INSTRUCTION MANUAL

Serial Number ____________

TYPE 4S1 PLUG-IN

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

070-329

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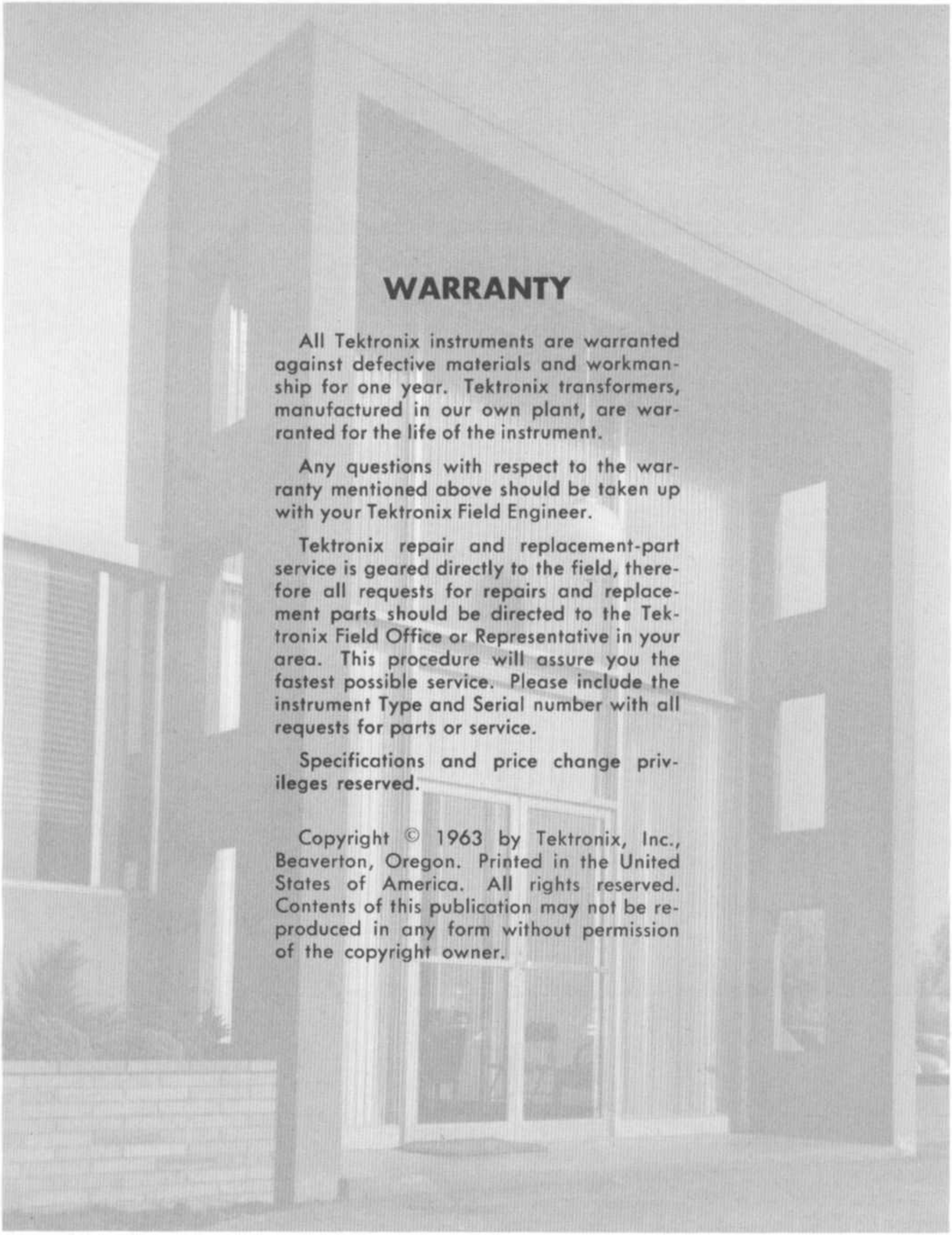


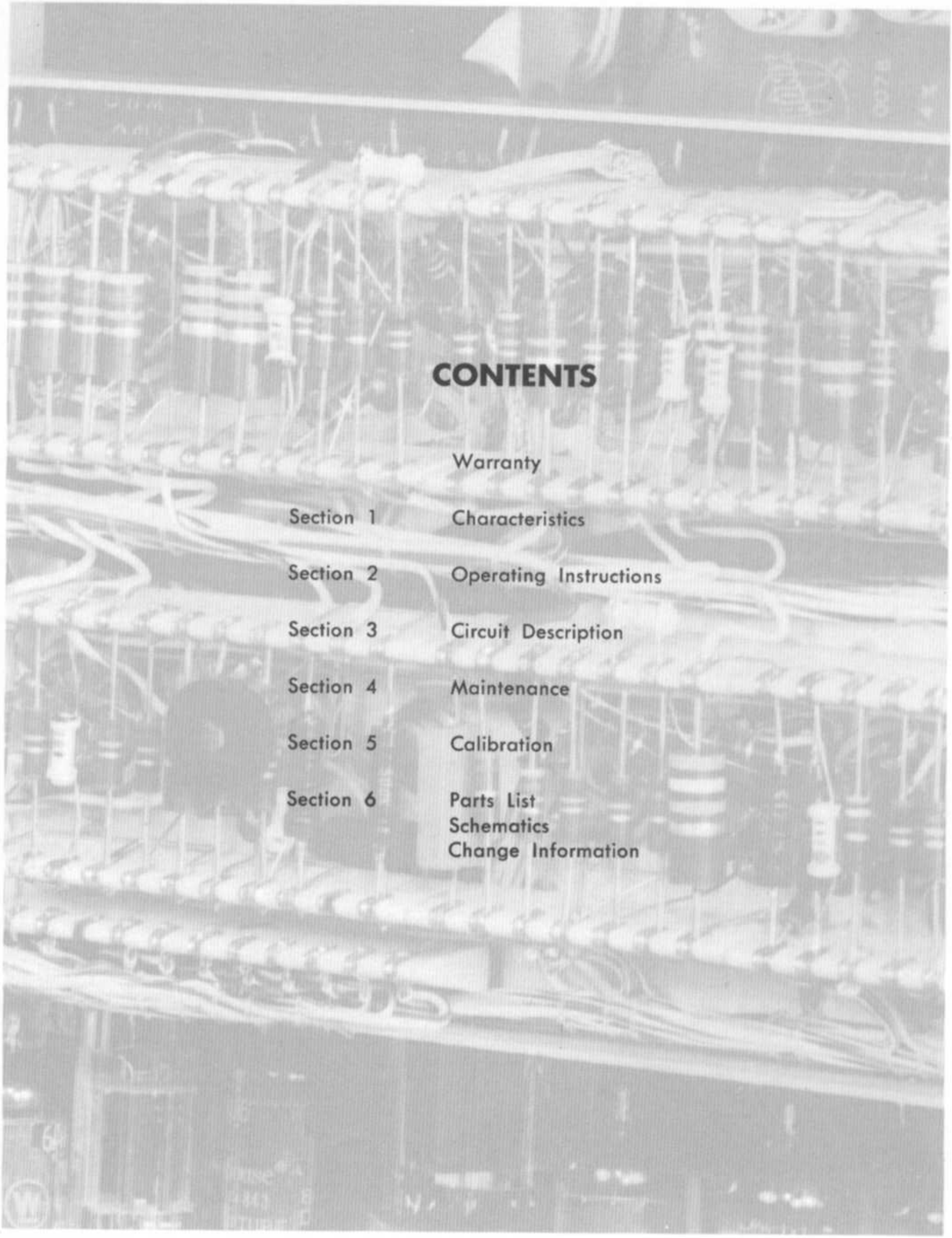
WARRANTY

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

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

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

Specifications and price change privileges reserved.



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TEKTRONIX, INC., PORTLAND, OREGON, U.S.A.

SECTION 1
CHARACTERISTICS

GENERAL INFORMATION

The Tektronix Type 4S1 50 Ω Dual-Trace Sampling Unit is a general-purpose vertical-channel plug-in unit for use with the Type 661 Oscilloscope. It has a risetime of 0.35 nsec (nanosecond = 10^{-9} second) or less. Seven calibrated deflection factors range from 2 mv/cm to 200 mv/cm, and uncalibrated variable deflection factors between these steps provide up to three times increase in sensitivity at each step. Minimum deflection factor is about 2/3 mv/cm.

The Type 4S1 in a Type 661 Oscilloscope is capable of presenting either single- or dual-trace displays of repetitive fast-rise signals. Two signals may also be displayed in an X-Y mode (lissajous) or added algebraically. The balanced-bridge input and the error-sensing method of signal reconstruction provide a very low level of trace noise and minimum kick-back from the input circuit. Internal delay lines and trigger takeoff in the Type 4S1 allow the system to be operated with no external delay or trigger cables.

The system samples the input signal, each sample at a slightly later time, and reconstructs the signal on an equivalent time base.

OPERATING CHARACTERISTICS

Risetime

0.35 nsec or less, measured between 10% and 90% amplitudes.

Bandpass

Equivalent to Dc to 1 Gc (gigacycle = 10^9 cps).

Input Impedance

50 ohms. A higher impedance may be obtained by using Tektronix passive or cathode-follower signal probes.

Dynamic Range

2 volts peak-to-peak, without overloading input circuitry. Maximum short-time dc overload is plus or minus 10 volts.

Deflection Factors

Calibrated steps of 2, 5, 10, 20, 50, 100 and 200 mv/cm. Accuracy: ±1% at 200 mv/cm, with DISPLAY switch at NORMAL; ±3% from 100 mv/cm through 10 mv/cm; ±4% at 5 mv/cm and 2 mv/cm. With DISPLAY switch at INVERTED, 200 mv/cm accuracy is ±2%. An uncalibrated VARIABLE control, with a range of three-to-one, permits increasing the sensitivity between the calibrated steps of the MILLIVOLTS/CM switch. The 2 mv/cm deflection factor can be extended to 2/3 mv/cm with the VARIABLE control.

DC Offset

Up to ±1 volt, with a five-turn control, for making measurements or positioning the trace vertically. With a deflection factor of 200 mv/cm, the DC OFFSET control can cause a +1-volt (±12%) to —1-volt (±3%) change at the corresponding vertical output jack on the oscilloscope.

Offset Monitor

Front-panel jack permits measurement of dc voltage-level changes made with DC OFFSET control. Voltage change at OFFSET MONITOR jack is 100 times the voltage change seen in the display. Monitor voltage range is +104.5 volts (±10%) to —100 volts (±5%), and output impedance is 100 k ohms.

Modes of Operation

A Only, B Only, Dual Trace, Added Algebraic and A Vertical-B Horizontal (lissajous). Dual trace switching frequency is approximately 50 kc. Rejection ratio for Added Algebraic mode is 40:1 or better when each channel is driven with a ½-volt flat-topped pulse and the deflection factor for each channel is 50 mv/cm.

Internal Delay Lines

Approximately 45-nsec signal delay between trigger takeoff and sampling bridge, on each channel.

Internal Trigger Signal

Triggering signal is selected from either input channel for use by timing unit. Trigger amplitude to timing unit is about ⅛th the input signal amplitude, ac- or dc-coupled.

Time Coincidence Between Channels

In Dual Trace mode, display time difference between two indentical signals is no more than 30 psec (picoseconds = 10^{-12} seconds).

Display

Normal or inverted. A separate control for each channel permits inversion of either or both signals, allowing signals to be added or subtracted in the Added Algebraic mode. An additional ±1% error may be added to deflection factor error with DISPLAY switch at INVERTED position.

Noise

No more than 1 mv peak-to-peak, at 2 mv/cm, with SMOOTHING control at NORMAL, and MODE switch at A ONLY, B ONLY or A VERT. B HORIZ.; no more than 1.5 mv peak-to-peak with MODE switch at DUAL TRACE or ADDED ALGEB. Noise is typically less than 0.5 mv peak-to-peak with SMOOTHING control fully counterclockwise.

Smoothing

Reduces noise amplitude to about 1/2 the noise amplitude normally present. Useable when dot density is sufficient. Less than 3 mv noise when rotating SMOOTHING control slowly.

Crosstalk

Less than 1.5% crosstalk between channels when observing a 400 mv pulse such as the Delayed Pulse signal from the Type 661 Oscilloscope.

Dot Slash

No visible vertical drift of sampling dots with triggering rate above 150 cps; no more than 2 mm vertical drift at triggering rate of 50 cps.

Probe Power

Power provided through front-panel connector for operation of cathode-follower probes. Filament voltage is 12.6 volts dc (terminals B and C), and cathode-to-plate voltage is 100 volts (terminals A and D). These voltages are regulated by the oscilloscope.

Signal Outputs through Oscilloscope

Within 3% of signal voltages at input connectors, plus offset, when deflection factor is 200 mv/cm. Output impedance is 10 k ohms ±2%.

MECHANICAL

Construction

Aluminum-alloy chassis, with six plug-in subchassis units. Photo-etched anodized front panel.

Dimensions

Height—7 inches; width—8 1/2 inches; depth—14 inches.

Weight

Approximately 15 1/2 pounds.

STANDARD ACCESSORIES

2—50-ohm 10X T Attenuators, with GR connectors	017-044
2—50-ohm 5-nsec coax cables, with GR connectors	017-502
2—Instruction manuals	070-329

SECTION 2
OPERATING INSTRUCTIONS

GENERAL INFORMATION

The operating instructions in this section consist of the following: a brief description of front-panel controls and connectors; a discussion of probes and other methods of connecting to the signal source; instructions on operating the unit for the first time; a discussion of the various modes of operation, and some general applications.

The sampling system, consisting of a Type 661 Oscilloscope, a timing unit and the Type 4S1, is complete within itself under normal signal conditions. Each channel of the Type 4S1 has a trigger takeoff circuit which provides internal trigger signals to the timing plug-in unit. No external triggering signal is required if the input signal has fast-rise portions of sufficient amplitude. However, external triggering may be used if desired. See the timing unit instruction manual for specific triggering requirements.

Low-level signals and small portions of moderate-level signals may be viewed by using the DC OFFSET control in conjunction with the MILLIVOLTS/CM switch and the VARIABLE control. The minimum deflection factor is about 2/3 mv/cm and may be obtained with the MILLIVOLTS/CM switch in the 2 position and the VARIABLE control rotated clockwise.

High-resolution amplitude measurements can be made of any voltage waveform or any part of a waveform that can properly be displayed on the crt screen, through the use of the ±1-volt DC OFFSET control and the OFFSET MONITOR jack. Voltage measured at the OFFSET MONITOR jack is 100 times as great as the dc offset applied to the signal. External coaxial attenuators may be used to bring the amplitude of large signals down to the input limit of 2 volts peak-to-peak.

The SMOOTHING control is provided to reduce random noise when necessary, by decreasing the gain in the amplifier feedback loop. Smoothing will not significantly affect the risetime of the display if the interval between samples is short enough that the change in signal amplitude between samples is only a small increment of the total signal amplitude.

FRONT PANEL CONTROLS AND CONNECTORS

All controls and connectors required for the normal operation of the Type 4S1 are located on the front panel of the unit (Fig. 2-1). Table 2-1 gives a brief description of the function of each of these controls and connectors.

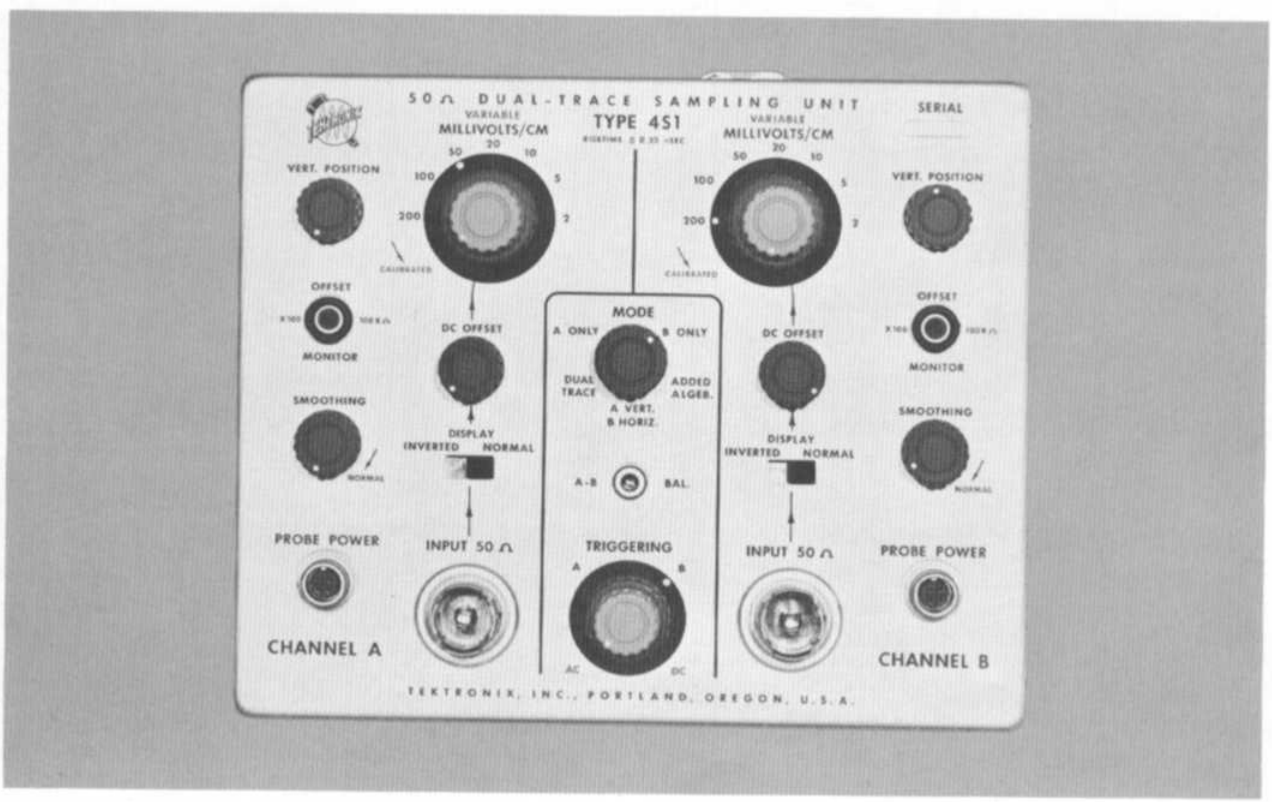


Fig. 2-1. Front-panel controls and connectors.

Table 2-1. Functions of Controls and Connectors

VERT. POSITION Control (both channels)	Permits display to be moved vertically on the crt screen through a range of about 10 centimeters. Further vertical positioning is provided by the DC OFFSET control.
MILLIVOLTS/CM Switch (both channels)	Permits selection of the desired vertical deflection factor by varying the gain of the channel. Front-panel values relate crt beam deflection to input signal amplitude. For example, for a switch setting of 10, each centimeter of trace deflection on the crt graticule represents 10 millivolts of input signal amplitude.
VARIABLE Control (both channels)	Provides three-to-one uncalibrated variable increase in input sensitivity, for adjusting display amplitude between steps of the MILLIVOLTS/CM switch. Deflection factor may be extended as fas as 2/3 mv/cm at the 2 mv position of the switch.
DC OFFSET Control (both channels)	Provides an internal variable dc voltage from +1 to —1 volt, to be added to the input signal. Offset voltage may be used for making accurate voltage measurements and for positioning the display past the range of the VERTICAL POSITION control. The amount of dc offset added to the signal may be accurately monitored at the OFFSET MONITOR jack.
OFFSET MONITOR Jack (both channels)	Provides amplified monitor for determining the amount of dc voltage added by the DC OFFSET control. The voltage at this jack is 100 times the setting of the DC OFFSET control. Measurement of the offset voltage should be made with a high impedance device.
DISPLAY Switch (both channels)	Permits either NORMAL or INVERTED display of the input signal voltage. With the switch in NORMAL position, positive-going is upward and negative-going is downward in the crt display. These conditions are reversed with the switch in INVERTED position.
SMOOTHING Control (both channels)	Reduces display noise by decreasing the gain in the amplifier feedback loop. See caution later in this section about dot transient response and use of the SMOOTHING control.
INPUT 50 Ω Connector (both channels)	Applies the input signal to the Type 4S1 input circuitry. Each INPUT connector is followed by a trigger take-off, a delay line, a 50-ohm termination, and a sampling bridge.
PROBE POWER Connector (both channels)	Provides filament and plate voltage for operation of a cathode-follower probe.
MODE Switch	Allows selection of one of five modes of operation: A ONLY—only Channel A signal is displayed; B ONLY—only Channel B signal is displayed; DUAL TRACE—both channels display separate signals simultaneously; ADDED ALGEB.—both channels operate to display the algebraic sum or difference of the two signals as a single trace; A VERT. B HORIZ—Channel A provides vertical deflection and Channel B provides horizontal deflection for X-Y operation, with oscilloscope Sweep Magnifier at X1.
A-B BAL. Control	Screwdriver adjust sets Channel A gain; provides external adjustment for matching the two channels when operating in differential mode (A – B).
TRIGGERING Switch	Allows selection of the internal triggering source from the input signal on either channel.
AC-DC Switch	Provides selection of either ac- or dc-coupling of internal triggering signal to timing unit.

Signal Outputs Through the Oscilloscope

In addition to the output signals to the crt deflection system, the Type 4S1 has two auxiliary output signals connected internally to the Type 661 Oscilloscope and available at the front-panel connectors labeled Signal Outputs, Vert. A and Vert. B. These auxiliary outputs are for use with analog pen recorders and oscilloscope monitors. Output impedance is 10 k ohms.

The amplitude of the sampled signal at each of the output connectors is ⅓rd of the amplitude of the vertical signal from the Type 4S1 to the oscilloscope vertical amplifier. With a calibrated crt display, this is equal to 200 mv for each centimeter of vertical deflection on the crt. Thus, when the MILLIVOLTS/CM switch is set to 200, a one-volt input signal will produce a one-volt output signal at the Vertical Output jack. The output waveform is the real-time waveform of the sampled signal displayed on the crt screen. If the signal is driven out of the dynamic range of the sampling channel, the signal at the output jack will be distorted.

INSTALLING THE TYPE 4S1

CAUTION

ALWAYS TURN OFF OSCILLOSCOPE POWER BEFORE INSERTING OR REMOVING PLUG-IN UNITS.

With the oscilloscope power switch turned off, begin installation of the plug-in unit by first pulling outward on the locking latch, located above the lower plug-in compartment of the oscilloscope, until the latch is perpendicular to the front panel. Next insert the Type 4S1 into the compartment and push it in as far as possible by hand. The latch will be at about a 45° angle with the panel if the unit has been pushed far enough. Complete the operation by pressing in on the latch until it touches the front panel.

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

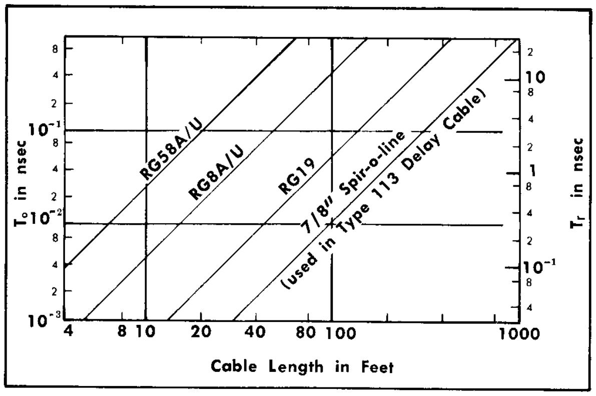


Fig. 2-2. Risetimes of Common Coaxial Cables, in Relation to Cable Length.

CONNECTING THE INPUT SIGNAL

General Information

The input circuits of the Type 4S1 are designed to have the characteristics of 50-ohm transmission lines. This permits the use of 50-ohm coaxial cables for extending the input terminals a moderate distance from the oscilloscope while maintaining the same input characteristics. A 50-ohm source can drive several feet of 50-ohm cable without significant loss. Avoid the use of long cable lengths in order to minimize high-frequency losses. It is important to note that the risetime of the output signal from a coaxial cable, compared to the input signal, deteriorates in proportion to the square of the length of the cable. Fig. 2-2. illustrates the 0% to 50% risetime (T_o) and the 10% to 90% risetime (T_r) of various common coaxial cables, in response to a step input. (The 10% to 90% risetime is approximately 30 T_o). As an example of signal deterioration due to cable length, a 5-nsec cable (about 4 feet) of RG58A/U will degrade a 0.2-nsec risetime (T_r) to about 0.3 nsec, but a 20 nsec length (about 16 feet) of the same type cable will degrade the 0.2-nsec risetime to about 1.2 nsec.

The 50-ohm INPUT connectors on the Type 4S1 are GR Type 874 and should be mated to 50-ohm cables with the same type connectors. If it is necessary to use other than 50-ohm cables, suitable matching devices should be used to couple between cables or connectors that have different characteristic impedances.

When making signal-comparison or time-difference determinations, the two signals should travel through coax cables which have identical losses and time delay. The velocity of propagation and the nature of signal losses depend on the characteristics of the cables.

For relatively high-impedance measurements of nanosecond signals, special passive or cathode-follower signal probes are available for use with the Type 4S1 Sampling Unit. Some of these special probes are described in the following paragraphs.

Passive Probes

The Tektronix P6034 10X Probe and the P6035 100X Probe are moderate-resistance passive probes designed for use with the Type 4S1. They are small in size, permitting measurements to be made in miniaturized circuitry. Power rating is 0.5 watt up to a frequency of 500 Mc. Momentary voltage peaks up to 500 volts can be permitted at low frequencies, but voltage derating is required at higher frequencies due to high-frequency power limitations. Dynamic characteristics and curves are presented in the probe instruction manuals.

The P6034 10X Probe places 500 ohms resistance and less than 0.8 pf capacitance in parallel with the signal source at low frequencies. At 1 gigacyle the input resistance is about 300 ohms and the capacitive reactance is about 450 ohms. The probe bandpass is dc to 3.5 gigacycles, and risetime is less than 100 picoseconds (10% to 90%).

The P6035 100X Probe places 5000 ohms resistance and less than 0.7 pf capacitance in parallel with the signal source at low frequencies. At 1 gigacycle the input resistance is about 2000 ohms and the capacitive reactance is about 450 ohms. Bandpass of the probe is dc to 1.5 gigacycles, and risetime is less than 200 picoseconds (10% to 90%).

The P6026 Passive Probe, with slightly longer risetime, can serve many measurement applications with the Type 4S1. It is designed for use with 50-ohm sampling systems. Frequency response is dc to 600 Mc (dc-coupled). The P6026 consists of a GR Type 874 50-ohm connector-to-probe adapter, a dc-coupled 50-ohm termination, an ac-coupled 50-ohm termination, a 50-ohm RG-58A/U 10-nsec cable, a removable ground clip, and seven attenuator heads. Attenuation ratios from 5 to 5000 are provided, either ac- or dc-coupled. One of the 50-ohm terminations must be used with the attenuators in order to attain the stated attenuation. The various heads can not be stacked to obtain other values of attenuation.

Cathode-Follower Probe

The Tektronix P6032 Cathode-Follower Probe is a high-impedance high-frequency probe for Tektronix sampling systems. It is provided with seven plug-on attenuators that give attenuation ratios from 10X to 1000X for the combination of probe and attenuator. The P6032 has a risetime of less than 0.4 nanosecond, and a basic 3 db upper frequency response of 850 Mc for all attenuator heads. Input resistance is 10 megohms at dc, and the parallel capacitance ranges from 1.3 pf to 3.6 pf, depending on the particular head used. At 1 gigacycle the input resistance is down to about 100 ohms for the 10X head and to about 2000 ohms for the 1000X head, and the capacitive reactance is about 100 ohms.

The advantage of the cathode-follower probe is the high input resistance and low capacitive loading at moderately high frequencies. Dynamic characteristics and curves are included in the P6032 instruction manual.

Other Signal Coupling Methods

A very satisfactory method of coupling fractional nanosecond signals from within a circuit is to design the circuit with a built-in 50-ohm output terminal. With this method the circuit can be monitored without being disturbed, and when it is not being tested, a 50-ohm terminating resistor can be substituted for the test cable. If it is not convenient to build in a permanent 50-ohm test point, an external coupling circuit, which may be considered a probe, can be attached to the circuit.

A number of items must be considered when constructing such built-in signal probes. Both internal and external characteristics affect their operation. A probe is built to transfer energy from a source to a load, with controlled fidelity and attenuation. It must be equally responsive to all frequencies within the limits of the system, be able to carry a given energy level, and be mechanically adaptable to the measured circuit. The use of 1/4-watt and 1/8-watt resistors is advantageous in the construction of signal-coupling circuits since their small size aids in obtaining good high-frequency response. The probe must not load the circuit heavily or the display may not present a true representation of the circuit operation. Heavy loading may even disrupt the operation of the circuit. A base-band nature (dc to some upper frequency) is not required of all probes, as some needs lie only within a specific bandpass.

The only probes considered here will be signal-monitoring probes, since signal-injecting probes apply more appropriately to the operation of signal generators.

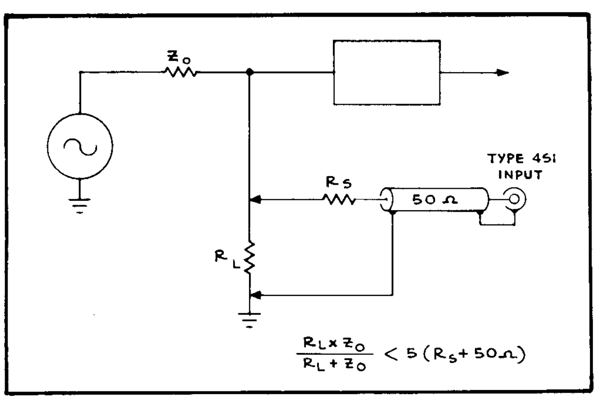


Fig. 2-3. Parallel method of coupling a signal from within a circuit.

In the parallel method of coupling, shown in Fig. 2-3, resistor R_s is connected in series with the 50-ohm input cable to the Type 4S1. This places R_s +50 ohms across the impedance in the circuit under test. In order to avoid overloading the circuit, the total resistance of R_s + 50 ohms should not be less than five times the impedance of the device (R_L in parallel with Z), requiring 20% correction. The ground lead must be very short. The physical position of R_s will affect the fidelity of the coupling. This method usually requires the use of an amplitude correction factor.

In the series coupling method, shown in Fig. 2-4, the 50-ohm input of the Type 4S1 replaces the impedance of the circuit under test. If the replaced impedance, R_L, was more than 50 ohms, place a resistance in series with the input cable to the Type 4S1. This resistance plus 50 ohms should equal the original impedance of the circuit. If R_L equals 50 ohms, simply substitute the 50-ohm test cable with no additional series resistance. It is best to locate R_s in the original position of R_L and ground the coax where R_L was grounded. When not testing, a 50-ohm resistor can replace the cable.

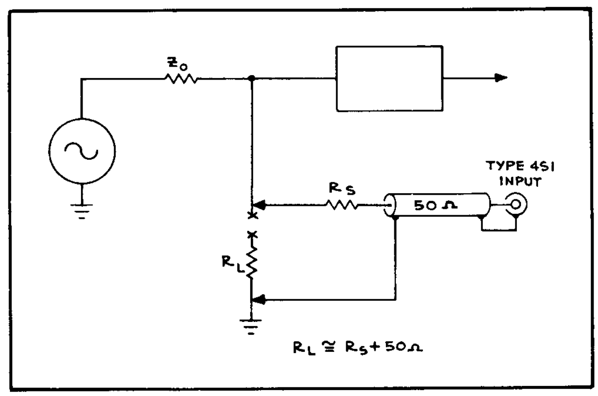


Fig. 2-4. Series method of coupling a signal from within a circuit.

A variation of the parallel method is the reverse-terminated network shown in Fig. 2-6. This system is highly versatile and may be used across any impedance up to about 200 ohms. At higher source impedances, circuit loading would require more than 20% correction. The .01-μf capacitor in the probe network blocks any dc component and protects the resistors. Use of the capacitor is optional.

The two 100-ohm resistors across the cable input in Fig. 2-6 serve to reverse-terminate any small reflections due to imperfect connectors, cables, attenuators, etc. In general, these resistors are needed only when observing signals at high gain, and when a small reflection will distort the display. If reflections of a few per cent are unimportant, then the two resistors can be deleted with a two-times increase in signal amplitude. Or if signals of short duration are to be observed, the reflections may occur late enough that they will not be seen in the oscilloscope display.

Voltage-sensing, "non-loading" probes can be grouped into the four basic categories shown in Fig. 2-5. Since a removable probe must be designed with the same electrical parameters as a built-in probe, no distinction will be made between the two. Types IA1 and IA2 are of primary interest

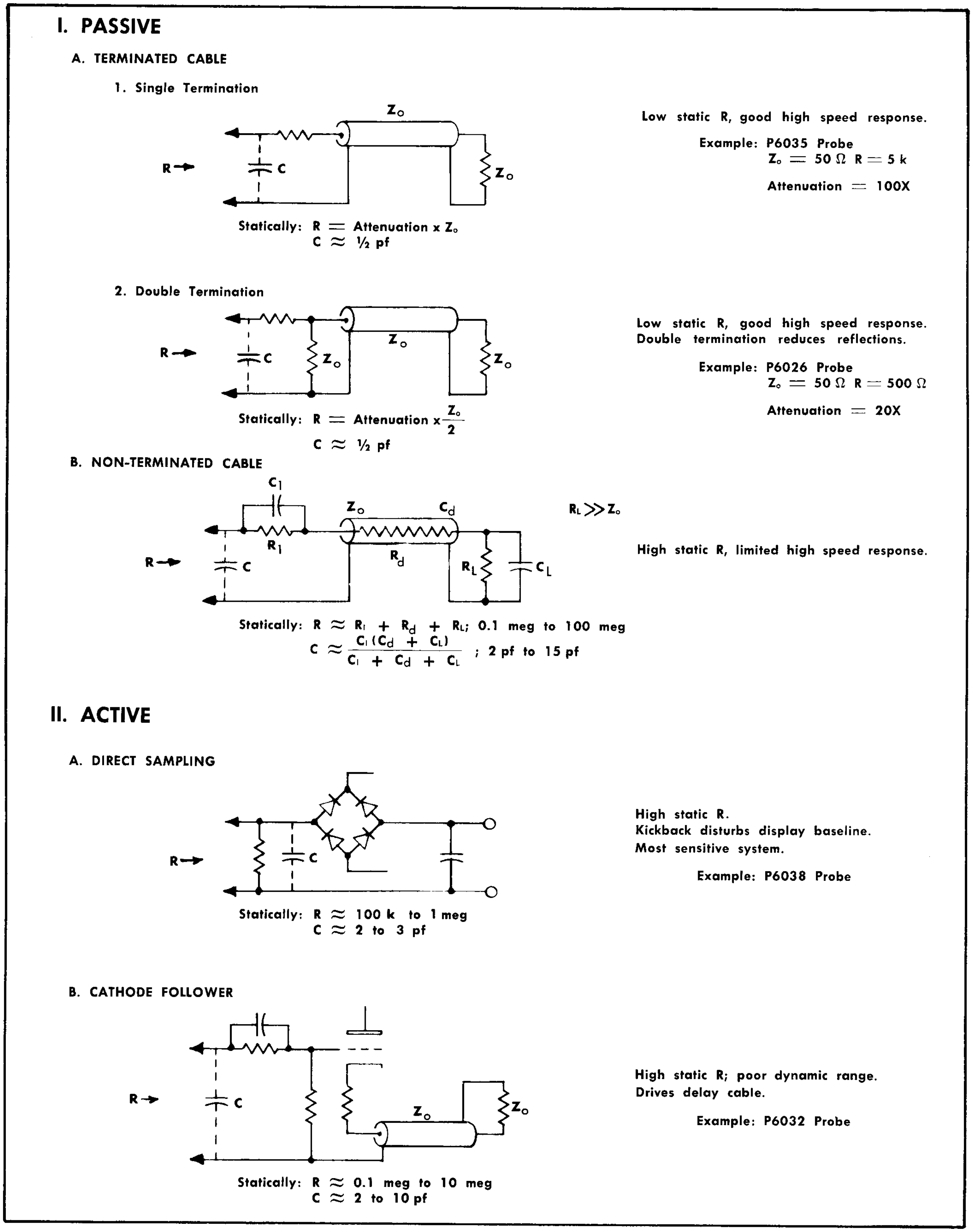


Fig. 2-5. Types of "non-loading" voltage-sensing probes.

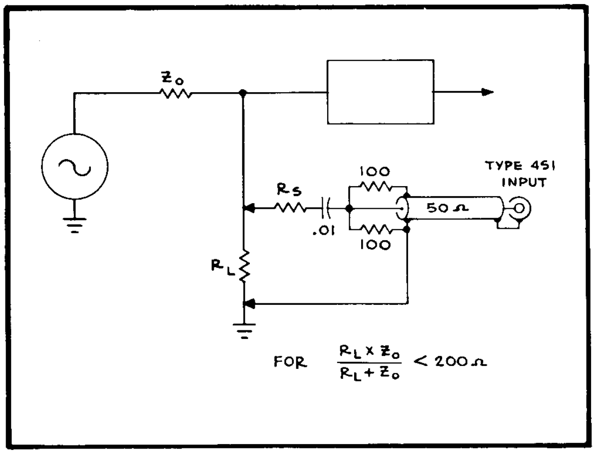
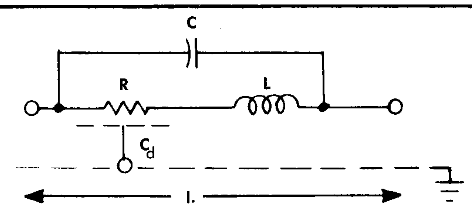


Fig. 2-6. Reverse-terminated parallel method of coupling a signal from within a circuit.



R = Normal resistance, modified by skin effect.

C = Axial capacitance, end-to-end. Typically 0.1 to 0.5 pf.

C_d = Distributed radial capacitance, ≈1/3 pf per cm of *l*. C_d varies by a factor of ≈2, depending on third terminal distance.

L = Series inductance, ≈ 3.3nh/cm. Value varies ± 200%, depending upon current return path. Inductance can be increased by manufacturing methods, for example, using a spiral configuration.

Examples:

1. 100 Ω, ½w, 1½ cm. C ≈ 0.1 pf C_d ≈ 1/3 x 1½ = ½ pf. L ≈ 3.3 x 1½ = 5 nh

   RC = 10 psec and L/R = 50 psec.

   C_d divided in 3 places;
   Center: C_d/2; each end C_d/4
   R/4 x C_d/4 = 100/4 x 1/8 = 3 psec.

2. 1000 Ω, ½w, 1½ cm. RC = 100 psec and L/R = 5 psec. RC_d/16 = 30 psec.

Fig. 2-7. Equivalent circuit and environment of a deposited carbon resistor.

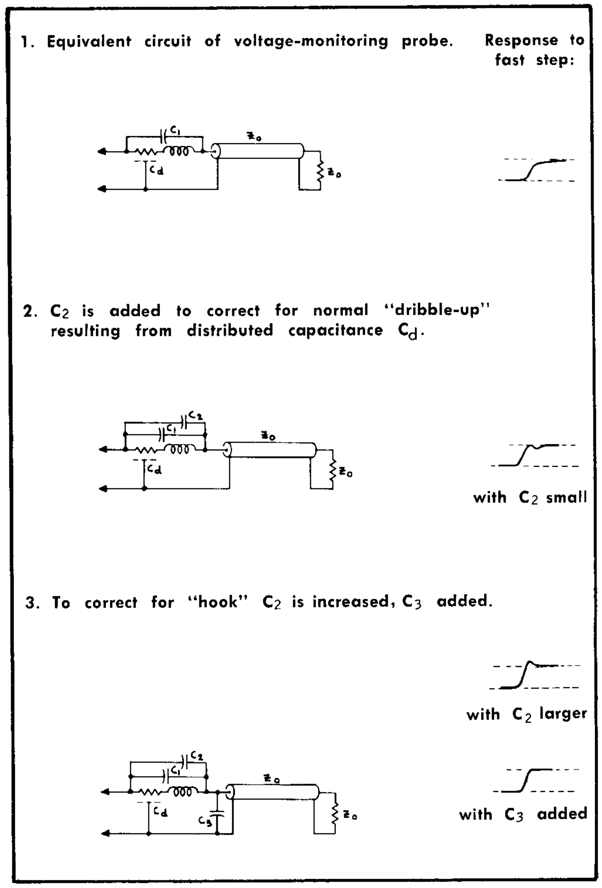


Fig. 2-8. Fractional nanosecond compensation of low resistance passive probes.

for sampling work because of the good high-speed response. Small passive probes of the Type IA1 are available with rise-times of 100 picoseconds and 200 picoseconds.

Major limiting factors, when building attenuator probes, are the resistor characteristics at fractional nanosecond speeds. Fig. 2-7 shows the equivalent circuit of a deposited carbon resistor with normal axial leads. Because of these equivalent circuit characteristics, frequency compensation of the terminated cable probes of Fig. 2-5(IA) requires the special construction techniques shown in Fig. 2-8.

The static input resistance of signal probes is measurable with an ohmmeter. Yet at high frequencies, the input resistance drops to a value equal to either the transient damping resistance or the resistance of the termination. The drop in input resistance with increasing frequency is due to the drop in reactance of the compensating capacitor across the input resistor, exposing the low-resistance parts of the probe to the input. Fig. 2-9 shows general curves of the types of probes shown in Fig. 2-5.

Since the input resistance is down at high frequencies, any series inductance will be significant. Fig. 2-10 shows an equivalent circuit of a common high-speed probe with a

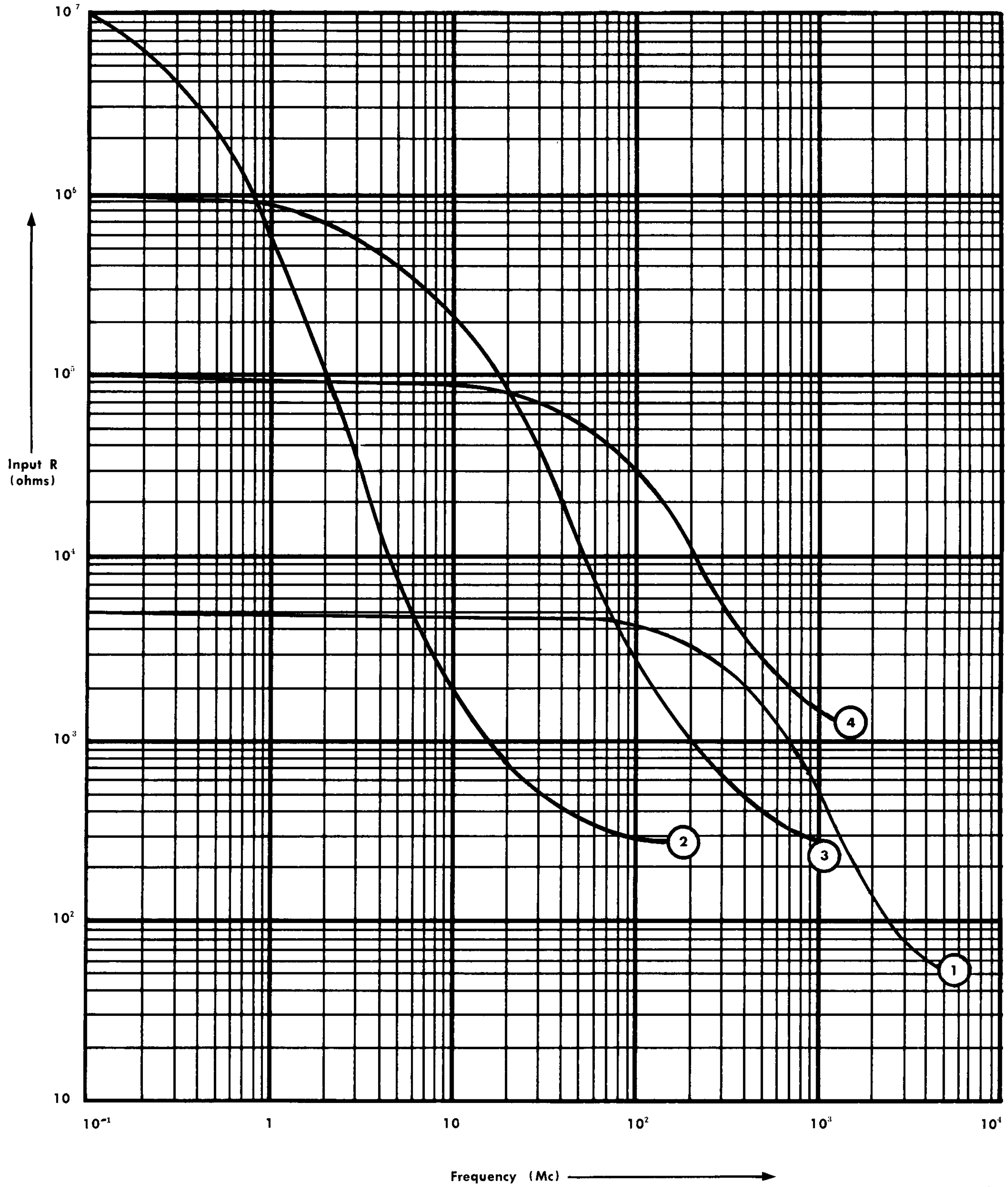


Fig. 2-9. Input resistance drop of some signal probes shown in Fig. 2-5: 1. Terminated cable; 2. Non-terminated cable; 3. Cathode-follower; 4. Direct-sampling.

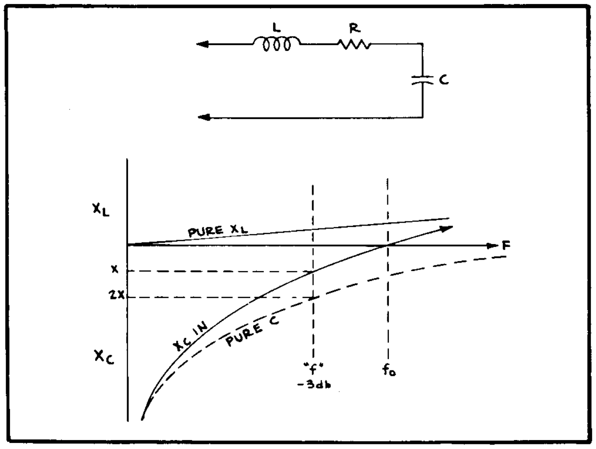


Fig. 2-10. Equivalent circuit of a high speed probe at frequency "f" and general input reactance curve to a frequency past the point of resonance.

general curve showing that the apparent input capacitance at the 3-db down point is double the low-frequency value. Thus, when using probes to measure fractional nanosecond pulses, the signal source impedance must be low enough to drive the increased capacitance in order to assure good display fidelity.

When it is necessary to ac-couple a high speed probe, the capacitor should be placed between the input attenuator resistor and the probe cable (see Fig. 2-6). This minimizes the differences between high-frequency input characteristics with and without the coupling capacitor. In this 50-ohm environment, stray capacitance to ground has a shorter and more uniform time constant than it would if the capacitor were placed next to the signal source which usually has a higher impedance of unknown value.

To use a signal probe and obtain good display fidelity requires not only knowledge of the probe, but also of the circuit being measured. Fig. 2-11 is a simple example of how a signal can be distorted by the measuring system.

Fig. 2-11e shows the normal waveform at the transistor collector before connecting the probe. When the probe is connected in the manner illustrated, and the transistor is off, E_I drops to $V_{cc}/2$ due to the voltage division between R_L and the probe resistor. Fig. 2-11f is the collector waveform with the probe connected. The initial step readily follows the input because R_T is very low compared to R_L or the probe resistance. However, when the transistor turns off, the waveform rolls off slightly because R_T becomes very high and discharge is through the two 1 k resistors in parallel. This waveform distortion could be nearly eliminated by using a probe with a higher input resistance.

The loss in amplitude in Fig. 2-11f can be eliminated by insertion of a coupling capacitor at the input to the Type 4S1 (Fig. 2-11d). In this case the initial step will still be fast, and the turn-off will be only slightly slower than before. Due to the ac-coupling, the voltage level will shift to center on the average signal level (Fig. 2-11g).

Use of the series method of coupling would be difficult in this example, unless the chassis of the device under test could be isolated from the oscilloscope chassis ground.

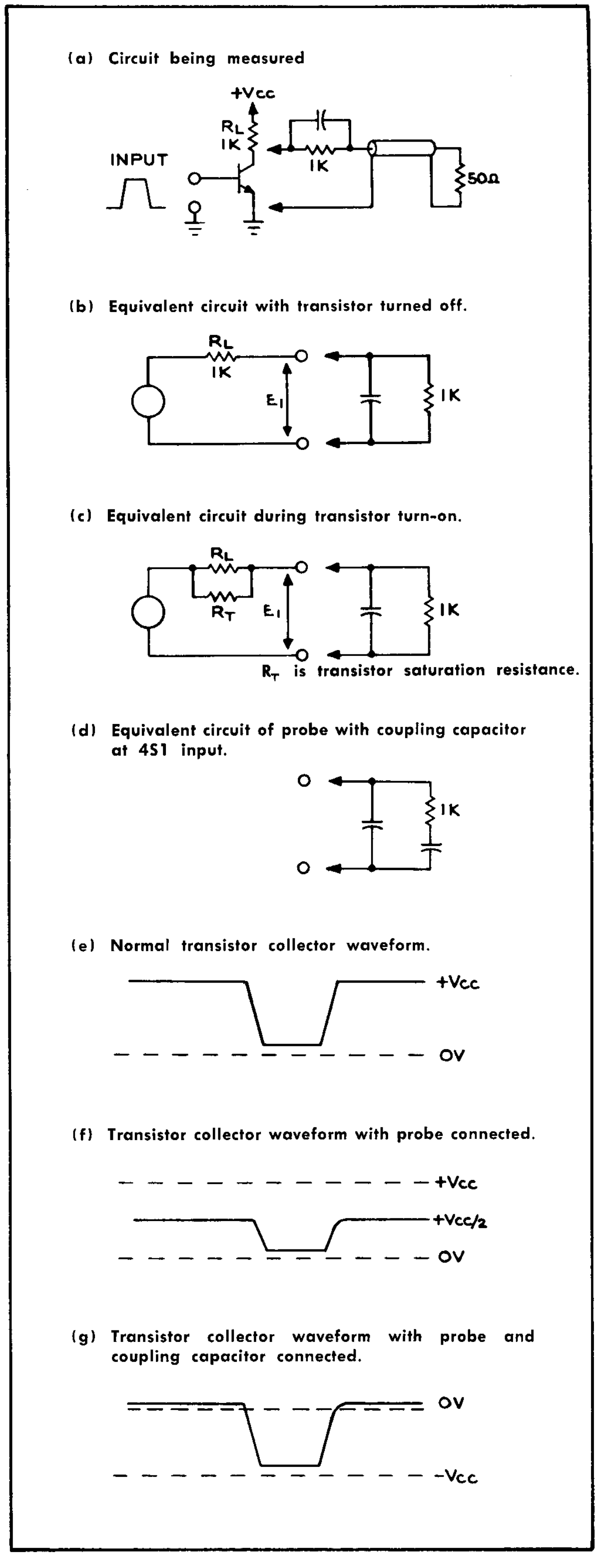


Fig. 2-11. Typical measurement problem. Waveform distortion produced by test probe must be taken into consideration.

FIRST-TIME OPERATION

Since the Type 4S1 Sampling Unit is part of a system, you should also read the operating instructions for the Type 661 Oscilloscope and the '5'-Series timing unit used with it.

With the Type 4S1 installed in the lower plug-in compartment and a '5'-Series timing plug-in unit in the upper compartment of a Type 661 Oscilloscope, switch on the power and set front-panel controls as follows:

Type 4S1

MODE	A ONLY
Channel A POSITION	Centered
Channel A MILLIVOLTS/CM	200
Channel A VARIABLE	CALIBRATED (at detent)
Channel A DC OFFSET	Set to zero at OFFSET MONITOR.
TRIGGERING	A, AC
Channel A DISPLAY	NORMAL
Channel A SMOOTHING	NORMAL

Timing Unit

Sweep Mode	Normal (Repetitive)
Samples/Cm	100
Triggering	Internal +
Threshold	Between — and O
Recovery Time	Minimum
Time Position (Delay)	Clockwise on Type 5T1A (Minimum)
Sweep Rate	20 nsec/cm, calibrated

Oscilloscope

Horizontal Display	X1
Position	Centered
Amplitude/Time Calibrator	Off
Intensity	90° clockwise from center

Connect an input signal to the Channel A INPUT connector through a 50-ohm coaxial cable. If the signal amplitude is over 2 volts peak-to-peak, be sure to attenuate it properly between the cable and the INPUT connector. If the dc component of the signal is over one volt, ac-couple the source to the Type 4S1.

Locate the trace on the crt with the positioning controls. Trigger the display with the timing unit triggering controls and adjust the Intensity, Focus and Astigmatism for the best presentation.

Since the oscilloscope and each plug-in unit is independently calibrated at the factory, minor gain and timing adjustments may be required before making accurate amplitude or time measurements. The adjustment for gain is given in the Calibration section of this manual and in the Operating Instructions section of the oscilloscope manual.

Do not replace or exchange plug-in subchassis without reading the precautions given at the beginning of the Calibration procedure. Do not interchange A and B Memory circuits. The Type 4S1 has been calibrated as a unit, so parts or sections cannot be changed without requiring some recalibration of the unit.

Use of the Smoothing Control

Time and amplitude noise may be objectionable when operating at minimum deflection factors or maximum sweep rates. This is often important when making documentation photographs. The SMOOTHING control in the amplifier feedback loop reduces the channel loop gain to allow random noise reduction.

The SMOOTHING control will normally not affect the risetime of the display unless the interval between samples is a significant percentage of the total signal amplitude. To test whether or not the SMOOTHING control is degrading the display, change the timing unit Samples/Cm switch by a factor of 2 or more and observe the amount of change in the waveform display. If the change is insignificant, the SMOOTHING control is not substantially affecting the dot transient response. Fig. 2-12 shows the advantage of using the SMOOTHING control when observing low-level signals.

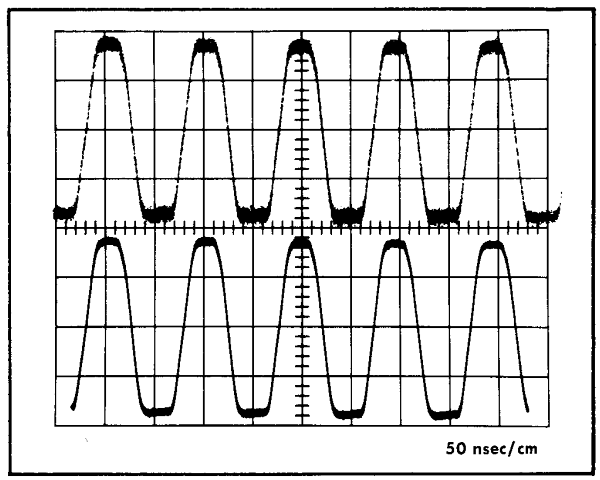


Fig. 2-12. 10 mv 10 Mc calibrator signal. Upper trace, normal SMOOTHING. Lower trace, full SMOOTHING.

Use of the DC Offset Control

The DC OFFSET control for each channel of the Type 4S1 can be used in conjunction with the OFFSET MONITOR jack for making accurate dc measurements of the input waveform. The procedure for using dc offset for measuring voltages is given under Voltage Measurements, later in this section.

Each DC OFFSET control also permits cancellation of the effects of a relatively high (up to ±1 volt) dc voltage in the presence of a low-amplitude signal. By adjusting this control to cancel the dc voltage, any particular level of the display (such as peak points) can be made to remain at the same position on the crt screen while switching between various steps of the MILLIVOLTS/CM switch.

To adjust the DC OFFSET control for observation of a particular level of the waveform, proceed as follows:

1. Obtain a display of the input waveform in the usual manner.

2. Set the MILLIVOLTS/CM switch to the lowest deflection factor (highest sensitivity) to be used. With the DC OFFSET control, move the selected level of the display to the graticule centerline.

3. Switch the MILLIVOLTS/CM to the highest deflection factor to be used. Again center the selected level on the graticule, this time with the VERT. POSITION control.

4. Repeat steps 2 and 3 for the final adjustment.

Now leave the DC OFFSET control in this final position while making observations of the display. The selected level will stay at the same vertical position on the crt screen while the MILLIVOLTS/CM switch is rotated between its various positions. See Fig. 2-13. Use only the VERT. POSITION controls for moving the display vertically on the crt screen.

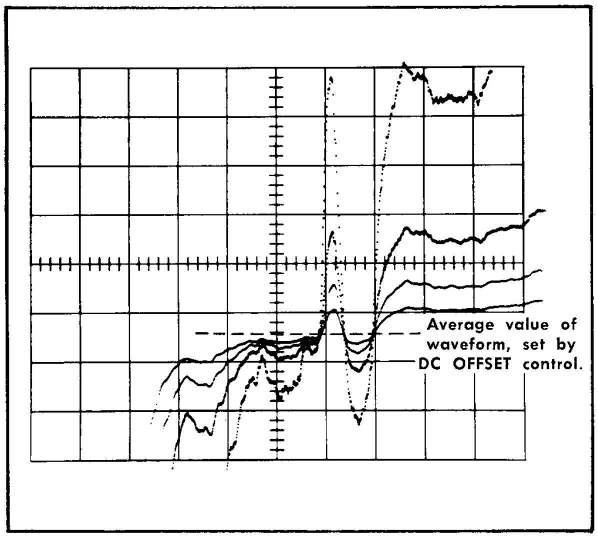


Fig. 2-13. Display of Delayed Pulse output held stable at the level of the dashed line through use of the DC OFFSET control.

VOLTAGE MEASUREMENTS

Vertical displacement of the crt trace is directly proportional to the voltage at the INPUT connector of the Type 4S1. (For A VERT. B HORIZ. operation, the horizontal displacement is proportional to the voltage at the Channel B INPUT connector.) The amount of displacement for any given voltage can be selected with the MILLIVOLTS/CM switch. To provide sufficient deflection for best resolution, set the MILLIVOLTS/CM switch so the display spans a large portion of the graticule. When measuring between points on a display, be sure to measure consistently from either the top or the bottom of the trace. This will avoid including the width of the trace in the measurements.

Voltage Measurements from Display

To make a voltage-difference measurement between two points on a display, proceed as follows.

1. Using the graticule as a scale, note the vertical deflection, in divisions, between the two points on the display. Be sure the VARIABLE control is in the CALIBRATED position.

2. Multiply the divisions of vertical deflection by the numerical setting of the MILLIVOLTS/CM switch and the attenuation factor, if an attenuator or probe is used. The product is the voltage difference between the two points measured.

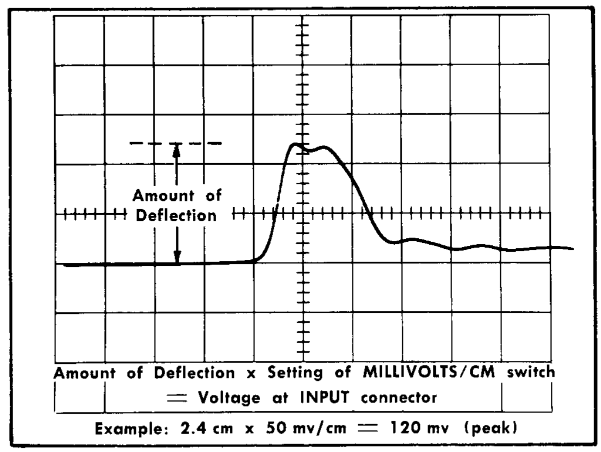


Fig. 2-14. Voltage measurement from display.

As an example, Fig. 2-14 shows 2.4 divisions of deflection between two points on the display. With the MILLIVOLTS/CM switch set at 50, multiply the 50 by 2.4, the amount of deflection, to obtain a product of 120 millivolts. This is the voltage at the INPUT connector of the Type 4S1. Assuming there is a 10X attenuator between the voltage source and the INPUT connector, multiply the 120 millivolts by 10, the attenuation factor, to obtain 1200 millivolts (1.2 volts) as the voltage at the source.

To measure the instantaneous (dc) voltage-to-ground of a signal, use the same general procedure as described previously. Before connecting the signal, establish a ground reference level on the crt. To do this, set the timing unit for a free-running trace, then vertically position the trace so that it is exactly aligned with one of the horizontal graticule lines. The graticule line should be selected on the basis of polarity and amplitude of the applied signal. From this time on, make no further adjustments with the VERT. POSITION or DC OFFSET controls. After establishing the ground reference, apply the signal and measure the voltage in the manner previously described. Use the established ground-reference as the point from which to make all measurements.

If the applied signal has a relatively high dc level, the ground-reference point and the input signal may be so far apart that only one will be in the graticule viewing area.

If this is the case, use the DC OFFSET control and the OFFSET MONITOR as described in the following paragraphs to measure the voltage.

DC Offset Voltage Measurements

Voltage measurements made with the Type 661 Oscilloscope and the Type 4S1 can be far more accurate than the normal resolution of a crt display, by using the DC OFFSET control and the OFFSET MONITOR. Use the following procedure for making measurements:

1. Obtain the desired display through normal operating procedures.

2. With the VERT. POSITION or the DC OFFSET controls, position the bottom of the waveform (or other desired reference portion) to the graticule centerline.

3. Measure the voltage at the OFFSET MONITOR jack with a high impedance voltmeter, and record the reading. This voltage will be 100 times the applied offset voltage.

4. Using only the DC OFFSET control, position the top of the display (or other level to be compared) to the graticule centerline.

5. Again measure the OFFSET MONITOR voltage, and compare this value with the previous measurement. The difference between the two OFFSET MONITOR voltages, divided by 100, is the amplitude in volts at the INPUT connector. If the input includes an attenuator, the signal source voltage is then the final offset voltage value times the attenuation factor.

DUAL TRACE OPERATION

The Dual Trace feature of the Type 4S1 permits viewing signals into and out of an amplifier or other device, or signals of differing amplitude and time delay. This is accomplished by switching between the two channels at a 50 kc rate. However, Dual Trace does not provide for comparison of signals of differing repetition rates or frequencies, unless the signals are harmonically related.

NOTE

Even though the system operates at a 50-kc switching rate in Dual Trace mode, no 50-kc signal is contained in the triggering signal to the timing unit. The triggering signal is taken off at the input to the Type 4S1, not from a dual-trace switching circuit as in some conventional oscilloscopes. Thus the triggering is assured to be from one input only.

Connect the two input signals to the INPUT connectors of the Type 4S1, preferably with equal delay coax cables so the display time difference will be that of the device under test. For large signals, be sure to use adequate attenuation at the input. A discussion of phase measurements is included later in this section of the manual.

The Dual Trace mode of operation can be demonstrated by a signal from the oscilloscope calibrator if no other signal source is available. To do this, connect two dissimilar lengths of cable between the oscilloscope Amplitude/Time Calibrator and the two inputs on the Type 4S1. A coaxial tee or transformer-matched tee may be used to connect the cables. Such a display is illustrated in Fig. 2-15. The Calibrator output and each leg of the tee should present an impedance of 50 ohms to avoid signal distortion. This can be approximated by connecting a 2× or 5× attenuator on each leg of the tee.

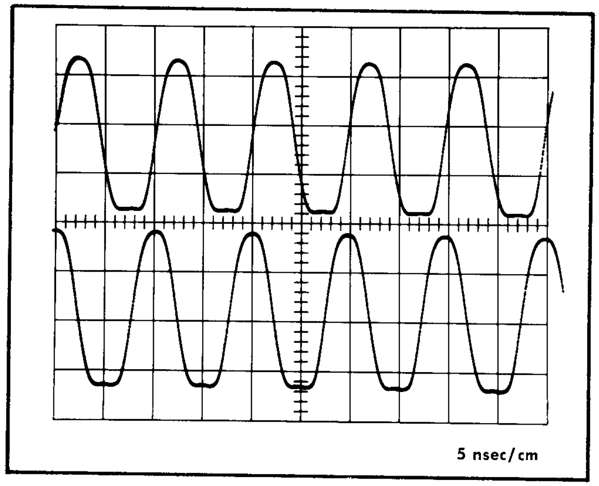


Fig. 2-15. Dual trace display showing 100 Mc calibrator waveform applied to Type 4S1 inputs through unequal length cables. The signal displayed on the lower trace is passed through 8 nsec more cable than the signal on the upper trace.

Use the following procedure for setting up the Type 4S1 for Dual Trace operation:

1. Set the oscilloscope and timing unit controls as given in First-Time Operation.

2. Set the MODE switch on the Type 4S1 to DUAL TRACE.

3. Set the MILLIVOLTS/CM switches to give approximately 3 or 4 centimeters of display on each channel.

4. Set the TRIGGERING switch to either A or B. It is usually most convenient to choose the trigger from the channel receiving the earlier input signal.

5. If the device under test inverts the output signal, you may wish to place one channel DISPLAY switch to NORMAL, and the other channel DISPLAY switch to INVERTED.

6. Set the timing unit Polarity switch to the polarity of the triggering signal.

7. Trigger the display with the Threshold control on the timing unit.

8. Select a sweep rate that will permit viewing two or three cycles of the waveforms. If unknown, start at 10 nsec/cm.

9. Adjust the triggering Time Position (Delay) and Samples/Cm controls to provide the best presentation.

10. Adjust the SMOOTHING controls as required to reduce random noise.

X-Y OPERATION

The X-Y (lissajous) mode of operation is convenient for measuring sinewave phase differences and for making accurate frequency or timing adjustments to a known frequency standard. This mode of operation is obtained by placing the MODE switch in the A VERT. B HORIZ. position and applying the two signals to the INPUT connectors on the Type 4S1. Channel A then controls the vertical deflection of the crt beam and Channel B controls the horizontal deflection. The procedure for making X-Y phase measurements is given later in this section of the manual.

Any two signals that are triggered by the same source, or are otherwise related to a single frequency source, can be conveniently displayed in X-Y mode. However, due to the nature of the display in a sampling oscilloscope, false displays can be obtained when comparing two signals that have completely independent frequency sources. Only very stable signals can be used satisfactorily. If either of the waveforms has frequency modulation or drift, the display will be meaningless. It is necessary to have frequency coincidence within 10 cps, regardless of the signal frequency, to obtain a true display of frequency comparison.

With stable signal sources, the difference between two signals can be adjusted to less than one cycle per second. (For a 100 Mc signal, 1 cps is equal to 1 part in 10^8). Thus the accuracy increases with increase in signal frequency. Adjustment should be made only after both sources have come to operating temperature.

To adjust one stable frequency source to a known standard, proceed as follows:

1. Connect the frequency standard signal to one INPUT connector on the Type 4S1, and connect the source to be adjusted to the other INPUT. Cable length is not critical, since phase is not important. Use attenuators, if necessary, to keep the signals at the INPUT connectors within the voltage limits of the Type 4S1.

2. Set the MODE switch to DUAL TRACE, and set the TRIGGERING switch to the channel with the standard source.

3. Adjust the controls of the timing unit and of the Type 4S1 according to normal operating procedures to obtain a stable display of the standard signal. (The other waveform may appear to be free running.) Use a high dot density. Adjust the sweep rate to display one or two cycles of the waveform.

4. Adjust the variable frequency source as accurately as possible to the standard frequency, while observing the dual-trace display.

5. Set the MODE switch to A VERT. B HORIZ.

6. Make the fine adjustment of the frequency source by adjusting the frequency control slightly until the lissajous pattern stabilizes. A single loop that nearly retraces itself indicates precise correlation of the two frequencies.

PHASE MEASUREMENTS

One complete cycle of a sinusoidal waveform, or other trigonometric waveform, is considered to be 360 degrees. Phase comparison between two waveforms of the same frequency can be made with the Type 4S1 and a '5'-Series timing unit in a Type 661 Oscilloscope. Either Dual Trace mode or an X-Y presentation may be used.

To retain phase relationships between the signals at their sources, they must be applied to the inputs of the Type 4S1 through identical delay lengths of coaxial cable.

It is not necessary to provide an external triggering signal from the reference waveform since internal triggering information is taken at the input connector selected by the TRIGGERING switch. However, external triggering may be used if the input signals are of low amplitude, or if external trigger countdown is used for high-frequency signals.

In making phase measurements it is very important that the width of the trace is not included. Measurements must be consistently made from the same edge of the trace.

Linear Method

For phase comparison using the Dual Trace mode, it is often convenient to first calibrate the oscilloscope sweep in degrees of phase angle per centimeter of display. For example, if the sweep rate is adjusted with the Sweep Time/Cm and Variable controls on the timing unit so that one cycle of the input waveform covers 8 centimeters of the graticule, each centimeter then corresponds to 45 degrees, and the display is calibrated at 45 degrees/cm. Any convenient relationship may be used for this calibration. The use of 45 degrees/cm is suggested because this produces a large display and also calibrates the sweep at 1 quadrant (90°) for every 2 centimeters.

The relative amplitude of the two signals does not affect the phase measurement, so long as both signals are centered about the horizontal centerline. However, it is often easier to read the phase difference if the amplitudes of the two signals have been adjusted to be the same, using the MILLIVOLTS/CM and VARIABLE controls on the Type 4S1.

Fig. 2-16 shows two 100 Mc sinewaves in a Dual Trace display where the apparent time difference is due to different lengths of coax cable being driven by a common source. The difference in electrical lengths of the two cables is seen to be 5.3 nsec. This display is also a true picture of the phase difference between the two 100 Mc input signals, but the phase difference in degrees would be difficult to read from this display. Fig. 2-16b shows the same waveform with the sweep rate changed to calibrate the displays at 45 degrees/cm. Now the phase difference between the two waveforms can easily be read directly from the graticule as 190 degrees. It is important to note that the two waveforms shown are present simultaneously on the crt.

Thus, to measure phase difference using the Dual Trace mode:

1. Set the MODE switch to the channel to be used for triggering.

2. Adjust the timing unit Sweep Time/Cm and Variable controls to calibrate the sweep in degrees/cm (for example, 45 degrees/cm as mentioned above).

3. Set the MODE switch to Dual Trace.

4. Adjust the Channel A and Channel B controls to produce the desired displays of the two signals. Both DISPLAY switches should be set the same, unless one waveform is known to be inverted. If necessary, move the display horizontally with the Time Position (Delay) control on the timing unit.

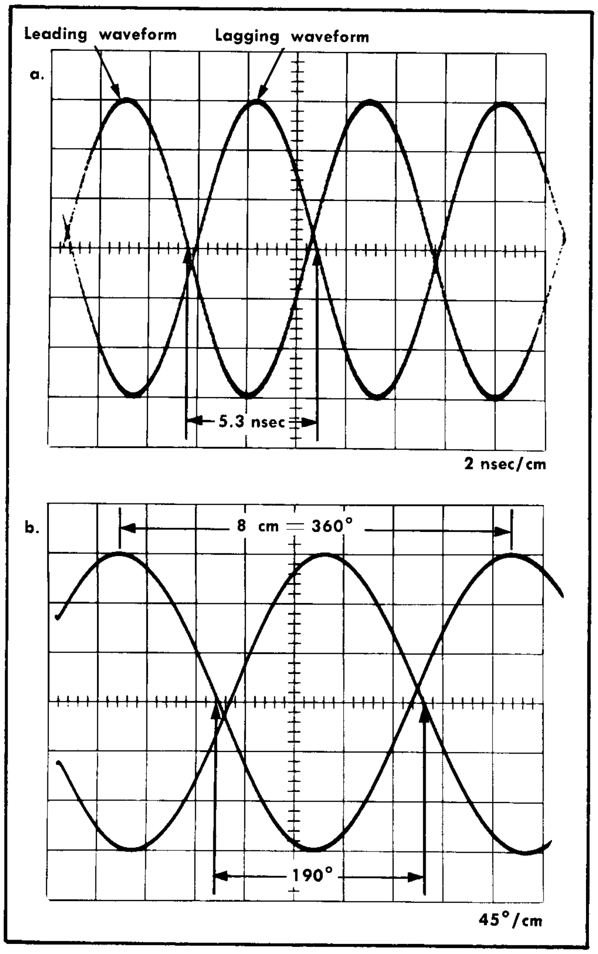


Fig. 2-16. (a) Dual trace display of 100 Mc sinewave at sweep rate of 2 nsec/cm; (b.) Same display with sweep calibrated at 45 degrees/cm.

5. Measure the horizontal difference in centimeters between corresponding points on the two phases.

6. Multiply the difference in centimeters by the number of degrees per centimeter. This product is the phase difference in degrees.

The "leading" waveform is generally considered to be the one to the left on the crt display. This nomenclature is only relative, however, since either waveform can be called the leading one on the display. If one signal is known to be from a signal source and the other is a response waveform, the source waveform usually leads the response.

X-Y Method

To measure the phase difference between two sine waves of the same frequency, using an X-Y display, proceed as follows:

1. Set the front-panel controls of the Type 4S1 as indicated:

MODE	B ONLY
DISPLAY (both channels)	NORMAL
DC OFFSET (both channels)	Midrange
TRIGGERING	A or B as desired
SMOOTHING (both channels)	NORMAL

2. With an unmagnified sweep, set the triggering controls of the timing unit for a stable display showing from one to five cycles of the input waveform.

3. Adjust the Channel B controls to obtain a display of approximately 4 to 7 cm of vertical deflection. Do not use the VARIABLE control, since it will not be in the circuit in X-Y mode.

4. Set the MODE switch to A ONLY and adjust the Channel A controls for approximately the same display amplitude as Channel B.

5. Set the MODE switch to A VERT. B HORIZ.

6. Center the display on the graticule with the Channel A VERT. POSITION control and either the Channel B DC OFFSET or the oscilloscope Horizontal Position control. The display at this point will probably be an ellipse. If the display appears as a diagonal straight line the two sine waves are either in phase (tilted upper right to lower left), or 180° out of phase (tilted upper left to lower right). If the display is a circle, the two sine waves are 90° out of phase. In any case, these instructions apply for measurement of phase differences.

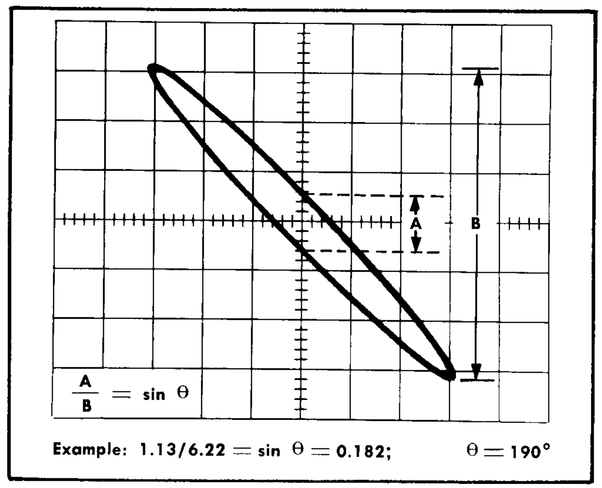


Fig. 2-17. X-Y method of calculating phase difference (θ) between two sinewaves.

7. Measure the distance 'A' and 'B' on the display as shown in Fig. 2-17. 'A' divided by 'B' equals the sine of the phase angle between the two sine waves.

ALGEBRAIC ADDITION

Signal Addition

The sum of two input signals may be obtained by placing the MODE switch in the ADDED ALGEB. position and the

DISPLAY switches for both channels in the NORMAL position. Either input signal may be used to trigger the display by setting the front-panel TRIGGERING switch to the desired channel. The positioning controls of both channels are effective for moving the single trace vertically on the crt. However, the DC OFFSET controls should be set to center the displays, and positioning should be done with the two VERT. POSITION controls. If the dc level of either signal is not centered in the dynamic range of its channel, distortion can result. See note below.

Differential Mode

The difference of two input signals can be displayed on the crt merely by inverting one of the input signals. When either of the DISPLAY switches is set to INVERTED and the other is in NORMAL position, the difference of the signals is obtained.

The front-panel control labeled A-B BAL., which is the Channel A gain control, can be used for minor adjustment of the Channel A gain to match that of Channel B for operating differentially. By applying the same waveform to both INPUT connectors through identical cables, and displaying the two inputs differentially, the A-B BAL. control can be adjusted for minimum deflection. There will probably be minor unbalance in the display that cannot be eliminated. This is not due to improper balance of the two channels, but rather to minor differences in delay and attenuation caused by the input cables.

NOTE

The dynamic range of each channel allows about 10 centimeters of display with no distortion, if the signals into the Dual Trace circuit are electrically centered. Therefore the input deflection factor for each channel should be set to produce no more than ten centimeters of deflection when displaying only the signal for that channel. The Dual Trace circuit is designed to operate around the center of its dynamic range, which is ±3 volts, producing the display amplitude of ten centimeters. In Added Algebraic mode, especially when operating differentially, it is possible to offset the Dual Trace input enough to obtain a distorted display, if the signal through the amplifiers exceeds the dynamic range of the circuits. In any other mode of operation, if the offset voltage were to move the Dual Trace input signal out of the proper range, the display would be moved off the screen and no distortion would be seen. In Added Algebraic mode, however, the offset voltages of the two channels can cancel each other and allow the display to be viewed even though part of the signal may exceed the dynamic range of the channel.

Centering of each signal into the Dual Trace circuitry can be readily adjusted with the DC OFFSET control. Note that this adjustment offsets any dc component of the input signal but does not zero the DC Offset, unless the signal is centered on zero. Set the MODE switch to Dual Trace and adjust the DC OFFSET control for each channel so that there is no vertical movement of the display while changing the DISPLAY switch of that channel from NORMAL to INVERTED position. Do not readjust the DC OFFSET controls again while using the differential mode of operation, unless another signal with a different dc level is used later. In this case, the offset will need to be readjusted.

Then, with the MODE switch set to ADDED ALGEB., the VERT. POSITION controls of the two channels can position the display over the entire area of the graticule with no distortion. If the signal amplitude through the circuitry is approaching the maximum permissible amplitude (10 cm of display), it may be necessary to operate both VERT. POSITION controls simultaneously to avoid display distortion.

Common-Mode Noise Reduction

In some applications, the desired signal appears with some undesired coherent noise signal. In many cases, it is possible to improve the signal-to-noise ratio through use of the differential mode of operation of the Type 4S1. Connect the signal source containing both the desired and the undesired signals to one INPUT connector. Connect a source consisting of only the undesired signal to the other INPUT. Be sure to use cable lengths that will allow the noise signal on the two cables to reach the two inputs in phase. Set the MODE switch to ADDED ALGEB., and set one DISPLAY switch to NORMAL and the other to INVERTED. In the channel containing only the noise signal, adjust the MILLIVOLTS/CM switch and the VARIABLE control to cancel or partially cancel the noise in the other channel, permitting observation of the desired signal.

Cable-Length Matching

Comparison can be made between the electrical lengths of two similar nanosecond cables by operating the Type 4S1 differentially. With the MODE and DISPLAY switches set for differential operation, apply a fast pulse to the INPUT connectors through the two input cables in parallel. If the cables are not identical in length, a pulse will be displayed. As they are made equal in length, the pulse disappears. To determine which of the cables is longer, pull out slightly on one of the cable connectors, partially disconnecting it. If the pulse increases in amplitude, this is the longer of the two cables; if the amplitude decreases it is the shorter cable.

PULSE REFLECTION MEASUREMENTS

The high-frequency response of the Type 4S1 permits precise display of transmission-line characteristics. Reflections that occur in a transmission line or its connections can be detected directly from the oscilloscope display.

With its dynamic range of several volts and sensitivity in the millivolt range, the Type 4S1 can resolve voltage reflections to better than 1 part in 10^3. Fractional nanosecond time resolution permits separation of points only a few centimeters apart on a transmission line.

A signal travels down a transmission line at a rate of propagation determined by the dielectric properties of the insulating material between the two conductors. Each time the signal encounters a mismatch, or different impedance, a reflection is generated and sent back along the line to the

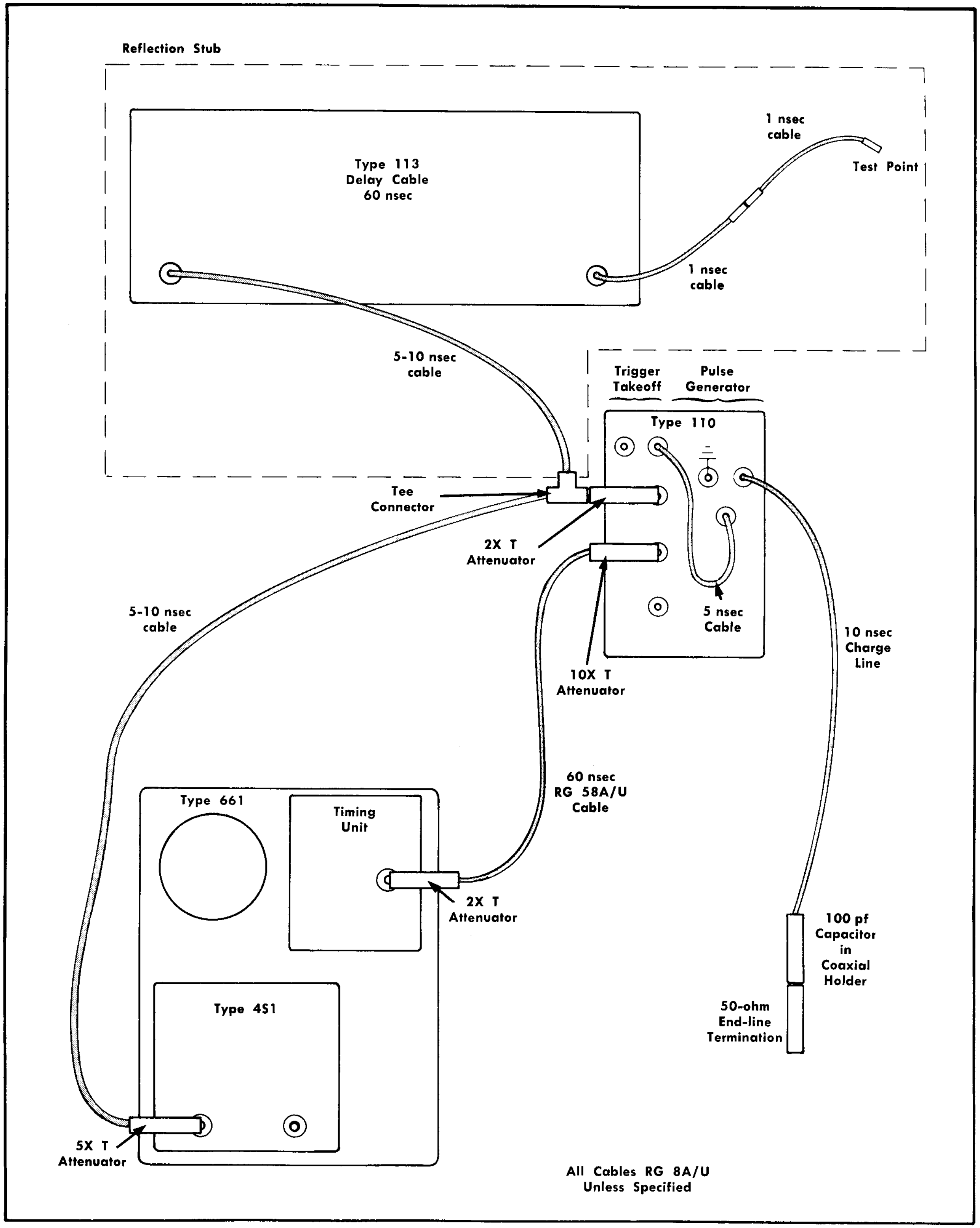


Fig. 2-18. Diagram of Pulse Reflection Measurement system with approximately 0.4 nsec Risetime at Test Point.

source, where it either adds to or subtracts from the input signal. The amplitude and polarity of the reflection are determined by the value of the mismatch impedance in relation to the characteristic impedance of the transmission line. If the impedance encountered is higher than that of the line, the reflection will be of the same polarity as the applied signal and will add to it. If the mismatch impedance is lower than that of the line, the reflection will be of opposite polarity and will subtract from the input signal at the source. The amplitude of the reflected wave increases with the degree of mismatch. In the two extreme cases of mismatch, zero and infinite impedance, the reflection amplitude is equal to that of the applied signal, so the reflection either doubles or cancels the signal.

The following sub-sections give typical methods used to correlate an observed reflection with a transmission line discontinuity, in amplitude and time, and to describe a system capable of 0.1% voltage reflection measurements.

Pulsing the Transmission Line

In the system diagrammed in Fig. 2-18, a flat-topped fast-rising step is generated by the Type 110 Pulse Generator. The series capacitance and resistance at the end of the charge line provides an exponential return to the initial voltage. Thus, the driving pulse has only one fast transition for interrogation of discontinuities. The single fast transition minimizes the confusion associated with the interpretation of waveforms, and reduces extraneous system reflections. Triggering energy is extracted in the trigger-takeoff section of the Type 110 and is delayed by 60 to 70 nsec before reaching the External Trigger Input connector of the timing unit. This delay is needed to place the test point reflected signal within the "time window" of the timing unit. An alternate triggering method is to locate a trigger-takeoff transformer near the test point, but this is not recommended since the transmission loss of the trigger device is included twice.

The output from the Type 110 passes directly through a 2X T attenuator into a 50-ohm tee connector. One half of the transmitted energy then travels toward the test point, and the other half travels toward the Type 4S1 input. In the path to the test point, the pulse is delayed well past the exponential decay of the drive pulse by the Type 113 Delay Cable, so the reflection signal arrives at the input to the Type 4S1 well separated from the drive pulse. The reflection from the test point returns to the tee section, and is divided, one half going to the Type 4S1 input and the other half going back toward the Type 110. The 2X T attenuator, between the Type 110 and the tee section, essentially eliminates any secondary reflections from the signal that goes back to the Type 110. The reflected signal going to the Type 4S1 passes through an attenuator that further reduces any small reflections of the system. Note that system reflections of 1%, considered small for most uses, can be quite disastrous when 0.1% resolution is desired. Fig. 2-19 is an idealized waveform showing the complete pulse train as seen at the Type 4S1 input.

Setting up the Test System

The Pulse Generator section of the Type 110 requires a single-ended set-up for this application, to assure that the signal for reflection measurements consists of a single trace. Only one contact of the mercury pulser is used for this application, with the other contact grounded.

Follow the system layout as diagrammed in Fig. 2-18. To standardize the amplitude of the reflection signal from the unterminated test point, use the following procedure:

Set the Type 4S1 controls:

MILLIVOLTS/CM	200
SMOOTHING	NORMAL

Type 661 Oscilloscope controls:

Sweep Magnifier	X1
Amplitude/Time Calibrator	OFF

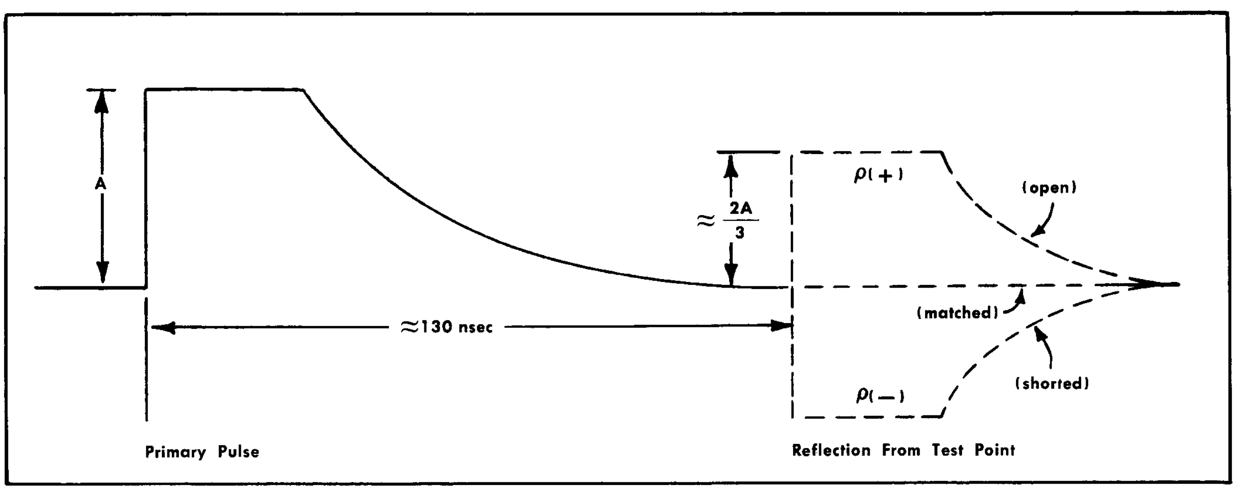


Fig. 2-19. Line drawing of complete pulse train.

Timing Unit controls:

Sweep Rate	5 nsec/cm
Triggering	External +
Recovery Time	Minimum
Samples/Cm	20
Threshold	Between O and +
Sweep Mode	Normal (Repetitive)

Type 110 controls:

Pulse Generator	On (Free Run)
Amplitude Voltage Range	50
Amplitude	30 to 50
Pulse Polarity	+
Takeoff-Ext 50 Ω	Takeoff
Attenuator	÷3.16
Inverter	+1
Amplifiers 1 and 2	X1
Ext. Output-Regenerator	Ext. Output
Trigger Sensitivity	Counterclockise

Obtain a stable display similar to Fig. 2-20. Note that changing the pulse generator amplitude does not shift the display base line. Use the VERT. POSITION control on the Type 4S1 and the pulse generator amplitude control to obtain eight centimeters of deflection on the crt. Position the display so that the top of the display is 2 cm below the top graticule line, then increase the pulse amplitude until the top of the display is at the top graticule line. This adjustment produces a display amplitude of 10 cm, or a pulse amplitude of 2 volts peak-to-peak at the INPUT connector of the Type 4S1.

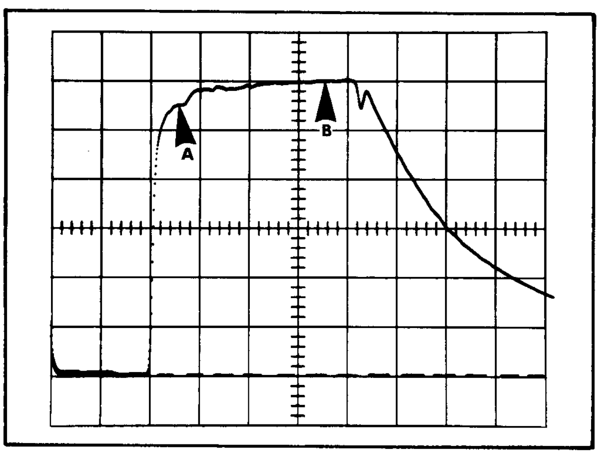


Fig. 2-20. Reflected signal from unterminated test point.

The reflected signal of Fig. 2-20 shows coax cable distributed losses. The slow signal rise between points A and B (called "dribble up") is a normal coax characteristic, and is a result of reduced high-frequency response due to conductor skin-effect resistance. Allowance must be made for this effect when setting the gain for accurate impedance measurements. For short duration impedance measurements, use point A to set the display at ten centimeters. For accurate long duration impedance measurements, use point B to set the display amplitude. For measurements between points A and B, use the amplitude associated with the transmission time of the particular device to set the gain. In any case, establishing the known amplitude with the MILLIVOLTS/CM switch set at 200 permits vertical magnification of the display up to 1000 times. When magnified at the 2 mv/cm position, each centimeter of displacement is equal to 0.1% reflection. The Type 4S1 SMOOTHING control can be usefully employed when operating at full sensitivity, if dot density is sufficient.

Impedance Measurements

Impedance determinations in the following calculations are based on standard 50-ohm systems. For other systems, the relationships should be calculated with the characteristic impedance of the system substituted for the 50 ohms in the following equations.

An impedance of Z_L encountered at the test point will produce a voltage reflection ρ in a system of impedance Z_O, as given in the following formula:

$$\rho = \frac{Z_L - Z_O}{Z_L + Z_O} \qquad \text{(Equation 2-1)}$$

If we let Δ represent the difference between the unknown impedance and that of the system;

$$\Delta = Z_L - Z_O$$

$$\text{or} \quad Z_L = \Delta + Z_O \qquad \text{(Equation 2-2)}$$

In a 50-ohm system, this becomes:

$$Z_L = \Delta + 50$$

Substituting in equation 2-1,

$$\rho = \frac{\Delta}{100 + \Delta} \qquad \text{(Equation 2-3)}$$

Thus the impedance difference is:

$$\Delta = \frac{100\ \rho}{1 - \rho} \qquad \text{(Equation 2-4)}$$

$$\text{and} \quad Z_L = Z_O + \frac{100\ \rho}{1 - \rho} \qquad \text{(Equation 2-5)}$$

Equation 2-5 is valid for sections of transmission line not less than 0.5 nsec in electrical length, and for resistive terminations.

For the special case where ρ is small, Z_L is close to 50 ohms, and Δ is also small. In this case, equation 2-3 becomes:

$$\rho = \frac{\Delta}{100}$$

$$\text{thus:} \quad \Delta = 100\ \rho$$

$$\text{and} \quad Z_L = Z_O + 100\ \rho \qquad \text{(Equation 2-6)}$$

When Z_L is nearly equal to the characteristic impedance of the system, highest resolution is possible by comparing an unknown impedance with a termination of known impedance, measured on an accurate bridge.

Location of Discontinuities

A length L, along the reflection stub described above, will have a transit time of $\frac{L}{V_p}$, where V_p is the propagation velocity. Since the reflection must travel back through the reflection stub, the oscilloscope will display the time between discontinuities in the stub as $\frac{2L}{V_p}$, where L is the physical separation. Thus, positions that are 30 cm apart on a coaxial line with air dielectric will appear 2 nsec apart in the reflection display. If it is desired to locate accurately the position of a small lumped discontinuity, it is usually possible to add a small reflection to the system near the discontinuity, calculate the rate of propagation in the line, then determine the position of the unknown discontinuity.

Measurement of Small Discontinuities

In many instances of pulse reflection tests, the major concern is with discontinuities which are both short in length and small in magnitude. Since the reflections from this type of discontinuity are very short compared to the risetime of the system, the reflections are reduced in amplitude and "smeared" in time by integration within the test system.

If the double transit time (2T) of a small impedance deviation in a transmission line is very short compared to the test system risetime (T_r), the observed voltage reflection (ρ_{obs}) will be less than the actual reflection (ρ), as stated in the relationship:

$$\rho = \rho_{obs} \frac{T_r}{2T} \qquad \text{(Equation 2-7)}$$

If the double transit time of a discontinuity is less than about .1 nsec (compared to the 0.35 nsec T_r of the Type 4S1), this variation should be taken into consideration for accurate determinations.

Gordon D. Long, "Pulse Reflections Pin Down Discontinuities," Electronic Design, May 10, 1963.

SECTION 3
CIRCUIT DESCRIPTION

GENERAL INFORMATION

The Type 4S1 is a balanced-bridge error-correction type sampling unit providing vertical deflection voltages for the Type 661 Oscilloscope. The unit has two independent channels controlled by the MODE switch. Each channel has an internal trigger-takeoff circuit which may be used to trigger the timing unit. The input signal is delayed 45 nsec after the trigger takeoff to allow the timing unit to begin the sampling cycle before the signal has reached the sampling gate diode bridge. A zero-order-hold memory is used in each channel to remember the value of the previous sample.

The sampling repetition rate ranges from 50 cps to 100 kc. This rate is determined by both the repetition rate of the triggering signal and the recovery time of the timing unit. If a rate slower than 150 cps is used, the memory output may drift, and memory "dot slash" may be seen. The maximum rate of 100 kc allows sufficient time for the sampling unit to pass a sample and recover before another sample is taken. Above 100 kc countdown must be provided, either by the timing unit or by some external device.

Most of the circuitry in the Type 4S1 is mounted on plug-in subchassis. The front panel and main frame unit contains only the controls, delay lines, interconnecting wiring, attenuators and Trigger Amplifier subchassis. The plug-in subchassis are: Sampler; AC Amplifier; Memory (one for each channel); Inverter, and Dual Trace. Each of these will be discussed here. The two interconnecting plugs at the rear of the frame, and the two coaxial connectors on top, connect the circuitry of the Type 4S1 to the oscilloscope and the timing unit.

This circuit description will be limited to a discussion of the operation of the various circuits. Anyone not familiar with the general concept and principles of sampling may also wish to refer to some introductory material on sampling, such as the Tektronix publication, "Sampling Notes."

SIMPLIFIED BLOCK DIAGRAM

A simplified diagram of the Type 4S1 circuitry is shown in Fig. 3-1. Each functional circuit is represented as a block, with external controls labeled. More detailed block diagrams may be found at the beginning of the Schematics section and with the descriptions of the individual circuits. Refer to the simplified block diagram during the following discussion.

The input signal is applied to the Type 4S1 through a 50-ohm coaxial connector, then travels through the Trigger Takeoff system and 45 nsec of 50-ohm delay cable to the Sampling Gate. The Trigger Takeoff circuit takes off a small portion of the input signal and sends trigger pulses to the Trigger Amplifier. The output of the Trigger Amplifier is then applied to the triggering circuitry of the timing unit to start the sampling cycle. The timing unit may also be triggered by pulses from an external trigger source.

After being triggered, the timing unit sends a command pulse to the Blocking Oscillator on the Sampler subchassis of the Type 4S1. The Blocking Oscillator pulses the Snap-Off circuit with a fast pulse and the Memory Driver with a slower pulse. Short push-pull pulses from the Snap-Off circuit are applied to the Sampling Gates in both channels, strobing the Sampling Gates into conduction for about 0.35 nsec. During this brief period, the input signal in each channel is passed through the Sampling Gate. The signal attempts to charge the stray capacitance (C_s) of the circuitry from its previous voltage level to the level of the input signal at the instant of sampling. However, the strobe pulse ends and the gate stops passing signal before the input capacitance has had time to charge completely.

The small correction sample pulse that was passed by the Sampling Gate is amplified about 2.5 times in the Sampler Amplifier, then passes through the MILLIVOLTS/CM switch, where it may be attenuated, and is sent on to the AC Amplifier to be inverted and amplified about 280 times.

By the time the signal pulse reaches the Memory Gate, the Memory Gate Driver has pulsed this gate into conduction, so the sample is passed from the AC Amplifier to the Memory circuit. The Memory re-inverts the signal and stores the value of the pulse on the memory capacitor. The output of the Memory is then applied to the Dual Trace circuit, either bypassing the Inverter for normal display, or passing through the Inverter for inverted display.

Between the Inverter and the Dual Trace circuit, the display gain is set by the A-B BAL. control (for Channel A) or the B CAL. control (for Channel B). Passage of either or both of the two signals through the Dual Trace circuit to the oscilloscope vertical circuitry is determined by an electronic switch controlled by the front-panel MODE switch.

A portion of the Memory output is sent back through a positive feedback loop to the sampling bridge. Since the Memory Gate stops conducting immediately after the sample pulse has passed, the feedback signal cannot regenerate through the main signal path. Amplitude of the signal in the feedback loop is set so that it will bring the charge on C_s up to the total input signal voltage at the instant it was sampled. The Sampler is then ready for the next sample, which will be initiated by the next trigger pulse.

Fig. 3-2 traces a single sample pulse through the sampling channel, and shows the effect of feedback. In the illustration, the attenuator switch is set at 200 MILLIVOLTS/CM (fully counterclockwise). A sample pulse is shown resulting from sampling the input signal ("a") at a time when it is 100 millivolts above the level at the output of the Sampling Gate. The level of the previous sample is taken as zero for convenience.

A very fast rise is seen at the output of the Sampling Gate ("b") while the gate is forward biased. The pulse amplitude reaches about 25 millivolts before the gate stops passing signal, then the signal begins to drop very slowly.

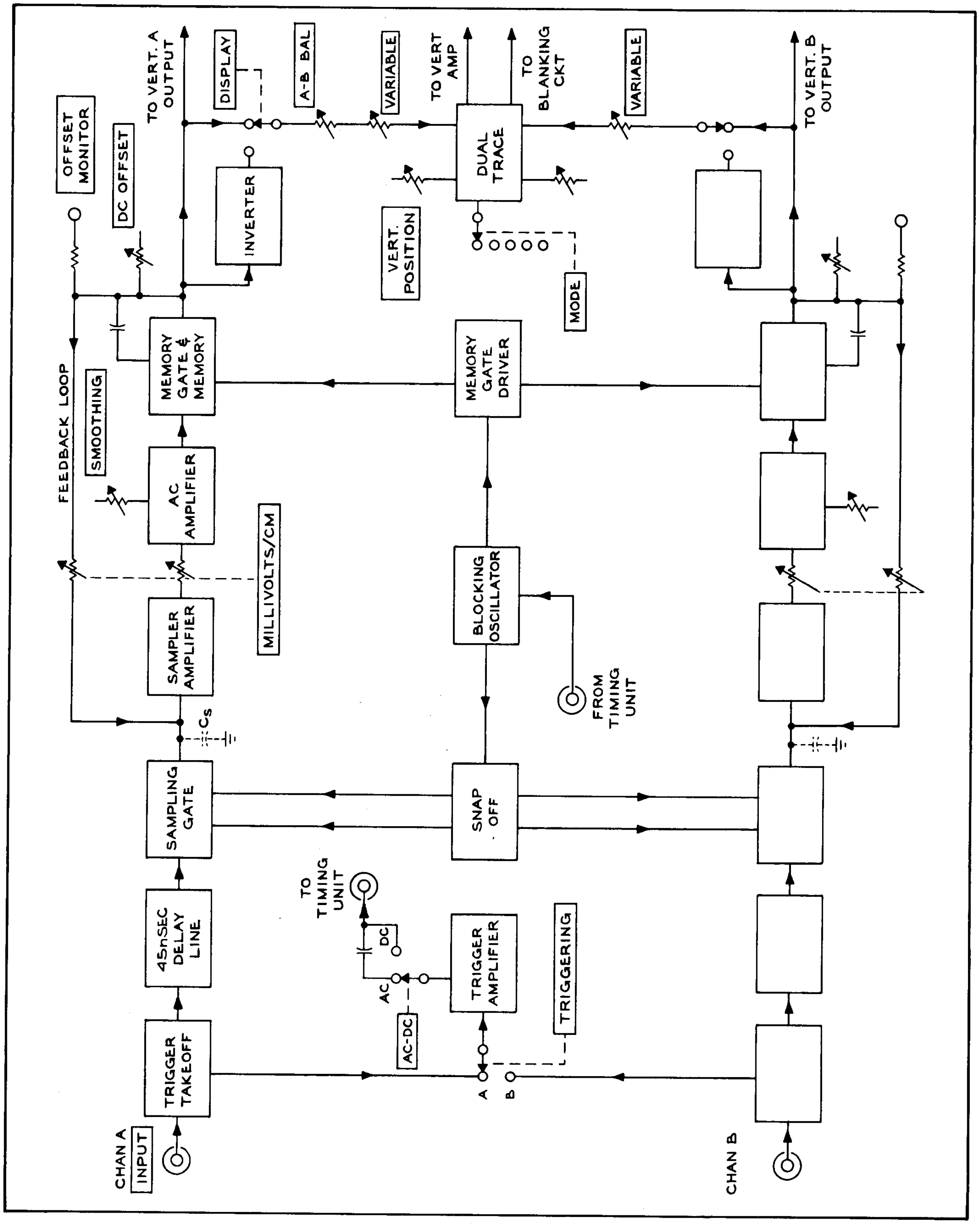


Fig. 3-1. Simplified Block Diagram of Type 4S1. Channel B is identical to Channel A, except where indicated.

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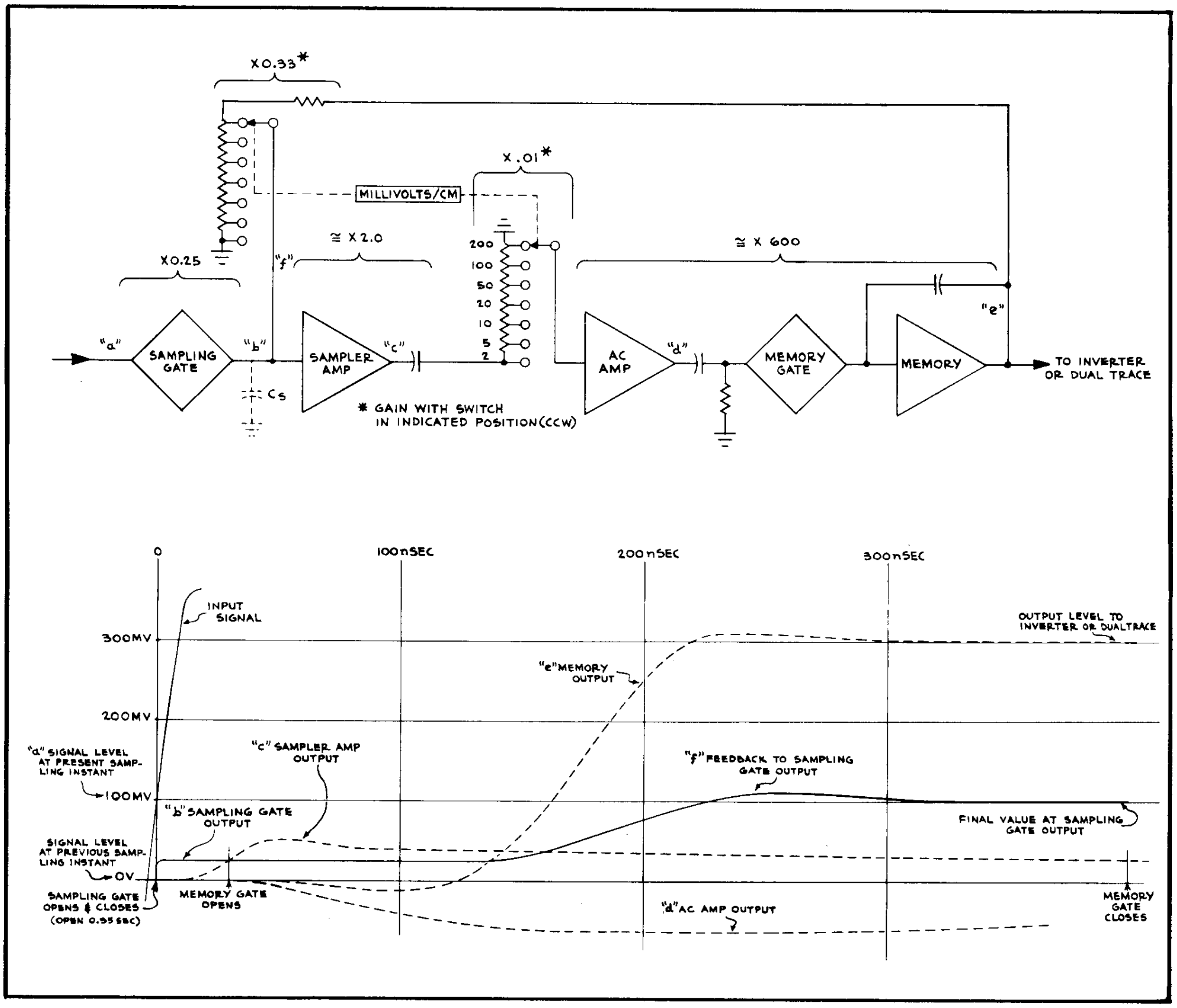


Fig. 3-2. A single sample signal traced through the feedback loop (see text).

The Sampler Amplifier amplifies the step about 2.5 times to give an output of 62 millivolts. Due to circuit losses, especially in capacitive coupling, the gain of this and subsequent stages is only about 60% of the cumulative gain of the individual circuits. Thus the actual amplitude out of the Sampler Amplifier is about 50 millivolts ("c"). The gain factors given in Fig. 3-2 are the actual gain factors in the various sections of the feedback loop. The Sampler Amplifier output is attenuated by a factor of 100 with the MILLIVOLTS/CM switch set at 200, giving an amplitude of .5 millivolts. The attenuated signal is not shown in the illustration. (Attenuation can be deceased to zero when the MILLIVOLTS/CM switch is set to 2).

The error-correction signal is then amplified about 280 times in the AC Amplifier to produce an output of about 100 millivolts ("d"). This amplitude is not seen at the input to the Memory circuit, however, due to the fact that the Memory is a high gain amplifier with negative feedback that holds its input nearly stationary.

Circuit gain of the Memory is about 3. Therefore, taking circuit losses into consideration, the gain from the AC Amplifier to the Memory output is about 600, producing an amplitude of about 300 millivolts in the illustration ("e"). The Memory Gate then stops conducting and the charge on the memory capacitor holds the output level at 300 millivolts. The output is sent back through the feedback attenuator where it is attenuated by a factor of 3 to give an amplitude of 100 millivolts. (Feedback attenuation can be inceased to 300 with the MILLIVOLTS/CM switch set to 2). The attenuator applies the signal to the Sampler to bring the output level of the Sampling Gate up to the 100 millivolt value of the input signal at the instant of sampling ("f"). The channel is then ready to take another sample.

Each subsequent sample is taken at a later point on the waveform, as determined by the staircase generator of the timing unit. Thus the signal through the circuitry, from the Sampler to the oscilloscope, is a series of pulses, each of which is proportional to the change in signal level between sampling instants. The series of level-correction signals from the Type 4S1 is sent to the oscilloscope vertical circuitry where it draws out the input signal as a series of dots on the crt. If the signal level does not change between samples, no signal passes through the circuitry, and a straight line of dots is presented.

Since the vertical circuitry of the Type 661 Oscilloscope requires 600 millivolts of signal amplitude from the sampling unit for each centimeter of trace deflection on the crt, the output deflection factor of the Type 4S1 must remain constant at 600 mv/cm in relation to the input. To maintain this relationship and still be able to change the input deflection factor for viewing both large and small signals, the signal gain of the channel and the sample-pulse amplification must both be varied. These two functions are performed simultaneously by the action of two attenuators operated by the front-panel MILLIVOLTS/CM switch, as explained later in the description of the Feedback Loop.

The front-panel SMOOTHING control in the AC Amplifier feedback decreases the gain of the sample amplification loop. This reduces random noise by limiting the ability of the circuit to keep up with input signal changes, but does not normally affect the crt display amplitude set by the feedback attenuator, circuit parameters and display gain controls.

INPUT AND TRIGGER TAKEOFF

Input

The input connectors on the Type 4S1 are 50-ohm GR Type 874 connectors. These assure maximum uniformity of input impedance and a universal quick-mate system. Characteristic impedance of the input is within 1% of 50 ohms.

Trigger Takeoff

The Trigger Takeoff circuit for each channel is located immediately behind the front-panel input connector. It consists of a ferrite core transformer, T1001 or T2001, and a dc connection to the coax center conductor. Fig. 3-3 shows an exploded view of the Trigger Takeoff.

In each channel the takeoff circuit extracts a total of about 1% of the input signal energy. Both the ac- and dc-coupled outputs are connected to the TRIGGERING switch, SW1004, which selects the channel to be used for triggering. The Trigger Takeoff in the channel selected for triggering is connected through the TRIGGERING switch to the inputs of the Trigger Amplifier. The Trigger Takeoff in the channel not used for triggering is connected to passive loads that simulate the Trigger Amplifier connections. Each takeoff circuit is frequency compensated so aberrations will not be introduced into the input signal.

Delay Line

To be able to display the signal that was used to trigger the first sampling cycle of a sweep, the input signal must be delayed by at least 40 nsec to allow for the 40 nsec the timing unit requires to respond to internal triggering information.

This signal delay is provided by passing the signal through a special 45-nsec delay cable between the Trigger Takeoff and the Sampling Gate. The timing unit can then start the sampling cycle before the signal reaches the input bridge, and samples can be taken on the leading edge of a fractional nanosecond signal. The delay line, which is manufactured by Tektronix to be within 2% of 50 ohms characteristic impedance, has negligible fast-rise signal reflections.

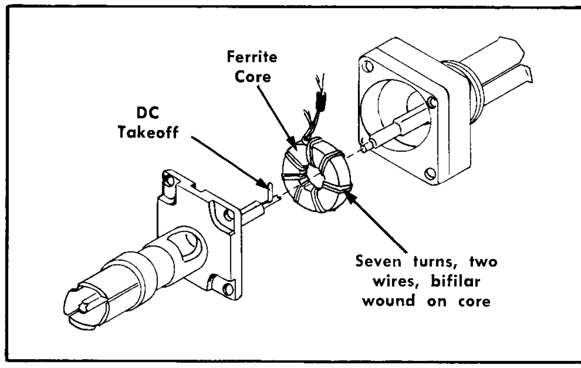


Fig. 3-3. Exploded view of trigger takeoff.

TRIGGER AMPLIFIER S/N 101-1349

The Trigger Amplifier circuit consists of a high-frequency section, Q1014, and a low-frequency section, Q1023 and Q1024. The two sections amplify the ac and dc outputs from the Trigger Takeoff, then combine them and send the composite signal to the timing unit. This is the internal triggering signal to be used for triggering from the selected input channel. Operating range of the Trigger Amplifier is from dc to 1 gigacycle, with effective crossover from dc- to ac-coupling occurring at about 350 kc. Amplitude of the signal to the timing unit is about 1/8th the amplitude of the applied input signal. Refer to Fig. 3-4 (inset) and the Trigger Amplifier diagram (S/N 101-1349) in the Schematics section during the following discussion.

Dc and low-frequency signals taken from the center conductor of the Trigger Takeoff are applied through R1002 (or R2002) and the TRIGGERING switch to the base of emitter follower Q1013. The emitter follower drives the low-frequency amplifier, Q1024, which is collector-coupled to the output through L1015 and the AC-DC switch, SW1019. Inductor L1015 serves to isolate Q1014 from the low-frequency section. Negative feedback in the low-frequency amplifier is provided by R1033 and C1023 for low frequencies, and by R1036, C1036 and C1037 for mid frequencies.

Inductively-coupled high-frequency signals from the trigger takeoff transformer (T1001 or T2001) are applied through the TRIGGERING switch and through C1014 and R1014 to the emitter of Q1014. The high-frequency signals are amplified by Q1014, then combined with the low-frequency signal from Q1024 to be sent to the timing unit.

TRIGGER AMPLIFIER S/N 1350-UP

The Trigger Amplifier circuit consists of an emitter follower, Q1013, and an amplifier transistor, Q1024. The ac and dc outputs from the Trigger Takeoff are amplified and mixed

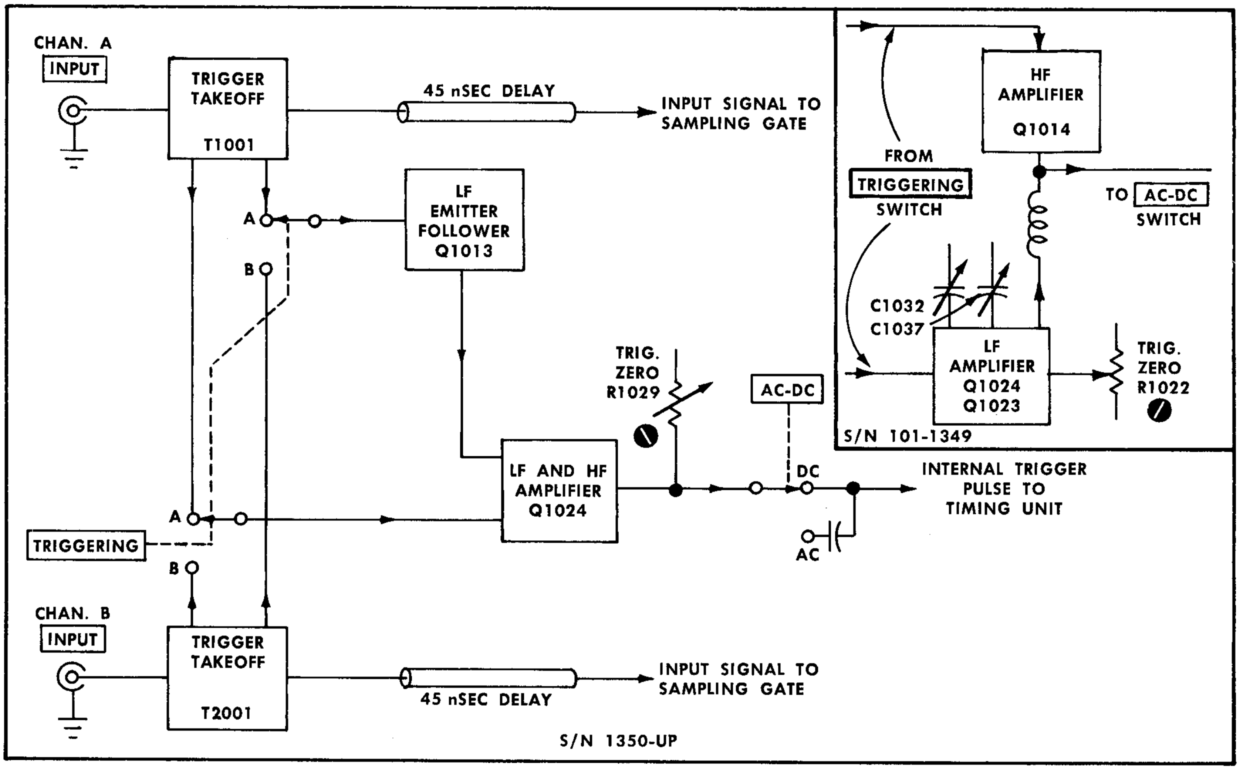


Fig. 3-4. Block Diagram of Trigger Amplifier.

by Q1024, then sent to the timing unit to provide internal triggering from the selected input channel. Operating range of the Trigger Amplifier is from dc to 1 gc, with effective crossover from dc- to ac-coupling occurring at about 3.5 Mc. Amplitude of the signal to the timing unit is about $\frac{1}{8}$th the amplitude of the applied input signal. Refer to Fig. 3-4 and the Trigger Amplifier diagram (S/N 1350-up) in the Schematics section during the following discussion.

Dc and low-frequency signals taken from the center conductor of the Trigger Takeoff are applied through R1002, L1002 (or R2002, L2002) and the TRIGGERING switch to the base of emitter follower Q1013. The output of Q1013 is then applied to the base of Q1024 where it is amplified and mixed with the high-frequency portion of the triggering signal.

Inductively-coupled high-frequency signals from the trigger takeoff transformer (T1002 or T2001) are applied through the TRIGGERING switch and through C1022 and R1022 to the emitter of Q1024. The high-frequency signal is amplified by Q1024 and mixed with the low-frequency signal applied at the base of the transistor. The combined triggering signal at the collector of Q1024 is coupled through D1026, C1023, T1024 and the AC-DC switch (SW1019) to the output jack. The output dc level is set to zero volts with the TRIG ZERO adjustment, R1029.

The dc current path to the output is through transformer T1024 and Zener diode D1026. At low and mid frequencies, the signal to the timing unit passes through this dc path and through C1023. At very high frequencies, however, T1024 prevents the signal from passing through D1026 and the output signal path is primarily through C1023.

SAMPLER
Subchassis Series 1 and 7

Mounted on the Sampler subchassis are a Sampling Gate diode bridge and Sampler Amplifier for each of the two channels, and also the Blocking Oscillator, the Snap-Off Circuit and the Memory Gate Driver. A detailed block diagram of the Sampler circuitry is shown in Fig. 3-5. Refer also to the Sampler schematic diagram in the back of this manual. Since the two channels are identical only the Channel A Sampler circuitry will be discussed.

Blocking Oscillator

A positive command pulse of about 2 volts is received from the timing unit by way of a 50-ohm coax which is threaded through a toroid to prevent transmission of stray pickup from the Sampler. The pulse is applied through C2018 and D2018 to the collector of the Blocking Oscillator transistor, Q2010, and is coupled to the base circuit as a negative pulse. Quiescently, Q2010 is turned off, being reverse-biased by D2013. When a pulse is received, the combination of a negative-going base and a positive-going collector causes this transistor to turn on and saturate very fast, due to the common-emitter configuration. As Q2010 turns on, a fast 10-volt positive pulse is sent through C2010 to T2004 in the Snap-Off circuit. At the same time the two-turn coil of

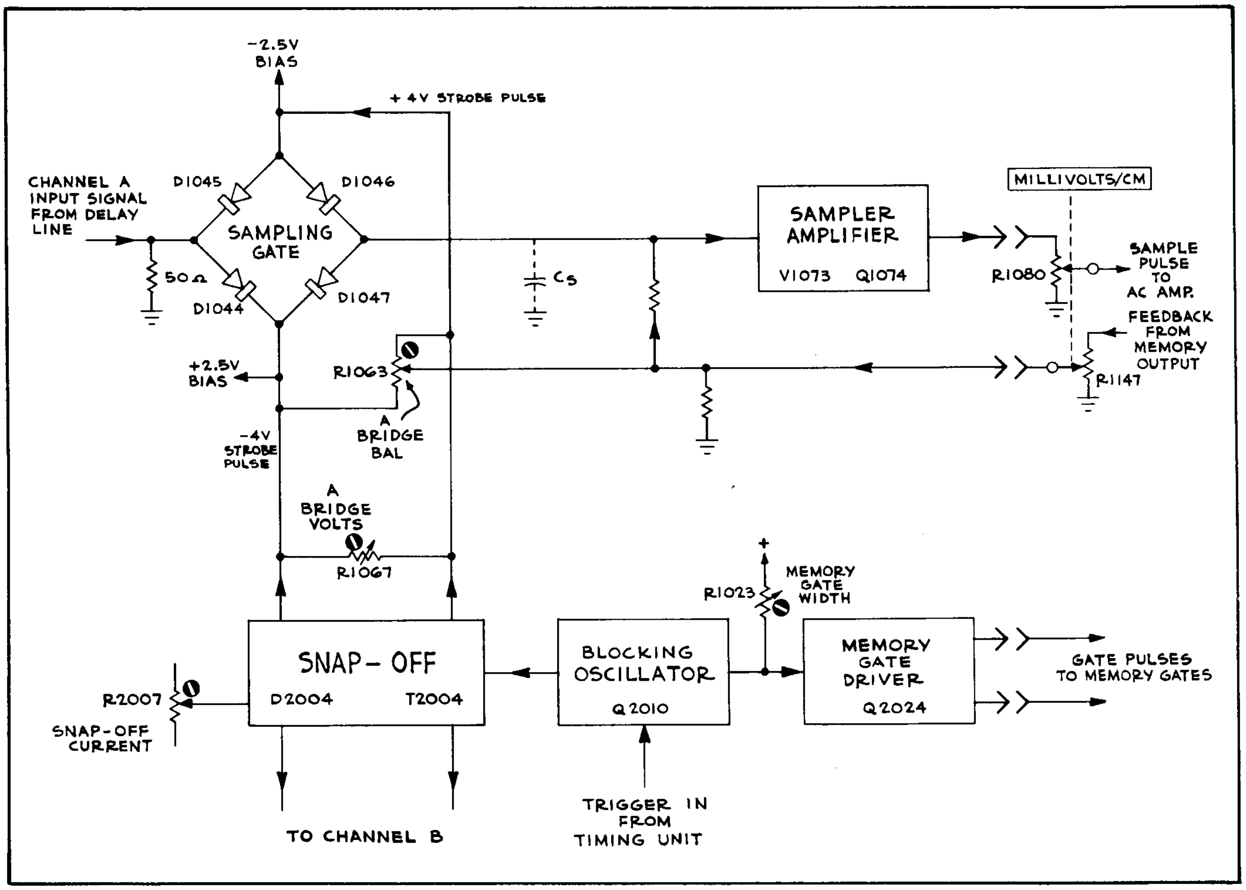


Fig.3-5. Block Diagram of Sampler.

T2010 couples a negative pulse to the Memory Gate Driver circuit.

After saturation has occurred in Q2010, the normal blocking oscillator backswing begins, but D2010 stops the backswing at about —19 volts, so that no overvoltage is applied to the transistor. At the same time, the charge on C2013 reverse-biases the base of Q2010, allowing a quick return to equilibrium.

Memory Gate Driver

The Memory Gate Driver transistor, Q2024, is normally biased to cutoff by a slightly positive voltage on its base. As a negative pulse is received from the Blocking Oscillator, D2022 conducts and forward biases Q2024 into conduction, then into saturation. Collector current flows through R2027, R2028 and the Memory Gate coils (not through D2024 and R2024).

As the pulse from the Blocking Oscillator ends, D2022 becomes reverse biased and decouples the circuits. The positive output pulse to the Memory Gates continues until the base of Q2024 becomes slightly positive again and cuts off this transistor. With D2022 reverse biased, the only discharge path for the base circuit is through R2022 and the MEMORY GATE WIDTH control, R2023. Therefore, these two resistors determine the length of time that Q2024 remains saturated, and thus the duration of the Memory Gate Driver output pulse. D2024 and R2024 reduce ringing in the collector circuit when Q2024 cuts off.

Snap-Off Circuit

Quiescently, the current-storage (snap-off) diode, D2004, is conducting with a forward current of about 10 to 80 milliamperes from —19 volts to ground, through the SNAP-OFF CURRENT control, R2007. This control adjusts the quiescent current and thus the storage of D2004. As transformer T2004 receives a positive pulse from the Blocking Oscillator, it converts the pulse to push-pull and applies it to D2004, which then begins to conduct heavily in the reverse direction as its stored charge is "swept out." This reverse current sends a heavy push-pull current pulse into the 50-ohm clipping line.

When the stored charge in the diode has been depleted, the current pulse ends sharply, forming push-pull voltage pulses at the input to the clipping line and the sampling bridge strobe leads. The voltage pulses pass through isolation and balancing circuitry to the Sampling Gate where they overcome the reverse bias of the bridge diodes and allow the Sampling Gate to pass the input signal for an instant. At the same time, the voltage pulses propagate down the clipping line, which is essentially a transmission line terminated in a short, and are reflected back as inverted pulses. When the inverted pulses reach the strobe leads, they cancel the strobe pulses, allowing the Sampling Gate to return to its normal non-conducting state. The double-transit time of the clipping line is approximately 0.35 nsec, establishing the duration of the sampling pulses. After D2004 has cut off, R2008 and C2008 act as a termination for the Blocking Oscillator until its pulse has ended. The reflection energy stored in C2004 discharges through the snap-off bias path before the next sample.

T1052 couples the push-pull strobe pulse to the corners of the sampling bridge and isolates the triggering circuitry and the bridge in the other channel from the signal input. L2057 and R2057 between the clipping line leads are provided to reduce multiple reflections of the strobe pulses.

Sampling Gate

The diodes in the Sampling Gate bridge (D1044 through D1047 in Channel A), are special gallium arsenide diodes with very fast switching characteristics. The delay line is terminated at the input to the Sampling Gate by the 50-ohm disc resistor, R1041, to prevent reflections.

Quiescently, the Sampling Gate bridge diodes are reverse biased, preventing passage of the input signal which is always connected through the delay line to the input of the bridge. Reverse bias is about 2.5 volts across each diode, set by the A BRIDGE VOLTS control, R1067. When a push-pull strobe signal from the Snap-Off circuit is received by the sampling bridge, about 1.5 volts of forward bias is applied across each of the four diodes, causing about 10 milliamps of forward current, and for a moment the diodes pass the applied input signal. Balance of the reverse bias is adjusted with the A BRIDGE BAL. control, R1063, so that no error-correction signals are produced when there is no voltage change at the input.

The Sampling Gate source resistance is 25 ohms, since the input circuit is a 50-ohm transmission line paralleled by a 50-ohm resistor. The response time of the Sampling Gate and the Sampler Amplifier grid circuit is determined by this resistance as well as by gate resistance, shunt stray capacitance and series inductance. The 0.35-nsec duration of the Snap-Off pulse, which is much shorter than the Sampler response time, limits the amplitude of the sampled signal to about 25% of the difference between the feedback level and the level of the new sample. If there is no difference between the feedback and the new sample level, no correction signal will pass through the channel, and the new dot will be displayed at the same level as the previous one.

The Blocking Oscillator, Snap-Off circuit and Sampling Gate are the critical circuits determining the effective duration of the strobe pulse, and thus the risetime of the unit. Because only about 25% of the difference signal gets through the Sampling Gate, leaving 75% of the Memory output signal to be made up by the amplifier stages, the Type 4S1 is said to have a sampling efficiency of 25%. A short time after the sample has been taken the positive feedback from the Memory output brings the level of the Sampling Gate output and strobe input corners up to the full signal value. Then the next sample corrects only for any change since the previous sample.

All the internal adjustments that control sampling efficiency for both channels are located on the Sampler subchassis. These are: SNAP-OFF CURRENT, R2007; MEMORY GATE WIDTH, R2023; A and B BRIDGE VOLTS, R1067 and R2067; and A and B BRIDGE BAL., R1063 and R2063.

Sampler Amplifier

The sampled pulses from the Sampling Gate are sent through L1070 to the Sampler Amplifier, consisting of V1073 and Q1074. V1073 amplifies the sample signal and sends it to the base of Q1074. The signal is amplified again by Q1074 and sent through blocking capacitor C1079 to the MILLIVOLTS/CM switch, SW1101, to be applied to the AC

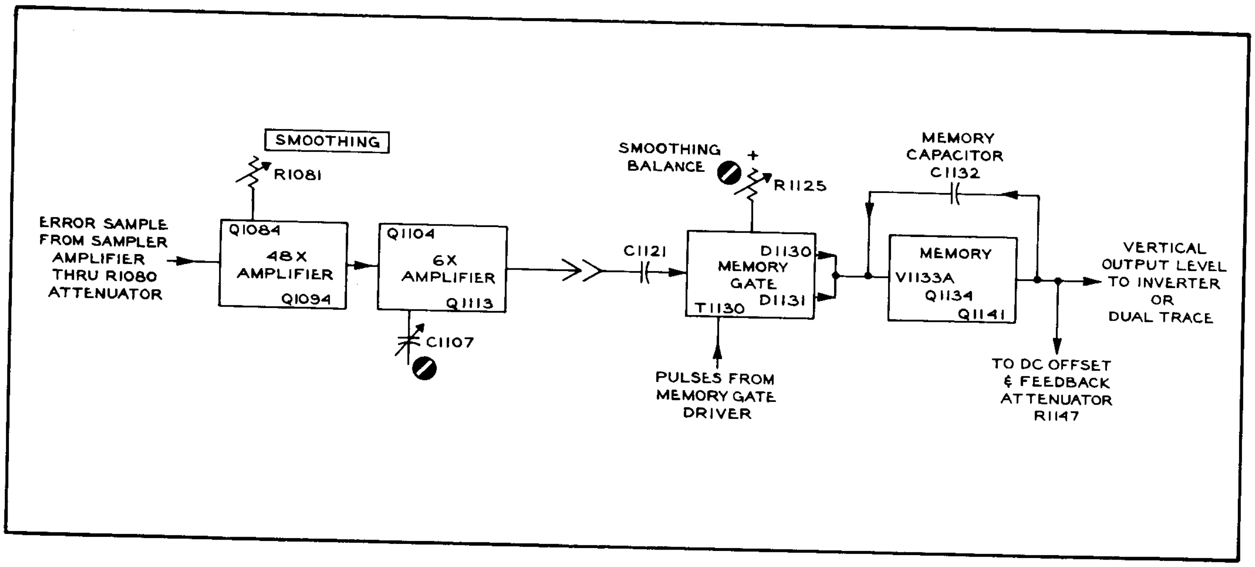


Fig. 3-6. Block Diagram of AC Amplifier and Memory.

Amplifier. Amplification through the Sampler Amplifier circuit is about 2.5 times, and the output is stretched due to the capacitance at the input grid. The feedback loop from the collector of Q1074 to the cathode of V1073 sets the output amplitude and also bootstraps V1073 to keep the impedance of the grid circuit relatively high.

Because the amplitude of the pulses from the Sampling Gate is proportional to the change in signal amplitude since the previous sample, the output signal from the Sampler Amplifier is only the amplified and stretched correction signal.

ERROR-SIGNAL ATTENUATOR

The sample signal passes through attenuator R1080 (R2080 in Channel B), on its way from the Sampler Amplifier to the AC Amplifier. The value of R1080 is controlled by the position of the front-panel MILLIVOLTS/CM switch SW1101 (SW2101 in Channel B), which also operates the feedback attenuator. Sample attenuation at each step of the switch is set to maintain a loop gain of 1 in the feedback loop as the output signal amplitude is changed by the feedback attenuator. R1080 provides seven attenuation values, ranging from zero at the 2 mv/cm position to 100X at 200 mv/cm.

AC AMPLIFIER

Subchassis Series 2

The AC Amplifier subchassis contains an amplifier for each of the two channels. Since the two amplifiers are identical, only Channel A will be described. Refer to the block diagram in Fig. 3-6, and to the AC Amplifier schematic diagram.

The amplifier receives signals (correction samples) from the Sampler Amplifier through the MILLIVOLTS/CM switch, amplifies them about 280 times, inverts the signals and sends them to the Memory circuit.

The AC Amplifier is made up of two stages of amplification with dc-coupled feedback for each stage, and a third dc feedback path around the whole circuit. The input dc level is zero volts to ground, and the input resistance to ground ranges from 10 ohms at 200 mv/cm to 1000 ohms at 2 mv/cm. Dc stabilization provided by R1115 in the external feedback loop does not affect the pulse signals through the circuit. The external feedback path includes the front-panel SMOOTHING control, R1081, that allows a gain reduction of about four-to-one to reduce random noise.

When the SMOOTHING control is set to NORMAL (zero resistance), the gain of the first stage (Q1084 and Q1094) is about 48, set by the ratio of R1089 to R1083. When using full smoothing, the gain is about 9, set by the ratio of R1089 to R1083 and R1081 (SMOOTHING) in series. The gain of the second stage (Q1104 and Q1113) remains fixed at about 6, set by the ratio of R1107 to R1096.

The high-frequency stability of the first amplifier stage is determined by the fixed capacitor, C1089. Compensation of the second stage is adjusted during calibration by C1107.

The duration of signal pulses passed by the amplifier is about 1 μsec. Normally the feedback loop limits the amplitude of the AC Amplifier output pulses to less than 1 volt, but if the display has to move 8 centimeters in one sample, the output pulse will be about 1.6 volts peak. The output impedance of the circuit is low, so it is able to drive the Memory input.

MEMORY

Subchassis Series 3, 8 and 11

Located on the Memory subchassis are the Memory Gate, the Memory and the DC Offset circuits. The two channels have separate plug-in Memory subchassis.

Just before the Memory Gate receives the stretched error-correction sample, it is pulsed into conduction by the Memory Gate Driver, and passes the signal to the Memory circuit. The Memory Gate then is allowed to return to its normal non-conducting state before the output of the AC Amplifier returns to its quiescent level and before the feedback has had time to regenerate through the amplifiers. The Memory inverts the signal and stores its final value. The output of the Memory is connected to the Inverter or Dual-Trace circuit and a portion is also coupled back to the Sampler Amplifier to correct the input level.

Memory Gate

The Memory Gate consists of diodes D1130 and D1131, which are pulsed by the Memory Gate Driver through T1130. Refer to the Memory schematic diagram and to the block diagram in Fig. 3-6 during the following discussion. The purpose of the Memory Gate is to allow the sampled error-correction signal to pass through to drive the Memory circuit, but prevent the feedback signal from being sent back through the amplifiers into the Memory again as a new error signal. Although feedback is coupled through the amplification channel to C1121, it does not pass through the Memory Gate between samples. C1121 discharges through the Smoothing Balance network consisting of R1123, R1124, R1127 and the SMOOTHING BALANCE control, R1125, and the circuit returns to a normal quiescent state before the next sample is received.

The gate diodes are normally reverse biased by the voltage across zener diode D1122. When the Memory Gate Driver sends a pulse through T1130, a voltage is developed across each winding, forward biasing the diodes. The signal then passes from C1121 through the gate to the input of the Memory circuit. The MEMORY GATE WIDTH control in the Memory Gate Driver circuit adjusts the duration of conduction of the Memory Gate so that signals are transmitted as a result of sample pulses only. Capacitor C1122 assures that both sides of D1122 follow the signal equally well.

The dc level at the Memory Gate input is set by the Smoothing Balance divider network. The balance is adjusted during calibration so that with no error signal present at the input, there will be no change in the Memory output level. Imbalance in the dc level is seen as trace shift when the SMOOTHING control is operated, thus the control for adjusting the Memory input balance is called the SMOOTH-

ING BALANCE control (early models were called MEMORY BALANCE). Diodes D1125 and D1127, which limit the signal amplitudes, are normally not conducting.

Memory Circuit

The Memory circuit is a feedback amplifier which has capacitors for both the input and the feedback elements. A block diagram of the Memory is shown in Fig. 3-6. The input capacitor is C1121, and the feedback (memory) capacitor is C1132. V1133A is the input cathode follower, Q1134 is the amplifier, and Q1141 is an output emitter follower. Although gain of the Memory is only a little more than 3, set by the ratio of C1132 to C1121, high gain capability is needed to keep the excursion at the grid of V1133A very small compared to the Memory output.

The action of the Memory develops a charge on C1132 opposing the charge applied to C1121. The circuit between the input to R1121 and the grid of V1133A is effectively 150 ohms in series with 510 pf when the Memory Gate is conducting. As a sample signal is received by C1121 from the AC Amplifier, this capacitor couples the pulse to the grid of V1133A. The input impedance in the grid circuit is very high, and any tendency for the grid level to change is amplified and returned as negative feedback through C1132, holding the grid level practically stationary. This feedback action places a charge on C1132 equal to that applied to the input capacitor. Then the Memory Gate disconnects the Memory before the stretched pulse from the AC Amplifier has ended, and C1132 is left in a charged condition. Between samples, C1121 discharges through the Smoothing Balance network, and the AC Amplifier output returns to a quiescent level. At the next sample, if there is a change at the input, C1121 will receive the new signal and will add or subtract the new signal from the residual charge on C1132, depending on whether the new level is above or below the previous value. Grid current in V1133A is very low, and total leakage from C1132 and diodes D1130 and D1131 is very small, so there is essentially no change in the Memory output voltage between samples, even when sampling at the low rate of 50 samples/second. Memory drift or "dot slash" at sampling rates in the range below 50 samples/second is caused by small leakage currents.

The following components in the Memory circuit perform the indicated functions: C1138 in the collector circuit of Q1134 corrects for transistor phase shift; D1136 determines the emitter voltage of Q1134; D1143 limits the positive swing of the output to the value determined by D1144; D1140 limits the negative swing of the output by setting the voltage on the collector of Q1141 and limiting the emitter to this value as the transistor saturates; R1145 suppresses reverse reflections in the output cable. The emitter-to-base junction of Q1141 is protected from over-voltage by D1142.

FEEDBACK LOOP

Each channel has a feedback loop consisting of the feedback attenuator, the Sampling Gate, the Sampler Amplifier, the error-signal attenuator, the AC Amplifier, the Memory Gate and the Memory. The purpose of the loop is to set the signal gain of the channel and to correct for the 25% sampling efficiency of the Sampling Gate. The loop in Channel B is identical to the Channel A loop described in the following paragraphs.

Since the Memory output level determines the level of each displayed sample, the amount of attenuation introduced into the feedback loop sets the signal gain by establishing the ratio between the voltage level at the Memory output and that at the Sampling Gate. The voltage excursion sent back to the Sampling Gate must be the same as that of the input signal, therefore the Memory output amplitude will change in proportion to the feedback attenuation. The front-panel MILLIVOLTS/CM switch operates the feedback attenuator, R1147, providing seven values of attenuation that range from 300X at the 2 mv/cm position of the switch, to 3X at the 200 mv/cm position.

For best response the feedback signal following each sample must be of the amplitude required to bring the level at the Sampling Gate up to the level of the input signal at the previous sampling instant. When it is set to do this, the loop is said to have a gain of 1. As feedback attenuation is increased, to change the signal gain, amplification of the error-correction samples must also be increased to keep the feedback loop gain at 1. Since the gain of the amplifiers is fixed, the additional amplification is produced by allowing more of the error-correction signal to pass through attenuator R1080 to the AC Amplifier. Thus, the error-signal attenuation produced by R1080 must decrease as the feedback attenuation of R1147 is increased. These two attenuators are operated simultaneously by the MILLIVOLTS/CM switch, SW1101.

Random noise through the system can be reduced by decreasing the gain of the feedback loop. The front-panel SMOOTHING control changes the loop gain without affecting the output amplitude, by reducing amplification in the first stage of the AC Amplifier. Smoothing also reduces the response of the system by allowing the feedback voltage to lag slightly behind the input signal changes, but it does not normally change the appearance of the display unless the dot density is too low. The display must have a dot density great enough for the feedback to follow the signal, or the transient response will be affected and the display amplitude may be reduced.

DC Offset

The DC Offset circuit consists of a cathode follower which introduces dc shift into the feedback loop. Fig. 3-7 is a block diagram of the DC Offset injection circuit. The grid voltage of V1133B is set by a resistance divider that includes the front-panel DC OFFSET control, R1159, in the main frame of the Type 4S1. Rotating the DC OFFSET control from one end to the other causes a —50-volt to +50-volt swing at the cathode of V1133B. The cathode swing, following the grid, produces a ±0.25-milliamp change through R1146. The DC OFFSET control ±100-volt swing also causes a ±0.50 milliamp change in current through R1149. The resulting voltage drop of ±1 volt across both R1146 and R1149 is the offset voltage injected into the feedback loop on both sides of attenuator R1147. Adding the dc offset voltage at these two points assures that no offset current will flow in R1147, so there will be no interaction between operation of the feedback attenuator and of the offset circuit.

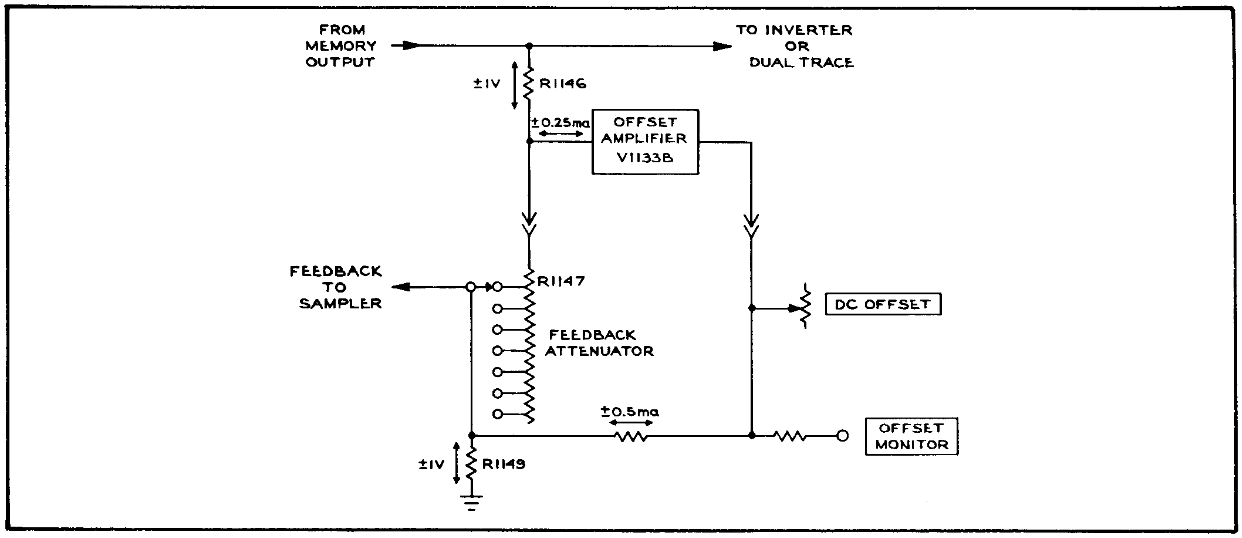


Fig. 3-7. DC Offset Injection and Memory Feedback.

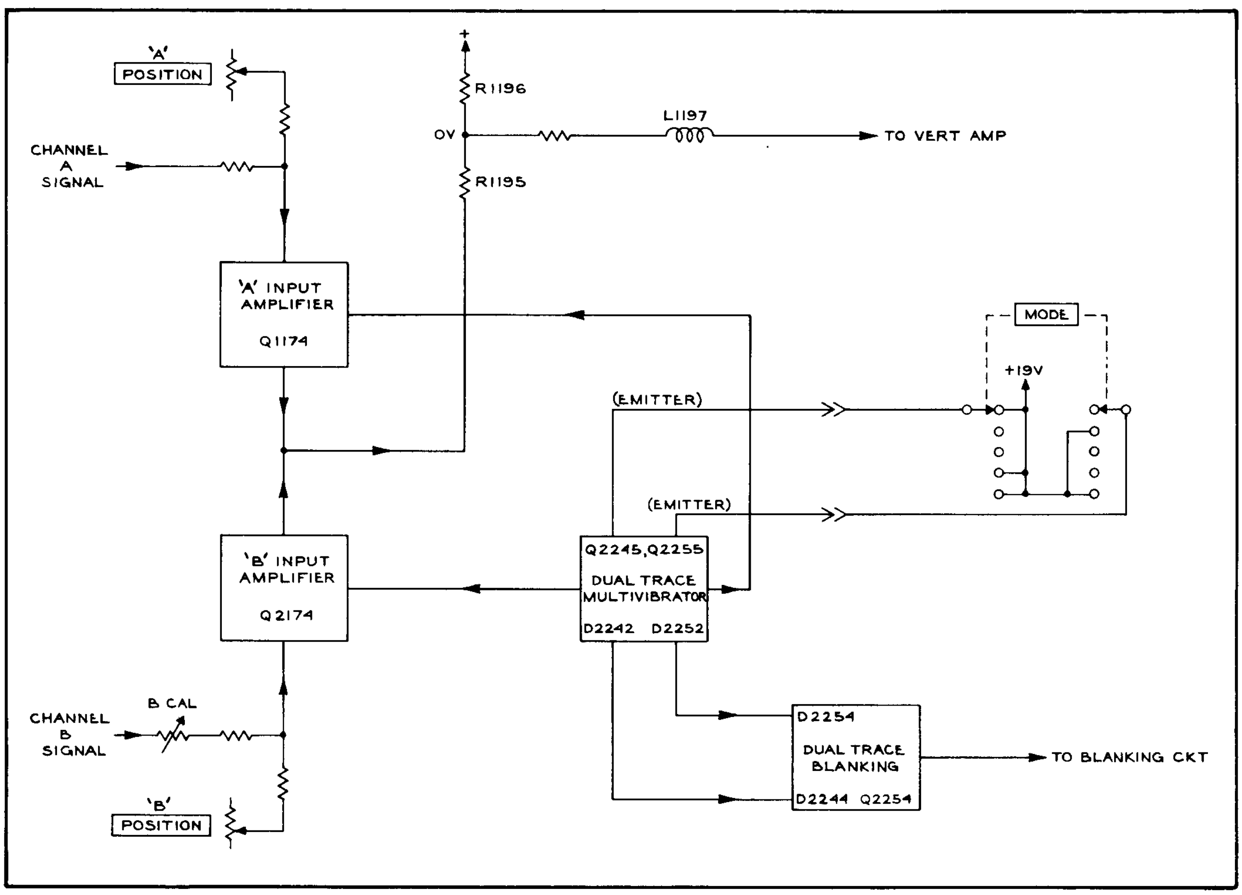


Fig. 3-8. Dual Trace Block Diagram, Models 1 and 2.

The front-panel OFFSET MONITOR jack permits connection of a voltmeter for reading the offset voltage amplified 100 times.

INVERTER

Subchassis Series 4 and 9

The Inverter consists of two X1 amplifiers, one for each channel, with inverted output signals. The function of each amplifier is to invert the display when the front-panel DISPLAY switch is in the INVERTED position. The following description pertains to Channel A. Operation of the Channel B Inverter is identical. Refer to the Inverter diagram in the Schematics section.

The Inverter input transistor, Q1164, is collector-coupled through D1167 to the output emitter follower, Q1163. D1167 is a voltage-offset zener diode that raises the voltage at the base of Q1163 above that at the collector of Q1164, without producing signal attenuation. R1161, the A INVERTER ZERO, and R1162 are a dc-balance network for adjusting the output dc level to eliminate trace shift when moving the DISPLAY switch from NORMAL to INVERTED. R1163 is the feedback resistor in the negative feedback loop.

With the DISPLAY switch set to INVERTED, the inverted output is connected to the Dual Trace circuit. When the DISPLAY switch is at NORMAL, the Inverter is bypassed through interconnecting wiring in the main frame of the Type 4S1, and the signal from the Memory is applied directly to the Dual Trace circuit.

DUAL TRACE

Subchassis 5

The Dual Trace circuitry determines which channel signal is allowed to be displayed by the oscilloscope. In some modes, both signals pass through the Dual Trace circuit. Figs. 3-8 and 3-9 are block diagrams of the Dual Trace circuitry. Because of the various modes of operation possible, both channels will be discussed.

Models 1 and 2 Only

Passage of the signals from the two channels is controlled by the two inverter amplifier transistors, Q1174 and Q2174, which are gated by the multivibrator, Q2245 and Q2255. Emitter voltage determining the mode of operation is applied to the multivibrator through the front-panel MODE switch. A 0.25-μsec delay line couples the signal from the Dual Trace circuit to the oscilloscope vertical output amplifier. This delay allows the signal to phase properly with the timing unit unblanking of the crt.

In the A ONLY and A VERT. B HORIZ. modes, only transistor Q2245 is energized, and in the B ONLY mode only Q2255 has voltage applied. In the ADDED ALGEB. mode neither transistor is conducting, and in the DUAL TRACE mode both are conducting. The multivibrator free runs in DUAL TRACE mode, at a switching rate of about 50 kc. Q2254 provides a dual-trace blanking signal to the oscilloscope when the multivibrator is switching.

Each of the Dual Trace input transistors receives its respective channel signal from the Memory or Inverter circuit through the DISPLAY switch, the VARIABLE control, and the display gain control. The signal is applied to the emitter circuit, which also provides positioning voltage through the front panel POSITION control (R1180 or R2180) and R1181 or R2181. The major emitter current path is from the +19-volt supply, through the MODE switch, SW2190, and through R1176 and R2176 to the two emitters. In the ADDED ALGEB. position of the MODE switch, current-limiting resistor R1179 (in the Type 4S1 switching circuitry) is inserted in the emitter circuit to keep the average voltage on the common lead the same as when only one transistor is conducting. The input inverter transistors are connected in the common base configuration. The voltage at each base is switched between two levels by the multivibrator to turn the transistors on or off.

In the A ONLY mode, transistor Q2255 is not conducting. Its collector, and thus the base of Q1174, is held at about −0.3 volt by D1184, so Q1174 conducts, passing the Channel A signal through R1195 and R1197 to the delay line. Transistor Q2245 is turned on by the MODE switch, with the emitter connected to the +19-volt supply through R2241. This sets the collector voltage of Q2245 and the base of Q2174 at about +3.3 volts, cutting off Q2174 in the Channel B signal path.

In the B ONLY mode, operation of the multivibrator and input transistors is just the opposite of operation in A ONLY. Q2255 is conducting, Q2245 and Q1174 are cut off and Q2174 is passing Channel B signal.

In the ADDED ALGEB. mode, neither transistor is supplied from the +19-volt supply and both are turned off. Thus both input transistors are conducting, allowing signals to pass. The output to the delay line then is the algebraic sum of the Channel A and Channel B signals.

Operation of the Dual Trace circuit in the A VERT. B HORIZ. mode is the same as in A ONLY. The Channel B signal bypasses the Dual Trace circuit and is applied through other circuitry to the horizontal deflection system of the oscilloscope.

In the DUAL TRACE mode, both Q2245 and Q2255 are energized, and operate as a free-running multivibrator at approximately 50 kc (some units operate at 40 kc). During dual-trace operation, the multivibrator switching time is determined by C2241 in series with the emitter-return resistor of the transistor that is not conducting (R2241 or R2251). As the collectors of the two multivibrator transistors alternately go negative, then positive, the input transistors alternately allow the Channel A signal to pass, then the Channel B signal, producing the dual-trace display. The collector-to-base coupling circuits (R2243-C2243 and R2253-C2253) are for high-frequency coupling to assure fast switching, and do not set the switching time.

Blanking transistor Q2254 normally rests in cutoff. As the multivibrator switches, C2244 or C2254 couples a negative pulse to the base of Q2254, turning it on. The 2 μsec positive blanking pulse from the collector is fed through the interconnecting wiring of the Type 4S1 main frame to the oscilloscope blanking circuit.

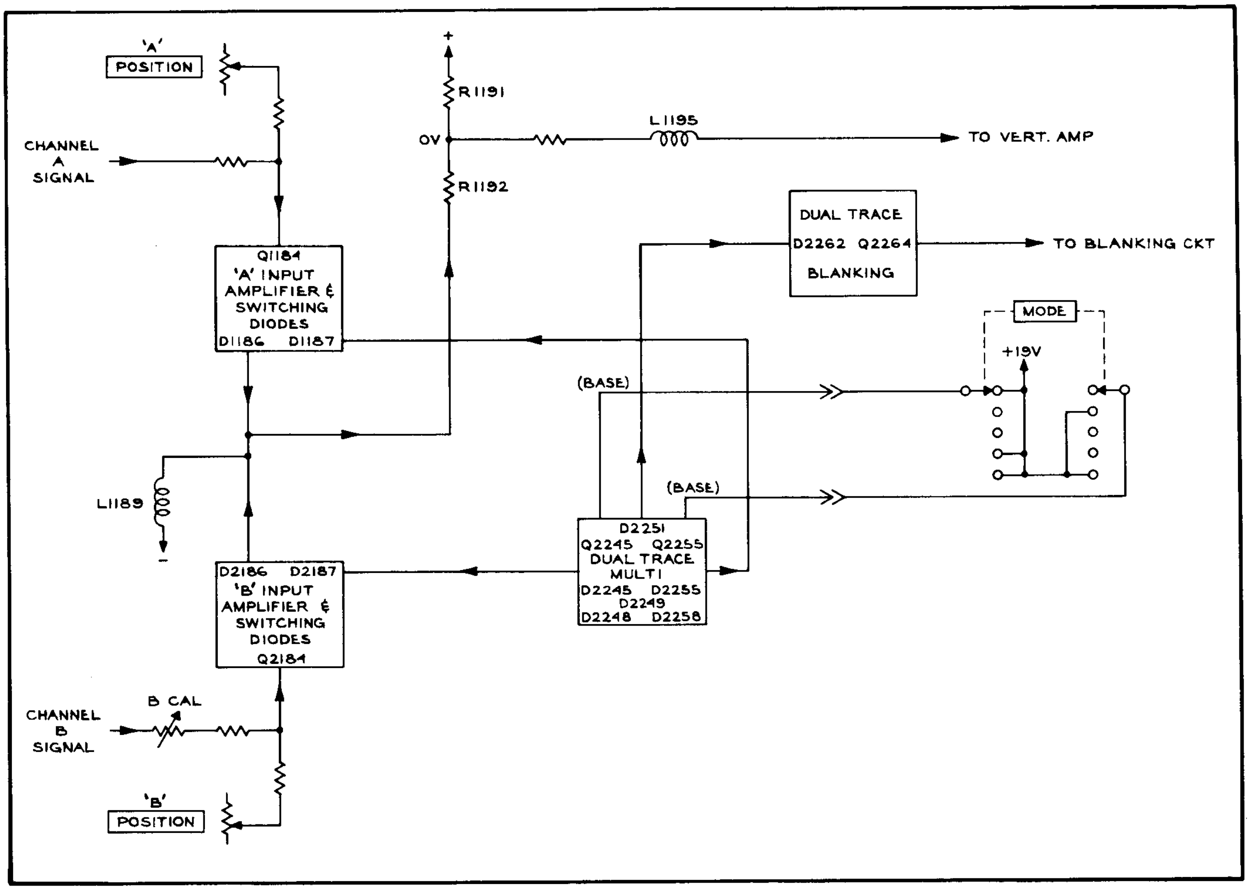


Fig. 3-9. Dual Trace Block Diagram, Model 3.

Model 3

Passage of the signals from the two channels is controlled by the two diode gates in the collector circuit of input amplifier transistors, Q1184 and Q2184. The diode gates are controlled by the state of multivibrator Q2245 and Q2255. The mode of operation of the multivibrator is determined by positive voltage applied through the MODE switch to the bases of the multivibrator transistors. See Fig. 3-9. A 0.25-μsec delay line couples the signal from the Dual Trace circuit to the oscilloscope vertical output amplifier. This delay allows the signal to phase properly with the timing unit unblanking of the crt.

In the A ONLY and A VERT. B HORIZ. modes, only transistor Q2255 conducts, and in the B ONLY mode only Q2245 conducts. In the ADDED ALGEB. mode both transistors are conducting, and in the DUAL TRACE mode, the multivibrator free runs at a switching rate of about 50 kc. Q2264 provides a dual-trace blanking signal to the oscilloscope when the multivibrator is switching.

Each of the dual trace input transistors receives its respective channel signal from the Memory or Inverter circuit through the DISPLAY switch, the VARIABLE control and the display gain control. The signal is applied to the emitter circuit, which also provides positioning voltage through the front panel POSITION control (R1180 or R2180) and through R1181 or R2181. The major emitter current path is from the +19-volt supply, through the MODE switch, SW2190, and through R1185 and R2185 to the two emitters. In the ADDED ALGEB. position of the MODE switch, current-limiting resistor R1179 (in the Type 4S1 main-frame circuitry) is inserted in the current path to keep the average voltage on the common lead the same as when only one transistor is passing signal to the output. The input transistors are connected in the common base configuration. The current at each collector is switched between two signal paths by the multivibrator, to connect or disconnect them from the common collector load, R1189. There is essentially no change in the current of either transistor whether or not it is connected to the output. The input impedance is that of the series input resistors, R1184 in Channel A, and R2182 and R2184 in Channel B. R1183 and R2183 are used to offset the input voltage to zero. The —4.5-volt output collector voltage is offset to zero by the series combination of R1191 and R1192.

During single-channel operation, with only one side of the multivibrator conducting, the conducting transistor saturates and zener diode D2251 conducts. In A ONLY operation, the +19-volt supply is connected to the base of Q2245 through R2243, cutting off the transistor. Voltage on the collector of Q2245 becomes negative, forward biasing both D2248 and D2187 and setting the voltage on the collector of Q2184 at about —11 volts. This reverse biases D2186, disconnecting Q2184 from the output and blocking passage of Channel B signal. At the same time, with Q2255 operating in saturation, its collector is held at about +0.4 volt by D2255. Both D2258 and D1187 are reverse biased by this voltage, allowing Q1184 to supply the Channel A output signal through D1186.

In the B ONLY mode, operation of the multivibrator and input transistors is just the opposite of operation in A ONLY. Q1184 is disconnected and Q2184 is passing Channel B signal to the output through D2186.

In the ADDED ALGEB. mode, neither multivibrator transistor is supplied from the +19-volt supply and both are conducting. Thus D1187 and D2187 are reverse biased, allowing both input transistors to pass signal through D1186 and D2186 to the output. The output to the delay line then is the algebraic sum of the Channel A and Channel B signals.

Operation of the Dual Trace circuit in the A VERT. B HORIZ. mode is the same as in A ONLY. The Channel B signal bypasses the Dual Trace circuitry through the MODE switch and is applied to the horizontal deflection system.

In DUAL TRACE mode positive voltage is applied to the bases of both Q2245 and Q2255 causing them to operate as a free-running multivibrator at a rate of approximately 50 kc. This causes D1186 and D2186 to pass signals alternately, providing a dual-trace display. During dual-trace operation, neither multivibrator transistor saturates, and zener diode D2251 does not conduct. The multivibrator switching time is determined by C2251 in series with the emitter return resistor of the nonconducting side (R2240 or R2250). The collector-to-base coupling circuits (R2246-C2246 and R2256-C2256) are for high-frequency coupling to assure fast switching, and do not set the switching time.

Blanking transistor Q2264 normally rests in cutoff with its base at about +0.8 volt. As the multivibrator switches, C2240 or C2250 couples about a —2-volt signal to the base of Q2264, turning it on. The pulse lasts only about 0.5 μsec, but this is long enough to saturate Q2264. Storage time of the blanking transistor is about 1 μsec to 1.5 μsec and is consistent for a particular instrument, so that the crt will be properly blanked during the time that the dual-trace multivibrator is switching channels.

NOTES

SECTION 4
MAINTENANCE

PREVENTIVE MAINTENANCE

Recalibration

The Type 4S1 Dual Trace Sampling Unit will not require frequent recalibration. However, to insure that the unit is operating properly at all times we suggest that you check the calibration after each 500-hour period of operation, or every six months if used only intermittently. A complete step-by-step procedure for calibrating the unit and checking its operation is included in the Calibration section of this manual.

The accuracy of measurements made with the Type 4S1 depends not only on the calibration of the Type 4S1, but also on the calibration of the associated oscilloscope and timing unit. The entire system must be well calibrated for proper operation.

If, during the operation of the Type 4S1, the instrument appears to be functioning poorly, the difficulty may be due to improper calibration of some part of the system, or to a malfunction resulting from improper operation or component failure. Check the calibration of the instruments before trouble-shooting the Type 4S1.

Visual Inspection

Certain types of trouble can be found by a visual inspection of the unit. For this reason, a complete visual check should be made each time the instrument is repaired or recalibrated. Look for such apparent defects as loose or broken connections, damaged connectors, improperly seated tubes or transistors, scorched parts and broken terminal strips. Corrective measures for most of these troubles are obvious, except in the case of heat damage. Quite often heat damage is the result of other less apparent trouble. It is essential that the cause of the overheating, as well as the apparent damage, be corrected before attempting to operate the unit. Otherwise the damage may be repeated.

REMOVAL AND REPLACEMENT OF PARTS

General

Procedures required for replacement of most parts in the Type 4S1 are simple and straightforward. The following paragraphs contain information that may be helpful when replacing some of the parts that are more difficult to remove, or require special care. It will be necessary to recalibrate portions of the instrument after replacing certain parts. Refer to the Calibration section of this manual for the procedures required.

Many components in the Type 4S1 are mounted in a particular position to reduce stray inductance and capacitance. Therefore, carefully install replacement components to duplicate lead length, lead dress, and location of the original component.

Removal of Subchassis Circuit Boards

CAUTION

BE SURE THE OSCILLOSCOPE POWER IS TURNED OFF WHENEVER REMOVING OR REPLACING PLUG-IN UNITS OR SUBCHASSIS.

Most of the circuitry of the Type 4S1 is located on subchassis circuit boards. Each subchassis has a 22-contact connector that mates with a connector jack in the main frame. Maintenance is made easier by the use of special extension cables that permit the Type 4S1 to be operated outside the oscilloscope, and by a special subchassis extender. These extensions are listed under Recommended Equipment in the Calibration section.

To remove any subchassis circuit board (except the Sampler) from the Type 4S1, first press down on the two levers located on the frame at the sides of the subchassis. The levers apply lifting pressure to the guides and are intended only to assist in removal of the subchassis units. Carefully lift the subchassis out of the frame. The Sampler circuit board is removed in the same manner, except that the two delay line connectors and the coax mini-connector from the timing unit fast ramp must be disconnected first.

CAUTION

Do not install any subchassis in any location other than the one in which the Series number on the subchassis matches the number on the main frame. (See caution in the Calibration section.) Fig. 4-1 shows the numbering system of the plug-in subchassis.

Installing one of the subchassis units in the frame of the Type 4S1 requires careful mating of the interconnecting plug on the subchassis with the connector jack in the frame. To replace a subchassis, insert it into the proper location in the frame and line up the connectors. The plastic guide pins at the sides of the interconnecting plug must mate with the holes in the frame beside the connector. When properly aligned, press the subchassis firmly in place. After replacing the Sampler, the delay and fast ramp cables must also be re-connected.

Removal of Trigger Amplifier

Most of the components in the Trigger Amplifier can be reached by merely removing the subchassis plug-in units. However, to work on some of the components in the Trigger Amplifier, the Trigger Takeoff, or inside the front panel, it is necessary to remove the Trigger Amplifier sub-assembly from the main frame of the Type 4S1. To remove this assembly, first remove the front three or four plug-in subchassis as described above. Disconnect the delay lines and the trigger-takeoff mini-coax from the Trigger Amplifier. Take

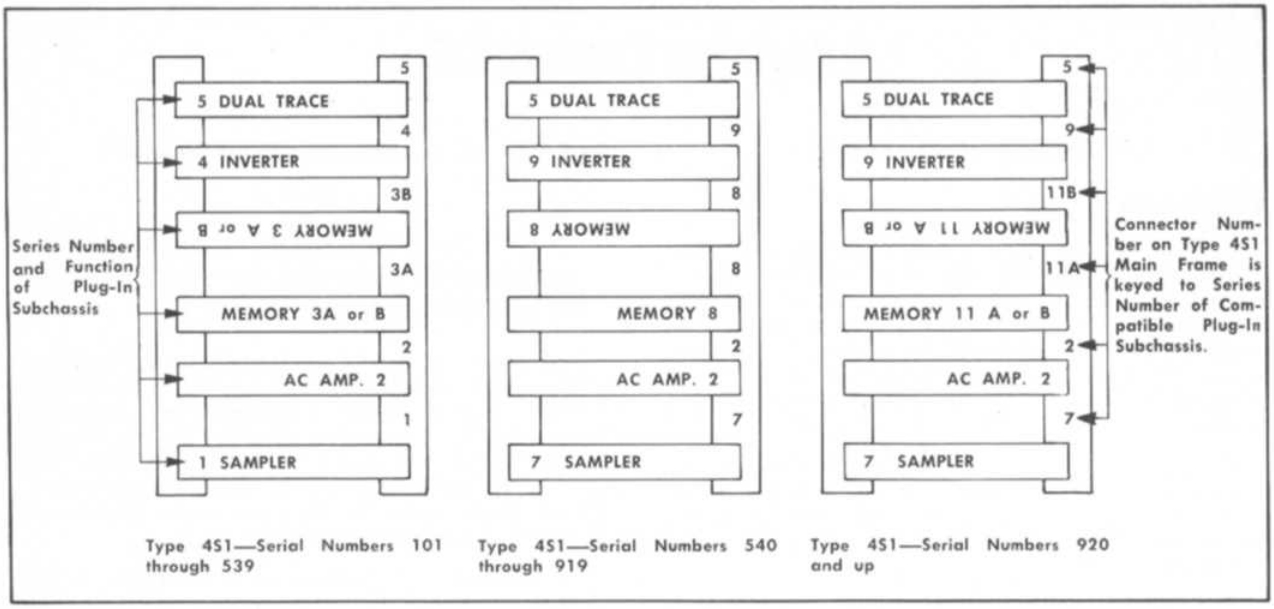


Fig. 4-1. Plug-In Subchassis Keying System.

out the screw near the top of the Trigger Amp chassis (see Fig. 4-2). Remove the knobs from the front-panel AC-DC and TRIGGERING switches, and unscrew the knurled nuts holding the two INPUT connectors to the front panel. The Trigger Amplifier assembly will then be disconnected from the frame of the Type 4S1, except for the three power leads. These leads may be unsoldered if necessary.

Reverse the above procedure to replace the chassis after repair has been completed. The knurled nuts on the INPUT connectors must be tight for proper ground of the connectors. Be sure to re-connect all coax cables and properly align the index dots on the TRIGGERING and AC-DC knobs.

Replacement of Trigger Amplifier Transistors

In order to replace any of the transistors in the Trigger Amplifier circuit, the Trigger Amplifier assembly must first be removed from the Type 4S1 as described previously.

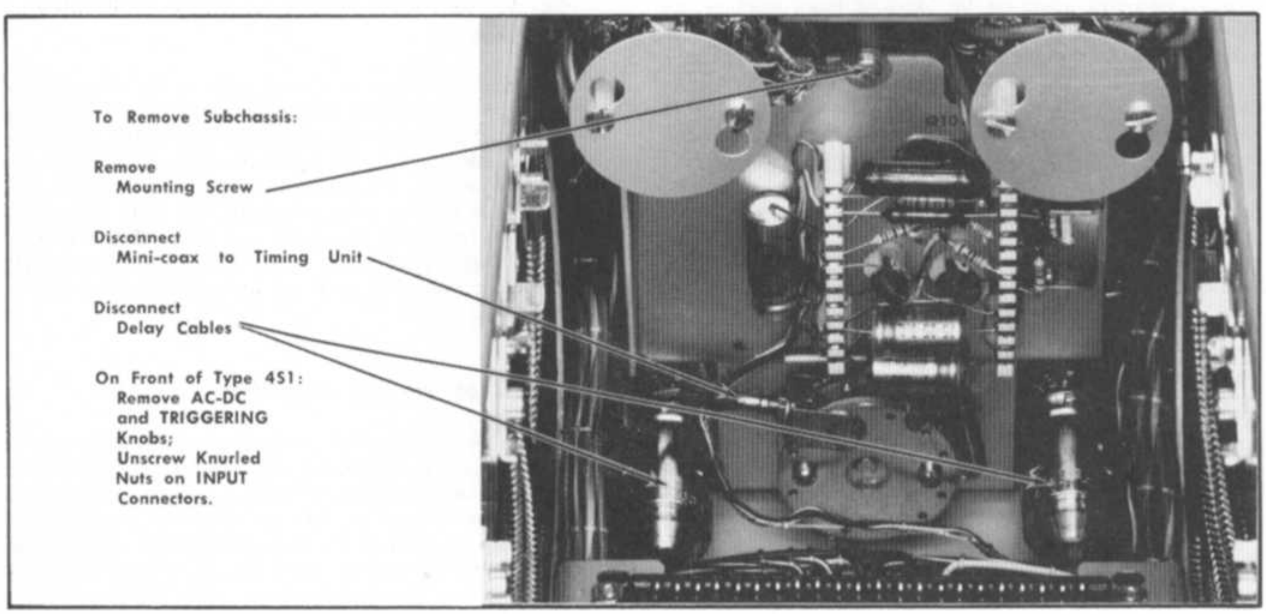


Fig. 4-2. Removal of Trigger Amplifier Assembly

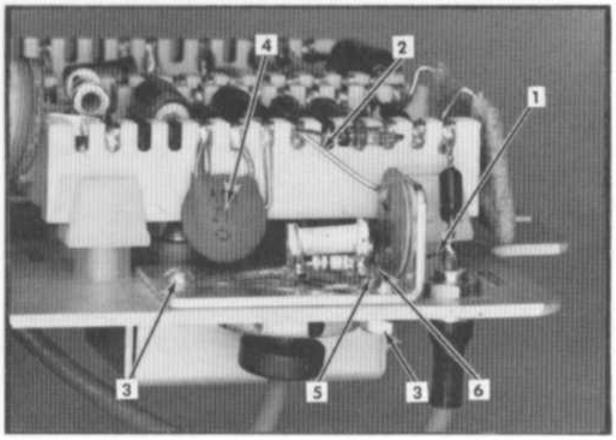


Fig 4-3. (Instruments S/N 101-1349.) Removal sequence for replacement of Q1014. See Text for procedure.

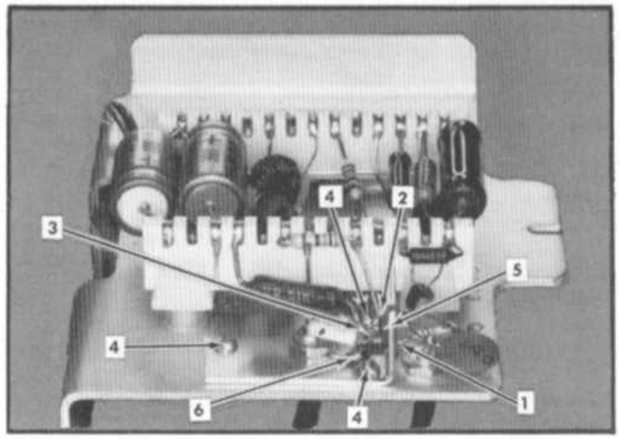


Fig. 4-4. (Instruments S/N 1350-up.) Removal sequence for replacement of Q1024. See text for procedure.

Instruments S/N 101-1349. Q1023 and Q1024 are socket-mounted under a shield on the Trigger Amplifier assembly. They may be replaced by direct substitution after removal of the shield.

Q1014, the high-frequency trigger amplifier transistor, is soldered in place for best performance and, therefore, must be disconnected from associated components before removal. The following procedure is suggested (refer to Fig. 4-3). Use a small soldering iron (about 30 watts) and be sure to heat-shunt the leads with a pair of needle-nose pliers.

1. Unsolder the collector from the junction of inductor L1015 and the output coax.

2. Unsolder the lead to capacitor C1018 at the ceramic strip notch.

3. Remove the 3 screws and nuts holding the capacitor-mounting plate to the assembly.

4. Bend capacitor C1023 up out of the way. It should now be possible to remove the plate and transistor from the Trigger Amplifier assembly without disconnecting the coax.

5. Unsolder the emitter lead and swing C1014 and R1014 out of the way.

6. Unsolder the base connection from capacitor C1018, freeing the transistor.

7. Cut the leads of the new transistor to the same lengths as those of the one just removed, then install the new transistor by reversing the removal procedure.

8. When finished, be sure that none of the transistor leads touch the mounting plate or the assembly subchassis.

Instruments S/N 1350-Up. Q1013 is socket-mounted under a shield on the Trigger Amplifier assembly. It may be replaced by direct substitution after removal of the shield.

Q1024, the trigger amplifier output transistor, is soldered in place for best high-frequency performance. The following procedure is suggested for replacement of Q1024 (refer to Fig. 4-4). Use a small soldering iron (about 30 watts), and be sure to heat-shunt the leads with a pair of needle-nose pliers.

1. Unsolder the collector lead from resistor R1023.

2. Unsolder the bus-wire lead from the ceramic strip at the point where it connects to C1013.

3. Unsolder R1021, C1022 and R1022 from the emitter. R1021 should also be unsoldered from the junction of C1022 and R1022 in this operation. Bend the free end of R1021 upward slightly.

4. Remove the three screws and nuts holding the capacitor-mounting plate to the assembly. Now the mounting plate may be raised slightly above the assembly without disconnecting the input coax.

5. Unsolder the base lead from C1013.

6. Unsolder the transistor shield lead from the mounting plate, freeing the transistor.

7. Cut the leads of the new transistor to the same lengths as those of the one just removed, then install the new transistor by reversing the removal procedure.

8. When finished, be sure none of the transistor leads touch the mounting plate or the assembly subchassis.

Gate Diode Replacement

The diodes in the Sampler Gates and Memory Gates are special gallium arsenide diodes manufactured by Tektronix. The sampler gate diodes occasionally cause memory dot slash, poor risetime or system noise. However, they should not be replaced unless all other possible sources of trouble have been eliminated. These diodes require close matching and affect several of the critical characteristics of the system.

Each diode has a colored dot on the cathode end. The color of the dot identifies its use in the instrument, as indicated in the following table:

Table 4-1. Gallium Arsenide Diodes

Dot Color	Circuit Number	Tektronix Part No.
Yellow	D1044, D1045, D2044, D2045	152-085*
Orange	D1046, D1047, D2046, D2047	152-084*
Red	D1130, D1131 (2 each)	152-083

***Supplied by Tektronix in matched pairs.**

The circuit number and polarity of each diode is shown on the schematic diagram. For the sampling gates this information is also marked on the subchassis near the diode mounting assembly.

If it is necessary to remove or replace any of the gallium arsenide diodes, use a pair of tweezers or a tweezer-type tool. Do not solder the diodes into their clips.

Replacement of Switches

Only a normal amount of care is required for the removal of a defective switch. When a switch is removed, the leads should be identified as they are detached in order to assure connecting the new switch properly. If one section of a wafer switch is defective, the entire switch should be replaced. Wafers are not normally replaced separately. Some switches may be ordered from Tektronix either with associated components wired in place, or unwired. Check the Parts List for the appropriate part numbers.

Soldering Precautions

In the production of Tektronix instruments, a silver-bearing solder is used to establish a bond with the ceramic terminal strips. This bond may be broken by the application of too much heat or by the repeated use of ordinary 40-60 tin-lead solder. However, occasional use of ordinary solder is permisible. For general repair work on Tektronix instruments, solder containing about 3% silver should be used. Silver-bearing solder is available locally from electronics distributors, or may be purchased through your Tektronix Field Office (Tektronix part number 251-514).

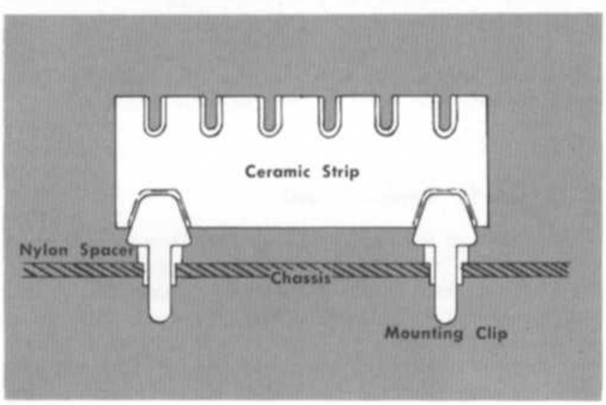


Fig. 4-5. The Assembled Ceramic Strip.

Because of the shape of the terminal notches in the ceramic strips, it is advisable to use a wedge-shaped tip on your soldering iron when installing or removing parts. A wedge-shaped tip permits the application of heat directly to the solder in the terminals and reduces the amount of heat required. It is important to use as little heat as possible. A 50-watt iron is adequate.

The proper technique for soldering and unsoldering short-lead components requires: (1) the use of needle-nose pliers to act as a heat shunt between the soldering point and the component; (2) the use of a hot iron for a short time; and (3) careful manipulation to avoid damage to small components. Use only enough solder to make a good bond.

Ceramic Strip Replacement

To replace a damaged ceramic terminal strip, first unsolder all connections, then remove the mounting clips and nylon spacers from the chassis. This may be done by prying the mounting clips, attached to the strip, out of the chassis. If the spacers do not come out with the clips, they can be left in the chassis or pulled out separately. If they are not damaged, the spacers may be used with the new ceramic strip assembly. Replacement strips are supplied with mounting clips already attached, so it is not necessary to salvage the old clips.

When the damaged strip and clip assembly have been removed, place the spacers into the mounting holes in the chassis and press the mounting clips of the new strip assembly into the spacers. It may be necessary to tap lightly or apply some pressure to the ceramic strip to make the clips seat down on the spacers. To avoid damage to the terminal strip, use a soft-tipped tool for any tapping, and apply force only to the part of the strip directly above the mounting clips. Fig 4-5 shows the assembled terminal strip. Cut off any excess length of the clips extending beyond the end of the spacers on the reverse side of the chassis. Re-solder all components and wires in place, as they were previously arranged. (Note soldering precautions given above.)

Checking Tubes and Semiconductors

Commercial testers are not recommended for checking the tubes and transistors used in the Type 4S1. Tube testers often fail to indicate defects that affect the performance of the circuits, or they may indicate a tube to be defective when it is operating satisfactorily in the circuit. The same applies to similar tests made on transistors. If a tube or transistor is operating properly in the circuit, it should not be replaced. Unnecessary replacement may require that the instrument be needlessly recalibrated.

Direct substitution is usually the best means of checking a tube or transistor. A characteristic curve display instrument, such as a Tektronix Type 570 or 575, may also be useful in checking a tube or transistor that is suspected of being defective.

Often a transistor or diode can be checked for an open or shorted condition merely by making an ohmmeter check between terminals. Measure the dc resistance first in one direction, then the other, and note the effect of polarity reversal.

CAUTION

Use of high-resisance scales of the ohmmeter should be avoided, because the internal voltage source of the ohmmeter can damage the semiconductor being checked.

Before installing a new component, be sure that the circuit voltages applied to it are normal. If replacement is made without checking out the circuit, the new component may be damaged by some defect in the circuit.

REPLACEMENT PARTS

Replacements for all parts used in the Type 4S1 can be purchased directly from Tektronix at current net prices. However, many of the electrical components can be obtained locally in less time. Before ordering or purchasing parts, be sure to consult the parts list to determine the tolerances and ratings required. Most mechanical parts and certain selected or specially manufactured components should be ordered directly from Tektronix since they are not available from other sources.

All parts can be ordered through the local Tektronix Field Office. When ordering parts be sure to include: (1) the complete description of the part as given in the parts list; (2) the type of instrument (Type 4S1); and (3) the Serial Number of your instrument. Some parts may have been superseded by improved components since the production of your instrument. In such cases, the new part may be shipped in place of the part ordered.

Plug-in subchassis are available as complete units from Tektronix. Be sure to state the subchassis Series number which is marked on the frame of the Type 4S1 right next to the subchassis connector. See Fig. 4-1.

TROUBLESHOOTING

General Information

The Type 4S1 derives all of its operating voltages from the oscilloscope, and operates with the oscilloscope and the timing unit to produce the display. Therefore, if trouble develops, determine which unit in the system is causing the trouble before proceding further. If more than one instrument is available, a quick check for isolating the trouble to a particular unit can be made by trying different combinations of the oscilloscopes, sampling units and timing units.

If trouble occurs in the Type 4S1, try to isolate it by quick operational and visual checks. First check the settings of all controls, then operate the controls to see what effect, if any, they have on the trouble symptoms. The normal or abnormal operation of each control may help locate the trouble. Many apparent troubles are caused by the improper setting of one or more controls, or by improper calibration of the unit. One of the first steps should be to check the calibration of the suspected circuit. The type of trouble will generally indicate what further checks to make. The cause of a trouble that occurs only in certain positions of a control can usually be determined immediately from the symptoms.

A display that may appear as trouble to someone not familiar with the sampling process can occur if triggering information stops arriving from the timing unit. In the crt display each dot is the result of a sample, after a pulse from the timing unit has been received by the Sampler. If the information stops, sampling stops immediately, even if the sweep has not been completed. The spot remains on the crt, but starts drifting up or down and finally goes out of sight. This is normal, and is not to be confused with trouble in the Type 4S1. It is caused by the Memory drifting slowly, without repeated correction. If the timing information should begin again, the dots will begin again and the interrupted trace will be completed.

In general, a troubleshooting procedure consists of two parts: circuit isolation and circuit troubleshooting. Since the Type 4S1 is a complex instrument, it will probably be necessary to read the circuit description in conjunction with a study of the schematics, to determine the location of the source of trouble. Knowing the functions of the various circuits and controls, the operational checks will usually isolate the trouble to a particular circuit. Then, after the circuit causing the trouble has been established, detailed troubleshooting procedures can be performed.

Circuit Tracing

For the purpose of circuit tracing, the wires in the Type 4S1 are all color-coded. Most power leads are coded with colored tracers indicating significant figures of the voltage, using the same color-code as is used for composition resistors. The widest tracer represents the first figure of the voltage. Tracers on signal leads are for identification only.

Where the circuit diagram shows more than one section to a wafer switch, each section is coded to indicate its position on the switch. Wafers are numbered from the front panel to the rear of the switch. The letters F and R indicate whether the front or rear of the wafer is used to perform the particular switching function. For example, the code designation 3R means the rear side of the third wafer.

Circuit Isolation

In general, the easiest way to determine if a trouble is in one of the plug-in subchassis units is to substitute other plug-in subchassis that are known to be in good operating condition, and check the operation of the Type 4S1. Although the instrument would not be in perfect calibration, it would be operable. The two Memory circuits can be interchanged temporarily if one is suspected of being defective. Replacement subchassis are available through your local Tektronix Field Office.

CAUTION

SUBSTITUTE ONLY SUBCHASSIS WITH THE SAME SERIES NUMBERS. See Fig. 4-1.

After isolating the trouble, return all plug-in subchassis to their original locations, to avoid unnecessary recalibration.

If no other plug-in subchassis are available, the circuitry may be checked with a test oscilloscope and voltmeter for voltages and waveforms into and out of the various circuits. The trouble may be isolated to a particular subchassis by placing the oscilloscope (with the Type 4S1 installed) on its side, removing the bottom cover and checking the waveforms at the interconnecting jacks. However, to locate the trouble on a particular subchassis, the Type 4S1 will have to be operated out of the oscilloscope, as in the Calibration procedure, and the various subchassis extended on the plug-in extension. All subchassis except the Sampler can be operated normally on the subchassis extension board.

If one of the channels of the Type 4S1 has no trace but the other channel operates, or if there is a trace but no signal passes through one channel, the trouble is much easier to locate than if no trace is present. With one channel in operation, comparison can be made between the two channels. In some instances, it may be sufficient to free run the timing unit and trace the sample pulses through the circuitry. In other cases, it will be necessary to apply a known signal to the two channels in parallel, and trace the signal through the instrument.

NOTE

If any of the loop gain controls (SNAP-OFF CURRENT, BRIDGE VOLTS, BRIDGE BAL., or MEMORY GATE WIDTH) have been adjusted since the trouble developed, the two channels will not respond identically to an input signal. A malfunction occurring in one of the circuits making up the feedback loop (Sampler Amplifier, AC Amplifier, Memory Gate, Memory, and DC Offset) will probably also be indicated throughout the loop. It could even cause the loop to cease functioning. Because of this, it may be helpful to ground the feedback of the particular Memory (terminal E on the Memory connector), or at the feedback input to the Sampler. Refer to the Plug-In Connectors and Switching schematic diagram for the subchassis input and output terminals.

If free-running the timing unit does not appear to be satisfactory for tracing the trouble, try operating the unit in a triggered mode while applying a 1 volt, 1 μsec/cycle sinewave from the oscilloscope calibrator. Set the MILLIVOLTS/CM switch to 200, and the timing unit sweep rate to about 1 μsec/cm. To view the sampled signal, the test oscilloscope sweep rate will have to be set much slower than the equivalent-time rate indicated on the Type 4S1. The test oscilloscope may be triggered externally (Ext.—) with pulses from the Delayed Pulse generator in the Type 661 Oscilloscope.

Component Failure

Most troubles in the Type 4S1 are caused by tube or semi-conductor failure, due to normal aging and use. Therefore, when trouble has been isolated to a particular circuit, the tubes and semiconductors in that circuit should be checked first. Be sure that all tubes and transistors are returned to their original sockets if they are found to be good.

Another common cause of trouble is misuse or improper operation. That is, the system has been subjected to excessive loads or has been damaged by careless operational or maintenance procedures. Be sure to observe the given limits of input voltage, etc., when operating the unit. Also be careful when checking inside the instrument with meter leads or probe tips. Careless shorting of leads can cause abnormal voltages or transients to be applied to the semiconductors, and can result in the destruction of the components.

SECTION 5
CALIBRATION

GENERAL INFORMATION

A complete procedure is provided in this section for checking the operation and calibration of the Type 4S1, and for making adjustments where necessary. These checks will assure the operator that the instrument is operating within specification limits. The steps of the procedure are arranged in convenient sequence to avoid unnecessary repetition.

The step-by-step instructions also furnish an orderly approach to the isolation of malfunctions that may develop, and provide information to aid in troubleshooting and repairing the instrument.

Test equipment used in a particular step should remain connected at the end of that step unless the instructions state otherwise. Similarly, controls not mentioned are to remain in the positions previously used.

Do not preset internal controls unless the instrument has been repaired or is known to be seriously out of adjustment. If repairs have been made, preset internal controls to mid-range in the affected circuits.

PRECAUTIONS

The following precautions should be observed whenever calibrating, operating or troubleshooting the Type 4S1.

1. DO NOT INSERT OR REMOVE THE TYPE 4S1 PLUG-IN UNIT, OR CONNECT OR DISCONNECT THE PLUG-IN EXTENSION POWER CABLE WHILE THE OSCILLOSCOPE POWER IS ON. When connecting the plug-in power cable, be sure to connect both ends to power connectors, and not one end to a readout connector. The power connector is the one nearest the center of the oscilloscope. Incorrect installation of the cable can damage the instruments.

2. DO NOT REMOVE OR INSTALL PLUG-IN SUB-CHASSIS WHILE THE OSCILLOSCOPE POWER IS ON.

3. INSTALL ONLY SUBCHASSIS WITH CORRECT SERIES NUMBERS. Each subchassis has a Series number marked on it, and each connector in the frame of the Type 4S1 has a number beside it indicating the Series of subchassis designed to operate in that position. All other Series should be considered incompatible. Each Series also has various Model Numbers, which indicate that minor changes have been made in the circuitry. All subchassis with the same Series number, regardless of Model number, are electrically interchangeable in the main frame of any Type 4S1 having that Series number by the subchassis connector. See the subchassis arrangement diagram in the Maintenance section of this manual.

4. WHEN REPLACING THE AC AMPLIFIER SHIELD, BE SURE IT DOES NOT TOUCH ANY OF THE COMPONENTS.

RECOMMENDED EQUIPMENT

The following items of equipment (or equivalents) are required for the calibration of the Type 4S1:

1. One oscilloscope, Tektronix Type 661, with '5'- Series timing plug-in unit.

2. One test oscilloscope, Tektronix 530-or 540-Series, with Type L vertical plug-in unit and 10X attenuator probe, dc to at least 15 Mc.

3. One square-wave generator, Tektronix Type 105.

4. One pulse generator, Tektronix Type 109.

5. One pretrigger pulse generator, Tektronix Type 111.

6. One volt-ohmmeter, with sensitivity to at least 20,000 ohm/volt.

7. Insulated adjustment tools.

For each of the following accessory items, the Tektronix part number is given in parentheses after the description of the item:

8. One flexible plug-in extension cable (012-064).

9. Two 50-ohm 3-ft. coaxial cables with Gremar connectors (012-070).

10. One 22-pin plug-in subchassis extension board (012-069).

11. One 2X T attenuator with 50-ohm GR connectors (017-003).

12. One 5X T attenuator with 50-ohm GR connectors (017-002).

13. Two 10X T attenuators with 50-ohm GR connectors (017-001).

14. One tee connector with 50-ohm GR connectors (017-069).

15. One connector adapter, 50-ohm GR to UHF jack (017-022).

16. Two 5-nsec coaxial cables with 50-ohm GR connectors (017-502).

17. One 10-nsec coaxial cable with 50-ohm GR connectors (017-501).

PROCEDURE

1. Check Circuit Resistances

This check is required only after failure or repair of the instrument. Perform the check with all subchassis installed, but before connecting the Type 4S1 to the oscilloscope. Attach the common lead of the voltmeter to the chassis of the Type 4S1 and check at the interconnecting plug terminals for the approximate resistance values indicated in Table 5-2.

Table 5-2
Resistances at Interconnecting Plugs

Terminal	P 1. Power Plug (Channel B side)	P 2. Readout Plug (Channel A side)
1	∞	∞
2	∞	∞
3	9-15 Ω	10 k
4	∞	∞
5	1.5 k	∞
6	∞	2 M
7	0	∞
8	∞	∞
9	0	∞
10	10 k	∞
11	10 k	∞
12	0	8-11 k
13	∞	∞
14	∞	0
15	15 k	∞
16	∞	∞
17	3 k	∞
18	300-500 Ω	2 M
19	∞	∞
20	∞	∞
21	10-50 M	∞
22	∞	∞
23	∞	10 k
24	3.5 k	∞

(∞ indicates infinite resistance)

2. Preset Front-Panel Controls

Connect the Type 4S1 to the Type 661 Oscilloscope with the cables listed above (equipment items 8 and 9). See Fig. 5-1. No cable is required for the readout connector. Extend the AC Amplifier subchassis from the Type 4S1 with the 22-pin plug-in extension, and remove the AC Amplifier shield. Install the 10X probe on the test oscilloscope. Switch on the power of the Type 661 and the other test instruments and allow them to warm up for a few minutes. Do not connect an input signal to the Type 4S1.

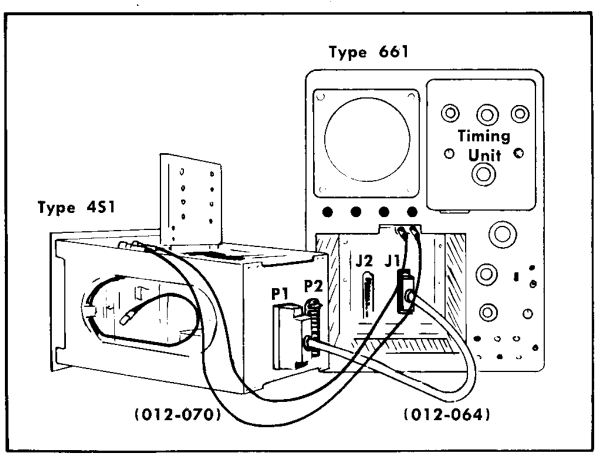


Fig. 5-1. Connections for operating the Type 4S1 outside the oscilloscope during calibration.

Set front-panel controls as follows:

Type 4S1

VERT. POSITION (both channels)	Centered
MILLIVOLTS/CM (both channels)	200
VARIABLE (both channels)	CALIBRATED
DISPLAY (both channels)	NORMAL
SMOOTHING (both channels)	NORMAL
MODE	DUAL TRACE
TRIGGERING	A
AC-DC	AC

Type 661

Horizontal Display	X1
Position and Vernier	Centered
Amplitude/Time Calibrator	Off

Timing Unit

Samples/Cm	100
Time Position (Delay)	Clockwise on Type 5T1A (Minimum)
Source	Internal +
Recovery Time	Minimum
Threshold	Between — and 0
Sweep Mode	Normal (Repetitive)
Sweep Rate	10 nsec/cm, calibrated
Time Expander	X1

Test Oscilloscope

Sweep rate	10 μsec/cm, calibrated
Input deflection factor	.05 volts/cm, calibrated
Input coupling	DC
Triggering	AC, Internal +
Stability	Clockwise (freerun)

3. Adjust Smoothing Balance

Locate the two traces on the crt screen with the DC OFFSET controls for the two channels.

Adjust the Channel A SMOOTHING (MEMORY) BALANCE control, R1125, on the front Memory subchassis, so that the crt trace does not shift when the Channel A SMOOTHING control is rotated. Display noise caused by slow rotation of the SMOOTHING control should not exceed one centimeter after the control has been rotated several times.

Perform the same adjustment on the Channel B SMOOTHING BALANCE control, R1125, located on the rear Memory subchassis, while rotating the Channel B SMOOTHING control.

Leave both SMOOTHING controls at NORMAL.

4. Set DC Offset to Zero

Center a free-running trace on the test oscilloscope, then touch the probe to the Channel A OFFSET MONITOR jack. Adjust the Channel A DC OFFSET control to again center the trace on the test scope crt.

Touch the probe tip to the Channel B OFFSET MONITOR jack and set the Channel B DC OFFSET control in the same manner.

Be careful not to bump the DC OFFSET controls after this, as they must remain at zero for step 5.

5. Adjust Bridge Balance

With the DC OFFSET controls set to zero, adjust the A BRIDGE BAL. control, R1063, located on the Sampler subchassis, for minimum vertical trace shift on the crt screen of the Type 661, while rotating the Channel A MILLIVOLTS/CM switch throughout its range. See Fig. 5-2 for the location of controls on the Sampler subchassis.

Adjust the B BRIDGE BAL. control, R2063, in the same manner, while rotating the Channel B MILLIVOLTS/CM switch. If necessary, disconnect the Gremar cable while this adjustment is made, then re-connect it.

Set both MILLIVOLTS/CM switches to 100.

6. Adjust Memory Gate Width

Set the timing unit sweep rate to 5 nsec/cm. Connect a 5-nsec 50-ohm coax from the Delayed Pulse output of the oscilloscope to the Channel A INPUT. Set the MODE switch to A ONLY. Adjust the Time Position (Delay) control to observe the pulse on the crt. While viewing the pulse, switch the Samples/Cm switch between the 5, 10 and 20 positions to observe the change in dot transient response.

Adjust the MEMORY GATE WIDTH control, R2023, on the front side of the Sampler subchassis for about 1 mm of (negative) overshoot, as seen in the display using 5, 10 and 20 samples/cm. If there is no overshoot, adjust for the squarest corner possible.

Move the input cable from Channel A to Channel B, and set the MODE switch to B ONLY. Check the adjustment of the MEMORY GATE WIDTH control, as for Channel A. If the adjustment made for Channel A is not the same as for Channel B, adjust the control on the channel having the most overshoot.

7. Adjust Snap-Off Current

With the oscilloscope Delayed Pulse connected to either input, adjust the SNAP-OFF control, R2007, on the Sampler subchassis, for no more than 1 mm of overshoot, while switching between 5, 10 and 20 samples/cm as in the previous step.

8. Adjust Bridge Volts

Set the MODE switch to A ONLY. Set the timing unit for 100 samples/cm, a sweep rate of 1 nsec/cm, and internal (+) triggering. Connect a positive output pulse from the Type 111 Pretrigger Pulse Generator to the Channel A INPUT, using a 10-nsec coax and 10X attenuation, to produce approximately $\frac{1}{2}$ volt at the input. Adjust the pulse generator for a repetition rate of approximately 15 kc. with the

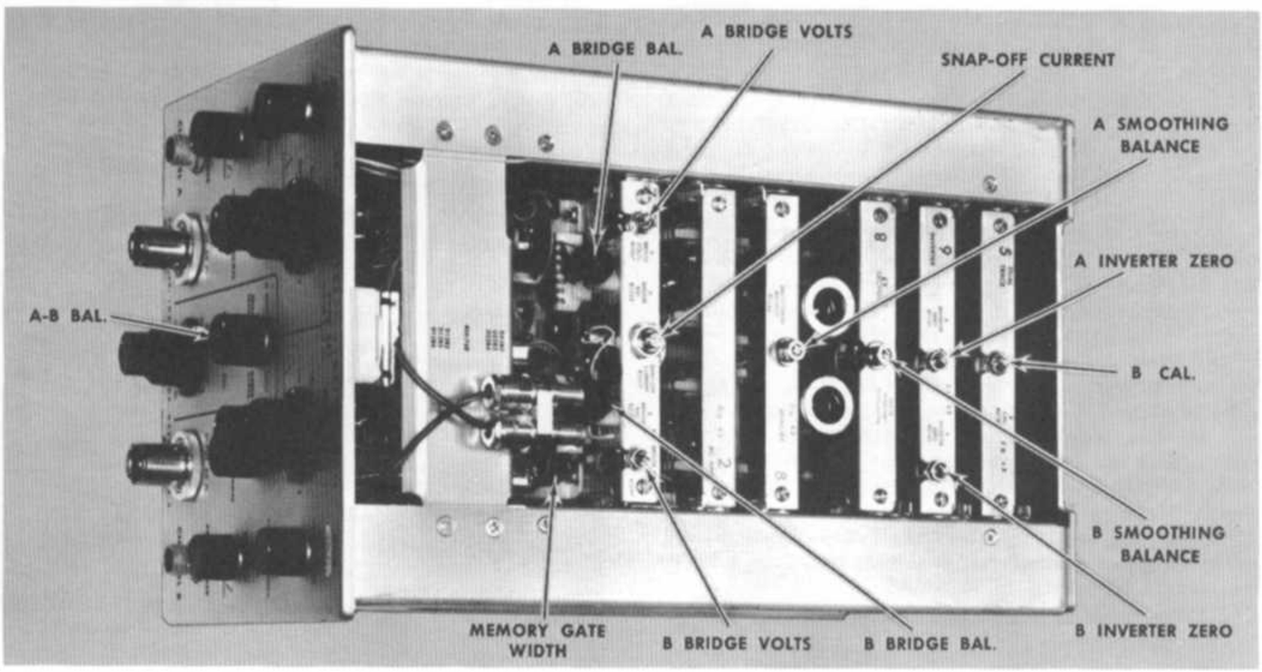


Fig. 5-2. Location of adjustments on top of Type 4S1.

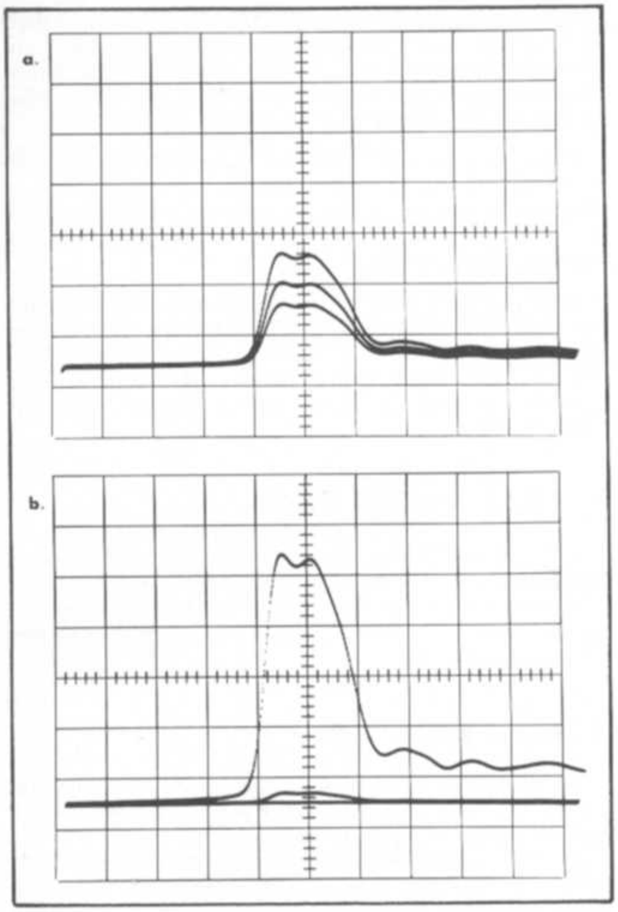


Fig. 5-3. Three-trace display for adjusting BRIDGE VOLTS control. (a) with SMOOTHING control counterclockwise; (b) with SMOOTHING at NORMAL.

test scope connected to the Pretrigger Output of the pulse generator. Set the Channel A SMOOTHING control fully counterclockwise. Trigger the display and position the pulse on the crt with the Time Position (Delay) control on the timing unit.

With the Channel A MILLIVOLTS/CM control set to 100, adjust the timing unit Threshold and Recovery Time controls for "false" (multi-trace) triggering. If necessary, reposition the pulse on the crt with the Time Position (Delay) control. Readjust the repetition rate of the pulse generator for a display of three traces such as that shown in Fig. 5-3a. Set the SMOOTHING control back to NORMAL. Adjust the variable capacitor, C1107, on the left half of the extended AC Amplifier subchassis, for maximum signal gain (top trace). Back off the capacitor about 20°. Adjust the A BRIDGE VOLTS control, R1067, located on the Sampler subchassis, for 2 mm of separation between the lower two traces (see Fig. 5-3b). Rotate the SMOOTHING control counterclockwise to check that only three traces are present, then return the control to NORMAL.

Move the pulse generator signal to the Channel B input. Set the TRIGGERING switch to B, the MODE switch to B ONLY, and perform these adjustments for Channel B. Adjust the variable capacitor, C2107, on the right half of the AC Amplifier subchassis, and the B BRIDGE VOLTS control, R2067, on the Sampler subchassis.

Remove the signal cable from the input. Set the MODE switch to DUAL TRACE, and adjust the dc offset to zero on both channels. Set the timing unit Threshold control to free run the trace. Recheck the A and B BRIDGE BAL. adjustments as in step 5.

9. Adjust Inverter Zero

Check to see that the voltage is still zero at both OFFSET MONITOR jacks. While watching the Channel A trace, switch the Channel A DISPLAY to INVERTED, then back to NORMAL. Adjust the A INVERTER ZERO control, R1161, on the Inverter subchassis for minimum trace shift when the DISPLAY switch is moved from NORMAL to INVERTED. Leave the switch in NORMAL position.

Adjust the B INVERTER ZERO control, R2161 similarly by watching the trace and switching the Channel B DISPLAY switch. Leave the switch at NORMAL.

10. Adjust Trigger Zero

Turn the Type 4S1 on its side. Be sure the extended AC Amplifier subchassis does not become disconnected. Set the AC-DC switch to DC, and set the timing unit Trigger Source switch to External. Set the test oscilloscope for maximum sensitivity, dc-coupled, and center a free-running trace. Connect the test probe to the output of the AC-DC switch on the Type 4S1, where the lead enters the coax (Fig. 5-4). Adjust the TRIG. ZERO control, R1029*, on the bottom of the Trigger Amplifier subchassis, to re-center the trace on the test oscilloscope crt.

11. (S/N 101-1349) Adjust Trigger Amplifier Response

With the test probe connected to the output of the AC-DC switch, connect the output of the Type 105 Square-

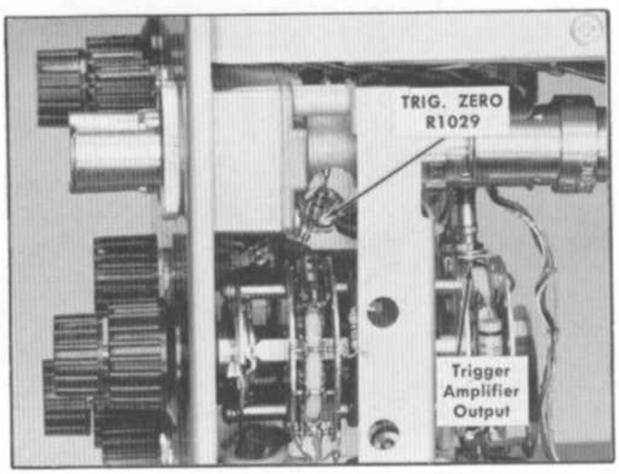


Fig. 5-4. Trigger Zero Adjustment.

***TRIG. ZERO is R1022 in instruments S/N 101-1349.**

Wave Generator, through a UHF-to-GR adapter and a 5X T attenuator, to the Channel B INPUT. Set the TRIGGERING switch to B. Adjust the square-wave generator for a frequency of 50 kc, and adjust the amplitude to produce about 75 millivolts on the screen of the test oscilloscope. Set the sweep rate of the test scope to about 10 μsec/cm, and trigger the display. Adjust C1032 and C1037, located on the bottom of the Type 4S1 Trigger Amplifier subchassis, for the best squarewave response without a large dip. The response should either be flat or have a slight hump.

Move the signal cable from Channel B to Channel A and set the TRIGGERING switch to A. Check for the same squarewave response. If there is a difference between the two channels, readjust C1032 and C1037 so that neither channel has a dip after the leading edge.

Set the AC-DC switch to AC and check for a differentiated waveform, indicating capacitive coupling. Remove the input cable.

12. Check Dual Trace Switching

Disconnect the test probe and turn the Type 4S1 upright again. Set the timing unit triggering to internal, and adjust the Threshold to free run the trace. With the MODE switch set to DUAL TRACE, position both traces on the crt screen of the Type 661. Set the test oscilloscope for a 20 μsec/cm sweep rate and .1 volt/cm deflection factor. Touch the test probe to the No. 3 terminal of the readout connector, P2, on the rear of the Type 4S1. Check the test scope display for the presence of a chopping signal of approximately 50 kc (1 cycle/cm).

13. Adjust Vertical Gain

Set the MODE switch to B ONLY, and the Channel B MILLIVOLTS/CM switch to 200. Check that the VARIABLE control is CALIBRATED and that SMOOTHING is at NORMAL. Connect the output of the Amplitude/Time Calibrator on the Type 661 to the Channel B INPUT connector. Set the timing unit for a sweep rate of about .5 μsec/cm, and internal Calibrator triggering. Set the oscilloscope Calibrator for 1000 mv and 1 μsec/cycle. Trigger the display. Adjust the B CAL. control, on the Dual Trace subchassis, for exactly 5 cm of deflection, using one edge of the trace for the measurement.

Set the oscilloscope Calibrator for 10 mv. Check the Channel B MILLIVOLTS/CM switch accuracy by observing the trace deflection with the Calibrator settings indicated in Table 5-3. Insert the attenuators in series, as needed. If necessary, readjust B CAL. slightly to bring all ranges within 4% of the indicated deflection values.

Table 5-3

Millivolts/Cm Check

Attenuator	MILLIVOLTS/ CM	Calibrator (mv)	Deflection (cm)
—	2	10	5
—	20	100	5
5X	5	100	4
5X	50	1000	4
2X	10	100	5
2X	100	1000	5

Remove the attenuator, but leave the calibrator signal connected to the input of the Type 4S1. Set the oscilloscope calibrator for 100 millivolts, and set the Channel B MILLIVOLTS/CM switch to 50, to obtain 2 cm of deflection. Rotate the VARIABLE control and check for a three-to-one range (a maximum deflection of at least 6 cm). Leave the VARIABLE control in CALIBRATED position.

Set the MODE switch to A ONLY and the Channel A MILLIVOLTS/CM switch to 200. Move the Calibrator signal to the Channel A input. Set the Calibrator for 1000 mv. Adjust the gain of Channel A with the front-panel A-B BAL. screw-driver adjustment for exactly 5 cm of display. Set the Calibrator for 10 mv amplitude. Check the Channel A MILLIVOLTS/CM switch and the VARIABLE control, as was done for Channel B.

Disconnect the input cable. Turn off the power switch of the oscilloscope, and disconnect the extension cables. Remove the AC Amplifier subchassis extender, replace the AC Amplifier shield, and insert this subchassis in the Type 4S1. Install the Type 4S1 in the Type 661 Oscilloscope. Turn on the power and allow a few minutes warm-up.

14. Check Noise and Microphonics

Set both MILLIVOLTS/CM switches to 2. Set the timing unit for a sweep rate of .2 μsec/cm and internal triggering. Adjust the Threshold control to free run the sweep. Check for less than 1 mv of system noise on the trace. Strike the front panel of the Type 4S1 lightly with the side of your hand, while observing crt trace. There should be less than 3 cm deflection due to microphonics.

Set the MODE switch to B ONLY and check for noise and microphonics in Channel B.

15. Check X-Y (Lissajous) Operation

Set both MILLIVOLTS/CM switches to 20, and the MODE switch to A VERT. B. HORIZ. Connect the output of the oscilloscope calibrator through a tee connector and two equal length coax cables to the INPUT connectors of the Type 4S1. Set the timing unit for Calibrator triggering, and a sweep rate of 5 nsec/cm. Set the Calibrator for 100 mv and .01 μsec/cycle. Trigger and center the display, and check for less than 2 mm of noise on the X-Y display.

16. Check Rejection Ratio

Disconnect the tee connector from the Calibrator output, and re-connect it through 5X attenuation to the output of the Type 105 Square-Wave Generator. Set the MODE switch to A ONLY and both MILLIVOLTS/CM switches to 100. Adjust the frequency of the Type 105 to 1 Mc. Set the timing unit for a sweep rate of .2 μsec/cm and (+) internal triggering. Trigger the display and adjust the output amplitude of the Type 105 to produce 5 cm of signal (½-volt) on the crt of the Type 661 Oscilloscope. Set the Channel A DC OFFSET control so the display excursion does not change when the DISPLAY switch is moved from NORMAL to INVERTED. Switch the MODE switch to B ONLY and adjust the Channel B DC OFFSET control for no trace shift while switching the

DISPLAY from NORMAL to INVERTED. Set both MILLIVOLTS/CM switches to 50 and the MODE switch to ADDED ALGEB. Place one of the DISPLAY switches in the INVERTED position. Check the trace for no more than 3 mm of deflection. Move both DISPLAY switches to the opposite positions and repeat the check. Return the DISPLAY switches to NORMAL.

17. Check Added Algebraic

Disconnect the tee connector from the Type 105 and reconnect it through 10X attenuation to the pulse output of the Type 111 Pretrigger Pulse Generator. Set the pulse generator for a short 1-volt positive output pulse. Set the timing unit for a sweep rate of 2 nsec/cm. Set both MILLIVOLTS/CM switches to 200 and the MODE switch to DUAL TRACE. Adjust the repetition rate of the Type 111 to about 90 kc and trigger the display. Locate the pulse waveforms with the Time Position (Delay) and VERT. POSITION controls.

Note the pulse amplitude of the two traces. Switch to ADDED ALGEB. and check the amplitude for twice the single-channel amplitude.

18. Check Memory Dot Slash

Set the MODE switch to A ONLY. Set the sweep rate to 5 nsec/cm. With a triggered display of the Type 111 output pulse on the crt, rotate the Time Position (Delay) control to move the pulse off the screen. Set the timing unit Samples/CM switch to 5. Set the test oscilloscope for a sweep rate of 2 msec/cm and a deflection factor of .1 volt/cm. Reduce the repetition rate of the pulse generator to about 50 cps by touching the probe tip to the Pretrigger Pulse Output of the Type 111, and adjusting the pulse repetition rate to display 1 pulse at each ~~and~~ of the graticule on the test scope display. Check the display on the Type 661 Oscilloscope for less than 2 mm of vertical slash of the display dots.

Set the MODE switch for B ONLY and check the trace for memory dot slash.

19. Check Delay Between Channels

Reset the repetition rate of the pulse generator to about 90 kc. Remove the cables and tee connector. Connect the Type 111 pulse output to the Channel A INPUT connector through 10X attenuation (2X and 5X stacked). Connect the pretrigger pulse output of the pulse generator to the External Trigger Input on the timing unit, through 100X attenuation. Set the timing unit for 100 samples/cm and external (+) triggering. Set the MODE switch to DUAL TRACE. Trigger the display and position the pulse on the crt with the Time Difference control of the Type 111 and the Time Position (Delay) control of the timing unit. With the Channel A VARIABLE control, adjust the pulse amplitude for an 8 cm display. Center the display between the upper and lower graticule lines.

Move the input signal to the Channel B input, and adjust the Channel B VARIABLE control for an 8 cm display, centered vertically on the graticule.

Magnify or expand the sweep rate by a factor of 20, to give a sweep rate of 100 psec/cm. Re-center the waveform with the Time Position (Delay) control so that the rising portion of the pulse is positioned exactly on the graticule vertical centerline. Move the input cable from Channel B to Channel A. Check for less than 3 mm (30 psec) of time difference between channels.

Switch the sweep magnification back to 1X.

20. Check Scaling Drift

Remove the pulse signal form the input. Set the timing unit for 5 samples/cm. Set both MILLIVOLTS/CM switches to 10, both VARIABLE controls to CALIBRATED, and the MODE switch to A ONLY. With the display externally triggered, position the trace on the graticule centerline. Decrease the repetition rate of the Type 111 from 100 kc to 50 cps and check to see that the trace has not shifted vertically more than ~~3 mm~~ 1 cm.

Set the MODE switch to B ONLY. Center the trace and check Channel B for scaling drift, by increasing the pulse repetition rate from 50 cps to 100 kc.

21. Check Internal Triggering

Set the repetition rate of the Type 111 to about 50 kc Remove the external trigger cable from the timing unit, and connect the pulse output of the Type 111 through 100X attenuation to the Channel A INPUT connector. Set the timing unit for internal (+) triggering, and 100 samples/cm. Set the MILLIVOLTS/CM switches of both channels to 20, the MODE switch to A ONLY, and TRIGGERING to A. Trigger the display. Position the pulse on the crt with the Time Position (Delay) control, and check for stable internal positive triggering. Switch the polarity of the pulse generator to (—) and the timing unit to (—) triggering. Retrigger the display and check for stable internal negative triggering.

Set the MODE switch to B ONLY and the TRIGGERING switch to B. Move the input cable to Channel B. Check for stable internal triggering, both positive and negative.

22. Check Offset Compression

Remove the cable from the Type 111. Connect the Channel A INPUT connector to the pulse output of a Type 109 pulse Generator, through a 5-nsec coax. Connect a 10-nsec charge line between the charge line connectors of the Type 109. Set the MODE switch to A ONLY, the TRIGGERING switch to A, and the MILLIVOLTS/CM switches to 200. Set the timing unit for a sweep rate of 5 nsec/cm, and turn the trigger delay control to zero. Trigger the unit on internal (+).

Adjust the output amplitude of the pulse generator to display an 8 cm pulse. Check for no more than 3% overshoot or rolloff on the leading corner. Turn the Channel A VERT. POSITION control fully counterclockwise, then re-center the display on the crt screen with the DC OFFSET control. Check for 8 cm of signal. Set the DISPLAY switch to INVERTED, turn the VERT. POSITION control fully clockwise, and re-center the display with the DC OFFSET control. Check for 8 cm of signal. Switch the pulse polarity to (—) and the triggering polarity to (—). Re-trigger the display, turn the VERT. POSITION control fully counterclockwise and re-center the display with the DC OFFSET control. Check for 8 cm of signal. Set the DISPLAY switch to NORMAL and turn the VERT. POSITION fully clockwise. Re-center the display with the DC OFFSET control and check for 8 cm of signal.

Move the input cable to Channel B, switch the MODE switch to B ONLY, the TRIGGERING switch to B, and check Channel B offset compression and overshoot.

After completing the step, leave both DISPLAY switches at NORMAL position.

23. Check Crosstalk

Set the pulse generator polarity to (+) and the triggering polarity to (+). Remove the charge line from the pulse generator. With the pulse applied to the Channel B input, trigger the display and observe the short pulse. Set the MILLIVOLTS/CM switch to 50 and adjust the amplitude of the Type 109 output to produce 8 cm of deflection on the crt (400 mv). Switch both MILLIVOLTS/CM switches to 2. Set the MODE switch to A ONLY. Position the display with the Channel A positioning controls, and check for less than 3 cm of crosstalk signal.

Move the input cable to Channel A, set the TRIGGERING switch to A, and the MODE switch to B ONLY. Position the trace on the crt and check for less than 3 cm of crosstalk signal.

24. Check Risetime

Switch the MILLIVOLTS/CM switches to 100. Remove the signal cable from the pulse generator and connect the output of the oscilloscope Delayed Pulse generator to the Channel A INPUT connector. Set both DISPLAY switches to INVERTED, and the MODE switch to A ONLY. Set the timing unit for a sweep rate of 2 nsec/cm. Adjust the Threshold control for free run operation. Adjust the Time Position (Delay) control to display the rising portion of the waveform. Expand or magnify the sweep rate by a factor of 20 to produce a sweep rate of .1 nsec/cm. Center the display on the graticule. With the VARIABLE control, adjust the display amplitude for exactly 8 cm of deflection. Check the 10% to 90% risetime of the system for .35 nsec or less (see Fig. 5-5).

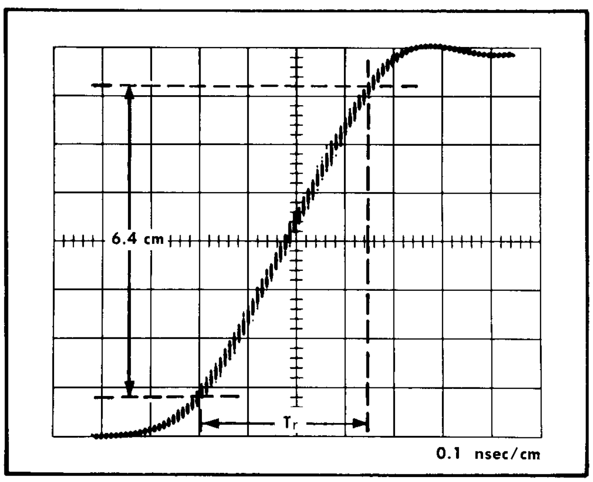


Fig. 5-5. Measuring risetime of the system.

NOTE

If a Type 661 Oscilloscope with Serial Number 269 or less is used, and if the Delayed Pulse generator has not been modified (Replacement Kit 050-072), the display risetime should be .38 to .39 nsec. If a Type 661 with Serial Number 270 or above is used, or if the Delayed Pulse generator has been modified, the display risetime should be .35 nsec or less.

Switch the MODE switch to B ONLY. Move the Delayed Pulse signal to the Channel B input. Adjust the pulse amplitude with the Channel B VARIABLE control to 8 cm and check the risetime of Channel B.

Remove the signal cable and return the magnification to X1.

25. Check DC Offset

Set both MILLIVOLTS/CM switches to 200. Set the test oscilloscope for a deflection factor of .05, dc-coupled at the input. Free run the test scope. Touch the test probe to the Vertical A Signal Output connector on the Type 661 Oscilloscope and check for a voltage swing of ±1 volt as the DC OFFSET control is rotated throughout its range. Move the test probe to the Channel B Vertical Output connector and check the DC OFFSET range for Channel B.

26. Check Offset Monitor

Switch the test oscilloscope deflection factor to 5 volts/cm. Touch the test probe to the Channel A OFFSET MONITOR jack. Rotate the DC OFFSET control through its range and check for a voltage swing of ±100 volts. Move the test probe to the Channel B OFFSET MONITOR jack and check the OFFSET MONITOR range for Channel B.

27. Check Probe Power

With a dc voltmeter, check between pins A and D (top two) of the Channel A PROBE POWER jack for approximately 100 volts. Check for approximately 12.6 volts between pins B and C (bottom two).

Repeat this check for the Channel B PROBE POWER jack.

NOTES

SECTION 6

PARTS LIST and DIAGRAMS

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix Field Office.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number including any suffix, instrument type, serial number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix Field Office will contact you concerning any change in part number.

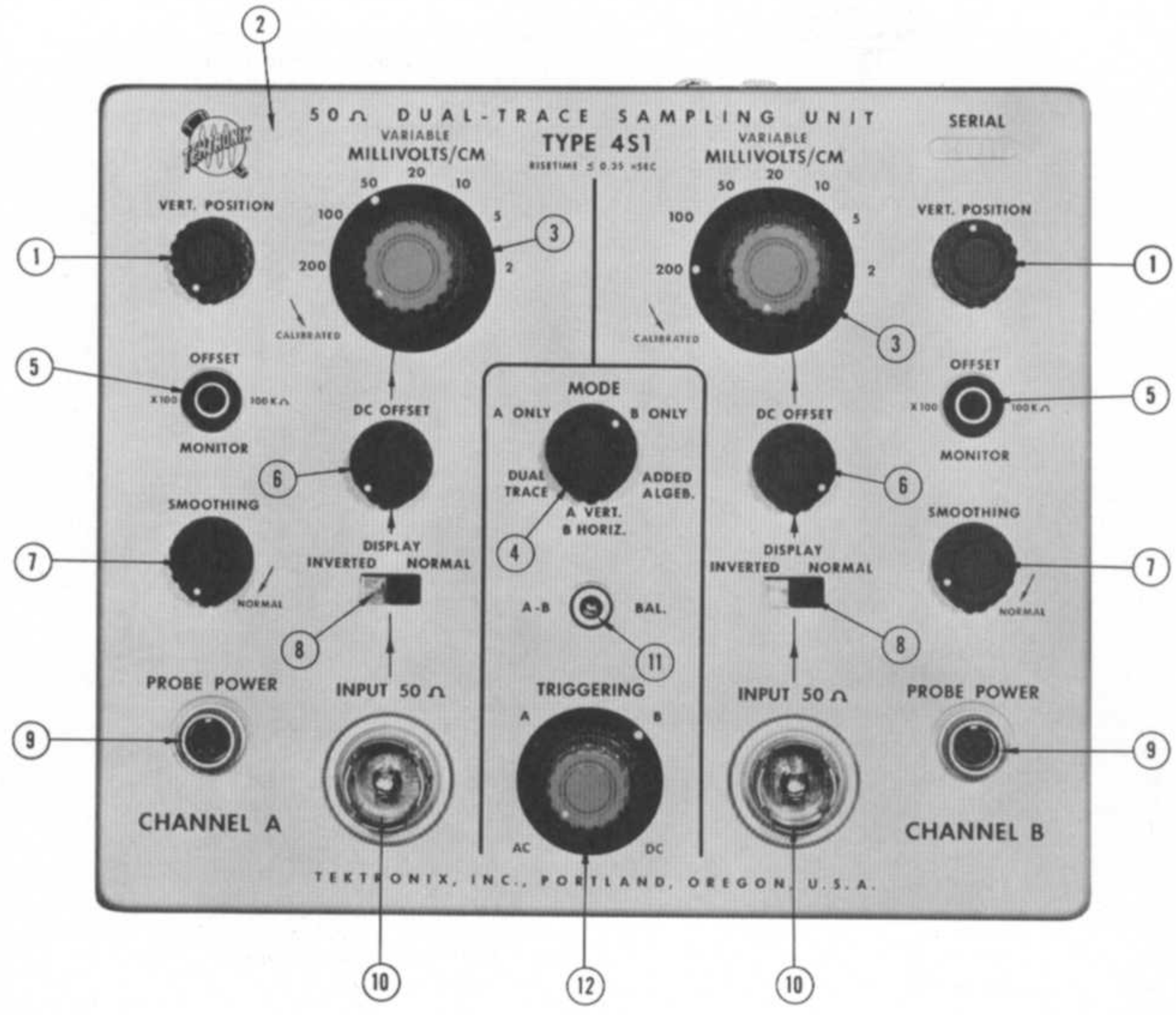
ABBREVIATIONS AND SYMBOLS

a or amp	amperes
BHS	binding head steel
C	carbon
cer	ceramic
cm	centimeter
comp	composition
cps	cycles per second
crt	cathode-ray tube
CSK	counter sunk
dia	diameter
div	division
EMC	electrolytic, metal cased
EMT	electroyltic, metal tubular
ext	external
f	farad
F & I	focus and intensity
FHS	flat head steel
Fil HS	fillister head steel
g or G	giga, or 10^{9}
Ge	germanium
GMV	guaranteed minimum value
h	henry
hex	hexagonal
HHS	hex head steel
HSS	hex socket steel
HV	high voltage
ID	inside diameter
incd	incandescent
int	internal
k or K	kilohms or kilo (10^{3})
kc	kilocycle
m	milli, or 10^{-3}
mc	megacycle
mm	millimeter
meg or M	megohms or mega (10^{6})
met.	metal
μ	micro, or 10^{-6}
n	nano, or 10^{-9}
Ω	ohm
OD	outside diameter
OHS	oval head steel
p	pico, or 10^{-12}
PHS	pan head steel
piv	peak inverse voltage
plstc	plastic
PMC	paper, metal cased
poly	polystyrene
Prec	precision
PT	paper tubular
PTM	paper or plastic, tubular, molded
RHS	round head steel
rms	root mean square
sec	second
Si	silicon
S/N	serial number
t or T	tera, or 10^{12}
TD	toroid
THS	truss head steel
tub.	tubular
v or V	volt
Var	variable
w	watt
w/	with
w/o	without
WW	wire-wound

SPECIAL NOTES AND SYMBOLS

X000	Part first added at this serial number.
000X	Part removed after this serial number.
*000-000	Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, or reworked or checked components.
Use 000-000	Part number indicated is direct replacement.
	Internal screwdriver adjustment.
	Front-panel adjustment or connector.

FRONT


50 Ω DUAL-TRACE SAMPLING UNIT
TYPE 4S1
SERIAL
VARIABLE
MILLIVOLTS/CM
VERT. POSITION
CALIBRATED
OFFSET
X100
100 K Ω
MONITOR
DC OFFSET
MODE
A ONLY
B ONLY
DUAL TRACE
ADDED ALGEB.
A VERT. B HORIZ.
SMOOTHING
NORMAL
DISPLAY
INVERTED
NORMAL
A-B
BAL.
PROBE POWER
INPUT 50 Ω
TRIGGERING
A
B
AC
DC
CHANNEL A
CHANNEL B
TEKTRONIX, INC., PORTLAND, OREGON, U.S.A.
1
2
3
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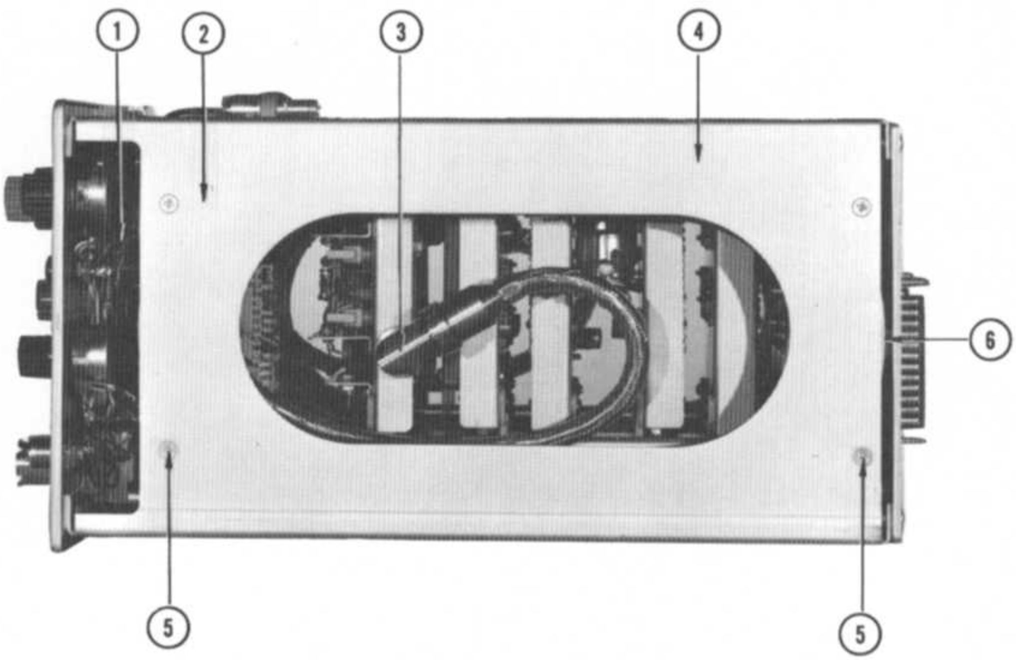
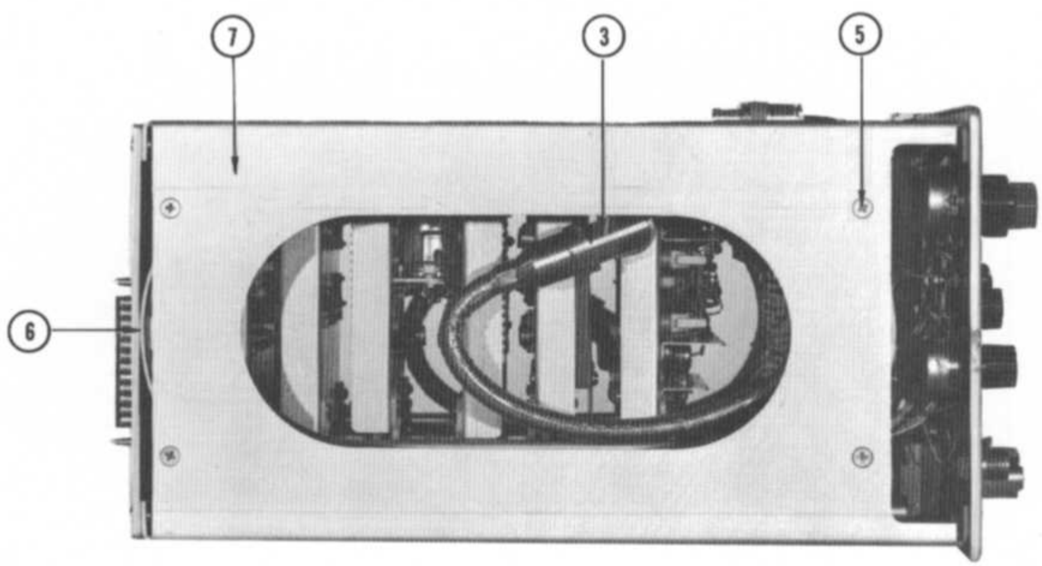
5
6
7
8
9
10
11
12

FRONT

REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
1	366-148			2	KNOB, charcoal, VERT. POSITION
	210-413			2	NUT, hex, 3/8-32 x 1/2
	210-840			2	WASHER, .390 ID x 9/16 OD
	210-013			2	LOCKWASHER, int, 3/8 x 11/16
2	333-689			1	PANEL, front
	004-149			1	COVER, panel, plastic
	387-613			1	PLATE, front subpanel
3	366-160			2	KNOB, large charcoal, MILLIVOLTS/CM
	366-038			2	KNOB, red, VARIABLE
4	366-113			1	KNOB, charcoal, MODE
	210-413			1	NUT, hex, 3/8-32 x 1/2
	210-840			1	WASHER, .390 ID x 9/16 OD
5	136-052			2	SOCKET, banana jack
	210-895			2	WASHER, insulating
	210-223			2	LUG, solder, 1/4
	210-465			4	NUT, hex 1/4-32 x 3/8
6	366-148			2	KNOB, charcoal, DC OFFSET
	210-413			2	NUT, hex, 3/8-32 x 1/2
	210-840			2	WASHER, .390 ID x 9/16 OD
	210-207			2	LUG, solder, pot, plain, 3/8
	210-012			2	LOCKWASHER, int, 3/8 x 1/2
	200-263			2	COVER, pot
7	366-148			2	KNOB, charcoal, SMOOTHING
	210-413			2	NUT, hex, 3/8-32 x 1/2
	210-840			2	WASHER, .390 ID x 9/16 OD
	210-207			2	LUG, solder, pot, plain, 3/8
	210-012			2	LOCKWASHER, int, 3/8 x 1/2
8	210-406			4	NUT, hex, 4-40 x 3/16 (slide switch mtg.)
9	131-206			2	CONNECTOR, probe power
	210-941			2	WASHER, 11/16 OD x .448 ID
	210-559			2	NUT, hex, 7/16-28
10	132-002			2	SLEEVE, conductor, outer
	132-007			2	RING, snap
	132-028			2	INSULATOR
	132-029			2	CONDUCTOR, inner
	132-093			2	NUT, panel mount
	132-094			2	NUT, retaining
11	358-054			1	BUSHING, banana jack
	210-471			1	NUT, hex, 1/4-32 x 5/16
12	366-142			1	KNOB, charcoal, TRIGGERING
	366-031			2	WASHER, red, AC-DC
	210-865			2	WASHER, fiber, 3/8 ID x 5/8 OD

RIGHT SIDE—LEFT SIDE

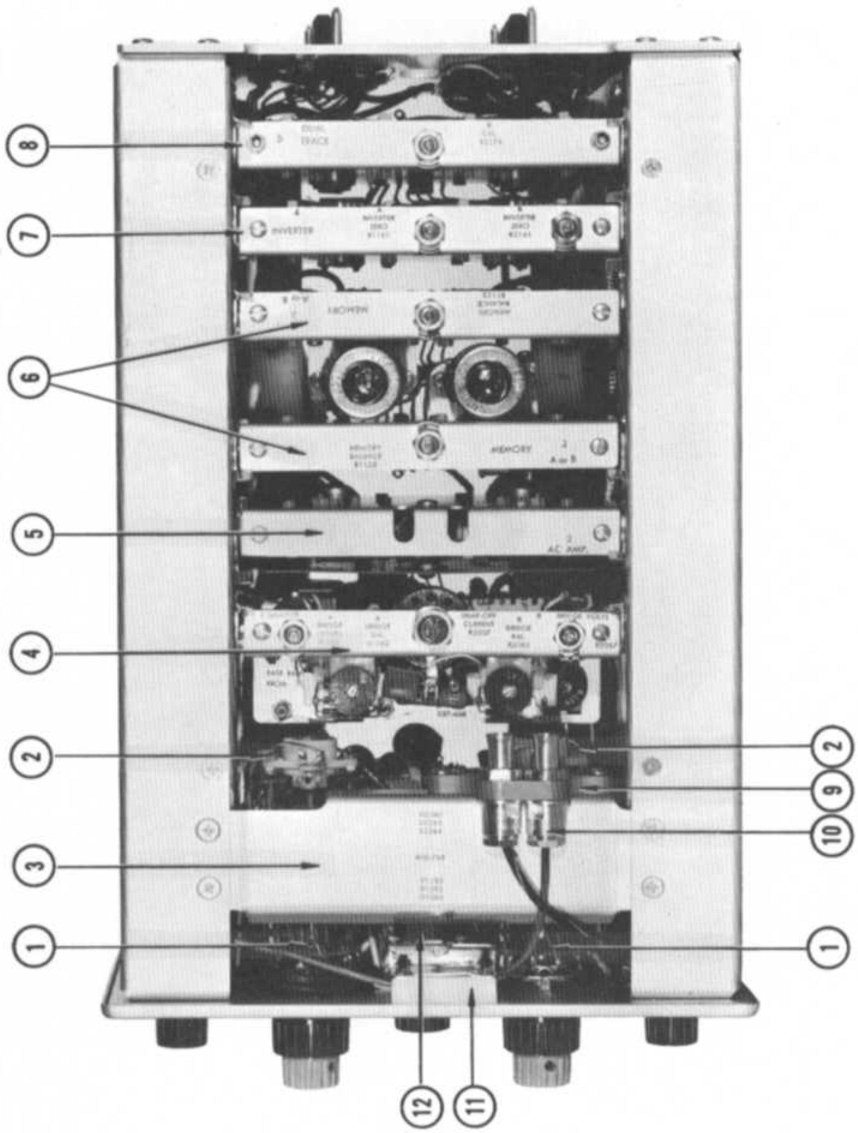




RIGHT SIDE—LEFT SIDE

REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
1	179-624	101	539	1	CABLE, harness, trigger output #1
	179-744	540		1	CABLE, harness, trigger output #1
2	636-002			1	ASSEMBLY, Delaay Line (1 matched pair)
	- - - - -			-	Includes:
3	132-001			6	COUPLING, nut
	132-002			2	SLEEVE, conductor, outer
	132-007			6	RING, snap
	132-028			6	INSULATOR
	132-029			2	CONDUCTOR, inner
	132-030			4	TRANSITION, inner
	132-031			2	TRANSITION, outer
	132-033			4	FERRULE
	132-044			2	ELBOW, outer
	132-092			2	CONDUCTOR, center, elbow
	132-096			2	CONNECTOR, outer transition
	132-097			2	CONNECTOR, outer conductor
	355-068			4	STUD, 8-32 x 11/16 inch
	358-088	101	279	2	BUSHING, rod
	358-201	280		2	BUSHING, rod
4	426-146			1	FRAME, side rail, right
	387-626	101	539	1	PLATE, right, assembly (not shown)
	387-763	540	919	1	PLATE, right, assembly (not shown)
	387-842	920		1	PLATE, right, assembly (not shown)
	- - - - -			-	Mounting Hardware: (not included)
	213-107			4	SCREW, thread forming, 4-40 x 1/4 FHS phillips slot
5	211-559			8	SCREW, 6-32 x 3/8 inch FHS 100° phillips slot
	384-594			8	ROD, spacer
	211-510			8	SCERW, 6-32 x 3/8 inch BHS
6	105-039			4	DRUMLINER, delay line
	387-614			8	PLATE, delay line shim
	344-076			6	CLIP, delay line
7	426-147			1	FRAME, side rail, left
	387-627			1	PLATE, left, assembly (not shown)
	- - - - -			-	Mounting Hardware: (not included)
	213-107			4	SCREW, thread forming, 4-40 x 1/4 FHS phillips slot
	- - - - -			-	Mounting Hardware For Assembly: (not included)
	211-559			8	SCREW, 6-32 x 3/8 inch FHS 100° phillips slot
	211-510			8	SCREW, 6-32 x 3/8 inch BHS

TOP



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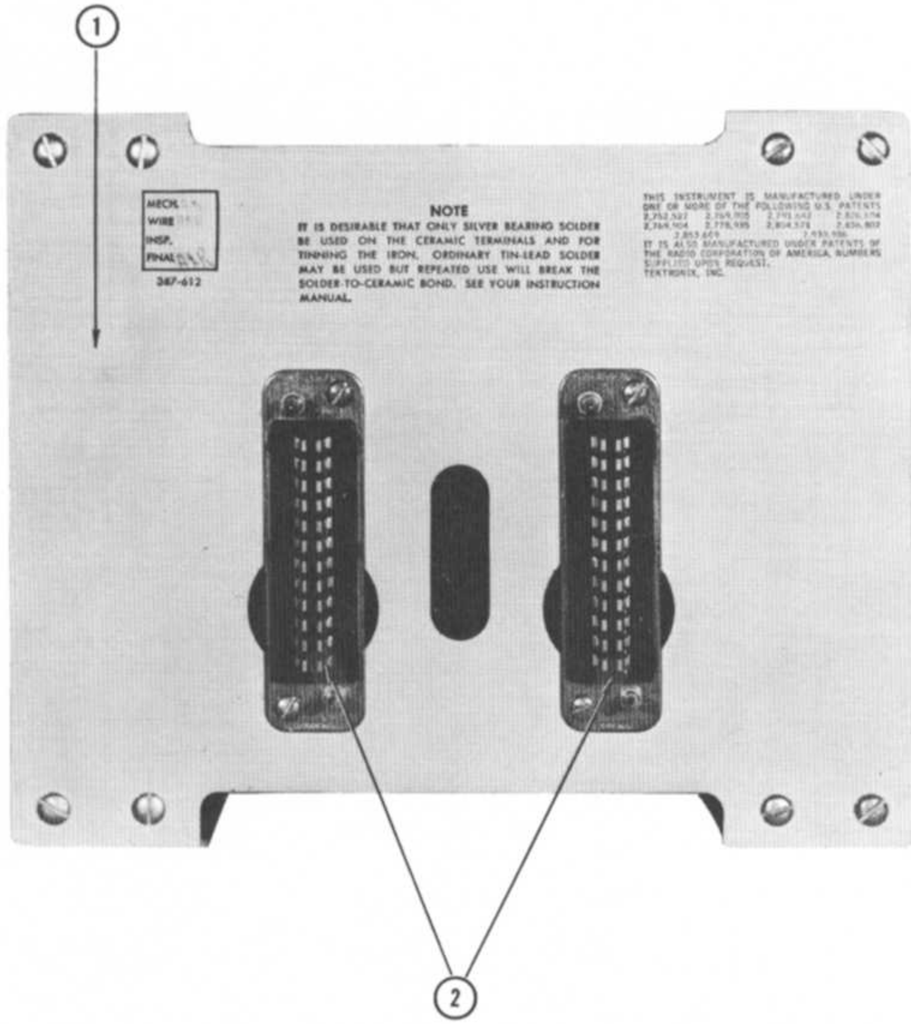
TOP

REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
1	262-468	101	539	2	SWITCH, MILLIVOLTS/CM, wired
	262-551	540		2	SWITCH, MILLIVOLTS/CM, wired
					Each Includes:
	260-434			1	SWITCH, MILLIVOLTS, unwired
2	210-406	101	313	2	NUT, hex, 4-40 x 3/16
	316-041	314		2	SPACER, hex
	211-007	314		2	SCREW, 4-40 x 3/16 BHS
	337-554	314		2	SHIELD, switch
					Mounting Hardware For Each Switch: (not included)
	210-413			1	NUT, hex, 3/8-32 x 1/2
	210-012			1	LOCKWASHER, int, 3/8 x 1/2
3	406-769			1	BRACKET, 50 Ω connector
					Mounting Hardware: (not included)
	211-559			4	SCERW, 6-32 x 3/8 FHS 100° phillips slot
4	605-006	101	539	1	ASSEMBLY, Sampler Plug-in Chassis
	605-011	540		1	ASSEMBLY, Sampler Plug-in Chassis
5	605-002			1	ASSEMBLY, A.C. Amplifier Plug-in Chassis
6	605-005	101	539	2	ASSEMBLY, Memory Plug-in Chassis
	605-010	540		2	ASSEMBLY, Memory Plug-in Chassis
7	605-003	101	539	1	ASSEMBLY, Inverter Plug-in Chassis
	605-009	540		1	ASSEMBLY, Inverter Plug-in Chassis
8	605-004			1	ASSEMBLY, Dual Trace Plug-in Chassis
9	426-152			1	MOUNT, 50 Ω line connector
					Mounting Hardware: (not included)
	211-511			2	SCREW, 6-32 x 1/2 BHS
	210-006			2	LOCKWASHER, int. #6
	210-407			2	NUT, hex, 6-32 x 1/4
10	131-221			2	CONNECTOR, push on bulkhead jack
	358-172			2	BUSHING, rod
	131-155			2	CONNECTOR, coaxial, miniature (not shown)
11	214-222			1	SPRING, striker
	361-029			1	SPACER, latch spring
					Mounting Hardware: (not included)
	211-082			2	SCREW, 4-40 x 3/4 FHS socket head
	210-004			2	LOCKWASHER, int. #4
	210-406			2	NUT, hex, 4-40 x 3/16
12	406-781			1	BRACKET, diode
					Mounting Hardware: (not included)
	211-538			2	SCREW, 6-32 x 5/16 FHS 100° phillips slot
	210-006			2	LOCKWASHER, int. #6
	210-407			2	NUT, hex, 6-32 x 1/4
	124-149			2	STRIP, ceramic, 7/16 x 7 notches
·	361-007			4	SPACER, nylon, molded

REAR



REF. NO.	PART NO	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
1	387-612			1	PLATE, rear
2	131-149			2	CONNECTOR, chassis mt., 24 contact, male
					Mounting Hardware For Each: (not included)
	211-008			2	SCREW, 4-40 x 1/4 BHS
	210-004			1	LOCKWASHER, int. #4
	210-201			1	LUG, solder, SE 4
	210-406			2	NUT, hex, 4-40 x 3/16

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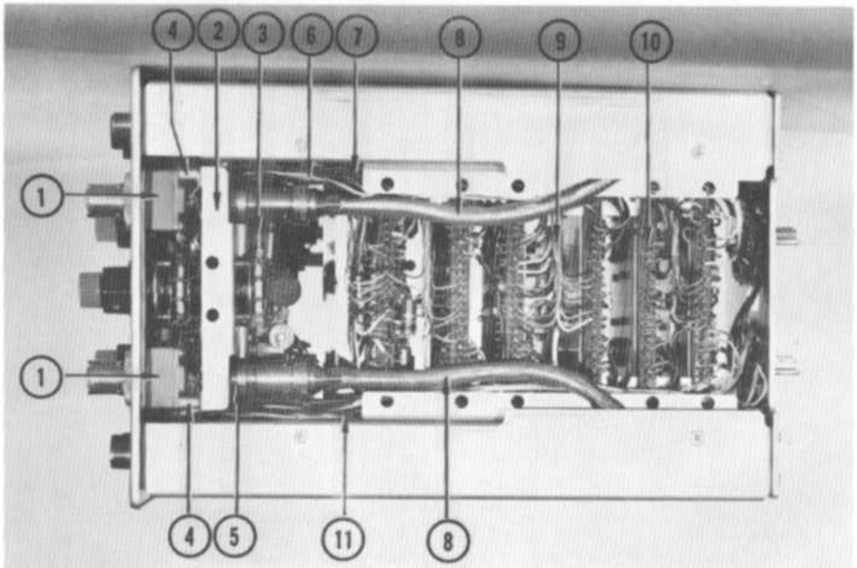
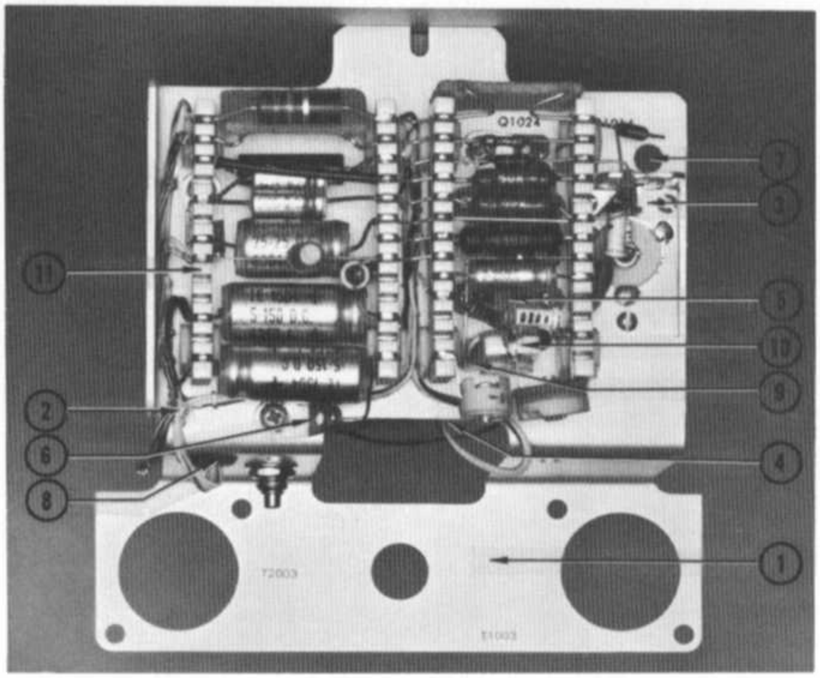
BOTTOM



REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
1	380-036			2	HOUSING, trigger take-off
	200-370			2	COVER, trigger take-off
					Mounting Hardware For Each: (not included)
	211-507			3	SCREW, 6-32 x $^5/_{16}$ BHS
	210-227			1	LUG, solder, SE 6
2	262-470			1	SWITCH, TRIGGER, wired
					Includes:
	260-436			1	SWITCH, TRIGGERING, unwired
3	131-156			1	CONNECTOR, coaxial, miniature, chassis mt.
	344-071			1	CLIP, coaxial
					Mounting Hardware For Switch: (not included)
4	211-514			2	SCREW, 6-32 x $^3/_4$ BHS
	210-202			2	LUG, solder, SE 6
	166-033			2	TUBE, spacer
	211-008			2	SCREW, 4-40 x $^1/_4$ BHS
	210-851			2	WASHER, .119 ID x $^3/_8$ OD
5	132-001			2	COUPLING, nut
	132-002			2	SLEEVE, conductor, outer
	132-007			2	RING, snap
	132-028			2	INSULATOR
	132-029			2	CONDUCTOR, inner
	358-088	101	659	4	BUSHING, resistor holding
	358-201	660		4	BUSHING, resistor holding
	131-211			2	CONNECTOR, conductor center trigger
6	179-623	101	539	1	CABLE harness, trigger take-off
	179-743	540		1	CABLE, harness, trigger input
7	179-625			1	CABLE harness, trigger output #2
8					Subpart of Delay Line Assembly
9	179-631			1	CABLE harness, power supply
10	131-220			6	CONNECTOR, 22 contact, female
					Mounting Hardware For Each: (not included)
	211-578			2	SCREW, 6-32 x $^7/_{16}$ PHS phillips slot
	210-006			2	LOCKWASHER, int. #6
	210-407			2	NUT, hex, 6-32 x $^1/_4$
11	179-632			1	CABLE harness, digital readout

TRIGGER CHASSIS



REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	Q T Y.	DESCRIPTION
1	441-420			1	CHASSIS, trigger take-off
					Mounting Hardware: (not included)
	211-507			2	SCREW, 6-32 x $^{5}/_{16}$ BHS
	211-014			1	SCREW, 4-40 x $^{1}/_{2}$ BHS
	384-541			1	ROD, spacing
	210-851			1	WASHER, .119 ID x $^{3}/_{8}$ OD
	211-038			1	SCREW, 4-40 x $^{5}/_{16}$ FHS phillips slot
2	179-630			1	CABLE harness, trigger
3	406-762			1	BRACKET, trigger capacitor
					Mounting Hardware: (not included)
	211-022			3	SCREW, 2-56 x $^{3}/_{16}$ RHS
	210-001			3	LOCKWASHER, int. #2
	210-405			3	NUT, hex, 2-56 x $^{3}/_{16}$
4	385-080			1	ROD, hex (not shown)
					Mounting Hardware: (not included)
	211-507			1	SCREW, 6-32 x $^{5}/_{16}$ BHS
	200-376			1	COVER, transistor (not shown)
					Mounting Hardware: (not included)
	211-507			1	SCREW, 6-32 x $^{5}/_{16}$ BHS
5	136-095			2	SOCKET, 4 pin transistor
					Mounting Hardware For Each: (not included)
	213-113			2	SCREW, 2-32 x $^{5}/_{16}$ RHS phillips slot
6	210-201			3	LUG, solder, SE 4
	213-044			3	SCREW, thread cutting, 5-32 x $^{3}/_{16}$ PHS phillips slot
7	131-208			1	CONNECTOR, cable termination (not shown)
8	348-003			1	GROMMET, rubber, $^{5}/_{16}$
9	348-031			1	GROMMET, poly. snap-in
10	124-118			1	STRIP, ceramic, $^{7}/_{16}$ x 1 notch
	361-008			1	SPACER, nylon, molded
11	124-147			4	STRIP, ceramic, $^{7}/_{16}$ x 13 notches
	361-008			8	SPACER, nylon, molded

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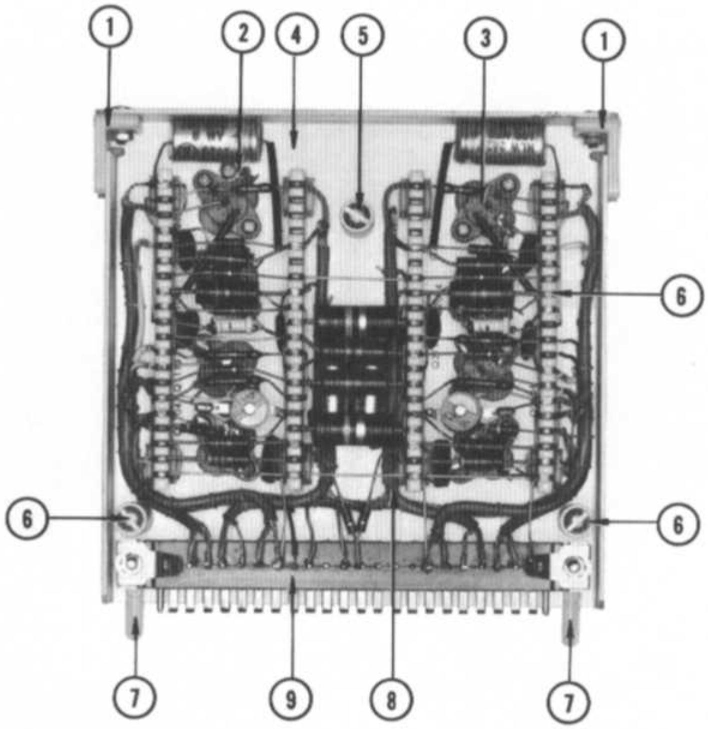
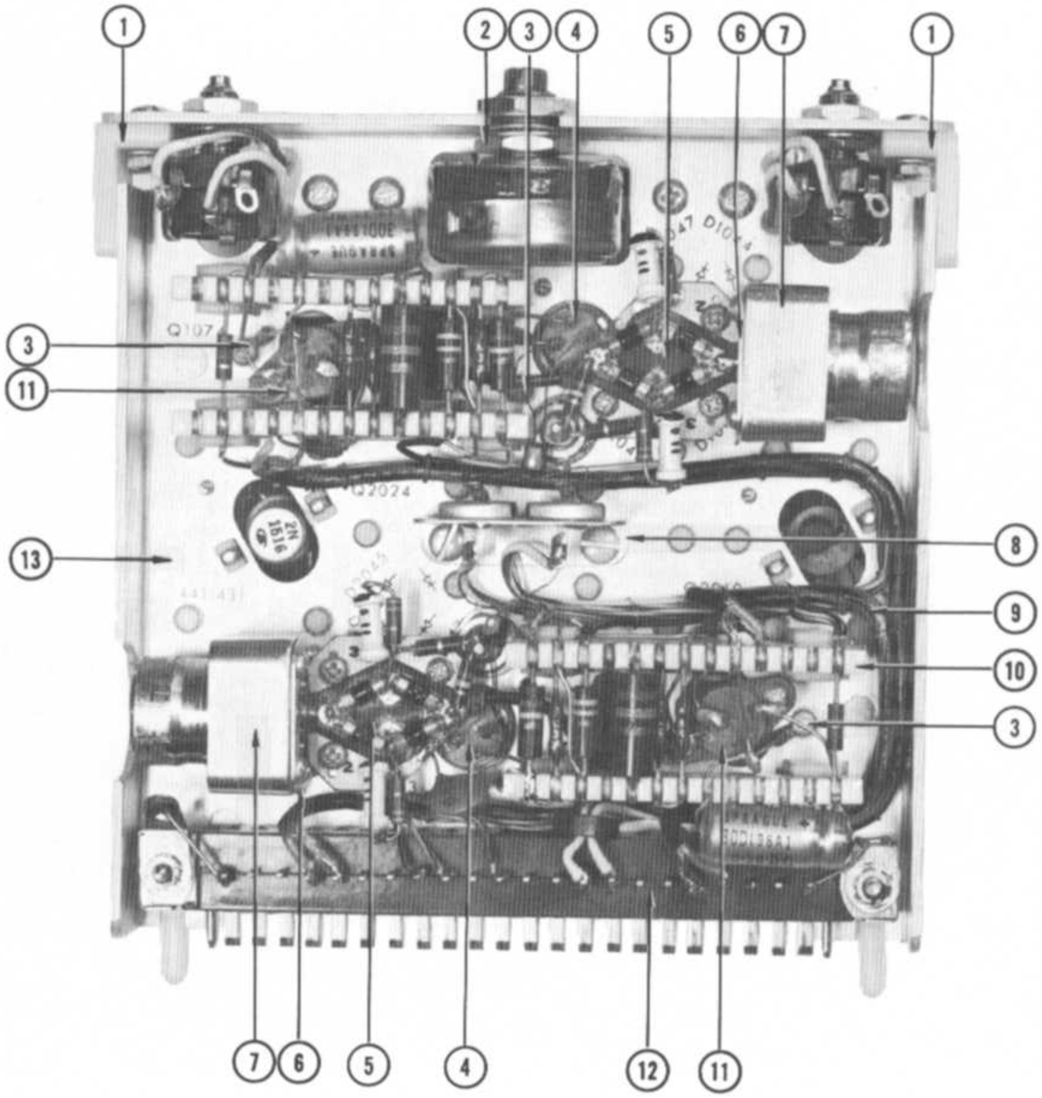
A.C. AMPLIFIER PLUG-IN CHASSIS

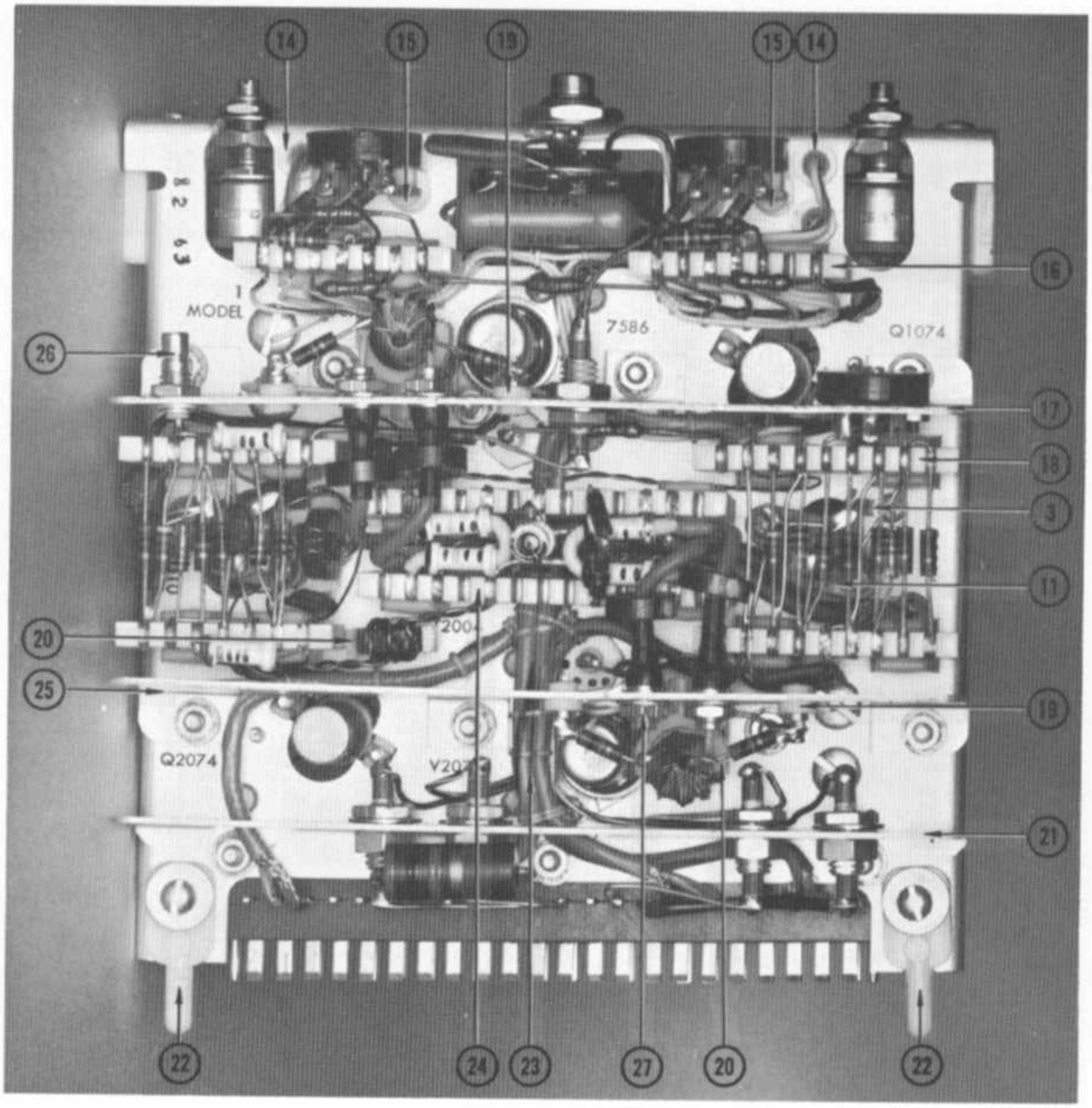


REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
	605-002			1	ASSEMBLY, A.C. Amplifier Plug-in Chassis, slot 2
					Includes:
1	352-039			2	HOLDER, plug-in chassis
					Mounting Hardware For Each: (not included)
	211-011			1	SCREW, 4-40 x 5/16 BHS
	210-004			1	LOCKWASHER, int. #4
	210-406			1	NUT, hex, 4-40 x 3/16
2	210-215			5	LUG, banana, peewee
	213-055			5	SCREW, thread cutting, 2-56 x 3/16 PHS phillips slot
3	136-095			8	SOCKET, 4 pin transistor
					Mounting Hardware For Each: (not included)
	211-081			2	SCREW, 2-56 x 9/16 RHS phillips slot
	361-035			2	SPACER, transistor socket
4	441-424			1	CHASSIS
5	385-160			3	ROD, spacer
					Mounting Hardware For Each: (not included)
	211-507			1	SCREW, 6-32 x 5/16 BHS
	337-492			1	SHIELD, A.C. Amplifier(not included in ass'y—not shown)
					Mounting Hardware: (not included)
	211-543			3	SCREW, 6-32 x 5/16 RHS
6	124-145			4	STRIP, ceramic, 7/16 x 20 notches
	361-008			8	SPACER, nylon, molded
7	384-593			2	ROD, pin index
8	179-626			1	CABLE harness
9	131-218			1	CONNECTOR, 22 contact
					Mounting Hardware: (not included)
	211-016			2	SCREW, 4-40 x 5/8 RHS
	210-003			2	LOCKWASHER, ext. #4
	210-201			2	LUG, solder, SE 4
	210-406			2	NUT, hex, 4-40 x 3/16

SAMPLER PLUG-IN CHASSIS
S/N 101-539



SAMPLER PLUG-IN CHASSIS
S/N 101-539



SAMPLER PLUG-IN CHASSIS
S/N 101-539

REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
	605-006	101	539	1	ASSEMBLY, Sampler Plug-in Chassis, slot 1
					Includes:
1	352-039			2	HOLDER, plug-in chassis
					Mounting Hardware For Each: (not included)
	211-011			1	SCREW, 4-40 x $^5/_{16}$ BHS
	210-004			1	LOCKWASHER, int. #4
	210-406			1	NUT, hex, 4-40 x $^3/_{16}$
2	210-413			1	NUT, hex, $^3/_8$-32 x $^1/_2$
	210-840			1	WASHER, .390 ID x $^9/_{16}$ OD
	210-207			1	LUG, solder, pot, plain, $^3/_8$
	210-012			1	LOCKWASHER, int, $^3/_8$ x $^1/_2$
3	210-215			5	LUG, banana, peewee
	213-055			5	SCREW, thread cutting, 2-56 x $^3/_{16}$ PHS phillips slot
4	136-101			2	SOCKET, 5 pin
					Mouning Hardware For Each: (not included)
	213-055			2	SCREW, thread cutting, 2-56 x $^3/_{16}$ PHS phillips slot
5	670-018			2	ASSEMBLY, Bridge Board
					Each Includes:
	344-064			9	CLIP, diode
					Mounting Hardware For Each: (not included)
	213-055			2	SCREW, thread cutting, 2-56 x $^3/_{16}$ PHS phillips slot
	211-081			1	SCREW, 2-56 x $^9/_{16}$ RHS phillips slot
	166-251			1	TUBE, spacer
	210-001			1	LOCKWASHER, int. #2
	210-405			1	NUT, hex, 2-56 x $^3/_{16}$
6	406-764			2	BRACKET, sampler board
					Mounting Hardware For Each: (not included)
	211-022			4	SCREW, 2-56 x $^3/_{16}$ RHS
7	204-114			2	BODY, 50 Ω female
					Mounting Hardware For Each: (not included)
	211-504			2	SCREW, 6-32 x $^1/_4$ BHS
	131-210			2	CONNECTOR, inner conductor
	344-056			2	CLIP, formed, 50 Ω attenuator
	361-036			2	SPACER, ring, resistor
8	406-798			1	BRACKET, sampler capacitor
					Mounting Hardware: (not included)
	211-007			2	SCREW, 4-40 x $^3/_{16}$ BHS
	210-004			2	LOCKWASHER, int. #4
	210-406			2	NUT, hex, 4-40 x $^3/_{16}$
9	179-633			1	CABLE harness, sampler amp
10	124-147			4	STRIP, ceramic, $^7/_{16}$ x 13 notches
	361-008			8	SPACER, nylon, molded
11	136-095			4	SOCKET, 4 pin transistor
					Mounting Hardware For Each: (not included)
	211-081			2	SCREW, 2-56 x $^9/_{16}$ RHS phillips slot
	361-035			2	SPACER, transistor socket
12	131-218			1	CONNECTOR, 22 contact
					Mounting Hardware: (not included)
	211-016			2	SCREW, 4-40 x $^5/_8$ RHS
	210-003			2	LOCKWASHER, ext. #4
	210-201			2	LUG, solder, SE 4
	210-406			2	NUT, hex, 4-40 x $^3/_{16}$
13	441-431	MODL 1	MODL 1	1	CHASSIS, plug-in
	441-451	MODL 2		1	CHASSIS, plug-in
14	348-031			4	GROMMET, poly. snap-in
15	406-635			2	BRACKET, low capacity pot mounting
					Mounting Hardware For Each: (not included)
	213-044			2	SCREW, thread cutting, 5-32 x $^3/_{16}$ PHS phillips slot
	210-438			2	NUT, hex, 1-72 x $^5/_{32}$ (pot mounting)
16	124-149			4	STRIP, ceramic, $^7/_{16}$ x 7 notches
	361-008			8	SPACER, nylon, molded

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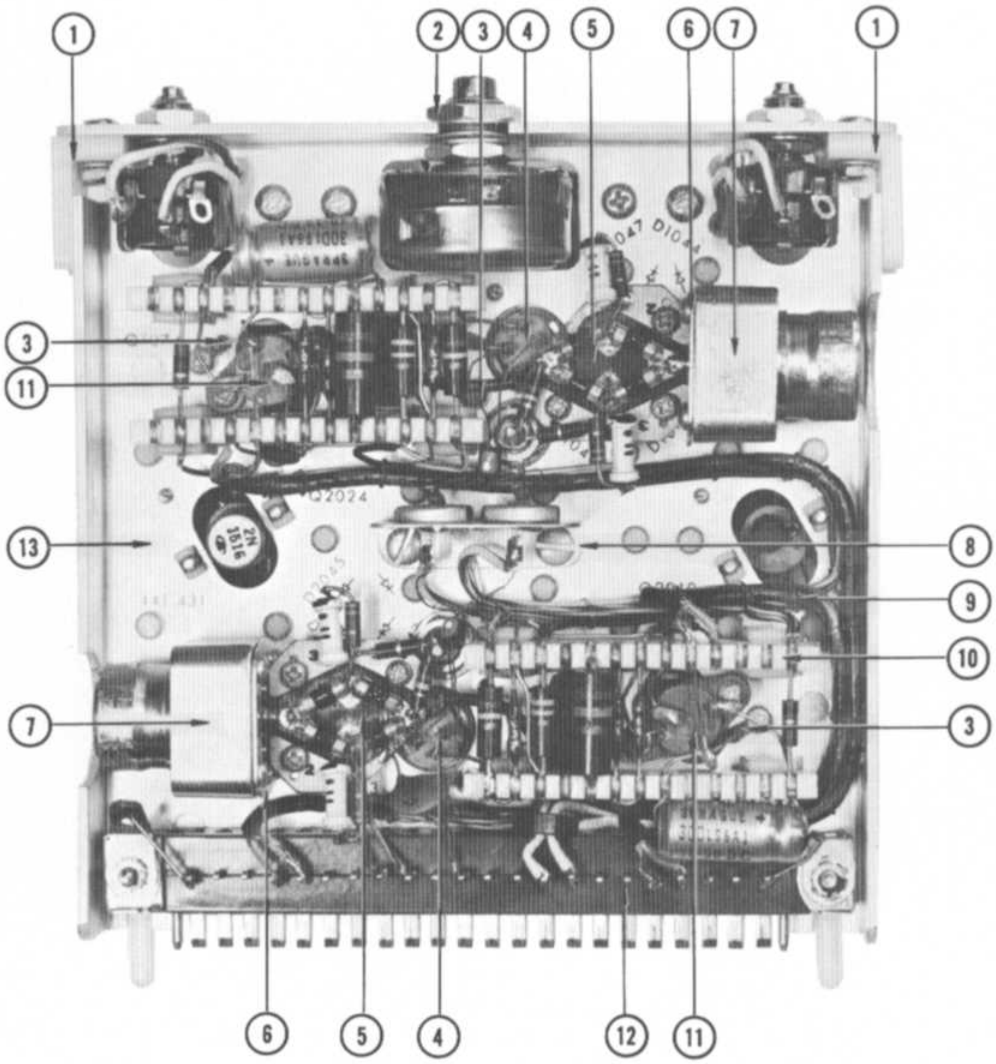
SAMPLER PLUG-IN CHASSIS
S/N 101-539

REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
17	377-486			1	SHIELD, greater sampler
					Mounting Hardware: (not included)
	210-004			4	LOCKWASHER, int. #4
	210-406			4	NUT, hex, 4-40 x 3/16
18	124-148			2	STRIP, ceramic, 7/16 x 9 notches
	361-008			4	SPACER, nylon, molded
19	131-180	MODL 2		4	CONNECTOR, terminal stand-off
	358-135	MODL 2		4	BUSHING, teflon
20	426-121			5	MOUNT, toroid
	361-007			5	SPACER, nylon, molded
21	337-487			1	SHIELD, lesser sampler
					Mounting Hardware: (not included)
	210-004			3	LOCKWASHER, int. #4
	210-406			3	NUT, hex, 4-40 x 3/16
22	384-593			2	ROD, pin index
23	179-634	MODL 1	MODL 1	1	CABLE harness, sampler driver
	179-670	MODL 2		1	CABLE harness, sampler driver
24	124-148	MODL 1	MODL 1	2	STRIP, ceramic, 7/16 x 9 notches
	124-147	MODL 2		2	STRIP, ceramic, 7/16 x 13 notches
	361-007			4	SPACER, nylon, molded
25	337-493			1	SHIELD, intermediate
					Mounting Hardware: (not included)
	210-004			4	LOCKWASHER, int. #4
	210-406			4	NUT, hex, 4-40 x 3/16
26	131-156			1	CONNECTOR, coaxial, miniature
27	131-208			4	CONNECTOR, cable termination

SAMPLER PLUG-IN CHASSIS
S/N 540-up



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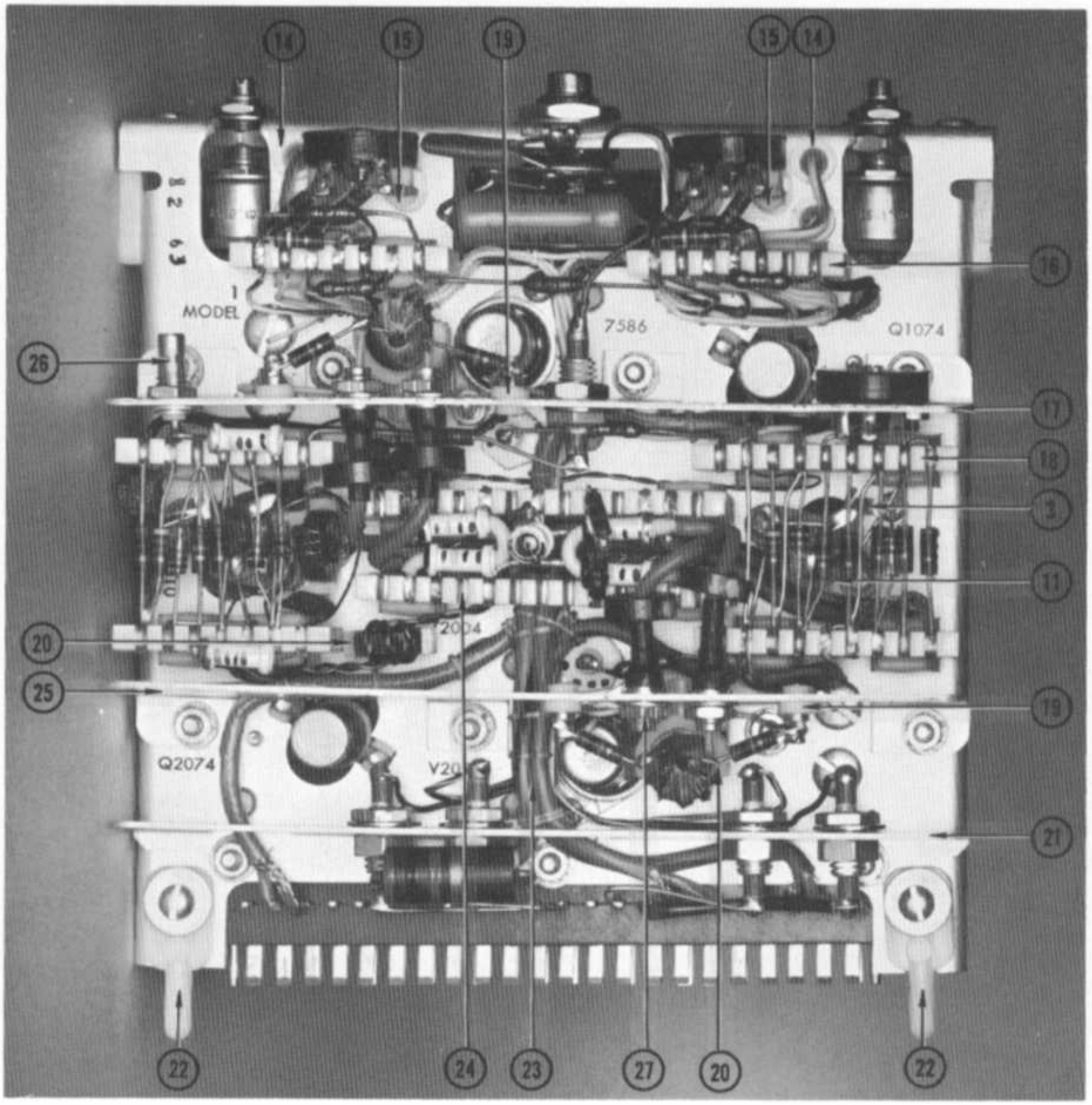
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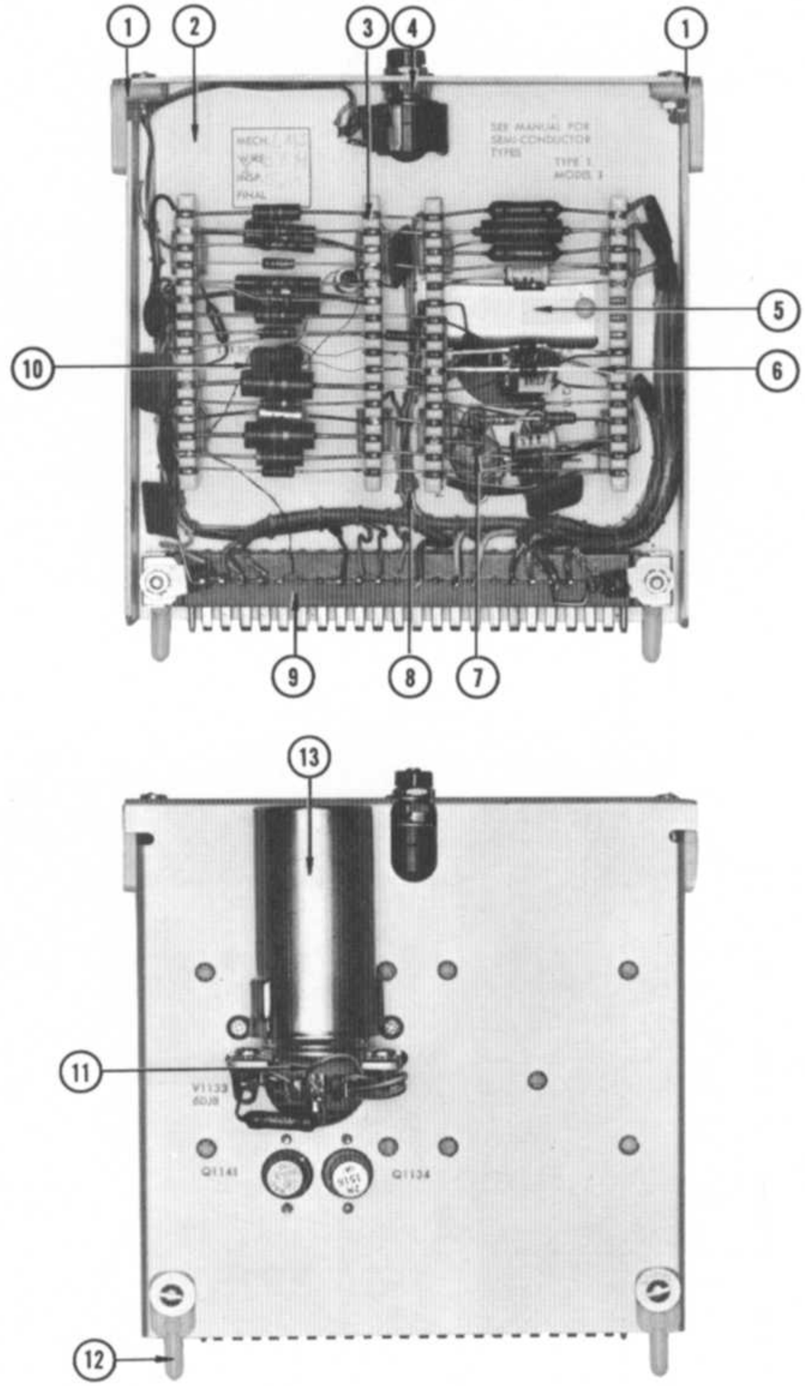
SAMPLER PLUG-IN CHASSIS
S/N 540-up

REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
	605-011	540		1	ASSEMBLY, Sampler Plug-in Chassis, slot 7
					Includes:
1	352-039			2	HOLDER, plug-in chassis
					Mounting Hardware For Each: (not included)
	211-011			1	SCREW, 4-40 x $^5/_{16}$ BHS
	210-004			1	LOCKWASHER, int. #4
	210-406			1	NUT, hex, 4-40 x $^3/_{16}$
2	210-413			1	NUT, hex, $^3/_8$-32 x $^1/_2$
	210-840			1	WASHER, .390 ID x $^9/_{16}$ OD
	210-207			1	LUG, solder, pot, plain, $^3/_8$
	210-012			1	LOCKWASHER, int, $^3/_8$ x $^1/_2$
3	210-215			5	LUG, banana, peewee
	213-055			5	SCREW, thread cutting, 2-56 x $^3/_{16}$ PHS pillips slot
4	136-101			2	SOCKET, 5 pin
					Mounting Hardware For Each: (not included)
	213-055			1	SCREW, thread cutting, 2-56 x $^3/_{16}$ PHS phillips slot
5	670-018			2	ASSEMBLY, Bridge Board
					Each Includes:
	344-064			9	CLIP, diode
					Mounting Hardware For Each: (not included)
	213-055			2	SCREW, thread cutting, 2-56 x $^3/_{16}$ PHS phillips
	211-081			1	SCREW, 2-56 x $^9/_{16}$ RHS phillips slot
	166-251			1	TUBE, spacer
	210-001			1	LOCKWASHER, int. #2
	210-405			1	NUT, hex, 2-56 x $^3/_{16}$
6	406-764			2	BRACKET, sampler board
					Mounting Hardware For Each: (not included)
	211-022			4	SCREW, 2-56 x $^3/_{16}$ RHS
7	204-114			2	BODY, 50 Ω female
					Mounting Hardware For Each: (not included)
	211-504			2	SCREW, 6-32 x $^1/_4$ BHS
	131-210			2	CONNECTOR, inner conductor
	344-056			2	CLIP, formed, 50 Ω attenuator
	361-036			2	SPACER, ring, resistor
8	406-798			1	BRACKET, sampler capacitor
					Mounting Hardware: (not included)
	211-007			2	SCREW, 4-40 x $^3/_{16}$ BHS
	210-004			2	LOCKWASHER, int. #4
	210-406			2	NUT, hex, 4-40 x $^3/_{16}$
9	179-633			1	CABLE harness, sampler amp
10	124-147			4	STRIP, ceramic, $^7/_{16}$ x 13 notches
	361-008			8	SPACER, nylon, molded
11	136-095			4	SOCKET, 4 pin transistor
					Mounting Hardware For Each: (not included)
	211-081			2	SCREW, 2-56 x $^9/_{16}$ RHS phillips slot
	361-035			2	SPACER, transistor socket
12	131-218			1	CONNECTOR, 22 contact
					Mounting Hardware: (not included)
	211-016			2	SCREW, 4-40 x $^5/_8$ RHS
	210-003			2	LOCKWASHER, ext. #4
	210-201			2	LUG, solder, SE 4
	210-406			2	NUT, hex, 4-40 x $^3/_{16}$
13	441-481			1	CHASSIS, plug-in
14	348-031			4	GROMMET, poly. snap-in
15	406-635			2	BRACKET, low capacity pot mounting
					Mounting Hardware For Each: (not included)
	213-044			2	SCREW, thread cutting, 5-32 x $^3/_{16}$ PHS phillips slot
	210-438			2	NUT, hex, 1-72 x $^5/_{32}$ (pot mounting)
16	124-149			4	STRIP, ceramic, $^7/_{16}$ x 7 notches
	361-008			8	SPACER, nylon, molded

SAMPLER PLUG-IN CHASSIS
S/N 540-UP

REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
17	337-486			1	SHIELD, greater sampler
					Mounting Hardware: (not included)
	210-004			4	LOCKWASHER, int. #4
	210-406			4	NUT, hex, 4-40 x 3/16
18	124-148			2	STRIP, ceramic, 7/16 x 9 notches
	361-008			4	SPACER, nylon, molded
19	131-180			4	CONNECTOR, terminal stand-off
	358-135			4	BUSHING, teflon
20	426-121			5	MOUNT, toroid
	361-007			5	SPACER, nylon, molded
21	337-487			1	SHIELD, lesser sampler
					Mounting Hardware: (not included)
	210-004			3	LOCKWASHER, int. #4
	210-406			3	NUT, hex, 4-40 x 3/16
22	384-593			2	ROD, pin index
23	179-670			1	CABLE harness, sampler driver
24	124-147			2	STRIP, ceramic, 7/16 x 13 notches
	361-007			4	SPACER, nylon, molded
25	337-493			1	SHIELD, intermediate
					Mounting Hardware: (not included)
	210-004			4	LOCKWASHER, int. #4
	210-406			4	NUT, hex, 4-40 x 3/16
26	131-156			1	CONNECTOR, coaxial, miniature
27	131-208			4	CONNECTOR, cable termination

MEMORY PLUG-IN CHASSIS
S/N 101-539



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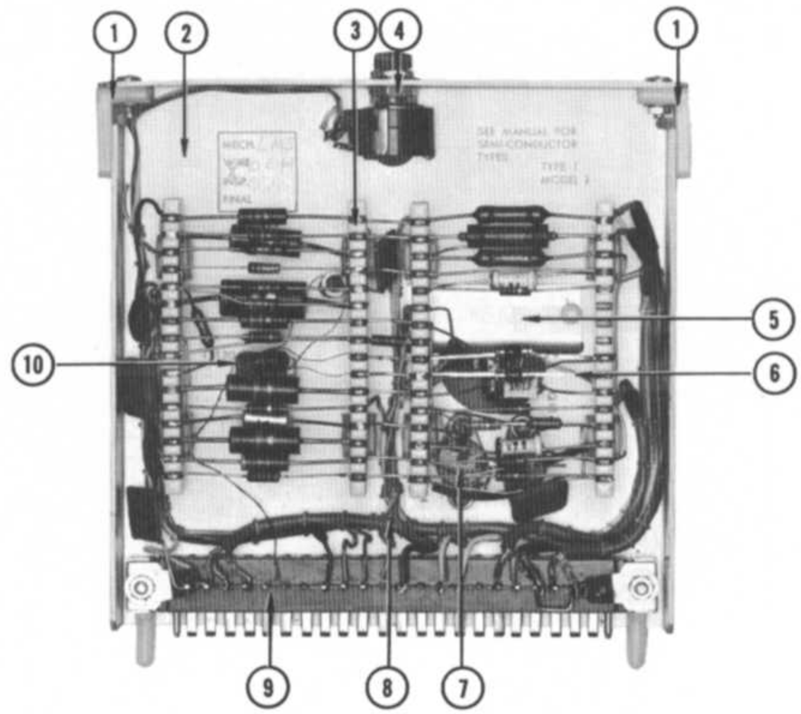
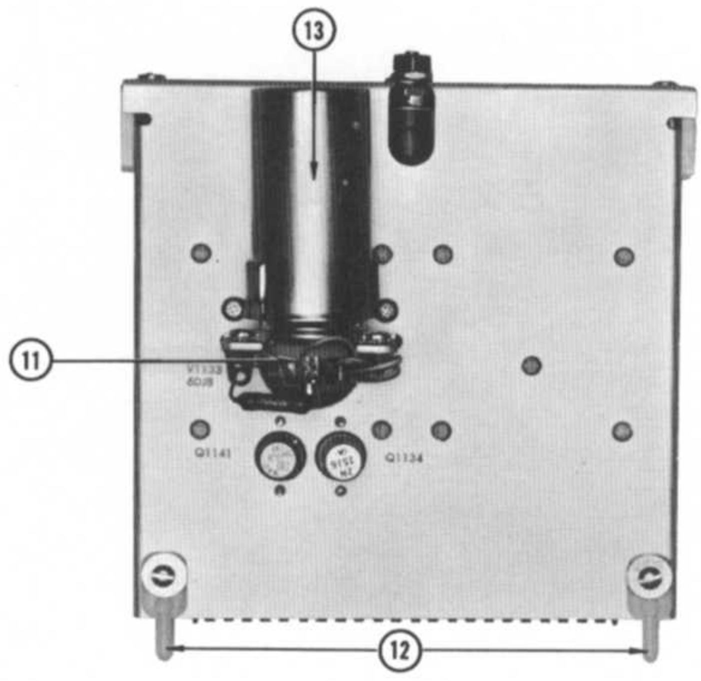
MEMORY PLUG-IN CHASSIS
S/N 101-539

REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
	605-005	101	539	2	ASSEMBLY, Memory Plug-in Chassis, slot 3
					Each Includes:
1	352-039			2	HOLDER, plug-in chassis
					Mounting Hardware For Each: (not included)
	211-011			1	SCREW, 4-40 x $^{5}/_{16}$ BHS
	210-004			1	LOCKWASHER, int. #4
	210-406			1	NUT, hex, 4-40 x $^{3}/_{16}$
2	441-419			1	CHASSIS
3	124-146			4	STRIP, ceramic, $^{7}/_{16}$ x 16 notches
	361-008			8	SPACER, nylon, molded
4	210-465			1	NUT, hex, $^{1}/_{4}$-32 x $^{3}/_{8}$
5	406-765			1	BRACKET, socket mount
					Mounting Hardware For Each: (not included)
	213-044			2	SCREW, thread cutting, 5-32 x $^{3}/_{16}$ PHS phillips slot
	200-174			1	CAP, screw, protective
6	344-061			4	CLIP, diode
7	136-095			2	SOCKET, 4 pin transistor
					Mounting Hardware For Each: (not included)
	213-113			2	SCREW, 2-32 x $^{5}/_{16}$ RHS phillips slot
	210-215			1	LUG, banana, peewee
8	179-627			1	CABLE harness
9	131-218			1	CONNECTOR, 22 contact
					Mounting Hardware: (not included)
	211-016			2	SCREW, 4-40 x $^{5}/_{8}$ RHS
	210-003			2	LOCKWASHER, ext. #4
	210-201			2	LUG, solder, SE 4
	210-406			2	NUT, hex, 4-40 x $^{3}/_{16}$
10	426-121			1	MOUNT, toroid
	361-007			1	SPACER, nylon molded
11	136-085			1	SOCKET, 9 pin shielded base
					Mounting Hardware: (not included)
	211-033			2	SCREW, 4-40 x $^{5}/_{16}$ PHS w/lockwasher
	210-004			1	LOCKWASHER, int. #4
	210-201			1	LUG, solder, SE 4
	210-406			2	NUT, hex, 4-40 x $^{3}/_{16}$
12	384-593			2	ROD, pin index
13	337-008			1	SHIELD, tube (not included in assembly)

MEMORY PLUG-IN CHASSIS
S/N 540-919





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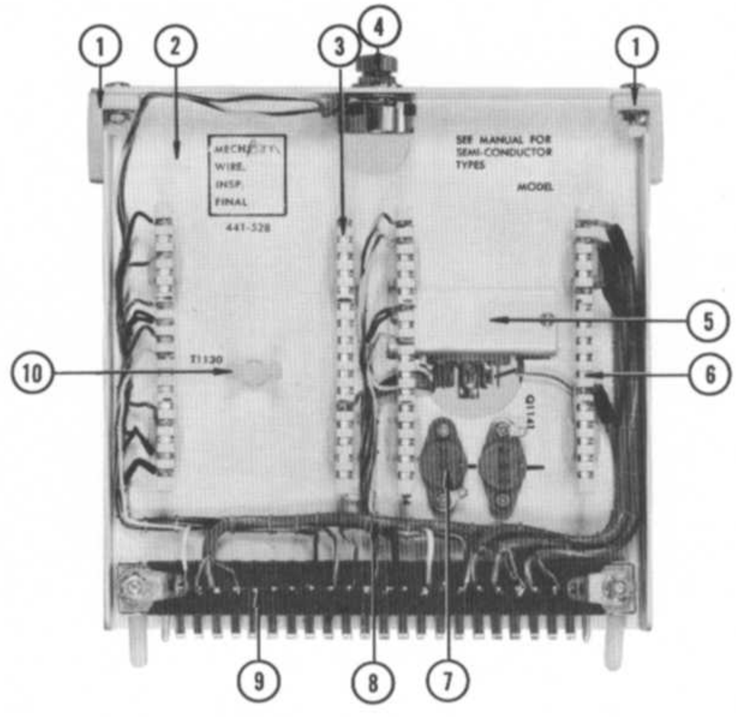
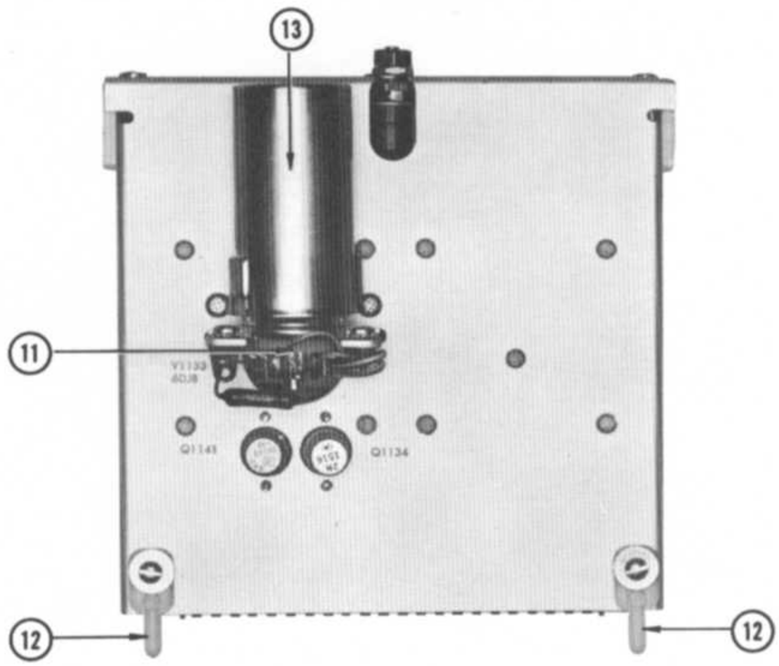
MEMORY PLUG-IN CHASSIS
S/N 540-919

REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
	605-010	540		2	ASSEMBLY, Memory Plug-in Chassis, slot 8
					Each Includes:
1	352-039			2	HOLDER, plug-in chassis
					Mounting Hardware For Each: (not included)
	211-011			1	SCREW, 4-40 x 5/16 BHS
	210-004			1	LOCKWASHER, int. #4
	210-406			1	NUT, hex, 4-40 x 3/16
2	441-480			1	CHASSIS
3	124-146			4	STRIP, ceramic, 7/16 x 16 notches
	361-008			8	SPACER, nylon, molded
4	210-465			1	NUT, hex, 1/4-32 x 3/8
5	406-765			1	BRACKET, socket mount
					Mounting Hardware: (not included)
	213-044			2	SCREW, thread cutting, 5-32 x 3/16 PHS phillips slot
	200-174			1	CAP, screw, protective
6	344-061			4	CLIP, diode
7	136-095			2	SOCKET, 4 pin transistor
					Mounting Hardware For Each: (not included)
	213-113			2	SCREW, 2-32 x 5/16 PHS phillips slot
	210-215			1	LUG, banana, peewee
8	179-627			1	CABLE harness
9	131-218			1	CONNECTOR, 22 contact
					Mounting Hardware: (not included)
	211-016			2	SCREW, 4-40 x 5/8 RHS
	210-003			2	LOCKWASHER, ext. #4
	210-201			2	LUG, solder, SE 4
	210-406			2	NUT, hex, 4-40 x 3/16
10	426-121			1	MOUNT, toroid
	361-007			1	SPACER, nylon, molded
11	136-085			1	SOCKET, 9 pin shielded base
					Mounting Hardware: (not included)
	211-033			2	SCREW, 4-40 x 5/16 PHS w/lockwasher
	210-004			1	LOCKWASHER, int. #4
	210-201			1	LUG, solder, SE 4
	210-406			2	NUT, hex, 4-40 x 3/16
12	384-593			2	ROD, pin index
13	337-008			1	SHIELD, tube (not included in assembly)

MEMORY PLUG-IN CHASSIS
S/N 920-up

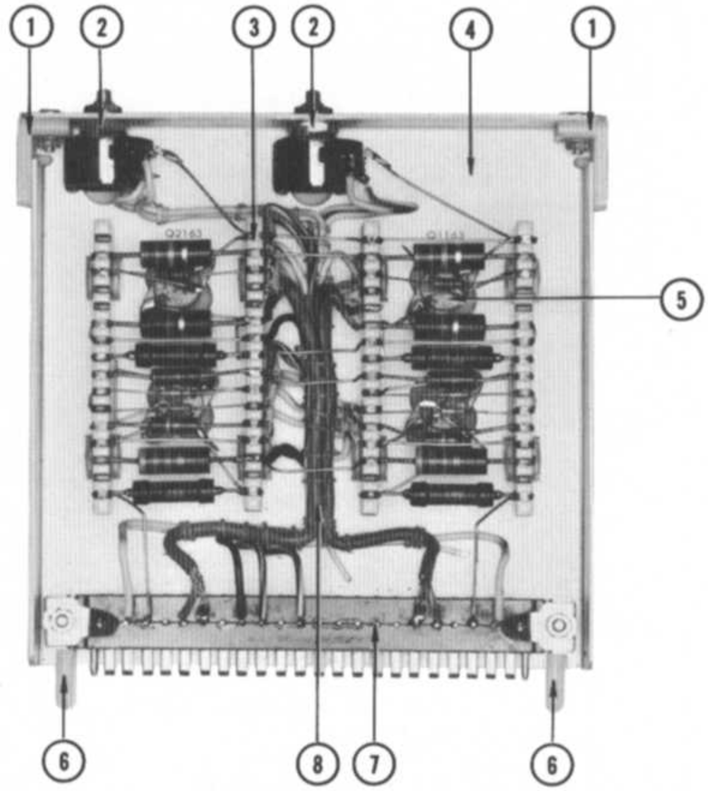




MEMORY PLUG-IN CHASSIS
S/N 920-UP

REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
	605-015	920		2	ASSEMBLY, Memory Plug-in Chassis, series 11
	- - - - -			-	Each Includes:
1	352-039			2	HOLDER, plug-in chassis
	- - - - -			-	Mounting Hardware For Each: (not included)
	211-011			1	SCREW, 4-40 x 5/16 inch BHS
	210-004			1	LOCKWASHER, int. #4
	210-406			1	NUT, hex, 4-40 x 3/16 inch
2	441-528			1	CHASSIS
3	124-146			4	STRIP, ceramic, 7/16 inch x 16 notches
	361-008			8	SPACER, nylon, molded
4	210-465			1	NUT, hex, 1/4-32 x 3/8 inch
5	406-765			1	BRACKET, socket mount
	- - - - -			-	Mounting Hardware: (not included)
	213-044			2	SCREW, thread cutting, 5-32 x 3/16 inch PHS phillips slot
	200-174			1	CAP, screw, protective
6	344-061			4	CLIP, diode
7	136-095			2	SOCKET, 4 pin transistor
	- - - - -			-	Mounting Hardware For Each: (not included)
	213-113			2	SCREW, 2-32 x 5/16 inch PHS phillips slot
	210-215			1	LUG, banana, peewee
8	179-627			1	CABLE, harness
9	131-218			1	CONNECTOR, 22 contact
	- - - - -			-	Mounting Hardware: (not included)
	211-016			2	SCREW, 4-40 x 5/8 inch RHS
	210-003			2	LOCKWASHER, ext. #4
	210-201			2	LUG, solder, SE4
	210-406			2	NUT, hex, 4-40 x 3/16 inch
10	426-121			1	MOUNT, toroid
	361-007			1	SPACER, nylon, molded
11	136-085			1	SOCKET, 9 pin shielded base
	- - - - -			-	Mounting Hardware: (not included)
	211-033			2	SCREW, 4-40 x 5/16 inch PHS with lockwasher
	210-044			1	LOCKWASHER, int. #4
	210-201			1	LUG, solder, SE 4
	210-406			2	NUT, hex, 4-40 x 3/16 inch
12	384-593			2	ROD, pin index
13	337-008			1	SHIELD, tube (not included in assembly)

INVERTER PLUG-IN CHASSIS
S/N 101-539



REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
	605-003	101	539	1	ASSEMBLY, Inverter Plug-in Chassis, slot 4
					Includes:
1	352-039			2	HOLDER, plug-in chassis
					Mounting Hardware For Each: (not included)
	211-011			1	SCREW, 4-40 x 5/16 BHS
	210-004			1	LOCKWASHER, int. #4
	210-406			1	NUT, hex, 4-40 x 3/16
2	210-465			2	NUT, hex, 1/4-32 x 3/8
3	124-146			4	STRIP, ceramic, 7/16 x 16 notches
	361-008			8	SPACER, nylon, molded
4	441-418			1	CHASSIS
5	136-095			4	SOCKET, 4 pin transistor
					Mounting Hardware For Each: (not included)
	211-081			2	SCREW, 2-56 x 9/16 RHS phillips slot
	361-035			2	SPACER, transistor socket
6	384-593			2	ROD, pin index
7	131-218			1	CONNECTOR, 22 contact
					Mounting Hardware: (not included)
	211-016			2	SCREW, 4-40 x 5/8 RHS
	210-003			2	LOCKWASHER, ext. #4
	210-201			2	LUG, solder, SE 4
	210-406			2	NUT, hex, 4-40 x 3/16
8	179-628			1	CABLE harness

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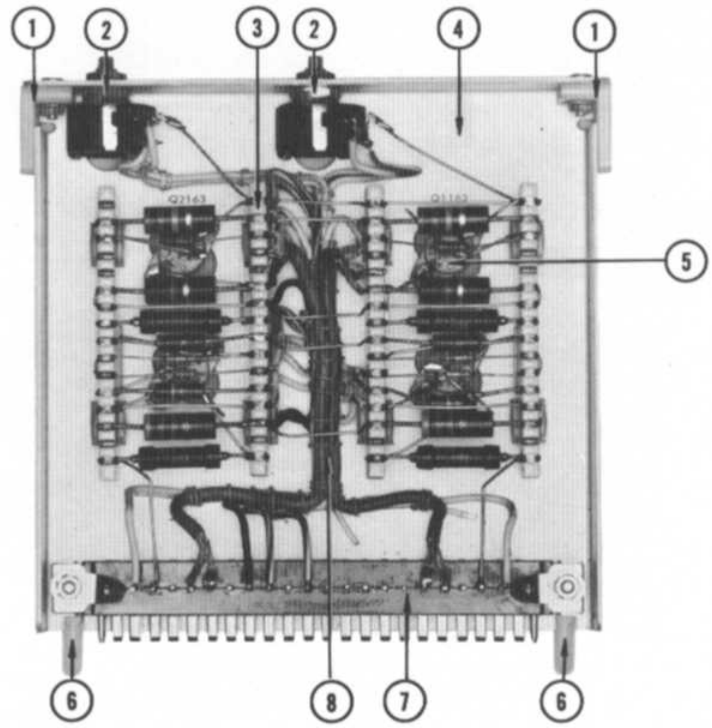
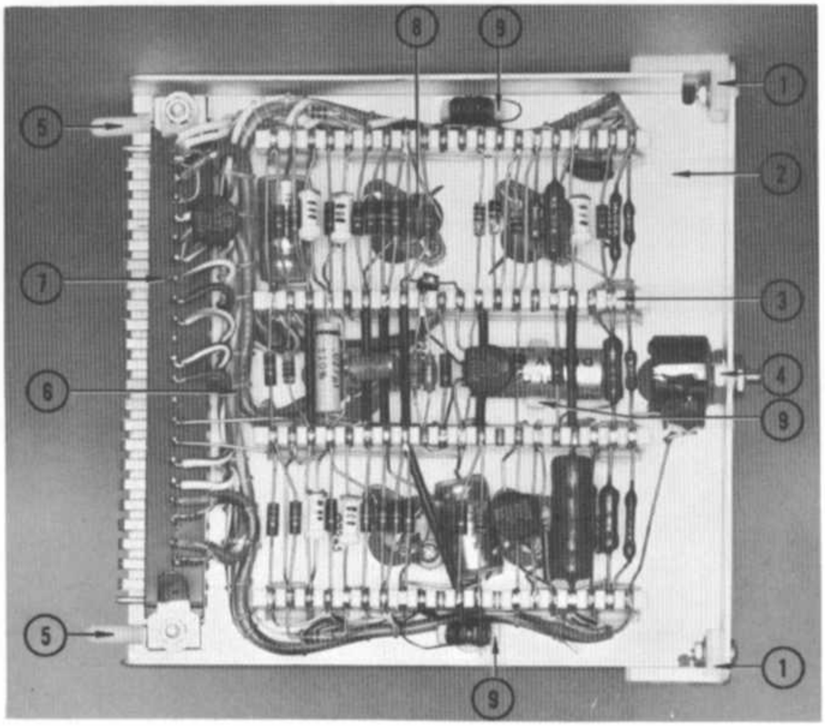
INVERTER PLUG-IN CHASSIS
S/N 540-UP



REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
	605-009	540		1	ASSEMBLY, Inverter Plug-in Chassis, slot 9
					Includes:
1	352-039			2	HOLDER, plug-in chassis
					Mounting Hardware For Each: (not included)
	211-011			1	SCREW, 4-40 x $^5/_{16}$ BHS
	210-004			1	LOCKWASHER, int. #4
	210-406			1	NUT, hex, 4-40 x $^3/_{16}$
2	210-465			2	NUT, hex, $^1/_4$-32 x $^3/_8$
3	124-146			4	STRIP, ceramic, $^7/_{16}$ x 16 notches
	361-008			8	SPACER, nylon, molded
4	441-479			1	CHASSIS
5	136-095			4	SOCKET, 4 pin transistor
					Mounting Hardware For Each: (not included)
	211-081			2	SCREW, 2-56 x $^9/_{16}$ RHS phillips slot
	361-035			2	SPACER, transistor socket
6	384-593			2	ROD, pin index
7	131-218			2	CONNECTOR, 22 contact
					Mounting Hardware: (not included)
	211-016			2	SCREW, 4-40 x $^5/_8$ RHS
	210-003			2	LOCKWASHER, ext. #4
	210-201			2	LUG, solder, SE 4
	210-406			2	NUT, hex, 4-40 x $^3/_{16}$
8	179-628			1	CABLE harness

DUAL TRACE PLUG-IN CHASSIS



REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
	605-004			1	ASSEMBLY, Dual Trace Plug-in Chassis, slot 5
					Includes:
1	352-039			2	HOLDER, plug-in chassis
					Mounting Hardware For Each: (not included)
	211-011			1	SCREW, 4-40 x 5/16 BHS
	210-004			1	LOCKWASHER, int. #4
	210-406			1	NUT, hex, 4-40 x 3/16
2	441-423	MODL 1	MODL 2	1	CHASSIS
	441-471	MODL 3		1	CHASSIS
3	124-145			4	STRIP, ceramic, 7/16 x 20 notches
	361-008			8	SPACER, nylon, molded
4	210-465			1	NUT, hex, 1/4-32 x 3/8
5	384-593			2	ROD, pin index
6	179-629	MODL 1	MODL 2	1	CABLE harness
	179-715	MODL 3		1	CABLE harness
7	131-218			1	CONNECTOR, 22 contact
					Mounting Hardware: (not included)
	211-016			2	SCREW, 4-40 x 5/8 RHS
	210-003			2	LOCKWASHER, ext. #4
	210-201			2	LUG, solder, SE 4
	210-406			2	NUT, hex, 4-40 x 3/16
8	136-095			5	SOCKET, 4 pin transistor
					Mounting Hardware For Each: (not included)
	211-081			2	SCREW, 2-56 x 9/16 RHS phillips slot
	361-035			2	SPACER, transistor socket
9	426-121	MODL 3		3	MOUNT, toroid
	361-007	MODL 3		3	SPACER, nylon, molded

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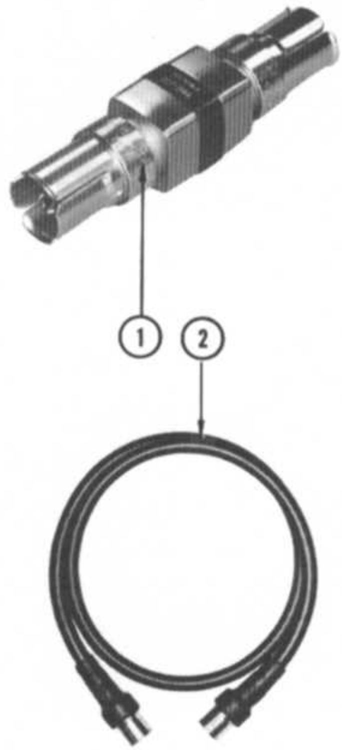
ACCESSORIES

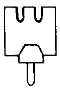


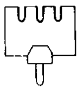
REF. NO.	PART NO	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
1	017-044			2	50 Ω 10X ATTENUATOR
2	017-502			2	50 Ω 5 NSEC CABLE

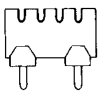
CERAMIC STRIPS AND MOUNTINGS

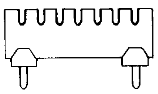
3/4 inch

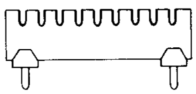

1 notch 124-100

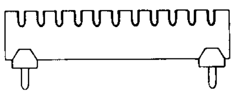

2 notch 124-086


3 notch 124-087


4 notch 124-088

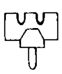

7 notch 124-089

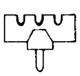

9 notch 124-090

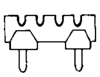

11 notch 124-091

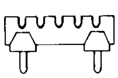
7/16 inch

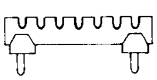

1 notch 124-118

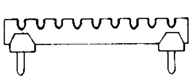

2 notch 124-119

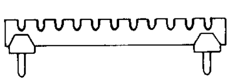

3 notch 124-092


4 notch 124-120

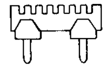

5 notch 124-093

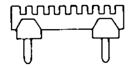

7 notch 124-094

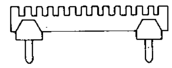

9 notch 124-095

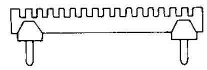

11 notch 124-106

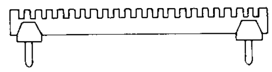
7/16 inch SMALL NOTCH —Short Stud


7 notch 124-149

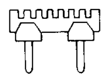

9 notch 124-148

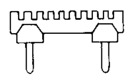

13 notch 124-147

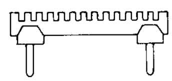

16 notch 124-146

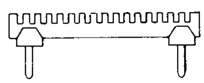

20 notch 124-145

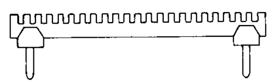
7/16 inch SMALL NOTCH —Tall Stud


7 notch 124-158


9 notch 124-157


13 notch 124-156


16 notch 124-155

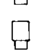

20 notch 124-154

MOUNTINGS


Stud, nylon, short . . 355-046


Stud, nylon, tall . . 355-082


Spacer, $^{11}/_{32}$ inch . . 361-039


Spacer, $^{3}/_{8}$ inch . . 361-009


Spacer, $^{1}/_{4}$ inch . . . 361-008


Spacer, $^{5}/_{32}$ inch . . . 361-007

Ceramic strips include studs, but spacers must be ordered separately by part no.

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ELECTRICAL PARTS LIST

Values are fixed unless marked Variable.

Capacitors

Tolerance ±20% unless otherwise indicated.

Tolerance of all electrolytic capacitors are as follows (with exceptions):

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

Ckt. No.	Tektronix Part No.	Description					S/N Range
C1003	283-004	.02 μf	Disc Type		150 v		101-1349X
C1012	290-026	5 μf	EMT		25 v		101-1349X
C1013	283-582	.0054 μf	Mica		500 v	5%	101-1349
C1013	283-106	100 pf	Cer				1350-up
C1014	281-501	4.7 pf	Cer		500 v	±1 pf	101-1349
C1014	283-003	.01 μf	Cer		150 v		1350-up
C1015	290-149	5 μf	EMT		150 v		101-1349X
C1016	290-026	5 μf	EMT		25 v		101-1349X
C1017	290-105	100 μf	EMT		6 v		101-749
	290-107	25 μf	EMT		25 v		750-1349X
C1018	283-056	.01 μf	Disc Type		500 v		101-1349X
C1019	283-058	.027 μf	Disc Type		100 v	10%	101-1349
C1019	285-624	.027 μf	PTM		100 v		1350-up
C1021	290-121	2 μf	EMT		25 v		101-1349X
C1022	281-615	3.9 pf	Cer		200 v		X1350-up
C1023	283-023	.1 μf	Disc Type		10 v		
C1027	290-149	5 μf	EMT		150 v		
C1032	281-060	2-8 pf	Cer	Var			101-1349X
C1036	281-524	150 pf	Cer		500 v		101-749
C1036	281-523	100 pf	Cer		350 v		750-1349X
C1037	281-022	8-50 pf	Cer	Var			101-1349
C1037	290-107	25 μf	EMT		25 v		1350-up
C1038	290-107	25 μf	EMT		25 v		X1350-up
C2003	283-004	.02 μf	Disc Type		150 v		101-1349X
C2240	283-003	.01 μf	Disc Type		150 v		

Diodes

Ckt. No.	Tektronix Part No.	Description	S/N Range
D1012	152-008	Germanium	101-1349X
D1016	*152-107	Silicon Replaceable by 1N647	X750-1349X
D1022	152-016	Zener RT6 6 v	101-1349X
D1023	152-016	Zener RT6 6 v	101-1349X
D1026	152-034	Zener 1N753, .4 w, 6.2 v, 10%	X1350-up
D1282	152-066	Silicon 1N3194	
D1283	152-066	Silicon 1N3194	
D1284	152-066	Silicon 1N3194	
D2282	152-066	Silicon 1N3194	
D2283	152-066	Silicon 1N3194	
D2284	152-066	Silicon 1N3194	

Inductors

Ckt. No.	Tektronix Part No.	Description	S/N Range
L1000†	*636-0002-00	Delay Line Assembly	
L1001	108-213	2.5 mh	101-1349X
L1002	*120-345	Toroid 21T	X1350-up
L1003	*108-146	5 μh	X1350-up
L1015	*108-057	8.8 μh	101-749
	*108-215	1.1 μh	750-1349X
L1019	*108-109	60 μh	
L1020	*108-181	.2 μh	X750-1349
L1020	276-528	Core, Ferramic Suppressor	1350-up
L1037	*120-312	Toroid 15T	X1350-up
L1038	*120-312	Toroid 15T	X1350-up
L2000†	*636-0002-00	Delay Line Assembly	
L2001	108-213	2.5 mh	101-1349X
L2002	*120-345	Toroid 21T	X1350-up

Resistors

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

Ckt. No.	Tektronix Part No.	Value	Wattage	Description	Type	Tolerance	S/N Range
R1001	*308-224	2.45 k	½ w		WW	1%	101-1349X
R1002	318-012	25 k	⅛ w		Prec	1%	101-1349
R1002	321-225	2.15 k	⅛ w		Prec	1%	1350-up
R1003	315-101	100 Ω	¼ w			5%	
R1004	315-101	100 Ω	¼ w			5%	
R1006	315-470	47 Ω	¼ w			2%	101-1349
R1006	321-149	348 Ω	⅛ w		Prec	1%	1350-up
R1008	321-149	348 Ω	⅛ w		Prec	1%	X1350-up
R1010	317-100	10 Ω	1/10 w			5%	X1350-up
R1012	*308-222	12 k	2 w		WW	2%	101-1349X
R1013	321-268	6.04 k	⅛ w		Prec	1%	X1350-up
R1014	317-390	39 Ω	1/10 w			5%	101-1349
R1014	321-185	825 Ω	⅛ w		Prec		1350-up
R1015	*310-594	5.5 k	4 w	Mica Plate			101-1349
R1015	321-227	7.50 k	⅛ w		Prec	1%	1350-up
R1017	309-270	3.92 k	½ w		Prec	1%	101-1349X
R1018	309-209	950 Ω	½ w		Prec	1%	101-1349X
R1019	315-510	51 Ω	¼ w			5%	101-1349
R1019	317-510	51 Ω	1/10 w			5%	1350-up
R1021	315-433	43 k	¼ w			5%	101-1349
R1021	309-133	2.51 k	½ w		Prec	1%	1350-up
R1022	311-159	20 k		Var		TRIG ZERO	101-1349
R1022	317-390	39 Ω	1/10 w			5%	1350-up
R1023	316-102	1 k	¼ w				101-1349
R1023	317-470	47 Ω	1/10 w			5%	1350-up
R1024	304-183	18 k	1 w				101-1349
R1024	308-054	10 k	5 w		WW	5%	1350-up
R1026	322-249	3.83 k	¼ w		Prec	1%	X1350-up
R1027	309-090	50 k	½ w		Prec	1%	101-1349X
R1028	309-133	2.51 k	½ w		Prec	1%	X1350-up
R1029	311-172	2.5 k		Var		TRIG ZERO	X1350-up
R1031	*310-593	4.5 k	4 w	Mica Plate		2%	101-1349X
R1032	316-223	22 k	¼ w				101-749X
R1033	318-100	36 k	⅛ w		Prec	1%	101-1349X
R1034	318-037	500 Ω	⅛ w		Prec	1%	101-749
	318-076	475 Ω	⅛ w		Prec	5%	750-1349X

†L1000 and L2000 furnished as a unit.

Resistors *(Cont'd.)*

Ckt. No.	Tektronix Part No.	Description					S/N Range
R1036	318-010	5.03 k	1/8 w		Prec	1%	101-1349X
R1080A	318-103	600 Ω	1/8 w		Prec	1%	
R1080B	318-083	200 Ω	1/8 w		Prec	1%	
R1080C	318-040	100 Ω	1/8 w		Prec	1%	
R1080D	318-104	60 Ω	1/8 w		Prec	1%	
R1080E	318-056	20 Ω	1/8 w		Prec	1%	
R1080F	318-052	10 Ω	1/8 w		Prec	1%	
R1080G	318-052	10 Ω	1/8 w		Prec	1%	
R1081	use 311-220	1 k		Var		SMOOTHING A	
R1147A	318-089	583 k	1/8 w		Prec	1%	
R1147B	318-088	229.7 k	1/8 w		Prec	1%	
R1147C	318-087	112 k	1/8 w		Prec	1%	
R1147D	318-086	53 k	1/8 w		Prec	1%	
R1147E	318-085	17.67 k	1/8 w		Prec	1%	
R1147F	318-073	5.88 k	1/8 w		Prec	1%	
R1148	301-683	68 k	1/2 w			5%	101-539
	315-154	150 k	1/4 w			5%	540-up
R1149	309-370	2.091 k	1/2 w		Prec	1/4%	101-539
	321-601	2.141 k	1/8 w		Prec		540-up
R1157	303-623	62 k	1 w			5%	
R1158	301-104	100 k	1/2 w			5%	
R1159	311-271	200 k		Var		DC OFFSET A	
R1160	309-369	200 k	1/2 w		Prec	1/4%	
R1169	301-104	100 k	1/2 w			5%	
R1170	309-393	15 k	1/2 w		Prec	1%	101-539
	321-603	15 k	1/8 w		Prec	1/4%	540-up
R1171	309-154	30 k	1/2 w		Prec	1%	101-539
	321-604	30 k	1/8 w		Prec	1/4%	540-up
R1172	311-172	2.5 k		Var		A-B BAL	
R1173†	*311-296	7 k		Var	WW	VARIABLE A	
R1179	315-912	9.1 k	1/4 w			5%	
R1180	311-016	10 k	2 w	Var		VERT POSITION A	
R1283	301-225	2.2 meg	1/2 w			5%	
R2001	*308-224	2.45 k	1/2 w		WW	1%	101-1349X
R2002	318-012	25 k	1/8 w		Prec	1%	101-1349
R2002	321-225	2.15 k	1/8 w		Prec	1%	1350-up
R2080A	318-103	600 Ω	1/8 w		Prec	1%	
R2080B	318-083	200 Ω	1/8 w		Prec	1%	
R2080C	318-040	100 Ω	1/8 w		Prec	1%	
R2080D	318-104	60 Ω	1/8 w		Prec	1%	
R2080E	318-056	20 Ω	1/8 w		Prec	1%	
R2080F	318-052	10 Ω	1/8 w		Prec	1%	
R208G	318-052	10 Ω	1/8 w		Prec	1%	
R2081	use 311-220	1 k		Var		SMOOTHING B	
R2147A	318-089	583 k	1/8 w		Prec	1%	
R2147B	318-088	229.7 k	1/8 w		Prec	1%	
R2147C	318-087	112 k	1/8 w		Prec	1%	
R2147D	318-086	53 k	1/8 w		Prec	1%	
R2147E	318-085	17.67 k	1/8 w		Prec	1%	
R2147F	318-073	5.88 k	1/8 w		Prec	1%	
R2148	301-683	68 k	1/2 w			5%	101-539
	315-154	150 k	1/4 w			5%	540-up

†Furnished as a unit with SW1282.

Resistors *(Cont'd.)*

Ckt. No.	Tektronix Part No.	Description					S/N Range
R2149	309-370	2.091 k	½ w		Prec	¼%	101-539
	321-601	2.141 k	⅛ w		Prec	¼%	540-up
R2157	303-623	62 k	1 w			5%	
R2158	301-104	100 k	½ w			5%	
R2159	311-271	200 k		Var		DC OFFSET B	
R2160	309-369	200 k	½ w		Prec	¼%	
R2169	301-104	100 k	½ w			5%	
R2170	309-393	15 k	½ w		Prec	1%	101-539
	321-603	15 k	⅛ w		Prec	¼%	540-up
R2171	309-154	30 k	½ w		Prec	1%	101-539
	321-604	30 k	⅛ w		Prec	¼%	540-up
R2173[1]	*311-296	7 k		Var		VARIABLE B	
R2175	315-753	75 k	¼ w			5%	X540-up
R2180	311-016	10 k	2 w	Var		VERT POSITION B	
R2240	301-101	100 Ω	½ w			5%	
R2283	301-225	2.2 meg	½ w			5%	

Switches

Ckt. No.	Unwired	Wired	Description		S/N Range
SW1004 } SW1019 }	260-436	*262-470	Rotary Rotary	TRIGGERING AC/DC	101-1349
SW1004 } SW1019 }	260-582	*262-616	Rotary Rotary	TRIGGERING AC/DC	1350-up
SW1101	260-434	*262-468	Rotary	MILLIVOLTS/CM A	101-539
	260-434	*262-551			540-up
SW1171	260-212		Slide	DISPLAY A	
SW1282[2]	*311-296			CALIBRATED A	
SW2101	260-434	*262-468	Rotary	MILLIVOLTS/CM B	101-539
	260-434	*262-551			540-up
SW2171	260-212		Slide	DISPLAY B	
SW2190	260-435	*262-469	Rotary	MODE	101-539
	260-514	*262-550			540-up
SW2282[3]	*311-296			CALIBRATED B	

Transformers

Ckt. No.	Tektronix Part No.	Description	S/N Range
T1001	Use *050-060	Replacement Kit	101-199
	*120-283	Toroid 7T	200-up
T1003[4]	*120-259	Toroid 4T	
T1012	276-512	Core, Powder Iron	X750-up
T1019	276-525	Core, Ferrite	
T1024	*120-269	Toroid 4T	X1350-up
T2001	use *050-060	Replacement Kit	101-199
	*120-283	Toroid 7T	200-up
T2003[4]	*120-259	Toroid 4T	

Transistors

Ckt. No.	Tektronix Part No.	Description	S/N Range
Q1013	*151-133	Selected from 2N3251	X1350-up
Q1014	use 151-027	2N700	101-1349X
Q1023	151-079	2N1429	101-1349X
Q1024	151-080	2N706B	101-749
	*151-103	Replaceable by 2N2219	750-1349
	151-138	2N2857	1350-up

[1]Furnished as a unit with SW2282.
[2]Furnished as a unit with R1173
[3]Furnished as a unit with R2173.
[4]S/N 101-529 T1003 and T2003 have to be replaced at the same time.

SAMPLER Series 1 (S/N 101-539)

Ckt. No.	Tektronix Part No.	Description				Model No.
	*605-006	Complete Board				

Capacitors

Ckt. No.	Tektronix Part No.	Description				Model No.
C1046	281-504	10 pf	Cer	500 v	10%	
C1047	281-504	10 pf	Cer	500 v	10%	
C1050	281-548	27 pf	Cer	500 v		
C1055	281-564	24 pf	Cer	500 v	5%	
C1056	281-564	24 pf	Cer	500 v	5%	
C1076	283-024	.1 μf	Disc Type	30 v		
C1078	290-145	10 μf	EMT	50 v		
C1079	283-000	.001 μf	Disc Type	500 v		1, 2, 3, 4
	283-065	.001 μf	Disc Type	100 v	5%	5-up
C2004	281-519	47 pf	Cer	500 v	10%	
C2005	283-000	.001 μf	Disc Type	500 v		
C2006	281-559	.0015 μf	Cer	500 v		
C2007	283-026	.2 μf	Disc Type	25 v		
C2008	281-536	.001 μf	Cer	500 v	10%	
C2010	283-000	.001 μf	Disc Type	500 v		
C2011	283-000	.001 μf	Disc Type	500 v		
C2012	283-026	.2 μf	Disc Type	25 v		
C2013	283-000	.001 μf	Disc Type	500 v		
C2018	281-525	470 pf	Cer	500 v		
C2025	283-026	.2 μf	Disc Type	25 v		
C2030	283-563	.001 μf	Mica	500 v	10%	
C2031	283-003	.01 μf	Disc Type	150 v		
C2032	283-003	.01 μf	Disc Type	150 v		
C2033	283-563	.001 μf	Mica	500 v	10%	
C2034	281-559	.0015 μf	Cer	500 v		
C2035	281-559	.0015 μf	Cer	500 v		
C2036	281-559	.0015 μf	Cer	500 v		
C2037	281-559	.0015 μf	Cer	500 v		
C2046	281-504	10 pf	Cer	500 v	10%	
C2047	281-504	10 pf	Cer	500 v	10%	
C2050	281-548	27 pf	Cer	500 v		
C2055	281-564	24 pf	Cer	500 v	5%	
C2056	281-564	24 pf	Cer	500 v	5%	
C2076	283-024	.1 μf	Disc Type	30 v		
C2078	290-145	10 μf	EMT	50 v		
C2079	283-000	.001 μf	Disc Type	500 v		1, 2, 3, 4
	283-065	.001 μf	Disc Type	100 v	5%	5-up

Diodes

Ckt. No.	Tektronix Part No.	Description
D1044 D1045 D1046 D1047	Use *153-014	Checked, 2 matched pairs
D2004†	use *152-115	Snap off, pretested

† Inside C2004.

Diodes *(Cont'd.)*

Ckt. No.	Tektronix Part No.	Description	Model No.
D2010	152-071	Germanium ED2007	
D2013	152-008	Germanium T12G	
D2018	152-071	Germanium ED2007	
D2022	152-071	Germanium ED2007	
D2024	152-008	Germanium T12G	
D2044 D2045 D2046 D2047	use *153-014	Checked, 2 matched pairs	

Inductors

Ckt. No.	Tektronix Part No.	Description	Model No.
L1070	276-507	Core, Ferramic Suppressor	X2-up
L2005	*120-258	Toroid 6T	
L2057	*108-241	.05 μh	
L2070	276-507	Core, Ferramic Suppressor	X2-up

Resistors

Ckt. No.	Tektronix Part No.	Description					Model No.
R1041	307-068	50 Ω				1%	
R1046	315-331	330 Ω	¼ w			5%	
R1047	315-331	330 Ω	¼ w			5%	
R1049	316-274	270 k	¼ w				
R1050	316-125	1.2 meg	¼ w				
R1051	316-473	47 k	¼ w				
R1053	315-103	10 k	¼ w			5%	
R1054	315-103	10 k	¼ w			5%	
R1060	301-305	3 meg	½ w			5%	
R1061	301-205	2 meg	½ w			5%	1, 2
	301-155	1.5 meg	½ w			5%	3-up
R1062	315-433	43 k	¼ w			5%	X3-up
R1063	311-115	100 k		Var		A BRIDGE BAL	1, 2
	311-078	50 k	.1 w	Var			3-up
R1064	315-433	43 k	¼ w			5%	X3-up
R1065	use 301-105	1 meg	½ w			5%	
R1066	315-223	22 k	¼ w			5%	1
	315-753	75 k	¼ w			5%	2
	315-563	56 k	¼ w			5%	3-up
R1067	311-068	500 k	.2 w	Var		A BRIDGE VOLTS	1
	311-110	100 k		Var			2-up
R1072	301-274	270 k	½ w			5%	
R1073	303-273	27 k	1 w			5%	
R1074	318-097	1.5 k	⅛ w		Prec	1%	
R1075	318-049	1 k	⅛ w		Prec	1%	
R1076	318-012	25 k	⅛ w		Prec	1%	

Resistors *(Cont'd.)*

Ckt. No.	Tektronix Part No.	Description					Model No.
R1077	301-244	240 k	½ w			5%	
R1078	316-101	100 Ω	¼ w				
R2005	315-220	22 Ω	¼ w			5%	
R2006	308-104	167 Ω	5 w		WW	5%	
R2007	Use 311-413	1 k	2 w	Var		SNAP-OFF CURRENT	
R2008†	317-510	51 Ω	1/10 w			5%	
R2011	315-471	470 Ω	¼ w			5%	
R2012	315-100	10 Ω	¼ w			5%	
R2013	315-102	1 k	¼ w			5%	
R2015	315-223	22 k	¼ w			5%	
R2018	315-222	2.2 k	¼ w			5%	
R2021	315-471	470 Ω	¼ w			5%	
R2022	315-103	10 k	¼ w			5%	
R2023	311-115	100 k		Var		MEMORY GATE WIDTH	
R2024	315-221	220 Ω	¼ w			5%	
R2025	315-100	10 Ω	¼ w			5%	
R2027	315-621	620 Ω	¼ w			5%	
R2028	315-621	620 Ω	¼ w			5%	
R2030	305-101	100 Ω	2 w			5%	
R2041	307-068	50 Ω				1%	
R2046	315-331	330 Ω	¼ w			5%	
R2047	315-331	330 Ω	¼ w			5%	
R2049	316-274	270 k	¼ w				
R2050	316-125	1.2 meg	¼ w				
R2051	316-473	47 k	¼ w			5%	
R2053	315-103	10 k	¼ w			5%	
R2054	315-103	10 k	¼ w			5%	
R2057	315-510	51 Ω	¼ w			5%	
R2060	301-305	3 meg	½ w			5%	
R2061	301-205	2 meg	½ w			5%	1, 2
	301-155	1.5 meg	½ w			5%	3-up
R2062	315-433	43 k	¼ w			5%	X3-up
R2063	311-115	100 k		Var		B BRIDGE BAL	1, 2
	311-078	50 k	.1 w	Var			3-up
R2064	315-433	43 k	¼ w			5%	X3-up
R2065	use 301-105	1 meg	½ w			5%	
R2066	315-223	22 k	¼ w			5%	1
	315-753	75 k	¼ w			5%	2
	315-563	56 k	¼ w			5%	3
R2067	311-068	500 k	.2 w	Var		B BRIDGE VOLTS	1
	311-110	100 k		Var			2-up
R2072	301-274	270 k	½ w			5%	
R2073	303-273	27 k	1 w			5%	
R2074	318-097	1.5 k	⅛ w		Prec	1%	
R2075	318-049	1 k	⅛ w		Prec	1%	
R2076	318-012	25 k	⅛ w		Prec	1%	
R2077	301-244	240 k	½ w			5%	
R2078	316-101	100 Ω	¼ w				

† Inside C2008.

Transformers

Ckt. No.	Tektronix Part No.	Description	Model No.
T1052	*120-253	Toroid 6T	
T1055	*120-254	Toroid 2T	1
T1055A,B	*120-282	Toroid 1T	2-up
T2004	*120-257	Toroid 4T	
T2010	*120-256	Toroid 2T-4T	
T2019	276-525	Core, Ferrite	
T2030	276-517	Core, Powder Iron	
T2031	*120-269	Toroid 4T	
T2032	*120-269	Toroid 4T	
T2052	*120-253	Toroid 6T	
T2055	*120-254	Toroid 2T	1
T2055A,B	*120-282	Toroid 1T	2-up

Transistors

Q1074	151-063	2N2207
Q2010	*151-083	Selected from 2N964
Q2024	151-015	2N1516
Q2074	151-063	2N2207

Electron Tubes

V1073	154-306	7586
V2073	154-306	7586

SAMPLER Series 7 (S/N 540-up)

Use *610-0094-00 Complete Board

Capacitors

C1046	281-504	10 pf	Cer	500 v	10%	
C1047	281-504	10 pf	Cer	500 v	10%	
C1050	281-548	27 pf	Cer	500 v		
C1055	281-564	24 pf	Cer	500 v	5%	
C1056	281-564	24 pf	Cer	500 v	5%	
C1076	283-024	.1 μf	Disc Type	30 v		
C1078	290-145	10 μf	EMT	50 v		
C1079	283-065	.001 μf	Disc Type	100 v	5%	
C2004	281-519	47 pf	Cer	500 v	10%	1
	Use 285-006	68 pf	Glass	500 v	5%	2-up
C2005	283-000	.001 μf	Disc Type	500 v		
C2006	281-559	.0015 μf	Cer	500 v		
C2007	283-026	.2 μf	Disc Type	25 v		
C2008	281-536	.001 μf	Cer	500 v	10%	
C2010	283-000	.001 μf	Disc Type	500 v		

Capacitors *(Cont'd.)*

Ckt. No.	Tektronix Part No.	Description				Model No.
C2011	283-000	.001 μf	Disc Type	500 v		
C2012	283-026	.2 μf	Disc Type	25 v		
C2013·	283-000	.001 μf	Disc Type	500 v		1
	283-065	.001 μf	Disc Type	100 v		2-up
C2018	281-525	470 pf	Cer	500 v		
C2025	283-026	.2 μf	Disc Type	25 v		
C2030	283-563	.001 μf	Mica	500 v	10%	
C2031	283-003	.01 μf	Disc Type	150 v		
C2032	283-003	.01 μf	Disc Type	150 v		
C2033	283-563	.001 μf	Mica	500 v	10%	
C2034	281-559	.0015 μf	Cer	500 v		
C2035	281-559	.0015 μf	Cer	500 v		
C2036	281-559	.0015 μf	Cer	500 v		
C2037	281-559	.0015 μf	Cer	500 v		
C2046	281-504	10 pf	Cer	500 v	10%	
C2047	281-504	10 pf	Cer	500 v	10%	
C2050	281-548	27 pf	Cer	500 v		
C2055	281-564	24 pf	Cer	500 v	5%	
C2056	281-564	24 pf	Cer	500 v	5%	
C2076	283-024	.1 μf	Disc Type	30 v		
C2078	290-145	10 μf	EMT	50 v		
C2079	283-065	.001 μf	Disc Type	100 v	5%	

Diodes

Ckt. No.	Tektronix Part No.	Description
D1044, D1045, D1046, D1047	use *153-014	Checked, 2 matched pairs
D2004†	*152-115	Snap-off, pretested
D2010	152-071	Germanium ED2007
D2013	152-008	Germanium T12G
D2018	152-071	Germanium ED2007
D2022	152-071	Germanium ED2007
D2024	152-008	Germanium T12G
D2044, D2045, D2046, D2047	use *153-014	Checked, 2 matched pairs

Inductors

Ckt. No.	Tektronix Part No.	Description
L1070	276-507	Core, Ferramic Suppressor
L2005	*120-258	Toroid 6T
L2057	*108-241	.05 μh
L2070	276-507	Core, Ferramic Suppressor

† Inside C2004, Model 1 only.

Resistors

Ckt. No.	Tektronix Part No.	Description					Model No.
R1041	307-068	50 Ω				1%	
R1046	315-331	330 Ω	¼ w			5%	
R1047	315-331	330 Ω	¼ w			5%	
R1049	316-274	270 k	¼ w				
R1050	318-109	500 k	⅛ w		Prec	1%	
R1051	318-033	20.4 k	⅛ w		Prec	1%	
R1053	315-103	10 k	¼ w			5%	
R1054	315-103	10 k	¼ w			5%	
R1060	318-096	1.5 meg	⅛ w		Prec	1%	
R1061	318-115	750 k	⅛ w		Prec	1%	
R1062	315-153	15 k	¼ w			5%	
R1063	311-017	10 k	.1 w	Var		A BRIDGE BAL	
R1064	315-153	15 k	¼ w			5%	
R1065	318-109	500 k	⅛ w		Prec	1%	
R1066	315-393	39 k	¼ w			5%	
R1067	311-374	250 k	¾ w	Var		A BRIDGE VOLTS	
R1072	301-274	270 k	½ w			5%	
R1073	303-273	27 k	1 w			5%	
R1074	318-097	1.5 k	⅛ w		Prec	1%	
R1075	318-049	1 k	⅛ w		Prec	1%	
R1076	318-012	25 k	⅛ w		Prec	1%	1, 2
	318-101	57.6 k	⅛ w		Prec	1%	3-up
R1077	301-244	240 k	½ w			5%	
R1078	316-101	100 Ω	¼ w				
R2005	315-220	22 Ω	¼ w			5%	
R2006	308-104	167 Ω	5 w		WW	5%	
R2007	use 311-413	1 k	5 w	Var		SNAP-OFF CURRENT	
R2008†	317-510	51 Ω	1/10 w			5%	
R2011	315-471	470 Ω	¼ w			5%	
R2012	315-100	10 Ω	¼ w			5%	
R2013	315-102	1 k	¼ w			5%	
R2015	315-223	22 k	¼ w			5%	
R2018	315-222	2.2 k	¼ w			5%	
R2021	315-471	470 Ω	¼ w			5%	
R2022	315-103	10 k	¼ w			5%	
R2023	311-115	100 k		Var		MEMORY GATE WIDTH	
R2024	315-221	220 Ω	¼ w			5%	
R2025	315-100	10 Ω	¼ w			5%	
R2027	315-621	620 Ω	¼ w			5%	
R2028	315-621	620 Ω	¼ w			5%	
R2030	305-101	100 Ω	2 w			5%	
R2041	307-068	50 Ω				1%	
R2046	315-331	330 Ω	¼ w			5%	
R2047	315-331	330 Ω	¼ w			5%	

† Inside C2008.

Resistors *(Cont'd.)*

Ckt. No.	Tektronix Part No.	Description					Model No.
R2049	316-274	270 k	1/4 w				
R2050	318-109	500 k	1/8 w		Prec	1%	
R2051	318-033	20.4 k	1/8 w		Prec	1%	
R2053	315-103	10 k	1/4 w			5%	
R2054	315-103	10 k	1/4 w			5%	
R2057	315-510	51 Ω	1/4 w			5%	
R2060	318-096	1.5 meg	1/8 w		Prec	1%	
R2061	318-115	750 k	1/8 w		Prec	1%	
R2062	315-153	15 k	1/4 w			5%	
R2063	311-017	10 k	.1 w	Var		B BRIDGE BAL	
R2064	315-153	15 k	1/4 w			5%	
R2065	318-109	500 k	1/8 w		Prec	1%	
R2066	315-393	39 k	1/4 w			5%	
R2067	311-374	250 k	3/4 w	Var		B BRIDGE VOLTS	
R2072	301-274	270 k	1/2 w			5%	
R2073	303-273	27 k	1 w			5%	
R2074	318-097	1.5 k	1/8 w		Prec	1%	
R2075	318-049	1 k	1/8 w		Prec	1%	
R2076	318-012	25 k	1/8 w		Prec	1%	1, 2
	318-101	57.6 k	1/8 w		Prec	1%	3-up
R2077	301-244	240 k	1/2 w			5%	
R2078	316-101	100 Ω	1/4 w				

Transformers

Ckt. No.	Tektronix Part No.	Description	Model No.
T1052	*120-253	Toroid 6T	1
	*120-321	Toroid 6T	2-up
T1055A,B	*120-282	Toroid 1T	1X
T2004	*120-257	Toroid 4T	
T2010	*120-256	Toroid 2T-4T	
T2019	276-525	Core, Ferrite	
T2030	276-517	Core, Powder Iron	
T2031	*120-269	Toroid 4T	
T2032	*120-269	Toroid 4T	
T2052	*120-253	Toroid 6T	1
	*120-321	Toroid 6T	2-up
T2055A,B	*120-282	Toroid 1T	1X

Transistors

Ckt. No.	Tektronix Part No.	Description
Q1074	151-063	2N2207
Q2010	*151-083	Selected from 2N964
Q2024	151-015	2N1516
Q2074	151-063	2N2207

Electron Tubes

Ckt. No.	Tektronix Part No.	Description	Model No.
V1073	154-306	7586	
V2073	154-306	7586	

AC AMPLIFIER Series 2

	Use *610-0061-00	Complete Board	

Capacitors

Ckt. No.	Tektronix Part No.	Description					Model No.
C1081	290-105	100 μf	EMT		6 v		
C1089	281-501	4.7 pf	Cer		500 v	±1 pf	
C1107	281-060	2-8 pf	Cer	Var			
C1108	283-026	.2 μf	Disc Type		25 v		
C1109	290-145	10 μf	EMT		50 v		
C1113	283-023	.1 μf	Disc Type		10 v		
C1116	283-004	.02 μf	Disc Type		150 v		
C1119	283-004	.02 μf	Disc Type		150 v		
C2081	290-105	100 μf	EMT		6 v		
C2089	281-501	4.7 pf	Cer		500 v	±1 pf	
C2107	281-060	2-8 pf	Cer	Var			
C2108	283-026	.2 μf	Disc Type		25 v		
C2109	290-145	10 μf	EMT		50 v		
C2113	283-023	.1 μf	Disc Type		10 v		
C2116	283-004	.02 μf	Disc Type		150 v		
C2119	283-004	.02 μf	Disc Type		150 v		

Inductors

Ckt. No.	Tektronix Part No.	Description	Model No.
L1082	*120-306	Toroid, 40 turns, Single	X5-up
L2082	*120-306	Toroid, 40 turns, Single	X5-up

Resistors

Ckt. No.	Tektronix Part No.	Description				Model No.
R1082	303-164	160 k	1 w		5%	X4-up
R1083	318-064	250 Ω	1/8 w	Prec	1%	
R1086	303-223	22 k	1 w		5%	
R1087	315-222	2.2 k	1/4 w		5%	
R1088	306-154	150 k	2 w			
R1089	315-103	10 k	1/4 w		5%	1
	318-074	11.8 k	1/8 w	Prec	1%	2-up
R1095	303-153	15 k	1 w		5%	
R1096	319-042	1 k	1/4 w	Prec	1%	
R1097	315-392	3.9 k	1/4 w		5%	
R1105	301-473	47 k	1/2 w		5%	
R1107	use 309-388	6 k	1/2 w	Prec	1%	
R1108	301-561	560 Ω	1/2 w		5%	
R1109	316-101	100 Ω	1/4 w			
R1113	315-101	100 Ω	1/4 w		5%	
R1115	301-102	1 k	1/2 w		5%	
R1116	316-101	100 Ω	1/4 w			

Resistors *(Cont'd.)*

Ckt. No.	Tektronix Part No.	Description				Model No.
R1119	316-102	1 k	¼ w			
R2082	303-164	160 k	1 w		5%	X4X
R2083	318-064	250 Ω	⅛ w	Prec	1%	
R2086	303-223	22 k	1 w		5%	
R2087	315-222	2.2 k	¼ w		5%	
R2088	306-154	150 k	2 w			
R2089	315-103	10 k	¼ w		5%	1
	318-074	11.8 k	⅛ w	Prec	1%	2-up
R2095	303-153	15 k	1 w		5%	
R2096	319-042	1 k	¼ w	Prec	1%	
R2097	315-392	3.9 k	¼ w		5%	
R2105	301-473	47 k	½ w		5%	
R2107	use 309-388	6 k	½ w	Prec	1%	
R2108	301-561	560 Ω	½ w		5%	
R2109	316-101	100 Ω	¼ w			
R2113	315-101	100 Ω	¼ w		5%	
R2115	301-102	1 k	½ w		5%	
R2116	316-101	100 Ω	¼ w			
R2119	316-102	1 k	¼ w			

Transistors

Q1084	151-015	2N1516
Q1094	151-015	2N1516
Q1104	151-015	2N1516
Q1113	151-056	T1483
Q2084	151-015	2N1516
Q2094	151-015	2N1516
Q2104	151-015	2N1516
Q2113	151-056	T1483

MEMORY (2 required) Series 3 (S/N 101-539)

	*605-005	Complete Board

Capacitors

C1121	281-580	470 pf	Cer	500 v	10%
C1122	283-026	.2 μf	Disc Type	25 v	
C1127	283-003	.01 μf	Disc Type	150 v	
C1128	283-026	.2 μf	Disc Type	25 v	
C1129	283-024	.1 μf	Disc Type	30 v	
C1132	use 285-007	160 pf	Glass	500 v	5%
C1138	281-504	10 pf	Cer	500 v	10%
C1140	283-024	.1 μf	Disc Type	30 v	
C1153	283-003	.01 μf	Disc Type	150 v	

Diodes

Ckt. No.	Tektronix Part No.	Description	Model No.
D1122	152-016	Zener RT6 6 v	
D1125	152-071	Germanium ED2007	
D1127	152-071	Germanium ED2007	
D1130 D1131	*152-083	Capacitance 0.6 pf up (1 pair)	
D1136	152-066	Silicon 1N3194 (or equal)	
D1140	152-064	Zener 10 v ¼ w 10%	
D1142	*152-026	Germanium Tek Spec	
D1143	152-008	Germanium	
D1144	152-004	Zener 1N707 6.2-8 v	

Resistors

R1120	306-104	100 k	2 w			
R1121	316-101	100 Ω	¼ w			
R1122	304-333	33 k	1 w			
R1123	318-034	2 k	⅛ w		Prec	1%
R1124	318-034	2 k	⅛ w		Prec	1%
R1125	use 311-343	1 k		Var		SMOOTHING BAL
R1127	318-045	3.92 k	⅛ w		Prec	1%
R1129	316-100	10 Ω	¼ w			
R1134	301-563	56 k	½ w			5%
R1135	315-101	100 Ω	¼ w			5%
R1138	301-473	47 k	½ w			5%
R1139	303-103	10 k	1 w			5%
R1140	315-103	10 k	¼ w			5%
R1144	303-153	15 k	1 w			5%
R1145	315-820	82 Ω	¼ w			5%
R1146	309-371	3.965 k	½ w		Prec	1%
R1150	309-243	193 k	½ w		Prec	1%
R1151	315-104	100 k	¼ w			5%
R1152	315-101	100 Ω	¼ w			5%
R1153	315-101	100 Ω	¼ w			5%
R1154	309-289	1.07 meg	½ w		Prec	1%
R1155	301-156	15 meg	½ w			5%
R1156	309-143	950 k	½ w		Prec	1%

Transformers

T1130	*120-255	Toroid 3T

Transistors

Q1134	use *153-511	2N1516	selected
Q1141	151-067	2N1143	

Electron Tubes

V1133	154-187	6DJ8

MEMORY (2 required) Series 8 (S/N 540-919)

Ckt. No.	Tektronix Part No.	Description					Model No.
	*605-010	Complete Board					
		Capacitors					
C1121	use 285-001	510 pf	Glass		300 v	1%	
C1122	283-026	.2 μf	Disc Type		25 v		
C1127	283-003	.01 μf	Disc Type		150 v		
C1128	283-026	.2 μf	Disc Type		25 v		
C1129	283-024	.1 μf	Disc Type		30 v		
C1132	use 285-000	160 pf	Glass		500 v	1%	
C1138	281-504	10 pf	Cer		500 v	10%	
C1140	283-024	.1 μf	Disc Type		30 v		
C1153	283-003	.01 μf	Disc Type		150 v		
		Diodes					
D1122	152-016	Zener RT6 6 v					
D1125	152-071	Germanium ED2007					
D1127	152-071	Germanium ED2007					
D1130 } D1131 }	*152-083	Capacitance 0.6 pf up (1 pair)					
D1136	152-066	Silicon 1N3194 (or equal)					
D1140	152-064	Zener 10 v ¼ w 10%					
D1142	*152-026	Germanium Tek Spec					
D1143	152-008	Germanium					
D1144	152-064	Zener 10 v ¼ w 10%					
		Resistors					
R1120	306-104	100 k	2 w				
R1121	316-101	100 Ω	¼ w				
R1122	304-333	33 k	1 w				
R1123	318-034	2 k	⅛ w		Prec	1%	
R1124	318-034	2 k	⅛ w		Prec	1%	
R1125	311-343	1 k		Var		SMOOTHING BAL	
R1127	318-045	3.92 k	⅛ w		Prec	1%	
R1129	316-100	10 Ω	¼ w				
R1134	301-563	56 k	½ w			5%	
R1135	315-101	100 Ω	¼ w			5%	
R1138	301-473	47 k	½ w			5%	
R1139	303-103	10 k	1 w			5%	
R1140	315-103	10 k	¼ w			5%	
R1143	316-683	68 k	¼ w				X2-up
R1144	303-153	15 k	1 w			5%	
R1145	315-820	82 Ω	¼ w			5%	
R1146	321-602	3.908 k	⅛ w		Prec	¼%	
R1150	321-605	186.2 k	⅛ w		Prec	¼%	
R1151	301-513	51 k	½ w			5%	
R1152	315-101	100 Ω	¼ w			5%	

Resistors *(Cont'd.)*

Ckt. No.	Tektronix Part No.	Description				Model No.
R1153	315-101	100 Ω	¼ w		5%	
R1154	323-602	107 k	½ w	Prec	¼%	
R1155	323-603	1.5 meg	½ w	Prec	¼%	
R1156	323-601	92 k	½ w	Prec	¼%	

Transformers

T1130	*120-255	Toroid 3T	

Transistors

Q1134	*153-511	2N1516	selected
Q1141	151-067	2N1143	

Electron Tubes

V1133	154-187	6DJ8

MEMORY (2 required) Series 11 (S/N 920-up)

Use *610-0110-00 Complete Board

Capacitors

C1121	use 285-001	510 pf	Glass	300 v	1%
C1122	283-026	.2 μf	Disc Type	25 v	
C1127	283-003	.01 μf	Disc Type	150 v	
C1128	283-026	.2 μf	Disc Type	25 v	
C1129	283-024	.1 μf	Disc Type	30 v	
C1132	use 285-000	160 pf	Glass	500 v	1%
C1138	281-504	10 pf	Cer	500 v	10%
C1140	283-024	.1 μf	Disc Type	30 v	
C1153	283-003	.01 μf	Disc Type	150 v	

Diodes

D1122	152-016	Zener RT6 6 v	
D1125	152-071	Germanium ED2007	
D1127	152-071	Germanium ED2007	
D1130 D1131	*152-083	Capacitance 0.6 pf up (1 pair)	1 & 2
D1130 D1131	*152-145	With Leads (1 pair) Ga As	3-up
D1136	152-066	Silicon 1N3194 (or equal)	
D1140	152-064	Zener 10 v ¼ w 10%	
D1142	152-026	Germanium Q6100	
D1143	152-008	Germanium T12G	
D1144	152-064	Zener 10 v ¼ w 10%	

Resistors

Ckt. No.	Tektronix Part No.	Description					Model No.
R1120	306-104	100 k	2 w				
R1121	316-101	100 Ω	¼ w				
R1122	304-333	33 k	1 w				
R1123	318-034	2 k	⅛ w		Prec	1%	
R1124	318-034	2 k	⅛ w		Prec	1%	
R1125	311-343	1 k		Var		SMOOTHING BAL	
R1127	318-045	3.92 k	⅛ w		Prec	1%	
R1129	316-100	10 Ω	¼ w				
R1130	309-058	2 Ω	½ w		Prec	1%	
R1134	301-563	56 k	½ w			5%	
R1135	315-101	100 Ω	¼ w			5%	
R1137	315-113	11 k	¼ w			5%	X6-up
R1138	301-473	47 k	½ w			5%	
R1139	303-103	10 k	1 w			5%	
R1140	315-103	10 k	¼ w			5%	
R1143	316-683	68 k	¼ w				
R1144	303-153	15 k	1 w			5%	
R1145	315-820	82 Ω	¼ w			5%	
R1146	321-602	3.908 k	⅛ w		Prec	¼%	
R1150	321-605	186.2 k	⅛ w		Prec	¼%	
R1151	301-513	51 k	½ w			5%	
R1152	315-101	100 Ω	¼ w			5%	
R1153	315-101	100 Ω	¼ w			5%	
R1154	323-602	107 k	½ w		Prec	¼%	
R1155	323-603	1.5 meg	½ w		Prec	¼%	
R1156	323-601	92 k	½ w		Prec	¼%	

Transformers

T1130	*120-255	Toroid 3T	

Transistors

Q1134	*153-511	2N1516	selected
Q1141	151-067	2N1143	

Electron Tubes

V1133	Use *157-102	7308 (Checked)

INVERTER Series 4 (S/N 101-539)

	*605-003	Complete Board

Diodes

Ckt. No.	Tektronix Part No.	Description	Model No.
D1165	152-025	Germanium 1N634	
D1166	152-025	Germanium 1N634	
D1167	152-004	Zener 1N707 6.2-8 v	
D2165	152-025	Germanium 1N634	
D2166	152-025	Germanium 1N634	
D2167	152-004	Zener 1N707 6.2-8 v	

Resistors

R1161	311-153	10 k		Var		A INVERTER ZERO
R1162	301-224	220 k	½ w			5%
R1163	309-100	10 k	½ w		Prec	1%
R1164	309-100	10 k	½ w		Prec	1%
R1165	301-752	7.5 k	½ w			5%
R1166	303-433	43 k	1 w			5%
R1167	304-334	330 k	1 w			
R1168	304-223	22 k	1 w			
R2161	311-153	10 k		Var		B INVERTER ZERO
R2162	301-224	220 k	½ w			5%
R2163	309-100	10 k	½ w		Prec	1%
R2164	309-100	10 k	½ w		Prec	1%
R2165	301-752	7.5 k	½ w			5%
R2166	303-433	43 k	1 w			5%
R2167	304-334	330 k	1 w			
R2168	304-223	22 k	1 w			

Transistors

Q1163	151-058	RT5204
Q1164	*151-054	Selected from 2N1754
Q2163	151-058	RT5204
Q2164	*151-054	Selected from 2N1754

INVERTER Series 9 (S/N 540-up)

Use *610-0093-00 Complete Board

Diodes

D1165	152-025	Germanium 1N634
D1166	152-025	Germanium 1N634
D1167	use 152-064	Zener 10 v ¼ w 10%
D2165	152-025	Germanium 1N634
D2166	152-025	Germanium 1N634
D2167	use 152-064	Zener 10 v ¼ w 10%

Resistors

Ckt. No.	Tektronix Part No.	Description					Model No.
R1161	311-153	10 k		Var		A INVERTER ZERO	
R1162	301-224	220 k	½ w			5%	
R1163	309-100	10 k	½ w		Prec	1%	
R1164	309-160	9.85 k	½ w		Prec	1%	
R1165	301-752	7.5 k	½ w			5%	
R1166	303-433	43 k	1 w			5%	
R1167	304-334	330 k	1 w				
R1168	304-223	22 k	1 w				
R2161	311-153	10 k		Var		B INVERTER ZERO	
R2162	301-224	220 k	½ w			5%	
R2163	309-100	10 k	½ w		Prec	1%	
R2164	309-160	9.85 k	½ w		Prec	1%	
R2165	301-752	7.5 k	½ w			5%	
R2166	303-433	43 k	1 w			5%	
R2167	304-334	330 k	1 w				
R2168	304-223	22 k	1 w				

Transistors

Q1163	151-058	RT5204
Q1164	*151-054	Selected from 2N1754
Q2163	151-058	RT5204
Q2164	*151-054	Selected from 2N1754

DUAL TRACE Series 5

Use *610-0090-00 Complete Board

Capacitors

C1176	283-003	.01 μf	Disc Type	150 v		X2X
C1181	283-004	.02 μf	Disc Type	150 v		X3-up
C1189	283-004	.02 μf	Disc Type	150 v		X3-up
C1190	283-003	.01 μf	Disc Type	150 v		1, 2X
C1191	281-542	18 pf	Cer	500 v	10%	X3-up
C1192	283-003	.01 μf	Disc Type	150 v		1, 2X
C2181	283-004	.02 μf	Disc Type	150 v		X3-up
C2186	283-003	.01 μf	Disc Type	150 v		1, 2X
C2189	283-004	.02 μf	Disc Type	150 v		X3-up
C2240	281-543	270 pf	Cer	500 v	10%	X3-up
C2241	use 283-027	.02 μf	Disc Type	30 v		1, 2X
C2243	281-523	100 pf	Cer	350 v		1, 2X
C2244	281-524	150 pf	Cer	500 v		1, 2X
C2246	281-542	18 pf	Cer	500 v	10%	X3-up
C2250	281-543	270 pf	Cer	500 v	10%	X3-up

Capacitors *(Cont'd.)*

Ckt. No.	Tektronix Part No.	Description				Model No.
C2251	285-624	.027 μf	PTM	100 v	10%	X3-up
C2253	281-523	100 pf	Cer	350 v		1, 2X
C2254	281-524	150 pf	Cer	500 v		1, 2X
C2256	281-542	18 pf	Cer	500 v	10%	X3-up
C2266	290-107	25 μf	EMT	25 v		X3-up
C2268	290-107	25 μf	EMT	25 v		X3-up

Diodes

D1182	152-065	Silicon HD5000	1, 2X
D1183	152-045	Silicon Selected 1N622A	1, 2X
D1184	*152-026	Germanium Tek Spec	1, 2X
D1186	152-071	Germanium ED2007	X3-up
D1187	152-071	Germanium ED2007	X3-up
D1192	152-076	Zener 3 v ¼ w 10%	1, 2X
D1193	152-071	Germanium ED2007	1, 2X
D1197	152-095	Silicon 1N625	X3-up
D1198	152-095	Silicon 1N625	X3-up
D2182	152-065	Silicon HD5000	1, 2X
D2183	*152-045	Silicon Selected 1N622A	1, 2X
D2184	*152-026	Germanium Tek Spec	1, 2X
D2186	152-071	Germanium ED2007	X3-up
D2187	152-071	Germanium ED2007	X3-up
D2242	*152-026	Germanium Tek Spec	1, 2X
D2244	152-071	Germanium ED2007	1, 2X
D2245	152-008	Germanium	X3-up
D2248	152-008	Germanium	X3-up
D2249	152-055	Zener 11 v ¼ w 5%	X3-up
D2251	152-016	Zener RT6 6 v	X3-up
D2252	*152-026	Germanium Tek Spec	1, 2X
D2254	152-071	Germanium ED2007	1, 2X
D2255	152-008	Germanium	X3-up
D2258	152-008	Germanium	X3-up
D2262	152-008	Germanium	X3-up

Inductors

L1189	*120-304	Toroid 3T	X3-up
L1195	119-021	Delay Line 1500 Ω .25 μsec	X3-up
L1197	119-021	Delay Line 1500 Ω .25 μsec	1, 2X
L2266	*120-266	Toroid 10T	X3-up
L2268	*120-266	Toroid 10T	X3-up

Resistors

R1175	319-053	1.82 k	¼ w	Prec	1%	1, 2X
R1176	315-183	18 k	¼ w		5%	1, 2X
R1181	316-563	56 k	¼ w			1, 2
	315-563	56 k	¼ w		5%	3-up
R1183	318-094	193 k	⅛ w	Prec	1%	X3-up

Resistors *(Cont'd.)*

Ckt. No.	Tektronix Part No.	Description					Model No.
R1184	315-103	10 k	¼ w			5%	1, 2
	319-053	1.82 k	¼ w		Prec	1%	3-up
R1185	309-429	16.5 k	½ w		Prec	1%	X3-up
R1189	318-105	5.62 k	⅛ w		Prec	1%	X3-up
R1190	316-101	100 Ω	¼ w				1, 2X
R1191	318-105	5.62 k	⅛ w		Prec	1%	1, 2
	324-415	205 k	1 w		Prec	¼%	3-up
R1192	315-392	3.9 k	¼ w			5%	1, 2
	309-387	3.32 k	½ w		Prec	1%	3-up
R1195	309-387	3.32 k	½ w		Prec	1%	1, 2
	315-272	2.7 k	¼ w			5%	3-up
R1196	304-224	220 k	1 w				1, 2X
R1197	309-387	3.32 k	½ w		Prec	1%	1, 2
	315-152	1.5 k	¼ w			5%	3-up
R1198	315-152	1.5 k	(nominal value)		selected		1, 2X
R2174	311-172	2.5 k		Var		B CAL	1, 2X
R2175	319-053	1.82 k	¼ w		Prec	1%	1, 2X
R2176	315-183	18 k	¼ w			5%	1, 2X
R2181	316-563	56 k	¼ w				1, 2
	315-563	56 k	¼ w			5%	3-up
R2182	311-172	2.5 k		Var		B CAL	X3-up
R2183	318-094	193 k	⅛ w		Prec	1%	X3-up
R2184	315-103	10 k	¼ w			5%	1, 2
	319-053	1.82 k	¼ w		Prec	1%	3-up
R2185	309-429	16.5 k	½ w		Prec	1%	X3-up
R2186	316-101	100 Ω	¼ w				1, 2X
R2189	319-031	1 meg	¼ w		Prec	1%	X3-up
R2195	315-623	62 k	¼ w			5%	X3-up
R2196	315-183	18 k	¼ w			5%	X3-up
R2199	315-363	36 k	¼ w			5%	X3-up
R2240	315-102	1 k	¼ w			5%	X3
	301-102	1 k	½ w			5%	4-up
R2241	315-222	2.2 k	¼ w			5%	1, 2X
R2242	315-301	300 Ω	¼ w			5%	1, 2
	315-223	22 k	¼ w			5%	3-up
R2243	315-682	6.8 k	¼ w			5%	1, 2
	315-103	10 k	¼ w			5%	3-up
R2244	315-332	3.3 k	¼ w			5%	1, 2X
R2245	315-223	22 k	¼ w			5%	1, 2X
R2246	315-103	10 k	¼ w			5%	1, 2
	315-273	27 k	¼ w			5%	3-up
R2247	315-224	220 k	¼ w			5%	X3-up
R2248	315-202	2 k	¼ w			5%	X3
R2248	301-102	1 k	½ w			5%	4-up
R2249	315-822	8.2 k	¼ w			5%	X3
R2250	315-102	1 k	¼ w			5%	X3
R2250	301-102	1 k	½ w			5%	4-up
R2251	315-222	2.2 k	¼ w			5%	1, 2X
R2252	315-301	300 Ω	¼ w			5%	1, 2
	315-223	22 k	¼ w			5%	3-up

Resistors *(Cont'd.)*

Ckt. No.	Tektronix Part No.		Description		Model No.
R2253	315-682	6.8 k	¼ w	5%	1, 2
	315-103	10 k	¼ w	5%	3-up
R2254	315-332	3.3 k	¼ w	5%	1, 2X
R2255	315-223	22 k	¼ w	5%	1, 2X
R2256	315-273	27 k	¼ w	5%	X3-up
R2257	315-224	220 k	¼ w	5%	X3-up
R2258	315-472	4.7 k	¼ w	5%	1, 2
	315-202	2 k	¼ w	5%	X3
	301-102	1 k	½ w	5%	4-up
R2261	315-332	3.3 k	¼ w	5%	X3-up
R2264	315-823	82 k	¼ w	5%	X3-up

Transistors

Ckt. No.	Tektronix Part No.	Description	Model No.
Q1174	151-015	2N1516	1, 2X
Q1184	151-076	2N2048	X3-up
Q2174	151-015	2N1516	1, 2X
Q2184	151-076	2N2048	X3-up
Q2245	151-015	2N1516	1, 2
	151-076	2N2048	3-up
Q2254	151-015	2N1516	1, 2X
Q2255	151-015	2N1516	1, 2
	151-076	2N2048	3-up
Q2264	151-015	2N1516	X3-up