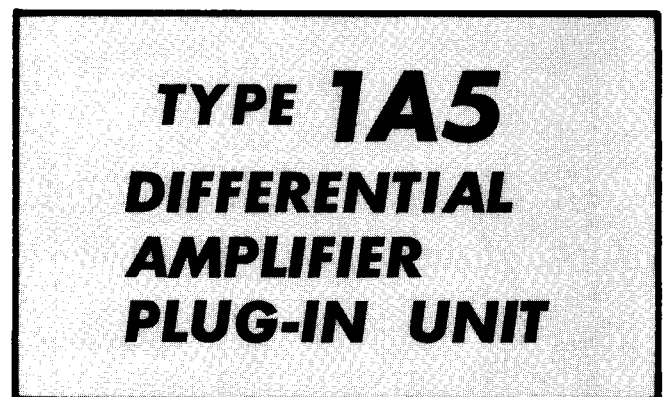


INSTRUCTION MANUAL

Serial Number _____



Tektronix, Inc.

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070-0638-00

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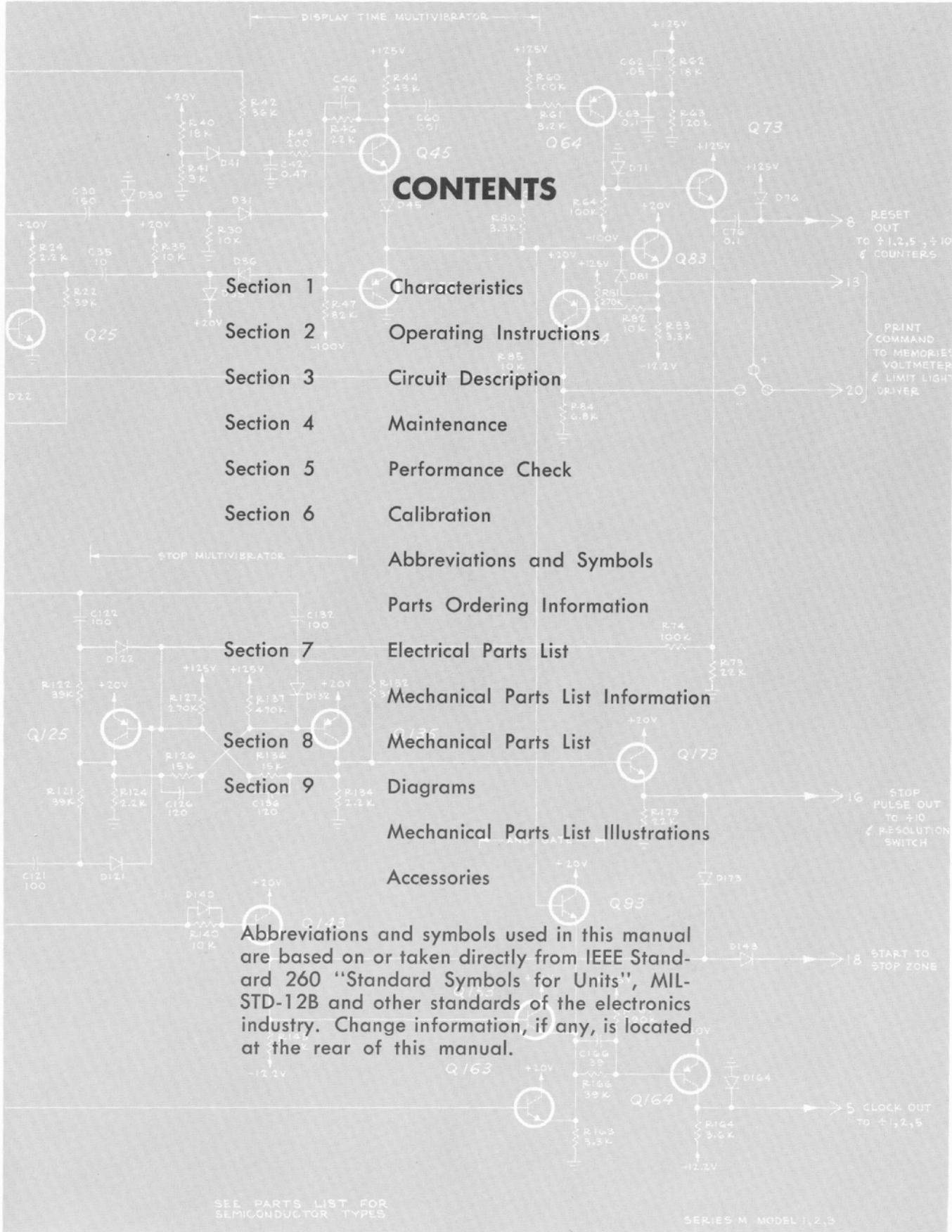
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Abbreviations and symbols used in this manual are based on or taken directly from IEEE Standard 260 "Standard Symbols for Units", MIL-STD-12B and other standards of the electronics industry. Change information, if any, is located at the rear of this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



SEE PARTS LIST FOR SEMICONDUCTOR TYPES

SERIES M MODEL 1,2,3

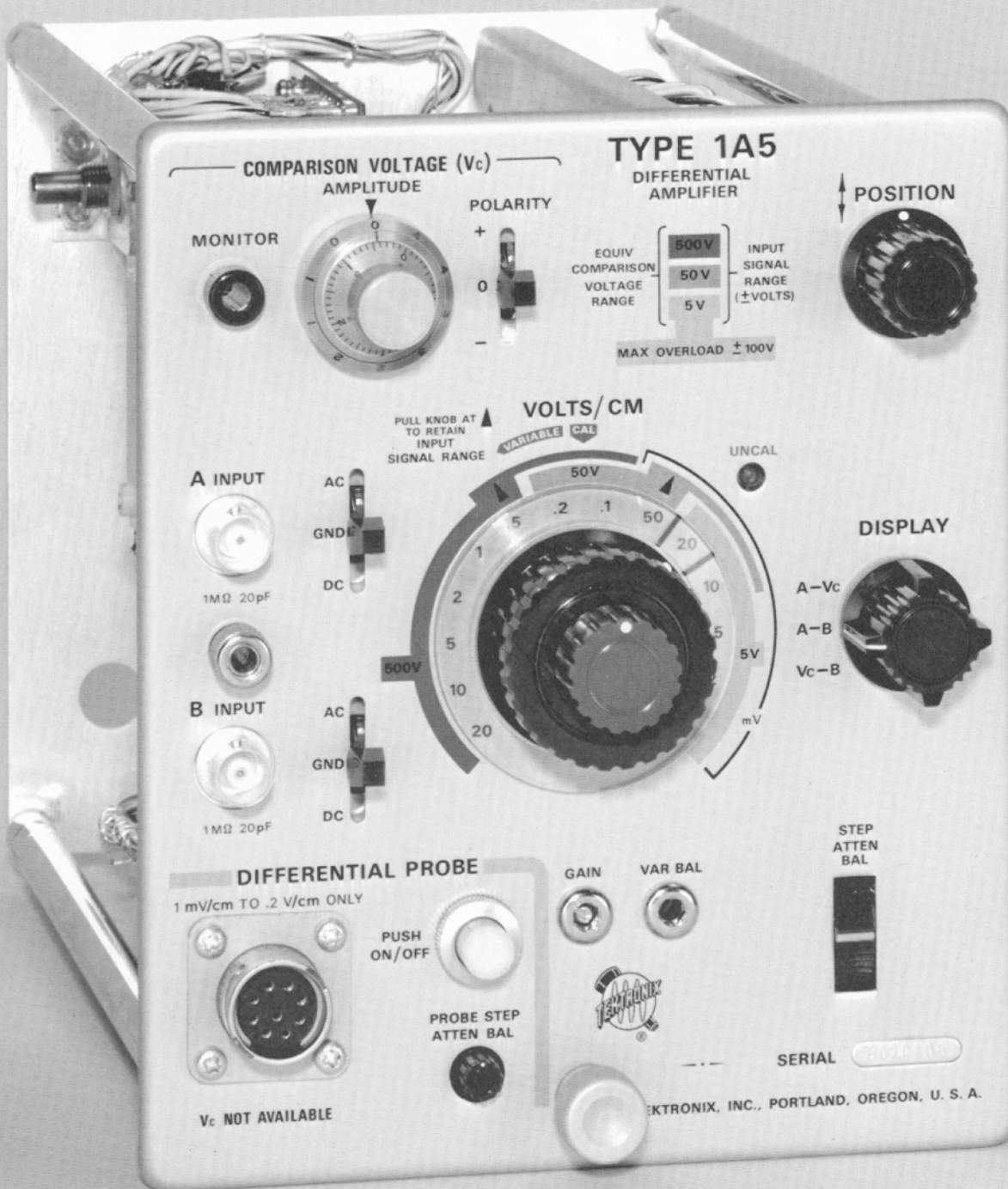


Fig. 1-1. Type 1A5 Differential Amplifier Plug-In Unit.

SECTION 1

CHARACTERISTICS

Introduction

The Type 1A5 Differential Amplifier is a wide band, high gain and high common-mode rejection ratio plug-in unit designed for use in Tektronix Type 544, 546, 547 and 556 Oscilloscopes and their rackmount equivalents. It can be operated in all other 540 series and in all 530, 550 and 580 series oscilloscopes with some reduction in performance.

Flexibility is built into the Type 1A5 Differential Amplifier, in that it can be used with either passive or active probes. The active probe provision enhances the inherently high sensitivity and common mode rejection ratio features of the Type 1A5, by performing differential adding in the probe at the signal source.

Basic capabilities of the Type 1A5 Differential Amplifier (when used with an appropriate oscilloscope) include, but are not limited to, the following:

Passive Probe Inputs

Differential Amplifier Operation: Simultaneous comparison of two signals against each other to determine their algebraic difference.

Conventional Amplifier Operation: Observation and measurement of a signal by comparison against ground reference; referred to as single ended operation.

Differential Comparator Operation: Observation and measurement of a signal by comparison against a calibrated internal DC source.

Active Probe Inputs

Differential Amplifier Operation: Simultaneous comparison of 2 signals against each other to determine their algebraic difference.

Conventional Amplifier Operation: Observation and measurement of a signal by comparison against ground.

ELECTRICAL CHARACTERISTICS

Table 1-1 lists the Type 1A5 Differential Amplifier electrical characteristics. Figure 1-2 illustrates the Type 1A5 common-mode rejection ratio values given in Table 1-1 and also shows the CMRR response curve of a typical Type 1A5.

TABLE 1-1
Electrical Characteristics

Characteristic	Performance Requirement	Supplemental Information
Bandwidth		
DC Coupled		
5 mV/cm to 20 V/cm	DC to ≥ 50 MHz at -3 dB	VOLTS/CM "Knob In" positions
2 mV/cm	DC to ≥ 45 MHz at -3 dB	Also pertains to 20 mV and .2 V Retained Range positions
1 mV/CM	DC to ≥ 40 MHz at -3 dB	Also pertains to 10 mV and .1 V Retained Range positions
AC Coupled		
5 mV/CM to 20 V/CM	≤ 2 Hz to ≥ 50 MHz at -3 dB	VOLTS/CM "Knob In" positions
2 mV/CM	≤ 2 Hz to ≥ 45 MHz at -3 dB	Also pertains to 20 mV and .2 V Retained Range positions
1 mV/CM	≤ 2 Hz to ≥ 40 MHz at -3 dB	Also pertains to 10 mV and .1 V Retained Range positions
Transient Response		
Risetime		
5 mV/CM to 20 V/CM	≤ 7 ns	VOLTS/CM "Knob In" positions
2 mV/CM	≤ 8 ns	Also pertains to 20 mV and .2 V Retained Range positions
1 mV/CM	≤ 9 ns	Also pertains to 10 mV and .1 V Retained Range positions

TABLE 1-1 (cont)

Electrical Characteristics

Characteristic	Performance Requirement	Supplemental Information
Common-Mode Rejection Ratio DC Coupled 1 mV/CM to 20 mV/CM (×1)	≥ 20,000:1, DC to 100 kHz, 0°C to 50°C ≥ 10,000:1, 100 kHz to 1 MHz, 0°C to 50°C; decreasing to ≥ 1000:1 at 10 MHz with a + and -0.5-V signal applied	See Fig. 1-1 + and -5-V signal applied
	≥ 200:1 at 20 MHz	+ and -0.25-V signal applied
	10 mV/CM to 2 V/CM (×10, ×100)	≥ 2000:1, DC to 10 kHz
5 V/CM to 20 V/CM (×1000)	≥ 100:1, DC to 10 kHz	
AC Coupled 1 mV/CM to 20 mV/CM (×1)	≥ 1000:1 at 60 Hz	+ and -5-V signal applied
Vertical Deflection Factor (VOLT/CM) Range	1 mV/CM to 20 V/CM in 1-2-5 sequence	
Accuracy 1 mV/CM to 20 mV/CM (×1)	±2%, 25°C within ±10°C ±2.5%, 0°C to +50°C	
10 mV/CM to 20 V/CM (×10, ×100, ×1000)	±2.5%, 25°C within ±10°C ±3%, 0°C to +50°C	
Common-mode Dynamic Range (Input Signal Range) 1 mV/CM to 20 mV/CM (×1)	≥ ±5 V DC + peak AC	
10 mV/CM to .2 V/CM (×10)	≥ ±50 V DC + peak AC	
.1 V/CM to 20 V/CM (×100, ×1000)	≥ ±500 V DC + peak AC	
DC Drift With Time Long Term	≤ 200 μV/hour at 25°C	
Short Term	≤ 200 μV/min at 25°C	
With Temperature	≤ 200 μV/°C	
With Line Voltage	≤ 300 μV (105 V AC to 125 V AC)	
DC Shift Due to Overdrive	≤ 1% of + or - overdrive signal or ≤ 10 mV, whichever is smaller	
Overdrive Recovery Time	Within 10 mV of DC shifted level after 1 μs	
Attenuator Crosstalk 1 mV/CM to 20 mV/CM	≤ 1%, DC to 50 MHz	+ and - 5-V signal applied
10 mV/CM to .2 V/CM	≤ 1%, DC to 50 MHz	+ and - 50-V signal applied (10 mV and 20 mV Retained Range positions)
Total Crosstalk	≤ 5%, DC to 50 MHz	
Noise	≤ 50 μV RMS	
Microphonics	≤ 100 μV	
Input Characteristics DC Resistance	1 MΩ ±0.15% (1 mV/CM to 20 V/CM)	
Time Constant	Normalized with 20 pF normalizer for ≤ 1% overshoot, rounding or tilt of Type 106 1 kHz square wave.	
Maximum Input Voltage 1 mV/CM to 20 mV/CM	±100 V DC + peak AC	Also applies to maximum allowable difference between A and B INPUT voltages.
10 mV/CM to 20 V/CM	±500 V DC + peak AC	Applies to 10 mV/CM and 20 mV/CM only in Retained Range positions of VOLTS/CM control.

TABLE 1-1 (cont)
Electrical Characteristics

Characteristic	Performance Requirement	Supplemental Information
Gate Current	≤ 0.1 nA at 25°C ≤ 1.0 nA at 50°C	
COMPARISON VOLTAGE (Vc) 1 mV/CM to 2 V/CM Range	0 V to + or - 5 V	
Accuracy	within ± 5 mV or $\pm 0.5\%$ of indicated voltage, whichever is greater (0°C to 50°C)	
5 V/CM to 20 V/CM Range	0 V to + or - 0.5 V	
Accuracy	± 1 mV or $\pm 1\%$ of indicated voltage, whichever is greater (0°C to +50°C)	
Control Range VARIABLE VOLTS/CM	$\geq 2.5:1$	
POSITION	≥ 12 cm	
STEP ATTEN BAL	≥ 20 mV ($\times 1$)	

MECHANICAL CHARACTERISTICS

The Type 1A5 Differential Amplifier is 14½ inches long, 4¼ inches wide and 6¼ inches high. It is designed to fit all Tektronix one-series plug-in compartments and is held in place by a threaded shaft connected to a front-panel knob. Ventilation for the Type 1A5 is provided by the oscilloscope ventilating system. All of the controls used in operating the Type 1A5 are accessible at the front-panel. An anodized finish is used to provide a durably attractive appearance.

ACCESSORIES

Standard accessories supplied with the Type 1A5 Differential Amplifier consist of two manuals.

The P6046 Active Differential Probe has been designed for use with the Type 1A5 Differential Amplifier. Information regarding it can be obtained from your Tektronix Field Engineer or Field Office.

Additional accessories are listed in the Tektronix, Inc., catalog.

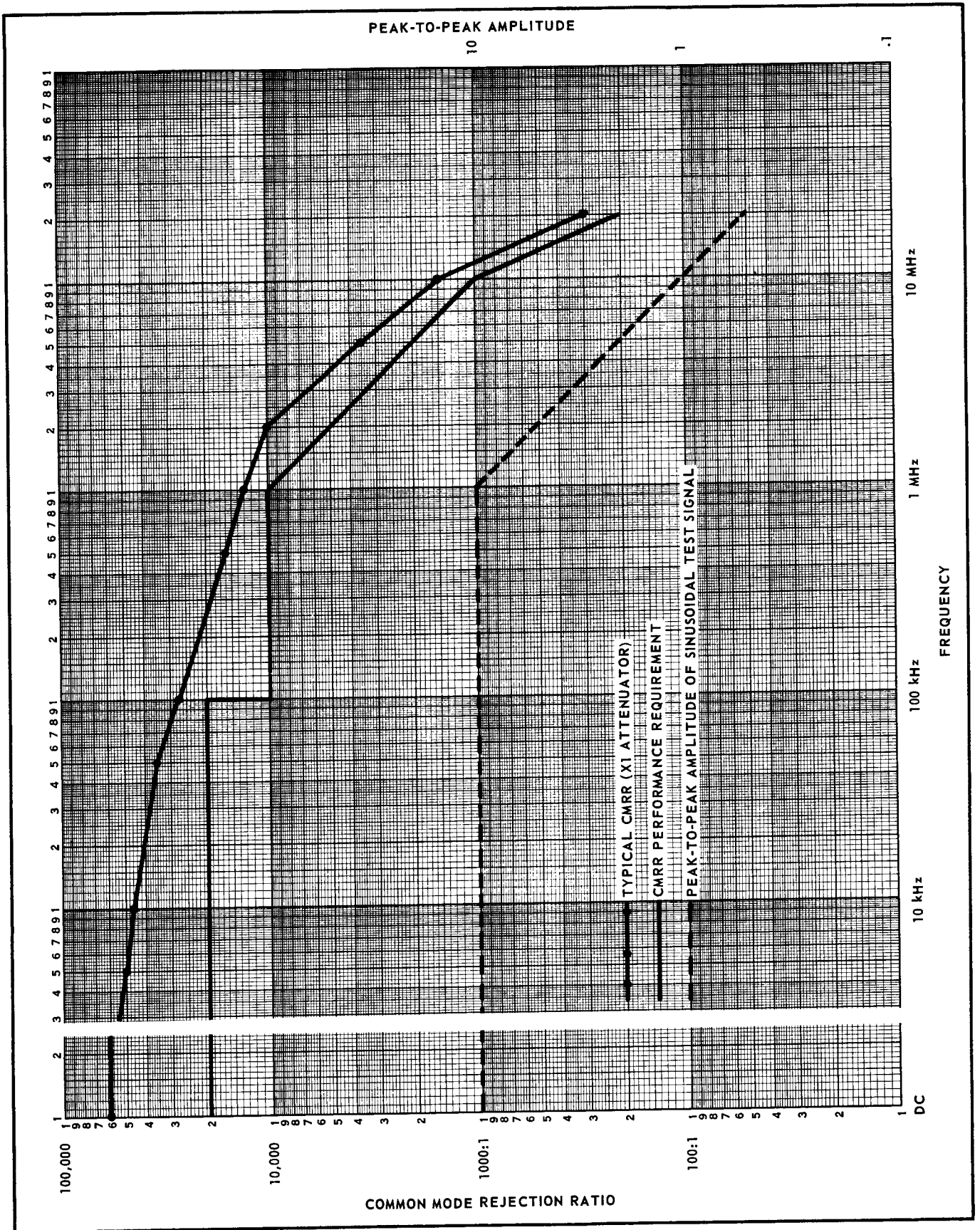


Fig. 1-2. Type 1A5 common-mode rejection ratio graph. Pertains to 1 mV/CM through 20 mV/CM sensitivities.

SECTION 2

OPERATING INSTRUCTIONS

Introduction

This section contains a description of differential amplifiers in general, of the Type 1A5 Differential Amplifier controls, connectors and indicators, and of the Type 1A5 Differential Amplifier operation.

GENERAL DIFFERENTIAL AMPLIFIER INFORMATION

An oscilloscope with a differential amplifier is a device that amplifies and displays a voltage difference that exists at every instant between signals applied to its two input channels. The following conclusions can be drawn from this definition when two signals are applied to the input of a differential amplifier.

1. If two signals are in phase and of equal amplitude (hereafter called common-mode), the output will be zero.
2. If the two signals are in phase but of different amplitudes the output will equal the amplitude difference.
3. If the two signals are out of phase and of equal amplitude the output will be the phasor difference between the two signals. (Sinusoidal signals.)
4. If the two signals are out of phase and of different amplitude the output signal is a complex quantity derived from both amplitude and phase differences.

Common Mode Rejection

The definition of the term "differential amplifier" implies a rejection of equal amplitude, coincident signals. This implication is correct. However, the degree of rejection depends primarily on the symmetry of the amplifier inputs. The amount of difference signal contributed by a particular amplifier at a specific frequency is documented with a mathematical relationship that is called the common-mode rejection ratio (CMRR). This ratio and associated terms are defined as follows:

Common Mode: Refers to signals that are identical in both amplitude and time. It is also used to identify the respective parts of two signals that are identical in amplitude and time.

Common-Mode Rejection: The ability of a differential amplifier to reject common-mode signals.

Common-Mode Rejection Ratio (CMRR): The ratio of the amplitude of the common-mode input signal to the difference input signal which would produce the same deflection on the CRT screen.

NOTE

Since the differential amplifier is part of an oscilloscope, the output signal used to calculate the CMRR is measured from the CRT screen and VOLTS/CM switch setting. Thus, a differential amplifier that produces a .001 volt output when

driven by a 10 volts peak to peak common-mode signal has a CMRR of $10 \div .001$ or 10,000:1.

Amplitude and Common-Mode Rejection

In the text which follows, the term "Input Signal Range" means the common-mode operating range of voltage through which the amplifier will produce a useable output. This should not be confused with the maximum (non-destructive) input voltage, which is related to the breakdown limits of the amplifier components.

Factors Which Affect CMRR

Frequency: Since the common-mode output voltage is a factor of phase differences as well as gain between channels, the frequency of the input common-mode signal has a direct bearing on the CMRR. Generally, as the frequency of the input signal increases, the CMRR decreases. (Exception: with AC-coupled input the CMRR will become higher as frequency is increased from DC to over 100 Hz.)

Source Impedance: The specified CMRR assumes that the points being measured have identical source impedance. The source impedance and the amplifier input impedance form an RC divider which determines the portion of the signal that appears across the amplifier input, and the apparent effect on CMRR. See Fig. 2-2 and 2-3.

The user may desire to construct a similar graph of CMRR versus frequency for specific applications where the source or signal transporting lead impedances are unbalanced. Fig. 2-4 is therefore included.

Signal Transporting Leads: A principle requirement for maximum CMRR is that the signals arrive at the amplifier's two inputs with no change in phase or amplitude. Slight differences in attenuation factors, or phase shift between two input attenuators may reduce the CMRR 20% or more.

Attenuator probes extend the usable voltage range of a differential amplifier by reducing the input signal level below the maximum common-mode input voltage. However, a reduction in the apparent CMRR will usually occur because of component value differences within the probes. For example, Fig. 2-5 illustrates the change in CMRR (apparent) due to $\times 10$ probes that are within 1, 2, and 3% of their attenuation value.

In measurements where attenuator probes must be used because of high voltage levels, and at the same time a high (above 100:1) CMRR must be maintained, the Tektronix Type P6023 Probe is recommended. The attenuation factor of this $\times 10$ low capacitance probe is adjustable over a $\pm 2.5\%$ range.

Ground Connections: Proper grounding reduces signals generated from ground loop currents. It is usually best to electrically connect the probe or signal lead shields together at the probe body or signal source, but not to the instrument ground. See Fig. 2-6.

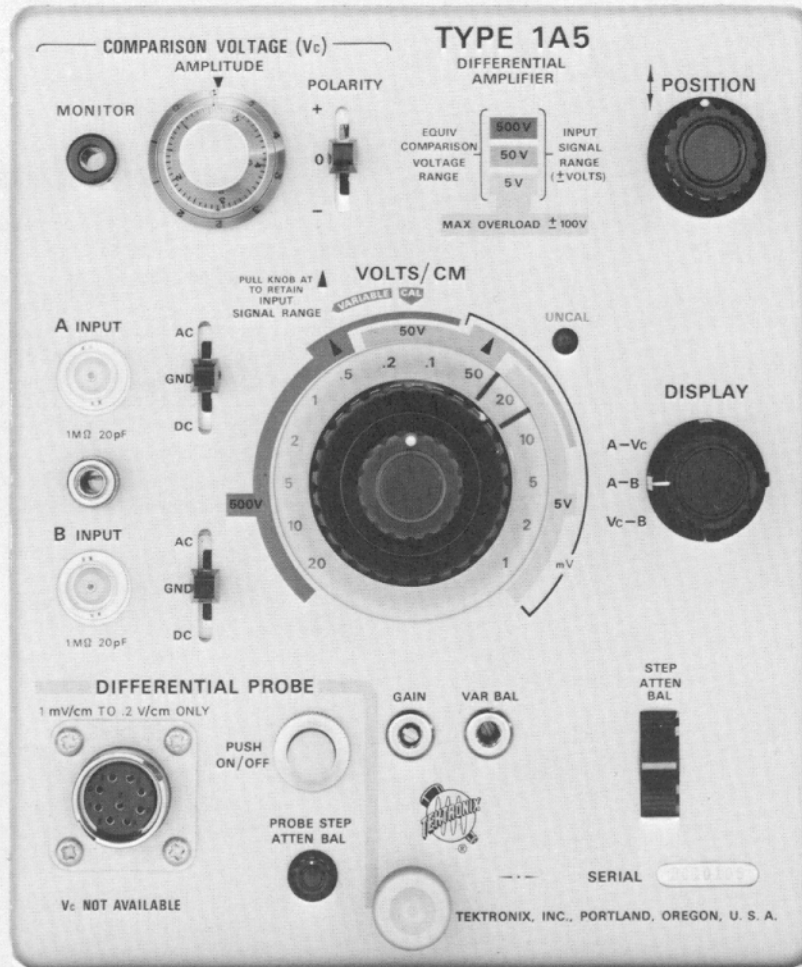


Fig. 2-1. Type 1A5 front panel.

Differential Amplifier Applications

In differential measurements, each input to the amplifier acts as a reference for the other, and ground connections are only used for safety reasons. Fig. 2-7 illustrates a typical differential measurement application.

In applications such as examining a signal superimposed on some DC level with DC coupling, an offset voltage may be applied to the other input of the differential amplifier to slide the signal back on the CRT screen. For example, if a differential amplifier is set for a vertical sensitivity of 10 mV/cm (trace on-screen) and a +1 volt DC voltage is applied to input A, the trace will be deflected upward off screen. If a +1 volt DC voltage is now applied to input B, the trace will return on screen, or the signal will slide back on screen as a result of the voltage (slide-back voltage) applied to input B. The DC voltage applied to input B is, in effect, common-mode with that of input A; thus, both are rejected by the amplifier.

TYPE 1A5 FRONT PANEL CONTROLS, CONNECTORS and INDICATORS

Figure 2-1 illustrates the controls, connectors and indicators of the Type 1A5 Differential Amplifier. The following information describes their purpose and use.

COMPARISON VOLTAGE (V_c)

MONITOR	A banana jack making selected V _c available for external monitoring.
AMPLITUDE	Sets absolute value of V _c (5 V maximum) to be applied to A or B channel when selected by DISPLAY switch. The actual V _c value must be multiplied by the attenuation factor in use to determine the equivalent input voltage represented. See Fig. 2-8 and the explanation which accompanies it.
POLARITY POSITION	Establishes polarity of V _c , or sets V _c to 0. Controls vertical position of trace on CRT. Used to set DC reference.
A INPUT	BNC connector. A positive signal applied causes an upward deflection.
B INPUT	BNC connector. A positive signal applied causes a downward deflection.
AC-GROUND-DC	Selects input coupling method, or grounds input of corresponding channel.
VOLTS/CM	Selects calibrated vertical deflection factor of CRT display. 14 positions with knob in. 4 positions with knob out (Retained Range position). Controls Input Signal Range as indicated by color coding. Maximum allowable input voltage changes between the 20 and 50 mV/CM positions. See Fig. 2-9.
VARIABLE	Varies deflection factor between calibrated settings. Lights UNCAL lamp when out of CAL detent.

UNCAL	Lights whenever VARIABLE control is out of CAL detent.
DISPLAY	Three position selector switch. Connects A or B INPUT signal to corresponding amplifier channel and V _c to opposite one (A-V _c ; V _c -B), or simultaneously couples each input to its corresponding amplifier channel (A-B).
GAIN	Screwdriver adjustment for calibrating vertical deflection factor.
VAR BAL	Variable Balance Adjustment. Screwdriver adjustment for minimum trace shift accompanying VARIABLE gain change.
STEP ATTEN BAL	Thumbwheel adjustment for minimum trace shift accompanying VOLTS/CM selector position changes.
DIFFERENTIAL PROBE	Usable in 1 mV/CM to .2 V/CM positions of VOLTS/CM switch only.
PUSH ON/OFF	Selects DIFFERENTIAL PROBE or conventional A INPUT/B INPUT operation. Disabled when VOLTS/CM switch selects .5 V/CM or a less sensitive vertical deflection factor. Built in lamp indicates when DIFFERENTIAL PROBE operation is selected.
PROBE STEP ATTEN BAL	Adjustment for minimum trace shift when switching VOLTS/CM control between 20 mV and 1 mV.
Differential Probe Connector	Couples signal and supply voltages between Differential Probe and 1A5. Voltages are always present when Type 1A5 is energized.

Comparison Voltage AMPLITUDE Control

This unit is made up of a graduated knob connected to a ten turn potentiometer and a movable outer ring dial, both of which are read against a scribe mark on a stationary ring which separates the two. See Fig. 2-8A.

NOTE

Refer to the front panel of a Type 1A5 Differential Amplifier to follow the color-related description presented here.

The large dial represents volts, and moves one graduation after each revolution of the knob, alternately aligning black and red numbers with the stationary scribe mark. The color opposite the scribe mark indicates the color which must be read from the graduated knob.

The numbered graduations on the knob represent tenth of volt positions and increase the value indicated by the outer ring dial. Graduations between numbered positions on the knob represent hundredths of volts.

The AMPLITUDE control can provide a +5 to -5 volt range to the selected amplifier channel and to the MONITOR jack in all except the 5, 10 and 20 V/CM positions of the VOLTS/CM control. In the excepted positions a

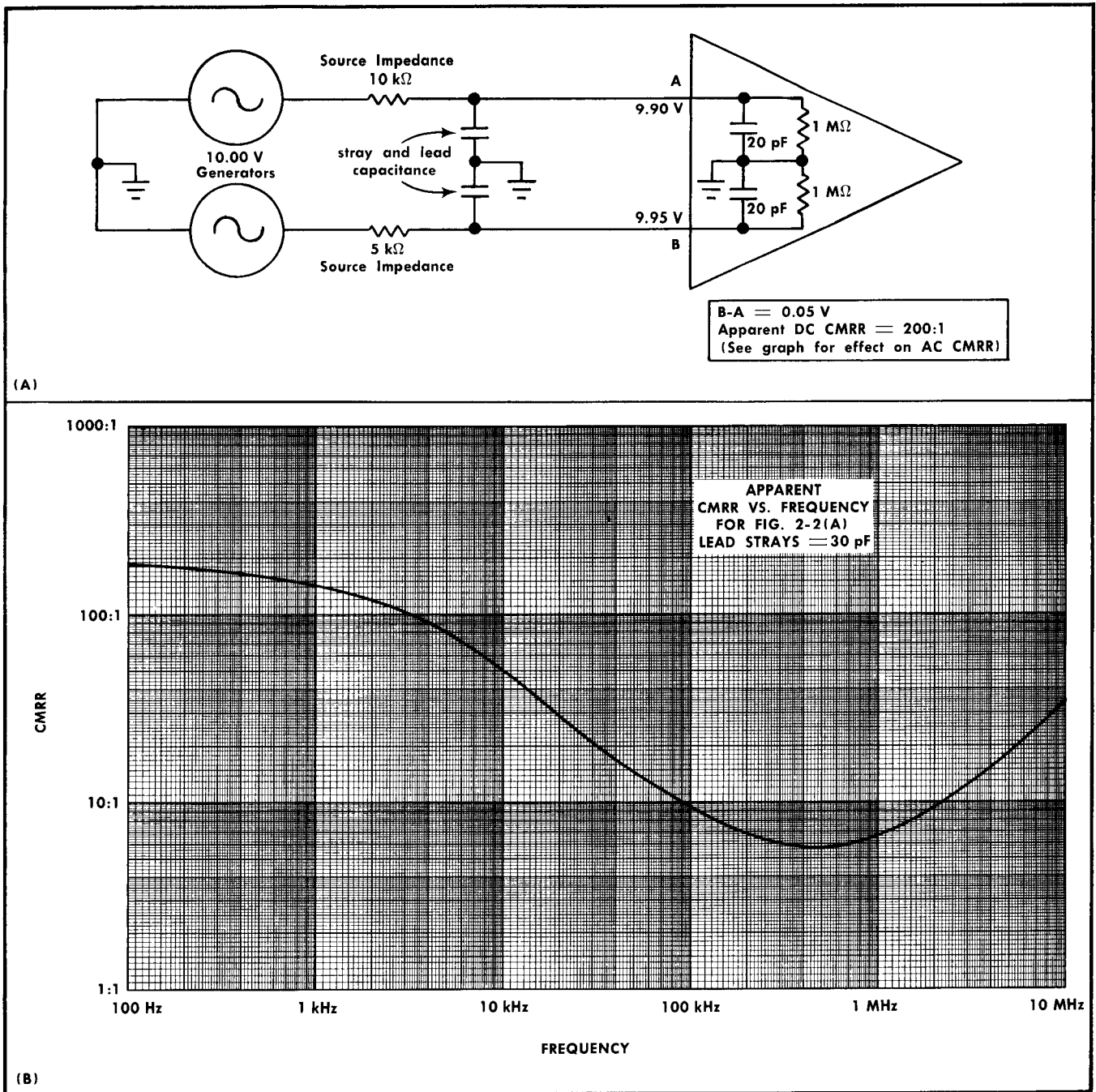


Fig. 2-2. The effect of difference in source impedance upon apparent CMRR. (High impedance sources.)

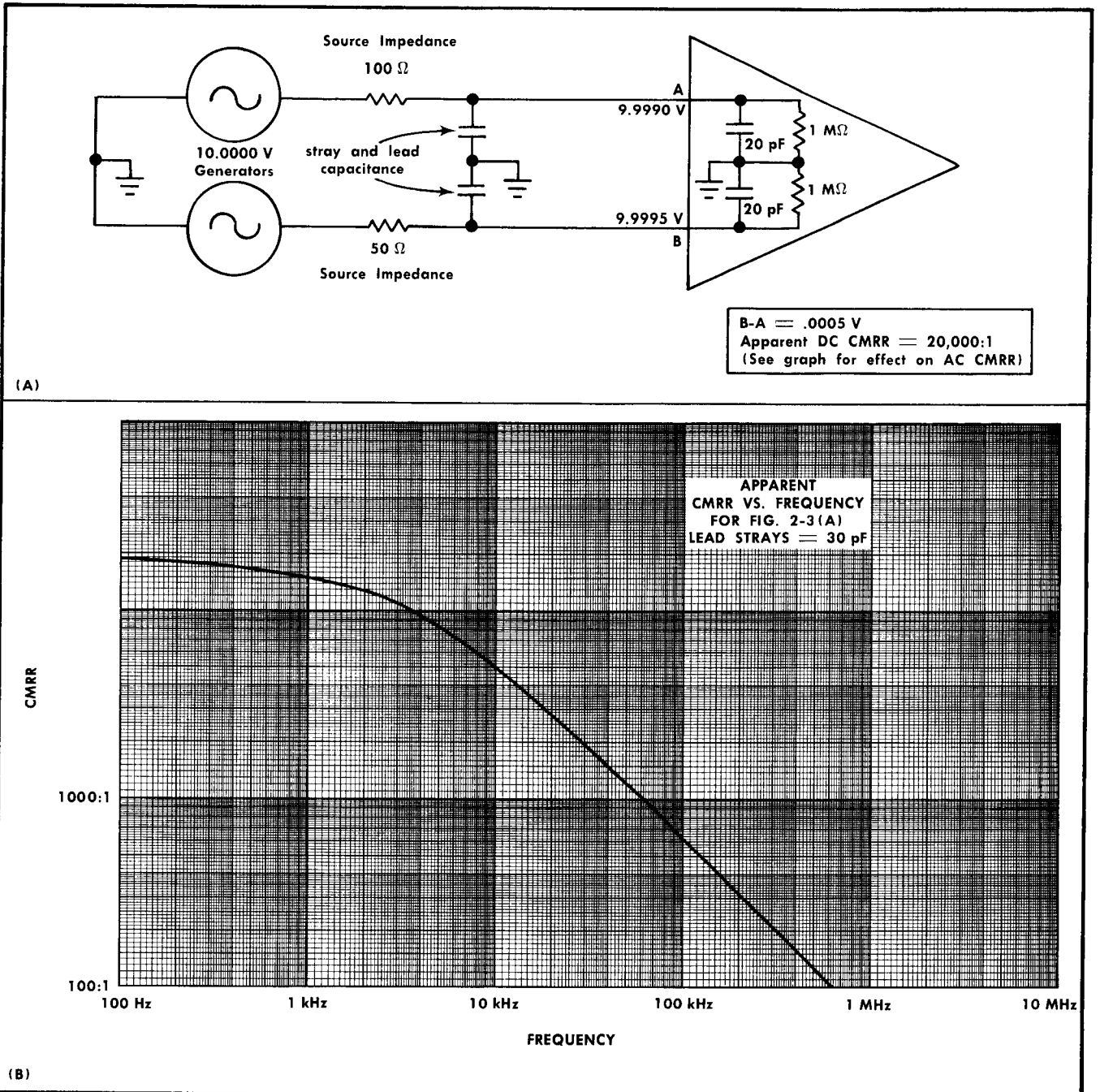


Fig. 2-3. The effect of difference in source impedance upon apparent CMRR. (Low impedance sources.)

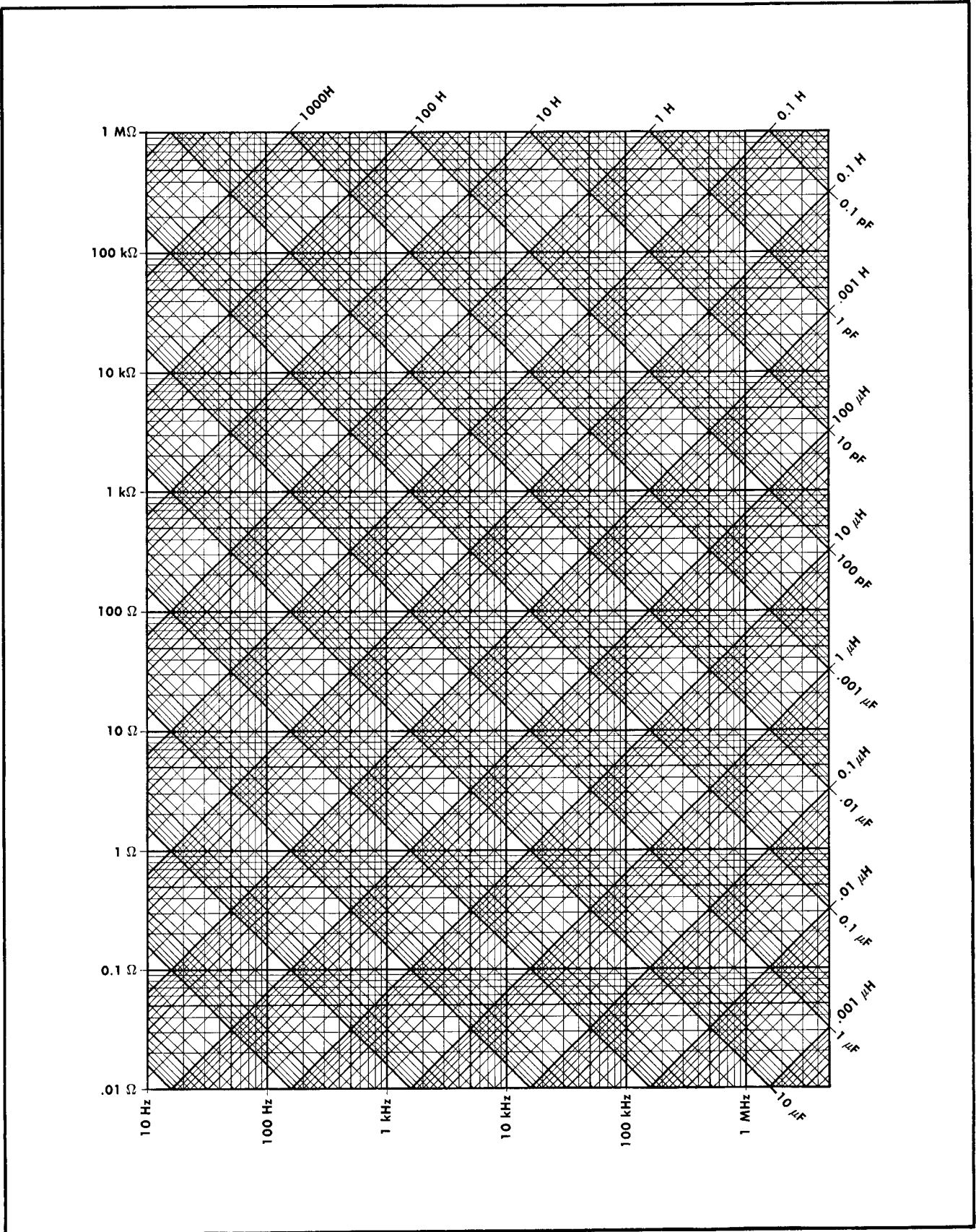


Fig. 2-4. Capacitive and inductive reactance versus frequency.

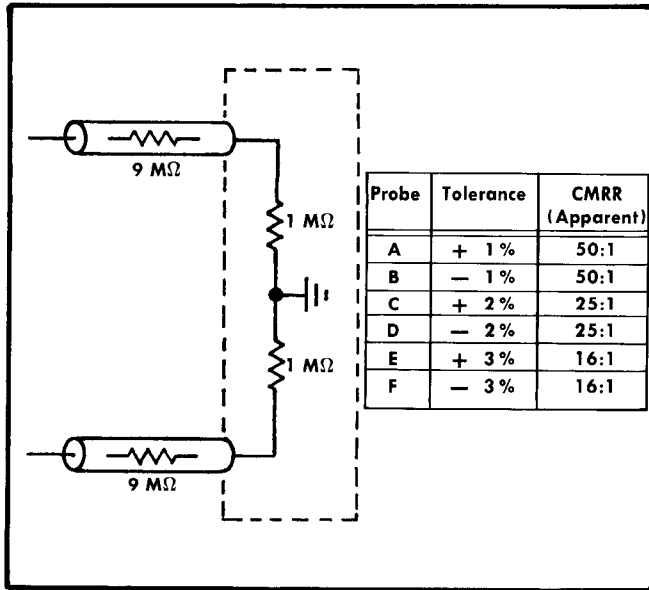


Fig. 2-5. Simplified input circuit and table to show the change in CMRR (apparent) due to $\times 10$ probes that are within 1, 2, and 3% of their attenuation values.

voltage divider reduces the output range to ± 0.5 V to keep the Equivalent Comparison Voltage Range consistent with the maximum input voltage range. To determine the actual voltage present in these three positions, read the Vc AMPLITUDE dials as instructed and divide the results by 10.

The Vc is applied directly to the input amplifier within the Type 1A5. Because it by-passes the attenuator, it is equivalent to an input signal which is the product of Vc and the attenuator in use. In the 1, 2, 5, 10 and 20 mV/CM positions it is equivalent to a ± 5 -V range of input signals because a $\times 1$ attenuation factor is in effect. The $\times 10$ attenuator in the 50 mV, .1 and .2 V/CM positions makes it equivalent to a ± 50 -V input voltage range, and the $\times 100$ attenuator in the .5, 1 and 2 V/CM positions provides an equivalent range of ± 500 V. Since the Vc range is reduced to ± 0.5 V in the 5, 10 and 20 V/CM sensitivity positions, the $\times 1000$ attenuator in use again provides an equivalent range of ± 500 V.

The equivalent voltage ranges just explained are indicated through color-coding on the front panel of the Type 1A5. This color coding is explained in conjunction with the VOLTS/CM control assembly.

All Vc settings in this manual are written as three digits separated by hyphens. Samples of this method are illustrated in Fig. 2-8B, C and D.

VOLTS/CM Control Assembly

The setting of the VOLTS/CM control assembly determines the deflection factor, the Input Signal Range, the Equivalent Comparison Voltage Range and the maximum input voltage of the Type 1A5.

Refer to Fig. 2-9A. The large gray knob is attached to a shaft which controls the gain of the output stages of the Type 1A5. A white dot on this knob indicates the deflec-

tion factor of the Type 1A5 and oscilloscope combination at any instant.

The clear plastic flange between the gray knob and the front panel of the Type 1A5 is connected to an intermittent drive planetary gearing which simultaneously switches attenuators in the A and B INPUT circuits. Attenuator

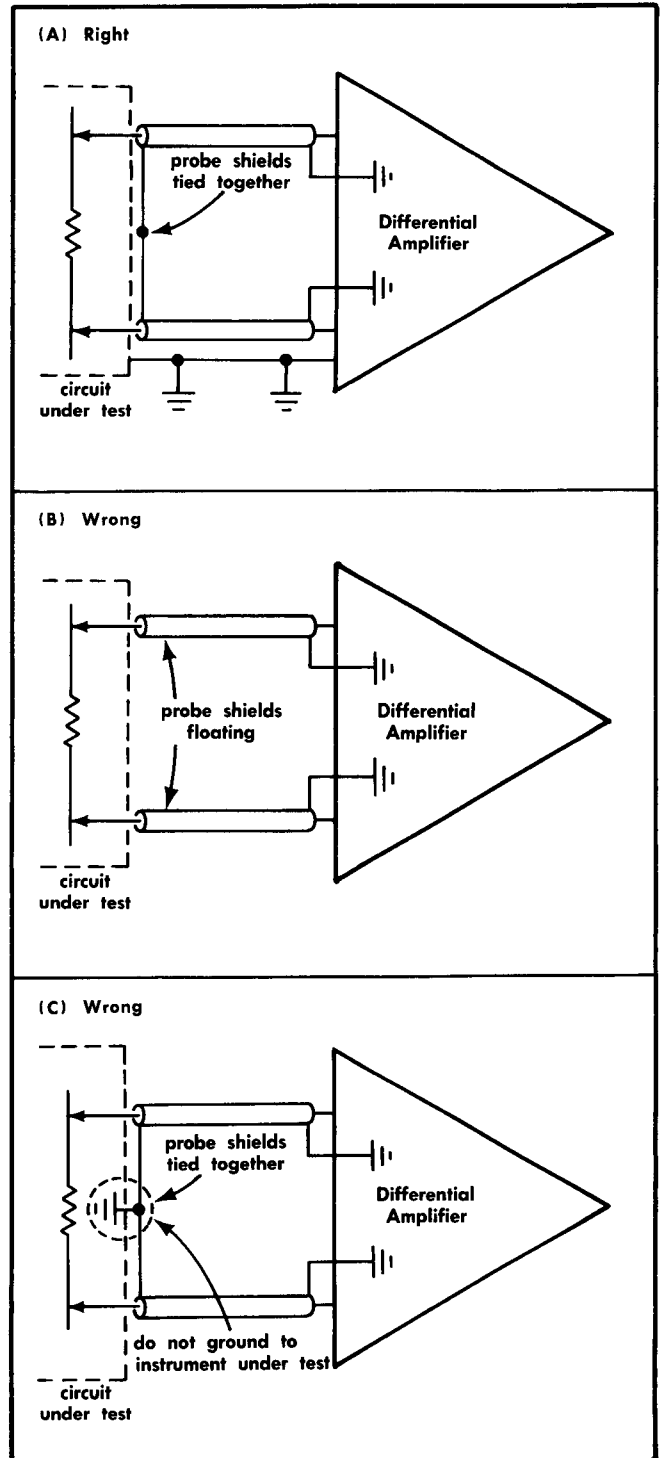


Fig. 2-6. Connecting a differential amplifier across a circuit. The ground shown in (C) is not essential to the measurement.

Operating Instructions—Type 1A5

switching occurs between the 20 mV and 50 mV positions (from $\times 1$ to $\times 10$); between the .2 V and .5 V positions (from $\times 10$ to $\times 100$); and between the 2 V and 5 V positions (from $\times 100$ to $\times 1000$).

Three differently shaded green arcs are printed adjacent to the attenuator switching flange. The specific shade bracketed by the two black radial lines (range indicators) on the range indicator flange indicates the attenuator in use, the Input Signal Range, the Equivalent Comparison Voltage Range and the maximum input voltage range in effect at any instant. The color translation is given in Table 2-1.

For convenient reference, the Input Signal Range and the Equivalent Comparison Voltage Range translations are printed on the green arcs and on the separate color coding explanation near the top right of the Type 1A5 front panel.

CAUTION

The difference between the voltages into the A and B INPUT connectors must never exceed the Maximum Input Voltage Range given in table 2-1.

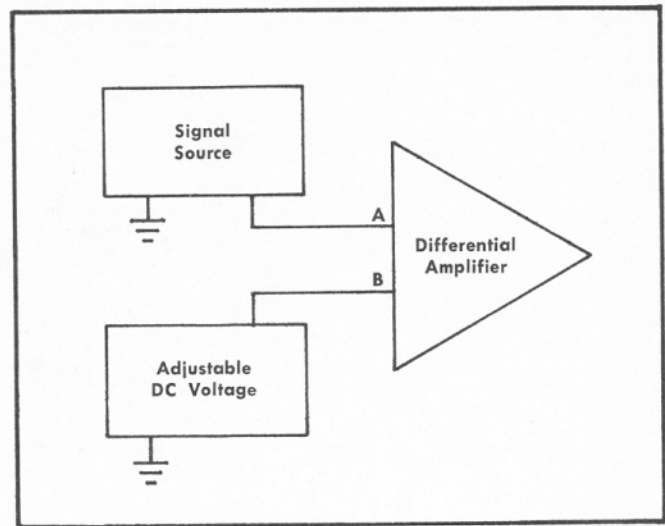


Fig. 2-7. Circuit connections for the slide-back technique described in the text.

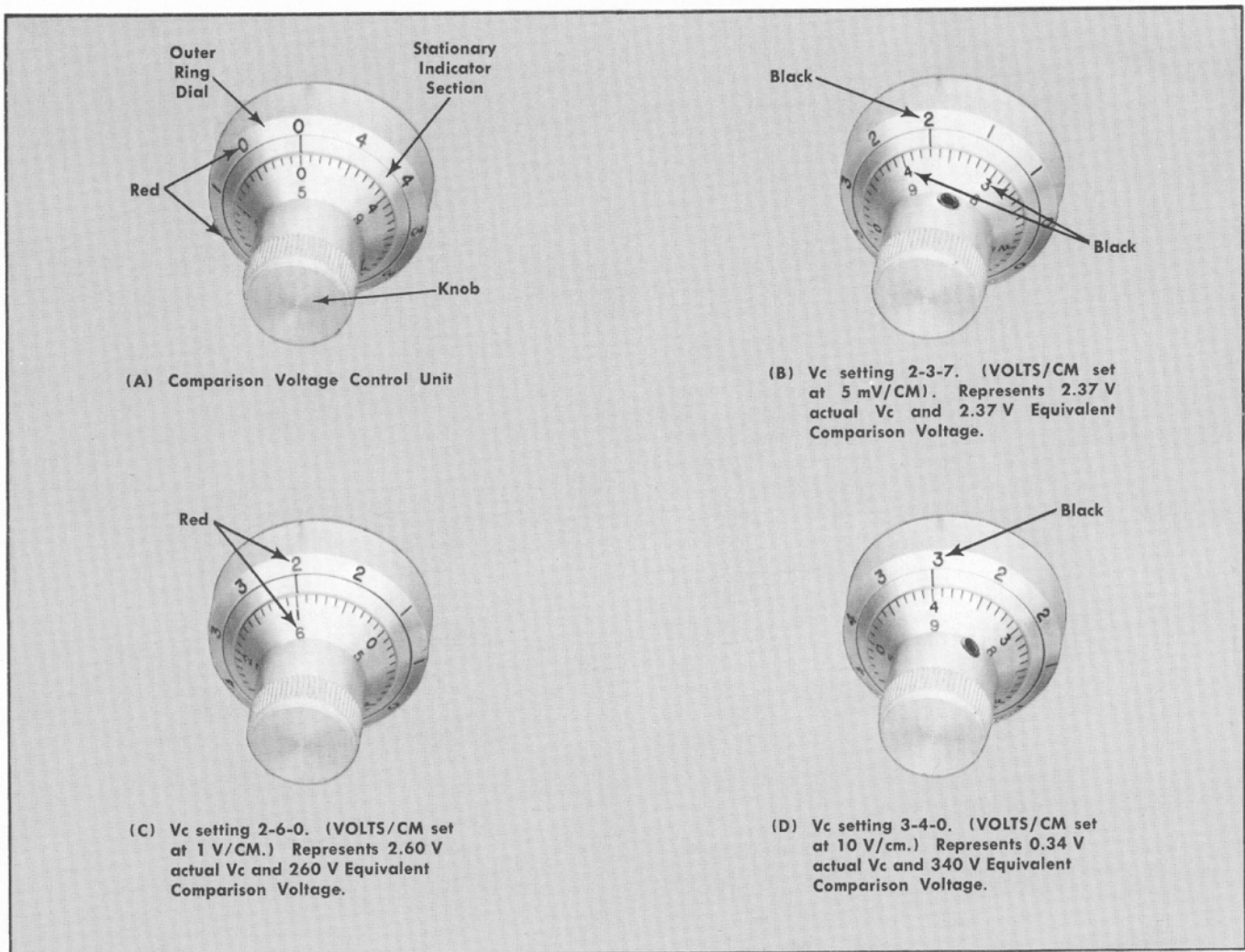


Fig. 2-8. Comparison Voltage (Vc) control.

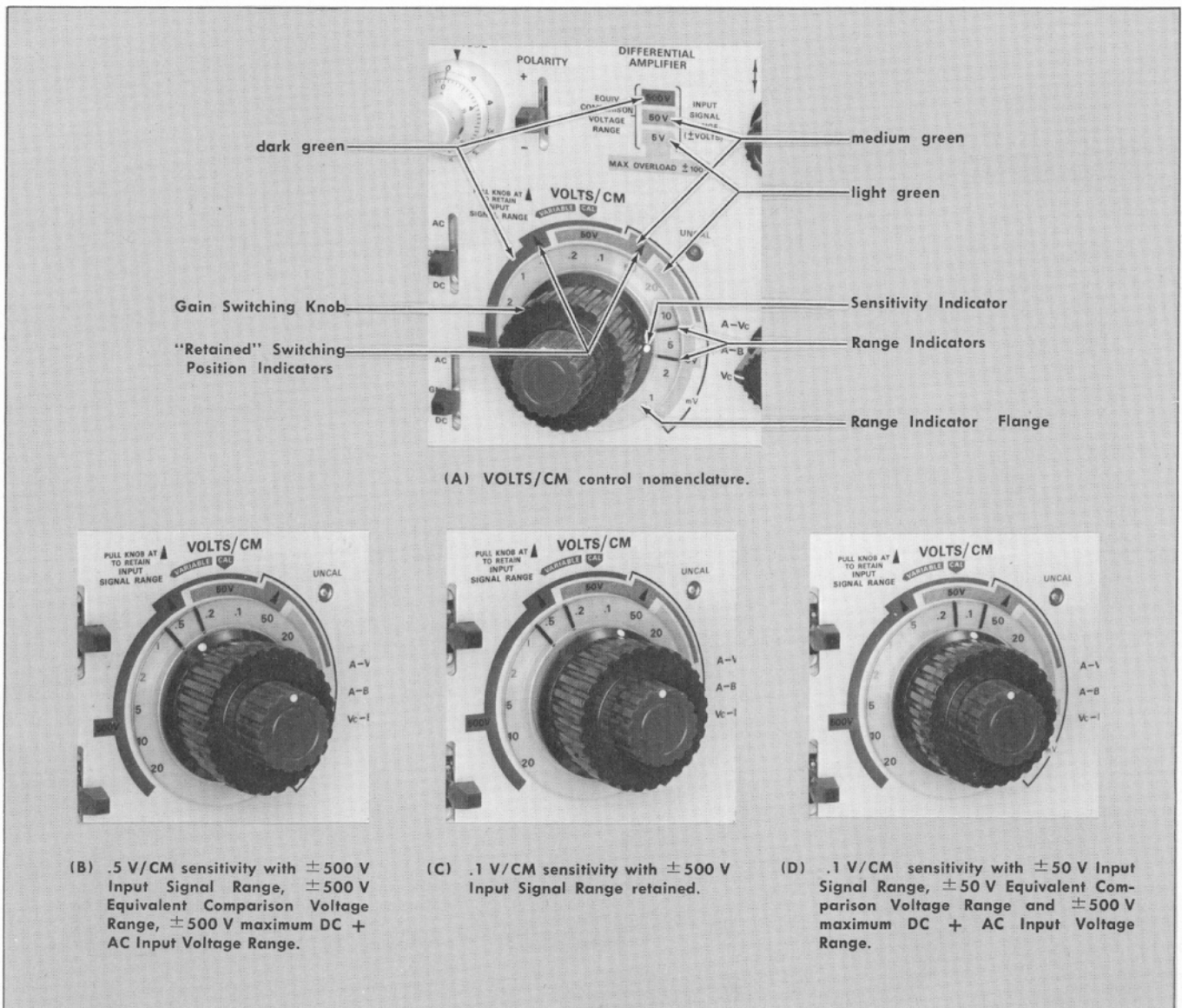


Fig. 2-9. VOLTS/CM control; detailed description.

TABLE 2-1
Front Panel Color Coding

Color	Attenuator in use	Input Signal Range	Equivalent Comparison Voltage Range	Maximum Input Voltage Range ¹
Light green	$\times 1$	± 5 V	± 5 V	± 100 V
Medium green	$\times 10$	± 50 V	± 50 V	± 500 V
Dark green	$\times 100$, $\times 1000$	± 500 V	± 500 V	± 500 V

¹In A-B operation this value refers to the maximum difference that may exist between the A and B input voltages.

The gain switching knob and the range indicator flange are normally slaved together by a spring loaded key and detent arrangement. The gain switching knob can be released from the range indicator flange at two switch positions. When the deflection factor and range indicators are aligned with either of the black triangles which appear in the green arcs, the gain switching knob can be pulled out approximately one eighth of an inch and rotated clockwise to either of the next two deflection factor positions. This arrangement allows retention of a larger attenuation factor, a higher Input Signal Range and a higher Equivalent Comparison Voltage than is normally possible for the deflection factors involved. (VOLTS/CM positions arrived at in this manner will be referred to as "Retained Range" positions.)

Note that when "Retained Range" positions are used the attenuator, the Input Signal Range, the Equivalent Com-

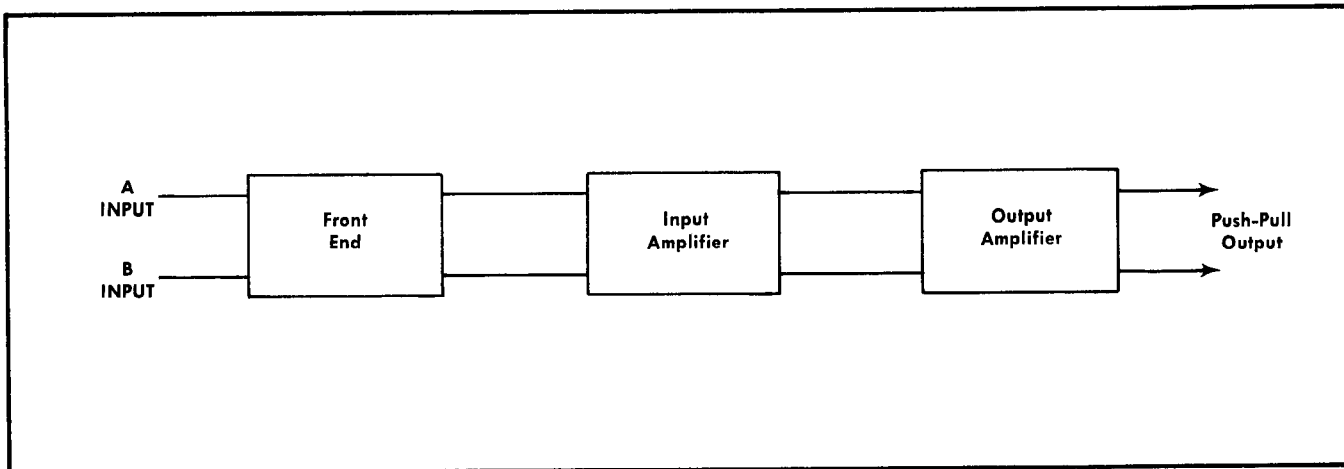


Fig. 2-10. Type 1A5 basic block diagram.

parison Voltage Range, the maximum input voltage range and the deflection factor will still be indicated as previously described.

Figures 2-9B, C and D illustrate three of the 18 possible VOLTS/CM control settings.

TYPE 1A5 DIFFERENTIAL AMPLIFIER BLOCK DIAGRAM

A basic understanding of the equipment being used is useful in determining just what the instrument can and is doing. A study of the block diagram information which follows should prove helpful in operation of the Type 1A5.

Refer to Figure 2-10. The Type 1A5 can be broken down into three principle sections, namely the "front end", the input amplifier and the output amplifier. The "front end" controls the input coupling, attenuation factor, mode of operation, and comparison voltage. The input amplifier rejects common mode signals and amplifies the remaining signal (or the active differential probe signal, if selected). The output section is concerned primarily with signal amplification, providing a push-pull output to the oscilloscope.

Two essentially identical signal channels, referred to as the A and B channels, are contained in the Type 1A5. A positive signal applied to the A INPUT will result in a signal passing through the A channel, applying a positive signal to the oscilloscope's upper deflection plate, causing upward deflection of the CRT trace. A positive signal applied to the B INPUT will pass through the B channel, resulting in a negative signal to the upper deflection plate, causing downward deflection. (A signal of opposite polarity will simultaneously be applied to the CRT's lower deflection plate.)

Refer to Fig. 2-11. The channels are equipped with coupling switches that operate independently of each other. They determine which part of the signal will pass into the channel: AC—only the AC component; GND—none; DC—both the AC and DC components. The signal is presented to the attenuators, which are an integral part of the deflec-

tion factor (VOLTS/CM) switch. The A and B channel attenuators step in unison whenever the VOLTS/CM switch is moved through an attenuator switching position. The selected attenuator routes the signal to contacts of the DISPLAY switch. If the DISPLAY switch accepts only one channel's signal, the other channel is automatically connected to the COMPARISON VOLTAGE (V_c) section. The V_c network can supply 0 to 5 V DC of either polarity, or a fixed 0 voltage, as determined by settings of POLARITY and AMPLITUDE controls. If 0 POLARITY is selected, the CRT deflection will be affected only by the selected input signal. If + or — POLARITY is selected, the CRT signal deflection will be opposed if V_c is of the same polarity as the signal, or aided if V_c is opposite to signal polarity. The V_c voltage does not pass through the attenuator section. When compared against an input signal which has passed through an attenuator, V_c is equivalent to the basic value of V_c (0 to 5 V) multiplied by the attenuation factor in use. See Fig. 2-8.

If the DISPLAY switch is positioned to select A-B operation, both the A INPUT and B INPUT signals will be accepted by their respective channels and CRT deflection will be a result of their difference. V_c cannot affect the CRT presentation in A-B mode.

Signals from the A and B channels are made available to contacts of the Differential Probe relay and will be processed whenever Differential Probe operation is not selected. (In Differential Probe operation, the Differential Probe signal received at the relay will have been processed by the probe in a manner similar to that described for A-B mode in the preceding explanation.)

Regardless of the source, a comparator in the amplifier section will determine the difference between the signals processed by the two input channels and convert it to a push-pull voltage which will be amplified by the double-ended output amplifier.

STEP ATTEN BAL and PROBE STEP ATTEN BAL adjust for undesirable trace shift caused by circuit unbalances and will be discussed in more detail in the Circuit Description section.

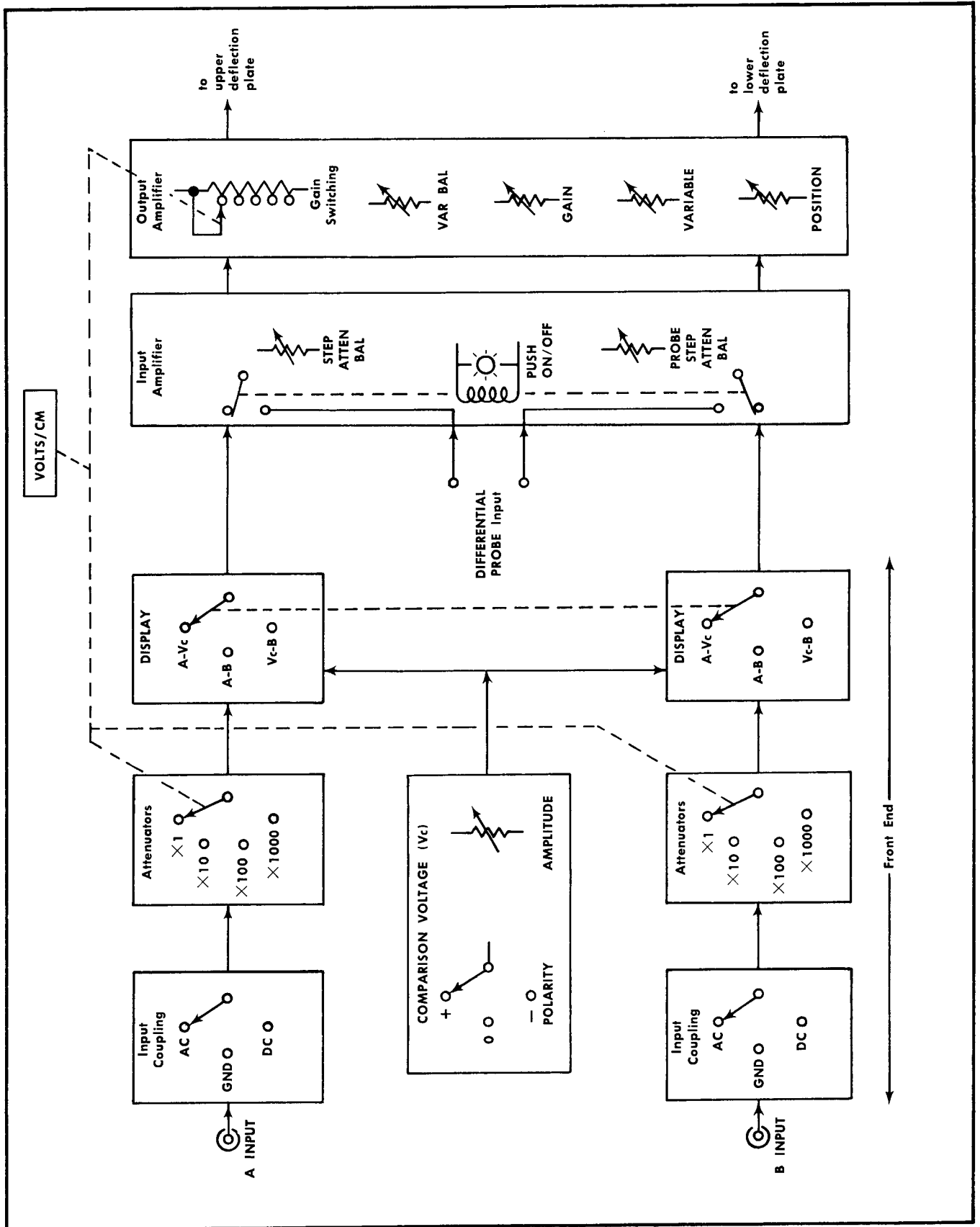


Fig. 2-11. Type 1A5 Differential Amplifier simplified block diagram.

Operating Instructions—Type 1A5

Gain switching in the output amplifier is controlled by the VOLTS/CM control and is the only factor causing changes in signal amplification in the 1 to 20 mV switch settings. Combining gain switching with various attenuators (in the front end of the Type 1A5 or in the Active Differential Probe) provides for the wide range of less sensitive settings of the VOLTS/CM switch. The VARIABLE control affects the amplifier gain and can be used to vary the sensitivity between any of the VOLTS/CM calibrated settings.

VAR BAL and GAIN are used for balancing and gain calibration of the amplifier.

The trace can be vertically controlled with the POSITION knob. DC zero reference for signal measurement is established by grounding the signal inputs and using this control.

The POSITION control should not be used to offset large amounts of signal deflection when attempting to make accurate observations. If the input signal causes the input amplifier to operate in its maximum limits, distortion may be introduced. Since the POSITION control affects only the output amplifier, the distortion would be amplified and the waveform would be unreliable. AC coupling, or the Comparison Voltage feature should be used instead of the POSITION control to eliminate DC levels at the input. A less sensitive VOLTS/CM setting (larger deflection factor) should be used to correct for excessively large AC deflections.

TYPE 1A5 DIFFERENTIAL AMPLIFIER OPERATION

First Time Operation

The operating description which follows is designed to assist in providing a CRT display, and to familiarize the operator with the features of the instrument. A Type 544 oscilloscope is used for the following instructions, but the procedure will be essentially the same for any oscilloscope with which the Type 1A5 is compatible.

Initial Setup

1. Insert the Type 1A5 into the oscilloscope. Lock it into position with the securing knob.

2. Preset Type 1A5 controls as follows:

COMPARISON VOLTAGE (Vc)	
AMPLITUDE	CCW to 0
POLARITY	0
POSITION	Midrange
AC-GND-DC (A Input)	GND
AC-GND-DC (B Input)	GND
DISPLAY	A-B
VOLTS/CM	20 V
VARIABLE	CAL

3. Set the oscilloscope Intensity knob ccw, preset controls for a free-running 0.5 ms/cm sweep. Turn on the oscilloscope and, after the time delay relay operates, increase the intensity until a trace appears on the CRT. If no trace appears, observe the vertical position indicator

lights and move the STEP ATTEN BAL to bring the trace to the center of the CRT.

Operation

Become acquainted with the operation of the Type 1A5 by manipulating controls as follows. Observe that no appreciable change occurs in the sweep for any setup except as noted.

1. Rotate POSITION knob cw and ccw. Observe the up and down movement of the trace. Return the trace to CRT center.

2. With VOLTS/CM knob "in", rotate it to each position. At .5 V/CM position, pull the knob out and rotate it cw to .2 and .1 V/CM position. Return to .5 V/CM "knob in" position. At 50 mV/CM position, pull the knob out and rotate cw to 20 mV and 10 mV positions. Return to 50 mV/CM "knob in" position. "Knob out" positions will hereafter be referred to as "Retained Range" positions.

3. Place A Input and B Input AC-GND-DC switches to DC and then to AC positions.

4. Switch DISPLAY selector to A-Vc position, VOLTS/CM to 20 mV and POLARITY to +.

5. Rotate AMPLITUDE clockwise to 0-0-6. Observe that the trace shifts down to the -3 cm position. Switch POLARITY to -. Observe that the trace instantly moves up to +3 cm position.

6. Change the DISPLAY control to Vc-B position. Observe that the trace moves to the -3 cm position. Switch POLARITY to +. Observe that the trace instantly moves to the +3 cm position.

7. Return AMPLITUDE to 0. The trace should return to CRT center. Place POLARITY to 0.

8. Rotate the VARIABLE knob through its range. Note that the UNCAL lamp is lighted when VARIABLE is not detented. Return VARIABLE knob to CAL. The UNCAL lamp should go out.

9. Depress the DIFFERENTIAL PROBE PUSH ON/OFF button. A Probe On light built into the button should light. Depress the PUSH ON/OFF button two more times. Observe that the Probe On lamp extinguishes, then re-lights. Rotate the VOLTS/CM switch to 1 mV/CM and note that the Probe On light stays on. Switch VOLTS/CM to .5 V. The light should go out. Note that the PUSH ON/OFF button has no effect in the .5 V/CM position or in any less sensitive setting (higher VOLTS/CM setting).

WARNING

Voltages are present at the Differential Probe connector jack whenever the Type 1A5 is energized, regardless of the status of the Probe On lamp.

Front Panel Adjustments

These adjustments must be accomplished each time the Type 1A5 is placed in a different oscilloscope, and should

be checked prior to any critical measurements of waveforms.

Preset Type 1A5 controls as follows:

POLARITY	0
STEP ATTEN BAL	Centered
A Input AC-GND-DC	GND
VOLTS/CM	20 mV
DISPLAY	A-Vc
Probe On lamp	Off

Allow 20 minutes for warm-up.

GAIN Adjustment

1. Connect a 50 Ω BNC connector cable from the oscilloscope Cal Out jack to the A INPUT jack. Set Cal Out to 0.1 V. Place A Input AC-GND-DC switch to DC. Set the oscilloscope triggering controls to obtain a stable display.

2. Check GAIN for exactly 5 cm deflection. Use POSITION knob as necessary to superimpose waveform top and bottom on the $+2\frac{1}{2}$ and $-2\frac{1}{2}$ cm lines respectively. If gain is incorrect, refer to the GAIN adjustment procedure in the Calibration section of this manual.

3. Disconnect the 50 Ω cable from the A INPUT connector.

STEP ATTEN BAL Adjustment

1. Place the A Input AC-GND-DC switch to GND.

2. Set VOLTS/CM control to 20 mV.

3. Using POSITION CONTROL, set the trace to CRT center.

4. Switch VOLTS/CM control to 1 mV.

5. Using STEP ATTEN BAL, re-adjust the trace to CRT center.

6. Return the VOLTS/CM control to 20 mV and repeat the process until no trace shift accompanies change of VOLTS/CM control setting.

VAR BAL Adjustment

1. Switch A Input AC-GND-DC to GND. Using POSITION control, set the trace to CRT center.

2. Rotate VARIABLE adjustment through its entire range. Adjust VAR BAL to eliminate any trace shift which accompanies the VARIABLE adjustment. Use the POSITION knob to keep trace near CRT center during adjustment. Return the VARIABLE knob to CAL position.

3. Recheck the STEP ATTEN BAL Adjustment.

PROBE STEP ATTEN BAL Adjustment

This adjustment must be done prior to each use of the Type 1A5 with an active probe. It should also be done just prior to using an active probe for critical measurement of waveforms.

1. Connect the Differential Probe to the Type 1A5 connector. Short the probe tips together.

2. Set VOLTS/CM control to 20 mV.

3. Using POSITION control, set the trace to CRT center.

4. Depress DIFFERENTIAL PROBE PUSH ON/OFF button. Observe that the Probe On lamp lights.

5. Switch VOLTS/CM control to 10 mV and adjust PROBE STEP ATTEN BAL to return the trace to CRT center. Repeat this adjustment at the 5, 2 and 1 mV positions.

6. Repeat steps 2, 3 and 5 until no further adjustment is necessary.

Operating Modes of the Type 1A5

Numerous combinations of operating modes and signal coupling methods are available with the Type 1A5. Table 2-2 and the information accompanying it outline Type 1A5 set-ups, operating hints and procedures.

Table 2-3 outlines passive methods for coupling signals into the Type 1A5. Many of the probes included in the table require adjustment prior to use with specific equipment. An adjustment procedure, using the Type P6023 probe, accompanies Table 2-3.

For information concerning active probe operation, consult the appropriate probe manual.

Signal Inputs

CAUTION

The input circuitry may be damaged by exceeding the Maximum (non-destructive) Input Voltage Range determined by the VOLTS/CM switch. It is ± 100 volts DC + peak AC in the 1 to 20 mV "knob in" positions and ± 500 volts DC plus peak AC in all other positions. In addition the difference between the A and B Input voltages must never exceed the applicable Maximum Input Voltage Range.

For reliable results, operate within the Input Signal Range indicated on the front panel.

Before measuring an unknown voltage, determine that the maximum voltage to be expected is within the range of the Type 1A5. Then set the VOLTS/CM switch to its least sensitive position (20 V/CM). Connect the signal to the Type 1A5 INPUT and set the sensitivity control to the position desired for waveform measurement.

When making single ended input measurements, establish a common ground connection between the device under test and the Type 1A5. Normally the shield of a coaxial cable serves this purpose.

Differential measurements require no common ground connection. If it is desired that the oscilloscope and equipment under test be common grounded for safety reasons, it should be done with a cable other than the signal lead shields.

TABLE 2-2
Operational Set-Ups

Operating Mode	Diff. Probe PUSH ON/OFF	DISPLAY	Signal INPUT Connector	AC-GND-DC	VOLTS/CM	Vc
Passive Probe						
1. Differential Amplifier	OFF	A-B	A INPUT and B INPUT	Both to either AC or DC	Any	N.A.
2. Conventional Amplifier (Method a)	OFF	A-B	A INPUT or B INPUT ²	Selected input to AC or DC. Other input to GND.	Any	N.A.
3. Conventional Amplifier (Method b)	OFF	A-Vc or Vc-B	As selected by DISPLAY ²	Selected input to AC or DC.	Any	0
4. Differential Comparator	OFF	A-Vc or Vc-B	As selected by DISPLAY ²	Selected input to AC or DC.	Any	POLARITY and AMPLITUDE po- sitioned as nec- essary to offset signal deflection.
Active Probe						
5. Differential Amplifier	ON	N.A.	DIFFEREN- TIAL PROBE	N.A.	1 mV through .2 V	N.A.
6. Conventional Amplifier	ON	N.A.	DIFFEREN- TIAL PROBE	N.A.	1 mV through .2 V	N.A.

²B INPUT inverts waveform presentation.

Consider the signal source loading and the resulting change in the source operating characteristics due to the input circuit of the Type 1A5 and the signal cables. The circuit at the input connectors can normally be represented by a 1 MΩ resistance to ground paralleled by 20 pF. A few feet of shielded cable may increase the capacitance to 60 pF or more, which could be excessive in many situations. To minimize these effects, it may be advisable to use an attenuator probe.

Attenuator probes decrease the resistive and capacitive loading of the signal source, and extend the measurement range of the Type 1A5. Attenuator probes and their effect were discussed previously in this section.

Input Coupling

To display both the AC and DC components of an applied signal, set the appropriate A Input or B Input AC-GND-DC switch to DC. To display only the AC component of a signal, set the Input AC-GND-DC switch to AC.

Since a coupling capacitor is used to block the DC component in AC-coupled operation, the AC low frequency half power point occurs at 2 Hz, and additional attenuation must be expected below this frequency. When using a 10× 10-MΩ probe, the AC-coupled low frequency response is about 0.2 Hz. If a 100× 10-MΩ probe is used, AC-coupled low frequency response is again 2 Hz.

The ground positions of the AC-GND-DC switches provide a reference for DC zeroing of the CRT trace. However, this method does not take into consideration ground loop currents that may be present between the oscilloscope and the equipment under test. For single ended operation un-

der small signal conditions, and whenever extreme accuracy is necessary, it is recommended that DC zeroing be done with the AC-GND-DC switch in DC position and the signal probe and shield grounded at the equipment under test.

NOTE

When operating in A-Vc or Vc-B mode, the POLARITY switch must be set at 0 to perform DC zeroing.

In differential operation, DC zeroing should be done with the probe tips connected together, and the AC-GND-DC switches in DC position.

Coupling Capacitor Precharge-Discharge Circuit

A coupling capacitor Precharge-Discharge Circuit is built into the Type 1A5 input. It allows a small AC signal riding on a larger DC voltage to be capacitively coupled in without having the amplifier circuitry overloaded by the capacitor's DC charging current. The circuit is not automatic, but can be used easily as follows:

1. Place selected signal Input AC-GND-DC switch to GND.
2. Connect a signal source to the Type 1A5. The coupling capacitor will charge rapidly to the DC level of the signal source.
3. Change the Input AC-GND-DC switch to AC and proceed with waveform measurement.
4. When the Waveform measurement is completed, disconnect the Type 1A5 from the signal source and discharge

the coupling capacitor by placing the AC-GND-DC switch to DC.

CAUTION

A charged coupling capacitor can damage components connected to the next point tested. It can also be detrimental to the Type 1A5 input circuitry if not discharged properly. Step 4 will safely discharge the coupling capacitor. The coupling capacitor precharge-discharge procedure should become a habit in all AC input coupled measurements.

It may be noted that if the precharge-discharge procedure is followed faithfully, the Input Signal Range for the most sensitive Type 1A5 settings can be extended to ± 500 volts, providing the AC component does not exceed 5 volts.

Display Polarity

Signals applied to the A INPUT connector will produce a vertical deflection in phase with the input signal. Signals applied to the B INPUT connector will be inverted.

Determining Signal Amplitude

In single-ended operation the signal amplitude is determined by multiplying the number of centimeters of trace deflection by the deflection factor. (The deflection factor of the Type 1A5 and oscilloscope combination is the product of the probe attenuation and the setting of the VOLTS/CM control.)

Example: Operational setup 2 from Table 2-2 has been selected, a $10\times$ probe is in use, VOLTS/CM is at 5 mV and there are 3 cm of deflection on the CRT. Deflection factor (10×5 mV) times deflection (3 cm) equals 150 mV signal amplitude.

In differential amplifier operation, the deflection factor multiplied by the amount of trace deflection indicates the difference in amplitude between the two signals under test.

Example: Operational setup 1 from Table 2-2 has been selected, $1\times$ probes are used, DC coupling selected for both inputs, VOLTS/CM set to 2 mV, and 4.5 cm deflection occurs. Deflection factor (1×2 mV) times deflection (4.5 cm) equals 9 mV signal difference. (If the DC + AC amplitude of either input were desired to be known, it should be determined under single ended operation as in the first example.)

Differential comparator operation can also be used to determine signal amplitude, and its accuracy can be relied upon to three significant digits. Under setup 4 from Table 2-2, the deflection on the CRT will be the difference between the signal amplitude and the amount of comparison voltage introduced to the other channel. The signal amplitude can be determined by multiplying the deflection factor by the amount of deflection and adding Vc (from the AMPLITUDE control) to the product.

Example: Operational setup 4 from Table 2-2 selected, $1\times$ probe coupled into A INPUT, AC-GND-DC switch at DC, Vc POLARITY at —, Vc AMPLITUDE at 240 V (2-4-0 posi-

tion), VOLTS/CM at 2 V, —3 cm trace deflection on CRT. Deflection factor (1×2 V) times deflection (—3 cm) equals —6 V. Adding the Vc —240 V (which removed 240 V from the trace deflection by common-mode rejection) results in a —246 volt total signal input.

The above example is characteristic of the measurement of AC riding on a DC level. If the entire voltage had been DC, the measurement would have been simplified by introducing enough Vc to put the trace at the DC reference position. Then the deflection factor could have been ignored and the total signal voltage read directly from the Vc AMPLITUDE dial. In either case, notice that the Vc feature allowed determination of a voltage which, in single-ended operation, would have deflected the trace off of the face of the CRT, even with the Type 1A5 set up in its least sensitive calibrated position.

NOTE

The explanation concerning the deflection factor is true only when the VARIABLE control is set to the CAL position

The VARIABLE control can increase the deflection factor to more than 2.5 times the value indicated by the VOLTS/CM control setting. This provides uncalibrated vertical deflection factors between the calibrated settings of the VOLTS/CM switch, and when in the 20 V/cm position extends the maximum total waveform display capability to at least 300 volts peak to peak.

Vc MONITOR

COMPARISON VOLTAGE (Vc) can be read on a voltmeter or oscilloscope connected to the MONITOR pin-jack. The AMPLITUDE and POLARITY controls make 0 to ± 5 V available in all of the VOLTS/CM control settings except the 5-V, 10-V and 20-V positions, where it is reduced to a ± 0.5 V maximum value. If a high impedance voltmeter (one which draws little or no current from the measured voltage) is used, the value will be within $\pm 0.5\%$ or ± 5 mV (whichever is greater) of the Vc AMPLITUDE dial setting.

If an accurate, low impedance measuring device is used, the value read will be the value applied to the selected input channel, but it will disagree with the Vc AMPLITUDE control setting. The amount of difference will be determined by the degree of loading caused by the measuring device. When the load is removed by disconnecting the measuring device, the voltage will return to that indicated by the AMPLITUDE control.

The Vc MONITOR output can be used as a voltage source, but the accuracy and value of Vc will vary inversely with the loading effect, just as it does with a measuring device connected to it. This is illustrated in Fig. 2-12.

NOTE

Use shielded leads whenever connecting to the MONITOR JACK while waveform observations are being made. Stray voltages of 10 mV or more can be picked up by unshielded cables connected to the MONITOR jack. This induced noise will affect the CRT presentation whenever the DISPLAY switch is in the A-Vc or Vc-B position.

Operating Instructions—Type 1A5

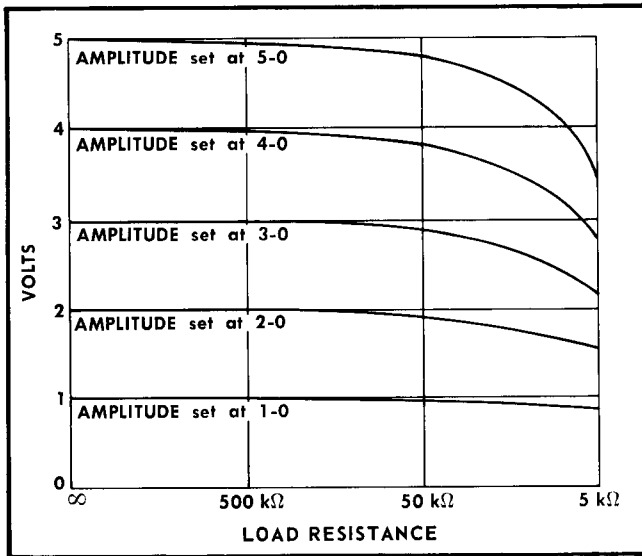


Fig. 2-12. Effect of external load connected to Comparison Voltage (V_c) MONITOR jack. (Does not apply when VOLTS/CM control is set to 5 V, 10 V or 20 V positions.)

Overdrive Recovery Time

In any oscilloscope, when a signal causes the trace to deflect off the CRT face, a certain amount of recovery time is required before the trace will return and waveform observation/measurement can continue. This is annoying and

time consuming. The operator can minimize this problem by using the following procedure:

1. AC operation. Use the precharge/discharge procedure outlined earlier in this section.

2. AC single ended operation. Before inserting the signal, set the VOLTS/CM control to allow all of the maximum expected AC waveform to appear on the CRT viewing area.

3. DC single ended operation. Before inserting the signal, set the VOLTS/CM control to allow all of the maximum expected AC + DC waveform to appear on the CRT viewing area.

4. Differential Comparator operation. Keep the selected signal Input AC-GND-DC switch at GND and the V_c POLARITY switch at 0 until the signal and a comparable value of V_c are inserted. Simultaneously switch the signal Input AC-GND-DC switch to DC and V_c POLARITY switch to the polarity of the signal being common-moded. Regardless of the signal amplitude, only the difference between V_c and the signal will appear as trace deflection.

5. Differential Amplifier Operation. Place both AC-GND-DC switches at GND before connecting signal sources to the Type 1A5. After connections have been made, simultaneously switch both AC-GND-DC switches to either AC or DC as desired. Regardless of the amplitude of the signals, only the difference between the two will cause trace deflection.

6. Active Differential Probe operation. Keep V_c POLARITY at 0 and Differential Probe lamp off until both contacts of the active Differential Probe are connected. Then press PUSH ON/OFF button to accept active probe signals.

TABLE 2-3

Passive Signal Coupling Methods

Method	Advantages	Limitations	Accessories Required	Source Loading	Precautions
1. Open test leads.	Simplicity.	Limited frequency response. Subject to stray pickup.	BNC to Binding Post adapter (103-0033-00). Two test leads.	$1\text{ M}\Omega$ and 20 pF at input, plus test leads.	Stray pickup. Insert a 47-ohm resistor in series with the leads.
2. Underterminated coaxial cable.	Full sensitivity.	Limited frequency response. High capacitance of cable.	Coaxial cable with BNC connector(s).	$1\text{ M}\Omega$ and 20 pF plus cable capacitance.	High capacitive loading.
3. Terminated coaxial cable. Termination at 1A5 input.	Full sensitivity. Total 1A5 bandwidth. Relatively flat-response resistive loading. Long cable with uniform response.	Presents R_o (typically $50\ \Omega$) loading at end of coaxial cable. May need blocking capacitor to prevent DC loading or damage to termination.	Coaxial cable with BNC connector(s) R_o termination at 1A5 input. (BNC $50\ \Omega$ Termination 011-0049-00).	R_o plus 20 pF at 1A5 end of coaxial cable can cause reflections.	Reflection from 20 pF at input. DC and AC load on test point. Power limit of termination.
4. Same as 3, with coaxial attenuator at termination.	Less reflection from 20 pF at termination.	Sensitivity is reduced (increased deflection factor).	BNC coaxial attenuators.	R_o only.	DC and AC loading on test point. Power limit of attenuator.

TABLE 2-3 (cont)

Passive Signal Coupling Methods

Method	Advantages	Limitations	Accessories Required	Source Loading	Precautions
5. Tap into terminated coaxial system. (BNC T at 1A5 input.)	Permits signal to go to normal load. DC or AC coupling without coaxial attenuators.	20-pF load at tap point.	BNC T and BNC connectors on signal cables.	1 M Ω and 20 pF at tap point.	Reflection from 20 pF input.
6. 1 \times , 1M Ω Probe.	Full sensitivity. Total Type 1A5-Oscilloscope bandwidth.	High capacitance of cable.	P6011 and P6028 are 1 \times probes.	1 M Ω and \approx 60 pF. 1 M Ω and \approx 28 pF.	High capacitance loading.
7. 10 \times probe.	Reduced resistive and capacitive loading; nearly full bandwidth of 1A5.	\times 0.1 sensitivity.	P6006, P6008, P6010 and P6023 are 10 \times probes.	P6006: \approx 7 pF, 10 M Ω . P6008: \approx 7.5 pF, 10 M Ω . P6010: \approx 10 pF, 10 M Ω P6023: \approx 12 pF, 8 M Ω	Check probe frequency compensation. Use square wave frequency less than 5 kHz, preferably 1 kHz.
100 \times , 9.1 M Ω probe.		\times 0.01 sensitivity.	P6007: 100 \times	P6007: \approx 2 pF, 10 M Ω .	
1000 \times , 100 M Ω probe.		\times 0.001 sensitivity.	P6015: 1000 \times	P6015: \approx 2.7 pF, 100 M Ω .	
8. 500 Ω and 5 k Ω probes. (Must be terminated in 50 Ω at 1A5 input.)	Reduced capacitive loading to about 0.7 pF. Bandwidth that of 1A5.	Resistive loading. \times 0.1 or \times 0.01 sensitivity. May need blocking capacitor to prevent DC loading or damage to termination. Limited low-frequency response when AC coupled. See Fig. 2-13.	P6034: 10 \times . P6035: 5 k Ω , 0.6 pF.	P6034: 500 Ω , 0.7 pF.	DC and AC loading. Voltage rating of probe.
9. Current transformer. Terminated in 50 Ω at 1A5.	Current transformer can be permanent part of test circuit. Less than 2.2 pF to test circuit chassis. Measure signal current in transistor circuits: CT-1—20 A peak. CT-2—100 A peak.	RMS current rating: CT-1—0.5 A CT-2—2.5 A Sensitivity: CT-1—5 mV/mA. CT-2—1 mV/mA.	CT-1: coaxial cable, adapter and BNC termination. CT-2: Additional coaxial cable for either transformer as necessary.	CT-1: Insertion; 1 Ω paralleled by about 5 μ H. Up to 1.5 pF. CT-2: Insertion; 0.04 Ω paralleled by about 5 μ H. Up to 2.2 pF.	Not a quick-connect device. CT-1: Low-frequency limit about 75 kHz. CT-2: Low-frequency limit about 1.2 kHz, and is 1/5th as sensitive as the CT-1.
10. P6019 or P6020 Current Probe and Type 134 Amplifier.	Measure signal currents. AC current saturation rating: 15 A peak to peak.	Low frequency limit: \approx 30 Hz. Basic deflection factor: 50 mV/mA.	None.	Insertion Z with step function applied: 0.04 Ω after 0.1 μ s.	Avoid scratching probe current transformer core to preserve low-frequency response.

Type P6023 Probe Adjustment Procedure

The following equipment is recommended for this procedure:

Oscilloscope to be used with the Type 1A5.

Type 1A5 Differential Amplifier plug-in unit.

Type P6023 Probe. (Two required for differential operation.)

BNC binding post adapter. Tektronix Part No. 103-0033-00.

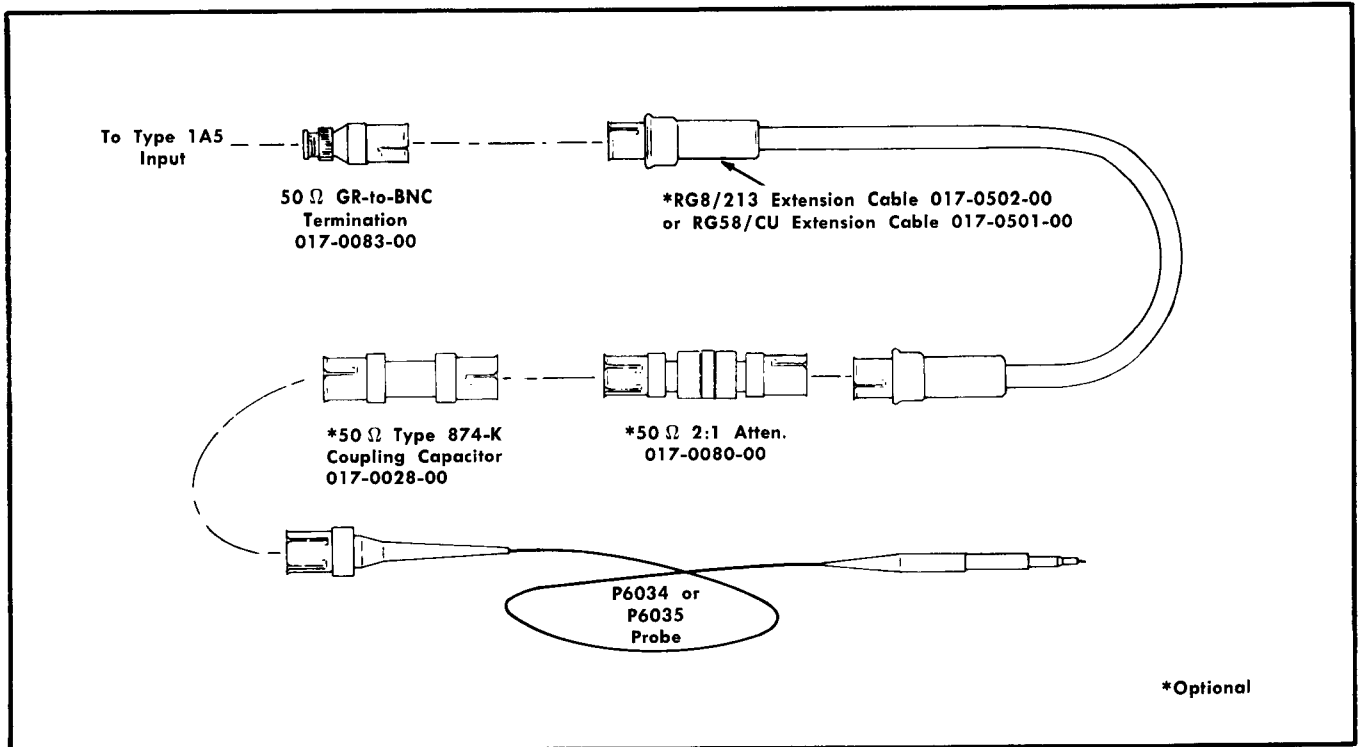


Fig. 2-13. Recommended component sequence when using the P6034 or P6035 probe. See Table 2-3.

Procedure:

- a. Insert the plug-in unit into the oscilloscope. Turn on the oscilloscope and allow 20 minutes for warm-up.
- b. Set the front-panel controls as follows:

Type 544

Amplitude Calibrator	1 V
Horizontal Position	Centered
Horizontal Display	Normal (×1)
Time/CM	.5 ms
Triggering Mode	Auto
Triggering Slope	+
Triggering Coupling	AC
Triggering Source	Norm

Type 1A5

STEP ATTEN BAL	Adjust as outlined in Front Panel Adjustments
VOLTS/CM	20 mV
POSITION	Centered
DISPLAY	A-B
AC-GND-DC (A Input)	GND
AC-GND-DC (B Input)	GND

- c. Attach the BNC-binding post adapter to the oscilloscope Cal Out connector.

- d. Connect the compensation box of the P6023 probe to the Type 1A5 A INPUT connector. Connect the probe tip to the binding post attached to the Cal Out connector.

- e. Check that the oscilloscope Intensity control is set for normal brightness. Position the trace to graticule center with the Type 1A5 POSITION control.

- f. Switch the A Input AC-GND-DC control to DC. Adjust the oscilloscope Triggering Level and Type 1A5 POSITION control to provide a centered, triggered display.

- g. Check that the Type 1A5 VARIABLE control is at CAL position.

- h. Adjust the probe DC ATTEN CALIBRATION to obtain exactly 5 cm vertical display amplitude, as measured between the trailing edges of the square waves. See Fig. 2-14 (A).

- i. Adjust the probe AC COMP FINE ADJUST (and AC COARSE COMP if necessary) for optimum flatness and squareness at the bottom left corner of the square wave. See Fig. 2-14 (B).

- j. Switch the oscilloscope Amplitude Calibrator to Off. The probe is now properly adjusted. If two probes are to be used for making CMRR measurements, a second probe must be adjusted to match the first. The remaining procedure explains an effective method for performing the adjustment.

- k. Connect the compensation box of the second probe to the B INPUT connector; connect the probe tip to the junction of the binding post and the first probe tip.

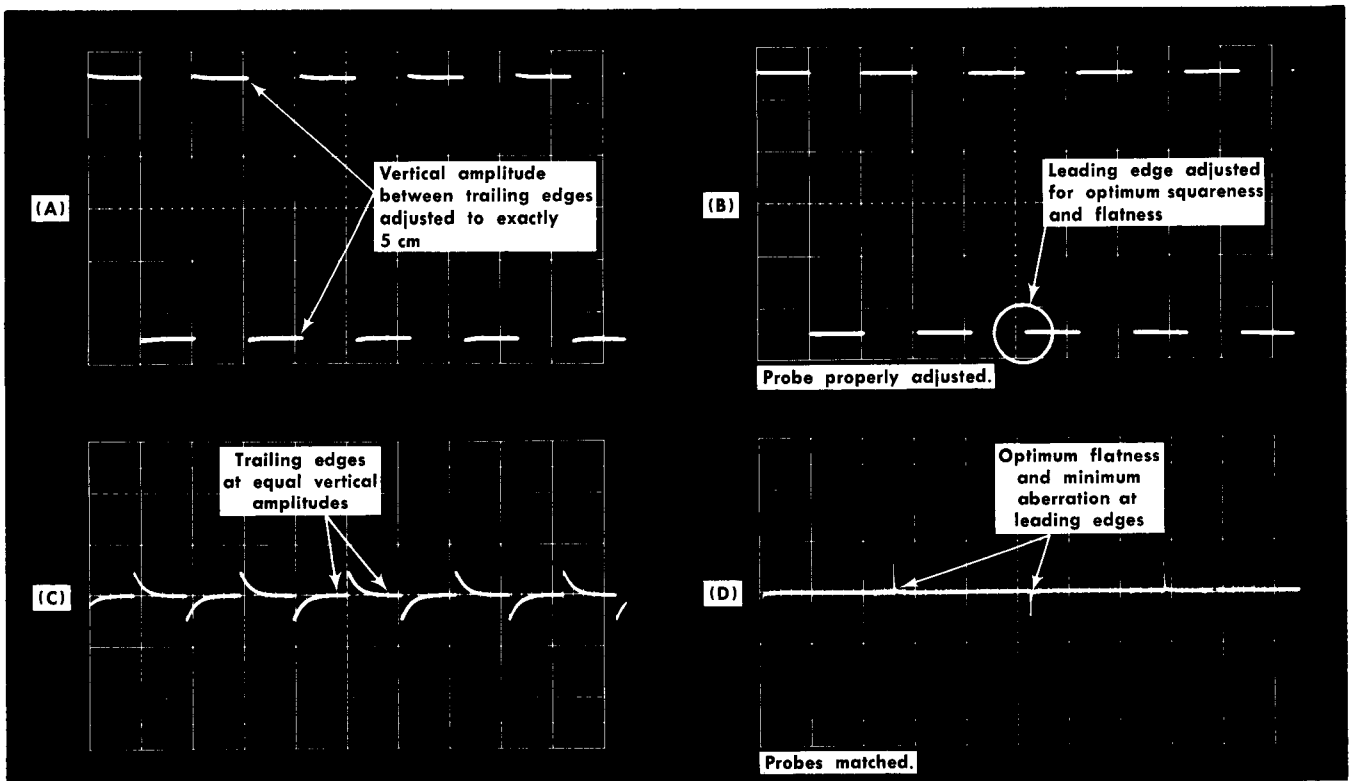


Fig. 2-14. Adjusting the P6023 Probe. (A) Adjusting DC ATTEN CALIBRATION; (B) Adjusting AC COMP; (C) Matching DC ATTEN CALIBRATION of second probe to that of first probe; (D) Matching AC COMP of second probe to that of first probe. Sweep rate: (A), (B) and (C)—.5 ms/cm; (D)—.2 ms/cm; vertical sensitivity; 20 mV/cm.

l. Switch the B Input AC-GND-DC controls to DC. Switch the Amplitude Calibrator to 20 V and adjust the Type 1A5 POSITION control as necessary to center the display.

m. Adjust the DC ATTEN CALIBRATION of the second probe until the trailing edges of the square waves are all at the same vertical display amplitude, as shown in Fig. 2-14 (C).

n. Switch the oscilloscope Time/cm to .2 ms.

o. Adjust the AC COMP FINE ADJUST (and AC COARSE COMP if necessary) of the second probe to obtain optimum flatness and minimum aberration at the leading edges of the square waves, as shown in Fig. 2-14 (D).

p. Switch the Amplitude Calibrator to Off and the Type 1A5 A and B Input AC-GND-DC controls to GND. The probes are now adjusted for use with the Type 1A5, and matched to each other.

Prior to probe use in critical common-mode applications, connect both probe tips to one of the two points to be compared. Set the Type 1A5 VOLTS/CM control to the sensitivity setting which will be used in the actual application. Readjust the second probe to provide maximum CMRR as observed on the CRT.

Examples of Voltage/Signal Measurements

The rest of this section provides examples of how to make various voltage/waveform measurements. All examples pre-

sume that the Type 1A5 front panel adjustments have been made satisfactorily. Reasons for the steps or their sequence are not covered here, but can be understood if the operator has read the information contained earlier in this section. These examples can be duplicated by an operator to serve as familiarization exercises.

NOTE

In all cases the Vc AMPLITUDE control and the VOLTS/CM switch were set on the basis of a voltage input whose approximate value was known. If the approximate value of voltage is not known, (but is definitely within the maximum input signal range of the Type 1A5), it can be determined by single ended or differential comparator methods, starting with the least sensitive VOLTS/CM setting (20 V/CM).

Type 544 Oscilloscope set-up for all examples:

Triggering Mode	Auto
Triggering Slope	+
Triggering Coupling	AC
Triggering Source	Norm Int
Time/CM	2 ms
Horizontal Display	Normal (X1)
Amplitude Calibrator	50 mV

Example 1. Single-ended operation, DC measurement. Measure the voltage output of a 1.5V battery. (Any con-

Operating Instructions—Type 1A5

venient DC source can be substituted and the sensitivity of the Type 1A5 set accordingly.)

Type 1A5 set-up

Vc POLARITY	0
POSITION	Centered
AC-GND-DC (A Input)	GND
A INPUT	Connected to battery positive terminal. (Connect battery negative terminal to Type 1A5 Ground terminal.)
VARIABLE	CAL
DISPLAY	A-Vc

- Perform the STEP ATTEN BAL adjustment as outlined in the front panel adjustment procedure.
- Set the VOLTS/CM switch to .5V.
- Use POSITION control to set the trace to DC-0 reference.
- Place the A Input AC-GND-DC switch to DC.
- Multiply centimeters of deflection by deflection factor (3 cm \times .5V). Input voltage amplitude is 1.5V.

Note that if the input had been applied to the B INPUT terminal and the DISPLAY switch set to Vc-B, the deflection would have been downward, since the B INPUT causes an inverted presentation.

Example 2. Differential Comparator Operation, DC measurement. Measure the voltage output of a 1.5V battery.

Type 1A5 set-up

Vc POLARITY	0
POSITION	Centered
AC-GND-DC (A Input)	GND
A INPUT	Connected to battery positive terminal. (Connect battery negative terminal to Type 1A5 Ground terminal.)
VARIABLE	CAL
DISPLAY	A-Vc

- Perform the STEP ATTEN BAL adjustment as outlined in front panel adjustments.
- Set the Vc AMPLITUDE to expected input voltage. (1.5V on 5V range. Setting 1-5-0.)
- Set the VOLTS/CM control to 20 mV.
- Using POSITION control, set the trace to DC zero reference.
- Simultaneously place A Input AC-GND-DC switch to DC, and Vc POLARITY switch to the polarity of the input voltage, +.
- Using Vc AMPLITUDE control, reset the trace to DC zero reference.

- Read the value of the input voltage from the Vc AMPLITUDE dial, +1.5V.

Example 3. Single-Ended Operation—waveform measurement. Measure the oscilloscope Cal Out waveform and DC level.

Type 1A5 set-up

POSITION	Centered
AC-GND-DC (A Input)	GND
AC-GND-DC (B Input)	GND
A INPUT	Connected to oscilloscope Cal Out connector via coaxial cable
VARIABLE	CAL
DISPLAY	A-B

- Perform the STEP ATTEN BAL adjustment as outlined in front panel adjustments.
- Set the VOLTS/CM control to 10 mV position.
- Set the oscilloscope Amplitude Calibrator control to 50 mV.
- Place A Input AC-GND-DC switch to its AC position. Set the oscilloscope triggering controls as necessary for a stable presentation.
- Compute AC waveform amplitude, using the POSITION control as necessary to set the waveform to a reference line. (5 cm deflection times 10 mV deflection factor equals 50 mV.)
- Determine the DC level on which the waveform is riding. Do this as explained in example 1 or 2, noting the DC level of the top, middle or bottom of waveform, as desired.

Note that for signals with a high AC to DC ratio, the AC and DC components can be evaluated simultaneously by using DC coupling and single-ended operation methods.

If a very low frequency is involved (less than 2 Hz), the waveform measurement must be made using DC input coupling. AC and DC signal components can be determined simultaneously by introducing Vc to offset the DC component. The AC component can be determined by comparison against the CRT graticule and the DC component can be read from the Vc AMPLITUDE dial.

Example 4. Differential Amplifier Operation. Measure the difference between the oscilloscope Cal Out waveform and modified Cal Out waveform.

Oscilloscope set-up

Set the Amplitude Calibrator control to Off.

Connect a BNC T adapter to the Cal Out connector.

Build and connect a voltage divider to the BNC T as illustrated in Fig. 2-15.

Type 1A5 set-up

POSITION	Centered
AC-GND-DC (A Input)	GND
AC-GND-DC (B Input)	GND

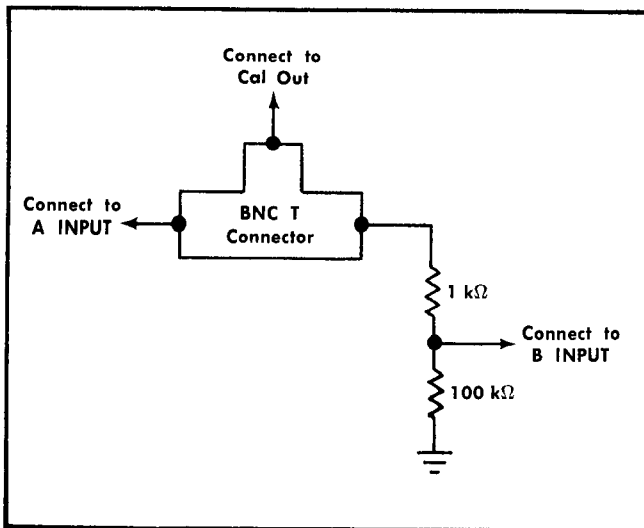


Fig. 2-15. Voltage divider for Example 4.

A INPUT	Connected to Cal Out through a BNC T connector.
B INPUT	Connected to junction of 1 kΩ and 100 kΩ resistor.
DISPLAY	A-B

- a. Perform the STEP ATTEN BAL adjustment as outlined in front panel adjustments.
- b. Place the VOLTS/CM switch to 20 mV.
- c. Set the oscilloscope Cal Out control to 5 volts.
- d. Using the POSITION control, set the trace to DC zero reference.
- e. Simultaneously place both AC-GND-DC switches to DC. Adjust the oscilloscope triggering controls if necessary to obtain a stable waveform.
- f. Measure the waveform amplitude. It will be equal to the difference between the two input waveforms—approximately 50 mV. (This is the amount dropped across the 1 kΩ resistor.)

SECTION 3

CIRCUIT DESCRIPTION

Introduction

A detailed description of the Type 1A5 circuitry is contained in this section. The scope of coverage includes a block diagram description of overall operation, the theory of operation of individual circuits, and the functions of specific components within the circuits. This description is intended to provide enough information about the Type 1A5 to enable a technician to troubleshoot any part of it.

Simplified drawings are provided where necessary for effective circuit explanation. No attempt is made to explain basic operations of components except for those that are not general knowledge. Some additional information regarding components is included in the Maintenance Section of this manual.

Resistors on schematics are valued in ohms unless otherwise indicated. Capacitor values which are not assigned the symbol " μF " are indicated as follows: pF—whole numbers; μF —decimal numbers. Example: 0.1 is in μF ; 33 is in pF.

BLOCK DIAGRAM DESCRIPTION

The Operating Instructions section of this manual provides a block diagram and a basic description of the Type 1A5 circuitry, with emphasis on front panel controls and adjustments. It is suggested that it be reviewed before continuing in this section.

Refer to the Block Diagram in Section 9. The A channel and B channel make up most of the Type 1A5 circuitry. These two channels are identical except that a signal applied to the A channel will cause a displayed signal of the same polarity as the input signal, and a signal applied to the B channel will cause an inverted display signal. The two channels are distinct until after they enter the Comparator circuit. From there on they operate in push-pull, providing outputs to be applied to the oscilloscope vertical amplifier. If desired, signals can be accepted from an active differential probe instead of from the A INPUT and B INPUT circuitry.

Four operating voltages are developed within the Type 1A5: +20.7 and +60 volts for circuit operation; +6.2 V for reed switch and active probe operation; and a variable 5 volts for input voltage comparison purposes. In addition, +50 volts and -50 volts are developed within the Type 1A5 for Differential Probe operation.

Assume that A-Vc has been selected by the DISPLAY switch and a Comparison Voltage of 0 is applied to the B channel.

A signal applied to the A INPUT connector passes through the Input Coupling selector switch to the Input Attenuator circuit where it is attenuated by a factor of 1, 10, 100 or 1000. The output of the selected attenuator is applied to a contact of the DISPLAY switch. From the DISPLAY switch the signal goes to the gate of field effect transistor (FET)

Q123A. The output is taken from the source of Q123A and passes through emitter follower Q143 to a contact of a relay controlled by the Differential Probe PUSH ON/OFF button. Transistors Q133 and Q128 aid in the operation of the FET circuit.

If Differential Probe operation has not been selected, a relay routes the signal to Q164 in the Comparator circuit. The Comparator acts as a paraphase amplifier which provides a push-pull output in response to signals from either the A channel or the B channel. With a signal applied, Q164 provides an inverted output through V164 and emitter-follower Q183 to gain switching amplifier Q314-Q334. Responding to the same signal into Q164, the other half of the Comparator (Q264, V264 and Q283) provides Q324-Q344 with a signal having a polarity opposite to that applied to Q314.

The amount of amplification provided by the Gain Switching Amplifier (Q314-Q324) is controlled by the VOLTS/CM control. The Output Amplifier further amplifies the push-pull signal from Q314-Q324 and provides an output which is impedance-matched to the oscilloscope's vertical amplifier circuit.

Returning to the Comparator circuit, if the Comparator receives signals simultaneously from the two input channels, its output will be an amplification of the difference between the two. Therefore, if the two signals are equal in amplitude and phase (common-mode), the Comparator will have no signal output. In A-B mode, this "differential amplifier" action occurs and provides an output which is representative of the difference between the signals applied at the A and B INPUT connectors.

With the DISPLAY switch in A-Vc or in Vc-B position, the COMPARISON VOLTAGE (Vc) network can be used to supply a voltage to one of the signal channels. The Comparator will accept this as a DC signal, and will cancel an equal amount from the signal in the other channel.

When the Differential Probe signal is selected by depressing the PUSH ON/OFF button, a push-pull signal goes from the probe to the Comparator. The Comparator then acts as a conventional push-pull amplifier.

Power Supplies. The Type 1A5 receives the following voltages from the oscilloscope: +225 V, +100 V, +75 V, -150 V DC, and 6.3 V AC. Circuits within the Type 1A5 provide four additional regulated voltages for Type 1A5 operation. The +20.7 and +6.2 volt supplies are located on the Input Amplifier board and use the +75-V input as their source. An adjustable +60-V supply, located on the Output Amplifier board, is powered by the +100-V input. A COMPARISON VOLTAGE (Vc) supply is derived from the +100-V or -150 V input and can be either + or -5 V as determined by the POLARITY control. The Differential Probe is powered by the +6.2/+20.7-V supply and by +50-V and -50-V supplies derived from the +60-V and -150-V supplies respectively.

DETAILED CIRCUIT DESCRIPTION

Input Circuitry

This explanation of the A Input circuitry can be adapted to the B Input circuitry, since the two are essentially identical.

Input Coupling

The Input Amplifier schematic shows the A Input Coupling circuit, which includes J101, C101, R101 and SW101. Input signals pass through J101 and connect to coupling capacitor C101 and the DC terminal of Input Coupling switch SW101. C101, SW101 and R101 form a combination input coupling and precharge-discharge circuit. With SW101 connected to the GND terminal, the A amplifier channel input is grounded and C101 charges through R101 to the DC value of the input signal. When SW101 is subsequently switched to the AC position, the amplifier is not disturbed by any DC charging current.

Under AC input coupling conditions, C101 retains its DC charge after the input signal is removed. It can be discharged safely through R101 by placing SW101 to the DC position.

C101 and the B Input channel's C201 are matched to within 1% to ensure at least 1000:1 CMRR at 60 Hz.

Attenuators

Matched attenuators are simultaneously inserted into the A and B INPUT signal paths by the VOLTS/CM switch. The $\times 1$, $\times 10$, $\times 100$ and $\times 1000$ attenuators divide the input signal by the indicated factor and also control the Input Signal Range and the Maximum (non-destructive) Input Voltage for the Type 1A5. The VOLTS/CM switching schematic shows details of the switching and attenuator circuitry, and Table 3-1 lists the attenuator in use in each switch position.

The $\times 10$, $\times 100$ and $\times 1000$ attenuators consist of RC voltage dividers which combine with the remaining input circuitry to provide the indicated fractional output to the gates of Q123. (The $\times 1$ attenuator provides a direct path through the attenuator unit and therefore involves no components.) Resistor tolerances are 0.1% and provide low frequency attenuation accuracy of 0.2% in single-ended operation. Attenuation accuracy at higher frequencies is obtained by using adjustable capacitors.

Matching between the A and B Input Attenuators is obtained by adjusting one to the other after attenuation accuracy has been obtained. A DC common-mode rejection ratio of 2000:1 is obtained with the $\times 10$ and $\times 100$ attenuator in use by adjusting R105D and R106D respectively. The AC common-mode rejection ratio for $\times 10$ and $\times 100$ attenuator operation is obtained by adjusting C205D and C206B. Table 3-2 lists all the attenuator circuitry adjustments and their purposes.

TABLE 3-1

VOLTS/CM Switch Selection Data

VOLTS/CM POSITION		Input Signal Range ¹	Attenuator in Use				Reed Switches Actuated			
Knob In	Knob Out (Retained Range)		$\times 1$	$\times 10$	$\times 100$	$\times 1000$	K301	K304 K305	K307	K311 K313
1 mV		5 V	x				x	x		
2 mV		5 V	x					x		
5 mV		5 V	x						x	x
10 mV		5 V	x							x
	10 mV	50 V		x			x	x		
20 mV		5 V	x							
	20 mV	50 V		x				x		
50 mV		50 V		x					x	x
.1 V		50 V		x						x
	.1 V	500 V			x		x	x		
.2 V		50 V		x						
	.2 V	500 V			x			x		
.5 V		500 V			x				x	x
1 V		500 V			x					x
2 V		500 V			x					
5 V		500 V				x			x	x
10 V		500 V				x				x
20 V		500 V				x				

¹Also applies to Equivalent Comparison Voltage Range

TABLE 3-2
Input Attenuator Adjustments

Purpose Of Adjustment	Adjustments							
	"A" Input Attenuators				"B" Input Attenuators			
	×1	×10	×100	×1000	×1	×10	×100	×1000
Input Capacitance	C108	C105A	C106A	C107A	C208	C205A	C206A	C207A
H.F. Attenuation		C105B	C106B	C107B		C205B	C206B	C207B
L.F. CMRR		R105D	R106D					
H.F. CMRR						C205D	C206B	

The output of the attenuator circuit develops across R108, C108, R121, C122 and R122. C108 adjusts the input capacitance to 20 pF. C122 also affects the input capacitance, but is adjusted primarily to improve the high frequency common-mode rejection ratio. R108 and R121 form a suppression network to improve circuit stability. C109 and R109 are inserted in the signal path to improve transient response.

Source Follower and Bootstrap Circuitry

Identical source follower and bootstrap circuits are contained in the A and B channels. A simplified schematic of the A channel is presented in Fig. 3-1.

Signals passing through the input circuitry are applied to the gate of FET Q123A. (An operational analogy exists between a field effect transistor and a vacuum tube, with the gate comparing to a grid, the source to a cathode and the drain to a plate.) In typical cathode-follower manner, the signal is developed at the source of Q123A and applied to the base of emitter-follower Q143. The signal from the emitter of Q143 is applied to relay contact K295A.

The source of Q123A operates quiescently at approximately +0.6 V. This voltage is established by a relatively constant current through the high impedance source resistors R123 and R127 and constant current transistor Q128. R129 is adjusted to balance this voltage between the A and B channels during quiescence. When R129 is adjusted properly, there will be no trace shift when switching from one gain setting to another with no signal applied.

Part of the Q123A source impedance is made up of the Q143 base-emitter circuit. Resistor R141 and potentiometer R140 are placed in parallel with this circuit to allow adjustment of differences between the A and the B channel loading effects. With R140 (COMMON-MODE BAL) properly adjusted, no trace shift will result when DC or low-frequency common-mode signals within the input signal range are applied simultaneously to the A and B channels.

The bootstrap (positive feedback) circuitry consists of R148, R149 and Q133. A majority of the signal occurring at the emitter of Q143 is felt across R149 and is applied to the base of Q133. The polarity of this signal is the same as that applied to the gate of Q123A. Q133 and Q123A therefore act in unison and form a high impedance input circuit relatively independent of the gain of the active devices, and provide a gain of approximately 1 from the FET gate to the emitter of Q143.

Input Protection Circuitry

Protection from positive input signals is provided by the circuit design and D133. The high impedance source load

of Q123A allows the source voltage to follow the gate signal up to +100 V without component damage. This voltage dictates the value to which the emitter of Q143 and the base of Q133 will go. As the input signal rises and the base of Q133 approaches +20 V, the collector-base junction of Q133 becomes forward biased; D133 becomes back biased. All connections to Q123A, Q133 and Q143 are allowed to rise to the vicinity of the voltage at the gate of Q123A and no stress approaching breakdown voltage exists across any components.

Negative signal input protection up to -100 V is obtained through B122, R138, R139 and Q137. During normal operating conditions, Q137 is saturated and has about 0.2 V dropped across it. The voltage at its base is approximately +21 V. When the signal on the gate of Q123A reaches about -60 V, B122 ionizes and maintains approximately 55 V across itself. This places the base of Q137 near -5 V, forcing its emitter to follow. Any further change in gate voltage will be transferred directly to Q137, keeping the difference in voltage between Q123A source and Q137 emitter within component breakdown values.

Refer back to the Input Amplifier schematic to follow the discussion of the remaining components in the A channel source-follower circuit.

Input cross-talk (inter-action) at high frequencies through the capacitance of de-ionized neon tubes B122 and B222 is kept to a minimum by decoupling action of C139. C126 (in the base biasing network of Q128 and Q228) minimizes cross-talk between the constant current circuits. C124 and C148 improve high frequency response. The series combination of C132 and R132 provides high frequency damping. The source and emitter circuit capacitances of Q123A and Q143 are set for optimum CMRR in the 1 to 10 MHz range by adjusting C123. Resistor R145 is shunted by C144 to improve the gain of Q143 at high frequencies. R159, R259 and PROBE STEP ATTEN BAL R158 allow balancing of the A and B channels during active probe operation.

B channel operation can be followed by relating the components in the B channel to their counterparts in the A channel.

Comparator Circuit

The comparator is made up of two cascaded, emitter-coupled amplifiers with a gain of about 4. It provides a push-pull output in response to any unbalance of inputs at TP160 and TP260. This unbalance can be the result of a signal input from one channel or the difference between the signals from the two channels.

Circuit Description—Type 1A5

Under quiescent conditions, each half of the comparator is receiving half of the current being supplied by the constant current circuit including R170, R171, R271, Q174, R174, R175 and R176. If a positive signal is received by one half of the comparator, current through it will increase. The additional current is obtained from the constant current source by decreasing the current through the other half of the comparator.

A positive signal at TP160 causes current through Q164 (and therefore through load resistor R168) to increase,

resulting in a negative signal at the plate of V164. The increase of current through Q164 is obtained through R167 by decreasing current through the Q264-R268 circuit. This results in a positive signal at the plate of V264.

Ideally, if common-mode signals arrive at TP160 and TP260, the trans-impedance of the two halves of the comparator remain balanced to each other. The constant current circuit prevents any change of current in either half, and no signal output can result. Under actual common-mode signal conditions, the constant current circuit cannot

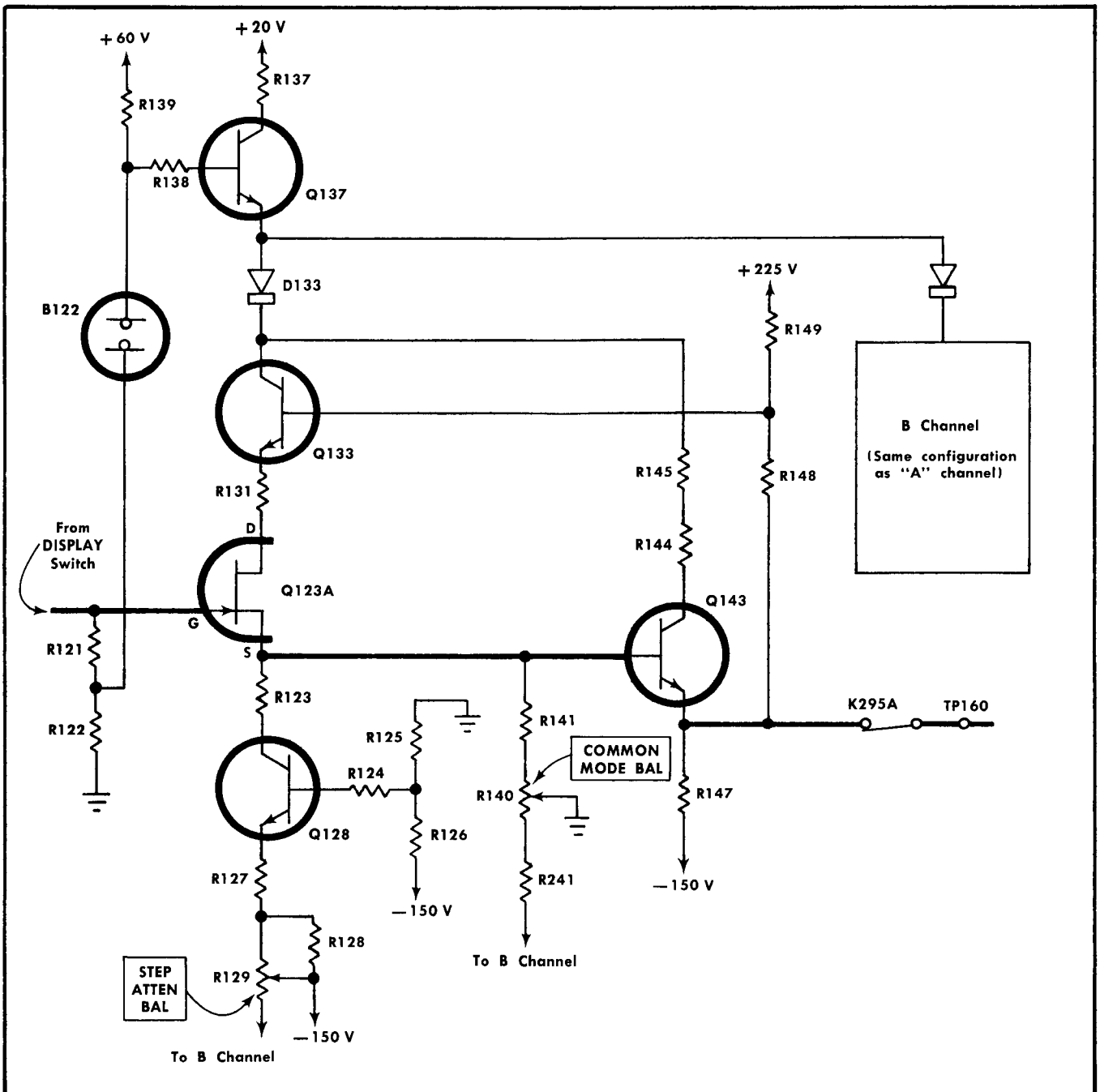


Fig. 3-1. "A" Channel Source Follower circuit, simplified.

maintain 100% constant current, but it keeps changes to a minimum. The minor changes which occur at the plates of V164 and V264 are equal and, being common-mode, will have no effect upon trace deflection.

R179, C179, R279 and C279 are bootstrapping components which help in minimizing these minor common-mode current changes through Q164 and Q264. As was previously explained, the emitter of Q133 follows the gate voltage of Q123A. AC voltage changes at Q133 emitter are coupled through R179 and C179 to the collector of the comparator constant current transistor, Q174.

The change at the collector of Q174 is therefore of the same polarity and virtually the same amplitude as that occurring at the emitter of Q164. Changing both values by the same amount in the same direction results in no change in the voltage drop across R170 and R171, and the current through them remains constant.

If identical signals are applied to both the A and B channels, the emitters of Q164 and Q264 will remain at equal voltages. The two sides of the comparator circuit are then in balance and no current will flow through R167.

The resultant constant current through R170 and R171 is the same current that flows through R168. With no change in current through R168, the voltage drop across it cannot change and the output of the amplifier remains constant. This same effect occurs in the B side of the comparator.

If any inequality exists between the signals into the two channels, the voltages at the emitters of Q164 and Q264 will not be at equal levels. Current will flow across R167, resulting in an increase of current through one transistor and a decrease through the other, causing the previously described push-pull reaction.

D167A and D167B are a matched pair of diodes which provide overload protection for the comparator circuit. They are packaged as a single unit for thermal balance. Under overload conditions, the input source-follower and emitter-follower are allowed to follow the input signal voltage in a positive or negative direction. This voltage is coupled into TP160 and TP260, and under extreme conditions would cause the breakdown voltages of components to be exceeded. D167A and D167B become reverse biased and isolate the two halves of the comparator from each other before breakdown values are exceeded. In addition to providing protection, D167A and B improve recovery time for the Type 1A5.

T167A and B improve transient response for the comparator circuit by providing instantaneous coupling of high-frequency signals from one half of the comparator to the other. V164 and V264 decrease the operating voltage across Q164 and Q264 and respond in step with them. R164, R165, R166, R264, R265 and R266 are biasing and signal coupling components for V164 and V264.

Coarse balancing of the Type 1A5 is done through DC BAL potentiometer R170. This internal adjustment acts the same and is accomplished in much the same manner as the STEP ATTEN BAL.

Transient response is improved through R169, C169, and C269. C267 adjusts the high-frequency common-mode rejection ratio of the comparator stage; C163 and C263 allow for balancing of the input capacitance to it. Decoupling of the constant current transistor's base through C176 improves

circuit stability. Emitter-followers Q183 and Q283 lower the output impedance of the comparator circuit to allow efficient transmission of the signal to the Output Amplifier board and to provide impedance matching to the gain switching stage. R181 and R281 suppress parasitic oscillations which could occur if the transistors were connected directly to the +60-V supply.

Output Amplifier Circuitry

The Output Amplifier section consists of the gain switching amplifier and output amplifier circuitry.

Gain Switching Amplifier

Refer to the Output Amplifier schematic in Section 9. The A and B Gain Switching Amplifiers receive equal and opposite signals from the Input Amplifier board and, except for polarities, respond in a manner identical to each other. The Q314-Q334 amplifier section will be discussed here.

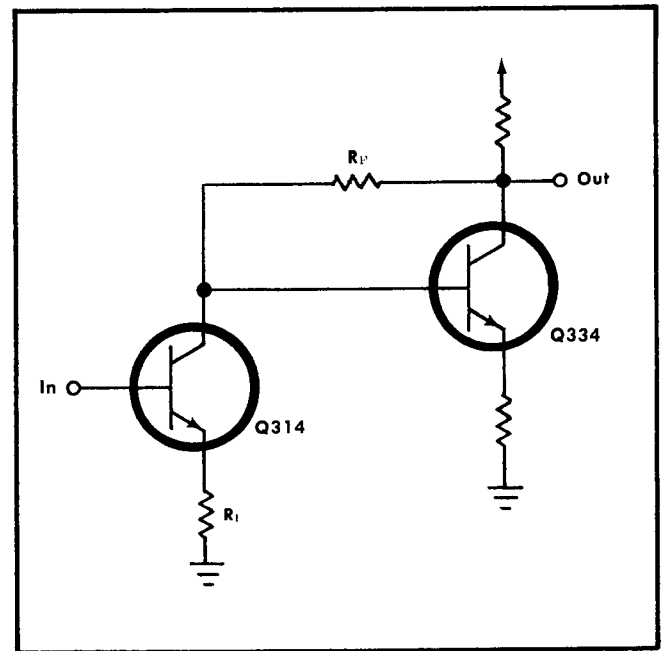


Fig. 3-2. Gain Switching Amplifier, simplified.

The simplified version of the Q314-Q334 amplifier circuit shown in Fig. 3-2 can be recognized as an operational amplifier. R_i represents the gain switching resistors in the emitter circuit of Q314 and R_F represents R333.

With a positive change of voltage at the Q314 base, an almost identical change occurs at the Q314 emitter. Current will increase through the transistor by an amount equal

to the voltage change divided by R_i . ($\frac{\Delta e_{in}}{R_i} = \Delta i_{R_i}$). The

majority of this current increase will flow through Q314 collector circuit and the collector voltage will attempt to drop due to normal transistor action. As the collector voltage of Q314 attempts to drop, Q334's emitter current decreases. A voltage rise occurs at the collector of Q334 and current

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through R_F increases by an amount equal to the change of Q334 collector voltage divided by R_F . ($\frac{\Delta e_{out}}{R_F} = \Delta i_{R_F}$). When Δi_{R_F} equals Δi_{R_I} the circuit is balanced at the new operating level.

Because of Q334's amplification factor, the voltage at the base of Q334 changes by an insignificant amount and this point can be referred to as a virtual ground. The change of voltage that must occur at Q334 collector with respect to the voltage change at Q314 base is the circuit gain.

The change that occurred at the base of Q314 also occurred at its emitter and $\frac{\Delta e_{in}}{R_I} = \Delta i_{R_I}$. The change at the Q334 collector resulted in a current change through R_F to balance the circuit and $\frac{\Delta e_{out}}{R_F} = \Delta i_{R_F}$. Since $\Delta i_{R_I} = \Delta i_{R_F}$, it is logical to say $\frac{\Delta e_{in}}{R_I} = \frac{\Delta e_{out}}{R_F}$. Revising the equation results in $\frac{\Delta e_{out}}{\Delta e_{in}} = \frac{R_F}{R_I}$. Since $\frac{\Delta e_{out}}{\Delta e_{in}}$ is circuit gain, the ratio of $\frac{R_F}{R_I}$ must also equal circuit gain.

In response to signal inputs, the emitters of Q314 and Q324 always change equal amounts in opposite directions. A point midway between the resistances connecting the two emitters sees no change and represents AC ground. R_I of the Q314-Q334 operational amplifier therefore equals one-half of the resistance between the emitters of Q314 and Q324 under any switching condition.

R_F of the operational amplifier is R333, the resistance between the collector of Q334 and its base; the point of virtual AC ground.

Since an increase of current through the A amplifier is accompanied by a decrease through the B amplifier, R317 and R327 provide a constant current for the operation of the two amplifiers under all signal conditions.

VAR BAL potentiometer R330 and resistors R331 and R341 provide an adjustable amount of current to the two amplifiers to allow balancing of the following stages. When R330 is properly set, changing gain by rotating the VARIABLE control (R350) will have no effect upon the trace position under "no signal" conditions.

Circuit stability is aided by oscillation damping components C300, R300, L337², R336, R346 and C338. The numerous capacitors and inductors in the emitter gain switching circuitry are frequency compensating components.

Reed switches are used to control the emitter resistance for gain switching. In some instances, pairs of contacts are used to insert a single circuit. This is done to keep emitter circuit capacitance as low as possible. Table 3-1 lists the switches actuated in each VOLTS/CM switch position. The

²L337 and numerous other "L" designated components within the Type 1A5 are not conventional coils. They are constructed by passing a wire (it may be a component lead) through the center of a ferrite core. The core is referred to as a "ferrite bead" on the schematic diagrams.

value of emitter to emitter resistance and the gain factor of the gain switching amplifier circuit in the five basic deflection factor settings are outlined in Table 3-3.

TABLE 3-3
Gain Switching Amplifier

VOLTS/CM	1 mV	2 mV	5 mV	10 mV	20 mV
Emitter-to-Emitter Resistance	135 Ω	289 Ω	761 Ω	1576 Ω	3360 Ω
Gain of Stage (Approx)	6	3	1.2	0.6	0.3

Output Amplifier

Q354, Q374 and associated components form the A Channel Output Amplifier circuit for the Type 1A5. This amplifier is essentially the same as the gain switching amplifier and the function of most of the components can be determined by comparison against that circuit. L375 and C375 are oscillation damping components. Type 1A5 gain calibration is set by adjusting GAIN potentiometer R360 with the VARIABLE control detented at 0 resistance. The gain of the Output Amplifier circuit is set to approximately four, and decreases to about 1.6 when R350 is totally inserted. UNCAL lamp B355 indicates whenever R350 is not detented.

Position Range potentiometer R370 is an internal adjustment for balancing the operation of Q374 and Q384. This adjustment is in parallel with the front panel POSITION control and therefore provides for equal range of the POSITION control above and below the graticule center. High frequency compensation is provided by T389, C378, C379, C389, R379 and R389. Adjustable components are set in the 20 mV/cm sensitivity range. R378 and R388 correct the output impedance for compatibility with the oscilloscope vertical amplifier.

Comparison Voltage

The comparison Voltage circuitry is shown on the Input Amplifier schematic. A positive or negative 9 volts, (dependent on the POLARITY switch position), is regulated by Zener diode D111 and is applied to the voltage divider consisting of R113, R114 and R115. R113 (Vc Cal) is adjusted to provide 5 V (± 2.5 mV), across R115. The 10-turn Helipot AMPLITUDE control, R115, determines how much voltage is available for application to the selected FET gate. Its dial can be read to 3 significant digits. R116 is a ground loop current limiter. C114 filters Zener noise, and the C117-R117 combination decouples spurious voltages which may otherwise reach the FET gates.

Reed switch relay K119 is activated when the VOLTS/CM control is in the 5-V, 10-V or 20-V position. R118 and R119 then are placed in parallel with R115, and the resultant decrease in resistance causes the voltage across R115 to decrease to 0.5 V. This holds the effective Vc voltage range to 500 volts even though the $\times 1000$ attenuator is in use. Vc $\times 10$ Cal (R119) allows calibration of the 0.5 V.

The equivalent Comparison Voltage Range is listed in Table 3-1 for each position of the VOLTS/CM control. It is the same value as the Common-Mode Linear Dynamic Range of the Type 1A5 in all instances.

The MONITOR jack is connected to the amplifier circuit whenever the DISPLAY switch is in A-Vc or Vc-B position, regardless of the POLARITY switch setting. Only shielded cables should be connected to it when waveform observations are being made.

Operating Voltages

The Type 1A5 receives -150 V , $+100\text{ V}$, $+225\text{ V}$ and $+75\text{ V DC}$, and 6.3 V AC from the oscilloscope, as indicated on the Output Amplifier schematic. The $+100\text{-V}$ and $+225\text{-V}$ supplies are shunted together through R396 to avoid overloading of the $+100\text{-V}$ supply by the Type 1A5 circuitry. These voltage sources are equipped with decoupling networks in the oscilloscope and in the Type 1A5. Therefore, slightly lower values will be read at the Type 1A5, as indicated by the blue figures on the Input Amplifier and the Output Amplifier schematics.

Internal Power Supplies

A $+60\text{-V}$ supply is created within the Type 1A5 by inserting series regulator Q393 in the $+100\text{-V}$ supply circuit. Refer to Fig. 3-3. Output DC Level (R390) adjusts the base voltage of Q393 to set the voltage at P11 terminals 1 and 3 to 67.5% of the actual value of the $+100\text{-V}$ supply. This insures compatibility between the Type 1A5 and the oscillo-

scope. If the circuit requires a current increase, Q393 increases its emitter-base forward bias and the demanded current is provided. The increase in current is accompanied by a decrease in trans-resistance of Q393, allowing the power supply to maintain its 60-V level. A decrease in current demand causes the reverse effect.

A regulated $+20.7\text{-V}$ supply (illustrated on the Input Amplifier schematic) is provided by parallel regulator transistor Q297. The base of Q297 is referenced to $+20\text{-V}$ by Zener diode D292. This effectively clamps the emitter to $+20.7\text{-V}$ and the resistance of Q297 is automatically regulated to maintain this level.

Current passing through Q297 develops a 6.2-V supply across Zener diode D296 in the collector circuit for activating the reed switches in the gain switching amplifier and Comparison Voltages circuits. This 6.2-V source will change with load changes when VOLTS/CM control settings are changed. R296 shunts Q297 to provide sufficient current for circuit demands.

The $+20.7\text{-V}$ supply is returned to $+75\text{ V}$ through 12-V relay K295 and resistor R295 when Differential Probe operation is selected. Otherwise it is returned through R294, which provides a resistance equivalent to that of the relay circuit. Differential Probe operation is selected by the PUSH ON/OFF button assembly which contains SW297. Mechanical construction of SW297 keeps it electrically connected in its last selected position. However, relay K295 is bypassed

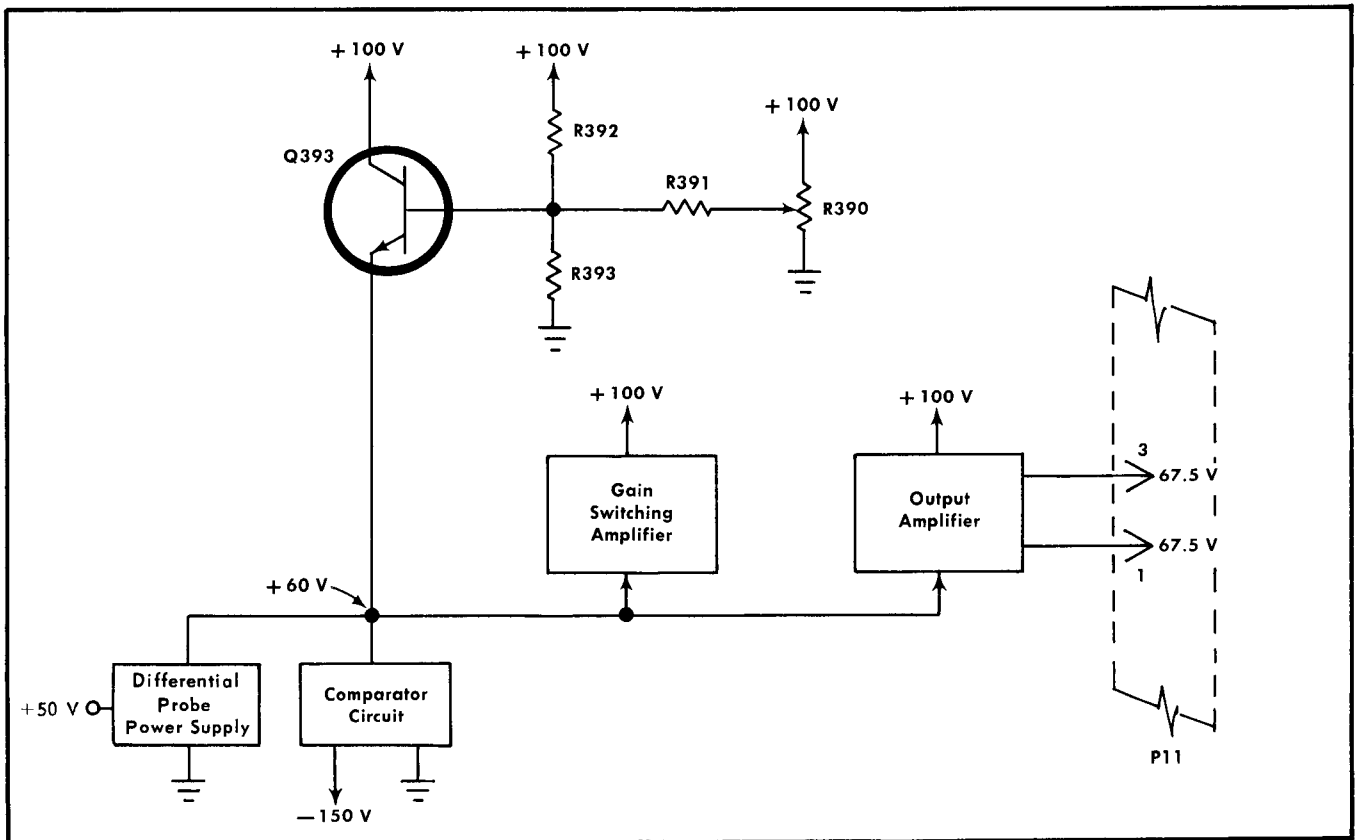


Fig. 3-3. $+60\text{ V}$ Power Supply, simplified.

SECTION 4

MAINTENANCE

Introduction

Information which will aid in keeping the Type 1A5 operating at its peak performance is contained in this section. Cleaning, lubricating and visual inspection hints are included under preventive maintenance. The section on corrective maintenance includes troubleshooting and correction procedures. Parts identification and soldering techniques are included where necessary.

PREVENTIVE MAINTENANCE

General

The instrument should be cleaned, lubricated, inspected and recalibrated at regular intervals. A recommended schedule for average operating conditions is every 6 months or every 500 hours of operation, whichever occurs first.

Cleaning

Cleaning the instrument, in addition to improving its appearance, aids its operation and lengthens its operating life. Dirt on components causes overheating and may result in short circuits. A dry, soft cloth and a soft-bristled brush are recommended for removing loose dirt from the outside of the instrument. Dirt on the inside should be loosened with a soft-bristled brush and removed by using a vacuum cleaner or a stream of low-pressure air. High-pressure air can damage the equipment and should not be used.

WARNING

Use an eye-shield when cleaning with pressurized air.

Hardened dirt should be removed by using a mild detergent and water solution on a cotton-tipped swab or a soft cloth. Avoid excessive use of water. Do not allow water to penetrate any parts. Dry the instrument thoroughly before energizing it. Avoid the use of abrasives and chemical cleaning agents.

Keep the oscilloscope side panels in place and the air filters clean to insure proper air flow over the instrument. Protect the instrument from dirt and damage by keeping it covered when not in use. (See your Tektronix, Inc. catalog for plug-in unit carrying cases and storage racks.)

Lubrication

Keep potentiometers, rotary switches and other moving parts properly lubricated. Use a cleaning-type lubricant on shaft bushings and switch contacts. Lubricate switch detents with a slight amount of grease. Potentiometers should be lubricated with a lubricant which will not affect electrical

characteristics. Do not overlubricate. Contact your Tektronix Field Representative for any additional information regarding lubricants or lubrication.

Visual Inspection

After cleaning, the instrument should be carefully inspected for defects such as poor connections, damaged parts and improperly seated tubes or transistors.

Tube and Transistor Checks

Checking tubes and transistors as a preventive maintenance function is not recommended. Circuit performance is thoroughly checked during recalibration, and unacceptable tubes and transistors will be detected at that time.

Calibration

Performing re-calibration as part of preventive maintenance is necessary for several reasons: 1) The calibration of an instrument changes slightly with age, use and operating conditions; 2) Calibration may be affected during the cleaning process; and 3) Troubles not apparent during regular operation may be revealed and corrected during calibration.

The calibration status can be determined rapidly by accomplishing the Performance Check in section 5. A step-by-step Calibration Procedure is contained in section 6.

CORRECTIVE MAINTENANCE

General

If trouble occurs in the Type 1A5, the following corrective maintenance procedure is recommended to accomplish rapid and effective repairs.

1. Check that the plug-in unit and the oscilloscope connectors are not damaged, and that the plug-in unit is properly inserted. Check that the oscilloscope plug-in sensing switch is activated (if applicable).
2. Inspect the front panel of the Type 1A5 and associated oscilloscope to be sure that the trouble is not from an incorrect control setting.
3. Insure that the parent oscilloscope is not at fault by inserting a known-good plug-in unit and checking its operation.
4. Check the Type 1A5 screwdriver adjustment settings.
5. Determine all trouble symptoms.
6. Perform a visual inspection of the Type 1A5.
7. Repair or replace obviously defective parts.

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8. Troubleshoot the Type 1A5 circuitry as necessary.
9. Recalibrate the Type 1A5.

Parent Oscilloscope

The quickest check of the oscilloscope is to use it with a good plug-in unit, or check the questionable plug-in unit with another oscilloscope. Refer to the oscilloscope manual if necessary to verify proper operation of the oscilloscope.

Operating Procedures and Control Settings

Refer to the Operating Instructions section of this manual to verify operating procedures and front panel control settings of the Type 1A5.

Trouble Symptoms

After it is confirmed that a casualty exists, Type 1A5 response to all front panel controls should be observed. The first-time operation listed in section 2 or the Performance Check in section 5 can be used for this purpose. All trouble symptoms should be evaluated and compared against each other. A casualty will often create a combination of symptoms that will pinpoint the trouble. A good example of this is power supply trouble, which will usually cause symptoms to occur in otherwise unrelated circuits.

Visual Inspection

In physically examining the Type 1A5, take special note of the area indicated by evaluation of symptoms. Look for loose or broken connections, improperly seated tubes or transistors, and burned or otherwise damaged components. Repair or replace all obviously defective parts. Investigate the cause of heat damage to components.

Calibration Check

Troubles can frequently be located and corrected by recalibrating the instrument. Unless the casualty has definitely been isolated to a specific circuit, it is recommended that the calibration procedure contained in section 6 be performed to provide a logical circuit troubleshooting sequence.

Detailed Troubleshooting

General

If the casualty has not been disclosed and corrected through the procedure outlined, a detailed troubleshooting analysis will have to be performed. The Circuit Description section, the Schematic Diagrams, and the troubleshooting aids contained in this section are designed to expedite troubleshooting.

The Circuit Description section provides a fundamental understanding of circuit operation and is referenced to the Schematic Diagrams. The Schematic Diagrams contain voltage and resistance values and signal waveforms. The specified operating conditions should be duplicated before making voltage or waveform comparisons.

NOTE

Voltages and waveforms may vary slightly between instruments. Those given in the schematics

should be checked against each instrument while it is operating properly. Deviations should be noted on the schematics for later reference.

Test Equipment Recommended for Troubleshooting

The test equipment listed here should suffice for most troubleshooting jobs. Test equipment required for re-calibration is listed in the Calibration section of this manual.

High Impedance Voltmeter (20,000 Ω /V DC or greater)

Ohmmeter (2 mA or less current on the \times 1 k scale)

Test Oscilloscope

Flexible Plug-In Extension Cable (Tektronix Part No. 012-0038-00)

Transistor Curve Tracer or Transistor Tester.

DC Balance Check

A properly operating oscilloscope will have its trace centered vertically on the CRT only when the Type 1A5 has a balanced output. The Type 1A5 is a balanced amplifier. With no signal or comparison voltage applied to the FET gates, any point in the A channel should have a potential equal (within 50 to 75 mV) to that at an identical point in the B channel.

If the CRT trace is deflected as a result of a Type 1A5 problem, unbalances will exist. They can be detected by connecting a high impedance voltmeter between identical points. (A plug-in extension is needed during this procedure to allow access to the points being checked.)

If the output balance is checked first and is in error, work toward the front until an unbalance no longer is detected. This localizes the trouble to the circuitry between the points providing balance and those providing unbalance.

Some of the Type 1A5 circuits respond to current changes with no appreciable voltage change. For this reason, the above check is not effective at the base of Q374 or of Q354.

Troubleshooting by Direct Replacement

Vacuum tubes and semi-conductor failures account for the majority of electronic equipment troubles. The ease of replacing vacuum tubes and transistors often makes substitution the most practical means of repair. If this method is used, these guide lines should be followed:

Determine that the circuit is safe for the substitute component.

Use only substitute components that are known to be good.

Remove the plug-in from the oscilloscope before substituting components, to protect both you and the equipment.

Be sure components are inserted properly. Use Fig. 4-1 as an aid.

Check operation after each component is replaced.

Return good components to their original sockets.

	SOCKETS		COMPONENT (Bottom View)	INSTALLED VIEW
	(Top View)	(View from bottom of board)		
Vacuum Tube				<p>V164, V264</p> <p>No distinctive characteristics</p>
Transistor, Dual			<p>FET, Dual</p> <p>Transistor, single</p>	<p>FET, Dual Q123</p> <p>locating index removed prior to installation</p> <p>Transistors Q143, Q243 Q164, Q264 Q183, Q283</p> <p>(Each socket is covered with a plastic thermal cap.)</p>
Transistor				<p>Q137, Q153 Q174, Q393</p> <p>Q163, Q263</p>
Transistor				<p>Dimple</p> <p>Q128, Q228, Q133, Q233, Q314, Q324, Q334, Q344, Q354, Q364</p>
Transistor			<p>+ indicates clipped lead</p>	<p>Q374, Q384</p> <p>locating index and dimple aligned</p>

Fig. 4-1. Vacuum tube and transistor installation.

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Check calibration after a bad component has been replaced.

WARNING

Voltage, either positive or negative, is always present on the cases of transistors Q137, Q153, Q174, Q297 and Q393 when the Type 1A5 is energized.

Transistor Troubleshooting

Transistor defects usually take the form of the transistor opening, shorting or developing excessive leakage. The best means of checking a transistor for these and other defects is by using a transistor curve display instrument such as a Tektronix Type 575. If a 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 resistances, or by the substitution method previously described.

When troubleshooting by using a voltmeter, measure the emitter-to-base and emitter-to-collector voltages to determine whether the voltages are consistent with normal circuit voltages. Voltages across a transistor vary with the type of device and its circuit function. Some of these voltages are predictable. The base-emitter voltage of a conducting germanium transistor will normally be 0.2 V and that of a silicon transistor will normally be 0.5 V to 0.7 V. The collector-emitter voltage of a saturated transistor will be about 0.2 V. Because these values are small, the best way to check them is by connecting the voltmeter across the junction and using a sensitive voltmeter setting.

If values less than these are obtained, either the device is shorted or no current is flowing in the circuit. If values are in excess of the base-emitter values given, the junction is back-biased or the device is defective (open). Values in excess of those given for emitter-collector could indicate either a non-saturated device operating normally, or a defective (open) transistor. If the device is conducting, voltage will be developed in resistances in series with it, whereas if it is open, no voltage will be developed in resistances in series with it unless current is being supplied by a parallel path.

TABLE 4-1

Transistor Resistance Checks

Ohmmeter Connections ¹	Resistance Reading That Can Be Expected Using the R × 1 k Range
Emitter-Collector	High readings both ways (100 kΩ to 500 kΩ, approx.)
Emitter-Base	High reading one way (200 kΩ or more). Low reading the other way (400 Ω to 3.5 kΩ, approx.)
Base-Collector	High reading one way (200 kΩ or more). Low reading the other way (400 Ω to 3.5 kΩ, approx.)

¹Test prods from the ohmmeter are first connected to the transistor leads and then the test lead connections are reversed. Thus, the effects of the polarity reversal of the voltage applied from the ohmmeter to the transistor can be observed.

An ohmmeter can be used to check a transistor if the ohmmeter's voltage source and current are kept within safe limits. 1½ V and 2 mA are generally acceptable. Selecting the × 1 k scale on most ohmmeters will automatically provide voltage and current below these values. If the voltage and maximum output current of a specific ohmmeter is in doubt, it should be checked by connecting the test leads to another multimeter before using it on transistors.

Table 4-1 contains the normal values of resistance to expect when making an ohmmeter check of an otherwise unconnected transistor. Fig. 4-1 illustrates transistors and sockets for pin location purposes.

Diode Troubleshooting

Checks on diodes (other than Zeners) can be performed in much the same manner as on transistor base-emitter junctions. Germanium diodes should have approximately 0.2 V and silicon diodes should have about 0.6 V across the junction when conducting. Higher readings indicate they are back biased or defective, depending on polarity. The ohmmeter precautions pertaining to transistors should also be observed when checking diodes. Some diodes used in the Type 1A5 are color coded to identify the diode type. A blue or pink first band indicates that the next three colors translate to the last three digits of a Tektronix part number. Diode polarity can be determined by color code position. See Fig. 4-2.

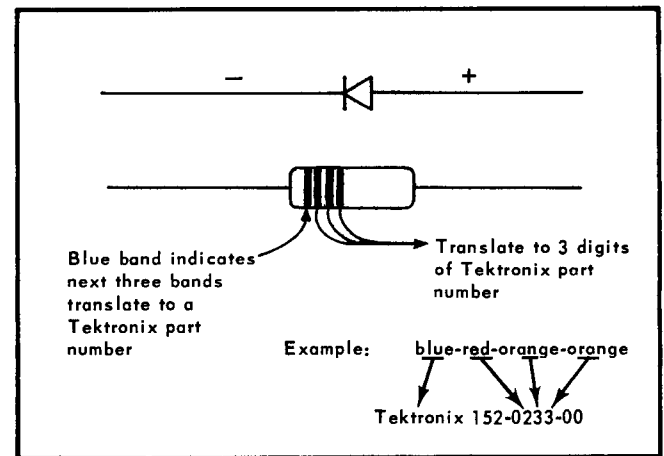


Fig. 4-2. Diode polarity and color code.

Field Effect Transistor Checks

Field Effect Transistors can be checked in the same manner as other transistors. However, it should be remembered that normal operation in the Type 1A5 has the gate-to-source junction reverse biased just as the control grid-to-cathode is biased in vacuum tubes.

Wire Color Code

Insulated wires in this instrument are color coded to indicate operating voltages and to make wire tracing easier. Table 4-2 lists the color code translations for regulated voltage supplies. It may be noted that the translations are based on the IEEE standard color code for resistors.

TABLE 4-2
Wire Color Code

Supply	Color Code
+225 V	red-red-brown on white
+100 V	brown-black-brown on white
+75 V	violet-green-black on white
+60 V	blue-black on white
+20 V	red-black-black on white
+6 V	blue on white
-150 V	brown-green-brown on tan

When it is necessary to disconnect several wires from components, make a record of the connections for installation reference.

Resistors

The types and accuracies of resistors found in this instrument vary in accordance with the circuit needs. Composition, metal film and wire-wound resistors are used. Replacement resistors should be of the same type and must be at least as accurate as those originally contained in the

circuit, to maintain the high common-mode rejection ratio. The size, location and lead length are often critical because of frequency considerations.

Resistor values are indicated by one of three methods in the Type 1A5:

3 bands (digit, digit, multiplier—tolerance)

4 bands (digit, digit, digit, multiplier—tolerance)

Values are printed on wire-wound and metal film resistors.

The first two methods translate to the IEEE color-code equivalent and are illustrated in Fig. 4-3. The last method is used on metal film resistors whose values are expressed to four significant figures.

Capacitors

The common disc and small electrolytic capacitors used in the Type 1A5 have their capacitive value marked in microfarads on the component body. White ceramic capacitors are color-coded in picofarads, using a modified IEEE code. See Fig. 4-3.

Resistance Checks

Resistances between specified points of the Type 1A5 are listed in Table 4-3. Location of these points can be determined from the parts location diagrams in this sec-

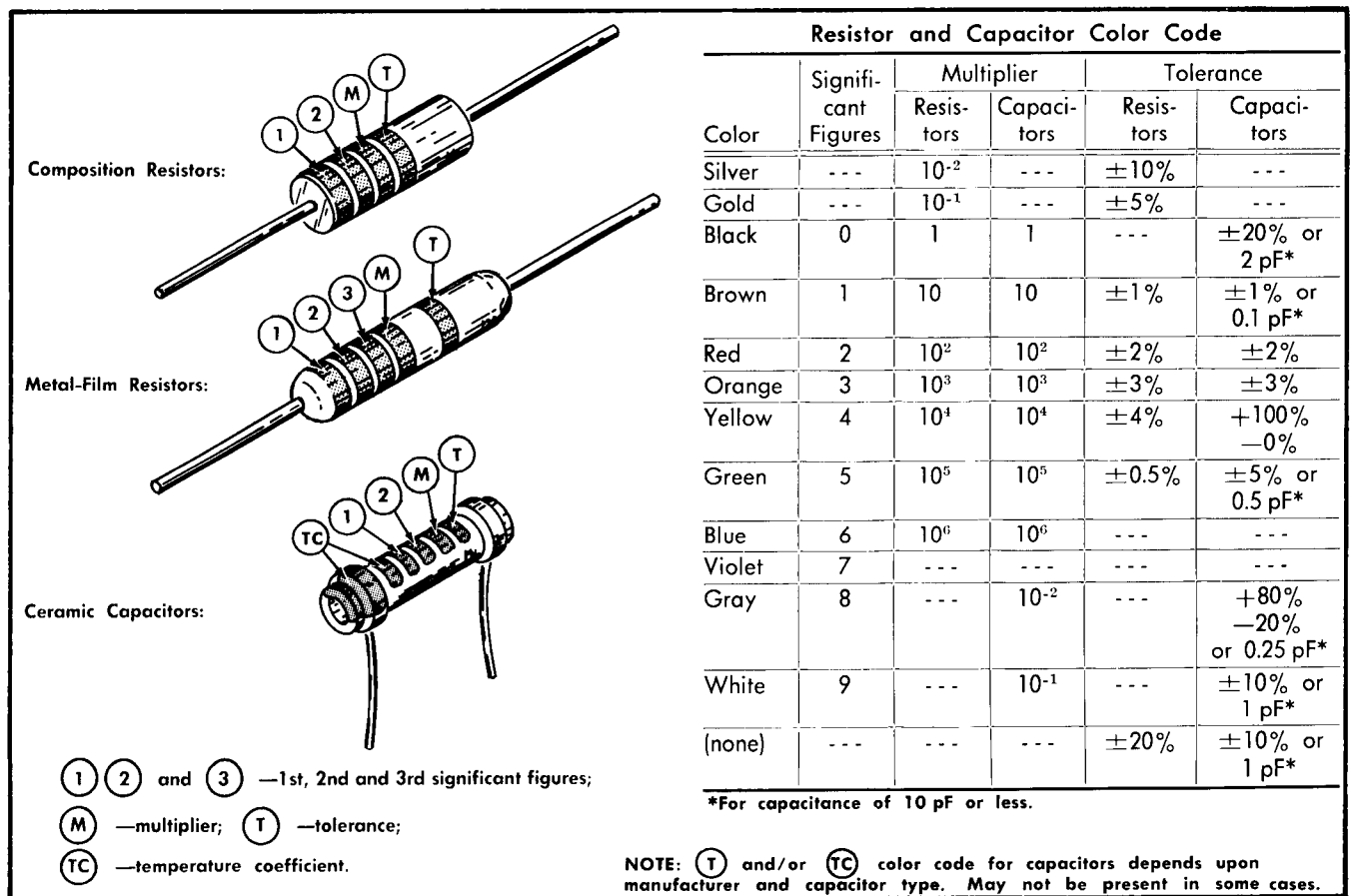


Fig. 4-3. Color code for resistors and ceramic capacitors.

TABLE 4-3

Typical Resistance Values

Conditions: Type 1A5 removed from oscilloscope.
 Control settings—POLARITY 0, POSITION midrange, DISPLAY A-B
 Ohmmeter setting— $R \times 1 k$
 Meter current limited to less than 2 mA; 1.5 V supply
 All readings taken with respect to chassis ground.

Point	Resistance	Resistance With Leads Reversed	Comments
P11-1	8 k Ω	7 k Ω	
P11-2	0	0	
P11-3	8 k Ω	7 k Ω	
P11-9	12 k Ω	18 k Ω	
P11-10	5.5 k Ω	5.5 k Ω	
P11-11	10 k Ω	10 k Ω	
P11-15	>0.5 k Ω	>0.5 k Ω	
J101	Inf	Inf	1 M Ω with SW101 at DC
J201	Inf	Inf	1 M Ω with SW201 at DC
TP160	12 k Ω	33 k Ω	
TP260	12 k Ω	33 k Ω	
J150-A	0	0	
J150-B	0	0	
J150-C	2 k Ω	>30 k Ω	
J150-E	>0.25 k Ω	>0.25 k Ω	
J150-F	5.5 k Ω	7.5 k Ω	
J150-J	2 k Ω	>30 k Ω	
J150-K	22 k Ω	25 k Ω	

tion. The presence of semi-conductors can cause the reading of a specific instrument to vary from the values given. The ohmmeter used to take the readings can produce an apparent difference. It is therefore recommended that readings of each instrument be taken while in proper operating condition, using the same type ohmmeter which will normally be used for troubleshooting. Space is provided in the table for these individual readings and they should be updated after each calibration to remain reliable.

Switches

Rotary switch wafers are coded with a number and a letter. The number indicates the wafer position in the switch assembly, counting from the front (mounting end). The letters "F" and "R" indicate whether the front or rear of the wafer performs the switching function. For example, a switch section designated 2R is contained on the rear of the second wafer as viewed from the front of the switch.

Individual wafers or mechanical parts of rotary switches are normally not replaced. If a switch is defective, replace the entire assembly. Wired and unwired replacement switches are available; refer to the Parts List for part numbers.

Procedures for the removal of most switches are generally obvious. When a switch is removed, make careful notation of the leads to the switch for installation reference.

CAUTION

Use extreme care when soldering wafer-type switch terminals. Excessive heat, or solder flowing around and beyond the rivet will destroy the contact's spring tension. Excessive heat will damage plastic switches.

Component Replacement

NOTE

Many electrical components are mounted in a particular way to reduce or control stray capacitance and inductance. Parts orientation and lead dress should duplicate the original installation. When a repair is made, a performance check (contained in Section 5) should be performed and the instrument should be recalibrated as necessary.

WARNING

Disconnect the instrument from the power source before removing or replacing components.

Parts Procurement

All parts used in this instrument can be purchased through Tektronix Field Offices or Representatives. However, replacements for standard electronic items can readily be obtained from local electronic parts stores. Before purchasing, consult the Electrical Parts List in Section 7 to determine the required specifications.

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. All replacement parts should be direct replacements unless it is known that a different component will not adversely affect instrument performance.

Special Parts. Some electrical parts are specially reworked, quality checked, or manufactured by or for Tektronix to fulfill a specific requirement. Most mechanical parts used are common to only Tektronix instruments, or to a particular type of instrument. All electrical parts whose stock number is preceded by an asterisk in Section 7, and most mechanical parts, can be obtained only through Tektronix Field Offices or Representatives. Ordering information precedes the Electrical Parts List in Section 7.

Soldering Equipment and Techniques

Soldering Equipment. Soldering irons and solder should be selected in accordance with the work being done. Recommended combinations are as follows:

Soldering on circuit boards—15- to 40-watt iron, $\frac{1}{8}$ -inch tip, 3% silver-content solder only.

Soldering to metal terminals such as on switches and potentiometers—40- to 75-watt iron, $\frac{1}{8}$ -inch tip, 3% silver-content solder or ordinary electrical solder.

Soldering to heavy metal such as the chassis or binding posts—40- to 75-watt iron, $\frac{1}{4}$ -inch tip, 3% silver-content solder or ordinary electrical solder.

Solder containing 3% silver is used extensively in Tektronix instruments to provide proper bonding to circuit board connections. Although adequate bonds can be made once or twice with common solder, its continued use will degrade the circuitry. Solder containing 3% silver works well in all applications and is recommended for general circuit repairs. It is available through most sales outlets or can be obtained through Tektronix Field Representatives. The Tektronix part number is 251-0514-00.

Component size and density demands the use of needle-nose pliers and needle-nose end nipper pliers when replacing components. Tweezers are also useful. Heat sinks such as small alligator clips are invaluable in protecting components, leaving both hands free for soldering. A hold-down aid can be made from a wooden dowel, 6 to 8 inches long and $\frac{1}{4}$ to $\frac{3}{8}$ inch in diameter. Shape one end like a pencil tip and the other end similar to a screwdriver tip. Note that the wood will absorb only a minimum of heat from the iron, but will not guard against heat transfer to the parts being soldered. Flux remover solvent and cotton-tipped swabs are needed to remove flux from soldered connections to prevent corrosion.

A solder-removing device such as an EDSYN SOLDA-PULLT, Tektronix part number 003-0428-00, is extremely useful in removing solder from circuit boards to expedite component removal and replacement.

Other soldering aids should be made or purchased to suit specific needs.

General Soldering Techniques. Keep the soldering iron tip well tinned and wiped clean. To avoid excessive heating of the general area around the connection, the iron should be completely heated before being applied. When removing components, heat only long enough to allow the part to be removed easily. (Applying a small amount of solder between the tip and the joint will usually aid in heat transfer on difficult connections. This will decrease heating of the general area.) Use the extreme tip of needle-nosed pliers to avoid drawing off too much heat. When connecting components, heat the solder sufficiently to allow free flow. Apply the solder to the wire being joined, not to the soldering iron. This will insure proper bonding. Applying a small amount of solder between the iron and the wire will again aid in initial heat transfer. Once solder flows between the tip and the wire, the solder should be applied to the opposite side of the wire to complete the process. Do not use more solder than is necessary to make a neat and effective bond.

Use heat sinks between the body of the components and the joint being soldered whenever small components and/or short leads are involved. After soldering has been completed, clip off excess wire, deflecting wire ends with a gloved finger or other device to avoid damage to fingers, eyes or circuit components. Remove clipped leads from the chassis. Clean the newly soldered area with flux remover solvent and a cotton-tipped swab.

Circuit Board Soldering Techniques. Use a 15 to 40 watt iron with a $\frac{1}{8}$ -inch tip and solder containing 3% silver. Keep the tip well tinned and clean. Do not overheat components or circuit board. Do not put excessive pressure on the board.

To remove a component, grip a lead with the tip of a pair of needle-nosed pliers. Touch the tip of the soldering iron to the connection. When the solder melts, gently pull the lead from the board. If a clean hole is not left in the board, reheat it and remove the solder with a solder removing device, or bore it out gently with a tooth-pick or a similar non-abrasive device.

Defective multiple-lead components that cannot be removed by the above process should first be removed by cutting leads. Then remove leads one at a time and clean holes as necessary.

To replace components, first bend the leads to proper shape. Cut the leads to proper size if the extra lead length interferes with installation, or cannot be reached for cutting after installation. Insert the leads in holes and set the component to the position of the original part. Re-heat the holes if necessary for proper insertion of the part. Apply heat sinks to component leads as necessary. Apply the iron and a small amount of solder to the connection. Do not remove the iron until the solder flows freely. Remove the iron and hold the component steady until solder is firm. Clip excess lead wire. Clean the soldered area with a cotton-tipped swab and flux remover.

CAUTION

Silk screen lettering dissolves when contacted by flux remover.

Specific Component Replacement Information

VAR BAL Potentiometer. This is screwed into a mounting post which is fastened to the rear of the front panel. Use an allen wrench to remove and replace the nut which secures the assembly to the front panel.

Front-Panel Knobs. Allow enough clearance for free knob movement when securing knobs to shafts.

VARIABLE knob. Place the VOLTS/CM knob in a "Retained Range" position before the VARIABLE knob is fastened to its shaft.

Probe On Lamp. Unscrew the outer knurled nut that surrounds the lamp housing. Pull the lamp housing out to extract the bulb from it.

Input Amplifier Board. Most of the components on this board can be replaced without removing the board

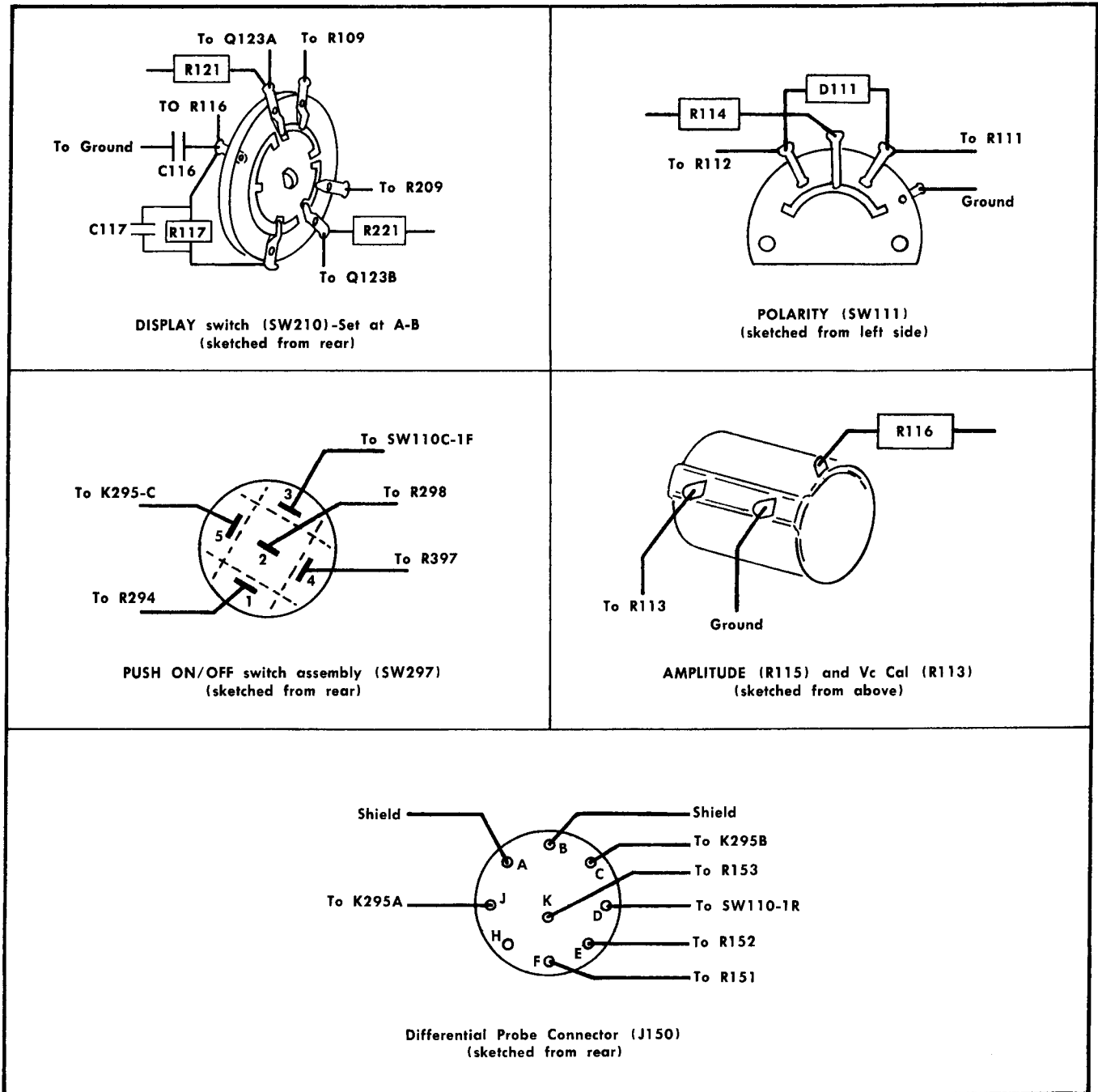


Fig. 4-4. Component wiring.

from the chassis. A solder removing device, such as the SOLDAPULLT listed under soldering equipment, is recommended for removing solder from the board, thereby expediting component removal and replacement. To remove the entire board use the following procedure:

Check wire color code against Fig. 4-6. Note any exceptions.

Disconnect all square-pin connectors from the exposed side of the board.

Disconnect the 8 square-pin connectors from the underside of the board.

At the board, unsolder the 5 leads/components which go to the DISPLAY switch.

At the DISPLAY switch, unsolder the 2 lead which go to the attenuator section.

Remove the 8 hold-down screws from the board.

Move the board toward the rear of the chassis until components clear the DISPLAY switch. Then lift up on the rear of the board and remove it from the chassis.

Replacement of the Input Amplifier board is done by reversing the above procedure, insuring that the 2 leads from

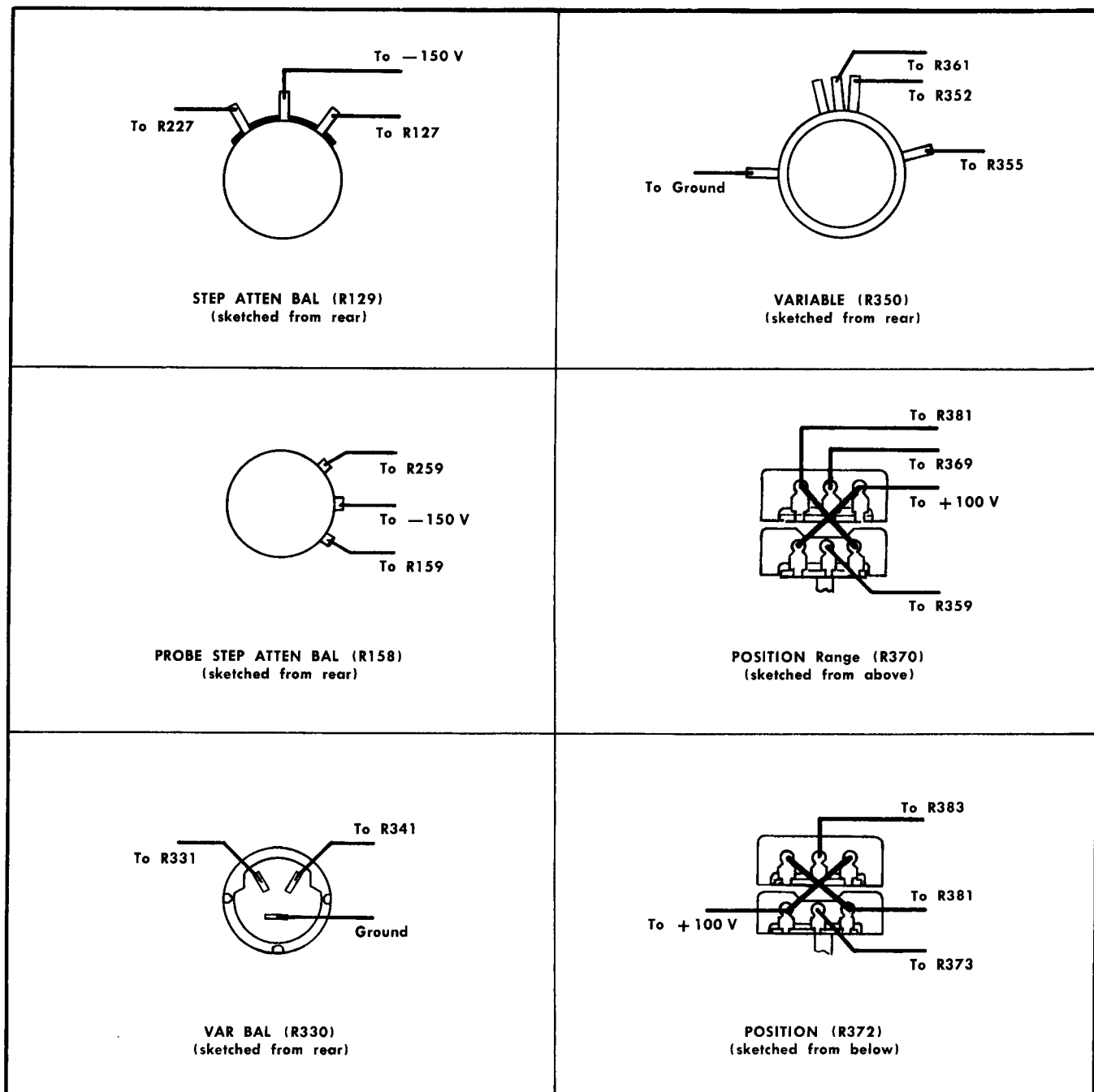


Fig. 4-5. Component wiring.

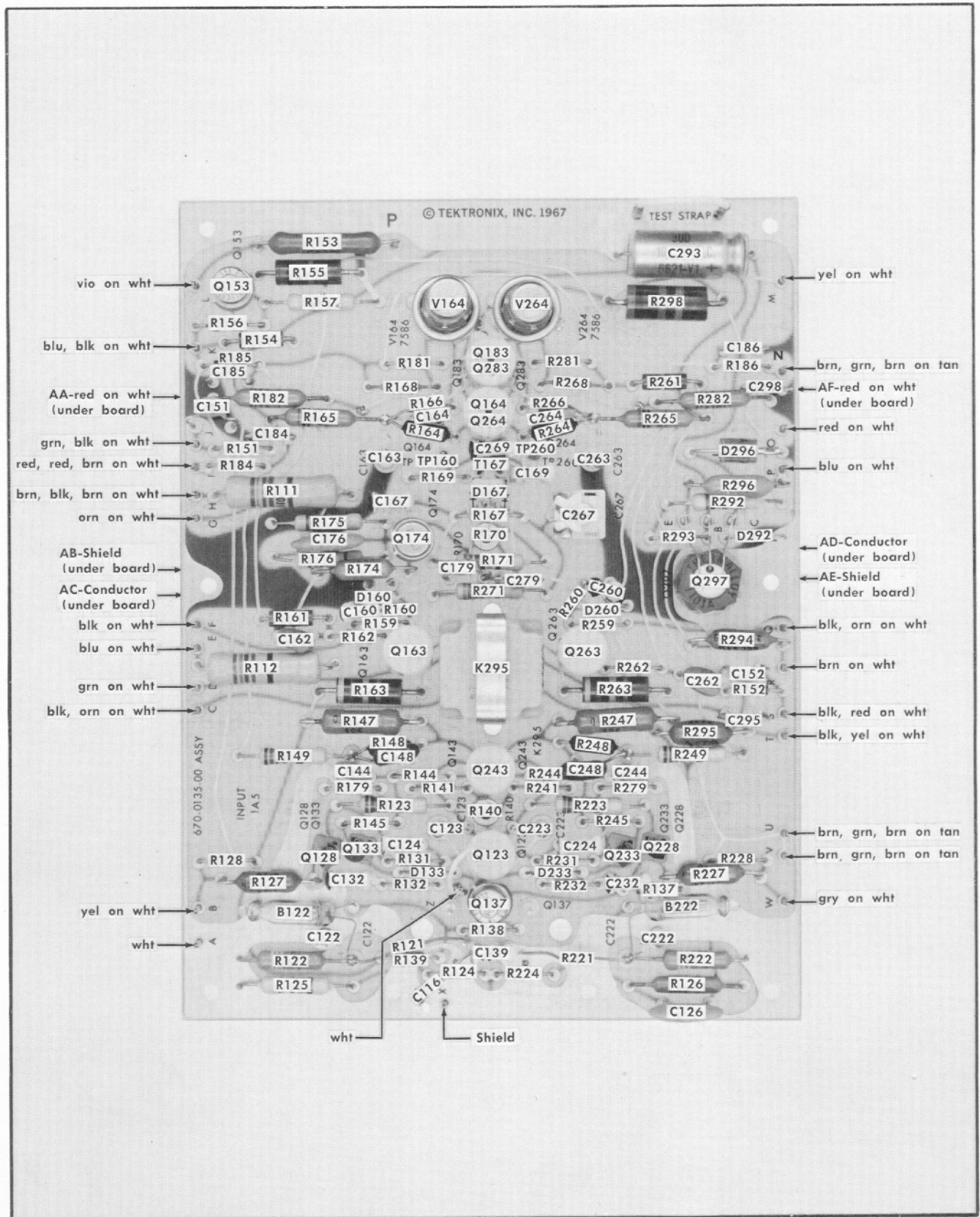


Fig. 4-6. Input Amplifier board assembly; component identification.

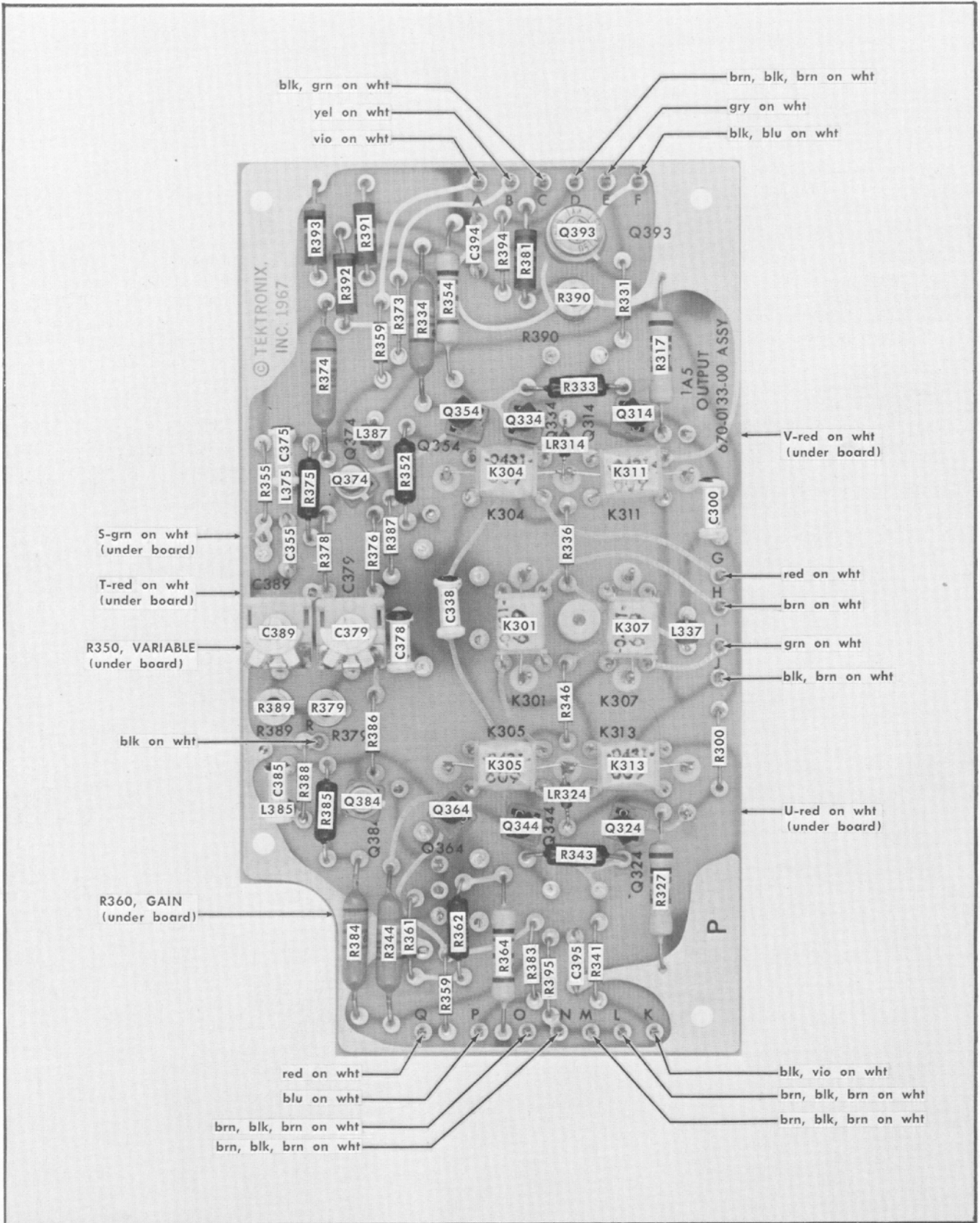


Fig. 4-7. Output Amplifier board assembly with High Frequency Compensation Component board removed.

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the attenuator section pass through the holes in the board. After soldering these leads to the DISPLAY switch, they should be positioned so that they are nearly centered in the hole in the metal chassis.

Transistor locations on the Input Amplifier board are illustrated in Fig. 4-6. (Fig. 4-1 illustrates proper placement of transistors within bases.) The plastic caps must be kept securely in place to insure balanced heating and thermal insulation for transistors. Plastic caps can be removed by pulling up on the lower edge of the cover at the flat surface of the transistor mounting base, using a bent soldering aid or similar device. To replace caps, simply snap them in place.

Q297 is packed in silicone grease in its heat sink. The locating tab must be removed from the transistor before it is put into the heat sink. The heat sink mounting nuts must be kept tight. Note that both mounting nuts are insulated from the board by mica washers.

To remove relay K295, the legs of the clamp must be sprung out and up. The contacts should be cleaned with a cleaning-type lubricant whenever necessary. When re-installing the relay, align the locating pin with the hole in the board. Make certain that the clamp snaps securely in place.

Output Amplifier Board. This board does not require removal for component replacements. If removal is necessary, observe the following precautions:

Check the wire color code against Fig. 4-7 and note any exceptions.

Note the 4 square-pin connectors on the underside of the board.

Potentiometers can be removed with the board by loosening the set screws on the front of the couplings and pulling the shafts forward until they disconnect. Hold back on the coupling while pulling on the shaft.

Component locations are indicated in Fig. 4-7. (Proper placement of transistors within bases is shown in Fig. 4-1.)

The High Frequency Compensation Component board (Fig. 4-8) can be removed from the Output Amplifier board by removing one screw from the center of the board and lifting the board out. Keep it parallel to the Output Amplifier board during removal and replacement to avoid bending the square pin connectors. (Bending the square pin connectors may damage the reed switches.) When replacing it, insure that all pins engage their sockets. Fig. 4-8 shows the High Frequency Compensation Component board and identifies components located on it.

Reed switches and coil assemblies can be replaced as assemblies or as individual components. To replace an assembly, cut all 6 wire leads close to the coil and switch. Remove the assembly and unsolder and remove the 4 leads from the Output Amplifier board and the two leads from the

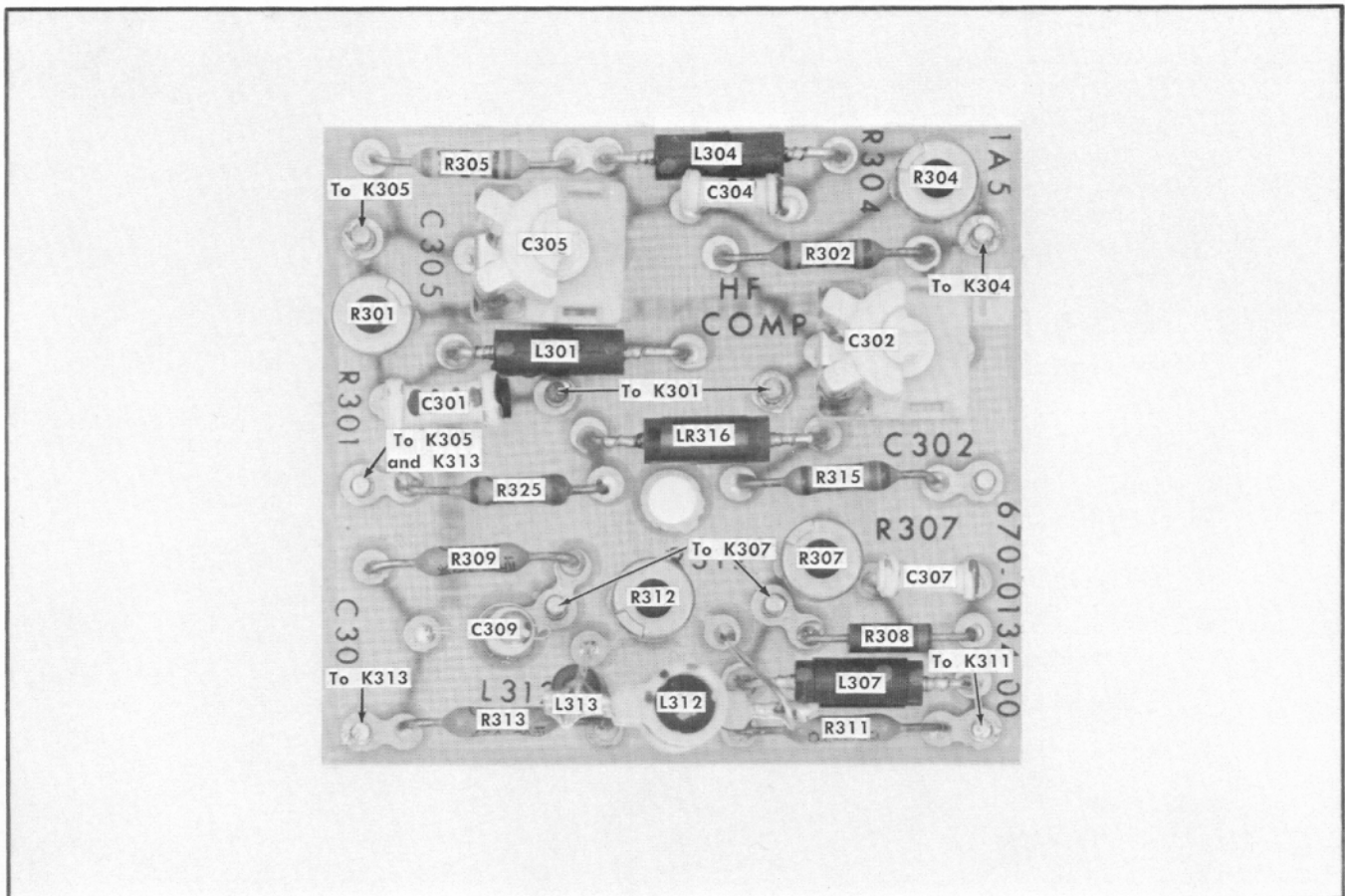


Fig. 4-8. High Frequency Compensation Component board. (Attaches to Output Amplifier board.)

terminal posts. Clean the holes through the board as necessary. Install the assembled unit and solder the six leads in place, insuring that the switch contacts are longitudinally centered in the coil.

CAUTION

Avoid mechanical shocks to the switch. Do not bend the switch leads unless pliers are used to grip the lead between the glass and the point to be bent.

To replace only the coil, cut the 4 coil-leads close to the coil. Unsolder the 2 switch leads from the terminal posts and remove the assembly. Pull on the larger wire to extract the switch from the coil. Insert the switch in a new coil, centering the contacts longitudinally. Install the assembled unit and solder the 6 leads in place.

WARNING

Eyes must be shielded from glass chips when cutting the 2 wires connected to the center of the reed switch assembly.

To replace only the switch, unsolder the 2 switch leads from the terminal posts. Pull on the larger lead to extract the switch from the center of the coil. (It may be necessary to unsolder the coil to provide room for the reed switch to be pulled past the terminal post.) Insert the new switch; center

the contacts longitudinally in the coil and solder the switch leads in place. Resolder any disconnected coil leads.

Ferrite cores are used on the Output Amplifier board to suppress oscillations. The cores and the wires (or component leads) which pass through them form L337, L375, L385 and L387. They must be returned to their designed position whenever associated components are replaced. Fig. 4-7 and 4-8 indicate their proper locations.

Attenuator and VOLTS/CM Switch Assembly. Procedure for removing this assembly as one unit follows. Note that any adjustments or movement of components or wires will require a recheck of the instrument's calibration. Attenuator section component locations are illustrated in Fig. 4-9 and 4-10.

Loosen the set screws from the front section of the 2 couplings which are connected to the potentiometers under the Output Amplifier board. Remove the VARIABLE knob and shaft, and the GAIN shaft through the front panel of the Type 1A5. Hold back on the couplings while pulling the shafts free.

Remove the Attenuator section cover after removing the top screw and loosening the 6 side and end screws.

Before disconnecting any wires, note their locations and color codes. Unsolder 5 wires from the first wafer of the rear section of the switch assembly (SW110C, wafer 1), and one wire from the third wafer. At the DISPLAY switch (SW210), unsolder the two leads which connect to the atten-

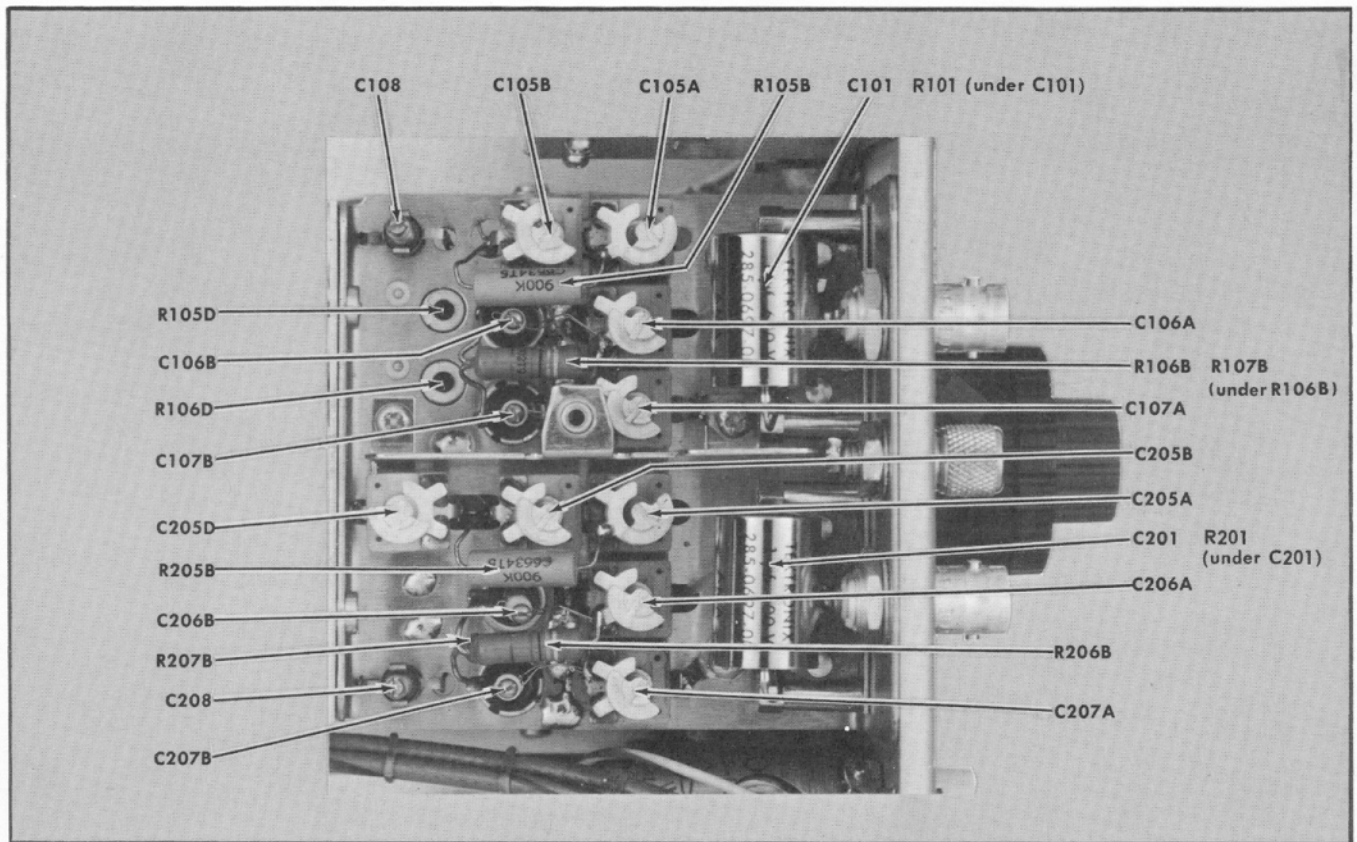


Fig. 4-9. Attenuator Section—adjustment side.

Maintenance—Type 1A5

uator switches. Unsolder the shield straps of the 2 Coupling capacitors (C101 and C201) from the INPUT connector terminals. Disconnect the two shielded leads which straddle the rear of the switch assembly and disconnect the 4 square-pin connectors from the Output Amplifier board. At the Input Amplifier board, disconnect the 2 square-pin connectors which lead to the Attenuator section. Remove the 4 screws from the Output Amplifier board. Remove the cable clamp from the rear of the attenuator housing by removing one screw.

Pull the AC-GND-DC switch knobs off. Note the position of the VOLTS/CM knobs and then remove them. These knobs pull directly off the front of the shaft after 2 set screws in each knob are loosened. Remove the nut and washer from the front of the switch assembly shaft. Remove the nut from the rear of the front panel Ground terminal. Remove the nuts from the rear of the INPUT connectors and then remove the connectors. Remove the 2 chassis mounting screws from the rear of the switch assembly. The attenuator and switch assembly is now free.

Raise the Output Amplifier board and slide the switch and attenuator assembly toward the rear of the chassis until the front is free. Then lift the assembly out of the chassis, front first.

Replacement Procedure. If sections of the switch mechanism were switched independent of the rest of the unit while disassembled, the switches must be re-aligned to each other. Use the VOLTS/CM Switching schematic as a guide. Before

replacing the switch, loosen the four screws on the mounting plate between the Attenuator housing and the rear switch section. This will allow the parts to slip enough to align themselves during assembly.

Insert the Attenuator and Switch assembly in the chassis by reversing the removal procedure. Replace and tighten the INPUT Connector washers and nuts. Replace and tighten the washer and nut on the front of the Switch and Attenuator assembly shaft. Replace and tighten the front panel ground post. Replace the two chassis screws in the mounting plate between the attenuator housing and rear switch section. Draw the mounting plate down to the chassis, but do not tighten screws. Tighten the 4 screws located on the mounting plate between the attenuator housing and the rear switch section, allowing the rear switch section to align itself with the front of the assembly. Tighten the 2 chassis mounting screws which were previously inserted.

Resolder the following connections: 2 coupling capacitor shields to INPUT connector terminals; 5 leads to SW110C wafer 1 and 1 lead to wafer 3; 2 leads to the DISPLAY switch. Reconnect 2 leads from attenuator housing to square-pin connectors on the Input Amplifier Board.

Tighten down the Output Amplifier Board. Reconnect leads to 4 square-pin connectors on top of the board and 2 on the bottom. Reconnect the 2 shielded leads which previously straddled the rear of the switch assembly. Attach the cable clamp to the rear of the attenuator housing.

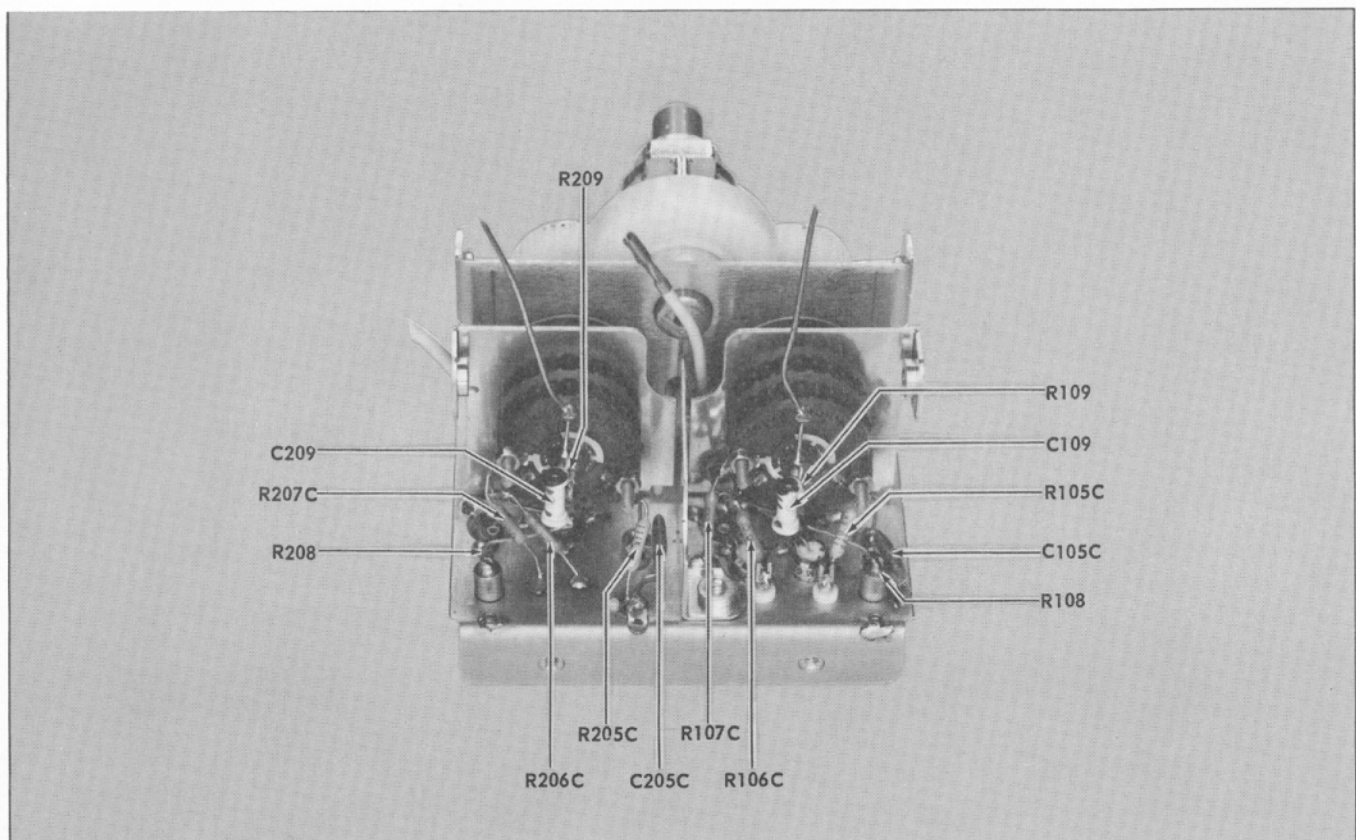


Fig. 4-10. Attenuator Section—switch side.

Replace the attenuator housing cover, VOLTS/CM control knobs and the AC-GND-DC knobs. Re-install the GAIN shaft and fasten the set screw. Re-install the VARIABLE shaft and knob. Place the VOLTS/CM knob in a "Retained Range" position before fastening the VARIABLE knob set screw.

Other Components. Fig. 4-11 locates components which are not included in other illustrations. Fig. 4-4 and 4-5 list physical locations and destinations of wires connected to miscellaneous switches, potentiometers and controls.

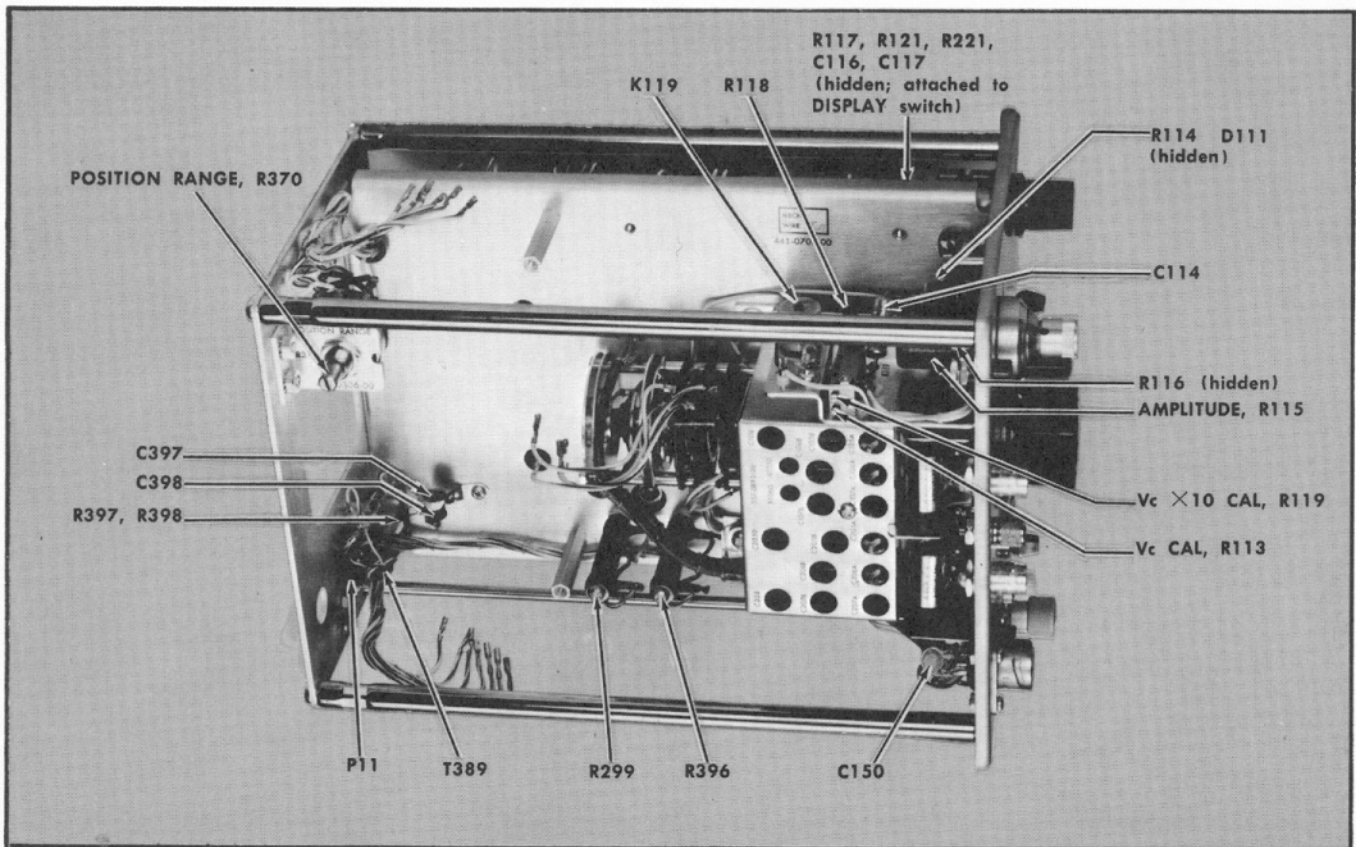


Fig. 4-11. Miscellaneous component locations.

SECTION 5

PERFORMANCE CHECK

Introduction

This performance check offers a means of rapidly checking the operation of the Type 1A5. Only front-panel controls and adjustments are referred to. Waveforms provided are reproductions of actual waveform photographs.

Recommended Equipment

The equipment listed here is recommended for use in performance-checking the Type 1A5. Substitute equipment must meet or exceed the minimum requirements listed with each item.

Items available through Tektronix Field Offices or Representatives are identified with a Tektronix Type or Part Number.

All equipment used must be within calibration limits to obtain valid results.

1. Oscilloscope, Tektronix Type 544, 546, 547 or 556. (Type 544 settings are given in this procedure.)

2. Standard Amplitude Calibrator. Voltage Range 5 mV to 100 V into 1 M Ω . 1 kHz square wave output. Amplitude accuracy within 0.25%. Tektronix Part No. 067-0502-00.

3. DC Non-Loading Voltmeter. Voltage range 0 to 5 volts plus and minus; accuracy 0.02%. Fluke Model 825A.

4. Square Wave Generator. Hi Amplitude output of 1 to 50 volts at 1 kHz, and 10 volts at 10 kHz. Fast Rise output of 50 mV to 500 mV into 50 Ω at 1 kHz, with 1 ns or less risetime. Tektronix Type 106.

5. Constant Amplitude Sine Wave Generator. 20 mV to 10 V at frequencies of 50 kHz and 1 MHz to 50 MHz. Amplitude accuracy $\pm 3\%$ from 50 kHz to 50 MHz. Tektronix Type 191 Constant Amplitude Signal Generator.

6. Low Frequency Sine Wave Generator. Frequency range of 2 Hz to 100 kHz; amplitude range from 1 V to more than 20 volts. General Radio Type 1310-A Oscillator.

7. Coaxial cable, 42 inch - 50 ohm, equipped with BNC—male connectors. Tektronix Part No. 012-0057-00.

8. Cable, Type RG8/213, GR connectors, 5 ns delay; (5 ns GR cable); Tektronix Part No. 017-0502-00.

9. Adapter, Dual BNC-male to BNC-female, (flexible T connector); Tektronix Part No. 067-0525-00.

10. Adapter, GR to BNC-male; Tektronix Part No. 017-0064-00.

11. Termination, 50 ohm, GR-to-BNC; Tektronix Part No. 017-0083-00.

12. Attenuator, 2:1, 50 ohm, GR Type; Tektronix Part No. 017-0080-00.

13. Attenuator, 5:1, 50 ohm, GR Type; Tektronix Part No. 017-0079-00.

14. Attenuator, 10:1, 50 ohm, GR Type; two required. Tektronix Part No. 017-0078-00.

15. Input RC Normalizer, 20 pF; BNC connectors; Tektronix Part No. 067-0538-00.

16. Adapter, dual banana plug-to-BNC female connector; General Radio Company Type 274-QBJ.

17. Screwdriver, adjusting, 1/8-inch tip.

Procedure Format

A preliminary equipment setup is provided. Controls should be changed only as directed by the procedure. If any step is obtained when doubt exists as to whether or not the dark refer to the preceding step(s) to determine control settings.

Names of the 1A5 controls are entirely capitalized, oscilloscope and test equipment control names have only their first letters capitalized.

PERFORMANCE CHECK PROCEDURE

1. Preliminary

- Plug the Type 1A5 into the oscilloscope.
- Energize all equipment to be used during the procedure. Allow 20 minutes for warm-up time.
- Set the Type 1A5 and oscilloscope controls as follows:

Type 1A5 Controls

POLARITY	0
POSITION	Midrange
A Input AC-GND-DC	GND
B Input AC-GND-DC	GND
VOLTS/CM	20 mV
VARIABLE	CAL
DISPLAY	A-B

Oscilloscope Controls

Intensity	Optimum
Focus	Optimum
Astigmatism	Optimum
Scale Illumination	Optimum
Triggering Level	Approximately 0
Mode	Auto Stability
Slope	+
Coupling	AC
Source	Norm
Time/cm	.5 mSec
Variable	Calibrated
Horizontal Display	Normal ($\times 1$)
Position	Midrange
Amplitude Calibrator	Off

Performance Check—Type 1A5

2. Check Differential Probe Relay Operation

REQUIREMENT—PUSH ON/OFF button controls Differential Probe Relay.

- a. CHECK—Depress PUSH ON/OFF button. Observe that the Probe On lamp illuminates.
- b. Depress PUSH ON/OFF button, returning Probe On lamp to "Off" state.

3. Check Vertical Balance

REQUIREMENT—No trace shift accompanies VOLTS/CM switching or rotation of VARIABLE gain.

- a. Using the POSITION control, set trace to graticule center.
- b. CHECK—Switch VOLTS/CM to 1 mV. Trace should remain at graticule center.
- c. ADJUST—STEP ATTEN BAL to return trace to graticule center.
- d. Switch back to 20 mV and repeat steps a, b, and c until no further adjustment is necessary.
- e. Switch VOLTS/CM control to 20 mV.
- f. CHECK—UNCAL lamp lights when VARIABLE is moved from CAL position.
- g. CHECK—No trace shift occurs as VARIABLE knob is rotated.
- h. ADJUST—VAR BAL until no trace shift accompanies rotation of VARIABLE knob.
- i. Return VARIABLE to CAL position.

4. Check Gain

REQUIREMENT—Gain within 2% of standard.

- a. Connect a flexible T connector to the A and B INPUT connectors.
- b. Connect a 0.1 V - 1 kHz square wave output from the Standard Amplitude Calibrator to the center of the flexible T connector, using a coaxial cable equipped with BNC connectors.
- c. Switch the A Input AC-GND-DC control to DC. Adjust POSITION control to center the display.
- d. Adjust oscilloscope Triggering Level to obtain an untriggered sweep.
- e. CHECK—5 cm \pm 1 mm display amplitude, allowing for trace width.
- f. ADJUST—GAIN for exactly 5 cm display amplitude.
- g. CHECK—A INPUT gain under setups given in Table 5-1.

TABLE 5-1

Type 1A5 VOLTS/CM Setting	Standard Amplitude Calibrator Amplitude Setting	Display Amplitude
1 mV	5 mV	5 cm \pm 1 mm
2 mV	10 mV	5 cm \pm 1 mm
5 mV	20 mV	4 cm \pm 0.8 mm
10 mV	50 mV	5 cm \pm 1 mm
10 mV Retained Range	50 mV	5 cm \pm 1.25 mm
20 mV Retained Range	.1 V	5 cm \pm 1.25 mm
20 mV	.1 V	5 cm \pm 1 mm
50 mV	.2 V	4 cm \pm 1 mm
.1 V	.5 V	5 cm \pm 1.25 mm
.1 V Retained Range	.5 V	5 cm \pm 1.25 mm
.2 V Retained Range	1 V	5 cm \pm 1.25 mm
.2 V	1 V	5 cm \pm 1.25 mm
.5 V	2 V	4 cm \pm 1 mm
1 V	5 V	5 cm \pm 1.25 mm
2 V	10 V	5 cm \pm 1.25 mm
5 V	20 V	4 cm \pm 1 mm
10 V	50 V	5 cm \pm 1.25 mm
20 V	100 V	5 cm \pm 1.25 mm

h. Switch A Input AC-GND-DC control to GND and the B Input AC-GND-DC control to DC. Use POSITION control to center the display.

i. CHECK—B Input gain by repeating the setups given in Table 5-1, progressing from bottom to top.

5. Check VARIABLE Control Range

REQUIREMENT—VARIABLE control range of 2.5:1 or greater.

- a. Rotate VARIABLE fully counterclockwise.
- b. CHECK—Display amplitude is 2 cm or less.
- c. Return VARIABLE to CAL position.
- d. Use of the Standard Amplitude Calibrator has been completed. Disconnect the coaxial cable from the flexible T connector.

6. Check Comparison Voltage (Vc) Accuracy

REQUIREMENT—1 mV/CM to 2 V/CM: \pm 5 mV or 0.5% of indicated voltage, whichever is greater; 5 V/CM to 20 V/CM: \pm 1 mV or \pm 1% of indicated voltage, whichever is greater.

- a. Switch DISPLAY to A—Vc.
- b. Connect a non-loading voltmeter to the MONITOR banana jack.
- c. Rotate Vc AMPLITUDE control fully counterclockwise.

- d. CHECK—Vc AMPLITUDE index is within 1 line width of 0-0-0.
- e. Switch POLARITY to +.
- f. CHECK—Comparison voltage under each setup given in Table 5-2.

TABLE 5-2

AMPLITUDE	Volts
0-0-0 (CCW)	0 ± 0.005
1-0-0	+1 ± 0.005
2-0-0	+2 ± 0.010
3-0-0	+3 ± 0.015
4-0-0	+4 ± 0.020
0-0-0 (CW)	+5 ± 0.025
Switch POLARITY to —	
0-0-0 (CW)	−5 ± 0.025
4-0-0	−4 ± 0.020
3-0-0	−3 ± 0.015
2-0-0	−2 ± 0.010
1-0-0	−1 ± 0.005
0-0-0 (CCW)	0 ± 0.005

- g. Switch VOLTS/CM to 5 V and rotate AMPLITUDE clockwise to 0-0-0.
- h. CHECK—−0.5 V ± 5 mV MONITOR output.
- i. Switch POLARITY to +.
- j. CHECK—+0.5 V ± 5 mV MONITOR output.
- k. Use of the voltmeter has been completed. Disconnect the cable from the MONITOR jack.

7. Check POSITION Control Range

REQUIREMENT—12 cm or more range.

- a. Rotate POSITION fully clockwise.
- b. Rotate Vc AMPLITUDE counterclockwise until the trace is positioned to the +3 cm line.
- c. Using the POSITION control, move the trace down 6 cm to the −3 cm line.
- d. Switch the DISPLAY control to Vc—B.
- e. Again rotate the Vc AMPLITUDE control counterclockwise until the trace is positioned to the +3 cm line.
- f. CHECK—POSITION range. Rotate POSITION control fully counterclockwise. Trace should move to or below the −3 cm line for a total of 12 cm or more POSITION control range.
- g. Switch POLARITY to 0.

8. Check STEP ATTEN BAL Control Range

REQUIREMENT—20 mV or more range.

- a. Switch VOLTS/CM to 5 mV.

- b. Using the POSITION control, set the trace to graticule vertical center.
- c. CHECK—Rotate STEP ATTEN BAL from limit to limit. 4 cm (20 mV) or more trace movement should result.
- d. Using the STEP ATTEN BAL, reset the trace to graticule vertical center.

9. Check Microphonics

REQUIREMENT—100 μV or less microphonics.

- a. Switch B Input AC-GND-DC control to GND, VOLTS/CM to 1 mV and DISPLAY to A—B.
- b. CHECK—1 mm or less oscillation or ringing results in response to tapping finger tips against the front panel.

10. Check Input Transistor Gate Current

REQUIREMENT—0.1 nA or less gate current.

- a. Attach a 50-Ω GR-to-BNC termination to the center of the flexible T connector.
- b. CHECK—1 mm or less trace shift occurs at the instant the A Input AC-GND-DC control is switched to AC. Return the control to the GND position.
- c. CHECK—1 mm or less trace shift occurs at the instant the B Input AC-GND-DC control is switched to AC. Return the control to the GND position.
- d. Remove the flexible T connector from the A and B INPUT connectors.

11. Check Noise

REQUIREMENT—50 μV RMS or less.

- a. Connect the following components to the A INPUT connector in the sequence listed:
 - GR-BNC 50-Ω Termination
 - GR 5 ns Cable
 - 2 - 10:1 50-Ω GR Attenuators
 - 1 - 5:1 50-Ω GR Attenuator
 - Type 106 Square Wave Generator Fast Rise + Output
- b. Set the oscilloscope Time/CM control to 10 μSec and the Triggering Level fully clockwise.
- c. Set the Type 1A5 A Input AC-GND-DC control to DC.
- d. Set the Square Wave Generator controls as follows:

Repetition Rate Range	1 kHz
Multiplier	CCW
Hi Amplitude/Fast Rise	Fast Rise
- e. Adjust the Square Wave Generator + Transition Amplitude to provide 2 separate traces. (Caused by the upper and lower excursions of the square wave being presented on an untriggered sweep.)

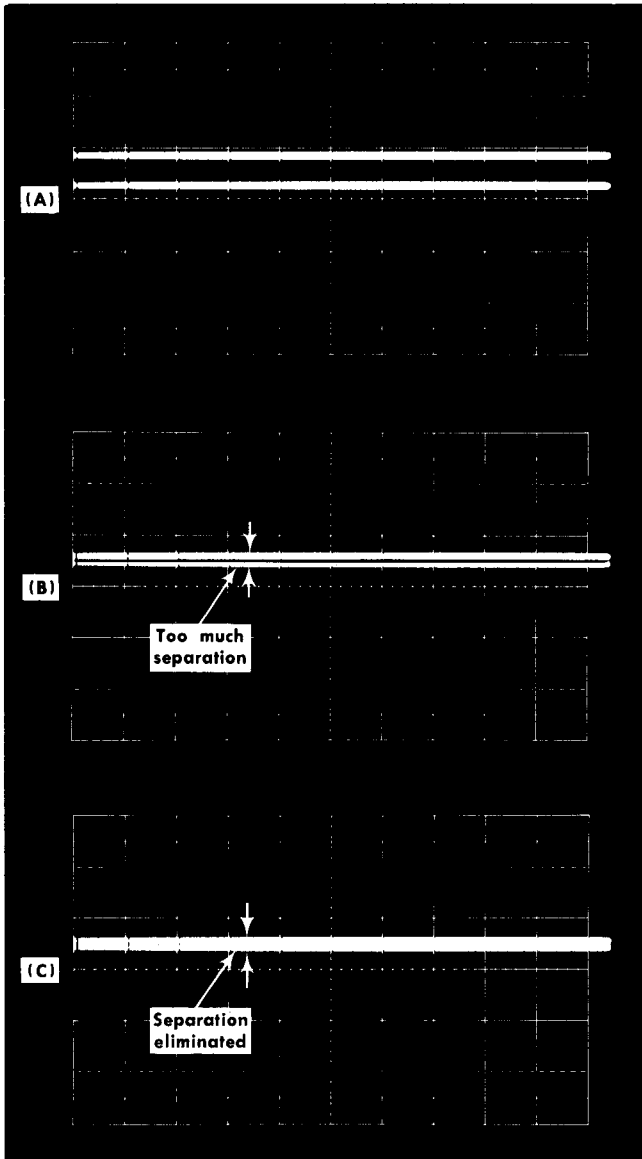


Fig. 5-1. Noise measurement waveforms. (A) Initial waveform, step 11-e; (B) Too much separation, step 11-f; (C) Desired waveform, step 11-f. (Sweep rate $10 \mu\text{s}/\text{cm}$, vertical sensitivity $1 \text{ mV}/\text{cm}$.)

f. Decrease the + Transition Amplitude as necessary to barely eliminate the dark line between the 2 traces. Use Fig. 5-1 (A), (B) and (C) as guides. (The desired presentation is obtained when doubt exists as to whether or not the dark line is eliminated.)

g. Remove one 10:1 attenuator from the signal path. (Two separate traces will again appear.)

h. CHECK—Measure the amplitude between trace centers. Divide by 20. Result should be $50 \mu\text{V RMS}$, or less, noise.

12. Check Total Crosstalk

REQUIREMENT—5% or less, DC to 50 MHz.

- a. Switch the Type 1A5 VOLTS/CM control to 20 mV.

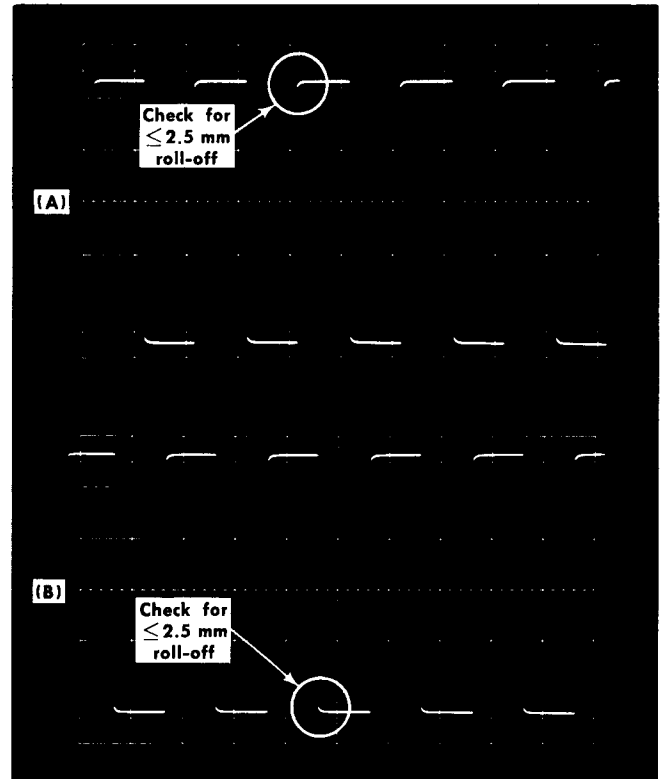


Fig. 5-2. Total crosstalk waveforms, step 12. (A) A INPUT crosstalk; (B) B INPUT crosstalk. (Sweep rate $.5 \text{ ms}/\text{cm}$; vertical sensitivity $20 \text{ mV}/\text{cm}$.)

- b. Switch the oscilloscope Time/cm to $.5 \text{ ms}$.
- c. Remove the 10:1 attenuator from the signal path.
- d. Adjust the Square Wave Generator + Transition Amplitude to provide a 5 cm display; adjust Triggering Level for a triggered display.
- e. Switch the B Input AC-GND-DC control to DC.
- f. CHECK—A INPUT crosstalk. 2.5 mm or less rounding at upper left corner of square wave. See Fig. 5-2 (A).
- g. Move the $50\text{-}\Omega$ termination and cable to the B INPUT connector; adjust POSITION control to center the display.
- h. CHECK—B INPUT crosstalk. 2.5 mm or less rounding at lower left corner of square wave. See Fig. 5-2 (B).

13. Check Input Capacitance

REQUIREMENT— $\frac{1}{2} \text{ mm}$ or less rounding, overshoot or tilt of a square wave input signal.

- a. Switch the oscilloscope Time/cm to $.2 \text{ ms}$ and the Triggering Slope to —.
- b. Switch the A Input AC-GND-DC control to GND.
- c. Insert a 20 pF Input RC Normalizer between the $50\text{-}\Omega$ GR-BNC termination and the B INPUT connector.
- d. Move the 5:1 attenuator and GR cable to the Square Wave Generator Hi Amplitude Output.

e. Switch the Square Wave Generator Hi Amplitude/Fast Rise switch to High Amplitude.

f. CHECK—squareness of corner of 5 cm square wave for 1/2 mm or less rounding, overshoot or tilt in each setup given in Table 5-3. Adjust the Square Wave Generator Amplitude control and the Type 1A5 POSITION control as necessary to maintain a centered 5 cm display. See Fig. 5-3 for typical waveforms.

14. Check Overdrive Recovery Time and DC Shift Due To Overdrive

REQUIREMENT—Overdrive recovery time: within 10 mV of DC shifted level after 1 μ s; DC shift due to overdrive: 1% or less of \pm overdrive signal, or 10 mV, whichever is smaller.

- Switch VOLTS/CM to the 1 V position.
- Remove the 20 pF Input RC Normalizer from the signal path.
- Replace the 5:1 attenuator with a 2:1 attenuator.
- Switch the oscilloscope Time/cm to 50 μ s, the Triggering Slope to + and the Triggering Source control to Ext; connect a 42" coaxial cable from the Square Wave Generator Trigger Output to the oscilloscope Trigger Input connector.
- Set the Square Wave Generator frequency to 10 kHz and the Amplitude control for a 5 cm display amplitude.
- Switch the oscilloscope Time/cm to 1 μ s and adjust the Horizontal Position controls to place the beginning of the

TABLE 5-3

Input Signal Connected to	AC-GND-DC		VOLTS/CM	Triggering Slope	Check Point		
	A	B					
B INPUT	GND	DC	20 mV	—	lower left		
			50 mV	—	lower left		
			Remove 5:1 attenuator				
			.5 V	—	lower left		
			Replace 50- Ω termination with a GR-to-BNC adapter				
A INPUT	DC	GND	5 V	—	lower left		
			Replace adapter with the GR-to-BNC 50- Ω termination				
			.5 V	+	upper left		
			Insert 5:1 attenuator				
			50 mV	+	upper left		
			20 mV	+	upper left		

leading edge of the positive square wave at the 2 cm line as in Fig. 5-4 (A).

- Switch the Type 1A5 VOLTS/CM control to 10 mV.
- Adjust the Type 1A5 POSITION control to set the right side of the visible portion of the trace to vertical center of the graticule as in Fig. 5-4 (B).

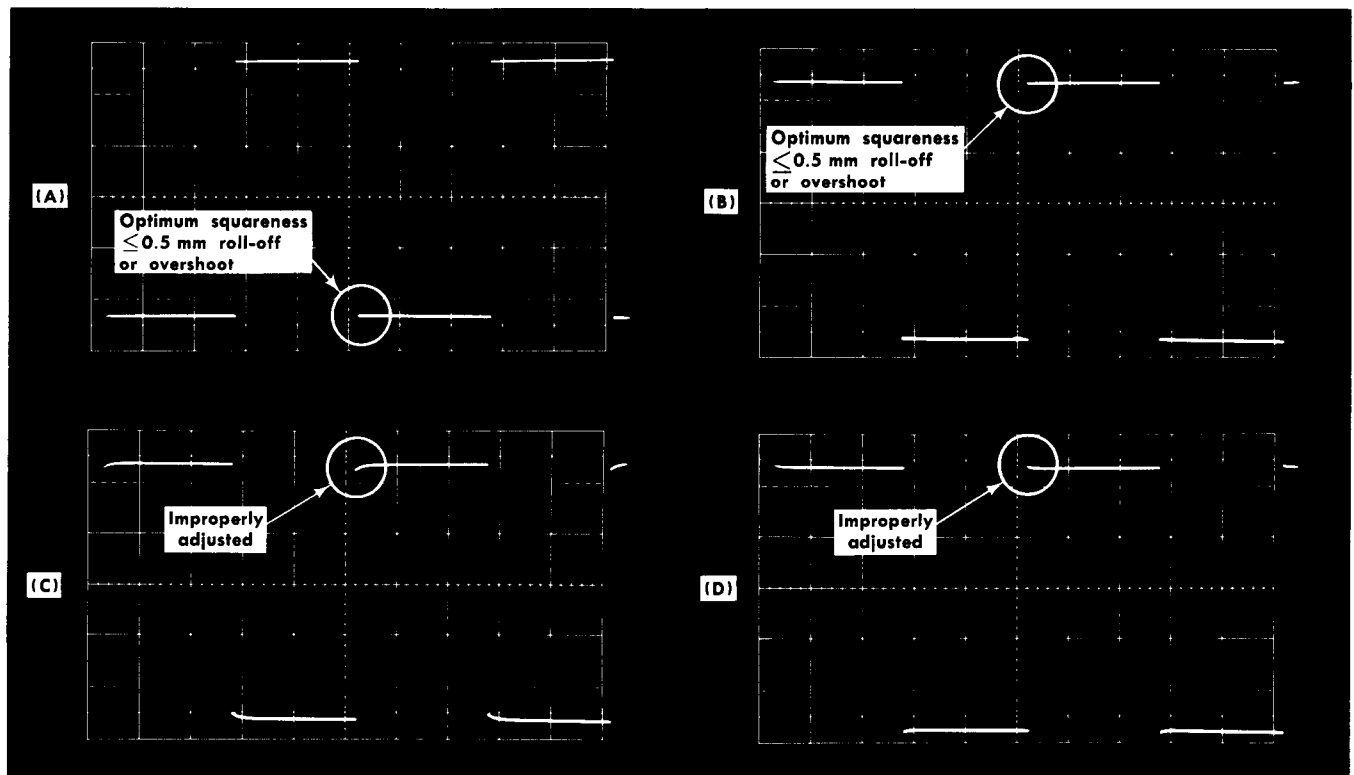


Fig. 5-3. Input capacitance waveforms, step 13. (A) B input capacitance properly adjusted; (B) A input capacitance properly adjusted; (C) and (D) A input capacitance improperly adjusted. (Sweep rate .2 ms/cm; vertical sensitivity dependent upon capacitance being checked.)

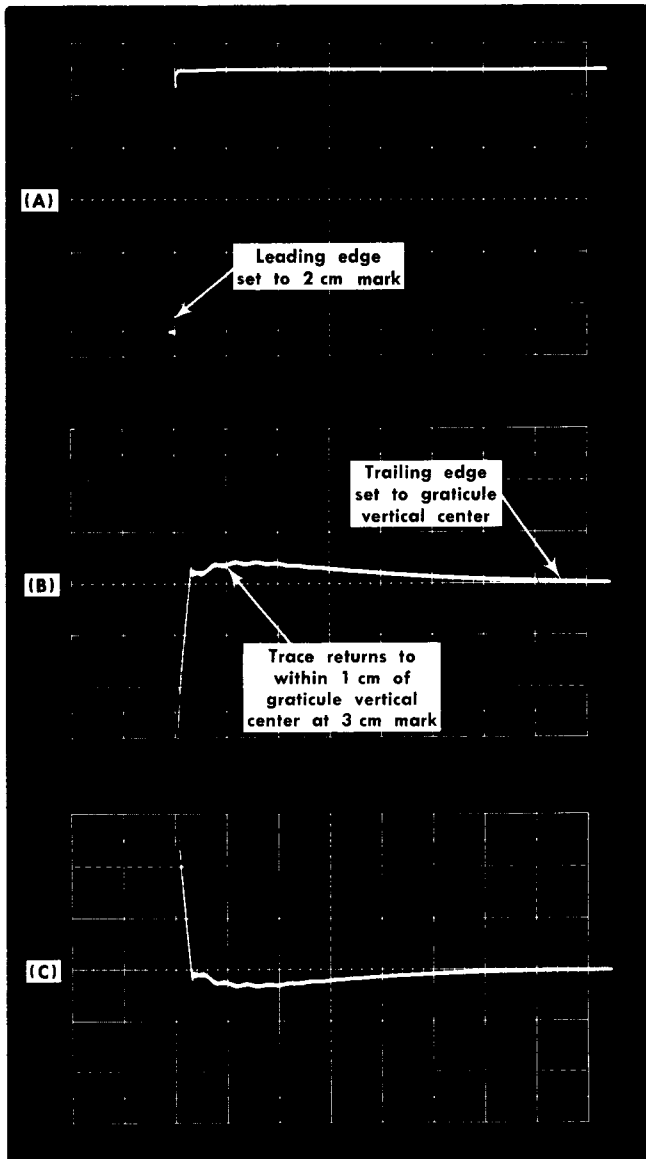


Fig. 5-4. Overdrive recovery waveforms, step 14. (A) Preliminary waveform, step 14-f; (B) A INPUT waveform, step 14-i; (C) B INPUT waveform, step 14-q. (Sweep rate 1 μ s/cm; vertical sensitivity 1 V/cm in A and 10 mV/cm in B and C.)

- i. CHECK—A Input overdrive recovery time. Trace should return to within 1 cm (10 mV) of graticule vertical center by the time the trace reaches the 3 cm line as in Fig. 5-4(B). (10 mV or less within 1 μ s.)
- j. Switch the A Input AC-GND-DC control to GND.
- k. Wait one minute; using POSITION control, set trace to vertical center of graticule.
- l. CHECK—A Input DC shift due to overdrive. Top of waveform should be within 1 cm (10 mV) of the vertical center of the graticule 1 second after the A Input AC-GND-DC control is switched to DC. Return AC-GND-DC switch to the GND position.
- m. Move the 50 Ω termination and cable from the A INPUT to the B INPUT connector.

- n. Using POSITION control, set trace to vertical center of graticule.
- o. CHECK—B input DC shift due to overdrive. Top of waveform should be within 1 cm (10 mV) of vertical center of graticule 1 second after the B Input AC-GND-DC control is switched to DC.
- p. Adjust POSITION control to set right side of visible portion of trace to graticule vertical center.
- q. CHECK—B input overdrive recovery time. Trace should return to within 1 cm (10 mV) of graticule vertical center by the time the trace reaches the 3 cm line. See Fig. 5-4(C).
- r. Disconnect the GR cable and 42-inch coaxial cable from the Square Wave Generator. Use of the Square Wave Generator has been completed.
- s. Switch oscilloscope Triggering Source to NORM and move the coaxial cable from the Trigger Input connector.

15. Check High Frequency Response

REQUIREMENT—5 mV/CM to 20 mV/CM "knob in" positions: 50 MHz or higher at -3 dB; 2 mV/CM and Retained Range settings of 20 mV/CM and .2 V/CM: 45 MHz or higher at -3 dB; 1 mV/CM and Retained Range settings of 10 mV/CM and .1 V/CM: 40 MHz or higher at -3 dB.

- a. Replace the 2:1 attenuator with a 5:1 attenuator and connect the GR cable and attenuator to the Type 191 Constant Amplitude Signal Generator.
- b. Set the oscilloscope Time/cm control to .5 ms.
- c. CHECK—High frequency response for each of the setups given in Table 5-4, using the following procedure:
 - (1) Set the VOLTS/CM control to indicated setting.
 - (2) Set the Constant Amplitude Signal Generator frequency to 50 kHz and adjust its amplitude to provide 4 cm display amplitude.
 - (3) Set the frequency of the Constant Amplitude Signal Generator to the value opposite the applicable VOLTS/CM setting in Table 5-4.
 - (4) CHECK—2.8 cm or more display amplitude.

TABLE 5-4

Type 1A5 VOLTS/CM	Constant Amplitude Signal Generator Frequency (MHz)
1 mV	40
2 mV	45
5 mV	50
10 mV	50
20 mV	50

NOTE

The relationship between upper frequency limit and risetime can be expressed as $T_r = .35/f$. Rise-times of 7, 8 and 9 nanoseconds are indicated by the 50, 45 and 40 MHz frequency responses that have just been checked.

16. Check Attenuator Crosstalk

REQUIREMENT—1 mV/CM to 20 mV/CM: 1% or less, DC to 50 MHz with + and - 5-V signal applied; 10 mV/CM to .2 V/CM: 1% or less, DC to 50 MHz with + and - 50-V signal applied.

- a. Remove the 5X attenuator. Replace the 50-Ω termination with the GR-to-BNC adapter and connect it to the B INPUT connector.
- b. Set the A and B Input AC-GND-DC controls to DC.
- c. Set the Constant Amplitude Signal Generator controls as follows:

Frequency	50 MHz
Amplitude	50
Variable	Cal
Amplitude Range	.5-5 V

- d. CHECK—5 cm or less vertical display amplitude (1%, or less, of input signal) under each setup given in Table 5-5.

TABLE 5-5

Signal Input Connected To	DISPLAY Position	VOLTS/CM Position
B	A-Vc	20 mV Retained Range
B	A-Vc	20 mV
A	Vc-B	20 mV
A	Vc-B	20 mV Retained Range

17. Check X1 High Frequency Common-Mode Rejection

REQUIREMENT—10,000:1 or more — 100 kHz to 1 MHz with 10 V peak-to-peak sine wave applied, decreasing to 1000:1 or more at 10 MHz with 1 V peak-to-peak sine wave applied; 200:1 or more at 20 MHz with 0.5 V peak-to-peak sine wave applied.

- a. Disconnect the GR-to-BNC adapter from the A INPUT connector.
- b. Switch the Type 1A5 DISPLAY control to A-B and the VOLTS/CM control to 1 mV.
- c. Connect the symmetrical ends of a flexible T connector to A and B INPUT connectors.
- d. Connect the GR-to-BNC adapter and GR 5 ns cable to the flexible T connector.
- e. CHECK—Common-Mode Rejection Ratio by measuring the display amplitude under each setup given in Table 5-6.

TABLE 5-6

Constant Amplitude Signal Generator			Display Amplitude	CMRR
Frequency	Amplitude Range	Amplitude		
1 MHz	.5-5 V	50	≤ 1 cm	≥ 10,000:1
10 MHz	50-500 mV	50	≤ 1 cm	≥ 1,000:1
20 MHz	50-500 mV	25	≤ 2.5 cm	≥ 200:1

- f. Disconnect the GR-to-BNC adapter and GR cable from the flexible T connector. Use of the Constant Amplitude Signal Generator has been completed.

18. Check DC Coupled Common-Mode Rejection Ratio at 100 kHz

REQUIREMENT—20,000:1 with + and - 5 V signal applied.

- a. Connect the output of the General Radio Type 1310A Oscillator to the center of the flexible T connector, using a banana-jack to BNC adapter and a coaxial cable.
- b. Set the VOLTS/CM control to 2 V and the B Input AC-GND-DC switch to GND.
- c. Adjust the Oscillator for a 100-kHz, 10-V peak-to-peak output (5 cm display amplitude). Verify frequency against oscilloscope time base (10 μs per cycle).
- d. Switch the B Input AC-GND-DC control to DC and the VOLTS/CM control to 1 mV.
- e. CHECK—1/2 cm or less display amplitude for 20,000:1 or greater CMRR.

19. Check DC Coupled X10 and X100 Common-Mode Rejection

REQUIREMENT—2000:1 or greater, DC to 10 kHz with + and - 50-V sine wave applied.

- a. Switch the VOLTS/CM control to 20 V/CM and the B Input AC-GND-DC control to GND.
- b. Adjust the oscillator to its maximum amplitude output (do not exceed 100 V peak to peak) at 10 kHz. (Verify frequency against oscilloscope time base: 0.1 ms per cycle.)
- c. Measure signal amplitude and divide by 2000. Record the results.
- d. Switch the B Input AC-GND-DC control to DC and the VOLTS/CM to .1 V Retained Range.
- e. CHECK—DC coupled X100 CMRR. Display amplitude should not exceed the value recorded in step c.
- f. Switch the VOLTS/CM control to 10 mV Retained Range.
- g. CHECK—DC coupled X10 CMRR. Display amplitude should not exceed the value recorded in step c.

20. Check X1 AC-Coupled Common-Mode Rejection Ratio

REQUIREMENT—1000:1 or greater CMRR at 60 Hz with + and - 5-V signal applied.

- a. Switch the Type 1A5 VOLTS/CM control to 2 V, the A Input AC-GND-DC control to AC and the B Input AC-GND-DC control to GND.
- b. Switch the oscilloscope Time/cm control to 10 ms.
- c. Adjust the Oscillator for a 60-Hz, 10-V peak-to-peak output (5 cm vertical display). Verify the frequency against the oscilloscope time base: 1 2/3 ms per cycle.

Performance Check—Type 1A5

- d. Switch the Type 1A5 B Input AC-GND-DC control to AC and the VOLTS/CM control to 10 mV.
- e. CHECK—1 cm or less display amplitude for 1000:1 or greater AC-coupled CMRR.

21. Check AC-Coupled Low Frequency Response

REQUIREMENT—2 Hz or less at -3 dB.

- a. Switch the Type 1A5 VOLTS/CM to 20 mV, the A Input AC-GND-DC control to DC and the B Input AC-GND-DC control to GND.

- b. Switch the oscilloscope Time/cm to 0.2 s.

c. Set the oscillator for a 2-Hz, 100-mV (5 cm) output. (Verify frequency against time base. 0.5 s per cycle.) Insert an attenuator into the signal path if necessary to reduce the signal amplitude to 100 mV.

- d. CHECK—Switch the A Input AC-GND-DC control to AC and check for 3.5 cm or more display amplitude.

e. CHECK—Switch A Input AC-GND-DC control to GND and the B Input AC-GND-DC control to AC. Check for 3.5 cm or more display amplitude.

This concludes the performance check.

SECTION 6

CALIBRATION

Introduction

The Type 1A5 Differential Amplifier should be calibrated every 500 operating hours or every six months, whichever occurs first. Calibration should be preceded by a thorough cleaning and inspection as explained in the Maintenance section.

A calibration record and index is contained at the beginning of the calibration procedure. It refers to each step by number and gives the name and a brief description of the adjustment or check performed. Duplicating the calibration record and index will allow copies of it to be used as a permanent check-off list and calibration record, leaving the original as an unmarked reference for rapid location of individual adjustment procedures.

Malfunctions

Correct all malfunctions at the time they are disclosed by the procedure. Failure to do so will probably affect other adjustments, requiring that they be done again after the trouble is finally corrected.

Procedure Format

The equipment setup is given at the beginning of the calibration procedure. Principal control settings are again listed at the beginning of each group of adjustments requiring a substantial change. A picture accompanies each setup.

The step sequence used is designed to allow rapid calibration with a minimum of setups and interaction. Each step continues from the equipment status that existed at the end of the preceding step.

Those steps containing adjustments are identified by the symbol **Ⓐ** appearing on the right margin of the column. "ADJUST" indicates the point within the numbered steps at which the actual adjustment is performed. "CHECK" identifies either a pre-adjustment check or a performance check of a non-adjustable parameter. "INTERACTION" comments are included when the performance of an adjustment affects another.

The names of Type 1A5 front-panel controls and internal adjustments are written in upper-case letters. Oscilloscope and test equipment controls have the first letter of their names capitalized. Pictures indicating adjustment locations and pictures of actual waveforms accompany the procedure. Waveforms have been offset from reference positions in many instances to avoid their being hidden by the graticule lines.

Complete Calibration Procedure

Do each step in sequence when performing a complete calibration procedure. For best results, refine all adjustments, even though the pre-adjustment check is within allowable limits. INTERACTION comments can be ignored, since the procedure logic takes them into consideration.

Partial Calibration Procedure

Any step in the calibration procedure can be done individually. If a pre-adjustment check is within allowable limits, it is suggested that the adjustment be bypassed to save time and to avoid unnecessary interaction with other adjustment steps. When an adjustment is made, any steps listed under INTERACTION must be checked.

CALIBRATION EQUIPMENT, ACCESSORIES AND TOOLS

A Tektronix Type 544 oscilloscope is used in this calibration procedure. A Type 546, 547 or 556 oscilloscope can be substituted, with allowance made for control settings.

Calibration equipment, accessories and tools necessary to calibrate the Type 1A5 are listed here and pictured in Fig. 6-1, 6-2 and 6-3. Part or type numbers are included for identification and ordering purposes.

All equipment used must be operating within its calibration limits. Test equipment substituted for that specified in this procedure must meet or exceed the minimum specifications stated here.

1. Oscilloscope, Tektronix Type 544.
2. Standard amplitude calibrator. Amplitude accuracy within 0.25%. Signal amplitude 5 mV to 100 V. Output square wave frequency of 1 kHz. Tektronix Standard Amplitude Calibrator, Part No. 067-0502-00, recommended.
3. Square wave generator. Frequency 1 kHz and 10 kHz. High Amplitude output 2 to 5 V into 50 Ω ; Fast Rise output variable from 50 mV to 500 mV into 50 Ω , with 1 nanosecond or less rise time. Tektronix Type 106 Square Wave Generator recommended.
4. Constant amplitude sine wave generator. Frequency 50 kHz and 1 MHz to 50 MHz. Output amplitude 5 mV to 10 V. Amplitude accuracy $\pm 3\%$ from 50 kHz to 50 MHz. Tektronix Type 191 Constant Amplitude Signal Generator recommended.
5. DC non-loading voltmeter. Range 0 to 100 V. Accuracy 0.02%. Fluke Model 825A used in this procedure.

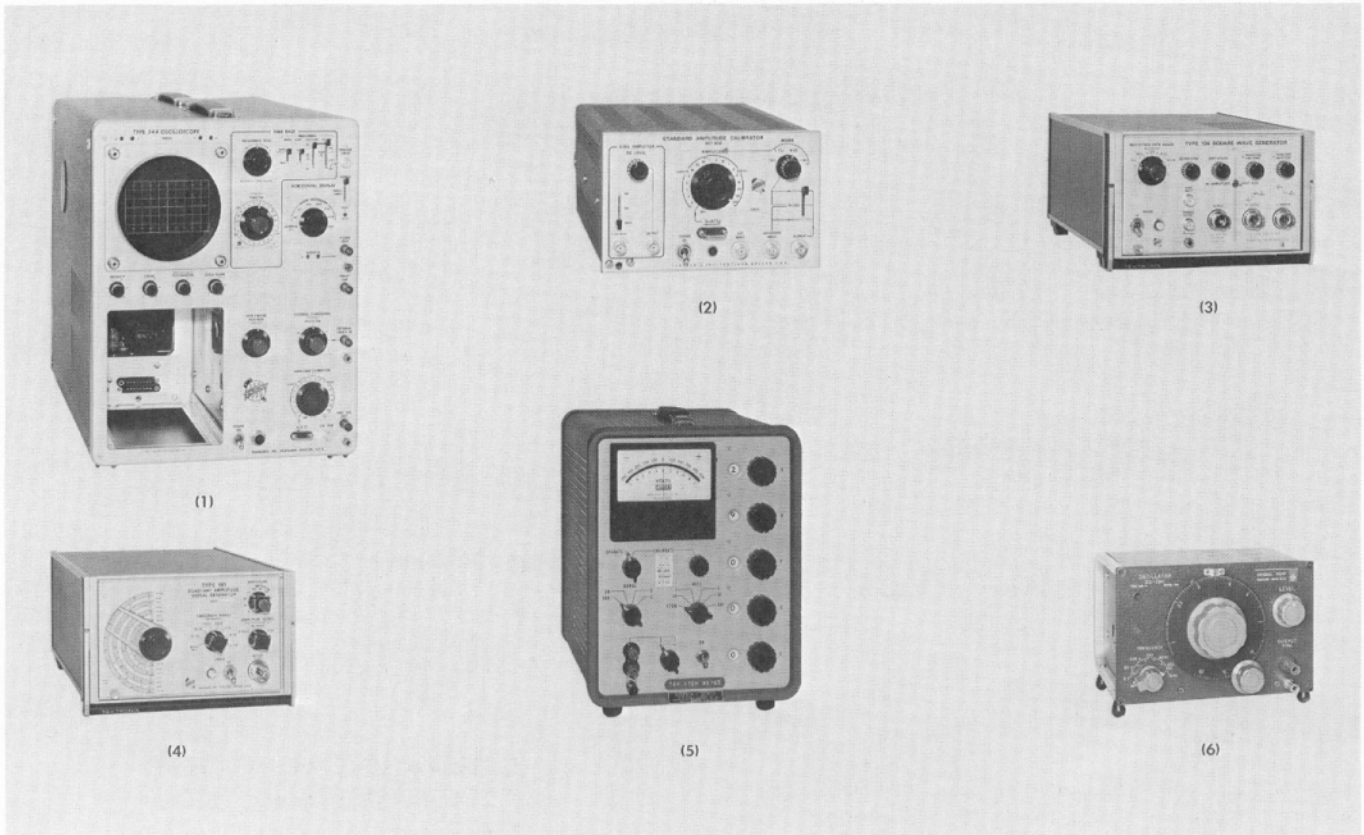


Fig. 6-1. Equipment required for the calibration of the Type 1A5.

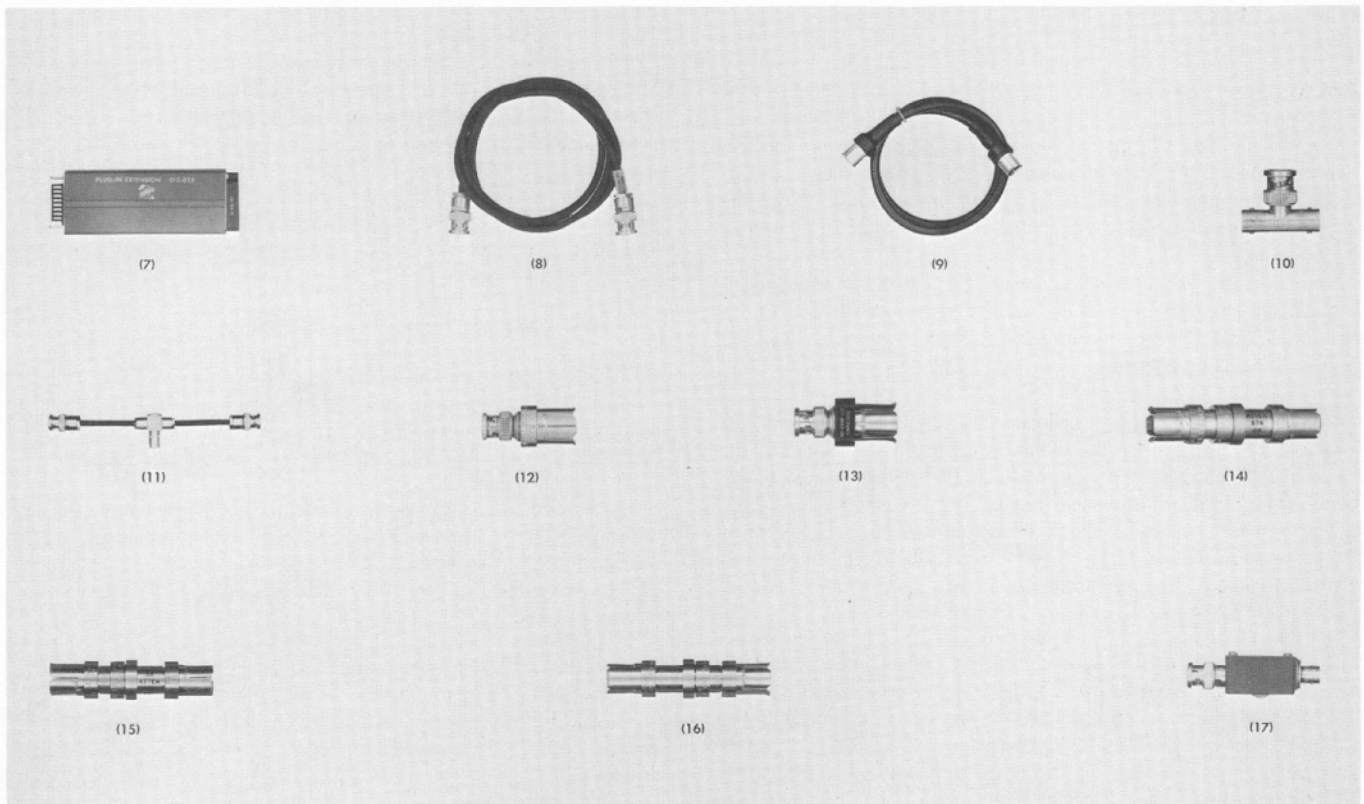


Fig. 6-2. Equipment required for the calibration of the Type 1A5.

6. Low frequency sine wave generator. Frequency 2 Hz to 10 kHz; output amplitude 1 V to more than 20 V. General Radio Oscillator Type 1310-A used in this procedure.
7. Plug-in extension (rigid; Tektronix Part No.013-0055-00.
8. Coaxial cables, 42 inch-50 ohm, equipped with BNC male connectors; two required; Tektronix Part No. 012-0057-00.
9. Cable, type RG8/213, GR connectors, 5 nanosecond delay; (5 ns GR cable); Tektronix Part No. 017-0502-00.
- 10 Adapter, BNC-T, male to two female; Tektronix Part No. 103-0030-00.
11. Adapter, Dual BNC male to BNC female, (flexible T connector); Tektronix Part No. 017-0525-00.
12. Adapter, GR to BNC male; Tektronix Part No. 017-0064-00.
13. Termination, 50 ohm, GR-to-BNC; Tektronix Part No. 017-0083-00.
14. Attenuator, 2:1, 50 ohm, GR type; Tektronix Part No. 017-0080-00.
15. Attenuator, 5:1, 50 ohm, GR type; Tektronix Part No. 017-0079-00.
16. Attenuators, 10:1, 50 ohm, GR type; two required; Tektronix Part No. 017-0078-00.

17. Input RC Normalizer, 20 pF, BNC connectors; Tektronix Part No. 067-0538-00.
18. Aligning tool, plastic handle and shaft, metal screwdriver tip; Tektronix Part No. 003-0000-00.
19. Aligning tool handle, nylon; Tektronix Part No. 003-0307-00.
20. Aligning tool insert, recessed wire; Tektronix Part No. 003-0308-00.
21. Aligning tool insert, recessed metal tip; Tektronix Part No. 003-0334-00.
22. Aligning tool insert, for 5/64 ID hex cores; Tektronix Part No. 003-0310-00.
23. Adapter, dual banana plug-to BNC female connector; General Radio Company Type 274-QBJ. (Not shown.)

CALIBRATION RECORD AND INDEX

The title and performance requirement of each calibration procedure step is listed here. This record and index can be used as a calibration check-off list, a record of calibration, a page index for the calibration procedure itself, or it can be used as a short form calibration procedure for experienced calibrators. It is recommended that duplicate copies be made for repeated check-off and record usage.

Type 1A5, Serial No. _____

Calibration Date _____

Calibration Technician _____

- 1. Check Differential Probe Relay operation. Page 6-6
PUSH ON/OFF button lights Probe On lamp.
- 2. Check and adjust Internal Power Supplies. OUTPUT DC LEVEL (R390) Page 6-6
+20.7 V \pm 1.0 V (non-adjustable).
+6.2 V \pm 0.31 V (non-adjustable).
+60 V. OUTPUT DC LEVEL, R390, Adjusts 1A5 output voltage for 67.5% of oscilloscope +100 V power supply value.
- 3. Adjust Comparison Voltage. (Vc CAL - R113, Vc \times 10 CAL - R119) Page 6-7
Vc CAL (R113) adjusted for +5 V \pm 0.002-V MONITOR output.
Vc \times 10 CAL (R119) adjusted for 0.5 V \pm 0.002-V MONITOR output.
- 4. Adjust DC Vertical Balance. (DC BAL - R170, VAR BAL - R330, POSITION RANGE - R370) Page 6-8
DC BAL adjusts for no trace shift accompanying VOLTS/CM switching.
VAR BAL adjusts for no trace shift accompanying change of VARIABLE control setting.
POSITION RANGE sets trace to graticule vertical center.

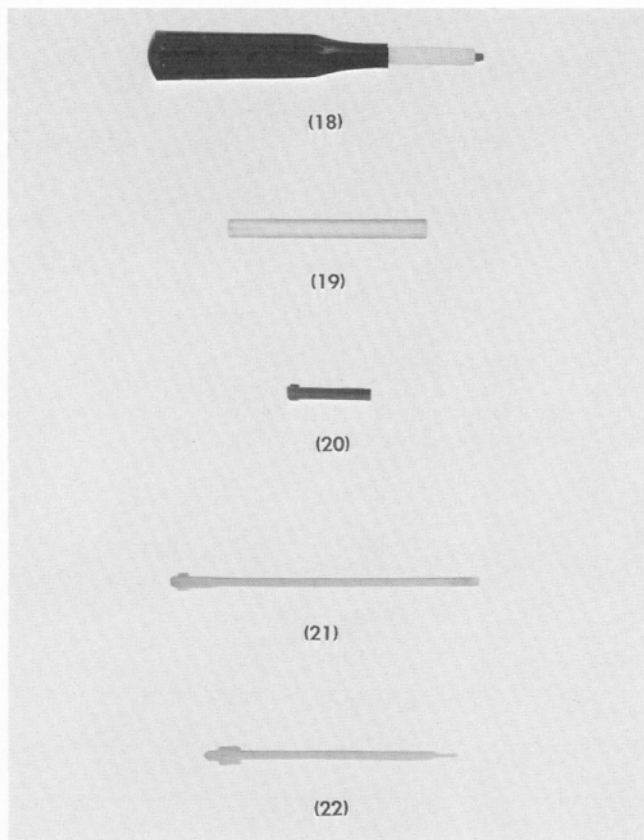


Fig. 6-3. Tools required for the calibration of the Type 1A5.

Calibration—Type 1A5

- 5. Adjust GAIN (R360). Check gain switching Page 6-9
Adjust for proper vertical deflection at 20 mV/CM position. Check at all other $\times 1$ VOLTS/CM gain switching positions.
- 6. Check attenuator accuracy. Page 6-10
Check for gain at all $\times 10$, $\times 100$ and $\times 1000$ attenuator positions of the VOLTS/CM control.
- 7. Check VARIABLE Range (R350) Page 6-10
Reduces gain to 40% or less of CAL position value. (2.5:1 or greater control range.)
- 8. Check Noise Page 6-11
50 μ V RMS or less.
- 9. Check Microphonics Page 6-12
100 μ V or less.
- 10. Check Input Transistor Gate Current Page 6-12
0.1 nA or less at 25°C.
- 11. Check POSITION (R372) Control Range Page 6-12
12 cm or more.
- 12. Check STEP ATTEN BAL (R129) Range Page 6-13
20 mV or more in $\times 1$ range.
- 13. Adjust DC Common-Mode Balance Page 6-14
COMMON MODE BAL (R140) for 20,000:1 CMRR in $\times 1$ range. R105D and R106D for 2000:1 CMRR in $\times 10$ and $\times 100$ ranges.
- 14. Adjust $\times 1$ Input Capacitance (C108, C208) Page 6-16
 $\frac{1}{2}$ mm or less overshoot, rounding or tilt of corner of square wave input. 20 pF Input RC Normalizer used.
- 15. Adjust $\times 1$ High Frequency Common-Mode Rejection Page 6-18
C267, C122, C222, C123, C223 for $\geq 10,000:1$ CMRR at 1 MHz. C163, C263 for $\geq 1000:1$ CMRR at 10 MHz.
- 16. Adjust Attenuator Input Capacitance (C105A, C105B, C106A, C106B, C107A, C107B, C205A, C205B, C206A, C206B, C207A, C207B) Page 6-20
 $\frac{1}{2}$ mm or less aberration at corner in response to square wave input.
- 17. Adjust $\times 10$ and $\times 100$ DC-Coupled Common-Mode at 10 kHz. (C205D, C206B) Page 6-22
CMRR 2000:1 or greater.
- 18. Check AC-Coupled Common-Mode Rejection at 60 Hz Page 6-23
CMRR 1000:1 or greater.
- 19. Check AC-Coupled Low-Frequency Response Page 6-23
Amplitude down 30% or less at 2 Hz.
- 20. Adjust High-Frequency Compensation (C379, R379, C389, R389, L312, R312, R307, C309, R304, C305, R301, C302) Page 6-24
Optimum square corner in response to 10 kHz fast rise square wave input.
Risetime 7 nanoseconds or less in 20 mV/CM, 10 mV/CM and 5 mV/CM positions of VOLTS/CM control.
Risetime 8 and 9 nanoseconds or less in 2 and 1 mV/CM positions, respectively.
- 21. Check Total Crosstalk. Page 6-25
5% or less roll-off.
- 22. Check Ovedrive Recovery Time and DC Shift Due to Overdrive Page 6-27
Recovers to within 10 mV in 1 μ s.
Shift 10 mV or less in 1 second.
- 23. Check Attenuator Crosstalk Page 6-29
1% or less of 50 MHz input signal.
- 24. Check Bandwidth Page 6-30
50 MHz except 45 MHz in 2 mV/CM and 40 MHz in 1 mV/CM positions of VOLTS/CM control.

NOTES

CALIBRATION PROCEDURE

NOTE

The oscilloscope and all test equipment must be within calibration limits before an effective calibration can be performed on the Type 1A5.

Preliminary Procedure

1. Remove the side panels from the oscilloscope.
2. Move the oscilloscope plug-in sensing switch to its "out" position. (Upper-right rear corner of plug-in compartment of Type 544, 546 and 547 oscilloscopes only.)

3. Remove the Test Strap from the Input Amplifier board and set it aside for future use. (Location is shown in Fig. 6-5).
4. Connect the rigid plug-in extender (item 7) to the Type 1A5 and the oscilloscope plug-in jack.
5. Set up the Type 1A5 and the Type 544 oscilloscope according to Fig. 6-4 and the accompanying list of control settings.
6. Energize the oscilloscope and all test equipment which will be used in the calibration procedure. Adjust the Type 1A5 POSITION control as necessary to bring the oscilloscope trace into the viewing area.
7. Allow 20 minutes warm-up before performing the calibration procedure.

NOTES

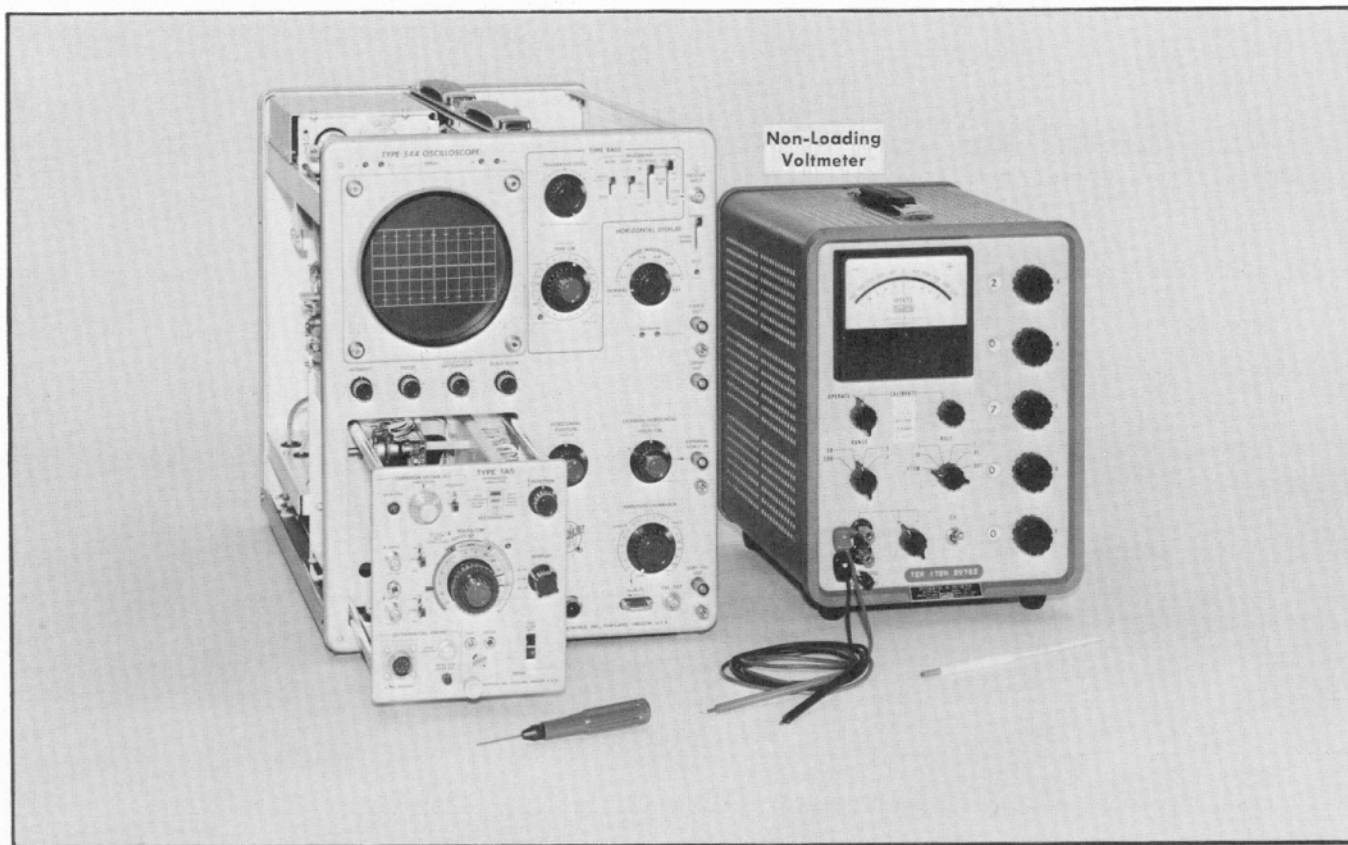


Fig. 6-4. Equipment setup for steps 1, 2, 3 and 4.

Type 1A5 Controls

V _c AMPLITUDE	CCW to 0-0-0
V _c POLARITY	0
POSITION	Midrange
A Input AC-GND-DC	GND
B Input AC-GND-DC	GND
VOLTS/CM	5 mV
VARIABLE	CAL
DISPLAY	A-V _c
STEP ATTEN BAL	Midrange

Type 544 Oscilloscope Controls

Intensity	Optimum
Focus	Optimum
Astigmatism	Optimum
Scale Illumination	Optimum
Triggering Level	Fully clockwise
Triggering Mode	Auto Stability
Triggering Slope	+
Triggering Coupling	AC
Triggering Source	Norm
Time/cm	.2 ms
Variable	Cal
Horizontal Display	Norm (×1)
Horizontal Position	Midrange
Horizontal Position Vernier	Midrange
Amplitude Calibrator	Off

1. Check Differential Probe Relay Operation

- a. Equipment setup is shown in Fig. 6-4.
- b. CHECK—Probe on lamp (located in PUSH ON/OFF button) goes on when PUSH ON/OFF button is pushed.
- c. Depress PUSH ON/OFF button and return lamp to the "off" state.

2. Check and Adjust Internal Power Supplies (OUTPUT DC LEVEL - R390)

- a. Equipment setup is shown in Fig. 6-4. Test points are shown in Fig. 6-5 and 6-6.
- b. Switch VOLTS/CM control to 5 V.
- c. CHECK—Q297 emitter and collector voltages for approximately 20 V and 6 V respectively. (No adjustments are associated with them.)
- d. Measure the voltage at the oscilloscope +100-V test point, using the differential voltmeter (item 5). Multiply the reading by 0.675 and record the result.
- e. Using POSITION control, set the trace to the graticule vertical center.
- f. CHECK—Differential voltmeter connected to pin R on the Type 1A5 Output Amplifier board (Fig. 6-6) reads the value recorded in step c, ±1%.

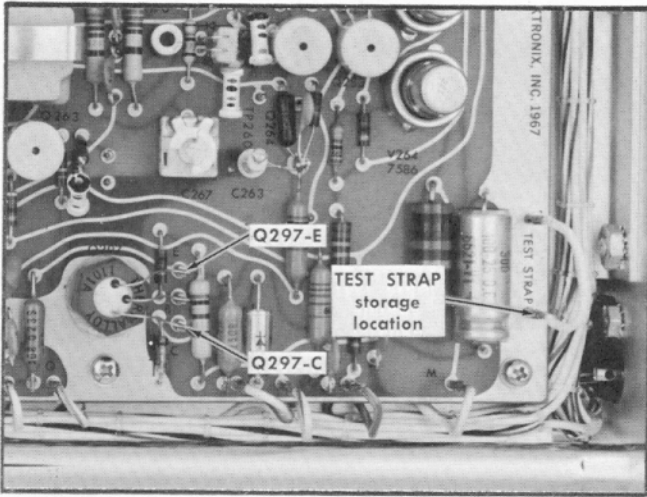


Fig. 6-5. Voltage check points for step 2.

g. ADJUST—OUTPUT DC LEVEL (R390, Fig. 6-6) to provide a voltage at pin R equal to the value recorded in step d, $\pm 1\%$. (Use POSITION control to keep trace at center during this adjustment.)

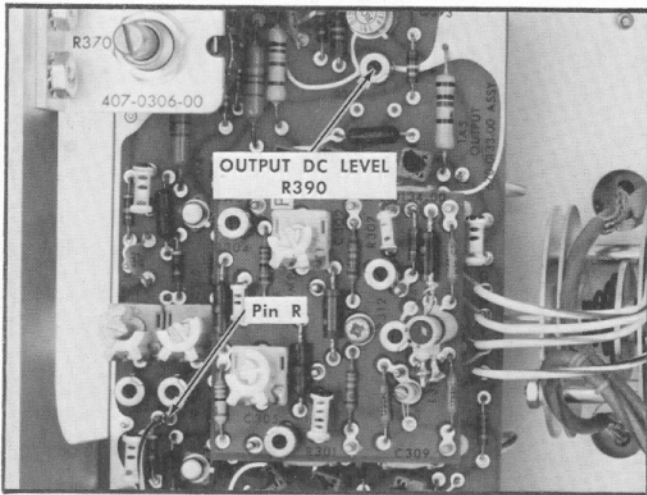


Fig. 6-6. Locations of voltage test points and adjustment for step 2.

3. Adjust Comparison Voltage (V_c CAL - R113, $V_c \times 10$ CAL - R119) ❶

a. Equipment setup is shown in Fig. 6-4. Adjustment locations are shown in Fig. 6-7.

b. Switch the VOLTS/CM control to 1 V.

c. Connect the differential voltmeter to the MONITOR jack and set the POLARITY switch to +.

d. CHECK—Differential voltmeter reads within 2 mV of 0 volts. (AMPLITUDE control CCW against mechanical stop and Dial reading within 1 linewidth of 0-0-0.)

e. ADJUST—AMPLITUDE knob to read within 1 line width of 0-0-0 when against CCW mechanical stop (loosen set screw to adjust).

f. Rotate AMPLITUDE control clockwise to 0-0-0.

g. CHECK—+5.00 V ± 0.003 V MONITOR output.

h. ADJUST— V_c CAL (R113, Fig. 6-7) for +5.00 V ± 0.002 V MONITOR output.

i. CHECK—Voltage accuracy for AMPLITUDE and POLARITY settings listed in Table 6-1.

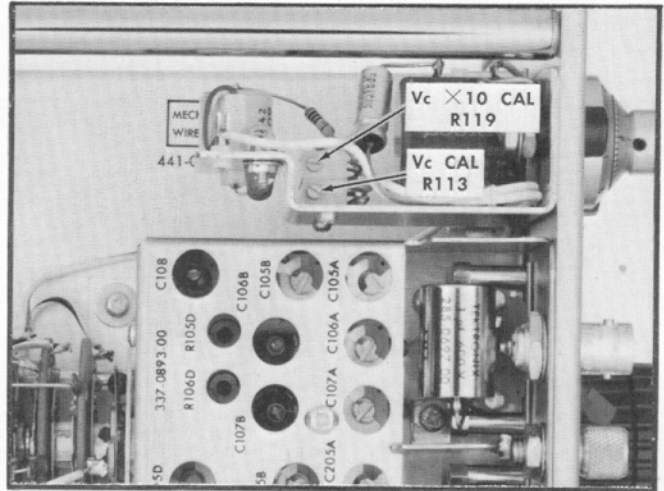


Fig. 6-7. Location of adjustments for step 3.

TABLE 6-1
Comparison Voltage Linearity Checks

AMPLITUDE	POLARITY	VOLTS
4-0-0	+	+4.00 ± 0.020
3-0-0	+	+3.00 ± 0.015
2-0-0	+	+2.00 ± 0.010
1-0-0	+	+1.00 ± 0.005
1-0-0	—	—1.00 ± 0.005
2-0-0	—	—2.00 ± 0.010
3-0-0	—	—3.00 ± 0.015
4-0-0	—	—4.00 ± 0.020
0-0-0 (CW)	—	—5.00 ± 0.025

j. Set VOLTS/CM control to 5 V.

k. CHECK—0.5 V ± 0.005 V MONITOR output.

l. ADJUST— $V_c \times 10$ CAL (R119, Fig. 6-7) for -0.500 V ± 0.002 V MONITOR output.

m. Switch POLARITY to 0 and disconnect the differential voltmeter from the MONITOR jack. Use of the differential voltmeter has been completed.

4. Adjust DC Vertical Balance (DC BAL - R170, VAR BAL - R330, POSITION RANGE - R370)

- a. Equipment setup is shown in Fig. 6-4. Locations of test points and adjustments are shown in Fig. 6-8.
- b. Set the POSITION control and STEP ATTEN BAL control at midrange, the DISPLAY switch to A-B and the VOLTS/CM control to 20 mV.
- c. ADJUST—DC BAL (R170, Fig. 6-8) as necessary to prevent trace shift while switching the VOLTS/CM control between the 20 mV and 1 mV positions. Repeat this step until no trace shift accompanies switching.

- d. Switch the VOLTS/CM control to 20 mV.
- e. CHECK—Trace shift while rotating VARIABLE from limit to limit.
- f. ADJUST—VAR BAL (R330, Fig. 6-8) until no trace shift accompanies rotation of VARIABLE control.
- g. CHECK—The UNCAL lamp is on except when VARIABLE is at CAL position. Return VARIABLE to CAL position.
- h. CHECK—Trace is at graticule vertical center.
- i. ADJUST—POSITION RANGE (R370, Fig. 6-8) to set trace to graticule vertical center.
- j. REPEAT—Steps d through i; then continue with step 5.

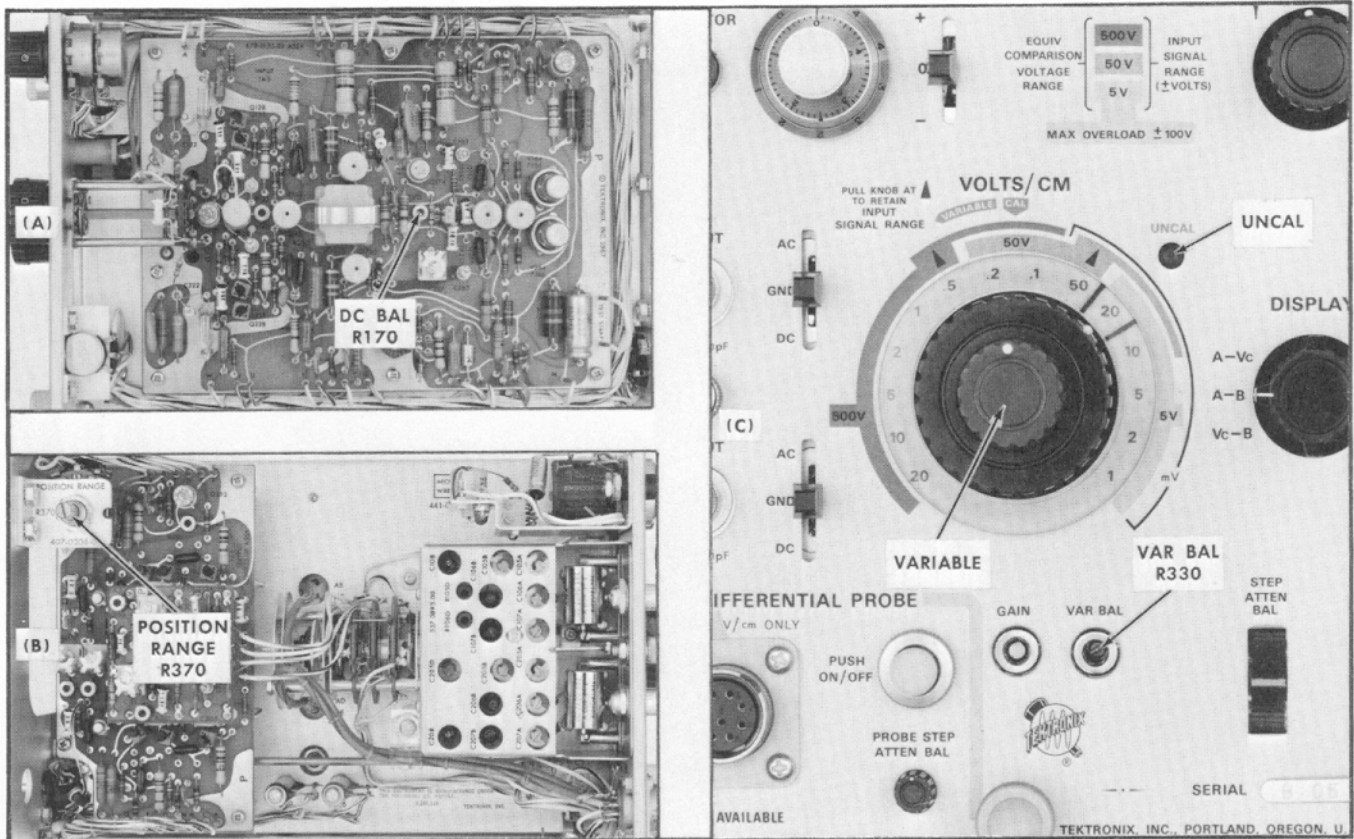


Fig. 6-8. Locations of adjustments for step 4.

NOTES

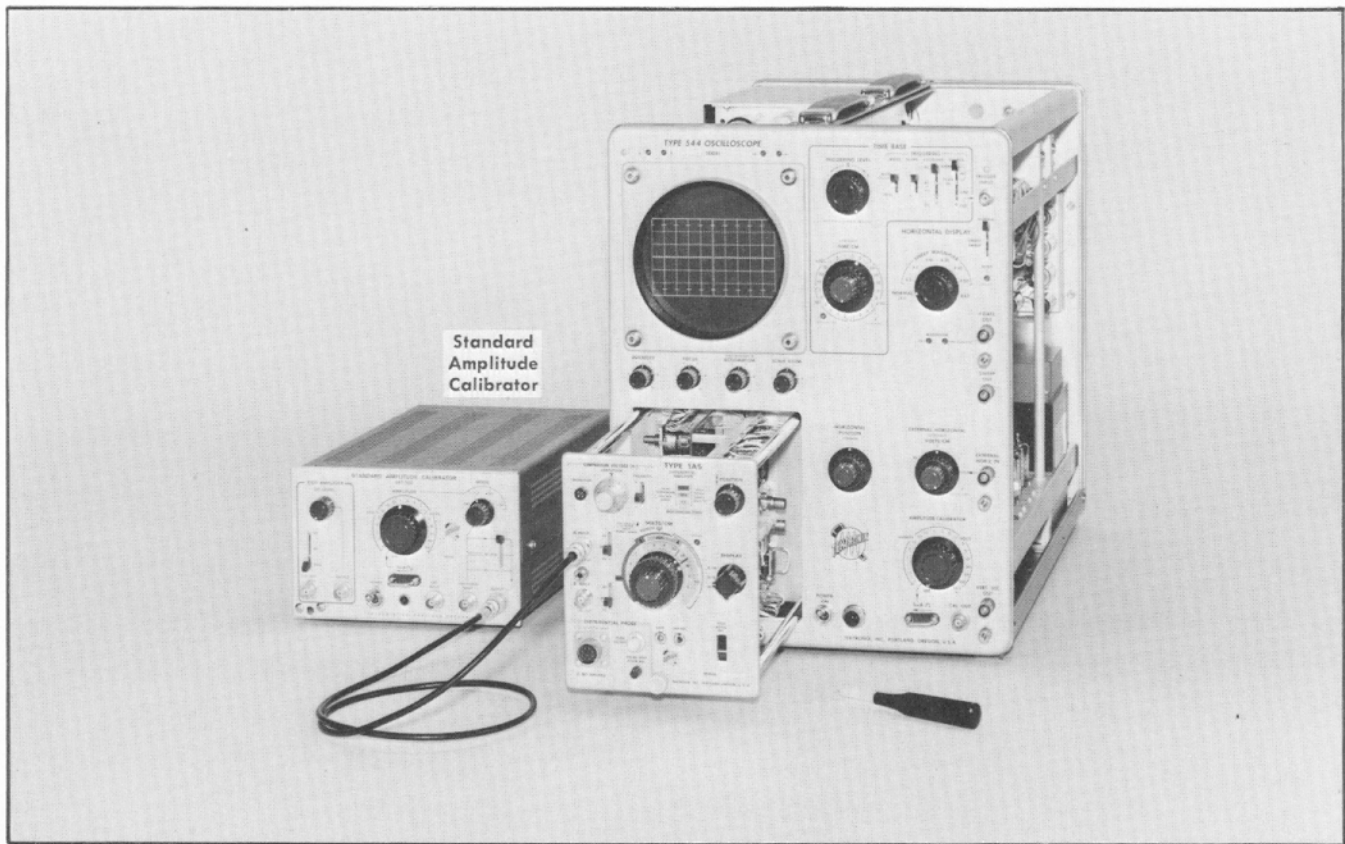


Fig. 6-9. Equipment setup for steps 5, 6 and 7.

Type 1A5 Controls

POSITION	Midrange
A Input AC-GND-DC	GND
B Input AC-GND-DC	GND
VOLTS/CM	20 mV
VARIABLE	CAL
DISPLAY	A-B
STEP ATTEN BAL	Midrange

Type 544 Oscilloscope Controls

Triggering Mode	Auto Stability
Triggering Source	Norm
Time/cm	.2 ms
Horizontal Display	Norm (X1)

Standard Amplitude Calibrator

.1 V - 1 kHz square wave output

5. Adjust GAIN (R360); Check Gain Switching ⓘ

a. Equipment setup is shown in Fig. 6-9. Location of adjustment is shown in Fig. 6-10. UNCAL lamp must remain off during entire procedure.

b. Connect a .1 V-1 kHz square wave output from the Standard Amplitude Calibrator (item 2) to the A INPUT connector, using a coaxial cable equipped with BNC connectors (item 8).

c. Using the POSITION control, set the trace 2.5 cm below the graticule vertical center.

d. Switch the A Input AC-GND-DC control to DC. (Adjust oscilloscope Triggering Level to obtain a free-running sweep.)

e. CHECK—Exactly 5 cm vertical display amplitude, allowing for trace width.

f. ADJUST—GAIN (R360, Fig. 6-10) for exactly 5 cm display amplitude, allowing for trace width. Readjust POSITION control as necessary to center the square wave.

g. CHECK—Vertical display amplitude under setups listed in Table 6-2. Reset POSITION control as necessary for convenient measurements. UNCAL lamp must remain off during entire check.

TABLE 6-2

Gain Switching Accuracy

Type 1A5 VOLTS/CM Settings	Standard Amplitude Calibrator Amplitude Settings	Vertical Display Amplitude
10 mV	50 mV	5 cm ±1 mm
5 mV	20 mV	4 cm ±0.8 mm
2 mV	10 mV	5 cm ±1 mm
1 mV	5 mV	5 cm ±1 mm

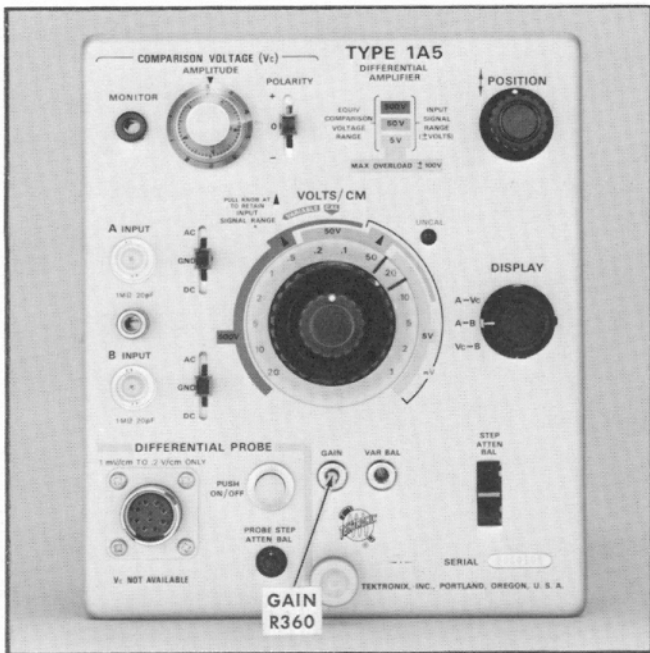


Fig. 6-10. Location of adjustment for step 5.

6. Check Attenuator Accuracy

- a. Equipment setup is shown in Fig. 6-9.
- b. CHECK—Vertical display amplitude within limits given in Table 6-3 with the Type 1A5 and the Standard Amplitude Calibrator set to indicated values. Reset POSITION control as necessary for convenient measurement. UNCAL lamp must remain off during entire check.
- c. Set the A Input AC-GND-DC switch to GND. Move the coaxial cable from the A INPUT to the B INPUT connector.
- d. Place the B Input AC-GND-DC switch to the DC position. Center the display, using the POSITION control.
- e. CHECK—B Input attenuators by repeating step b.

TABLE 6-3

Type 1A5 VOLTS/CM Settings	Standard Amplitude Calibrator Amplitude Settings	Vertical Display Amplitude
20 V	100 V	5 cm ± 1.25 mm
10 V	50 V	5 cm ± 1.25 mm
5 V	20 V	5 cm ± 1.25 mm
2 V	10 V	5 cm ± 1.25 mm
1 V	5 V	5 cm ± 1.25 mm
.5 V	2 V	4 cm ± 1 mm
.2 V Retained Range	1 V	5 cm ± 1.25 mm
.1 V Retained Range	.5 V	5 cm ± 1.25 mm
.2 V	1 V	5 cm ± 1.25 mm
.1 V	.5 V	5 cm ± 1.25 mm
50 mV	.2 V	4 cm ± 1 mm
20 mV Retained Range	.1 V	5 cm ± 1.25 mm
10 mV Retained Range	50 mV	5 cm ± 1.25 mm

7. Check VARIABLE Range (R350)

- a. Equipment setup is shown in Fig. 6-9, except that the B Input AC-GND-DC control is set to DC.
- b. Set the Amplitude control on the Standard Amplitude Calibrator to .1 V.
- c. Set the Type 1A5 VOLTS/CM control to 20 mV. Observe 5 cm deflection on the oscilloscope. Adjust POSITION control as necessary for convenient measurement.
- d. CHECK—Vertical display amplitude reduces to 2 cm or less when VARIABLE is rotated to CCW limit (2.5:1 or more control range.) Return VARIABLE to CAL position.
- e. Switch the B Input AC-GND-DC control to GND and disconnect the coaxial cable from the B INPUT connector.

NOTES

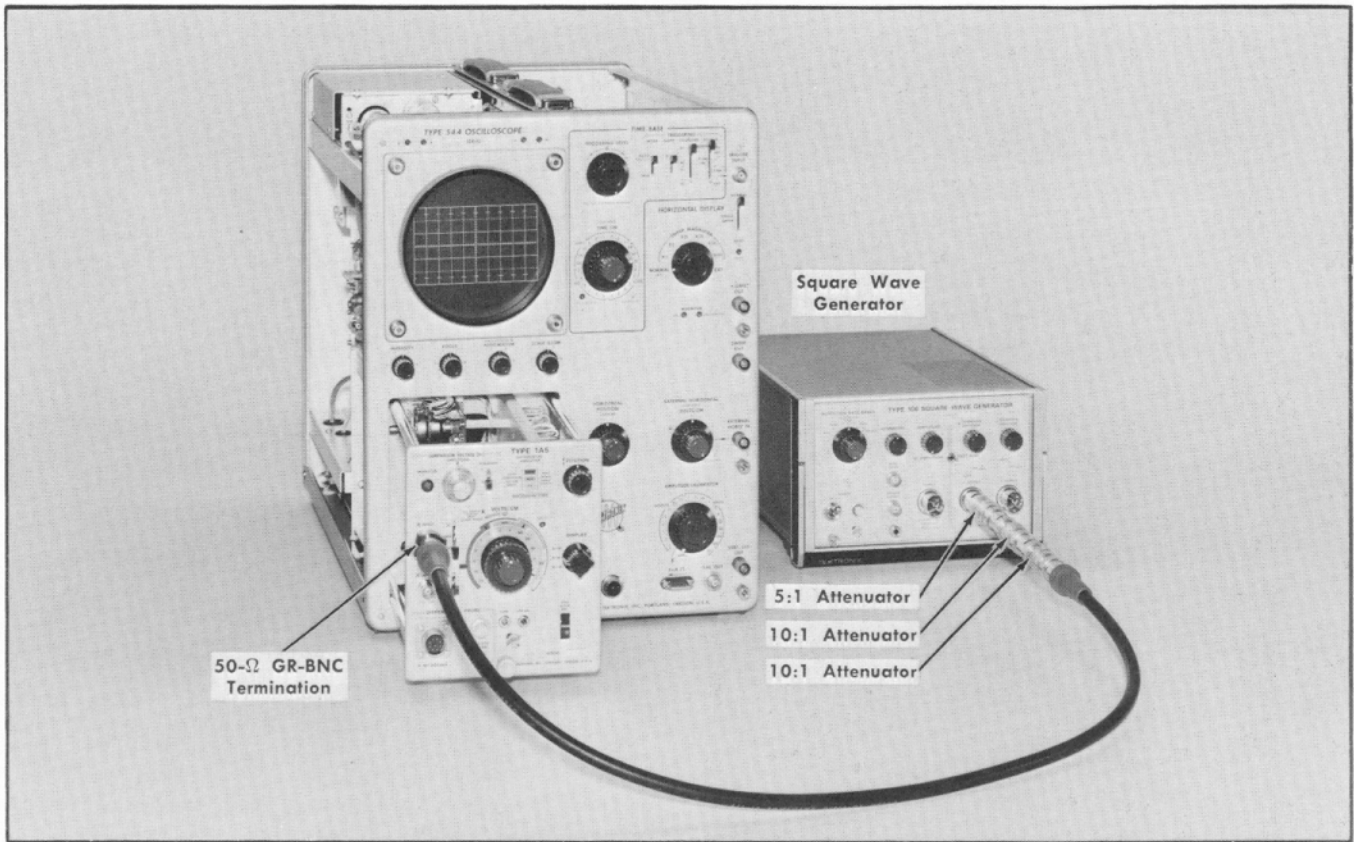


Fig. 6-11. Equipment setup for steps 8 through 12.

Type 1A5 Controls

POSITION	Midrange
A Input AC-GND-DC	DC
B Input AC-GND-DC	GND
VOLTS/CM	1 mV
VARIABLE	CAL
DISPLAY	A-B
STEP ATTEN BAL	Midrange

Type 544 Oscilloscope Controls

Triggering Level	Fully Clockwise
Triggering Mode	Auto Stability
Triggering Source	Norm
Time/cm	10 μ s
Variable	Cal
Horizontal Display	Norm ($\times 1$)

Square Wave Generator

Repetition Rate Range	1 kHz
Multiplier	CCW
Hi Amplitude/Fast Rise	Fast Rise
+ Output	

8. Check Noise

a. Equipment setup is shown in Fig. 6-11. Typical waveforms appear in Fig. 6-12.

b. Connect the following components to the A INPUT connector in the sequence given:

GR-to-BNC 50 Ω Termination (item 13)

GR 5 ns Cable (item 9)

2—10:1—50 Ω —GR Type Attenuators (item 16)

1—5:1—50 Ω —GR Type Attenuator (item 15)

Type 106 Square Wave Generator + Output (item 3)

c. Set the Oscilloscope Time/cm control to 10 μ s and the Triggering Level control to its clockwise limit. Set Intensity, Focus and Astigmatism for optimum CRT viewing.

d. Set the Type 1A5 A Input AC-GND-DC switch to DC and the VOLTS/CM control to 1 mV. Check that the UNCAL lamp is off.

e. Set the Square Wave Generator Hi Amplitude-Fast Rise switch to Fast Rise, the Repetition Rate Range to 1 kHz, and the Multiplier CCW. Increase the Square Wave Generator + Transition Amplitude to provide 2 separate traces on the CRT. (Caused by the upper and lower excursions of the square wave being presented on a free running sweep.)

f. Decrease the + Transition Amplitude as necessary to just eliminate the dark line between the two traces. Use Fig. 6-12 (A), (B) and (C) as guides. (The desired presentation is obtained when a point is reached where doubt exists as to whether the black line is or is not eliminated.) The two trace centers are now separated by twice the RMS value of noise.

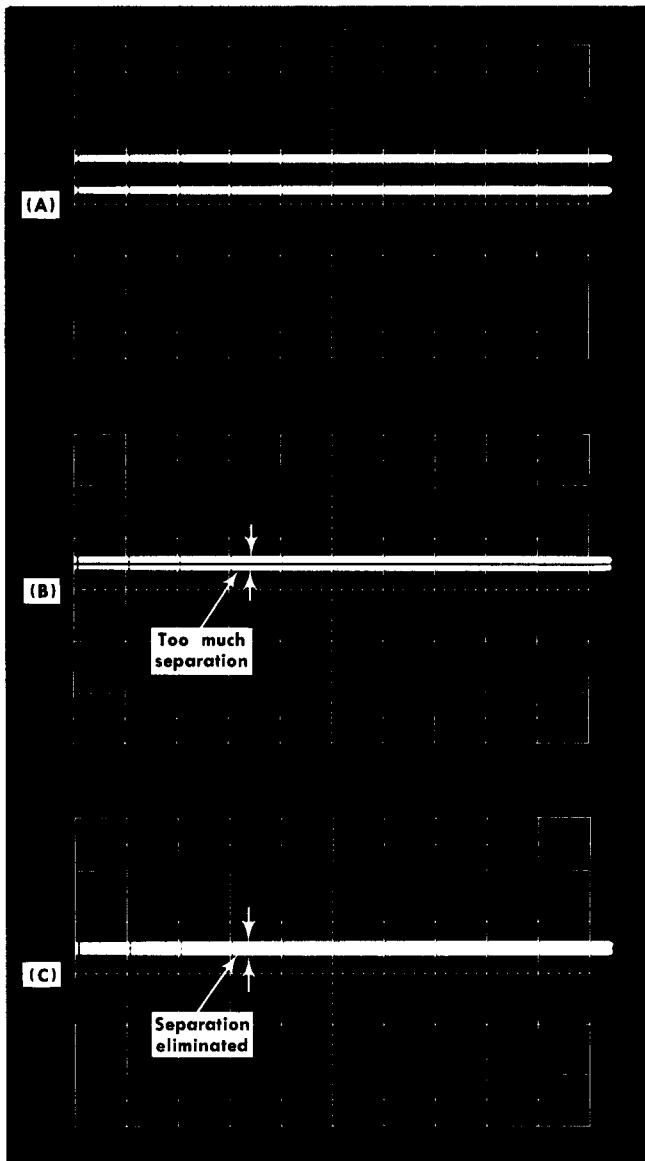


Fig. 6-12. (A) Initial waveform for noise measurement, step 8-e; (B) Too much separation between traces, step 8-f; (C) Desired waveform, step 8-f: (Sweep rate $10 \mu\text{s}/\text{cm}$; vertical sensitivity $1 \text{ mV}/\text{cm}$).

g. Remove one 10:1 attenuator. (This increases trace separation by 10 times, allowing more accurate measurement.)

h. CHECK—Noise. Measure distance between trace centers in mV. Divide by 20. The result should be $50 \mu\text{V}$ RMS, or less, noise. (Division by 10 compensates for the removed attenuator. Division by 2 converts visual measurement into RMS value.)

i. Disconnect the GR cable, leaving the 50Ω GR-to-BNC termination attached to the A INPUT connector.

NOTE

A fast but much less accurate check of noise can be made by an alternate display method. Set the CRT controls for optimum display. With the VOLTS/CM

control at 1 mV, DISPLAY switch at A-B and both AC-GND-DC switches at GND, check for approximately 2.5 mm or less trace width.

9. Check Microphonics

- a. Equipment setup is shown in Fig. 6-11 except:
 - No connections are made to the A INPUT connector.
 - UNCAL lamp must remain off.
- b. Switch the A Input AC-GND-DC control to GND.
- c. CHECK 1 mm or less oscillation or ringing on the trace in response to finger-tapping on the Type 1A5 front panel.

10. Check Input Transistor Gate Current

- a. Equipment setup is shown in Fig. 6-11 except:
 - Square Wave Generator is not used.
 - Only a 50Ω termination is attached to A INPUT.
 - A Input AC-GND-DC control is at GND.
 - UNCAL lamp must remain off.
- b. CHECK—Less than 1 mm of trace shift occurs at the instant the A Input AC-GND-DC switch is moved from GND to the AC position. Return the switch to the GND position.
- c. Move the 50Ω GR to BNC termination from the A INPUT connector to the B INPUT connector.
- d. CHECK—Less than 1 mm of trace shift occurs at the instant the B Input AC-GND-DC switch is moved from GND to the AC position. Return the switch to the GND position.
- e. Remove the 50Ω termination from the B INPUT connector.

11. Check POSITION (R372) Control Range

- a. Equipment setup is shown in Fig. 6-11 except:
 - No connections are made to the A INPUT connector.
 - A Input AC-GND-DC control is at GND.
- b. Set DISPLAY switch to A-Vc, POSITION control fully CCW, Vc POLARITY to — and VOLTS/CM control to 20 V. Check that the UNCAL lamp is off.
- c. Adjust Vc AMPLITUDE as necessary to position the trace to the —3 cm line.
- d. Rotate POSITION control clockwise until the trace is positioned upward 6 cm to the +3 cm line.
- e. Switch POLARITY to +.
- f. Adjust Vc AMPLITUDE counterclockwise as necessary to again position the trace to the —3 cm line.
- g. CHECK—POSITION control range. Rotate POSITION knob fully clockwise. Trace should move up 6 cm or more for a total of 12 cm or more control range.

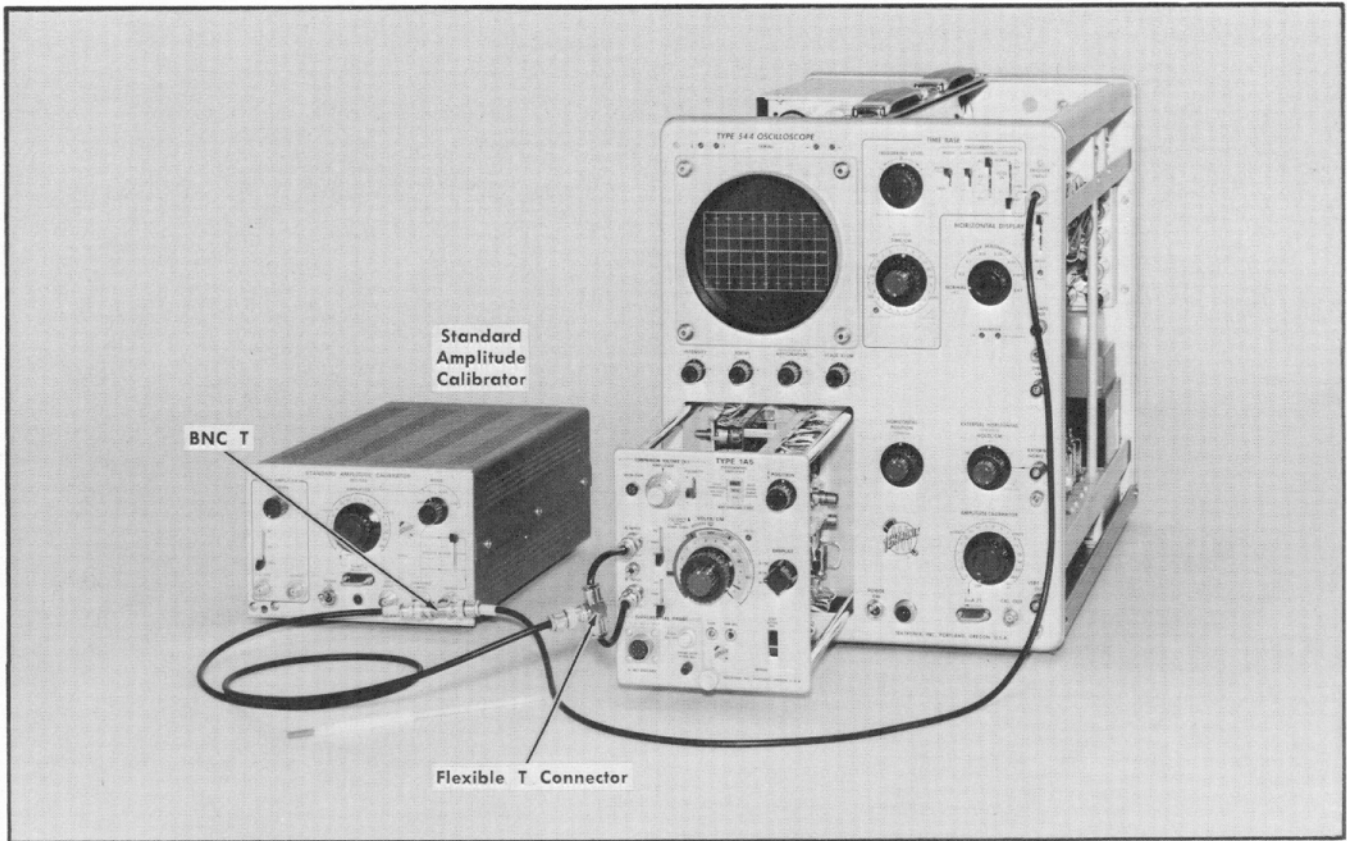


Fig. 6-13. Equipment setup for step 13.

Type 1A5 Controls

POSITION	Midrange
A Input AC-GND-DC	GND
B Input AC-GND-DC	GND
VOLTS/CM	20 mV
VARIABLE	CAL
DISPLAY	A-B
STEP ATTEN BAL	Midrange

Type 544 Oscilloscope Controls

Triggering Level	near 0
Triggering Mode	Auto Stability
Triggering Slope	+
Triggering Coupling	AC
Triggering Source	EXT
Time/CM	.5 mS
Variable	Cal
Horizontal Display	Norm (X1)

Standard Amplitude Calibrator

5 V-1 kHz Square Wave Output

13. Adjust DC Common-Mode Balance (COMMON-MODE BAL - R140, and R105D, R106D)

a. Equipment setup is shown in Fig. 6-13. Location of adjustments is shown in Fig. 6-14 (A) and (B). A typical adjustment waveform is shown in Fig. 6-14 (C).

b. Connect the two symmetrical ends of a flexible T connector (item 11) to the A and B INPUT connectors of the Type 1A5. Connect a BNC-T adapter (item 10) to the Standard Amplitude Calibrator square wave output connector. Connect a 50 Ω coaxial cable from the flexible T to the BNC-T adapter on the Standard Amplitude Calibrator. Connect a 50 Ω coaxial cable from the oscilloscope trigger Input connector to the BNC-T adapter on the Standard Amplitude Calibrator.

c. Set the Standard Amplitude Calibrator Amplitude control for a 5 V square wave output.

- d. Set the DISPLAY switch to A-B.
- e. Simultaneously set both AC-GND-DC switches to DC.
- f. Switch the VOLTS/CM control to 1 mV.
- g. Set the oscilloscope Triggering Source to Ext, Time/cm control to .5 ms and set the Triggering Level to trigger the sweep.
- h. CHECK—2.5 mm or less vertical display amplitude between trailing edges of square waves (20,000:1 CMRR). Disregard any aberrations that exist near the beginning of the square waves.
- i. ADJUST—COMMON MODE BAL (R140) for minimum amplitude between the trailing edges of the square waves (2.5 mm or less for 20,000:1 CMRR in $\times 1$ range). See Fig. 6-14 (C). Disregard aberrations that may exist near the leading edge of the square waves.
- j. CHECK— $\times 10$ and $\times 100$ attenuator DC common-mode balance for the same results as in h, using the setups given in Table 6-4.
- k. ADJUST— $\times 10$ and $\times 100$ attenuator DC common-mode balance for the same results as in i. Equipment setups and adjustments are listed in Table 6-4. Refer to Fig. 6-14 (B) for location of adjustments. (2000:1 CMRR in $\times 10$ and $\times 100$ ranges.)

TABLE 6-4

$\times 10$ and $\times 100$ DC Common-Mode Adjustments

Type 1A5 VOLTS/CM Settings	Standard Amplitude Calibrator Amplitude Settings	Type 1A5 Adjustments	Vertical Display Amplitude
10 mV Retained Range	50 V	R105D	2.5 cm or less
.1 V Retained Range	100 V	R106D	0.5 cm or less

- l. Switch both AC-GND-DC switches to GND.
- m. Use of the Standard Amplitude Calibrator has been completed. Turn it off and disconnect the flexible T connector from the A and B inputs, and the coaxial cable from the oscilloscope Trigger Input.
- n. Switch the VOLTS/CM control to 20 mV.

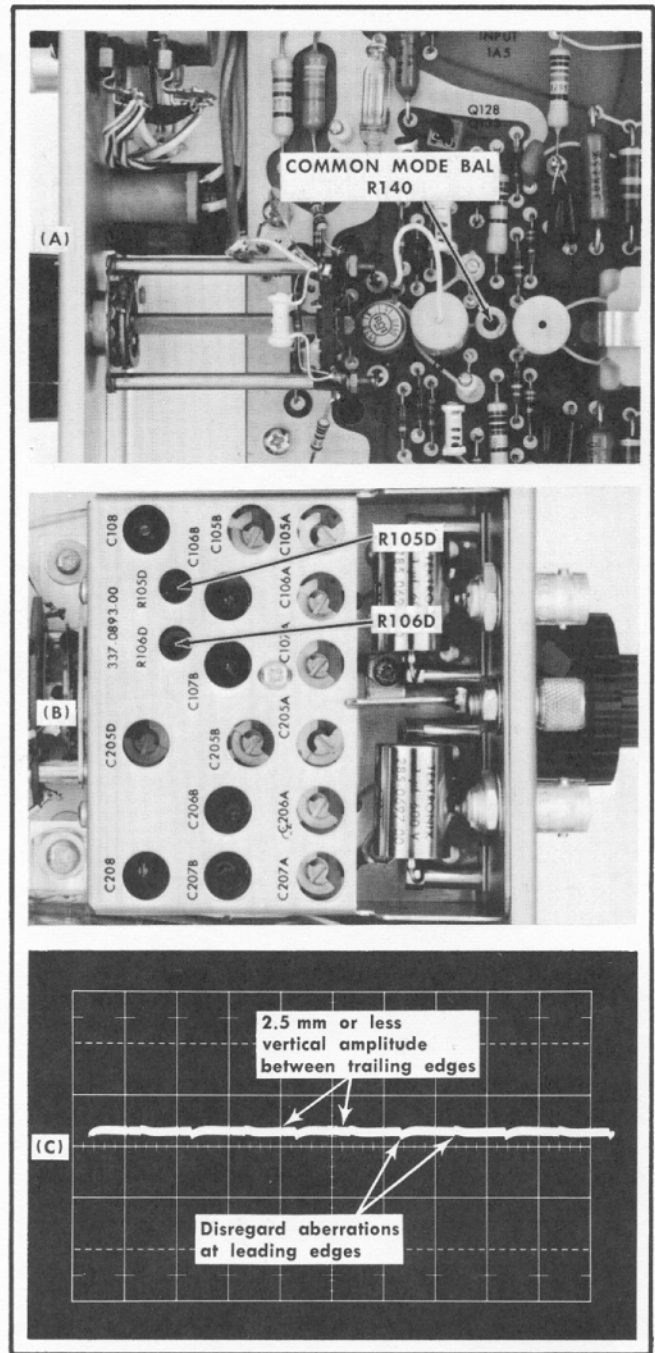


Fig. 6-14. DC common-mode balance, step 13. (A) and (B) Adjustment locations; (C) Typical waveform. (Sweep rate 0.5 ms/cm; vertical sensitivity 1 mV/cm)

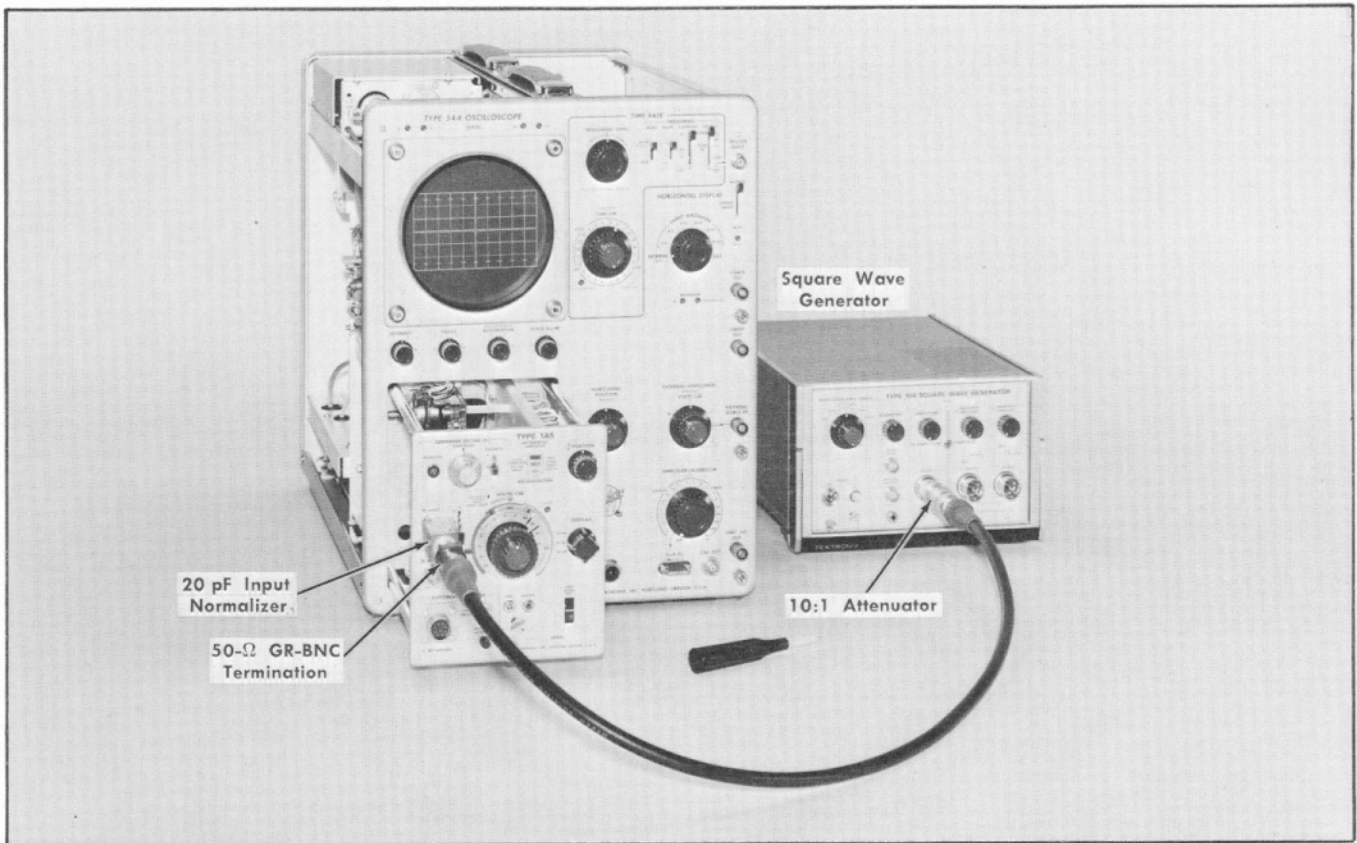


Fig. 6-15. Equipment setup for steps 14 and 16.

Type 1A5 Controls

A Input AC-GND-DC	DC
B Input AC-GND-DC	GND
VOLTS/CM	20 mV
VARIABLE	CAL
DISPLAY	A-B

Type 544 Oscilloscope Controls

Triggering Mode	Auto Stability
Triggering Slope	+
Triggering Coupling	AC
Triggering Source	Norm
Time/cm	.2 ms
Variable	Cal
Horizontal Display	Norm (×1)

Square Wave Generator

Hi Amplitude/Fast Rise	Hi Amplitude
Repetition Rate Range	1 kHz
Multiplier	CCW
Hi Amplitude Output	

14. Adjust ×1 Input Capacitance (C108, C208) ⓘ

a. Equipment setup is shown in Fig. 6-15. Location of adjustments is given in Fig. 6-16 (A). Typical waveforms are shown in Fig. 6-16 (B), (C), (D) and (E).

b. Connect the following equipment to the A INPUT connector in the sequence given:

- 20 pF Input RC Normalizer (item 17)
- 50 Ω GR-to-BNC Termination
- 5 ns GR Cable
- 10:1 50 Ω GR Attenuator
- Type 106 Square Wave Generator—Hi Amplitude Output

c. Set the Square Wave Generator controls as follows:

- Hi Amplitude Fast Rise—Hi Amplitude
- Repetition Rate Range—1 kHz
- Multiplier—fully CCW
- Amplitude—fully CCW

d. Set the oscilloscope Time/cm control to .2 ms and the Triggering Source to Norm.

e. Set the A Input AC-GND-DC switch to DC.

f. Adjust the Square Wave Generator Amplitude control to provide a 5 cm vertical display. Adjust POSITION control as necessary to obtain a centered display. Adjust Triggering Level as necessary to obtain a triggered sweep.

g. CHECK—Optimum square corner and flat top at the upper left corner of the square wave. 1/2 mm or less aberration. See Fig. 6-16.

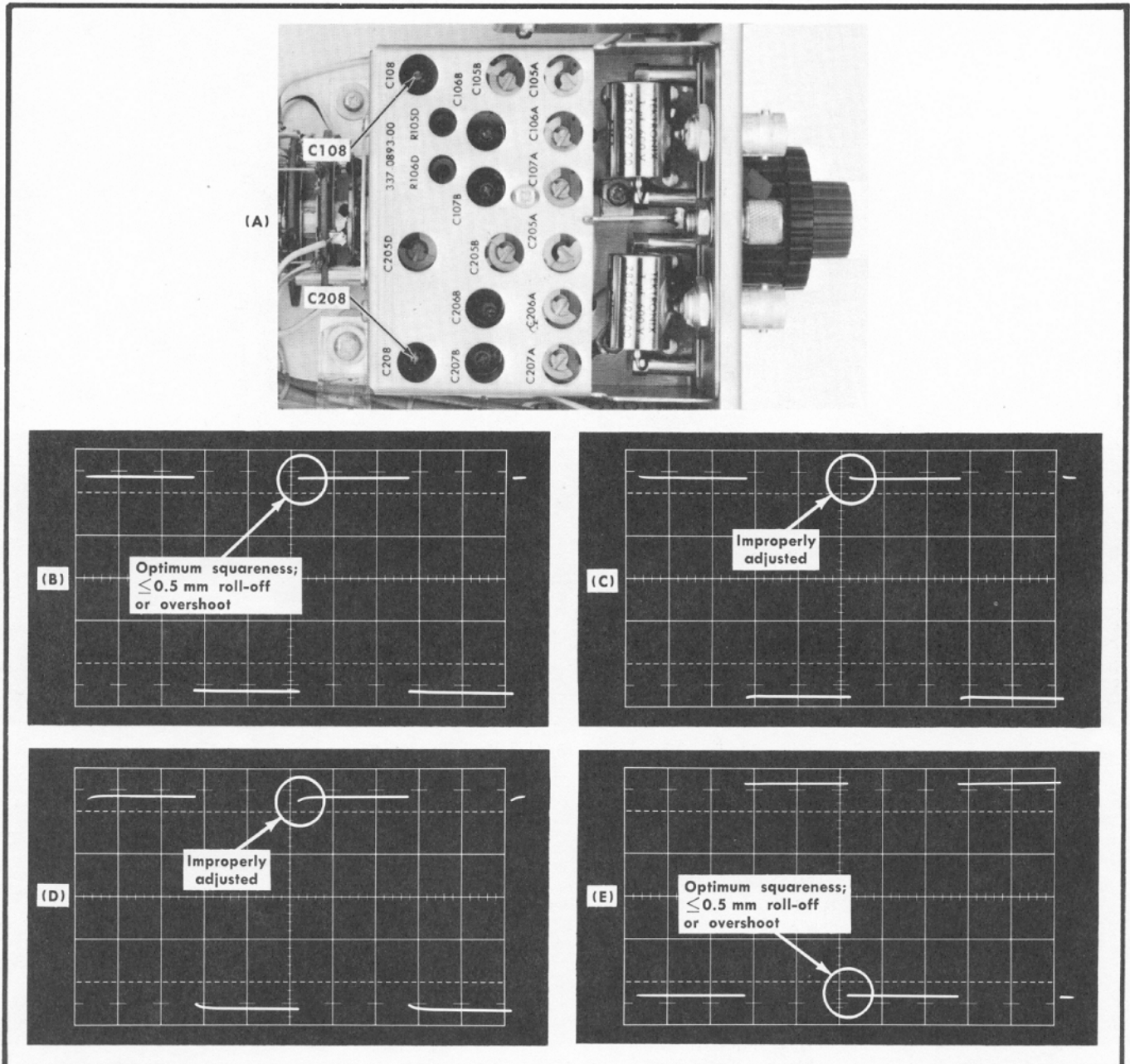


Fig. 6-16. Input capacitance adjustment, step 14. (A) Adjustment locations; (B) Optimum waveform, steps 14-g and h; (C) and (D) Improperly adjusted; (E) Optimum waveform, steps 14-m and n. (Sweep rate 0.2 ms/cm; vertical sensitivity 20 mV/cm).

h. ADJUST—C108, Fig. 6-16 (A), for optimum flatness and squareness at the upper left corner of the square wave. $\frac{1}{2}$ mm or less overshoot, rounding or tilt should remain. Fig. 6-16 (B) shows the desired results; Fig. 6-16 (C) and (D) show improper results.

- i. Switch the A Input AC-GND-DC switch to GND.
- j. Switch the oscilloscope Triggering Slope to —.
- k. Move the 20 pF input RC normalizer and associated components to the B INPUT connector.
- l. Switch the B Input AC-GND-DC switch to DC. Adjust the POSITION control as necessary to obtain a centered display.

m. CHECK—Optimum flatness and squareness at the lower left corner of the square wave. $\frac{1}{2}$ mm or less aberration. See Fig. 6-16 (E).

n. ADJUST—C208 for optimum flatness and squareness at the lower left corner of the square wave. $\frac{1}{2}$ mm or less overshoot, rounding or tilt should remain. See Fig. 6-16 (E).

o. Switch the B Input AC-GND-DC switch to GND and disconnect the 20 pF normalizer and associated components from the B INPUT connector.

p. INTERACTION—Check steps 15, 16 and 17.

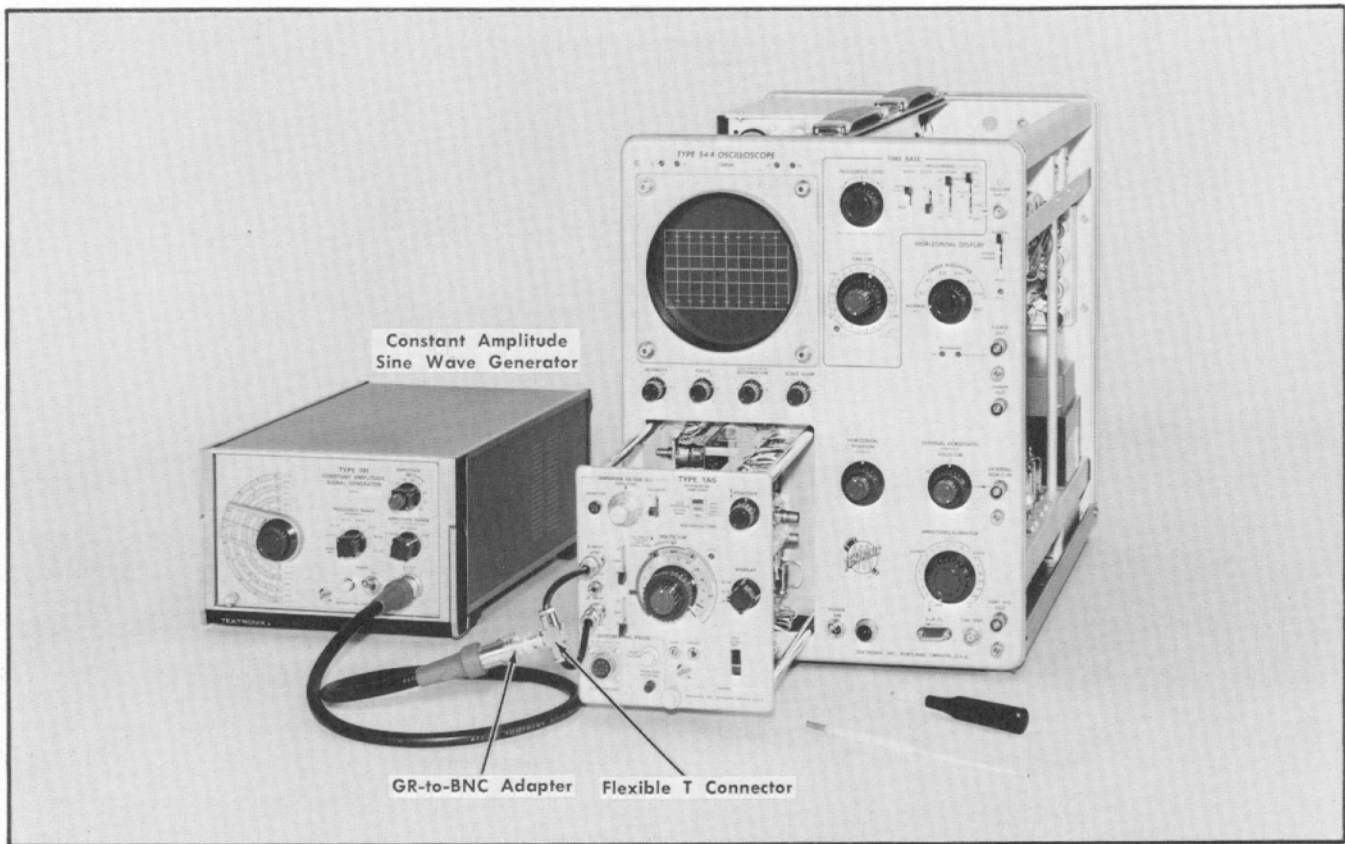


Fig. 6-17. Equipment setup for step 15.

Type 1A5 Controls

POSITION	Midrange
A Input AC-GND-DC	GND
B Input AC-GND-DC	GND
VOLTS/CM	20 mV
VARIABLE	CAL
DISPLAY	A-B

Type 544 Oscilloscope Controls

Triggering Mode	Auto Stability
Triggering Source	Norm
Time/cm	.2 ms
Horizontal Display	Norm (X1)

Constant Amplitude Sine Wave Generator

Frequency	1 MHz
Amplitude	50
Variable	Cal
Amplitude Range	.5-5 V

15. Adjust X1 High Frequency Common-Mode Rejection (C267, C122, C222, C123, C223, C163, C263)

a. Equipment setup is shown in Fig. 6-17. Locations of adjustments and test points are shown in Fig. 6-18.

b. Using the test strap, (removed from its Type 1A5 storage location during the Preliminary Procedure), connect TP 160 to TP 260. See Fig. 6-18 for test point locations.

WARNING

Use extreme care if the test strap is attached while the Type 1A5 is energized. If the Type 1A5 is briefly de-energized while connecting the TEST STRAP, allow 5 minutes or more warm-up time after power is re-applied.

c. Connect the two symmetrical ends of a flexible T connector to the A and B INPUTS of the Type 1A5. Connect the center of the T connector to a GR to BNC adapter (item 12). Connect the Type 191 Constant Amplitude Signal Generator (item 4) to the GR adapter, using its 5 ns GR cable.

d. Set the Constant Amplitude Signal Generator for a 10 V-1 MHz output. (An amplitude setting of 5 V on the Type 191 Provides 10 V to the 1 MΩ input of the Type 1A5 when no 50 Ω termination is used.)

e. Set the VOLTS/CM switch to 1 mV. Set the POSITION control to midrange and adjust R170 (DC BAL, Fig. 6-18) as necessary to position trace at the center of the graticule.

f. Simultaneously switch the A and B Input AC-GND-DC switches to DC.

g. ADJUST—C267 (Fig. 6-18) for minimum display amplitude (optimum common-mode rejection).

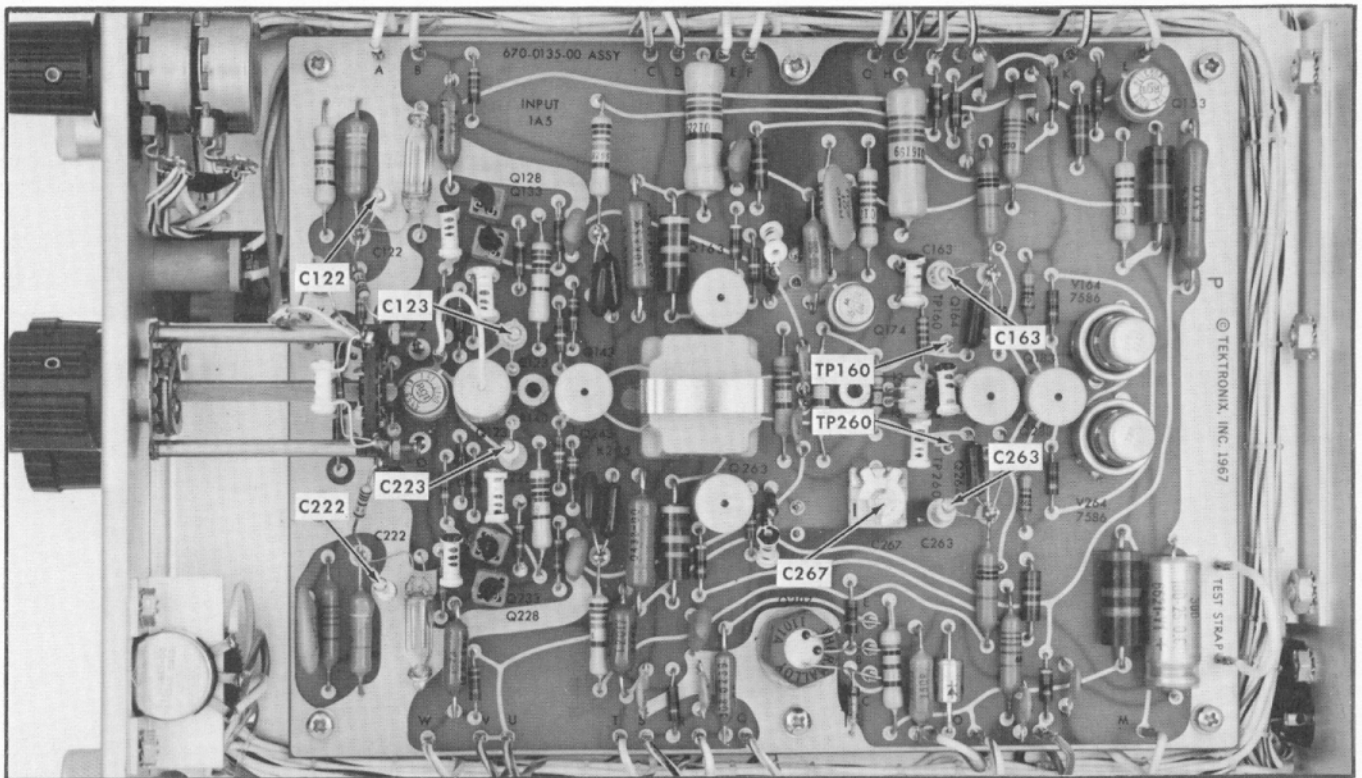


Fig. 6-18. Adjustment locations for step 15.

- h. Set the A and B Input AC-GND-DC switches to GND.
- i. Remove the test strap from TP 160—TP260.
- j. Check that the POSITION control and STEP ATTEN BAL control are at midrange and adjust R170 (Fig. 6-18) to set the trace to the center of the graticule.
- k. Set the A and B Input AC-GND-DC switches to DC.
- l. CHECK—1 cm or less display amplitude. (CMRR 10,000:1 or greater).
- m. ADJUST—C122 or C222 and C123 or C223 (Fig. 6-18) for minimum display amplitude. (1 cm or less vertical display amplitude for 10,000:1 or greater common-mode rejection ratio.)

NOTE

Use a non-metallic screwdriver. Preset C122, C222, C123, C223, C163 and C263 so that their threads are engaged by approximately two turns. When adjusting, screw in only the one that improves common-mode rejection in each pair.

- n. Change the Constant Amplitude Signal Generator control settings to 500 mV and 10 MHz.
- o. CHECK—1 cm or less vertical display amplitude. (CMRR 1000:1 or greater).
- p. ADJUST—Either C163 or C263 (Fig. 6-18) for minimum display amplitude. 1 cm or less vertical display amplitude for 1000:1 or greater common-mode rejection.
- q. Repeat steps d, m, n and p until less than 1 cm display amplitude exists for both steps m and p.
- r. Switch the VOLTS/CM control to 20 mV; simultaneously place the A and B Input AC-GND-DC switches to the GND position; disconnect the flexible T connector from the A and B INPUT connectors.
- s. Set the oscilloscope Triggering Slope to + and repeat step 14, parts a through n; then continue with step 16.
- t. INTERACTION—Check steps 16 and 17.

16. Adjust Attenuator Input Capacitance ❶

a. Equipment setup is shown in Fig. 6-15 except as follows:

Triggering Slope	—
A Input AC-GND-DC	GND
B Input AC-GND-DC	DC

20 pF Input RC Normalizer and associated equipment is connected to the B INPUT connector. Typical waveforms and locations of adjustments are shown in Fig. 6-19.

b. CHECK— $\frac{1}{2}$ mm or less aberration at lower left corner of a 5 cm negative square wave under setups given in Table 6-5. (See Fig. 6-19.)

c. ADJUST—B attenuator input capacitance as outlined in Table 6-5. Change the Square Wave Generator output as necessary to maintain a 5 cm vertical display amplitude. Observe optimum flatness and squareness at the lower left corner of the square wave. Adjust for $\frac{1}{2}$ mm or less aberration. See Fig. 6-19 (A), (B), (C) and (D).

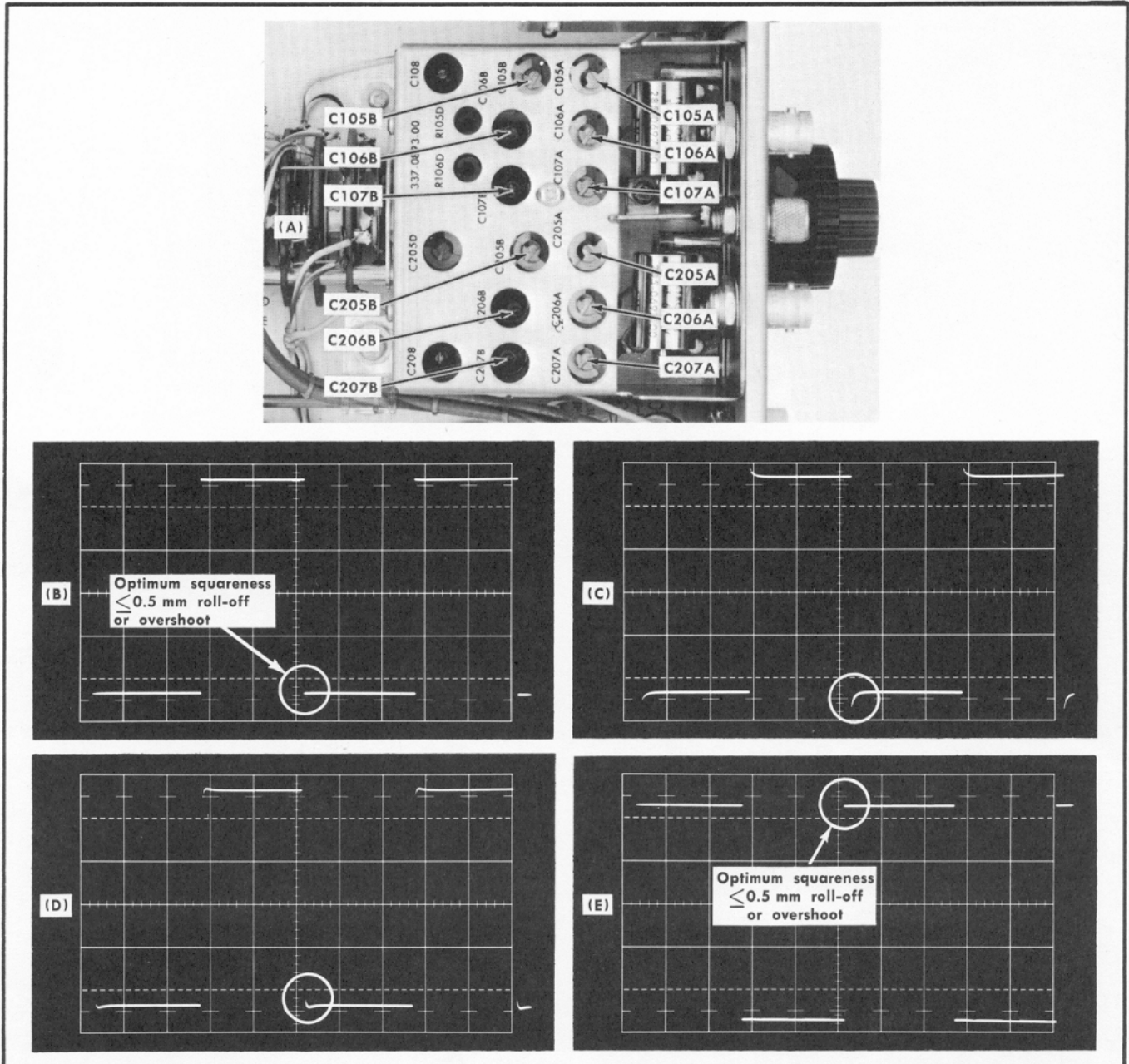


Fig. 6-19. Attenuator input capacitance adjustment, step 16. (A) Adjustment locations; (B) Optimum waveform for steps 16-b and c; (C) and (D) Improperly adjusted; (E) Optimum waveform for steps 16-g and h. (Sweep rate 0.2 ms/cm; vertical sensitivity set according to Tables 6-6 and 6-7).

TABLE 6-5
B Attenuator Input Capacitance

VOLTS/CM		Adjust
50 mV		C205A, C205B
.5 V	Remove 10:1 attenuator	C206A, C206B
5 V	Replace 50-Ω termination with a GR-to-BNC adapter	C207A, C207B

d. Change the oscilloscope Triggering Slope control to +.

e. Make the following changes in the Type 1A5 control setup:

A Input AC-GND-DC DC
B Input AC-GND-DC GND

f. Move the 20 pF input RC normalizer from the B to the A INPUT connector. Adjust POSITION control as necessary to center the display.

g. CHECK— $\frac{1}{2}$ mm or less aberration at the upper left corner of a 5 cm square wave under setups given in Table 6-6. (See Fig. 6-19.)

h. ADJUST—A attenuator input capacitance as outlined in Table 6-6. Change the Square Wave Generator output as necessary to maintain a 5 cm vertical display amplitude. Observe optimum flatness and squareness at the upper left corner of the square wave. Adjust for $\frac{1}{2}$ mm or less aberration. See Fig. 6-19 (E).

TABLE 6-6

A Attenuator Input Capacitance

VOLTS/CM		Adjust
5 V		C107A, C107B
.5 V	Replace GR-to-BNC adapter with the GR-to-BNC 50 Ω termination.	C106A, C106B
50 mV	Re-insert 10:1 attenuator	C105A, C105B

i. Switch the A Input AC-GND-DC control to GND and disconnect the 20 pF input RC normalizer and associated components from the A INPUT connector.

j. INTERACTION—Check step 17.

NOTES

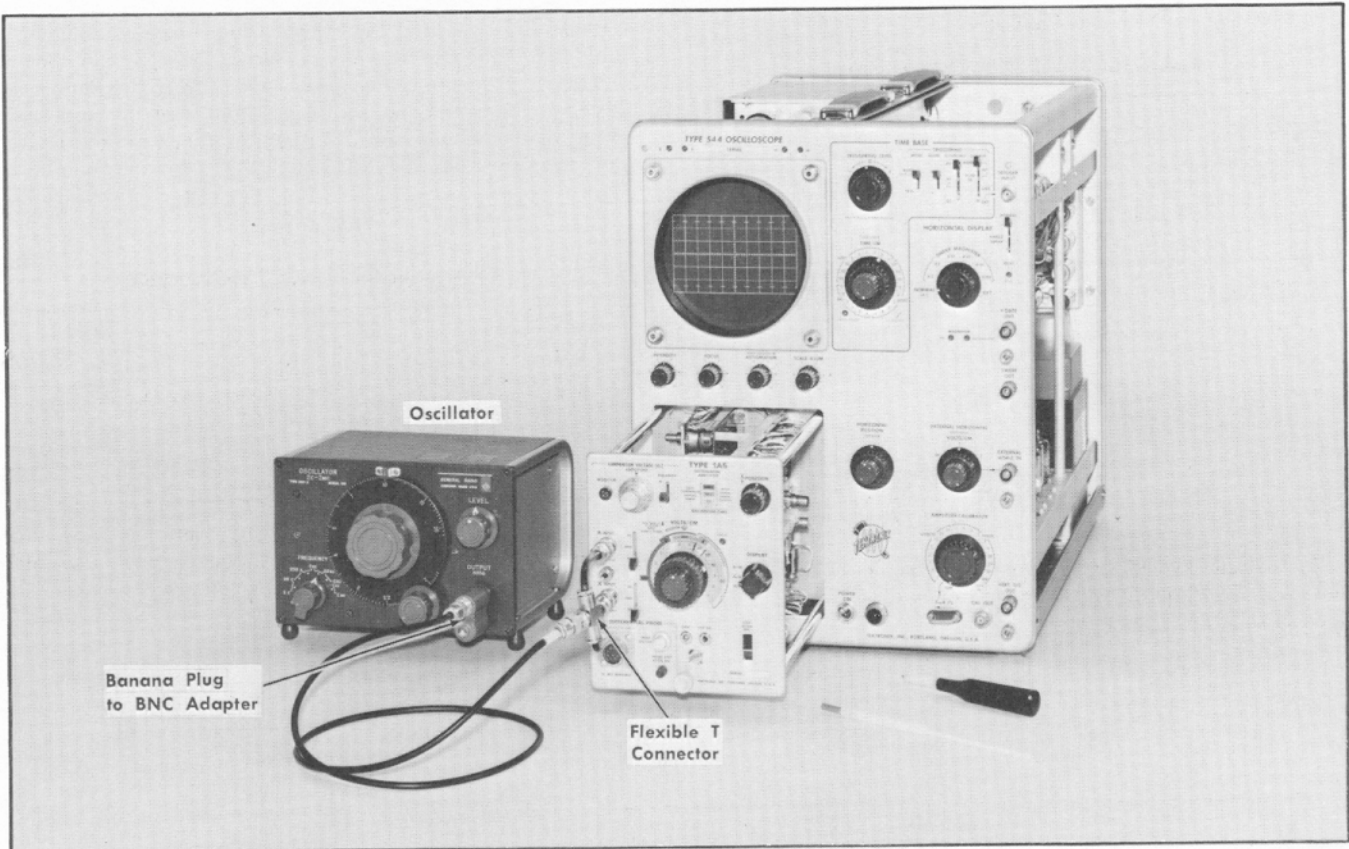


Fig. 6-20. Equipment setup for steps 17 through 19.

Type 1A5 Controls

POSITION	Midrange
A Input AC-GND-DC	DC
B Input AC-GND-DC	GND
VOLTS/CM	5 V
VARIABLE	CAL
DISPLAY	A-B

Type 544 Oscilloscope Controls

Triggering Mode	Auto Stability
Triggering Slope	+
Triggering Coupling	AC
Triggering Source	Norm
Time/cm	.2 ms
Variable	Cal
Horizontal Display	Norm (X1)

Oscillator

10 kHz —20 V peak-to-peak output

17. Adjust X10 and X100 DC- Coupled Common-Mode Rejection at 10 kHz. ①

a. Equipment setup is shown in Fig. 6-20. Adjustment location is indicated in Fig. 6-21.

b. Connect symmetrical ends of a flexible T connector to the A and B INPUT connectors. Connect the output of the General Radio Type 1310-A Oscillator (item 6) to the flexible T connector, using a banana-to-BNC adapter (item 23) and a coaxial cable.

c. Set the Type 1A5 VOLTS/CM control to 5 V and the A Input AC-GND-DC control to DC.

d. Set the Oscillator for a 10 kHz - 20 V peak-to-peak output. (4 cm of trace deflection.)

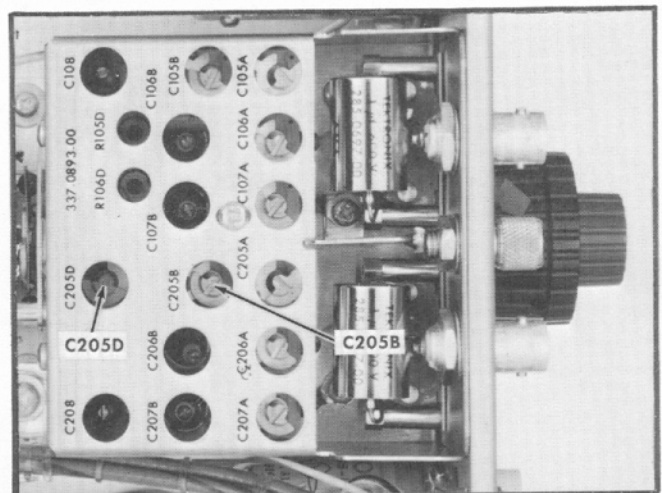


Fig. 6-21. Adjustment locations for step 17.

- e. Switch the B Input AC-GND-DC control to DC.
- f. Switch the VOLTS/CM control to 10-mV - Retained Range.
- g. CHECK—1 cm or less vertical display amplitude (2000:1 or greater CMRR).
- h. ADJUST—C205D (Fig. 6-21) for minimum vertical display amplitude. (1 cm or less for 2000:1 CMRR. Ratios of 5000:1 or more are not uncommon.)
- i. Switch the VOLTS/CM control to the 20 V position.
- j. Switch the B Input AC-GND-DC control to GND.
- k. Set the Oscillator amplitude to its maximum value. Measure its peak-to-peak value and divide it by 2000. Record the results.
- l. Switch the B input AC-GND-DC control to DC, and the VOLTS/CM control to .1 V - Retained Range.
- m. CHECK—Vertical display amplitude equal to or less than that recorded in step k. (CMRR 2000:1 or greater.)
- n. ADJUST—C206B (Fig. 6-21) for vertical display amplitude equal to or less than that recorded in step k. (CMRR 2000:1 or greater. Ratios of 5000:1 or more are not uncommon.)

18. Check AC-Coupled Common-Mode Rejection at 60 Hz

- a. Equipment setup is shown in Fig. 6-20.
- b. Set the oscilloscope Time/cm control to 5 ms.
- c. Switch the Type 1A5 VOLTS/CM control to 2 V and the B Input AC-GND-DC control to GND.

- d. Set the Oscillator for a 60 Hz - 10 V peak-to-peak output. (5 cm trace deflection.)
- e. Switch the B Input AC-GND-DC control to DC and the VOLTS/CM control to 2 mV.
- f. CHECK—2.5 mm or less vertical display amplitude.
- g. Simultaneously switch the A and B AC-GND-DC controls to AC.
- h. CHECK—Display amplitude 5 cm or less. (1000:1 CMRR).

19. Check AC-Coupled Low Frequency Response

- a. Equipment setup is shown in Fig. 6-20.
- b. Switch the Type 1A5 VOLTS/CM control to 20 mV, the A Input AC-GND-DC switch to DC, and the B Input AC-GND-DC switch to GND.
- c. Set the oscilloscope Time/CM control to .5 s.
- d. Change the Oscillator output to 2 Hz, 100 mV peak-to-peak, providing exactly 5 cm vertical amplitude. Insert an attenuator in the signal path to reduce the amplitude, if necessary.
- e. Switch the A Input AC-GND-DC switch to AC.
- f. CHECK—3.5 cm or more display amplitude.
- g. Switch the A Input AC-GND-DC switch to GND and the B Input AC-GND-DC switch to AC.
- h. CHECK—3.5 cm or more display amplitude.
- i. Switch the B Input AC-GND-DC switch to GND and disconnect the flexible T connector from the INPUT connectors. Use of the oscillator has been completed.

NOTES

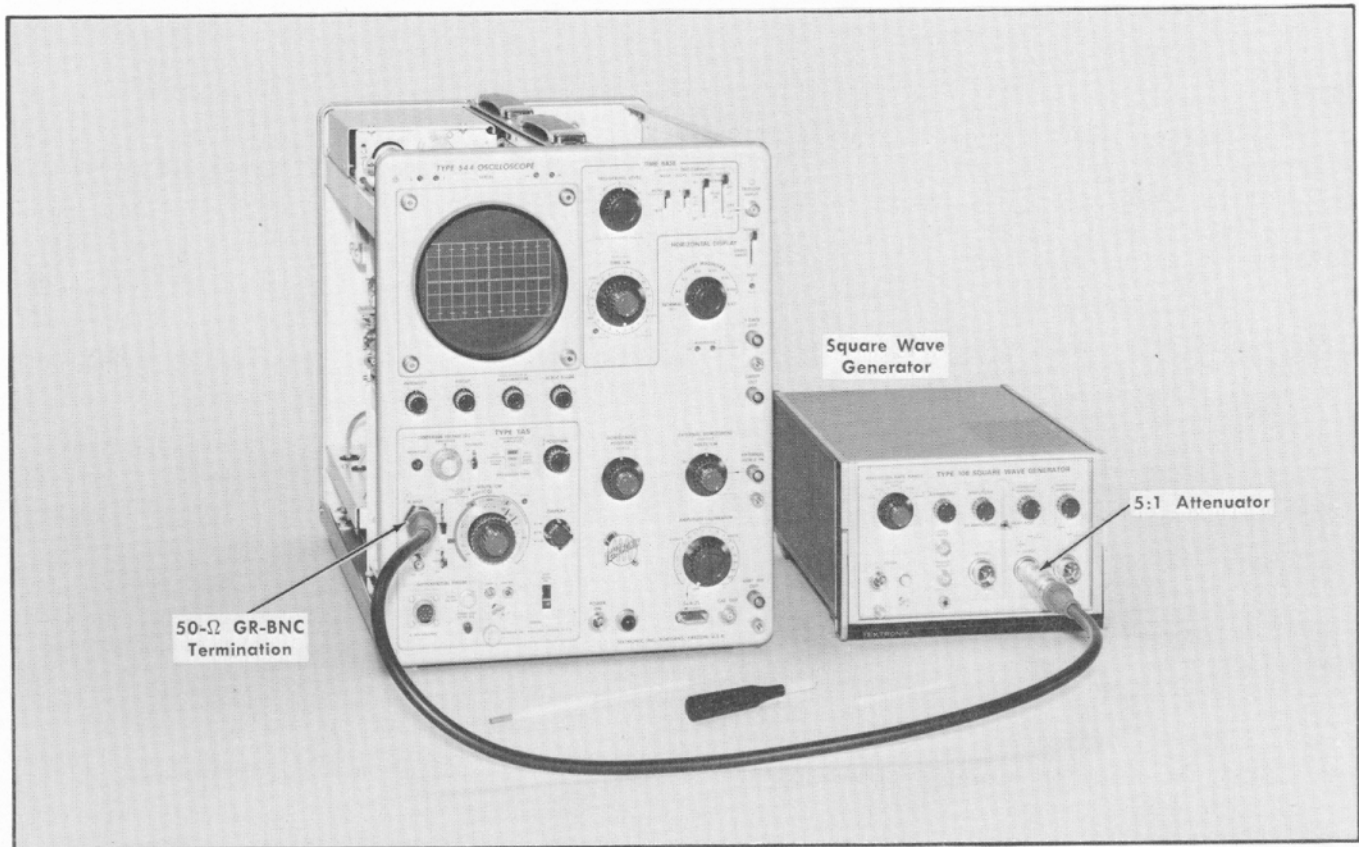


Fig. 6-22. Equipment setup for steps 20 and 21.

Type 1A5 Controls

POSITION	Midrange
A Input AC-GND-DC	DC
B Input AC-GND-DC	GND
VOLTS/CM	20 mV
VARIABLE	CAL
DISPLAY	A-B

Type 544 Oscilloscope Controls

Triggering Mode	Auto Stability
Triggering Slope	+
Triggering Coupling	AC
Triggering Source	Norm
Time/cm	.1 μ s
Variable	Cal
Horizontal Display	Norm (\times 1)

Square Wave Generator

Hi Amplitude/Fast Rise	Fast Rise
+ Output	
Repetition Rate Range	100 kHz
Multiplier	CCW

20. Adjust High Frequency Compensation ⓘ

a. Equipment setup is shown in Fig. 6-22. Adjustment locations and typical waveforms are indicated in Fig. 6-23.

b. Disconnect the Type 1A5 from the plug-in extension and attach the test strap to its storage location. (Fig. 6-18).

c. Disconnect the plug-in extension and plug the Type 1A5 directly into the oscilloscope. Tighten the securing knob to insure actuation of the sensing switch.

d. Attach the following components to the Type 1A5 A INPUT connector in the sequence given:

50- Ω GR-to-BNC Termination.

5 ns GR Cable

5:1 50- Ω GR Type Attenuator

Type 106 Square Wave Generator Fast Rise + output.

e. Switch the A Input AC-GND-DC control to DC.

f. Switch the oscilloscope Time/cm to .1 μ s.

g. Set the Square Wave Generator Repetition Rate Range to 100 kHz, Multiplier CCW and the Hi Amplitude-Fast Rise switch to Fast Rise. Set the + Transition Amplitude to provide a 5 cm vertical display amplitude. Adjust the Type 1A5 POSITION control as necessary to center the square wave.

h. Adjust the Horizontal Position controls to display the leading edge of the positive-going square wave near the center of the graticule. See Fig. 6-23 (B). Adjust the Intensity, Focus and Astigmatism for optimum presentation.

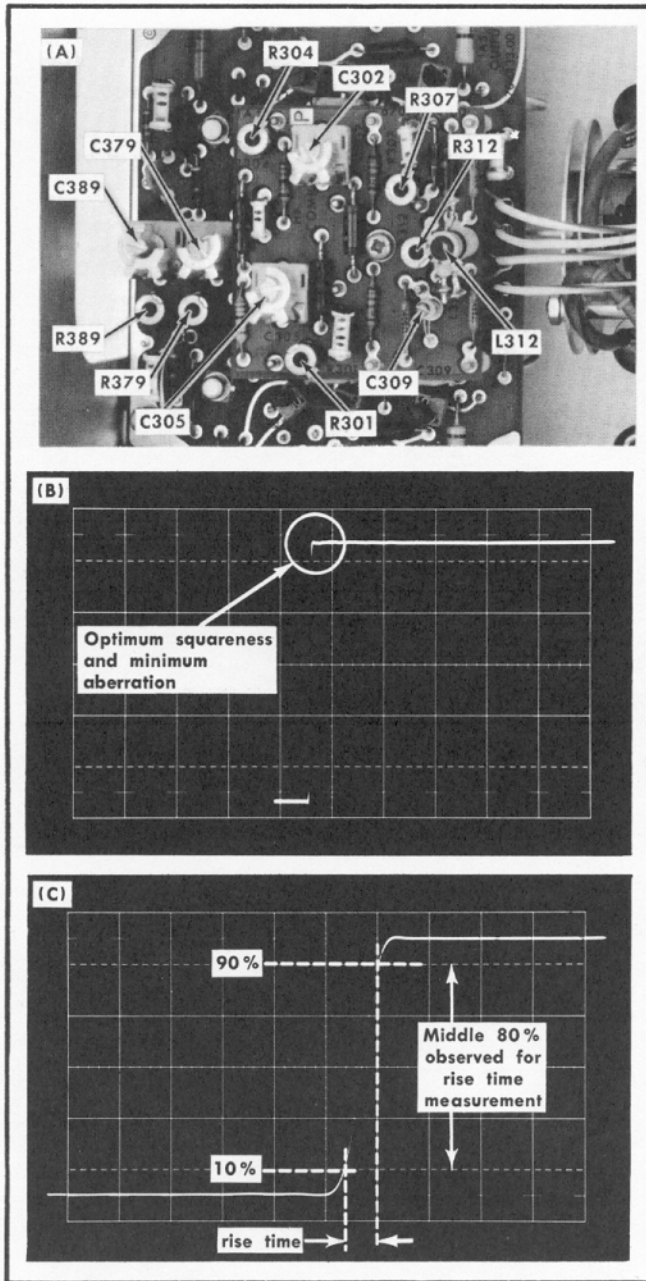


Fig. 6-23. High-frequency compensation adjustment, step 20. (A) Adjustment locations; (B) Waveform for steps 20-g through j, (sweep rate 0.1 $\mu\text{s}/\text{cm}$); (C) Waveform for step 20-l, (sweep rate 0.01 $\mu\text{s}/\text{cm}$). Vertical sensitivity 20 mV/cm or as given in Table 6-8.

- i. CHECK—Squareness and Flatness of upper left corner of square wave. (See Fig. 6-23).
- j. ADJUST—C379, R379, C389 and R389 to provide optimum flatness and squareness at the upper left corner of the square wave as shown in Fig. 6-23 (A) and (B).
- k. Switch the oscilloscope Sweep Magnifier control to $\times 10$. (10 ns/cm is now being displayed.)
- l. CHECK—7 ns or less rise time between the 10% and 90% points as shown in Fig. 6-23 (C). Repeat step j if necessary to obtain 7 ns or less rise time.

m. CHECK—Flatness and squareness at the upper left corner of a 5 cm square wave in each setup given in Table 6-7.

n. ADJUST—High frequency response and check rise time in each gain switching sensitivity position according to Table 6-7, following the same general procedure as in steps g through k. See Fig. 6-23A for location of adjustments.

TABLE 6-7

Gain Switching High Frequency Adjustments

VOLTS/CM	Sweep Magnifier	Adjust	Rise Time
10 mV	$\times 1$	L312/R312	
	$\times 10$		≤ 7 ns
5 mV	$\times 1$	R307/C309	
	$\times 10$		≤ 7 ns
Insert a 10:1 50- Ω GR Type attenuator between the GR cable and the 5:1 attenuator			
2 mV	$\times 1$	R304/C305	
	$\times 10$		≤ 8 ns
1 mV	$\times 1$	R301/C302	
	$\times 10$		≤ 9 ns

o. INTERACTION—Step 24.

21. Check Total Crosstalk

- a. Equipment setup is shown in Fig. 6-22. Typical waveforms are shown in Fig. 6-24.
- b. Remove the 10:1 attenuator (inserted in step 20 n).
- c. Switch the oscilloscope Horizontal Display control to Normal ($\times 1$) and Time/cm to .5 ms. Set the Horizontal Position controls to midrange.
- d. Switch the VOLTS/CM control to 20 mV.
- e. Change the Square Wave Generator Frequency to 1 kHz and adjust the + Transition Amplitude to provide a 5 cm presentation.
- f. Check for a square upper left corner of square wave as in Fig. 6-24 (A).
- g. Switch the B Input AC-GND-DC control to DC.
- h. CHECK—2.5 mm or less A INPUT roll-off at upper left corner of square wave. See Fig. 6-24 (B).
- i. Switch the A Input AC-GND-DC control to GND and move the termination and cable to the B INPUT connector.
- j. Check for a square lower left corner of square wave as in Fig. 6-24 (C).
- k. Switch the A Input AC-GND-DC control to DC.
- l. CHECK—2.5 mm or less B INPUT roll-off at lower left corner of square wave. See Fig. 6-24. (D).
- m. Disconnect the equipment from the B INPUT connector.

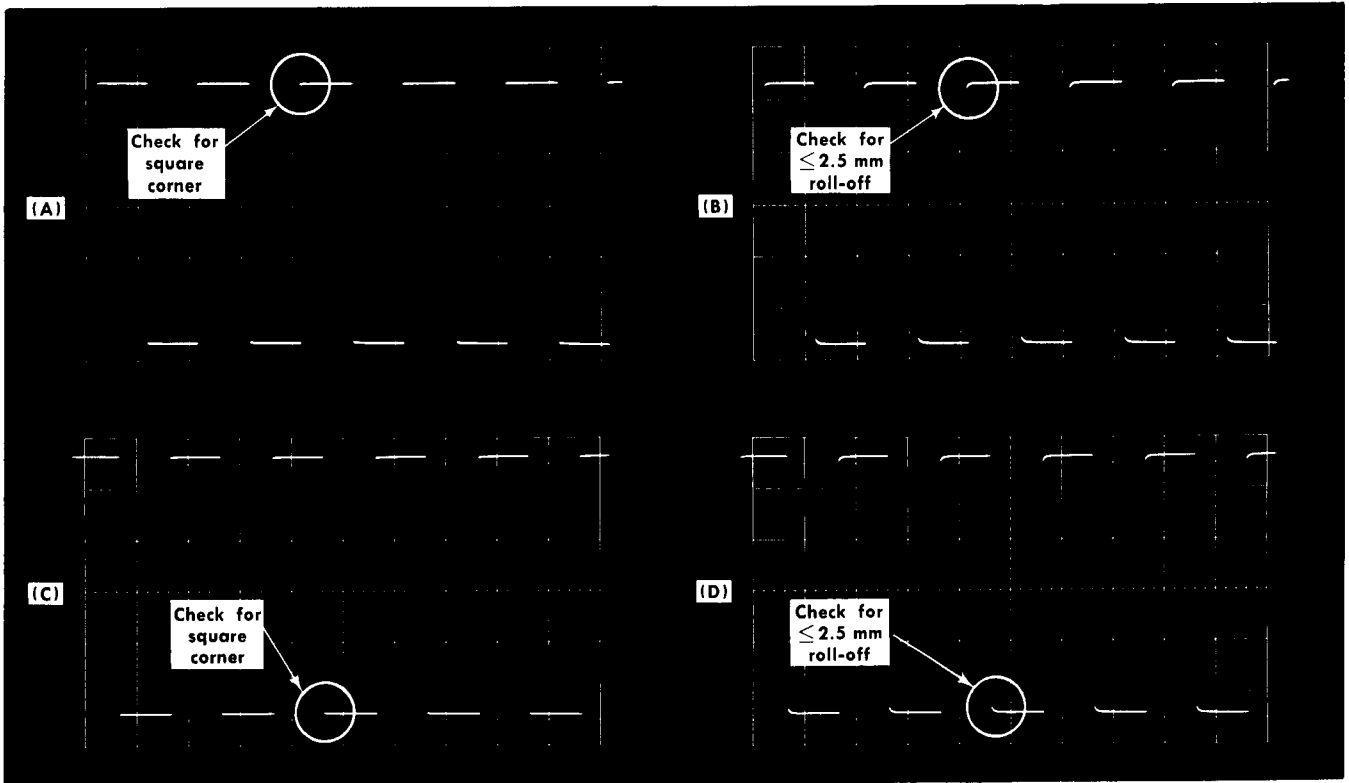


Fig. 6-24. Total crosstalk check—step 21. (A) and (B): A INPUT. (C) and (D): B INPUT.

NOTES

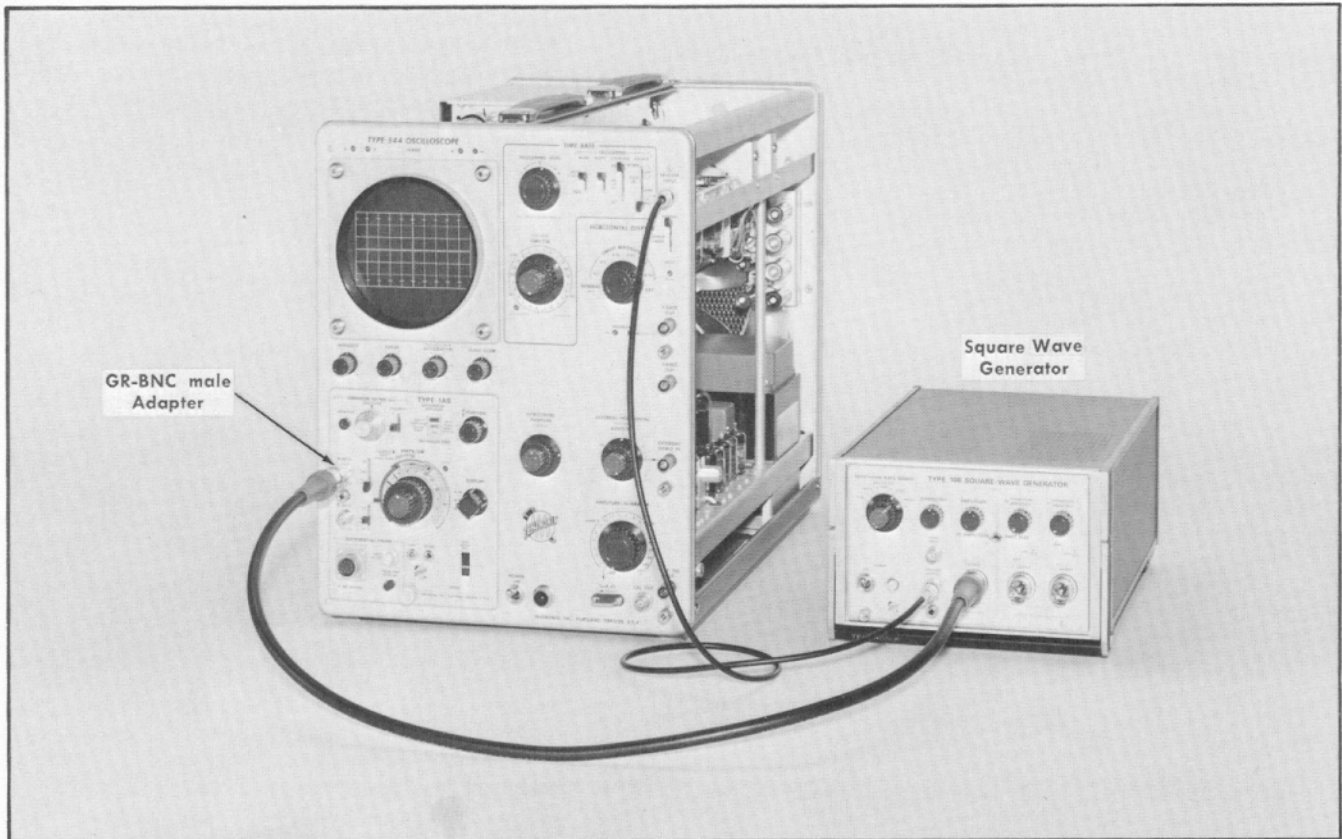


Fig. 6-25. Equipment setup for step 22.

Type 1A5 Controls

POSITION	Midrange
A Input AC-GND-DC	DC
B Input AC-GND-DC	GND
VOLTS/CM	1 V
VARIABLE	CAL
DISPLAY	A-B

Type 544 Oscilloscope Controls

Triggering Level	Adjust for triggered sweep
Triggering Mode	Auto Stability
Triggering Slope	+
Triggering Coupling	AC
Triggering Source	EXT
Time/cm	50 μ s
Variable	Cal
Horizontal Display	Norm ($\times 1$)

Square Wave Generator

High Amplitude/Fast Rise	Hi Amplitude
Repetition Rate Range	10 kHz
Muliplier	CCW
Hi Amplitude Output	

22. Check Overdrive Recovery Time and DC Shift Due to Overdrive

a. Equipment setup is shown in Fig. 6-25. Typical waveforms are shown in Fig. 6-26.

b. Set the Type 1A5 controls as follows:

VOLTS/CM	1 V
A Input AC-GND-DC	DC
B Input AC-GND-DC	GND

c. Set the oscilloscope controls as follows:

Time/cm	50 μ s
Triggering Source	Ext

d. Set the Type 106 Square Wave Generator controls as follows:

Hi Amplitude/Fast Rise	Hi Amplitude
Amplitude	Fully CCW
Repetition Rate Range	10 kHz
Muliplier	Fully CCW

e. Connect the following equipment to the A INPUT connector in the sequence given:

- 50 Ω GR-to-BNC Termination
- 5 ns GR Cable
- 2:1 50 Ω GR Attenuator (item 14)

Type 106 Square Wave Generator Hi Amplitude Output

f. Connect the Square Wave Generator Trigger Output to the oscilloscope Trigger Input connector.

g. Adjust the Square Wave Generator Amplitude control to provide 5 cm vertical display amplitude.

Calibration—Type 1A5

h. Switch the oscilloscope Time/cm to $1\ \mu\text{s}$ and adjust the Horizontal Position controls to place the beginning of the leading edge of the positive square wave at the 2 cm line as in Fig. 6-26(A).

i. Switch the Type 1A5 VOLTS/CM control to 10 mV.

j. Adjust the Type 1A5 POSITION control to set the right side of the visible portion of the trace to vertical center of the graticule as in Fig. 6-26 (B).

k. CHECK—A Input overdrive recovery time. Trace should return to within 1 cm (10 mV) of graticule center by the time the trace reaches the 3 cm line as in Fig. 6-26 (B). (10 mV or less within $1\ \mu\text{s}$.)

l. Switch the A Input AC-GND-DC control to GND.

m. Wait one minute; using POSITION control, set the trace to the vertical center of the graticule.

n. CHECK—A Input DC shift due to overdrive. The top of the waveform should be within 1 cm (10 mV) of the vertical center of the graticule 1 second after the A Input AC-GND-DC control is switched to DC. Return the AC-GND-DC switch to the GND position.

o. Move the $50\ \Omega$ termination and cable from the A INPUT to the B INPUT connector.

p. Using the POSITION control, set trace to vertical center of graticule.

q. CHECK—B Input shift due to overdrive. Top of waveform should be within 1 cm (10 mV) of vertical center 1 second after the B Input AC-GND-DC control is switched to DC.

r. Adjust the POSITION control to set the right side of the visible portion of the trace to graticule vertical center.

s. CHECK—B Input overdrive time. Trace returns to within 1 cm (10 mV) of graticule vertical center by the time the trace reaches the 3 cm line.

t. Disconnect the equipment from the oscilloscope and the Type 1A5. Use of the Square Wave Generator has been completed. Reset the oscilloscope Triggering Source to Norm and Horizontal Position controls to midrange.

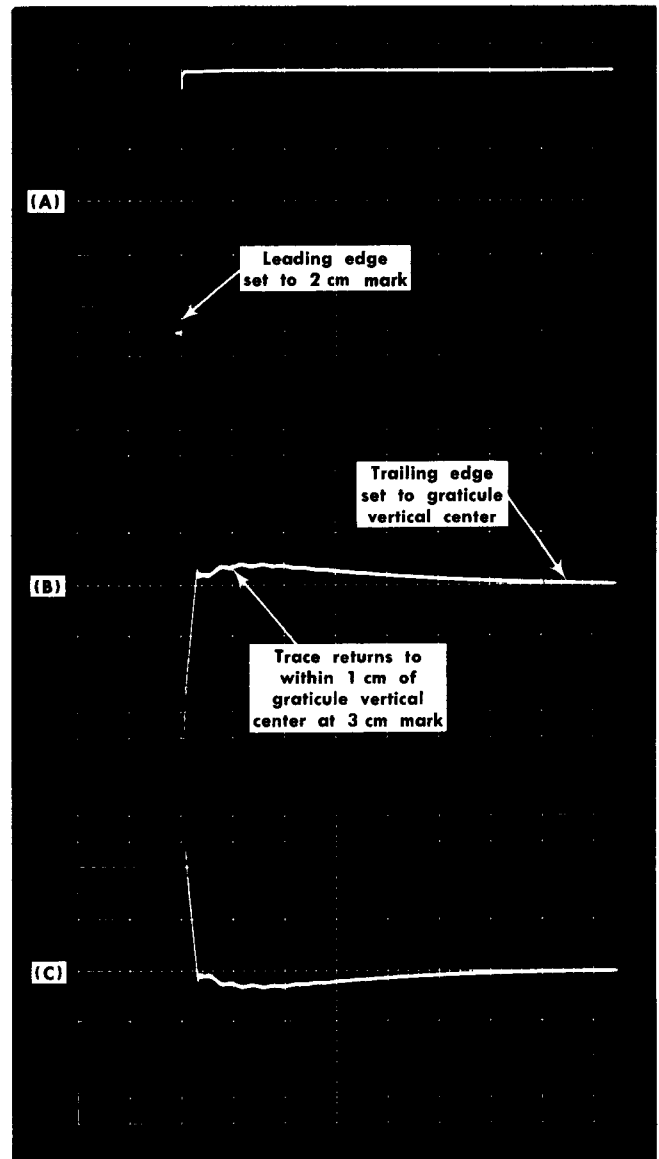


Fig. 6-26. (A) Preliminary waveform for check of overdrive recovery time, step 22-h. (B) A INPUT overdrive recovery time waveform, steps 22-j and k. (C) B INPUT overdrive recovery time waveform, steps 22-r and s.

NOTES

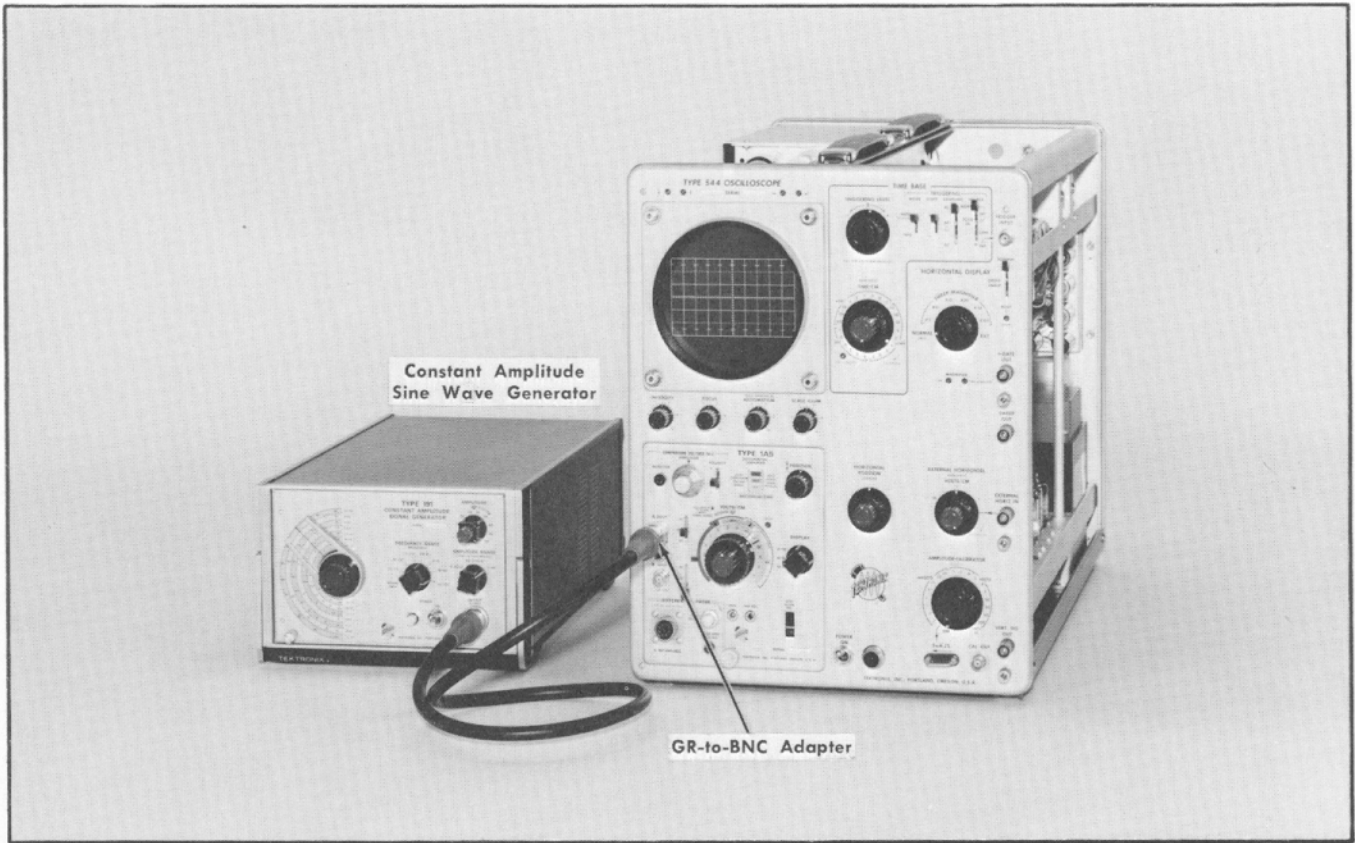


Fig. 6-27. Equipment setup for steps 23 and 24.

Type 1A5 Controls

POSITION	Midrange
A Input AC-GND-DC	GND
B Input AC-GND-DC	GND
VOLTS/CM	20 mV
VARIABLE	CAL
DISPLAY	Vc-B
GAIN	Midrange
VAR BAL	Midrange

Type 544 Oscilloscope Controls

Triggering Mode	Auto Stability
Triggering Slope	+
Triggering Coupling	AC
Triggering Source	Norm
Time/cm	1 μ s
Variable	Cal
Horizontal Display	Norm (\times 1)

Constant Amplitude Sine Wave Generator

Frequency	50 MHz
Amplitude	50
Variable	Cal
Amplitude Range	.5-5 V

23. Check Attenuator Crosstalk

- a. Equipment setup is shown in Fig. 6-27.
- b. Connect the Type 191 Constant Amplitude Signal Generator Output connector to the Type 1A5 INPUT connector indicated in Table 6-8, using the 5 ns GR cable and a GR to BNC adapter.
- c. Set the A and B Input AC-GND-DC switches to DC.
- d. Set the Constant Amplitude Signal Generator frequency to 50 MHz, Amplitude to 50, Variable to Cal, and Amplitude Range to .5-5 V.
- e. CHECK—5 cm or less vertical display amplitude (1% or less of input signal) under each setup given in Table 6-8.

TABLE 6-8

INPUT Connector	DISPLAY	VOLTS/CM
A	Vc-B	20 mV
A	Vc-B	20 mV Retained Range
B	A-Vc	20 mV Retained Range
B	A-Vc	20 mV

- f. Disconnect the cable from the B INPUT connector.

Calibration—Type 1A5

24. Check High Frequency Response

- a. Equipment setup is shown in Fig. 6-27.
- b. Connect the following equipment to the A INPUT connector in the sequence given.
 - 50-Ω GR-to-BNC Termination
 - 5 ns GR Cable
 - 5:1 50 Ω GR Type Attenuator
 - Type 191 Constant Amplitude Signal Generator
- c. Set the oscilloscope Time/cm control to .5 ms.
- d. CHECK—High frequency response for each of the setups given in Table 6-9, using the following procedure:
 - (1) Set the VOLTS/CM control to indicated setting.
 - (2) Set the Constant Amplitude Signal Generator frequency to 50 kHz and adjust its amplitude to provide 4 cm display amplitude.
 - (3) Set the frequency of the Constant Amplitude Signal Generator to the value opposite the applicable VOLTS/CM setting in Table 6-9.

(4) CHECK—2.8 cm or more display amplitude. Repeat step 20 if results are unsatisfactory.

TABLE 6-9

Type 1A5 VOLTS/CM	Constant Amplitude Signal Generator Frequency (MHz)
1 mV	40
2 mV	45
5 mV	50
10 mV	50
20 mV	50

- e. Disconnect the equipment. This concludes the calibration procedure.

NOTE

See the applicable active probe manual for instructions regarding the PROBE STEP ATTEN BAL adjustment procedure.

ABBREVIATIONS AND SYMBOLS

A or amp	amperes	L	inductance
AC or ac	alternating current	λ	lambda—wavelength
AF	audio frequency	\gg	large compared with
α	alpha—common-base current amplification factor	$<$	less than
AM	amplitude modulation	LF	low frequency
\approx	approximately equal to	lg	length or long
β	beta—common-emitter current amplification factor	LV	low voltage
BHB	binding head brass	M	mega or 10^6
BHS	binding head steel	m	milli or 10^{-3}
BNC	baby series "N" connector	M Ω or meg	megohm
X	by or times	μ	micro or 10^{-6}
C	carbon	mc	megacycle
C	capacitance	met.	metal
cap.	capacitor	MHz	megahertz
cer	ceramic	mm	millimeter
cm	centimeter	ms	millisecond
comp	composition	—	minus
conn	connector	mtg hdw	mounting hardware
\sim	cycle	n	nano or 10^{-9}
c/s or cps	cycles per second	no. or #	number
CRT	cathode-ray tube	ns	nanosecond
csk	countersunk	OD	outside diameter
Δ	increment	OHB	oval head brass
dB	decibel	OHS	oval head steel
dBm	decibel referred to one milliwatt	Ω	ohms—ohms
DC or dc	direct current	ω	omega—angular frequency
DE	double end	p	pico or 10^{-12}
$^\circ$	degrees	/	per
$^\circ$ C	degrees Celsius (degrees centigrade)	%	percent
$^\circ$ F	degrees Fahrenheit	PHB	pan head brass
$^\circ$ K	degrees Kelvin	ϕ	phi—phase angle
dia	diameter	π	pi—3.1416
\div	divide by	PHS	pan head steel
div	division	+	plus
EHF	extremely high frequency	\pm	plus or minus
elect.	electrolytic	PIV	peak inverse voltage
EMC	electrolytic, metal cased	plstc	plastic
EMI	electromagnetic interference (see RFI)	PMC	paper, metal cased
EMT	electrolytic, metal tubular	poly	polystyrene
ϵ	epsilon—2.71828 or % of error	prec	precision
\geq	equal to or greater than	PT	paper, tubular
\leq	equal to or less than	PTM	paper or plastic, tubular, molded
ext	external	pwr	power
F or f	farad	Q	figure of merit
F & I	focus and intensity	RC	resistance capacitance
FHB	flat head brass	RF	radio frequency
FHS	flat head steel	RFI	radio frequency interference (see EMI)
Fil HB	fillister head brass	RHB	round head brass
Fil HS	fillister head steel	ρ	rho—resistivity
FM	frequency modulation	RHS	round head steel
ft	feet or foot	r/min or rpm	revolutions per minute
G	giga or 10^9	RMS	root mean square
g	acceleration due to gravity	s or sec.	second
Ge	germanium	SE	single end
GHz	gigahertz	Si	silicon
GMV	guaranteed minimum value	SN or S/N	serial number
GR	General Radio	\ll	small compared with
$>$	greater than	T	tera or 10^{12}
H or h	henry	TC	temperature compensated
h	height or high	TD	tunnel diode
hex.	hexagonal	THB	truss head brass
HF	high frequency	θ	theta—angular phase displacement
HHB	hex head brass	thk	thick
HHS	hex head steel	THS	truss head steel
HSB	hex socket brass	tub.	tubular
HSS	hex socket steel	UHF	ultra high frequency
HV	high voltage	V	volt
Hz	hertz (cycles per second)	VAC	volts, alternating current
ID	inside diameter	var	variable
IF	intermediate frequency	VDC	volts, direct current
in.	inch or inches	VHF	very high frequency
incd	incandescent	VSWR	voltage standing wave ratio
∞	infinity	W	watt
int	internal	w	wide or width
\int	integral	w/	with
k	kilohms or kilo (10^3)	w/o	without
k Ω	kilohm	WW	wire-wound
kc	kilocycle	xmfr	transformer
kHz	kilohertz		



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. |

SECTION 7

ELECTRICAL PARTS LIST

Values are fixed unless marked Variable.

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff Disc	Description
Bulbs			
B122	150-0055-00		Neon, 5 AB-B
B222	150-0055-00		Neon, 5 AB-B
B291	150-0036-00		Incandescent, GE #345
B355	150-0030-00		Neon, NE 2 V
Capacitors			
Tolerance $\pm 20\%$ unless otherwise indicated.			
C101 ¹	*295-0105-00		0.1 μ F 600 V
C105A	281-0102-00		1.7-11 pF, Var Air
C105B	281-0102-00		1.7-11 pF, Var Air
C105C	283-0107-00		51 pF 200 V 5%
C106A	281-0103-00		1.8-13 pF, Var Air
C106B } C106C }	281-0113-00		0.2-1.5 pF, Var Tub. 100 pF Mica
C107A } C107B } C107C }	281-0103-00 281-0108-00		1.8-13 pF, Var Air 0.2-1.5 pF, Var Tub. 1000 pF Mica
C108	281-0043-00		0.7-3 pF, Var Tub.
C109	281-0601-00		7.5 pF Cer 500 V ± 0.5 pF
C114	290-0289-00		1 μ F Elect. 25 V
C116	283-0000-00		0.001 μ F Cer 500 V
C117	281-0523-00		100 pF Cer 350 V
C122	281-0064-00		0.2-1.5 pF, Var Tub.
C123	281-0064-00		0.2-1.5 pF, Var Tub.
C124	281-0525-00		470 pF Cer 500 V
C126	283-0002-00		0.01 μ F Cer 500 V
C132	281-0504-00		10 pF Cer 500 V 10%
C139	281-0523-00		100 pF Cer 350 V
C144	283-0068-00		0.01 μ F Cer 500 V
C148	283-0616-00		75 pF Mica 500 V 5%
C150	283-0065-00		0.001 μ F Cer 100 V 5%
C151	283-0000-00		0.001 μ F Cer 500 V
C152	283-0000-00		0.001 μ F Cer 500 V
C160	281-0544-00		5.6 pF Cer 500 V 10%
C162	283-0068-00		0.01 μ F Cer 500 V
C163	281-0064-00		0.2-1.5 pF, Var Tub.
C164	283-0000-00		0.001 μ F Cer 500 V
C167	281-0547-00		2.7 pF Cer 500 V 10%

¹C101 and C201 furnished as a unit (matched pair).

Electrical Parts List—Type 1A5

Capacitors (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description		
C169	281-0523-00		100 pF	Cer	350 V	
C176	283-0002-00		0.01 μ F	Cer	500 V	
C179	283-0000-00		0.001 μ F	Cer	500 V	
C184	283-0000-00		0.001 μ F	Cer	500 V	
C185	283-0000-00		0.001 μ F	Cer	500 V	
C186	283-0000-00		0.001 μ F	Cer	500 V	
C201 ²	*295-0105-00		0.1 μ F		600 V	
C205A	281-0102-00		1.7-11 pF, Var	Air		
C205B	281-0102-00		1.7-11 pF, Var	Air		
C205C	283-0107-00		51 pF	Cer	200 V	5%
C205D	281-0098-00		1.2-3.5 pF, Var	Air		
C206A	281-0103-00		1.8-13 pF, Var	Air		
C206B } C206C } C207A }	281-0113-00		0.2-1.5 pF, Var 100 pF	Tub. Mica		
C207B } C207C }	281-0108-00		0.2-1.5 pF, Var 1000 pF	Tub. Mica		
C208	281-0043-00		0.7-3 pF, Var	Tub.		
C209	281-0601-00		7.5 pF	Cer	500 V	± 0.5 pF
C222	281-0064-00		0.2-1.5 pF, Var	Tub.		
C223	281-0064-00		0.2-1.5 pF, Var	Tub.		
C224	281-0525-00		470 pF	Cer	500 V	
C232	281-0504-00		10 pF	Cer	500 V	10%
C244	283-0068-00		0.01 μ F	Cer	500 V	
C248	283-0616-00		75 pF	Mica	500 V	5%
C260	281-0544-00		5.6 pF	Cer	500 V	10%
C262	283-0068-00		0.01 μ F	Cer	500 V	
C263	281-0064-00		0.2-1.5 pF, Var	Tub.		
C264	283-0000-00		0.001 μ F	Cer	500 V	
C267	281-0076-00		1.2-3.5 pF, Var	Air		
C269	281-0529-00		1.5 pF	Cer	500 V	± 0.25 pF
C279	283-0000-00		0.001 μ F	Cer	500 V	
C293	290-0215-00		100 μ F	Elect.	25 V	
C295	283-0000-00		0.001 μ F	Cer	500 V	
C298	283-0000-00		0.001 μ F	Cer	500 V	
C300	281-0529-00		1.5 pF	Cer	500 V	± 0.25 pF
C301	281-0579-00		21 pF	Cer	500 V	5%
C302	281-0080-00		1.7-11 pF, Var	Air		
C304	281-0617-00		15 pF	Cer	200 V	
C305	281-0080-00		1.7-11 pF, Var	Air		

²C201 and C101 furnished as a unit. (matched pair).

Capacitors (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description
C307	281-0611-00		2.7 pF	Cer 200 V ±0.25 pF
C309	281-0064-00		0.2-1.5 pF, Var	Tub.
C338	281-0593-00		3.9 pF	Cer 10%
C355	283-0000-00		0.001 μF	500 V
C375	281-0529-00		1.5 pF	Cer 500 V ±0.25 pF
C378	281-0504-00		10 pF	Cer 500 V 10%
C379	281-0081-00		1.8-13 pF, Var	Air
C385	281-0529-00		1.5 pF	Cer 500 V ±0.25 pF
C389	281-0081-00		1.8-13 pF, Var	Air
C394	283-0000-00		0.001 μF	Cer 500 V
C395	283-0000-00		0.001 μF	Cer 500 V
C397	283-0068-00		0.01 μF	Cer 500 V
C398	283-0068-00		0.01 μF	Cer 500 V

Diodes

D111	152-0308-00		Zener	GREA-35, 9 V, 5%, TC
D133	*152-0061-00		Silicon	Tek Spec
D160	*152-0233-00		Silicon	Tek Spec
D167A } D167B }	*152-0316-00		Silicon	Assembly, Tek Spec (matched pair)
D233	*152-0061-00		Silicon	Tek Spec
D260	*152-0233-00		Silicon	Tek Spec
D292	152-0304-00		Zener	1N968B 0.4 W, 20 V, 5%
D296	152-0309-00		Zener	1N3828A 1 W, 6.2 V, 5%

Connectors

P11	131-0017-00		16 contact, male
J101	131-0342-00		BNC, female
J115	*136-0140-00		Socket, Banana Jack Assembly
J150	136-0089-00		Socket, 9 pin
J201	131-0342-00		BNC, female

Relays

K119	*108-0442-00		Coil, Reed
K119-1	260-0552-00		Reed
K295	148-0027-00		12 V DC
K301	*108-0431-00		Coil, Reed
K301-1	260-0839-00		Reed
K304	*108-0431-00		Coil, Reed
K304-1	260-0839-00		Reed
K305	*108-0431-00		Coil, Reed
K305-1	260-0839-00		Reed
K307	*108-0431-00		Coil, Reed

Electrical Parts List—Type 1A5

Relays (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	No. Disc	Description
K307-1	260-0839-00			Reed
K311	*108-0431-00			Coil, Reed
K311-1	260-0839-00			Reed
K313	*108-0431-00			Coil, Reed
K313-1	260-0839-00			Reed

Inductors

L301	*108-0211-01			0.5 μ H	
L304	*108-0211-01			0.5 μ H	
L307	*108-0105-01			1.8 μ H	
L312	*114-0231-00			5-10 μ H	Core 276-0506-00
L313	*108-0147-01			2.2 μ H	
L337	276-0528-00			Core, Ferramic Suppressor	
L375	276-0528-00			Core, Ferramic Suppressor	
L385	276-0528-00			Core, Ferramic Suppressor	
L387	276-0528-00			Core, Ferramic Suppressor	
LR314	*108-0268-01			0.1 μ H (wound on a 36 Ω resistor)	
LR316	*108-0441-00			4.5 μ H (wound on a 1.5 k Ω resistor)	
LR324	*108-0268-01			0.1 μ H (wound on a 36 Ω resistor)	

Transistors

Q123A,B	151-1008-00		Dual FET	Tek Spec
Q128	151-0190-00		Silicon	2N3904
Q133	151-0190-00		Silicon	2N3904
Q137	*151-0150-00		Silicon	Replaceable by 2N3440
Q143 ³	*153-0547-00		Silicon	MPS-918
Q153	151-0208-00		Silicon	2N4036
Q163 ⁴	*153-0547-00		Silicon	MPS-918
Q164 ⁵	*153-0547-00		Silicon	MPS-918
Q174	*151-0103-00		Silicon	Replaceable by 2N2219
Q183	*151-0198-00		Silicon	Replaceable by MPS-918
Q228	151-0190-00		Silicon	2N3904
Q233	151-0190-00		Silicon	2N3904
Q243 ³	*153-0547-00		Silicon	MPS-918
Q263 ⁴	*153-0547-00		Silicon	MPS-918
Q264 ⁵	*153-0547-00		Silicon	MPS-918

³Matched pair. Furnished as a unit.

⁴Matched pair. Furnished as a unit.

⁵Matched pair. Furnished as a unit.

Transistors (Cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	No. Disc	Description
Q283	*151-0198-00		Silicon	Replaceable by MPS-918
Q297	151-0208-00		Silicon	2N4036
Q314	*151-0198-00		Silicon	Replaceable by MPS-918
Q324	*151-0198-00		Silicon	Replaceable by MPS-918
Q334	*151-0198-00		Silicon	Replaceable by MPS-918
Q344	*151-0198-00		Silicon	Replaceable by MPS-918
Q354	*151-0198-00		Silicon	Replaceable by MPS-918
Q364	*151-0198-00		Silicon	Replaceable by MPS-918
Q374	*151-0109-00		Silicon	Selected from 2N918
Q384	*151-0109-00		Silicon	Selected from 2N918
Q393	*151-0150-00		Silicon	Replaceable by 2N3440

Resistors

Resistors are fixed, composition, $\pm 10\%$ unless otherwise indicated.

R101	315-0105-00	1 M Ω	$\frac{1}{4}$ W		5%
R105B ⁶	325-0004-00	900 k Ω	$\frac{1}{4}$ W	Prec	0.1%
R105C ⁷	325-0020-00	110.6 k Ω	$\frac{1}{8}$ W	Prec	0.1%
R105D	311-0635-00	1 k Ω , Var			
R106B	323-0614-07	990 k Ω	$\frac{1}{2}$ W	Prec	0.1%
R106C	321-0736-07	10.06 k Ω	$\frac{1}{8}$ W	Prec	0.1%
R106D	311-0622-00	100 Ω , Var			
R107B	323-0623-07	999 k Ω	$\frac{1}{2}$ W	Prec	0.1%
R107C	321-0735-07	1.001 k Ω	$\frac{1}{8}$ W	Prec	0.1%
R108	315-0681-00	680 Ω	$\frac{1}{4}$ W		5%
R109	321-0114-00	150 Ω	$\frac{1}{8}$ W	Prec	1%
R111	324-0313-00	17.8 k Ω	1 W	Prec	1%
R112	324-0603-00	27.8 k Ω	1 W	Prec	1%
R113	311-0669-00	2 k Ω , Var			
R114	321-0239-00	3.01 k Ω	$\frac{1}{8}$ W	Prec	1%
R115	311-0360-01	5 k Ω , Var			
R116	315-0102-00	1 k Ω	$\frac{1}{4}$ W		5%
R117	317-0151-00	150 Ω	$\frac{1}{10}$ W		5%
R118	321-0126-00	200 Ω	$\frac{1}{8}$ W	Prec	1%
R119	311-0649-00	100 Ω , Var			
R121	321-0193-00	1 k Ω	$\frac{1}{8}$ W	Prec	1%
R122	323-0623-07	999 k Ω	$\frac{1}{2}$ W	Prec	0.1%
R123	323-0320-00	21 k Ω	$\frac{1}{2}$ W	Prec	1%
R124	315-0101-00	100 Ω	$\frac{1}{4}$ W		5%
R125	323-0353-00	46.4 k Ω	$\frac{1}{2}$ W	Prec	1%

⁶R105B and R205B furnished as a unit (matched pair).

⁷R105C and R205C furnished as a unit (matched pair).

Electrical Parts List—Type 1A5

Resistors (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	No. Disc	Description		
R126	323-0329-00		26.1 kΩ	1/2 W	Prec	1%
R127	308-0397-00		12.5 kΩ	2 W	WW	5%
R128	315-0331-00		330 Ω	1/4 W		5%
R129	311-0663-00		500 Ω, Var			
R131	315-0680-00		68 Ω	1/4 W		5%
R132	315-0270-00		27 Ω	1/4 W		5%
R137	315-0101-00		100 Ω	1/4 W		5%
R138	315-0472-00		4.7 kΩ	1/4 W		5%
R139	315-0363-00		36 kΩ	1/4 W		5%
R140	311-0613-00		100 kΩ, Var			
R141	315-0104-00		100 kΩ	1/4 W		5%
R144	315-0330-00		33 Ω	1/4 W		5%
R145	315-0302-00		3 kΩ	1/4 W		5%
R147	308-0432-00		30 kΩ	3 W	WW	1%
R148	321-0275-00		7.15 kΩ	1/8 W	Prec	1%
R149	323-0392-00		118 kΩ	1/2 W	Prec	1%
R151	315-0150-00		15 Ω	1/4 W		5%
R152	315-0150-00		15 Ω	1/4 W		5%
R153	308-0273-00		6.5 kΩ	5 W	WW	2%
R154	301-0561-00		560 Ω	1/2 W		5%
R155	303-0202-00		2 kΩ	1 W		5%
R156	321-0234-00		2.67 kΩ	1/8 W	Prec	1%
R157	323-0298-00		12.4 kΩ	1/2 W	Prec	1%
R158	311-0419-00		500 kΩ, Var			
R159	315-0114-00		110 kΩ	1/4 W		5%
R160	315-0301-00		300 Ω	1/4 W		5%
R161	301-0183-00		18 kΩ	1/2 W		5%
R162	315-0470-00		47 Ω	1/4 W		5%
R163	323-0354-00		47.5 kΩ	1/2 W	Prec	1%
R164	321-0289-00		10 kΩ	1/8 W	Prec	1%
R165	323-0481-00		1 MΩ	1/2 W	Prec	1%
R166	315-0221-00		220 Ω	1/4 W		5%
R167	321-0125-00		196 Ω	1/8 W	Prec	1%
R168	321-0159-00		442 Ω	1/8 W	Prec	1%
R169	315-0333-00		33 kΩ	1/4 W		5%
R170	311-0635-00		1 kΩ, Var			
R171	323-0278-00		7.68 kΩ	1/2 W	Prec	1%
R174	308-0258-00		6 kΩ	3 W	WW	5%
R175	323-0321-00		21.5 kΩ	1/2 W	Prec	1%
R176	323-0330-00		26.7 kΩ	1/2 W	Prec	1%
R179	315-0301-00		300 Ω	1/4 W		5%
R181	315-0270-00		27 Ω	1/4 W		5%
R182	323-0297-00		12.1 kΩ	1/2 W	Prec	1%
R184	315-0470-00		47 Ω	1/4 W		5%
R185	315-0270-00		27 Ω	1/4 W		5%

Resistors (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description		
R186	315-0470-00		47 Ω	$\frac{1}{4}$ W		5%
R201	315-0105-00		1 M Ω	$\frac{1}{4}$ W		5%
R205B ⁸	325-0004-00		900 k Ω	$\frac{1}{4}$ W	Prec	0.1%
R205C ⁹	325-0020-00		111 k Ω	$\frac{1}{8}$ W	Prec	0.1%
R206B	323-0614-07		990 k Ω	$\frac{1}{2}$ W	Prec	0.1%
R206C	321-1289-07		10.1 k Ω	$\frac{1}{8}$ W	Prec	0.1%
R207B	323-0623-07		999 k Ω	$\frac{1}{2}$ W	Prec	0.1%
R207C	321-0735-07		1.001 k Ω	$\frac{1}{8}$ W	Prec	0.1%
R208	315-0681-00		680 Ω	$\frac{1}{4}$ W		5%
R209	321-0114-00		150 Ω	$\frac{1}{8}$ W	Prec	1%
R221	321-0193-00		1 k Ω	$\frac{1}{8}$ W	Prec	1%
R222	323-0623-07		999 k Ω	$\frac{1}{2}$ W	Prec	0.1%
R223	323-0320-00		21 k Ω	$\frac{1}{2}$ W	Prec	1%
R224	315-0101-00		100 Ω	$\frac{1}{4}$ W		5%
R227	308-0397-00		12.5 k Ω	2 W	WW	5%
R228	315-0331-00		330 Ω	$\frac{1}{4}$ W		5%
R231	315-0680-00		68 Ω	$\frac{1}{4}$ W		5%
R232	315-0270-00		27 Ω	$\frac{1}{4}$ W		5%
R241	315-0104-00		100 k Ω	$\frac{1}{4}$ W		5%
R244	315-0330-00		33 Ω	$\frac{1}{4}$ W		5%
R245	315-0302-00		3 k Ω	$\frac{1}{4}$ W		5%
R247	308-0432-00		30 k Ω	3 W	WW	1%
R248	321-0275-00		7.15 k Ω	$\frac{1}{8}$ W	Prec	1%
R249	323-0392-00		118 k Ω	$\frac{1}{2}$ W	Prec	1%
R259	315-0114-00		110 k Ω	$\frac{1}{4}$ W		5%
R260	315-0301-00		300 Ω	$\frac{1}{4}$ W		5%
R261	301-0183-00		18 k Ω	$\frac{1}{2}$ W		5%
R262	315-0470-00		47 Ω	$\frac{1}{4}$ W		5%
R263	323-0354-00		47.5 k Ω	$\frac{1}{2}$ W	Prec	1%
R264	321-0289-00		10 k Ω	$\frac{1}{8}$ W	Prec	1%
R265	323-0481-00		1 M Ω	$\frac{1}{2}$ W	Prec	1%
R266	315-0221-00		220 Ω	$\frac{1}{4}$ W		5%
R268	321-0159-00		442 Ω	$\frac{1}{8}$ W	Prec	1%
R271	323-0278-00		7.68 k Ω	$\frac{1}{2}$ W	Prec	1%
R279	315-0301-00		300 Ω	$\frac{1}{4}$ W		5%
R281	315-0270-00		27 Ω	$\frac{1}{4}$ W		5%
R282	323-0297-00		12.1 k Ω	$\frac{1}{2}$ W	Prec	1%
R292	323-0268-00		6.04 k Ω	$\frac{1}{2}$ W	Prec	1%
R293	315-0101-00		100 Ω	$\frac{1}{4}$ W		5%
R294	308-0239-00		84 Ω	3 W	WW	1%

⁸R205B and R105B furnished as a unit (matched pair).

⁹R205C and R105C furnished as a unit (matched pair).

Electrical Parts List—Type 1A5

Resistors (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	No. Disc	Description		
R295	308-0431-00		120 Ω	3 W	WW	5%
R296	308-0218-00		150 Ω	3 W	WW	5%
R298	305-0821-00		820 Ω	2 W		5%
R299	308-0013-00		200 Ω	10 W	WW	5%
R300	315-0681-00		680 Ω	$\frac{1}{4}$ W		5%
R301	311-0635-00		1 k Ω , Var			
R302	321-0136-01		255 Ω	$\frac{1}{8}$ W	Prec	0.5%
R304	311-0635-00		1 k Ω , Var			
R305	321-0145-01		316 Ω	$\frac{1}{8}$ W	Prec	0.5%
R307	311-0635-00		1 k Ω , Var			
R308	315-0621-00		620 Ω	$\frac{1}{4}$ W		5%
R309	321-0737-01		1.466 k Ω	$\frac{1}{8}$ W	Prec	0.5%
R311	321-0738-01		1.485 k Ω	$\frac{1}{8}$ W	Prec	0.5%
R312	311-0635-00		1 k Ω , Var			
R313	321-0738-01		1.485 k Ω	$\frac{1}{8}$ W	Prec	0.5%
R315	321-0739-01		1.68 k Ω	$\frac{1}{8}$ W	Prec	0.5%
R317	323-0303-00		14 k Ω	$\frac{1}{2}$ W	Prec	1%
R325	321-0739-01		1.68 k Ω	$\frac{1}{8}$ W	Prec	0.5%
R327	323-0303-00		14 k Ω	$\frac{1}{2}$ W	Prec	1%
R330	311-0329-00		50 k Ω , Var			
R331	315-0104-00		100 k Ω	$\frac{1}{4}$ W		5%
R333	321-0612-00		475 Ω	$\frac{1}{8}$ W	Prec	1%
R334	323-0245-00		3.48 k Ω	$\frac{1}{2}$ W	Prec	1%
R336	315-0100-00		10 Ω	$\frac{1}{4}$ W		5%
R341	315-0104-00		100 k Ω	$\frac{1}{4}$ W		5%
R343	321-0162-00		475 Ω	$\frac{1}{8}$ W	Prec	1%
R344	323-0245-00		3.48 k Ω	$\frac{1}{2}$ W	Prec	1%
R346	315-0100-00		10 Ω	$\frac{1}{4}$ W		5%
R350 ¹⁰	*311-0666-00		375 Ω , Var			
R352	321-0085-00		75 Ω	$\frac{1}{8}$ W	Prec	1%
R354	323-0298-00		12.4 k Ω	$\frac{1}{2}$ W	Prec	1%
R355	315-0473-00		47 k Ω	$\frac{1}{4}$ W		5%
R359	315-0104-00		100 k Ω	$\frac{1}{4}$ W		5%
R360	311-0653-00		100 Ω , Var			
R361	315-0201-00		200 Ω	$\frac{1}{4}$ W		5%
R362	321-0085-00		75 Ω	$\frac{1}{8}$ W	Prec	1%
R364	323-0298-00		12.4 k Ω	$\frac{1}{2}$ W	Prec	1%
R369	315-0104-00		100 k Ω	$\frac{1}{4}$ W		5%
R370	311-0225-00		2 x 100 k Ω , Var			
R372	311-0225-00		2 x 100 k Ω , Var			
R373	315-0393-00		39 k Ω	$\frac{1}{4}$ W		5%
R374	323-0230-00		2.43 k Ω	$\frac{1}{2}$ W	Prec	1%
R375	321-0162-00		475 Ω	$\frac{1}{8}$ W	Prec	1%
R376	315-0100-00		10 Ω	$\frac{1}{4}$ W		5%

¹⁰Furnished as a unit with SW350.

Inductors (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	No. Disc	Description	
R378	315-0470-00		47 Ω	1/4 W	5%
R379	311-0635-00		1 kΩ, Var		
R381	301-0113-00		11 kΩ	1/2 W	5%
R383	315-0393-00		39 kΩ	1/4 W	5%
R384	323-0230-00		2.43 kΩ	1/2 W	Prec 1%
R385	321-0162-00		475 Ω	1/8 W	Prec 1%
R386	315-0100-00		10 Ω	1/4 W	5%
R387	315-0431-00		430 Ω	1/4 W	5%
R388	315-0470-00		47 Ω	1/4 W	5%
R389	311-0607-00		10 kΩ, Var		
R390	311-0613-00		100 kΩ, Var		
R391	301-0223-00		22 kΩ	1/2 W	5%
R392	301-0153-00		15 kΩ	1/2 W	5%
R393	301-0303-00		30 kΩ	1/2 W	5%
R394	315-0470-00		47 Ω	1/4 W	5%
R395	315-0470-00		47 Ω	1/4 W	5%
R396	308-0021-00		4.5 Ω	10 W	WW 5%
R397	315-0220-00		22 Ω	1/4 W	5%
R398	315-0220-00		22 Ω	1/4 W	5%

Switches

Unwired or Wired				
SW101	260-0621-00		Lever	AC-GND-DC
SW110A	} wired *262-0809-00		Rotary	VOLTS/CM
SW110B			Rotary	VOLTS/CM
SW110A	260-0837-00		Rotary	VOLTS/CM
SW110B	260-0836-00		Rotary	VOLTS/CM
SW110C	260-0835-00		Rotary	VOLTS/CM
SW111	260-0833-00		Lever	POLARITY
SW201	260-0621-00		Lever	AC-GND-DC
SW210	260-0832-00		Rotary	DISPLAY
SW297	260-0864-00		Push	ON-OFF
SW350 ¹¹	*311-0666-00			

Test Points

TP160	*214-0506-00	Pin, Connector
TP260	*214-0506-00	Pin, Connector

¹¹Furnished as a unit with R350.

Electrical Parts List—Type 1A5

Transformers

Ckt. No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Description
T167A,B	*120-0478-00			Toroid, 5 turns, bifilar
T389	*120-0477-00			Toroid, 3 turns, bifilar

Electron Tubes

V164	154-0306-00		7586	
V264	154-0306-00		7586	

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)

FIG. 1 FRONT

FIG. 2 ATTENUATOR SWITCH & ASSOCIATED PARTS

FIG. 3 CIRCUIT BOARDS, CHASSIS & REAR

SECTION 8

MECHANICAL PARTS LIST

FIG. 1 FRONT

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	No. Disc	Q					Description	
				f	y	1	2	3		4
1-1	333-0963-01			1						PANEL, front
-2	386-1153-00			1						PLATE, front sub-panel
-3	366-0322-01			1						KNOB, charcoal—DISPLAY
	- - - - -			-						knob includes:
	213-0004-00			1						SCREW, set, 6-32 x $\frac{3}{16}$ inch, HSS
-4	260-0832-00									SWITCH, unwired—DISPLAY
	- - - - -			-						mounting hardware: (not included w/switch)
-5	210-0840-00			1						WASHER, flat, 0.390 ID x $\frac{9}{16}$ inch OD
-6	210-0413-00			1						NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch
-7	366-0173-00			1						KNOB, charcoal—POSITION
	- - - - -			-						knob includes:
	213-0004-00			1						SCREW, 6-32 x $\frac{3}{16}$ inch, HSS
-8	- - - - -			1						RESISTOR, variable
	- - - - -			-						mounting hardware: (not included w/resistor)
-9	210-0840-00			1						WASHER, flat, 0.390 ID x $\frac{9}{16}$ inch OD
-10	210-0413-00			1						NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch
-11	260-0864-00			1						SWITCH, push button—ON/OFF
	- - - - -			-						switch includes:
-12	220-0473-00			1						NUT, hex., 0.50-32 x 0.562 inch
-13	210-1039-00			1						LOCKWASHER, internal, 0.521 ID x 0.625 inch OD
-14	220-0474-00			1						NUT, knurled, 0.50-32 x 0.562 inch
-15	220-0475-00			1						NUT, knurled, 0.50-32 x 0.562 inch
-16	366-0125-00			1						KNOB, plug-in securing
	- - - - -			-						knob includes:
	213-0004-00			1						SCREW, set, 6-32 x $\frac{3}{16}$ inch, HSS
-17	210-0894-00			1						WASHER, plastic, 0.190 ID x $\frac{7}{16}$ inch OD
-18	358-0305-00			1						BUSHING, 0.312-32 inch retainer rod
	- - - - -			-						mounting hardware: (not included w/bushing)
	210-0580-00			1						NUT, hex., $\frac{5}{16}$ -32 x $\frac{3}{8}$ inch
-19	384-0653-00			1						ROD, plug-in securing
	- - - - -			-						rod includes:
-20	354-0025-00			1						RING, retaining
-21	366-0215-01			1						KNOB, charcoal—POLARITY
-22	260-0833-00			1						SWITCH, lever—POLARITY
	- - - - -			-						mounting hardware: (not included w/switch)
-23	220-0413-00			2						NUT, hex., 4-40 x $\frac{3}{16}$ x 0.562 inch long

Mechanical Parts List—Type 1A5

FIG. 1 FRONT (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Q					Description	
				t	y	1	2	3		4
1-24	366-0215-01			2						KNOB, charcoal—AC GND DC
-25	366-0341-00			1						KNOB, charcoal—STEP ATTEN BAL
	- - - - -			-						knob includes:
	213-0076-00			2						SCREW, set, 2-56 x 1/8 inch, HSS
-26	- - - - -			1						RESISTOR, variable
	- - - - -			-						mounting hardware: (not included w/resistor)
-27	210-0940-00			1						WASHER, flat, 1/4 ID x 3/8 inch OD
-28	210-0465-00			1						NUT, hex., 1/4-32 x 3/8 inch
	- - - - -									
-29	407-0163-00			1						BRACKET, attenuator balance
	- - - - -			-						mounting hardware: (not included w/bracket)
-30	210-0486-00			2						NUT, keps, 4-40 x 1/4 inch
	- - - - -									
-31	136-0089-00			1						SOCKET, connector, 9 pin
	- - - - -			-						mounting hardware: (not included w/socket)
-32	211-0012-00			4						SCREW, 4-40 x 3/8 inch, PHS
	210-0201-00			1						LUG, solder, SE #4
-33	210-0586-00			4						NUT, keps, 4-40 x 1/4 inch
	- - - - -									
-34	131-0342-00			2						CONNECTOR, coaxial, 1 contact, BNC, w/mounting hardware
-35	136-0140-00			1						SOCKET, banana jack, charcoal cap
	- - - - -			-						mounting hardware: (not included w/socket)
-36	210-0895-00			1						WASHER, plastic, insulating
-37	210-0465-00			2						NUT, hex., 1/4-32 x 3/8 inch
-38	210-0223-00			1						LUG, solder, 1/4 ID x 7/16 inch OD, SE
	- - - - -									
-39	129-0053-00			1						ASSEMBLY, binding post
	- - - - -			-						assembly includes:
-40	355-0507-00			1						STEM, binding post
-41	200-0103-00			1						CAP, knurled
	- - - - -			-						mounting hardware: (not included w/assembly)
	210-0223-00			1						LUG, solder, 1/4 ID x 7/16 inch OD, SE
	210-0455-00			1						NUT, hex., 1/4-28 x 3/8 inch
	- - - - -									
-42	376-0051-00			1						ASSEMBLY, coupling
	- - - - -			-						assembly includes:
-43	354-0251-00			2						RING, coupling
-44	376-0049-00			2						COUPLING, plastic, 3/8 x 0.424 inch long
	213-0022-00			4						SCREW, set, 4-40 x 3/16 inch, HSS
-45	384-0656-00			1						ROD, extension, 1/8 x 8.119 inches
-46	348-0031-00			1						GROMMET, plastic, 5/32 inch diameter
-47	358-0054-00			1						BUSHING, banana jack
	- - - - -			-						mounting hardware: (not included w/bushing)
-48	210-0465-00			1						NUT, hex., 1/4-32 x 3/8 inch

FIG. 1 FRONT (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No.		Q † y	Description
		Eff	Disc		
					1 2 3 4 5
1-49	- - - - -			1	RESISTOR, variable
	- - - - -			-	mounting hardware: (not included w/resistor)
-50	210-0471-00			1	NUT, hex., $\frac{1}{4}$ -32 x $\frac{5}{16}$ x $1\frac{19}{32}$ inch long
-51	210-0223-00			1	LUG, solder, $\frac{1}{4}$ ID x $\frac{7}{16}$ inch OD, SE
-52	358-0054-00			1	BUSHING, banana jack
-53	331-0181-00			1	DIAL CONTROL
-54	407-0320-00			1	BRACKET, amplitude
-55	- - - - -			1	RESISTOR, variable
	- - - - -			-	mounting hardware: (not included w/resistor)
-56	211-0081-00			2	SCREW, 2-56 x $\frac{3}{16}$ inch, RHS
-57	210-0001-00			2	LOCKWASHER, internal, #2
-58	210-0405-00			2	NUT, hex., 2-56 x $\frac{3}{16}$ inch
-59	210-0201-00			2	LUG, solder, SE #4
	- - - - -			-	mounting hardware for each: (not included w/lug)
-60	211-0008-00			1	SCREW, 4-40 x $\frac{1}{4}$ inch, PHS
-61	210-0586-00			1	NUT, keps, 4-40 x $\frac{1}{4}$ inch
-62	131-0433-00			1	CONNECTOR, stand-off
	- - - - -			-	mounting hardware: (not included w/connector)
-63	358-0241-00			1	BUSHING, plastic, insulating
-64	352-0067-00			1	HOLDER, neon, single
	- - - - -			-	mounting hardware: (not included w/holder)
-65	211-0109-00			1	SCREW, 4-40 x $\frac{7}{8}$ inch, FHS
-66	210-0406-00			2	NUT, hex., 4-40 x $\frac{3}{16}$ inch
-67	378-0541-00			1	FILTER, lens, neon
-68	384-0631-00			4	ROD, spacer, $\frac{8}{8}$ inches long
-69	366-0283-00			1	KNOB, charcoal—PROBE STEP ATTEN BAL
-70	- - - - -			1	RESISTOR, variable
	- - - - -			-	mounting hardware: (not included w/resistor)
-71	213-0020-00			1	SCREW, set, 6-32 x $\frac{1}{8}$ inch, HSS
-72	366-0038-00			1	KNOB, red—VARIABLE CAL
	- - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $\frac{3}{16}$ inch, HSS
-73	366-0372-00			1	KNOB, charcoal—VOLTS/CM
	- - - - -			-	knob includes:
	213-0115-00			2	SCREW, set, 4-40 x $\frac{5}{16}$ inch, HSS
-74	366-0418-00			1	KNOB, clear—VOLTS/CM
	- - - - -			-	knob includes:
	213-0022-00			2	SCREW, set, 4-40 x $\frac{3}{16}$ inch, HSS
-75	179-1179-00			1	CABLE HARNESS, coaxial
	- - - - -			-	cable harness includes:
-76	131-0371-00			4	CONNECTOR, single contact, female

FIG. 2 ATTENUATOR ASSEMBLY & ASSOCIATED PARTS

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	No. Disc	Qty	Q	Description
2-1	262-0809-00			1		ASSEMBLY, switch—ATTENUATOR
-	-			-		assembly includes:
-2	260-0837-00			1		SWITCH, unwired, top, w/shield
-3	260-0836-00			1		SWITCH, unwired, bottom, w/shield
-4	407-0311-00			1		BRACKET, double angle
-5	401-0027-00			1		WHEEL, index
-	-			-		wheel includes:
	213-0020-00			1		SCREW, set, 6-32 x 1/8 inch, HSS
-6	214-0821-00			1		GEAR, cluster
-7	214-0499-00			1		NEEDLE, bearing
-8	214-0541-00			1		GEAR, index
-9	426-0336-01			1		FRAME, switch coupler
-	-			-		frame includes:
-10	213-0004-00			2		SCREW, set, 6-32 x 3/16 inch, HSS
-11	213-0022-00			1		SCREW, set, 4-40 x 3/16 inch, HSS
-	-			-		mounting hardware: (not included w/frame)
-12	211-0033-00			2		SCREW, sems, 4-40 x 5/16 inch, PHS
-13	210-0261-00			1		LUG, solder, high voltage
-14	214-0824-00			2		GEAR, spur
-	-			-		each gear includes:
	213-0004-00			1		SCREW, set, 6-32 x 3/16 inch, HSS
-15	386-1154-00			1		PLATE, mounting
-16	407-0310-00			1		BRACKET, angle
-	-			-		mounting hardware: (not included w/bracket)
-17	210-0851-00			2		WASHER, flat, 0.119 ID x 3/8 inch OD
-18	211-0008-00			2		SCREW, 4-40 x 1/4 inch, PHS
-19	441-0702-00			1		CHASSIS, attenuator
-	-			-		mounting hardware: (not included w/chassis)
-20	210-0851-00			2		WASHER, flat, 0.119 ID x 3/8 inch OD
-21	211-0008-00			2		SCREW, 4-40 x 1/4 inch, PHS
-22	-			8		CAPACITOR
-	-			-		mounting hardware for each: (not included w/capacitor)
-23	214-0456-00			1		FASTENER, plastic, capacitor
-24	131-0433-00			2		CONNECTOR, terminal stand-off
-	-			-		mounting hardware for each: (not included w/connector)
-25	358-0241-00			1		BUSHING, plastic
-26	260-0621-00			2		SWITCH, lever—AC GND DC
-	-			-		mounting hardware for each: (not included w/switch)
-27	220-0413-00			2		NUT, hex., 4-40 x 3/16 x 0.562 inch long
-28	337-0892-00			1		SHIELD, electrical, right
-29	337-0891-00			1		SHIELD, electrical, left
-	-			-		mounting hardware: (not included w/shield)
-30	211-0008-00			2		SCREW, 4-40 x 1/4 inch, PHS
-31	210-0261-00			1		LUG, solder, high voltage
-32	210-0223-00			1		LUG, solder, 1/4 ID x 7/16 inch OD, SE
-	-			-		mounting hardware: (not included w/assembly)
	211-0008-00			2		SCREW, 4-40 x 1/4 inch, PHS
	210-0851-00			2		WASHER, flat, 0.119 ID x 3/8 inch OD

FIG. 2 ATTENUATOR ASSEMBLY & ASSOCIATED PARTS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	No. Disc	Q					Description	
				†	1	2	3	4		5
2-33	337-0893-00			1						SHIELD, attenuator assembly
	- - - - -			-						mounting hardware: (not included w/shield)
-34	211-0008-00			4						SCREW, 4-40 x 1/4 inch, PHS
-35	210-0851-00			4						WASHER, flat, 0.119 ID x 3/8 inch OD
-36	343-0003-00			1						CLAMP, cable, 1/4 inch plastic
	- - - - -			-						mounting hardware: (not included w/clamp)
-37	210-0803-00			1						WASHER, flat, 0.150 ID x 3/8 inch OD
-38	211-0504-00			1						SCREW, 6-32 x 1/4 inch, PHS
-39	260-0835-00			1						SWITCH, unwired—VOLTS/DIVISION
	- - - - -			-						mounting hardware: (not included w/switch)
-40	210-0049-00			1						LOCKWASHER, internal, 5/8 ID x 7/8 inch OD
-41	210-0479-00			2						NUT, hex., 5/8-24 x 3/4 inch
	210-1010-00			1						WASHER, flat, 0.643 ID x 0.875 inch OD
-42	376-0050-00			1						ASSEMBLY, coupling
	- - - - -			-						assembly includes:
-43	376-0046-00			1						COUPLING, plastic, 3/8 x 0.424 inch long
-44	354-0251-00			2						RING, coupling
	213-0022-00			4						SCREW, set, 4-40 x 3/16 inch, HSS
-45	384-0657-00			1						ROD, extension, 1/8 x 6.9 inches long

FIG. 3 CIRCUIT BOARDS, CHASSIS & REAR

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	No. Disc	Q					Description	
				†	Y	1	2	3		4
3-1	441-0703-00			1						CHASSIS
	- - - - -			-						mounting hardware: (not included w/chassis)
	212-0040-00			4						SCREW, 8-32 x 3/8 inch, FHS
-2	210-0458-00			7						NUT, keps, 8-32 x 1 1/32 inch
	-3	348-0063-00		3						GROMMET, plastic, 1/2 inch diameter
	-4	210-0201-00		1						LUG, solder, SE #4
	-	- - - - -		-						mounting hardware: (not included w/lug)
	-5	213-0044-00		1						SCREW, thread forming, 5-32 x 3/16 inch
	-6	- - - - -		2						RESISTOR
	-	- - - - -		-						mounting hardware for each: (not included w/resistor)
	-7	211-0553-00		1						SCREW, 6-32 x 1 1/2 inches, PHS
	-8	210-0601-00		1						EYELET, tapered barrel
	-9	210-0478-00		1						NUT, hex., 6-32 x 5/16 x 2 1/32 inch long
	-10	211-0507-00		1						SCREW, 6-32 x 5/16 inch, PHS
	-11	131-0181-00		2						CONNECTOR, terminal standoff
	-	- - - - -		-						mounting hardware for each: (not included w/connector)
	-12	358-0136-00		1						BUSHING, plastic, insulating
	-13	670-0135-00		1						ASSEMBLY, circuit board—INPUT
	-	- - - - -		-						assembly includes:
		388-0835-00		1						BOARD, circuit
	-14	214-0506-00		38						PIN, connector, straight, male
	-15	136-0224-00		2						SOCKET, nuvistor, 5 pin
	-16	136-0220-00		4						SOCKET, transistor, 3 pin to 18
	-17	136-0235-00		3						SOCKET, transistor, 6 pin
	-18	136-0183-00		5						SOCKET, transistor, 3 pin
	-19	136-0235-01		1						SOCKET, transistor, 5 pin
	-20	200-0737-00		1						ASSEMBLY, transistor ground
	-	- - - - -		-						assembly includes:
		200-0687-00		1						COVER, plastic, transistor
		214-0872-00		1						SPRING, conical
		210-0841-00		1						WASHER, flat, 0.067 ID x 0.312 inch OD
		131-0371-00		1						CONNECTOR, single contact, female
	-21	200-0687-00		5						COVER, plastic, transistor
	-22	344-0119-00		3						CLIP, electrical
	-23	131-0344-00		4						CONNECTOR, terminal feed thru
	-	- - - - -		-						mounting hardware for each: (not included w/connector)
	-24	358-0241-00		1						BUSHING, plastic, insulating
	-25	131-0433-00		4						CONNECTOR, terminal stand-off
	-	- - - - -		-						mounting hardware for each: (not included w/connector)
	-26	358-0241-00		1						BUSHING, plastic, insulating

FIG. 3 CIRCUIT BOARDS, CHASSIS & REAR (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	No. Disc	Q † y	1 2 3 4 5					Description
3-27	214-0289-00			1						HEAT SINK, transistor
	- - - - -			-						mounting hardware: (not included w/heat sink)
-28	210-0909-00			2						WASHER, flat, mica, 0.196 ID x 0.625 inch OD
-29	210-0805-00			1						WASHER, flat, 0.204 ID x 0.438 inch OD
-30	220-0410-00			1						NUT, keps, 10-32 x $\frac{3}{8}$ inch
	- - - - -			-						mounting hardware: (not included w/assembly)
-31	211-0116-00			8						SCREW, sems, 6-32 x $\frac{5}{16}$ inch, PHS
-32	175-0674-00			1						WIRE, lead, 1.875 inch long, w/female connector
-33	386-1152-00			1						PLATE, rear
	- - - - -			-						mounting hardware: (not included w/plate)
-34	212-0044-00			4						SCREW, 8-32 x $\frac{1}{2}$ inch, RHS
-35	131-0017-00			1						CONNECTOR, 16 contact, male
	- - - - -			-						mounting hardware: (not included w/connector)
-36	211-0097-00			2						SCREW, 4-40 x $\frac{5}{16}$ inch, PHS
-37	210-0586-00			2						NUT, keps, 4-40 x $\frac{1}{4}$ inch
-38	210-0202-00			1						LUG, solder, SE #6
	- - - - -			-						mounting hardware: (not included w/lug)
-39	211-0504-00			1						SCREW, 6-32 x $\frac{1}{4}$ inch, PHS
-40	210-0457-00			1						NUT, keps, 6-32 x $\frac{5}{16}$ inch
-41	- - - - -			1						RESISTOR, variable
	- - - - -			-						mounting hardware: (not included w/resistor)
-42	210-0012-00			1						LOCKWASHER, internal, $\frac{3}{8}$ ID x $\frac{1}{2}$ inch OD
-43	210-0840-00			1						WASHER, flat, 0.390 ID x $\frac{9}{16}$ inch OD
-44	210-0413-00			1						NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch
-45	407-0306-00			1						BRACKET, variable resistor
	- - - - -			-						mounting hardware: (not included w/bracket)
-46	211-0507-00			2						SCREW, 6-32 x $\frac{5}{16}$ inch, PHS
-47	210-0457-00			2						NUT, keps, 6-32 x $\frac{5}{16}$ inch
-48	670-0133-00			1						ASSEMBLY, circuit board—OUTPUT
	- - - - -			-						assembly includes:
	388-0823-00			1						BOARD, circuit
-49	214-0506-00			22						PIN, connector, straight, male
-50	136-0183-00			1						SOCKET, transistor, 3 pin
-51	136-0220-00			8						SOCKET, transistor, 3 pin
-52	131-0499-00			10						CONNECTOR, plastic, terminal
-53	- - - - -			1						RESISTOR, variable
	- - - - -			-						mounting hardware: (not included w/resistor)
-54	210-0046-00			1						LOCKWASHER, internal, $\frac{1}{4}$ ID x 0.400 inch OD
-55	210-0465-00			2						NUT, hex., $\frac{1}{4}$ -32 x $\frac{3}{8}$ inch

FIG. 3 CIRCUIT BOARDS, CHASSIS & REAR (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	No. Disc	Q					Description
				t	1	2	3	4	
3-56	407-0312-00			2					BRACKET, variable resistor
-57	- - - - -			1					RESISTOR, variable
	- - - - -			-					mounting hardware: (not included w/resistor)
-58	210-0940-00			1					WASHER, flat, 1/4 ID x 3/8 inch OD
-59	210-0583-00			1					NUT, hex., 1/4-32 x 5/16 inch
-60	129-0120-00			1					POST, plastic
	- - - - -			-					mounting hardware: (not included w/post)
-61	211-0116-00			1					SCREW, sems, 4-40 x 5/16 inch
	- - - - -			-					mounting hardware: (not included w/assembly)
-62	211-0116-00			4					SCREW, 4-40 x 5/16 inch, PHS
-63	220-0455-00			2					NUT, hex., 5/16 x 1 3/8 inch
-64	670-0134-00			1					ASSEMBLY, circuit board—HIGH FREQUENCY COMPENSATION
	- - - - -			-					assembly includes:
	388-0856-00			1					BOARD, circuit
-65	136-0254-00			10					SOCKET, connector spring
-66	- - - - -			1					COIL
	- - - - -			-					mounting hardware: (not included w/coil)
-67	213-0088-00			1					SCREW, thread forming, 4-40 x 1/4 inch
	- - - - -			-					mounting hardware: (not included w/assembly)
-68	211-0008-00			1					SCREW, 4-40 x 1/4 inch, PHS
-69	220-0455-00			2					NUT, block, 4-40 x 0.281 inch square
	- - - - -			-					mounting hardware for each: (not included w/nut)
	211-0008-00			1					SCREW, 4-40 x 1/4 inch, PHS
-70	179-1177-00			1					CABLE HARNESS, chassis
	- - - - -			-					cable harness includes:
-71	131-0371-00			31					CONNECTOR, single contact, female
-72	131-0371-00			4					CONNECTOR, single contact, female
STANDARD ACCESSORIES									
	070-0638-00			2					MANUAL, instruction (not shown)
OPTIONAL ACCESSORY									
	010-0213-00			1					P6046 Probe Package

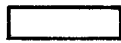
DIAGRAMS

SECTION 9

The following symbols are used on the diagrams:



Screwdriver adjustment



Front, side, or rear-panel control or connector



Clockwise control rotation in direction of arrow



Refer to indicated diagram

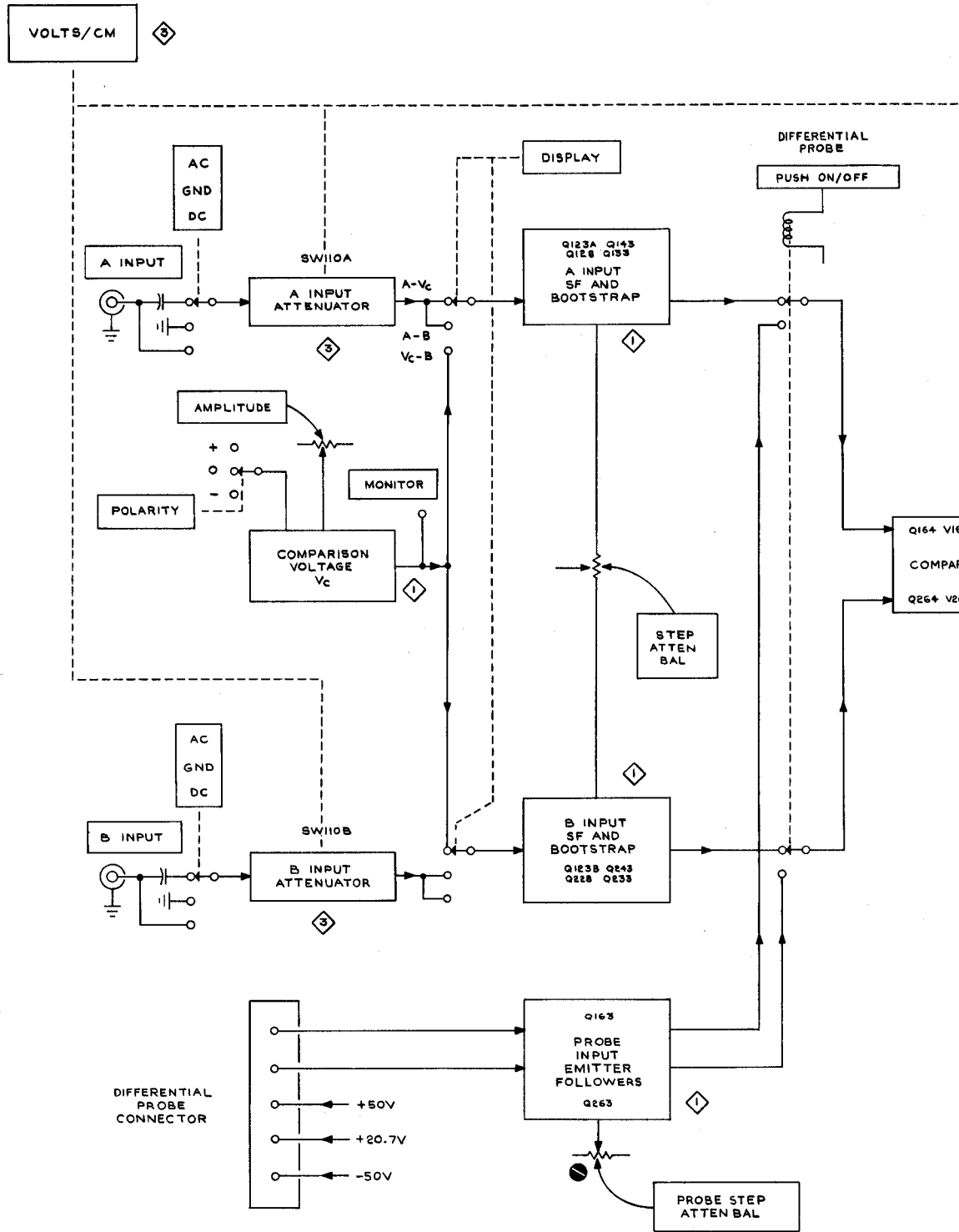


Connection to circuit board made with pin connector at indicated pin

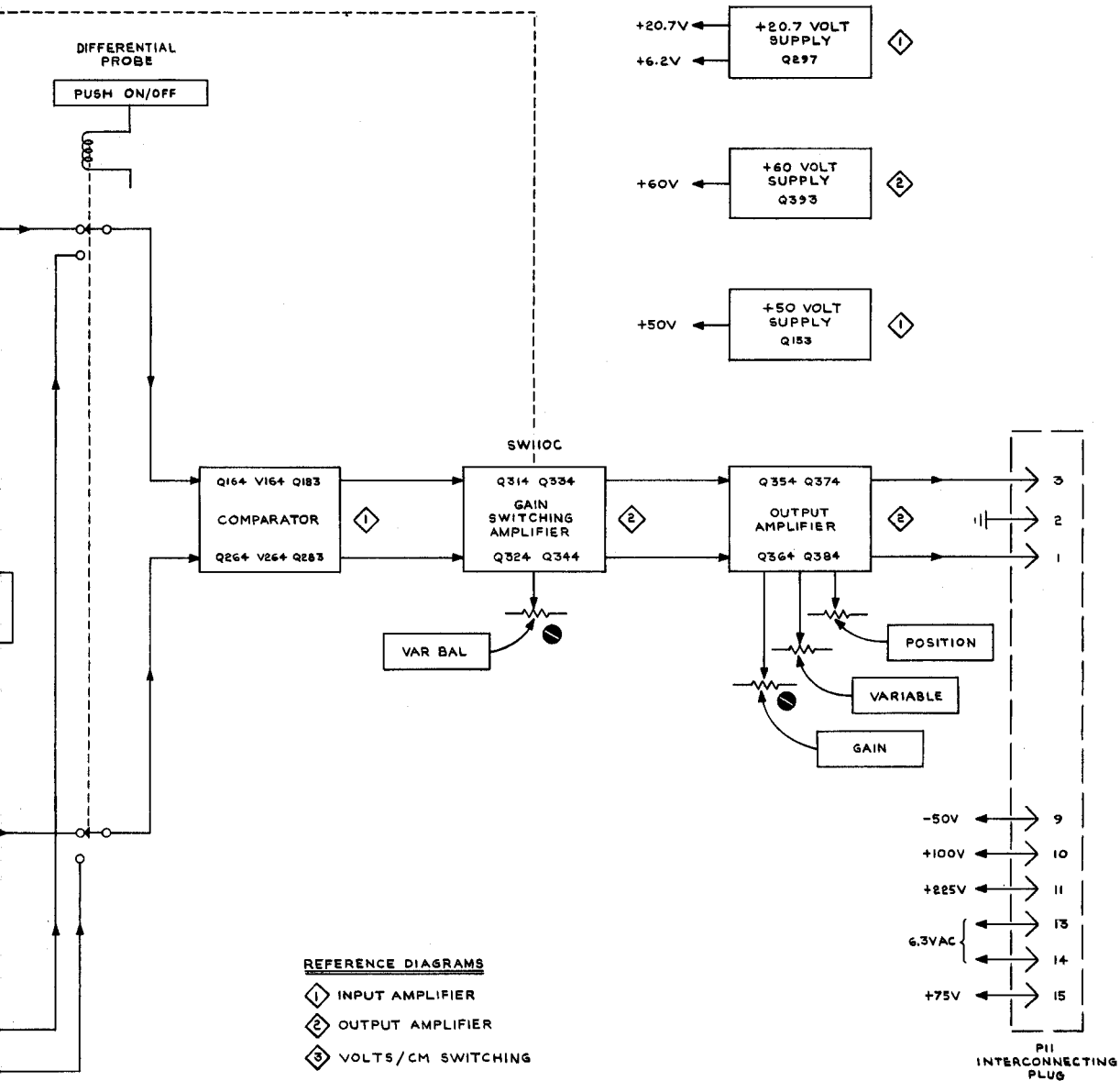


Connection soldered to circuit board

Blue line encloses components located on circuit board



TYPE IA5 DIFFERENTIAL AMPLIFIER



BE STEP
TEN BAL

A

BLOCK DIAGRAM SKP 267

VOLTAGE AND WAVEFORM INFORMATION

Typical voltages and waveforms are indicated in blue on the schematics.

The Type 1A5 was attached to an oscilloscope through a Flexible Extension, Tektronix Part Number 012-0038-00, to allow access to points checked. (The plug-in sensing switch located near the top right of the rear of Type 544, 546 and 547 oscilloscope plug-in compartments must be manually placed in its "out" position when the Type 1A5 is used with the Flexible Extension.)

Voltages were measured with a 20,000 Ω/V DC voltmeter under "no signal" conditions.

Waveforms are reproductions of photographs taken with a Tektronix Camera System and Projected Graticule. The slight differences between voltmeter readings and voltages given with waveforms are caused by the difference between test equipment loading.

The voltages and waveforms provided are typical, but may vary between instruments. Variations will also occur because of the type of test equipment used.

Voltage readings and waveforms were taken under the following conditions:

Type 1A5

Vc POLARITY	+
POSITION	Oscilloscope display centered vertically
INPUT	VOLTAGES-none
	WAVEFORMS-1 V oscilloscope Amplitude Calibrator signal applied to the A INPUT connector
A Input AC-GND-DC	AC
B Input AC-GND-DC	GND
VOLTS/CM	.2 V/CM
DISPLAY	A—B
STEP ATTEN BAL	Adjustment made

Test Oscilloscope

Externally triggered by Type 1A5 signal input source to provide time related waveforms

Trigger slope +

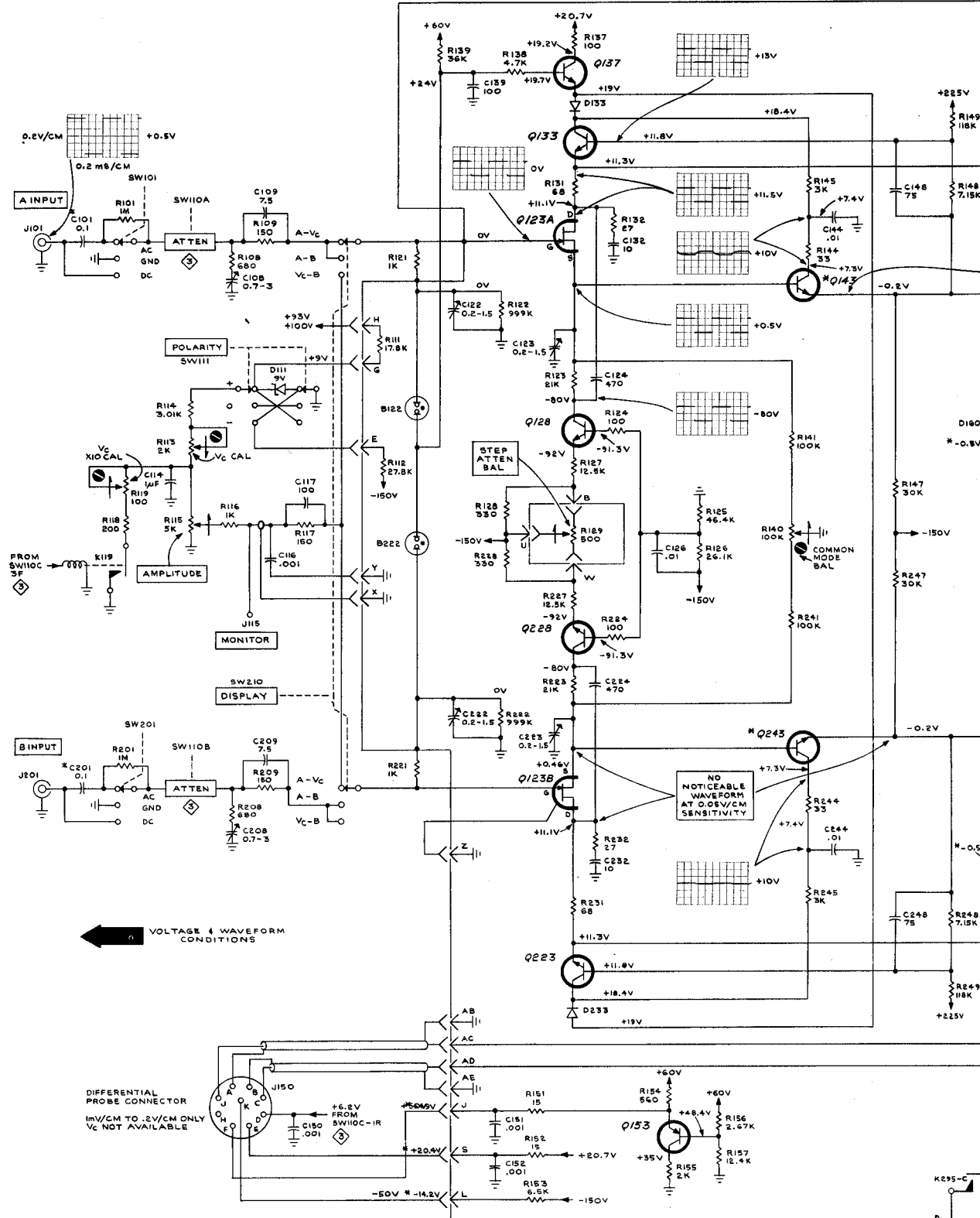
Sweep rate .2 mS/CM

10X Probe used to minimize loading

Vertical Sensitivity of 10X Probe and Oscilloscope combination is 0.05 V/cm except as noted on specific waveforms

AC Input Coupling used to photograph waveforms

DC Input Coupling used to determine waveform operating level



VOLTAGE & WAVEFORM CONDITIONS

DIFFERENTIAL PROBE CONNECTOR
 1mV/CM TO .2V/CM ONLY
 Vc NOT AVAILABLE

REFERENCE DIAGRAMS

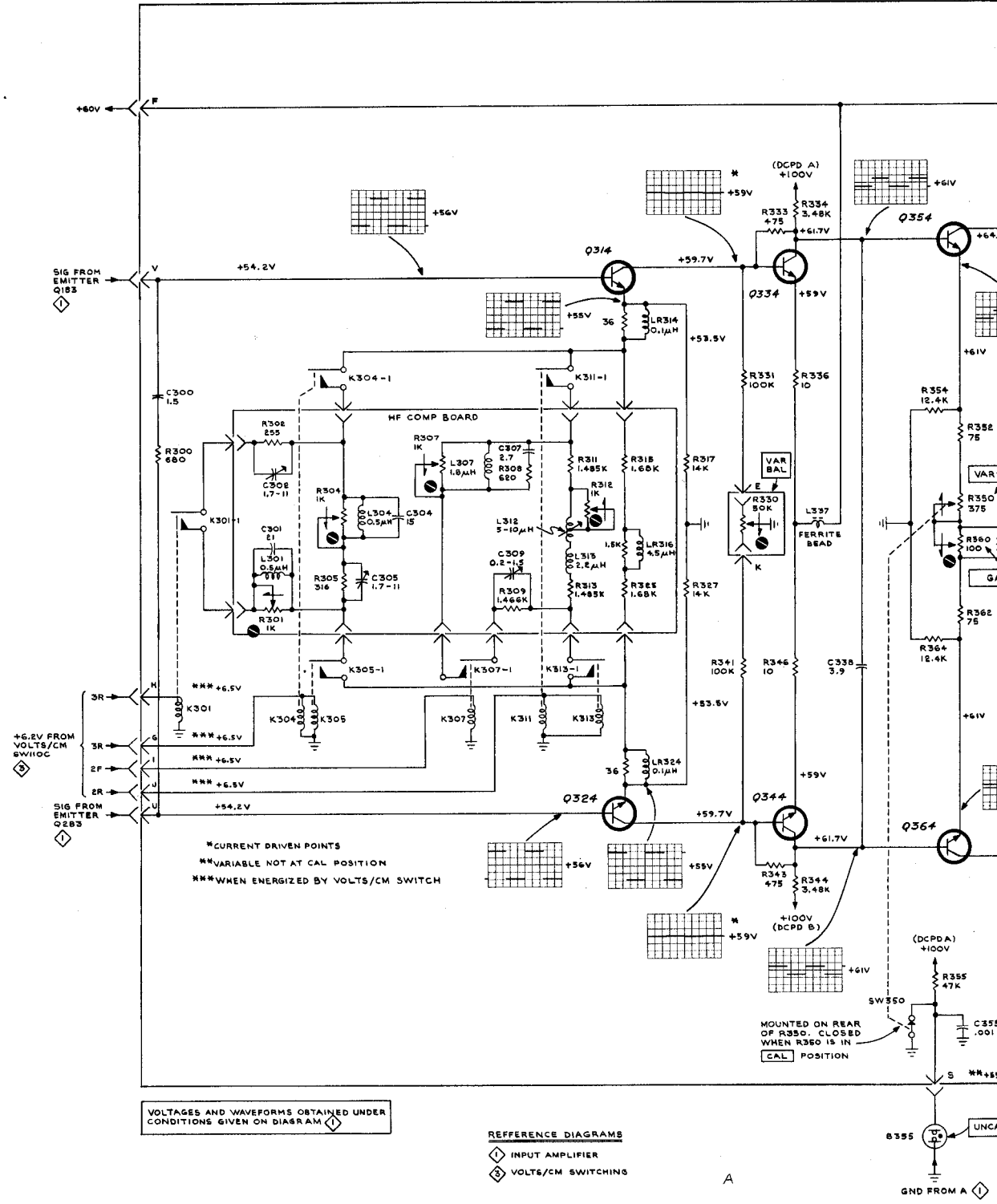
- ② OUTPUT AMPLIFIER
- ③ VOLTS/CM SWITCHING



TYPE 1A5 DIFFERENTIAL AMPLIFIER

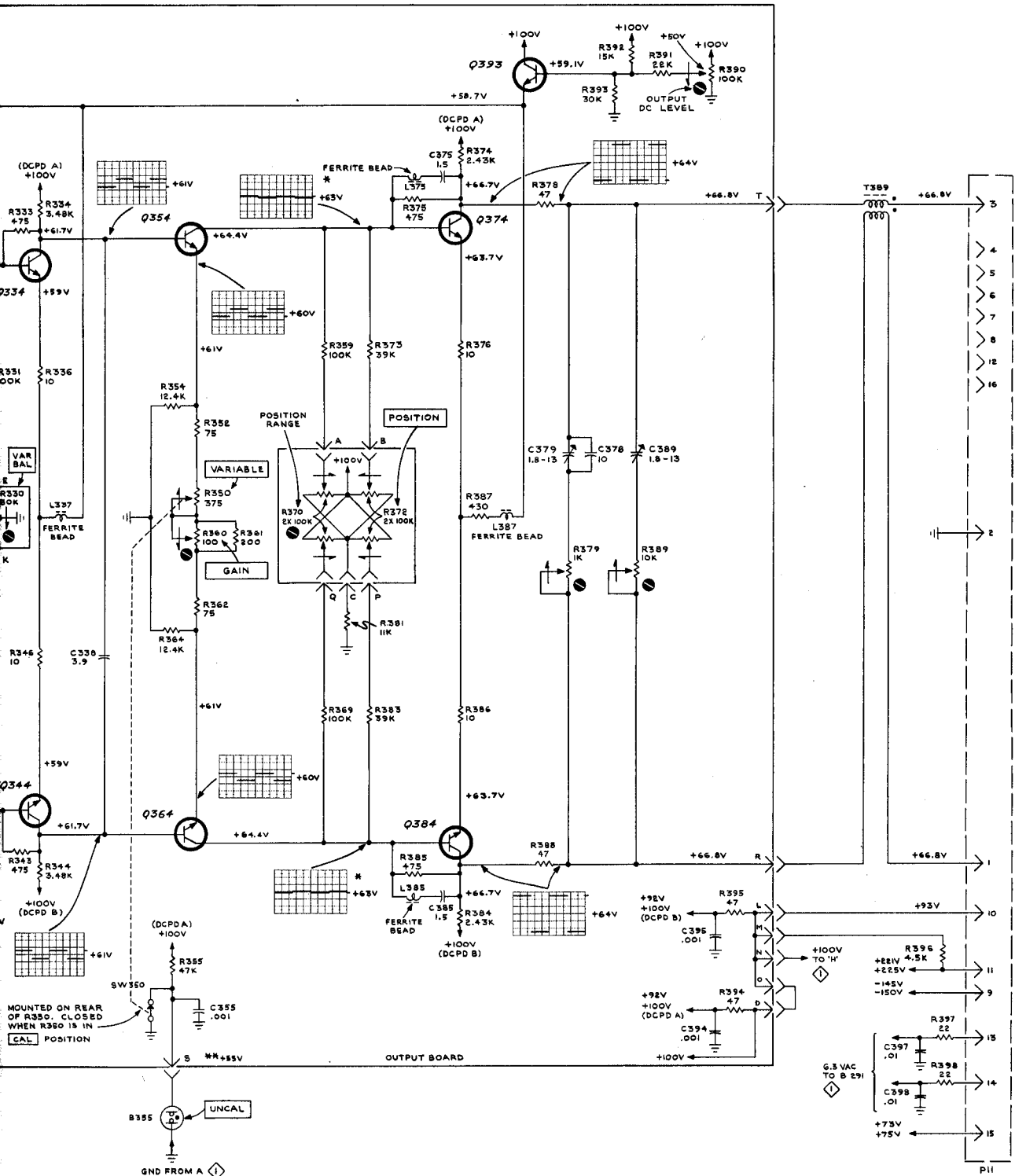
* DIFFERENTIAL PROBE DISCONNECTED; 20mV/CM SENSITIVITY;
 PROBE ON LAMP LIGHTED; PROBE STEP ATTEN BAL
 ADJUSTED FOR A CENTERED DISPLAY

(PROBE ON)



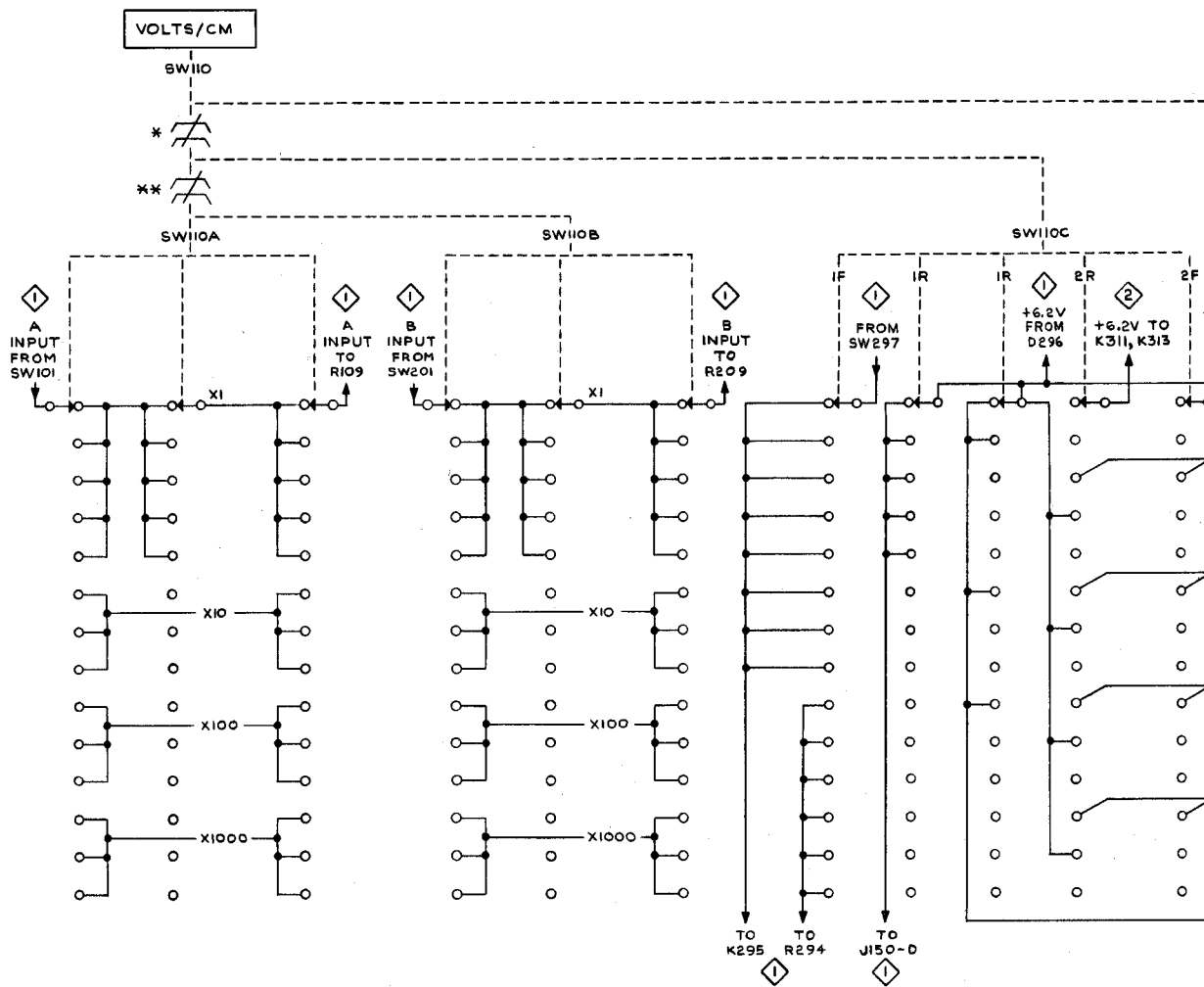
TYPE IA5 DIFFERENTIAL AMPLIFIER





OUTPUT AMPLIFIER ②

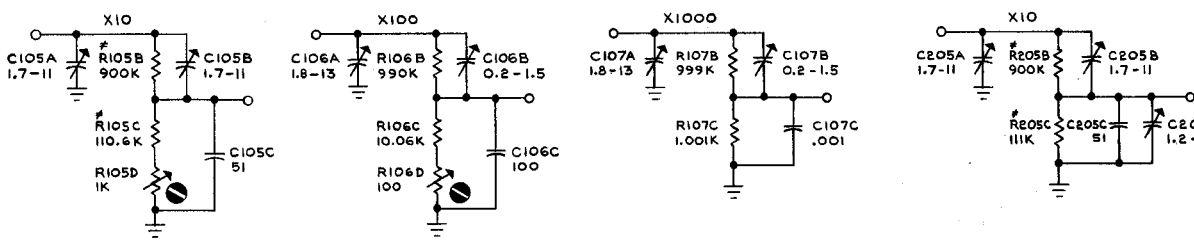
367 EXP



* CAN BE DISCONNECTED AT 50mV AND .5V POSITIONS BY PULLING VOLTS/CM KNOB "OUT", SECTIONS 3F AND 3R OF SW110C CAN THEN BE SWITCHED 1 OR 2 POSITIONS CLOCKWISE, INDEPENDENT OF REMAINDER OF SW110 ASSEMBLY

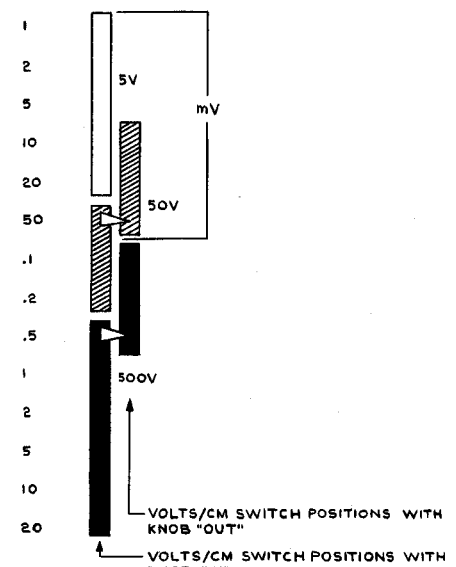
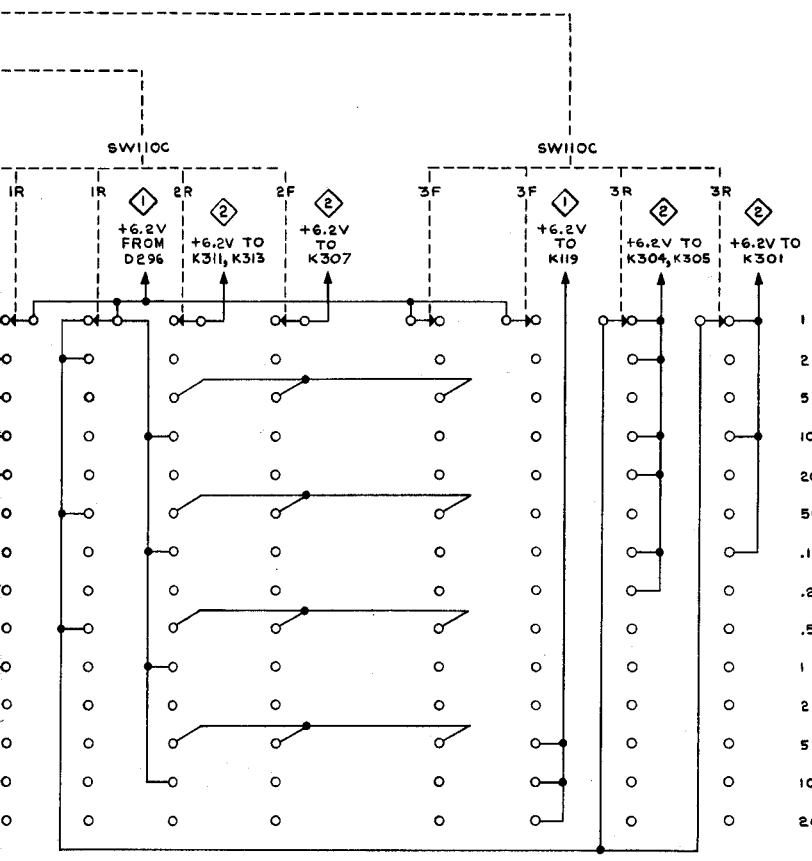
** SW110A AND SW110B SWITCH ONLY WHEN SW110 IS SWITCHED BETWEEN 20mV AND 50mV, .2V AND .5V, OR 2V AND 5V VOLTS/CM KNOB "IN" POSITIONS

A INPUT ATTENUATORS

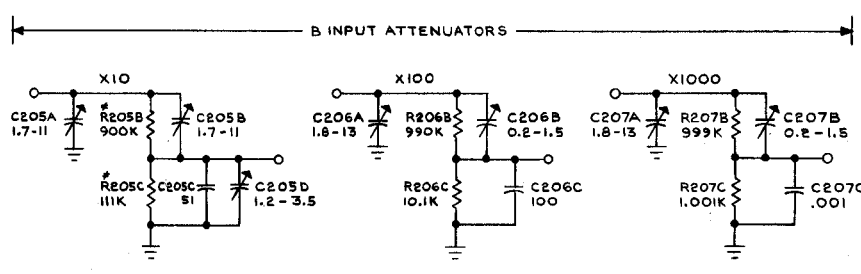


* R105B AND R205B ARE MATCHED PAIRS
R105C AND R205C ARE MATCHED PAIRS

TYPE 1A5 DIFFERENTIAL AMPLIFIER



- ▷ INDICATES POSITIONS AT WHICH VOLTS/CM KNOB CAN BE PULLED "OUT" FOR RETAINED RANGE SWITCHING
- 5V SIGNAL INPUT AND V_c RANGE; XI ATTENUATOR IN USE
- ▨ 50V SIGNAL INPUT AND V_c RANGE; X10 ATTENUATOR IN USE
- 500V SIGNAL INPUT AND V_c RANGE; X100 OR X1000 ATTENUATOR IN USE



REFERENCE DIAGRAMS

- ◇ 1 INPUT AMPLIFIER
- ◇ 2 OUTPUT AMPLIFIER

MATCHED PAIRS
MATCHED PAIRS

A

VOLTS/CM SWITCHING 3

367 EKP

FIG. 1 FRONT

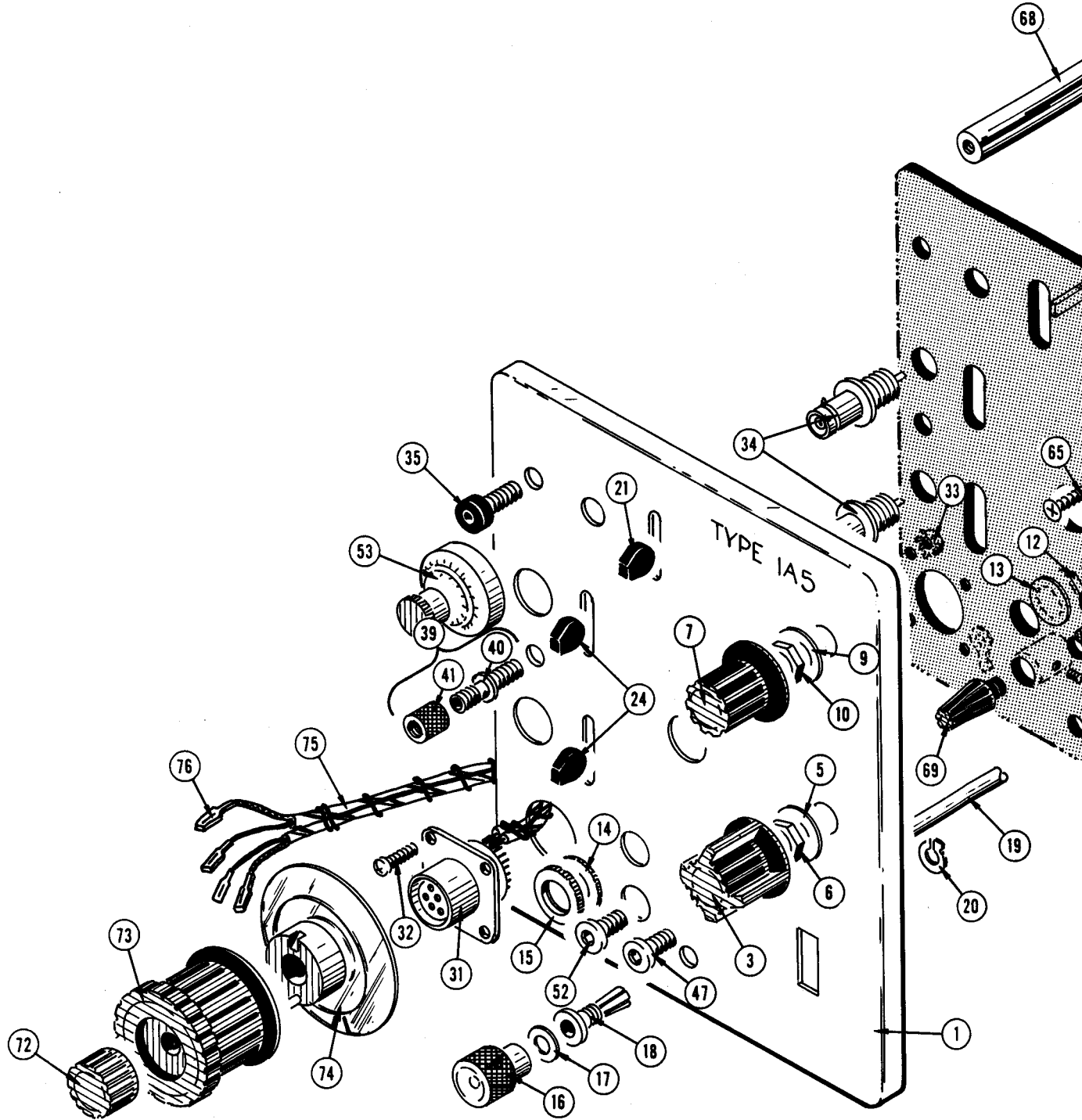
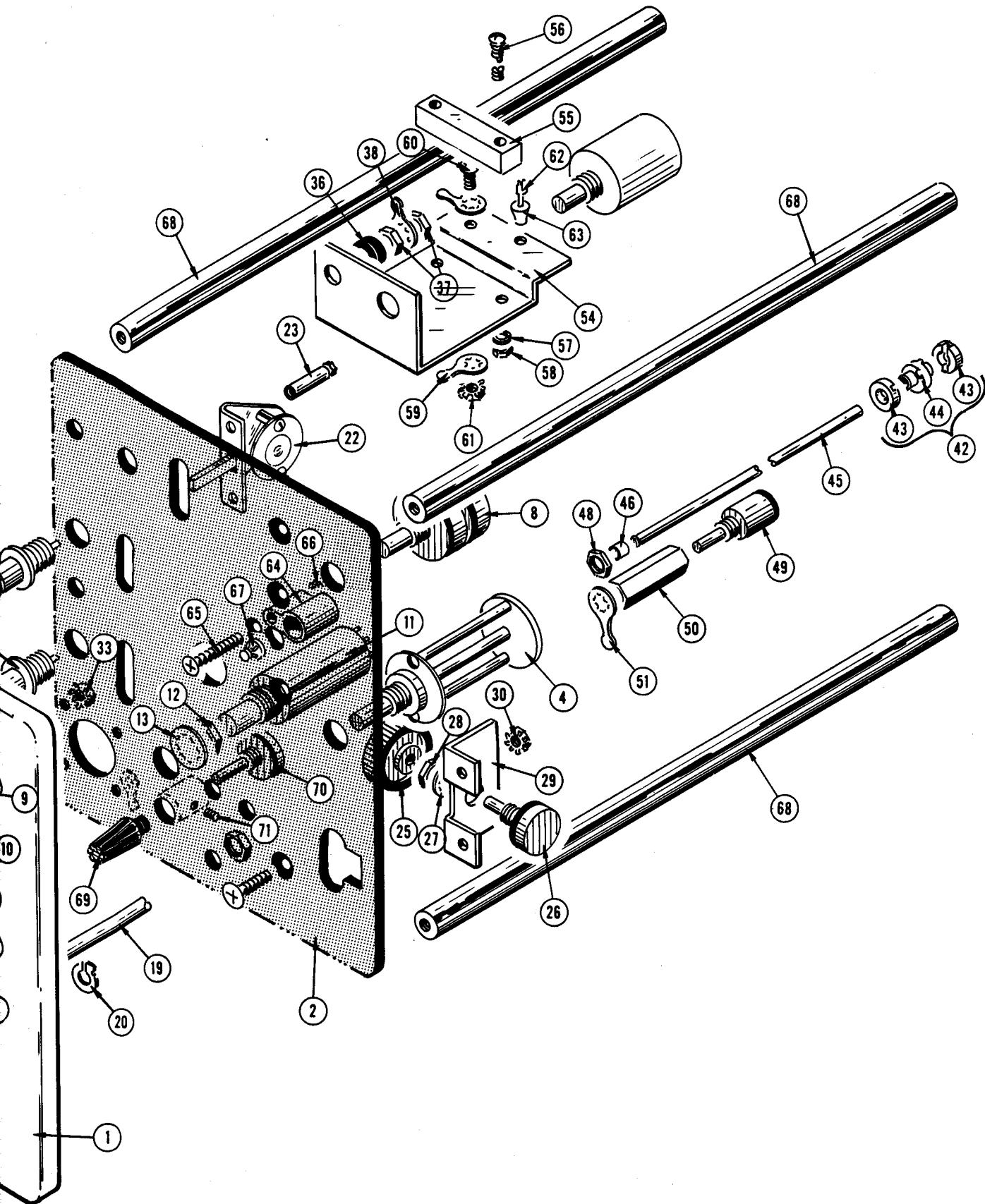
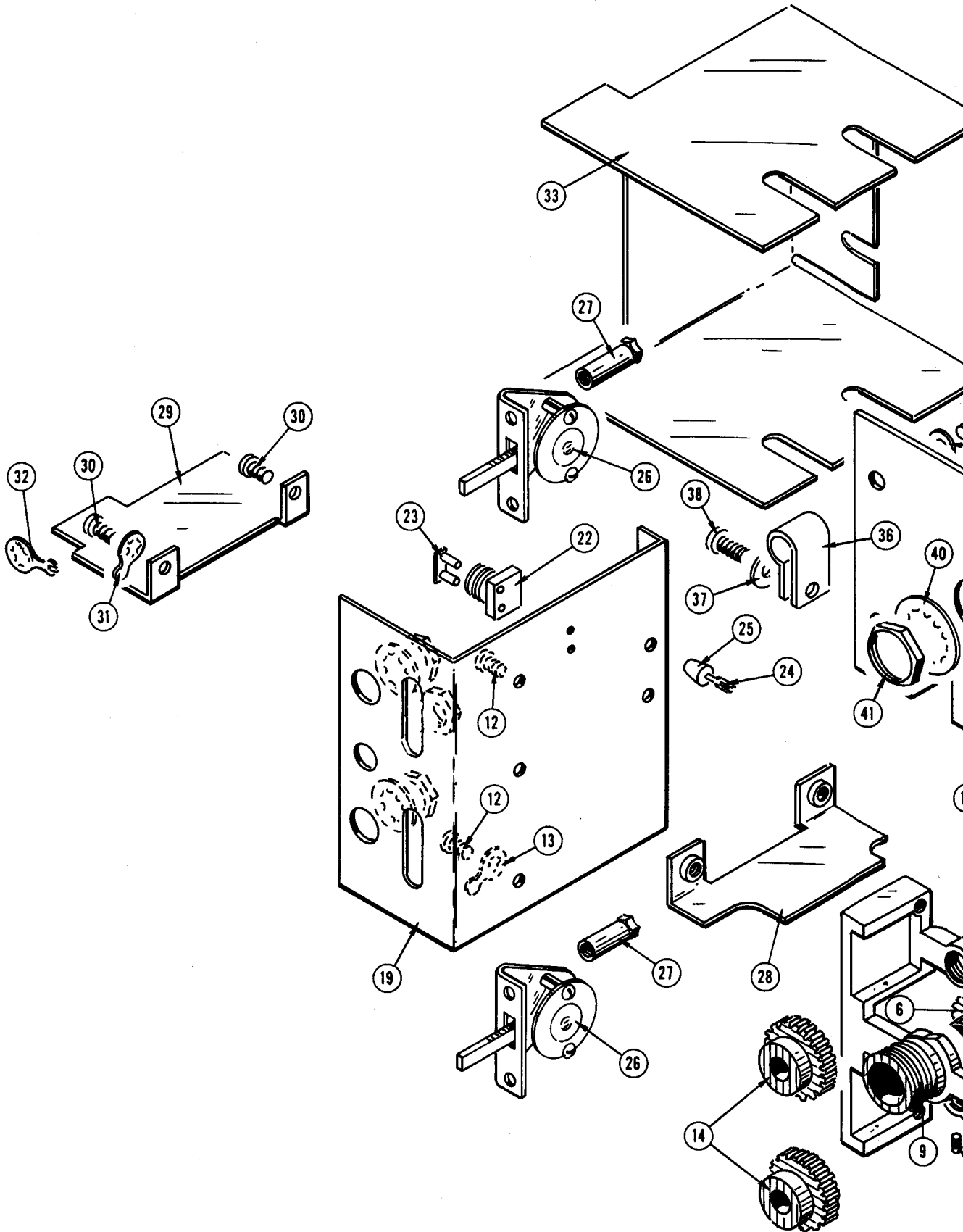


FIG. 1 FRONT



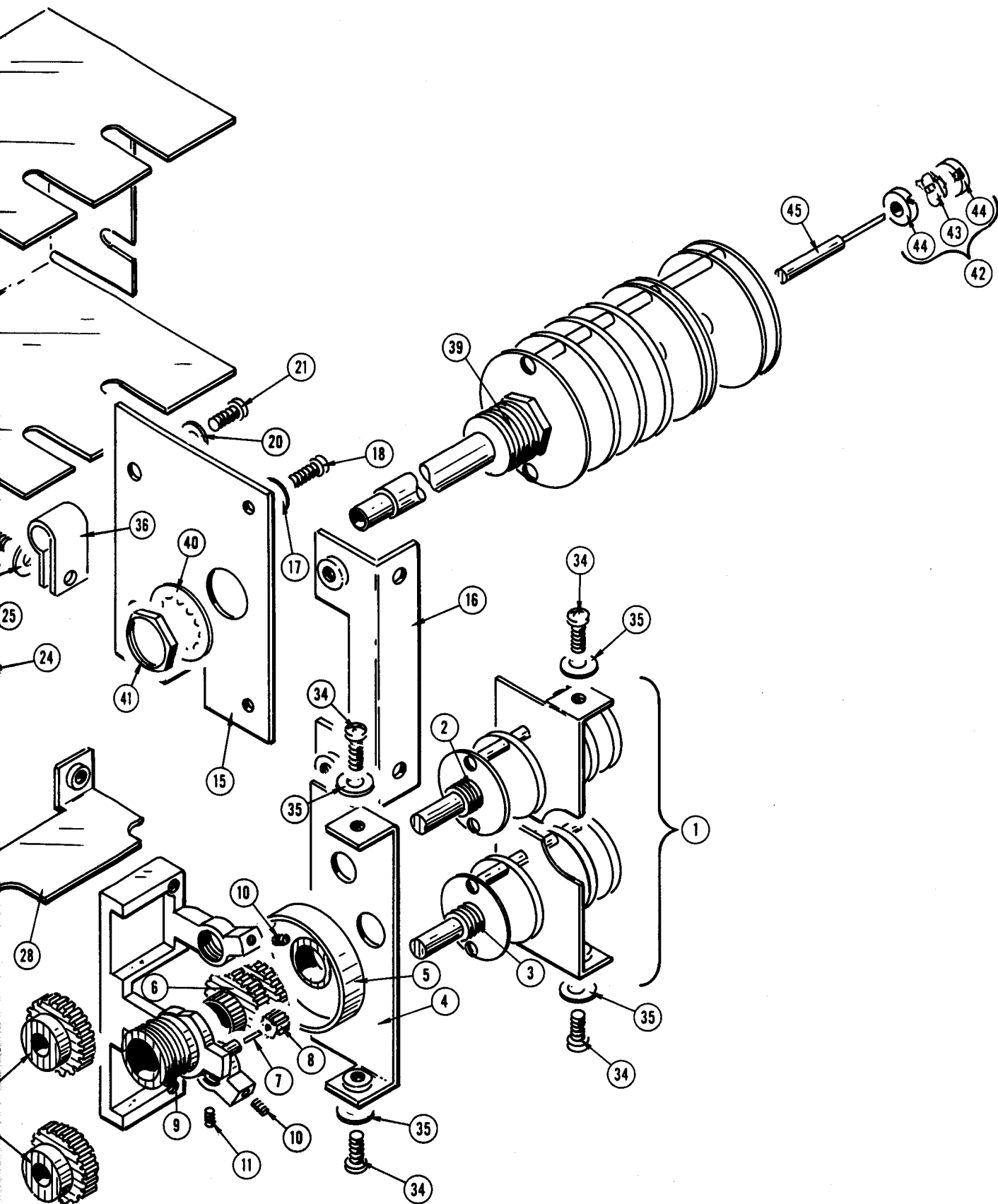
TYPE 1A5 DIFFERENTIAL AMPLIFIER

FIG. 2 ATTENUATOR SWITCH & ASSOC



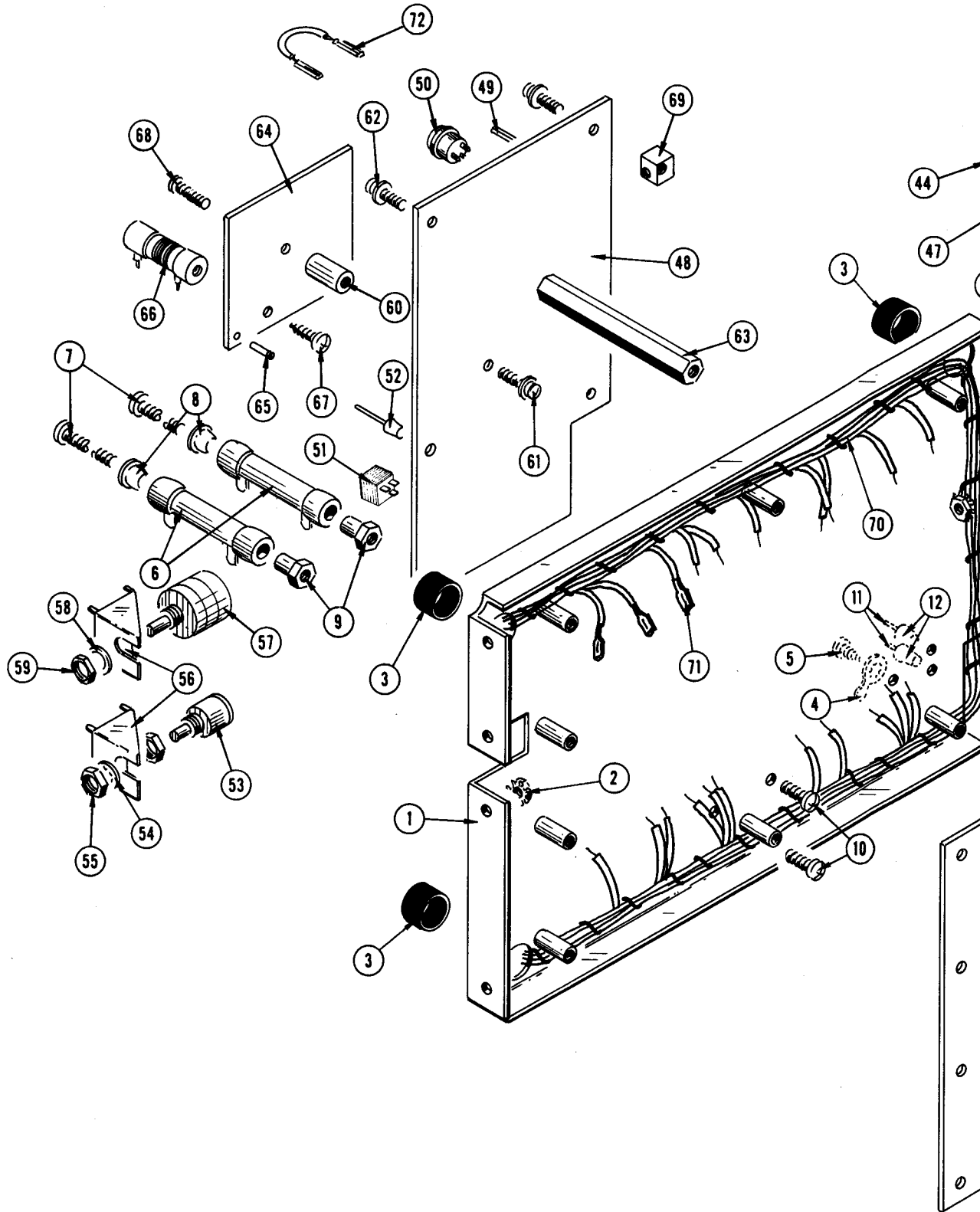
QUATOR SWITCH & ASSOCIATED PARTS

+



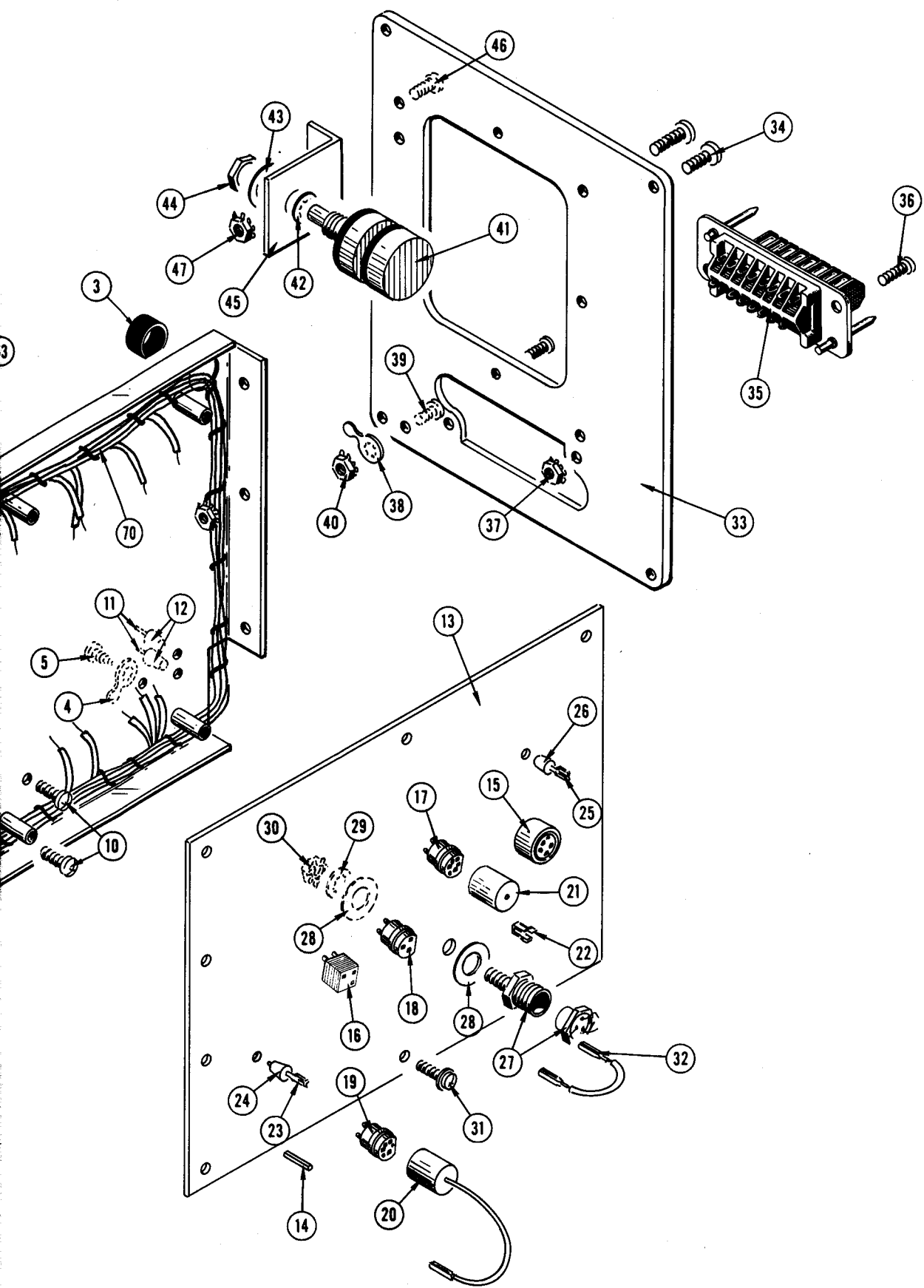
TYPE 1A5 DIFFERENTIAL AMPLIFIER

FIG. 3 CIRCUIT BOARDS, CHASSIS



CIRCUIT BOARDS, CHASSIS & REAR

+



TYPE 1A5 DIFFERENTIAL AMPLIFIER

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. If it does not, your manual is correct as printed.

TYPE 1A5

SCHEMATIC CORRECTION

INPUT AMPLIFIER

CHANGE: R163 to read 47.5 k

R263 to read 47.5 k

TYPE 1A5

TEXT CORRECTION

Section 3 Circuit Description

Page 3-5, Left column, Paragraph 8

DELETE sentence beginning with "T167A".

Page 3-5, Left column, Last paragraph

CHANGE the sentence beginning with "C267" and ending with "to it" to read "C163 and C263 balance the input capacitance of the comparator stage."

Page 3-6, Left column, 2nd to last paragraph, 2nd line

DELETE "C300, R300".

Page 3-6, Right column, 1st paragraph under "Output Amplifier".

DELETE sentence starting with "L375".

Section 4 Maintenance

Page 4-10, Fig. 4-6

DELETE	Location
T167	1" above board center
C167	1" to left and below T167
C267	1" to right and below T167

Page 4-11, Fig. 4-7

DELETE	Location
C300	At right margin of board
R300	At right margin of board
C375	Near left margin of board
L375	Near left margin of board
C385	Near left margin of board
L385	Near left margin of board

Page 4-12, Fig. 4-8

DELETE R308, located near bottom right corner of board.

Section 6 Calibration

Page 6-4, Step 15

DELETE "C267"

Page 6-5

DELETE Step 3 and renumber the remaining steps accordingly.

Page 6-18, In the equipment setup for the Constant Amplitude Sine Wave Generator, CHANGE "1 MHz" to read "10 MHz".

CHANGE ".5-5 V" to read "50-500 mV".

Page 6-18

DELETE Step 15 and substitute the following in its place.

15. Adjust X1 High Frequency Common-Mode Rejection (C122, C222, C123, C223, C163, C263).

a. Equipment setup is shown in Fig. 6-17. Location of adjustments and test points are shown in Fig. 6-18.

b. Connect the two symmetrical ends of a flexible T connector to the A and B INPUTS of the Type 1A5. Connect the center of the T connector to a GR to BNC adapter (item 12). Connect the Type 191 Constant Amplitude Signal Generator (item 4) to the GR adapter, using its 5 ns GR cable.

c. Set the Constant Amplitude Signal Generator frequency to 10 MHz, the Amplitude control to 50, Variable to Cal and the Amplitude Range to 50-500 mV. (This provides 1 V into the 1 m Ω input of the Type 1A5, since no 50 Ω termination is being used.)

d. Check that the POSITION control and STEP ATTEN BAL control are at midrange and adjust R170 (Fig. 6-18) to set the trace to the center of the graticule.

e. Set the A and B Input AC-GND-DC switches to DC.

f. CHECK --- 1 cm or less display amplitude. (CMRR 1000:1 or greater)

g. ADJUST --- C122 or C222, C123 or C223, and C163 or C263 (Fig. 6-18) for minimum display amplitude. (1 cm or less vertical display amplitude for 1000:1 or greater common-mode rejection ratio.)

NOTE

Use a non-metallic screwdriver. Preset C122, C222, C123, C223, C163 and C263 so that their threads are engaged by approximately two turns. When adjusting, screw in only the one that improves common-mode rejection in each pair.

h. Change the Constant Amplitude Signal Generator frequency to 1 MHz and the Amplitude Range to .5-5 v. (This provides the 1A5 with a 10-V signal.)

TYPE 1A5

- i. CHECK --- 1 cm or less vertical display amplitude. (CMRR 10,000:1 or greater)
- j. REPEAT --- Steps c, g, h and i untill 1 cm or less display amplitude exists for both steps g and i.
- k. Switch the VOLTS/CM control to 20 mV; simultaneously place the A and B INPUT AC-GND-DC switches to the GND position; disconnect the flexible T connector from the A and B INPUT connectors.
- l. Set the oscilloscope Triggering Slope to + and repeat step 14, parts a through m; then continue with step 16.
- m. INTERACTION --- Check steps 16 and 17.

Page 6-24, Step 20b

Place a period after extension. Delete the remainder of step b.

Page 6-19, Fig. 6-18

DELETE C267 and its label.

PARTS LIST CORRECTION

DELETE:

C167	281-0547-00	2.7 pF	Cer	500 V	10 %
C267	281-0076-00	1.2-3.5 pF	Air	Var	
C300, C375, C385	281-0529-00	1.5 pF	Cer	500 V	±0.25 pF
L375, L385	276-0528-00	Core, Ferramic Suppressor			
R300	315-0681-00	680 Ω		1/4 W	5 %
R308	315-0621-00	620 Ω		1/4 W	5 %
T167	120-0478-00	Toroid, 5 turns, bifilar			

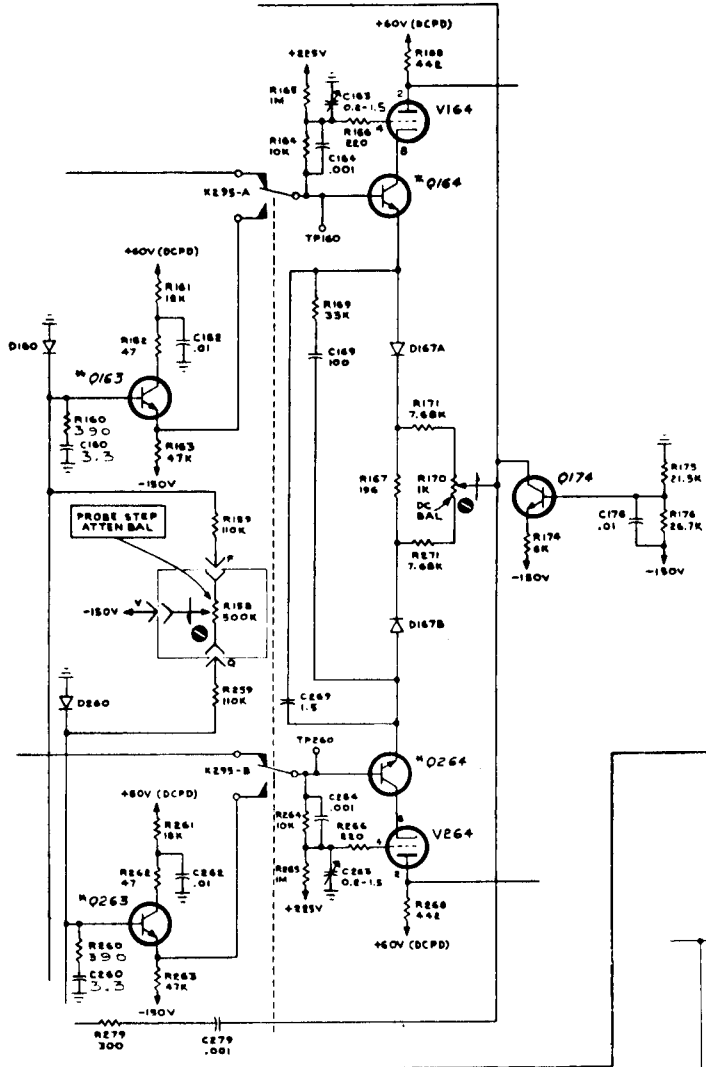
CHANGE TO:

C160, C260	281-0534-00	3.3 pF	Cer		±0.25 pF
C307	281-0599-00	1 pF	Cer	200 V	±0.25 pF
L307	108-0054-00	6.4 μH			
R160, R260	315-0391-00	390 Ω		1/4 W	5 %

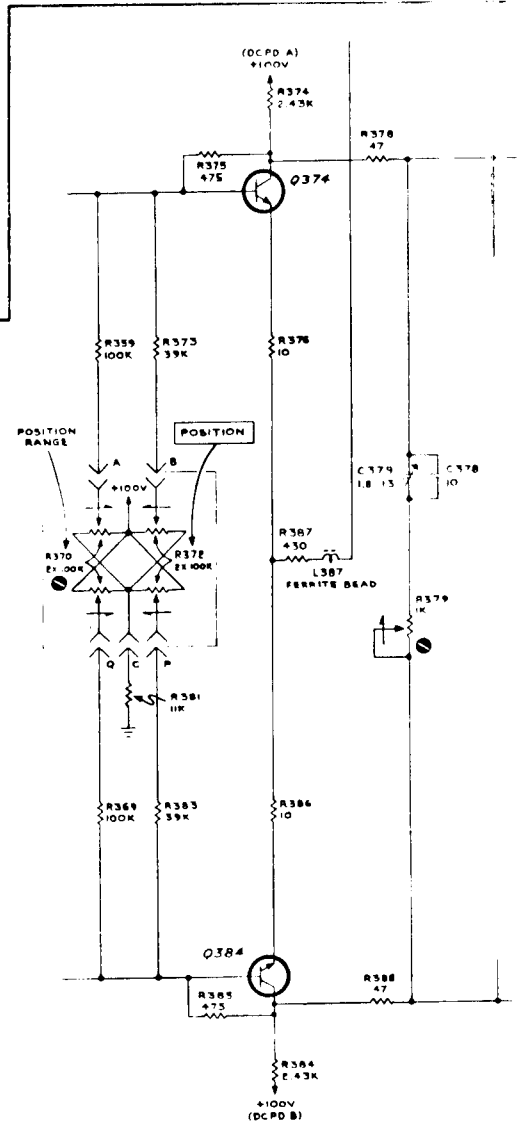
ADD:

C308	281-0611-00	2.7 pF	Cer	200 V	±0.25 pF
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M12,495/567



PARTIAL
INPUT AMPLIFIER 1



PARTIAL
OUTPUT AMPLIFIER 2