INSTRUCTION MANUAL

Serial Number ____________

TYPE 4S2A

DUAL-TRACE SAMPLING UNIT

Tektronix, Inc.
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070-0536-00
766

WARRANTY

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

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

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

Specifications and price change privileges reserved.

CONTENTS

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

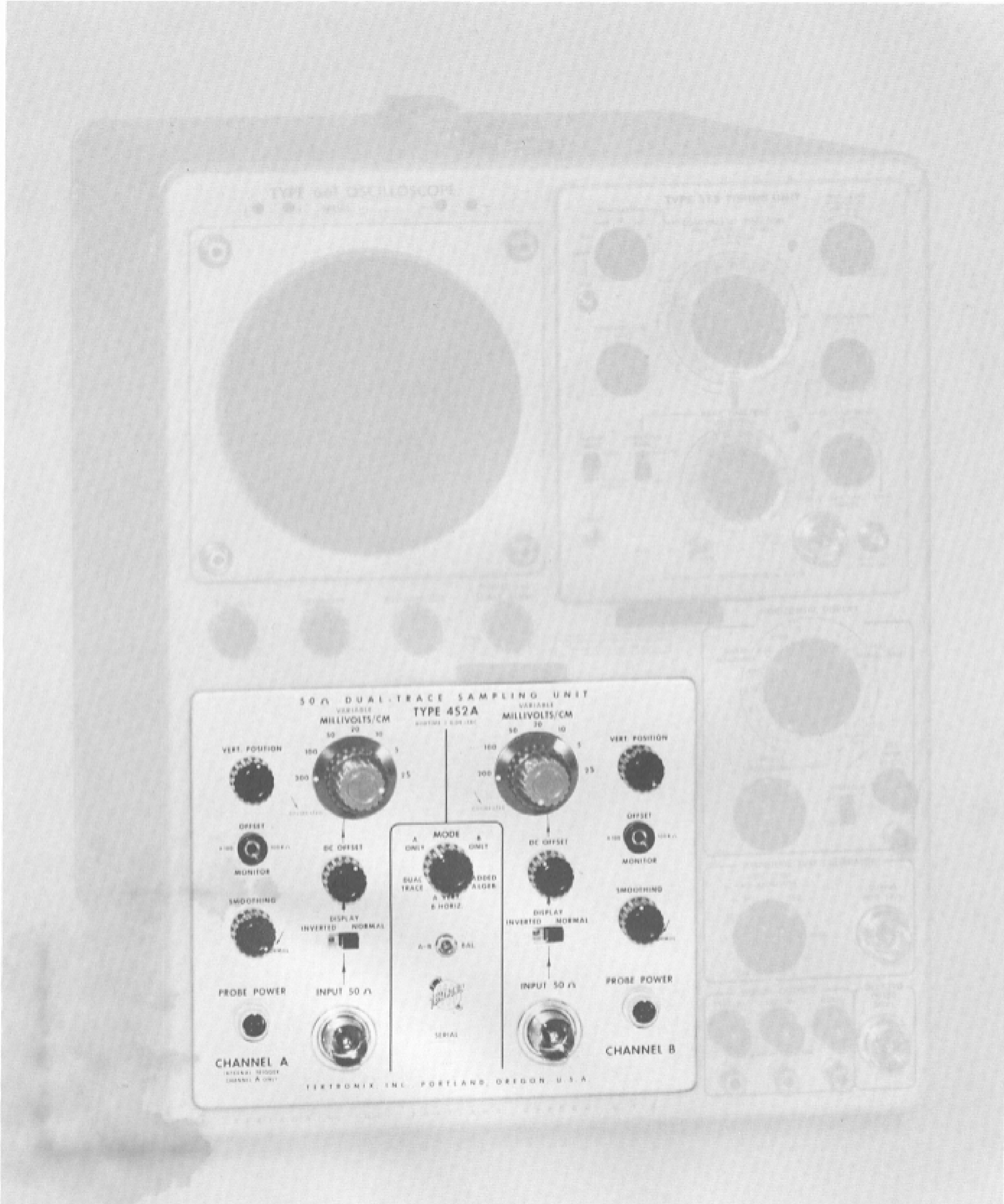


Fig. 1-1. Type 4S2A Dual-Trace Sampling Unit.

SECTION 1
CHARACTERISTICS

General Description

The Tektronix Type 4S2A 50 Ω Dual-Trace Sampling Unit is a vertical channel plug-in unit for the Type 661 Oscilloscope. When used in a sampling system consisting of the Type 661 Oscilloscope, Sampling Time Base Unit, and the Type 4S2A, the Type 4S2A enables the system to present accurate single- or dual-trace displays of repetitive high-speed signals with fractional nanosecond risetime. Such a system produces a CRT display by reconstructing the signal waveform from a series of single samples taken from many repetitions of the input signal. The Type 4S2A gives such a system an equivalent bandwidth of at least 3.9 GHz.

ELECTRICAL CHARACTERISTICS

The following characteristics indicated by footnote (1) apply over an ambient temperature range of 0° C to +50° C. Warm-up time for the given accuracy is 20 minutes.

Operating Modes

A Only, B Only, Dual Trace, Added Algebraically, and A Vertical—B Horizontal (X-Y) operation.

Rejection ratio for Added Algebraic mode is 40:1 or better when each channel is driven with a 1-volt flat-topped pulse and the deflection factor is 50 mV/cm, each channel.

Switching frequency in Dual Trace operation is approximately 50 kHz.

Deflection Factors

Calibrated steps of 2, 5, 10, 20, 50, 100, and 200 mV/cm. Accuracy[1] with the DISPLAY switch in the NORMAL position is ±2.5%; with the switch in the INVERTED position, accuracy is ±3%.

Risetime (T_r)

Risetime of the Type 4S2A is 90 ps or less, 10% to 90%.[2] Risetime and transient response of a randomly selected production-line unit are shown in Fig. 1-2. (Typical frequency response and VSWR curves are shown in Fig. 1-3.)

The displayed output of either or both channels can be presented either normally or inverted, premitting the addition or subtraction of dual-trace displays. This versatility is valuable in X-Y displays for observation of hysteresis loops, or for inverting the phase of signals into or out of an amplifier for phase comparison. Inverted operation can add an additional ½% error to the deflection factors.

[1]Performance requirement checked at the factory.

[2]T_r is somewhat dependent on ambient temperature. Adjustment of Bridge Volts Control may be necessary if operation at extremes of specified temperature range is required.

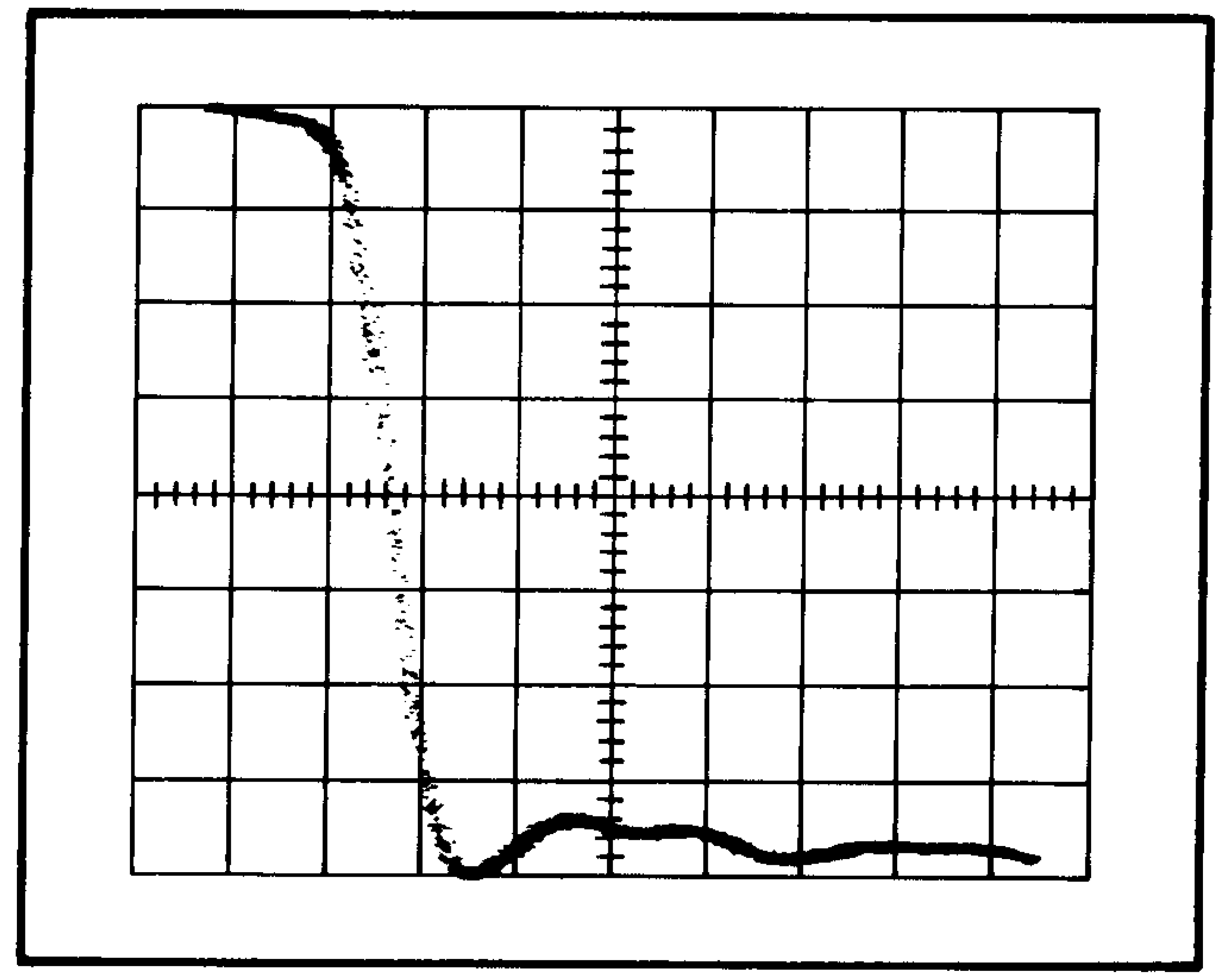


Fig. 1-2. Photograph showing risetime and transient response of the Type 4S2A. Horizontal scale 100 picoseconds/division.

Display Noise

At a deflection factor of 5 mV/cm, SMOOTHING control adjusted to unity dot transient response, MODE switch at A ONLY, B ONLY, or A VERT B HORIZ, 80% of the dots are within 4 mV peak to peak. With the MODE switch at DUAL TRACE or ADDED ALGEB, 80% of the dots are within 5 mV peak to peak. With the SMOOTHING control fully counterclockwise, 80% of the dots are within 2 mV peak to peak.

Smoothing

Each Channel SMOOTHING control permits reduction of random noise. The SMOOTHING control also permits adjustment of servo loop gain to exactly unity dot transient response (DTR).[3] At 200 mV/cm, the trace will not move more than 1.5 cm while rotating the SMOOTHING control.

Memory Drift

The sampling dot vertical stability is such that no drift is visible when triggering at a rate above about 150 Hz. At a triggering rate of 50 Hz, the dot drift does not exceed 0.2 cm.[1]

Co-Channel Time Coincidence

Dual-trace display of a fast-rise pulse will produce no more than a 20-picosecond time difference between channels.

[3]Setting the SMOOTHING control for a DTR <1 helps to reduce random noise effects when operating in equivalent time and at low deflection factors. When operating a sampling system in real time mode with a timing unit such as the Type 5T3, certain measurements require that the SMOOTHING control have sufficient range to permit the Type 4S2A DTR to be adjusted through unity.

DC Offset

The DC component of a signal can be offset up to ±1 volt (with a five-turn control) to bring a display back onto the CRT, or to make an incremental measurement.

Offset Monitoring

The voltage change at the front-panel OFFSET MONITOR jack is 100 times the voltage change (±1%) of the display produced by use of the DC OFFSET control.[1] The OFFSET MONITOR jack permits accurate measurement of DC voltage level changes.

Input Impedance

50 ohms ±1% at DC. Fig. 1-3 shows input VSWR to 5 GHz. Passive probes, cathode follower probes and a 1 megohm to 50 Ω probe adapter are available for higher input impedance at reduced sensitivity and/or bandwidth.

Probe Power

The two front-panel PROBE POWER connectors permit operation of Tektronix cathode-follower probes and accessory devices.

Input Coupling

DC coupled from the 50 Ω input connectors to the sampling bridges.

Dynamic Range

Input signals as high as ±1 volt can be viewed without overloading the system. Safe overload is ±5 VDC, or 10 volt peak-to-peak pulses if the duty factor is 50% or less.

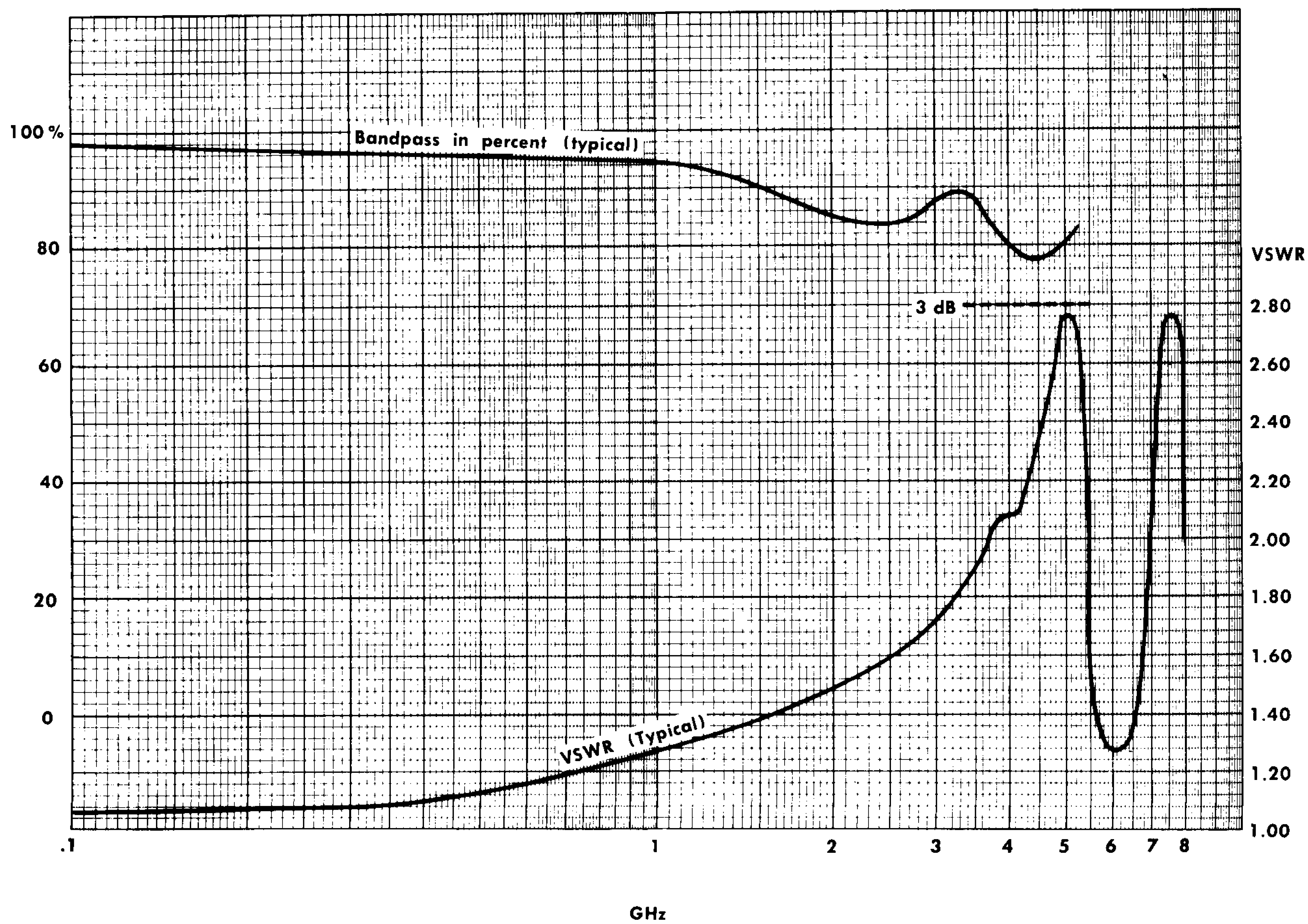


Fig. 1-3. Typical Type 4S2A VSWR and relative amplitude response to sine waves.

Triggering Output

Internal triggering takeoff from Channel A only. The amplitude of the trigger output to the time base unit is 0.1 × signal voltage. Risetime of the trigger pulse is less than 1 ns, 10% to 50%.

Signal Outputs to Type 661

The signal output voltages to the Type 661 are within 3% of a 1-volt signal applied to the input connectors when the deflection factor is 200 mV/cm (this 3% figure does not include any error that may be introduced between the output of the Type 4S2A and a reading obtained from the CRT display).

ENVIRONMENTAL CHARACTERISTICS

Temperature

Operating—0° C to +50° C.

Non-Operating— —40° C to +65° C.

Altitude

Operating—15,000 feet maximum

Non-Operating—50,000 feet maximum

MECHANICAL CHARACTERISTICS

Construction

Aluminum-alloy chassis with six plug-in circuit card assemblies. The front-panel is anodized and printed.

Forced-air cooling is provided by the fan in the Type 661, which means that the oscilloscope system should be operated with side panels in place. A constant temperature is important for proper operation of the instrument.

Dimensions

Height 7 inches, width 8½ inches, depth 14 inches.

Weight

9 pounds, 9 ounces.

STANDARD ACCESSORIES

Standard accessories supplied with the Type 4S2A are listed on the last pullout page at the rear of this manual. For optional accessories available for use with this instrument, see the current Tektronix, Inc. catalog.

NOTES

SECTION 2
OPERATING INSTRUCTIONS

Introduction

This section of the manual provides the basic information required for operation of the Type 4S2A. The basic equivalent-time sampling process is discussed first for the benefit of those unfamiliar with sampling techniques, then operating instructions are given to acquaint the operator with the Type 4S2A.

CAUTION

Turn off the oscilloscope power before inserting or removing plug-in units.

BASIC SAMPLING TECHNIQUES

Sampling oscilloscopes are designed primarily to be used for viewing high-frequency or fast-rise repetitive waveforms. Most modern sampling systems accomplish this by taking samples from each of many repetitions of a cycle of the input signal, then reconstructing the waveform in equivalent time on the CRT screen. To recreate a repetitive signal using the sampling technique, samples must be taken over the portion of the signal that it is desired to measure or display.

Starting with a basic sampling system such as that shown in Fig. 2-1, the trigger circuit opens the sampling gate in the vertical system and allows a sample of the incoming signal to pass through. Such a system will sample only a fixed point on a waveform. Likewise, the system cannot take a sample on the leading edge of the signal because of the finite time delay in the trigger circuit. However, if a delay is introduced into the input circuit of the vertical system, the trigger circuit will have time to open the sampling gate in the vertical system just as the leading edge of the incoming signal reaches the gate. Fig. 2-2 shows a sampling system block diagram with a delay line added to the vertical system.

Although the system represented in Fig. 2-2 could sample an incoming signal at one point on its leading edge, it could not sample the signal over its entire duration. Instead, it would consistently sample the same point on the signal each time the system was triggered. In order to sample over the entire duration of the signal, a stepping delay must be introduced so that samples can be taken at successively later and later points on the signal.

The delay circuit generally used in sampling systems produces an electronic delay by a method called trigger slewing (see Fig. 2-3). When the selected trigger point of the input signal occurs, the trigger circuit generates a trigger pulse, which is applied to a fast-ramp circuit. The fast-ramp circuit initiates a fast-falling voltage ramp, which is applied to one input of a comparator. The other input to the comparator is a staircase voltage from a staircase generator. Each time the fast-ramp voltage falls to the level of the staircase voltage, the comparator activates the slewed pulse generator. The slewed pulse generator generates a pulse which opens the sampling gate, taking a sample, and at the same time steps the staircase voltage one increment. On the next triggering event, the fast-ramp voltage must fall to the new level of the staircase voltage before a comparison can be made, thus increasing the delay between the triggering event and the generation of the slewed pulse. The length of time the slewed pulse is delayed from the triggering event depends upon the slope of the fast ramp and the level at which the staircase voltage is resting. Thus, in a stepped fashion, the sampling gate is opened at successively later instants with respect to each initiating trigger.

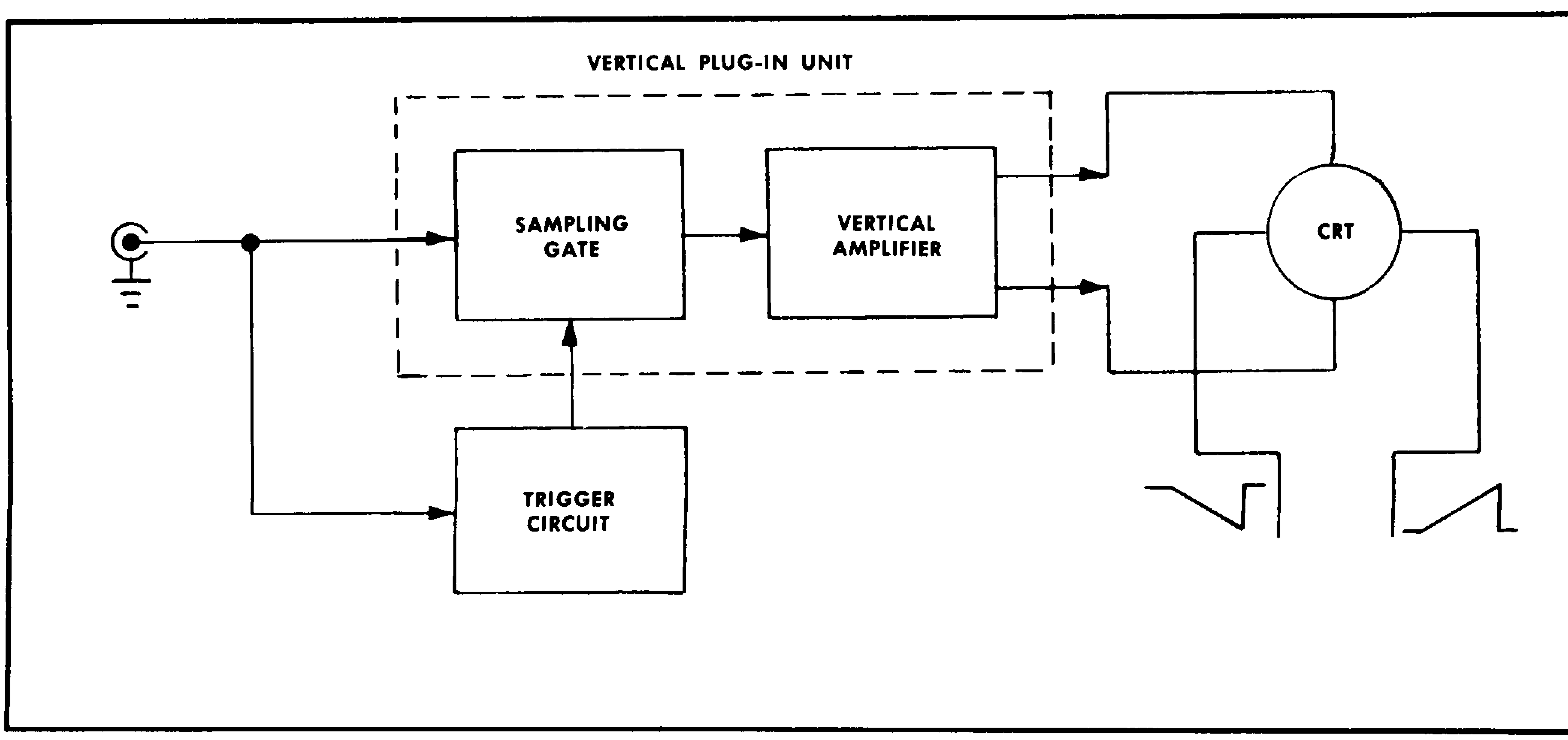


Fig. 2-1. Circuit required for sampling at a fixed point on an input signal.

Horizontal deflection voltages in a sampling system must move the spot on the CRT in step with the slewed pulse. Horizontal deflection voltage and a slewing voltage to the comparator can be obtained from manual controls in many instruments, but are normally obtained from the staircase generator, which increases the staircase voltage after each sample is taken, as previously explained.

In the discussion of a sampling system, the terms "equivalent time" and "real time" are often used. The basic difference between these two techniques is the number of cycles of input signal required to present a single sweep or display on the face of the CRT. In equivalent-time sampling the CRT display is built up by taking one sample from each of many repetitions of a cycle or other event in the input signal; in real-time sampling the CRT display is built up of many samples taken from one cycle or event in the input signal.

Equivalent-Time Sampling

The equivalent-time portions of the sampling system are shown in Fig. 2-3. The vertical channel uses an input bridge that can take quick samples of the input signal, and a memory circuit that remembers the level of each sample until another sample is taken. The horizontal sweep is produced by the staircase voltage which advances one step each time a new sample is to be displayed. In triggered operation, one excursion of the input triggering signal actuates the trigger circuit, which then initiates one cycle of the sampling process to produce one dot of the CRT display. Each displayed sample requires a separate triggering event.

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

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

The sampling operation is triggered each time at the same initial point on the triggering waveform, but the sample is taken progressively later on the waveform, due to the increasing delay between the triggering event and the time at which the slewed pulse opens the sampling gate. In an equivalent-time display, no two samples are taken on the same cycle of the input waveform, though if the waveform is of a very high frequency, several cycles may occur between samples, due to the inherent recovery time (and resultant count-down) of the trigger circuit.

Real Time Sampling

The primary advantage of real-time sampling is that it extends the operation of the oscilloscope system down to low frequencies without having to use additional plug-in units. Moreover, single events can be clearly displayed by real-time

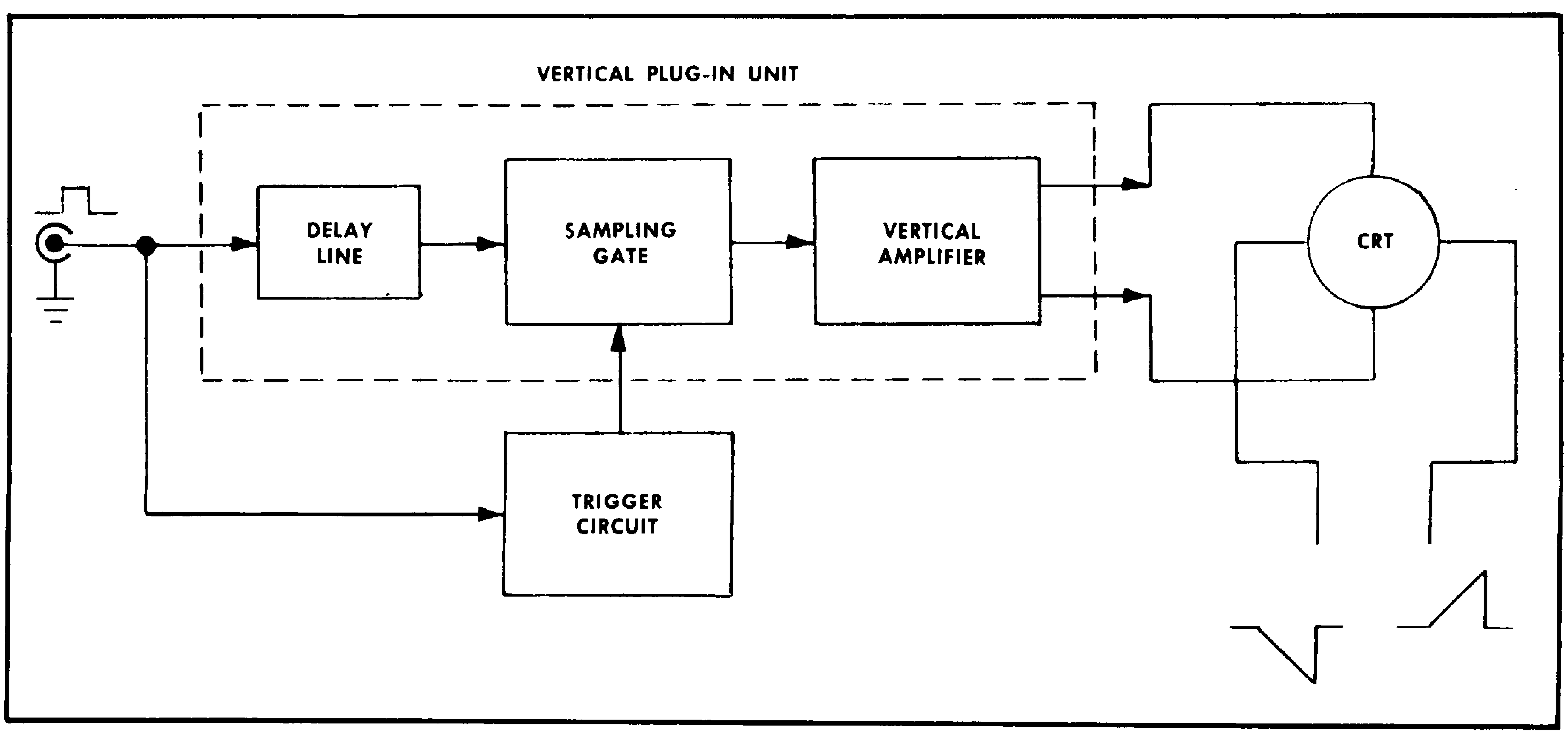


Fig. 2-2. Delay line added to the circuit of Fig. 2-1 so sampling takes place on the leading edge of the input signal.

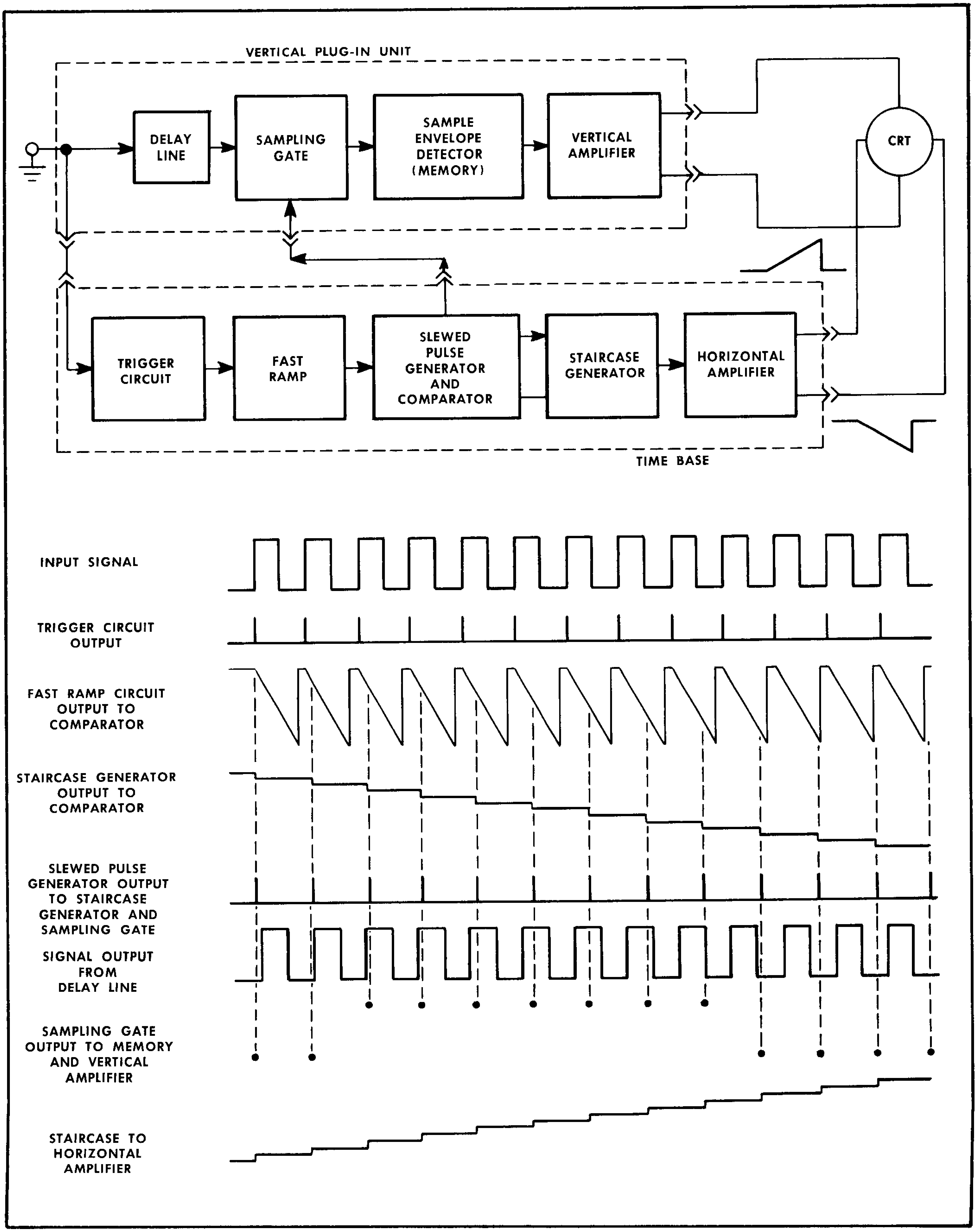


Fig. 2-3. Block diagram and significant waveforms of a complete sampling system.

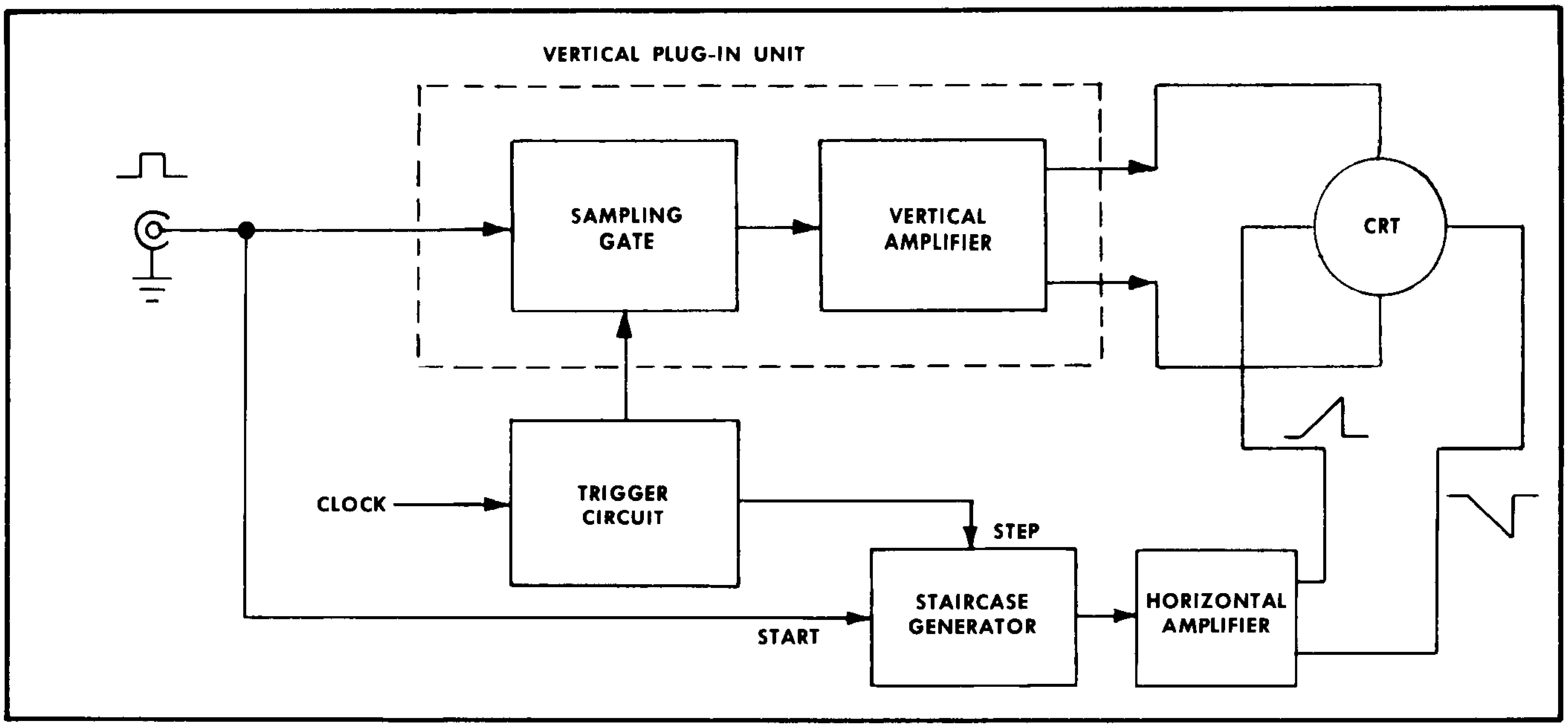


Fig. 2-4. Block diagram of typical real-time sampling system.

sampling, whereas a repetitive signal is required for equivalent-time sampling. However, the range of sweep rates available for use in real-time sampling is from the slowest rate available with the oscilloscope to about 0.1 ms/cm. At the crossover point from real-time to equivalent time samplaing, the display dots begin to have significant horizontal dimension, due to their duration in real time.

Fig. 2-4 shows the block diagram and Fig. 2-5 the waveforms of a typical real-time sampling system. The sampling operation performed by the sampling unit is identical to that performed in equivalent time, and some of the sweep and triggering functions remain the same. In real-time mode, however, the sampling process and the staircase advance are not initiated by the input signal, but rather by a real-time clock circuit or by free-running the trigger circuit. Both methods require special circuitry to provide a gate circuit with which the clock pulses or free-running trigger pulses are gated on at the proper instant to obtain a stable display. Trigger pulses to operate the gate circuit are obtained from internal circuitry in some systems; in other cases they are externally applied.

In real-time sampling, sweep rates are generally quite slow ($\leq$1 ms/div), and samples are taken at a rapid rate continuously along the waveform as contrasted with equivalent-time sampling where one sample is taken from each of a series of repetitive waveforms. The CRT display is thus made up of a series of dots that actually follow the changes of the input waveform. Only one trigger event is required per sweep (as in a conventional non-sampling oscilloscope), rather than one trigger per sample as in equivalent-time sampling.

OPERATION OF THE TYPE 4S2A

General Information

The Type 4S2A is designed to operate with the Tektronix Type 661 indicator oscilloscope and a sampling time base unit such as the Type 5T3. By using equivalent-time sampling techniques, the sampling oscilloscope system described is capable of viewing repetitive waveforms with risetimes in the 90 picosecond range or frequencies up to 3.5 GHz or more. The equivalent time display is produced by taking one sample from each of many cycles of the waveform and reconstructing the waveform on the CRT screen. A bright CRT display is produced, since each displayed dot is momentarily stationary. The system described also permits the use of real-time sampling techniques, where the display is constructed by taking many samples from each repetition of the waveform or triggering event.

When operated as part of a sampling system with the Type 661 Oscilloscope, the Type 4S2A is a dual-channel, servo-type, slide-back sampling unit. Each channel contains a sampling gate and rachet memory. The sampling principle is essentially that of an error signal device that corrects a memory output voltage each time a sample is taken. An internal trigger pick-off (Channel A only) provides trigger signals to the associated timing unit.

A minimum deflection factor of about $^2/_3$ mV/cm permits viewing of low-level signals or portions of signals with a peak-to-peak value up to 1 volt. High resolution amplitude measurements can be made of any waveform, or any part of a waveform, through the use of the $\pm$1-volt DC OFFSET controls. Front-panel terminals permit voltmeter measurements of the offset voltage, at 100 times the internal $\pm$1-volt maximum signal offset value.

At minimum deflection factors, random noise can be reduced by the use of the SMOOTHING controls. Smoothing does not significantly affect the display risetime, but will reduce noise if each sample taken represents only a small increment of the total signal amplitude.

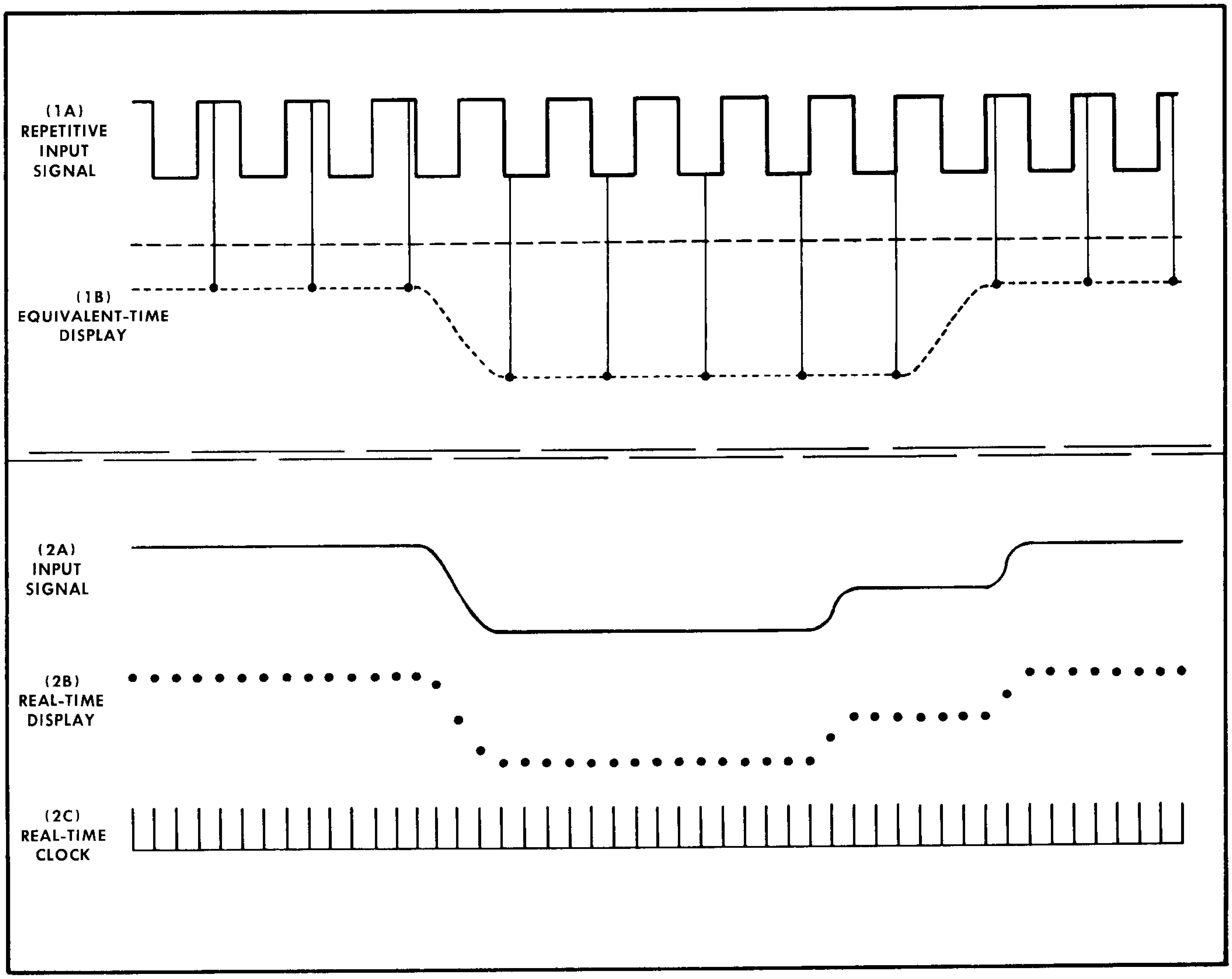


Fig 2-5. Comparison between sampling equivalent-time and real-time adapter.

Functions of Front-Panel Controls and Connectors

All controls and connectors required for the normal operation of the Type 4S2A are located on the front panel of the unit (see Fig. 2-6). To make full use of the capabilities of the instrument, the operator should be familiar with the function and use of each of these controls and connectors. Brief descriptions are presented in the following tabulation and further information, if necessary, is included later in this section under an appropriate heading. The nature of the input signal and the display desired will determine the setting of the controls.

MODE Switch — This switch selects one of five operational modes as follows:

A ONLY; Only Channel A is displayed

B ONLY; Only Channel B is displayed

DUAL-TRACE; The signal outputs of the two channels time share the display, the switching rate being about 50 kHz.

A VERT B HORIZ; With the Type 661 Sweep Magnifier at ×1, Channel A provides the vertical deflection and Channel B provides the horizontal deflection. This mode provides X-Y operation at full bandwidth.

ADDED ALGEB; Both channels are combined to display the algebraic sum or difference of two signals as a single trace.

VERT POSITION Controls — These controls provide about 10 cm of vertical trace positioning.

MILLIVOLTS/CM Switches — These controls permit selection of the desired vertical deflection factor. For example, with the MILLIVOLTS/CM switch at 100, each major division of vertical deflection corresponds to 100 millivolts of applied signal.

VARIABLE Controls — The three-to-one range uncalibrated VARIABLE controls make possible a decreased

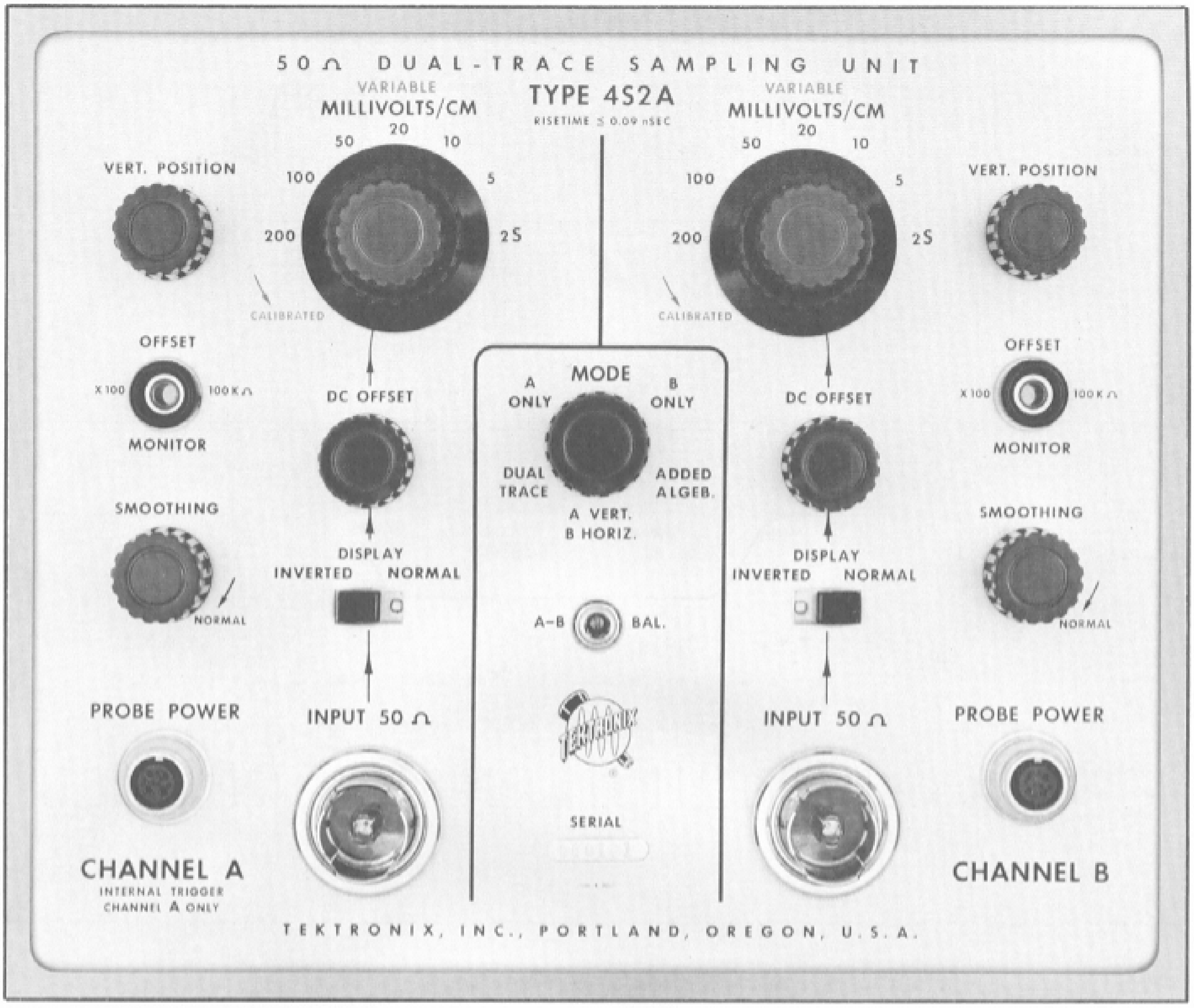


Fig. 2-6. Type 4S2A front-panel controls and connectors.

deflection factor at each position of their associated MILLIVOLTS/CM switch. These controls decrease the minimum deflection factor of each channel to about 2/3 millivolt/cm.

SMOOTHING Controls — These are gain controls in the servo amplifiers that permit reduction of random noise.

NOTE

Time and amplitude noise may be objectionable when operating at minimum deflection factors or maximum sweep rates. This is important when making documentation photographs. The SMOOTHING control reduces the loop gain of the automatic slideback feed-back system, thereby reducing random noise. (See Use of The Smoothing Control on page 2-8, this section.)

DC OFFSET Controls — These controls apply internal signal offset voltages of —1 to +1 volt. They can be used to cancel the DC components of a signal and permit the viewing of small AC components. Also, chosen portions of a waveform can be kept relatively fixed on the face of the CRT as the deflection factor is changed. By monitoring the voltage at the OFFSET MONITOR jacks, highly accurately display voltage-difference measurements can be made (see Use of The DC OFFSET Control Page 2-8, this section).

OFFSET MONITOR Jacks — The voltages at these jacks are 100 times the offset voltages applied to the vertical signals. By monitoring these jacks and using the DC OFFSET controls, accurate voltage-difference measurements of all or part of the displayed signals can be made.

DISPLAY Switches — When these switches are in the NORMAL position, the CRT display has the same polarity as the applied signal (+ up and

	— down). By placing one DISPLAY switch at NORMAL, the other at INVERTED, and the MODE switch at ADDED ALGEB, the difference of two signals can be presented as a single trace.
INPUT 50 Ω Connectors	These are 50 Ω GR Type 874 connectors to which the input signals are applied. Each channel has its own 50 Ω termination, sampling bridge, and feedback system.
PROBE POWER Jacks	These jacks provide heater and plate power for Tektronix cathode follower probes and other accessories.
A-B BAL	This is a screwdriver adjustment of Channel A gain. (Channel B gain adjustment is internal.) The A-B BAL control permits the gain of Channel A to be adjusted ±10% to equal the Channel B gain. This control is useful when making common mode and/or differential measurements.

Auxiliary Signal Outputs

The Type 4S2A has two auxiliary output signal connections (in addition to the regular vertical signals to the CRT). The two outputs are connected internally to the Type 661 front panel and are available at the connectors labeled SIGNAL OUTPUTS, VERT A and VERT B, both at 200 mV/cm through 10 kΩ. External loading of the signal output leads does not disturb normal sampling operations or the CRT display. The two auxiliary outputs are for use by external analog paper recorders or oscilloscope monitors.

First Time Operation

Since the Type 4S2A 50 Ω Dual-Trace Sampling Unit is normally used as part of a complete sampling system, it is necessary that the operator be familiar with the operating instructions for the other units of the system.

CAUTION

Turn off oscilloscope power before inserting or removing plug-in units.

Installing and Removing the Type 4S2A. With the Type 661 power off, begin plug-in insertion by placing the gray locking latch perpendicular to the oscilloscope front panel, then push the Type 4S2A as far into the cell as possible. Move the locking latch flush to the panel. This locks the plug-in in place.

To remove the plug-in, first turn off the power, move the gray locking latch perpendicular to the front panel, then withdraw the unit.

Familiarization. The first 6 steps of the following procedure describe setting up a sampling system consisting of a Type 661 Oscilloscope, 5T3 Timing Unit, and 4S2A 50 Ω Dual-Trace Sampling Unit to obtain a CRT display. The remaining steps of the procedure are given to demonstrate the basic operation of the Type 4S2A front-panel controls. If the operator is not already familiar with the operation of the Type 661 Oscilloscope and Type 5T3 Timing Unit, he should read the First Time Operation portions of the manuals for these instruments before proceeding.

1. With the Type 661 Oscilloscope power turned off, insert the Type 4S2A into the plug-in compartment.

2. Set the oscilloscope Intensity control counterclockwise.

3. Connect a 50 Ω cable with GR connectors between the oscilloscope Amplitude/Time calibrator Output Into 50 Ω connector and the Type 4S2A CHANNEL A INPUT 50 Ω connector.

4. Set controls as follows:

Type 661

Horizontal Display	Sweep Magnifier ×1
Position and Vernier	Centered
Amplitude/Time Calibrator	1000 mV Amplitude, 1 μSEC/Cycle
Intensity	Counterclockwise
Focus and Astigmatism	Centered

Type 5T3

Equivalent Time/Cm	.2 μSEC (Magnifier engaged with Time Position Range)
Equivalent Time/Cm Variable	Cal (counterclockwise at detent)
Equivalent Time Samples/Cm	20
Time Position	Clockwise
Time Position Fine	Centered
Sweep Mode	Norm
Real Time/Cm	.5 mSEC
Real Time/Cm Variable	Cal (counterclockwise at detent)
Real Time Sampling Rate	100 kc
Triggering Level	Clockwise
Stability or UHF Sync	Clockwise (but not at Auto Recovery detent)
Trigger Source	FREE RUN
Slope	+
External Trigger Mode	1 MΩ AC

Type 4S2A

MILLIVOLTS/CM	200
MILLIVOLTS/CM VARIABLE	CALIBRATED
Mode	A ONLY
VERT POSITION	Centered
DISPLAY	NORMAL
DC OFFSET	Centered (2.5 turns)
SMOOTHING	NORMAL

5. Turn on the oscilloscope power and allow 2 to 3 minutes of warm-up time.

6. Turn the oscilloscope Intensity control clockwise for normal trace intensity.

7. Turn the Timing Unit trigger source switch to INT and adjust the triggering level and stability controls for a stable, triggered display.

8. Adjust the oscilloscope focus and astigmatism controls for the smallest dots possible, with equal horizontal and vertical dimensions of the dots.

9. Adjust the oscilloscope horizontal position controls so the trace strats at the left edge of the graticule.

10. Adjust the Type 4S2A DC OFFSET and VERT POSITION controls to position the trace near the CRT horizontal center line. Switch the DISPLAY switch back and forth between INVERTED and NORMAL while readjusting the DC OFFSET and VERT POSITION controls until the trace does not shift vertically when the DISPLAY switch is switched back and forth.

11. Set the oscilloscope calibrator mV Amplitude control to 10 and the Type 4S2A MILLIVOLTS/CM control to 5. Recenter the display with the VERT POSITION and DC OFFSET controls. Adjust the Type 5T3 triggering level control for a stable display.

12. Turn the Type 5T3 Samples/Cm to 5 and the Type 4S2A SMOOTHING control fully counterclockwise. Notice the decrease in display amplitude, due to the combination of full smoothing and low dot density. This illustrates the need for a relatively high dot density when smoothing is used. However, the use of the SMOOTHING control permits reduction of display noise.

13. Return the MILLIVOLTS/CM switch to 200 and the mV Amplitude switch to 1000. Center the trace and obtain a stable triggered display.

14. Insert a 10× attenuator in the signal path and readjust the triggering controls for a stable display.

15. Set the VERT POSITION control to midrange.

16. Center the trace with the DC OFFSET control.

17. Turn the VERT POSITION control through its range of rotation. The overall range of the control is more than 10 cm, thus positioning the display off-screen both upward and downward. Leave the VERT POSITION control at midrange.

18. Turn the DC OFFSET control fully counterclockwise, then fully clockwise (the knob is designed to slip when the control reaches the end of its range). Notice that the positioning capability of the control is more than ±5 cm, representing ±1 volt at this 200 mV/cm deflection factor.

19. Set the MILLIVOLTS/CM switch to 20. Turn the DC OFFSET control and notice that the display positioning capability has increased, since at this deflection factor the ±1 volt offset provides ±50 cm of positioning. (At 2 mV/cm the positioning range is ±500 cm.)

20. Place a GR 874 T connector on the cable from the oscilloscope's Amplitude/Time calibrator. Connect two cables of identical electrical length to the T connector and apply the calibrator signal to both channels of the 4S2A.

21. Turn the MODE switch to DUAL TRACE and obtain a dual trace display.

22. Turn the MODE switch to ADDED ALGEB. Note the addition or subtraction of the two inputs as either DISPLAY switch is switched back and forth between its two positions.

23. Turn the MODE switch to A VERT B HORIZ. Using the Channel A VERT POSITION control and either the Channel B DC OFFSET control or the Type 661 (horizontal) POSITION control, center the display both vertically and horizontally. If the two input cables are electrically identical, the display should be a straight line running diagonally across the screen. If the two cables are not identical, or if there is unequal phase shift in the two channels, the display will be an ellipse.

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 significant, the SMOOTHING control is not substantially affecting the dot transient response. Fig. 2-7 shows the advantage of using the SMOOTHING control when observing low-level signals.

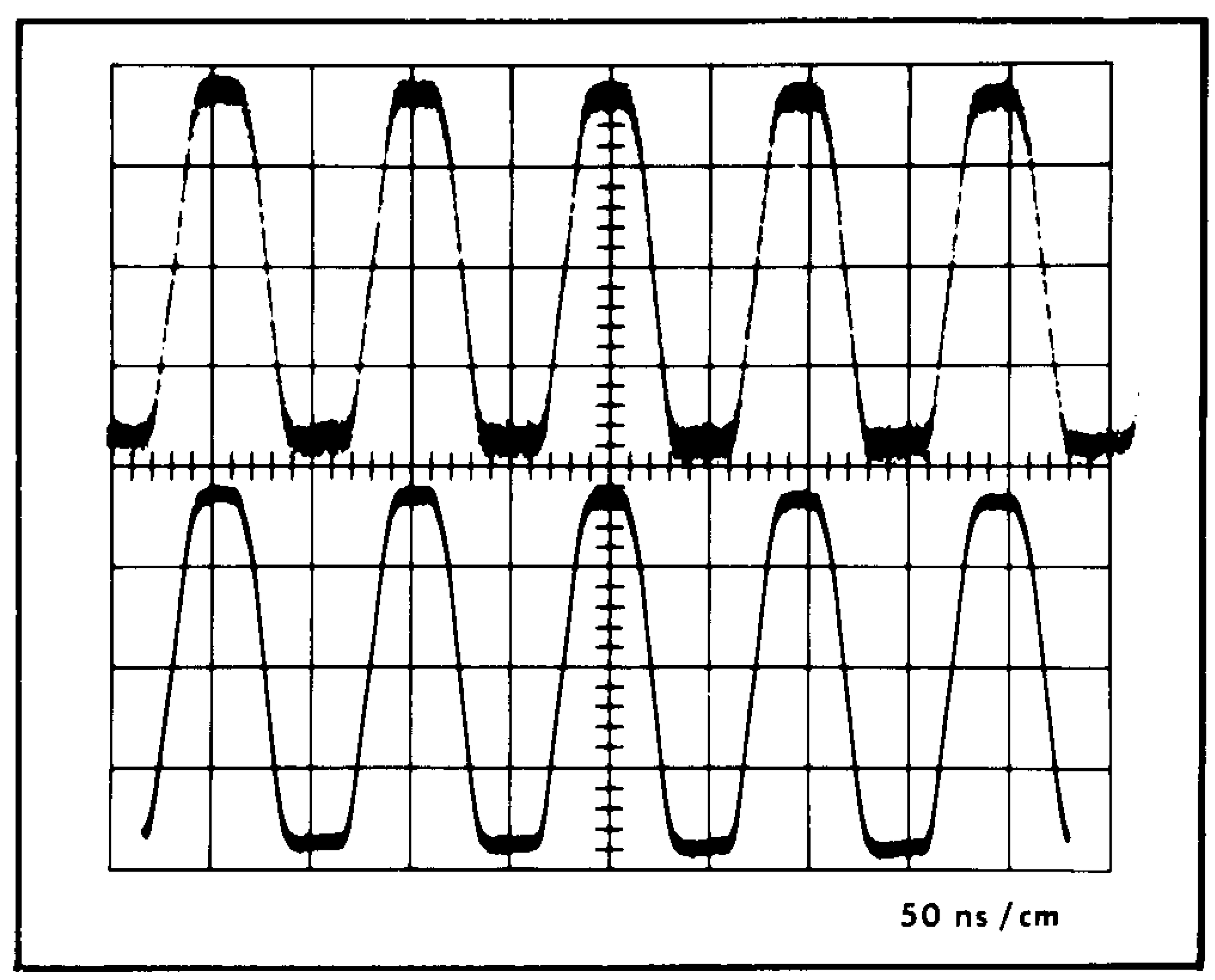


Fig. 2-7. 10 mV 10 MHz calibrator signal. Upper trace, normal SMOOTHING. Lower trace, full SMOOTHING.

Use of the DC Offset Control

The DC OFFSET control for each channel of the Type 4S2A 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 of 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 center horizontal line.

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. 2-8. Use only the VERT POSITION controls for moving the display vertically on the CRT screen.

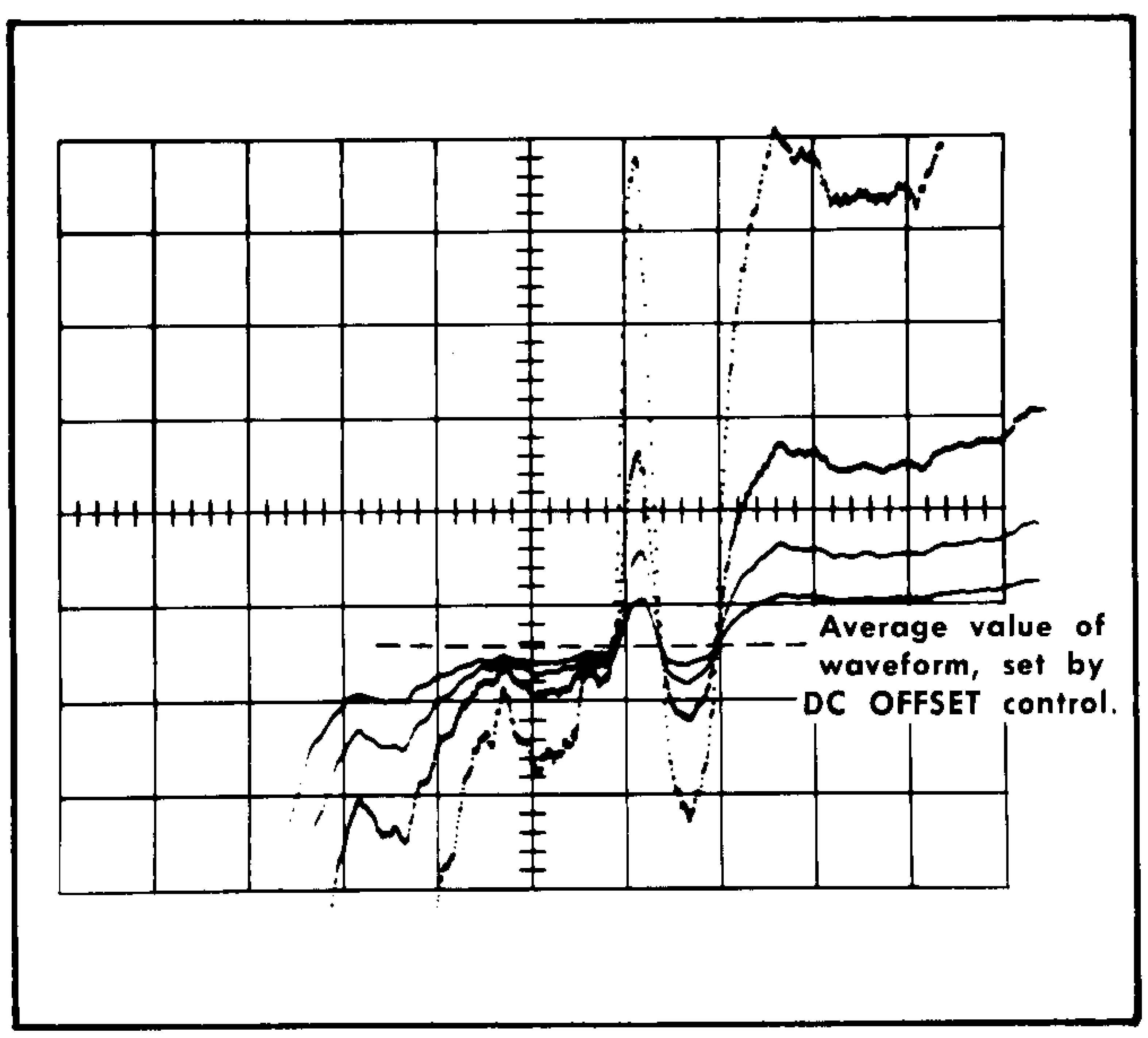


Fig. 2-8. Display of Delayed Pulse output held stable at the level of the dashed line through use of the DC OFFSET control.

CONNECTING THE INPUT SIGNAL

When connecting the signal from the source to the Type 4S2A, many factors must be taken into consideration. These factors include loading of the source, signal losses in the cables, time delay, coupling and attenuating the signal, and matching impedances. This portion of the manual discusses these factors with respect to the vertical input signal.

CAUTION

Signal level at the input connectors must not exceed the values listed under Dynamic Range on Page 1-2.

General Considerations

The Type 4S2A is designed with 50-ohm transmission line input circuits. The signal to be displayed may be connected to either INPUT 50 Ω connector. Both are GR 874, 50 ohm connectors and should be mated to a 50-ohm cable with the same type connector.

The 50-ohm input circuits permit the input terminals to be extended a reasonable distance through 50-ohm cables while maintaining the same input characteristics. A 50-ohm signal source can drive a 50-ohm cable directly for a distance of several feet without significant loss; however, the use of overly long cables should be avoided. If it is necessary to use other than 50-ohm cables, suitable matching devices should be used to couple between the cables or inputs that have different characteristic impedances.

Another factor to be considered is the signal velocity of propagation within the coaxial cables. This becomes important when making time-difference measurements between two signals in a dual-trace or X-Y operation. The two signals should travel through coaxial cables which have identical losses and delay times in order to preserve their time and amplitude relationships.

For relatively high-impedance measurements of nanosecond signals, special passive or cathode-follower signal probes are available for use with the Type 4S2A Sampling Unit. Some of these probes are described in the following paragraphs.

Passive Probes

The Tektronix P6034 10× Probe and the P6035 100× Probe are moderate-resistance passive probes designed for use with 50-ohm systems. 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 MHz. Momentary voltage peaks up to 500 volts are permissible at low frequencies, but voltage derating is required at higher frequencies. Characteristic data is given in the probe instruction manuals.

The P6034 10× Probe places 500 ohms resistance and less than 0.8 pF capacitance in parallel with the signal source at 3.5 GHz. Risetime is 100 ps or less (10% to 90%). At 1 GHz the input resistance is about 300 ohms and the capacitive reactance is about 450 ohms.

The P6035 100× Probe places 5 kΩ resistance and less than 0.7 pF capacitance in parallel with the signal source at low frequencies. Bandwidth of the probe is DC to approximately 1.5 GHz. Risetime is 200 ps or less (10% to 90%). At 1 GHz the input resistance is about 2 kΩ and the capacitive reactance is about 450 Ω.

The P6026 Passive Probe, also designed for use with 50-ohm systems, has a bandwidth of DC to approximately 600 MHz when DC-coupled, and a risetime of 600 ps or less. The probe consists of a coaxial cable, connectors, AC-coupled and DC-coupled 50-ohm terminations, and seven attenuator heads with attenuation factors from 5 to 5000. One of the 50-ohm terminations must be used with the attenuators in order to attain the stated attenuation. The various heads cannot be stacked to obtain other values of attenuation.

Cathode-Follower Probes

The Tektronix P6032 Cathode-Follower Probe is a high-impedance, high-frequency probe for Tektronix sampling systems. Bandwidth is DC to approximately 850 MHz and risetime is 400 ps or less. Seven attenuator heads are provided, with attenuation factors from 10× to 1000× for the combination of probe and attenuator. Input resistance is 10 megohms at DC. The parallel capacitance ranges from 1.3 pF to 3.6 pF, depending on the attenuator head used. At 1 GHz, the capacitive reactance is about 100 ohms and the input resistance is about 100 ohms for the 10× attenuator and 2 kilohms for the 1000× attenuator.

The advantage of the cathode-follower probe is the high input resistance and low capaitive loading at moderately high frequencies. Dynamic characteristic data is given in the probe instruction manual.

Type 282 Probe Adapter

The Type 282 Probe Adapter (Tektronix Part No. 015-0074-00) is designed to permit the use of high-impedance probes such as the P6011 with 50-ohm sampling systems. System risetime is slower when using a high-impedance probe and the Type 282, but the input impedance is raised to the megohm range. Power for the Type 282 is taken from the 4S2A front-panel Probe Power connector.

Built-In Probes

Another 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. When the circuit is not being tested, a 50-ohm terminating resistor can be substituted for the test cable. If it is not convenient to build a permanent 50-ohm test point, an external coupling circuit (which may be considered a probe) can be attached to the circuit.

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 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 bandwidth.

Fig. 2-9 shows three coupling methods. In the parallel method (Fig. 2-9A), a resistor (R_s) is connected in series with the 50 Ω input cable to the Type 4S2A. $R_s + 50$ ohms is then placed across the impedance in the circuit under test. A reasonable maximum circuit loading might be when the total resistance of R_s plus the 50-ohm input of the Type 4S2A is 5 times the impedance in the device (R_L in parallel with Z_o), requiring only 20% correction. The ground lead must be very short. The physical position of R_s affects the fidelity of the coupling. This method usually requires use of an amplitude correction factor to the display.

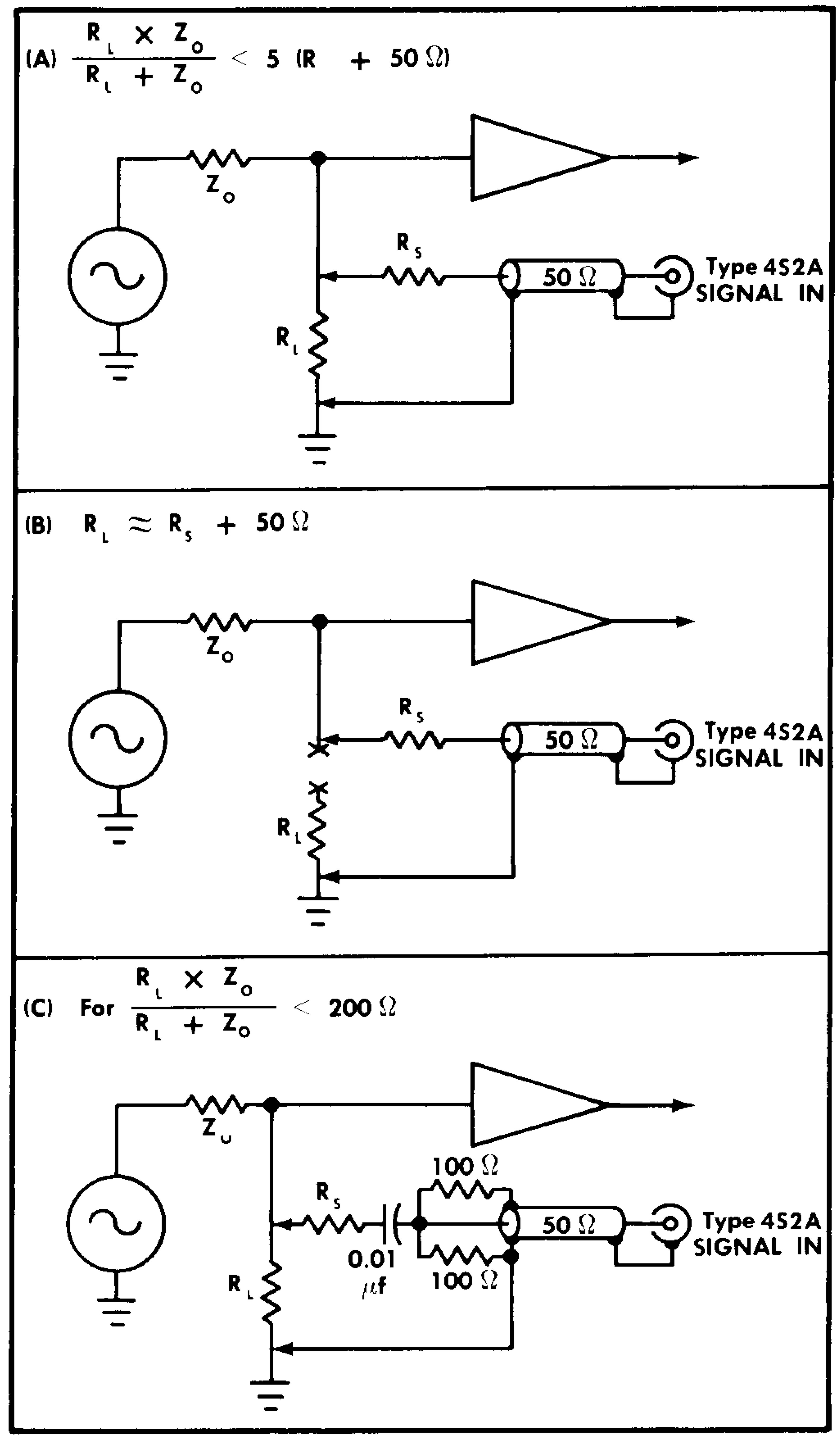


Fig. 2-9. Built-in probes for coupling to a test circuit. (A) Parallel method; (B) series method; (C) reverse-terminated parallel method.

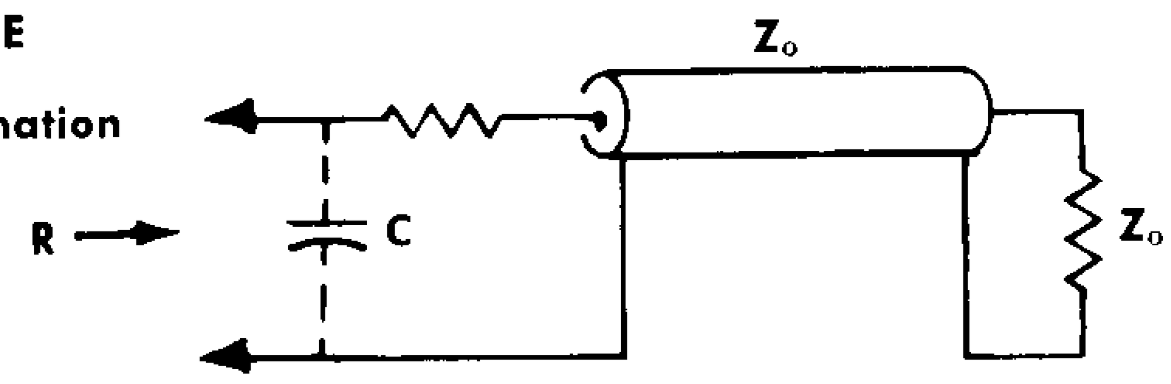
In the series coupling method (Fig. 2-9B), the 50-ohm input of the Type 4S2A replaces the impedance in the circuit under test. If the replaced impedance (shown as R_L) is more than 50 ohms, place a resistance in series with the cable input to the 4S2A. The size of this resistance, plus 50 ohms, should equal the original impedance in the circuit. If R_L equals 50 ohms, simply substitute the cable to the Type 4S2A input with no additional series resistance. It is best to locate R_s in the original position of R_L and ground the coaxial cable where R_L was grounded. When not testing, a 50 Ω resistor can replace the 50 Ω cable.

A variation of the parallel method is the reverse terminated network shown in Fig. 2-9C. This system is highly versatile and may be reasonably used across any impedance up to

I. PASSIVE

A. TERMINATED CABLE

1. Single Termination

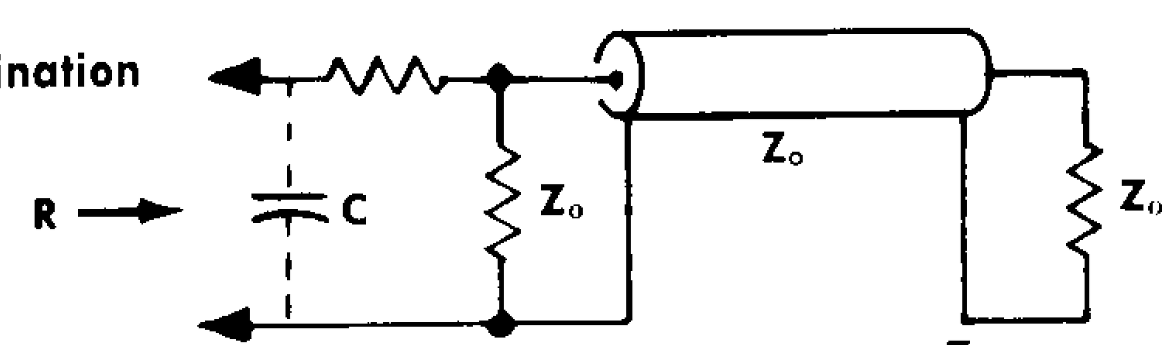


Statically: $R = \text{Attenuation} \times Z_o$
$C \approx 1/2$ pF

Low static R, good high speed response.

Example: P6035 Probe
$Z_o = 50\,\Omega$ $R = 5$ k
Attenuation $= 100\times$

2. Double Termination



Statically: $R = \text{Attenuation} \times \frac{Z_o}{2}$

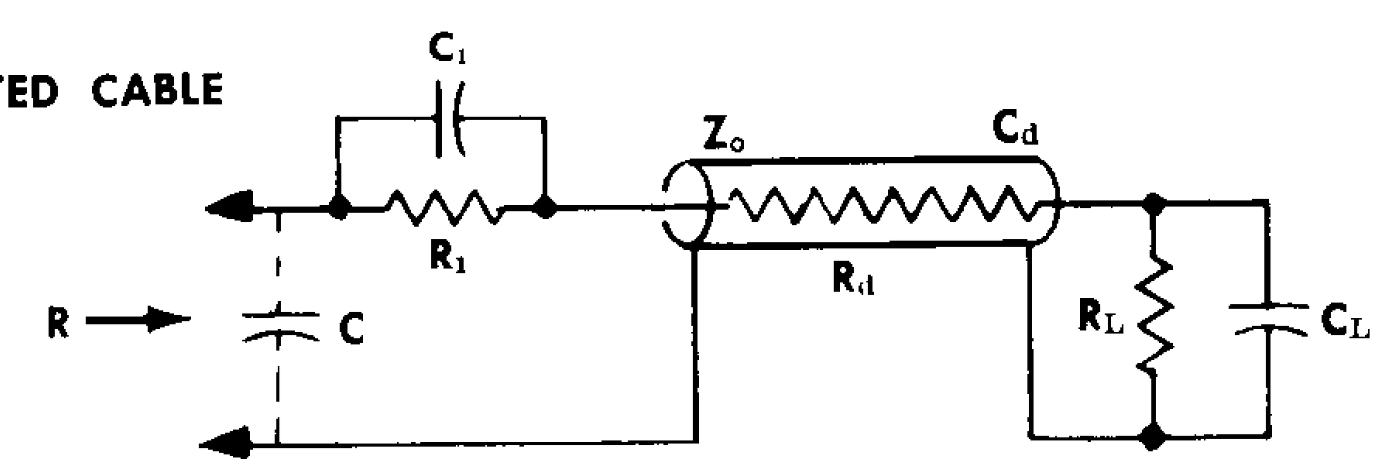
$C \approx 1/2$ pF

Low static R, good high speed response.

Double termination reduces reflections.

Example: P6026 Probe
$Z_o = 50\,\Omega$ $R = 500\,\Omega$
Attenuation $= 20\times$

B. NON-TERMINATED CABLE



Statically $R \approx R_1 + R_d\ R_L$; 0.1 meg to 100 meg

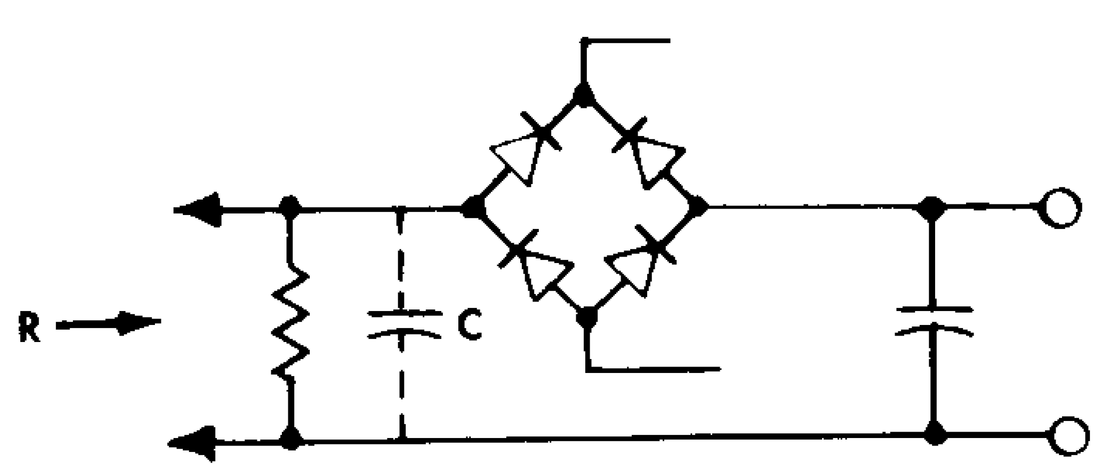
$$C \approx \frac{C_1\ (C_d + C_L)}{C_1 + C_d + C_L};\ 2\text{ pF to }15\text{ pF}$$

$R_L \gg Z_o$

High static R, limited high speed response.

II. ACTIVE

A. DIRECT SAMPLING



Statically: $R \approx 100$ k to 1 meg
$C \approx 2$ to 3 pF

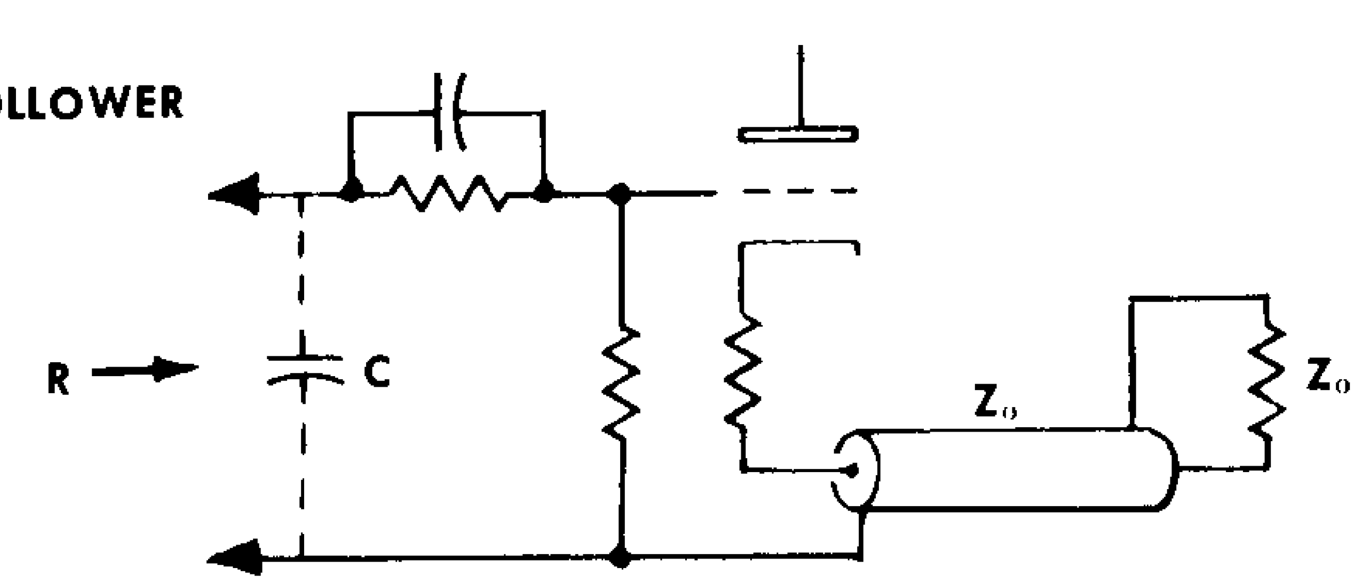
High static R.

Kickback disturbs display baseline.

Most sensitive system.

Example: P6038 Probe

B. CATHODE FOLLOWER



Statically: $R \approx 0.1$ meg to 10 meg
$C \approx 2$ to 10 pF

High static R; poor dynamic range.

Drives delay cable.

Example: P6032 Probe

Fig. 2-10. Types of non-loading voltage-sensing probes.

about 200 ohms. At higher source impedances, circuit loading requires more than 20% correction. The 0.01 μF capacitor in the probe network blocks any DC component and protects the resistors. Use of the 0.01 μF capacitor is optional.

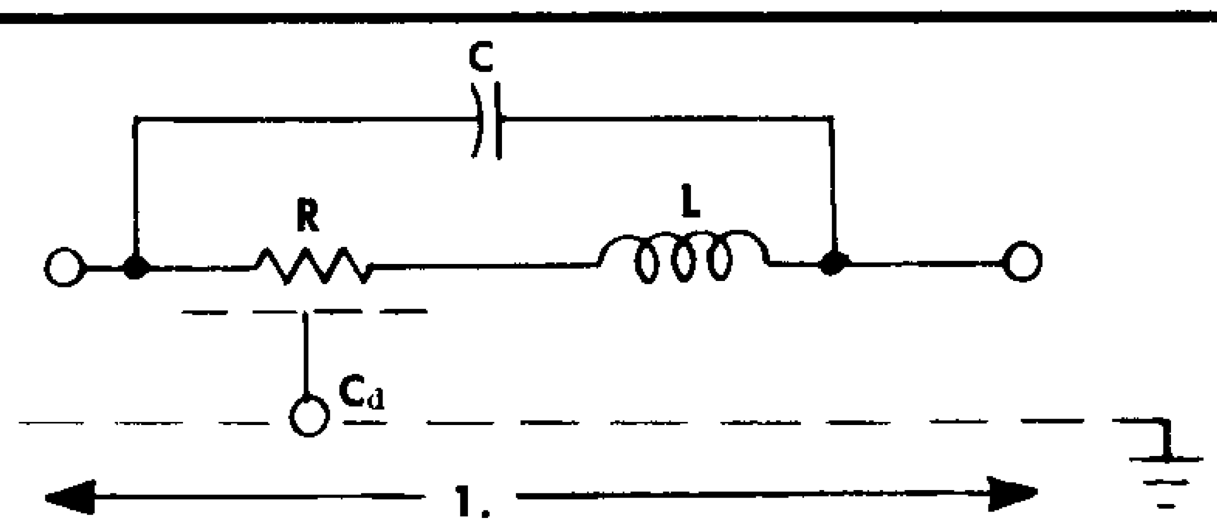
When it is necessary to AC-couple the probe, the capacitor should be placed between the series resistance and the probe cable to minimize differences between the input characteristics with and without the capacitor. In this 50-ohm environment, stray capacitance to ground has a shorter and more uniform time constant than if the capacitor were placed at the signal source where the impedance is usually higher and of unknown value.

The two 100 Ω resistors (Fig. 2-9) placed directly across the cable input serve to reverse-terminate any small reflections due to imperfect connectors, cables, attenuators, etc. If signals of short duration are to be observed, the reflections may occur off the oscilloscope time-base (to the right) and will not be seen. Or if reflections of a few percent are unimportant, then the two resistors can be deleted with a two times increase in signal. In general, the two 100 Ω resistors are needed only when observing signals at high gain, or when a small reflection will distort the display.

Voltage-sensing, non-loading probes can be grouped into the four basic categories shown in Fig. 2-10. 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. The types shown in Fig. 2-10 (IA1) and (IA2) are of primary interest for sampling work because of the good high-speed response. Small passive probes of the type shown in IA1 are available with risetimes of 100 picoseconds and 200 picoseconds.

Major limiting factors when building attenuator probes are the resistor characteristics at fractional nanosecond speeds. In constructing built-in signal probes, it is advantageous to use 1/4 or 1/8 watt resistors since their small size aids in obtaining good high-frequency response. Fig. 2-11 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. 2-10 (IA) requires the special construction techniques shown in Fig. 2-12.

The static input resistance of signal probes is measurable with an ohmmeter, but the ohmmeter reading tells very little about a probe's operation at high frequency. 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 com-



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 1. C_d varies by a factor of ≈2, depending on third terminal distance.

L = Series inductance, ≈3.3 nH/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, 1/2 W, 1 1/2 cm. C ≈ 0.1 pF C_d ≈ 1/3 × 1 1/2 = 1/2 pF. L ≈ 3.3 × 1 1/2 = 5 nH.

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

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

2. 1000 Ω, 1/2 W, 1 1/2 cm. RC = 100 ps and L/R = 5 ps. RC_d/16 = 30 ps.

Fig. 2-11. Equivalent circuit and environment of a deposited carbon resistor.

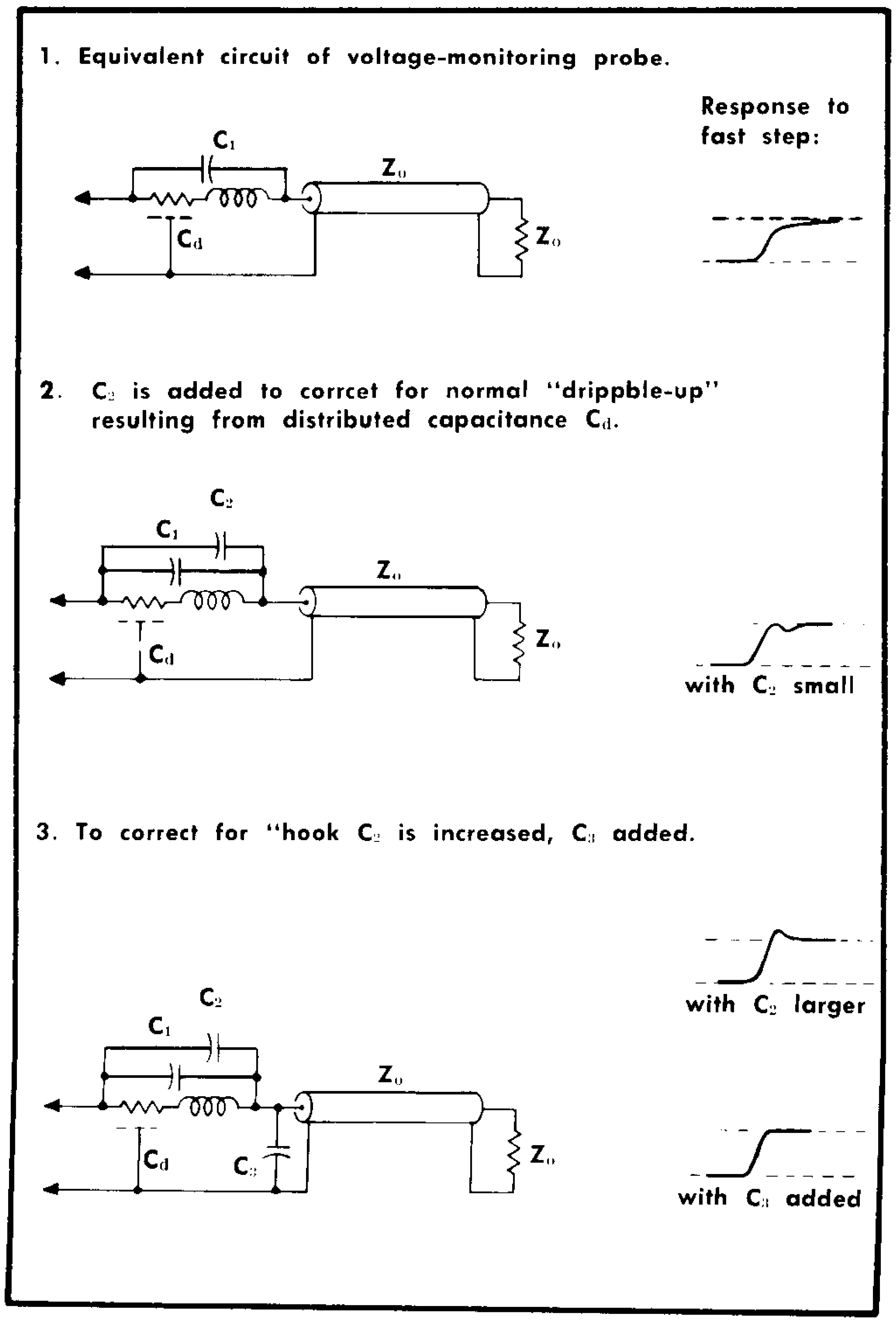


Fig. 2-12. Fractional nanosecond compensation of low resistance passive probes.

pensating capacitor across the input resistor, exposing the low-resistance parts of the probe to the input. Fig. 2-13 shows general curves of the types of probes shown in Fig. 2-10.

Since the input resistance is down at high frequencies, any series inductance will be significant. Fig. 2-14 shows an equivalent circuit of a common high-speed probe with a 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 ensure good display fidelity.

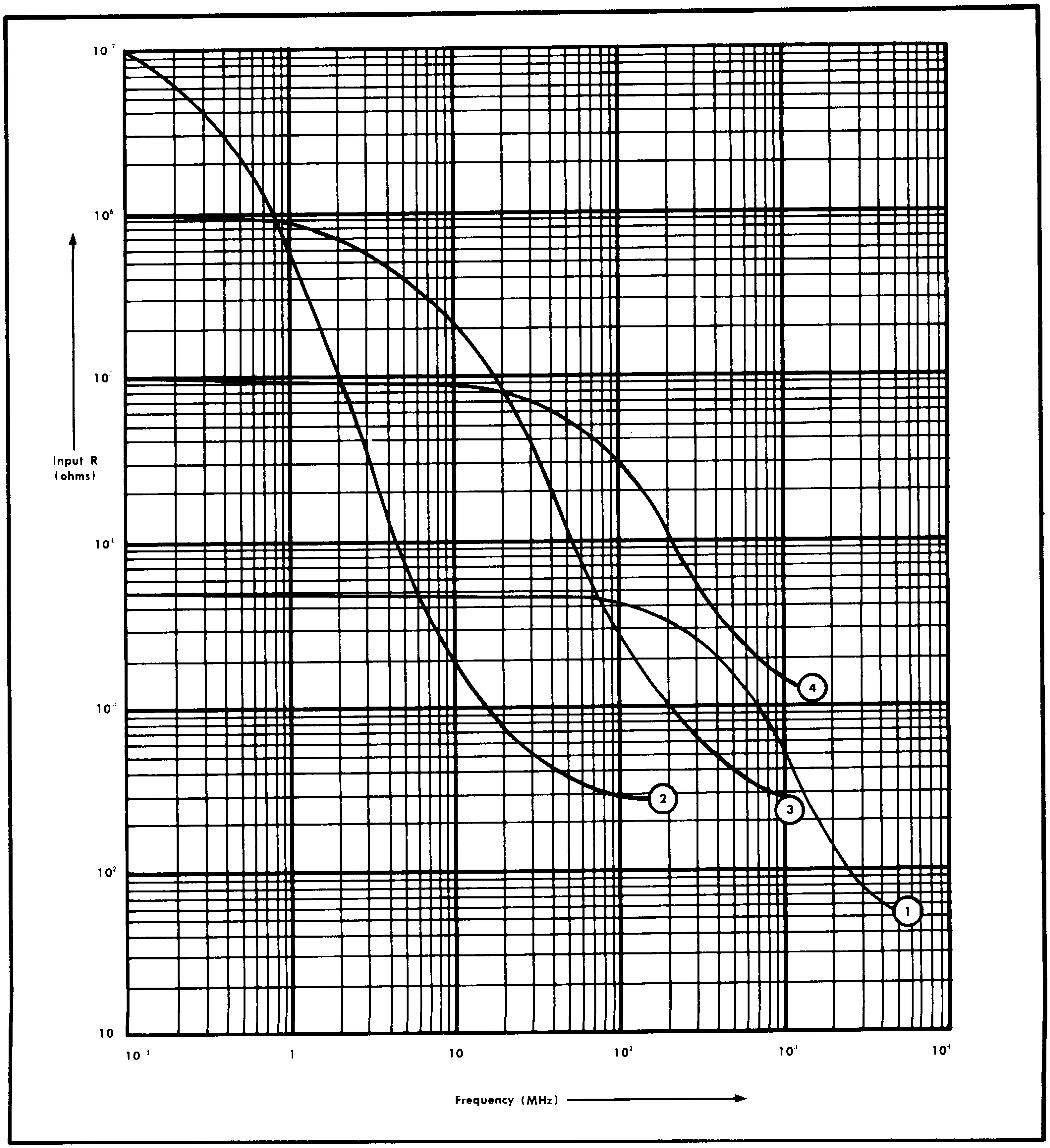


Fig. 2-13. Input resistance drop of some signal probes shown in Fig. 2-10. 1. Terminated cable; 2. Non-terminated cable; 3. Cathode-follower; 4. Direct-sampling.

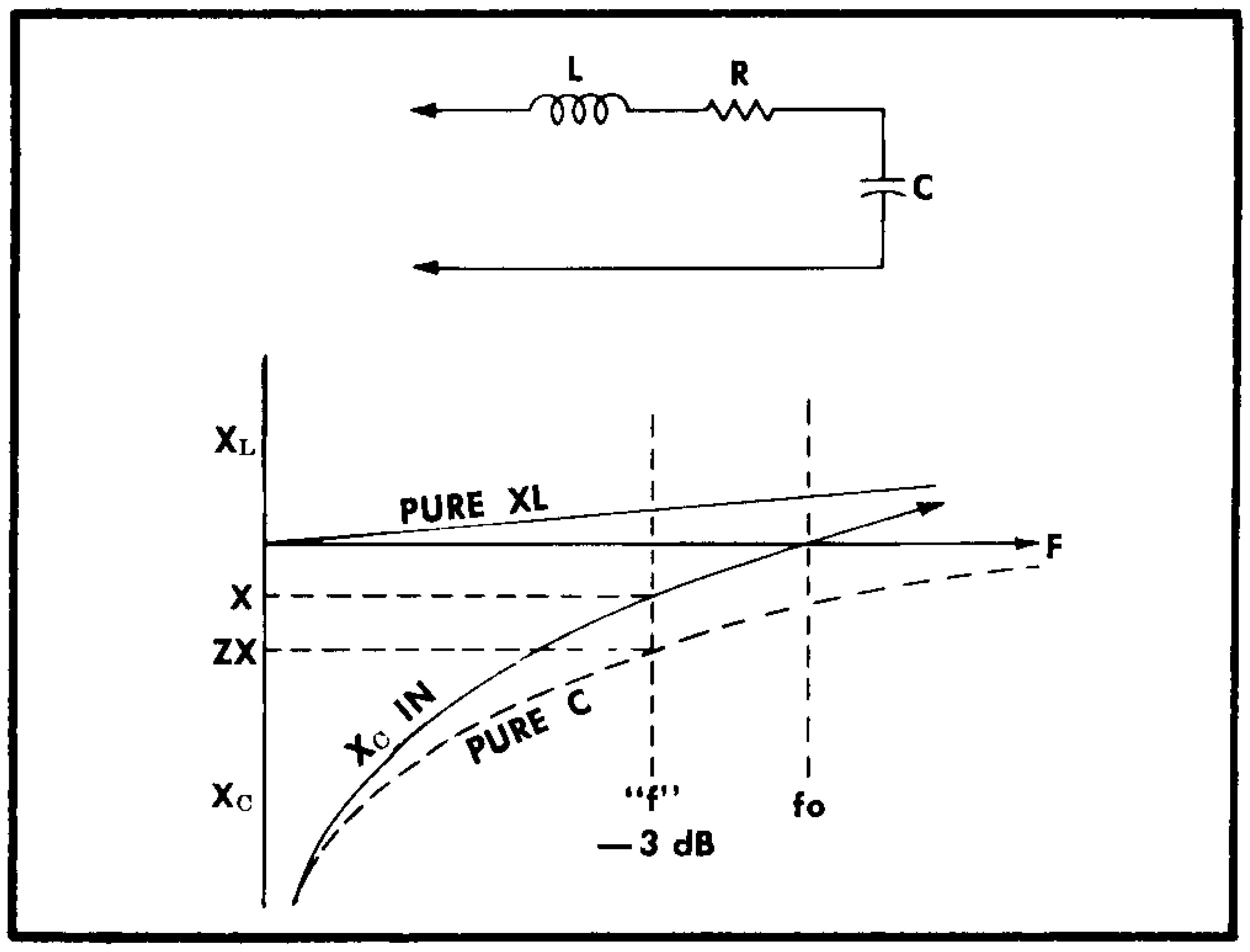


Fig. 2-14. Equivalent circuit of a high speed probe at frequency "f" and general input reactance curve to a frequency past the point of resonance.

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. 2-15 is a simple example of how a signal can be distorted by the measuring system.

Fig. 2-15E 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. 2-15F 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 kΩ 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. 2-15F can be eliminated by insertion of a coupling capacitor at the input to the Type 4S2A (Fig. 2-15D). 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. 2-15G).

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.

Coaxial Cables

Signal cables that connect the vertical signal from the source to the Type 4S2A INPUT 50 Ω connectors should have a characteristic impedance of 50 ohms. Impedances other than 50 ohms will cause reflections that make it difficult to interpret the display. High-quality, low-loss coaxial cables should be used to ensure that all the information obtained at the source is delivered to the 4S2A input. If it is necessary to use cables with characteristic impedances other than 50 ohms, suitable impedance-matching devices should be used.

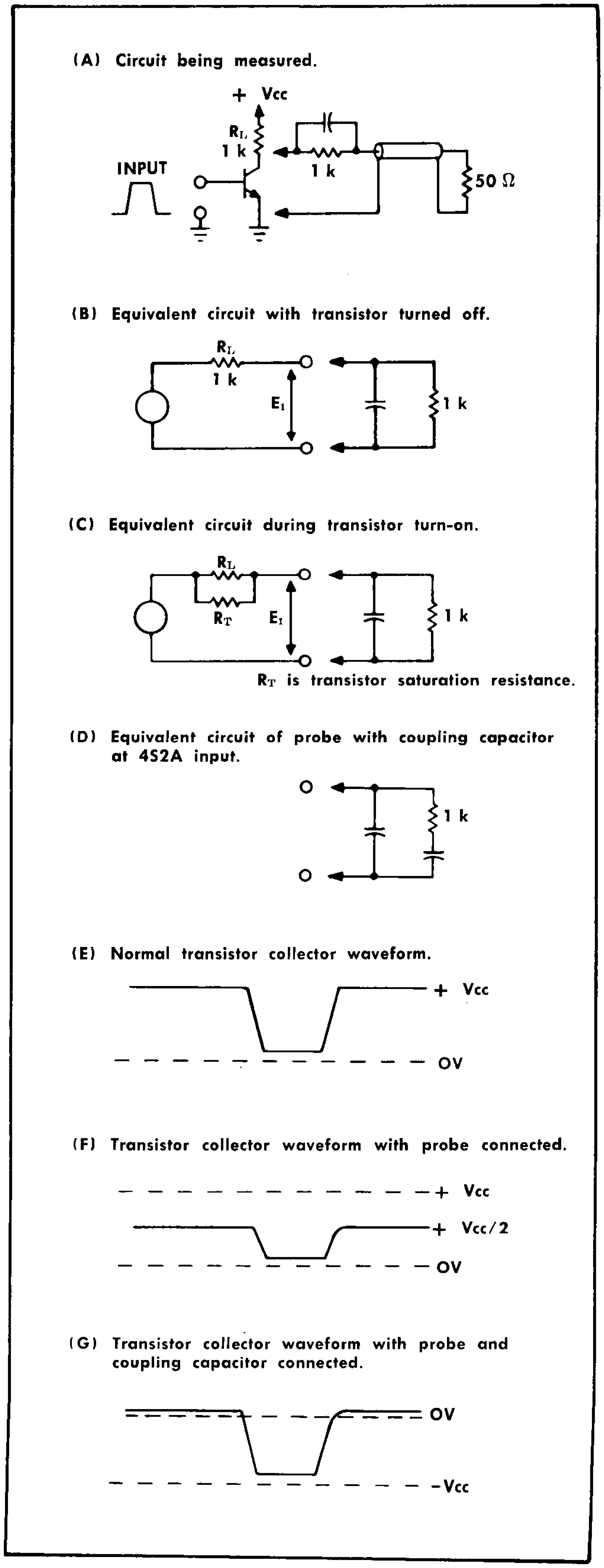


Fig. 2-15. Typical measurement problem. Waveform distortion produced by test probe must be taken into consideration.

The characteristic impedance, velocity of propagation and nature of signal losses in a coaxial cable are determined by the physical and electrical characteristics of the cable. Losses caused by energy dissipation in the dielectric are proportional to the signal frequency, therefore much of the high-frequency information in fast-rise pulse can be lost in a very few feet of interconnecting cable.

Fig. 2-16 shows the relative increase in output signal risetime when a step input signal is passed through several types of commonly used 50-ohm coaxial cables. This increase in output risetime must be taken into consideration when making risetime determinations. For example, a length of cable with a 225-ps output risetime degrades a 500-ps input risetime by about 10%. (This can be determined by the root of the sum of the squares formula.) As can be seen from the graph, it takes only 6 feet (9 ps) of RG-58A/U cable to cause this 10% change. However, it takes about 15 feet (22.5 ns) of RG-8A/U or 80 feet (95 ns) of Spir-o-line to cause the same amount of change. If signal delay greater than 60 ns is required, the use of a Tektronix Type 113 Delay Cable is recommended.

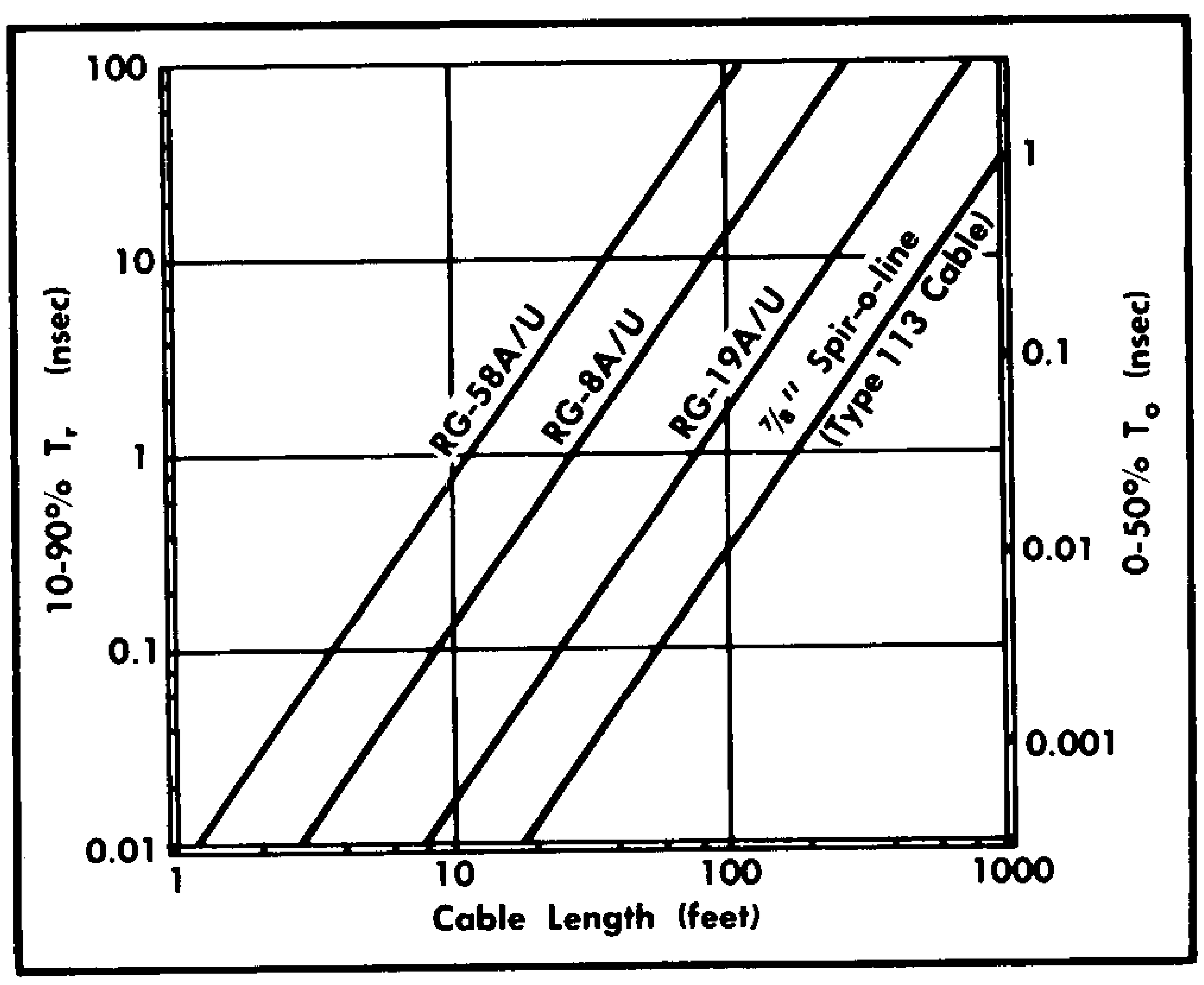


Fig. 2-16. Output signal risetime in response to a step input, given as a function of cable length for some common coaxial cables.

It is important to note that the risetime of the transmitted signal deteriorates approximately in proportion to the square of the length of the cable. As an illustration, a 500-ps risetime is increased to 1000 ps (100% increase) by a length of cable with a risetime of about 867 ps. From Fig. 2-16 it is seen that approximately 10 feet (15 ns) of RG-58A/U, 25 feet (37.5 ns) of RG-8A/U or 115 feet (137 ns) of Spir-o-line will cause this amount of risetime change. Comparing this result with the previous determination, it is seen that a 67% increase in cable length produces a 900% increase in risetime deterioration for the 500-ps pulse risetime.

Due to the high-frequency losses in coaxial cables, the 0-50% half-impedance risetime (T nought, T_0) is often used instead of the 10%-90% risetime of the coaxial cable output.

Occasionally, it may be desirable to use long 50-ohm cables to move reflections out of the time window of interest (delayed by double the transit time of the cable). Keep in mind, however, the degrading effect that long lengths of delay cable have on the pulse risetime.

Attenuation

If the signal amplitude at the source is too great, use an attenuator probe and/or externally-connected T-Attenuators. The attenuators that are used must have a bandwidth to about 4 GHz to avoid reducing the performance of the system. High-quality 50-ohm attenuators are available with attenuation factors of 10×, 5× and 2×. When the attenuators are stocked, their attenuation factors multiply. Thus, two 10× attenuators produce a 100× attenuation factor.

Impedance Matching

To provide a smooth transition between devices of different characteristic impedance, each device must encounter a total impedance equal to its own characteristic impedance. Thus, when a signal is applied to the Type 4S2A INPUT 50 Ω connectors, if the source impedance of the signal is not 50 ohms, a suitable impedance-matching device must be provided. If the impedances are not matched, reflections and standing waves in the cables result in distortion of the displayed waveform.

In many cases, insertion of a 50-ohm attenuator in the signal path will provide an approximate impedance match and will absorb most reflections. It should be noted, however, that the attenuation factor will not be the same as it would be if the impedances were the same on both sides.

Fig. 2-17 illustrates a simple resistive impedance-matching network that provides minimum attenuation. To match impedances with the network, the following conditions must exist:

$\frac{(R_1 + Z_2)\, R_2}{(R_1 + Z_2) + R_2}$ must equal Z_1; and $R_1 + \frac{Z_1 R_2}{Z_1 + R_2}$ must equal Z_2.

Therefore:

$$R_1 R_2 = Z_1 Z_2; \text{ and } R_1 Z_1 = R_2 (Z_2 - Z_1)$$

$$\text{or } R_1 = \sqrt{Z_2 (Z_2 - Z_1)};$$

$$\text{and } R_2 = Z_1 \sqrt{\frac{Z_2}{Z_2 - Z_1}}$$

As an example, to match a 50-ohm system to a 125-ohm system:

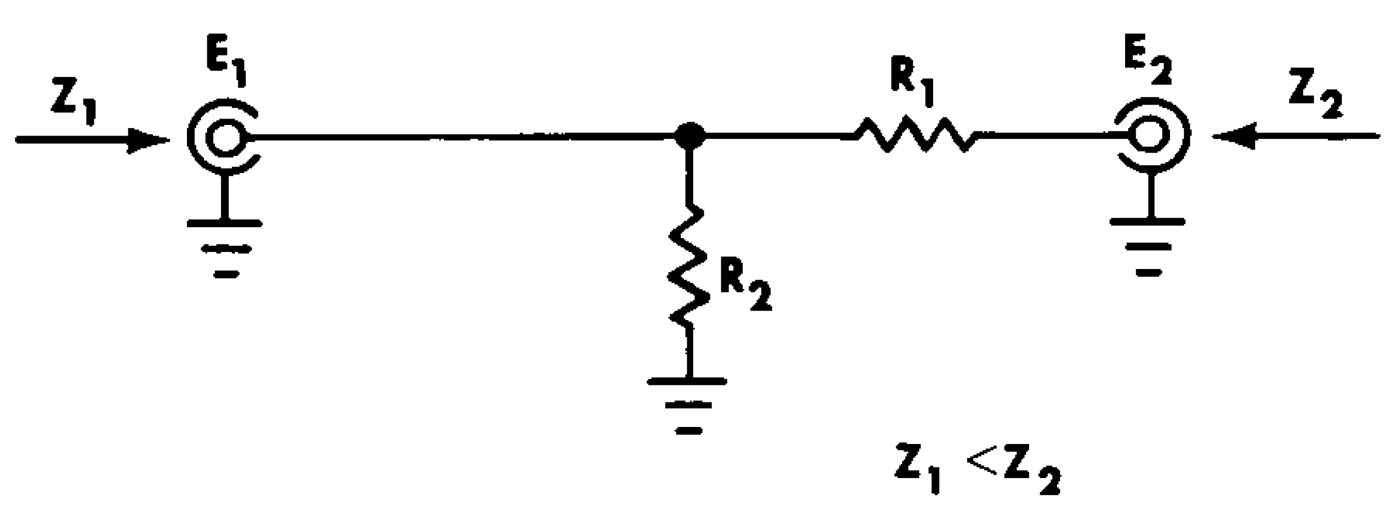
$Z_1 = 50$ ohms; and $Z_2 = 125$ ohms.

Therefore:

$$R_1 = \sqrt{125\,(125 - 50)} = 96.8 \text{ ohms}$$

$$\text{and } R_2 = 50 \sqrt{\frac{125}{125 - 50}} = 64.6 \text{ ohms}$$

When constructing such a device, the environment surrounding the components should also be designed to provide a transition between the impedances. Keep in mind that the characteristic impedance in a coaxial system is determined by the ratio between the outside diameter of the inner conductor and the inside diameter of the outer conductor ($Z_o = 138 \log_{10} D_1/D_2$).



To match impedances:

$$R_1 R_2 = Z_1 Z_2 \text{ and } R_1 Z_1 = R_2 (Z_2 - Z_1)$$

$$\text{or: } R_1 = \sqrt{Z_2 (Z_2 - Z_1)} \text{ and } R_2 = Z_1 \sqrt{\frac{Z_2}{Z_2 - Z_1}}$$

Voltage attenuation seen from Z_1 end:

$$A_1 = \frac{R_1}{Z_2} + 1; \qquad 1 < A_1 < 2$$

Voltage attenuation seen from Z_2 end:

$$A_2 = \frac{R_1}{R_2} + \frac{R_1}{Z_1} + 1;$$
$$1 < A_2 < 2Z_2/Z_1$$

Fig. 2-17. Simple resistive impedance-matching network providing minimum attenuation.

Though the network in Fig. 2-17 provides minimum attenuation for a purely resistive impedance-matching device, the attenuation as seen from one end does not equal that seen from the other end. A signal applied from the lower impedance source (Z_1) encounters a voltage attenuation (A_1) that may be determined as follows:

$$\text{Since: } IR_1 = IZ_2; \ \frac{E_1 - E_2}{R_1} = \frac{E_2}{Z_2}$$

$$\text{Therefore: } A_1 = \frac{E_1}{E_2} = \frac{R_1}{Z_2} + 1; \ (1 < A_1 < 2)$$

A signal applied from the higher impedance source (Z_2) will encounter a greater voltage attenuation (A_2) that may be determined similarly:

$$\text{Since } IR_1 = IR_2 + IZ_1; \ \frac{E_2 - E_1}{R_1} = \frac{E_1}{R_2} + \frac{E_1}{Z_1}$$

$$\text{Therefore: } A_2 = \frac{E_2}{E_1} = \frac{R_1}{R_2} + \frac{R_1}{Z_1} + 1;$$

$$(1 < A_2 < \frac{2Z_2}{Z_1})$$

In the example of matching 50 ohms to 125 ohms,

$$A_1 = \frac{96.8}{125} + 1 = 1.77;$$

$$\text{and } A_2 = \frac{96.8}{64.6} + 1 = 4.44$$

Note that if the 50-ohm source were used for pulsing a high-impedance load, R_1 would approximately equal the impedance of the load (high R) and R_2 would approximately equal the 50 ohms of the pulse source. In this situation, voltage attenuation would be about 2.

If a low-impedance load (<50 ohms) were to be encountered, the 50-ohm pulse source would be the Z_2 source. If the load impedance were to approach 0 ohms, the value of R_1 would then approach the load impedance (low R). Voltage attenuation in this case would become quite significant:

$$\text{Attenuation} = \frac{2Z_2}{Z} = \frac{100}{Z} \text{ (very high)}$$

The illustrated network can be modified to provide different attenuation ratios by adding another resistor ($<R_1$) in series between Z_1 and the junction of R_1 and R_2.

MEASUREMENT TECHNIQUES

Voltage Measurements

Vertical displacement of the CRT trace is directly proportional to the voltage at the INPUT connector of the Type 4S2A. (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.

As an example, Fig. 2-18 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 4S2A. Assuming there is a 10× 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.

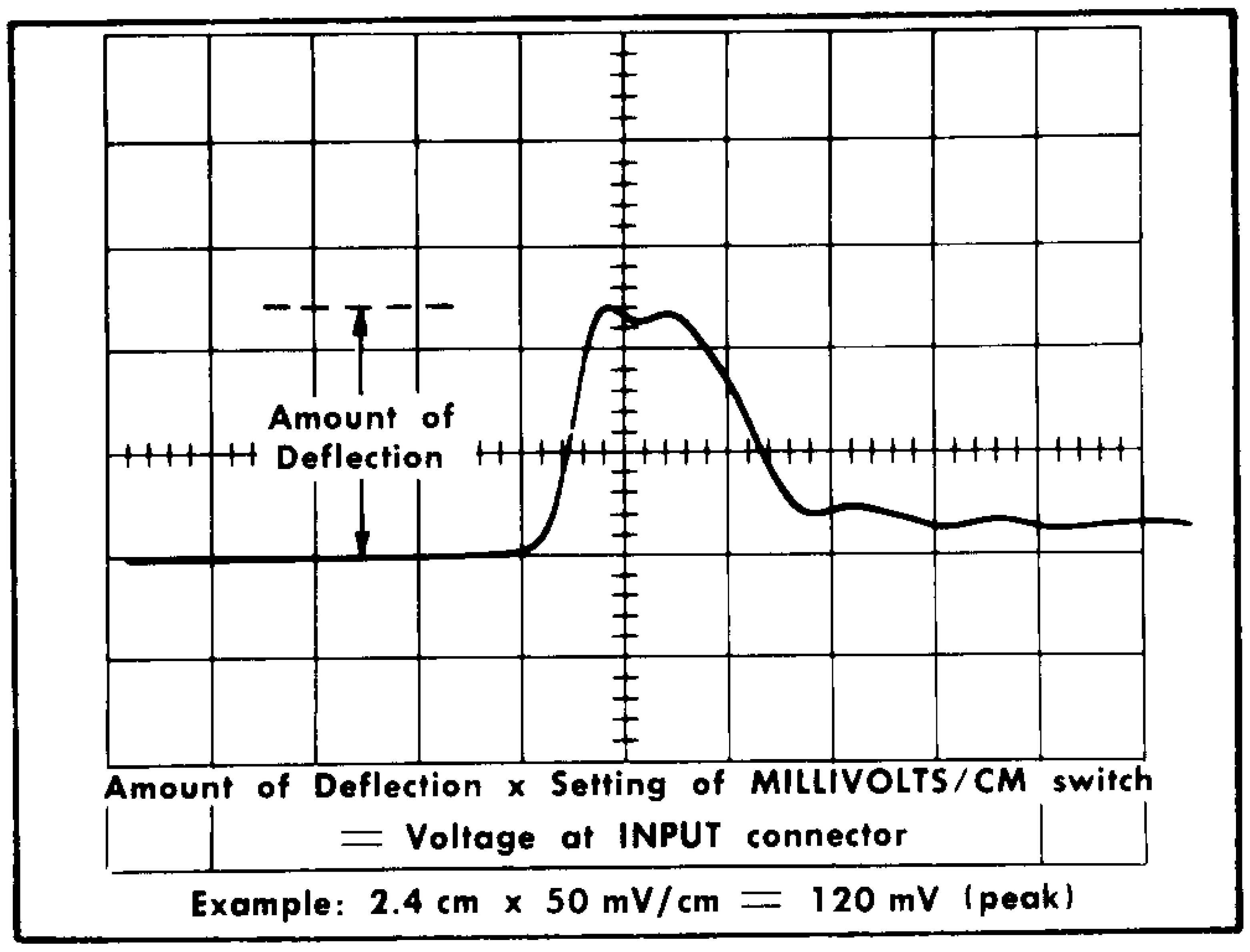


Fig. 2-18. Voltage measurement from display.

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 4S2A 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 4S2A 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 kHz 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-kHz switching rate in Dual Trace mode, no 50-kHz signal is contained in the triggering signal to the timing unit. The triggering signal is taken off at the input to the Type 4S2A, not from a dual-trace switching circuit as in some conventional oscilloscopes. Thus triggering is from one input only.

Connect the two input signals to the INPUT connectors of the Type 4S2A, preferably with equal delay coaxial 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 4S2A. A coaxial tee or transformer-matched tee may be used to connect the cables. Such a display is illustrated in Fig. 2-19. 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.

Use the following procedure for setting up the Type 4S2A 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 4S2A to DUAL TRACE.

3. Set the MILLIVOLTS/CM switches to give approximately 2 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 ns/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.

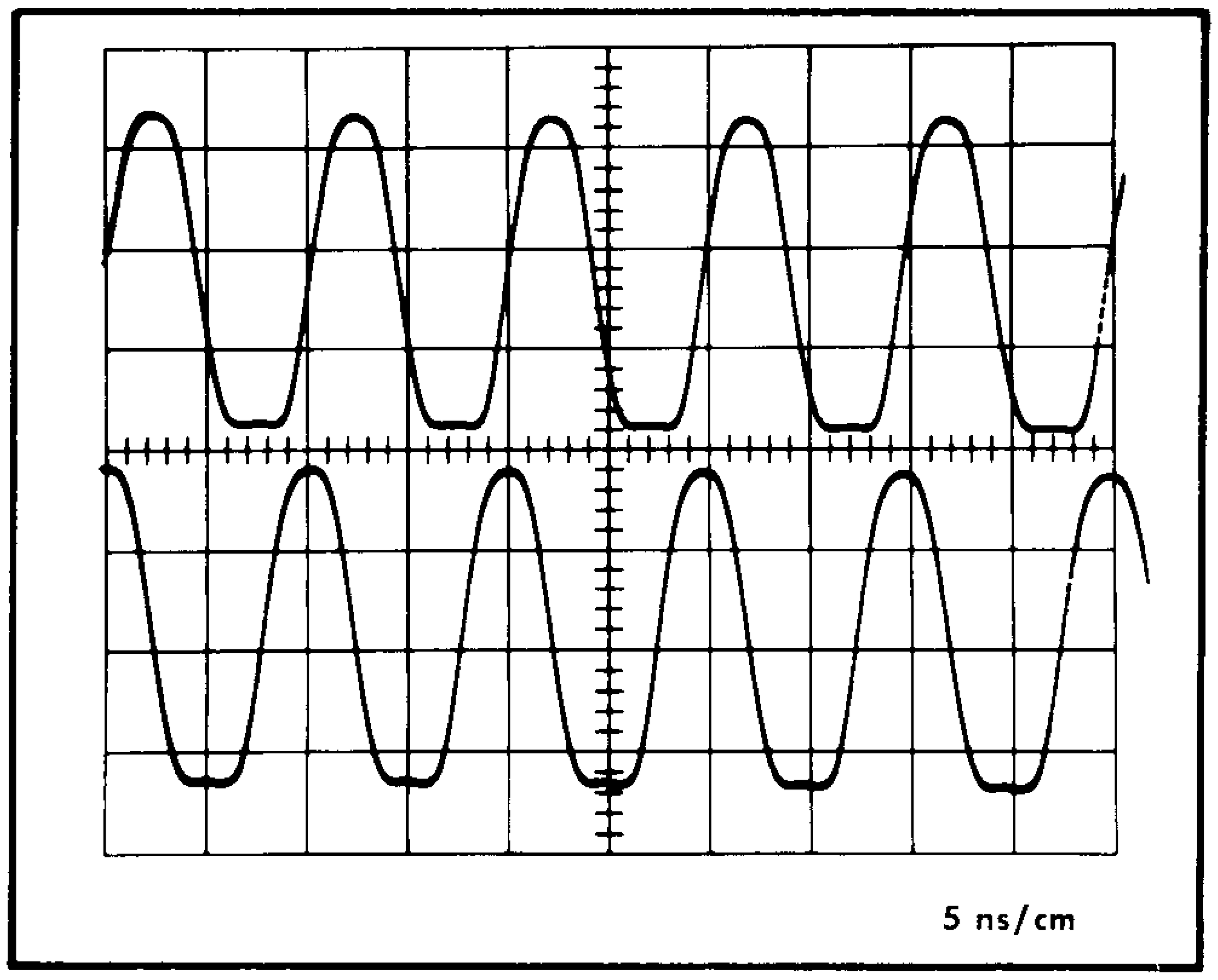


Fig. 2-19. Dual trace display showing 100 MHz calibrator waveform applied to Type 4S2A inputs through unequal length cables. The signal displayed on the lower trace is passed through 8 ns more cable than the signal on the upper trace.

X-Y Operation

The X-Y (lissajous) mode of operation is convenient for measuring sine wave 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 4S2A. 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 Hz, 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 MHz signal, 1 Hz 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 4S2A, 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 4S2A.

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 4S2A 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 4S2A 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 4S2A 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 center horizontal line. 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 4S2A.

Fig. 2-20 shows two 100 MHz sine waves in a Dual Trace display where the apparent time difference is due to different lengths of coaxial cable being driven by a common source. The difference in electrical lengths of the two cables is seen to be 5.3 ns. This display is also a true picture of the phase difference between the two 100 MHz input signals, but the phase difference in degrees would be difficult to read from this display. Fig. 2-20B shows the same waveform with the sweep rate changed to calibrate the displays at 45 dgrees/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.

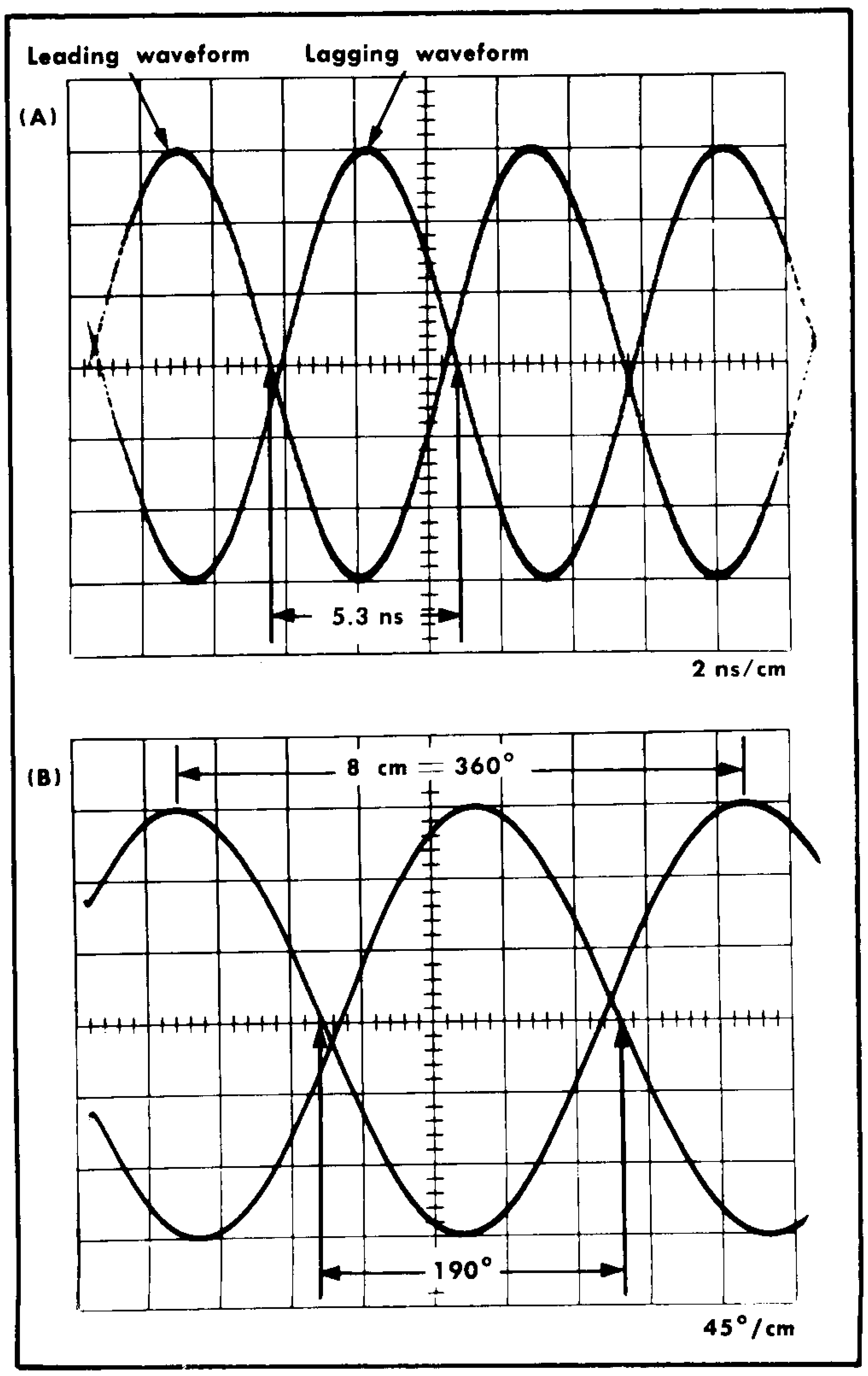


Fig. 2-20. (A) Dual trace display of 100 MHz sine wave at sweep rate of 2 ns/cm; (B) same display with sweep calibrated at 45 degrees/cm.

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.

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 4S2A as indicated:

MODE	B ONLY
DISPLAY (both channels)	NORMAL
DC OFFSET (both channels)	Midrange
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.

7. Measure the distance A and B on the display as shown in Fig. 2-21. A divided by B equals the sine of the phase angle between the two sine waves.

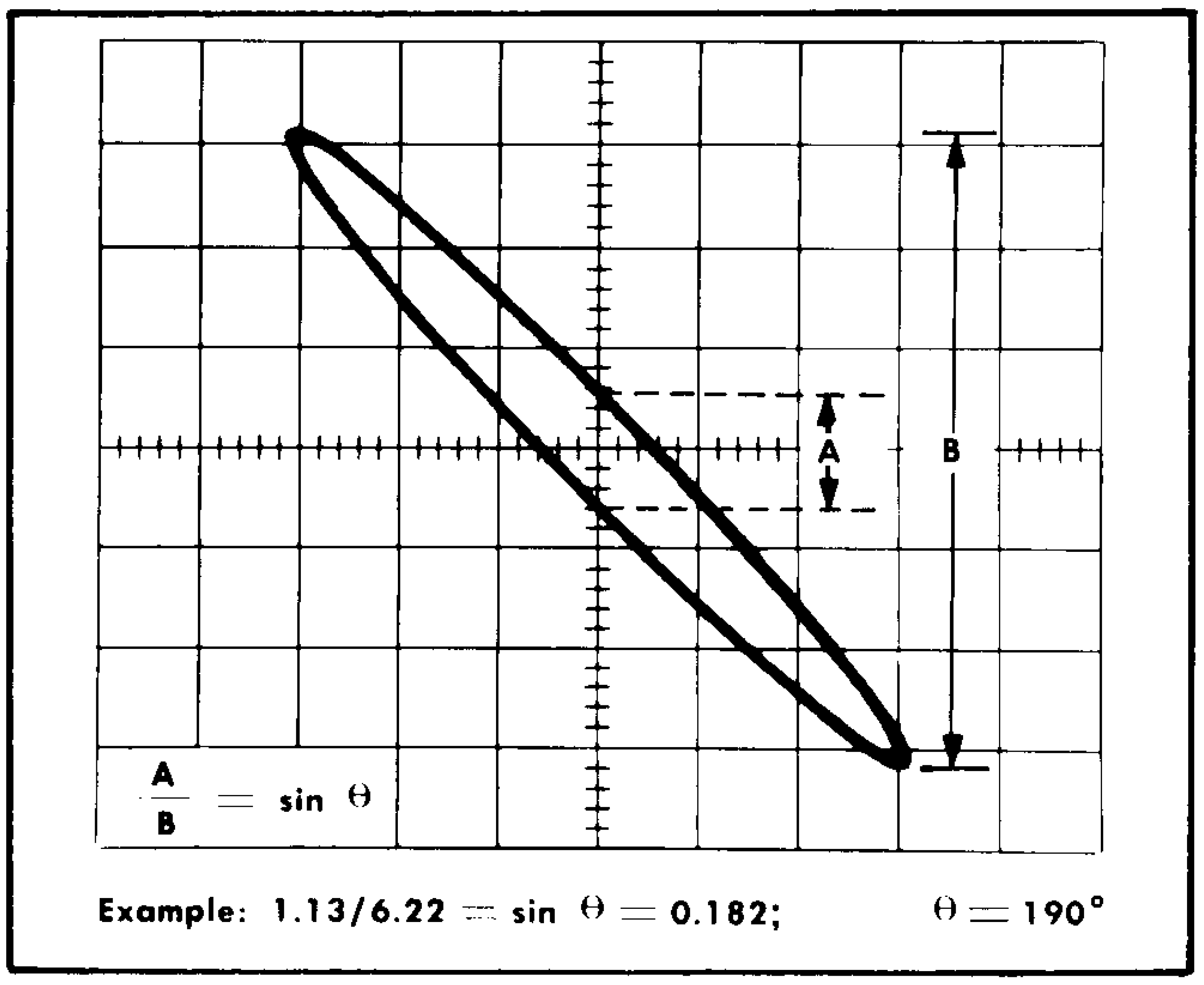


Fig. 2-21. X-Y method of calculating phase difference (θ) between two sine waves.

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. 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 4S2A. 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 4S2A 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

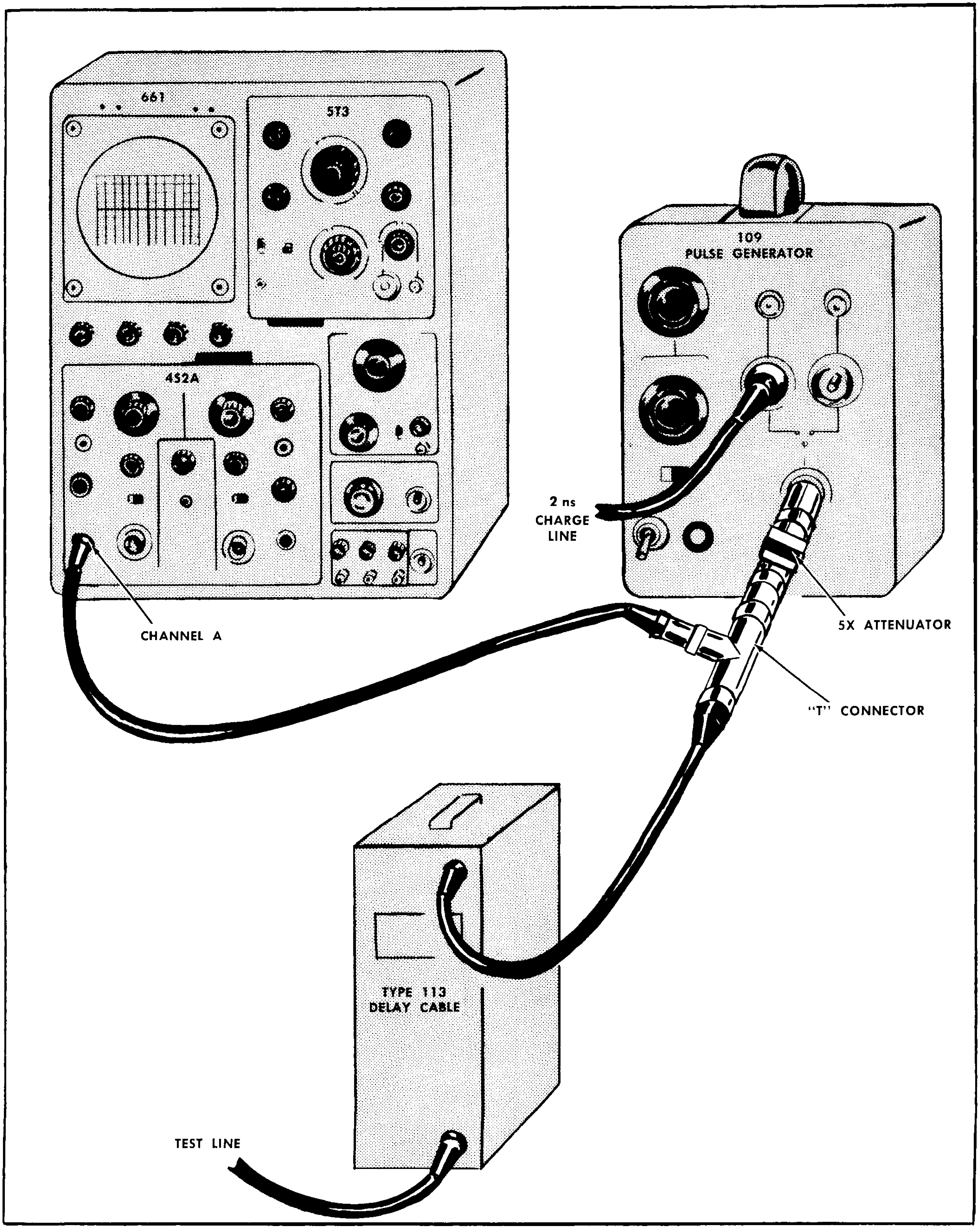


Fig. 2-22. Test setup for making TDR measurements with Type 109 Pulse Generator.

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

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 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.

Any mismatch in the system decreases system efficiency. To determine the efficiency of a transmission system, it is necessary to test and measure transmission line impedance and termination. One means of testing involves measuring the voltage standing wave ratio (VSWR) as a function of the frequency applied to the unit under test. A uniform line properly terminated will show a VSWR of 1.00. Any other value of VSWR shows non-uniformity in the line's characteristic impedance, improper termination, or a discontinuity in the system.

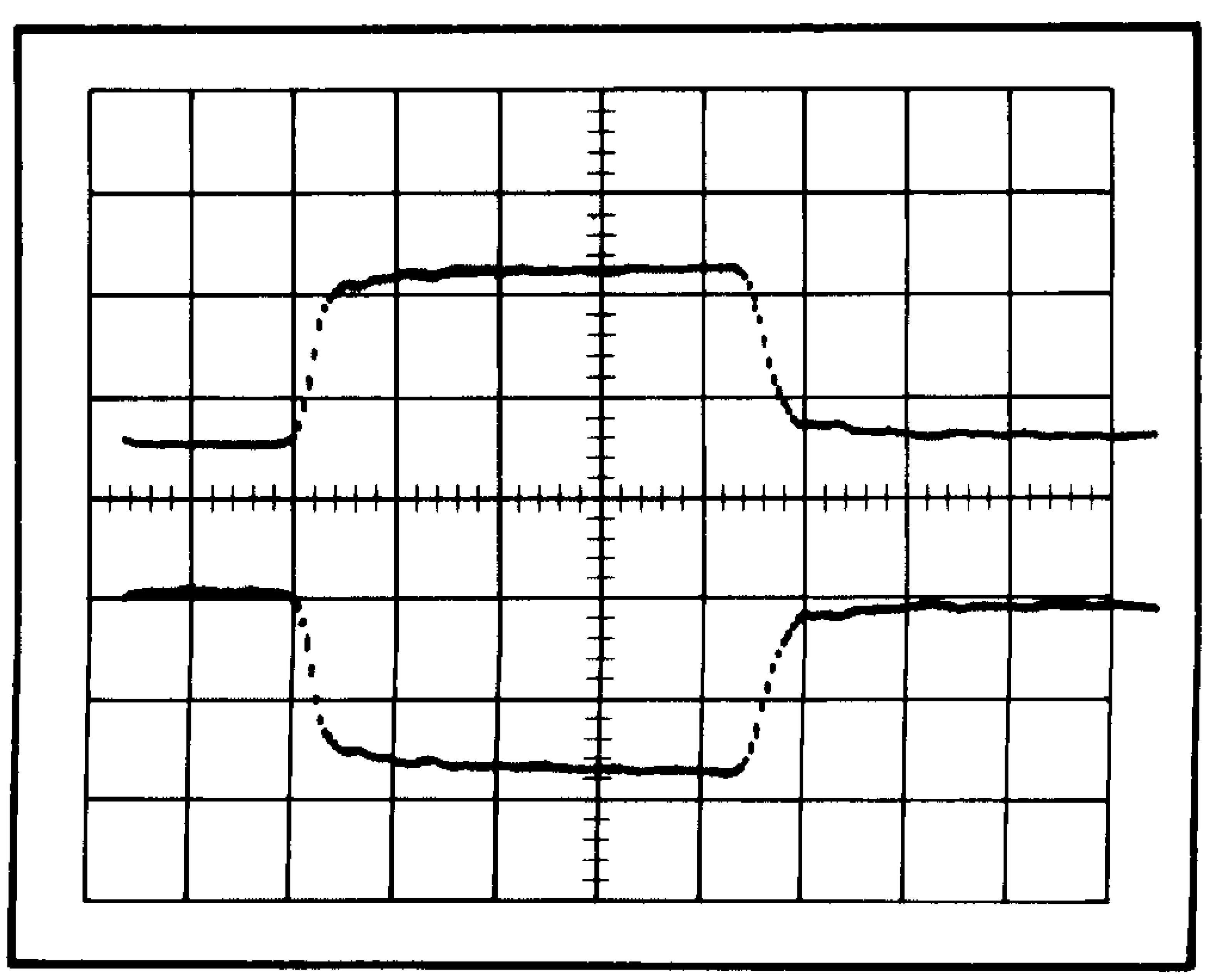


Fig. 2-23. Reflections obtained when transmission line is shorted (upper trace) or open (lower trace).

Another means of determining the efficiency of a transmission system is by time domain reflectometry. Here, the variable is the ratio of reflected voltage to incident voltage—defined by the voltage reflection coefficient P. With the reflection method, a fast-rising pulse is sent into the transmission line under test, and the returning reflections are observed. The amplitude of the reflection as related to that of the applied pulse describes the size of the non-uniformity, and the time delay after initial application of the pulse locates its position within the system.[1]

The 4S2A, with its dynamic range of ±one volt and sensitivity measurable in millivolts, can be used as part of a system for making very accurate pulse reflection measurements. Its high-frequency response 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. Moreover, the nature of the discontinuity can be determined since the reflection from each type of discontinuity in a transmission system has its own characteristic waveform.

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

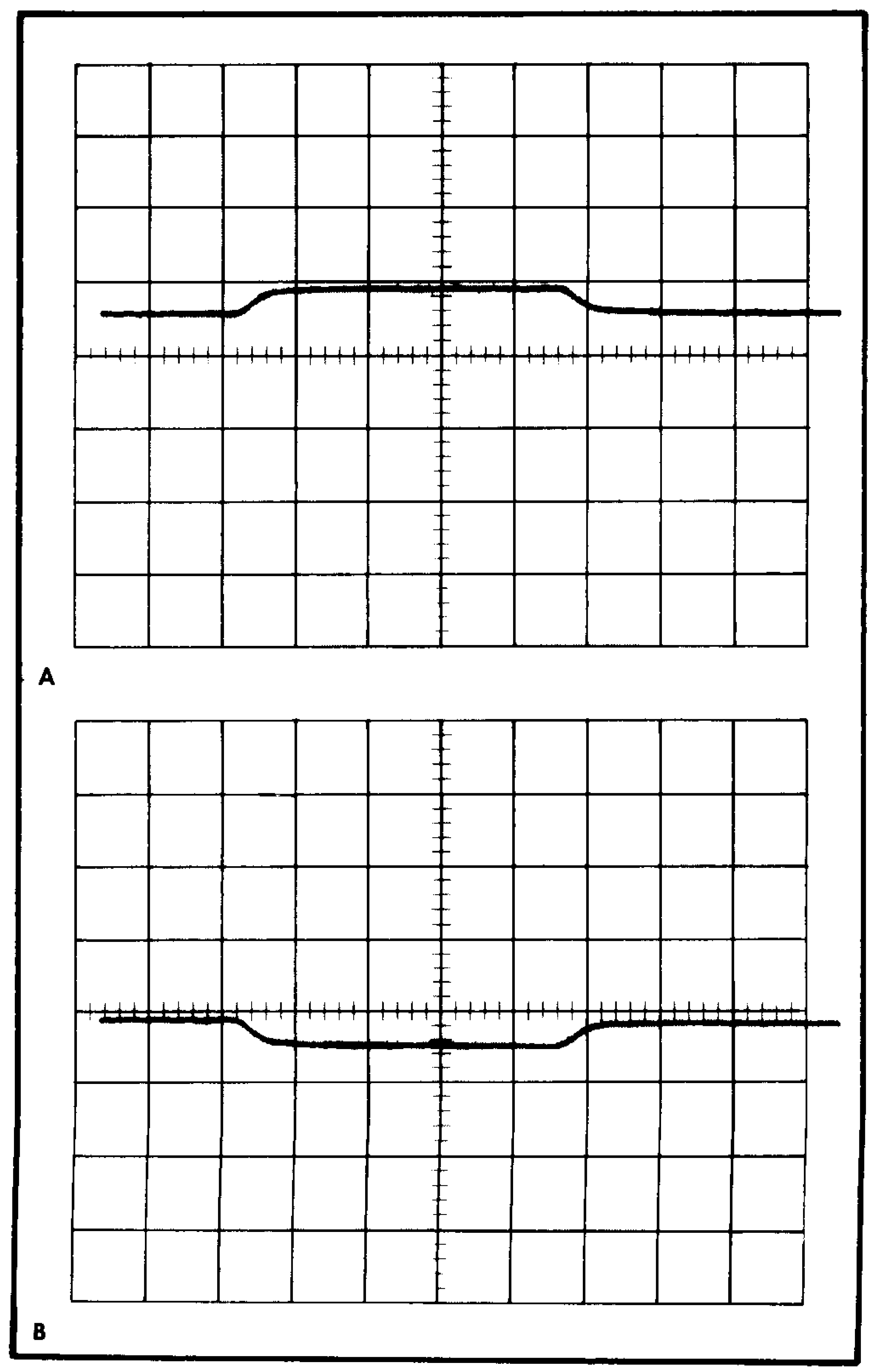


Fig. 2-24. Reflections obtained from pure resistance (A) greater than Z_o, (B) less than Z_o.

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The following paragraphs give typical methods used to correlate an observed reflection with a transmission line discontinuity, and describes system setups capable of 0.1% voltage reflection measurements.

Pulsing the Transmission Line (1). In the system diagrammed in Fig. 2-22, a flat-topped, fast-rising step is generated by the 109 Pulse Generator. Triggering energy is extracted from the Trigger Takeoff built into the A Channel of the Type 4S2A. The output of the Type 109 pulser is applied through a 5× attenuator to a GR T connector, one side of which is connected to the Channel A input of the 4S2A, the other side through a Type 113 Delay Cable to the line under test. The pulse width applied to the system is established by plugging the desired length of charge line into the 50 ohm charge line connector #1 on the Type 109. In the system shown, a 2 ns charge line is used, giving a pulse width of 4 ns. The 109 output was set for a pulse amplitude of 5 volts to stay within the input voltage rating of the 4S2A.

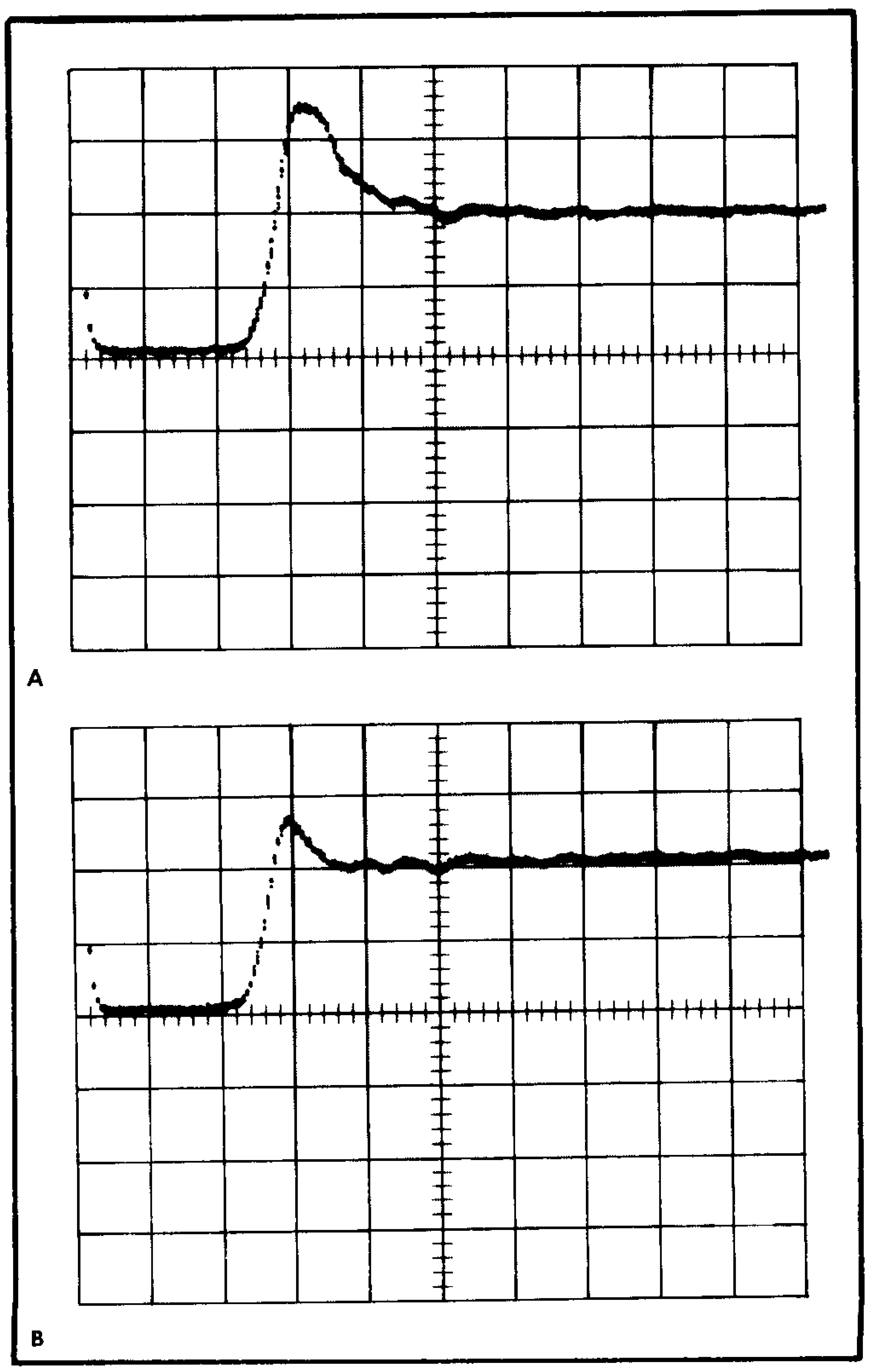

Fig. 2-25. Reflections obtained from combination of inductance and resistance.

Using the setup described in the foregoing paragraph, discontinuities were introduced into the system and photographs were taken of the reflections obtained. Figure 2-23 is a double exposure illustrating the reflections obtained when the line under test is terminated in an open circuit (upper trace) and in a short circuit (lower trace). Figure 2-24A shows the reflection from the same pulse and test line used in Fig. 2-23, but with the test line terminated in a pure resistance slightly greater than the Z_0 of the test line. Fig. 2-24B shows the reflection obtained when the test line is terminated with a pure resistance slightly less than the Z_0 of the line.

With the setup shown, reactive components show up as overshoot or undershoot in the reflected pulse. Fig. 2-25A shows the reflection obtained when the 50 ohm test line is terminated with a standard 100 ohm ½ watt composition resistor with leads approximately 1½ inches long. Note the overshoot due to lead inductance. Figure 2-25B shows the reduction in overshoot when the leads on the resistor are trimmed to ½ inch (the trailing edge of the pulse is out of the time window due to the sweep rate of the Type 5T3). Adding capacitance in shunt with a properly terminated line gives a reflection like that shown in Fig. 2-26. Here, a 1 pF capacitor is soldered across a non-reactive 50 ohm termination. A series inductance gives a similar reflection, but of opposite polarity.

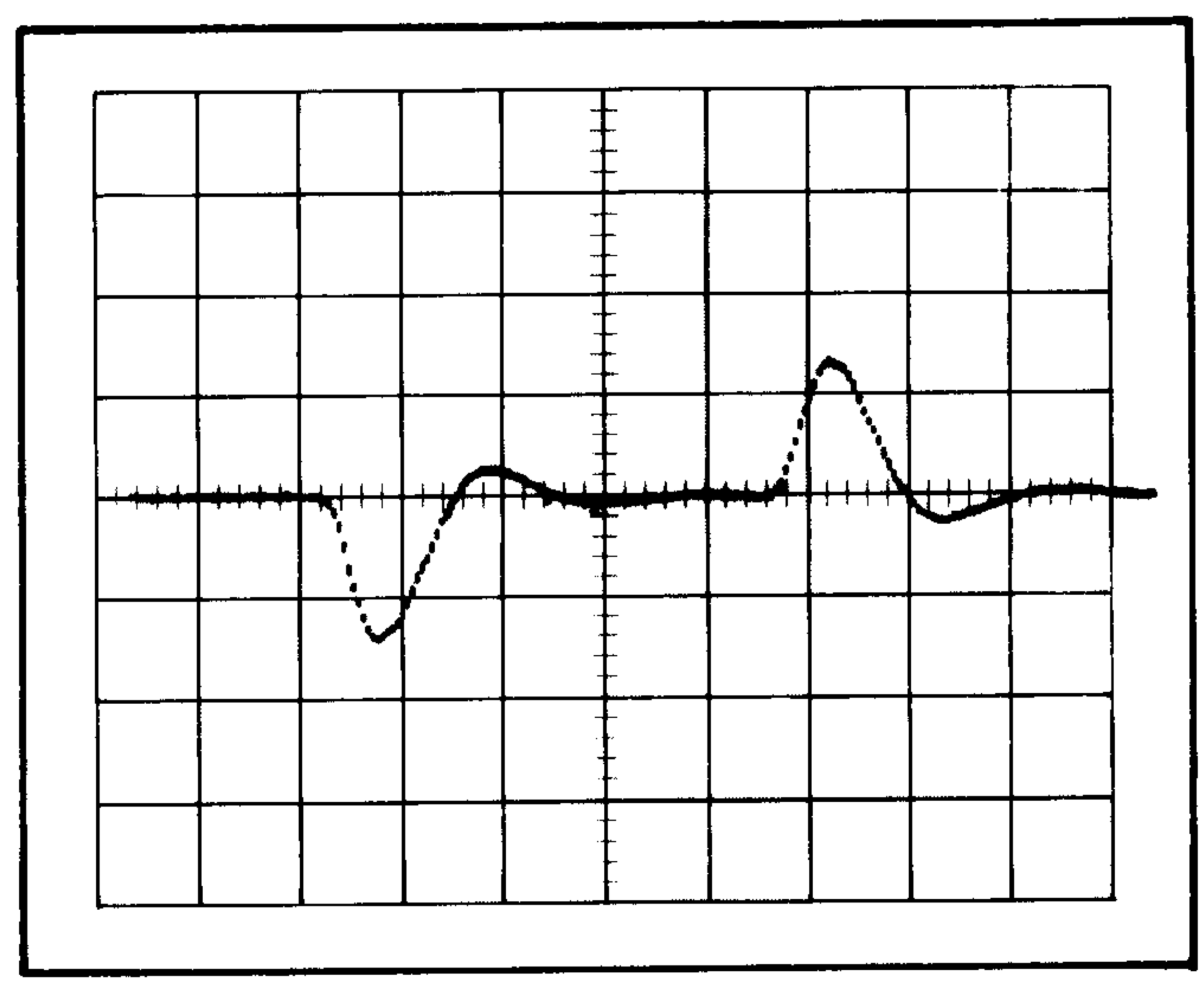

Fig. 2-26. Reflection obtained from 1 pF shunt capacitance in an otherwise properly terminated line.

The waveforms in the foregoing illustrations show the reflections resulting from deliberately introduced discontinuities, but the same techniques will also show discontinuities which get into the system accidentially. The system will show up a too-tight cable clamp, a poorly constructed connector, an open or shorted line, a high resistance connection, or other discontinuity. The location of the discontinuity can be determined by introducing a small discontinuity as a reference point, then measuring the time between the reference reflection and the reflection from the fault.

Pulsing the Transmission Line (2). Another setup for making pulse reflection measurements is shown in Fig. 2-27. A Tektronix Type 281 TDR Pulser is plugged into the Type 4S2A Channel A INPUT 50 Ω connector and power for the Type 281 is taken from the 4S2A PROBE POWER connector. The free connector of the Type 281 is connected through a 30 ns line or a Tektronix Type 113 delay cable to the test line or load.

In the system shown, the Type 281 TDR Pulser originates a repetitive, fast-risetime current pulse having a minimum pulse duration of 5 μs. The Type 281, acting as a current source, does not appreciably alter the characteristics of the reflected signal passing through it. The amplitude of the reflections as related to that of the applied pulse describes the size of the nonuniformities; their time delays after initial application of the pulse locate their positions within the transmission system.

Further details on pulse reflection measurement techniques are given in the Type 281 TDR Pulser instruction manual. If additional information is required, consult your local Tektronix Field Engineer.

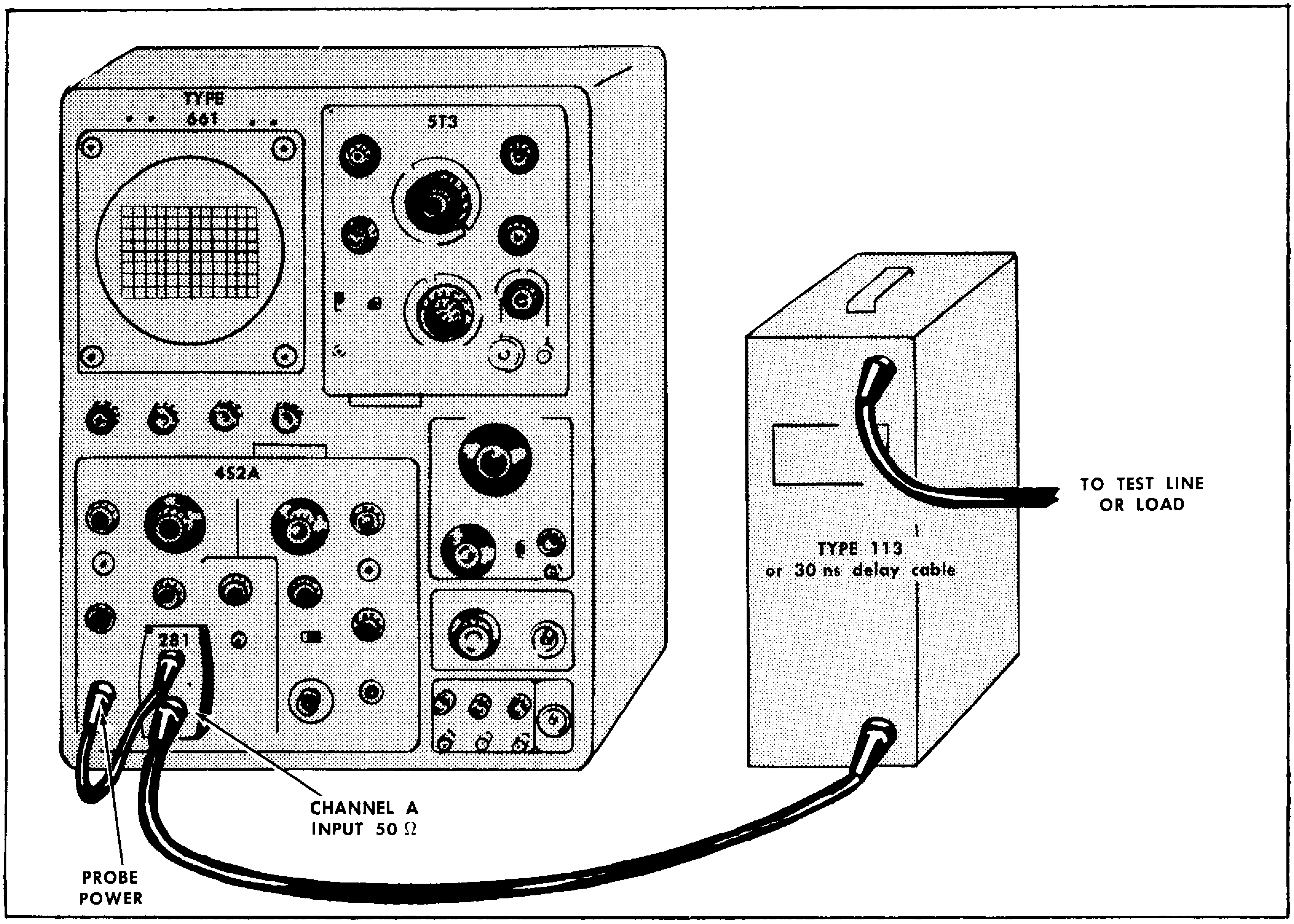

Fig. 2-27. Test setup for making TDR measurements with Type 281 TDR Pulser.

SECTION 3
CIRCUIT DESCRIPTION

Introduction

This section of the manual contains a block diagram analysis of the Type 4S2A followed by a detailed circuit description. The reader will find it helpful to refer to Basic Sampling Techniques in Section 2 of this manual if the purpose of a particular circuit is not immediately clear.

BLOCK ANALYSIS

The Type 4S2A simplified block diagram of Fig. 3-1 shows each circuit in block form, with all front panel and internal controls identified. Since the two channels are identical except for the internal trigger pickoff circuit, only the Channel A circuits are identified.

Trigger information (either picked off the input signal or externally applied) to the Timing Unit starts the sampling cycle. The Timing Unit in turn sends command pulses to the Type 4S2A Gate Generator. The Gate Generator sends very short duration push-pull pulses to both Sampler circuits, and slightly longer duration push-pull pulses to both Memory circuits. The two sets of pulses from the Gate Generator connect first the sampling gates to the sampler preamplifiers, and then connect the AC Amplifier to the Memory circuits.

Input signals travel through about three inches of 50-ohm air line into the Sampler which includes the sampling gate, charge-nulling amplifier, trigger pickoff, and sampler preamplifier. When the command pulse is received from the Gate Generator via J7, the sampling gate is biased to conduction. The sampling gate output signal is a series of pulses (one for each command pulse), which are amplified by the sampler preamplifier and coupled through the MILLIVOLTS/CM switch into the AC Amplifier. The AC Amplifier (gain of about 300) amplifies the signal and presents it to the Memory. The Gate Generator biases a gate at the Memory input to conduction as the signal arrives.

The Memory amplifies and stores the signal. The Memory output is applied to two circuits, one of which leads back to the Sampler, the other leading to the Type 661 indicator. The signal sent back to the Sampler sets the input circuit to the voltage of the signal at the time the sample was taken. (When the SMOOTHING control is set to unity dot transient response, the next sample corrects only for any signal changes since the last sample.) The Memory output signal to the Type 661 can be inverted by a unity-gain inverter, or applied without inversion. After the normal-inverted choice is made, the outputs of both channels then pass through the Dual Trace electronic switch where either or both are sent on to the Type 661. The signal applied to the Type 661 is used to produce the CRT display.

CIRCUIT ANALYSIS

Input and Sampler

The input and sampler (shown in simplified form in Fig. 3-2) are the heart of the sampling system where the 90 ps risetime performance is established. Input connectors on the Type 4S2A are 50 ohm General Radio Type 874 connectors. These connectors simplify input cabling problems and ensure close tolerance (1%) of the 50 ohm input impedance. The input termination is made up of a series-parallel resistor network which provides proper termination and a trigger pickoff point. Power dissipation rating of the terminating resistors limits the applied voltage to + or — 5 VDC, or pulse inputs of 10 volts peak to peak at 50% duty cycle.

The relay contacts shown in Fig. 3-2 represent an equivalent method of applying forward bias to the sampling gate and do not exist in the actual equipment. The sampling diodes D1011 and D1012 are normally reverse biased about 3 volts, but if the relay is momentarily closed, the gate becomes forward biased, permitting the signal to be applied to the sampler preamplifier. The actual forward biasing signal lasts slightly less than 90 ps; its period is so short, in fact, that the stray capacitance C_s of the input circuit combined with the input impedance and the series resistance of the sampling diodes limit the signal to the sampler preamplifier to about 2.5% of the input amplitude.

Operation of charge-nulling amplifier Q1004 (see circuit diagram at the rear of this manual) is explained as follows: If a square-wave signal is applied to the sampler gate, a charge of the amount C_dV is coupled to the preamplifier (V1033) grid, C_d being the shunt capacitance of the gate diodes and V is the voltage of the square wave. This charge is known as blow-by. A gate with extremely bad blow-by problems works very well on short (2 ns wide) pulses or on a 100 MHz sine-wave signal. With signals of this type, the relatively slow preamplifier does not have a chance to operate on the blown-in charge before the charge is pulled back out of the grid. The charge-nulling amplifier used in the Type 4S2A operates by cancelling out all low frequency blow-by components upon which the preamplifier could operate. A small sample of the real time square-wave signal is taken off through R1001 in the input termination and inverted by Q1004. If a capacitor C_{null} (C1010) of the correct size is placed between the output of Q1004 and the preamplifier grid, then the blown-in charge C_dV will be pulled back out by the nulling amplifier. Any charge blown into the preamplifier grid by a square-wave signal will thus be pulled back out in less than 2 ns by the inverting amplifier and does not appear in the output of the preamplifier.

The BRIDGE VOLTS control (R1023) adjusts the reverse bias on gate diodes D1011 and D1012. A higher reverse voltage allows the sampler diodes to be turned on for a shorter period of time. A lower voltage gives a slower risetime. Feedback is brought into BRIDGE BAL potentiometer R1027, which is adjusted to compensate for diode, strobe, and other system unbalance signals in synchronism with the strobe generator.

The preamplifier uses a single 6688 tube (V1033) triode connected and run at a gm of 25,000 μmho. This tube provides impedance transformation for driving emitter follower Q1043. The emitter follower drives the emitter of Q1044 in the common base stage through C1042.

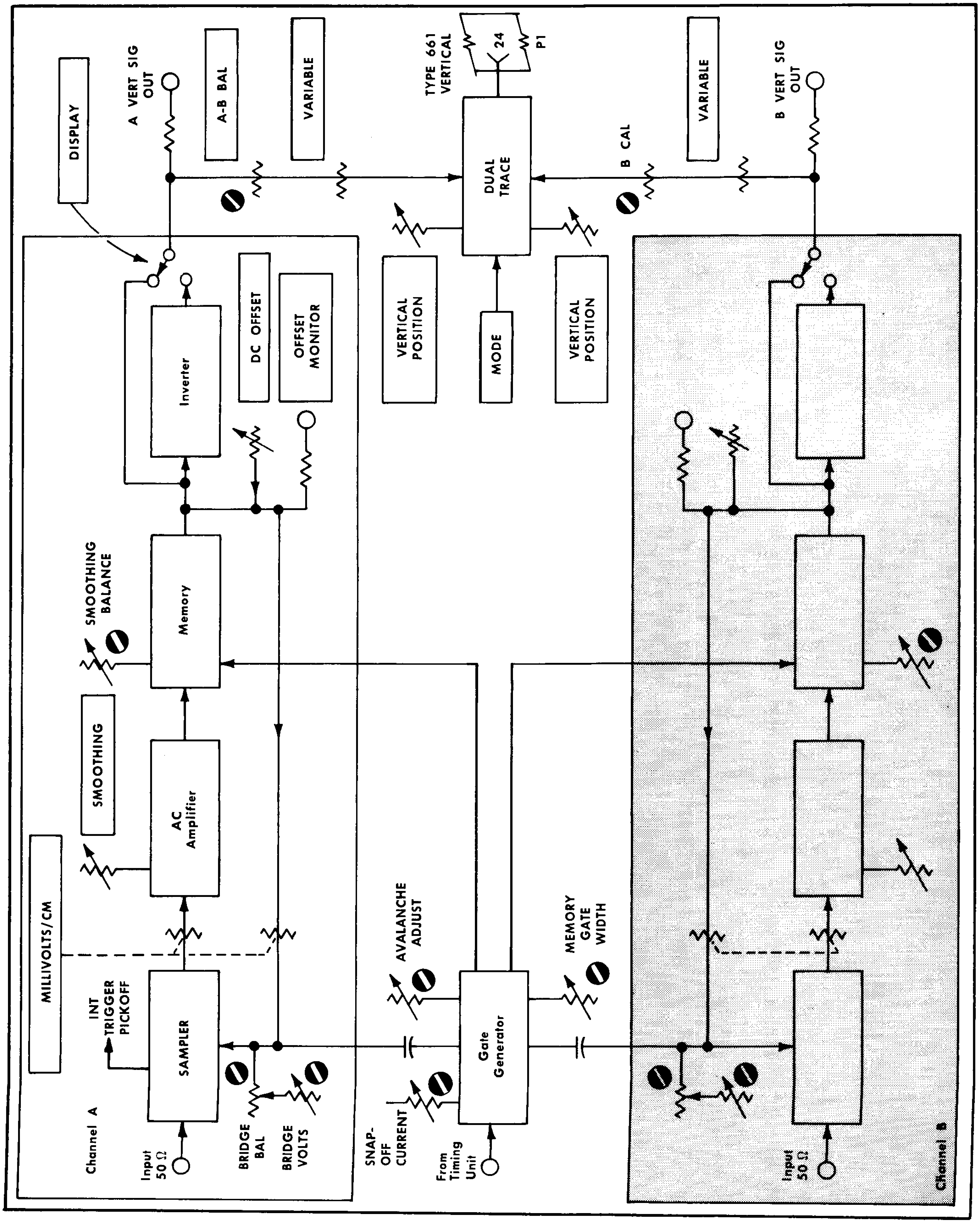

Fig. 3-1. Type 4S2A block diagram. Shaded area of Channel B is identical to corresponding area in Channel A.

Operation of the preamplifier is quite simple; a small sampled charge from the gate charges the grid-to-ground capacitance of V1033 to a small voltage V. This same voltage is made to appear across C1042, coupling the transistor emitters. A charge gain roughly equal to the ratio of emitter coupling capacitance to grid capacitance is achieved. Risetime of the preamplifier is about 40 ns, and by operating both the emitter follower and the common base stages at the same quiescent current levels, the preamplifier has very close to the same response for both plus and minus signals.

In Channel A, the output load for nulling amplifier transistor Q1004 is connected to the emitter of the grounded base, isolation amplifier Q1014. The grounded base stage supplies AC coupled trigger information to the timing unit. No delay line is incorporated, so the leading edge of a pulse cannot be viewed without pre-triggering the timing unit. The trigger pickoff is provided primarily for viewing high repetition rate pulses or sine-wave signals.

Gate Generator

The Gate Generator circuit board contains two basic circuits; the strobe generator and the memory gate driver.

Strobe Generator. The strobe pulses that gate the sampling diodes into conduction are formed by a special snap-off diode (charge storage diode), D1066, driven by a base-triggered, NPN silicon avalanche transistor, Q1054. Transistor

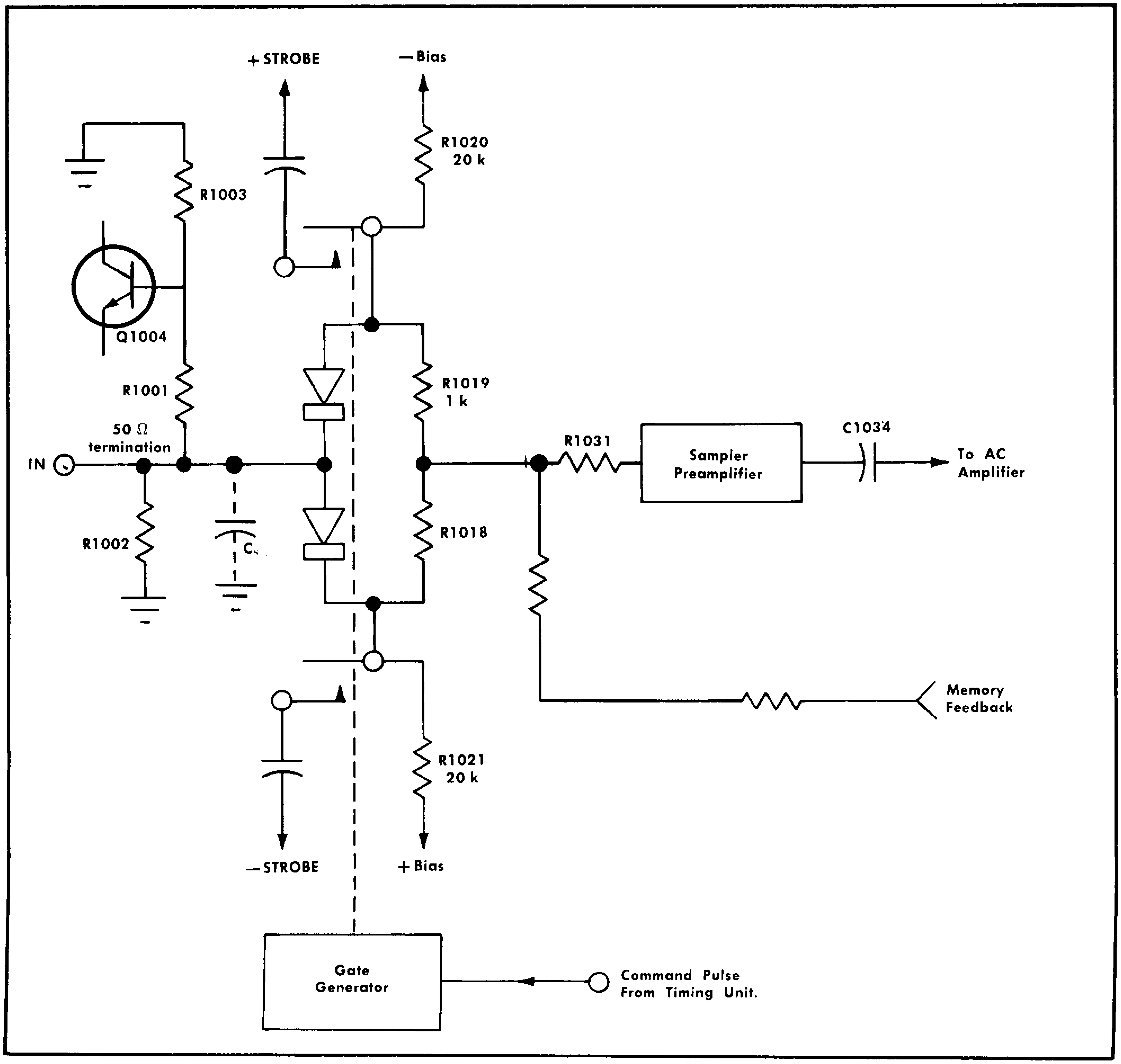

Fig. 3-2. Simplified sampling system input.

Q1054 is set for optimum operation by adjusting AVAL ADJ R1054, a 100 kΩ potentiometer that establishes the conducting bias of Q1053. The setting of R1054 and the conduction of Q1053 sets the collector voltage of Q1054 somewhere in the range between +100 and +175 volts since Q1054 operates without forward bias, and is normally non-conducting. The avalanche transistor is collector-coupled to the snap-off circuit through a small capacitor (C1058). The 10 kΩ collector load ensures ample time for the circuit to recover within a few tenths of a percent when operated at a 100 kHz repetition rate.

Between sampling-drive (trigger) pulses from the Timing Unit, snap-off diode D1066 is forward biased by the emitter current of Q1063. SNAP-OFF CURRENT adjustment R1063 adjusts the current through D1066, and thus adjusts the stored charge in the diode for best sampling efficiency. The 5-turn bifilar transformer changes the single-ended avalanche pulse output of Q1054 into a push-pull signal which reverse biases D1066. Diode D1066 is mounted in a very low inductance system of balanced clip lines and 50 Ω strip transmission lines for close control of the width and balance of the plus and minus strobe signals.

When a positive sampling drive pulse is received from the Timing Unit, the pulse is differentiated by C1051 and R1051, then applied to the base of Q1054. With the application of the pulse, Q1054 is biased into conduction, soon reaching the avalanche state and conducting very heavily. The collector voltage of Q1054 drops sharply, and the negative output of Q1054 is coupled through C1058 and R1058 to 5-turn pulse transformer T1065. The 5-turn pulse transformer turns the negative pulse into a push-pull signal which reverse biases D1066 and pulls out the charge stored therein. As soon as the charge is depleted, D1066 becomes a high impedance and the resulting fast voltage transition across the diode is sent through capacitors C1063 and C1064 to the clipping line. As the pulse travels down the clipping line, part of the energy is coupled out and sent to the sampling gates, biasing the sampling diodes into conduction. When the pulse hits the shorted end of the line, it is reflected back with opposite polarity, turning off the sampling gates.

Memory Gate Driver. Transistor Q1064 in the memory gate driver circuit operates as a saturated pulse standardizer, the output of which is applied to output transistor Q1074. The coupling circuit between the collector of Q1064 and the base of Q1074 consists of a ramp circuit. The collector voltage of Q1064, and therefore the height of the ramp, is set by MEMORY GATE WIDTH potentiometer R1067. The width of the ramp is determined by its height and the time constant of R1069 and C1068.

Under quiescent conditions, both transistors are biased to cutoff. Current flow through R1069 and series diode D1070 to the + 19-volt supply is 4 mA, 2 mA of which flows through R1071 from the —19-volt supply, the other 2 mA through shunt diode D1071 from ground.

The arrival of a sample drive pulse through L1051 and C1066 drives Q1064 into saturation for several hundred nanoseconds. The negative excursion of Q1064 collector is coupled to the base of Q1074 through C1068 and D1070. The negative pulse reverse biases D1070, and the junction of R1069 and D1070 is driven negative by the same amount that Q1064 collector voltage falls. Shunt diode D1071 turns off, and the 2 mA from the 10 kΩ resistor R1071 is now switched into Q1074, driving it into saturation. A memory drive pulse is thus started.

After this initial switching action, the Q1074 side of C1060 starts charging toward +19 volts from the current supplied to it by R1069. When the junction of R1069, C1068 and D1070 reaches +0.3 volts, D1070 turns on again and switches the charging current into the base of Q1074, turning off Q1074 and ending the memory drive pulse. A short time later Q1064 comes out of saturation, allowing the Q1064 side of C1068 to charge back toward the voltage value selected by the MEMORY GATE WIDTH Control.

AC Amplifier

The AC Amplifier receives its input signal (pulse) from the sampler preamplifier through the front panel MILLIVOLTS/CM switch, amplifies it 300 times, inverts it, and feeds the memory circuit. The input DC level (to ground) is zero, and the input resistance is switched from 25 ohms at 200 mV/cm to 1000 ohms at 5 and 2 mV/cm. The AC Amplifier is made up of two DC-coupled feedback amplifiers with a third DC feedback path around the whole circuit (see circuit diagram). The outside feedback path includes the front panel SMOOTHING control that allows a gain reduction of about 4 to 1 to reduce random noise. (When using SMOOTHING, the dot transient response must be considered and sufficient number of samples per centimeter obtained to make the display response correct.) The outside feedback path is for DC stabilization and does not act upon the main signal.

The signal pulses handled by the AC Amplifier are about 1 μs in duration. The amplifier output voltage can change 1.6 volts in about 0.1 μs. Normally the system causes the output pulses to be less than 1 volt, but if the display moves 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 can drive the memory input.

The gain of the first amplifier (Q1084 and Q1094) is about 45 when the SMOOTHING control (R1081) is set to NORMAL (zero resistance). The gain is set by the ratio of R1089 and R1083. When using full smoothing, the gain is about 8 to 10, set by the ratio of R1089 to R1083 and R1081 (SMOOTHING) in series. The gain of the second amplifier (Q1104 and Q1113) remains fixed at about 6, set by the ratio of R1107 and R1096.

The frequency response of the first amplifier is fixed-compensated by C1089. The second amplifier frequency response is adjusted during calibration by C1107.

Memory

A simplified schematic of the Memory circuit is shown in Fig. 3-3. The Gate Generator closes the Memory input gate (D1130 and D1131) at the correct time of each sampling cycle. The Memory circuit is a feedback amplifier with input and feedback elements both capacitors. The input capacitor is C1121, the feedback capacitor is C1132. V1133A (see circuit diagram) is an input cathode follower, Q1134 is the amplifier, and Q1141 is an output emitter follower.

Ⓐ

The input impedance at the grid of V1133A acts as a virtual ground because as the input signal changes the grid voltage, the signal is amplified and applied back to the input as negative feedback to cancel the original change.

The action of the memory is to transfer a charge from C1121 to C1132. The circuit between the AC Amplifier output and the grid of V1133A looks like 150 ohms and 510 pF in series (when the memory gate is conducting). Thus, as a signal appears at the AC Amplifier output, C1121 is charged. C1121 tries to couple the signal to the grid of V1133A, but feedback prevents the grid voltage from changing significantly; the result is that both C1121 and C1132 receive a charge.

When the memory gate is not conducting, the grid of V1133A has a very high impedance to ground, and at this time the only possible discharge path for C1132 is by V1133A grid current or leakage current. The grid current is very low, and can be either positive or negative. Total leakage current is so low that there is essentially no change in the output voltage between samples even when sampling at the low rate of 150 dots/sec.

The circuit elements between C1121 and the grid of V1133A serve several purposes:

1. D1125 and D1127 are amplitude-limiting diodes. They normally do not conduct.

2. D1122 is a 6-volt Zener to provide back-bias for the gating diodes D1130 and D1131.

3. The resistors all aid in standardizing the input quiescent voltage level.

4. T1130 is a pulse transformer that allows instantaneous turn-on of the gating diodes to connect the input circuit to V1133A.

5. C1122 assures that both sides of D1122 follow the signal equally.

Within the memory amplifier:

1. C1138 corrects for transistor phase shift.

2. D1136 permits Q1134 to turn on hard, long enough for the stored charge (of D1136) to be removed, preventing damage to Q1134 in the event of turn-on overload.

3. D1142 assures that fast positive pulses at the base of Q1141 will be coupled to C1132 and the output, even if Q1141 has been momentarily cut off.

4. D1144 limits the positive swing of the output lead to about 10 volts and D1143 assures a high impedance when D1144 is reverse biased.

5. D1140 sets the maximum collector voltage of Q1141 at —9 volts.

6. R1145 prevents reverse reflections in the output cable from disturbing the display.

Between samples, the AC Amplifier output returns to its quiescent level, and C1121 charge (that was gained at the last sample) is cancelled. At the last sample, if there is any change at the sampler unit, C1121 will receive a new charging signal and can add to or subtract from the residual charge of C1132.

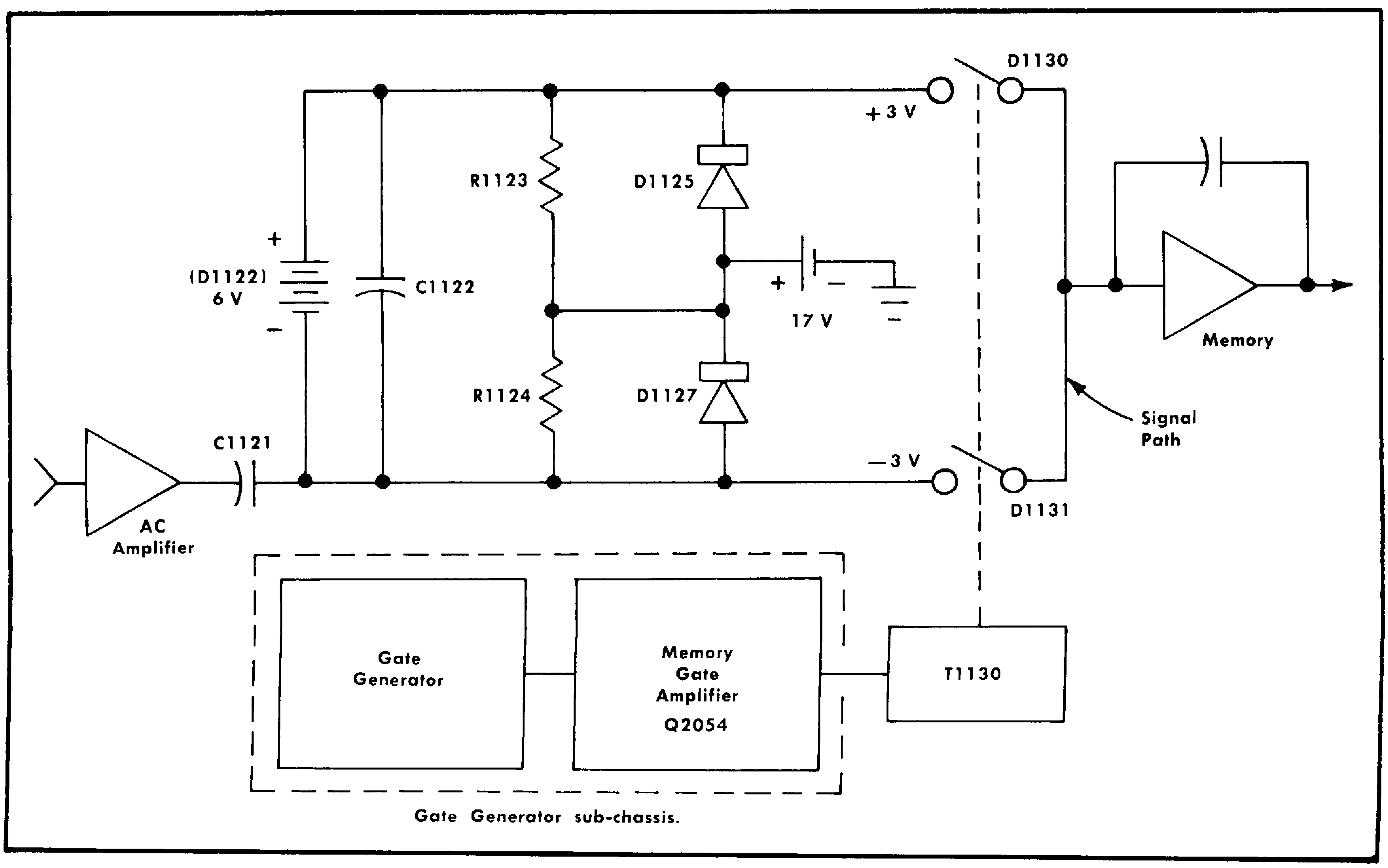

Fig. 3-3. Simplified memory gate.

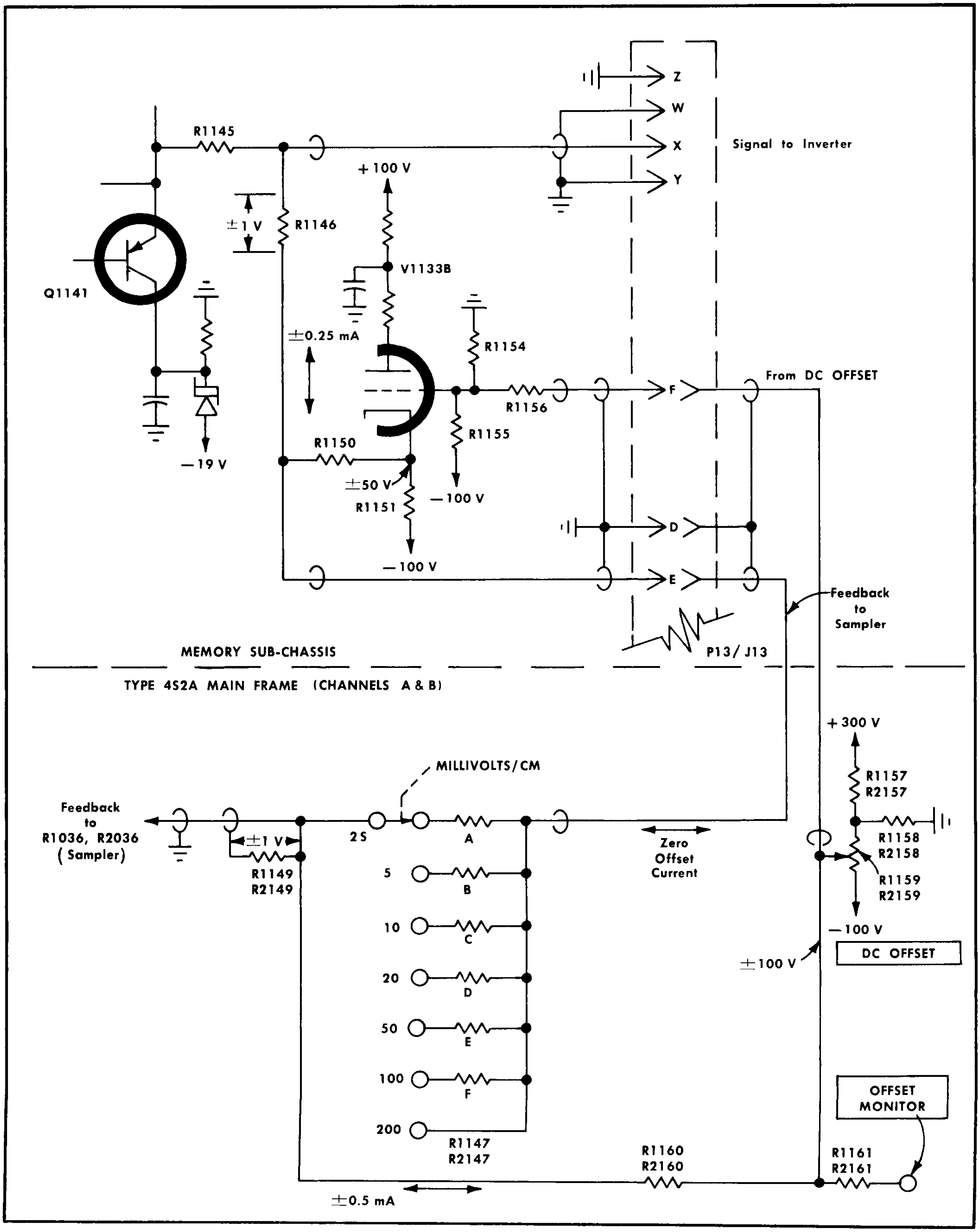

Fig. 3-4. DC Offset and Memory Feedback circuit.

System Operation With No Signal

Items to remember when examining signals at various points between the sampler amplifier output and the memory output:

1. It is impossible to install perfectly balanced sampling gate diodes, so at each interrogation there will be some small error signal sent into the system.

2. The memory circuit does not retain a perfectly stable output voltage because C1132 cannot hold a charge permanently.

3. The memory output is coupled back to the sampler input (with proper attenuation).

4. Theoretically, if there is no input at the sampling gate, there will be no AC Amplifier signal, and the memory output will be zero. The memory output will be essentially zero, but there will always be a small pulse at the AC Amplifier output.

5. The SMOOTHING BALANCE control (R1125) sets the quiescent DC level at the memory input and if incorrectly adjusted will cause an offset voltage that looks like a continuous signal. For example, assume the SMOOTHING BALANCE control is off by +1 mV. If the memory amplifier internal gain is 500 (it isn't actually), the memory output will now be off by —500 mV. The —500 mV feedback to the input bridge creates an error signal which will drive the memory output nearly back to zero. After several dots the memory output will stabilize near zero, but slightly off from zero to provide enough error signal to correct for the original +1 mV error. Thus, a continuous minor error signal is amplified to place the output level near zero. If the AC Amplifier gain is reduced by the SMOOTHING control, the memory output must now be larger so the error signal fed into the AC Amplifier is larger, restoring again the —1 mV correction at the memory input. (A trace shift seen when the SMOOTHING control is rotated away from NORMAL is the increased memory output to make up for the reduced amplifier gain). Thus the memory input balance control is called the SMOOTHING BALANCE because its effect is seen by rotation of the SMOOTHING control.

DC Offset

The memory output of Q1141 is fed to the inverter or to the dual trace circuit. It is also fed to a voltage divider that controls the feedback signal sent to the sampler. The feedback attenuator resistors, R1147, (Plug-In Connectors and Switching diagram, Channel A) set the feedback amplitude to keep the basic memory output of 600 mV/cm while the feedback voltage just matches the input signal.

The DC Offset circuit adds a DC shift to the feedback loop. It includes a current cancelling system that prevents offset current from flowing in R1147; see Fig. 3-4. The grid voltage of V1133B is set by the DC OFFSET control through a resistance divider. Rotating the DC OFFSET control from one end to the other causes a ±50 volt swing at the cathode of V1133B. The cathode of V1133B drives ±0.25 mA through R1146 via R1150. The DC OFFSET control ±100-volt swing drives ±0.2 mA through R1149 via R1160. The resulting voltage drop of ±1 volt across both R1146 and R1149 is the offset voltage sent to the sampler amplifier. The two points of offset injection ensure there is no offset current in R1147 so that the offset system is not affected by the MILLIVOLTS/CM switch.

The DC OFFSET control may be used to null certain levels of the input signal in order to measure amplitude. The OFFSET MONITOR jack allows a voltmeter connection to read the effective DC offset voltage ×100. The offset voltage is also useful when measuring small signals riding on larger signals.

Inverter

The Inverter is an ×1 amplifier pair (10 kΩ input, 10 kΩ feedback) for each channel. Its function is to invert the display when the front panel DISPLAY switch is in the INVERTED position. When the DISPLAY switch is in the NORMAL position, the inverter is bypassed by interconnecting wiring in the Type 4S2A main frame.

Q1164 is collector coupled to Q1163. D1167 is a voltage offset Zener to raise the voltage at the base of Q1163 above that at the collector of Q1164 without signal attenuation. Q1163 is an output emitter follower. R1161, the A INVERTER ZERO control, and R1162 are a DC balance network to adjust the output DC level, eliminating trace shift when moving the DISPLAY switch from NORMAL to INVERTED. R1163 is the feedback resistor.

Dual Trace

The Dual Trace subchassis determines which channel is displayed by the Type 661; under some conditions, the signals from both channels are fed to the Type 661. Because of the various modes of operation possible in dual-trace, both the A and B channel will be discussed.

Two gated inverter amplifiers, Q1184 and Q2184 (see circuit diagram) control passage of the signal. A multivibrator, Q2245 and Q2255, controls the two amplifiers via switching diodes D1187 and D2187. Multivibrator operation is controlled by the front panel MODE switch. In the A ONLY, B ONLY, and A VERT B HORIZ modes, only one side of the multivibrator conducts. In the ADDED ALGEB mode, neither side conducts, and in the DUAL TRACE mode, the multivibrator free-runs at a switching rate of about 50 kHz. Q2264 provides a dual-trace blanking signal to the Type 661 when the multivibrator switches.

A 0.25-μs delay line couples the output signal from the dual trace unit to the Type 661 indicator. The delay allows the signal to pass properly with the Timing Unit unblanking of the Type 661 CRT.

Refer to Fig. 3-5, the Dual Trace, and the Plug-In Connectors and Switching diagrams during the following discussion. Each inverter is fed signals from the DISPLAY switch for its channel. The Channel A signal arrives through R1184, the Channel B signal arrives through R2182 and R2184. The inverter amplifier emitter circuits include positioning controls (R1180 and R2180) in parallel with the emitter return resistors (R1185 and R2185). Positioning is by current injection into the emitter circuits through R1181 and R2181. The major emitter current comes from the +19-volt supply, through MODE switch SW2190 and to the emitters through R1185 and R2185. In the ADDED ALGEB position of the MODE switch, current limiting resistor R1179 is inserted in the emitter to keep the common output lead average voltage the same as when only one transistor is conducting.

The amplifiers are connected in a common-base configuration. The current at their collectors is switched between two 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 it is connected to the output or not. The input impedance is that of the series input resistors, R1184 in channel A, and R2182 and R2184 in channel B. Since the emitters of both transistors rest at about +0.2 volts, R1183 and R2183 are used to offset the input voltage to zero. The —4.5 volt collector voltage is offset to zero (for the output lead) by the series combination of R1191 and R1192.

Fig. 3-6 shows the MODE switch connections that set the operating conditions of the multivibrator. 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, multivibrator transistor Q2255 operates in saturation, and its collector is held at about +0.4 volt by D2255. This reverse biases both D2258 and D1187, so that Q1184 supplies the output signal. Since transistor Q2245 is cut off, R2248 forward biases both D2248 and D2187, bypassing Q2184 from the output.

Operation in the A VERT B HORIZ mode sets the multivibrator and the inverter amplifiers the same as in the A ONLY mode. The Channel B signal bypasses the Dual Trace circuit and is fed separately to the Type 661 horizontal deflection system. In the B ONLY mode, operation of the multivibrator and inverter transistors is the reverse, with Q1184 disconnected and Q2184 supplying the output signal.

In the ADDED ALGEB mode, neither multivibrator transistor conducts. Both inverters are turned on, combining both

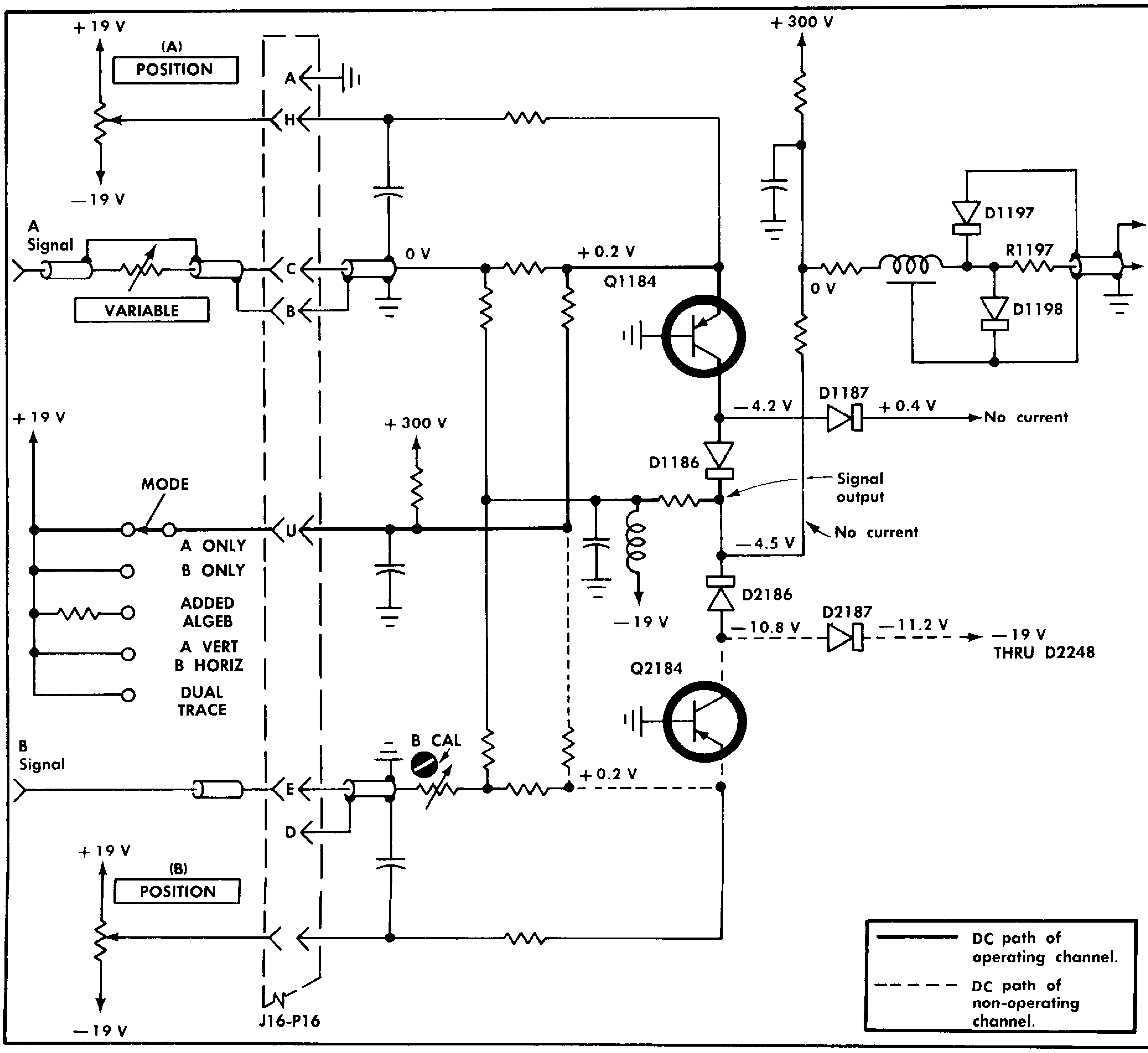

Fig. 3-5. Dual Trace circuit DC conditions. MODE A ONLY, DC OFFSET zero, trace centered, no signal, timing unit FREE RUN.

signals in the common collector circuit at R1189. The output to the delay line is the algebraic sum of the A and B signals.

In the DUAL TRACE mode, Q2245 and Q2255 operate as a free-running multivibrator at a frequency of at least 50 kHz. The inverter amplifiers pass signals alternately, providing a dual-trace display.

During multivibrator operation, neither transistor saturates, and Zener diode D2251 does not conduct. The multivibrator switching time constant, located between the emitters of Q2245 and Q2255, is composed of C2251 in series with the emitter return resistor (R2240 or R2250) of the non-conducting side. The collector-to-base coupling circuits (R2246-C2246 and R2256-C2256) do not set the time of operation; the capacitors are for high-frequency coupling to ensure fast switching.

Blanking Circuit

Blanking transistor Q2264 normally rests in cutoff with its base at about +0.8 volts. As the multivibrator switches, C2240 or C2250 couples about a —2 volt signal to the base of Q2264 to turn it on. The turn-on pulse lasts only about 0.5 μs, but it is heavy enough to saturate Q2264 and give it a storage time of about 1 to 1.5 μs. There is some positive overshoot immediately before the —2 volt pulse. This is kept from the base of Q2264 by D2262 so that the storage time of Q2264 will be fairly consistent, and the CRT will be properly blanked during the time the dual-trace multivibrator is switching channels.

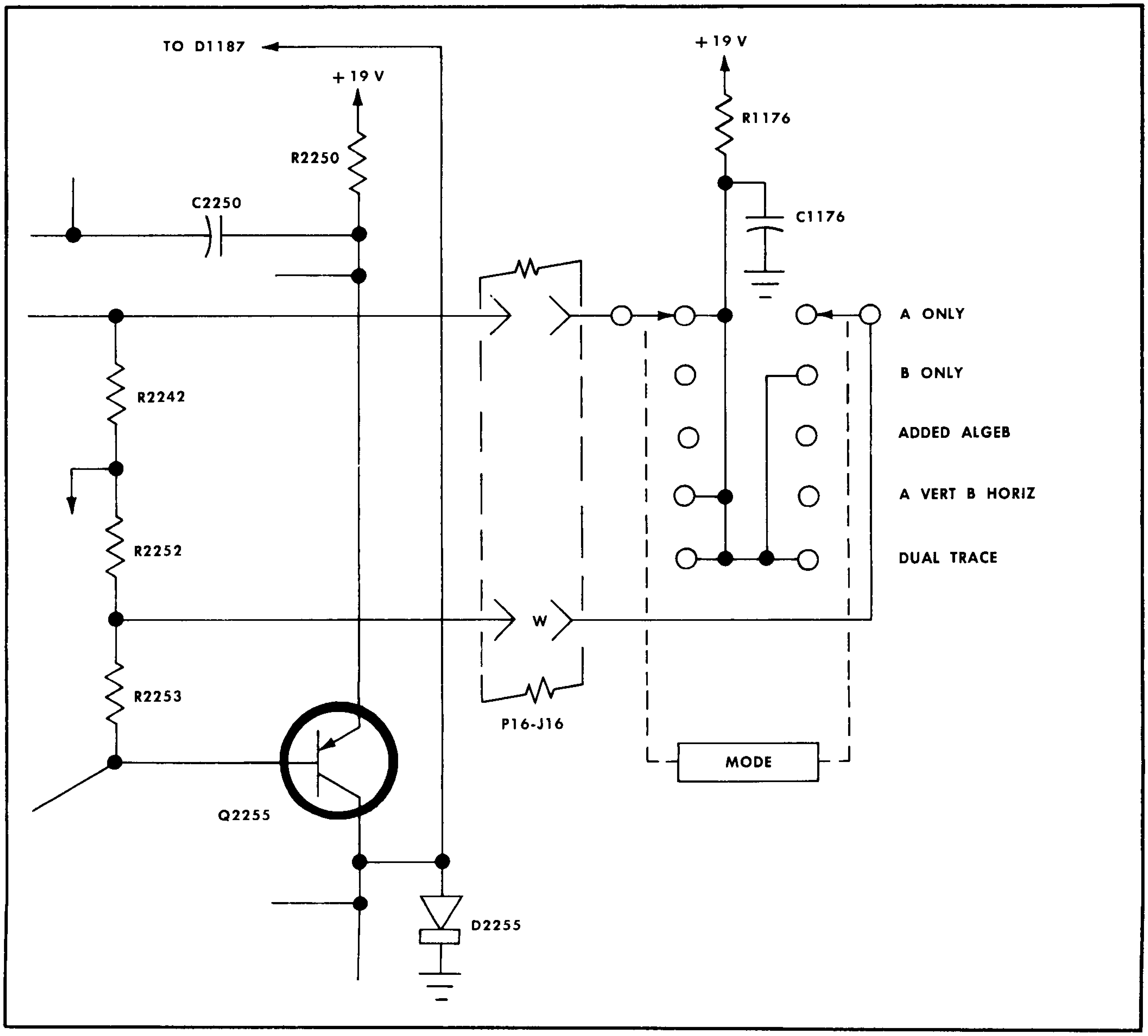

Fig. 3-6. MODE switch connections to the DUAL TRACE multivibrator.

NOTES

SECTION 4
MAINTENANCE

Introduction

This section contains maintenance instructions for the Tektronix Type 4S2A, and includes preventive maintenance, troubleshooting hints, and corrective maintenance.

Preventive Maintenance

Preventive maintenance consists of cleaning, visual inspection, lubrication, and, if needed, recalibration. Preventive maintenance is generally more economical than corrective maintenance, since preventive maintenance can usually be done during idle periods at a time convenient to the user. The preventive maintenance schedule established for the instrument should be based on the amount of use and the environment in which the instrument is used.

Cleaning. The Type 4S2A should be cleaned as often as operating conditions require. The Type 661 air filter provides nearly 100% protection against dust accumulating in the interior of the instrument, but a small amount of dust is brought in by circulating air. Operation without the oscilloscope side panels in place is never recommended for internal temperature control reasons.

Dirt on the circuit components prevents efficient heat dissipation and may cause component overheating. Clean the instrument by loosening the accumulated dust with a dry, soft paint brush. Remove the loosened dust by vacuum and/or dry, low-pressure compressed air (high-velocity air can damage some components). Hardened dirt and grease may be removed with a cotton-tipped swab or a soft cloth dampened with water and a mild detergent solution (such as Kelite or Spray White). Abrasive cleaners should not be used.

CAUTION

Do not permit water to get inside controls or shaft bushings. Store the instrument in a dust-tight covering when not in use.

Dirt in the Type 661 air filter chokes the flow of cooling air and leads to excessive Type 4S2A operating temperatures. Inspect and clean the air filter in accordance with the instructions in the Type 661 instruction manual.

Lubrication. The life of potentiometers and rotary switches is lengthened if these devices are kept properly lubricated. Use a cleaning type lubricant (such as Cramoline) on shaft bushing, plug-in connector contacts, and switch contacts. Lubricate the switch detents with a heavier grease (Beacon grease No. 325 or equivalent). The necessary materials and instructions for proper lubrication of Tektronix instruments are contained in a component lubrication kit which may be ordered from Tektronix. Order Tektronix Part No. 003-0342-00.

Visual Inspection. After cleaning, the instrument should be carefully inspected for such defects as poor connections, damaged parts, and improperly seated tubes or transistors. The remedy for most visible defects is obvious; however, if heat-damaged parts are discovered, determine the cause of overheating before the damaged parts are replaced. Otherwise, the damage may be repeated.

Tube and Transistor Checks. Periodic preventive maintenance checks consisting only of removing the tubes and transistors from the instrument and testing them in a tester are not recommended. The circuits within the instrument provide the only satisfactory means of checking tube and transistor performance. Defective tubes or transistors will usually be detected during recalibration of the instrument. Details of in-circuit tube and transistor checks are given in the troubleshooting procedures later in this section.

Recalibration. To ensure accurate measurements, the instrument calibration should be checked after each 500 hours of operation or every six months if the instrument is used intermittently. The calibration procedure is helpful in isolating major troubles in the instrument. Moreover, minor troubles not apparent during regular operation are frequently revealed and corrected during recalibration. Complete calibration instructions are contained in Section 6.

Corrective Maintenance—General

General Troubleshooting. If the instrument is not operating, attempt to isolate the trouble by a quick operational and visual check. Make sure that any apparent trouble is actually due to a malfunction within the Type 4S2A and not due to improper control settings or a fault in associated equipment.

Operate the controls to see what effect, if any, they have on the trouble symptoms. The normal or abnormal operation of each particular control helps in establishing the nature of the trouble. The normal function of each control is listed in Section 2 of this manual.

The Type 4S2A derives all of its operating voltages from the oscilloscope, and depends on the oscilloscope and the Timing Unit for its display; therefore, be sure that the oscilloscope is not the cause of trouble.

After the trouble symptoms are established, look first for simple causes of trouble. Check to see that the pilot light of the oscilloscope is on, feel for any irregularities in the operation of the controls, listen for any unusual sound, see that the tube filaments are lit, and visually check the entire instrument. The type of trouble will generally indicate the checks to make.

In general, a troubleshooting procedure consists of two parts: circuit isolation and circuit troubleshooting. Since the Type 4S2A is a complex unit consisting of many circuits, study each schematic carefully while reading the circuit description to help determine which circuit is defective. After isolating the circuit, troubleshoot in the circuit to find the cause of the trouble.

Trouble Symptoms

1. A display that may appear as trouble to someone not familiar with sampling techniques can occur when triggering information stops arriving from the Timing Unit. Each display dot is the result of a pulse from the Timing Unit arriving at the Type 4S2A Gate Generator via J7. If the information stops—even in the middle of a trace—sampling stops immediately. The spot does not extinguish, but it stops progressing across the CRT horizontally and starts drifting up or down the CRT and ultimately goes out of sight. This is normal, and is not to be confused with trouble in the Type 4S2A. (It is the Memory drifting, without repeated correction.) Should the Timing Unit information begin again, the dot will return to the CRT and the interrupted trace will be completed.

2. If the display appears to compress—or limit—at one end of the VERT POSITION control range, set the DC OFFSET control so that a voltmeter at the OFFSET MONITOR jack reads zero: Then reduce the input signal until it is 1 volt or less, peak to peak. If the symptom continues, recalibration of the Type 4S2A is necessary.

3. In order to view the Type 661 Delayed Pulse, it may be necessary to connect 40 ns or more of delay cable between the Delayed Pulse output connector and the Type 4S2A input. Use cable with good high frequency response (risetime 5 ns or less), such as the Tektronix Type 113 Delay Cable.

4. If the dots are scattered over the CRT, the Gate Generator is free-running. Recalibration of the Type 4S2A is necessary.

If the trouble cannot be located by means of front-panel checks, remove the Type 4S2A from the oscilloscope and operate it by means of extension cables. Check voltages and waveforms against those presented in the circuit description and schematics, starting with the power-supply connections.

CAUTION

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

Testing Precautions. When observing waveforms in the Type 4S2A circuitry, always make certain that the test oscilloscope frame is connected to the Type 4S2A frame. To look at fast pulses that are differential in nature inside the Type 4S2A circuits, observe the following. The Tektronix P6034 and P6035 signal probes, used on one sampling system to observe another, can be used singly in a differential fashion. If the circuit being measured is not at ground potential, both the probe center conductor and ground return must be AC-coupled. The center conductor can be AC-coupled using a General Radio Type 874-K in-line capacitor. The ground return can be AC-coupled (for fast signals) by use of a 0.001-μF capacitor at the probe ground clip. Use short leads. If the test oscilloscope frame is not connected to the Type 4S2A frame, a 60-Hz stray pickup between the chassis can damage components in the Type 4S2A.

Resistance Checks. In the event of trouble, Table 4-1 may be of value when searching for the fault. The table lists the DC resistance to ground of each pin (24 pin rear-panel connector) when the Type 4S2A is disconnected from the oscilloscope.

TABLE 4-1

P21 DC Resistances To Ground

Pin	Approximate Resistance
1 and 2	inf
3	1-2 kΩ
4	18 Ω
5	2.8 kΩ
6	inf
7	0.25 Ω
8	0.7 Ω
9	0
10 and 11	10 kΩ
12	0 Ω
13 and 14	inf
15	7.5 kΩ
16	inf
17	4 kΩ[1]
18	700 Ω
19	inf
20	0
21	13 kΩ[1]
22 and 23	inf
24	4 kΩ

[1]Depends upon ohmmeter polarity.

Removel of Subchassis Assemblies. Most of the circuitry of the Type 4S2A is located on subchassis assemblies. Each subchassis has a 22 contact connector that mates with the main frame cables. Maintenance is made easier by the use of a special subchassis extender, and special extension cables that permit the Type 4S2A to be operated outside of the Type 661 (identifed at the beginning of the calibration procedure). The Type 4S2A will operate correctly with any subchassis extended for testing.

Removal of the subchassis is accomplished by pressing down on the tabs located at each side of the unit being removed. The removal tabs apply lifting pressure to the guides, aiding in disconnecting it from the interconnecting socket.

Installation of a subchassis requires careful observation of the mating connector at the base of the unit. A number located by the interconnecting socket identifies the subchassis which will operate in that location (see Fig. 4-1). The number is shown in the lower right-hand corner of each schematic diagram. The series number is a circuit guide, not a physical position guide, and mates with a number on the top lip of each subchassis.

To replace a unit, align all pins and the two plastic tips with their proper position at the interconnecting socket, and apply hand prêssure to push the unit fully into position. Take care not to rotate small screwdriver adjustments, as they will change the calibration. When replacing the memory subchassis, be sure to return them to the same socket from which they were removed.

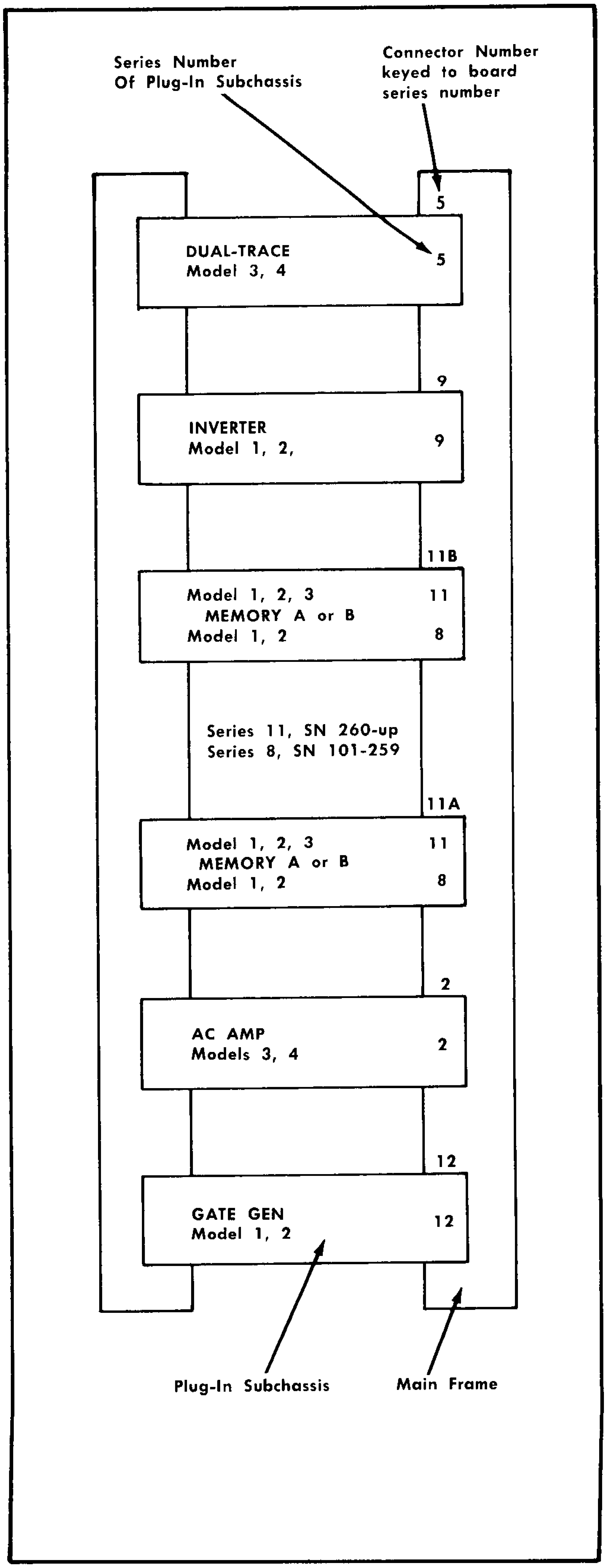

Fig. 4-1. 4S2A Plug-In Board keying system.

Transistor Testing. Transistors should not be replaced unless they are actually defective. Transistor defects usually take the form of the transistor opening, shorting, or developing excessive leakage. To check a transistor for these and other defects, use a transistor curve display instrument such as a Tektronix Type 575. However, if a good transistor checker is not readily available, a defective transistor can be found by signal-tracing, by making in-circuit voltage checks, by measuring the transistor forward-to-back resistance using proper ohmmeter resistances, or by using the substitution method. The location of all transistors is silk-screened on the chassis next to each socket.

To check transistors using a voltmeter, measure the emitter-to-base and emitter-to-collector voltages and determine if the voltages are consistent with normal resistances and current in the circuit (see Fig. 4-2).

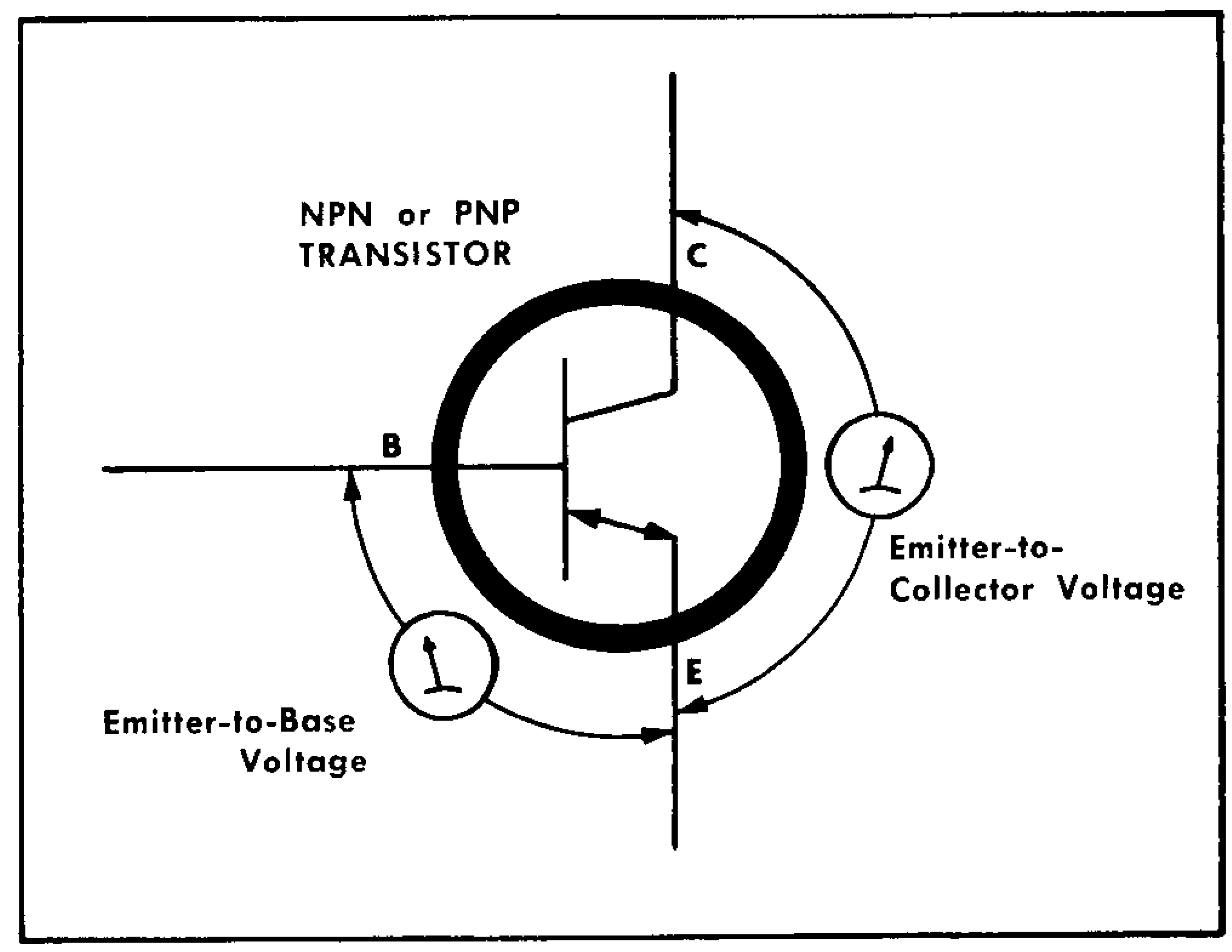

Fig. 4-2. In-Circuit voltage checks NPN or PNP transistors.

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

NOTE

As a general rule, use the R × 1 kΩ range where the current is usually limited to less than 2 mA and the internal voltage is usually 1½ volts. Check the current and voltage by inserting a multimeter between the ohmmeter leads and measuring the current and voltage for the ranges used.

When it has been determined which ohmmeter ranges will not harm the transistor, use those ranges to measure the resistance with the ohmmeter connected both ways as given in Table 4-2.

TABLE 4-2
Transistor Resistance Checks

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

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

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

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

Wiring Color Code. The wiring in the Type 4S2A is color coded to facilitate circuit tracing. In the case of power-supply leads, the color code indicates the voltage carried, with the widest stripe denoting the first significant figure. Table 4-3 lists the color combinations and the voltages indicated by the colors.

TABLE 4-3
Power Supply Color Coding

Supply	Color Code
+300	Orange/Black/Brown on White
+125	Brown/Red/Brown on White
+19	Red/Black on White
—19	Red/Black on Tan
—100	Brown/Brown/Black on Tan

Resistor Coding

The Type 4S2A uses a number of very stable metal film resistors identified by their gray background color and color coding.

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

The color-coding sequence is shown in Fig. 4-3.

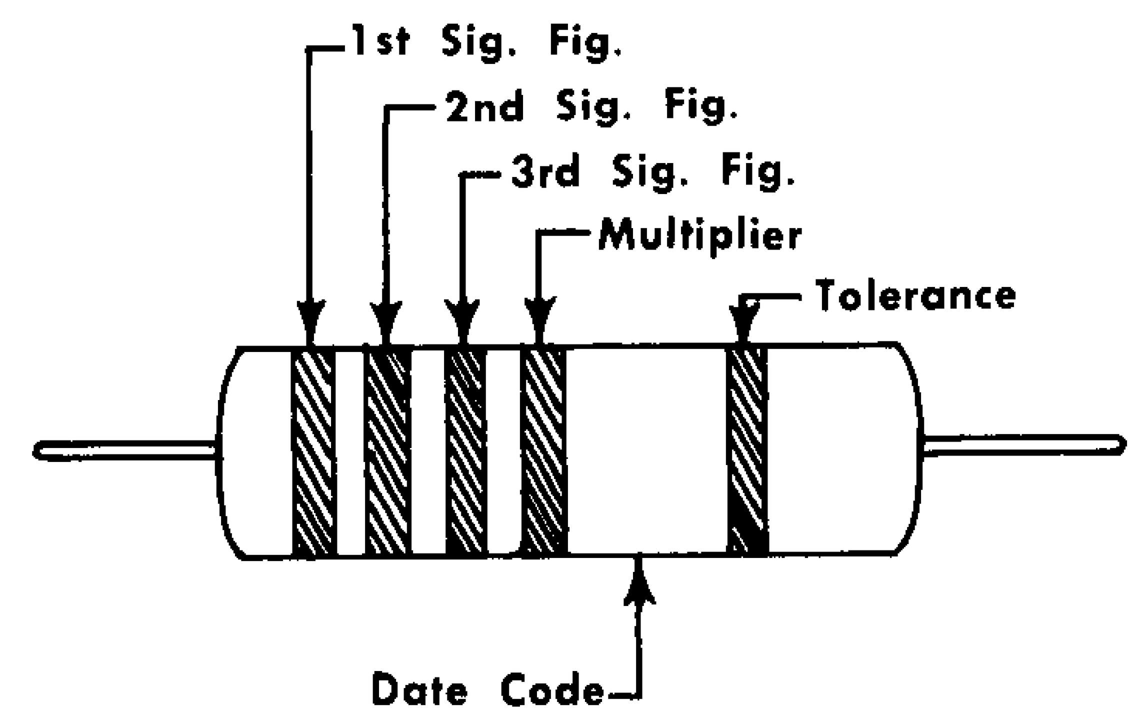

Fig. 4-3. Standard EIA color code for metal film resistors.

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

Parts Replacement

All parts used in the Type 4S2A can be purchased directly through your Tektronix Field Engineer or Field Office. However, replacements for standard electronic items can generally be obtained locally in less time than is required to obtain them from Tektronix. Replacements for the special parts used in the assembly of the Type 4S2A should be ordered from Tektronix since these parts are manufactured or selected by Tektronix to satisfy a particular requirement. Before purchasing or ordering, consult the Parts List to determine the value, tolerance, and ratings required. See Parts Ordering Information and Special Notes and Symbols on the page immediately preceding the Electrical Parts List.

Parts Location

All parts on the circuit cards and subchassis are identified in Figs. 4-9 through 4-13 at the end of this section.

NOTE

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

Removal of Sampling Bridge Diodes. The Sampling Bridge diodes may be removed or replaced through the access holes provided in the side of the Type 4S2A.

Fig. 4-4 shows a plastic diode holder assembly partially inserted through the access hole using Xcelite Forceps, Tektronix Part No. 003-0347-00.

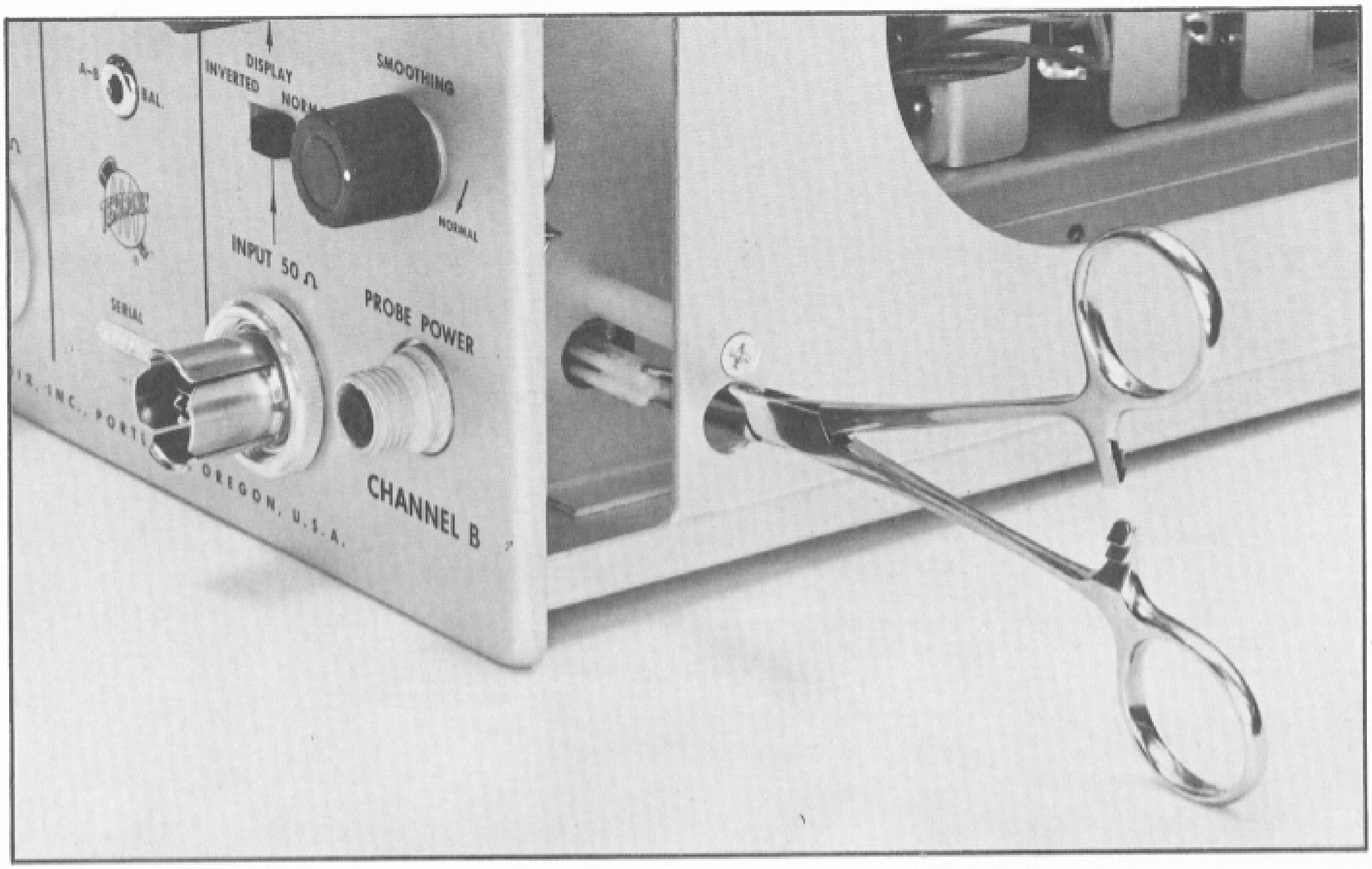

Fig. 4-4. Removal of sampling bridge diodes.

Fig. 4-6, Sampler Board with shields removed, shows the position of the Sampler Diode assembly.

Replacing Components on Circuit Cards. Use ordinary electronic grade 60/40 solder and a 35- to 40-watt pencil soldering iron with a ⅛ inch wide chisel tip. The tip of the iron should be clean and properly tinned for best heat transfer in a short time to a soldered connection. A higher wattage soldering iron, if used and applied for too long a time, ruins the bond between the wiring and base material by charring the glass epoxy laminate.

The step-by-step technique is as follows:

1. To remove a component, cut the leads near the body. This frees the leads for individual unsoldering.

2. Grip the lead with needle-nose pliers. Apply the tinned tip of the soldering iron to the lead between the pliers and the card; then pull gently.

3. When the solder first begins to melt, the lead will come out, leaving a clean hole. If the hole is not clean, use the soldering iron and a toothpick or a piece of enamel wire to open the terminal hole. Do not attempt to drill the solder out; the through-hole plating might be destroyed.

4. Clean the leads on the new component and bend them to the correct shape. Carefully insert the leads into the holes from which the defective component was removed.

5. Hold the leads of tunnel diodes with tweezers or pliers to form a heat sink. Apply the iron for a short time at each connection on the side of the board opposite the component to properly seat the component.

6. Apply the iron and a little solder to the connections to finish the solder joint.

Replacing Components on Ceramic Terminal Strips. Special silver-bearing solder is used to establish a bond to the ceramic terminal strips used in Tektronix instruments. This bond may be broken by repeated use of ordinary tin-lead solder or by excessive heating. Solder containing about 3% silver is recommended. Silver-bearing solder is usually available locally or may be purchased in one-pound rolls through your Tektronix Field Engineer or Field Office. Order by Tektronix Part No. 251-0514-00.

Because of the shape of the ceramic strip terminals it is recommended that a soldering iron with a wedge-shaped tip be used. A wedge-shaped tip allows the heat to be concentrated on the solder in the terminals. It is important to use as little heat as possible while producing a full-flow joint.

The step-by-step technique is as follows:

1. Use long-nose pliers for a heat sink. Attach pliers between the component and the point where heat is applied.

2. Use a 50- to 75-watt soldering iron with a clean tip, properly tinned with solder containing about 3% silver.

3. Apply heat directly to the solder in the terminal without touching the ceramic. Do not twist the iron in the notch as this may chip or break the ceramic strip.

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

5. Do not attempt to fill the notch with solder; instead apply only enough solder to cover the wires adequately and form a small fillet. Overfilling the notches may result in cracked terminal strips. If the lead extends beyond the solder joint, clip off the excess close to the joint.

6. Remove all wire clippings from the chassis.

Ceramic Strip Replacement. Unsolder all connections, then use a 3/8 inch diameter by 3 inch long plastic or hardwood dowel and a small (2 to 4 oz.) mallet to knock the stud pins out of the chassis. Place one end of the dowel on the end of the stud pin protruding through the chassis. Rap the opposite end of the dowel smartly with the mallet. When both studs of the strip to be removed have been loosened in this fashion, the strip is removed as a unit. The spacers will probably come out with the studs. If not, they can be pulled out separately. An alternative method of removing the terminal strip is to use diagonal cutters to cut off the sides of the studs. The ceramic strip is removed and the studs pulled from the chassis with a pair of pliers. Replacement ceramic strips are supplied with studs and spacers, so the old studs need not be salvaged. The ceramic strip and its parts are shown in Fig. 4-5.

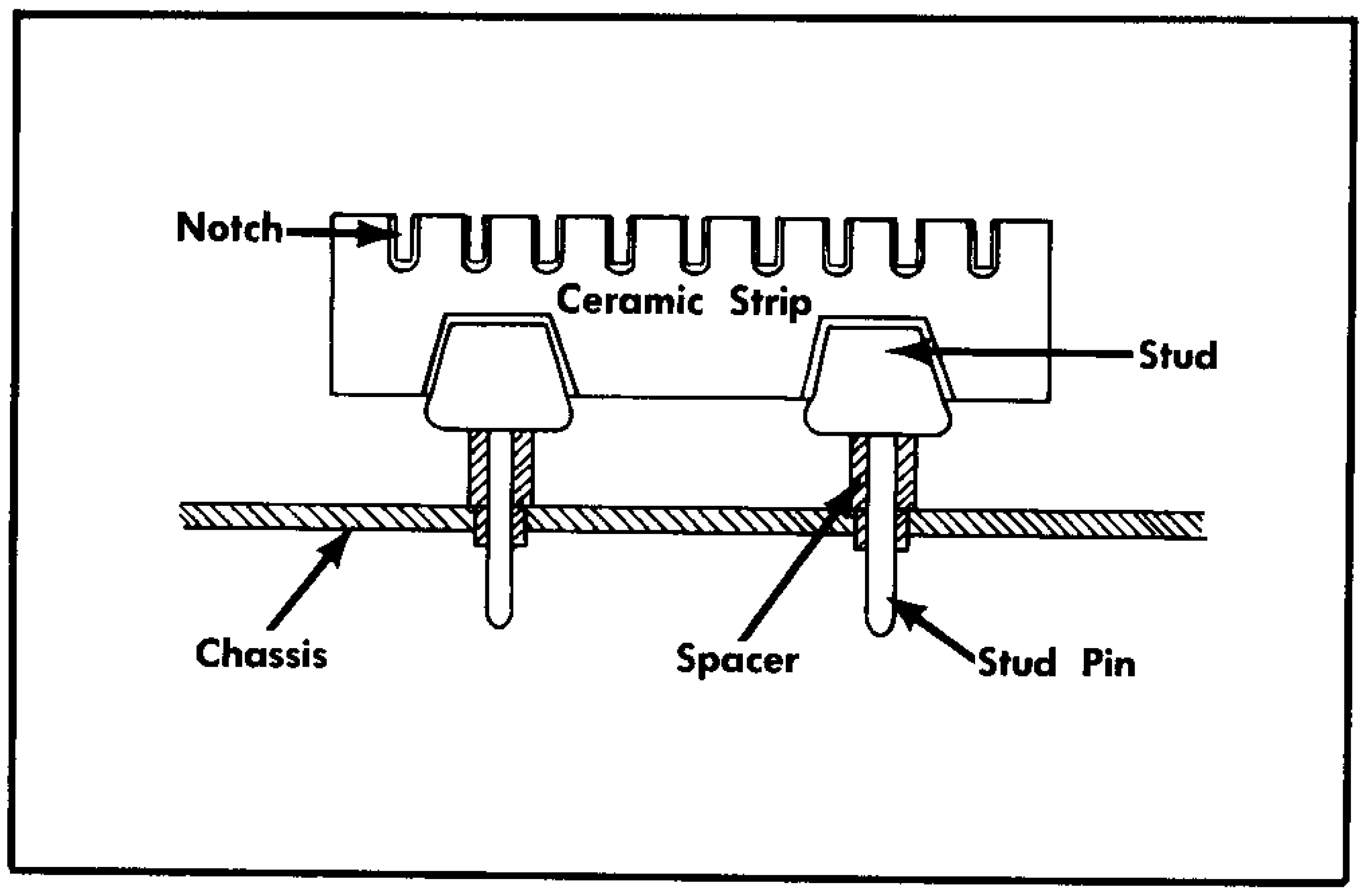

Fig. 4-5. The ceramic strip and its parts.

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

Procedures for the removal of defective switches are, for the most part, obvious and only a normal amount of care is required. If a switch is removed, careful notation of the leads to the switch should be made to facilitate connecting the new switch.

Removal of Sampler Gate Board from Chassis

Several components are mounted on the Gate Board under the shields. These components include the input terminating resistors R1001, R1002, R2001, R2002, resistors R1011, R1012, R2011, R2012, Capacitors C1011, C1012, C2011, C2012 and pulse transformers T1013 and T2013. The Gate Board should be removed from the chassis to facilitate removal of these parts.

The procedure follows:

(1) Remove the sampling bridge diodes to prevent them from damage due to surges when unsoldering leads.

(2) Remove the seven leads connected to terminals marked A, B, C, D, E, F, and G at the rear of the board (Fig. 4-7). Note the position of each lead.

(3) Remove the cable connectors from jacks J1009, J1019, J2009, J2019 and J1020 (Fig. 4-7).

(4) Very carefully unsolder the two leads indicated as points A and B in Fig. 4-7. Lift and straighten the ends of these leads.

(5) Remove the two 12 sided nuts which secure the GR connectors to the front panel, then remove the two bolts at the rear of the board.

(6) Lift the rear edge of the board and slide it toward the back of the instrument while lifting. Be careful that the two leads previously unsoldered do not hang up as the board is pulled away.

(7) Lift the board free of the chassis.

Procedure for Removing Shields and Input Connector

(1) Unsolder the leads attached to the shields (Fig 4-7). These leads should be unsoldered with a minimum of bending or twisting. They are attached through the 150 Ω resistors to the 5 pF capacitors, which are extremely fragile.

(2) Loosen, but do not remove, the four nuts holding the shield.

(3) Loosen the knurled nut enough to free the notched plate.

(4) Rotate the notched plate 90° and slide the Input Connector assembly away from the circuit board.

(5) Hold the bolt heads into the assembly while removing the four nuts.

(6) Lift off the top shield, keeping the assembly upright so that the spacers do not fall out.

(7) Remove the four spacers.

(8) Ease out the four bolts, lower shield and four bottom spacers as a unit.

The spacers mentioned above are precision parts and no substitute should be used.

Removal and Replacement of Pulse Transformer, T1013 or T2013

Note carefully lead dress, color of wires and exact position of the transformer. Position the replacement exactly as it was originally. Keep leads as short as possible. The transformer is very small and is best handled with tweezers.

Replacement of 5 pF Capacitors, C1011, C1012, C2011 and C2012

Note the position of the capacitor to be replaced on the stripline conductor. Carefully clean and tin the area on which

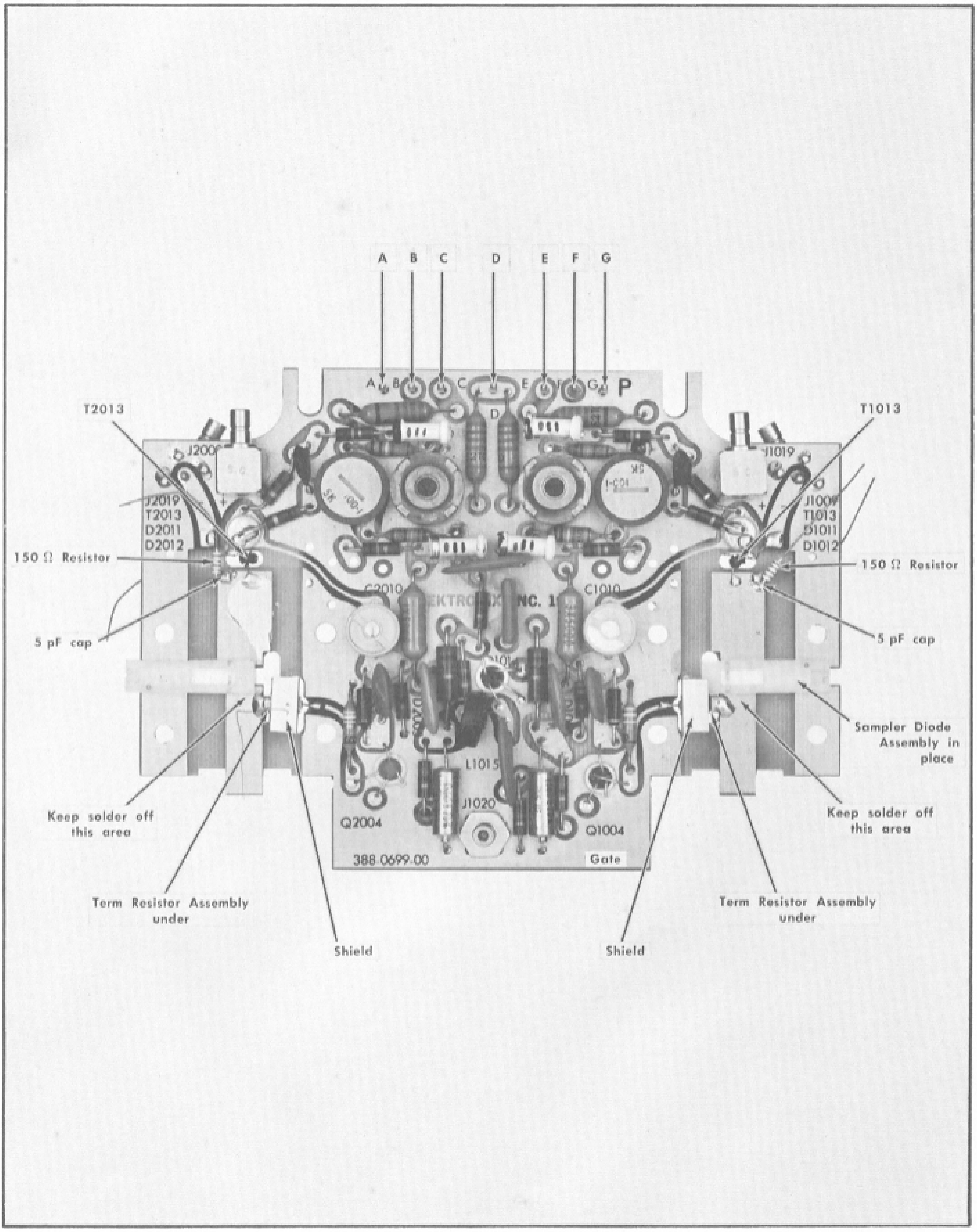

Fig. 4-6. Sampler board with shields removed.

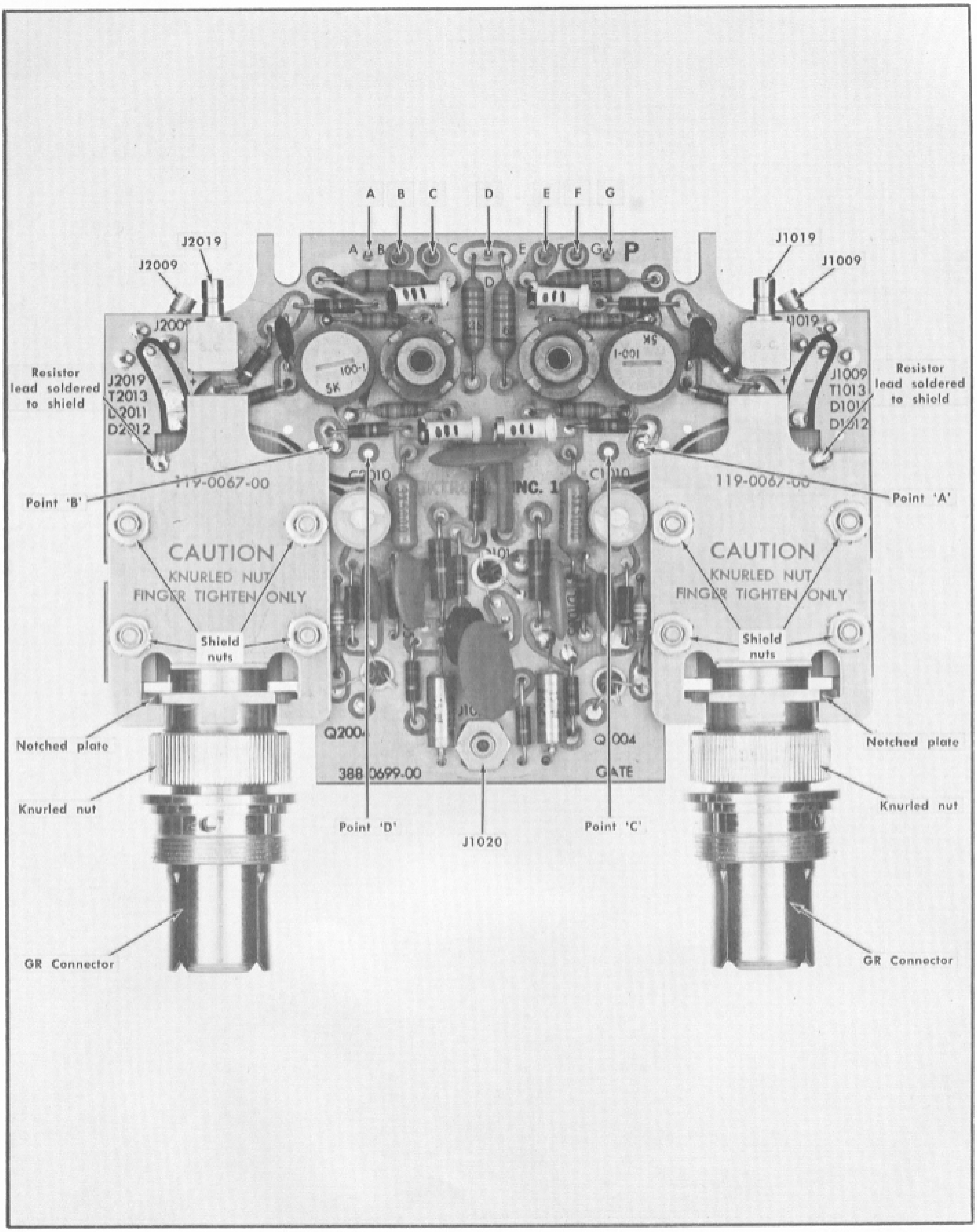

Fig. 4-7. Location of parts on Sampler Gate Board.

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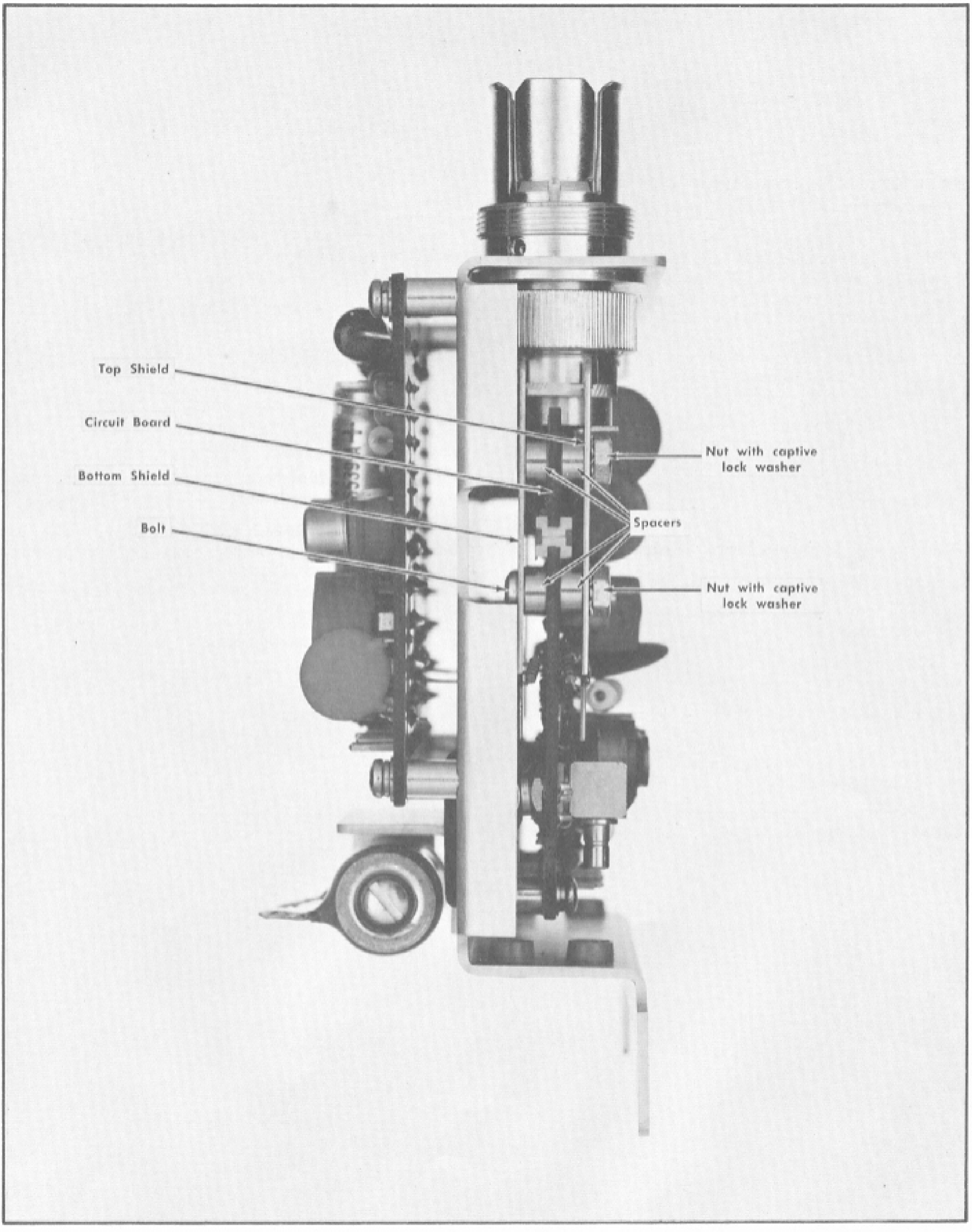

Fig. 4-8. Assembly of Sampler Gate Board.

the capacitor is to be mounted. Holding the soldering iron close to the mounting area, heat the copper strip until the solder flows and place the 5 pF capacitor in position with tweezers. The top of the capacitor may be tinned after it is soldered into position. These capacitors are easily damaged by excessive soldering heat. Keep the iron in contact with the surface of the capacitor as short a time as possible.

Removal and Replacement of Terminating Resistor Assembly, R1001, R1002 or (R2001, R2002) and shield

This assembly is composed of a 390 Ω resistor mounted through the center of a 56.4 Ω tubular resistor. A shield is soldered to the outside of the tubular resistor. This is a precision assembly, and great care should be taken in replacing it. The plated end of the assembly which attaches to the circuit board must be soldered to both sides of the board. The assembly must be centered properly in the board to prevent breakage of the tubular resistor when the shields are bolted into place.

Do not let solder flow out to areas that the sampling diodes leads will contact. An irregular contact area may prevent diode contact, which will prevent the sampler from operating.

Assembling Sampler Gate Board

To re-assemble the Sampler Gate Board,

(1) Insert a bolt through each of the four mounting holes in the bottom shield.

(2) Place a spacer on each bolt, then slide the bolts through the matching mounting holes in the circuit board.

(3) Add another spacer on each bolt on the top side of the circuit board, and set the top shield on the bolts.

(4) Start a nut with captive washer on to each bolt, but do not tighten the nuts at this time (Fig. 4-8).

(5) Slide the GR connector assembly on to the center conductor protruding from the circuit board, being careful not to force it. If the connector does not slide readily on to the inner conductor, back it off and realign it. As the connector asembly is pushed on to the circuit board, be sure that the notches in the outer conductor mate with the circuit board.

(6) Rotate the notched plate (Fig. 4-7) until the notches mate with the fingers on the shield.

(7) Tighten the knurled nuts finger-tight only, being sure that the shields make contact with the outer coaxial conductor.

(8) Holding the circuit board in one hand, push the GR connector assembly gently on to the board until the shield and connector assembly are properly positioned together.

(9) Tighten the nuts on the shield.

Replacing the Sampling Gate Board in Chassis

(1) Remove the two wires protruding through the ½ inch holes in the chassis. Replace these leads with 3 inch length of No. 22 tinned strapping wire.

(2) Start the ends of the protruding strapping wires through the holes marked points C and D on Fig. 4-7.

(3) Enter the GR connectors through the front panel holes and slide the assembly forward, being careful not to distort the 3 inch wire leads. Place bolts in the rear mounting holes and turn down, but do not tighten them at this time.

(4) Place the 12 sided nuts over the GR connectors on the front panel and tighten them.

(5) Tighten the rear mounting bolts. Bend protruding wire leads over to reach points marked A and B on Fig. 4-7, and insert the leads through the A and B holes. Trim leads so that only enough wire end remains to reach through the board.

(6) Solder the wires in place.

(7) Replace Subminax connectors to the five jacks, and replace the seven connectors to pins A, B, C, D, E, F, and G.

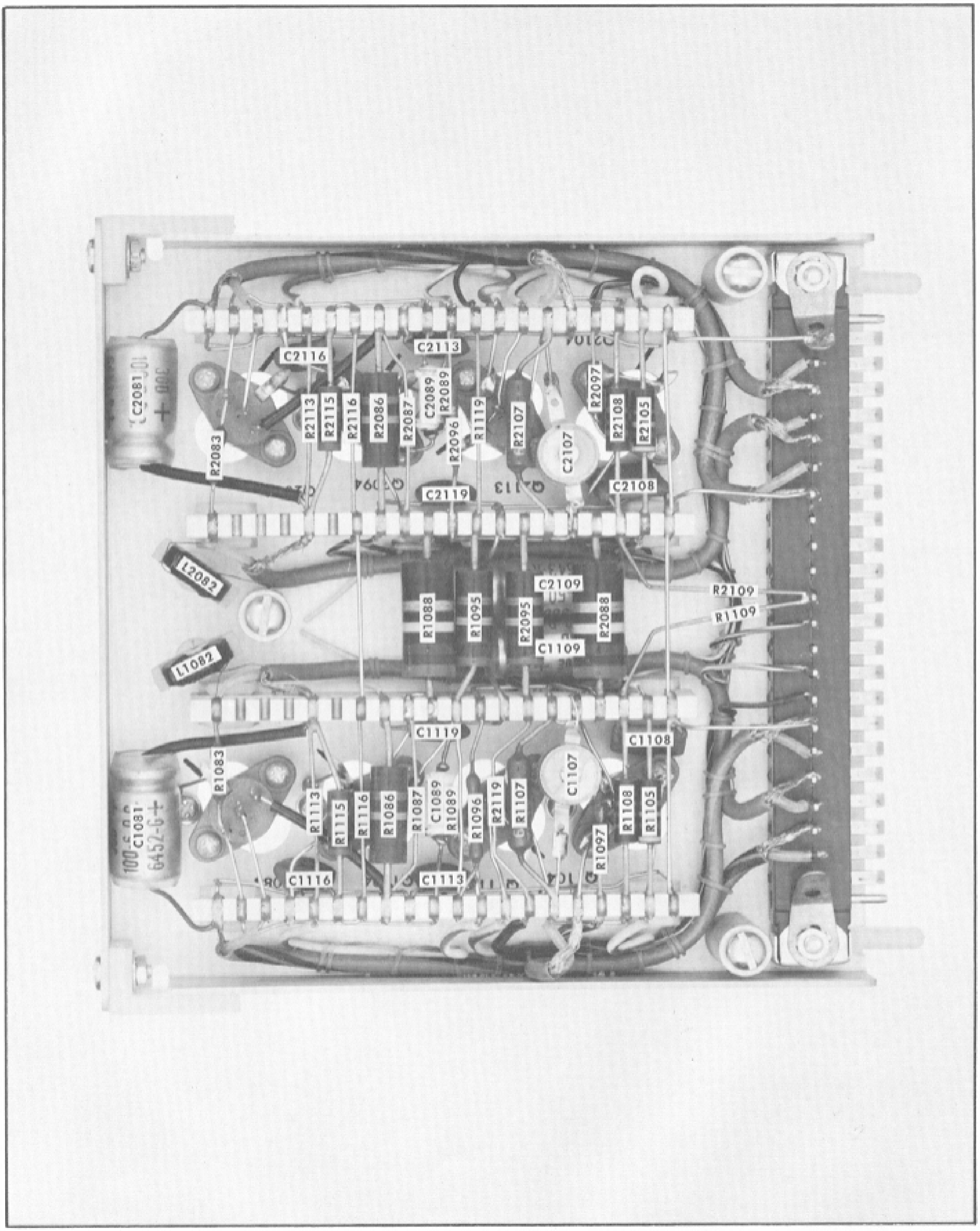

Fig. 4-9. AC Amplifier showing parts location.

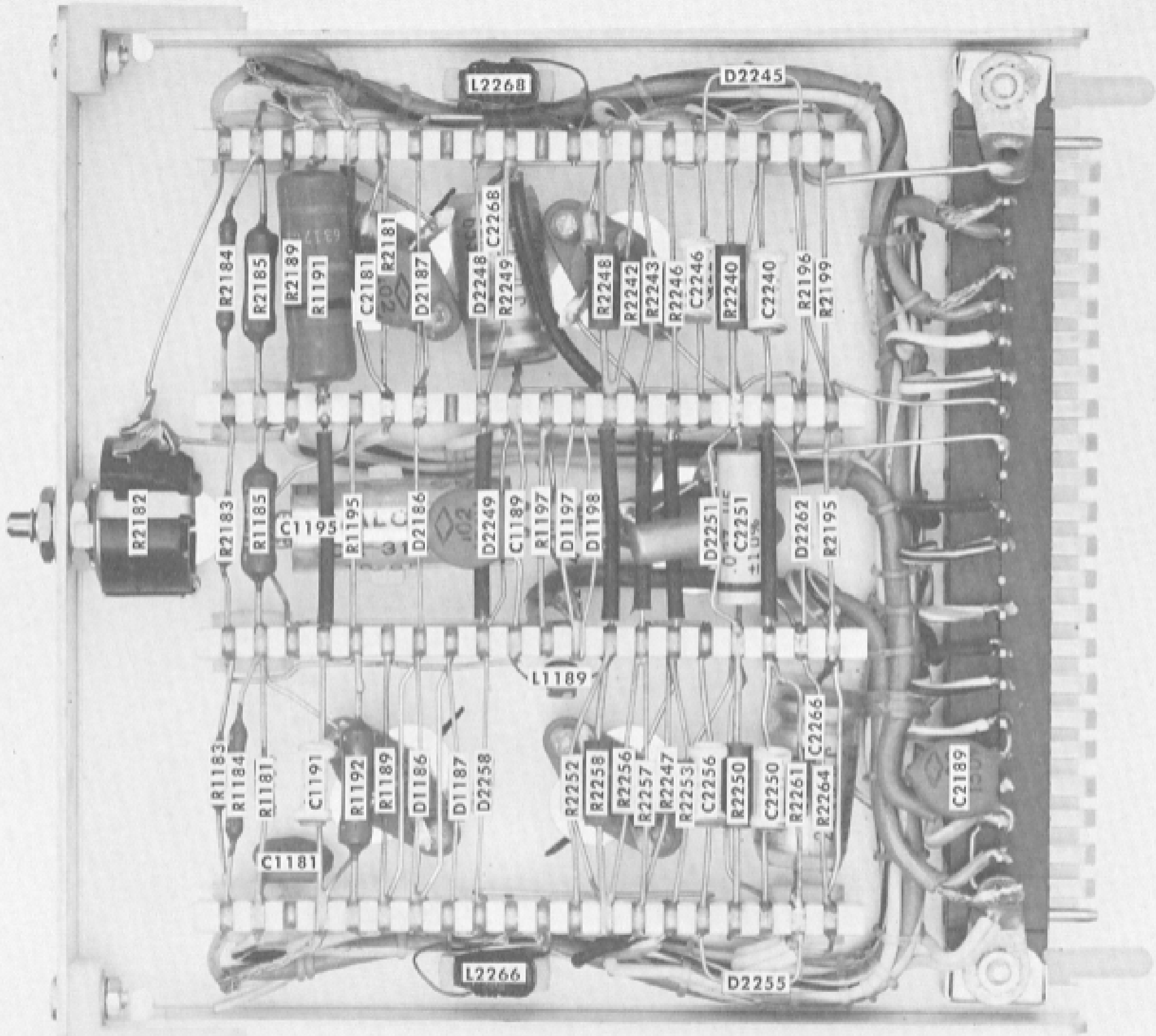

Fig. 4-10. Dual Trace subchassis showing parts location.

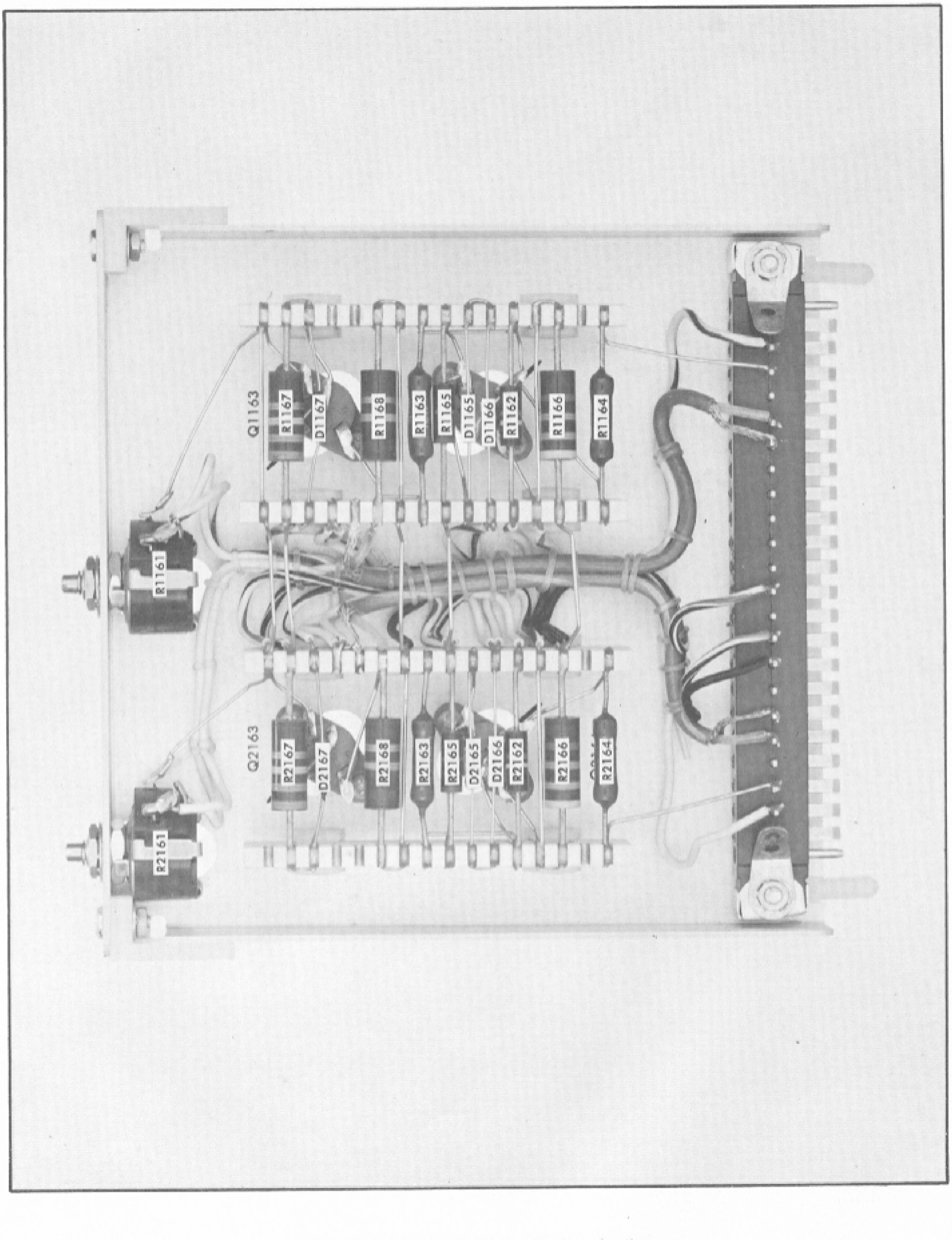

Fig. 4-11. Inverter subchassis showing parts location.

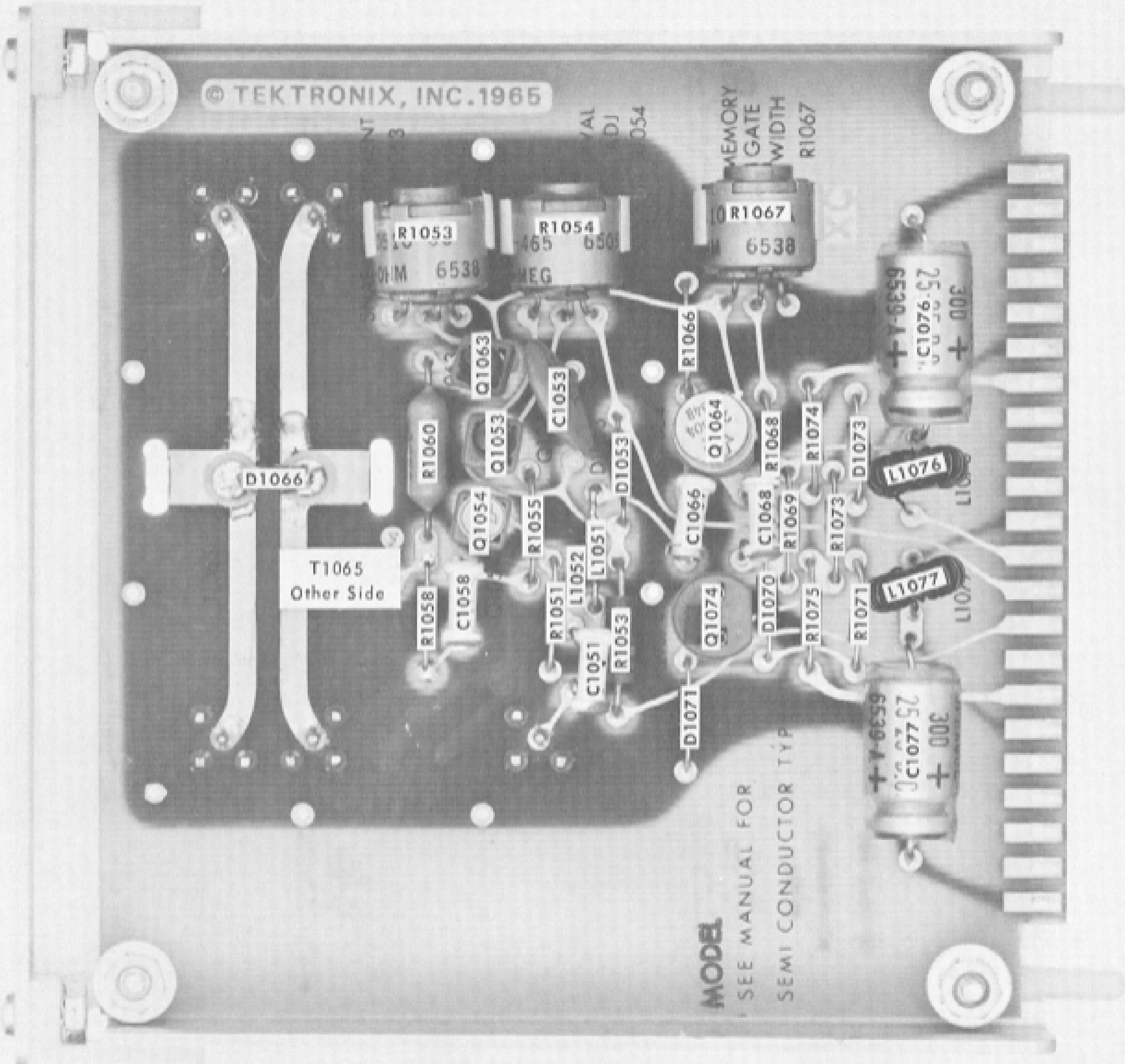

Fig. 4-12. Gate Generator assembly showing parts location.

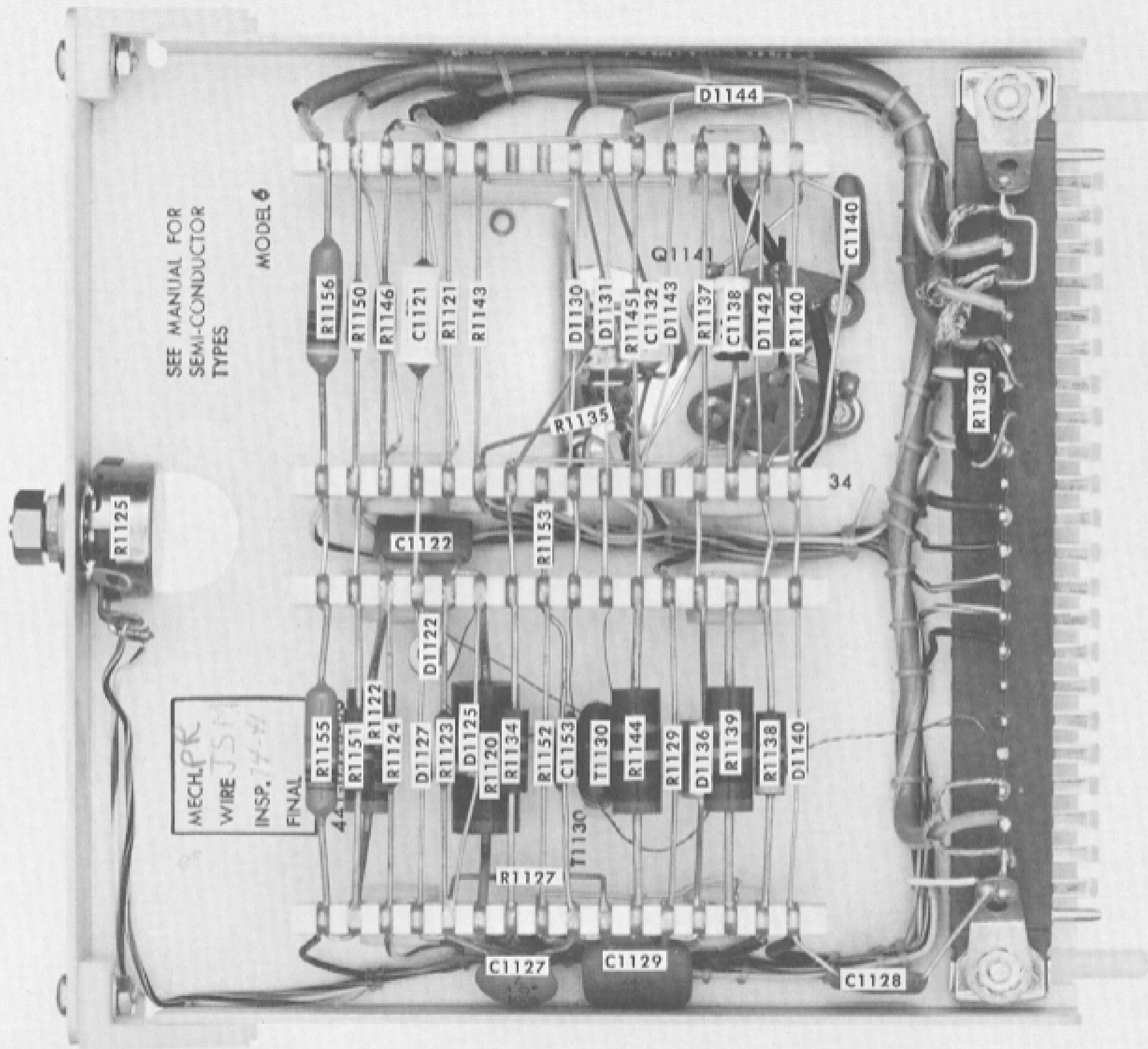

Fig. 4-13. Memory assembly showing parts location.

NOTES

SECTION 5
PERFORMANCE CHECK

Introduction

This section of the manual provides a means of rapidly checking the performance of the Type 4S2A. It is intended to check the calibration of the instrument without the need for performing the complete Calibration Procedure. The Performance Check does not provide for the adjustment of any internal controls. Failure to meet the requirements given in this procedure indicates the need for internal checks or adjustments, and the user should refer to the Calibration Procedure in this manual.

Recommended Equipment

The following equipment is recommended for a complete performance check. Specifications given are the minimum necessary to perform this procedure. All equipment is assumed to be calibrated and operating within the orginal specifications. If equipment is substituted it must meet or exceed the specifications of the recommended equipment.

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

1. Fast Rise Pulse Generator, Risetime 30 ps or less. Amplitude approximately 400 mV. Tektronix Part No. 067-0513-00 recommended.

2. Resistance Bridge, Accuracy ±0.1%. ESI Model PVB 300 recommended.

3. Differential DC Voltmeter, range not less than ±125 volts. John Fluke Model 801B or 825A recommended.

4. Standard Amplitude Calibrator, 50 Ω, range 12 mV to 1.2 volts square wave output. Tektronix 067-0508-00 Calibration fixture recommended.

5. Square-Wave Generator, risetime less than 1 ns at 500 mV into 50 Ω. Tektronix Type 106 Square-Wave Generator recommended.

6. Tektronix Type 661 Oscilloscope.

7. Tektronix Type 5T3 Sampling Time Base Plug-In.

8. 30 cm, 50 Ω Air Line, General Radio Type GR874-L30.

9. Tee Connector, 50 Ω, General Radio Type 874-T.

10. Two Attenuators, 10×, 50 Ω, with General Radio Type 874 connectors. Tektronix Part No. 017-0044-00 recommended.

11. Two 5 ns, 50 Ω cables with General Radio Type 874 connectors. Tektronix Part No. 017-0502-00 recommended.

12. One 42 inch, 50 Ω RG58/AU cable with BNC connectors. Tektronix Part No. 012-0057-00.

PERFORMANCE CHECK PROCEDURE

General

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

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

Preliminary Procedure

a. Plug the Type 4S2A into the vertical plug-in compartment, lower left, in the 661.

b. Set the 4S2A controls as follows:

A and B Channels	
mV/CM	20
VARIABLE	CALIBRATED
VERT POSITION	Midrange
DC OFFSET	Midrange
SMOOTHING	NORMAL
MODE	A ONLY
DISPLAY	NORMAL

c. Set the Type 661 controls as follows:

Horiz Display	×1
Horiz Position	Midrange
Vernier	Midrange

d. Set the Type 5T3 controls as follows:

Samples/Cm	100
Time Position Range	100 ns
Equiv Time/Cm	.1 ns
Variable	Calib
Trig Level	Midrange
Stability	Midrange
Trig Source	Ext
Trig Slope	+
Ext Trig Mode	DC
Time Position	Midrange

1. Check Input Resistance (with Type 661 turned off)

a. Requirement-50 Ω ±1% (0.5 Ω).

b. Connect an accurate, ±0.1% Resistance Bridge between the center and outer conductors of the INPUT connector.

c. Measure the resistance.

d. Remove the leads and short the test clips together.

e. Measure the lead resistance.

f. Subtract the lead resistance from the overall resistance.

g. Repeat resistance test on other channel.

h. Remove the test leads from the INPUT.

i. Turn the Type 661 power ON.

j. Allow 20 minutes warm up if the instrument is cold.

2. Check Risetime

a. Requirement-risetime must be 90 ps or less from the 10% to 90% amplitude points.

b. Connect the Pulse Output of the Fast Rise Pulse Generator through a 30 cm air line to INPUT A of the Type 4S2A.

c. Connect the Pretrigger jack of the Fast Rise Pulse Generator through a 5 ns cable to EXT TRIG INPUT, 50 Ω on the Type 5T3.

d. Locate the negative-going portion of the waveform on the Type 661 CRT. Adjust the TRIG LEVEL and STABILITY on the Type 5T3 for a stable trace.

e. Increase the display amplitude with the A mV/CM on the Type 4S2A for a display of 8 cm vertically.

f. Position the display as in Fig. 5-1. Read 90 ps or less from the 10% to 90% amplitude points.

g. A risetime greater than 90 ps may indicate an incorrect setting of the A BRIDGE VOLTS control.

h. Repeat the Risetime check for B Channel.

3. Check Co-Channel Time Coincidence

a. Requirement-no more than 20 ps time difference between simultaneous displays of the same waveform on the two channels of the Type 4S2A.

b. Connect the Fast Rise Pulse Generator output to both A and B Channels through a 30-cm air line, a GR Tee connector and two 5 ns coaxial cables.

c. Set the Type 5T3 Equivalent Time/Cm to 20 ps, and the Type 4S2A MODE switch to DUAL TRACE.

d. Adjust the CRT display for 8 cm of vertical deflection, and position the two traces so that they coincide vertically.

e. If time difference exists between the two channels, it will appear as a horizontal displacement of the vertical portion of one trace as related to the other.

f. The observed time difference can be eliminated or at least minimized, by sliding a cable connection slightly out of the GR Tee connector. Slide out the connector which controls the leading (farthest left) trace. This will move the vertical parts of the traces together.

g. Reverse the two cables to the Type 4S2A INPUT connectors.

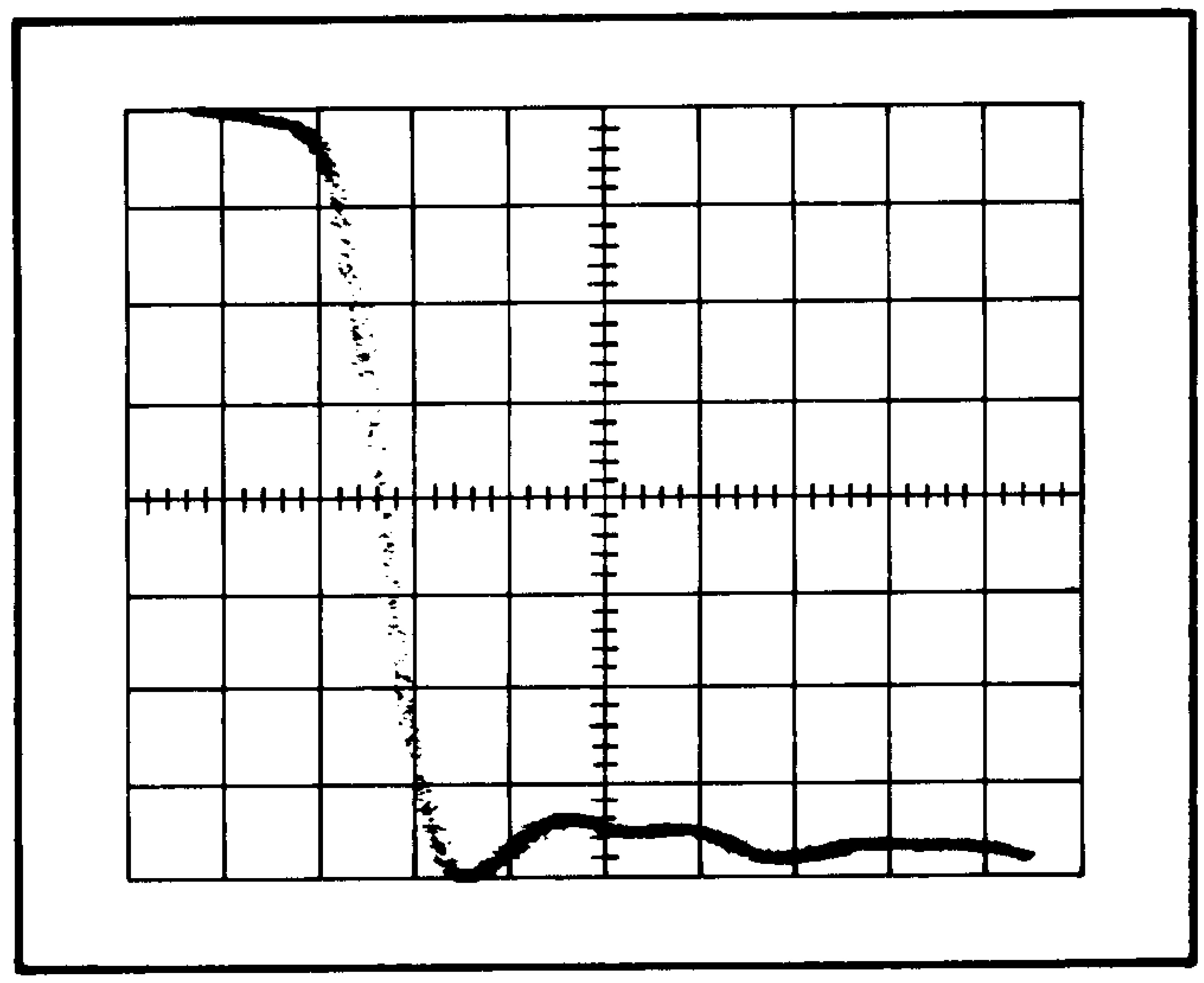

Fig. 5-1. Typical CRT display showing risetime.

h. Note any horizontal trace displacement. Divide the observed time displacement by two to obtain the actual displacement.

i. Maximum acceptable horizontal trace displacement is 20 ps (1 Cm).

4. Check MILLIVOLTS/CM Accuracy

a. Requirement-Amplitude accuracy within ±3%.

b. Connect the Standard Amplitude Calibrator Output through a 50 Ω cable to the Type 4S2A CHANNEL A INPUT 50 Ω. Set the Type 4S2A MODE switch to A ONLY, and CHANNEL A MILLIVOLTS/CM to 200.

c. Connect the Standard Amplitude Calibrator Trigger Output through a 50 Ω cable to the Type 5T3 Ext Trig In, 50 Ω. Set the Type 5T3 Trig Source to Ext, Ext Trig Mode to DC, 1 MΩ and Equivalent Time/Cm to 20 μsec.

d. Set the Standard Amplitude Calibrator Volts switch to 1.2, and observe a CRT display 6 cm high.

e. Check the Channel A MILLIVOLTS/CM Accuracy for all switch settings as shown in Table 5-1.

TABLE 5-1

Standard Amplitude Calibrator Volts	Type 4S2A mV/CM	Vertical Display Size	Amplitude Tolerance
1.2	200	6 cm	±3%
.6	100	6 cm	±3%
.3	50	6 cm	±3%
.12	20	6 cm	±3%
.06	10	6 cm	±3%
.03	5	6 cm	±3%
.012	2	6 cm	±3%

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f. Move the Standard Amplitude Calibrator Output to the Type 4S2A CHANNEL B INPUT 50 Ω, the Type 4S2A MODE switch to B only, and set the CHANNEL B MILLIVOLTS/CM switch to 200. Repeat steps d and e, using Table 5-1 again as a guide.

5. Check VARIABLE MILLIVOLTS/CM

a. Requirement-The VARIABLE MILLIVOLTS/CM control on each channel must vary display amplitude over a range of at least 3 to 1.

b. Set the Type 4S2A CHANNEL B MILLIVOLTS/CM at 200. Set Standard Amplitude Calibrator to .3 volts.

c. Observe 1.5 Divisions of display.

d. Rotate the CHANNEL B MILLIVOLTS/CM VARIABLE counterclockwise out of the detent position just far enough to cause the display to suddenly increase in amplitude.

e. Observe at least 4.5 cm of display.

f. Change the Standard Amplitude Calibrator signal connection to Channel A of the Type 4S2A and repeat steps a through e above.

6. Check Tangential Noise

a. Requirement-Not more than 4 mV of Tangential Noise displayed at Unity Dot Transient response; no more than 2 mV of Tangential Noise displayed with SMOOTHING control fully counterclockwise.

b. Set Type 4S2A Channel A MILLIVOLTS/CM switch to 100. Set SAMPLES/CM to 5.

c. Connect the Type 106 + Fast Rise Output to the Type 4S2A CHANNEL A INPUT 50 Ω through a 50 Ω coaxial cable. Set the Type 106 Amplitude controls for a display of approximately four divisions on the Type 661.

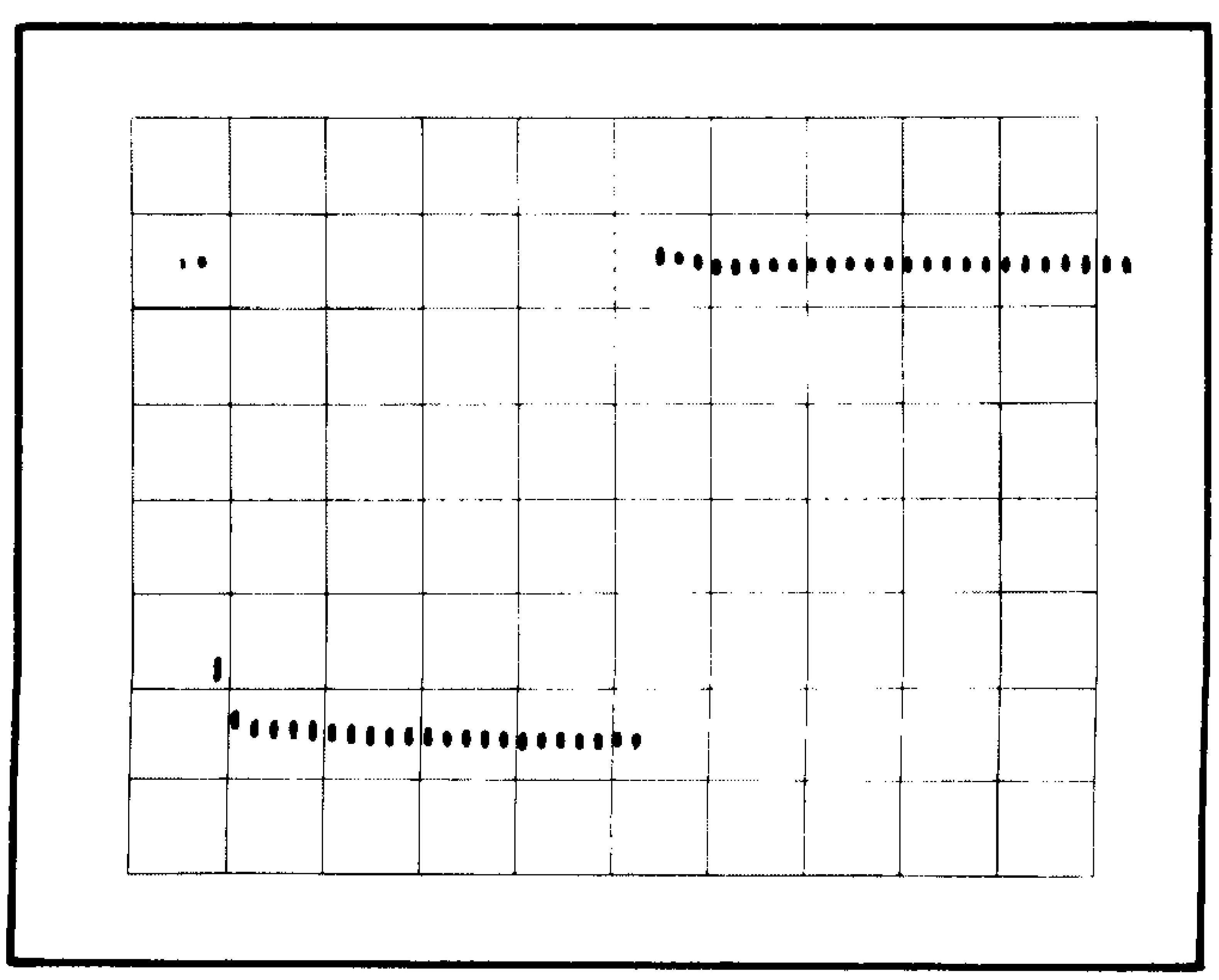

Fig. 5-2. Typical display showing unity dot transient response.

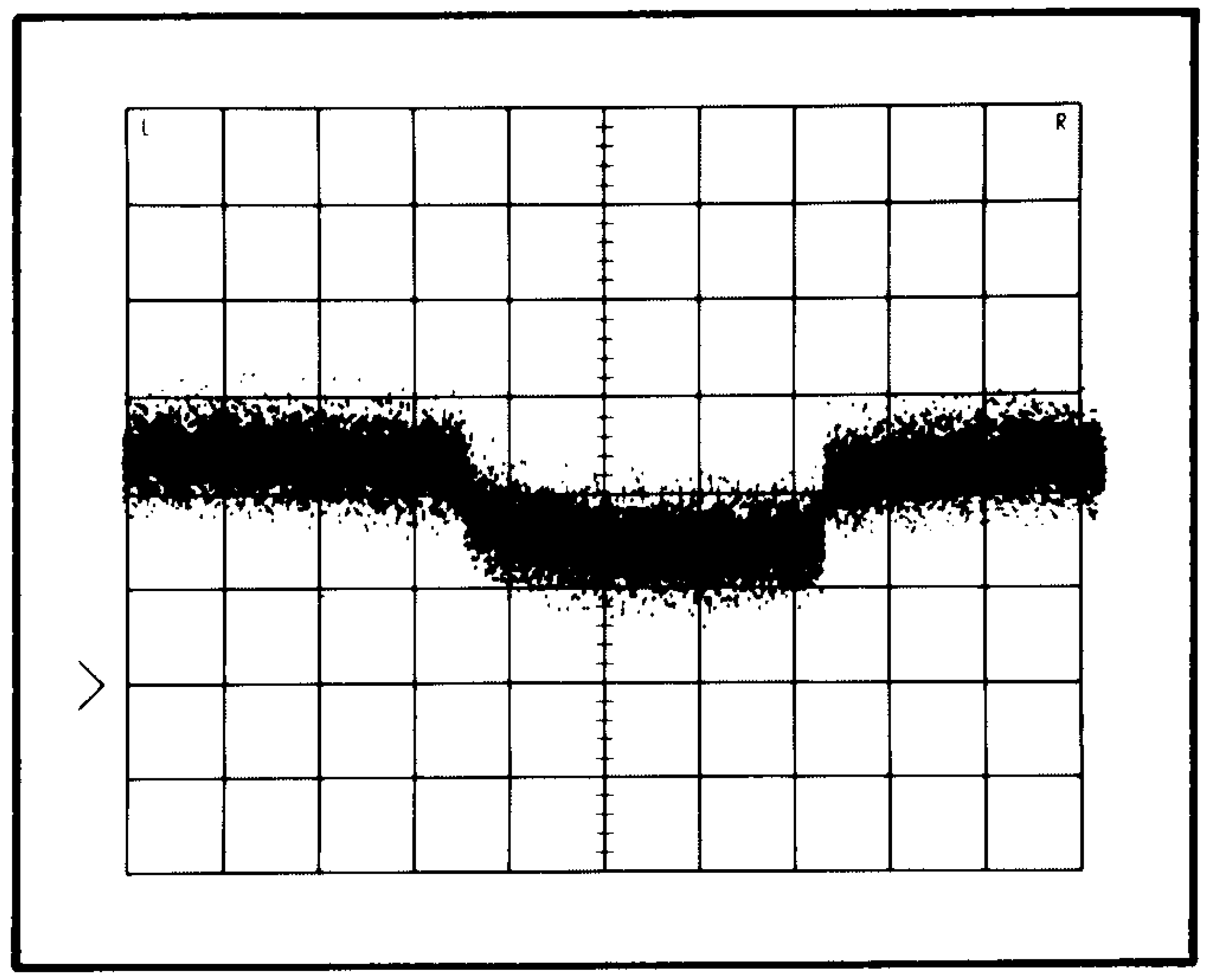

Fig. 5-3. Typical CRT display for tangential noise.

d. Using the Type 4S2A SMOOTHING control adjust the dot display on the CRT for no undershoot or overshoot (Unity Dot Transient Response—see Fig. 5-2).

e. Insert two 10× attenuators in the signal path between the Type 106 and the Type 4S2A.

f. Set the Type 4S2A Channel A MILLIVOLTS/CM switch to 5, and change the SAMPLES/CM to 100.

g. With the Type 4S2A POSITION control and the Type 106 + Transition Amplitude control, adjust the displayed signal so that approximately 10% of the baseline dots are above a given horizontal line, and approximately 10% are below the same horizontal line. (See Fig. 5-3.) This represents a signal-to-noise ration of 1:1.

h. Remove one of the 10× attenuators from the signal path.

i. Determine the amplitude of the displayed pulse in millivolts.

j. Divide the pulse amplitude by 10 to arrive at the amount of the Tangential Noise in mV.

k. Turn the Type 4S2A SMOOTHING control fully counterclockwise and repeat steps g through j.

l. Move the Type 106 signal to the Type 4S2A CHANNEL B INPUT 50 Ω and repeat steps b through k for channel B.

m. Disconnect the Type 106 signal from the Type 4S2A.

7. Check VERT POSITION Range

a. Requirement-The VERT POSITION controls of the Type 4S2A must be able to position the CRT trace over a range of + and —5 cm in the vertical direction.

b. Set the CHANNEL A MILLIVOLTS/CM control to 200 and the CHANNEL A VERT POSITION control fully counterclockwise.

c. Set the Type 5T3 for a free-running trace.

d. Position the trace to the bottom horizontal graticule line with the CHANNEL A DC OFFSET control.

e. Rotate the CHANNEL A VERT POSITION control clockwise to move the trace upward 5 cm.

f. Rotate the DC OFFSET control to again position the trace to the bottom horizontal graticule line.

g. Rotate the VERT POSITION control fully clockwise. The trace must move upward at least 5 cm.

h. Repeat steps b through h for CHANNEL B.

8. Check Dynamic Range

a. Requirement-No distortion of the displayed waveform over an amplitude range of + and — 1 volt.

b. Connect the Type 661 Amplitude/Time calibrator to the Type 4S2A CHANNEL A INPUT 50 Ω.

c. Set the Type 661 Amplitude/Time Calibrator to 100 mV and .01 μsec/cycle.

d. Set the Type 5T3 Trig Source to Cal.

e. Observe the displayed waveform.

f. Set the Amplitude/Time calibrator to 1000 mV and compare the displayed waveform with that shown at the lower amplitude. There should be no distortion in the shape of the displayed signal.

g. Move the Amplitude/Time Calibrator signal to the Type 4S2A CHANNEL B INPUT 50 Ω and repeat steps b through f.

h. Remove the Amplitude/Time calibrator signal.

9. Check CHANNEL A and CHANNEL B OFFSET MONITOR

a. Requirement-Control Range of —100 V ±5% to +100 V ±5% within ±1% accuracy.

b. Rotate the CHANNEL A DC OFFSET control completely counterclockwise.

c. Measure the voltage at the CHANNEL A OFFSET MONITOR with a precision DC differential voltmeter. It should read +100 V ±5%.

d. Remove the voltmeter. Rotate the CHANNEL A DC OFFSET completely clockwise.

e. Measure the voltage with the differential voltmeter at the CHANNEL A OFFSET MONITOR. The voltmeter should read —100 V ±5%.

f. Adjust the CHANNEL A DC OFFSET to zero volts measured at the CHANNEL A OFFSET MONITOR.

g. Set CHANNEL A MILLIVOLTS/CM to 5. Position the Type 661 trace to the graticule center horizontal line with the Type 4S2A CHANNEL A VERT POSITION control.

h. Remove the differential voltmeter.

i. Connect the Standard Amplitude Calibrator to CHANNEL A INPUT 50 Ω.

j. Set the Standard Amplitude Calibrator to 0.6 V.

k. Adjust the CHANNEL A DC OFFSET only to position the top of the signal to the center graticule horizontal line.

l. Remove the Standard Amplitude Calibrator Signal.

m. Measure the voltage at the CHANNEL A OFFSET MONITOR with the differential voltmeter. The meter reading should be 60 volts.

n. Deviation from 60 volts is expressed as a percentage of 60 volts. Maximum allowable deviation is ±1%.

o. Repeat steps b through n for CHANNEL B.

SECTION 6
CALIBRATION

Introduction

A complete calibration and verification procedure for the Type 4S2A is provided in this section. This procedure checks the instrument to the performance requirements given in the Characteristics section. A calibration record is included at the beginning of the procedure for use as a checklist to verify correct calibration and operation of the Type 4S2A or as a guide for quick calibration by an experienced calibrator.

The step by step instructions in the calibration procedure furnish an orderly approach to the isolation of possible malfunctions and thus serve as an aid in troubleshooting and repairing the instrument. Any maintenance that is known to be needed should be performed before starting the calibration procedure. If any troubles become apparent during calibration, these also should be corrected before proceeding. Repair and servicing information is given in the Maintenance section of this manual.

EQUIPMENT REQUIRED

The following (or equivalent) items of equipment are required for a complete calibration of the Type 4S2A. The equipment is illustrated in Fig. 6-1 and 6-2. If substitute equipment is used, it must equal or exceed the given requirements in order to calibrate the Type 4S2A to the given accuracy. If the equipment does not meet these requirements, the difference between the accuracy of the equipment used and the accuracy of the specified equipment must be added to the tolerance stated in the calibration step.

Some of the items listed are special calibration fixtures. These may be obtained from Tektronix, Inc. Order by part number through your local Tektronix Field Office or representative.

1. Voltohmmeter. Minimum sensitivity on DC ranges, 20,000 ohms per volt. Minimum DC volts range, 400. For example, Simpson Model 262.

2. Precision DC differential voltmeter. Minimum range ±125 volts. Accuracy within ±0.05%. For example, John Fluke Model 801B or 825A.

3. Resistance bridge. Accuracy, ±0.1%. For example, ESI Model PVB 300.

4. Test oscilloscope. Bandwidth, DC to 30 MHz; minimum deflection factor, 0.005 volts/division. Tektronix Type 545B Oscilloscope with a Type 1A1 Plug-In is recommended.

5. 10× Probe. Tektronix P6008 is recommended.

6. Tektronix Type 661 Oscilloscope with a Type 5T3 Sampling Time Base Plug-In.

7. Tektronix Type 1S1 Sampling Plug-In for use in the Test Oscilloscope.

8. 50 Ω Fast Rise Pulse Generator. Minimum risetime 30 ps. Minimum amplitude, 400 millivolts. Tektronix Calibration Fixture No. 067-0513-00 is recommended.

9. Cable, flexible interconnecting, with Amphenol 24 pin connectors. Tektronix Part No. 012-0064-00.

10. Cable (two). Impedance, 50 ohm; type, RG58A/U; length, 32 inch; connectors, Gremar. Tektronix Part No. 012-0070-00.

11. Attenuator (two). 10× Attenuation. Impedance, 50 Ω; connectors, General Radio Type 874. Tektronix Part No. 017-0044-00.

12. Extender, rigid, to extend 4S2A Plug-In chassis. Tektronix Part No. 012-0069-00.

13. Cable (two). Impedance, 50 ohm; delay, 5 ns; connectors, General Radio Type 874. Tektronix Part No. 017-0502-00.

14. Cable (two). Impedance, 50 ohm; delay, 2 ns; connectors, General Radio Type 874. Tektronix Part No. 017-0505-00.

15. Connector. Impedance, 50 ohm; Type, T. General Radio Type 874-T. Tektronix Part No. 017-0069-00.

16. Air Line. Impedance, 50 ohm; length, 30 cm. General Radio Type 874-L30.

17. Square Wave Generator. Risetime, less than 1 ns; amplitude, 500 millivolts; impedance, 50 ohm. Tektronix Type 106 Square-Wave Generator is recommended.

18. Amplitude Calibrator. Impedance, 50 ohm; Range 12 millivolts to 1.2 volts square wave output. Tektronix Calibration Fixture No. 067-0508-00 is recommended.

19. Patch cord (two). Length, 18 inch; terminals, banana plugs. For example, Tektronix Part No. 012-0054-00.

20. Cable. Impedance, 50 ohm; length, 42 inch; type, RG58A/U; connectors, BNC. For example, Tektronix Part No. 012-0057-00.

21. Coupling Capacitor. Impedance, 50 ohm; type, General Radio 874-K. Tektronix Part No. 017-0028-00.

Adjustment Tools

Description	Tektronix Part No.
Insulated screwdriver, 7 inch shaft non-metallic	003-0001-00
Screwdriver, 3 inch shaft	003-0192-00

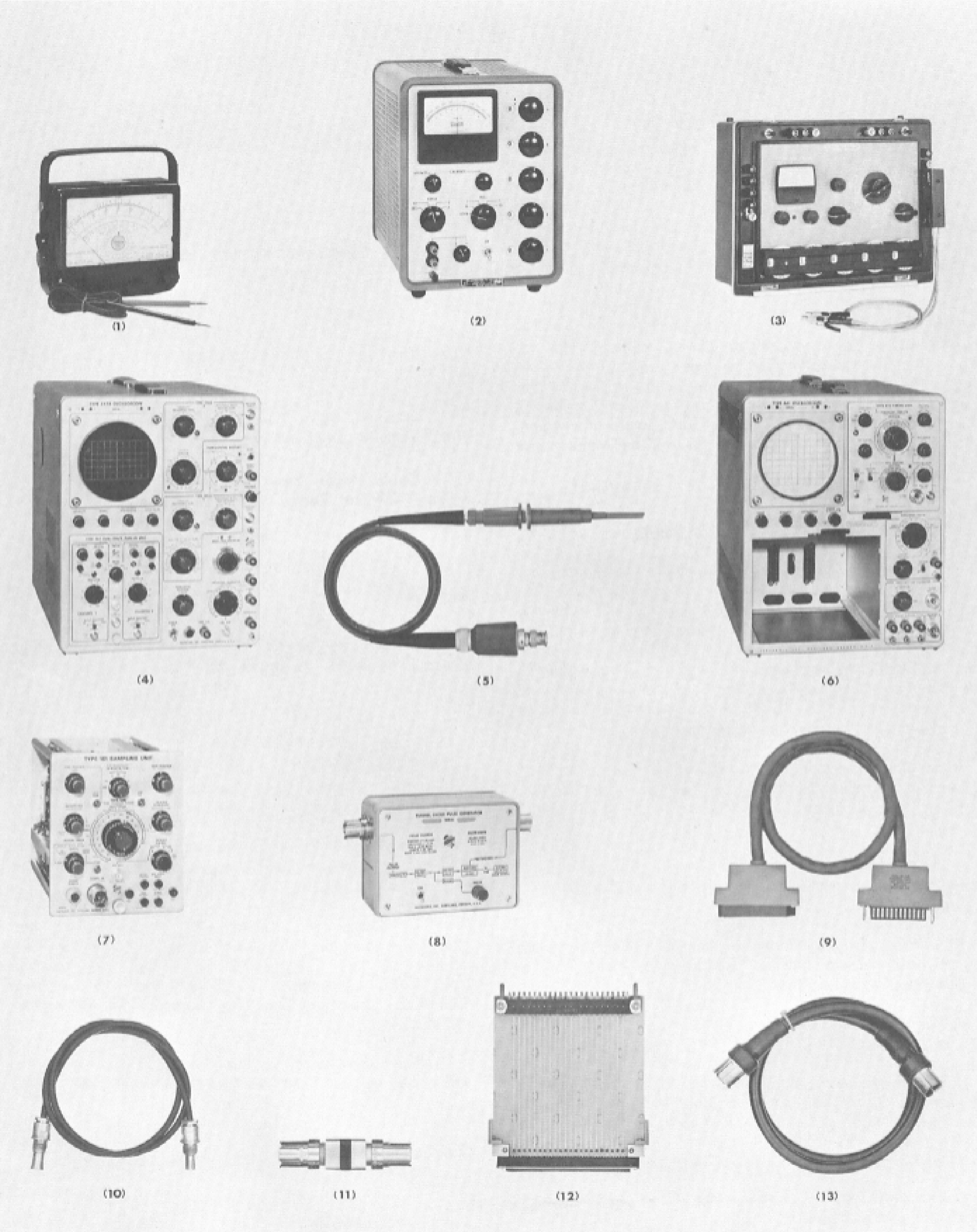

Fig. 6-1. Recommended Calibration Equipment, items 1 through 13.

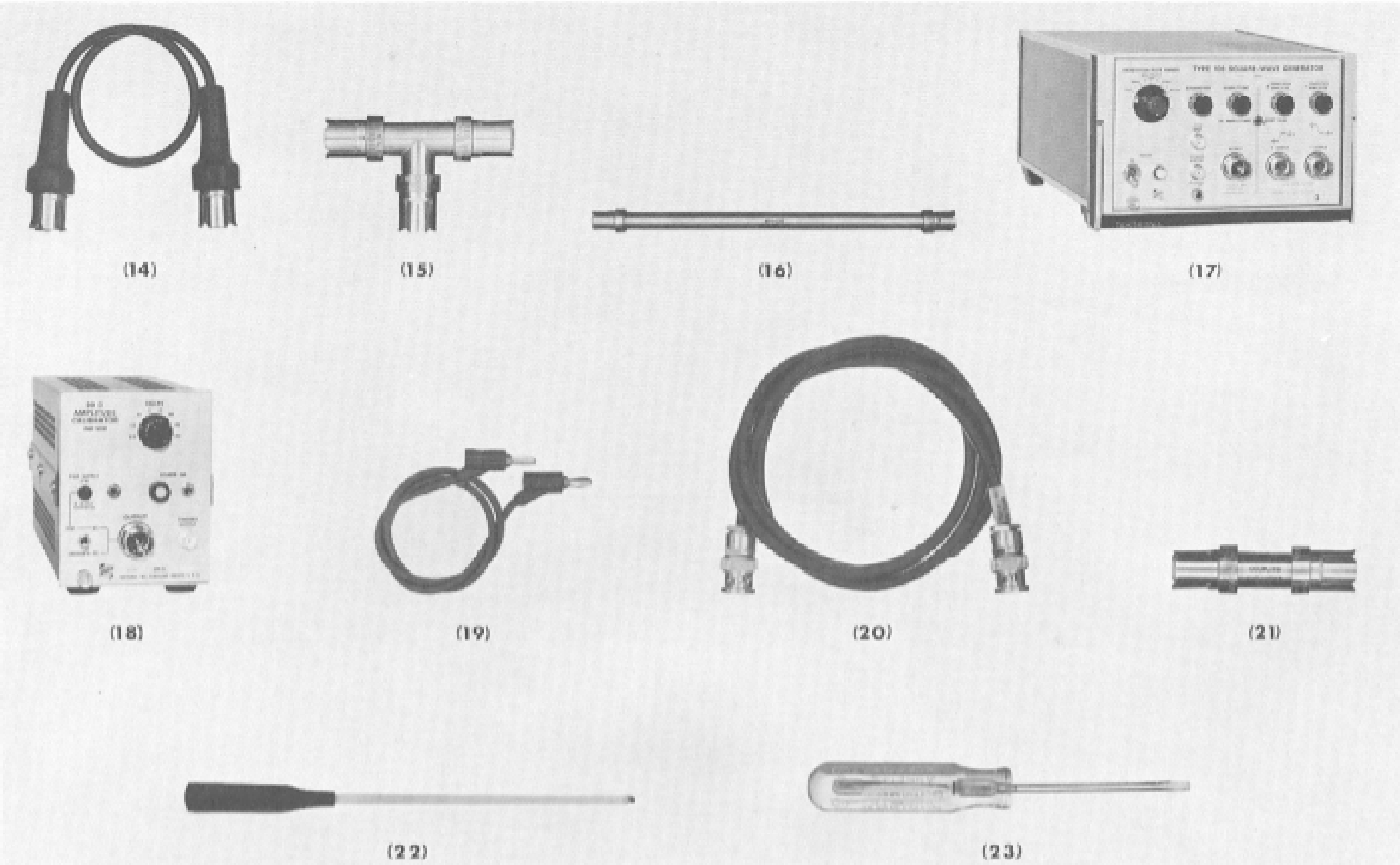

Fig. 6-2. Recommended Calibration Equipment, items 14 through 23.

CALIBRATION RECORD AND INDEX

This Abridged Calibration Procedure is provided to aid in checking the operation of the Type 4S2A. It may be used as a calibration guide by the experienced calibrator, or it may be used as a calibration record. Since the step numbers and titles used here correspond to those used in the complete Calibration Procedure, the following procedure serves as an index to locate a step in the complete Calibration Procedure. Characteristics are those listed in the Characteristics section of the Instruction Manual.

Type 4S2A, Serial No. ____________________

Calibration Date ____________________

☐ 1. Adjust Strobe Pulse amplitude (page 6-8)
Adjust AVALANCHE ADJUST control for correct operation; see Calibration Procedure.

☐ 2. Adjust Memory Gate Width (page 6-11)
150 ns, measured at 50% amplitude points.

☐ 3. Check DC Offset and Mode Positions (page 6-11)
Correct operation; see Calibration Procedure.

☐ 4. Adjust SMOOTHING BALANCE (page 6-13)
No trace shift while rotating the SMOOTHING control throughout its range.

☐ 5. Adjust Bridge Volts and Transient Response, Preliminary (page 6-13)
Correct operation; see Calibration Procedure.

☐ 6. Adjust C1010 and C2010 (page 6-15)
Flat top and bottom of the displayed waveform.

☐ 7. Adjust C1107 and C2107 (page 6-16)
Adjust for Loop Gain of 1.1.

☐ 8. Check Tangential Noise (page 6-17)
4 mV maximum noise with SMOOTHING at Unity Loop Gain 2 mV maximum noise with SMOOTHING counterclockwise.

☐ 9. Check Risetime (page 6-18)
90 ps or less.

☐ 10. Adjust Bridge Balance (page 6-20)
No trace shift while rotating mV/CM switch throughout its range.

☐ 11. Adjust Inverter Zero (page 6-20)
No trace shift while switching DISPLAY switch between NORMAL and INVERTED.

☐ 12. Check Dual Trace Operation (page 6-21)
Two traces, not more than 1 cm apart.
Both traces within 2 cm of graticule center.

☐ 13. Adjust A-B Gain Control (page 6-22)
Range, 6 cm, ±10%.
Set to exactly 6 cm.

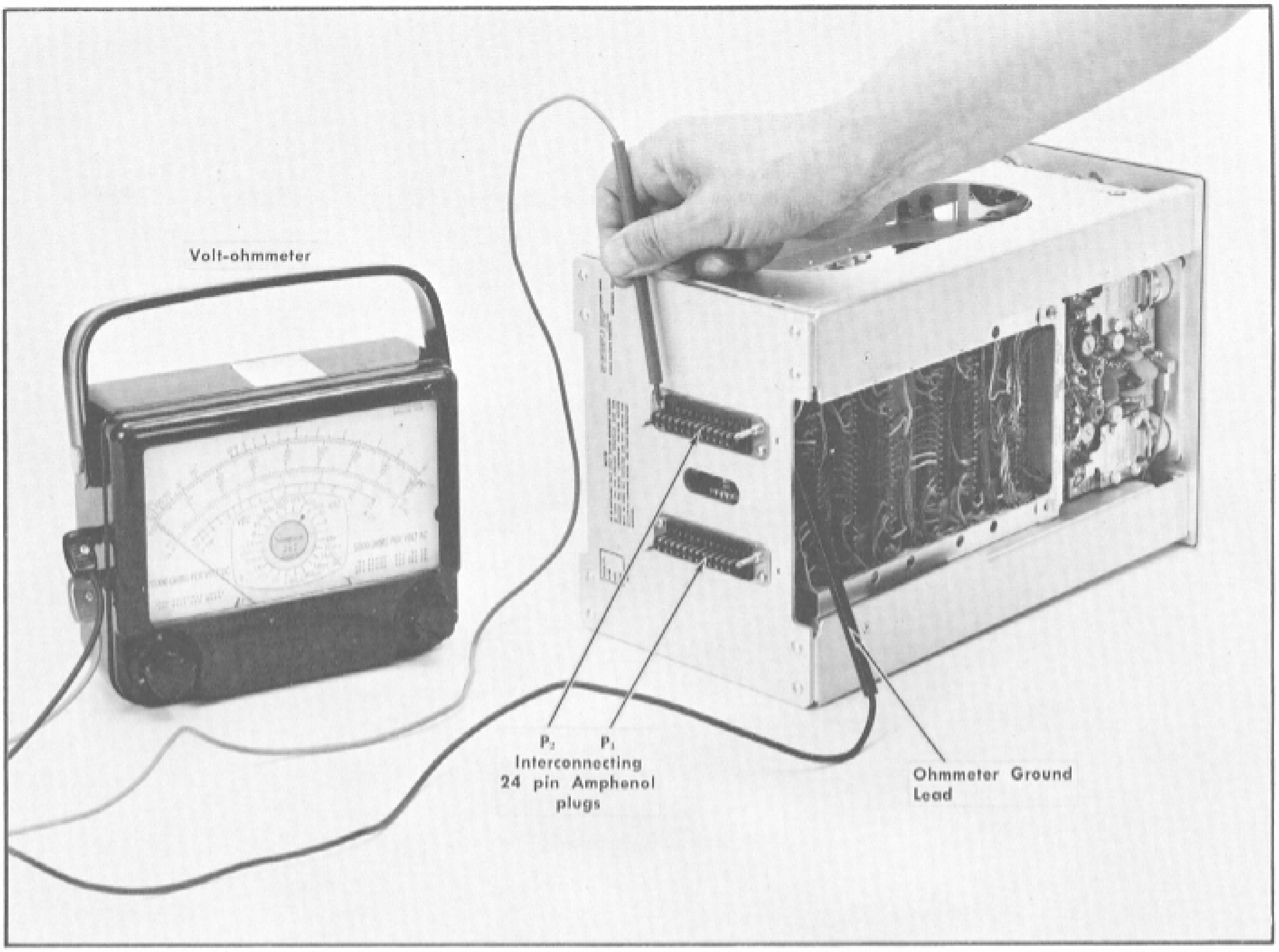

Fig. 6-3. Test equipment setup for step 2 of Preliminary Procedure.

☐ 14. Check A mV/CM Switch Positions (page 6-22)

6 cm, ±3%, on all mV/CM positions.

☐ 15. Adjust B CAL Gain Control (page 6-22)

Range, 6 cm, ±10%.

Set to exactly 6 cm.

☐ 16. Check B mV/CM Switch Positions (page 6-22)

6 cm, ±3%, on all mV/CM positions.

☐ 17. Check A and B mV/CM Variable Range (page 6-22)

Control Range at least 3:1.

☐ 18. Check Added Algeb operation (page 6-23)

Correct operation; see Calibration Procedure.

☐ 19. Check Common Mode Rejection Ratio (page 6-24)

Maximum amplitude, 25 mV with 5 volts common mode signal.

☐ 20. Check Vertical Signal Out, Gain and Tracking (page 6-26

Vert Sig Out equal to OFFSET MONITOR voltage divided by 100.

Accuracy, 2.5%, at all OFFSET MONITOR voltages other than zero.

Accuracy, at OFFSET MONITOR zero, ±55 mV.

☐ 21. Check A Vert-B Horizontal (page 6-27)

Correct operation; see Calibration Procedure.

☐ 22. Check Channel Time Coincidence (page 6-28)

Time difference not more than 20 ps.

CALIBRATION PROCEDURE

General

In the following calibration procedure, a test equipment setup is shown for each major setup change. Complete control settings are listed following the picture. To aid in locating individual controls which have been changed during complete calibration, these control names are printed in bold type. If only a partial calibration is performed, start with the nearest setup preceding the desired portion.

NOTE

When performing a complete recalibration, best performance will be provided if each adjustment is made to the exact setting, even if the Check is within the allowable tolerance.

Preliminary Procedure

Make a complete visual check of the instrument. If the calibration is being done as a result of trouble check for correct types and locations of transistors, tubes and sampler diodes.

Check to see that all plug-in board chassis are properly seated when installed. Check for tube shields on the Type 7308's on the Memory boards. Be sure the avalanche drive cable fits properly in the Gremar connections.

1. Preset the Type 4S2A controls as follows:

Front Panel

mV/CM	200
VARIABLE	CALIBRATED
POSITION	Midrange
SMOOTHING	Midrange
DC OFFSET	Midrange
DISPLAY	NORMAL
MODE	A ONLY
A-B BAL	Midrange

Internal

AVALANCHE ADJUST	Midrange
A BRIDGE VOLTS	Clockwise
A BRIDGE BALANCE	Midrange
B BRIDGE VOLTS	Clockwise
B BRIDGE BALANCE	Midrange
MEMORY GATE WIDTH	Midrange
A SMOOTHING BAL	Midrange
B SMOOTHING BAL	Midrange
A INVERTER ZERO	Midrange
B INVERTER ZERO	Midrange
B CAL	Midrange

2. Check resistance to ground at each of the 24 pins on the Power Plug, P1. The location of P1 and the equipment setup are shown in Fig. 6-3. Table 6-1 shows pin number, circuit function, ohmmeter range and the approximate resistance that should be measured.

TABLE 6-1

Pin No.	Circuit	Ohmmeter Range	Resistance
1	117 VAC	×100 k	Inf
2	6.3 VAC	×100 k	Inf
3	−19 V	×10	9-15 Ω
4	−25.2 V	×100 k	Inf
5	−100 V	×1 k	2-2.5 kΩ
6	Staircase in	×100 k	Inf
7	Gnd	×10	0
8	(B) out to Horiz	×10	0
9	Braid for 21	×10	0
10	(B) Vert out	×1 k	8-11 kΩ
11	(A) Vert out	×1 k	8-11 kΩ
12	Gnd	×10	0
13	117 VAC	×100 k	Inf
14	6.3 VAC	×100 k	Inf
15	+300 V	×1 k	9 kΩ
16	+400 V	×100 k	Inf
17	+100 V	×1 k	9 kΩ
18	+19 V	×100 k	400 to 500 Ω
19	Staircase out	×100 k	Inf
20	Braid for 8	×10	0
21	Blanking out	×100 k	10 to 50 MΩ
22	Braid for 10	×100 k	Inf
23	Braid for 11	×100 k	Inf
24	Vert sig out	×1 k	4-5 kΩ

Check resistance to ground at pin 2, Connector P2, as shown below.

Pin No.	Circuit	Ohmmeter Range	Resistance
2	−12.6 V	×100 k	Inf

NOTES

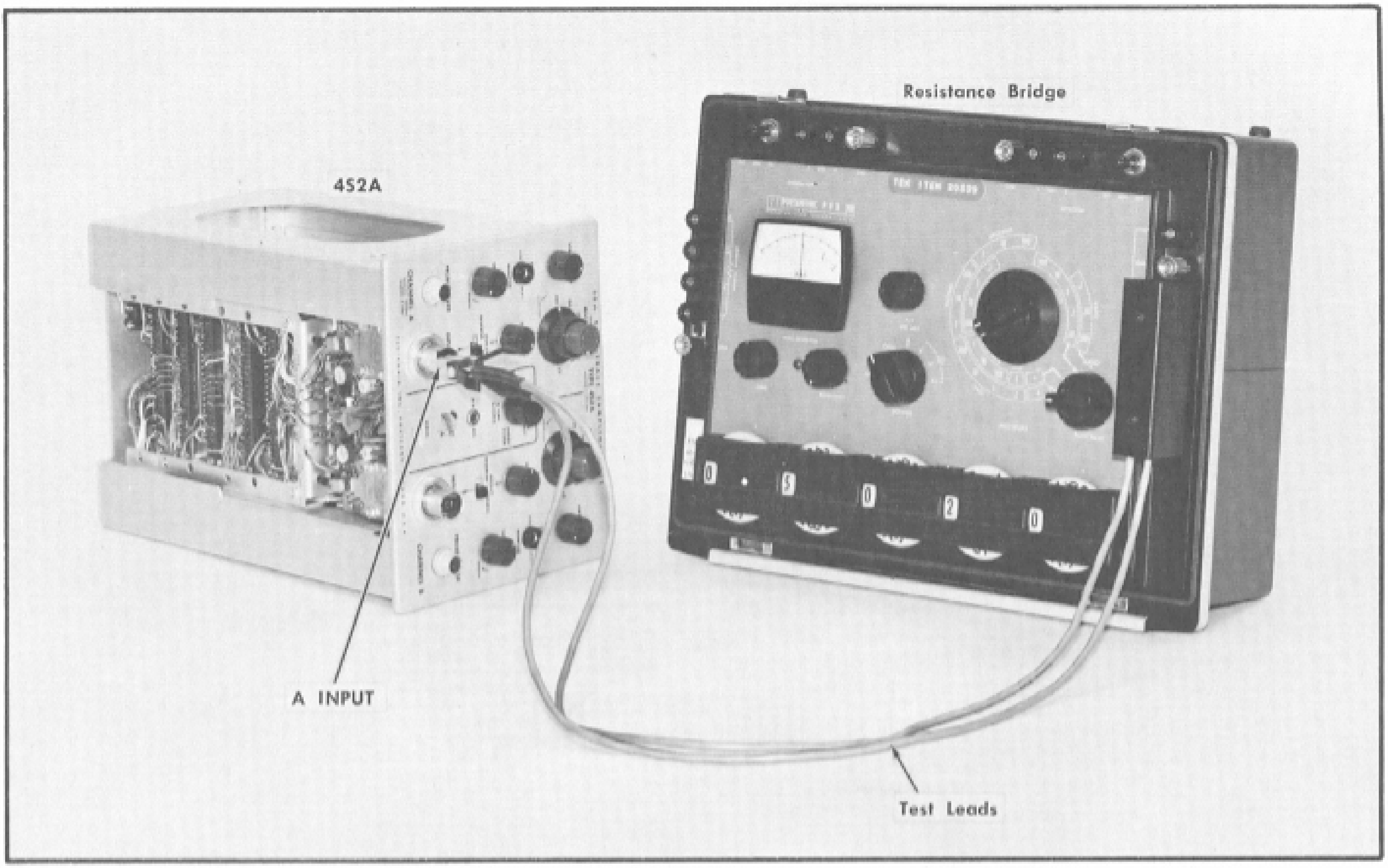

Fig. 6-4. Test equipment setup for step 3 of Preliminary Procedure.

3. Check Channel A and B INPUT Resistance as follows:

a. Connect the Resistance Bridge test leads to the proper Bridge terminals for resistance measurement, as shown in Fig. 6-4.

b. Short circuit the test leads at the Test Clips and measure the lead resistance.

c. Remove the short circuit from the Test Leads and connect the Test Clips to the inner and outer conductors of the Type 4S2A INPUT A connector.

d. Measure the combined resistance of the leads and the Type 4S2A INPUT A.

e. Subtract the lead resistance from the combined resistance. The INPUT A resistance should be 50 Ω, ±1%.

f. Measure Channel B INPUT resistance in the same manner.

4. Connect the Type 4S2A to the Type 661 as follows:

a. Connect the Type 4S2A Power Plug, P1, to the mating jack on the Type 661, using the interconnecting cable with 24 pin Amphenol connectors. See Fig. 6-5.

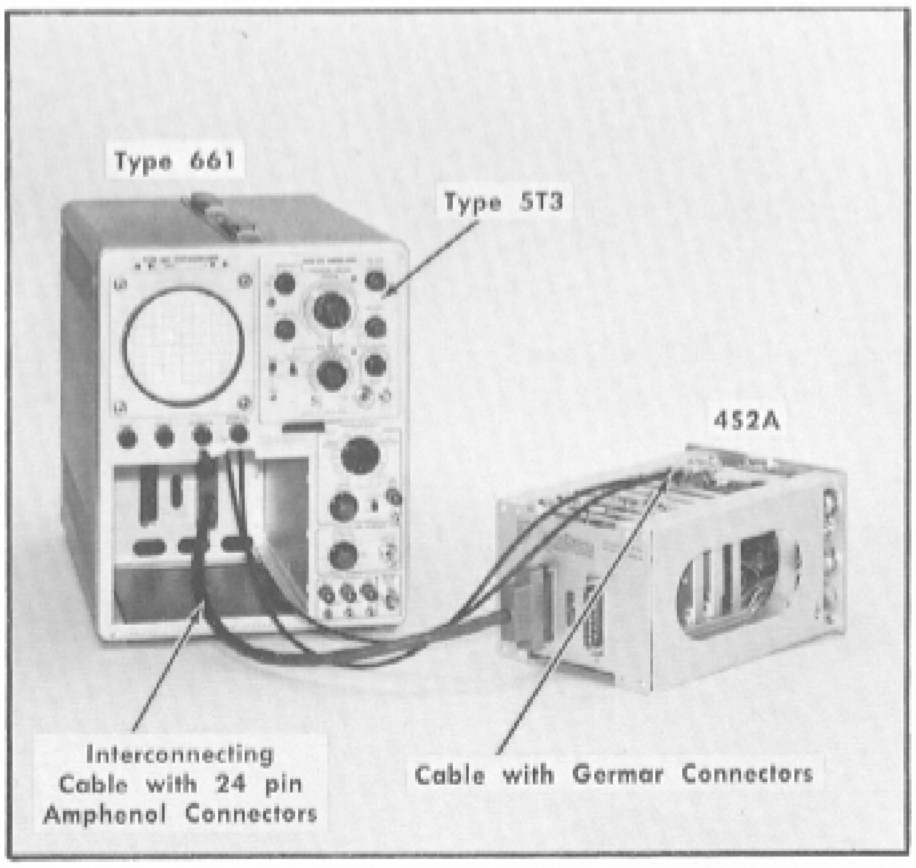

Fig. 6-5. Location of cables for operation of 4S2A outside the Type 661.

b. Connect the jacks on the top of the Type 4S2A to the jacks in the top of the Type 661 plug-in compartment with the two 32 inch cable with Gremar connectors. Be sure to connect the right hand jack on the Type 4S2A viewed from the front, to the right hand jack in the Type 661.

c. Turn on the Type 661 with the Power and Scale Illumination switch. Allow to warm up for 20 minutes at 20°C, ±5°C for the stated accuracy.

NOTES

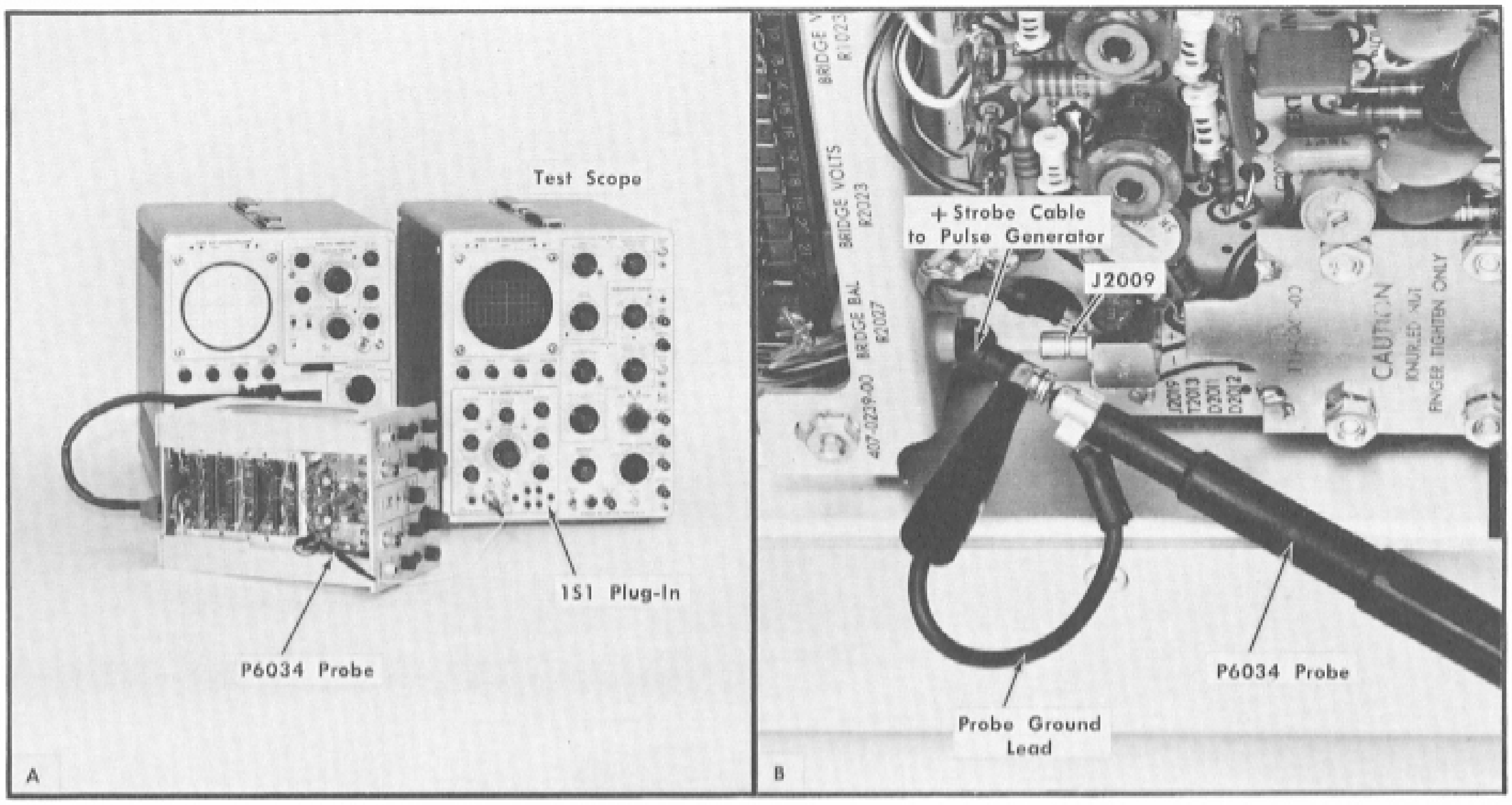

Fig. 6-6. Test equipment setup for step 1.

Control Settings:

Type 4S2A

mV/CM	200
VARIABLE	CALIB
POSITION	Midrange
DC OFFSET	Midrange
SMOOTHING	NORMAL
MODE	A ONLY
DISPLAY	NORMAL

Type 5T3

Samples/cm	100
Equiv Time/cm	Real Time
Variable	Calib
Sampling Rate	100 Kc
Trig Source	Free Run
Ext Trig Mode	DC, 50 Ω
Trig Level	Midrange
Stability	Midrange
Trig Slope	+

Type 661

Horiz Display	×1
Horiz Position	Midrange
Vernier	Midrange

Type 1S1

mV/cm	200
Variable	Calib
Time Position	Midrange
Time Position Range	50 ns
Time/cm	2 ns
Display Mode	Normal
Smoothing	Counterclockwise
Samples/cm	Counterclockwise, not in Swp Off
Position	Midrange
DC Offset	Midrange
Trig Source	+ Int
Trig Sensitivity	Midrange
Recovery Time	Midrange

Test Oscilloscope

Horiz Display	Ext, ×1
Variable 10-1	Midrange

1. Adjust Strobe Pulse Amplitude

a. Test equipment setup is shown in Fig. 6-6(A).

b. Connect an 18 inch lead with banana plugs from the Horizontal Output jack of the 1S1 to the Horizontal Input jack on the Test Oscilloscope.

c. Disconnect the cable from Jack J2009, on the sampler board. See Fig. 6-7(B).

d. Connect the P6034 10× probe to the 1S1 Sampling Plug-In input.

e. Connect the 10× probe tip to the Subminax connector on the cable removed from J2009. Maintain ground continuity with the probe ground lead as shown in Fig. 6-6(B).

f. Locate the strobe pulse on the test scope CRT. Adjust the 1S1 Time Position control, the Trig. Sensitivity control and the Recovery Time control for a stable display as shown in Fig. 6-7.

g. Adjust the SNAPOFF CURRENT control, R1063, on the PULSE GENERATOR board, for maximum amplitude of the strobe pulse seen on the test scope CRT.

h. Adjust the AVALANCHE ADJUST control R1054, on the PULSE GENERATOR board toward maximum amplitude of the strobe pulse as seen on the test scope CRT. When the observed trace breaks into instability, rotate the AVALANCHE ADJUST control counterclockwise a few degrees.

i. Set Voltohmmeter range to 400 volts DC.

j. Connect the DC voltmeter common lead to chassis ground.

k. Connect the voltmeter positive lead to the collector of Q1053, as shown in Fig. 6-8. Observe approximately +175 volts.

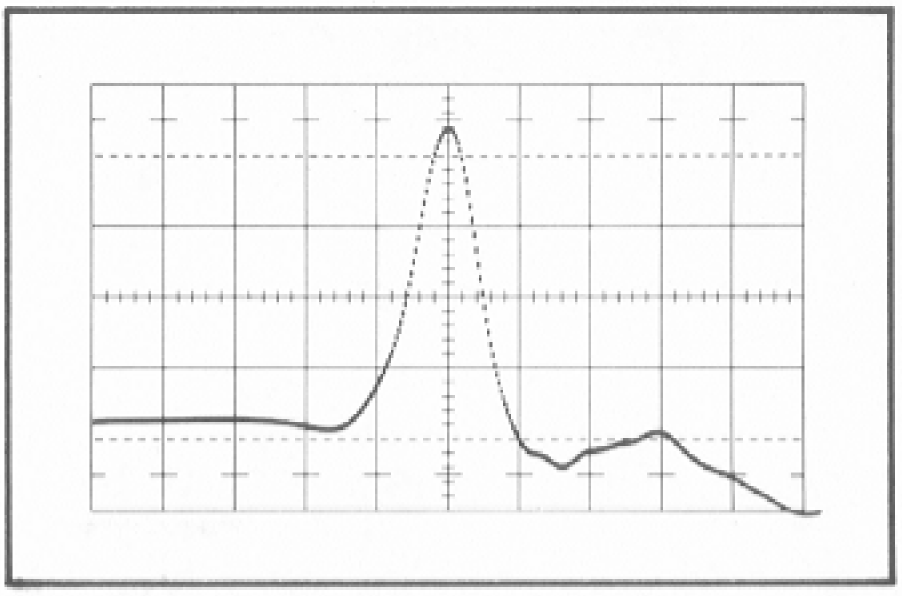

Fig. 6-7. Typical CRT display of Strobe Pulse.

l. Switch the 5T3 Equiv Time/Cm control alternately between 100 μsec and Real Time. Note any difference in voltage, indicated by the DC voltmeter, in the two switch positions.

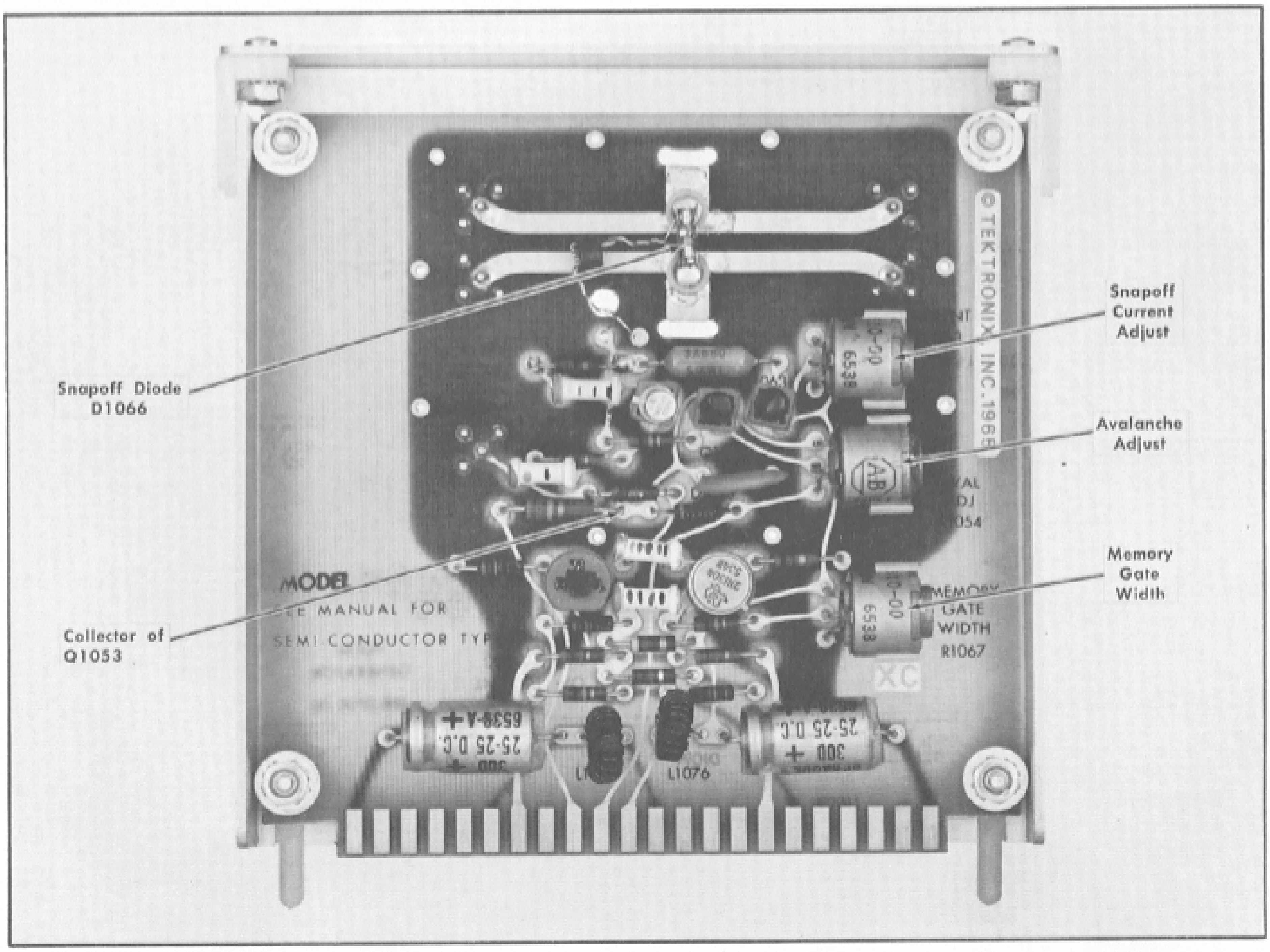

Fig. 6-8. Location of controls on Pulse Generator Card Assembly.

m. Slowly rotate the AVALANCHE ADJUST control counterclockwise until no difference in voltage is seen while switching between 100 μsec and Real Time on the Type 5T3.

n. Remove the Test Scope Probe from the Subminax connector. Replace the connector on J2009.

o. Locate the trace on the 661. If the trace shows noise on the display, rotate the AVALANCHE ADJUST control counterclockwise until a single trace is seen.

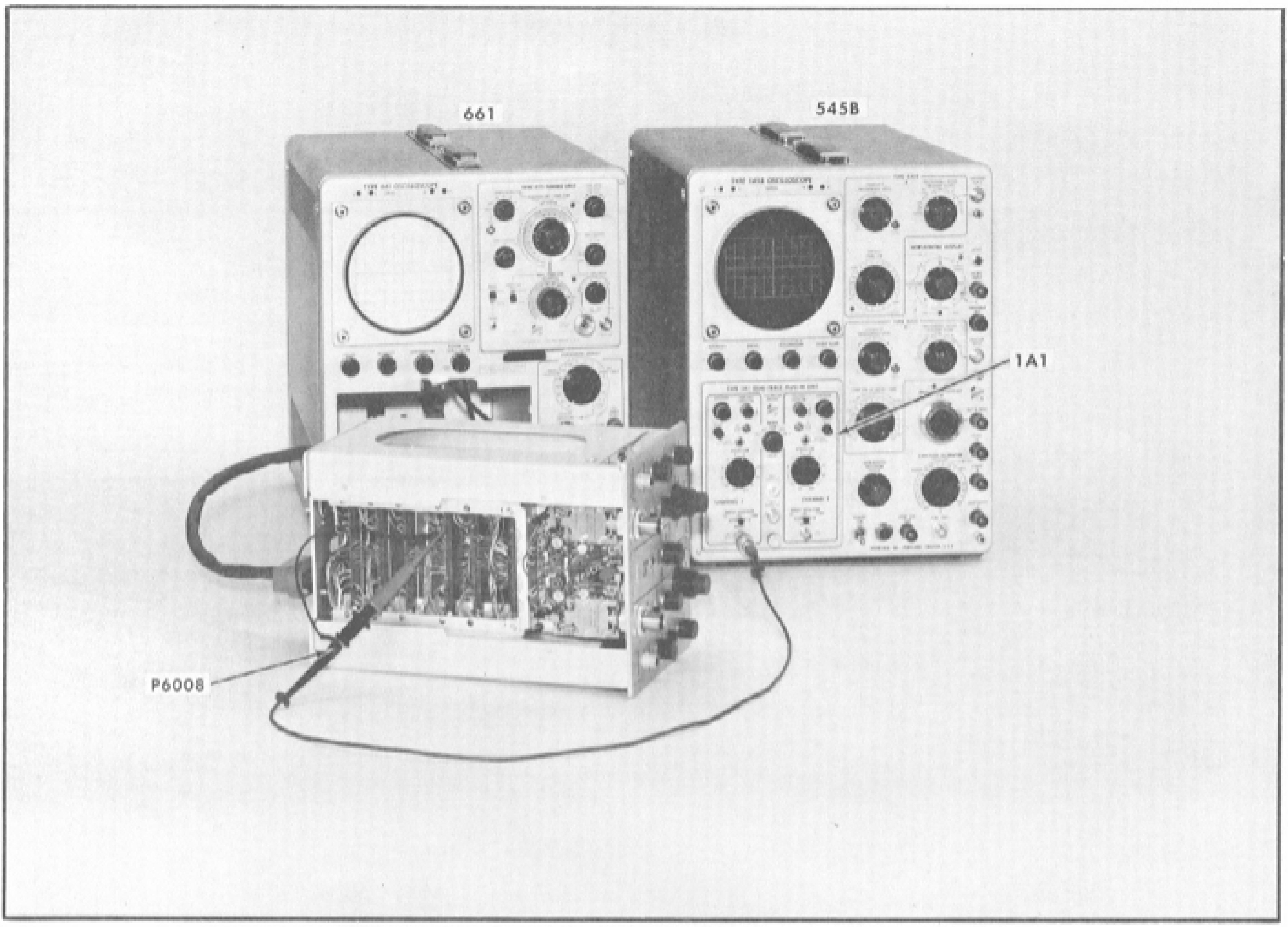

Fig. 6-9. Initial test equipment setup for steps 2 and 3.

Control Settings:

Type 4S2A

mV/CM	200
VARIABLE	CALIB
POSITION	Midrange
DC OFFSET	Midrange
SMOOTHING	NORMAL
MODE	A ONLY
DISPLAY	NORMAL

Type 5T3

Samples/cm	100
Equiv Time/cm	**5 ns**
Variable	Calibrated
Trig Source	Free Run
Ext Trig Mode	DC, 50 Ω
Trig Level	Midrange
Stability	Midrange
Trig Slope	+
Time Position	Midrange

Type 661

Horiz Display	×1
Horiz Position	Midrange
Vernier	Midrange

Type 1A1 Plug-In

Input Selector	AC
Volts/cm	.5

Variable	Calibrated
Mode	Ch 1
Position	Midrange

Test Oscilloscope

Time/cm	.1 μsec
Variable	Calibrated
Horiz Display	A
Trig Mode	AC
Trig Slope	+ Int
Stability	Stable Display

2. Adjust Memory Gate Width

a. Test equipment setup is shown in Fig. 6-9.

b. Connect the P6008 10× Probe to the Channel 1 Input of the Type 1A1 Plug-In.

c. Connect the 10× Probe tip to pin V of the A Channel Memory connector. Turn the Type 4S2A on its left side to reach this connection. See Fig. 6-10.

d. Observe a display of approximately 4 cm vertically on the Test Oscilloscope. Adjust the Test Oscilloscope Trig Level and Stability controls for a stable trace.

e. Adjust the MEMORY GATE WIDTH control on the Pulse Generator board for 150 ns pulse width as seen on the Test Oscilloscope. Pulse width is measured at the 50% amplitude points. See Fig. 6-11.

f. Check Channel B MEMORY connector, Pin V, for the same display as in step e.

g. Turn the Type 4S2A upright.

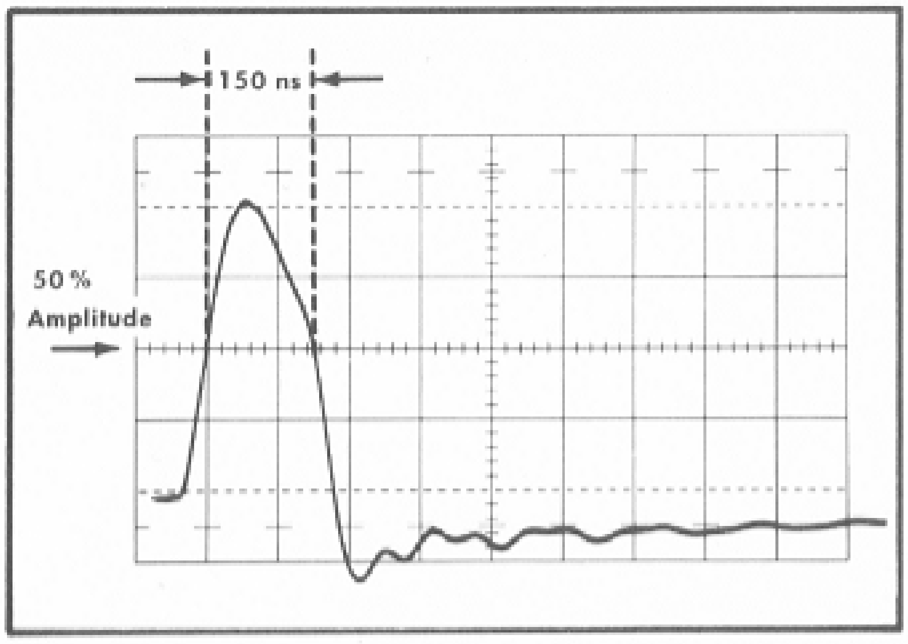

Fig. 6-11. Typical CRT display of Memory Gate Pulse.

3. Check DC Offset and Mode Positions

a. Test setup is given in step 2.

b. Center the Test Oscilloscope trace vertically with the Type 1A1 Position Control.

c. Connect the 10× Probe tip to the Type 4S2A Channel A OFFSET MONITOR jack. See Fig. 6-12.

d. Switch the Type 1A1 Input Selector to DC and center the trace, seen on the Test Oscilloscope, with the Type 4S2A DC OFFSET control.

e. Switch the Type 1A1 Volts/cm control to .005.

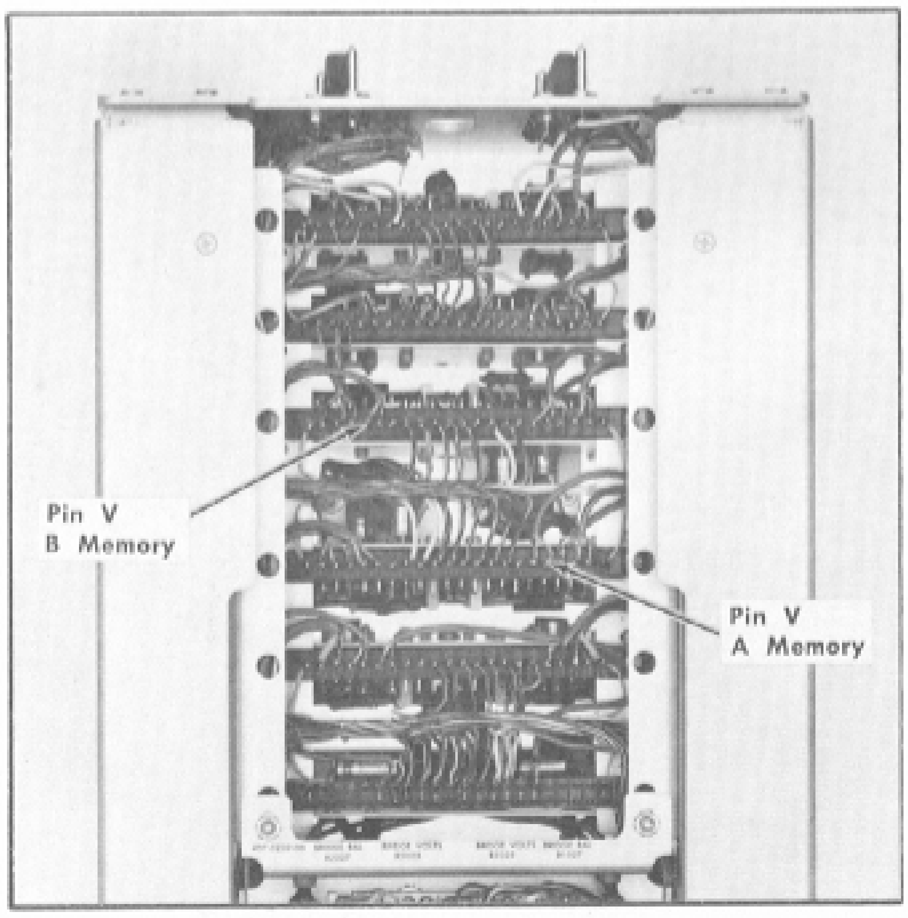

Fig. 6-10. Bottom view of 4S2A showing location of plug-in connectors.

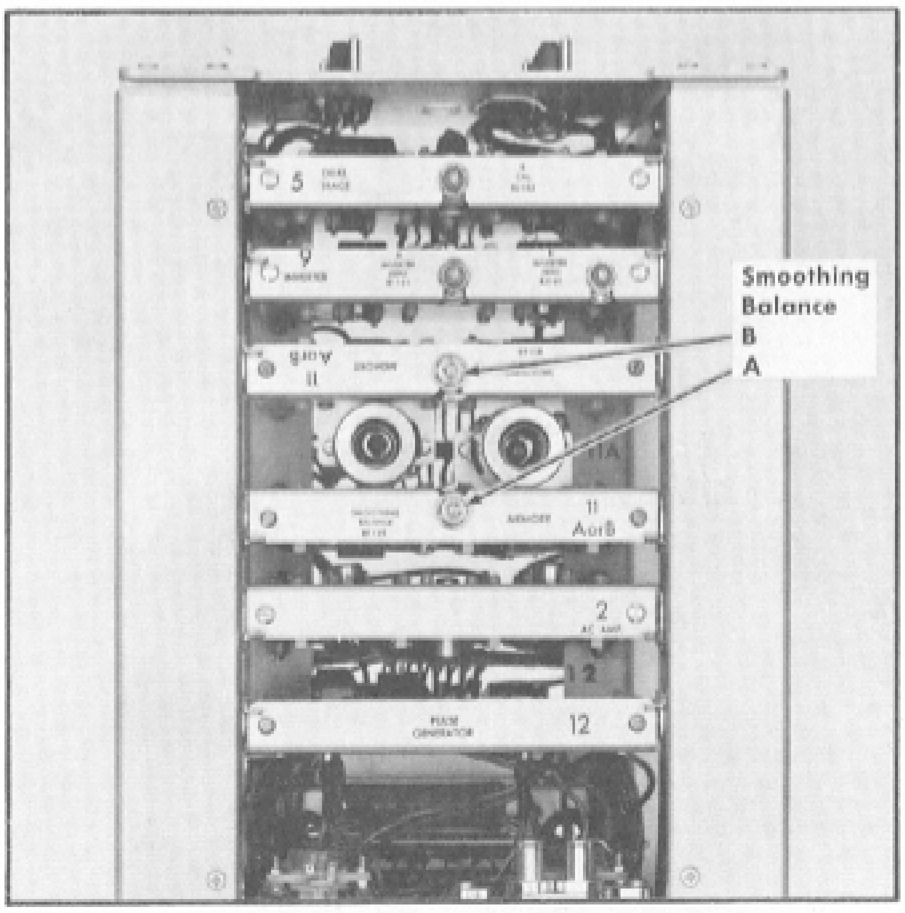

Fig. 6-12. Location of Type 4S2A circuit board controls.

f. Readjust the Type 4S2A DC OFFSET control to return the Test Oscilloscope trace to the center horizontal graticule line.

g. Locate the trace on the Type 661 CRT with A BRIDGE VOLTS, A BRIDGE BALANCE, A MEMORY SMOOTHING BALANCE and/or A SMOOTHING controls on the Type 4S2A. Do not move the DC OFFSET control.

h. Return the A SMOOTHING control on the Type 4S2A to NORMAL. If a double trace is seen with the SMOOTHING control NORMAL, back off the AVALANCHE ADJUST until a single trace is seen.

i. Switch the Type 4S2A MODE switch to B ONLY.

j. Switch the Type 1A1 Volts/cm control to .5.

k. Move the 10X Probe to B OFFSET MONITOR jack.

l. Adjust B DC OFFSET control to center the trace seen on the Test Oscilloscope.

m. Switch the Type 1A1 Volts/cm control to .005.

n. Readjust the DC OFFSET control to set the Test Oscilloscope trace to the center horizontal graticule line of the CRT.

o. Locate the B trace on the Type 661 with the B BRIDGE VOLTS, B BRIDGE BALANCE, B MEMORY SMOOTHING BALANCE and/or B SMOOTHING. Do not move the DC OFFSET control.

p. Return the B SMOOTHING control to NORMAL.

q. Check for the presence of a trace in ADDED ALGEB.

r. Check for two traces in DUAL TRACE.

s. Return the Type 4S2A MODE switch to A ONLY.

t. Remove the 10X Probe tip from the B OFFSET MONITOR jack.

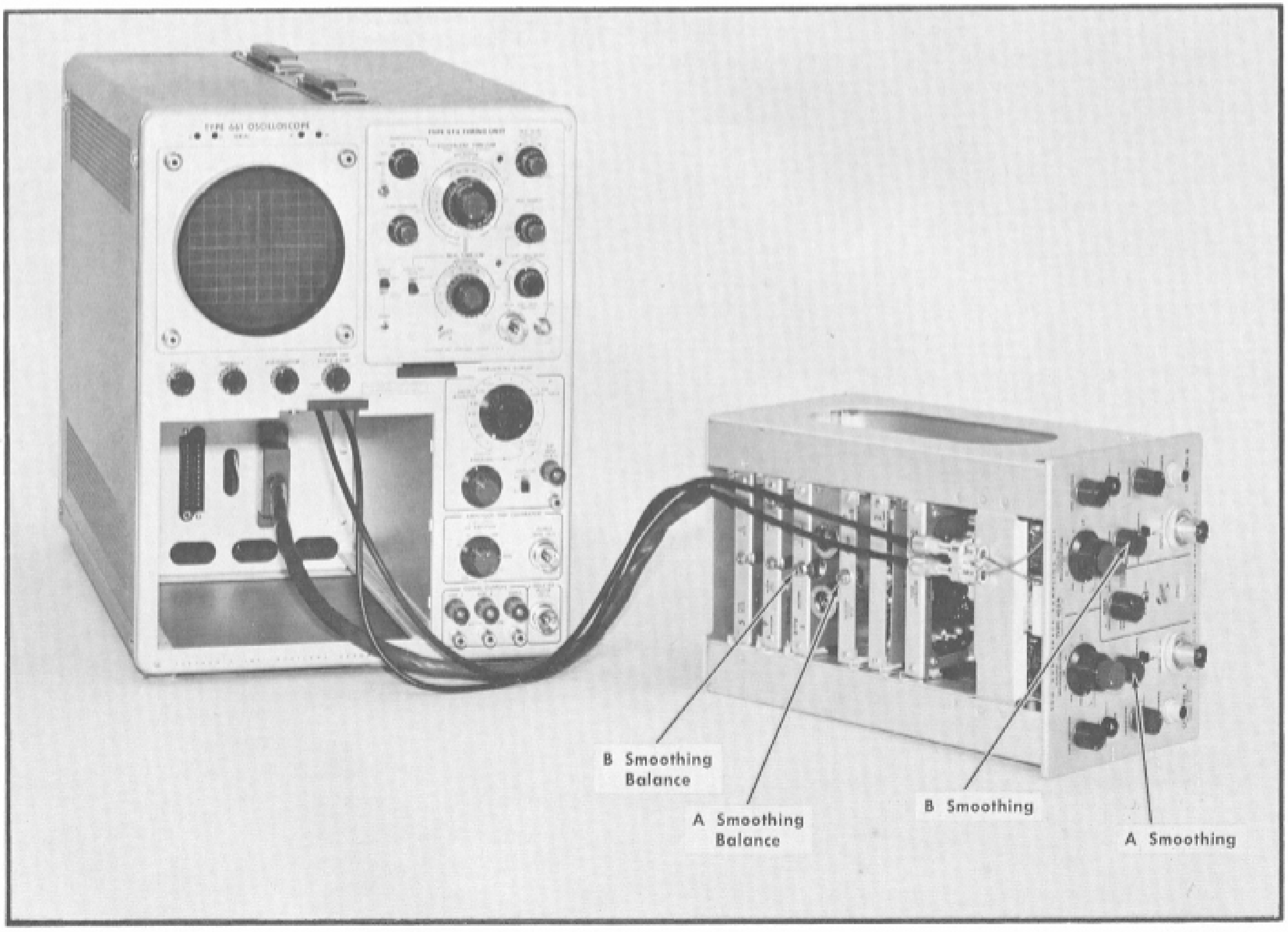

Fig. 6-13. Initial test equipment setup for steps 4 through 6.

Control Settings:

Type 4S2A

mV/CM	**20**
VARIABLE	CALIB
POSITION	Midrange
DC OFFSET	Midrange
SMOOTHING	NORMAL
MODE	A ONLY
DISPLAY	NORMAL

Type 5T3

Samples/cm	100
Equiv Time/cm	**20 ns**
Variable	Calibrated
Trig Source	Free Run
Ext Trig Mode	DC, 50 Ω
Trig Level	Midrange
Stability	Midrange
Trig Slope	+
Time Position	Midrange

Type 661

Horiz Display	×1
Horiz Position	Midrange
Vernier	Midrange

4. Adjust Smoothing Balance

a. Test Equipment setup is shown in Fig. 6-13.

b. Locate a trace on the Type 661 CRT.

c. Rotate the A SMOOTHING control counterclockwise. If the trace on the Type 661 shifts, adjust the Type 4S2A A SMOOTHING BALANCE for no trace shift while rotating the A SMOOTHING control throughout its range.

d. Turn the MODE switch to B ONLY.

e. Locate the trace on the Type 661 CRT.

f. Adjust the B SMOOTHING BALANCE for no trace shift on the Type 661 CRT while rotating the B SMOOTHING control throughout its range.

g. Return the Type 4S2A MODE switch to A ONLY.

5. Adjust Bridge Volts and Transient Response (Preliminary)

a. Test equipment setup is given in step 4.

b. Change the Type 4S2A mV/CM to 200.

c. Change the Type 5T3 Samples/cm to 5.

d. Connect a 50 Ω 5 ns cable with General Radio Type 874 connectors from the Delayed Pulse out jack on the Type 661 Oscilloscope to the A INPUT on the Type 4S2A.

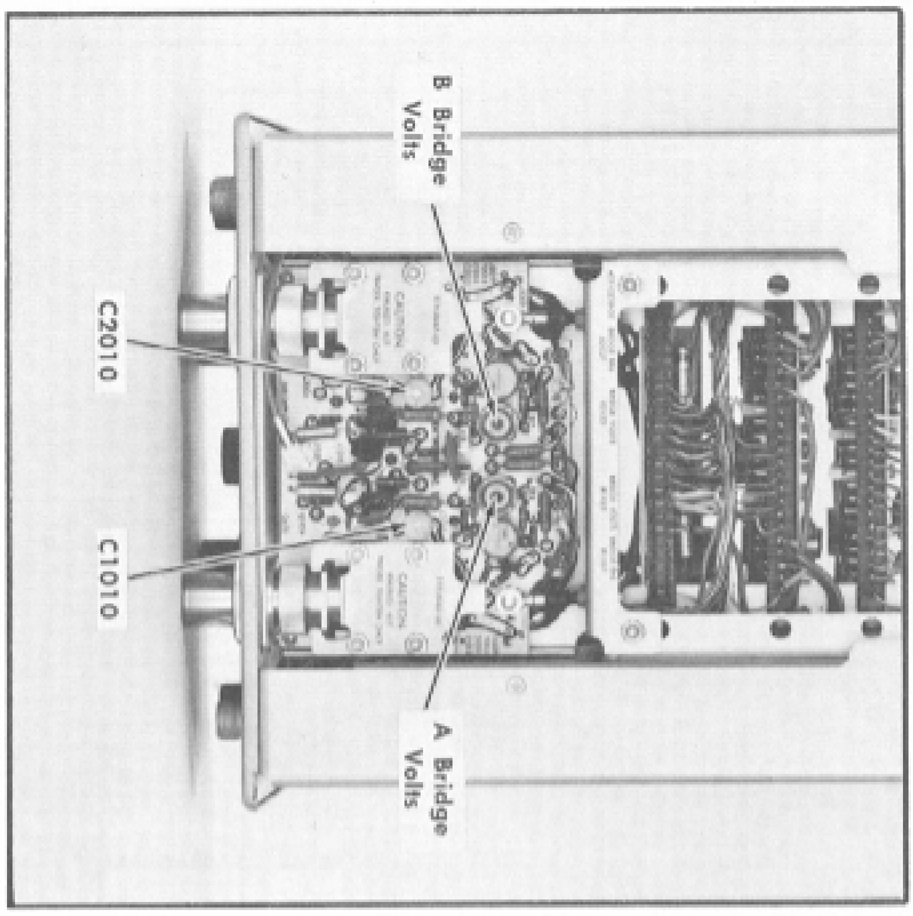

Fig. 6-14. Location of controls on Sampler Circuit board.

e. Adjust the A BRIDGE VOLTS control, Fig. 6-14, on the Type 4S2A for Unity Dot Transient Response as shown in Fig. 6-15. Incorrect adjustment is shown in Fig. 6-16, (A) and (B).

f. Adjust C1010, shown in Fig. 6-14, for the best transient response, as shown in Fig. 6-15. Incorrect adjustment is shown in Fig. 6-17, (A) and (B).

g. Move the input cable from the Type 4S2A INPUT A to INPUT B.

h. Switch the MODE switch to B ONLY.

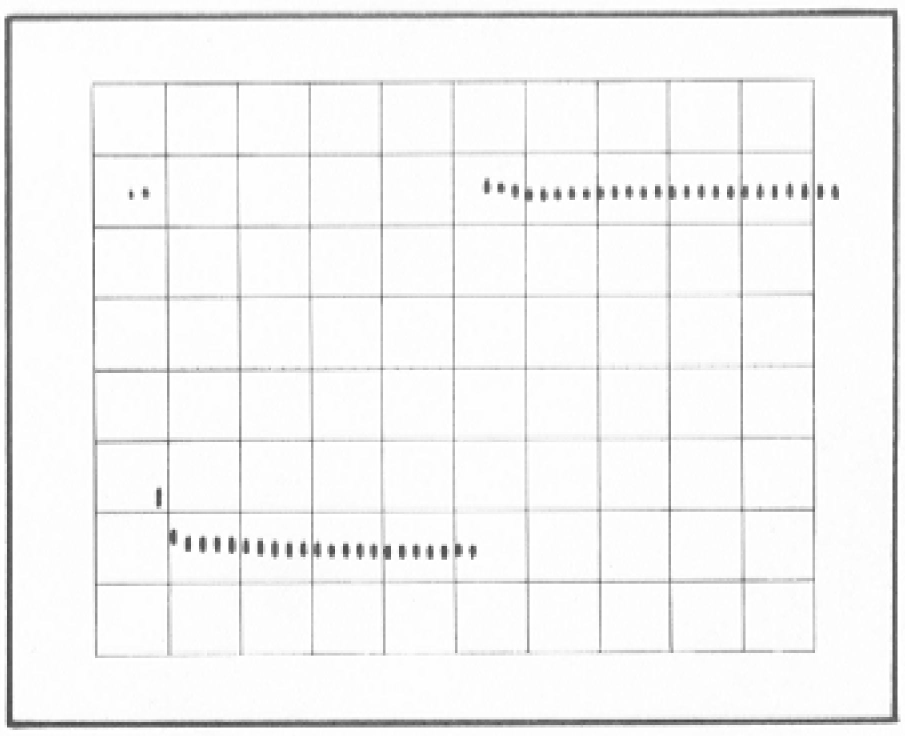

Fig. 6-15. Typical CRT display showing correct Bridge Volts and Transient Response Adjust.

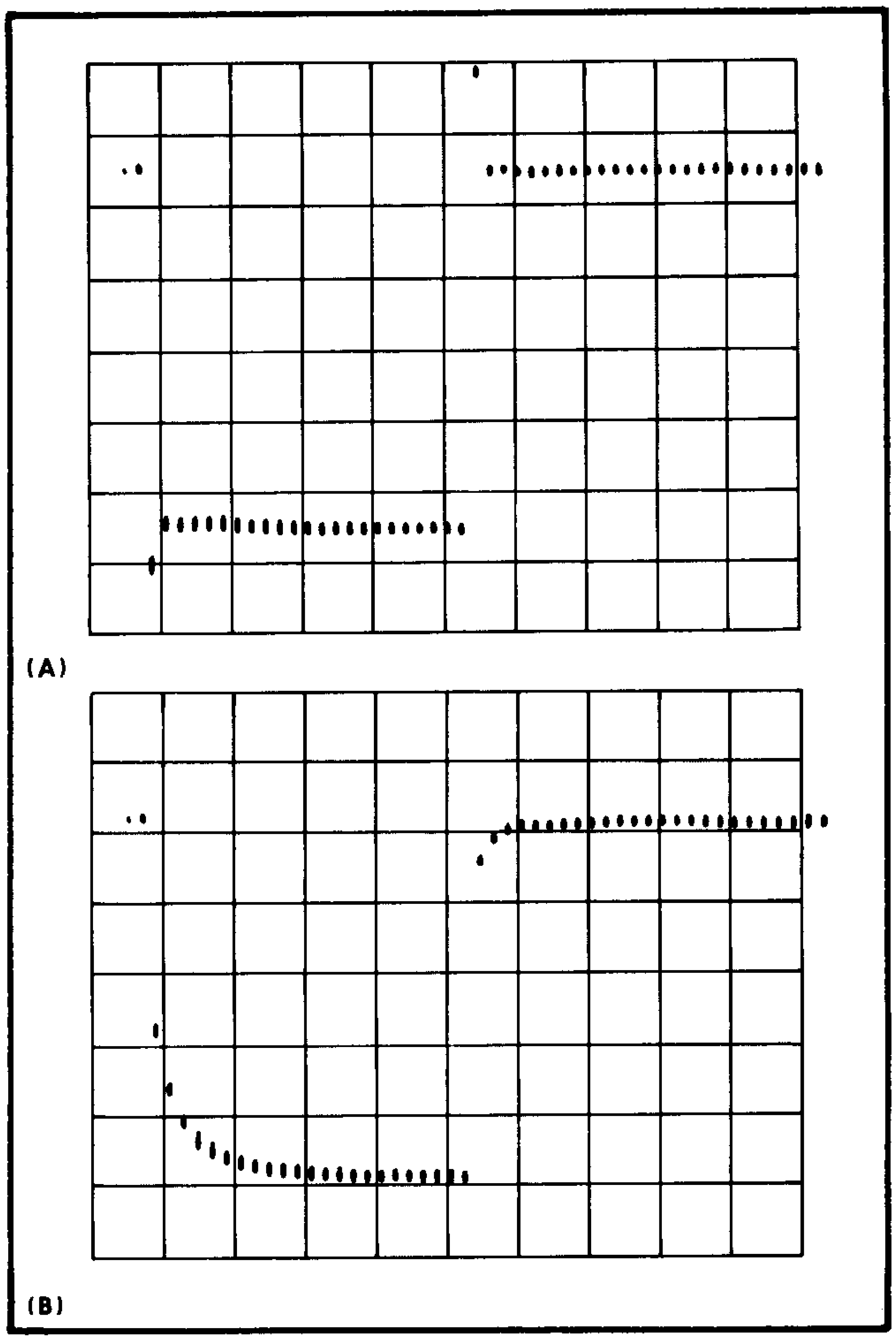

Fig. 6-16. Typical CRT display showing incorrect adjustment of Bridge Volts controls.

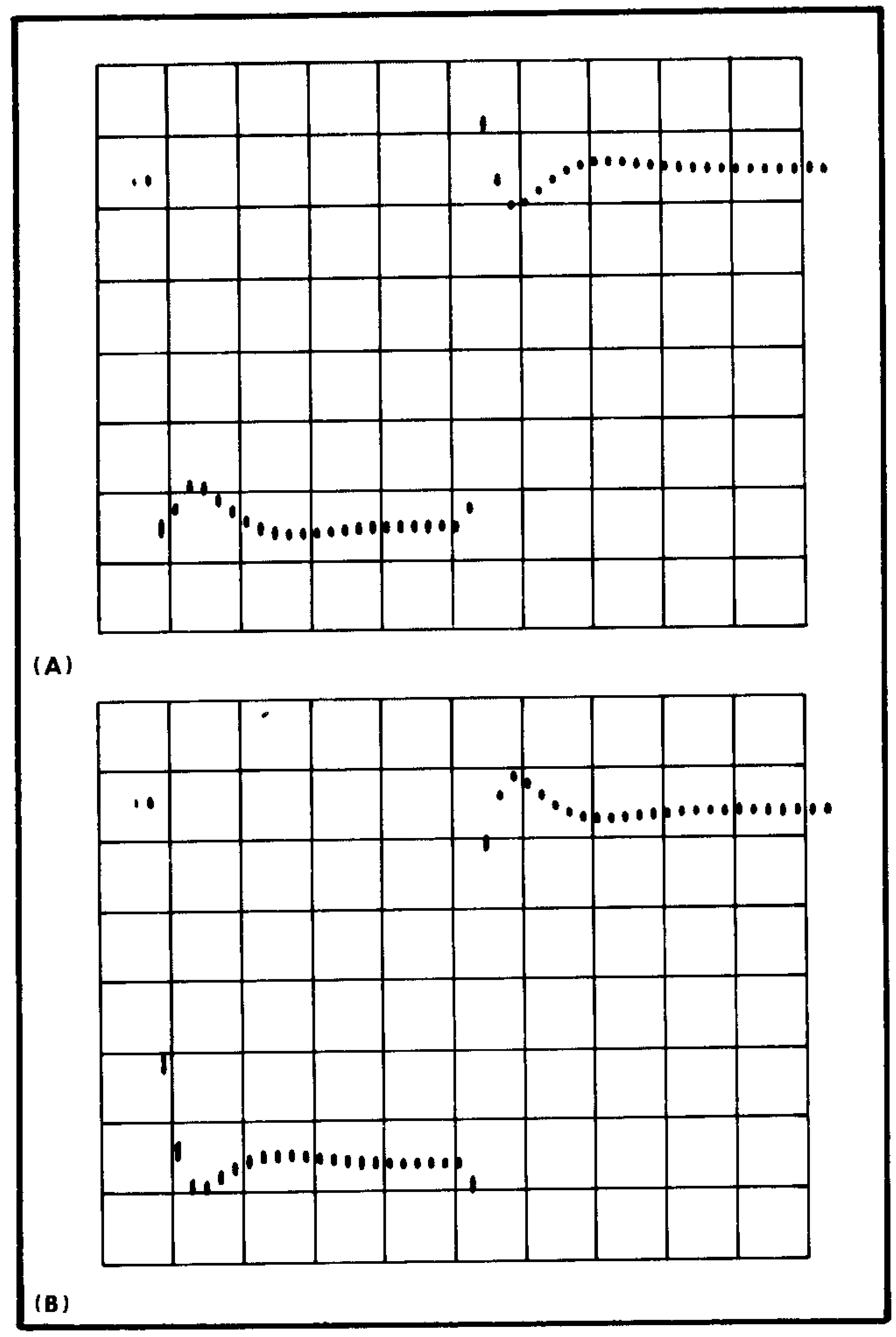

Fig. 6-17. Typical CRT display showing incorrect adjustment of Transient Response caps, C1010 and C2010.

NOTES

i. Adjust B BRIDGE VOLTS and C2010 as in steps e and f.

j. Disconnect the 50 Ω cable from the Type 661 Delayed Pulse Out, and connect it to the Ampl/Time Calibrator on the Type 661 Oscilloscope.

6. Adjust C1010 and C2010

a. Test Equipment setup is given in step 5.

b. Change the Type 5T3 Samples/cm to 100.

c. Change the Type 5T3 Equiv Time/cm to 1 μsec.

d. Change the Type 5T3 Trig Source to Cal.

e. Adjust the Type 5T3 Stability and Trig Level for a stable display on the Type 661 CRT.

f. Adjust C2010, Fig. 6-14, for flat top and bottom of the displayed waveform, as shown in Fig. 6-18(B). Fig. 6-18(A) shows incorrect adjustment.

g. Move the Calibrator signal from INPUT B to INPUT A, on the Type 4S2A.

h. Switch the Type 4S2A MODE switch to A ONLY. Locate the trace on the Type 661 CRT.

i. Adjust C1010, Fig. 6-14, for flat top and bottom of the displayed waveform, as shown in Fig. 6-18(B). Fig. 6-18(A) shows incorrect adjustment.

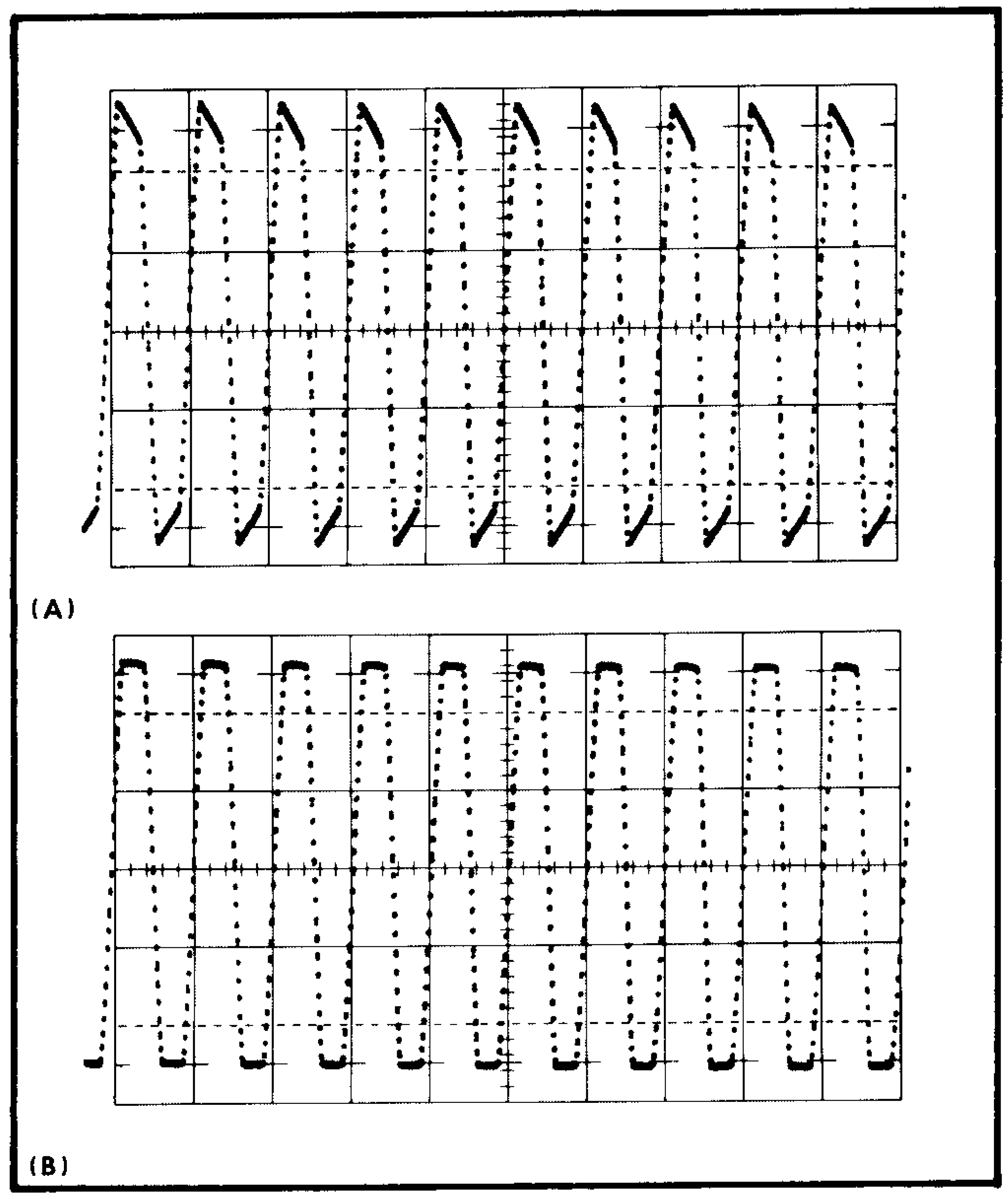

Fig. 6-18. Typical CRT display showing (A) Incorrect Adjustment

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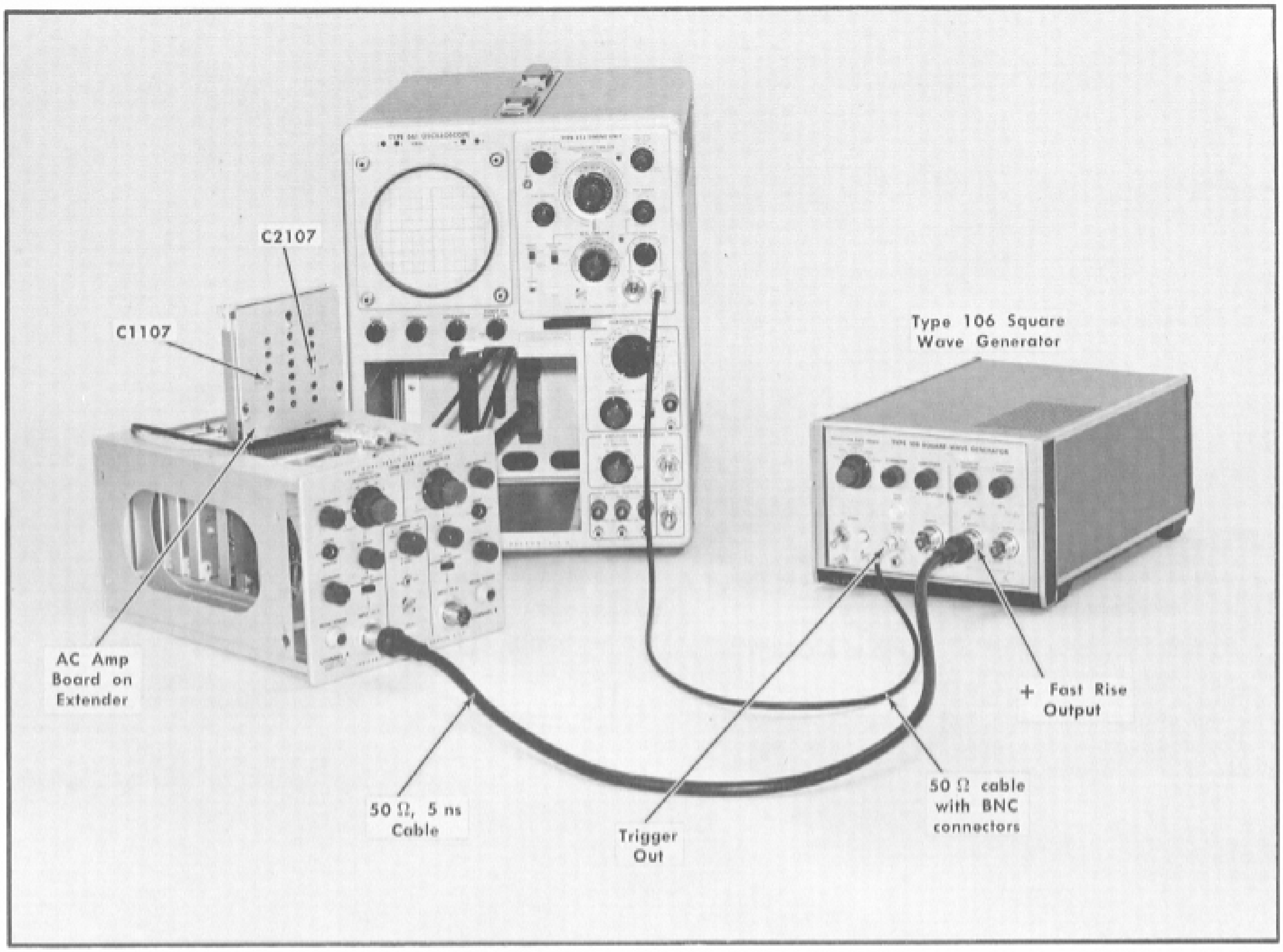

Fig. 6-19. Initial test equipment setup for steps 7 and 8.

Control Settings:

Type 4S2A

mV/CM	**200**
VARIABLE	CALIBRATED
POSITION	Midrange
DC OFFSET	Midrange
SMOOTHING	NORMAL
MODE	A ONLY
DISPLAY	NORMAL

Type 5T3

Samples/cm	**5**
Equiv Time/cm	**1 μsec**
Variable	Calibrated
Trig Source	**Ext**
Ext Trig Mode	**DC, 1 MΩ**
Trig Level	Midrange
Stability	Midrange
Trig Slope	+
Time Position	Midrange

Type 661

Horiz Display	×1
Horiz Position	Midrange
Vernier	Midrange

Square Wave Generator

Repetition Rate	100 kHz
Multiplier	1
Symmetry	Midrange
+ Transition Amplitude	Clockwise
Hi Ampl/Fast Rise	Fast Rise

7. Adjust C1107 and C2107 ⓘ

a. Test equipment setup is shown in Fig. 6-19.

b. Place the AC AMP board on the extender. Make sure that the plastic guide pins on the AMP board are aligned properly with the guide holes in the main chassis.

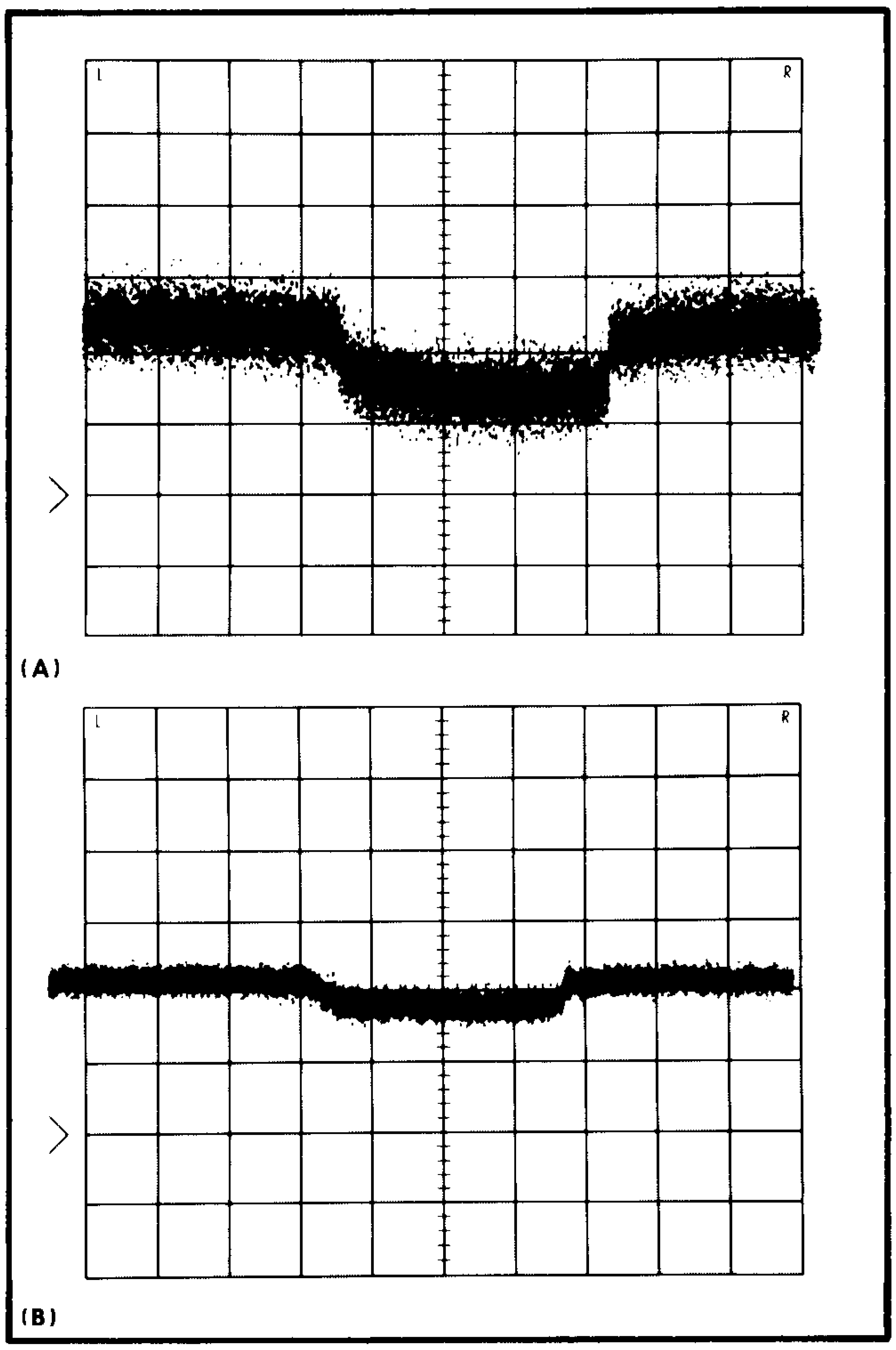

Fig. 6-20. Typical CRT display for Tangential Noise Measurement (A) Unity Loop Gain (B) Smoothed.

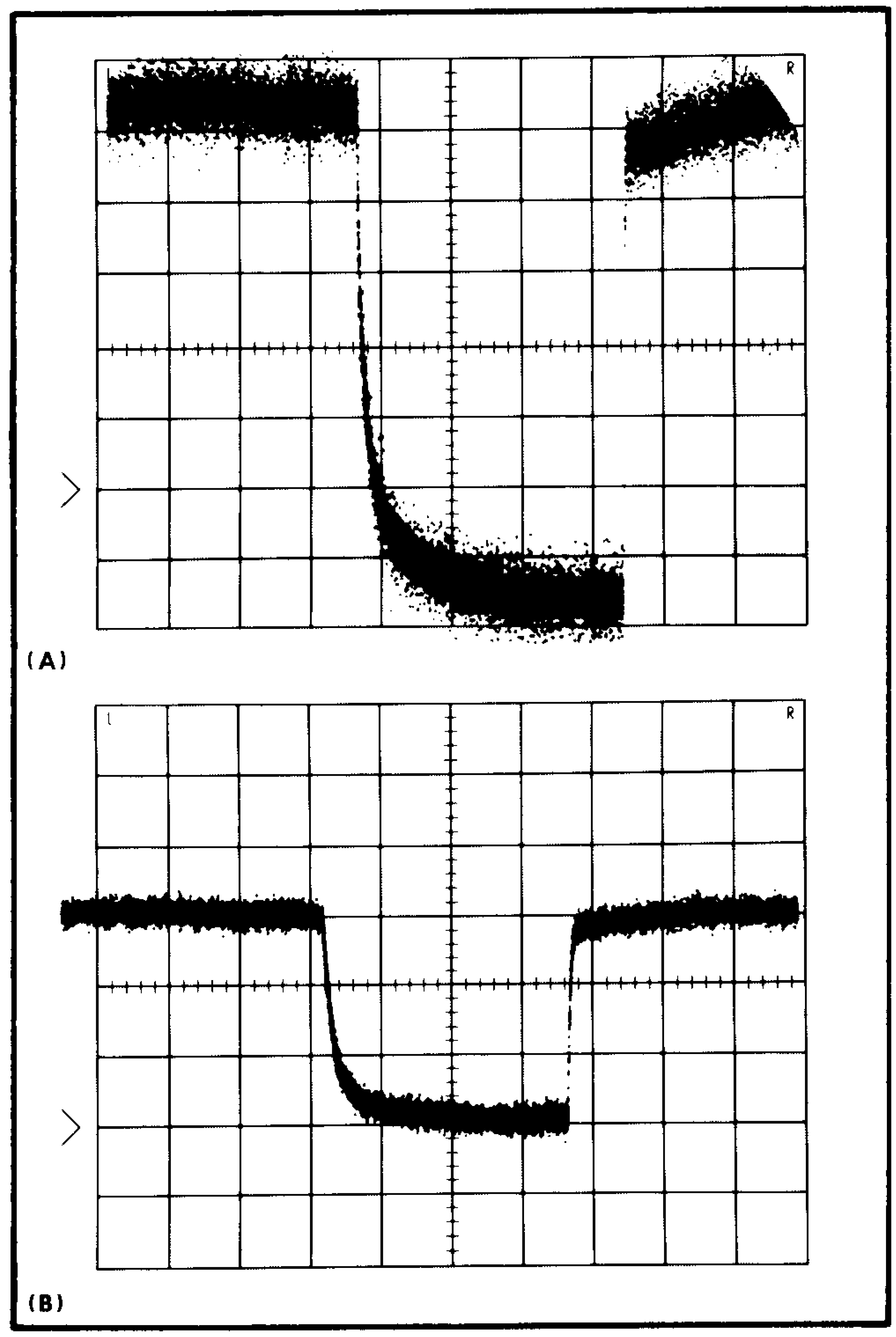

Fig. 6-21. Typical CRT display for Tangential Noise Measurement (A) Unity Loop Gain (B) Smoothed. (One 10× attenuator removed).

c. Connect a 50 Ω cable with General Radio Type 874 connectors from the + Fast Rise Output on the Square Wave Generator to the Type 4S2A A INPUT.

d. Connect a 50 Ω cable with BNC type connectors from the Square Wave Generator Trigger Output to the Type 5T3 1 MΩ Ext Trigger Input.

e. Observe the trace on the Type 661 CRT. It should be similar to that in Fig. 6-15.

f. Adjust C1107, Fig. 6-19, so that the first dot at the top of the positive going leading edge is at maximum amplitude. See Fig. 6-16.

g. Readjust A BRIDGE VOLTS control to bring the first dot at the top of the positive going leading edge to approximately 10% above the following dots in the display.

h. Move the signal from INPUT A to INPUT B.

i. Switch the MODE switch to B ONLY.

j. Locate the trace on the Type 661 CRT.

k. Adjust C2107, Fig. 6-19, as in step f.

l. Readjust B BRIDGE VOLTS control as in step g.

m. Leave the Square Wave Generator connected to INPUT B.

8. Check Tangential Noise

a. Test equipment setup is the same as step 7.

b. Observe the display on the Type 661 to be similar to Fig. 6-16.

c. Rotate the A SMOOTHING control counterclockwise to bring the first dot at the top of the positive going leading edge down to the level of the following display dots. (Unity loop gain) see Fig. 6-15.

d. Install two 10× Attenuators between the input cable from the Square Wave Generator and the Type 4S2A A INPUT.

e. Switch A mV/DIV to 5.

f. Adjust the Square Wave Generator + Transition Amplitude so that 10% of the dots on the display fall above a given horizontal line and 10% of the dots on the display fall below the same horizontal line. See Fig. 6-20(A).

g. Remove one of the 10× signal Attenuators from the signal path and observe the display on the Type 661 CRT. Maximum display amplitude, 8 Div. See Fig. 6-21(A). Divide the display amplitude in millivolts by 10 to calculate noise amplitude.

h. Replace the 10× Attenuator in the signal path.

i. Rotate A SMOOTHING control completely counterclockwise.

j. Adjust the Square Wave Generator + Transition Amplitude as in step f. See Fig. 6-20(B).

k. Remove one 10× Attenuator from the signal path and observe the display. See Fig. 6-21(B). Maximum display amplitude, 4 DIV. Divide the display amplitude in millivolts by 10 to calculate noise amplitude.

l. Replace the 10× Attenuator in the signal path.

m. Move the signal from the A INPUT to the B INPUT.

n. Switch the MODE switch to B ONLY.

o. Check B Channel Tangential Noise following steps b through k.

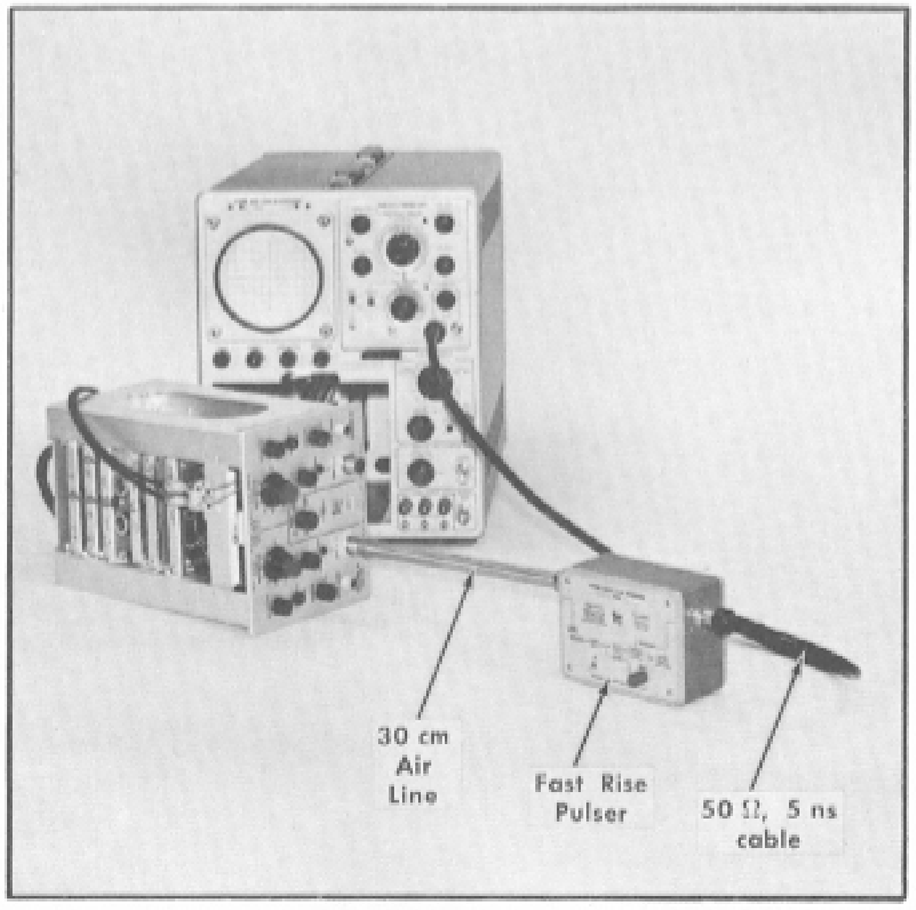

Fig. 6-22. Test equipment setup for step 9.

Control Settings:

Type 4S2A

mV/CM	200
VARIABLE	CALIBRATED
POSITION	Midrange
DC OFFSET	Midrange
SMOOTHING	NORMAL
MODE	A ONLY
DISPLAY	NORMAL

Type 5T3

Samples/cm	**100**
Equiv Time/cm	**.1 ns**
Variable	Calibrated
Trig Source	Ext
Ext Trig Mode	DC, 50 Ω
Trig Level	Stable Display
Stability	Stable Display
Trig Slope	+
Time Position	Midrange

Type 661

Horiz Display	×1
Horiz Position	Midrange
Vernier	Midrange

9. Check Risetime

a. Test equipment setup is shown in Fig. 6-22.

b. Connect the Pulse Output of the Fast Rise Pulser through a 30 cm Air Line to INPUT A of the Type 4S2A.

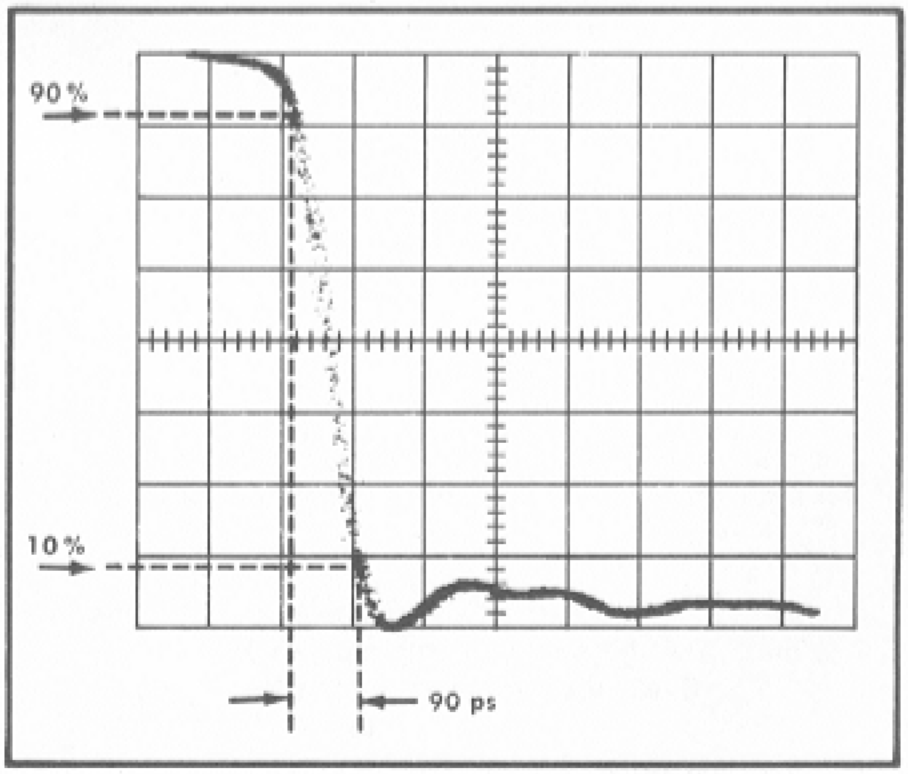

Fig. 6-23. Typical CRT display showing risetime.

c. Connect the Pretrigger out jack of the Fast Rise Pulser through a 5 ns cable with General Radio Type 874 connectors to the Ext Trig Input on the Type 5T3.

d. Locate the negative going portion of the waveform on the Type 661. (Use the Type 5T3 Trig Level, Stability and Time Position, the Type 4S2A A VERTICAL POSITION and/or DC OFFSET and the Fast Rise Pulse Generator Drive control.) Adjust the Type 5T3 Trig Level and Stability controls for a stable trace.

e. Increase the display amplitude with the A mV/CM VARIABLE control on the Type 4S2A for a display of 8 cm.

f. Position the display as shown in Fig. 6-23 and measure the risetime between the 10% and 90% amplitude points.

g. Check for a risetime of 90 ps or less.

h. A risetime greater than 90 ps may indicate an incorrect setting of the A BRIDGE VOLTS control.

i. Move the signal from A INPUT to B INPUT.

j. Switch the MODE switch to B ONLY.

k. Measure the risetime of the B channel, using steps d through h.

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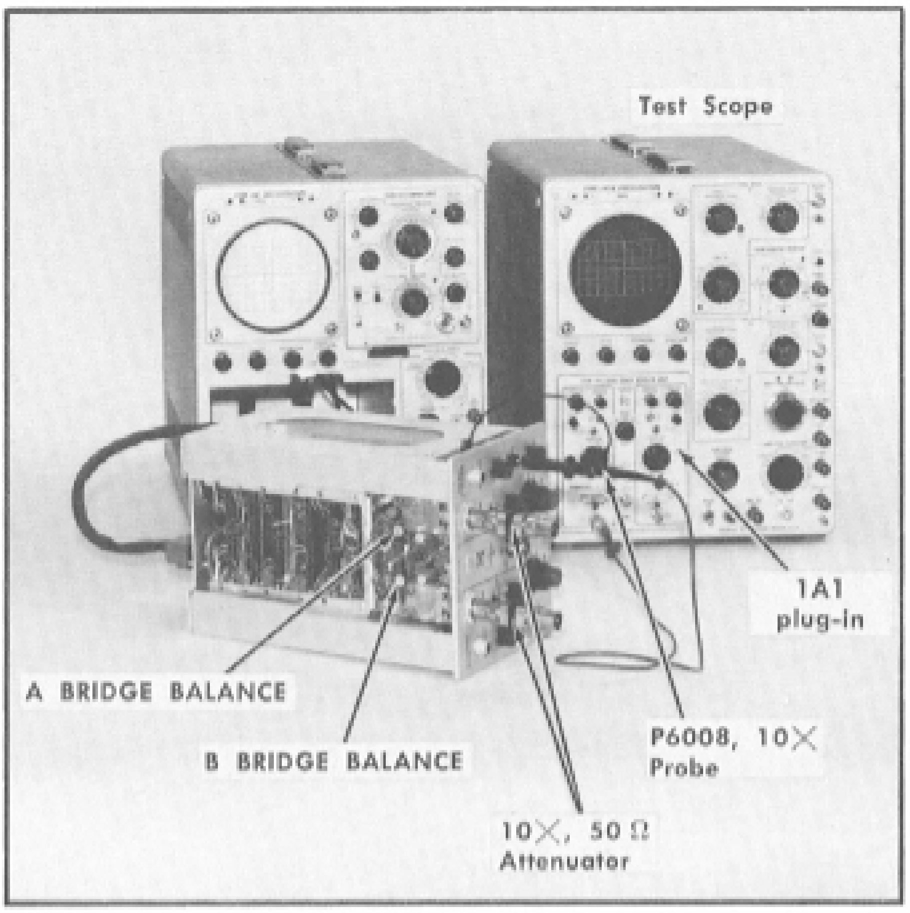


Fig. 6-24. Test equipment setup for steps 10, 11 and 12.

Control Settings:

Type 4S2A

mV/CM	200
VARIABLE	CALIBRATED
POSITION	Midrange
DC OFFSET	Midrange
SMOOTHING	NORMAL
MODE	A ONLY
DISPLAY	NORMAL

Type 5T3

Samples/cm	100
Equiv Time/cm	**1 μsec**
Variable	Calibrated
Trig Source	Free Run
Ext Trig Mode	DC, 50 Ω
Trig Level	Midrange
Stability	Midrange
Trig Slope	+
Time Position	Midrange

Type 661

Horiz Display	×1
Horiz Position	Midrange
Vernier	Midrange

Type 1A1 Plug-In

Input Selector	A, GND
Volts/cm	.005
Variable	Calibrated
Mode	Ch 1
Position	Midrange

Test Oscilloscope

Time/cm	.1 msec
Variable	Calibrated
Horiz Display	A
Trig Mode	AC
Trig Slope	+ Int
Stability	Clockwise

10. Adjust A and B Bridge Balance ⓘ

a. Test equipment setup is shown in Fig. 6-24.

b. Connect a 10×, 50 Ω Attenuator to each Type 4S2A INPUT connector.

c. Connect a P6008 10× Probe to the Type 1A1 Plug-In, Input Channel 1.

d. Set the Test Oscilloscope trace to the vertical center with the Type 1A1 Channel 1 Position control.

e. Switch the Type 1A1 Input Selector to DC.

f. Connect the 10× Probe tip to OFFSET MONITOR A jack on the Type 4S2A.

g. Adjust the Type 4S2A A DC OFFSET control to zero volts (centered trace) on the Test Oscilloscope. A lower sensitivity may have to be used on the first measurement. Start with .5 Volts/cm to locate the trace and increase the sensitivity as the voltage at the OFFSET MONITOR is reduced to zero.

h. Adjust the trace on the Type 661 to vertical center, using the Type 4S2A VERTICAL POSITION control.

i. Switch the Type 4S2A mV/cm to 2.

j. Adjust A BRIDGE BALANCE, Fig. 6-24, to set the trace on the Type 661 CRT to vertical center.

k. Readjust A BRIDGE BALANCE so that there is no trace shift on the Type 661 CRT while rotating the Type 4S2A mV/cm control throughout its range.

l. Switch the Type 4S2A MODE switch to B ONLY.

m. Adjust B BRIDGE BALANCE using steps b through k.

11. Adjust Inverter Zero ⓘ

a. Test equipment setup is given in step 10.

b. Connect the 10× Probe tip to pin X on the A Memory connector, as shown in Fig. 6-25.

c. Center the trace vertically on the Test Oscilloscope with the Type 1A1 Position control.

d. Switch the Type 1A1 Input Selector to DC.

e. Set the Type 4S2A A DC OFFSET control for zero volts as indicated on the Test Oscilloscope. (Vertically centered trace.)

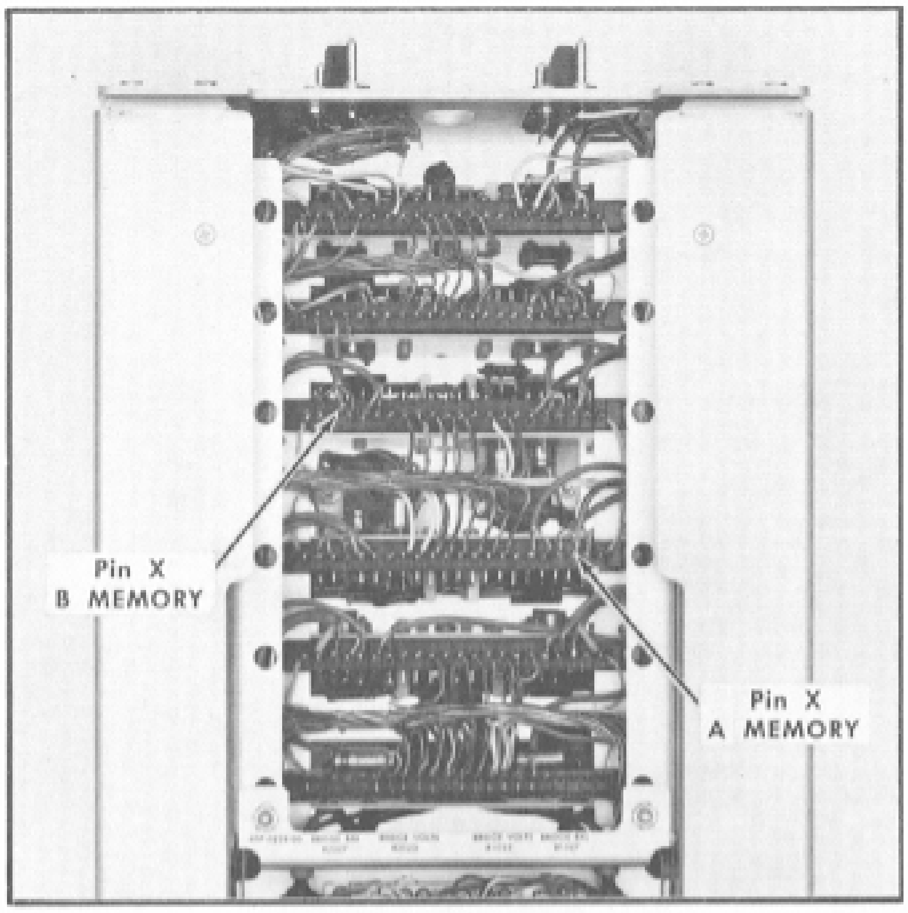


Fig. 6-25. Location of Pin X and A and B Memory connectors.

f. Center the display on the Type 661 with the Type 4S2A POSITION control.

g. Adjust the Type 4S2A INVERTER ZERO on the Inverter Board, Fig. 2-26, for no trace shift of the Type 661 display while switching the Type 4S2A DISPLAY switch between NORMAL and INVERTED.

h. Switch the Type 4S2A MODE switch to B ONLY.

i. Adjust the B INVERTER ZERO control using steps e through g.

j. Recheck the adjustments of A and B SMOOTHING BALANCE. Refer to step 4.

k. Leave DISPLAY switches in NORMAL, turn off the Type 661 and install the AC AMP Board without the extender. Turn on the Type 661 and allow to warm up for 5 minutes.

l. Recheck each channel for a loop gain of 1.1. Refer to step 17g. Reset BRIDGE VOLTS if necessary.

12. Check Dual Trace Operation

a. Test equipment setup is given in step 11.

b. Center the trace vertically on the Test Oscilloscope CRT with the Type 1A1 Position control.

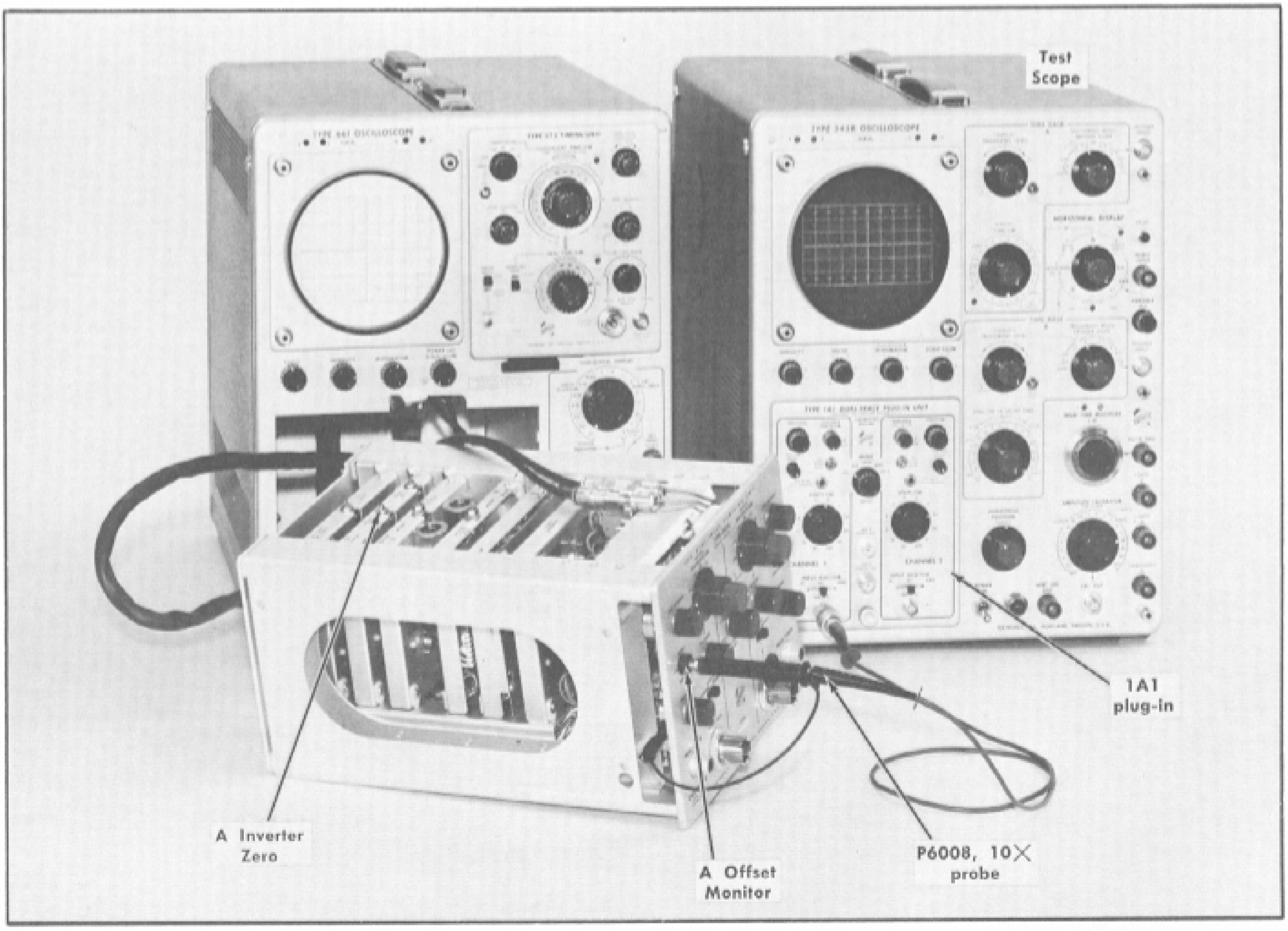


Fig. 6-26. Location of A and B Inverter Zero controls.

c. Connect the 10× Probe tip to the SIGNAL OUTPUT VERTICAL A Binding Post on the Type 661 front panel.

d. Switch the Type 1A1 Input Selector to DC.

e. Adjust the Type 4S2A A DC OFFSET control for zero volts (centered trace) on the Test Oscilloscope CRT.

f. Connect the 10× Probe tip to the center arm of the Type 4S2A A POSITION control. Adjust the Type 4S2A POSITION control for zero volts (centered trace) on the Test Oscilloscope. (In steps e and f initial measurement may have to be made on a less sensitive Type 1A1 Volts/cm range. Start with 1 volt/cm and increase the sensitivity while adjusting the voltage toward zero.)

g. Connect the 10× Probe tip to the SIGNAL OUTPUT VERTICAL B Binding Post on the Type 661 front panel.

h. Adjust the Type 4S2A B DC OFFSET control for zero volts, centered trace, on the Test Oscilloscope CRT.

i. Connect the 10× Probe tip to the center arm of the Type 4S2A B POSITION control. Adjust the Type 4S2A B POSITION control for zero volts (centered trace) on the Test Oscilloscope.

j. Two traces should be seen on the Type 661 CRT and should be not more than 1 cm apart. Both traces should be within 2 cm of the graticule center.

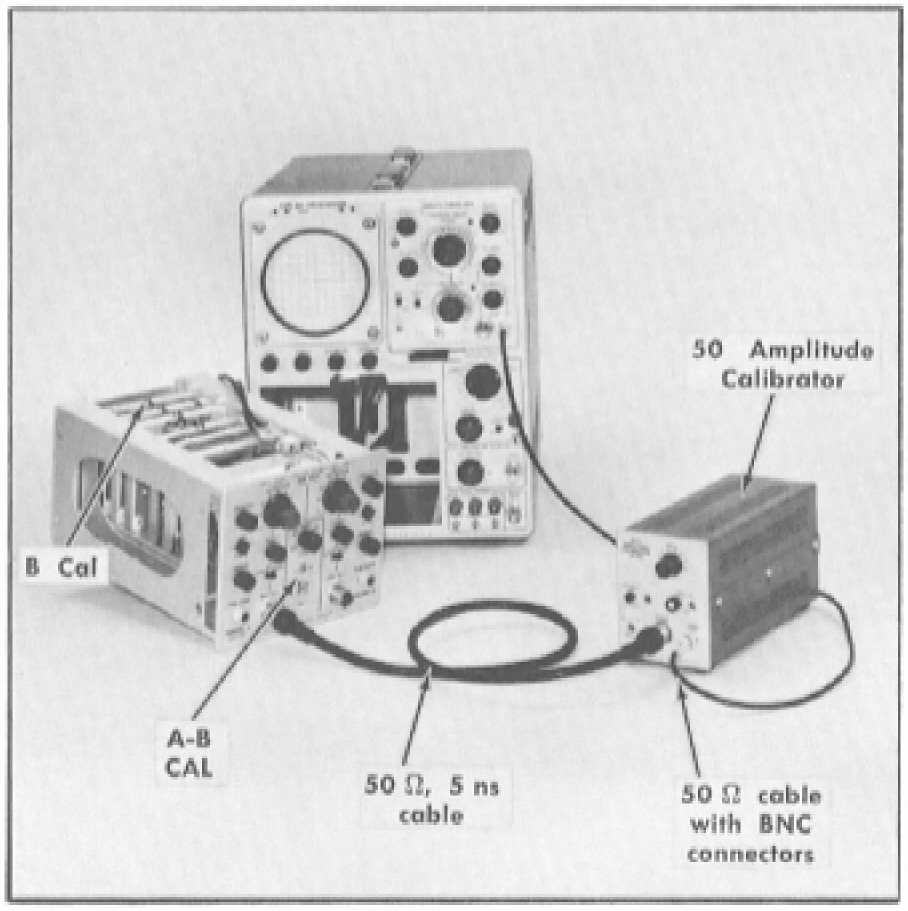


Fig. 6-27. Initial test equipment setup for steps 13 through 18.

Control Settings:

Type 4S2A

mV/cm	200
VARIABLE	CALIBRATED
POSITION	Midrange
DC OFFSET	Midrange
SMOOTHING	NORMAL
MODE	A ONLY
DISPLAY	NORMAL

Type 5T3

Samples/cm	100
Equiv Time/cm	**20 μsec**
Variable	Calibrated
Trig Source	Ext
Ext Trig Mode	**1 MΩ, AC**
Trig Level	**Stable Display**
Stability	**Stable Display**
Trig Slope	+
Time Position	Midrange

Type 661

Horiz Display	×1
Horiz Position	Midrange
Vernier	Midrange

50 Ω Amplitude Calibrator

Volts	1.2
Test Operate	Operate

13. Adjust A-B Gain Control

a. Initial test equipment setup is shown in Fig. 6-27.

b. Connect a 50 Ω cable with General Radio Type 874 connectors from the 50 Ω Amplitude Calibrator Output to the Type 4S2A A INPUT.

c. Adjust the Type 5T3 Trigger Level and Stability controls for a stable trace on the Type 661 CRT. (Display 2 cycles of the waveform.)

d. Check the range of the A-B CAL control. Should have a range of 6 cm of display, ±10%.

e. Adjust the A-B CAL control for exactly 6 cm of display.

14. Check A mV/CM Switch Positions

a. Test equipment setup is given in step 13.

b. Check the A mV/CM switch positions, using the settings shown in Table 6-2.

TABLE 6-2

50 Ω Amplitude Calib	mV/CM	Vertical Deflection	Tolerance
1.2 V	200	6 cm	0%
.6 V	100	6 cm	±1%
.3 V	50	6 cm	±1%
.12 V	20	6 cm	±1%
.06 V	10	6 cm	±1%
.03 V	5	6 cm	±3%
.012 V	2	6 cm	±3%

15. Adjust B CAL Gain Control

a. Test equipment setup is given in step 14.

b. Move the signal cable from A INPUT to B INPUT.

c. Switch the Type 4S2A MODE switch to B ONLY.

d. Set the Amplitude Calibrator volts to 1.2.

e. Set the Type 4S2A mV/CM switch at 200.

f. Check the range of the B CAL gain control for 6 cm of display $\pm 10\%$.

g. Adjust B CAL for exactly 6 cm of display.

16. Check B mV/CM Switch Positions

a. Test equipment setup is given in step 15.

b. Check the B mV/CM switch positions, using the settings shown in Table 6-2.

17. Check A and B mV/CM VARIABLE Range

a. Test equipment setup is given in step 16.

b. Set B mV/CM to 200.

c. Set Amplitude Calibrator volts to .3.

d. Observe 1.5 divisions of display on the Type 661 CRT.

e. Rotate the B mV/CM VARIABLE control counterclockwise out of the detent position just enough to cause the display to increase in amplitude. Observe at least 4.5 cm of display.

f. Move the Amplitude Calibrator signal from B INPUT to A INPUT.

g. Switch the Type 4S2A MODE switch to A ONLY.

h. Set A mV/CM to 200.

i. Check the range of A mV/CM VARIABLE control as in step e.

18. Check Added Algeb Operation

a. Test equipment setup is given in step 17.

b. Connect a 50 Ω 5 ns cable from the 50 Ω Amplitude Calibrator Output to the center of a 50 Ω General Radio T connector.

c. Connect each end of the GR 50 Ω T connector to a 50 Ω 2 ns cable.

d. Connect one of the 2 ns cables to A INPUT and the other to B INPUT.

e. Set each channel deflection, seen on the Type 661 CRT, to exactly 4 cm with the Type 4S2A mV/CM VARIABLE control.

f. Turn the MODE switch to ADDED ALGEB and observe 8 cm of display, ± 1 mm.

g. Readjust the A and B OFFSET MONITOR voltages to zero with the Test Oscilloscope as in step 3, b through f.

h. Readjust the A and B POSITION controls to zero volts with the Test Oscilloscope as in step 12f.

i. Readjust the A and B SMOOTHING BALANCE controls following the procedure in step 4.

j. Readjust the A and B BRIDGE BALANCE controls following the procedure in step 10.

k. Readjust the A and B INVERTER ZERO controls following the procedure in Step 11.

NOTES

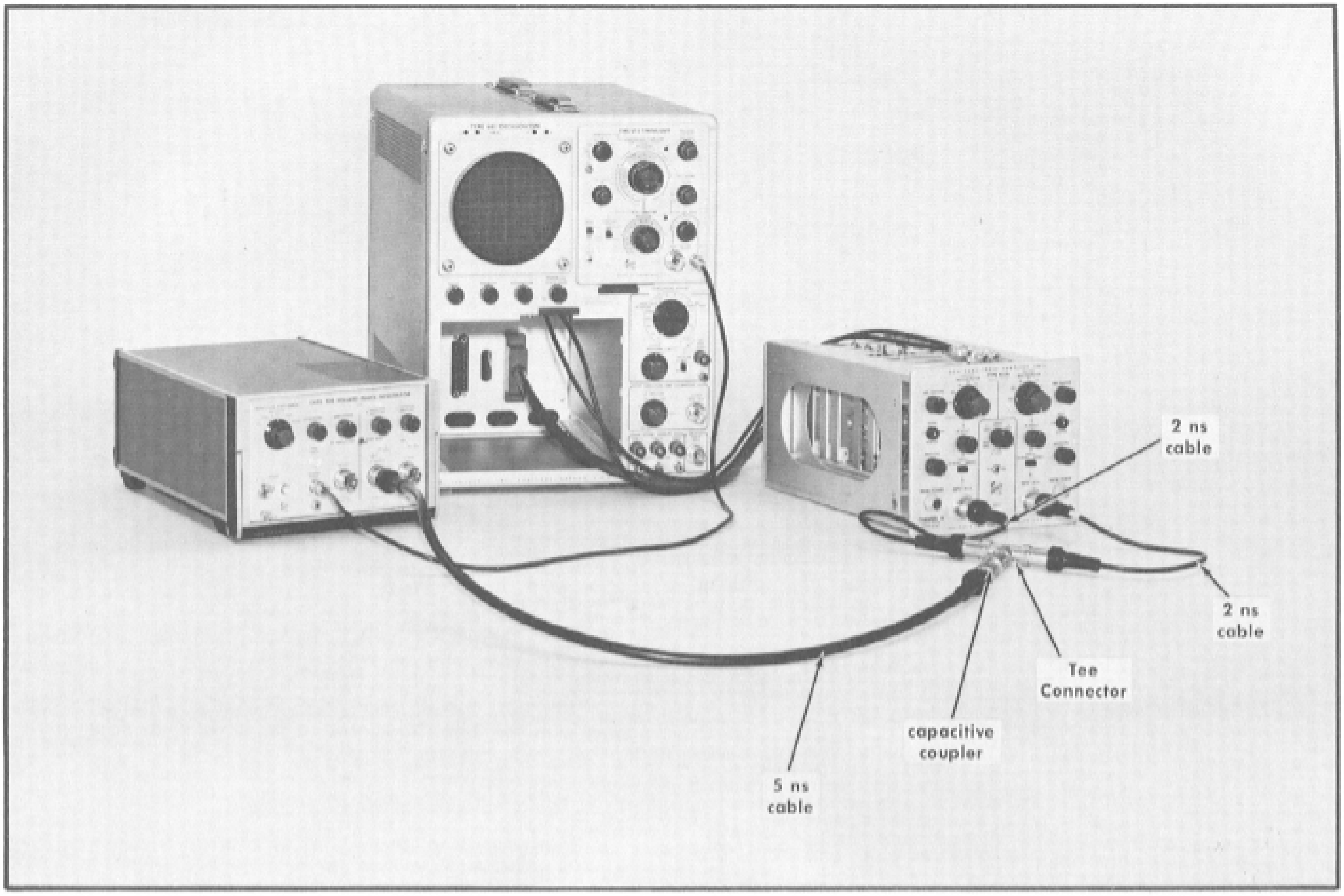


Fig. 6-28. Test equipment setup for step 19.

Control Settings:

Type 4S2A

mV/CM	200
VARIABLE	CALIBRATED
POSITION	Midrange
DC OFFSET	Midrange
SMOOTHING	NORMAL
MODE	A ONLY
DISPLAY	NORMAL

Type 5T3

Samples/cm	100
Equiv Time/cm	**1 μsec/cm**
Variable	Calibrated
Trig Source	Ext
Ext Trig Mode	1 MΩ, AC
Trig Level	Stable Display
Stability	Stable Display
Trig Slope	+
Time Position	Midrange

Type 661

Horiz Display	×1
Horiz Position	Midrange
Vernier	Midrange

Square Wave Generator

Repetition Rate	100 kHz
Multiplier	10
Symmetry	Midrange
+ Transition Amplitude	500 mV, clockwise
Hi Ampl/Fast Rise	Fast Rise

19. Check Common Mode Rejection Ratio

a. Test equipment setup is shown in Fig. 6-28.

b. Connect a 50 Ω 2 ns cable to each of the Type 4S2A INPUT connectors.

c. Connect these two cables to the ends of the General Radio Type 874-T T connector.

d. Connect a General Radio Type 874-K Coupling Capacitor to the center of the T connector.

e. Connect the GR Coupling Capacitor to the + Fast Rise Output of the Type 106 Square-Wave Generator.

f. Connect a 50 Ω cable with BNC connectors from the Type 106 Square-Wave Generator to the Type 5T3 Ext Trig Input, 1 MΩ.

g. Adjust the Type 106 Square-Wave Generator + Transition Amplitude for 2.5 cm of display on the Type 661 CRT.

h. Position the display on the Type 661 CRT to the center of the Graticule area with the Type 4S2A A POSITION and A DC OFFSET controls.

i. Switch the Type 4S2A MODE switch to B ONLY.

j. Position the display on the Type 661 CRT to the center of the Graticule area with the Type 4S2A B POSITION and B DC OFFSET controls.

k. Switch the Type 4S2A MODE to ADDED ALGEB.

l. Switch the Type 4S2A A DISPLAY to INVERTED, but be especially careful that the POSITION and DC OFFSET controls are not moved.

m. Observe a waveform on the Type 661 CRT as shown in Fig. 6-29(A).

n. Switch both Type 4S2A mV/CM switches to 50.

o. Maximum displacement shown on the Type 661 display should be 0.5 cm, as shown in Fig. 6-29(B).

p. Switch the Type 4S2A A and B DISPLAY switches simultaneously to the opposite positions. (A DISPLAY to NORMAL and B DISPLAY to INVERTED.)

q. Maximum displacement should be 0.5 cm.

r. Return both Type 4S2A mV/CM switches to 200.

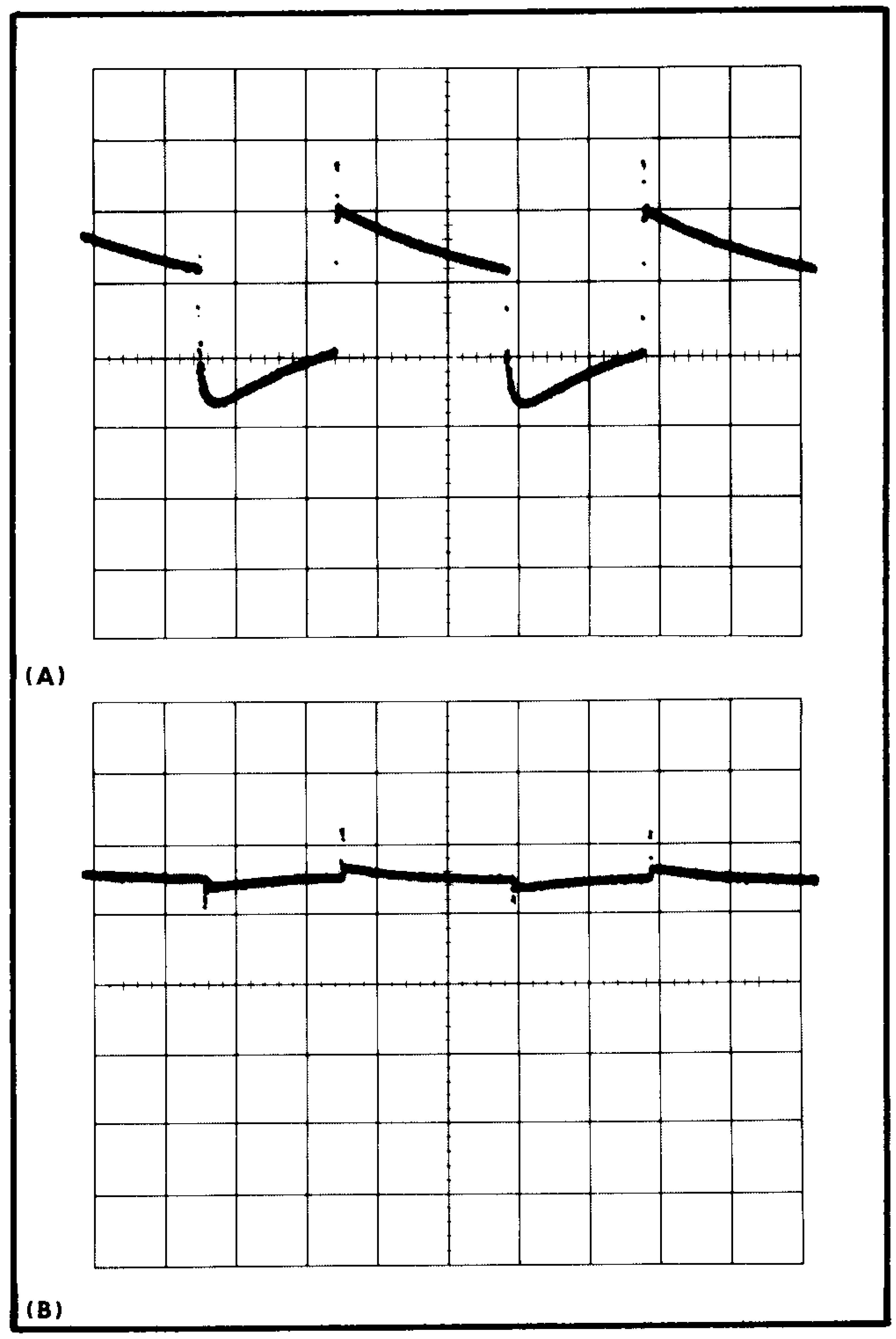


Fig. 6-29. Typical CRT display showing (A) AC coupled signal from Type 106, (B) typical displacement, Vertical Sensitivity 50 mV/CM.

NOTES

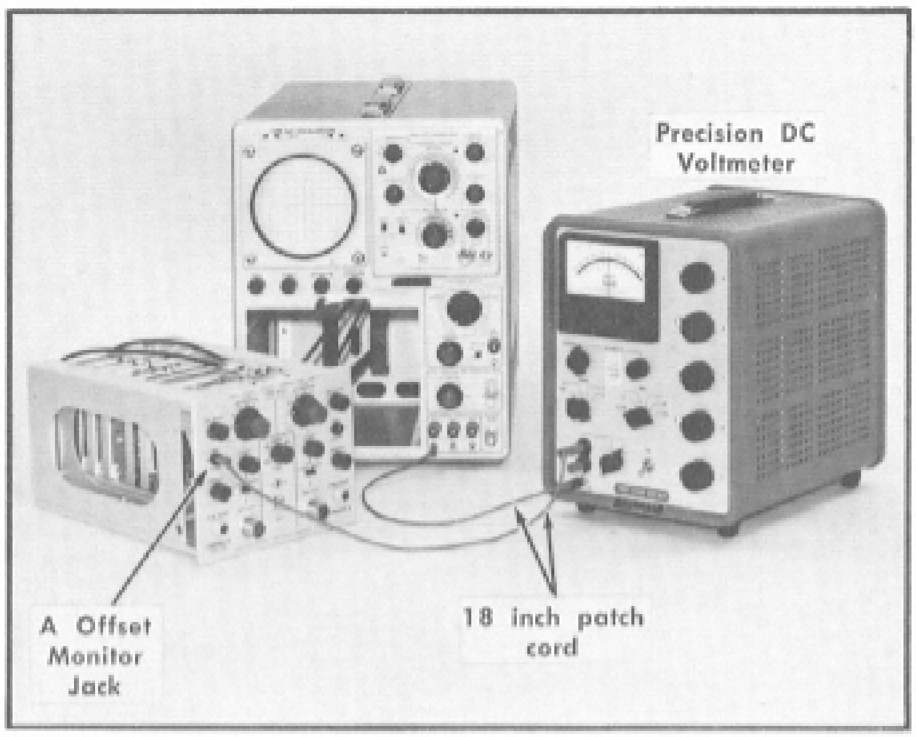


Fig. 6-30. Test equipment setup for step 20.

Control Settings:

Type 4S2A

mV/CM	200
VARIABLE	CALIBRATED
POSITION	Midrange
DC OFFSET	Midrange
SMOOTHING	NORMAL
MODE	A ONLY
DISPLAY	NORMAL

Type 5T3

Samples/cm	100
Equiv Time/cm	**10 μsec**
Variable	Calibrated
Trig Source	Ext
Ext Trig Mode	**1 MΩ, DC**
Trig Level	Stable Display
Stability	Stable Display
Trig Slope	+
Time Position	Midrange

Type 661

Horiz Display	×1
Horiz Position	Midrange
Vernier	Midrange

50 Ω Amplitude Calibrator

Volts	1.2
Test-Operate	Operate

20. Check Vertical Signal Out, Gain and Tracking

a. Test equipment setup is shown in Fig. 6-30.

b. Connect the Differential Voltmeter leads to the Type 4S2A A OFFSET jack and ground.

c. Set A OFFSET MONITOR voltage to —100, measured with the Differential Voltmeter, with the A DC OFFSET control.

d. Move the Differential Voltmeter leads from the A OFFSET MONITOR jack and ground to the Signal Output Vert A and Ground on the Type 661.

e. The Differential Voltmeter should read +1 volt, ±2.5%.

f. Repeat the above procedure for OFFSET MONITOR voltages shown in Table 6-3.

TABLE 6-3

When OFFSET MONITOR Voltage is	Vert A Sig Out Should be
—50	+0.5, ±2.5%
0	0, ±55 mV
+50	—0.5, ±2.5%
+100	—1.0, ±2.5%

g. Switch the MODE switch to B ONLY.

h. Connect the Differential Voltmeter leads to B OFFSET MONITOR and Ground on the Type 4S2A.

i. Set B OFFSET MONITOR voltage to —100 measured with the Differential Voltmeter, with the B DC OFFSET control.

j. Move the Differential Voltmeter leads from the B OFFSET MONITOR jack and Ground to Signal Output Vert B and Ground on the Type 661.

k. The differential Voltmeter should read +1 volt, ±2.5%.

l. Repeat the procedure for the OFFSET MONITOR voltages shown in Table 6-3.

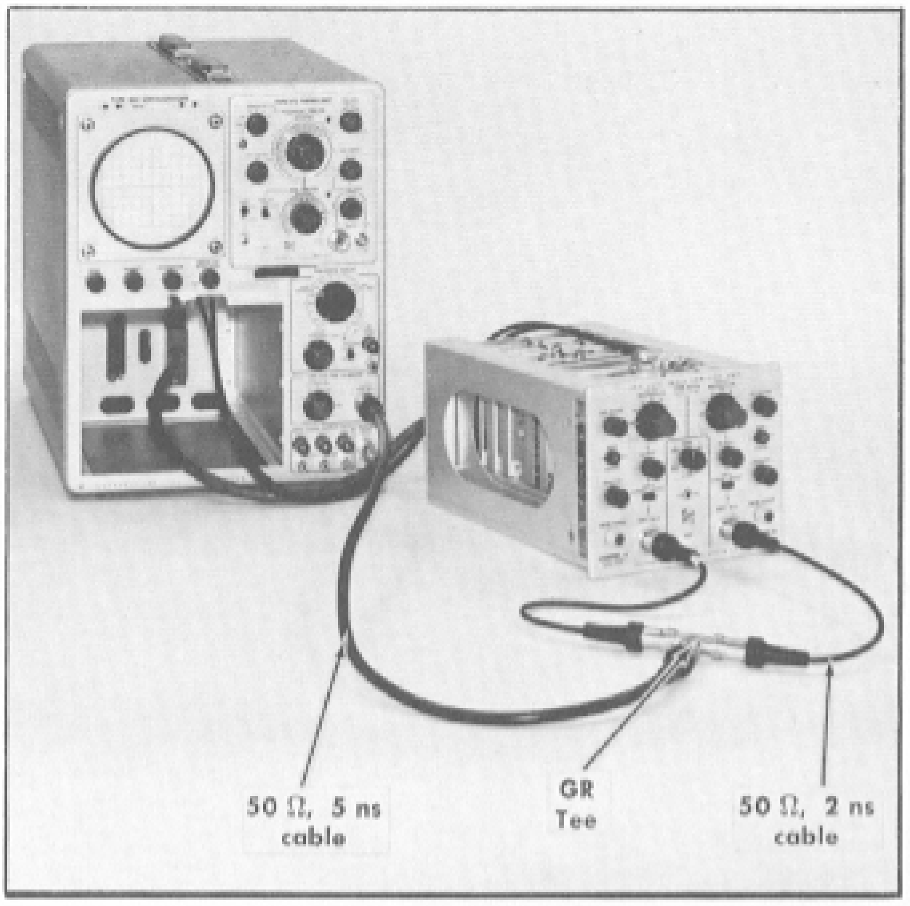


Fig. 6-31. Test equipment setup for step 21.

Control Settings:

Type 4S2A

mV/CM	200
VARIABLE	CALIBRATED
POSITION	Midrange
DC OFFSET	**Display Centered**
SMOOTHING	NORMAL
MODE	**DUAL TRACE**
DISPLAY	NORMAL

Type 5T3

Samples/cm	100
Equiv Time/cm	**50 ns**
Variable	Calibrated
Trig Source	**Cal**
Ext Trig Mode	1 MΩ, DC
Trig Level	**Midrange**
Stability	**Midrange**
Trig Slope	+
Time Position	Midrange

Type 661

Horiz Display	×1
Horiz Position	Midrange
Vernier	Midrange
Amplitude/Time Calibrator	
mV/Ampl	1000
μsec/cycle	.1

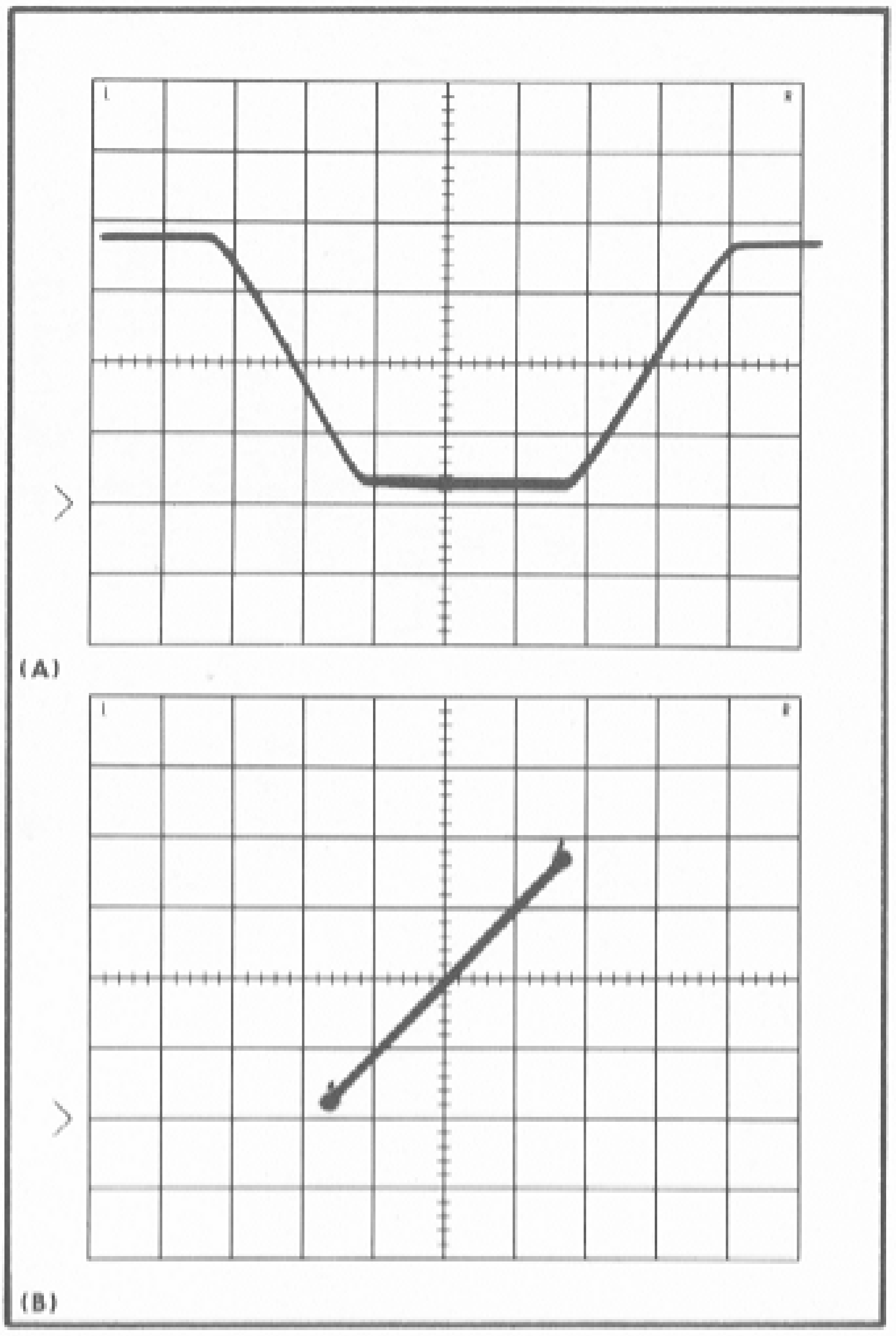


Fig. 6-32. Typical CRT display showing (A) traces coincident in Dual Trace Mode, (B) Trace in A Vert-B Horiz Mode.

21. Check A Vert—B Horiz

a. Test equipment setup is shown in Fig. 6-31.

b. Connect a 50 Ω 5 ns cable to the Type 661 Amplitude/Time Calibrator.

c. Connect the center of a General Radio Type 874-T T connector to the 5 ns cable.

d. Connect a 50 Ω 2 ns cable to each end of the GR T connector.

e. Connect the 50 Ω 2 ns cables to the Type 4S2A INPUTS, A and B.

f. Center the waveforms vertically on the Type 661 CRT, using the A and B DC OFFSET controls. Make a note of the amplitude of the display. See Fig. 6-32(A).

g. Switch the Type 4S2A MODE switch to A VERT-B HORIZ. The display should be a diagonal line of equal vertical and horizontal amplitude and equal to the vertical deflection noted in step f. See Fig. 6-32(B).

h. The display should fall horizontally within the center 8 cm of graticule.

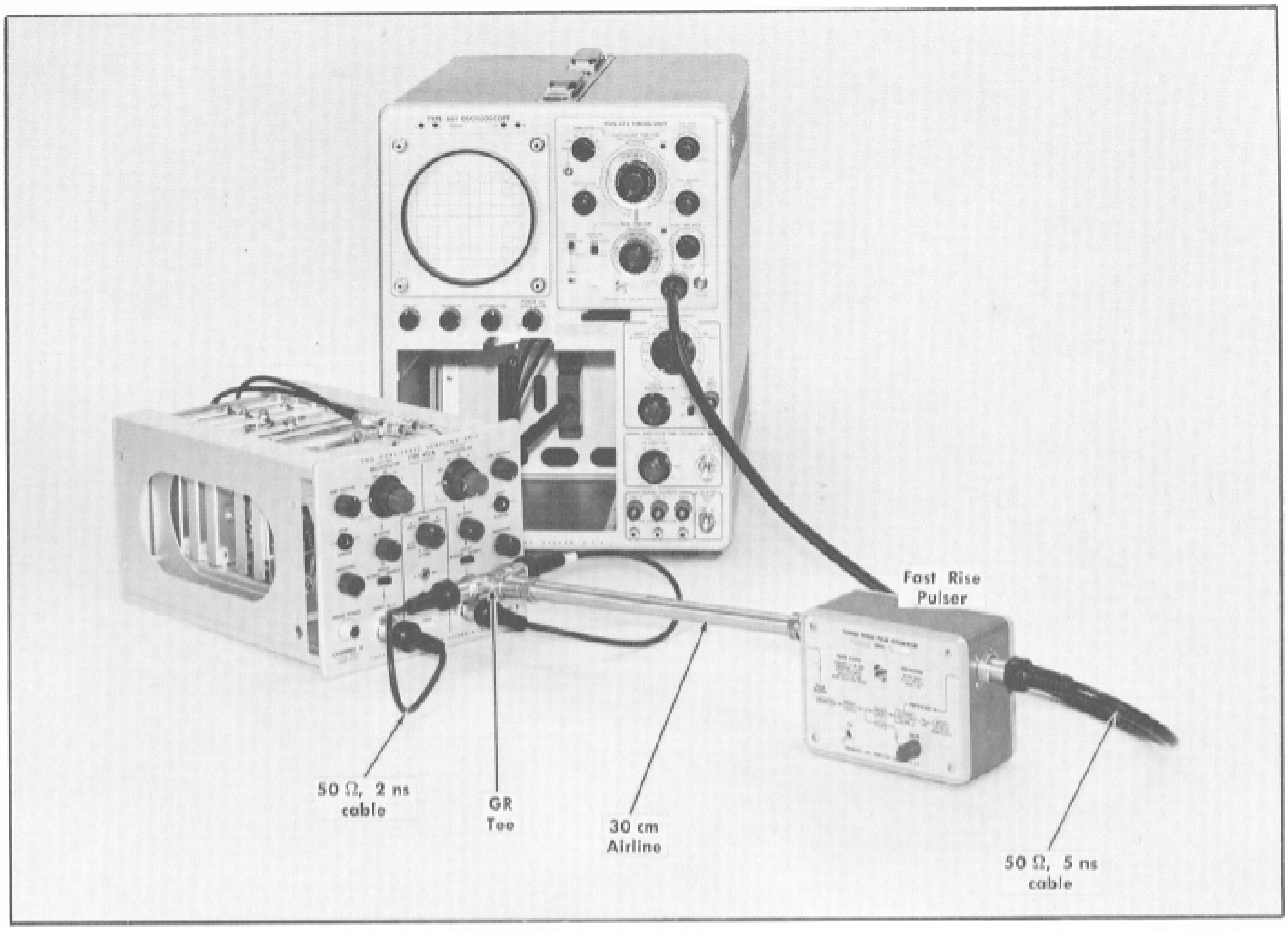


Fig. 6-33. Test equipment setup for step 22.

Control Settings:

Type 4S2A

mV/CM	**20**
VARIABLE	**Midrange**
POSITION	Midrange
DC OFFSET	**Midrange**
SMOOTHING	**Counterclockwise**
MODE	DUAL TRACE
DISPLAY	NORMAL

Type 5T3

Samples/cm	100
Equiv Time/cm	**1 ns**
Variable	Calibrated
Trig Source	**Ext**
Ext Trig Mode	**50 Ω, DC**
Trig Level	**Stable Display**
Stability	**Stable Display**
Trig Slope	+
Time Position	Midrange

Type 661

Horiz Display	**×10**
Horiz Position	Midrange
Vernier	Midrange

Fast Rise Pulse Generator

Pwr	On
Drive	Midrange

22. Check Channel Time Coincidence

a. Test equipment setup is shown in Fig. 6-33.

b. Connect the 30 cm Air Line to the Pulse Output of the Fast Rise Pulser.

c. Connect the center of a General Radio Type 874 T connector to the 30 cm Air Line.

d. Connect a 50 Ω 5 ns cable to each end of the GR T connector.

e. Connect the other ends of the 50 Ω 5 ns cables to the Type 4S2A INPUTS, A and B.

f. Connect a 50 Ω cable with General Radio Type 874 connectors to the Pretrigger Out connector on the Fast Rise Pulser.

g. Connect the other end of the 50 Ω cable to the Ext Trig Input 50 Ω on the Type 5T3.

h. Display 8 cm vertically, each channel, of the fast rise negative going portion of the Pulser signal. (Adjust to 8 cm with the Type 4S2A mV/CM and/or VARIABLE controls.)

i. Position both baselines to coincide at the top of the pulse, using the Type 4S2A POSITION controls.

j. Adjust for zero time difference between the two displays by sliding one of the 5 ns cables out of the T connector just far enough to give time coincidence of the displays.

k. Reverse the 5 ns cables at the Type 4S2A INPUTS. Reposition one trace with one Type 4S2A POSITION control so that the tops of both signals again coincide. Note the time difference.

l. Recheck steps i through k, and again note the time difference. For actual time coincidence error, divide the indicated time difference by two. The actual time difference should be not more than 20 ps.

m. Disconnect the Fast Rise Pulser. Turn off the Type 661 power. Remove the interconnecting cables and install the Type 4S2A in the Type 661.

NOTES

NOTES

ABBREVIATIONS AND SYMBOLS

A or amp	amperes
AC or ac	alternating current
AF	audio frequency
α	alpha—common-base current amplification factor
AM	amplitude modulation
$\approx$	approximately equal to
β	beta—common-emitter current amplification factor
BHB	binding head brass
BHS	binding head steel
BNC	baby series "N" connector
$\times$	by or times
C	carbon
C	capacitance
cap.	capacitor
cer	ceramic
cm	centimeter
comp	composition
conn	connector
$\sim$	cycle
c/s or cps	cycles per second
CRT	cathode-ray tube
csk	countersunk
dB	decibel
dBm	decibel referred to one milliwatt
DC or dc	direct current
DE	double end
°	degrees
°C	degrees Celsius (degrees centigrade)
°F	degrees Fahrenheit
°K	degrees Kelvin
dia	diameter
$\div$	divide by
div	division
EHF	extremely high frequency
EMC	electrolytic, metal cased
EMT	electrolytic, metal tubular
ε	epsilon—2.71828 or % of error
$\geq$	equal to or greater than
$\leq$	equal to or less than
ext	external
F or f	farad
F & I	focus and intensity
FHB	flat head brass
FHS	flat head steel
Fil HB	fillister head brass
Fil HS	fillister head steel
FM	frequency modulation
ft	feet or foot
G	giga or 10^9
g	acceleration due to gravity
Ge	germanium
GMV	guaranteed minimum value
GR	General Radio
$>$	greater than
H or h	henry
h	height or high
hex.	hexagonal
HF	high frequency
HHB	hex head brass
HHS	hex head steel
HSB	hex socket brass
HSS	hex socket steel
HV	high voltage
Hz	hertz (cycles per second)
ID	inside diameter
IF	intermediate frequency
in.	inch or inches
incd	incandescent
∞	infinity
int	internal
$\int$	integral
k	kilohms or kilo (10^3)
k Ω	kilohm
kc	kilocycle
λ	lambda—wavelength
$<$	less than
LF	low frequency
lg	length or long
LV	low voltage
M	mega or 10^6
m	milli or 10^{-3}
MΩ or meg	megohm
μ	micro or 10^{-6}
mc	megacycle
met.	metal
mm	millimeter
ms	millisecond
—	minus
mtg hdw	mounting hardware
n	nano or 10^{-9}
no. or #	number
ns	nanosecond
OD	outside diameter
OHB	oval head brass
OHS	oval head steel
Ω	omega—ohms
ω	omega—angular frequency
p	pico or 10^{-12}
/	per
%	percent
PHB	pan head brass
ϕ	phi—phase angle
π	pi—3.1416
PHS	pan head steel
+	plus
$\pm$	plus or minus
PIV	peak inverse voltage
plstc	plastic
PMC	paper, metal cased
poly	polystyrene
prec	precision
PT	paper, tubular
PTM	paper or plastic, tubular, molded
pwr	power
RC	resistance capacitance
RF	radio frequency
RFI	radio frequency interference
RHB	round head brass
ρ	rho—resistivity
RHS	round head steel
r/min or rpm	revolutions per minute
RMS	root mean square
s or sec.	second
SE	single end
Si	silicon
SN or S/N	serial number
T	tera or 10^{12}
TC	temperature compensated
TD	tunnel diode
THB	truss head brass
θ	theta—angular phase displacement
thk	thick
THS	truss head steel
tub.	tubular
UHF	ultra high frequency
V	volt
VAC	volts, alternating current
var	variable
VDC	volts, direct current
VHF	very high frequency
VSWR	voltage standing wave ratio
W	watt
w	wide or width
w/	with
w/o	without
WW	wire-wound
xmfr	transformer

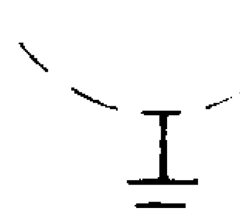
PARTS ORDERING INFORMATION

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

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

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

SPECIAL NOTES AND SYMBOLS

×000	Part first added at this serial number
00×	Part removed after this serial number
*000-0000-00	Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, Inc., or reworked or checked components.
Use 000-0000-00	Part number indicated is direct replacement.
	Screwdriver adjustment.
	Control, adjustment or connector.
	Heat sink.

SECTION 7

ELECTRICAL PARTS LIST

Values are fixed unless marked Variable.

Ckt. No.	Tektronix Part No.	Description					S/N Range

Capacitors

Tolerance ±20% unless otherwise indicated.

C1004	283-0092-00	0.03 μF	Cer		200 V	+80%—20%
C1005	283-0023-00	0.1 μF	Cer		10 V	
C1007	290-0135-00	15 μF	EMT		20 V	
C1008	283-0002-00	0.01 μF	Cer		500 V	
C1010	281-0091-00	2-8 pF	Cer	Var		
C1011	283-0133-00	5 pF	Cer		50 V	5%
C1012	283-0133-00	5 pF	Cer		50 V	5%
C1014	281-0504-00	10 pF	Cer		500 V	10%
C1015	283-0092-00	0.03 μF	Cer		200 V	+80%—20%
C1016	283-0059-00	1 μF	Cer		25 V	+80%—20%
C1017	283-0132-00	10 pF	Cer		50 V	5%
C1018	283-0132-00	10 pF	Cer		50 V	5%
C1019	283-0121-00	0.001 μF	Cer		200 V	
C1020	283-0000-00	0.001 μF	Cer		500 V	
C1023	281-0504-00	10 pF	Cer		500 V	10%
C1024	281-0504-00	10 pF	Cer		500 V	10%
C1033	283-0002-00	0.01 μF	Cer		500 V	
C1042	285-0719-00	0.015 μF	PTM		100 V	
C1044	281-0543-00	270 pF	Cer		500 V	10%
C1045	290-0200-00	12 μF	EMT		150 V	
C1046	290-0200-00	12 μF	EMT		150 V	
C1048	290-0107-00	25 μF	EMT		25 V	
C1049	290-0107-00	25 μF	EMT		25 V	
C1176	283-0003-00	0.01 μF	Cer		150 V	
C2005	283-0023-00	0.1 μF	Cer		10 V	
C2007	290-0135-00	15 μF	EMT		20 V	
C2008	283-0002-00	0.01 μF	Cer		500 V	
C2010	281-0091-00	2-8 pF	Cer	Var		
C2011	283-0133-00	5 pF	Cer		50 V	5%
C2012	283-0133-00	5 pF	Cer		50 V	5%
C2017	283-0132-00	10 pF	Cer		50 V	5%
C2018	283-0132-00	10 pF	Cer		50 V	5%
C2019	283-0121-00	0.001 μF	Cer		200 V	
C2020	283-0000-00	0.001 μF	Cer		500 V	
C2023	281-0504-00	10 pF	Cer		500 V	10%

Capacitors *(Cont)*

Ckt. No.	Tektronix Part No.	Description				S/N Range
C2024	281-0504-00	10 pF	Cer	500 V	10%	
C2033	283-0002-00	0.01 μF	Cer	500 V		
C2042	285-0719-00	0.015 μF	PTM	100 V		
C2044	281-0543-00	270 pF	Cer	500 V	10%	

Diodes

Ckt. No.	Tektronix Part No.	Description		S/N Range
D1005	152-0166-00	Zener 1N753A	0.4 W, 6.2 V, 5%	
D1011, D1012 [1]	*152-0259-00	GaAs, Tek Made (1 pair)		
D2005	152-0166-00	Zener 1N753A	0.4 W, 6.2 V, 5%	
D2011, D2012 [1]	*152-0259-00	GaAs, Tek Made (1 pair)		

Connectors

Ckt. No.	Tektronix Part No.	Description	S/N Range
P1	131-0149-00	Chassis mtd., 24 contact, male	
P2	131-0149-00	Chassis mtd., 24 contact, male	
J6	131-0221-00	Push on Bulkhead Jack w/captive contact	
J7	131-0221-00	Push on Bulkhead Jack w/captive contact	
J11	136-0156-00	Socket, 44 pin	
J12	131-0220-00	22 contact, female	
J13	131-0220-00	22 contact, female	
J14	131-0220-00	22 contact, female	
J15	131-0220-00	22 contact, female	
J16	131-0220-00	22 contact, female	
J1001[2]			
J1009	131-0265-00	Coax, right angle	
J1019	131-0265-00	Coax, right angle	
J1020	131-0391-00	Coax, 50 Ω, male	
P1020[3]	*175-0391-00	Cable Assembly	
P1051[4]	*175-0390-00	Cable Assembly	
J2001[2]			
J2009	131-0265-00	Coax, right angle	
J2019	131-0265-00	Coax, right angle	

Inductors

Ckt. No.	Tektronix Part No.	Description	S/N Range
L1015	*108-0406-00	80 μH	
L1045	*120-0398-00	Toroid, 15 turns, single	
L1048	*120-0398-00	Toroid, 15 turns, single	
L1049	*120-0398-00	Toroid, 15 turns, single	

[1] D1011, D1012 and D2011, D2012 furnished as a unit.

[2] See Mechanical Parts List.

[3] Furnished as a unit with J6.

[4] Furnished as a unit with J7.

Transistors

Ckt. No.	Tektronix Part No.	Description		S/N Range
Q1004	*151-0138-00	Silicon	Replaceable by 2N2857	
Q1014	*151-0142-00	Silicon	Selected from 2N3546	
Q1043	*151-0103-00	Silicon	Replaceable by 2N2219	
Q1044	*151-0103-00	Silicon	Replaceable by 2N2219	
Q2004	*151-0138-00	Silicon	Replaceable by 2N2857	
Q2043	*151-0103-00	Silicon	Replaceable by 2N2219	
Q2044	*151-0103-00	Silicon	Replaceable by 2N2219	

Resistors

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

Ckt. No.	Tektronix Part No.	Value	Wattage			Tolerance	S/N Range
R1001 } [5]	*119-0102-00	390 Ω	1/8 W			5%	
R1002 }		56.4 Ω	1/2 W				
R1003	321-0068-00	49.9 Ω	1/8 W		Prec	1%	
R1005	308-0307-00	5 kΩ	3 W		WW	1%	
R1007	315-0470-00	47 Ω	1/4 W			5%	
R1008	301-0202-00	2 kΩ	1/2 W			5%	
R1011	317-0151-00	150 Ω	1/8 W			5%	
R1012	317-0151-00	150 Ω	1/8 W			5%	
R1014	315-0330-00	33 Ω	1/4 W			5%	
R1015	315-0510-00	51 Ω	1/4 W			5%	
R1016	315-0102-00	1 kΩ	1/4 W			5%	
R1017	315-0101-00	100 Ω	1/4 W			5%	
R1018	316-0102-00	1 kΩ	1/4 W				
R1019	316-0102-00	1 kΩ	1/4 W				
R1020	315-0203-00	20 kΩ	1/4 W			5%	
R1021	315-0203-00	20 kΩ	1/4 W			5%	
R1023	311-0465-00	100 kΩ		Var			
R1025	322-0609-00	333 kΩ	1/4 W		Prec	1%	
R1026	321-0672-00	11.4 kΩ	1/8 W		Prec	1/2%	
R1027	311-0601-00	5 kΩ		Var			
R1028	321-0672-00	11.4 kΩ	1/8 W		Prec	1/2%	
R1029	322-0609-00	333 kΩ	1/4 W		Prec	1%	
R1031	316-0101-00	100 Ω	1/4 W				
R1033	308-0054-00	10 kΩ	5 W		WW	5%	
R1035	323-0205-00	1.33 kΩ	1/2 W		Prec	1%	
R1041	322-0251-00	4.02 kΩ	1/4 W		Prec	1%	
R1043	322-0251-00	4.02 kΩ	1/4 W		Prec	1%	
R1044	315-0102-00	1 kΩ	1/4 W			5%	
R1045	308-0192-00	5 kΩ	20 W		WW	5%	
R1046	315-0102-00	1 kΩ	1/4 W			5%	

[5] Furnished as an Assembly with ground clip (*214-0699-00).

Resistors *(Cont)*

Ckt. No.	Tektronix Part No.	Description					S/N Range
R1080B	318-0037-00	500 Ω	⅛ W		Prec	1%	
R1080C	318-0064-00	250 Ω	⅛ W		Prec	1%	
R1080D	318-0050-00	150 Ω	⅛ W		Prec	1%	
R1080E	318-0066-00	50 Ω	⅛ W		Prec	1%	
R1080F	318-0038-00	24.9 Ω	⅛ W		Prec	1%	
R1080G	318-0038-00	24.9 Ω	⅛ W		Prec	1%	
R1081	311-0220-00	1 kΩ		Var			
R1090	304-0331-00	330 Ω	1 W				
R1147A	318-0089-00	583 kΩ	⅛ W		Prec	1%	
R1147B	318-0088-00	229.7 kΩ	⅛ W		Prec	1%	
R1147C	318-0087-00	112 kΩ	⅛ W		Prec	1%	
R1147D	318-0086-00	53 kΩ	⅛ W		Prec	1%	
R1147E	318-0085-00	17.67 kΩ	⅛ W		Prec	1%	
R1147F	318-0073-00	5.88 kΩ	⅛ W		Prec	1%	
R1149	321-0601-00	2.141 kΩ	⅛ W		Prec	¼%	
R1159	311-0271-00	200 kΩ		Var			
R1160	321-0606-00	203 kΩ	⅛ W		Prec	¼%	
R1161	301-0104-00	100 kΩ	½ W			5%	
R1170	321-0603-00	15 kΩ	⅛ W		Prec	¼%	
R1171	321-0604-00	30 kΩ	⅛ W		Prec	¼%	
R1172	311-0443-00	2.5 kΩ		Var			
R1173[6]	*311-0296-00	7 kΩ		Var			
R1176	301-0101-00	100 Ω	½ W			5%	
R1179	315-0912-00	9.1 kΩ	½ W			5%	
R1180	311-0016-00	10 kΩ		Var			
R2001 }[7]	*119-0102-00	390 Ω	⅛ W			5%	
R2002 }		56.4 Ω	½ W				
R2003	321-0068-00	49.9 Ω	⅛ W		Prec	1%	
R2005	308-0307-00	5 kΩ	3 W		WW	1%	
R2007	315-0510-00	51 Ω	¼ W			5%	
R2008	301-0202-00	2 kΩ	½ W			5%	
R2011	317-0151-00	150 Ω	⅛ W			5%	
R2012	317-0151-00	150 Ω	⅛ W			5%	
R2014	315-0510-00	51 Ω	¼ W			5%	
R2018	316-0102-00	1 kΩ	¼ W				
R2019	316-0102-00	1 kΩ	¼ W				
R2020	315-0203-00	20 kΩ	¼ W			5%	
R2021	315-0203-00	20 kΩ	¼ W			5%	
R2023	311-0465-00	100 kΩ		Var			
R2025	322-0609-00	333 kΩ	¼ W		Prec	1%	

[6] Furnished as a unit with SW1282.
[7] Furnished as an Assembly with ground clip (*214-0699-00).

Ⓐ

Resistors *(Cont)*

Ckt. No.	Tektronix Part No.	Description					S/N Range
R2026	321-0672-00	11.4 kΩ	1/8 W		Prec	1/2%	
R2027	311-0601-00	5 kΩ		Var			
R2028	321-0672-00	11.4 kΩ	1/8 W		Prec	1/2%	
R2029	322-0609-00	333 kΩ	1/4 W		Prec	1%	
R2031	316-0101-00	100 Ω	1/4 W				
R2033	308-0054-00	10 kΩ	5 W		WW	5%	
R2035	323-0205-00	1.33 kΩ	1/2 W		Prec	1%	
R2041	322-0251-00	4.02 kΩ	1/4 W		Prec	1%	
R2043	322-0251-00	4.02 kΩ	1/4 W		Prec	1%	
R2044	315-0102-00	1 kΩ	1/4 W			5%	
R2080B	318-0037-00	500 Ω	1/8 W		Prec	1%	
R2080C	318-0064-00	250 Ω	1/8 W		Prec	1%	
R2080D	318-0050-00	150 Ω	1/8 W		Prec	1%	
R2080E	318-0066-00	50 Ω	1/8 W		Prec	1%	
R2080F	318-0038-00	24.9 Ω	1/8 W		Prec	1%	
R2080G	318-0038-00	24.9 Ω	1/8 W		Prec	1%	
R2081	311-0220-00	1 kΩ		Var			
R2147A	318-0089-00	583 kΩ	1/8 W		Prec	1%	
R2147B	318-0088-00	229.7 kΩ	1/8 W		Prec	1%	
R2147C	318-0087-00	112 kΩ	1/8 W		Prec	1%	
R2147D	318-0086-00	53 kΩ	1/8 W		Prec	1%	
R2147E	318-0085-00	17.67 kΩ	1/8 W		Prec	1%	
R2147F	318-0073-00	5.88 kΩ	1/8 W		Prec	1%	
R2149	321-0601-00	2.141 kΩ	1/8 W		Prec	1/4%	
R2159	311-0271-00	200 kΩ		Var			
R2160	321-0606-00	203 kΩ	1/8 W		Prec	1/4%	
R2161	301-0104-00	100 kΩ	1/2 W			5%	
R2170	321-0603-00	15 kΩ	1/8 W		Prec	1/4%	
R2171	321-0604-00	30 kΩ	1/8 W		Prec	1/4%	
R2173[8]	*311-0296-00	7 kΩ		Var			
R2175	315-0753-00	75 kΩ	1/4 W			5%	
R2180	311-0016-00	10 kΩ		Var			

Switches

	Unwired	Wired		
SW1101	260-0434-00	*262-0538-00	Rotary	MV/CM A
SW1171	260-0212-00		Slide	DISPLAY A
SW1282[9]	*311-0296-00			CALIBRATED A
SW2101	260-0434-00	*262-0538-00	Rotary	MV/CM B
SW2171	260-0212-00		Slide	DISPLAY B

[8] Furnished as a unit with SW2282.

[9] Furnished as a unit with R1173.

Switches *(Cont)*

Ckt. No.	Tektronix Part No.	Description			S/N Range
SW2190	260-0514-00	*262-0550-00	Rotary	MODE	
SW2282[10]	*311-0296-00			CALIBRATED B	

Transformers

T1013	*120-0438-00	Toroid, 2 turns, bifilar
T2013	*120-0438-00	Toroid, 2 turns, bifilar

Electron Tubes

V1033	154-0215-00	6688
V2033	154-0215-00	6688

PULSE GENERATOR CARD Series 12

Ckt. No.	Tektronix Part No.	Description	Model No.
	*670-0113-00	Complete Card	

Capacitors

Tolerance ±20% unless otherwise indicated.

C1051	281-0516-00	39 pF	Cer	500 V	10%
C1053	283-0079-00	0.01 μF	Cer	250 V	
C1058	281-0518-00	47 pF	Cer	500 V	
C1063	283-0135-00	100 pF	Cer		
C1064	283-0135-00	100 pF	Cer		
C1066	281-0524-00	150 pF	Cer	500 V	
C1068	281-0523-00	100 pF	Cer	350 V	
C1076	290-0107-00	25 μF	EMT	25 V	
C1077	290-0107-00	25 μF	EMT	25 V	

Connectors

J1051	131-0391-00	Coax, 50 Ω, male
J1066	131-0391-00	Coax, 50 Ω, male
J1067	131-0391-00	Coax, 50 Ω, male
J1068	131-0391-00	Coax, 50 Ω, male
J1069	131-0391-00	Coax, 50 Ω, male

[10] Furnished as a unit with R2173.

PULSE GENERATOR CARD Series 12 (Cont)

Diodes

Ckt. No.	Tektronix Part No.	Description			Model No.
D1053	152-0091-00	Zener	1N982	0.4 W, 75 V, 20%	
D1066	*152-0252-00	Snap Off	Tek Made		
D1070	*152-0185-00	Silicon	Replaceable by 1N3605		
D1071	*152-0185-00	Silicon	Replaceable by 1N3605		
D1073	*152-0185-00	Silicon	Replaceable by 1N3605		

Inductors

Ckt. No.	Tektronix Part No.	Description
L1051	*108-0260-00	0.1 μH
L1052	*108-0095-00	1.4 μH
L1066	*175-0389-00	Cable Assembly w/ferrite core
L1067	*175-0389-01	Cable Assembly w/ferrite core
L1068	*175-0389-00	Cable Assembly w/ferrite core
L1069	*175-0389-01	Cable Assembly w/ferrite core
L1076	*120-0398-00	Toroid, 15 turns, single
L1077	*120-0398-00	Toroid, 15 turns, single

Transistors

Ckt. No.	Tektronix Part No.	Description	
Q1053	151-0179-00	Silicon	2N3877A
Q1054	*153-0544-00	Silicon	Avalanche Tek Spec
Q1063	151-0166-00	Silicon	2N2923
Q1064	151-0069-00	Germanium	2N1304
Q1074	151-0188-00	Silicon	2N3906

Resistors

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

Ckt. No.	Tektronix Part No.	Description				
R1051	315-0510-00	51 Ω	¼ W			5%
R1053	301-0683-00	68 kΩ	½ W			5%
R1054	311-0465-00	100 kΩ		Var		
R1055	316-0103-00	10 kΩ	¼ W			
R1058	315-0220-00	22 Ω	¼ W			5%
R1060	308-0314-00	680 Ω	3 W		WW	5%
R1063	311-0510-00	10 kΩ		Var		
R1066	315-0102-00	1 kΩ	¼ W			5%
R1067	311-0510-00	10 kΩ		Var		
R1068	316-0103-00	10 kΩ	¼ W			
R1069	316-0472-00	4.7 kΩ	¼ W			
R1071	316-0103-00	10 kΩ	¼ W			
R1073	316-0221-00	220 Ω	¼ W			
R1074	315-0621-00	620 Ω	¼ W			5%
R1075	315-0621-00	620 Ω	¼ W			5%

PULSE GENERATOR CARD Series 12 (Cont)

Transformer

Ckt. No.	Tektronix Part No.	Description	Model No.
T1065	*120-0439-00	Toroid, 5 turns, bifilar	

AC AMPLIFIER PLUG-IN CHASSIS Series 2

	*610-0061-00	Complete Plug-In Chassis (Model 5-up)

Capacitors

Tolerance ±20% unless otherwise indicated.

C1081	290-0105-00	100 μF	EMT		6 V	
C1089	281-0501-00	4.7 pF	Cer		500 V	±1 pF
C1107	281-0060-00	2-8 pF	Cer	Var		
C1108	283-0026-00	0.2 μF	Cer		25 V	
C1109	290-0145-00	10 μF	EMT		50 V	
C1113	283-0023-00	0.1 μF	Cer		10 V	
C1116	283-0004-00	0.02 μF	Cer		150 V	
C1119	283-0004-00	0.02 μF	Cer		150 V	
C2081	290-0105-00	100 μF	EMT		6 V	
C2089	281-0501-00	4.7 pF	Cer		500 V	±1 pF
C2107	281-0060-00	2-8 pF	Cer	Var		
C2108	283-0026-00	0.2 μF	Cer		25 V	
C2109	290-0145-00	10 μF	EMT		50 V	
C2113	283-0023-00	0.1 μF	Cer		10 V	
C2116	283-0004-00	0.02 μF	Cer		150 V	
C2119	283-0004-00	0.02 μF	Cer			

Inductors

L1082	*120-0306-00	Toroid, 40 turns, single
L2082	*120-0306-00	Toroid, 40 turns, single

Connector

P12	131-0218-00	22 contact

Transistors

Q1084	151-0015-00	Germanium	2N1516
Q1094	151-0015-00	Germanium	2N1516
Q1104	151-0015-00	Germanium	2N1516
Q1113	*151-0056-00	Silicon	Tek Spec
Q2084	151-0015-00	Germanium	2N1516

AC AMPLIFIER PLUG-IN CHASSIS Series 2 (Cont)

Transistors *(Cont)*

Ckt. No.	Tektronix Part No.	Description				Model No.
Q2094	151-0015-00	Germanium	2N1516			
Q2104	151-0015-00	Germanium	2N1516			
Q2113	*151-0056-00	Silicon	Tek Spec			

Resistors

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

R1083	318-0064-00	250 Ω	1/8 W	Prec	1%
R1086	303-0223-00	22 kΩ	1 W		5%
R1087	315-0222-00	2.2 kΩ	1/4 W		5%
R1088	306-0154-00	150 kΩ	2 W		
R1089	318-0074-00	11.8 kΩ	1/8 W	Prec	1%
R1095	303-0153-00	15 kΩ	1 W		5%
R1096	319-0042-00	1 kΩ	1/4 W	Prec	1%
R1097	315-0392-00	3.9 kΩ	1/4 W		5%
R1105	301-0473-00	47 kΩ	1/2 W		5%
R1107	309-0388-00	6 kΩ	1/2 W	Prec	1%
R1108	301-0561-00	560 Ω	1/2 W		5%
R1109	316-0101-00	100 Ω	1/4 W		
R1113	315-0101-00	100 Ω	1/4 W		5%
R1115	301-0102-00	1 kΩ	1/2 W		5%
R1116	316-0101-00	100 Ω	1/4 W		
R1119	316-0102-00	1 kΩ	1/4 W		
R2083	318-0064-00	250 Ω	1/8 W	Prec	1%
R2086	303-0223-00	22 kΩ	1 W		5%
R2087	315-0222-00	2.2 kΩ	1/4 W		5%
R2088	306-0154-00	150 kΩ	2 W		
R2089	318-0074-00	11.8 kΩ	1/8 W	Prec	1%
R2095	303-0153-00	15 kΩ	1 W		5%
R2096	319-0042-00	1 kΩ	1/4 W	Prec	1%
R2097	315-0392-00	3.9 kΩ	1/4 W		5%
R2105	301-0473-00	47 kΩ	1/2 W		5%
R2107	309-0388-00	6 kΩ	1/2 W	Prec	1%
R2108	301-0561-00	560 Ω	1/2 W		5%
R2109	316-0101-00	100 Ω	1/4 W		
R2113	315-0101-00	100 Ω	1/4 W		5%
R2115	301-0102-00	1 kΩ	1/2 W		5%
R2116	316-0101-00	100 Ω	1/4 W		
R2119	316-0102-00	1 kΩ	1/4 W		

MEMORY PLUG-IN CHASSIS A, B (2) Series 11

*610-0110-00 Complete Plug-In Chassis (Model 6-up)

MEMORY PLUG-IN CHASSIS A, B (2) Series 11 (Cont)

Capacitors

Ckt. No.	Tektronix Part No.	Description				Model No.

Tolerance ±20% unless otherwise indicated.

C1121	285-0001-00	510 pF	Glass	300 V	1%	
C1122	283-0026-00	0.2 μF	Cer	25 V		
C1127	283-0003-00	0.01 μF	Cer	150 V		
C1128	283-0026-00	0.2 μF	Cer	25 V		
C1129	283-0024-00	0.1 μF	Cer	30 V		
C1132	285-0000-00	160 pF	Glass	500 V	1%	
C1138	281-0504-00	10 pF	Cer	500 V	10%	
C1140	283-0024-00	0.1 μF	Cer	30 V		
C1153	283-0003-00	0.01 μF	Cer	150 V		

Diodes

D1122	152-0016-00	Zener	RT-6, 5-7 V	
D1125	152-0071-00	Germanium	ED-2007	
D1127	152-0071-00	Germanium	ED-2007	
D1130 } D1131 }	*152-0145-00	GaAs	Tek Made (1 pair)	
D1136	152-0066-00	Silicon	1N3194	
D1140	152-0064-00	Zener	1N961A	0.4 W, 10 V, 10%
D1142	*152-0026-00	Germanium	Tek Spec	
D1143	152-0008-00	Germanium		
D1144	152-0064-00	Zener	1N961A	0.4 W, 10 V, 10%

Connectors

P13	131-0218-00	22 contact
P14	131-0218-00	22 contact

Transistors

Q1134	*153-0511-00	Germanium	Tek Spec
Q1141	151-0067-00	Germanium	2N1143

Resistors

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

R1120	306-0104-00	100 kΩ	2 W		
R1121	315-0101-00	100 Ω	1/4 W		5%
R1122	304-0333-00	33 kΩ	1 W		
R1123	318-0034-00	2 kΩ	1/8 W	Prec	1%
R1124	318-0034-00	2 kΩ	1/8 W	Prec	1%

MEMORY PLUG-IN CHASSIS A, B (2) Series 11 (Cont)

Resistors *(Cont)*

Ckt. No.	Tektronix Part No.	Description					Model No.
R1125	311-0343-00	1 kΩ		Var			
R1127	318-0045-00	3.92 kΩ	1/8 W		Prec	1%	
R1129	316-0100-00	10 Ω	1/4 W				
R1130	309-0058-00	2 Ω	1/2 W		Prec	1%	
R1134	301-0563-00	56 kΩ	1/2 W			5%	
R1135	316-0101-00	100 Ω	1/4 W				
R1137	315-0113-00	11 kΩ	1/4 W			5%	
R1138	301-0473-00	47 kΩ	1/2 W			5%	
R1139	303-0103-00	10 kΩ	1 W			5%	
R1140	315-0103-00	10 kΩ	1/4 W			5%	
R1143	316-0683-00	68 kΩ	1/4 W				
R1144	303-0153-00	15 kΩ	1 W			5%	
R1145	315-0820-00	82 Ω	1/4 W			5%	
R1146	321-0602-00	3.908 kΩ	1/8 W		Prec	1/4%	
R1150	321-0605-00	186.2 kΩ	1/8 W		Prec	1/4%	
R1151	301-0513-00	51 kΩ	1/2 W			5%	
R1152	315-0101-00	100 Ω	1/4 W			5%	
R1153	315-0101-00	100 Ω	1/4 W			5%	
R1154	323-0602-00	107 kΩ	1/2 W		Prec	1/4%	
R1155	323-0603-00	1.5 MΩ	1/2 W		Prec	1/4%	
R1156	323-0601-00	92 kΩ	1/2 W		Prec	1/4%	

Transformer

T1130	*120-0255-00	Toroid, 3 windings

Electron Tube

V1133	*157-0102-00	7308	Selected

INVERTER PLUG-IN CHASSIS Series 9

*610-0093-00 Complete Plug-In Chassis (Model 2-up)

Diodes

D1165	152-0025-00	Germanium	1N634	
D1166	152-0025-00	Germanium	1N634	
D1167	152-0064-00	Zener	1N961A	0.4 W, 10 V, 10%
D2165	152-0025-00	Germanium	1N634	
D2166	152-0025-00	Germanium	1N634	
D2167	152-0064-00	Zener	1N961A	0.4 W, 10 V, 10%

INVERTER PLUG-IN CHASSIS Series 9 (Cont)

Connector

Ckt. No.	Tektronix Part No.	Description	Model No.
P15	131-0218-00	22 contact	

Transistors

Ckt. No.	Tektronix Part No.	Description		Model No.
Q1163	*151-0058-00	Silicon	Tek Spec	
Q1164	*151-0054-00	Germanium	Selected from 2N1754	
Q2163	*151-0058-00	Silicon	Tek Spec	
Q2164	*151-0054-00	Germanium	Selected from 2N1754	

Resistors

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

Ckt. No.	Tektronix Part No.	Description					Model No.
R1161	311-0153-00	10 kΩ		Var			
R1162	301-0224-00	220 kΩ	½ W			5%	
R1163	309-0100-00	10 kΩ	½ W		Prec	1%	
R1164	309-0160-00	9.85 kΩ	½ W		Prec	1%	
R1165	301-0752-00	7.5 kΩ	½ W			5%	
R1166	303-0433-00	43 kΩ	1 W			5%	
R1167	304-0334-00	330 kΩ	1 W				
R1168	304-0223-00	22 kΩ	1 W				
R2161	311-0153-00	10 kΩ		Var			
R2162	301-0224-00	220 kΩ	½ W			5%	
R2163	309-0100-00	10 kΩ	½ W		Prec	1%	
R2164	309-0160-00	9.85 kΩ	½ W		Prec	1%	
R2165	301-0752-00	7.5 kΩ	½ W			5%	
R2166	303-0433-00	43 kΩ	1 W			5%	
R2167	304-0334-00	330 kΩ	1 W				
R2168	304-0223-00	22 kΩ	1 W				

DUAL TRACE PLUG-IN CHASSIS Series 5

*610-0090-00 Complete Plug-In Chassis (Model 4-up)

Capacitors

Tolerance ±20% unless otherwise indicated.

Ckt. No.	Tektronix Part No.	Description				Model No.
C1181	283-0004-00	0.02 μF	Cer	150 V		
C1189	283-0004-00	0.02 μF	Cer	150 V		
C1191	281-0542-00	18 pF	Cer	500 V	10%	
C2181	283-0004-00	0.02 μF	Cer	150 V		
C2189	283-0004-00	0.02 μF	Cer	150 V		

DUAL TRACE PLUG-IN CHASSIS Series 5 (Cont)

Capacitors *(Cont)*

Ckt. No.	Tektronix Part No.	Description				Model No.
C2240	281-0543-00	270 pF	Cer	500 V	10%	
C2246	281-0542-00	18 pF	Cer	500 V	10%	
C2250	281-0543-00	270 pF	Cer	500 V	10%	
C2251	285-0624-00	0.027 μF	PMT	100 V	10%	
C2256	281-0542-00	18 pF	Cer	500 V	10%	
C2266	290-0107-00	25 μF	EMT	25 V		
C2268	290-0107-00	25 μF	EMT	25 V		

Diodes

Ckt. No.	Tektronix Part No.	Description		
D1186	152-0071-00	Germanium	ED-2007	
D1187	152-0071-00	Germanium	ED-2007	
D1197	152-0095-00	Silicon	1N625	
D1198	152-0095-00	Silicon	1N625	
D2186	152-0071-00	Germanium	ED-2007	
D2187	152-0071-00	Germanium	ED-2007	
D2245	152-0008-00	Germanium		
D2248	152-0008-00	Germanium		
D2249	152-0055-00	Zener	1N962A	0.4 W, 11 V, 5%
D2251	152-0016-00	Zener	RT-6, 5-7 V	
D2255	152-0008-00	Germanium		
D2258	152-0008-00	Germanium		
D2262	152-0008-00	Germanium		

Inductors

Ckt. No.	Tektronix Part No.	Description
L1189	*120-0304-00	Toroid, 3 turns, single
L1195	119-0021-00	Delay Line
L2266	*120-0266-00	Toroid, 10 turns, single
L2268	*120-0266-00	Toroid, 10 turns, single

Connector

Ckt. No.	Tektronix Part No.	Description
P16	131-0218-00	22 contact

Transistors

Ckt. No.	Tektronix Part No.	Description	
Q1184	151-0076-00	Germanium	2N2048
Q2184	151-0076-00	Germanium	2N2048
Q2245	151-0076-00	Germanium	2N2048
Q2255	151-0076-00	Germanium	2N2048
Q2264	151-0015-00	Germanium	2N1516

DUAL TRACE PLUG-IN CHASSIS Series 5 (Cont)

Resistors

Ckt. No.	Tektronix Part No.	Description					Model No.

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

Ckt. No.	Tektronix Part No.	Description					Model No.
R1181	315-0563-00	56 kΩ	¼ W			5%	
R1183	318-0094-00	193 kΩ	⅛ W		Prec	1%	
R1184	319-0053-00	1.82 kΩ	¼ W		Prec	1%	
R1185	309-0429-00	16.5 kΩ	½ W		Prec	1%	
R1189	318-0105-00	5.62 kΩ	⅛ W		Prec	1%	
R1191	324-0415-00	205 kΩ	1 W		Prec	1%	
R1192	309-0387-00	3.32 kΩ	½ W		Prec	1%	
R1195	315-0272-00	2.7 kΩ	¼ W			5%	
R1197	315-0152-00	1.5 kΩ	¼ W			5%	
R2181	315-0563-00	56 kΩ	¼ W			5%	
R2182	311-0172-00	2.5 kΩ		Var			
R2183	318-0094-00	193 kΩ	⅛ W		Prec	1%	
R2184	319-0053-00	1.82 kΩ	¼ W		Prec	1%	
R2185	309-0429-00	16.5 kΩ	½ W		Prec	1%	
R2189	319-0031-00	1 MΩ	¼ W		Prec	1%	
R2195	315-0623-00	62 kΩ	¼ W			5%	
R2196	315-0183-00	18 kΩ	¼ W			5%	
R2199	315-0363-00	36 kΩ	¼ W			5%	
R2240	301-0102-00	1 kΩ	½ W			5%	
R2242	315-0223-00	22 kΩ	¼ W			5%	
R2243	315-0103-00	10 kΩ	¼ W			5%	
R2246	315-0273-00	27 kΩ	¼ W			5%	
R2247	315-0224-00	220 kΩ	¼ W			5%	
R2248	301-0102-00	1 kΩ	½ W			5%	
R2249	315-0822-00	8.2 kΩ	¼ W			5%	
R2250	301-0102-00	1 kΩ	½ W			5%	
R2252	315-0223-00	22 kΩ	¼ W			5%	
R2253	315-0103-00	10 kΩ	¼ W			5%	
R2256	315-0273-00	27 kΩ	¼ W			5%	
R2257	315-0224-00	220 kΩ	¼ W			5%	
R2258	301-0102-00	1 kΩ	½ W			5%	
R2261	315-0332-00	3.3 kΩ	¼ W			5%	
R2264	315-0823-00	82 kΩ	¼ W			5%	

FIGURE AND INDEX NUMBERS

Items in this section are referenced by figure and index numbers to the illustrations which appear on the pullout pages immediately following the Diagrams section of this instruction manual.

INDENTATION SYSTEM

This mechanical parts list is indented to indicate item relationships. Following is an example of the indentation system used in the Description column.

Assembly and/or Component
  Detail Part of Assembly and/or Component
  mounting hardware for Detail Part
    Parts of Detail Part
    mounting hardware for Parts of Detail Part
mounting hardware for Assembly and/or Component

Mounting hardware always appears in the same indentation as the item it mounts, while the detail parts are indented to the right. Indented items are part of, and included with, the next higher indentation.

Mounting hardware must be purchased separately, unless otherwise specified.

PARTS ORDERING INFORMATION

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

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

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

Change information, if any, is located at the rear of this manual.

ABBREVIATIONS AND SYMBOLS

For an explanation of the abbreviations and symbols used in this section, please refer to the page immediately preceding the Electrical Parts List in this instruction manual.

INDEX OF MECHANICAL PARTS LIST ILLUSTRATIONS

(Located behind diagrams)

SECTION 8

MECHANICAL PARTS LIST

FIG. 1 FRONT/GATE & PRE-AMP CIRCUIT BOARDS

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-1	333-0932-01			1	PANEL, front
-2	366-0148-00			2	KNOB, charcoal—VERT POSITION
	- - - - - -			-	each knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-3	- - - - - -			2	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
	210-0013-00			1	LOCKWASHER, internal, 3/8 ID x 11/16 inch OD
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-4	366-0148-00			2	KNOB, charcoal—SMOOTHING
	- - - - - -			-	each knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-5	366-0148-00			2	KNOB, charcoal—DC OFFSET
	- - - - - -			-	each knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-6	- - - - - -			4	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
	210-0207-00			1	LUG, solder, 3/8 ID x 5/8 inch OD, SE
	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-7	366-0113-00			1	KNOB, charcoal—MODE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-8	262-0550-00			1	SWITCH, wired—MODE
	- - - - - -			-	switch includes:
	260-0514-00			1	SWITCH, unwired—MODE
	- - - - - -			-	mounting hardware: (not included w/switch)
-9	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
-10	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-11	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-12	136-0052-00			2	SOCKET, banana jack, w/bushing
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-13	210-0895-00			1	WASHER, plastic, 0.255 ID x 0.375 inch OD
-14	210-0465-00			2	NUT, hex., 1/4-32 x 3/8 inch
-15	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch OD, SE

FIG. 1 FRONT/GATE & PRE-AMP CIRCUIT BOARDS *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
1-16	366-0038-00			2	KNOB, red—VARIABLE
	- - - - - -			-	each knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $^{3}/_{16}$ inch, HSS
-17	366-0160-00			2	KNOB, charcoal—MILLIVOLTS/CM
	- - - - - -			-	each knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $^{3}/_{16}$ inch, HSS
-18	262-0538-00			2	SWITCH, wired—MILLIVOLTS/CM
	- - - - - -			-	each switch includes:
	260-0434-00			1	SWITCH, unwired—MILLIVOLTS/CM
-19	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	resistor includes:
-20	384-0241-00			1	ROD, extension
	213-0022-00			1	SCREW, set, 4-40 x $^{3}/_{16}$ inch, HSS
	- - - - - -			-	mounting hardware: (not included w/resistor)
-21	210-0406-00			2	NUT, hex., 4-40 x $^{3}/_{16}$ inch
	- - - - - -			-	mounting hardware for each: (not included w/switch)
-22	210-0012-00			1	LOCKWASHER, internal, $^{3}/_{8}$ ID x $^{1}/_{2}$ inch OD
-22	210-0840-00			1	WASHER, flat, 0.390 ID x $^{9}/_{16}$ inch OD
	210-0413-00			1	NUT, hex., $^{3}/_{8}$-32 x $^{1}/_{2}$ inch
-24	387-0613-00			1	PLATE, sub-panel
-25	131-0206-00			2	CONNECTOR, probe power, 4 contact
	- - - - - -			-	mounting hardware for each: (not included w/connector)
-26	210-0941-00			1	WASHER, flat, 0.448 ID x $^{11}/_{16}$ inch OD
-27	210-0559-00			1	NUT, hex., $^{7}/_{16}$-28 x $^{9}/_{16}$ inch
-28	260-0212-00			2	SWITCH, slide—DISPLAY
	- - - - - -			-	mounting hardware for each: (not included w/switch)
	210-0406-00			2	NUT, hex., 4-40 x $^{3}/_{16}$ inch
-29	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-30	210-0046-00			2	LOCKWASHER, internal, $^{1}/_{4}$ ID x 0.400 inch OD
-31	210-0471-00			1	NUT, hex., $^{1}/_{4}$-32 x $^{5}/_{16}$ x $^{19}/_{32}$ inch long
-32	358-0054-00			1	BUSHING, banana jack
-33	200-0263-00			2	COVER, dust
-34	214-0222-00			1	SPRING, striker
	- - - - - -			-	mounting hardware: (not included w/spring)
-35	211-0082-00			2	SCREW, 4-40 x $^{3}/_{4}$ inch, FHS
-36	361-0029-00			1	SPACER, latch spring
-37	210-0004-00			2	LOCKWASHER, internal, #4
-38	210-0406-00			2	NUT, hex., 4-40 x $^{3}/_{16}$ inch
-39	179-0716-00			1	CABLE HARNESS, sub-panel power

FIG. 1 FRONT/GATE & PRE-AMP CIRCUIT BOARDS *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
- -	670-0114-00			1	ASSEMBLY, circuit board—GATE
	- - - - - -			-	assembly includes:
1-40	388-0699-00			1	BOARD, circuit
	- - - - - -			-	board includes:
-41	214-0506-00			7	PIN, connector
-42	119-0067-00			4	SECTION, line
-43	211-0014-00			8	SCREW, 4-40 x 1/2 inch, PHS
-44	361-0122-00			16	SPACER, sleeve
-45	210-0586-00			8	NUT, keps, 4-40 x 1/4 inch
-46	119-0102-00			2	ASSEMBLY, resistor & ground clip
-47	131-0265-00			4	CONNECTOR, coaxial, 1 contact, right angle
-48	131-0391-00			1	CONNECTOR, coaxial, 1 contact, straight
-49	- - - - - -			2	ADAPTER, section line (do not separate from circuit board)
-50	205-0062-00			2	SHELL, connector
-51	132-0007-00			4	RING, snap
-52	220-0460-00			2	NUT, coupling
-53	214-0697-00			2	CONTACT, electrical
-54	210-0588-00			2	NUT, panel mount
-55	103-0055-00			2	ADAPTER, inner conductor to section line
-56	132-0028-00			2	INSULATOR, plastic
-57	132-0029-00			2	CONDUCTOR, inner
-58	132-0002-00			2	SLEEVE, outer conductor
	- - - - - -			-	mounting hardware: (not included w/assembly)
-59	211-0116-00			2	SCREW, sems, 4-40 x 5/16 inch, PHB
-60	220-0459-00			2	NUT, dodecagon
-61	407-0239-00			1	BRACKET, circuit board
	- - - - - -			-	mounting hardware: (not included w/bracket)
-62	210-0586-00			2	NUT, keps, 4-40 x 1/4 inch
-63	348-0063-00			2	GROMMET, plastic, 1/2 inch diameter
-64	348-0055-00			4	GROMMET, plastic, 1/4 inch diameter
-65	179-1080-00			1	CABLE HARNESS, power #2
	- - - - - -			-	cable harness includes:
-66	131-0371-00			13	CONNECTOR, pin
-67	407-0241-00			1	BRACKET, resistor
	- - - - - -			-	mounting hardware: (not included w/bracket)
-68	211-0538-00			2	SCREW, 6-32 x 5/16 inch, 100° csk, FHS
-69	210-0457-00			2	NUT, keps, 6-32 x 5/16 inch
-70	- - - - - -			1	RESISTOR
	- - - - - -			-	mounting hardware: (not included w/resistor)
-71	212-0037-00			1	SCREW, 8-32 x 1 3/4 inches, Fil HS
-72	210-0808-00			1	WASHER, centering
-73	210-0462-00			1	NUT, hex., 8-32 x 1/2 x 23/64 inch
-74	212-0004-00			1	SCREW, 8-32 x 5/16 inch, PHS

FIG. 1 FRONT/GATE & PRE-AMP CIRCUIT BOARDS *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
- -	670-0112-00			1	ASSEMBLY, circuit board—PRE-AMP
	- - - - - -			-	assembly includes:
1-75	388-0698-00			1	BOARD, circuit
	- - - - - -			-	board includes:
-76	214-0506-00			14	PIN, connector
-77	136-0061-00			2	SOCKET, tube, 9 pin
-78	136-0183-00			4	SOCKET, transistor, 3 pin
	- - - - - -			-	mounting hardware: (not included w/assembly)
-79	211-0116-00			4	SCREW, sems, 4-40 x $^{5}/_{16}$ inch, PHB

FIG. 2 SIDES & REAR

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
2-1	175-0391-00			1	CABLE, internal trigger
	- - - - - -			-	cable includes:
-2	131-0221-00			1	CONNECTOR, jack
-3	175-0390-00			1	CABLE, start sample trigger
	- - - - - -			-	cable includes:
-4	131-0221-00			1	CONNECTOR, jack
-5	406-0769-00			1	BRACKET, connector
	- - - - - -			-	mounting hardware: (not included w/bracket)
-6	211-0559-00			4	SCREW, 6-32 x 3/8 inch, 100° csk, FHS
-7	426-0152-00			1	MOUNT, connector
	- - - - - -			-	mounting hardware: (not included w/mount)
-8	211-0511-00			2	SCREW, 6-32 x 1/2 inch, PHS
-9	358-0172-00			2	BUSHING, connector
-10	426-0147-00			1	FRAME, left side
	- - - - - -			-	mounting hardware: (not included w/frame)
-11	213-0107-00			4	SCREW, thread forming, 4-40 x 1/4 inch, FHS
-12	211-0559-00			8	SCREW, 6-32 x 3/8 inch, 100° csk, FHS
-13	384-0594-00			8	ROD, plastic
	- - - - - -			-	mounting hardware for each: (not included w/rod)
-14	211-0507-00			1	SCREW, 6-32 x 5/16 inch, PHS
-15	387-0627-00			1	PLATE, left side
-16	179-0717-01			1	CABLE HARNESS, signal
	- - - - - -			-	cable harness includes:
-17	131-0371-00			4	CONNECTOR, pin
-18	179-0631-01			1	CABLE HARNESS, power #1
-19	136-0156-00			1	SOCKET, circuit board, 44 pin
	- - - - - -			-	mounting hardware: (not included w/socket)
-20	211-0012-00			2	SCREW, 4-40 x 3/8 inch, PHS
	210-0004-00			2	LOCKWASHER, internal, #4
-21	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-22	131-0220-00			5	CONNECTOR, 22 contact
	- - - - - -			-	mounting hardware for each: (not included w/connector)
-23	211-0578-00			2	SCREW, 6-32 x 7/16 inch, PHS
	210-0006-00			2	LOCKWASHER, internal, #6
-24	210-0407-00			2	NUT, hex., 6-32 x 1/4 inch
-25	179-0718-01			1	CABLE HARNESS, subpanel signal
	- - - - - -			-	cable harness includes:
-26	131-0371-00			4	CONNECTOR, pin

FIG. 2 SIDES & REAR *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-27	387-0843-01			1	PLATE, right side
-28	426-0146-00			1	FRAME, right side
	- - - - - -			-	mounting hardware: (not included w/frame)
-29	213-0107-00			4	SCREW, thread forming, 4-40 x 1/4 inch, FHS
-30	211-0559-00			8	SCREW, 6-32 x 3/8 inch, 100° csk, FHS
-31	387-0612-00			1	PLATE, rear
	- - - - - -			-	mounting hardware: (not included w/plate)
-32	211-0510-00			8	SCREW, 6-32 x 3/8 inch, PHS
-33	131-0149-00			2	CONNECTOR, 24 contact
	- - - - - -			-	mounting hardware for each: (not included w/connector)
-34	211-0008-00			2	SCREW, 4-40 x 1/4 inch, PHS
-35	210-0004-00			1	LOCKWASHER, internal, #4
-36	210-0201-00			1	LUG, solder, SE #4
-37	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch

FIG. 3 PULSE GENERATOR CIRCUIT CARD (SERIES 12)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
	670-0113-00			1	ASSEMBLY, circuit card—PULSE GENERATOR
	- - - - - -			-	assembly includes:
3-1	388-0700-00			1	CARD, circuit
-2	384-0593-00			2	ROD, pin index
-3	407-0240-00			1	BRACKET, circuit card
	- - - - - -			-	mounting hardware: (not included w/bracket)
-4	211-0016-00			2	SCREW, 4-40 x 5/8 inch, RHS
-5	211-0014-00			2	SCREW, 4-40 x 1/2 inch, PHS
-6	210-0851-00			6	WASHER, flat, 0.119 ID x 3/8 inch OD
-7	166-0424-00			4	SPACER, sleeve
-8	210-0586-00			4	NUT, keps, 4-40 x 1/4 inch
-9	352-0039-00			2	HOLDER, plug-in chassis
	- - - - - -			-	mounting hardware for each: (not included w/holder)
-10	211-0097-00			1	SCREW, 4-40 x 5/16 inch, PHS
-11	210-0586-00			1	NUT, keps, 4-40 x 1/4 inch
-12	131-0391-00			5	CONNECTOR, coaxial, 1 contact, 50 Ω
-13	352-0086-00			3	HOLDER, plastic
-14	344-0061-00			2	CLIP, diode
-15	136-0183-00			2	SOCKET, transistor, 3 pin
-16	136-0220-00			3	SOCKET, transistor, 3 pin
-17	175-0389-00			1	CABLE, strobe (J1068 to J2019)
-18	175-0389-01			1	CABLE, strobe (J1069 to J2009)
-19	175-0389-00			1	CABLE, strobe (J1066 to J1009)
-20	175-0389-01			1	CABLE, strobe (J1067 to J1019)

FIG. 4 AC AMPLIFIER PLUG-IN CHASSIS (SERIES 2)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
	610-0061-00			1	ASSEMBLY, plug-in chassis—AC AMPLIFIER
	- - - - - -			-	assembly includes:
4-1	441-0424-00			1	CHASSIS, AC amplifier
-2	384-0593-00			2	ROD, pin index
-3	131-0218-00			1	CONNECTOR, 22 pin
	- - - - - -			-	mounting hardware: (not included w/connector)
-4	211-0016-00			2	SCREW, 4-40 x $^5/_8$ inch, RHS
-5	210-0003-00			2	LOCKWASHER, external, #4
-6	210-0201-00			2	LUG, solder, SE #4
-7	210-0406-00			2	NUT, hex., 4-40 x $^3/_{16}$ inch
-8	352-0039-00			2	HOLDER, plug-in chassis
	- - - - - -			-	mounting hardware for each: (not included w/holder)
-9	211-0097-00			1	SCREW, 4-40 x $^5/_{16}$ inch, PHS
-10	210-0004-00			1	LOCKWASHER, internal, #4
-11	210-0406-00			1	NUT, hex., 4-40 x $^3/_{16}$ inch
-12	136-0095-00			8	SOCKET, transistor, 4 pin
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-13	211-0081-00			2	SCREW, 2-56 x $^9/_{16}$ inch, RHS
-14	361-0035-00			2	SPACER, transistor socket
-15	426-0121-00			2	MOUNT, toroid
	- - - - - -			-	mounting hardware for each: (not included w/mount)
	361-0008-00			1	SPACER, plastic, 0.281 inch long
-16	210-0259-00			5	LUG, solder, SE #2
	- - - - - -			-	mounting hardware for each: (not included w/lug)
	213-0055-00			1	SCREW, thread forming, 2-32 x $^3/_{16}$ inch, PHS
-17	337-0492-00			1	SHIELD, AC amplifier
	- - - - - -			-	mounting hardware: (not included w/shield)
-18	211-0543-00			3	SCREW, 6-32 x $^5/_{16}$ inch, RHS
-19	385-0160-00			3	ROD, spacer
-20	211-0507-00			3	SCREW, 6-32 x $^5/_{16}$ inch, PHS
-21	124-0145-00			4	STRIP, ceramic, $^7/_{16}$ inch h, w/20 notches
	- - - - - -			-	each strip includes:
	355-0046-00			2	STUD, plastic
	- - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0008-00			2	SPACER, plastic, 0.281 inch long
-22	179-0626-00			1	CABLE HARNESS, AC amplifier

FIG. 5 MEMORY PLUG-IN CHASSIS (SERIES 11)

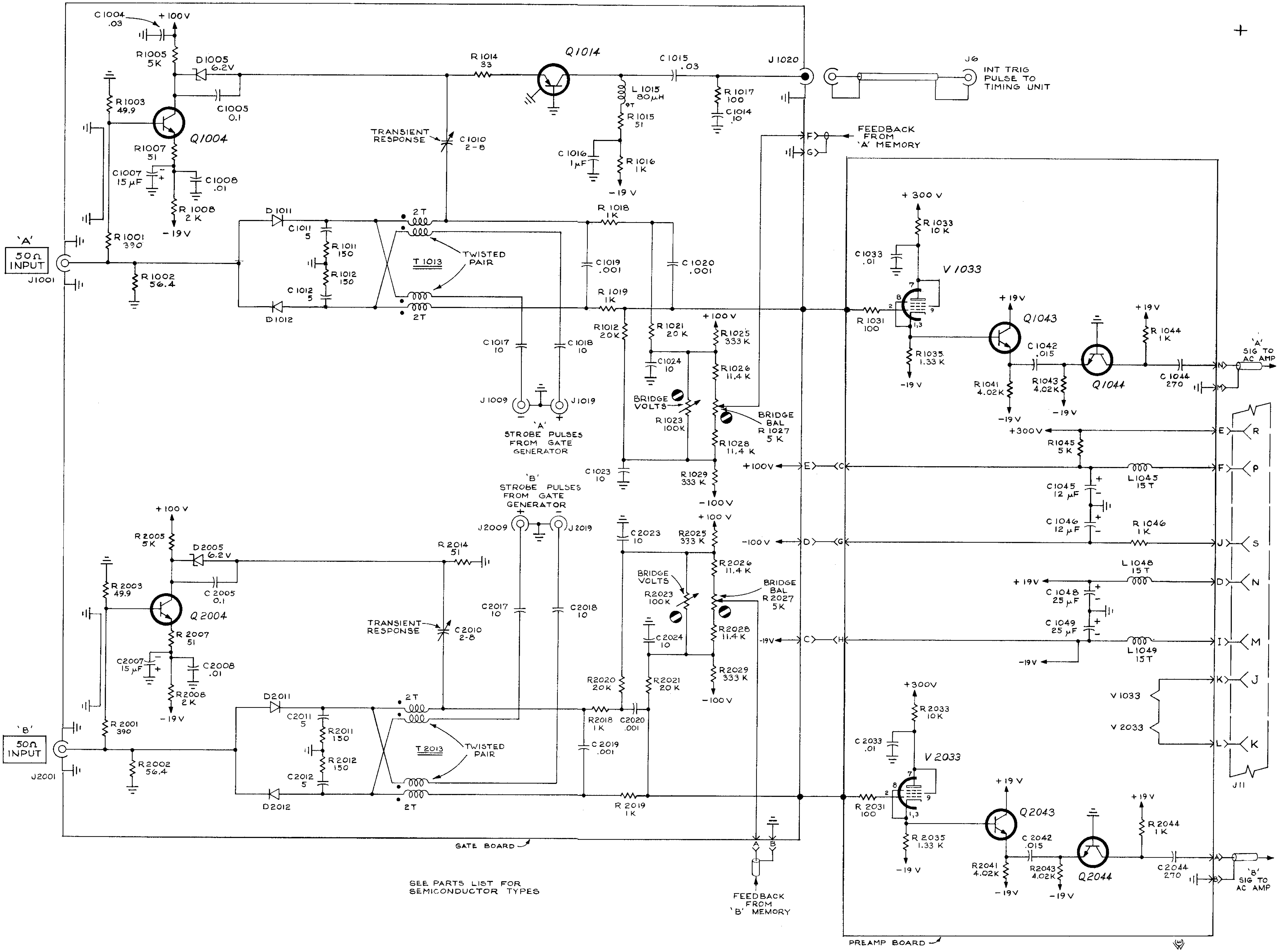
Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
	610-0110-00			2	ASSEMBLY, plug-in chassis—MEMORY
	- - - - - -			-	each assembly includes:
5-1	441-0528-00			1	CHASSIS, memory
-2	384-0593-00			2	ROD, pin index
-3	131-0218-00			1	CONNECTOR, 22 pin
	- - - - - -			-	mounting hardware: (not included w/connector)
-4	211-0016-00			2	SCREW, 4-40 x 5/8 inch, RHS
-5	210-0003-00			2	LOCKWASHER, external, #4
-6	210-0201-00			2	LUG, solder, SE #4
-7	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-8	352-0039-00			2	HOLDER, plug-in chassis
	- - - - - -			-	mounting hardware for each: (not included w/holder)
-9	211-0097-00			1	SCREW, 4-40 x 5/16 inch, PHS
-10	210-0004-00			1	LOCKWASHER, internal, #4
-11	210-0406-00			1	NUT, hex., 4-40 x 3/16 inch
-12	136-0095-00			2	SOCKET, transistor, 4 pin
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-13	213-0113-00			2	SCREW, 2-32 x 5/16 inch, RHS
-14	210-0259-00			1	LUG, solder, SE #2
-15	426-0121-00			1	MOUNT, toroid
	- - - - - -			-	mounting hardware: (not included w/mount)
	361-0007-00			1	SPACER, plastic, 0.188 inch long
-16	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-17	210-0046-00			1	LOCKWASHER, internal, 1/4 ID x 0.400 inch OD
-18	210-0905-00			1	WASHER, flat, 0.265 ID x 7/16 inch OD
-19	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-20	210-0598-00			1	NUT, hex., locking, 1/4-32 x 5/16 inch
-21	337-0008-00			1	SHIELD, tube
-22	136-0085-00			1	SOCKET, tube, 9 pin, w/shield
	- - - - - -			-	mounting hardware: (not included w/socket)
-23	211-0033-00			2	SCREW, sems, 4-40 x 5/16 inch, PHS
-24	210-0004-00			1	LOCKWASHER, internal, #4
-25	210-0201-00			1	LUG, solder, SE #4
-26	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-27	406-0765-00			1	BRACKET, socket mounting
	- - - - - -			-	mounting hardware: (not included w/bracket)
-28	213-0044-00			2	SCREW, thread forming, 5-32 x 3/16 inch, PHS
-29	179-0627-00			1	CABLE HARNESS, memory
-30	124-0146-00			4	STRIP, ceramic, 7/16 inch h, w/16 notches
	- - - - - -			-	each strip includes:
	355-0046-00			2	STUD, plastic
	- - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0008-00			2	SPACER, plastic, 0.281 inch long

FIG. 6 INVERTER PLUG-IN CHASSIS (SERIES 9)

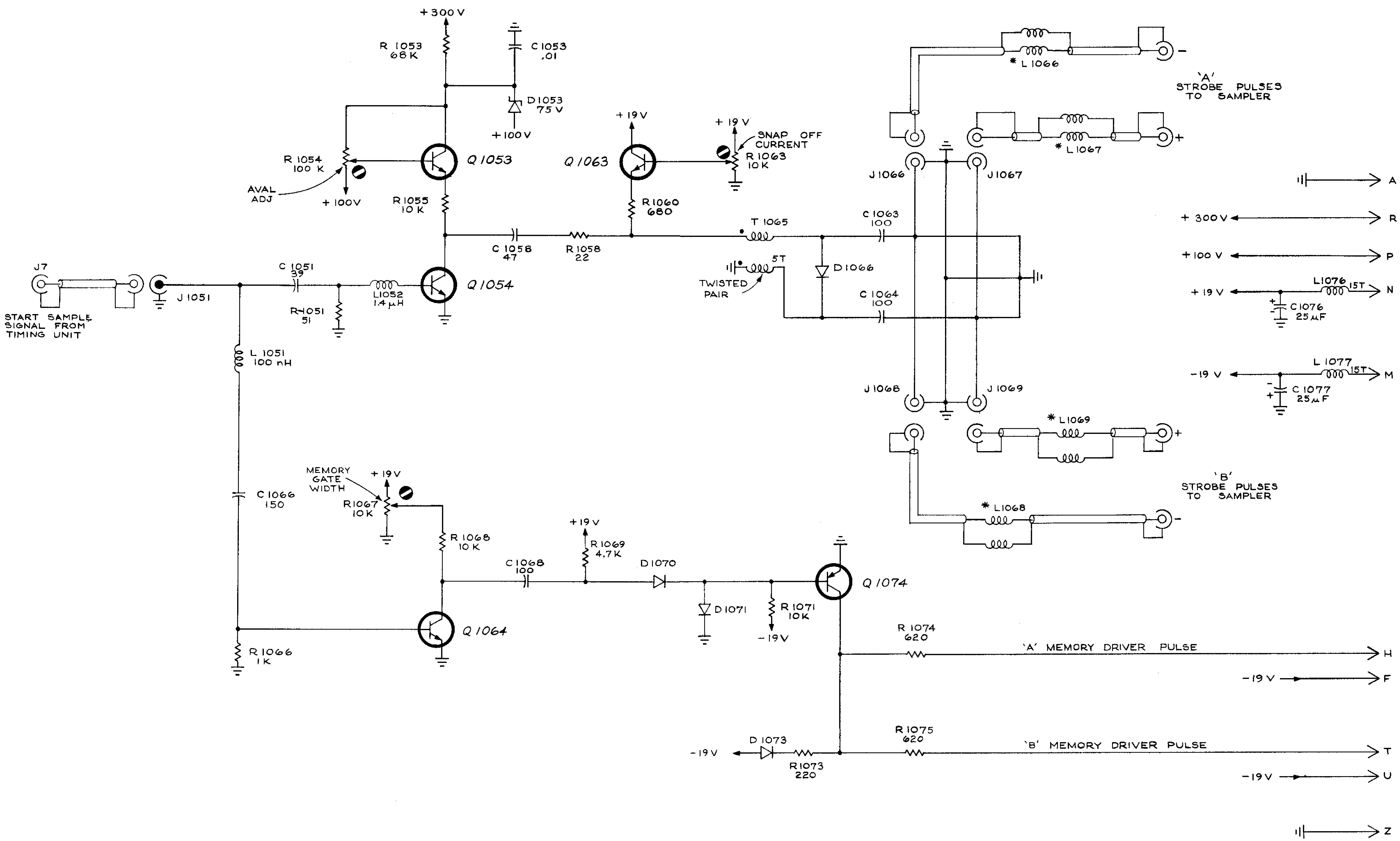
Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
	610-0093-00			1	ASSEMBLY, plug-in chassis—INVERTER
	- - - - - -			-	assembly includes:
6-1	441-0479-00			1	CHASSIS, inverter
-2	384-0593-00			2	ROD, pin index
-3	131-0218-00			1	CONNECTOR, 22 contact
	- - - - - -			-	mounting hardware: (not included w/connector)
-4	211-0016-00			2	SCREW, 4-40 x 5/8 inch, RHS
-5	210-0003-00			2	LOCKWASHER, external, #4
-6	210-0201-00			2	LUG, solder, SE #4
-7	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-8	352-0039-00			2	HOLDER, plug-in chassis
	- - - - - -			-	mounting hardware for each: (not included w/holder)
-9	211-0097-00			1	SCREW, 4-40 x 5/16 inch, PHS
-10	210-0004-00			1	LOCKWASHER, internal, #4
-11	210-0406-00			1	NUT, hex., 4-40 x 3/16 inch
-12	136-0095-00			4	SOCKET, transistor, 4 pin
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-13	211-0081-00			2	SCREW, 2-56 x 9/16 inch, RHS
-14	361-0035-00			2	SPACER, transistor socket
-15	- - - - - -			2	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
-16	210-0465-00			1	NUT, hex., 1/4-32 x 3/8 inch
-17	210-0046-00			1	LOCKWASHER, internal, 1/4 ID x 0.400 inch OD
-18	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-19	179-0628-00			1	CABLE HARNESS, inverter
-20	124-0146-00			4	STRIP, ceramic, 7/16 inch h, w/16 notches
	- - - - - -			-	each strip includes:
	355-0046-00			2	STUD, plastic
	- - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0008-00			2	SPACER, plastic, 0.281 inch long

FIG. 7 DUAL TRACE PLUG-IN CHASSIS (SERIES 5)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
	610-0090-00			1	ASSEMBLY, plug-in chassis—DUAL TRACE
	- - - - - -			-	assembly includes:
7-1	441-0471-00			1	CHASSIS, dual trace
-2	384-0593-00			2	ROD, pin index
-3	131-0218-00			1	CONNECTOR, 22 pin
	- - - - - -			-	mounting hardware: (not included w/connector)
-4	211-0016-00			2	SCREW, 4-40 x 5/8 inch, RHS
-5	210-0003-00			2	LOCKWASHER, external, #4
-6	210-0201-00			2	LUG, solder, SE #4
-7	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-8	352-0039-00			2	HOLDER, plug-in chassis
	- - - - - -			-	mounting hardware for each: (not included w/holder)
-9	211-0097-00			1	SCREW, 4-40 x 5/16 inch, PHS
-10	210-0004-00			1	LOCKWASHER, internal, #4
-11	210-0406-00			1	NUT, hex., 4-40 x 3/16 inch
-12	136-0095-00			5	SOCKET, transistor, 4 pin
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-13	211-0081-00			2	SCREW, 2-56 x 9/16 inch, RHS
-14	361-0035-00			2	SPACER, transistor socket
-15	426-0121-00			3	MOUNT, toroid
	- - - - - -			-	mounting hardware for each: (not included w/mount)
	361-0007-00			1	SPACER, plastic, 0.188 inch long
-16	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
-17	210-0465-00			1	NUT, hex., 1/4-32 x 3/8 inch
-18	210-0046-00			1	LOCKWASHER, internal, 1/4 ID x 0.400 inch OD
-19	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-20	179-0715-00			1	CABLE HARNESS, dual trace
-21	124-0145-00			4	STRIP, ceramic, 7/16 inch h, w/20 notches
	- - - - - -			-	each strip includes:
	355-0046-00			2	STUD, plastic
	- - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0008-00			2	SPACER, plastic, 0.281 inch long



TYPE 452A A SAMPLER ①



SEE PARTS LIST FOR SEMICONDUCTOR TYPES

* 2T 50Ω COAX ON FERRITE CORE

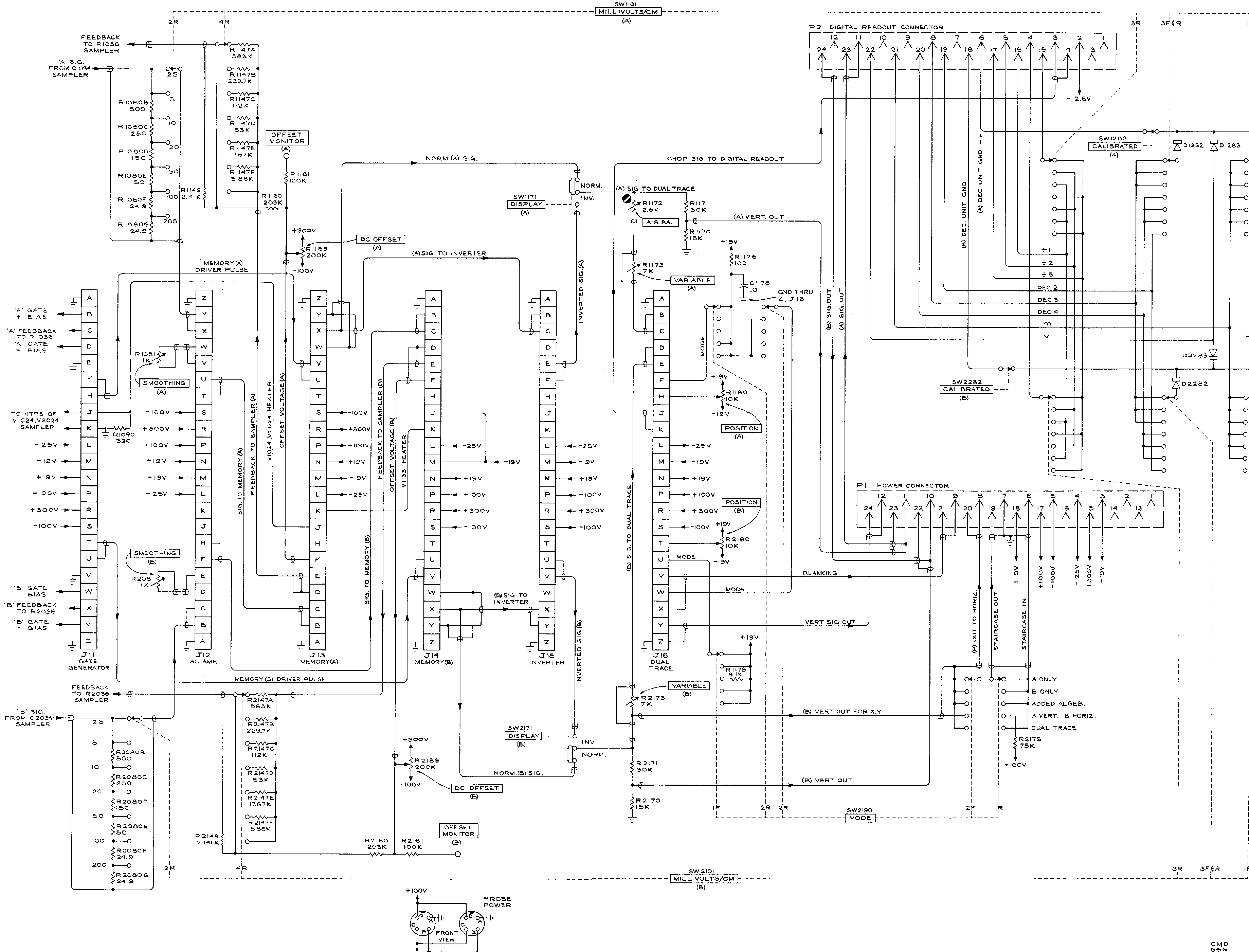
666

TYPE 452A

A

PULSE GENERATOR (2)

SERIES 12



TYPE 4S2A

A

INTERCONNECTORS & SWITCHING 3

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

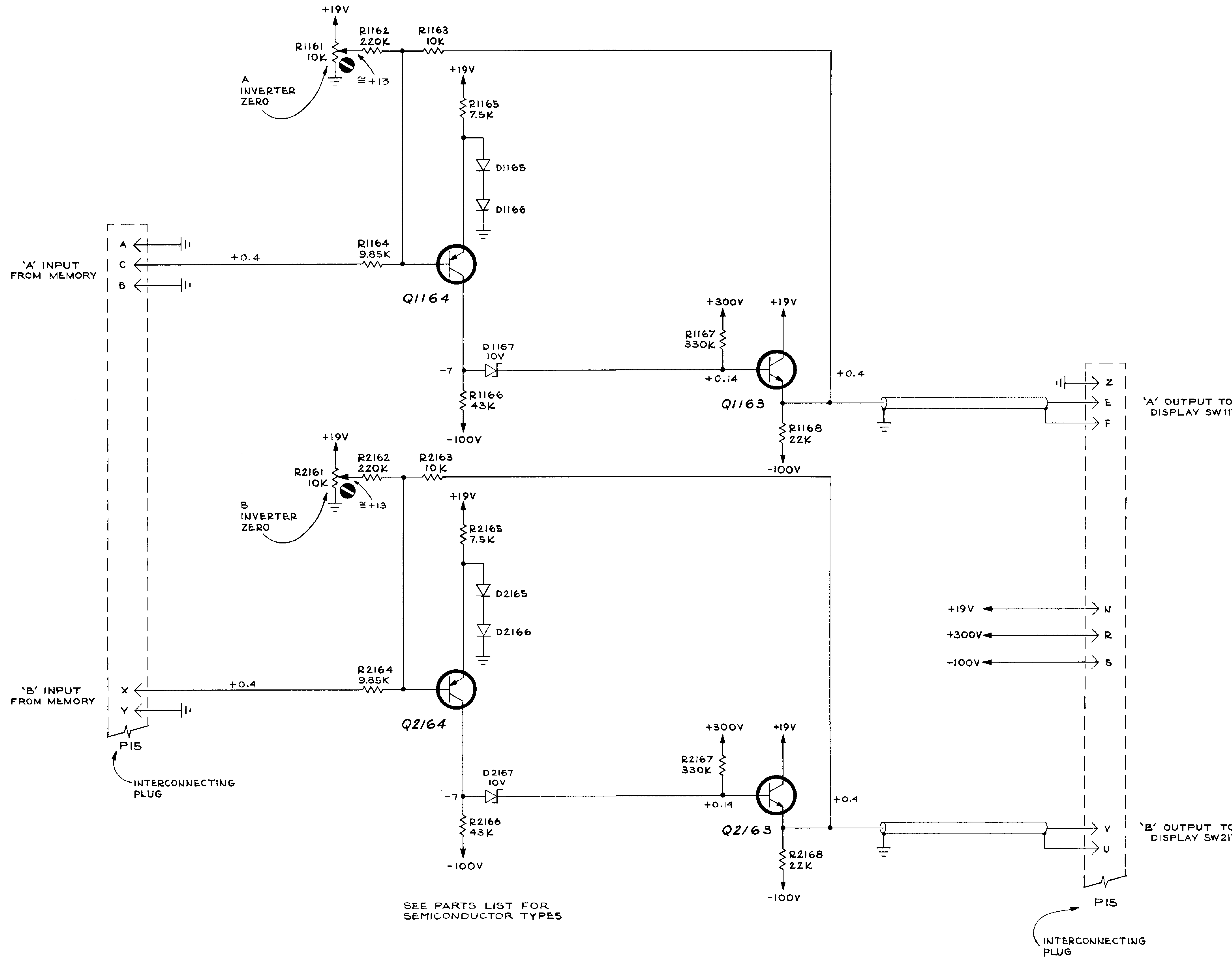
TYPE 4S2A

A

CMD 666

MEMORY ④

SERIES II MODEL 6



TYPE 4S2A

VOLTAGE READINGS WERE OBTAINED UNDER FOLLOWING CONDITIONS:	
DISPLAY	INVERTED
Trace	Centered

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JN
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INVERTER ⑤

SERIES 9 MODEL 2

TYPE 4S2A

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CMD
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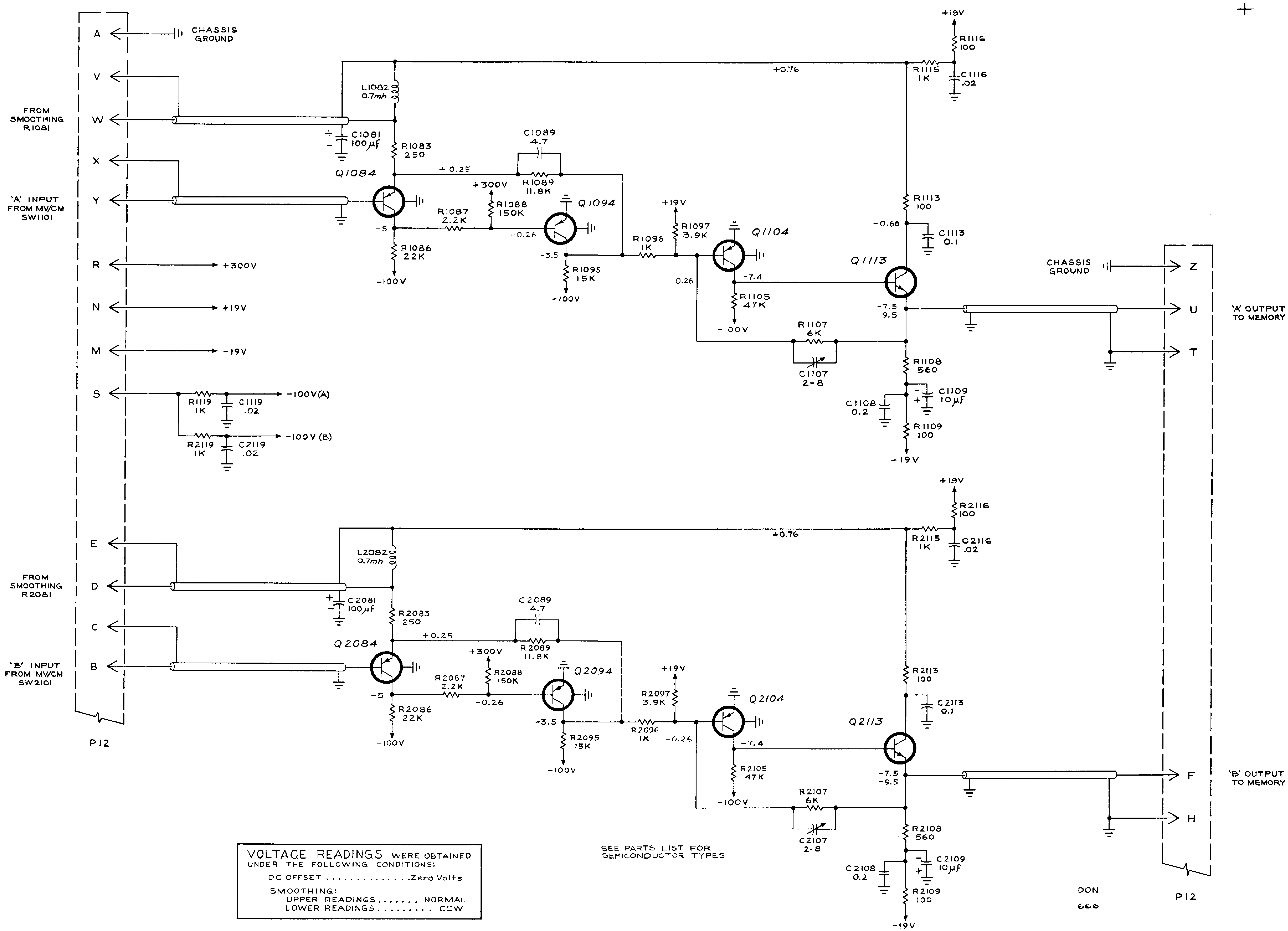
DUAL TRACE ⑥

SERIES 5 MODEL 4



VOLTAGE READINGS WERE OBTAINED UNDER THE FOLLOWING CONDITIONS:

DC OFFSET .... Zero Volts

SMOOTHING:
UPPER READINGS....... NORMAL
LOWER READINGS......... CCW

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

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666

TYPE 4S2A

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AC AMPLIFIER ⟨7⟩

SERIES 2
MODEL 5

FIG. 1 FRONT/GATE & PRE-AMP CIRCUIT BOARDS

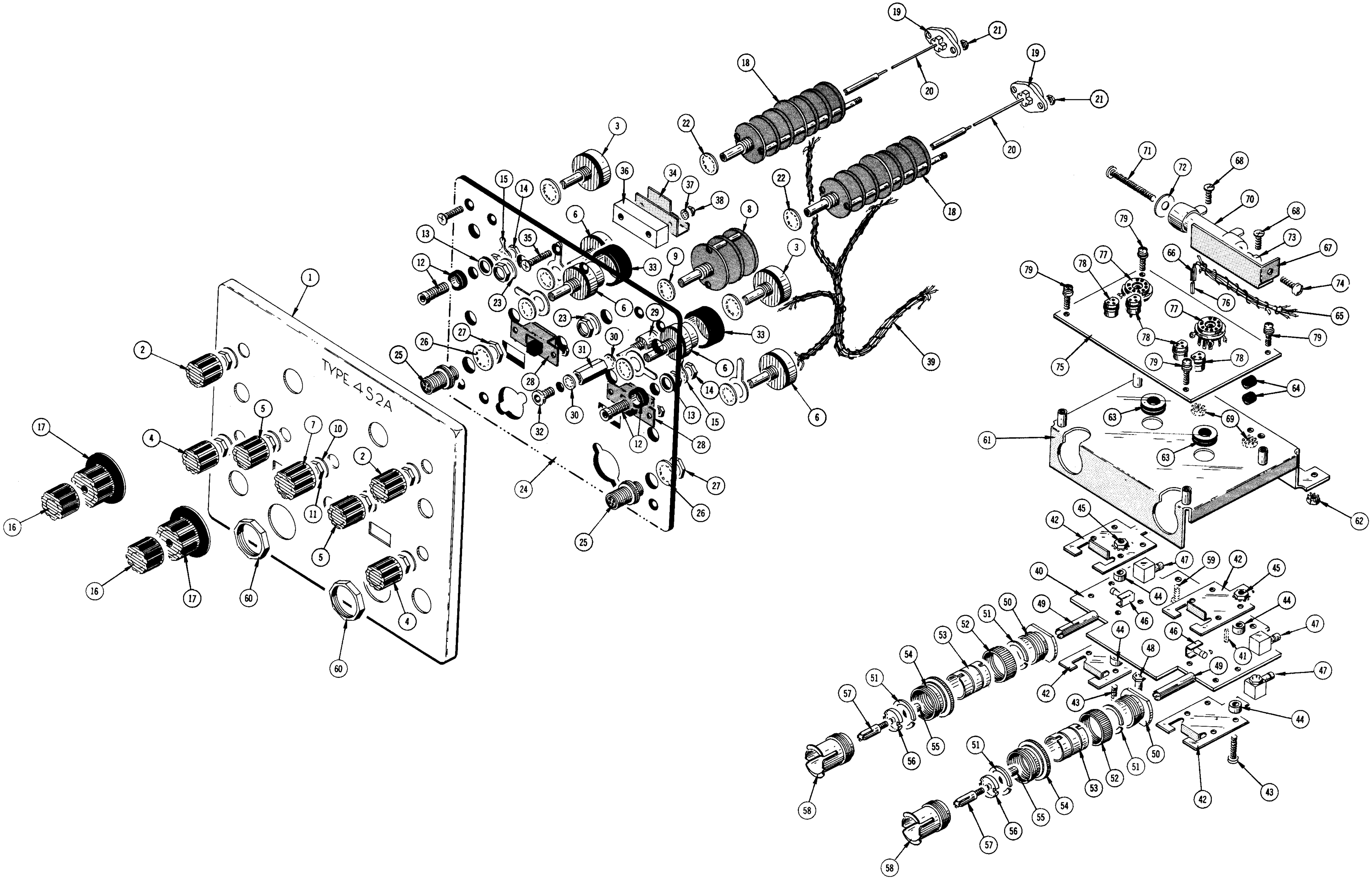


FIG. 2 SIDES & REAR

FIG. 3 PULSE GENERATOR CIRCUIT CARD (SERIES 12)

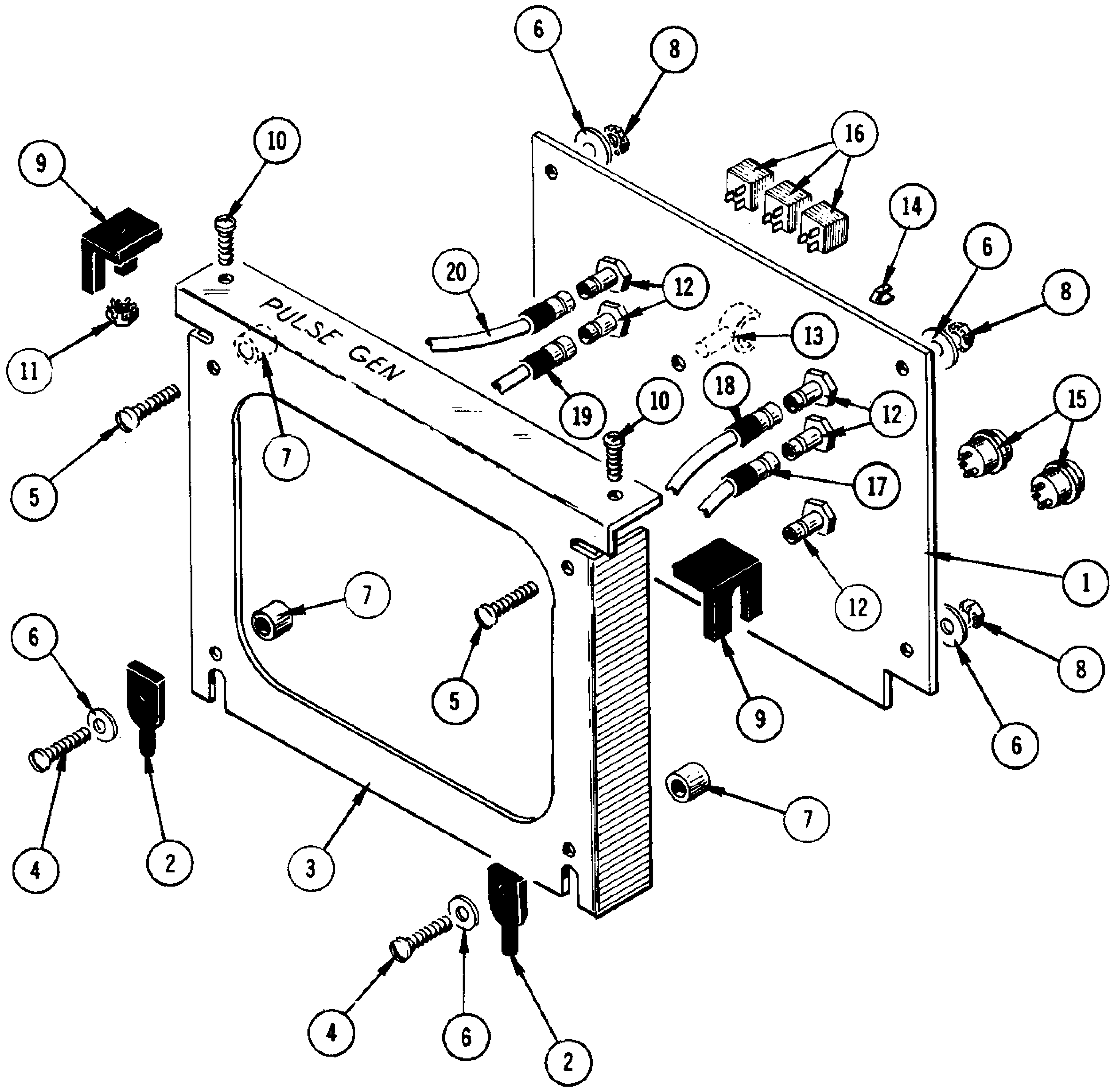
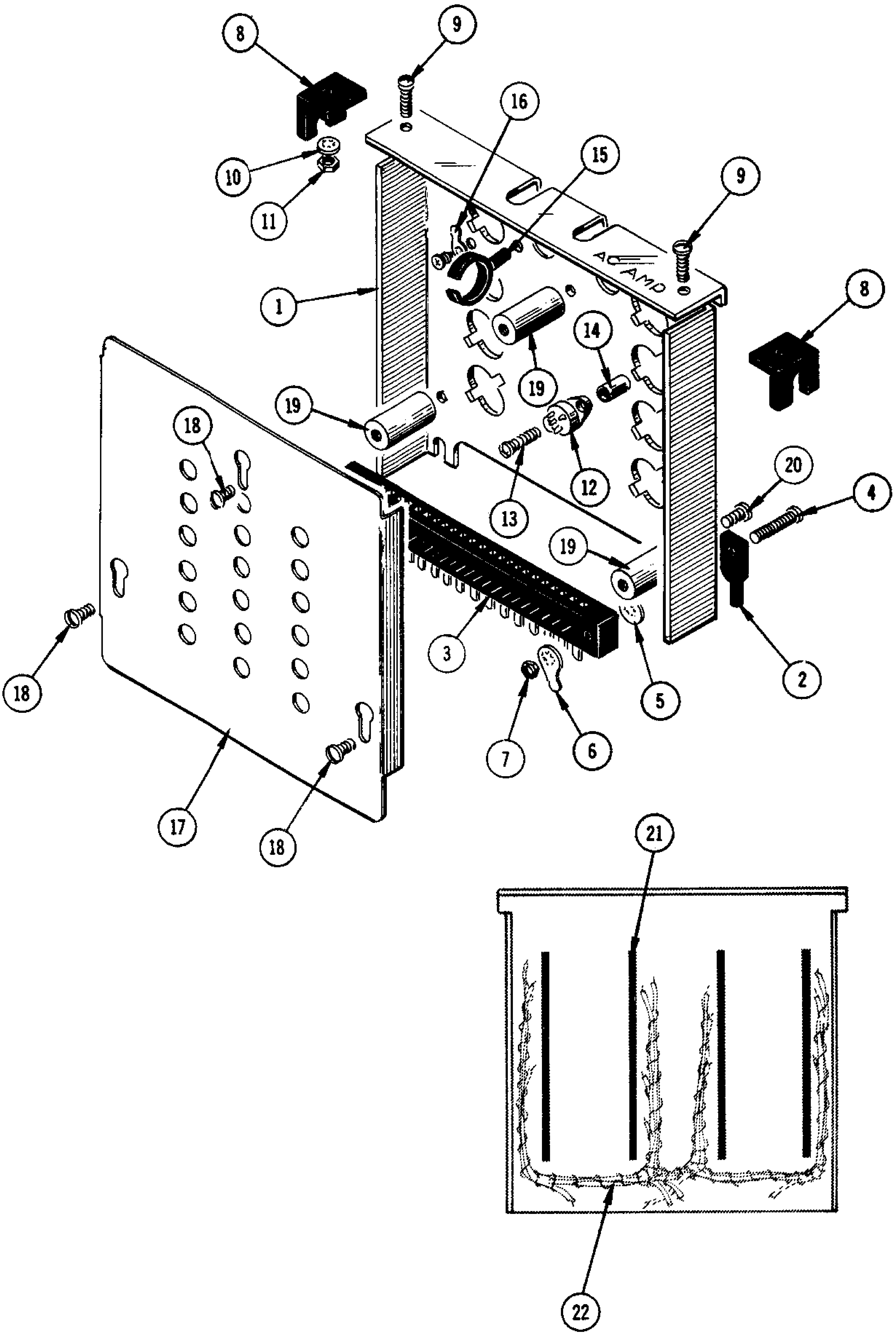
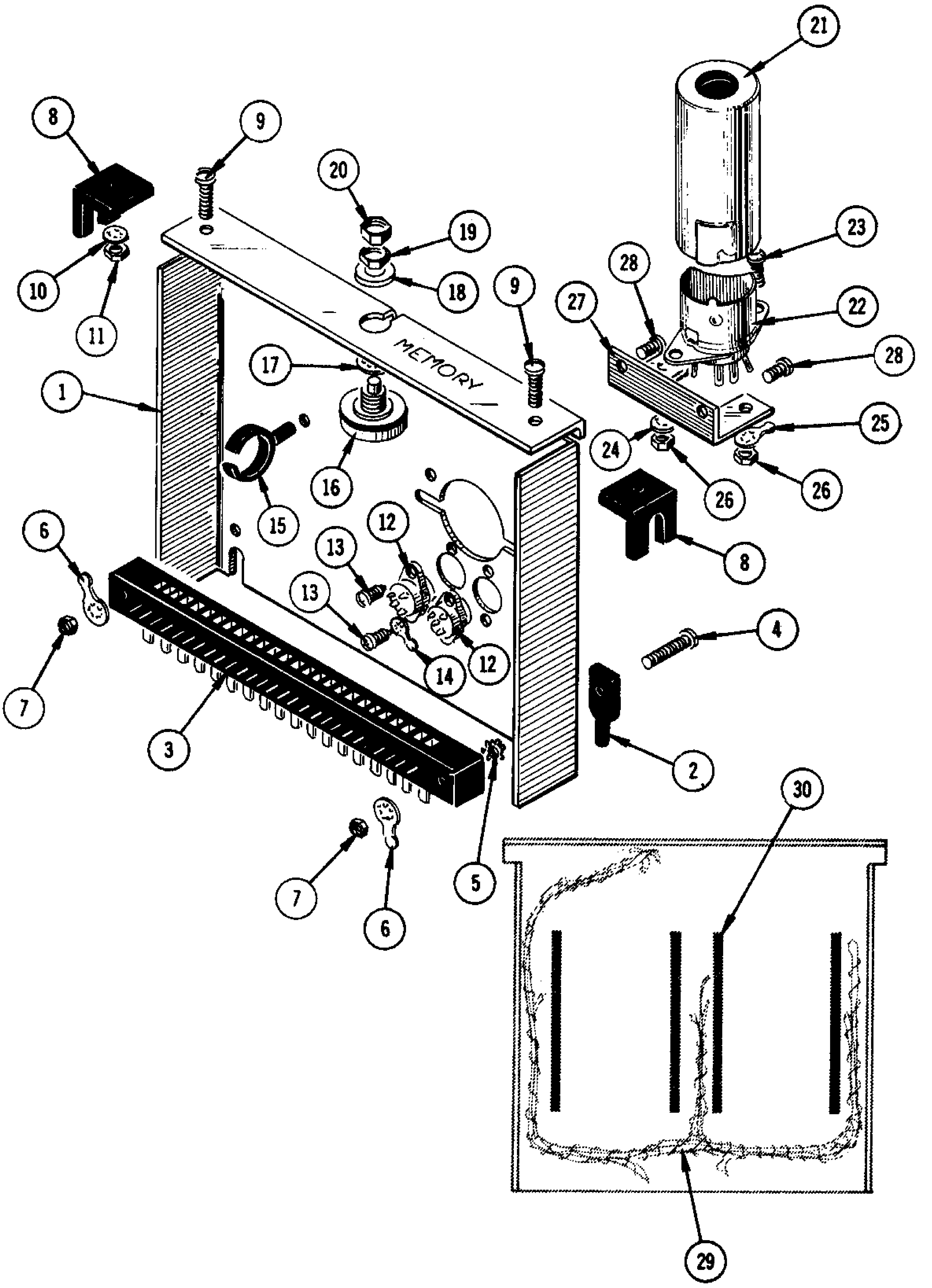


FIG. 4 AC AMPLIFIER PLUG-IN CHASSIS (SERIES 2)





MEMORY
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FIG. 6 INVERTER PLUG-IN CHASSIS (SERIES 9)

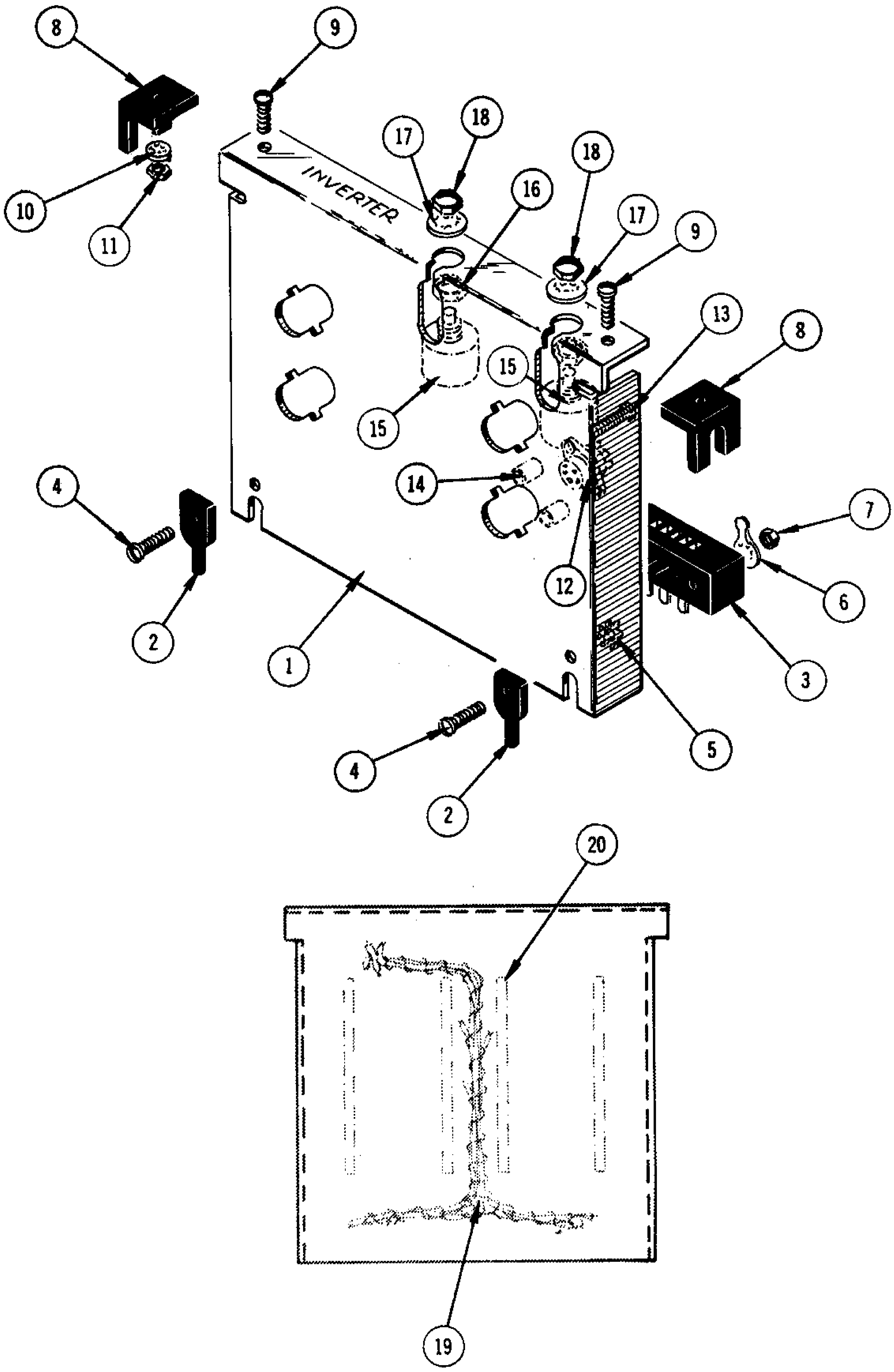
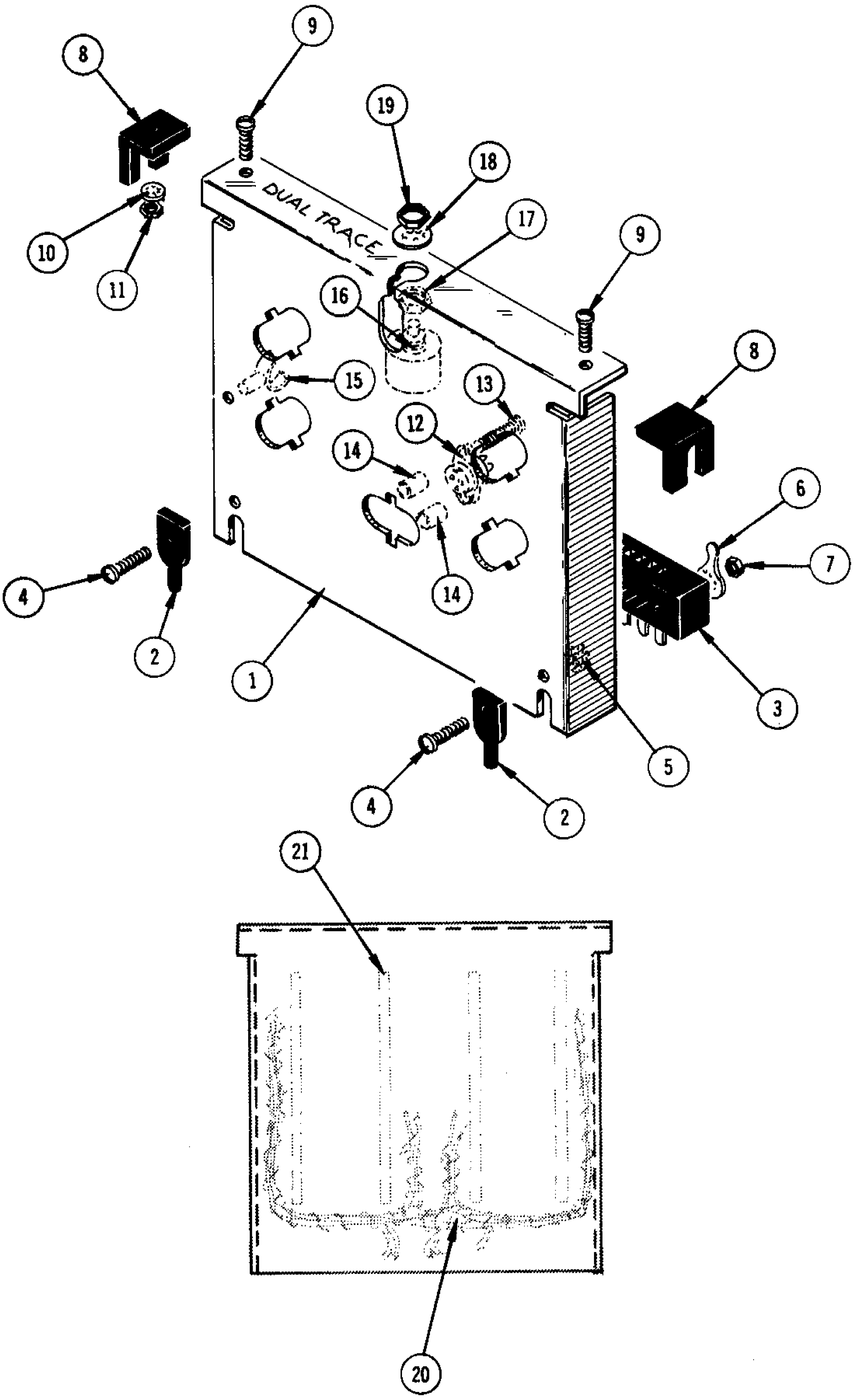
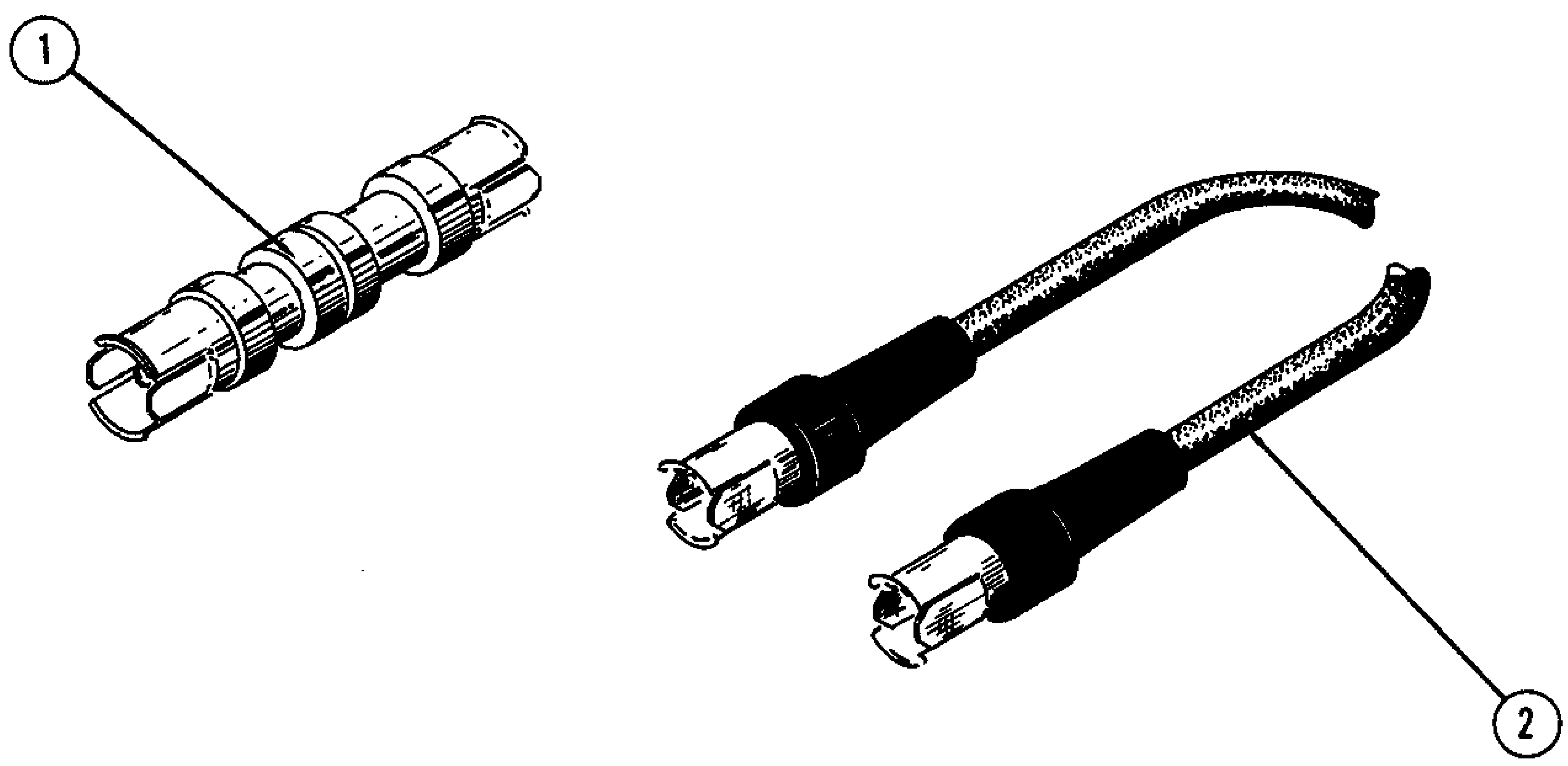


FIG. 7 DUAL TRACE PLUG-IN CHASSIS (SERIES 5)



A

FIG. 8 STANDARD ACCESSORIES



MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Sections of the manual are often printed at different times, so some of the information on the change pages may already be in your manual. Since the change information sheets are carried in the manual until ALL changes are permanently entered, some duplication may occur. If no such change pages appear in this section, your manual is correct as printed.