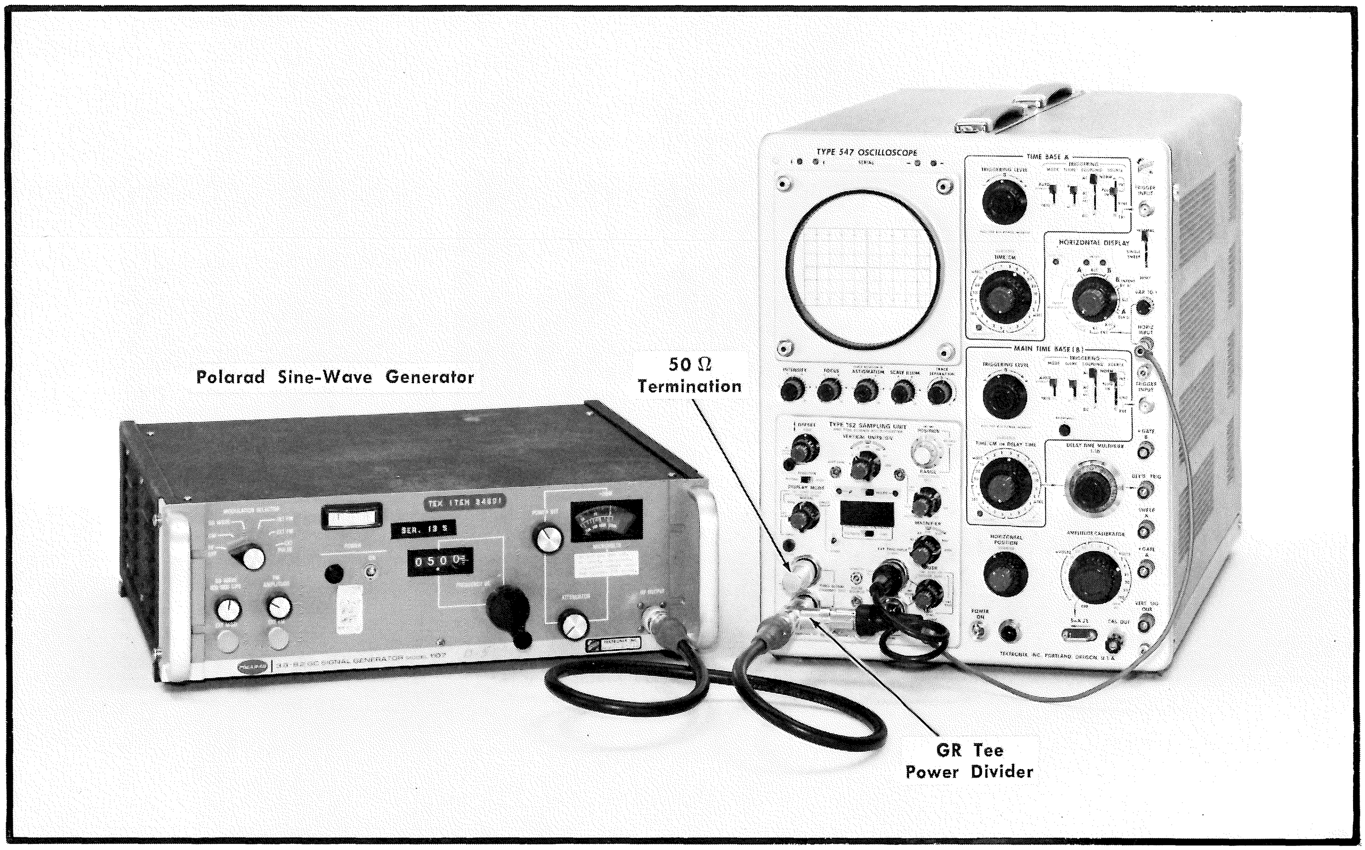


Fig. 7-37. Test equipment setup for step 45.

Control Settings

Type 1S2

OFFSET	Midrange
FINE	Midrange
VERTICAL UNITS/DIV	.1
VARIABLE	CAL
DISPLAY MODE	NORMAL
MANUAL SCAN	Clockwise
MODE	UHF SYNC
UHF SYNC OR TRIGGER SENS	Clockwise
MAGNIFIER	×100
RANGE	.1 μs, 10 m
POSITION	0.00
HORIZONTAL UNITS/ DIV	TIME
ρ—VOLTS	VOLTS
RESOLUTION	NORMAL
DIELECTRIC	AIR

Type 547 Oscilloscope

Horizontal Display	Ext, ×10
Variable 10-1	As previously set

45. Check UHF Sync Jitter (at 5 GHz)

a. Test equipment setup is shown in Fig. 7-37. Install the GR 50 Ω Termination in the upper THRU SIGNAL CHANNEL 50 Ω connector.

b. Connect a 50 Ω 5 ns cable from the Sine Wave Generator Output connector to the GR Tee Power Divider.

c. Connect the GR Tee Power Divider to the Type 1S2 lower THRU SIGNAL CHANNEL 50 Ω connector and a 50 Ω 2 ns cable from the GR Tee Power Divider to the EXT TRIG INPUT connector.

d. Set the Sine Wave Generator Frequency to 5 GHz.

e. Adjust the UHF SYNC OR TRIGGER SENS control for a stable display.

f. Set the Sine Wave Generator Output Amplitude for 3 divisions of display on the CRT.

g. Set the VERTICAL UNITS/DIV to .005 and reposition the display as necessary using the Type 1S2 POSITION control.

h. Check the display for not more than 30 ps (0.3 division) of horizontal jitter.

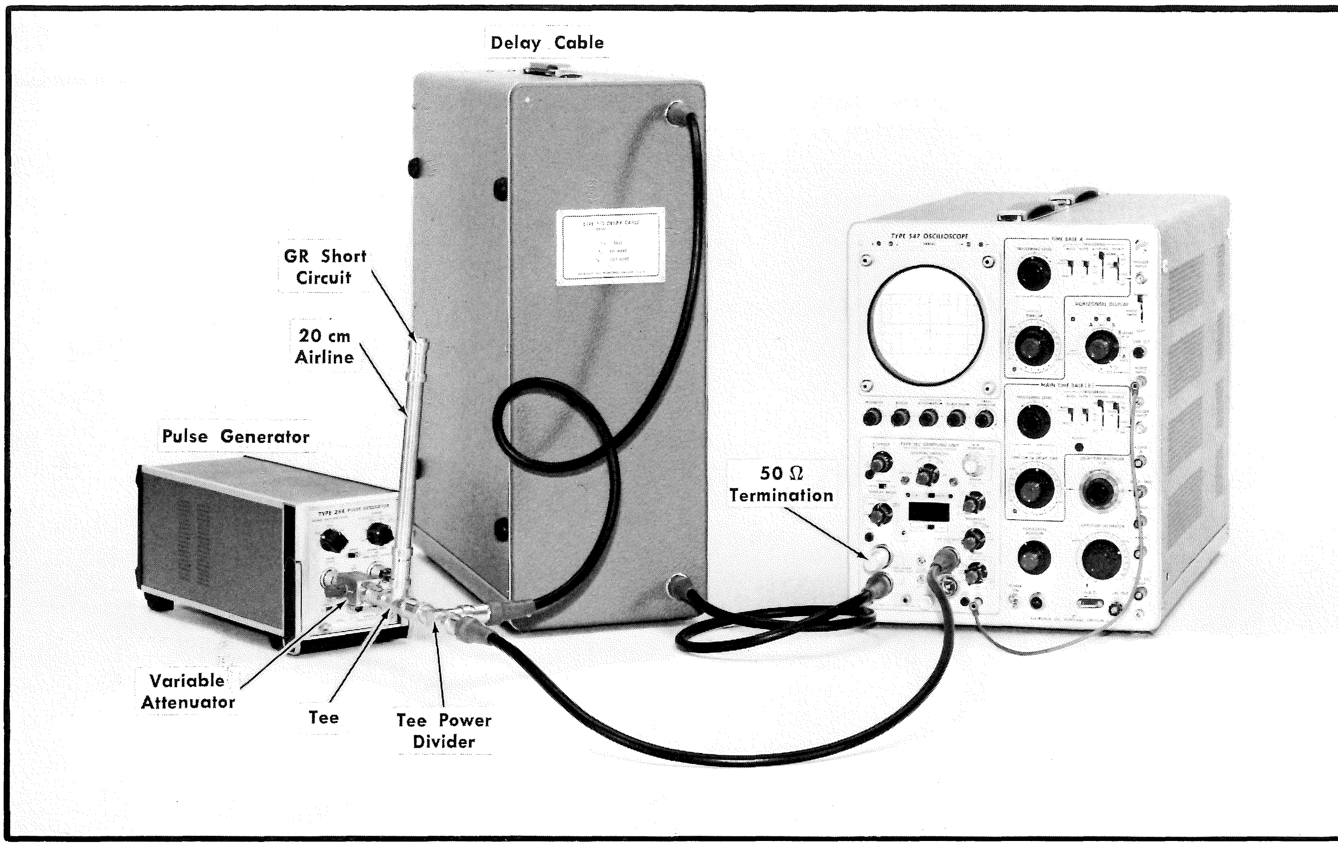


Fig. 7-38. Test equipment setup for step 46.

Control Settings

Type 1S2

OFFSET	Midrange
FINE	Midrange
VERTICAL UNITS/DIV	.1
VARIABLE	CAL
DISPLAY MODE	NORMAL
MANUAL SCAN	Clockwise
MODE	EXT TRIG
UHF SYNC OR TRIGGER SENS	Clockwise
MAGNIFIER	×1
RANGE	.1 μs, 10 m
POSITION	0.00
HORIZONTAL UNITS/DIV	TIME
RESOLUTION	NORMAL
ρ—VOLTS	VOLTS
DIELECTRIC	AIR

Type 547 Oscilloscope

Horizontal Display	Ext, ×10
Variable 10-1	As previously set

Pulse Generator

Mode	Pulse Output
Leadtime	70 ns

46. Check Trigger Jitter (50 mV Pulse Input)

a. Equipment setup is shown in Fig. 7-38. Connections are as follows:

Pulse Generator Pulse Output to Variable Attenuator, Tee connector, Tee Power Divider, 5 ns coaxial cable to the Delay Cable, and a 5 ns coaxial cable from the Delay Cable to the lower THRU SIGNAL CHANNEL 50 Ω connector.

Connect the 20 cm Air Line with GR Short Circuit to the Tee connector and connect a 5 ns coaxial cable from the Tee Power Divider to the Type 1S2 EXT TRIG INPUT connector.

Connect a 50 Ω Termination to the Type 1S2 upper THRU SIGNAL CHANNEL 50 Ω connector.

b. Adjust the UHF SYNC OR TRIGGER SENS for a stable display.

c. Adjust the Variable Attenuator for 5 divisions of display on the CRT.

d. Set the VERTICAL UNITS/DIV to .005 and the MAGNIFIER to ×100.

e. Position the leading edge of the display to the graticule area using the Type 1S2 POSITION control.

f. Check for not more than 100 ps (1 division) of horizontal jitter.

g. Remove all Signal and trigger cables from the Type 1S2 front panel.

47. Check Horizontal Units/Div Readout Lamp Operation

a. Check for proper operation of the HORIZONTAL UNITS/DIV readout lamps in all combinations of the DISTANCE-TIME, RANGE and MAGNIFIER positions. Table 7-3 shows switch positions and proper indications.

TABLE 7-3

RANGE	10 μs-1 km		1 μs-100 m		.1 μs-10 m	
MAGNIFIER	DISTANCE	TIME	DISTANCE	TIME	DISTANCE	TIME
×1	100 m	1000 ns	10 m	100 ns	100 cm	10 ns
×2	50 m	500 ns	5 m	50 ns	50 cm	5 ns
×5	20 m	200 ns	2 m	20 ns	20 cm	2 ns
×10	10 m	100 ns	1 m	10 ns	10 cm	1 ns
×20	5 m	50 ns	50 cm	5 ns	5 cm	500 ps
×50	2 m	20 ns	20 cm	2 ns	2 cm	200 ps
×100	1 m	10 ns	10 cm	1 ns	1 cm	100 ps

TIME and DISTANCE units will be extinguished when MAGNIFIER VARIABLE is out of the CAL position.

PARTS LIST ABBREVIATIONS

BHB	binding head brass
BHS	binding head steel
cap.	capacitor
cer	ceramic
comp	composition
conn	connector
CRT	cathode-ray tube
csk	countersunk
DE	double end
dia	diameter
div	division
elect.	electrolytic
EMC	electrolytic, metal cased
EMT	electrolytic, metal tubular
ext	external
F & I	focus and intensity
FHB	flat head brass
FHS	flat head steel
Fil HB	fillister head brass
Fil HS	fillister head steel
h	height or high
hex.	hexagonal
HHB	hex head brass
HHS	hex head steel
HSB	hex socket brass
HSS	hex socket steel
ID	inside diameter
inc	incandescent
int	internal
lg	length or long
met.	metal
mtg hdw	mounting hardware
OD	outside diameter
OHB	oval head brass
OHS	oval head steel
P/O	part of
PHB	pan head brass
PHS	pan head steel
plstc	plastic
PMC	paper, metal cased
poly	polystyrene
prec	precision
PT	paper, tubular
PTM	paper or plastic, tubular, molded
RHB	round head brass
RHS	round head steel
SE	single end
SN or S/N	serial number
S or SW	switch
TC	temperature compensated
THB	truss head brass
thk	thick
THS	truss head steel
tub.	tubular
var	variable
w	wide or width
WW	wire-wound

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix, Inc. Field Office or representative.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number, instrument type or number, serial or model number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix, Inc. Field Office or representative will contact you concerning any change in part number.

SPECIAL NOTES AND SYMBOLS

×000	Part first added at this serial number
00×	Part removed after this serial number
*000-0000-00	Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, Inc., or reworked or checked components.
Use 000-0000-00	Part number indicated is direct replacement.

SECTION 8
ELECTRICAL PARTS LIST

Values are fixed unless marked Variable.

Bulbs

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description
B370	150-0055-00			Neon, 5AB-B
B372	150-0055-00			Neon, 5AB-B
B940	150-0057-00			Incandescent, w/tinned leads
B941	150-0057-00			Incandescent, w/tinned leads
B942	150-0057-00			Incandescent, w/tinned leads
B943	150-0057-00			Incandescent, w/tinned leads
B944	150-0057-00			Incandescent, w/tinned leads
B945	150-0057-00			Incandescent, w/tinned leads
B946	150-0057-00			Incandescent, w/tinned leads
B947	150-0057-00			Incandescent, w/tinned leads
B951	150-0057-00			Incandescent, w/tinned leads
B952	150-0057-00			Incandescent, w/tinned leads
B953	150-0057-00			Incandescent, w/tinned leads
B954	150-0057-00			Incandescent, w/tinned leads
B956	150-0057-00			Incandescent, w/tinned leads
B957	150-0057-00			Incandescent, w/tinned leads

Capacitors

Tolerance ±20% unless otherwise indicated.

Ckt. No.	Tektronix Part No.	Eff	Disc	Description			
C110	283-0588-00	1990	2999	7.5 pF	Mica	500 V	5%
C110	283-0137-00	3000		7 pF	Cer		
C111	283-0588-00	1990	2999	7.5 pF	Mica	500 V	5%
C111	283-0137-00	3000		7 pF	Cer		
C114	283-0121-00	1990	2999	0.001 μF	Cer	200 V	
C114	283-0023-00	3000		0.1 μF	Cer	10 V	
C116	283-0004-00			0.02 μF	Cer	150 V	
C117	283-0032-00	1990	2999X	470 pF	Cer	500 V	5%
C118	283-0032-00	1990	2999X	470 pF	Cer	500 V	5%
C123	290-0135-00			15 μF	Elect.	20 V	
C125	290-0135-00			15 μF	Elect.	20 V	
C128	281-0091-00			2-8 pF, Var	Cer		
C129	283-0103-00			180 pF	Cer	500 V	5%
C130	283-0003-00	1990	2999	0.01 μF	Cer	150 V	
C130	283-0002-00	3000		0.01 μF	Cer	500 V	
C134	283-0113-00	1990	2999	56 pF	Cer	500 V	1%
C134	283-0054-00	3000		150 pF	Cer	200 V	5%
C136	281-0613-00			10 pF	Cer	200 V	10%
C137	281-0613-00	X3000		10 pF	Cer	200 V	10%
C142	283-0059-00			1 μF	Cer	25 V	+80%—20%
C145	283-0093-00	1990	2999X	15 pF	Cer	50 V	
C146	283-0135-00	1990	2999	100 pF	Cer		
C146	283-0121-00	3000		0.001 μF	Cer	200 V	
C147	283-0135-00	1990	2999	100 pF	Cer		
C147	283-0121-00	3000		0.001 μF	Cer	200 V	

Capacitors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
C148	283-0093-00			15 pF	Cer	50 V	
C149	283-0093-00			15 pF	Cer	50 V	
C155	283-0004-00			0.02 μF	Cer	150 V	
C158	283-0059-00			1 μF	Cer	25 V	+80%—20%
C159	283-0004-00			0.02 μF	Cer	150 V	
C160	283-0059-00			1 μF	Cer	25 V	+80%—20%
C163	283-0051-00			0.0033 μF	Cer	100 V	5%
C166	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C167	283-0067-00			0.001 μF	Cer	200 V	10%
C175	283-0077-00			330 pF	Cer	500 V	5%
C186	283-0059-00			1 μF	Cer	25 V	+80%—20%
C192	283-0026-00			0.2 μF	Cer	25 V	
C196	283-0027-00			0.02 μF	Cer	50 V	
C199	283-0032-00			470 pF	Cer	500 V	5%
C200	283-0103-00			180 pF	Cer	500 V	5%
C205	283-0115-00			47 pF	Cer	200 V	5%
C206	281-0504-00			10 pF	Cer	500 V	10%
C221	281-0523-00			100 pF	Cer	350 V	
C227	283-0059-00			1 μF	Cer	25 V	+80%—20%
C228	283-0059-00			1 μF	Cer	25 V	+80%—20%
C229	283-0059-00			1 μF	Cer	25 V	+80%—20%
C230	283-0026-00			0.2 μF	Cer	25 V	
C240	283-0594-00			0.001 μF	Mica	100 V	1%
C242	283-0067-00			0.001 μF	Cer	200 V	10%
C254	281-0504-00			10 pF	Cer	500 V	10%
C260	283-0602-00			53 pF	Cer	300 V	5%
C265	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C340	283-0026-00			0.2 μF	Cer	25 V	
C344	283-0115-00			47 pF	Cer	200 V	5%
C348	283-0067-00			0.001 μF	Cer	200 V	10%
C384	283-0114-00	1990	2999	0.0015 μF	Cer	200 V	
C384	283-0119-00	3000		2200 pF	Cer	200 V	5%
C385	290-0269-00			0.22 μF	Elect.	35 V	5%
C386	283-0002-00	X3000		0.01 μF	Cer	500 V	
C390	283-0004-00			0.02 μF	Cer	150 V	
C397	283-0067-00			0.001 μF	Cer	200 V	10%
C401	283-0103-00			180 pF	Cer	500 V	5%
C424	283-0095-00			56 pF	Cer	200 V	
C427	283-0070-00			30 pF	Cer	50 V	10%
C433	283-0069-00			15 pF	Cer	50 V	
C434	283-0069-00			15 pF	Cer	50 V	
C436	283-0072-01			0.01 μF	Cer		
C441	290-0261-00			6.8 μF	Elect.	35 V	
C453	283-0072-01			0.01 μF	Cer		
C458	290-0261-00			6.8 μF	Elect.	35 V	
C463	283-0072-01			0.01 μF	Cer		
C484	283-0072-01			0.01 μF	Cer		
C488	283-0067-00			0.001 μF	Cer	200 V	10%
C491	283-0069-00			15 pF	Cer	50 V	

Capacitors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
C493	283-0072-01			0.01 μF	Cer		
C494[1]							
C496	283-0059-00			1 μF	Cer	25 V	+80%—20%
C498	290-0261-00			6.8 μF	Elect.	35 V	
C499	283-0059-00			1 μF	Cer	25 V	+80%—20%
C504	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C505	283-0065-00			0.001 μF	Cer	100 V	5%
C507	283-0004-00			0.02 μF	Cer	150 V	
C516	283-0059-00			1 μF	Cer	25 V	+80%—20%
C517	283-0004-00			0.02 μF	Cer	150 V	
C518	283-0004-00			0.02 μF	Cer	150 V	
C520	283-0094-00			27 pF	Cer	200 V	10%
C526	281-0613-00			10 pF	Cer	200 V	
C528	283-0047-00			270 pF	Cer	500 V	5%
C529	283-0142-00			0.0027 μF	Cer	200 V	5%
C530	283-0004-00			0.02 μF	Cer	150 V	
C543	283-0059-00			1 μF	Cer	25 V	+80%—20%
C545	283-0116-00			820 pF	Cer	500 V	5%
C549	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C562	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C580	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C585B	281-0096-00			5.5-18 pF, Var Air			
C585C[2] } C585E }	*295-0101-00			Timing Capacitor			
C585G	285-0006-00			68 pF	Glass	500 V	5%
C586	283-0004-00			0.02 μF	Cer	150 V	
C602	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C615C[2]	*295-0101-00			Timing Capacitor			
C615D	283-0597-00			470 pF	Mica	300 V	10%
C615E[2]	*295-0101-00			Timing Capacitor			
C615F	281-0097-00			9-35 pF, Var	Cer		
C615G	283-0602-00	1990	3059	53 pF	Mica	300 V	5%
C615G	283-0634-00	3060	3109	65 pF	Mica	100 V	1%
C615G	283-0634-00	3110		65 pF (nominal value) Selected			
C615H	281-0097-00			9-35 pF, Var	Cer		
C618	283-0067-00			0.001 μF	Cer	200 V	10%
C632	283-0059-00			1 μF	Cer	25 V	+80%—20%
C634	283-0094-00	1990	3109	27 pF	Cer	200 V	10%
C634	283-0103-00	3110		180 pF	Cer	500 V	5%
C636	283-0060-00	1990	3109X	100 pF	Cer	200 V	5%
C670	283-0094-00			27 pF	Cer	200 V	10%
C672	283-0004-00			0.02 μF	Cer	150 V	
C673	283-0059-00			1 μF	Cer	25 V	+80%—20%
C675	283-0115-00			47 pF	Cer	200 V	5%
C694	283-0065-00			0.001 μF	Cer	100 V	5%
C695	290-0261-00			6.8 μF	Elect.	35 V	
C699	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C710	283-0077-00			330 pF	Cer	500 V	5%

[1]Part of etched wiring.
[2]C585C, C585E and C615C, C615E furnished as a unit.

Capacitors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
C740	290-0261-00			6.8 μF	Elect.	35 V	
C750	285-0703-00			0.1 μF	PTM	100 V	5%
C751	283-0004-00			0.02 μF	Cer	150 V	
C761	283-0103-00			180 pF	Cer	500 V	5%
C765	283-0060-00			100 pF	Cer	200 V	5%
C782	283-0060-00			100 pF	Cer	200 V	5%
C784	283-0065-00			0.001 μF	Cer	100 V	5%
C787	283-0065-00			0.001 μF	Cer	100 V	5%
C797	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C798	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C812	290-0300-00			1300 μF	Elect.	40 V	+75%—10%
C822	283-0094-00			27 pF	Cer	200 V	10%
C829	290-0286-00			50 μF	Elect.	25 V	+75%—10%
C852	290-0300-00			1300 μf	Elect.	40 V	+75%—10%
C862	283-0094-00			27 pF	Cer	200 V	10%
C869	290-0286-00			50 μF	Elect.	25 V	+75%—10%
C872	283-0103-00			180 pF	Cer	500 V	5%
C886	283-0027-00			0.02 μF	Cer	150 V	
C889	290-0285-00			4 μF	Elect.	200 V	+50%—10%

Semiconductor Device, Diodes

Ckt. No.	Tektronix Part No.	Eff	Disc	Description	
D110, D111	*152-0259-00	1190	3059	GaAs	(1 pair)
D110, D111	*152-0482-00	3060		Schottky Barrier	(1 pair)
D123	152-0195-00			Zener	1N751A 0.4 W, 5.1 V, 5%
D144	*152-0252-00			Silicon	Snap off
D148	152-0141-02	1990	2999X	Silicon	1N4152
D161	*152-0185-00			Silicon	Replaceable by 1N4152
D186	*152-0185-00			Silicon	Replaceable by 1N4152
D203	152-0008-00			Germanium	
D210	*152-0185-00			Silicon	Replaceable by 1N4152
D211	*152-0185-00			Silicon	Replaceable by 1N4152
D224	*152-0185-00			Silicon	Replaceable by 1N4152
D230	152-0195-00			Zener	1N751A 0.4 W, 5.1 V, 5%
D231	*152-0185-00			Silicon	Replaceable by 1N4152
D232	*152-0185-00			Silicon	Replaceable by 1N4152
D235	*152-0185-00			Silicon	Replaceable by 1N4152
D236	*152-0185-00			Silicon	Replaceable by 1N4152
D237	*152-0323-00			Silicon	Tek Spec
D238	*152-0185-00			Silicon	Replaceable by 1N4152
D239	*152-0323-00			Silicon	Tek Spec
D254	*152-0185-00			Silicon	Replaceable by 1N4152
D262	*152-0323-00			Silicon	Tek Spec
D263	*152-0323-00			Silicon	Tek Spec
D266	*152-0185-00			Silicon	Replaceable by 1N4152
D344	*152-0185-00			Silicon	Replaceable by 1N4152
D376	*152-0185-00			Silicon	Replaceable by 1N4152

Semiconductor Device, Diodes *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc		Description
D391	152-0268-00			Zener	1N979B 0.4 W, 56 V, 5%
D392	*152-0185-00			Silicon	Replaceable by 1N4152
D393	*152-0185-00			Silicon	Replaceable by 1N4152
D394	*152-0185-00			Silicon	Replaceable by 1N4152
D395	*152-0185-00			Silicon	Replaceable by 1N4152
D396	*152-0185-00			Silicon	Replaceable by 1N4152
D397	*152-0185-00			Silicon	Replaceable by 1N4152
D423	152-0140-01			Tunnel	8 pF, 10 mA
D424	152-0169-00			Tunnel	1N3712 1 mA
D425	*152-0277-00	1990	2049	Tunnel	Tek Spec 100 mA
D425	152-0375-00	2050		Tunnel	400 pf 100 mA
D435	*152-0276-00	1990	2242	Tunnel	Ass'y Tek Spec
D435	*152-0276-01	2243	2289	Tunnel	Ass'y Tek Spec
D435	*153-0043-00	2290		Tunnel	Ass'y Tek Spec
D455	*152-0185-00			Silicon	Replaceable by 1N4152
D456	*152-0185-00			Silicon	Replaceable by 1N4152
D465	*152-0185-00			Silicon	Replaceable by 1N4152
D466	*152-0185-00			Silicon	Replaceable by 1N4152
D483	152-0070-00			Back	BD4 0.1 mA
D484	152-0195-00			Zener	1N751A 0.4 W, 5.1 V, 5%
D485	152-0177-00			Tunnel	TD253B 10 mA
D493	*152-0185-00			Silicon	Replaceable by 1N4152
D504	*152-0185-00			Silicon	Replaceable by 1N4152
D515	*152-0322-00			Silicon	Tek Spec
D516	*152-0322-00			Silicon	Tek Spec
D517	*152-0322-00			Silicon	Tek Spec
D518	*152-0322-00			Silicon	Tek Spec
D520	*152-0185-00			Silicon	Replaceable by 1N4152
D522	*152-0075-00			Germanium	Tek Spec
D524	152-0070-00			Back	BD4 0.1 mA
D525	152-0177-00			Tunnel	TD253B 10 mA
D526	152-0008-00			Germanium	
D528	*152-0185-00			Silicon	Replaceable by 1N4152
D540	*152-0185-00			Silicon	Replaceable by 1N4152
D541	*152-0185-00			Silicon	Replaceable by 1N4152
D544	152-0079-00			Germanium	HD1841
D545	152-0177-00			Tunnel	TD253B 10 mA
D563	*152-0211-00	1990	3059	GaAs	w/leads
D563	*152-0457-00	3060		Schottky Barrier	
D603	*152-0211-00	1990	3059	GaAs	w/leads
D603	*152-0457-00	3060		Schottky Barrier	
D672	*152-0185-00			Silicon	Replaceable by 1N4152
D673	*152-0211-00	1990	3059	GaAs	w/leads
D673	*152-0457-00	3060		Schottky Barrier	
D675	*152-0125-00			Tunnel	Selected TD3A 4.7 mA
D695	*152-0125-00			Tunnel	Selected TD3A 4.7 mA
D710	*152-0185-00			Silicon	Replaceable by 1N4152
D724	*152-0185-00			Silicon	Replaceable by 1N4152
D725	*152-0373-00			Tunnel	Selected TD716 4.7 mA
D740	*152-0185-00			Silicon	Replaceable by 1N4152
D742	*152-0185-00			Silicon	Replaceable by 1N4152

Semiconductor Device, Diodes *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
D743	*152-0185-00			Silicon	Replaceable by 1N4152
D764	*152-0185-00			Silicon	Replaceable by 1N4152
D780	152-0061-00			Silicon	Tek Spec
D781	*152-0107-00			Silicon	Replaceable by 1N647
D782	*152-0107-00			Silicon	Replaceable by 1N647
D783	152-0195-00			Zener	1N751A 0.4 W, 5.1 V, 5%
D787	*152-0185-00			Silicon	Replaceable by 1N4152
D810	152-0066-00			Silicon	1N3194
D811	152-0066-00			Silicon	1N3194
D821	*152-0185-00			Silicon	Replaceable by 1N4152
D850	152-0066-00			Silicon	1N3194
D851	152-0066-00			Silicon	1N3194
D861	152-0195-00			Zener	1N751A 0.4 W, 5.1 V, 5%
D862	*152-0185-00			Silicon	Replaceable by 1N4152
D870	*152-0185-00			Silicon	Replaceable by 1N4152
D871	*152-0185-00			Silicon	Replaceable by 1N4152
D883	*152-0107-00			Silicon	Replaceable by 1N647
D884	*152-0185-00			Silicon	Replaceable by 1N4152
D885	152-0195-00			Zener	1N751A 0.4 W, 5.1 V, 5%

Connectors

Ckt. No.	Tektronix Part No.	Eff	Disc	Description
J115	131-0391-00			Coax, 50 Ω male
J135	131-0391-00			Coax, 50 Ω male
J269	*136-0140-00			Socket, Banana Jack Assembly
J348	*136-0140-00			Socket, Banana Jack Assembly
J496	131-0391-00			Coax, 50 Ω male
J585	131-0391-00			Coax, 50 Ω male
J615	131-0391-00			Coax, 50 Ω male
J770	*136-0140-00			Socket, Banana Jack Assembly
J784	*136-0140-00			Socket, Banana Jack Assembly

Inductors

Ckt. No.	Tektronix Part No.	Eff	Disc	Description
L268	*120-0402-00			Toroid, 3 turns, single
L435	*108-0270-01	1990	3029	0.25 μH
L435	*108-0270-00	3030		0.25 μH
L445	*108-0410-00			1 μH
L458	*120-0382-00			Toroid, 14 turns, single
L483	*108-0260-00			0.1 μH
L494	276-0507-00			Core, Ferramic Suppressor
L498	*120-0382-00			Toroid, 14 turns, single
L510	*120-0382-00			Toroid, 14 turns, single
L525	*108-0215-00			1.1 μH

Plug

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
P11	131-0017-00			Chassis mtd., 16 contact, male	

Transistors

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
Q115	151-1012-00			Silicon	FET
Q124	*151-0198-00			Silicon	Replaceable by MPS-918
Q133	151-0179-00			Silicon	2N3877A
Q134	*153-0556-00	1990	2999	Silicon	Avalanche to Tek Spec
Q134	151-0108-00	3000		Silicon	Replaceable by 2N2501
Q137	151-0250-00	X3000		Silicon	2N5184
Q143	151-0190-00			Silicon	2N3904
Q154	*151-0192-00			Silicon	Replaceable by MPS-6521
Q163	151-0220-00			Silicon	2N4122
Q164	151-0220-00			Silicon	2N4122
Q184	151-0190-00			Silicon	2N3904
Q193	151-0190-00			Silicon	2N3904
Q204	151-0190-00			Silicon	2N3904
Q214	151-0220-00			Silicon	2N4122
Q224	151-0190-00			Silicon	2N3904
Q244A,B	151-1007-00			FET	Dual
Q254	151-0220-00			Silicon	2N4122
Q263	151-0190-00			Silicon	2N3904
Q343	151-0190-00			Silicon	2N3904
Q344	151-0087-00			Silicon	2N1131
Q379	151-0179-00			Silicon	2N3877A
Q393A,B	151-1011-00	1990	3089	Silicon	Dual, FET
Q393A,B	151-1041-00	3090		Silicon	Dual, FET
Q403	151-0190-00			Silicon	2N3904
Q404	151-0190-00			Silicon	2N3904
Q414	151-0188-00			Silicon	2N3906
Q424	151-0134-00			Silicon	2N2905
Q434	151-0188-00			Silicon	2N3906
Q454	*151-0212-01	1990	2339	Silicon	Tek Spec
Q454	*151-0212-00	2340		Silicon	Tek Spec
Q464	*151-0212-01	1990	2339	Silicon	Tek Spec
Q464	*151-0212-00	2340		Silicon	Tek Spec
Q474	151-0131-00			Germanium	2N964
Q494	*151-0198-00			Silicon	Replaceable by MPS-918
Q503	*151-0219-00			Silicon	Replaceable by 2N4250
Q523	151-0190-00			Silicon	2N3904
Q524	151-0224-00			Silicon	2N3692
Q534	151-0224-00			Silicon	2N3692
Q544	151-0188-00			Silicon	2N3906
Q554	151-0221-00	1990	3109	Silicon	2N4258
Q554	151-0188-00	3110		Silicon	2N3906
Q563	151-0224-00			Silicon	2N3692
Q574	151-0220-00			Silicon	2N4122
Q581	151-0190-00			Silicon	2N3904
Q594	151-0221-00	1990	3109	Silicon	2N4258
Q594	151-0188-00	3110		Silicon	2N3906
Q603	151-0224-00			Silicon	2N3692

Transistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
Q614	151-0220-00			Silicon	2N4122
Q624	151-0190-00			Silicon	2N3904
Q634	151-0220-00			Silicon	2N4122
Q664	*151-0219-00			Silicon	Replaceable by 2N4250
Q673	151-0190-00			Silicon	2N3904
Q674A	151-0188-00			Silicon	2N3906
Q674B	151-0188-00			Silicon	2N3906
Q694	*153-0560-00			Germanium	Selected from 2N964
Q724	151-0190-00			Silicon	2N3904
Q734	151-0220-00			Silicon	2N4122
Q753A,B	151-0249-00	1990	2999	Silicon	Dual
Q753A,B	151-0232-00	3000		Silicon	Dual
Q761	*151-0192-00			Silicon	Replaceable by MPS-6521
Q783	*151-0195-00			Silicon	Replaceable by MPS-6515
Q823	151-0190-00			Silicon	2N3904
Q824	151-0190-00			Silicon	2N3904
Q827	*151-0148-00			Silicon	Selected from 40250 (RCA)
Q863	151-0190-00			Silicon	2N3904
Q864	151-0190-00			Silicon	2N3904
Q867	*151-0148-00			Silicon	Selected from 40250 (RCA)
Q874	*151-0228-00			Silicon	Tek Spec
Q884	151-0188-00			Silicon	2N3906
Q887	151-0149-00			Silicon	2N3441

Resistors

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

R104	317-0390-00	1990	2999	39 Ω	1/8 W		5%
R104	317-0510-00	3000		51 Ω	1/8 W		5%
R105	317-0390-00	1990	2999	39 Ω	1/8 W		5%
R105	317-0510-00	3000		51 Ω	1/8 W		5%
R106	317-0390-00	1990	2999	39 Ω	1/8 W		5%
R106	317-0510-00	3000		51 Ω	1/8 W		5%
R107	317-0390-00	1990	2999	39 Ω	1/8 W		5%
R107	317-0510-00	3000		51 Ω	1/8 W		5%
R110	317-0151-00	1990	2999	150 Ω	1/8 W		5%
R110	317-0201-00	3000		200 Ω	1/8 W		5%
R111	317-0151-00	1990	2999	150 Ω	1/8 W		5%
R111	317-0201-00	3000		200 Ω	1/8 W		5%
R115	315-0391-00	1990	2999X	390 Ω	1/4 W		5%
R116	321-0227-00			2.26 kΩ	1/8 W	Prec	1%
R117	315-0104-00	1990	2999	100 kΩ	1/4 W		5%
R117	317-0473-00	3000		47 kΩ	1/8 W		5%
R118	315-0104-00	1990	2999	100 kΩ	1/4 W		5%
R118	317-0473-00	3000		47 kΩ	1/8 W		5%
R120	317-0391-00			390 Ω	1/8 W		5%
R121	317-0472-00			4.7 Ω	1/8 W		5%
R122	301-0621-00			620 Ω	1/2 W		5%
R123	317-0510-00			51 Ω	1/8 W		5%
R124	317-0510-00			51 Ω	1/8 W		5%
R125	315-0202-00			2 kΩ	1/4 W		5%
R128	307-0103-00	1990	2999X	2.7 Ω	1/4 W		5%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R129	311-0607-00			10 kΩ, Var			
R130	315-0101-00	1990	2999	100 Ω	¼ W		5%
R130	317-0101-00	3000		100 Ω	⅛ W		5%
R131	311-0465-00			100 kΩ, Var			
R132	315-0393-00	1990	2999	39 kΩ	¼ W		5%
R132	317-0184-00	3000		180 kΩ	⅛ W		5%
R133	317-0154-00	X3000		150 kΩ	⅛ W		5%
R134	315-0103-00			10 kΩ	¼ W		5%
R135	317-0390-00	X3000		39 Ω	⅛ W		5%
R137	315-0104-00	X3000		100 Ω	¼ W		5%
R140	311-0510-00			10 kΩ, Var			
R141	317-0101-00	X3000		100 Ω	⅛ W		5%
R142	315-0100-00	1990	2999	10 Ω	¼ W		5%
R142	317-0100-00	3000		10 Ω	⅛ W		5%
R143	308-0252-00			390 Ω	3 W	WW	5%
R144	317-0100-00	1990	2999	10 Ω	⅛ W		5%
R144	317-0036-00	3000		3.6 Ω	⅛ W		5%
R145	317-0101-00			100 Ω	⅛ W		5%
R146	317-0101-00	X3000		100 Ω	⅛ W		5%
R147	317-0101-00	X3000		100 Ω	⅛ W		5%
R148	317-0680-00	X3000		68 Ω	⅛ W		5%
R149	317-0680-00	X3000		68 Ω	⅛ W		5%
R153	321-0262-01			5.23 kΩ	⅛ W	Prec	½%
R155	315-0101-00			100 Ω	¼ W		5%
R156	321-0372-00			73.2 kΩ	⅛ W	Prec	1%
R157	322-1393-00			123 kΩ	¼ W	Prec	1%
R158	315-0270-00			27 Ω	¼ W		5%
R159	315-0101-00			100 Ω	¼ W		5%
R160	315-0270-00			27 Ω	¼ W		5%
R162	317-0200-00			20 Ω	⅛ W		5%
R163	317-0101-00			100 Ω	1/10 W		5%
R164	315-0203-00			20 kΩ	¼ W		5%
R165	315-0392-00			3.9 kΩ	¼ W		5%
R166	315-0123-00			12 kΩ	¼ W		5%
R167	315-0101-00			100 Ω	¼ W		5%
R168	311-0634-00			500 Ω, Var			
R172A	321-0164-00			499 Ω	⅛ W	Prec	1%
R172B	321-0134-00			243 Ω	⅛ W	Prec	1%
R172C	321-0114-00			150 Ω	⅛ W	Prec	1%
R172D	321-0068-00			49.9 Ω	⅛ W	Prec	1%
R172E	321-0039-00			24.9 Ω	⅛ W	Prec	1%
R172F	321-0018-00			15 Ω	⅛ W	Prec	1%
R174A	321-0176-00			665 Ω	⅛ W	Prec	1%
R174B	321-0130-00			221 Ω	⅛ W	Prec	1%
R174C	321-0075-00			59 Ω	⅛ W	Prec	1%
R174D	321-0042-00			26.7 Ω	⅛ W	Prec	1%
R174E	321-0019-00			15.4 Ω	⅛ W	Prec	1%
R174F	321-0002-00			10.2 Ω	⅛ W	Prec	1%
R175	321-0164-00			499 Ω	⅛ W	Prec	1%
R176	321-0164-00			499 Ω	⅛ W	Prec	1%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R181	321-0339-00			33.2 kΩ	1/8 W	Prec	1%
R184	323-0339-00			33.2 kΩ	1/2 W	Prec	1%
R186	315-0392-00			3.9 kΩ	1/4 W		5%
R192	315-0101-00			100 Ω	1/4 W		5%
R193	301-0472-00			4.7 kΩ	1/2 W		5%
R195	321-0365-00			61.9 kΩ	1/8 W	Prec	1%
R196	315-0183-00			18 kΩ	1/4 W		5%
R197	315-0183-00			18 kΩ	1/4 W		5%
R199	315-0750-00			75 Ω	1/4 W		5%
R200	315-0102-00			1 kΩ	1/4 W		5%
R201	315-0510-00			51 Ω	1/4 W		5%
R202	315-0512-00			5.1 kΩ	1/4 W		5%
R205	315-0512-00			5.1 kΩ	1/4 W		5%
R210	315-0472-00			4.7 kΩ	1/4 W		5%
R211	315-0103-00			10 kΩ	1/4 W		5%
R214	315-0621-00			620 Ω	1/4 W		5%
R220	315-0392-00			3.9 kΩ	1/4 W		5%
R224	315-0511-00			510 Ω	1/4 W		5%
R225	315-0104-00			100 kΩ	1/4 W		5%
R227	315-0270-00			27 Ω	1/4 W		5%
R228	315-0270-00			27 Ω	1/4 W		5%
R229	315-0100-00			10 Ω	1/4 W		5%
R230	321-0270-00			6.34 kΩ	1/8 W	Prec	1%
R231	321-0222-00			2 kΩ	1/8 W	Prec	1%
R232	321-0222-00			2 kΩ	1/8 W	Prec	1%
R233	321-0270-00			6.34 kΩ	1/8 W	Prec	1%
R235	317-0102-00			1 kΩ	1/8 W		5%
R236	317-0102-00			1 kΩ	1/8 W		5%
R242	315-0102-00			1 kΩ	1/4 W		5%
R243	315-0912-00			9.1 kΩ	1/4 W		5%
R244	301-0204-00			200 kΩ	1/2 W		5%
R245	323-0420-00			232 kΩ	1/2 W	Prec	1%
R246	315-0222-00			2.2 kΩ	1/4 W		5%
R247	311-0634-00			500 Ω, Var			
R248	315-0222-00			2.2 kΩ	1/4 W		5%
R249	321-0316-00			19.1 kΩ	1/8 W	Prec	1%
R254	303-0513-00			51 kΩ	1 W		5%
R255	317-0511-00			510 Ω	1/8 W		5%
R261	315-0203-00			20 kΩ	1/4 W		5%
R262	317-0103-00			10 kΩ	1/8 W		5%
R263	317-0103-00			10 kΩ	1/8 W		5%
R264	315-0203-00			20 kΩ	1/4 W		5%
R265	315-0331-00			330 Ω	1/4 W		5%
R266	308-0398-00	1990	2109	13.3 kΩ	2 W	WW	5%
R266	308-0360-00	2110		13.3 kΩ	3 W	WW	1%
R267	316-0685-00			6.8 MΩ	1/4 W		

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R269	321-0289-00			10 kΩ	1/8 W	Prec	1%
R310	321-0222-00			2 kΩ	1/8 W	Prec	1%
R313	*311-0602-00			10 kΩ, Var			
R314	321-0222-00			2 kΩ	1/8 W	Prec	1%
R317	311-0091-00			1 kΩ, Var			
R318	321-0193-00			1 kΩ	1/8 W	Prec	1%
R320	321-0729-06			786 Ω	1/8 W	Prec	1/4%
R321	321-0727-01			84.54 kΩ	1/8 W	Prec	1/2%
R322	321-0726-01			42.27 kΩ	1/8 W	Prec	1/2%
R323	321-0725-01			25.36 kΩ	1/8 W	Prec	1/2%
R324	321-0723-01			8.454 kΩ	1/8 W	Prec	1/2%
R325	321-0722-01			4.227 kΩ	1/8 W	Prec	1/2%
R326	321-0721-01			2.536 kΩ	1/8 W	Prec	1/2%
R327	321-0730-06			5.703 kΩ	1/8 W	Prec	1/4%
R328	321-0281-06			8.25 kΩ	1/8 W	Prec	1/4%
R333	315-0103-00			10 kΩ	1/4 W		5%
R334	315-0103-00			10 kΩ	1/4 W		5%
R336	315-0201-00			200 Ω	1/4 W		5%
R337A,B	311-0553-00			2 X 10 kΩ, Var			
R338	315-0201-00			200 Ω	1/4 W		5%
R342	315-0224-00			220 kΩ	1/4 W		5%
R344	308-0361-00			14.5 kΩ	3 W	WW	1%
R347	321-0732-06			85.69 kΩ	1/8 W	Prec	1/4%
R348	321-0731-06			11.32 kΩ	1/8 W	Prec	1/4%
R351	311-0433-00			100 Ω, Var			
R352	321-0176-00			665 Ω	1/8 W	Prec	1%
R353	311-0442-00			250 Ω, Var			
R356	311-0634-00			500 Ω, Var			
R359	315-0134-00			130 kΩ	1/4 W		5%
R360	311-0633-00			5 kΩ, Var			
R361	321-0292-00			10.7 kΩ	1/8 W	Prec	1%
R362	321-0292-00			10.7 kΩ	1/8 W	Prec	1%
R365	321-0435-00			332 kΩ	1/8 W	Prec	1%
R367	321-0365-00			61.9 kΩ	1/8 W	Prec	1%
R368	316-0125-00			1.2 MΩ	1/4 W		
R369	321-0449-00			464 kΩ	1/8 W	Prec	1%
R370	315-0124-00			120 kΩ	1/4 W		5%
R371	315-0394-00			390 kΩ	1/4 W		5%
R372	315-0124-00			120 kΩ	1/4 W		5%
R374	315-0103-00			10 kΩ	1/4 W		5%
R375	315-0273-00			27 kΩ	1/4 W		5%
R377	315-0562-00			5.6 kΩ	1/4 W		5%
R378	315-0752-00			7.5 kΩ	1/4 W		5%
R379	315-0103-00			10 kΩ	1/4 W		5%
R384	323-0378-00			84.5 kΩ	1/2 W	Prec	1%
R385	321-0332-00			28 kΩ	1/8 W	Prec	1%
R386	321-0273-00			6.81 kΩ	1/8 W	Prec	1%
R387	301-0563-00			56 kΩ	1/2 W		5%
R388	311-0614-00			30 kΩ, Var			
R390	308-0429-00			22 kΩ	3 W	WW	1%
R393	301-0623-00			62 kΩ	1/2 W		5%
R394	315-0304-00			300 kΩ	1/4 W		5%
R395	321-0432-00			309 kΩ	1/8 W	Prec	1%
R396	311-0607-00			10 kΩ, Var			
R397	321-0394-00			124 kΩ	1/8 W	Prec	1%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R399	301-0433-00			43 kΩ	½ W		5%
R401	315-0183-00			18 kΩ	¼ W		5%
R404	315-0272-00			2.7 kΩ	¼ W		5%
R405	315-0102-00			1 kΩ	¼ W		5%
R407	315-0101-00			100 Ω	¼ W		5%
R408	315-0332-00			3.3 kΩ	¼ W		5%
R411	311-0608-00			2 kΩ, Var			
R413	301-0621-00			620 Ω	½ W		5%
R423	308-0387-00			178 Ω	3 W	WW	1%
R424	301-0330-00			33 Ω	½ W		5%
R427	315-0510-00			51 Ω	¼ W		5%
R428	311-0633-00			5 kΩ, Var			
R429	315-0153-00			15 kΩ	¼ W		5%
R430	307-0124-00			5 kΩ	Thermal		
R431	308-0443-00			330 Ω	2.5 W	WW	1%
R432	315-0821-00			820 Ω	¼ W		5%
R433	311-0608-00			2 kΩ, Var			
R434	317-0270-00			27 Ω	⅛ W		5%
R435	317-0270-00			27 Ω	⅛ W		5%
R436	317-0750-00			75 Ω	⅛ W		5%
R437	307-0099-00			48 Ω			1%
R438	315-0302-00	1990	2999	3 kΩ	¼ W		5%
R438	317-0302-00	3000		3 kΩ	⅛ W		5%
R439	311-0607-00			10 kΩ, Var			
R441	307-0103-00			2.7 Ω	¼ W		5%
R442	315-0821-00			820 Ω	¼ W		5%
R443	311-0609-00			2 kΩ, Var			
R444	303-0391-00			390 Ω	1 W		5%
R445	301-0181-00			180 Ω	½ W		5%
R447	315-0121-00			120 Ω	¼ W		5%
R448	315-0271-00			270 Ω	¼ W		5%
R449	315-0271-00			270 Ω	¼ W		5%
R454	317-0680-00			68 Ω	⅛ W		5%
R455	323-0174-00			634 Ω	½ W	Prec	1%
R464	317-0680-00			68 Ω	⅛ W		5%
R465	323-0174-00			634 Ω	½ W	Prec	1%
R480	315-0911-00			910 Ω	¼ W		5%
R481	311-0634-00			500 Ω, Var			
R482	315-0391-00			390 Ω	¼ W		5%
R484	315-0202-00			2 kΩ	¼ W		5%
R485	315-0202-00			2 kΩ	¼ W		5%
R488	315-0432-00			4.3 kΩ	¼ W		5%
R490	317-0511-00			510 Ω	⅛ W		5%
R491	315-0392-00			3.9 kΩ	¼ W		5%
R492	315-0183-00			18 kΩ	¼ W		5%
R493	315-0510-00			51 Ω	¼ W		5%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R494	315-0102-00			1 kΩ	¼ W		5%
R499	307-0103-00			2.7 Ω	¼ W		5%
R501	311-0631-00			100 kΩ, Var			
R504	315-0103-00			10 kΩ	¼ W		5%
R505	315-0101-00			100 Ω	¼ W		5%
R506	315-0220-00			22 Ω	¼ W		5%
R507	315-0123-00			12 kΩ	¼ W		5%
R509	301-0392-00			3.9 kΩ	½ W		5%
R515	315-0151-00			150 Ω	¼ W		5%
R516	301-0202-00			2 kΩ	½ W		5%
R517	301-0202-00			2 kΩ	½ W		5%
R518	317-0390-00			39 Ω	⅛ W		5%
R520	315-0104-00			100 kΩ	¼ W		5%
R523	311-0633-00			5 kΩ, Var			
R524	323-0233-00			2.61 kΩ	½ W	Prec	1%
R525	322-0229-00			2.37 kΩ	¼ W	Prec	1%
R527	315-0510-00			51 Ω	¼ W		5%
R528	323-0352-00			45.3 kΩ	½ W	Prec	1%
R530	315-0151-00			150 Ω	¼ W		5%
R531	315-0393-00			39 kΩ	¼ W		5%
R534	323-0345-00			38.3 kΩ	½ W	Prec	1%
R535	321-0289-00			10 kΩ	⅛ W	Prec	1%
R540	315-0183-00			18 kΩ	¼ W		5%
R543	307-0103-00			2.7 Ω	¼ W		5%
R544	311-0635-00			1 kΩ, Var			
R545	315-0751-00			750 Ω	¼ W		5%
R546	315-0751-00			750 Ω	¼ W		5%
R549	315-0220-00			22 Ω	¼ W		5%
R553	315-0200-00			20 Ω	¼ W		5%
R554	315-0471-00			470 Ω	¼ W		5%
R560	321-0222-00	1990	3109	2 kΩ	⅛ W	Prec	1%
R560	321-0165-00	3110		511 Ω	⅛ W	Prec	1%
R561	321-0309-00			16.2 kΩ	⅛ W	Prec	1%
R562	315-0220-00			22 Ω	¼ W		5%
R563	315-0183-00			18 kΩ	¼ W		5%
R580	315-0220-00			22 Ω	¼ W		5%
R584	315-0101-00			100 Ω	¼ W		5%
R585A	317-0510-00			51 Ω	⅛ W		5%
R585B	317-0510-00			51 Ω	⅛ W		5%
R586	308-0361-00			14.5 kΩ	3 W	WW	1%
R588	311-0540-00			2.5 kΩ, Var			
R593	315-0200-00			20 Ω	¼ W		5%
R594	315-0471-00			470 Ω	¼ W		5%
R600	321-0222-00	1990	3109	2 kΩ	⅛ W	Prec	1%
R600	321-0165-00	3110		511 Ω	⅛ W	Prec	1%
R601	321-0309-00			16.2 kΩ	⅛ W	Prec	1%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R602	315-0220-00			22 Ω	¼ W		5%
R603	315-0183-00			18 kΩ	¼ W		5%
R614	317-0240-00			24 Ω	⅛ W		5%
R615A	317-0510-00			51 Ω	⅛ W		5%
R616	308-0354-00			15 kΩ	3 W	WW	1%
R618	301-0272-00			2.7 kΩ	½ W		5%
R620	321-0161-00	1990	3059	464 Ω	⅛ W	Prec	1%
R620	321-0165-00	3060		511 Ω	⅛ W	Prec	1%
R621	311-0433-00			100 Ω, Var		Prec	1%
R622	322-0239-00			3.01 kΩ	¼ W	Prec	1%
R623	315-0220-00			22 Ω	¼ W		5%
R624	315-0102-00			1 kΩ	¼ W		5%
R625	315-0201-00			200 Ω	¼ W		5%
R626	317-0391-00	X3110		390 Ω	⅛ W		5%
R632	315-0270-00			27 Ω	¼ W		5%
R634	301-0102-00			1 kΩ	½ W		5%
R635	315-0510-00			51 Ω	¼ W		5%
R641	311-0626-01			2 kΩ, Var			
R642	321-0193-00			1 kΩ	⅛ W	Prec	1%
R645A	321-0630-00			6.81 kΩ	⅛ W	Prec	½%
R645C	321-0724-01			13.6 kΩ	⅛ W	Prec	½%
R645D	321-0302-00			13.7 kΩ	⅛ W	Prec	1%
R645E	321-0679-00			34 kΩ	⅛ W	Prec	½%
R645F	321-0282-00			8.45 kΩ	⅛ W	Prec	1%
R645G	321-0693-00			68.1 kΩ	⅛ W	Prec	½%
R645H	321-0277-00			7.5 kΩ	⅛ W	Prec	1%
R645J	321-0728-01			136 kΩ	⅛ W	Prec	½%
R645K	321-0275-00			7.15 kΩ	⅛ W	Prec	1%
R645L	321-0436-01			340 kΩ	⅛ W	Prec	½%
R645M	321-0274-00			6.98 kΩ	⅛ W	Prec	1%
R645N	321-0436-01			340 kΩ	⅛ W	Prec	½%
R645P	321-0436-01			340 kΩ	⅛ W	Prec	½%
R645R	321-0630-00			6.81 kΩ	⅛ W	Prec	½%
R650	311-0632-00			2 kΩ, Var			
R651	315-0223-00			22 kΩ	¼ W		5%
R652	321-0220-00			1.91 kΩ	⅛ W	Prec	1%
R653	321-0215-00			1.69 kΩ	⅛ W	Prec	1%
R654	321-0149-00			348 Ω	⅛ W	Prec	1%
R656	321-0219-00			1.87 kΩ	⅛ W	Prec	1%
R657	321-0627-01			25.6 kΩ	⅛ W	Prec	½%
R658	321-0666-00			3.04 kΩ	⅛ W	Prec	½%
R660	321-0303-00			14 kΩ	⅛ W	Prec	1%
R661	311-0609-00			2 kΩ, Var			
R662	321-0251-00			4.02 kΩ	⅛ W	Prec	1%
R663	321-0287-00			9.53 kΩ	⅛ W	Prec	1%
R664	311-0386-00			2 kΩ, Var			
R670	316-0225-00	1990	3059	2.2 MΩ	¼ W		
R670	315-0104-00	3060		100 kΩ	¼ W		5%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R671	315-0154-00			150 kΩ	¼ W		5%
R672	315-0151-00			150 Ω	¼ W		5%
R673	305-0223-00			22 kΩ	2 W		5%
R675	317-0391-00			390 Ω	⅛ W		5%
R676	317-0620-00			62 Ω	⅛ W		5%
R677	311-0605-00			200 Ω, Var			
R681	311-0613-00			100 kΩ, Var			
R682	315-0183-00			18 kΩ	¼ W		5%
R683	315-0101-00			100 Ω	¼ W		5%
R684	315-0101-00			100 Ω	¼ W		5%
R686	315-0123-00			12 Ω	¼ W		5%
R690	317-0200-00			20 Ω	⅛ W		5%
R691	315-0392-00			3.9 kΩ	¼ W		5%
R694	315-0681-00			680 Ω	¼ W		5%
R695	307-0103-00			2.7 Ω	¼ W		5%
R699	315-0220-00			22 Ω	¼ W		5%
R709	316-0106-00			10 MΩ	¼ W		
R710	316-0106-00			10 MΩ	¼ W		
R711	315-0113-00			11 kΩ	¼ W		5%
R712	315-0202-00			2 kΩ	¼ W		5%
R718	315-0113-00			11 kΩ	¼ W		5%
R720	315-0472-00			4.7 kΩ	¼ W		5%
R721	315-0471-00			470 Ω	¼ W		5%
R724	315-0510-00			51 kΩ	¼ W		5%
R730	315-0563-00			56 kΩ	¼ W		5%
R731	315-0104-00			100 kΩ	¼ W		5%
R734	315-0392-00			3.9 kΩ	¼ W		5%
R735	315-0472-00			4.7 kΩ	¼ W		5%
R740	321-0250-00			3.92 kΩ	⅛ W	Prec	1%
R741	315-0221-00			220 Ω	¼ W		5%
R742	321-0289-00			10 kΩ	⅛ W	Prec	1%
R750	315-0204-00			200 kΩ	¼ W		5%
R751	316-0226-00			22 MΩ	¼ W		
R752	315-0624-00			620 kΩ	¼ W		5%
R754	315-0334-00			330 kΩ	¼ W		5%
R756	321-0188-00			887 Ω	⅛ W	Prec	1%
R757	321-0315-00			18.7 kΩ	⅛ W	Prec	1%
R764	305-0204-00			200 kΩ	2 W		5%
R765	315-0512-00			5.1 kΩ	¼ W		5%
R766	315-0204-00			200 kΩ	¼ W		5%
R771	321-0299-00			12.7 kΩ	⅛ W	Prec	1%
R772	311-0531-00			100 kΩ, Var			
R780	321-0356-00			49.9 kΩ	⅛ W	Prec	1%
R782	321-0357-00			51.1 kΩ	⅛ W	Prec	1%
R784	315-0103-00			10 kΩ	¼ W		5%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R786	315-0221-00			220 Ω	¼ W		5%
R787	311-0634-00			500 Ω, Var			
R788	301-0242-00			2.4 kΩ	½ W		5%
R797	315-0220-00			22 Ω	¼ W		5%
R798	315-0220-00			22 Ω	¼ W		5%
R800	302-0393-00			39 kΩ	½ W		
R801	308-0416-00			380 Ω	20 W	WW	5%
R810	307-0103-00			2.7 Ω	¼ W		5%
R811	307-0103-00			2.7 Ω	¼ W		5%
R820	301-0433-00			43 kΩ	½ W		5%
R821	315-0472-00			4.7 kΩ	¼ W		5%
R823	315-0103-00			10 kΩ	¼ W		5%
R826	323-0683-00			1.86 kΩ	½ W	Prec	1%
R828	323-0683-00			1.86 kΩ	½ W	Prec	1%
R829	303-0102-00	1990	2199	1 kΩ	1 W		5%
R829	308-0496-00	2200		1 kΩ	2.5 W	WW	1%
R850	307-0103-00			2.7 Ω	¼ W		5%
R851	307-0103-00			2.7 Ω	¼ W		5%
R860	315-0183-00			18 kΩ	¼ W		5%
R861	315-0752-00			7.5 kΩ	¼ W		5%
R862	315-0153-00			15 kΩ	¼ W		5%
R863	315-0132-00			1.3 kΩ	¼ W		5%
R864	315-0103-00			10 kΩ	¼ W		5%
R866	323-0195-00			1.05 kΩ	½ W	Prec	1%
R867	311-0605-00			200 Ω, Var			
R868	323-0151-00			365 Ω	½ W	Prec	1%
R870	315-0472-00			4.7 kΩ	¼ W		5%
R874	315-0103-00			10 kΩ	¼ W		5%
R883	301-0623-00			62 kΩ	½ W		5%
R885	301-0680-00			68 Ω	½ W		5%
R886	308-0313-00			20 kΩ	3 W	WW	1%
R887	311-0635-00			1 kΩ, Var			
R888	323-0268-00			6.04 kΩ	½ W	Prec	1%

Switches

Ckt. No.	Unwired or Wired	Tektronix Part No.	Eff	Disc	Type	Function
SW172	Wired	*262-0782-00			Rotary	VERTICAL UNITS/DIV
SW172		260-0686-00			Rotary	VERTICAL UNITS/DIV
SW359		260-0816-00			Slide	p-VOLTS
SW430	Wired	*262-0780-01			Rotary	MODE
SW430		260-0795-01	1990	2259	Rotary	MODE
SW430		260-0795-02	2260		Rotary	MODE
SW585A SW585B	Wired	*262-0778-02	1990	3059	Rotary	RANGE DIELECTRIC
SW585A SW585B	Wired	*262-0778-03	3060		Rotary	RANGE DIELECTRIC
SW585A SW585B		260-0918-00			Rotary	RANGE DIELECTRIC
SW645	Wired	*262-0779-01			Rotary	MAGNIFIER

Switches *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
SW645	260-0791-01			Rotary	MAGNIFIER
SW657	260-0816-00			Slide	HORIZONTAL UNITS/DIV
SW710	260-0689-00			Push-Button	START
SW750	260-0816-00			Slide	RESOLUTION
SW770 Wired	*262-0781-03			Rotary	DISPLAY MODE
SW770	260-0687-01			Rotary	DISPLAY MODE

Transformers

Ckt. No.	Tektronix Part No.	Eff	Disc	Description
T114	*120-0438-00	1990	2999X	Toroid, 2 turns, bifilar
T135	*120-0511-00			Toroid, 2 windings
T144	*120-0444-00			Toroid, 5 turns, bifilar
T235	*120-0547-00			Toroid, 15 turns
T512	*120-0445-00			Toroid, 8 turns, bifilar
T675	*120-0374-00			Toroid, 2 windings
T810	*120-0559-00			Power

Test Points

Ckt. No.	Tektronix Part No.	Eff	Disc	Description
TP163	*214-0579-00			Pin, Test Point
TP193	*214-0579-00			Pin, Test Point
TP200	*214-0579-00			Pin, Test Point
TP235	*214-0579-00			Pin, Test Point
TP268	*214-0579-00			Pin, Test Point
TP525	*214-0579-00			Pin, Test Point
TP545	*214-0579-00			Pin, Test Point
TP673	*214-0579-00			Pin, Test Point
TP674	*214-0579-00			Pin, Test Point
TP783	*214-0579-00			Pin, Test Point
TP829	*214-0579-00			Pin, Test Point
TP869	*214-0579-00			Pin, Test Point
TP889	*214-0579-00			Pin, Test Point

FIGURE AND INDEX NUMBERS

Items in this section are referenced by figure and index numbers to the illustrations which appear either on the back of the diagrams or on pullout pages immediately following the diagrams of the instruction manual.

INDENTATION SYSTEM

This mechanical parts list is indented to indicate item relationships. Following is an example of the indentation system used in the Description column.

Assembly and/or Component
  Detail Part of Assembly and/or Component
  mounting hardware for Detail Part
    Parts of Detail Part
    mounting hardware for Parts of Detail Part
mounting hardware for Assembly and/or Component

Mounting hardware always appears in the same indentation as the item it mounts, while the detail parts are indented to the right. Indented items are part of, and included with, the next higher indentation.

Mounting hardware must be purchased separately, unless otherwise specified.

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix, Inc. Field Office or representative.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number, instrument type or number, serial or model number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix, Inc. Field Office or representative will contact you concerning any change in part number.

Change information, if any, is located at the rear of this manual.

ABBREVIATIONS AND SYMBOLS

For an explanation of the abbreviations and symbols used in this section, please refer to the page immediately preceding the Electrical Parts List in this instruction manual.

INDEX OF MECHANICAL PARTS LIST ILLUSTRATIONS

(Located behind diagrams)

SECTION 9
MECHANICAL PARTS LIST

FIG. 1 FRONT

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-1	366-0319-00			1	KNOB, red—FINE
	- - - - - -			-	knob includes:
	213-0020-00			1	SCREW, set, 6-32 x 1/8 inch, HSS
-2	366-0138-00			1	KNOB, charcoal—OFFSET
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-3	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-4	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-5	179-1246-00			1	CABLE HARNESS, switch
-6	179-1247-00			1	CABLE HARNESS, resistor
-7	366-0189-00			1	KNOB, red—EXT HORIZ ATTEN-MANUAL SCAN
	- - - - - -			-	knob includes:
	213-0020-00			1	SCREW, set, 6-32 x 1/8 inch, HSS
-8	366-0322-00			1	KNOB, charcoal—DISPLAY MODE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-9	262-0781-03			1	SWITCH, wired—DISPLAY MODE
	- - - - - -			-	switch includes:
	260-0687-01			1	SWITCH, unwired
-10	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	358-0312-00			1	BUSHING
-11	426-0289-00			1	FRAME
	210-1026-00			1	LOCKWASHER, external, 1/4 inch diameter
	210-0004-00			2	LOCKWASHER, internal, #4
-12	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
	- - - - - -			-	mounting hardware: (not included w/switch)
-13	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch (not shown)

FIG. 1 FRONT (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-14	366-0189-00			1	KNOB, red—VARIABLE-CAL-VARIABLE
	- - - - - -			-	knob includes:
	213-0020-00			1	SCREW, set, 6-32 x 1/8 inch, HSS
-15	366-0322-00			1	KNOB, charcoal—VERTICAL UNITS/DIV
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-16	262-0782-03			1	SWITCH, wired—VERTICAL UNITS/DIV
	- - - - - -			-	switch includes:
	260-0686-00			1	SWITCH, unwired
	179-1086-02			1	CABLE HARNESS, vertical (not shown)
	- - - - - -			-	cable harness includes:
	131-0371-00			4	CONNECTOR, single contact
-17	384-0358-00	1990	2229	1	ROD, extension
	384-0358-02	2230		1	ROD, extension
-18	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	resistor includes:
	213-0048-00			1	SCREW, set, 4-40 x 1/8 inch, HSS
	- - - - - -			-	mounting hardware: (not included w/resistor)
-19	211-0016-00			2	SCREW, 4-40 x 5/8 inch, RHS
	166-0026-00			2	TUBE, spacer, 0.125 ID x 3/16 OD x 3/8 inch long
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
-20	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-21	366-0189-00			1	KNOB, red—DIELECTRIC
	- - - - - -			-	knob includes:
	213-0020-00			1	SCREW, set, 6-32 x 1/8 inch, HSS
-22	366-0322-00			1	KNOB, charcoal—RANGE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-23	262-0778-02			1	SWITCH, wired—RANGE
	- - - - - -			-	switch includes:
	260-0918-00			1	SWITCH, unwired
-24	175-0403-00			2	ASSEMBLY, cable
	- - - - - -			-	mounting hardware: (not included w/switch)
-25	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
-26	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch

FIG. 1 FRONT (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-27	366-0189-00			1	KNOB, red—CAL VARIABLE
	- - - - - -			-	knob includes:
	213-0020-00			1	SCREW, set, 6-32 x 1/8 inch, HSS
-28	366-0322-00			1	KNOB, charcoal—MAGNIFIER
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-29	262-0779-01			1	SWITCH, wired—MAGNIFIER
	- - - - - -			-	switch includes:
	260-0791-01			1	SWITCH, unwired
-30	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-31	210-0590-00			1	NUT, hex., 3/8-32 x 7/16 inch
	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	210-0405-00			2	NUT, hex., 2-56 x 3/16 inch
	210-0053-00			1	LOCKWASHER, split, #2
-32	426-0261-00			1	FRAME, plastic, flexible
-33	384-0415-00			1	ROD, extension
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
-34	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-35	366-0189-00			1	KNOB, red—UHF SYNC OR TRIGGER SENS
	- - - - - -			-	knob includes:
	213-0020-00			1	SCREW, set, 6-32 x 1/8 inch, HSS
-36	366-0322-00			1	KNOB, charcoal—MODE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-37	262-0780-01			1	SWITCH, wired—MODE
	- - - - - -			-	switch includes:
	260-0795-01	1990	2259	1	SWITCH, unwired
	260-0795-02	2260		1	SWITCH, unwired
	384-0358-01			1	ROD, extension
-38	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-39	210-0046-00	1990	2259	1	LOCKWASHER, internal, 1/4 ID x 0.400 inch OD
-40	210-0583-00	1990	2259	1	NUT, hex., 1/4-32 x 5/16 inch
	358-0312-00	2260		1	BUSHING
	210-1026-00	2260		1	LOCKWASHER, external, 0.125 ID x 7/16 inch OD
	426-0261-00	2260		1	FRAME, flexible, plastic
	210-0405-00	2260		1	NUT, hex., 2-56 x 3/16 inch
-41	376-0050-00			1	ASSEMBLY, coupling, flexible
	- - - - - -			-	assembly includes:
	354-0251-00			2	RING, 3/8 inch diameter x 0.172 inch long
	213-0022-00			4	SCREW, set, 4-40 x 3/16 inch, HHS
	376-0049-00			1	COUPLING, plastic
	- - - - - -			-	mounting hardware: (not included w/switch)
-42	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
-43	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-44	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch

FIG. 1 FRONT (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
1-45	136-0140-00	1990	2229	4	SOCKET, banana jack
	136-0140-00	2230		2	SOCKET, banana jack
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-46	210-0895-00			1	WASHER, insulating, black plastic
-47	210-0465-00			2	NUT, hex., 1/4-32 x 3/8 x 3/32 inch
-48	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch OD, SE
	136-0140-00	2230		2	SOCKET, banana jack
	- - - - - -			-	mounting hardware for each: (not included w/socket)
	210-0895-00			1	WASHER, insulating, black plastic
	210-0465-00			2	NUT, hex., 1/4-32 x 3/32 inch
	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch OD, SE
	210-0269-00			1	LUG, terminal
	210-0046-00			1	LOCKWASHER,internal, 0.261 ID x 0.400 inch OD
-49	129-0053-00			1	ASSEMBLY, binding post
	- - - - - -			-	assembly includes:
	355-0507-00			1	STEM
	200-0103-00			1	CAP
	- - - - - -			-	mounting hardware: (not included w/assembly)
-50	210-0046-00			1	LOCKWASHER, internal, 1/4 ID x 0.400 inch OD
-51	210-0455-00			1	NUT, hex., 1/4-28 x 3/32 inch
-52	352-0084-00			2	HOLDER, neon light, 0.405 diameter x 0.650 inch long
-53	200-0643-00			2	CAP, lamp holder
-54	378-0541-00			2	FILTER, lens, neon light
-55	260-0816-00			1	SWITCH, slide—RESOLUTION
	- - - - - -			-	mounting hardware: (not included w/switch)
-56	211-0030-00			2	SCREW, 2-56 x 1/4 inch, FHS
-57	210-0406-00			2	NUT, hex., 2-56 x 3/16 inch
-58	260-0689-00			1	SWITCH, push-button—START
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
	210-0940-00			1	WASHER, flat 1/4 ID x 3/8 inch OD
-59	210-0465-00			1	NUT, hex., 1/4-32 x 3/8 x 3/32 inch
-60	260-0816-00			1	SWITCH, slide—ρ—VOLTS
	- - - - - -			-	mounting hardware: (not included w/switch)
	211-0030-00			2	SCREW, 2-56 x 1/4 inch, FHS (not shown)
-61	210-0405-00			2	NUT, hex., 2-56 x 3/16 inch
-62	260-0816-00			1	SWITCH, slide—HORIZONTAL UNITS/DIV
	- - - - - -			-	mounting hardware: (not included w/switch)
-63	210-0030-00			2	SCREW, 2-56 x 1/4 inch, FHS
-64	210-0405-00			2	NUT, hex., 2-56 x 3/16 inch

FIG. 1 FRONT (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-65	333-0935-04			1	PANEL, front
-66	386-1067-01			1	PLATE, front sub-panel
-67	- - - - - -			2	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
-68	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch OD, SE
-69	210-0471-00			1	NUT, hex., 1/4-32 x 5/16 diameter x 19/32 inch long
-70	358-0054-00			1	BUSHING, banana jack
-71	366-0125-00			1	KNOB, grey, plug-in securing
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-72	210-0894-00			1	WASHER, plastic, 0.190 ID x 7/16 inch OD
-73	384-0510-00			1	ROD, securing
	- - - - - -			-	rod includes:
-74	354-0025-00			1	RING, retaining
-75	331-0175-00			1	DIAL, w/o brakes—POSITION
	- - - - - -			-	dial includes:
	213-0022-00			2	SCREW, set, 4-40 x 3/16 inch, HSS
-76	386-1341-00			1	PLATE, readout
-77	214-1007-00			1	HEAT SINK, readout
-78	214-0889-00			1	DIVIDER, readout
-79	214-0890-00			1	HEAT SINK, readout
-80	670-0192-00			1	ASSEMBLY, circuit board—READOUT
	- - - - - -			-	assembly includes:
	388-0711-01			1	BOARD, circuit
	- - - - - -			-	mounting hardware: (not included w/assembly)
-81	210-0586-00			2	NUT, keps, 4-40 x 1/4 inch

FIG. 2 FRAME & CHASSIS

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	1 2 3 4 5 Description
2-1	670-0116-02			1	ASSEMBLY, circuit board—HORIZONTAL
	- - - - - -			-	assembly includes:
	388-0719-01			1	BOARD, circuit
-2	214-0579-00			10	PIN, test point
-3	131-0391-00			3	CONNECTOR, coaxial, 1 contact
-4	136-0220-00			21	SOCKET, transistor, 3 pin
-5	136-0235-00			2	SOCKET, transistor, 6 pin
	200-0678-01			1	COVER, transistor (not shown)
	- - - - - -			-	mounting hardware: (not included w/assembly)
-6	211-0601-00			5	SCREW, sems, 6-32 x 0.313 inch, PHB
-7	441-0675-00			1	CHASSIS, small
	- - - - - -			-	mounting hardware: (not included w/chassis)
-8	211-0504-00			3	SCREW, 6-32 x 1/4 inch, PHS
-9	211-0507-00			3	SCREW, 6-32 x 5/16 inch, PHS
-10	210-0457-00			3	NUT, keps, 6-32 x 5/16 inch
-11	- - - - - -			2	CAPACITOR
	- - - - - -			-	mounting hardware for each: (not included w/capacitor)
-12	344-0016-00			1	CLIP, capacitor mounting
-13	213-0044-00			1	SCREW, thread forming, 5-32 x 3/16 inch, PHS
-14	129-0069-00			4	POST, terminal
	- - - - - -			-	each post includes:
	129-0075-00			1	POST, plastic, tie off
-15	358-0176-00			1	BUSHING, plastic
	210-0686-00			1	EYELET (not shown)
	- - - - - -			-	mounting hardware for each: (not included w/post)
-16	361-0007-00			1	SPACER, plastic, 0.188 inch long
-17	348-0063-00			4	GROMMET, plastic, 1/2 inch diameter
-18	407-0243-00			1	BRACKET, bulkhead
	- - - - - -			-	bracket includes:
-19	211-0094-00			3	SCREW, 4-40 x 1/2 inch, THS
-20	343-0089-00			2	CLAMP, cable, plastic
-21	358-0215-00			1	BUSHING, plastic
-22	384-0631-00			4	ROD, spacer
	- - - - - -			-	mounting hardware for each: (not included w/rod)
-23	212-0044-00			1	SCREW, 8-32 x 1/2 inch, RHS

FIG. 2 FRAME & CHASSIS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
2-24	670-0115-01	1990	2999	1	ASSEMBLY, circuit board—VERTICAL
	670-0115-02	3000		1	ASSEMBLY, circuit board—VERTICAL
	- - - - - -			-	assembly includes:
	388-0718-01			1	BOARD, circuit
-25	214-0579-00			5	PIN, test point
-26	136-0183-00			2	SOCKET, transistor, 3 pin
-27	136-0220-00			12	SOCKET, transistor, 3 pin
-28	136-0235-00			2	SOCKET, transistor, 6 pin
-29	426-0121-00			1	HOLDER, plastic
-30	358-0214-00			1	BUSHING, insulator
	- - - - - -			-	mounting hardware: (not included w/assembly)
-31	211-0601-00			4	SCREW, sems, 6-32 x 0.313 inch, PHB
-32	441-0679-01			1	CHASSIS, main
	- - - - - -			-	mounting hardware: (not included w/chassis)
-33	211-0504-00			3	SCREW, 6-32 x 1/4 inch, PHS
-34	211-0507-00			1	SCREW, 6-32 x 5/16 inch, PHS
-35	210-0457-00			3	NUT, keps, 6-32 x 5/16 inch
-36	- - - - - -			1	RESISTOR
	- - - - - -			-	mounting hardware: (not included w/resistor)
-37	212-0037-00			1	SCREW, 8-32 x 1 3/4 inches, FIL HS
-38	210-0808-00			1	WASHER, centering
-39	210-0462-00			1	NUT, hex., 8-32 x 1/2 x 23/64 inch
-40	212-0004-00			1	SCREW, 8-32 x 5/16 inch, PHS
-41	441-0680-01			1	CHASSIS, power
	- - - - - -			-	mounting hardware: (not included w/chassis)
-42	211-0507-00			7	SCREW, 6-32 x 5/16 inch, PHS
-43	210-0457-00			7	NUT, keps, 6-32 x 5/16 inch
-44	- - - - - -			1	TRANSFORMER
	- - - - - -			-	mounting hardware: (not included w/transformer)
-45	211-0529-00			4	SCREW, 6-32 x 1 1/4 inches, PHS
-46	210-0457-00			4	NUT, keps, 6-32 x 5/16 inch
-47	348-0055-00			1	GROMMET, plastic, 1/4 inch diameter

FIG. 2 FRAME & CHASSIS (cont)

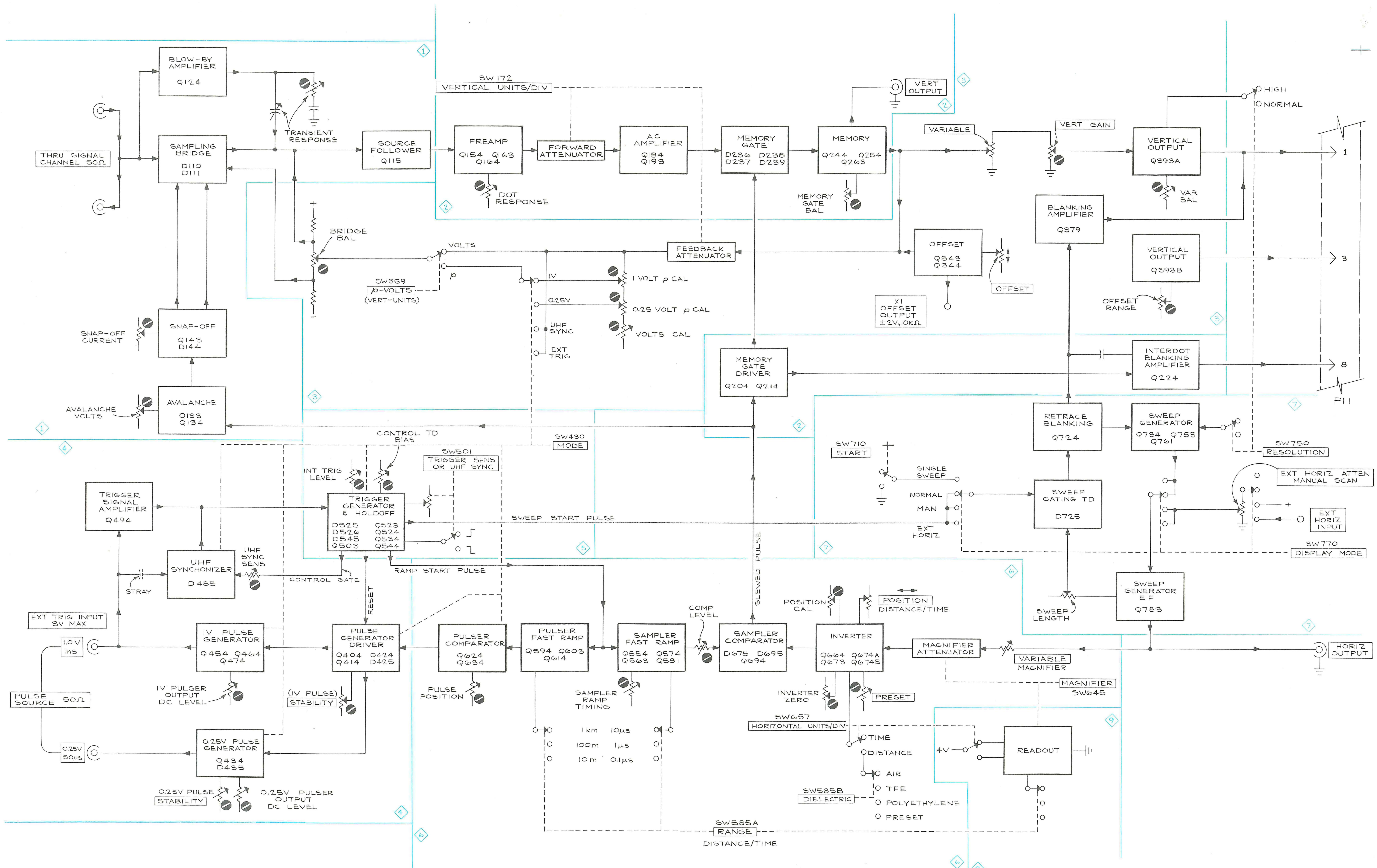
Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
2-48	- - - - - -			3	TRANSISTOR
	- - - - - -			-	mounting hardware for each: (not included w/transistor)
-49	211-0510-00			2	SCREW, 6-32 x 3/8 inch, PHS
-50	386-0143-00			1	PLATE, mica insulator
-51	210-0811-00			2	WASHER, fiber, shouldered, #6
-52	210-0802-00			2	WASHER, flat, 0.150 ID x 5/16 inch OD
-53	210-0005-00			1	LOCKWASHER, external, #6
-54	210-0202-00			1	LUG, solder, SE #6
-55	210-0407-00			2	NUT, hex., 6-32 x 1/4 inch
-56	131-0017-00			1	CONNECTOR, 16 contact
	- - - - - -			-	mounting hardware: (not included w/connector)
-57	211-0008-00			2	SCREW, 4-40 x 1/2 inch, PHS
-58	210-0586-00			2	NUT, keps, 4-40 x 1/4 inch
-59	210-0201-00			1	LUG, holder, SE #4
	- - - - - -			-	mounting hardware: (not included w/lug)
-60	211-0008-00			1	SCREW, 4-40 x 1/2 inch, PHS
-61	210-0586-00			1	NUT, keps, 4-40 x 1/4 inch
-62	386-1086-00			1	PLATE, rear
-63	670-0117-01			1	ASSEMBLY, circuit board—REGULATOR
-64	214-0506-00			12	PIN, connector
	388-0734-01			1	BOARD, circuit
	- - - - - -			-	board includes:
-64	214-0506-00			12	PIN, connector
-65	136-0220-00			5	SOCKET, transistor, 3 pin
-66	136-0183-00			1	SOCKET, transistor, 3 pin
-67	214-0579-00			3	PIN, test point
-68	352-0100-00			2	HOLDER, variable resistor
-69	358-0214-00			2	BUSHING, insulator
	- - - - - -			-	mounting hardware: (not included w/assembly)
-70	344-0131-00			4	CLIP, circuit board
-71	213-0088-00			4	SCREW, thread forming, #4 x 1/4 inch, PHS
-72	211-0116-00			1	SCREW, sems, 4-40 x 5/16 inch, PHB
-73	129-0098-00			1	POST, hex., 0.250 x 0.406 inch long
-74	211-0008-00			1	SCREW, 4-40 x 1/2 inch, PHS
-75	179-1085-02			1	CABLE HARNESS, horizontal & pulser
-76	179-1090-01			1	CABLE HARNESS, regulator & transformer
-77	- - - - - -			2	ASSEMBLY, cable (see Fig. 1 FRONT)
-78	344-0132-00			2	CLIP, circuit board
	- - - - - -			-	mounting hardware for each: (not included w/clip)
	213-0088-00			1	SCREW, thread forming, #4 x 1/4 inch, PHS

FIG. 3 SAMPLER & PULSER CIRCUIT BOARDS

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
3-	670-0118-04	1990	2999	1	ASSEMBLY, circuit board—SAMPLER
	670-0118-06	3000		1	ASSEMBLY, circuit board—SAMPLER
	- - - - - -			-	assembly includes:
	388-0721-03	1990	2999	1	BOARD, circuit, w/contacts
	- - - - - -			-	assembly includes:
-1	- - - - - -			1	BOARD, circuit (not replaceable)
	- - - - - -			-	board includes:
-2	214-0506-00	1990	2999	5	PIN, connector
	388-0721-04	3000		1	BOARD, circuit
	214-0697-00	3000		2	CONTACT, electrical
	214-0506-00	3000		6	PIN, connector
	136-0252-01	X3000		12	SOCKET, pin connector
-3	- - - - - -			2	CONTACT, electrical (not replaceable)
-4	132-0002-00			2	SLEEVE, outer conductor
-5	132-0029-00			2	CONDUCTOR, inner
-6	132-0028-00			2	INSULATOR, plastic
-7	103-0055-00			2	ADAPTER, inner conductor to section line
-8	132-0007-00			4	RING, snap
-9	205-0063-00			2	SHELL, connector
-10	214-0700-00			2	COUPLER
-11	220-0460-00			2	NUT, coupling
-12	103-0054-00			2	ADAPTER, section line
-13	131-0391-00			2	CONNECTOR, coaxial, 1 contact
-14	337-0847-00			1	SHIELD, bottom
	- - - - - -			-	mounting hardware: (not included w/shield)
-15	211-0014-00			2	SCREW, 4-40 x 1/2 inch, PHS
-16	361-0126-00			2	SPACER, sleeve, hex., 0.188 x 0.310 inch long
-17	337-0848-00			1	SHIELD, top
	- - - - - -			-	mounting hardware: (not included w/shield)
-18	211-0008-00			2	SCREW, 4-40 x 1/4 inch, PHS
-19	129-0097-00			2	POST, hex., 0.188 x 0.560 inch long
-20	136-0220-00	1990	2999X	2	SOCKET, transistor, 3 pin
-21	136-0219-00			1	SOCKET, transistor, 4 pin
-22	386-1127-00	1990	2999	2	PLATE
	386-1737-00	3000		1	PLATE
	386-1738-00	3000		1	PLATE
	- - - - - -			-	mounting hardware: (not included w/plate)
	211-0014-00	1990	2999	5	SCREW, 4-40 x 1/2 inch, PHS
	211-0014-00	3000		7	SCREW, 4-40 x 1/2 inch, PHS
-23	210-0586-00	1990	2999	5	NUT, keps, 4-40 x 1/4 inch
	210-0586-00	3000		7	NUT, keps, 4-40 x 1/4 inch
-24	344-0108-00			2	CLIP, diode
	- - - - - -			-	mounting hardware: (not included w/assembly)
	220-0459-00			2	NUT, dodecagon (not shown)

FIG. 3 SAMPLER & PULSER CIRCUIT BOARDS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
3-	670-0119-03			1	ASSEMBLY, circuit board—PULSER
	- - - - - -			-	assembly includes:
	388-0720-03			1	BOARD, circuit, w/contacts
	- - - - - -			-	assembly includes:
-25	- - - - - -			1	BOARD, circuit (not replaceable)
-26	- - - - - -			2	CONTACT, electrical (not replaceable)
	200-0642-00			1	CAP (not shown)
-27	136-0220-00			4	SOCKET, transistor, 3 pin
-28	132-0002-00			2	SLEEVE, outer conductor
-29	132-0029-00			2	CONDUCTOR, inner
-30	132-0028-00			2	INSULATOR, plastic
-31	103-0055-00			2	ADAPTER, inner conductor to section line
-32	132-0007-00			4	RING, snap
-33	205-0062-00			2	SHELL, contact
-34	214-0700-00			2	COUPLER
-35	220-0460-00			2	NUT, coupling
-36	103-0054-00			2	ADAPTER, section line
-37	131-0391-00			2	CONNECTOR, coaxial, 1 contact
-38	136-0183-00			1	SOCKET, transistor, 3 pin
-39	352-0100-00			3	HOLDER, variable resistor
	- - - - - -			-	mounting hardware for each: (not included w/holder)
-40	358-0214-00			1	BUSHING, insulator
-41	352-0097-00			1	HOLDER, rod resistor
-42	214-0259-00			1	SPRING, interlock pin
-43	210-0676-00			1	EYELET
-44	380-0103-00			1	HOUSING
-45	386-1127-00			2	PLATE
	- - - - - -			-	mounting hardware: (not included w/plate)
-46	211-0014-00			5	SCREW, 4-40 x 1/2 inch, PHS
-47	210-0586-00			5	NUT, keps, 4-40 x 1/4 inch
-48	352-0100-00			1	HOLDER, variable resistor
	- - - - - -			-	mounting hardware for each: (not included w/holder)
-49	361-0008-00			1	SPACER, plastic, 0.281 inch long
	- - - - - -			-	mounting hardware: (not included w/assembly)
	220-0459-00			2	NUT, dodecagon (not shown)
-50	175-0404-00			1	ASSEMBLY, cable



368

A1

BLOCK DIAGRAM
S/N 1990 - UP

VOLTAGE AND WAVEFORM TEST CONDITIONS

Typical voltage measurements and waveform photographs (shown in blue) were obtained under the following conditions unless noted otherwise on the individual diagrams:

Test Oscilloscope

Bandwidth	DC to 50 MHz
Probe Input Impedance	10 Megohms, 7 picofarads
Probe Ground Lead	Clipped to Type 1S2 chassis
Triggering	Internal unless indicated otherwise

DC Voltmeter

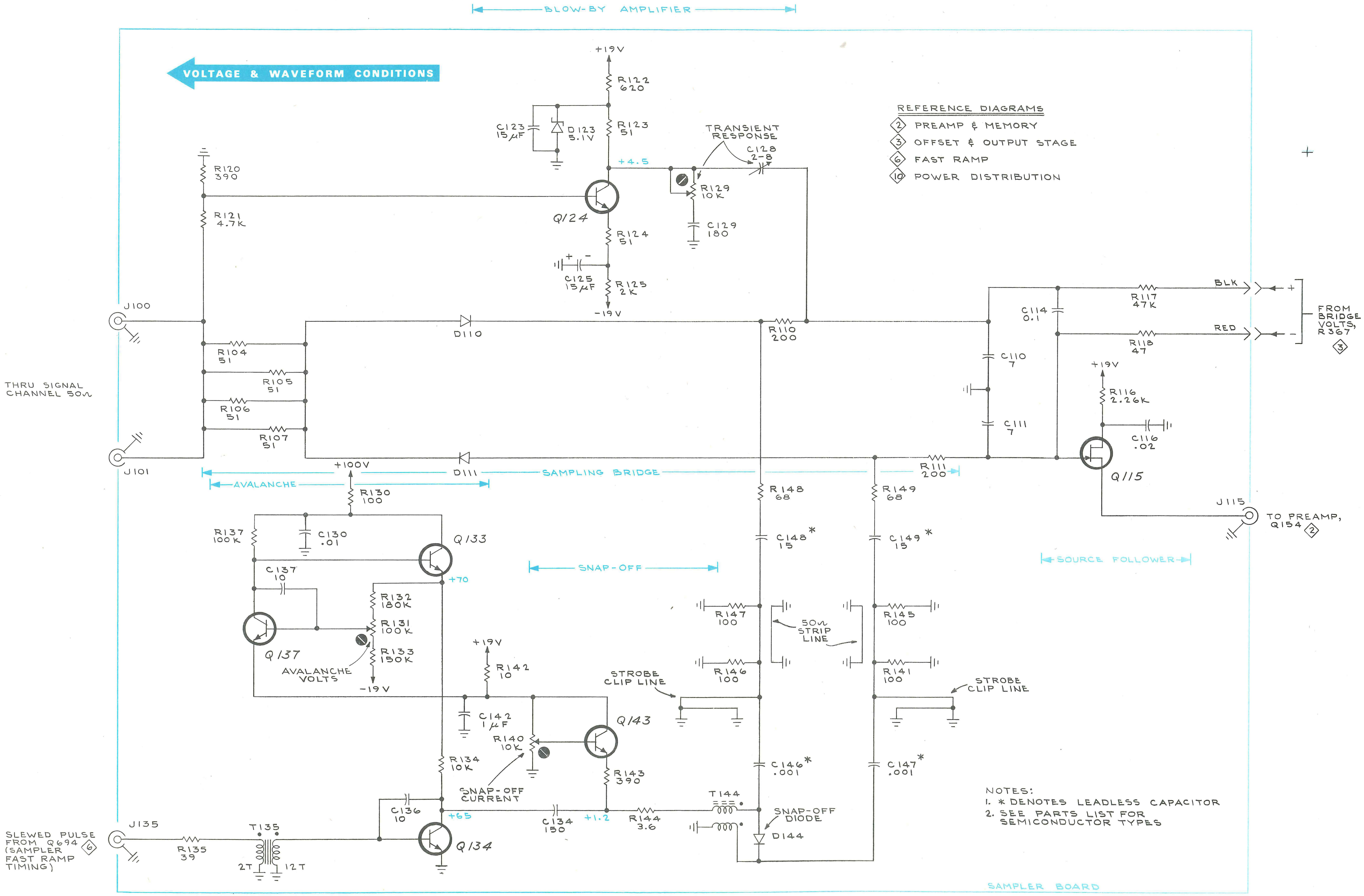
Type	Volt-Ohmmeter
Sensitivity	20,000 Ω/volt

Type 1S2 Conditions

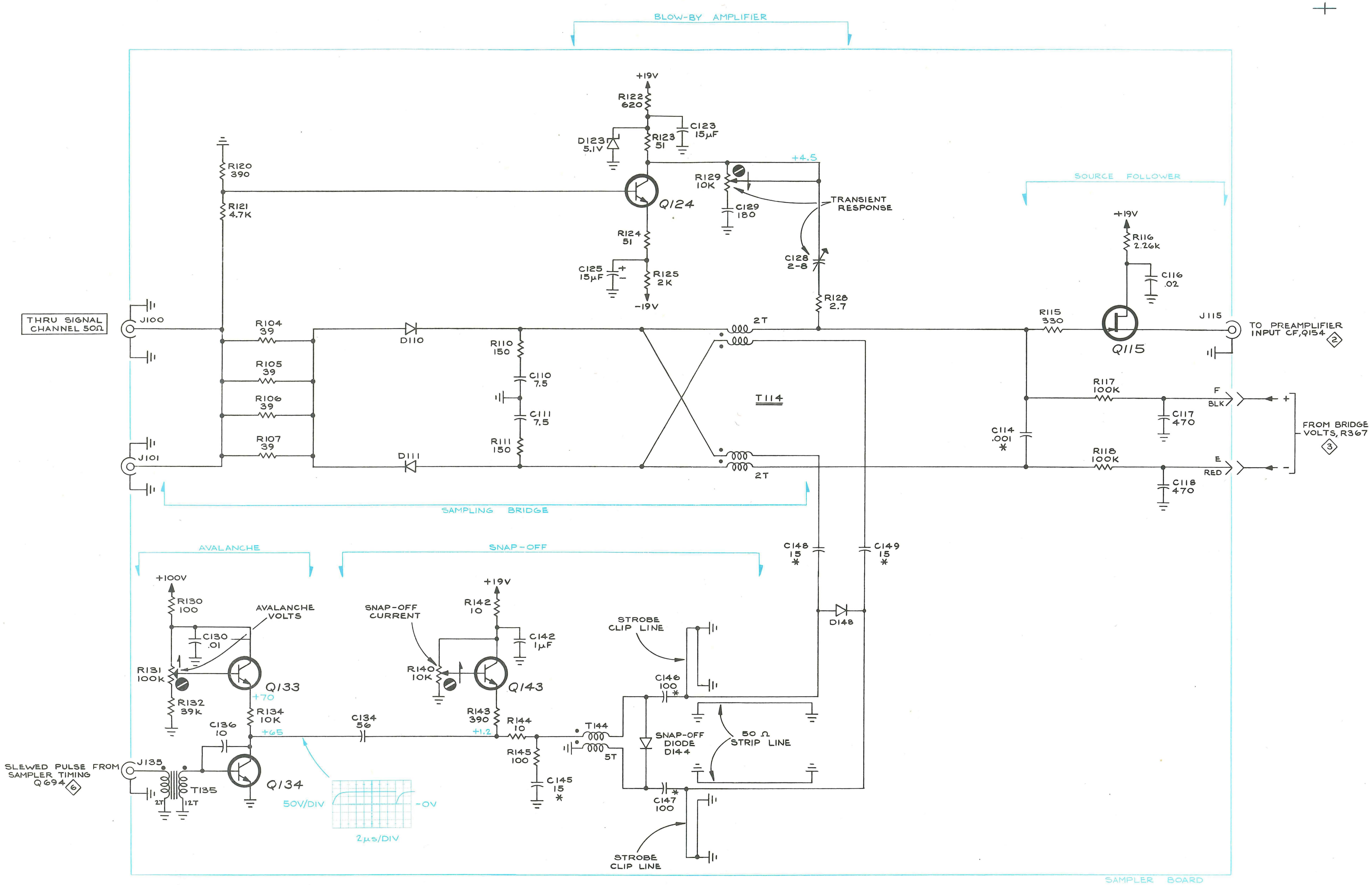
Connected to oscilloscope through 20 inch flexible extension (Tektronix Part No. 012-0038-00). An interference will be shown on the Oscilloscope unless the flexible extensions wire connecting pin 8 is shielded. Using the Type 547 Oscilloscope with the flexible extension, the white plunger inside the top rear of the Type 547 plug-in compartment must be pulled forward.

Vertical Input Signal	Type 1S2 0.25 volt pulse connected to the lower THRU SIGNAL CHANNEL 50 Ω and the upper THRU SIGNAL CHANNEL terminated in 50 Ω. Use two 90° Elbows (Tektronix Part No. 017-0070-00), and a 50 Ω End-line termination (Tektronix Part No. 017-0081-00).

SAMPLER ⟨1⟩


BLOW-BY AMPLIFIER
VOLTAGE & WAVEFORM CONDITIONS
REFERENCE DIAGRAMS
2 PREAMP & MEMORY
3 OFFSET & OUTPUT STAGE
6 FAST RAMP
10 POWER DISTRIBUTION
+19V
R122 620
C123 15µF
D123 5.1V
R123 51
+4.5
TRANSIENT RESPONSE
C128 2-8
R129 10K
C129 180
R120 390
R121 4.7K
Q124
R124 51
C125 15µF
R125 2K
-19V
J100
D110
R110 200
C114 0.1
R117 47K
BLK
RED
R118 47
FROM BRIDGE VOLTS, R367 3
R104 51
R105 51
R106 51
R107 51
THRU SIGNAL CHANNEL 50Ω
C110 7
+19V
R116 2.26K
C111 7
C116 .02
J101
D111
+100V
SAMPLING BRIDGE
R111 200
Q115
AVALANCHE
R130 100
R148 68
R149 68
J115
TO PREAMP, Q154 2
R137 100K
C130 .01
Q133
C148* 15
C149* 15
SOURCE FOLLOWER
C137 10
+70
SNAP-OFF
R132 180K
R131 100K
R147 100
50Ω STRIP LINE
R145 100
Q137
R133 150K
AVALANCHE VOLTS
-19V
+19V
R142 10
R146 100
R141 100
STROBE CLIP LINE
STROBE CLIP LINE
C142 1µF
Q143
R140 10K
R134 10K
SNAP-OFF CURRENT
R143 390
C146* .001
C147* .001
NOTES:
1. * DENOTES LEADLESS CAPACITOR
2. SEE PARTS LIST FOR SEMICONDUCTOR TYPES
C136 10
+65
C134 150
+1.2
R144 3.6
T144
SNAP-OFF DIODE
D144
SLEWED PULSE FROM Q694 6 (SAMPLER FAST RAMP TIMING)
J135
R135 39
T135
2T
12T
Q134
SAMPLER BOARD

SAMPLER 1



REFERENCE DIAGRAMS

- 2 PREAMP & MEMORY
- 3 OFFSET & OUTPUT STAGE
- 6 FAST RAMP
- 10 POWER DISTRIBUTION

* DENOTES LEADLESS CAPACITOR

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

0370

TYPE 1S2 SAMPLING UNIT

B1

SAMPLER 1

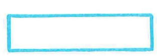
S/N 1990-2999

Type 1S2 Control Settings:

VERTICAL UNITS/DIV	.2
OFFSET	Set for 0 V at ×1 OFFSET OUTPUT connector
RESOLUTION	NORMAL
DISPLAY MODE	NORMAL
ρ—VOLTS	ρ
HORIZONTAL UNITS/DIV	DISTANCE
POSITION	0.000
DIELECTRIC	AIR
RANGE	1 μs, 100 m
MAGNIFIER	×1
MODE	INT PULSE .25 V
UHF SYNC OR TRIGGER SENS	Midrange

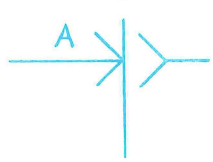
The following symbols are used on the schematics:


Screwdriver adjustment


Front-, side- or rear-panel control or connector

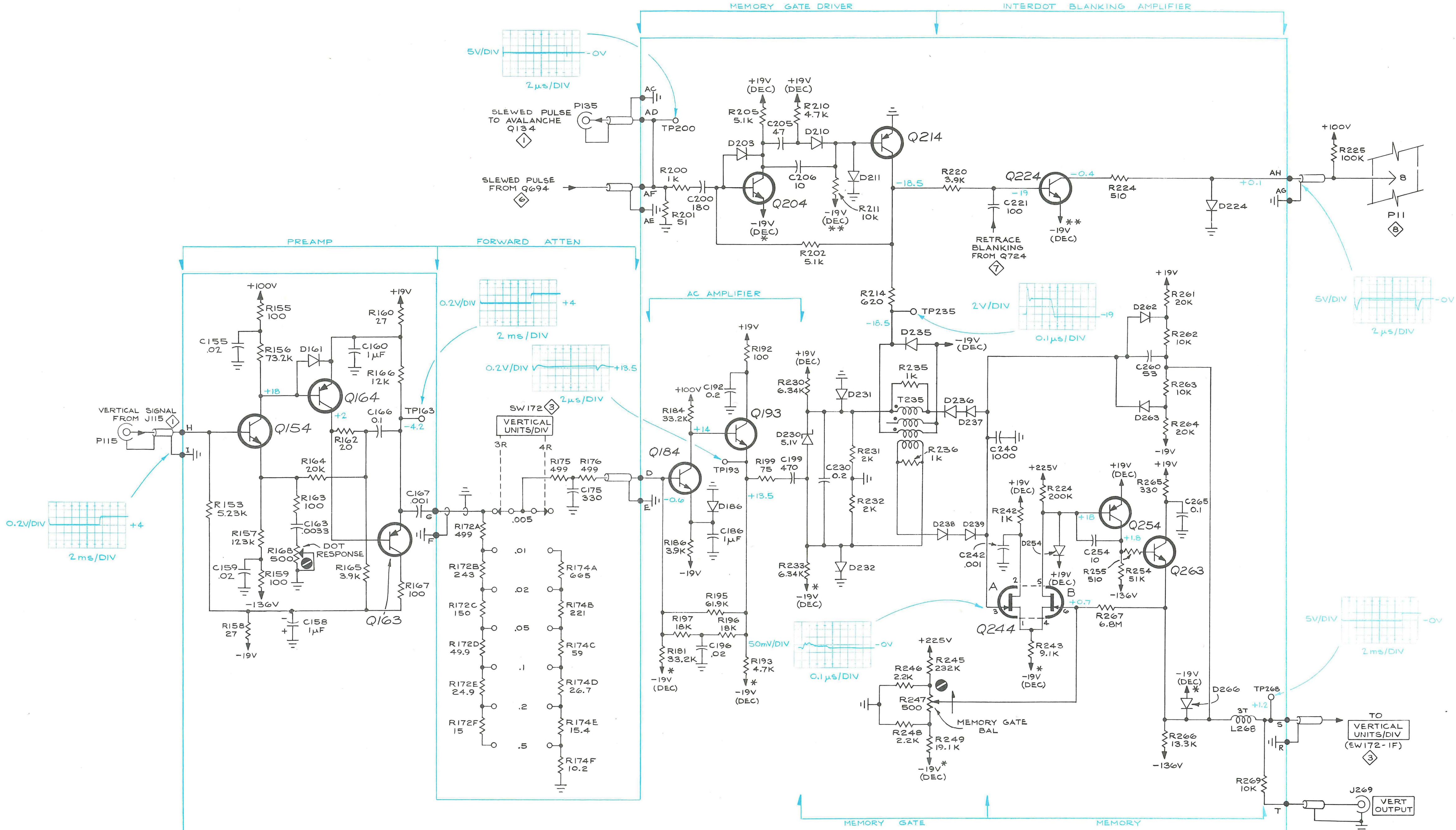

Clockwise control rotation in direction of arrow

Refer to indicated diagram



Connection to circuit board made with pin connector at indicated pin

Blue line encloses components located on circuit board



* DENOTES DECOUPLING NETWORK #1
** DENOTES DECOUPLING NETWORK #2
(SEE ⟨10⟩)

REFERENCE DIAGRAMS
- ⟨1⟩ SAMPLER
- ⟨3⟩ OFFSET & OUTPUT STAGE
- ⟨6⟩ FAST RAMP
- ⟨7⟩ SWEEP GENERATOR
- ⟨8⟩ POWER SUPPLY
- ⟨10⟩ POWER DISTRIBUTION

PARTIAL VERTICAL BOARD

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

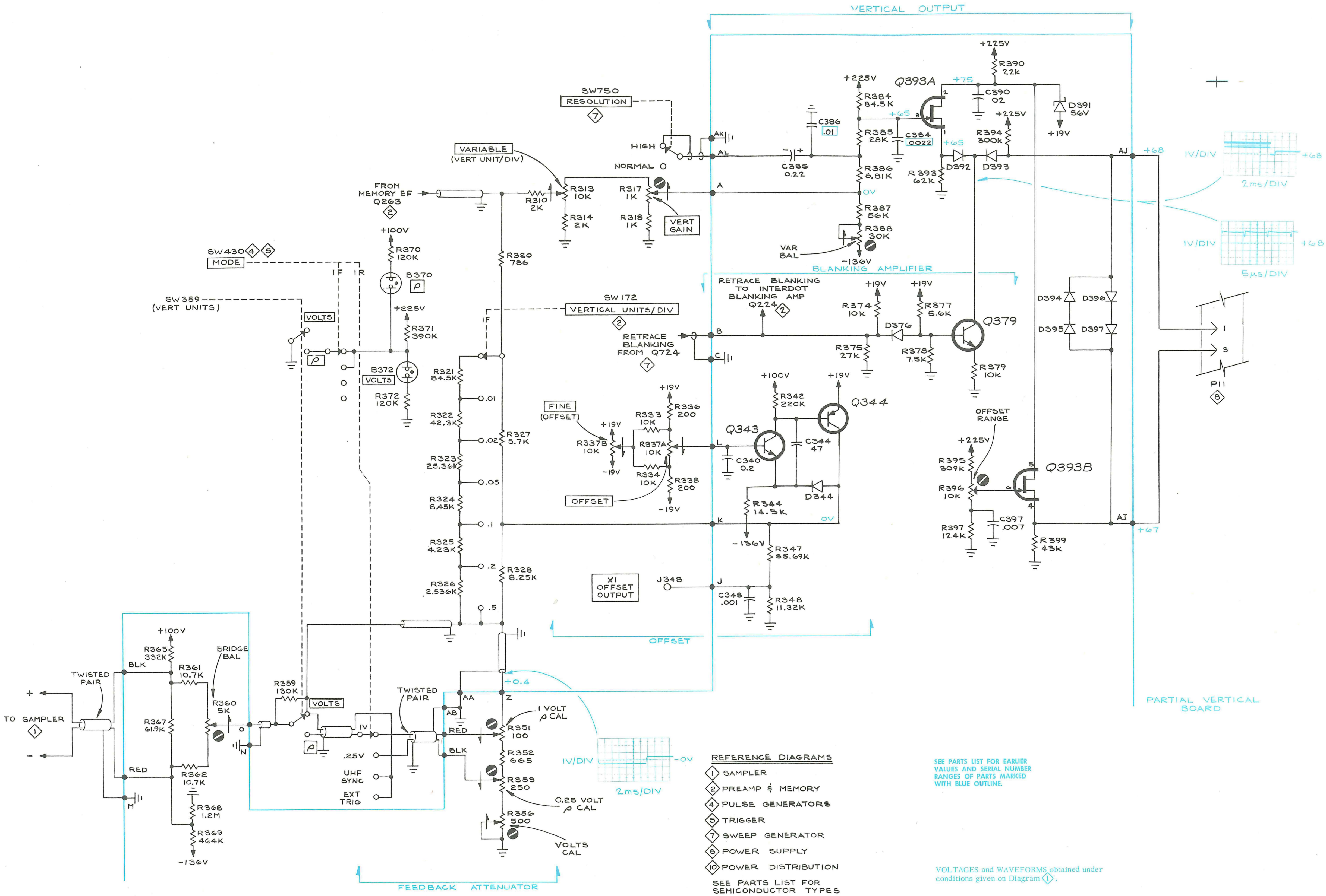
368

TYPE 1S2 SAMPLING UNIT

A

PREAMP & MEMORY ⟨2⟩
S/N 1990-UP

VOLTAGES and WAVEFORMS obtained under conditions given on Diagram ⟨1⟩.



REFERENCE DIAGRAMS

1. SAMPLER
2. PREAMP & MEMORY
4. PULSE GENERATORS
5. TRIGGER
7. SWEEP GENERATOR
8. POWER SUPPLY
10. POWER DISTRIBUTION

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

VOLTAGES and WAVEFORMS obtained under conditions given on Diagram 1.

0370

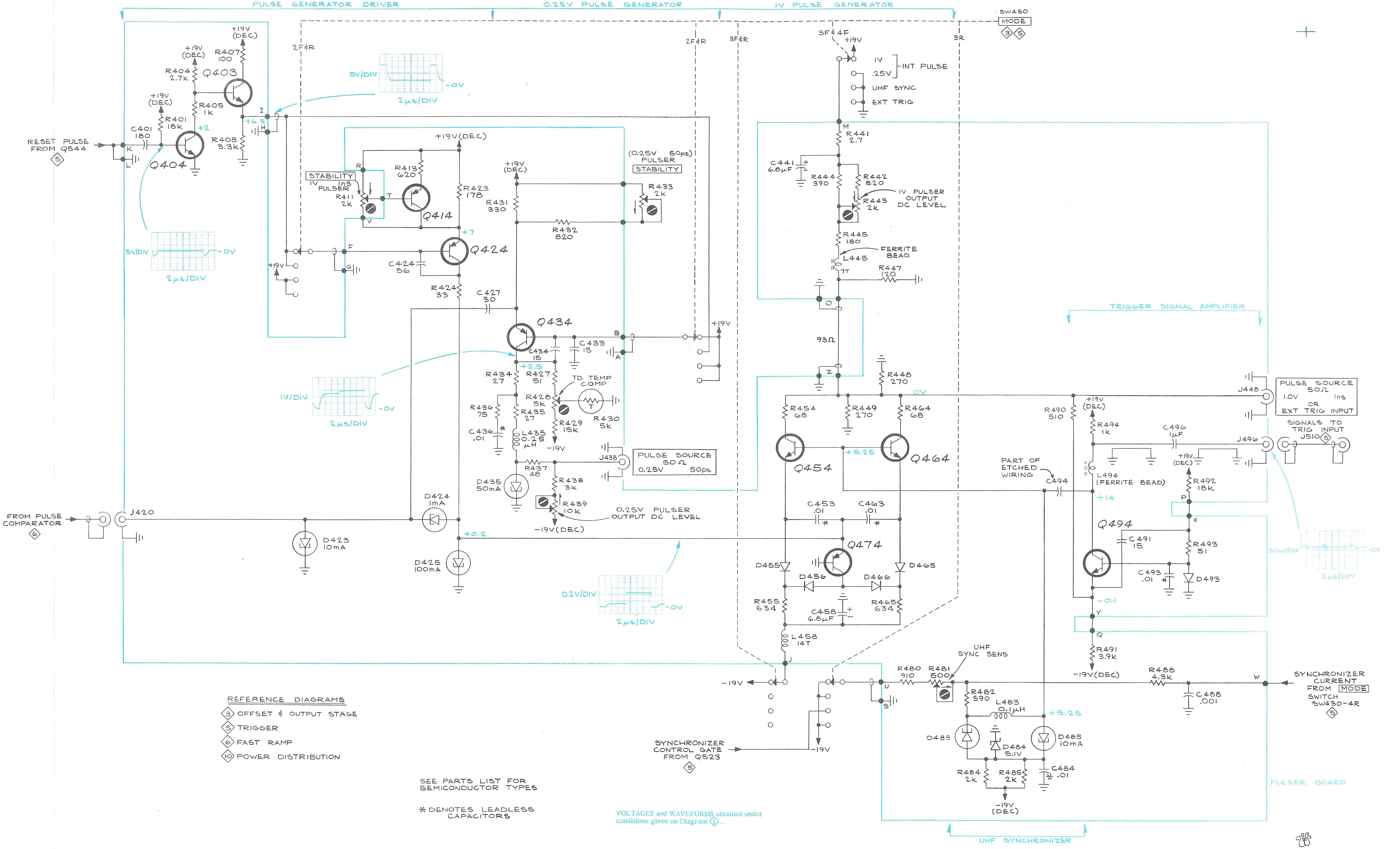
TYPE 1S2 SAMPLING UNIT

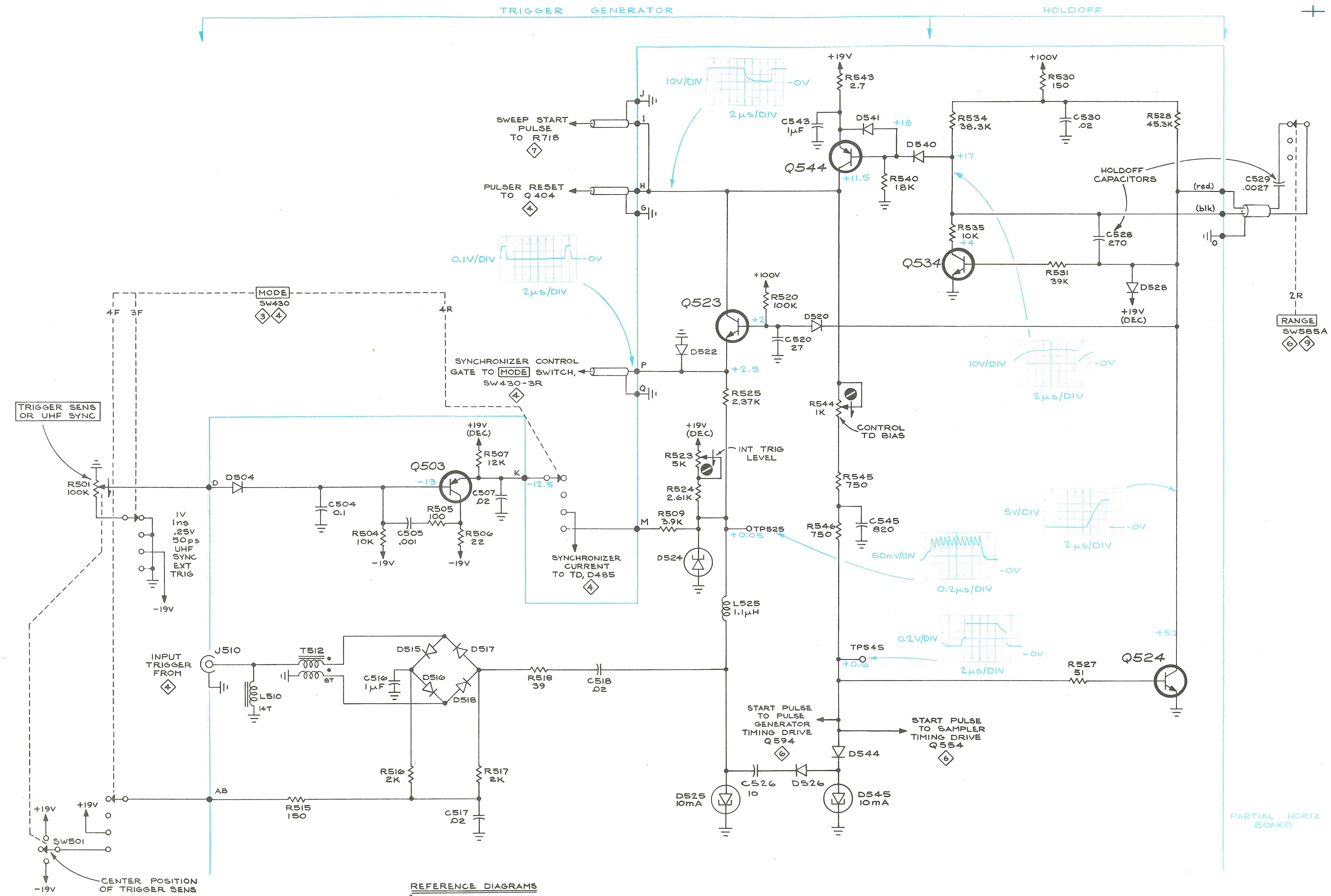
B2

OFFSET & OUTPUT STAGE 3

S/N 1990 & UP

OFFSET & OUTPUT 3


PULSE GENERATOR DRIVER
0.25V PULSE GENERATOR
1V PULSE GENERATOR
SW430 MODE
RESET PULSE FROM Q544
FROM PULSE COMPARATOR
J420
Q403
Q404
Q414
Q424
Q434
Q454
Q464
Q474
Q494
STABILITY 1V 1ns PULSER R411 2k
(0.25V 50ps) PULSER STABILITY
1V PULSER OUTPUT DC LEVEL
0.25V PULSER OUTPUT DC LEVEL
TD TEMP COMP
FERRITE BEAD
PULSE SOURCE 50Ω 0.25V 50ps
PULSE SOURCE 50Ω 1.0V 1ns OR EXT TRIG INPUT
SIGNALS TO TRIG INPUT J510
PART OF ETCHED WIRING
L494 (FERRITE BEAD)
INT PULSE
UHF SYNC
EXT TRIG
TRIGGER SIGNAL AMPLIFIER
UHF SYNC SENS
UHF SYNCHRONIZER
SYNCHRONIZER CURRENT FROM MODE SWITCH SW430-4R
SYNCHRONIZER CONTROL GATE FROM Q523
PULSER BOARD
5V/DIV
2µs/DIV
1V/DIV
0.2V/DIV
50mV/DIV
REFERENCE DIAGRAMS
3 OFFSET & OUTPUT STAGE
5 TRIGGER
6 FAST RAMP
10 POWER DISTRIBUTION
SEE PARTS LIST FOR SEMICONDUCTOR TYPES
* DENOTES LEADLESS CAPACITORS
VOLTAGES and WAVEFORMS obtained under conditions given on Diagram 1.



REFERENCE DIAGRAMS

- 3 OFFSET & OUTPUT STAGE
- 4 PULSE GENERATOR
- 6 FAST RAMP
- 7 SWEEP GENERATOR
- 9 READOUT SWITCHING
- 10 POWER DISTRIBUTION

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

VOLTAGES and WAVEFORMS obtained under conditions given on Diagram 1.

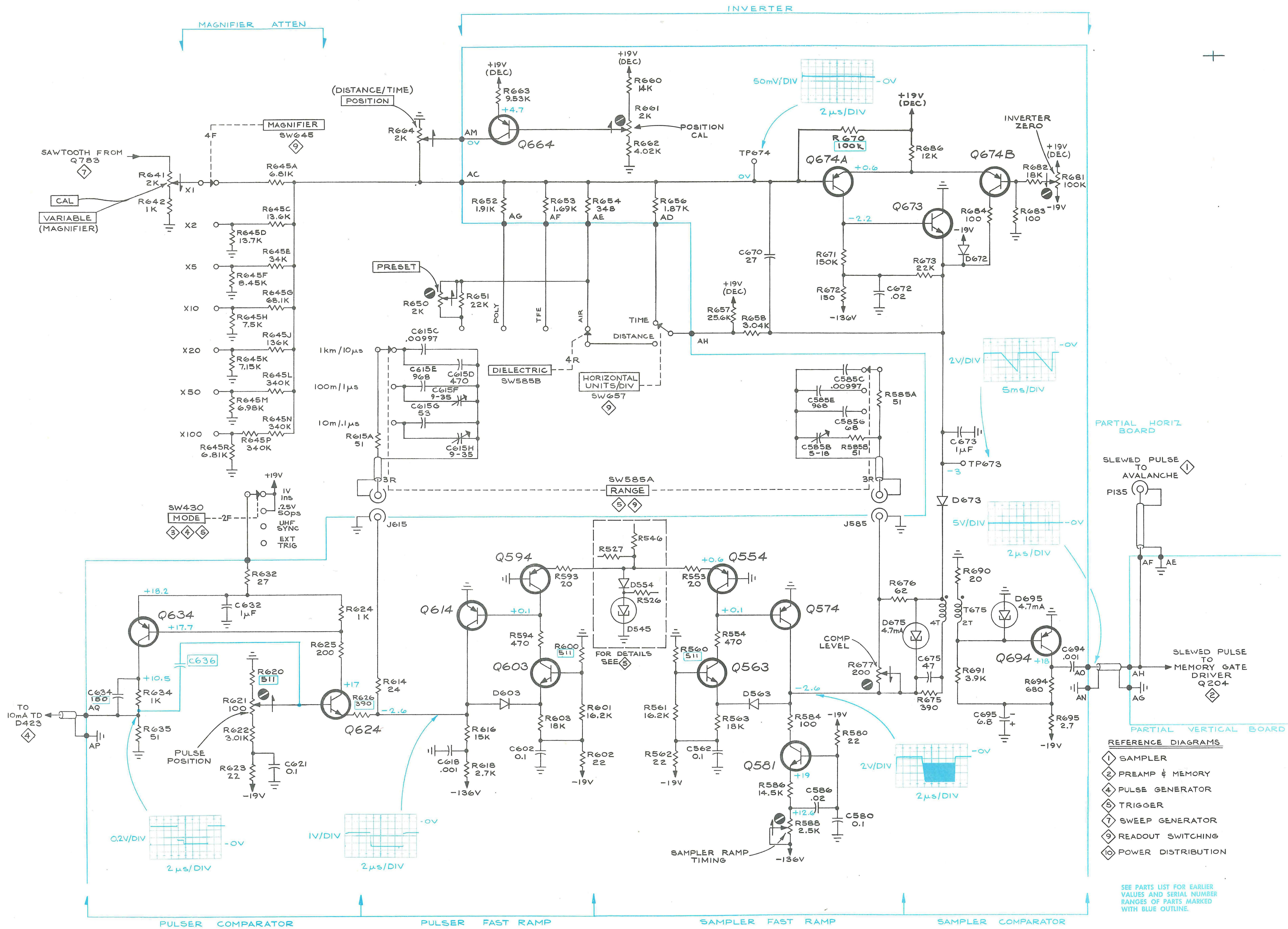
TYPE 1S2 SAMPLING UNIT

A2

368

TRIGGER 5
S/N 1990 & UP

TRIGGER 5



TYPE 1S2 SAMPLING UNIT

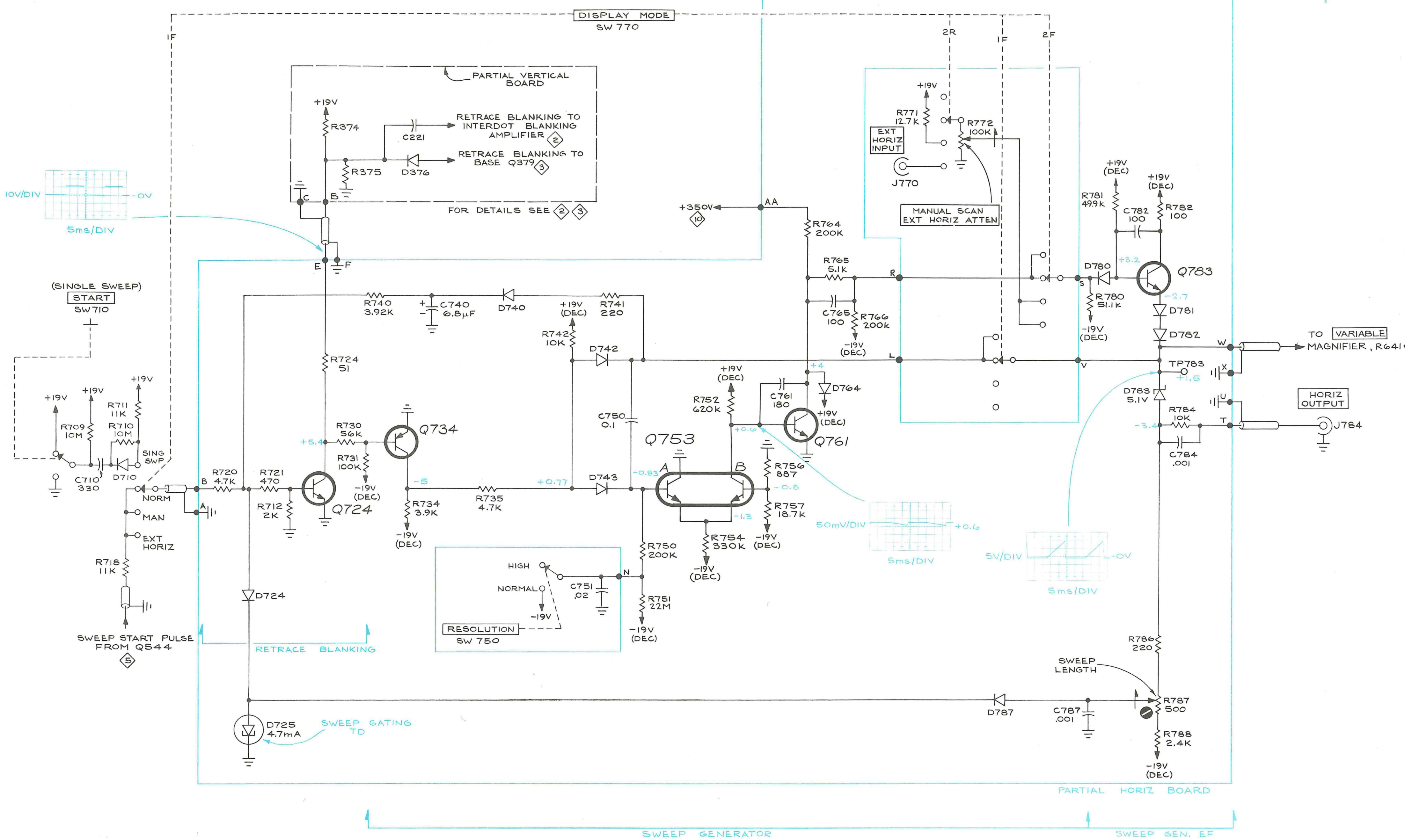
VOLTAGES and WAVEFORMS obtained under conditions given on Diagram 1.

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

1270

FAST RAMP 6

S/N 1990 & UP



REFERENCE DIAGRAMS
- 2 PREAMP & MEMORY
- 3 OFFSET & OUTPUT STAGE
- 5 TRIGGER
- 6 FAST RAMP
- 10 POWER DISTRIBUTION

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

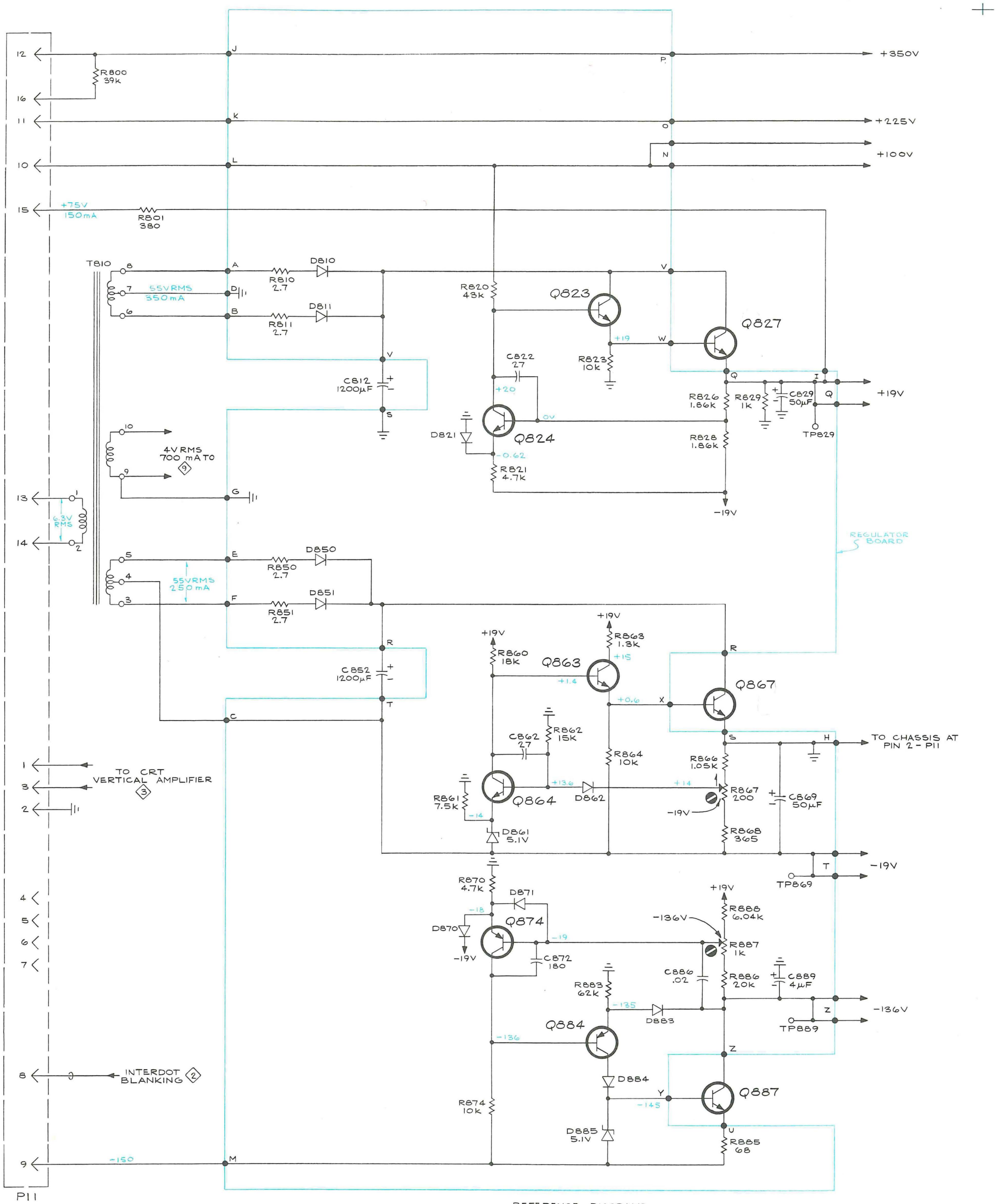
VOLTAGES and WAVEFORMS obtained under conditions given on Diagram 1.

368

TYPE 1S2 SAMPLING UNIT

A

SWEEP GENERATOR 7
S/N 1990 & UP



VOLTAGES obtained under conditions given on Diagram ⟨1⟩.

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

REFERENCE DIAGRAMS

⟨2⟩ SAMPLER
⟨3⟩ OFFSET & OUTPUT STAGE
⟨9⟩ READOUT & SWITCHING
⟨10⟩ POWER DISTRIBUTION

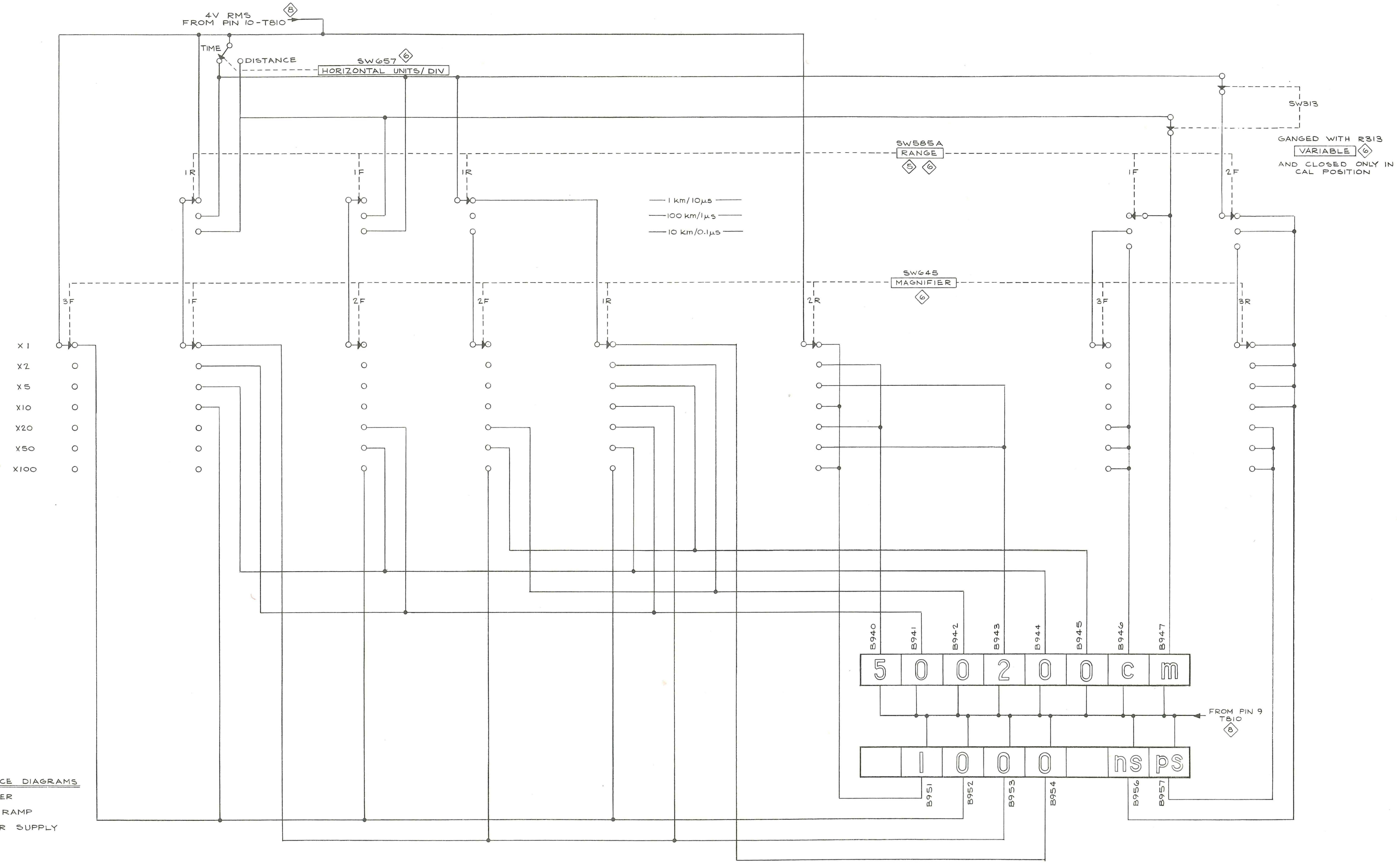
368

TYPE 1S2 SAMPLING UNIT

A

POWER SUPPLY ⟨8⟩

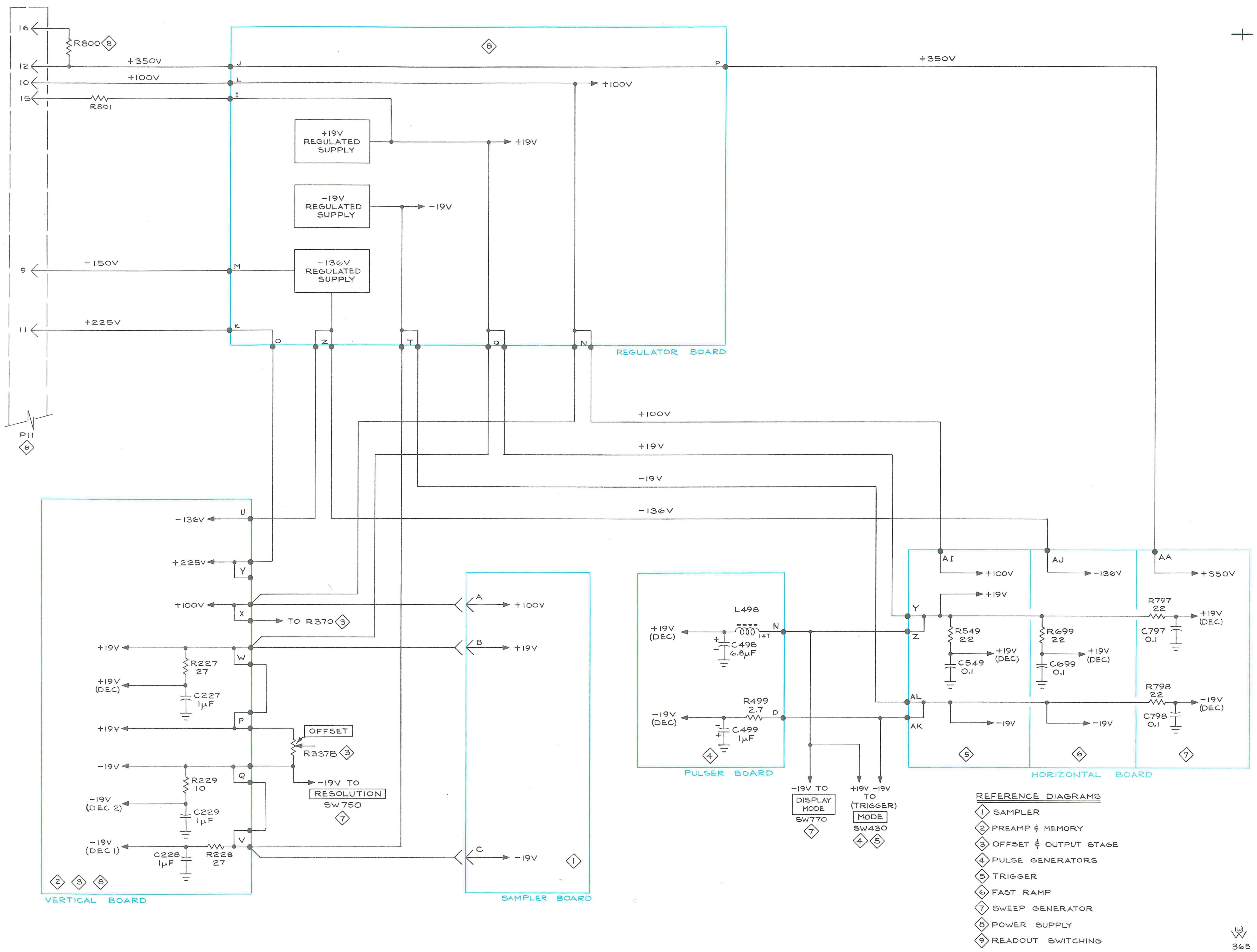
S/N 1990 & UP



REFERENCE DIAGRAMS
5 TRIGGER
6 FAST RAMP
8 POWER SUPPLY

READOUT SWITCHING 9
S/N 1990 & UP

368



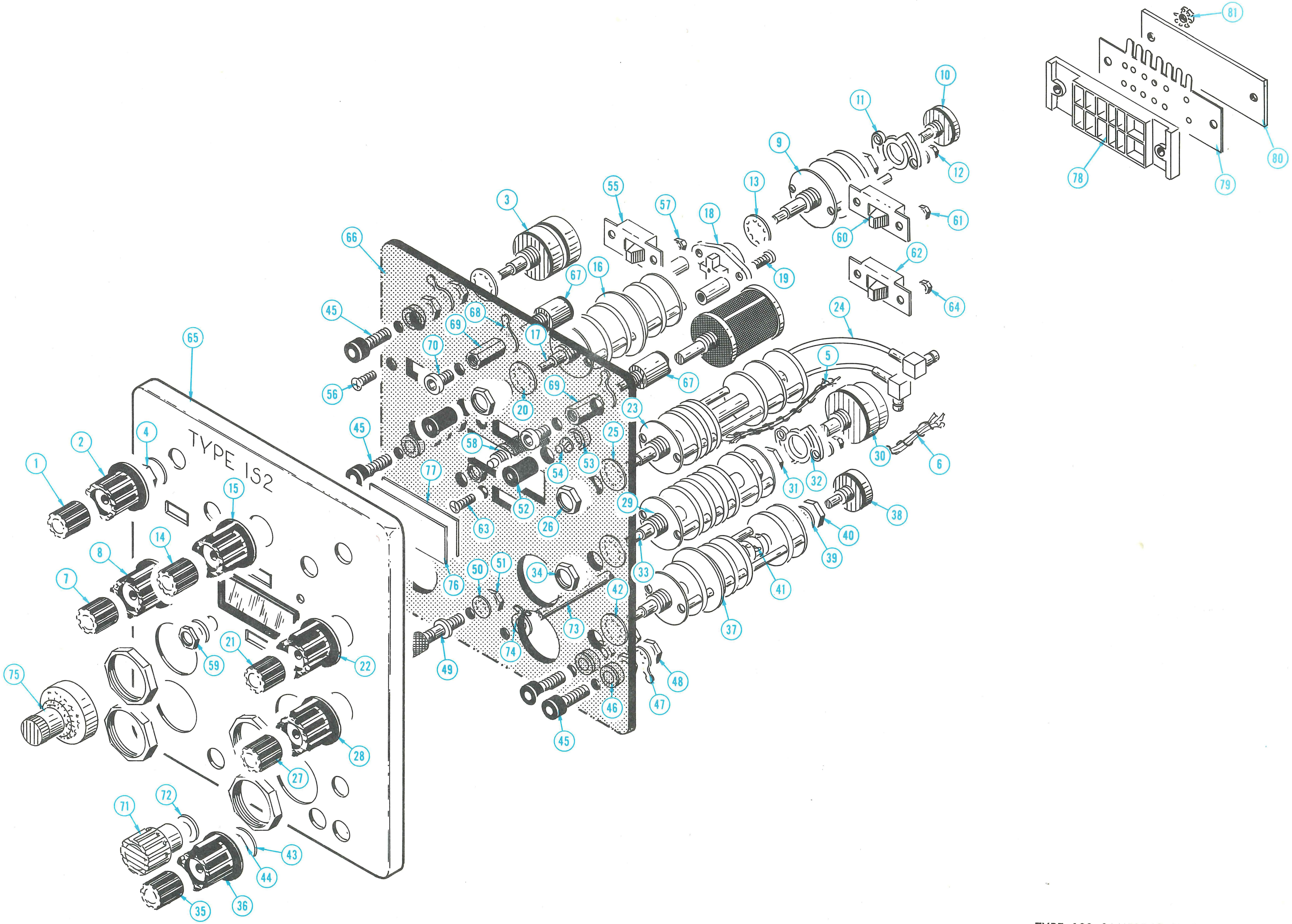
TYPE 1S2 SAMPLING UNIT

A

POWER DISTRIBUTION 10

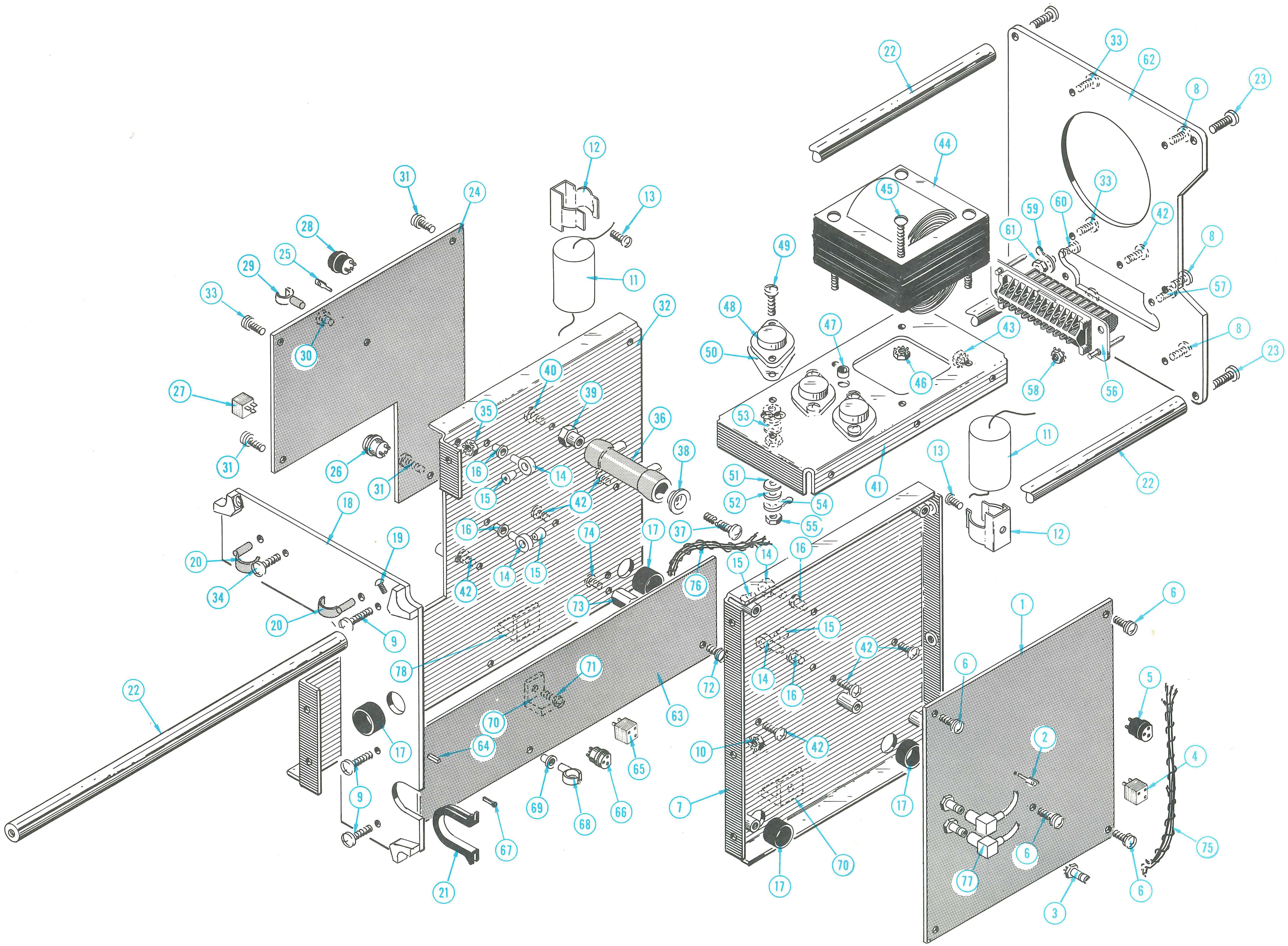
S/N 1990 & UP

FIG. 1 FRONT



TYPE 1S2 SAMPLING UNIT

FIG. 2 FRAME & CHASSIS



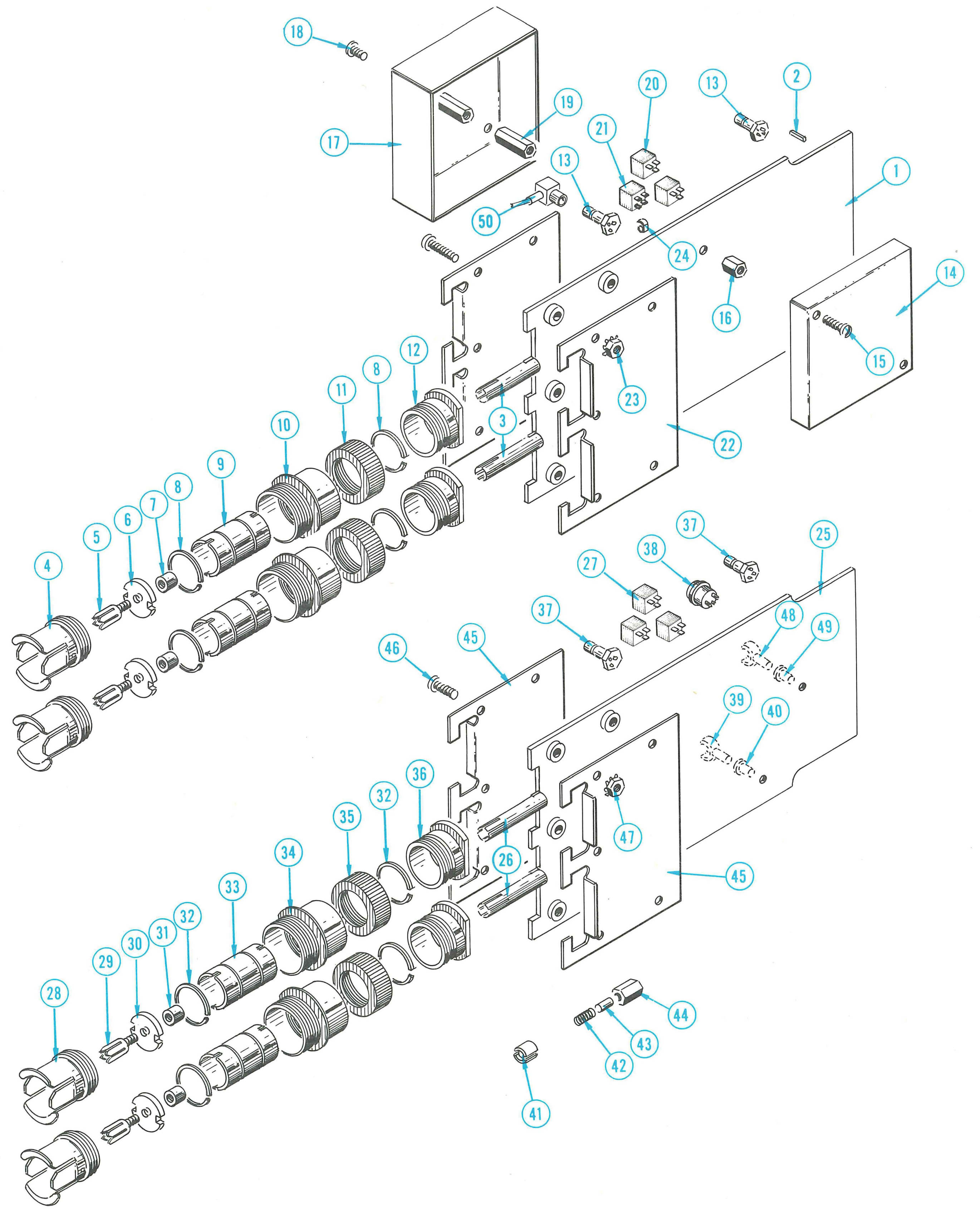
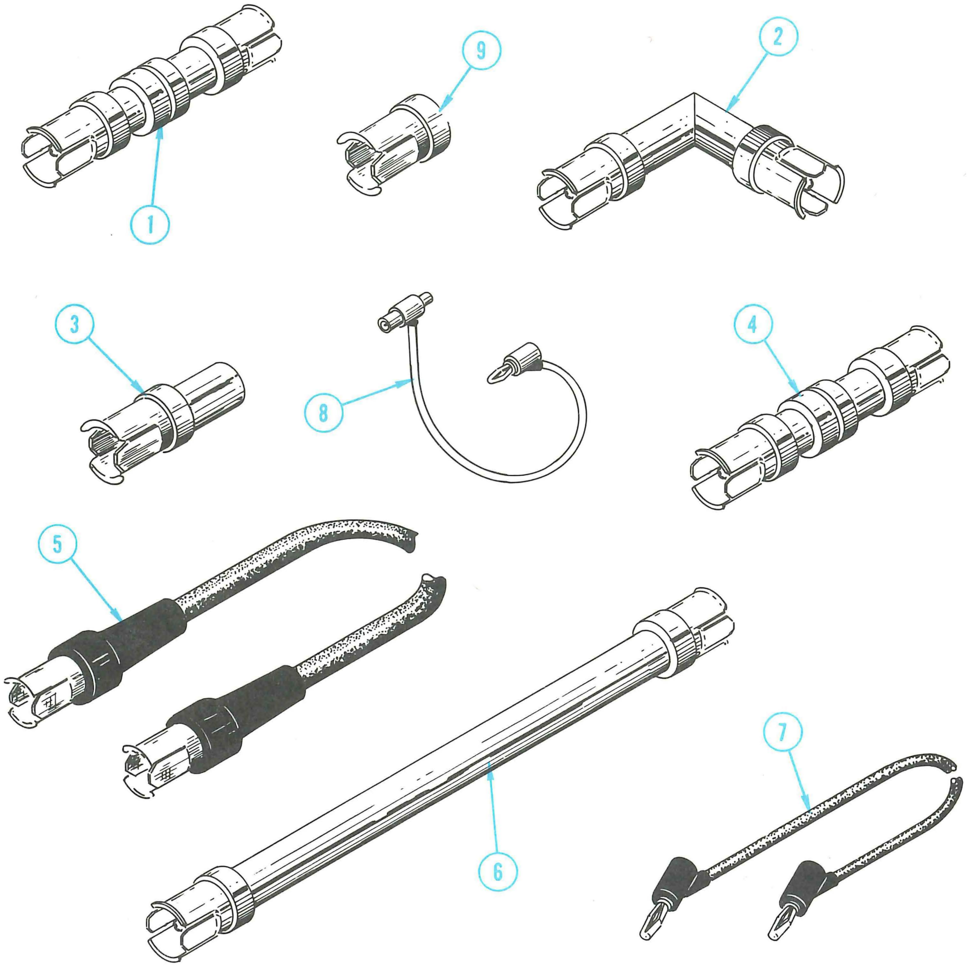


FIG. 4 STANDARD ACCESSORIES



A

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	1 2 3 4 5 Description
4-1	017-0079-00			1	ATTENUATOR, 50 Ω, 5X
-2	017-0070-00	1990	2229	2	ELBOW, GR 90°
	017-0513-00	2230		1	CABLE, assembly, RF
-3	017-0081-00			1	TERMINATION, 50 Ω
-4	017-0080-00			1	ATTENUATOR, 50 Ω, 2X
-5	017-0502-00			1	CABLE, 50 Ω, 5 Nsec
-6	017-0084-00			1	LINE, 50 Ω, 20 CM
-7	012-0039-00			1	CORD, patch, 18 inches, red
-8	012-0090-00			1	CORD, patch, 18 inches, red, BNC to Banana
-9	017-0087-00			1	TERMINATION, 50 Ω, short circuit
	070-0889-00			2	MANUAL, instruction (not shown)

Ⓑ

MANUAL CHANGE INFORMATION

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

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

A single change may affect several sections. Since the change information sheets are carried in the manual until all changes are permanently entered, some duplication may occur. If no such change pages appear following this page, your manual is correct as printed.

SERVICE NOTE

Because of the universal parts procurement problem, some electrical parts in your instrument may be different from those described in the Replaceable Electrical Parts List. The parts used will in no way alter or compromise the performance or reliability of this instrument. They are installed when necessary to ensure prompt delivery to the customer. Order replacement parts from the Replaceable Electrical Parts List.

CALIBRATION TEST EQUIPMENT REPLACEMENT

Calibration Test Equipment Chart

This chart compares TM 500 product performance to that of older Tektronix equipment. Only those characteristics where significant specification differences occur, are listed. In some cases the new instrument may not be a total functional replacement. Additional support instrumentation may be needed or a change in calibration procedure may be necessary.

Comparison of Main Characteristics

DM 501 replaces 7D13		
PG 501 replaces 107	PG 501 - Risetime less than 3.5 ns into 50 Ω.	107 - Risetime less than 3.0 ns into 50 Ω.
108	PG 501 - 5 V output pulse; 3.5 ns Risetime.	108 - 10 V output pulse; 1 ns Risetime.
111	PG 501 - Risetime less than 3.5 ns; 8 ns Pretrigger pulse delay.	111 - Risetime 0.5 ns; 30 to 250 ns Pretrigger Pulse delay.
114	PG 501 - ±5 V output.	114 - ±10 V output. Short proof output.
115	PG 501 - Does not have Paired, Burst, Gated, or Delayed pulse mode; ±5 V dc Offset. Has ±5 V output.	115 - Paired, Burst, Gated, and Delayed pulse mode; ±10 V output. Short-proof output.
PG 502 replaces 107		
108	PG 502 - 5 V output	108 - 10 V output.
111	PG 502 - Risetime less than 1 ns; 10 ns Pretrigger pulse delay.	111 - Risetime 0.5 ns; 30 to 250 ns Pretrigger pulse delay.
114	PG 502 - ±5 V output	114 - ±10 V output. Short proof output.
115	PG 502 - Does not have Paired, Burst, Gated, Delayed & Undelayed pulse mode; Has ±5 V output.	115 - Paired, Burst, Gated, Delayed & Undelayed pulse mode; ±10 V output. Short-proof output.
2101	PG 502 - Does not have Paired or Delayed pulse. Has ±5 V output.	2101 - Paired and Delayed pulse; 10 V output.
PG 506 replaces 106	PG 506 - Positive-going trigger output signal at least 1 V; High Amplitude output, 60 V.	106 - Positive and Negative-going trigger output signal, 50 ns and 1 V; High Amplitude output, 100 V.
067-0502-01	PG 506 - Does not have chopped feature.	0502-01 - Comparator output can be alternately chopped to a reference voltage.
SG 503 replaces 190,		
190A, 190B	SG 503 - Amplitude range 5 mV to 5.5 V p-p.	190B - Amplitude range 40 mV to 10 V p-p.
191	SG 503 - Frequency range 250 kHz to 250 MHz.	191 - Frequency range 350 kHz to 100 MHz.
067-0532-01	SG 503 - Frequency range 250 kHz to 250 MHz.	0532-01 - Frequency range 65 MHz to 500 MHz.
TG 501 replaces 180,		
180A	TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. Trigger output - slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time.	180A - Marker outputs, 5 sec to 1 μs. Sinewave available at 20, 10, and 2 ns. Trigger pulses 1, 10, 100 Hz; 1, 10, and 100 kHz. Multiple time-marks can be generated simultaneously.
181	TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns.	181 - Marker outputs, 1, 10, 100, 1000, and 10,000 μs, plus 10 ns sinewave.
184	TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. Trigger output - slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time.	184 - Marker outputs, 5 sec to 2 ns. Sinewave available at 50, 20, 10, 5, and 2 ns. Separate trigger pulses of 1 and .1 sec; 10, 1, and .1 ms; 10 and 1 μs. Marker amplifier provides positive or negative time marks of 25 V min. Marker intervals of 1 and .1 sec; 10, 1, and .1 ms; 10 and 1 μs.
2901	TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. Trigger output - slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time.	2901 - Marker outputs, 5 sec to 0.1 μs. Sinewave available to 50, 10, and 5 ns. Separate trigger pulses, from 5 sec to 0.1 μs. Multiple time-marks can be generated simultaneously.

NOTE: All TM 500 generator outputs are short-proof. All TM 500 plug-in instruments require TM 500-Series Power Module.