TEKTRONIX®

# TYPE W

## PLUG-IN UNIT

## SN7000 — — UP

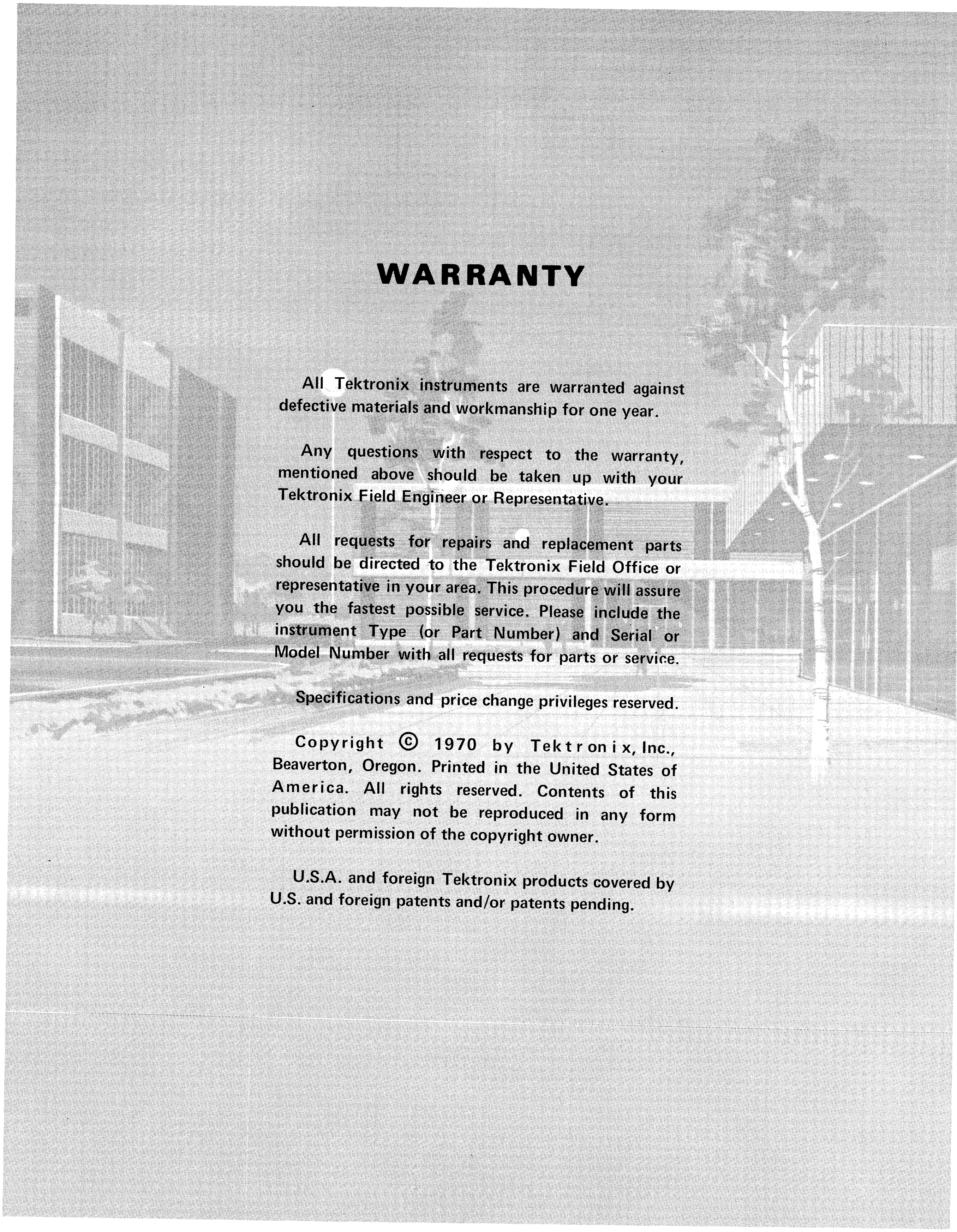
INSTRUCTION MANUAL

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

Serial Number ____________________

070-1109-00

1170



# WARRANTY

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

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

All requests for repairs and replacement parts should be directed to the Tektronix Field Office or representative in your area. This procedure will assure you the fastest possible service. Please include the instrument Type (or Part Number) and Serial or Model Number with all requests for parts or service.

Specifications and price change privileges reserved.



U.S.A. and foreign Tektronix products covered by U.S. and foreign patents and/or patents pending.

# TABLE OF CONTENTS



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

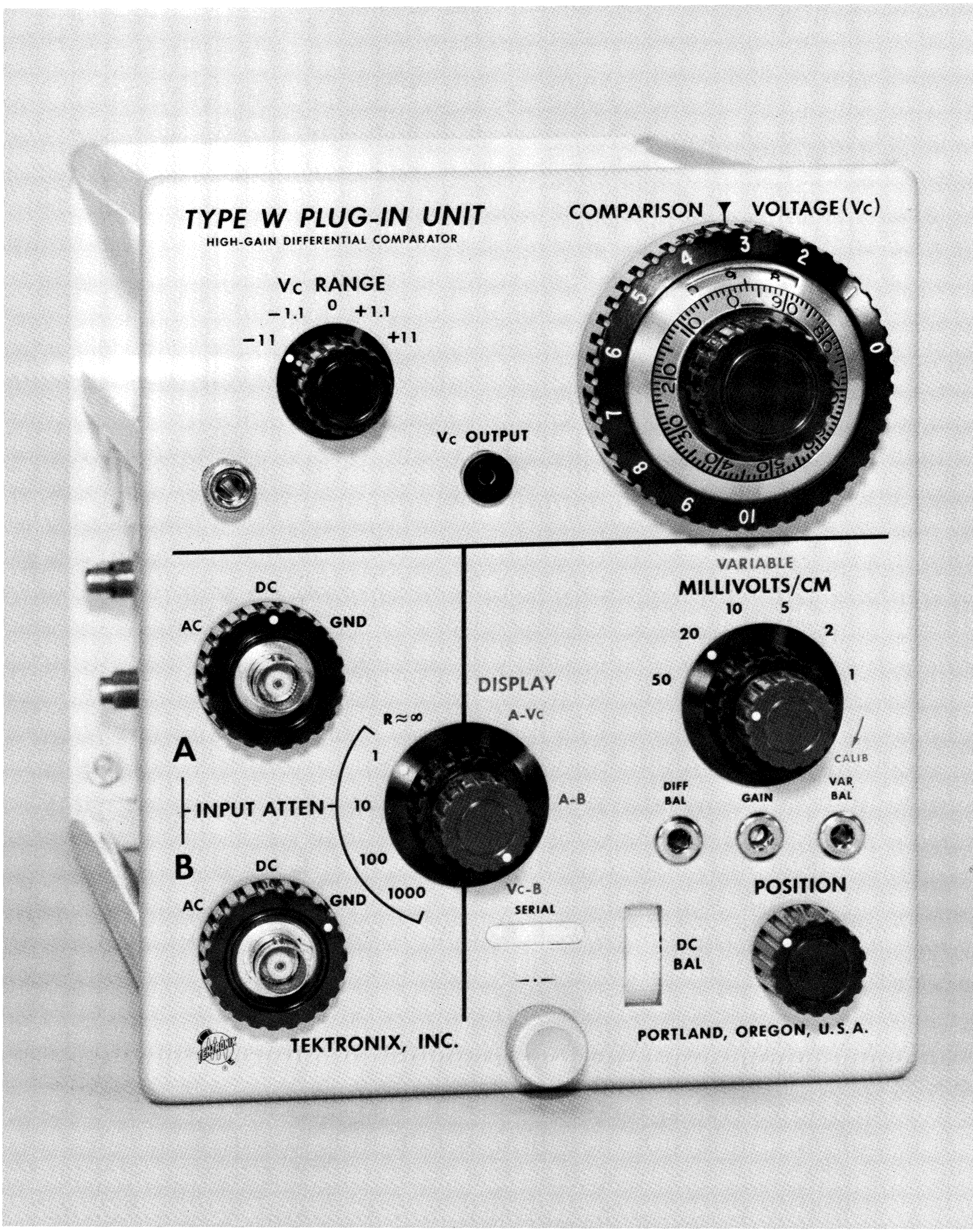



Fig. 1-1. Type W Plug-in Unit.

# SECTION 1
# SPECIFICATION

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

## General Information

The Type W Plug-In Unit is a high-gain calibrated differential comparator. It can be used in all Tektronix 530, 540, and 550-Series oscilloscopes or their rackmount equivalents. The W Unit can be used with the 580-Series oscilloscopes by employing a Type 81 or 81A adapter. The W Unit may also be used with other oscilloscopes and devices through the use of Tektronix Types 127, 132, or 133 plug-in power supplies. The primary operating modes for the unit are: (1) conventional plug-in preamplifier, (2) differential input preamplifier, or (3) differential comparator.

As a differential input preamplifier, the dynamic range of the W Unit permits common-mode signals up to ±15 volts in amplitude to be applied to the amplifier without attenuation. A rejection ratio of about 20,000 to 1 for DC or low-frequency signals permits small signals of 1 mV or less to be measured on large common-mode signals. Common-mode signals which exceed the dynamic range of the W Unit can be attenuated by means of an input attenuator before being applied to the amplifier.

As a differential comparator, voltage measurements using the slide-back technique can be made with this unit. The high accuracy and stability of the DC comparison voltage added differentially to the input signal makes precise voltage measurements possible. Using this mode of operation, the W Unit has an effective screen height of ±11,000 cm. This is equivalent to a ±11-volt dynamic signal range at a maximum sensitivity of 1 mV/cm. Within this range, calibrated ±DC comparison voltages can be added differentially to the input signal to permit a maximum of about 0.001% or 100 µV per mm to be resolved.

## ELECTRICAL CHARACTERISTICS

The electrical characteristics described in this section are valid over the stated environmental range for instruments calibrated at an ambient temperature of +20°C to +30°C, operating fully installed in a calibrated mainframe, with a warmup period of at least 20 minutes.

### Noise

No more than 150 µV peak to peak tangentially measured.

### Maximum Input Gate Current

2 nanoamperes or less.

### Overdrive Recovery

Recovers to within 10 mV of the reference point within 300 ns after the signal returns to the screen. Certain overdrive signals can cause an additional slow (thermal) shift of up to 5 mV in the reference level (overdrive DC shift).

## AS A CONVENTIONAL PREAMPLIFIER

### Deflection Factor

The MILLIVOLTS/CM switch has six calibrated positions: 1, 2, 5, 10, 20, and 50 mV/cm. In addition, a variable (uncalibrated) control provides for continuously-variable adjustment between steps from 1 mV/cm to at least 125 mV/cm.

### Accuracy

An adjustment is provided for setting the gain of the unit. When this adjustment is accurately set with the MILLIVOLTS/CM switch in the 50 mV/cm position, the vertical sensitivity for any other position of the switch will be within 3% of the panel reading for that position.

TABLE 1-1
CONVENTIONAL PREAMPLIFIER

| Type W Unit And Oscilloscope | MILLIVOLTS/ CM Setting | Minimum Bandwidth[1] (−3 dB) | Risetime[2] |
|---|---|---|---|
| 544, 545B, 546, 547, 556, 585A[3] | 50 | DC to 26 MHz | 14 ns |
| | 1 | DC to 8 MHz | 44 ns |
| 549 | 50 | DC to 22 MHz | 16 ns |
| | 1 | DC to 7 MHz | 50 ns |
| 551 | 50 | DC to 20 MHz | 18 ns |
| | 1 | DC to 7.5 MHz | 47 ns |
| 535A | 50 | DC to 13 MHz | 27 ns |
| | 1 | DC to 7 MHz | 50 ns |

[1]**Bandwidth decreases as deflection factor (VOLTS/DIV) increases. Bandwidth measured with signals that do not overscan the graticule height, using DC coupling. The low frequency (−3 dB) point for AC coupling is 2 Hz or less.**

[2]**Risetime is calculated from the measured bandwidth.**

[3]**A Type 81A Adapter is required.**

## Input Impedance

For the 1, 10, 100, and 1000 positions of the INPUT ATTEN switch, input impedance is 1 megohm paralleled by 20 pF (nominal). 1X input resistance matches the 10X input resistance within ±0.1%. For the R $\cong \infty$ position, input resistance is on the order of 10,000 to 50,000 megohms paralleled by about 19 pF.

## Input Attenuation

Four decade steps covering range 1 to 1000. Accuracy listed in Table 1-2.

TABLE 1-2

| INPUT ATTEN Switch Position | Attenuation Accuracy |
|---|---|
| 10 | ±0.05% |
| 100 | ±0.15% |
| 1000 | ±3% |

## Maximum Input Voltage Rating

TABLE 1-3

| Coupling | Maximum Safe Input Voltage for all INPUT ATTEN positions (Differential or Common Mode) |
|---|---|
| AC (Capacitive) | 500 V (DC + peak AC), 500 V (P-P) |
| DC (Direct) | 350 V (DC + peak AC), 350 V (P-P) |

# AS A DIFFERENTIAL INPUT PREAMPLIFIER

## Maximum Common-Mode Signal Amplitude

See Table 1-3.

## Common-mode Rejection Ratio

DC Coupled: At least 20,000:1 from DC to 20 kHz decreasing to 500:1 or more at 500 kHz with ±15 V signal applied.

AC Coupled: At least 1000:1 with a 60 Hz, 30 V peak-to-peak signal applied.

# AS A CALIBRATED DIFFERENTIAL COMPARATOR

## Comparison Voltages

Two voltage ranges are provided: From 0 to ±1.1 volt, and from 0 to ±11 volts.

## Comparison Voltage Accuracy and Drift

Within 0.15% of indicated value plus 0.05% of Vc RANGE setting.

## Comparator Resolution

Resolution is 100 μV per mm at maximum sensitivity.

# OTHER CHARACTERISTICS

## Environment

Storage: −40°C to +60°C, to 50,000 ft.

Operating Temperature: 0°C to +50°C.

Operating Altitude: To 15,000 ft.

## Mechanical Specifications

Construction: Aluminum-alloy chassis.

## Accessories

Information on accessories for use with this instrument is included at the rear of this manual.

# SECTION 2
# OPERATING INSTRUCTIONS

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

## Front Panel

A front-panel view of the Type W Unit is shown in Fig. 2-1. In addition, a brief functional description is given of the front-panel controls, input connectors, and securing rod.

## Connecting the W Unit to the Oscilloscope

Connect the W Unit to the associated oscilloscope as follows:

*NOTE*

*To provide the best possible turn-on conditions for the unit, make sure the oscilloscope power is off before inserting the unit in the compartment. Thus, circuit protection provided by the oscilloscope time-delay relay will be fully utilized.*

1. Insert the unit into the plug-in compartment and tighten the W Unit securing rod.

2. Set the W Unit front-panel controls as follows:

| | |
|---|---|
| Vc RANGE | As is |
| COMPARISON VOLTAGE | As is |
| AC-DC-GND (both inputs) | GND |
| INPUT ATTEN | 1 |
| DISPLAY | A—B |
| MILLIVOLTS/CM | 50 |
| VARIABLE | CALIB |
| POSITION | Midrange |

3. With the Intensity control of the oscilloscope turned fully counterclockwise, switch on the oscilloscope power.

4. ,Wait about 20 minutes for the oscilloscope and plug-in to warm up and stabilize.

5. Turn up the intensity and set the oscilloscope triggering controls to produce a free-running sweep. The trace should appear near graticule center on the CRT.

*NOTE*

*If the trace is not near center or is off the CRT, first check the DC BAL and VAR BAL adjustments by following the procedures described next.*

## Preliminary Operational Adjustments

After the unit has warmed up and stabilized, check its operation to see if adjustment of one or more of the following controls is necessary. Be sure that the oscilloscope used in conjunction with the W Unit is correctly calibrated in the vertical-deflection circuit, and that the calibrator output voltage is correct. In the Amplifier DC Balance and Variable Balance procedures that follow, the procedures assume that the W Unit is being used for the first time. Once these adjustments are made, the DC BAL is the only adjustment that needs occasional "touching up" during normal use of the unit.

### 1. Amplifier DC Balance

Any vertical shift of the trace when the VARIABLE control is rotated with the AC-DC-GND switches set to GND, indicates need for adjusting the DC BAL control (see Fig. 2-1). To make this adjustment, proceed as follows:

a. First, set the front-panel controls to the same positions as listed in the preceding topic titled, "Connecting the W Unit to the Oscilloscope".

b. Adjust the DC BAL control to eliminate any vertical shift of the trace as the VARIABLE control is rotated back and forth.

c. Set the MILLIVOLTS/CM switch to 5. If the trace is off the CRT, adjust the VAR BAL control (see Fig. 2-1) to position the trace near the center of the CRT.

d. Repeat step 1b.

e. Set the MILLIVOLTS/CM switch to 1. If the trace is off the CRT, adjust the VAR BAL control to position the trace near the center of the CRT.

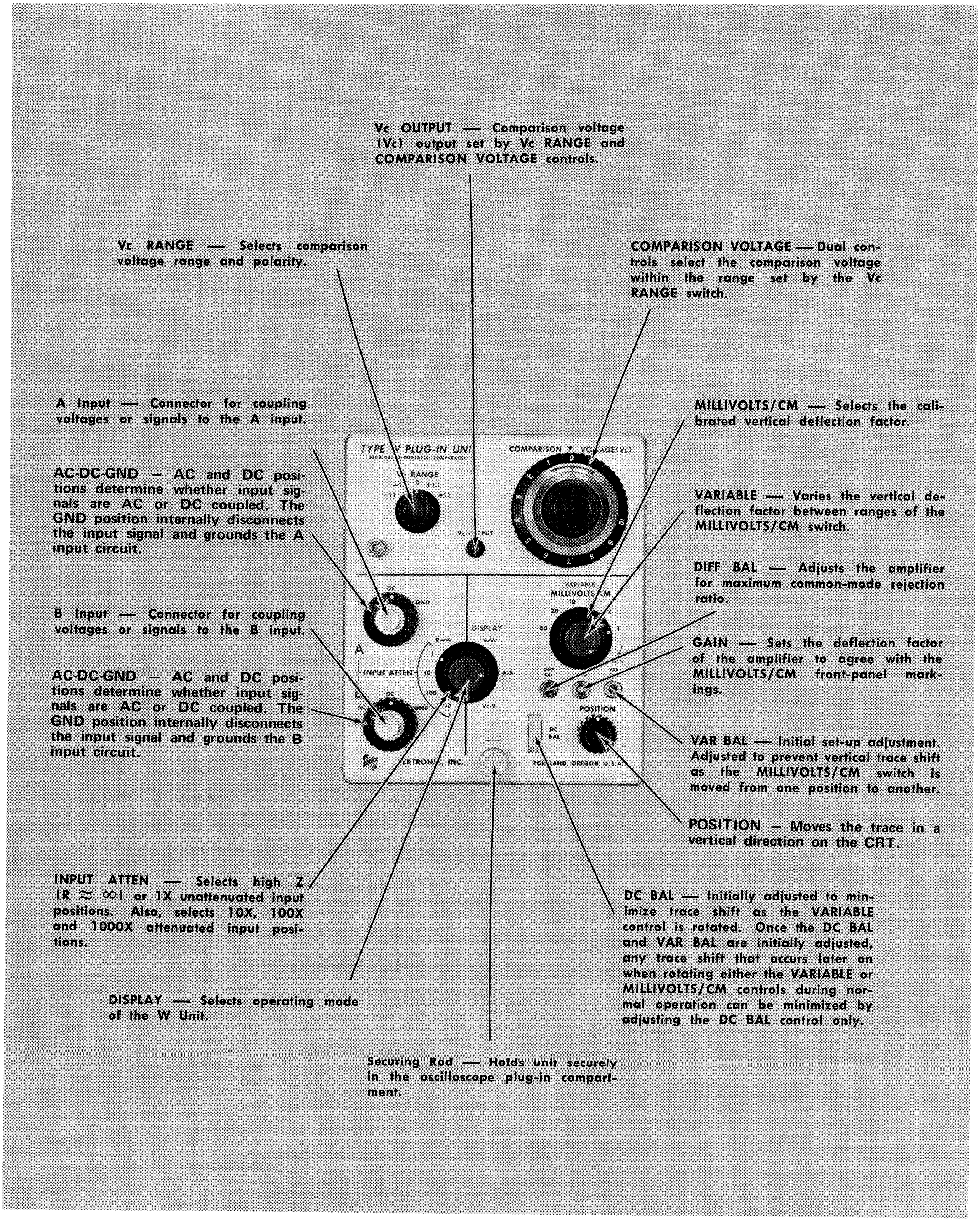



Fig. 2-1. Functions of front-panel controls, input connectors, and Securing Rod.

f. Repeat step 1b. While repeating step 1b, keep the trace centered by adjusting the VAR BAL control since there is interaction between this control and the DC BAL control.

*NOTE*

*Once the DC BAL and VAR BAL (next step) controls are initially adjusted, only the DC BAL control need be adjusted occasionally to minimize trace shift as either the VARIABLE or MILLIVOLTS/CM control is rotated. This also applies when the W Unit is transferred from one oscilloscope to another.*

## 2. Variable Balance

If the trace shifts as the MILLIVOLTS/CM switch is moved from one position to the next through all its positions, this indicates that the VAR BAL adjustment needs to be checked. Since this adjustment interacts with the DC BAL control, perform step 1 "Amplifier DC Balance" adjustment procedure first if you have not already done so. Leave the controls as they are, upon completing step 1, and then proceed as follows:

a. Adjust the VAR BAL control to minimize any vertical shift of the trace as the MILLIVOLTS/CM switch is switched from the 1 to the other positions and back again. Repeat this procedure as often as is necessary to minimize the trace shift.

b. Repeat step 1b in the "Amplifier DC Balance" procedure and 2a in this procedure as often as necessary to minimize trace shift.

*NOTE*

*Once the VAR BAL control is adjusted as desired, it ordinarily does not require readjustment. Any trace shift that results from rotating the VARIABLE or MILLIVOLTS/CM controls during normal use of the W Unit can be minimized by adjusting the DC BAL control.*

## 3. Gain

The GAIN adjustment (see Fig. 2-1) should be checked periodically to assure correct vertical deflection factors. The adjustment can be made using the oscilloscope calibrator as the signal source. If greater accuracy is needed, a signal source with more precise amplitude accuracy can be used.

a. Set the front-panel controls as follows:

| | |
|---|---|
| AC-DC-GND (A) | DC |
| AC-DC-GND (B) | GND |
| INPUT ATTEN | 1 |
| DISPLAY | A—B |
| MILLIVOLTS/CM | 50 |
| VARIABLE | CALIB |

b. Apply a 0.2-volt peak-to-peak calibrator signal through a coaxial cable to the A input connector.

c. Using the POSITION control, position the display to the center of the CRT viewing area. Set the oscilloscope controls to display several cycles of the waveform.

d. Adjust the GAIN control to obtain exactly 4 centimeters of vertical deflection.

## 4. Differential Balance

Differential balance may be quickly checked in the following manner.

a. Set the front-panel controls as follows:

| | |
|---|---|
| AC-DC-GND (A and B) | DC |
| INPUT ATTEN | 1 |
| DISPLAY | A—B |
| MILLIVOLTS/CM | 1 |
| VARIABLE | CALIB |
| POSITION | Midrange |

b. Apply 10 volts of calibrator signal through a T connector and coaxial cables to both A and B input connectors.

c. Ignoring the positive and negative spikes, adjust the DIFF BAL control (see Fig. 2-1) to eliminate any square-wave response; that is, to obtain a straight-line appearance of the trace.

## Block Diagram

The simplified block diagram shown in Fig. 2-2 is useful for studying the electrical location of the AC-DC-GND, INPUT ATTEN, COMPARISON VOLTAGE, and MILLIVOLTS/CM controls. Particularly, the diagram shows where the INPUT ATTEN switches are located with respect to the location of the MILLIVOLTS/CM switch and the COMPARISON VOLTAGE control.

When a signal is applied to the W Unit input connector, attenuation of the signal takes place in the INPUT ATTEN switch before the signal is applied through the DISPLAY switch to the amplifier. The INPUT ATTEN switch does

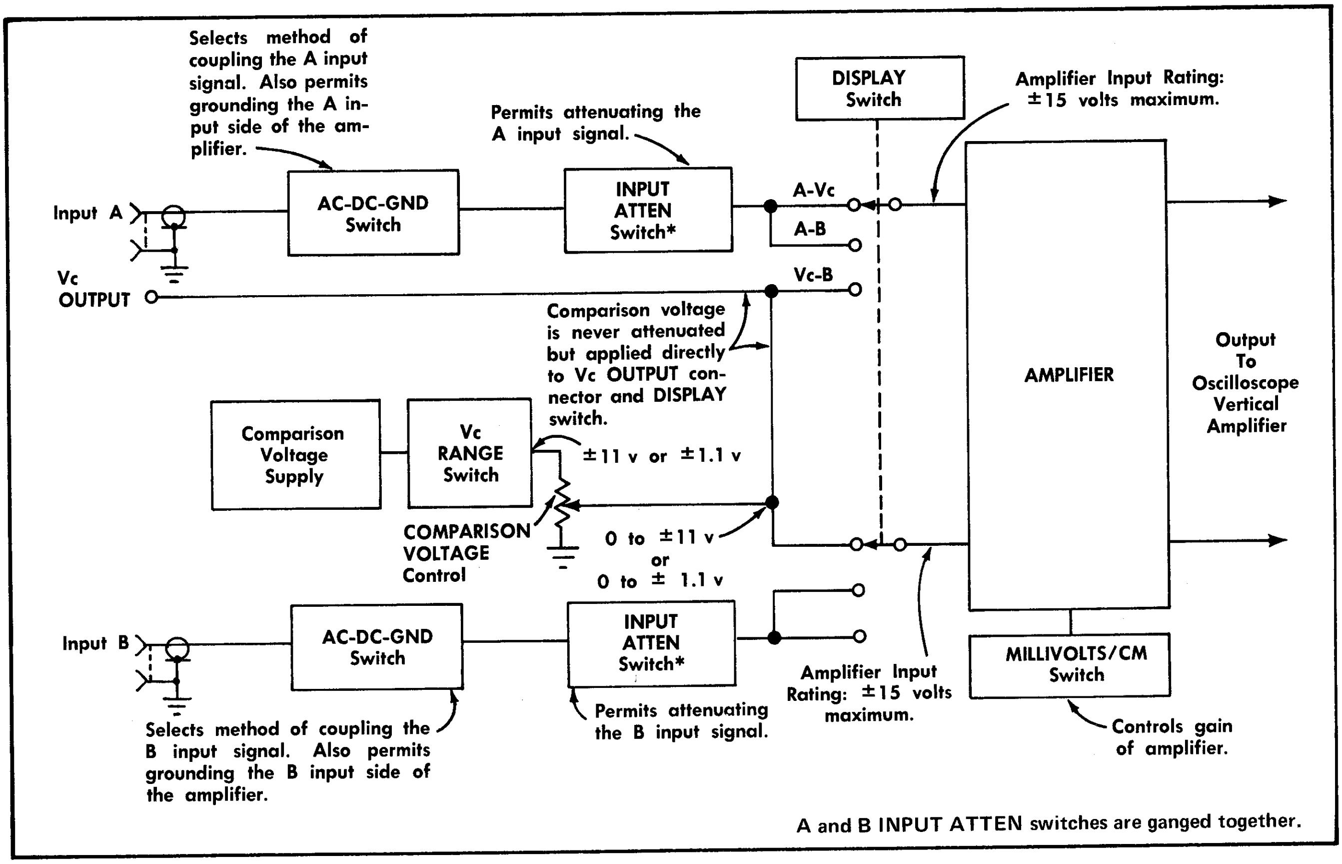



Fig. 2-2. Simplified block diagram showing DISPLAY switch positions and Vc OUTPUT connection.

not attenuate the comparison voltage because the comparison voltage is applied separately through the DISPLAY switch (in the A—Vc or Vc—B positions) directly to the input of the amplifier.

It is also important to note that there are two ways to obtain the same sensitivity when using the INPUT ATTEN and MILLIVOLTS/CM switches. One way gives more bandwidth; the other way gives less bandwidth but greater slide-back voltage capabilities. The following methods show two ways to get 10 mV/cm sensitivity. Also, for explanation purposes, assume the W Unit is used with the Type 540-series oscilloscope.

**Method 1:**

Set the INPUT ATTEN switch to 1 and the MILLIVOLTS/CM switch to 10. This gives a bandwidth of about 21 MHz for signals that do not overscan the screen. If the W Unit is used as a differential comparator to null out a DC or low-frequency AC component of a signal, the maximum slide-back comparison voltage is 11 volts. For example, if 10 volts were applied to the W Unit, 10 volts of comparison voltage is needed to null the 10 volts of applied voltage.

**Method 2:**

Set the INPUT ATTEN switch to 10 and the MILLIVOLTS/CM switch to 1. This gives a bandwidth of only 8 MHz (for signals that do not overscan the screen) and a slightly noisy trace. However, when using differential-comparator mode of operation to null out a DC or low-frequency component of a signal, the true slide-back voltage is 10X greater using this method rather than Method 1. For example, if 10 volts were applied to the W Unit, the INPUT ATTEN switch attenuates the 10 volts to 1 volt using Method 2 and a comparison voltage of only 1 volt is all that is needed to null the 10 volts of applied voltage. Thus, the 1 volt of comparison voltage is really equal to 10 volts since it nulls the 10-volt applied voltage.

Using differential-comparator operation and Method 2 (for example), 110 volts maximum can be applied to the W Unit because the INPUT ATTEN switch setting at 10 attenuates the 110 volts to 11 volts before the voltage is applied to the amplifier. The 11 volts is within the ±15-volt rating of the amplifier input stage and can be nulled by the 11-volt maximum comparison voltage available in the unit. The COMPARISON VOLTAGE control dial indication is not affected by the setting of the MILLIVOLTS/CM switch because the MILLIVOLTS/CM switch acts as null resolution or null sensitivity control. True comparison voltage using either method is determined by using this formula.

| | | | | | | |
|---|---|---|---|---|---|---|
| True Comparison Voltage | = | COMPARISON VOLTAGE Control Reading in Volts | X | INPUT ATTEN Switch Position: 1, 10, 100, or 1000 | X | Probe Attenuation Factor |

## Input Signal Connections

Before connecting signals to the A and/or B connectors on the W Unit, consider the method of coupling that will be used. Table 2-1 lists a choice of seven different methods. For each method the table lists the advantages, limitations, accessories required, source loading and precautions to consider. Check through the table and select the method which is suitable for your particular application.

## Use of Probes

Attenuator probes reduce loading of the signal source. However, in addition to providing isolation of the oscilloscope from the signal source, an attenuator probe also decreases the amplitude of the displayed waveform by the attenuation factor of the probe. When making amplitude measurements with an attenuator probe, be sure to multiply the observed amplitude by the attenuation of the probe.

An adjustable capacitor in the probe compensates for variations in input capacitance from one plug-in unit to another. To assure the accuracy of pulse and transient measurements, this adjustment should be checked frequently. To make this adjustment, proceed as follows:

1. Set the oscilloscope Amplitude Calibrator for an output of suitable amplitude.

2. Place the DISPLAY switch to the A-B position.

3. Set the AC-DC-GND switch to DC for the input in use. Set the unused input AC-DC-GND switch to GND.

4. Touch the probe tip to the calibrator output connector and adjust the oscilloscope controls to display several cycles of the waveform.

5. Adjust the probe compensation for best square-wave response.

*NOTE*

*If a square-wave source other than the oscilloscope calibrator is used for compensating the probe do not use a repetition rate higher than 5 kHz. At higher repetition rates, the waveform amplitude appears to change as the probe is compensated. Thus, proper compensation is difficult to attain. If the probe remains improperly compensated, transient and frequency response of the system will be poor and measurements will be inaccurate.*

## Conventional Preamplifier Operation

When the W Unit is used as a conventional preamplifier, there are two ways to set up the controls. Either the A or B input can be used, but for explanation purposes assume that the signal is to be applied to the A input to obtain an upright display (see Fig. 2-3). One way to set up the controls is as follows:

a. Set the DISPLAY switch to A-B.

b. Apply the signal to input A.

c. Set input A AC-DC-GND switch to AC or DC, depending on the method of signal coupling desired.

d. Set input B AC-DC-GND switch to GND.

The other method is as follows:

a. Set the DISPLAY switch to A—Vc and the Vc RANGE switch to 0.

b. Apply the signal to input A.

c. Set input A AC-DC-GND switch to AC or DC, depending on the method of signal coupling desired. The B input AC-DC-GND switch can be left in any position.

Operation of the unit with input B used, instead of input A, and the controls set to their appropriate positions, is essentially the same, except that signals applied to the B input connector are inverted on the display. Positive voltages produce an upward deflection when applied to the A connector, and a downward deflection when applied to the B connector (see Fig. 2-3).

The amount of vertical deflection produced by a signal is determined by the settings of the INPUT ATTEN, MILLIVOLTS/CM, and VARIABLE controls. Calibrated deflec-

TABLE 2-1

Signal Coupling Methods

| Method of Coupling the Signal | Advantages | Limitations | Accessories Required | Source Loading[1] | Precautions |
|---|---|---|---|---|---|
| 1. Open (unshielded) test leads. | Simplicity. | Limited frequency response. Subject to stray pickup. | BNC to Banana Jack adapter (103-0033-00). Two test leads. | 1 Meg Ω and 20 pF at input, plus test leads. | Stray pickup and spurious oscillations. Insert series 47-ohm resistor. |
| 2. Unterminated coax cable | Full sensitivity. | Limited frequency response. High capacitance of cable. | Coax cable with BNC connector(s). | 1 Meg Ω and 20 pF plus cable capacitance. | High capacitance loading. |
| 3. Terminated coax cable. Termination at Type W input. | Full sensitivity. Total Type W/Oscilloscope bandwidth. Relatively flat resistive loading. Long cable with uniform response. | Presents $R_O$ (typically 50Ω) loading at end of coax. May need blocking capacitor to prevent DC loading or damage to termination. | Coax cable with BNC connector(s). $R_O$ termination at Type W input. (BNC 50 Ω Termination, 011-0049-00). | $R_O$ plus 20 pF at Type W end of coax can cause reflections. | Reflection from 20 pF at input. DC and AC loading 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. |
| 5. Tap into terminated coax system (BNC T: UG-274/U) at Type W 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 Meg Ω and 20 pF at tap point. | Reflections from 20 pF input. |
| 6. 10X Probe.<br><br>100X Probe.<br><br>1000X Probe. | Reduced resistive and capacitive loading, nearly full Type W/Oscilloscope bandwidth (21 MHz) using P6023 probe; full bandwidth using the other probe types. | X0.1 sensitivity.<br><br>X0.01 sensitivity.<br><br>X0.001 sensitivity. | P6023 is 10X.<br><br>P6007 is 100X.<br><br>P6015 is 1000X. | P6023: ≅ 12 pF, 8 Meg Ω.<br>P6007: ≅ 2 pF, 10 Meg Ω.<br>P6015: ≅ 2.7 pF, 100 Meg Ω. | Check probe frequency compensation. Use square-wave frequency less than 5 kHz preferably 1 kHz. |
| 7. Current transformer. Terminated in 50 Ω at Type W. Upper bandwidth is that of Type W/Oscilloscope system. | Measure signal currents in transistor circuits. Current xfmr can be permanent part of test circuit. Less than 2.2 pF to test circuit chassis. CT-1: 20 amps pk CT-2: 100 amps pk | Rms current rating:<br>CT-1: 0.5 amp<br>CT-2:2.5 amps<br><br>Sensitivity:<br>CT-1: 5 mV/mA<br>CT-2: 1 mV/mA | CT-1: Coax adapter and BNC termination.<br><br>CT-2: Nothing extra. (Perhaps additional coax cable for either transformer.) | CT-1: Insertion; 1 Ω paralleled by about 5 µH. Up to 1.5 pF.<br><br>CT-2: Insertion; 0.04 Ω paralleled by about 5 µH. Up to 2.2 pF. | Not a quick-connect device. CT-1: low frequency limit about 75 kHz.<br><br>CT-2: low frequency limit about 1.2 kHz, and is 1/5th as sensitive as the CT-1. |

[1] Applies to 1, 10, 100, and 1000 positions of the INPUT ATTEN switch.

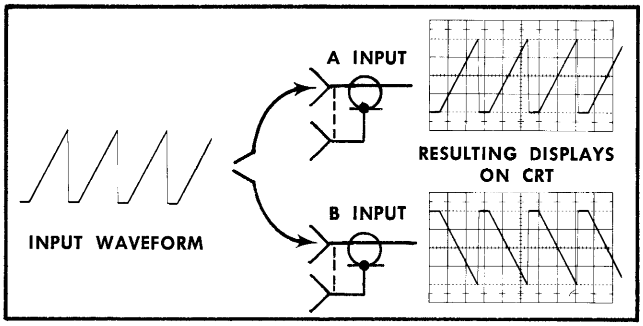



Fig. 2-3. Waveforms applied to the A input connector produce an upright display, while waveforms applied to the B input are inverted.

tion factors indicated by the MILLIVOLTS/CM switch apply only when the VARIABLE control is set to the CALIB detent position. Serious errors in display measurements may result if the setting of this control is inadvertently moved away from the CALIB position.

The range of the VARIABLE control is about 2.5 to 1 with respect to the calibrated level, to provide continuously variable (uncalibrated) vertical-deflection factors between calibrated settings of the MILLIVOLTS/CM switches. As the control is rotated a few degrees counterclockwise from the CALIB position, a switch is actuated which increases the gain about 10%. This increase provides overlapping coverage between calibrated steps.

Voltage measurements in millivolts may be made directly from the CRT by noting the amount of vertical deflection on the CRT. Then multiply the deflection on the CRT by the setting of the MILLIVOLTS/CM switch, the INPUT ATTEN switch, and attenuation factor, if any, of the probe.

Placing the AC-DC-GND switch in the AC position inserts a DC blocking capacitor in series with the input circuit. In the AC position the input time constant is 0.1 second and the low-frequency response is 2 Hz at 30% down. Thus, some attenuation exists even at 60 Hz. Two principle occasions where AC coupling is used are:

1. When it is desired to get a quick look at the AC component of a signal which has a large DC component.

2. To measure the peak-to-peak voltage of the AC component while blocking the DC component.

In the DC position of the AC-DC-GND switch, both the AC and DC components of an applied signal can be observed. This position is useful for measuring DC levels of voltages or for measuring the instantaneous DC level at a given point on a waveform.

The GND position of the AC-DC-GND switch allows the signal to be disconnected from the W Unit amplifier input without having to physically disconnect the applied signal externally. This position provides an easy method for determining the zero DC reference of the trace. However, this method does not take into account trace deviation from exact zero due to ground-loop and grid currents. If these voltages are significant and utmost measurement accuracy is desired, touch the probe tip to the point you wish to use as the reference instead of setting the AC-DC-GND switch to GND.

## Differential Preamplifier Operation

The primary purpose of differential operation is to eliminate undesirable common-mode signals. The term "common-mode signal" is defined as that signal which is common to both inputs of a differential amplifier. It usually, but not necessarily, represents unwanted hum or noise.

This mode of operation can be used, for example, to observe the signal across one circuit element while effectively eliminating the remainder of the circuit from the observations. This is accomplished by connecting the signal at one end of the element to one input of the W Unit and the signal at the other end of the element to the other input of the unit.

Differential operation between the two inputs is obtained by setting the DISPLAY switch to A—B and both AC-DC-GND switches to the same AC or DC positions, depending on the method of coupling desired. For low frequencies, maximum common-mode rejection ratio is obtained when the AC-DC-GND switches are set to DC and MILLIVOLTS/CM switch is set to 1. The VARIABLE control should be set to CALIB.

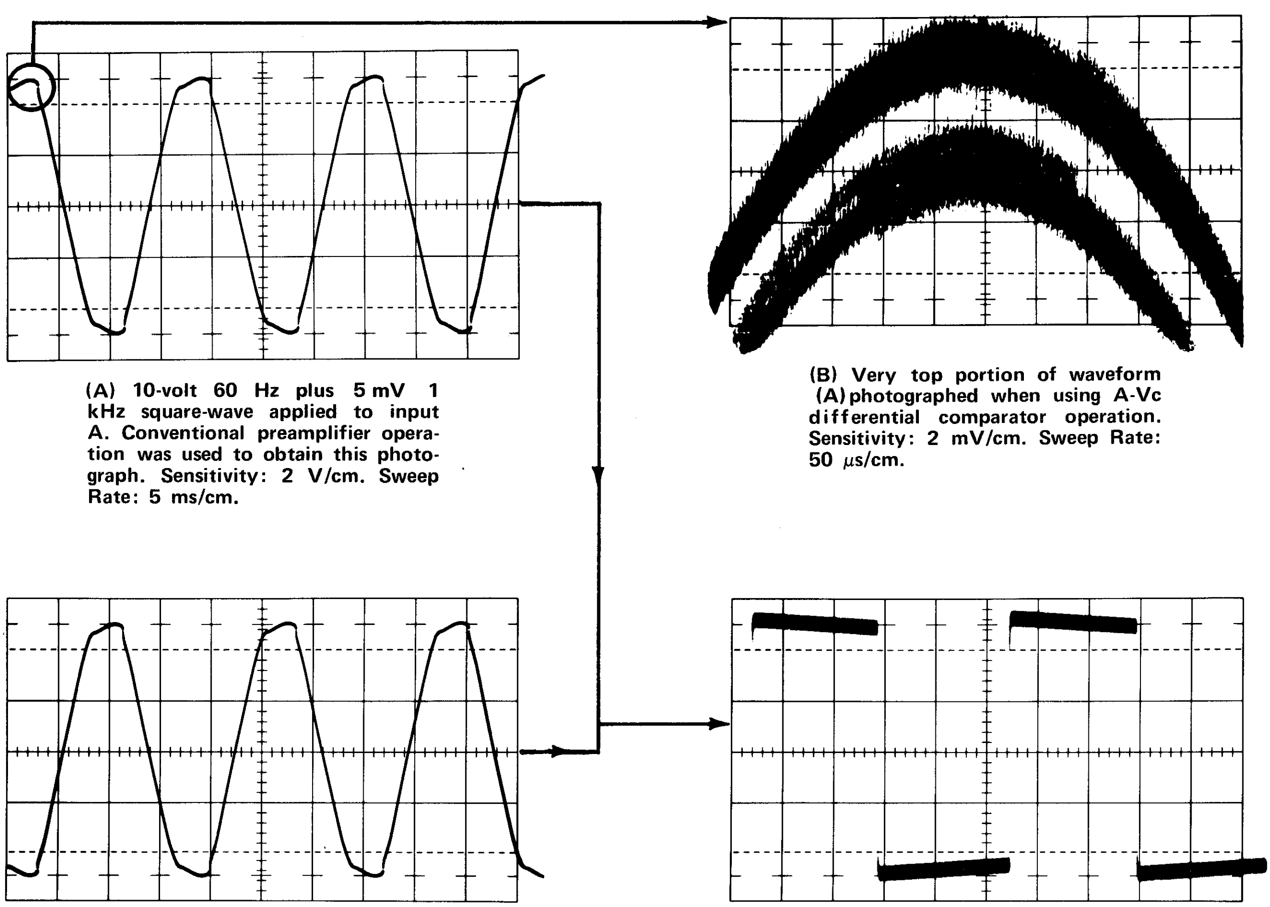
Differential or common-mode rejection ratio is a function of frequency in practical amplifiers. It is 20,000 to 1 for DC common-mode signals in the W Unit and remains near that value through audio frequencies, decreasing as the frequency increases.

The common-mode rejection ratio of the W Unit describes the ability of the unit to reject common-mode signals. This ratio can also be defined as the ratio of amplifier response to that part of the input signal not common to both inputs, as compared to the response of the amplifier to any input signal common to both inputs. It can be shown numerically by using the following example.

If an input signal consists of 10 volts (peak-to-peak) of 60 Hz hum and 5 millivolts of desired signal, the 10-volt hum causes 10 volts divided by 1 mV/cm or 10,000 cm of deflection at maximum sensitivity using conventional preamplifier mode of operation. The 5-millivolt signal will produce 5 cm of deflection superimposed on the 10,000-cm waveform. Using conventional preamplifier operation, the desired signal is deflected off the CRT and cannot be observed. However, by using DC-coupled differential operation at a ratio of 20,000 to 1, the hum can be differentially suppressed to an amplitude of 0.5 mV and this causes a deflection of only 0.5 cm or less on the 5-cm desired signal. Thus, by suppressing the hum the desired signal can be easily observed and measured.

The preceding example is shown in the series of waveform photographs shown in Fig. 2-4. A combined 10-volt hum and 5-millivolt square-wave signal is shown in Fig. 2-4(A). Although the square-wave signal does not seem to be present, it can be seen by increasing the sensitivity of the W Unit to 2 mV/cm, which increases the effective height of the waveform so it produces a deflection of 5,000 cm on the CRT. To view the top portion of this waveform, a DC comparison voltage (using differential comparator operation explained later in this section) of approximately 5 volts is used to bring the top portion of the combined signals into view as shown by the waveform photograph in Fig. 2-4(B). The square-wave signal, superimposed on the hum but not synchronized with it, causes the double appearance of the waveform.

A 10-volt peak-to-peak hum signal is applied to input B. This signal is actually in phase with the A-input hum signal but is inverted as it passes through the W Unit amplifier as shown in Fig. 2-4(C). The B input signal differentially sup-



(A) 10-volt 60 Hz plus 5 mV 1 kHz square-wave applied to input A. Conventional preamplifier operation was used to obtain this photograph. Sensitivity: 2 V/cm. Sweep Rate: 5 ms/cm.

(B) Very top portion of waveform (A) photographed when using A-Vc differential comparator operation. Sensitivity: 2 mV/cm. Sweep Rate: 50 μs/cm.

(C) 10-volt 60 Hz only applied to input B. Conventional preamplifier operation was used to obtain this photograph. W-Unit amplifier inverts the signal resulting in the display as shown. Sensitivity: 2 V/cm. Sweep Rate: 5 ms/cm.

(D) Using A-B differential preamplifier operation, hum is differentially suppressed and only the 1 kHz square wave is displayed. Square-wave tilt was present on the applied signal. Sensitivity: 1 mV/cm. Sweep Rate: 0.2 ms/cm.

Fig. 2-4. Common-mode rejection by the W Unit.

presses the hum portion of the signal applied to input A. The resulting display using A-B differential preamplifier operation is shown in Fig. 2-4(D).

The following operational notes provide helpful information to obtain optimum performance from the W Unit when using differential mode of operation.

1. Both AC-DC-GND switches should be in the DC position, if possible, to obtain best common-mode rejection at the lower frequencies (below 20 kHz).

2. Differential rejection ratio may decrease slightly as the VARIABLE control is rotated away from the CALIB position.

3. Either input signal alone may be viewed by setting the AC-DC-GND switch for one of the inputs to GND. Then, set the INPUT ATTEN and MILLIVOLTS/CM switches to positions that will attenuate the signal sufficiently so the entire peak-to-peak amplitude of the waveform can be viewed within the graticule area.

4. If conventional passive attenuator probes are used, consider that the probe resistor tolerance is about 1%. If the tolerance between the probes is in opposite directions, this difference will decrease the attenuation accuracy and hence the differential capabilities of the W Unit. To avoid this, use the Type P6023 Probe. This probe can be adjusted to compensate for the slight differences. The attenuation factor of this 10X low capacitance probe is adjustable over a ±2.5% range.

## Type P6023 Probe Adjustment Procedure

The following equipment is recommended for this procedure:

Oscilloscope to be used with the Type W.

Type W Differential Comparator plug-in unit.

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

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

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:

**Oscilloscope**

| | |
|---|---|
| Amplitude Calibrator | 1 V |
| Horizontal Position | Centered |
| Horizontal Display | Normal (X1) |
| Time/CM | .5 ms |
| Triggering Mode | Auto |
| Triggering Slope | + |
| Triggering Coupling | AC |
| Triggering Source | Norm |

**Type W**

| | |
|---|---|
| BALANCE | Adjust as outlined on pages 2-1 through 2-4. |
| VOLTS/CM | 20 mV |
| POSITION | Centered |
| DISPLAY | A-B |
| AC-DC-GND (A Input) | GND |
| AC-DC-GND (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 W 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 W POSITION control.

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

g. Check that the Type W 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. 2-5(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. 2-5(B).

j. Switch the oscilloscope Amplitude Calibrator to Off. The probe is now properly adjusted. If two probes are to be

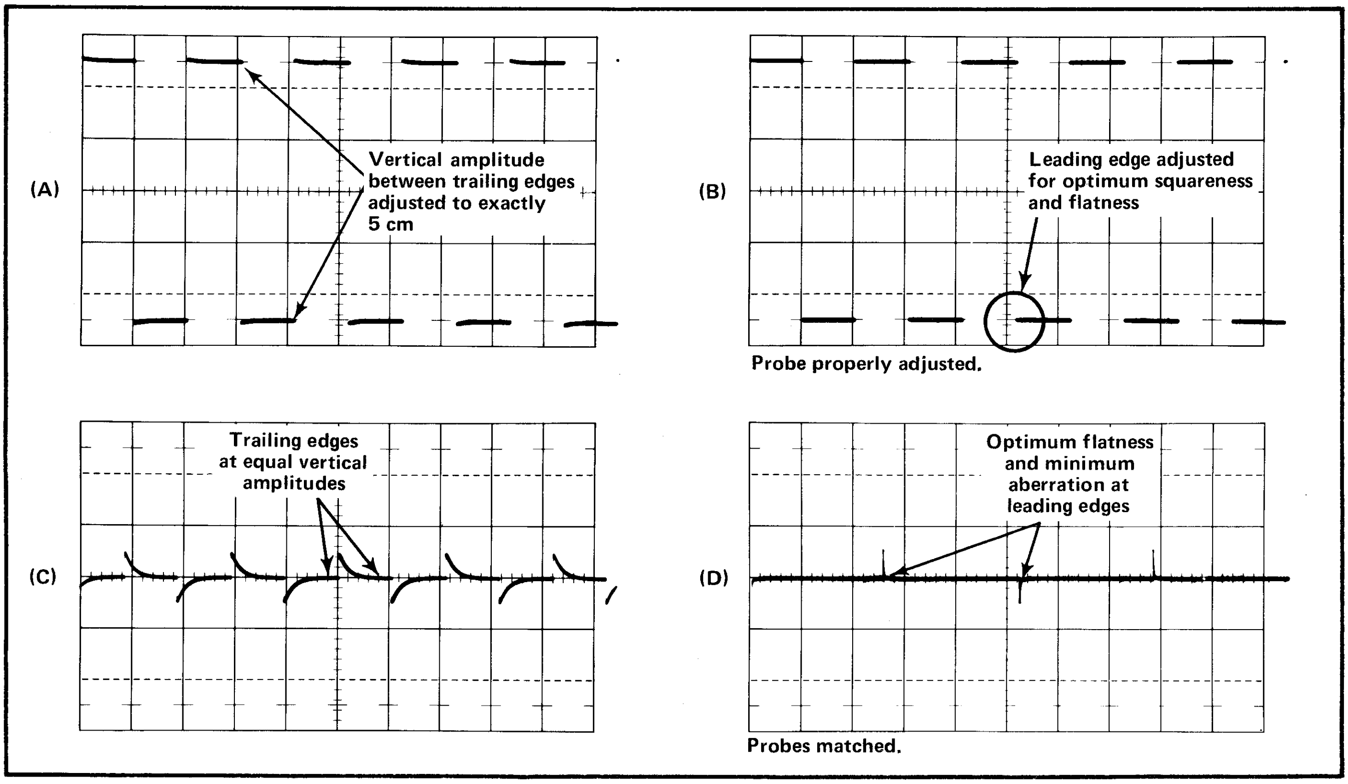



Fig. 2-5. Adjusting the P6023 Probe. (A) Adjusting DC ATTEN CALIBRATION; (B) Adjusting AC COMP; (C) Matching DC ATTEN CALIBRATION of second probe to that of first probe; (D) Matching AC COMP of second probe to that of first probe. Sweep rate: (A), (B) and (C) —.5 ms/cm; (D) —.2 ms/cm; vertical sensitivity;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

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.

l. Switch the B Input AC-DC-GND controls to DC. Switch the Amplitude Calibrator to 20 V and adjust the Type W 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. 2-5(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. 2-5(D).

p. Switch the Amplitude Calibrator to Off and the Type W A and B Input AC-DC-GND controls to GND. The probes are now adjusted for use with the Type W 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 W 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.

### Calibrated Differential Comparator Operation

When the DISPLAY switch is in the A—Vc or Vc—B position and the Vc RANGE switch is set to one of the + and — voltage ranges, the W Unit operates as a calibrated differential comparator or slide-back voltmeter. The calibrated comparison voltage, which has a range of 0 to 11 volts, may be added (differentially) to either input signal to obtain a null. Table 2-2 shows the maximum signal that can be nulled using the 1, 10, 100, and 1000 positions of the INPUT ATTEN switch.

TABLE 2-2

| Maximum Signal[1] | INPUT ATTEN Switch Position |
|---|---|
| 11 | 1 |
| 110 | 10 |
| 500[2] | 100 or 1000 |

[1]Maximum DC, DC and peak AC, or peak-to-peak AC signal in volts that can be nulled using up to 11 volts comparison voltage available in the W Unit.

[2]Maximum input voltage rating of the W Unit.

In this mode of operation a calibrated DC comparison voltage is internally applied to differentially offset any unwanted portion or component of the applied signal, thereby allowing accurate measurements of relatively small AC or DC signals riding on top of relatively large AC or DC signals.

When the DISPLAY switch is in the A—Vc position, the comparison voltage is applied internally to the amplifier input where the B signal is ordinarily applied during differential mode of operation. The AC-DC-GND switch in the B section is not used (see Fig. 2-2). Thus, signals applied to the B input connector will not be displayed.

In the Vc—B position of the DISPLAY switch, the comparison voltage is applied to the amplifier input where the A input signal is normally applied during differential mode of operation. The AC-DC-GND switch and input connector for the A input are not used.

*NOTE*

*If a high-amplitude signal is applied to the unused connector, the AC-DC-GND switch for that connector should be set to GND to prevent possible crosstalk.*

The DC comparison voltage is set by two controls: the Vc RANGE switch and the COMPARISON VOLTAGE control. The Vc RANGE switch has 4 ranges: 0 to −11, 0 to −1.1, 0 to +1.1, and 0 to +11 volts. The COMPARISON VOLTAGE control varies the comparison voltage over the range selected by the Vc RANGE switch and indicates the precise comparison voltage at a particular setting. The comparison voltage as read from the COMPARISON VOLTAGE control dial is independent of the MILLIVOLTS/CM or VARIABLE controls.

*NOTE*

*The comparison voltage supply circuit in the W Unit maintains constant, accurate comparison voltage as long as the −150- and +225-volt power supplies are in regulation and within their output voltage tolerance ratings. Be sure these and other regulated power supplies in the oscilloscope are operating properly.*

Differential comparator mode of operation may be used to make the following voltage measurements: (1) measuring DC voltages, (2) measuring small AC or DC signals superimposed on DC (3) measuring small AC signal variations on large AC, and (4) measuring high-amplitude low-frequency AC signals.

### (1) Measuring DC Voltages

When the W Unit is used to make DC voltage measurements, the following general procedure (using input A as an example) can be used:

a. Check that the DC BAL adjustment has been set properly.

b. Place input A AC-DC-GND switch to GND, the DISPLAY switch to A—Vc and the MILLIVOLTS/CM switch to 50.

c. Set the INPUT ATTEN switch to a position that will attenuate the applied DC to a voltage of about 10 volts or less.

d. Set the Vc RANGE switch to 0.

e. Establish a reference line on the CRT. This line will usually be the horizontal centerline of the graticule. Use the POSITION control to set the trace to the reference line. Once the trace is set, do not move the POSITION control until the measurement has been made or a recheck is necessary.

*NOTE*

*For greatest accuracy in establishing a reference, set the input A AC-DC-GND switch to DC and touch the probe tip to ground on the device under test. Then position the trace to the reference line.*

f. Set input A AC-DC-GND switch to DC.

g. Connect input A probe to the DC voltage to be measured.

h. Set the Vc RANGE switch to a voltage sufficient to offset the attenuated DC voltage of step c. The offsetting comparison voltage should be of the same polarity as the applied DC voltage.

i. Set the COMPARISON VOLTAGE control to bring the trace onto the CRT. Set the trace exactly on the reference line with the COMPARISON VOLTAGE control.

j. Recheck the reference by setting the A AC-DC-GND switch to GND (or ground the probe tip) and the Vc RANGE switch to 0. If the trace does not coincide with the reference established in step e, reposition the trace to the reference with the POSITION control. Return the switches to their former positions.

*NOTE*

*When making large DC measurements, allow a few moments for the trace to return to its original position.*

k. Now the voltage can be determined by using the following formula:

$$\text{True Comparison Voltage in Volts} = \text{COMPARISON VOLTAGE Control Reading in Volts} \times \text{INPUT ATTEN Switch Position} \times \text{Probe Attenuation Factor}$$

The applied DC voltage is equal to the true comparison voltage. For example, supposing a +300-volt power supply is being measured and a 10X attenuator probe is used to connect to the power supply. Finally, assume the INPUT ATTEN switch has been set to 10, the Vc RANGE switch to +11 and the COMPARISON VOLTAGE control to 2-9-85 (+2.985 volts). Substituting these values in the formula, the result is:

True Comparison Voltage = (+2.985) (10) (10)

True Comparison Voltage = +298.5 volts

Thus, the +300-volt supply is actually +298.5 volts.

*NOTE*

*To increase the resolution when matching the reference line and trace as in step i, set the MILLIVOLTS/CM switch to a higher sensitivity (lower deflection factor). Re-establish the reference and repeat the measurement as described in steps j and k. The formula given in step k applies regardless of the MILLIVOLTS/CM switch position.*

## (2) Measuring Small AC or DC Signals Superimposed on DC

Small AC or DC signals superimposed on a DC component can be measured accurately by first using the comparison voltage to effectively eliminate the DC component. The general procedure, using input A as the example, is as follows:

a. Set the input A AC-DC-GND switch to DC, the DISPLAY switch to A—Vc and the POSITION control to midrange.

b. Set the INPUT ATTEN switch so the combined signal to be applied to input A is attenuated to about 10 volts or less.

c. Set the MILLIVOLTS/CM switch so the small AC or DC signal is not expected to overscan the screen.

d. Apply the signal to input A.

e. Set the Vc RANGE switch to a voltage sufficient to offset the attenuated signal of step b. Use the same polarity comparison voltage as the DC component signal to be offset.

f. Set the COMPARISON VOLTAGE control so the small AC or DC signal is positioned onto the screen.

g. If the small signal waveform overscans the screen or is too low in amplitude, reset the MILLIVOLTS/CM switch so the waveform is of suitable size.

h. Measure the small AC or DC signal in the same manner as is done in conventional preamplifier operation using the ordinary formula:

$$\text{P-P Signal in Millivolts} = \text{Vertical Deflection in cm} \times \text{MILLIVOLTS/CM Switch Position} \times \text{INPUT ATTEN Switch Position} \times \text{Probe Attenuation Factor}$$

or measure the signal by using the COMPARISON VOLTAGE control. First, use the COMPARISON VOLTAGE control to measure the difference between the lowest and highest points on the small AC or DC signal. Substitute this information in the following formula:

$$\text{P-P Signal in Volts} = \text{COMPARISON VOLTAGE Control Difference Measurement in Volts} \times \text{INPUT ATTEN Switch Position} \times \text{Probe Attenuation Factor}$$

### (3) Measuring Small AC Signal Variations on Large AC

The technique for measuring small AC-signal component variations on a large AC signal is essentially the same as that described for measuring small AC or DC signals superimposed on DC. The only difference is that the AC-DC-GND switch can be set to AC to block any DC component (if desired). The comparison voltage is then used to position the small AC signal component into view so the measurement can be made.

### (4) Measuring High-Amplitude Low-Frequency AC Signals

High-amplitude low-frequency (below 20 kHz) AC signals, up to 500 volts peak-to-peak applied to the W Unit input connector, can be measured using the slide-back technique. This type of measurement is very similar to DC measurements except that it is **not** necessary to establish a zero voltage reference line.

a. Before applying the signal to the W Unit, set the INPUT ATTEN switch to a setting that will reduce the expected amplitude of the signal to about 10 volts or less peak-to-peak amplitude.

b. Set the A input AC-DC-GND switch to AC.

c. Set the DISPLAY switch to A—Vc and the MILLIVOLTS/CM switch to 50.

d. Apply the signal to the A input connector.

e. Set the Vc RANGE switch to a range sufficient to offset the attenuated signal.

f. Use the COMPARISON VOLTAGE control to bring the desired point on the waveform to graticule center. Note the dial reading.

g. Set the Vc RANGE switch to a range in opposite polarity to that used in step (4)e.

h. Use the COMPARISON VOLTAGE control to bring the other desired point on the waveform to graticule center. Note the dial reading.

i. Find the difference voltage between the two dial readings obtained in step (4)f and (4)h. Then substitute this information in this formula:

$$\text{P-P Signal in Volts} = \text{COMPARISON VOLTAGE Control Difference Measurement in Volts} \times \text{INPUT ATTEN Switch Position} \times \text{Probe Attenuation Factor}$$

## AC-DC-Voltage Measurements Exceeding 500 Volts

Table 2-2 lists the maximum signal handling capabilities of the W Unit. If AC, DC or both AC and peak AC voltage components are greater than 500 volts maximum (350 volts when DC coupled), use an attenuation probe to apply such voltages to the unit. The formula previously given already includes the probe attenuation as one of the factors to consider when obtaining a measurement. When the probe is used, do not exceed the maximum input voltage rating of the probe.

For example, if a P6023 Probe is used, the maximum rating of the probe is 1000 volts. If a 750-volt signal is applied to the probe tip, then the INPUT ATTEN switch should be set to 10 to attenuate the signal still further so the W-Unit amplifier is not overdriven. The probe attenuation and INPUT ATTEN switch reduces the signal to 7.5 volts which is well within the W-Unit amplifier rating and comparison voltage slide-back capabilities.

## Vc OUTPUT Connector

The Vc OUTPUT connector mounted on the front panel of the W Unit permits monitoring the comparison voltage. The voltage at the connector is the same as that set up by the Vc RANGE and COMPARISON VOLTAGE controls, provided meter loading is no greater than one or two microamperes. Any infinite impedance voltmeter such as a digital voltmeter or any nulling type meter which draws negligible current can be used for monitoring purposes.

If the connector is loaded more heavily by an external meter, the comparison voltage available at the connector and applied to the input gate of the W Unit amplifier will not be the same as indicated by the COMPARISON VOLTAGE control. However, the voltmeter which is connected to the Vc OUTPUT connector will indicate the actual slide-back voltage. Therefore, it is possible to load the circuit considerably and still use the comparison voltage with considerable accuracy as long as the COMPARISON VOLTAGE dial reading is ignored and the reading of the voltmeter is used.

*NOTE*

*Accidental grounding of the Vc OUTPUT connector will not damage the internal circuitry.*

## R ≅ ∞ Position of the INPUT ATTEN Switch

When the INPUT ATTEN switch is set to R ≅∞ position, the input connector is connected directly to the gate of the first stage and the gate-to-ground circuit is opened. For low-frequency measurements the input impedance is very high. The high input impedance is useful for measuring voltages in high-impedance circuits where minimum loading is desired and the voltage to be measured is within the ±11 volt range of the W unit; for example, measuring grid-to-cathode bias. Differential comparator operation is used to make the measurement. At null, the comparison voltage is equal to the voltage being measured.

*IMPORTANT*

*When using the R ≅ ∞ position, be sure to set the AC-DC-GND switch to DC for the input to be used. DC Coupling permits the gate to be returned to ground through the device under test.*

If the external device does not provide a DC return path for the gate, an external resistance (adequately shielded) must be connected between the input connector and ground. A practical resistor value to use for this purpose is 1000 megohms. If this value is used, the input resistance of the W Unit will be approximately 1000 megohms.

Gate current through a 1000-megohm resistor typically does not exceed 2 nanoamperes. This low current can be easily offset by using the comparison voltage.

For example, if the A input is used, connect the 1000-megohm resistor between the A input connector and the Vc OUTPUT connector. Set input A AC-DC-GND switch to DC and input B AC-DC-GND switch to GND. Set the DISPLAY switch to A—B and the Vc RANGE switch to −1.1. Then, set the COMPARISON VOLTAGE control so the trace returns to a graticule line which will be used as a reference.

For instance, a current of 1 nanoampere through a 1000-megohm resistor is equal to 1-volt or 200 cm of deflection at 5 mV/cm. This amount of deflection is offset by −1-volt comparison voltage so the W Unit can be used as a current meter for making 5 pA/cm measurements. Dynamic measurements of extremely high values of leakage resistance not ordinarily possible with the usual 1- or 10-meg input resistor can be made. Transmission line leakage resistance, for example, can be measured by connecting a well-filtered voltage source between the ungrounded shield of the coax and ground. The center conductor of the coax is connected to the W-Unit input connector. As an example, assume +50 volts is applied to the shield and the trace moves two cm from the reference. This is equal to 10 picoamperes of current. Using Ohm's law, the leakage resistance is $5 \times 10^{12}$ ohms.

# SECTION 3
# CIRCUIT DESCRIPTION

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

## BLOCK DIAGRAM DESCRIPTION

This description is based on the block diagram located at the back of this manual. Signals applied to the A and B input connectors pass through the INPUT ATTEN and DISPLAY switches to the gates of Field Effect Transistors Q113A and Q113B in the Input Source Follower stages. The INPUT ATTEN switches control the magnitude of the input signals applied to the stages, and the DISPLAY switch controls the mode of operation for the W Unit.

Accurate ±DC comparison voltages are obtained from the $V_C$ supply. These voltages can be applied to the gate of either Q113A or Q113B by means of the DISPLAY switch. In differential-comparator mode of operation, the voltages are applied to one gate and the signal is applied to the other.

The low-capacitance, high-impedance input of the Input Source Follower stages isolate the input circuit from the succeeding stages. The Input Source Followers are designed to accept input signals as great as ±15 volts without being overloaded. Special constant-current circuits tend to prevent the source followers from cutting off or drawing gate current with high-amplitude, low-frequency signals.

The output of the Input Source Followers is applied to the base circuits of the Differential Amplifier stage. This stage also employs a constant-current circuit to permit handling large common-mode signals without distortion. Gain of the stage, and hence the vertical deflection factor, can be controlled by means of the MILLIVOLTS/CM switch.

In differential-comparator mode of operation the voltages add differentially to the signal within the Differential Amplifier stage. When the W Unit is used for differential-input-preamplifier mode of operation, a similar operation occurs because the signals applied to both inputs add differentially in this stage. The resultant output is applied to the Output Amplifier stage. Here the signals are further amplified and then applied to the input of the oscilloscope vertical amplifier through pins 1 and 3 of the interconnecting plug. Overall gain of the W Unit at a maximum sensitivity of 1 mV/cm is 100, push-pull.

Throughout the following discussions refer to both the block and circuit diagrams at the back of this manual.

## DETAILED CIRCUIT DESCRIPTION

### Comparison Voltage Supply

To make the W Unit operate at its specified comparison voltage accuracy, the comparison voltage ($V_C$) supply must maintain a constant voltage independent of environmental temperature changes and differences in the regulated power supply voltages between one oscilloscope and another. To obtain this high accuracy the comparison voltage is derived from a precision diode reference element D301. This element is a special device which compensates itself for temperature. Its output is nominally 11.7 volts and the voltage remains constant within 0.001% per degree centigrade change.

When the $V_C$ RANGE switch SW310 is set to the +11 or +1.1 position, D301 cathode is connected through R301 to the +225-volt supply to provide the plus (+) comparison voltage to the $V_C$ output circuit. D301 anode is connected to ground. R301 sets the current for D301 so the element can operate in its temperature-stable region. The $V_C$ output circuit, composed of the COMPARISON VOLTAGE control SW320 and R325 with associated components, make up the load for D301.

When the $V_C$ RANGE switch is set to 0, D301 anode connects through R303 to the −150-volt supply and the $V_C$ output circuit is disconnected. To take the place of the $V_C$ output circuit, R306 is connected across D301 to simulate normal loading for the reference element. D301 cathode connects to ground.

When the $V_C$ RANGE switch is set to −11 or −1.1, D301 anode connects through R303 to the −150-volt supply and the cathode is connected to ground. D301 anode also connects to the $V_C$ output circuit to provide the minus (−) comparison voltages.

### Comparison Voltage Range

The comparison voltage range circuitry consists of R308, R310, R313, and R315 connected to the associated switch positions of the $V_C$ RANGE switch. The $V_C$ RANGE switch selects the range; the COMPARISON VOLTAGE control in the $V_C$ output circuit selects the digits within that range.

Resistor R308 is selected for value when paired with D301. The reference element is a 5% diode and so a value for R308 is chosen that will set the comparison voltage well within the adjustment range of the $V_C$ CAL control R310. The $V_C$ CAL control is small in value to minimize effect of R310 temperature coefficient and to provide sufficient resolution so the comparison voltage can be set accurately. The control is adjusted so the comparison voltage is exactly +11 volts as measured between the $V_C$ OUTPUT connector and ground. As a necessary condition prior to adjusting R310, the $V_C$ RANGE switch is set to +11 and the COMPARISON VOLTAGE control to 11 (10-10-0). This condition essentially places the $V_C$ OUTPUT connector at the same voltage level as that obtained between the top end of R330 (referring to the Switching Diagram) and ground.

When the $V_C$ RANGE switch is set to +1.1 or −1.1, a precision divider network consisting of R313 and R315 reduces the comparison voltage by 10:1 so the voltage is exactly 1.1 volt as measured between the $V_C$ OUTPUT and ground with the COMPARISON VOLTAGE control set to 10-10-0 which, in this case, is 1.10.

When the $V_C$ RANGE switch is set to the 0 position, no comparison voltage is applied to this portion of the circuitry or the $V_C$ output circuit.

The use of ±11- and ±1.1-volt ranges instead of the usual ±10- and 1-volt ranges extends the comparison voltage ranges by 10%. This permits using the 10% increase range for overlapping coverages between the ranges and to extend the highest ranges. For example, when using the 1.1-volt range, the COMPARISON VOLTAGE control can be used at the 1-volt level to make measurements without having to switch to the next higher range.

## Comparison Voltage Output Circuit

The comparison voltage output circuit (see Fig. 3-1 and the Switching Diagram) is composed of the COMPARISON VOLTAGE control SW230 and R325 with associated circuitry. The COMPARISON VOLTAGE control is a combination of two controls: (1) switch SW320 selects the first digit within the range set by the $V_C$ RANGE switch, and (2) the 10-turn potentiometer R325 selects the remaining digits.

Twelve resistors R330 to R341, make up the main divider in the $V_C$ output circuit. The comparison voltage is

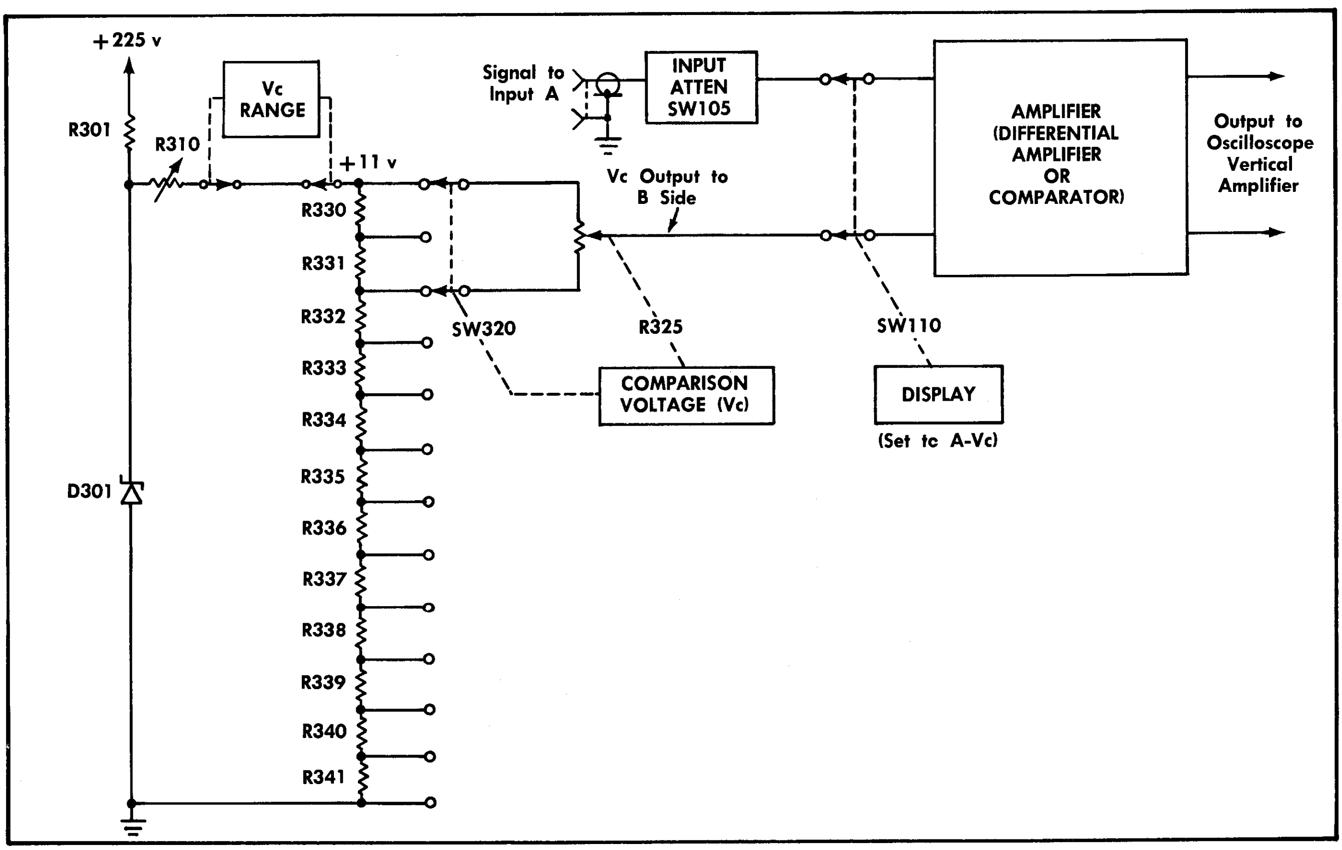



**Fig. 3-1. Simplified diagram of the comparison voltage circuit and how it is connected to the amplifier for A−$V_C$ differential-comparator mode of operation.**

applied to the top end of the divider and the bottom end is grounded. A shunt divider consisting of R322, R323, and R325 is connected across two of the resistors in the main divider by means of SW320. The equivalent resistance of the shunted portion of the main divider is equal to 1 kΩ. The TRACKING control R323 provides the means for setting this resistance accurately. Thus, the main divider is actually divided into eleven equal divisions of 1 kΩ each. If the $V_C$ RANGE switch is set to +11 or −11, for example, there will be one-volt drop across each 1 kΩ resistor.

Switch SW320 has 11 positions to permit switching the shunt divider across two resistors at a time along the string of resistors in the main divider. Each position corresponds to one digit of voltage. Variable control R325 in the shunt circuit is the vernier control for dividing the comparison voltage further so the smaller divisions of the voltage can be measured. For example, if the $V_C$ RANGE switch is set to +11, SW320 is set to 6 and R325 is set to 125, the comparison voltage reading is +6.125 volts.

The comparison voltage set by R325 is applied through the DISPLAY switch directly to the comparator. In contrast, any signals applied to the A or B input connectors, depending on which input is selected, must pass through the INPUT ATTEN switch. The switch, by means of selectable attenuators, attenuates the signal 1, 10, 100, or 1000 times.

Besides being applied through the DISPLAY switch to the comparator, the same comparison voltage from R325 is also applied to the front-panel $V_C$ OUTPUT connector. This connector permits connecting any nulling-type meter or infinite-impedance-type meter to this point so the voltage can be monitored. The output voltage at the connector is very limited in current output, therefore, meters which draw negligible current should be used to prevent measurement errors. For further information refer to the topic "$V_C$ OUTPUT Connector" in the Operating Instructions section of this manual.

Signals applied to input connectors A and B of the W Unit must pass through the AC-DC-GND switches to the INPUT ATTEN switches. Since the input circuits of the unit are the same and the amplifier is push-pull, the signal path for input A is described in some detail in this circuit description.

When the AC-DC-GND switch SW101 is set to AC, the signal is coupled through C102 to INPUT ATTEN switch SW105. When SW101 is set to DC, input coupling capacitor C102 is bypassed and the signal is applied directly to SW105. When SW101 is set to GND, the A input signal is disconnected and the input path to the INPUT ATTEN switch is grounded to prevent stray signal pickup and to permit operating the W Unit as a conventional preamplifier.

## Input Attenuation

The INPUT ATTEN switch SW105/SW205 is a dual, gear driven, single-drive, five-position switch that selects the various attenuator sections for both inputs simultaneously. When the INPUT ATTEN switch is set to R $\approx \infty$, no attenuation takes place and there is no gate-to-ground resistance. Instead, the resistance path is through the external load to ground, provided the AC-DC-GND switch for the input connector to be used is set to DC.

When the INPUT ATTEN switch is set to 1, there is no attenuation of the signal. The gate-to-ground resistance is R105A and R105B connected in series. Resistor R105B is adjusted so the input resistance matches the 10X input resistance.

For the 10, 100, and 1000 settings of the INPUT ATTEN switch, attenuator networks are individually switched into the circuit to attenuate the signal before it is applied to the Input Source Follower stage. The attenuator networks are frequency-compensated RC voltage dividers. At DC and very low frequencies the dividers are resistive because the impedance of the capacitors is high and their effect in the circuit is negligible. As the frequency of the input signal increases, however, the impedance of the capacitors decreases and their effect in the circuit becomes more pronounced.

When the INPUT ATTEN switch is set to 10, for example, R106E adjusts the DC attenuator ratio so it is exactly 10 to 1. For higher frequencies, C106C, a coarse adjustment, and C106E, a fine adjustment, are used to frequency-compensate the divider so the capacitive reactance ratio is equal to the resistance ratio. The adjustments in the B input 10X attenuator are adjusted the same as the A input adjustments. When the input attenuator adjustments are accurately set, optimum common-mode rejection is achieved.

C106B in the 10X attenuator is adjusted so the input RC of the attenuator is 20 pF X 1 MΩ. When making the adjustment, an Input Time-Constant Normalizer is used as the reference. Each attenuator is "normalized" in this manner. Thus, an attenuator probe, when connected to the input connector and properly adjusted, will work into the same input time constant regardless of the INPUT ATTEN switch position with the exception of the R $\approx \infty$ position.

## DISPLAY Switch

The DISPLAY switch SW110 connects one or the other input, or both in the A—B position, to the Input Source Follower stages. In the A—$V_C$ position the A input signal is applied to the gate of Q113A and the comparison voltage is applied to the gate of Q113B. A normal or upright display will be obtained. That is, a + voltage applied to input A moves the trace upward on the CRT. A + comparison voltage, added differentially by the W Unit amplifier stages, drives the trace downward for obtaining a null.

In the $V_C$—B position, the B input signal is applied to the gate of Q113B and the comparison voltage is applied to the gate of Q113A. The display will be inverted; that is, if a + voltage is applied to the B input, the trace moves downward. A + comparison voltage applied to the A input moves the trace upward to obtain a null.

In the A—B position, the W Unit is an ordinary differential amplifier. Both inputs are active and the difference between the A and B signals is displayed. In this mode of operation the comparison voltage is not used, but it is available at the $V_C$ OUTPUT connector.

## Input FET Source Follower Stages

Signals from the display switch are applied to the Input FET Source Follower stages. The stage for the A input side consists of Q113A, Q104, V124A, V114A, and associated circuitry. For the B side, the stage consists of Q113B, Q204, V214A, V124B and associated circuitry.

The wide dynamic operating range of the W Unit requires constant current operation of the Input FET Source Follower and the Differential Amplifier stage that follows. To achieve this type of operation, Q113A source connects through V124A, R126, R127 to −150-volts. Q104 acts as a Gm multiplier for Q113A (Q204 performs a like function for Q113B). 15-volt signal swings applied to the gate of Q113A cause only a 0.5-volt change at the cathode of V124A. This produces considerably less current change than if the source of Q133A were connected through a resistor to −150-volts. In addition, the drain of Q113A is bootstrapped by V114A. The bootstrapping action is through voltage-dividing resistors R118 and R119. Bootstrapping minimizes capacitance from gate to drain. For example, 1-volt change on the gate results in about 1-volt change on the drain. There is insignificant change in potential, so there is no charge current, and looking into the input there seems to be no capacitance.

The R101-C101 network aids in compensating for negative input resistance of the Input Source Follower.

R110 limits the current in case of overload (maximum input voltage is 500 volts AC coupled, 350 volts DC coupled). C112 is a frequency compensation bypass.

Input protection circuitry is provided by the bipolar limiting circuits, consisting of D113A, D113B, D130, D131, D132, R133, C130, D120, D121, D122, R120 and C120. The input voltage at the junction of R110 and the gate of Q113A cannot exceed −15-volts. D213A and D213B also limit the input voltage for the B channel to protect its input circuitry.

Q195 and Q196 with their associated circuitry comprise another protective circuit. This circuit keeps Q134 from conducting until approximately 45 seconds after power is applied to the W Unit (after the oscilloscope relay has activated). When power is first applied, Q195 is in the ON condition and Q196 is in the OFF state, until C196 charges up. When C196 is charged, Q196 turns ON and Q195 turns OFF. This allows Q134 to start conducting. D195 limits the voltage to Q195 and Q196 junctions when power is first applied to the W Unit.

D140 holds the collector of Q134 near ground during the 45 second warm-up time. This protects Q154A from drawing too much current at that time. At the end of warm-up time, diode D140 becomes reverse biased, and the required current flows through V114A, V124A, and V114B.

The DIFF BAL control R223, in conjunction with R122 and R222 serve to load the cathodes of the bootstrapping cathode followers V114A and V214A so both sides can be gain-balanced. By adjusting R223 the gain of V114A, for instance, can be made to decrease while the gain of V214A increases. This will differentially adjust the gain of V114A and V214A to make up for small differences in the characteristics of Q113A and Q113B. The gains of Q113A and Q113B must be the same to obtain optimum common-mode rejection.

To prevent trace shift when changing MILLIVOLTS/CM switch SW150 position or rotating the VARIABLE control R155 after the unit has warmed up, the emitter potentials of Q154 must be equal and the plate potentials of V114B and V214B have to be the same. This is accomplished by adjusting the DC BAL control R127. Adjustment of R127 varies the source voltage of Q113A and Q113B (through V124A and V124B) in opposite directions to compensate for slight DC differences between the two sides.

## Differential Amplifier

Signals at the sources of Q113A and Q113B are applied through D142A and D142B to the bases of Q154A and Q154B in their respective channels of the Differential Amplifier stage. This stage consists of V114B, Q154A, Q134, Q154B, and V214B with associated circuitry. The tube-and-transistor combination forms a hybrid circuit which has a very high output impedance and gain of slightly over 10 at a sensitivity of 1 mV/cm. This circuit is capable of handling a large common-mode signal and differentially suppressing this signal so that it will not be applied to the bases of transistors Q174 and Q274 of the following stage. The high output impedance aids in minimizing any current change in the circuit due to the common-mode signal.

Transistors Q154A and Q154B are the comparators in the circuit because they divide up the current passing through them. The current through each transistor is dependent on the relative difference voltages on each base. Q134 is the current source for the comparator transistor and for diodes D142A and D142B. The diodes serve to disconnect the Differential Amplifier stage from the Input Source Followers whenever large signals overdrive the input stage. For example, if B input is grounded and a large negative-going signal overdrives the A Input Source Follower stage, D142A will reverse bias to disconnect the Differential Amplifier from the preceding stage. If a large positive-going signal overdrives the A input side, the opposite occurs. That is, diode D142B reverse biases and disconnects the Differential Amplifier stage from the B Input Source Follower stage. The result is the same as applying a large negative-going signal to the B input side.

The gain of the stage is set by rotating VARIABLE control R155 to its lowest resistance CALIB setting, and by adjusting GAIN control R157 to get the correct amplitude display on the CRT. When the VARIABLE control is turned fully counterclockwise away from its CALIB position, the gain is decreased by a factor of at least 2.5. However, this ratio is actually greater than 2.5 to 1 due to SW155. When the control is turned a few degrees counterclockwise from the CALIB position, SW155 closes and shorts out R157. Gain increases somewhat, thus providing overlapping coverage between the calibrated MILLIVOLTS/CM switch settings.

Resistor R152, connected from the emitter of Q154A to the grid of V114B, bootstraps V114B. The cathode bias for V114B is the emitter-to-collector bias of Q154A. If the emitter rises, the grid rises. In the 1 mV/cm position of SW150 the load resistor for one side is R149 and for the other side it is R249. This makes the load equal to 3 kΩ differentially. To decrease the gain in a 1-2-5 sequence, R165 through R169 are used as shunt resistors. Thus, the sensitivity of the W Unit can be changed from 1 mV/cm to 50 mV/cm. In differential-comparator mode of operation this 50-to-1 gain range is useful as a vertical magnifier for the signal. The vertical size of the waveform changes, but not the comparison voltage.

T150 is a ferrite bead that acts as a suppressor for high-frequency oscillations. Using the bead is similar to adding a resistor in the circuit to lower the Q of the inductance.

## Output Amplifier

The Output Amplifier circuitry consists of two stages of amplification (see Fig. 3-2).

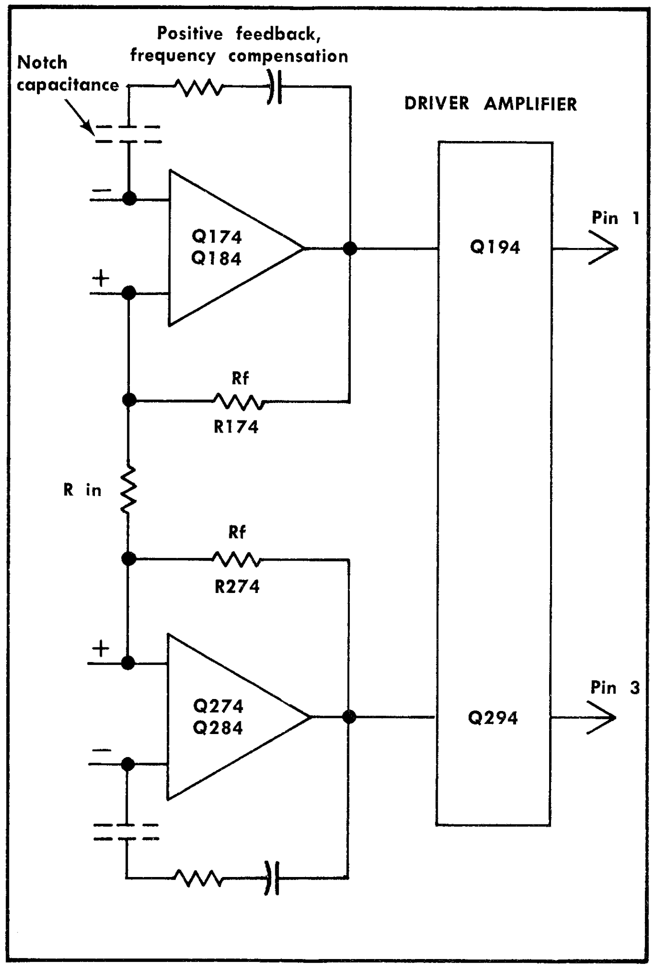



**Fig. 3-2. Block diagram of the Output Amplifier circuit.**

The first stage utilizes Q174, Q184, Q274, and Q284 with their associated components and is configured as two operational amplifiers sharing a $R_{in}$ (the common emitter network of Q174 and Q274, which is essentially the value of R179). R174 and R274 function as the $R_f$ elements for their respective operational amplifier circuits. The $R_{in}$ to $R_f$ ratio of this stage is such that the push-pull signals applied to the stage are amplified by a factor of about 8.

The DC Level control R280 (see Fig. 3-3)., is an adjustment that affects the quiescent DC voltage levels of both Output Amplifier stages. It is adjusted to obtain a 6-volt drop between TP291 and TP296. This voltage drop provides the proper operating voltage for Q194 and Q294. R282 is a selected value that provides the proper range for the DC LEVEL adjustment.

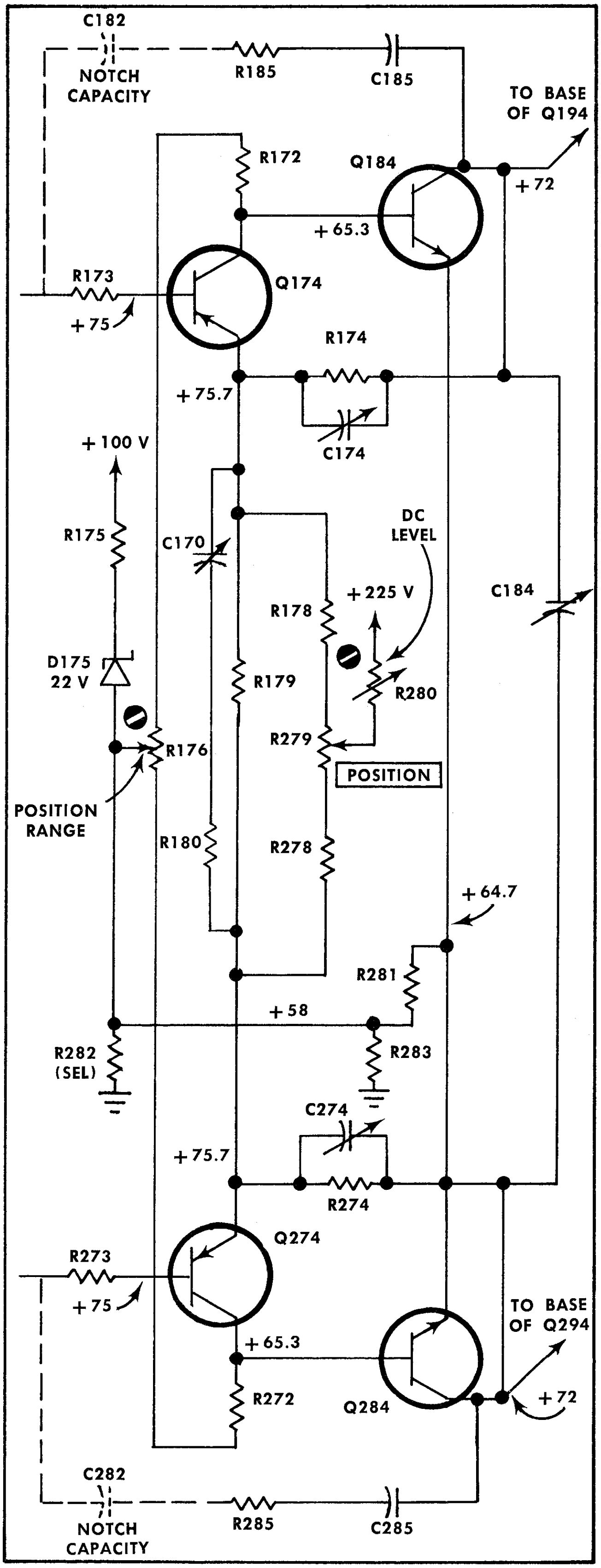



**Fig. 3-3. Partial schematic showing first stage of Output Amplifier circuit.**

Trace positioning is accomplished by diverting current from one side of the circuit to the other with POSITION control, R297. The complementary Position Range control, R176, provides a means of centering the approximate 15 cm of trace positioning range with respect to the oscilloscope graticule centerline.

Frequency compensation for the stage is provided by the adjustable capacitors C174, C274, and C184 and by the two positive feedback circuits which consist of C185, R185, and C182 and of C285, R285, and C282. The capacitance of C182 and C282 is the approximate 0.9 pF between two ceramic strip notches.

The second stage is a driver amplifier consisting of Q194 and Q294 with their associated components (see Fig. 3-4). The circuitry is arranged as a conventional emitter coupled amplifier and is operated in a push-pull mode. Since the gain of this stage is about 2, the gain of the Output Amplifier is approximately 10.

The circuit formed by R287, D293, and R288 provides a low impedance voltage source (D293) for this stage. This circuit will also limit the change in DC voltage level at connector pins 1 and 3 in the event of a severe Output Amplifier circuit imbalance.

## Power Supply Decoupling

The +225-, +100-, and −150-volt supplies are decoupled to prevent any oscilloscope power-supply signals from affecting the operation of the W Unit. Capacitor C286 provides a bypass path to ground for any signal variations that might come in from the +75-volt source.

## Heater Circuit

Direct current is used too operate the heaters in the W Unit. A constant DC voltage source instead of AC is used to avoid the possibility of cathode modulation at line frequency.

A total current of 180 mA is required for proper heater operation. A current of 150 mA is available through pin 15 of the interconnecting plug and the balance (30 mA) is obtained from pin 10 (decoupled +100-volt supply) through R286.

The voltage at pin 15 is +75 volts. This voltage is obtained from the +100-volt regulated supply by dropping 25 volts either across two tubes or a resistor in the oscilloscope, depending on whether the oscilloscope has two time bases or one. Since the heater string requires only 36 volts for proper operation, about 39 volts is dropped across resistors R290 and R292.

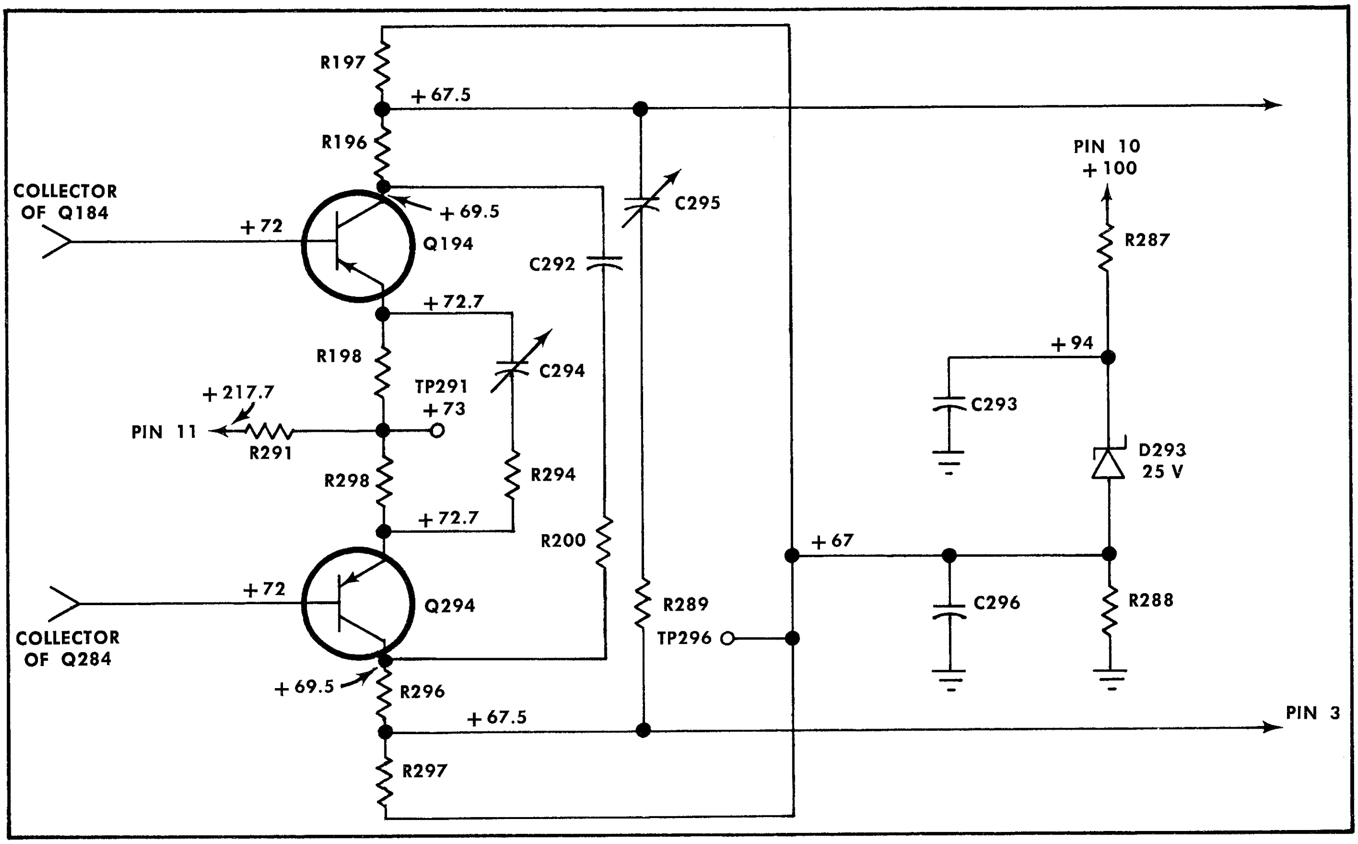



Fig. 3-4. Partial schematic showing the second stage of the Output Amplifier circuit.

## 81-Volt Supply

+81 volts is obtained at the junction of D175 and R175 for application to the plate circuits of V114B and V214B. This voltage establishes the DC output level at pins 1 and 3 of the interconnecting plug.

## 24-Volt Power Source

The +24-volt power is obtained from Zener D193. The cathode end of D193 connects through R193 to the +100-volt supply and the anode terminal connects to ground.

The +24 volts is applied to the center arm of the DIFF BAL control R223. Elevating the control to this voltage level reduces the loading effect on V114A and V214A by reducing the standing current. Since the arm of R223 usually ends up being near center when properly adjusted, current drawn through R122 and R222 is very small.

## NOTES

# SECTION 4 MAINTENANCE

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

## PREVENTIVE MAINTENANCE

### Cleaning the Interior

To clean the interior of the W Unit, blow off the accumulated dust using low-velocity compressed air. A very high-velocity air stream should be avoided, however, to prevent damage to some of the components.

### Visual Inspection

Many potential or existing troubles can be detected by a visual inpsection of the unit. For this reason, a complete visual check should be preformed periodically or every time the unit is inoperative, needs repair, or needs to be calibrated. Visual defects may include loose or broken connections, damaged connectors, improperly seated tubes or semiconductors, and scorched or burned parts.

The remedy for these troubles is readily apparent except in the case of heat-damaged parts. Damage to parts due to heat is often the result of other less apparent troubles in the unit. It is essential that the cause of overheating be determined and corrected before replacing the damaged parts.

### Checking Tubes and Semiconductors

Periodic checks on the tubes and semiconductors using a tester are not recommended. Tube and semiconductor testers in many cases indicate a defect when a component is operating satisfactorily in a circuit, and fail to indicate defects which affect circuit performance.

The true test of tube or semiconductor usability is whether or not the component works properly in the circuit. If it is working correctly, it should not be replaced.

### Calibration

The W Unit should provide many hours of trouble-free operation. However, to insure the reliability of measurements, check the calibration of the unit after each 500-hour period of operation (or every six months if the unit is used intermittently). A complete step-by-step procedure for calibrating the unit and checking its operation is given in the Calibration section of this manual.

## CORRECTIVE MAINTENANCE

### Soldering Techniques

**Replacing Components on the Circuit Board.** Use ordinary electronic grade 60/40 solder and a 35- to 40-watt pencil soldering iron with a 1/8-inch wide chisel tip. The tip of the iron should be clean and properly tinned for best heat transfer in a short time to a soldered connection. A higher wattage soldering iron, if used and applied for too long a time, may ruin the bond between the etched wiring and base material by charring the glass epoxy laminate. Component replacement techniques are as follows:

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

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

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

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

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

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

7. Clean all flux from the joint, thus assuring good environmental characteristics and appearance.

**Soldering to metal terminals.** When soldering to metal terminals (e.g., interconnecting plug, tube, or transistor socket), use ordinary 60/40 solder and a 40- to 75-watt soldering iron. Use a soldering iron tip having a shank diameter of 1/8-inch to reach connections located in high-density component areas.

Allow the joint to heat sufficiently to permit the solder to flow freely and to form a smooth, slight fillet around the wire. Due to the high-frequency requirements of the W Unit, the leads on some components are cut short; for example, in the input circuits of the amplifiers when these components are replaced, the leads should be clipped to match the leads of the components that were removed. After clipping the wires, be sure to remove all clippings that fall into the unit.

In soldering leads or coax braids to ground, use a 50- to 75-watt iron with a tip having a shank diameter of about 1/4-inch. The higher wattage iron and heavier tip will assure that the connection receives adequate heat to make a good solder joint.

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

**Soldering to Ceramic Terminal Strips.** A special silver-bearing solder is used to establish a bond to the ceramic terminal strips. This bond can be broken by repeated use of ordinary tin-lead solder, or by excessive heating of the junction with a soldering iron. Occasional use of ordinary tin-lead solder will not break the bond if normal heat is applied.

If you frequently perform work on Tektronix instruments it is advisable to have a stock of solder containing about 3% silver. This type of solder is used often in printed circuitry and is generally available locally. It may also be purchased directly from Tektronix in one-pound rolls. To order the solder specify part number 251-0514-00.

Because of the shape of the terminals on the ceramic terminal strips, you may prefer to use a wedge-shaped tip on your soldering iron. Such a tip allows you to apply heat directly to the junction and reduces the overall heating effect. It is important to use as little heat as possible while producing a full-flow joint.

When removing or replacing components mounted on the ceramic strips, the procedure can be summed up as follows:

1. Use a soldering iron having a rating of about 40 to 75 watts.

2. Apply one corner of the soldering iron tip to the notch where you intend to unsolder the lead.

*NOTE*

*If the tip of the iron is placed partly in the notch, do not twist the iron as this might chip or break the ceramic strip.*

3. Apply only enough heat to melt the solder and remove the lead. If long-nose pliers are used to grip the lead to be removed, use the very tip of the pliers to keep from drawing away too much heat.

4. When resoldering the lead, apply enough heat to make the solder flow freely.

5. Do not attempt to fill the notch on the strip with solder; instead, apply sufficient solder to cover the wire adequately and to form a slight fillet on the wire.

6. Clean the flux from the joint.

## Removing Ceramic Terminal Strips

To remove a ceramic terminal strip, unsolder all components and connections, then pry the strip with nylon studs attached out of the chassis. Another method is to use diagonal cutters to cut off one side of each stud to free the strip, but try not to damage the nylon spacer. After removing the strip, the remainder of each stud can be easily extracted from the chassis with a pair of pliers. The studs need not be salvaged since new ones are furnished with the new strips. If the spacers are not damaged, they may be reused as long as they hold the strip assembly securely.

To install a new strip, place the spacers in the chassis holes, insert the stud through the spacers, and press down on top of the strip above the studs. Use a plastic

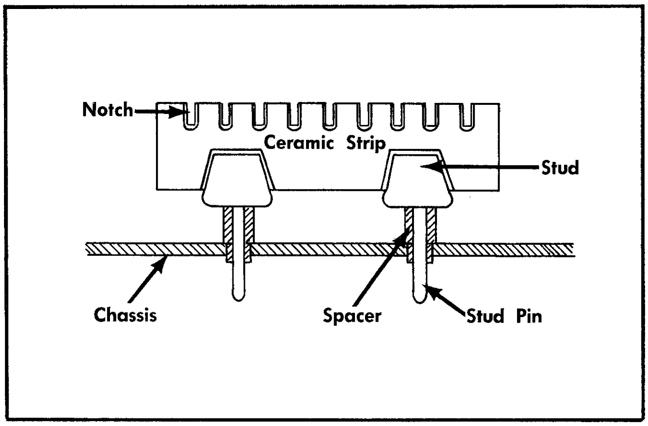



Fig. 4-1. Installation of a ceramic strip.

or hard rubber mallet, if necessary, to seat the studs firmly. Be sure to tap lightly **directly above** the studs and drive them down in equal increments to keep from placing too great a strain on the strip. Fig. 4-1 illustrates the way the parts fit together. If desired, the extending portion of the stud pins can be cut off to within about an eighth of an inch of the lower end of the spacers.

Observe all soldering precautions described earlier when soldering leads to the strip.

## Removing and Replacing Switches

If either of the AC-DC-GND switches is defective, remove and replace the switch. Use normal care in disconnecting and reconnecting the leads. To remove the nut that mounts the switch to the panel, use a 1" open end wrench which is ground down for clearance.

Single wafers or mechanical parts on rotary switches are not normally replaced. If the switch is defective, the entire switch should be replaced. The INPUT ATTEN, DISPLAY, and the MILLIVOLTS/CM switches can be ordered through your local Tektronix Field office or representative either unwired or wired, as desired. Refer to the Parts List to find the unwired and wired switch part numbers.

**CAUTION**

*When disconnecting or connecting leads to a wafer-type switch, do not let solder flow around and beyond the rivet on the switch terminal. Excessive solder can destroy the spring tension of the contact.*

# OBTAINING REPLACEMENT PARTS

## Standard Parts

Replacements for all parts used in constructing the W Unit can be purchased through your local Tektronix Field office or representative. Many of the components, however, are standard electronic parts that can usually be purchased locally in less time than required to obtain them from Tektronix, Inc. Before purchasing a part, be sure to consult the Parts List of this manual to determine the tolerance and rating required. The Parts List gives the values, tolerances, rating, and Tektronix part number for all components used in the unit.

## Special Parts

In addition to the standard electronic components mentioned in the previous paragraph, special parts are also used. These parts are manufactured or selected by Tektronix to satisfy particular requirements, or are manufactured especially for Tektronix by other companies. These parts and most mechanical parts should be ordered from Tektronix, since they are normally difficult or impossible to obtain from other sources. Order all parts through your local Tektronix Field Office or representative.

# TROUBLESHOOTING INFORMATION

## Introduction

In the event a trouble develops, use the information in this portion of the manual to more efficiently troubleshoot the W Unit. The information starts with preliminary checks to make, and then advances to detailed circuit troubleshooting.

## Front-Panel Controls

Before troubleshooting, double-check the front-panel controls for proper settings. Also, check the front-panel screwdriver adjustments to determine if their settings are proper. This is important since symptoms caused by incorrect front-panel control settings are not described in this section of the manual.

If you are in doubt as to the proper settings of the controls or their functions, refer to the Operating Instructions section. If the front-panel controls are properly set and you find that a trouble definitely exists, first check to determine whether the trouble is in the oscilloscope or the W Unit.

## Type W or Oscilloscope

When following a troubleshooting procedure, it is assumed that the oscilloscope used with the W Unit is operating normally. Since this is not always the case, check the operation of the oscilloscope before attempting to troubleshoot the W Unit.

Troubles occuring in the oscilloscope can usually be detected by substituting another plug-in unit for the W Unit.

*NOTE*

*Be sure the proper line voltage is applied to the oscilloscope used with the W Unit.*

If the W Unit is definitely at fault and not the associated oscilloscope, make a careful operational check of the W Unit. Carefully note the effect that each front-panel control has on the symptom. By analyzing such effects, you can sometimes isolate a trouble to either a defective control or circuits containing the trouble. In addition, the normal or abnormal operation of each control should indicate checks to make.

The remainder of this section deals with more detailed troubleshooting. Table 4-1 gives several symptoms of troubles as an aid to isolating the trouble to certain stages or circuits.

A step-by-step method for checking and adjusting the W Unit is given in the Calibration section. The calibration procedure can be used to check the operational standards of the unit. Any deficiency that shows up while performing the steps can lead you to the area at fault and the possible causes.

## Diagrams

Block and circuit diagrams are contained at the back of this manual. The circuit diagrams contain component circuit numbers, voltages, and waveforms. Conditions under which the voltages and waveforms were taken are also indicated adjacent to the diagrams.

## Coding of Switch Wafers

Switch wafers shown on the circuit diagrams are coded to indicate the physical location of the wafer on the actual switches. The number portion of the code refers to the wafer number of the switch assembly. Wafers are numbered from the first wafer located behind the detent section of the switch to the last wafer. The letters F and R indicate whether the front or rear of the wafer is used to perform the particular switching function. For example, 2R of the MILLIVOLTS/CM switch is the second wafer when counting back from the detent section, and R is the rear side of the wafer.

## Cable Color Coding

All wiring in the W Unit is color coded to facilitate circuit tracing. The power-supply wires originating at the W Unit interconnecting plug and the +24-volt source are identified by the following code.

| Supply Voltage | Cable Color Code |
|---|---|
| +225 V | Red/red/brown on white |
| +100 V | Brown/black/brown on white |
| +75 V | Green on white |
| +24 V | Red/black/brown on white |
| −150 V | Brown/green/brown on tan |

## Test Equipment

When preparing to circuit troubleshoot the W Unit, you may find useful some of the minimum equipment described here.

(1) Transistor Tester

Description: Tektronix Type 576 Transistor-Curve Tracer.

Purpose: Test transistors and diodes used in the W Unit.

(2) VOM

Description: 20,000 Ω/V DC. Be sure the test prods are well insulated (except for the very tip) to prevent accidental shorts when reaching a test point.

Purpose: Precision and general-purpose use. Can also be used to check transistors and diodes if used with care. When checking semiconductors use ohmmeter ranges (usually R X 1K and higher) that deliver less than 2 mA of current at full deflection. Preferably, use a good transistor and diode tester in place of the VOM for this purpose.

(3) Test Oscilloscope

Description: Bandwidth, DC to 300 kHz or better. Calibrated vertical deflection factors down to 5 mV/cm without a 10X probe (with a 10X probe, 50 mV/cm). Input resistance, 1 megohm without a 10X probe; 10 megohms with a 10X probe.

Purpose: For low-frequency signal-tracing and checking DC levels in the amplifier stages.

(4) Flexible Plug-In Extension

Description: 30 inches long, Tektronix Part No. 012-0038-00.

Purpose: Permits operating the W Unit out of the oscilloscope plug-in compartment for better accessibility.

(5) BNC Coaxial Cables (two required)

Description: Equipped with BNC plug connectors on each end. Tektronix Part No. 012-0057-01.

Purpose: Use in low-frequency signal-tracing setup to apply the oscilloscope calibrator signal to the W Unit and to the test oscilloscope Ext Trig input connector.

(6) BNC T Connector

Description: Fits a BNC jack and accepts 2 BNC plugs. Tektronix Part No. 103-0030-00.

Purpose: Use in a low-frequency signal-tracing setup for connecting to the two BNC coaxial cables (item 5) and to the Cal Out connector on the oscilloscope used with the W Unit.

(7) Miscellaneous: Replacement tubes, transistors, and diodes.

## Troubleshooting Chart

The Troubleshooting Chart, Table 4-1, lists a variety of symptoms with possible causes and the probable area of fault. If there is an apparent trouble in your W Unit, find the symptom in the table that most nearly describes the trouble in your plug-in unit.

Then perform the checks described in the table. For further aid, the chart may direct you to either of two topics that follow the chart. The topics are (1) Isolating DC Imbalance, and (2) Signal Tracing.

## Isolating DC Imbalance

To make a free-running trace appear within the usable viewing area of the CRT, the DC output voltage at pins 1 and 3 of the interconnecting plug must be essentially equal — that is, within a fraction of a volt (see Fig. 4-2). As little as 0.4-volt difference between

**TABLE 4-1**

**Troubleshooting Chart**

| Symptoms | Checks to Make: Possible Causes | Checks to Make: Area at Fault |
|---|---|---|
| No trace. | Check these nominal supply voltages in the W Unit: +225 V, +100 V, +81 V, +75 V, +24 V, and −150 V. If any of these voltages are incorrect, find the trouble before going to the third column. Some possible causes are:<br>Defective interconnecting plug.<br>R190, R192, or R195 open.<br>Open filament in one of the tubes. | Check for DC imbalance in the W Unit amplifier stages. Refer to topic — Isolating DC Imbalance. |
| Stationary trace.<br>Cannot be positioned. | C184 or C295 shorted. | Check Output Amplifier. |
| Trace but no signal display when signal is applied to input A. | Defective AC-DC-GND switch SW101.<br>Open connection at the A input connector or at SW101 switch. | Check input circuit of Q113A. |
| Trace but no signal display when signal is applied to input B. | Defective AC-DC-GND switch SW201.<br>Open connection at the B input connector or at SW201 switch. | Check input circuit of Q113B. |
| Low Gain. | | Signal trace through the W Unit. Refer to topic — Signal Tracing. |
| Comparison Voltage incorrect; RANGE switch set to −11, −1.1, +1.1, or +11. | D301 defective. | Check for trouble in these circuits: Vc Supply, Vc Range, or Vc Output. |

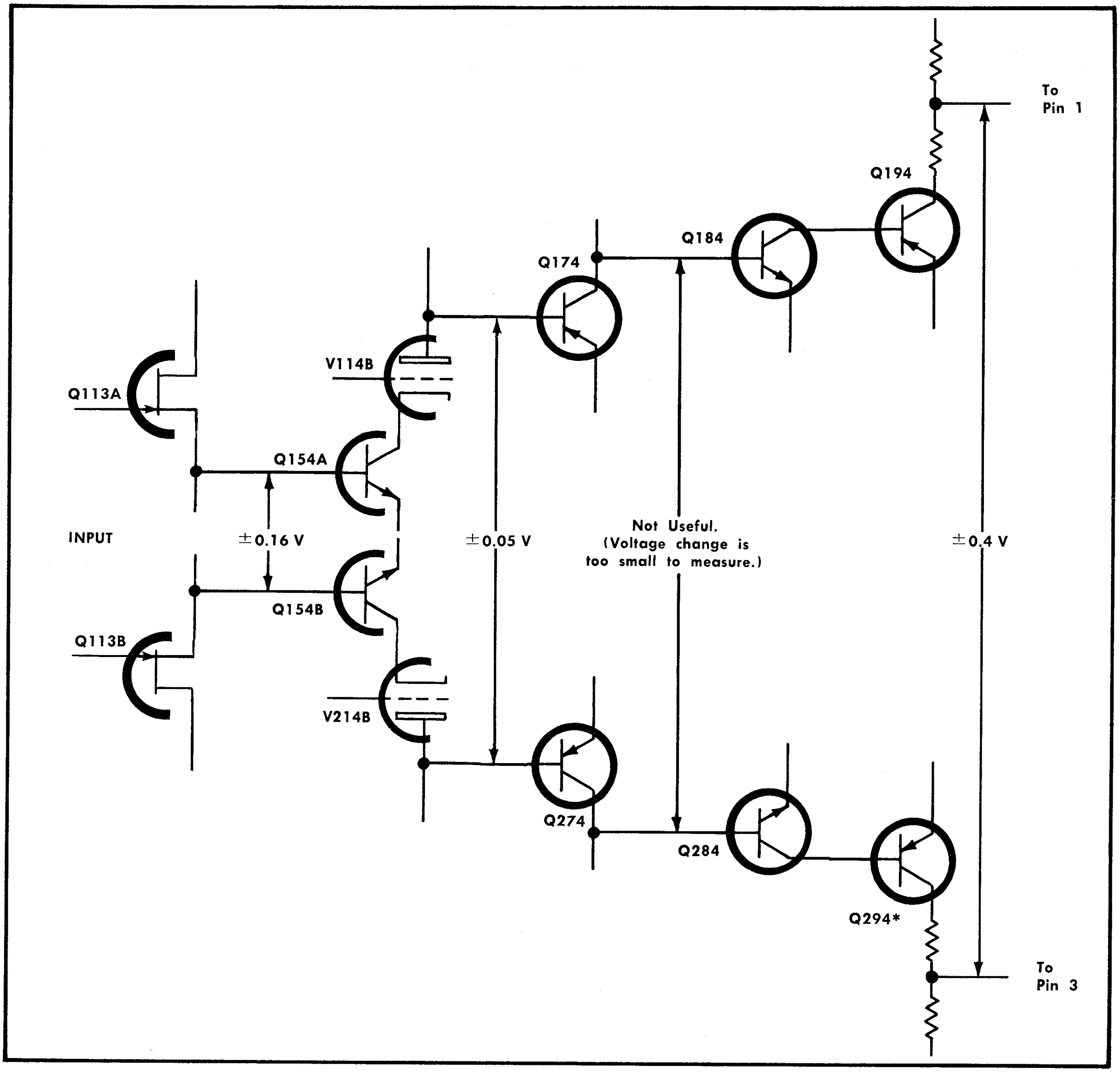



Fig. 4-2. Simplified schematic diagram of the W Unit amplifier stages.

these two points positions the beam above or below the range of visibility, assuming the W Unit is used with an oscilloscope having a 6-cm high viewing area.

The DC output voltages depend on the DC balance in all stages of the W Unit amplifier. Since the stages are DC coupled, a condition anywhere between the input and output that unbalances the output voltage more than 0.4 volt can cause the trace to deflect out of the viewing area.

The procedure for isolating the cause of DC imbalance is to set the W Unit front-panel controls as follows:

| | |
|---|---|
| Vc RANGE | As is |
| COMPARISON VOLTAGE | As is |
| AC-DC-GND (both A and B) | GND |
| INPUT ATTEN | 1 |
| DISPLAY | A-B |
| MILLIVOLTS/CM | 50 |
| VARIABLE | CALIB |
| POSITION | Centered |

Then, connect a DC voltmeter (starting from the input) between corresponding points in the amplifier as shown in Fig. 4-2 to determine where the imbalance originates. For example, if the voltmeter is connected between the sources of Q113A and Q113B and the reading is within the range indicated in the illustration, then this stage is properly DC balanced. It also means that the DIFF BAL, and DC BAL controls are properly set. If the voltmeter is connected between the plate of V114B and the plate of V214B and if the reading is greater than the voltage range given in the illustration, then the DC imbalance is originating in the Amplifier stage V114B/Q154A/Q134/Q154B/V214B. Make detailed voltage and resistance checks to determine the exact cause of the DC imbalance.

## Signal Tracing

The following information supplements Table 4-1. A method is described here for checking waveform amplitude, polarity, and DC level at the points where the waveforms were obtained on the diagrams. The technique used here is limited to low frequency because a plug-in cable extension is used to operate the W Unit out of the oscilloscope plug-in compartment. Using the cable extension permits access to all sides of the W Unit for detailed signal tracing and troubleshooting.

After the W Unit is working properly at the low frequencies, then it is easy to go directly to the Calibration procedure to check square-wave response or differential rejection at the higher frequencies.

*IMPORTANT*

*The amplitude and DC level shown adjacent to each waveform in the schematics are intended as a guide and are not absolute. They may vary due to gain-adjustment setting, normal manufacturing tolerances, and characteristics of tubes and semiconductors.*

To signal trace the W Unit amplifier stages, proceed as follows:

1. Set the front-panel controls of the W Unit to the same positions as indicated in the chart adjacent to the High-Gain Differential Comparator schematic diagram.

2. Connect a 30 inch plug-in cable extension 012-0038-00 between the W Unit and the associated oscilloscope.

3. Apply a 2-volt peak-to-peak calibrator signal from the oscilloscope Cal Out connector through coax cables to the W Unit A input connector and to the test oscilloscope Ext Trig input connector.

4. Set the test oscilloscope input coupling switch to AC.

5. Touch the tip of the probe to the rear side of the A input connector. Set the front-panel controls on the test oscilloscope to display one or two cycles of the calibrator waveform. Be sure to set the test oscilloscope triggering controls for external triggering and display the first 1/2-cycle of the waveform as positive going. The displayed waveform will then correspond to the input waveform polarity shown at the A input connector on the schematic diagram. Disconnect the probe.

6. Touch the probe tip to the desired test point in the W Unit circuitry. Set the test oscilloscope Volts/Cm switch to correspond to the setting given at the left of the waveform on the diagram.

7. Check amplitude and phase of the waveform. Then disconnect the probe.

8. Set the test oscilloscope input coupling switch to DC. Preset the test oscilloscope Volts/Cm switch such that the expected DC voltage to be measured in step 9 will keep the display within the graticule area. Ground the probe tip to the W Unit chassis and position the trace to establish a zero reference point.

9. Touch the probe tip to the same test point you used in step 6 of this procedure. Determine the DC level of the waveform by measuring the voltage between the reference point established in step 8 and the DC-level point indicated at the right side of the waveform shown on the schematic. Disconnect the probe.

10. Continue on to the next test point and repeat steps 6 through 9 until you reach a test point where an abnormal indication is obtained. Then proceed with detailed troubleshooting checks to find the cause of the trouble. Such checks usually consist of transistor or tube substitution, and voltage and resistance checks.

## Circuit Boards

Fig. 4-3 shows the Output Amplifier board, Fig. 4-4 shows the FET Input Amplifier board. The component numbers are shown, and the connections from the board to the associated circuits are identified to facilitate circuit tracing.

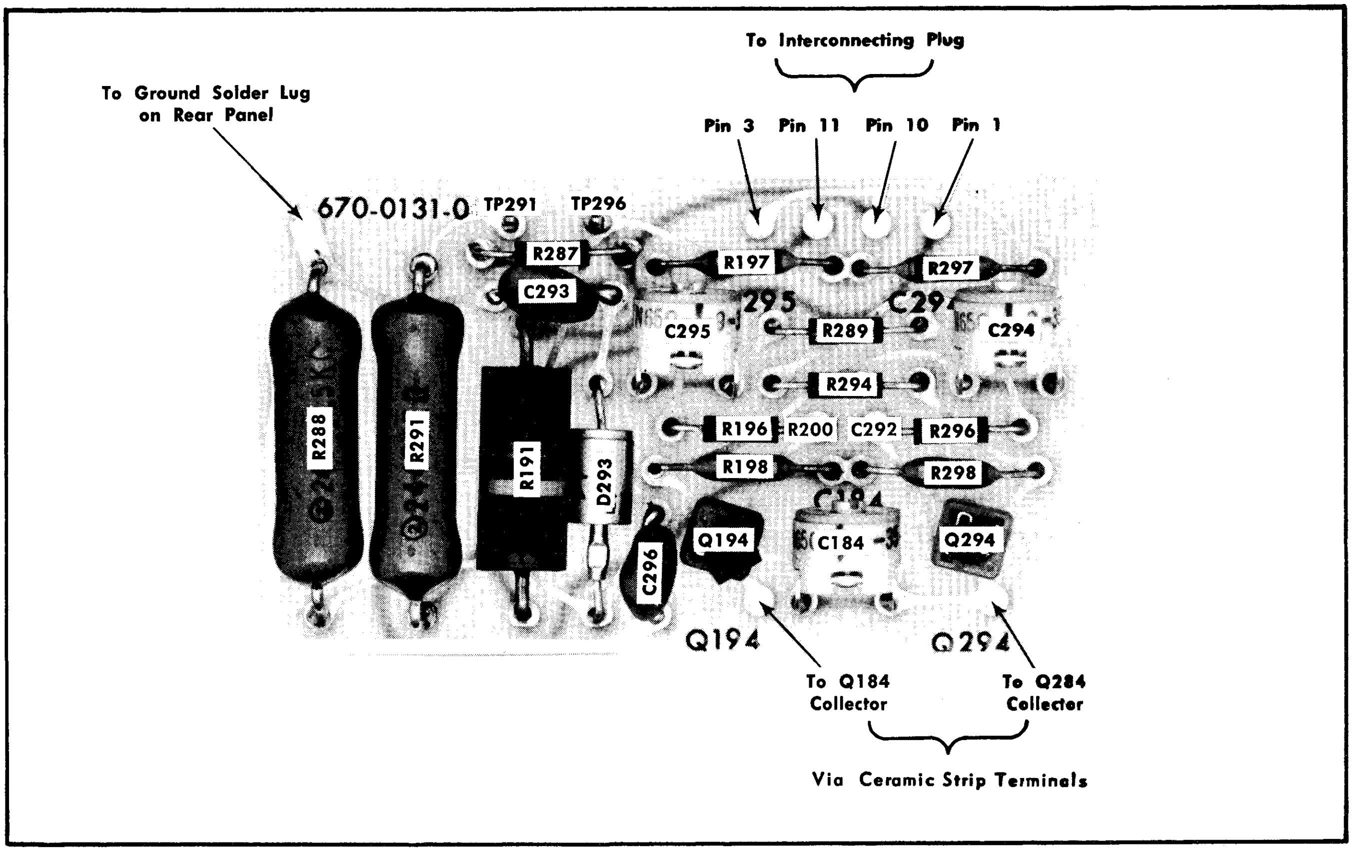



Fig. 4-3. Output Amplifier board.

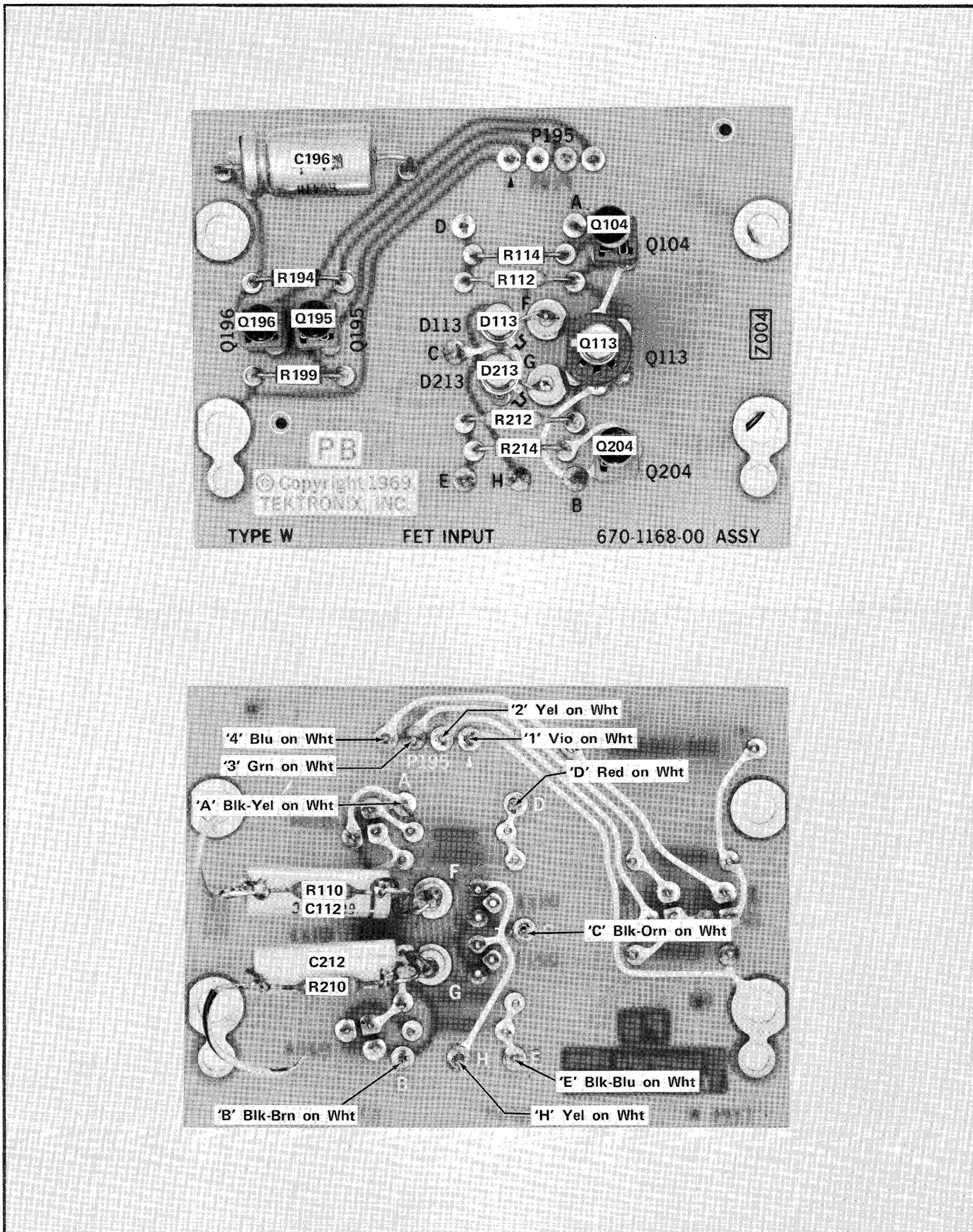



Fig. 4-4. FET Input Amplifier board. Front and back view showing parts location and lead connections.

# NOTES

# SECTION 5
# CALIBRATION

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

## Introduction

This section of the manual contains a complete verification and control adjustment procedure for the Type W. To ensure that the instrument is operating within the specifications given in Section 1, it should be checked and recalibrated as necessary, after corrective maintenance is performed or after each 500 hours of operation or 6 months of intermittent use.

Each step in the procedure begins with either "Check" or "Adjust", identifying it as either a verification or as an adjustment step. The symbol ◐ is provided as a convenience in locating the adjustment steps. The step sequence is arranged with consideration for control interaction and for a minimum of equipment reconnection. If steps are omitted or performed out of sequence, control interaction may be expected and it may be necessary to refer to preceding steps for equipment connection and control setting instructions.

## Equipment Required

The following items of test equipment (or substitute equivalents) are required for a complete calibration of the Type W. The specifications listed with an item are the minimum required and they should be used as a guide when it is necessary to select substitute test equipment.

(1) Type 530, 540, or 550-series oscilloscope.

Requirement: Vertical amplifier gain, bandwidth, and risetime must meet the specifications of the W unit.

*NOTE*

*If a 530-series oscilloscope is used, omit steps 14 and 15 in the calibration procedure, since the effect of high-frequency adjustments will not be apparent.*

(2) Amplitude calibrator (optional).

Description: Output frequency of about 1 kHz; peak to peak output amplitudes of 5 mV, 10 mV, 20 mV, 50 mV, 100 mV, 200 mV and 5 volts; amplitude accuracy of 1% or better.

Purpose: For use in performing steps 10, 11, 26 and 27 of the calibration procedure if greater accuracy than that provided by the oscilloscope (item 1) calibrator is needed.

(3) Precision DC voltmeter. Nulling type with infinite impedance at null.

Required specification: Accuracy of 0.05% or better; resolution of 50 $\mu$V or better. If a John Fluke DC Differential Voltmeter is available, use Model 801B or equivalent. If an accuracy of ±0.01% is desired, use a Model 825A.

(4) DC voltmeter (VOM). Sensitivity of 20,000 $\Omega$/V at full deflection. Triplett Model 630 P.L. or equivalent.

(5) Audio sine-wave generator, General Radio Type 1310A, or equivalent.

Required specifications: Output frequencies of 60 Hz, 20 kHz and 500 kHz at 30 volts peak to peak (15-volt peak reference to ground).

(6) Sine-wave generator. Tektronix Type 191 Constant-Amplitude Signal Generator or equivalent.

Required specifications: Output frequencies of 50 kHz (reference) and a range of 8 to 26 MHz; output amplitude must be adjustable (manually or automatically) for a constant amplitude at the stated frequencies; output amplitude range adjustable from 40 mV to 10 volts peak to peak.

(7) Square-wave generator, Tektronix Type 106 or equivalent.

Required specifications: (Hi Amplitude) 10 to 100 volts across its 600 ohm internal load, 13 ns or less risetime into 50 ohm termination, output frequency of 1 kHz and 10 kHz.

Required specifications: (Fast-Rise ±) 0.1 to 0.5 volts peak to peak, 3 ns or less risetime into a 50 ohm coaxial cable with 50 ohm termination, output frequency of 100 kHz.

Termination, 50 ohm, GR to BNC, supplied with the Type 106. (For above requirements, the termination is attached to the opposite end of the cable from the generator. If generator amplitude is too high, one or more 10:1 attenuators may be inserted at the generator end of the cable.)

(8) Input time constant normalizer 20 pF, BNC. Tektronix Type 067-0538-00.

(9) Two 50-ohm (nominal impedance) coaxial cables, approximately 42 inches long, with a BNC connector on each end. Tektronix Part No. 012-0057-01 or similar.

(10) 50-ohm (nominal impedance) coaxial jumper cable, approximately 18 inches long; equipped with BNC connector on each end. Tektronix Part No. 012-0076-00 or similar.

(11) 50-ohm 10:1 attenuator, 1/2 W, with BNC plug and jack connector fittings. Tektronix Part No. 011-0059-01. (If generator and cable are GR type, use 017-0078-00 or equivalent).

(12) 50-ohm termination, 1 W, with BNC plug and jack connector fittings. Tektronix Part No. 011-0049-01. (If generator cable is GR type, use 017-0083-00 GR to BNC type attenuator as supplied with Type 106 or 191 generators.)

(13) BNC T connector. Fits a BNC jack and accepts two BNC plugs. Tektronix Part No. 103-0030-00.

(14) Connector adapter. Single binding post fitted with a BNC-jack connector fitting. Binding post accepts a banana plug. Tektronix Part No. 103-0033-00.

(15) Two patch cords, 6 inches long, with banana plug-and-jack combination connector on each end. Tektronix Part No. 012-0024-00.

(16) Two patch cords, 18 to 24 inches long, with banana plug-and-jack combination connector on each end. Tektronix Part No. 012-0031-00 (18 inch cord).

(17) Precision DC Divider. 10:1 and 100:1 attenuation. Tektronix Part No. 067-0503-00.

(18) Miscellaneous (one each).

Small screwdriver with a 1/8 inch wide tip to fit the small screwdriver adjust potentiometers.

Screwdriver with a 3/16 inch wide tip to fit the larger screwdriver adjust potentiometers.

Insulated low-capacitance screwdriver, Jaco No. 125, 1 1/2 inch shank, 1/8 inch wide metal tip. Tektronix Part No. 003-0000-00.

4 inch jumper lead with miniature insulated alligator clips on each end.

6 inch jumper lead with tip plug on one end and banana plug-and-jack combination on the other.

Resistor, fixed, 1 meg, 1/4 W or 1/2 W, 1%.

Resistor, fixed, 47 Ω, 1/2 W, 10%.

## PRELIMINARY PROCEDURE

(1) Lay the oscilloscope on its right side. Remove the left side and bottom panels from the oscilloscope. Leave the oscilloscope on its right side.

(2) Insert the W Unit into the oscilloscope plug-in compartment.

(3) Connect the oscilloscope power cord to the operating voltage for which the oscilloscope is wired.

(4) Turn on the oscilloscope and allow 20 minutes for warmup and stabilization.

(5) Set the oscilloscope sweep rate and triggering controls to obtain a 0.5 ms/cm free-running sweep.

(6) Preset the W Unit front-panel controls to these settings:

| | |
|---|---|
| Vc Range | +11 |
| COMPARISON VOLTAGE | 11.00 (10-10-0) |
| AC-DC-GND (both inputs) | GND |
| INPUT ATTEN | 1 |
| DISPLAY | A—B |
| MILLIVOLTS/CM | 50 |
| VARIABLE (MILLIVOLTS/CM) | CALIB |
| POSITION | Midrange |

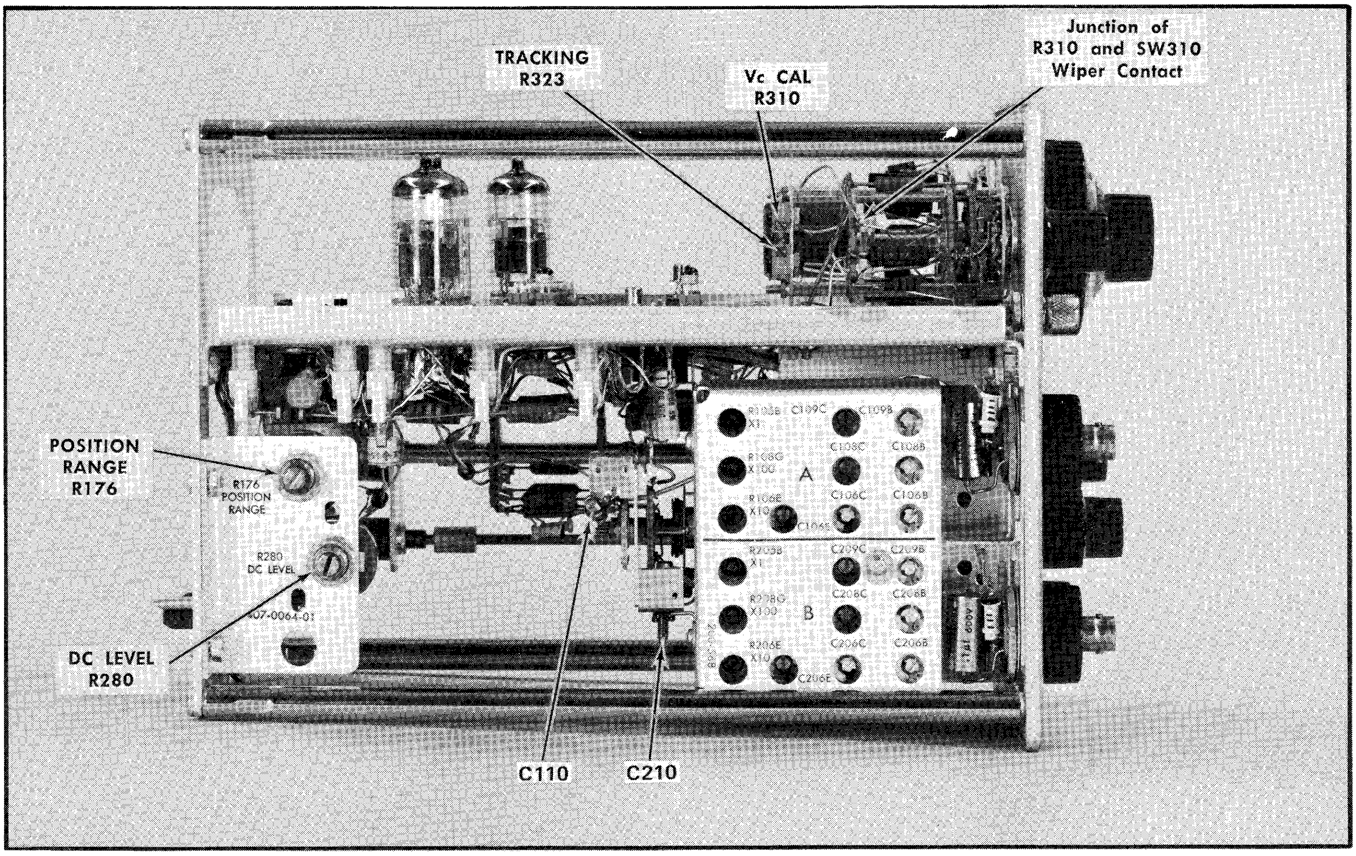



Fig. 5-1. Location of the calibration adjustments and test point (left-side view; securing rod removed for picture).

## CALIBRATION PROCEDURE

### 1. Adjust Vc CAL R310

a. Set the non-loading voltmeter (item 3) to +11 volts.

b. Connect the voltmeter between the Vc OUTPUT connector and ground.

c. Adjust the Vc CAL control R310 (see Fig. 5-1) for a null reading on the meter.

### 2. Adjust TRACKING R323

a. Set the COMPARISON VOLTAGE control to 1.00 (0-10-0).

b. Set the non-loading voltmeter to +1 volt.

c. Adjust the TRACKING control R323 (see Fig. 5-1) for a null reading on the meter.

### 3. Check Tracking of COMPARISON VOLTAGE control

Using the non-loading voltmeter, check the voltage at each major dial reading of the COMPARISON VOLTAGE control. For example: a voltage of +2 volts should be obtained when the COMPARISON VOLTAGE control is set to 2.00 (1-10-0). Tolerance is ±0.2%.

### 4. Check Vc Range Switch

a. Set the COMPARISON VOLTAGE control to 10.10 (10-10-0).

b. Set the Vc RANGE switch to +1.1. The Vc OUTPUT connector voltage should be +1.1 volts.

c. Set the Vc RANGE switch to −1.1 and then to −11. The Vc OUTPUT voltage should measure accordingly.

d. Set the Vc RANGE switch to 0 and check for zero volts at the Vc OUTPUT connector.

e. Disconnect the non-loading voltmeter from the Vc OUTPUT connector and ground.

## 5. Adjust POSITION RANGE R176

*NOTE*

*This is a preliminary adjustment. Final adjustment is made while performing step 6.*

a. Turn the oscilloscope power off. Connect a short jumper clip lead from one wiper contact of SW150 (MILLIVOLTS/CM switch) to the other (see Fig. 5-2). Turn oscilloscope power on and allow a few minutes warmup. (The protective circuit Q195 and Q196 creates an added approximate 45 second delay after the oscilloscope relay is activated before the Type W input amplifiers become operational. This delay will occur each time the oscilloscope power is turned off and then back on.)

b. Check that the POSITION control is set to midrange.

c. Adjust the POSITION RANGE control R176 (see Fig. 5-1) so the trace coincides with graticule center.

## 6. Adjust DC LEVEL R280

a. Set the VOM to its 8 volt or higher DC range, connect the common lead to TP296; connect the positive lead to TP291 (see Fig. 5-2).

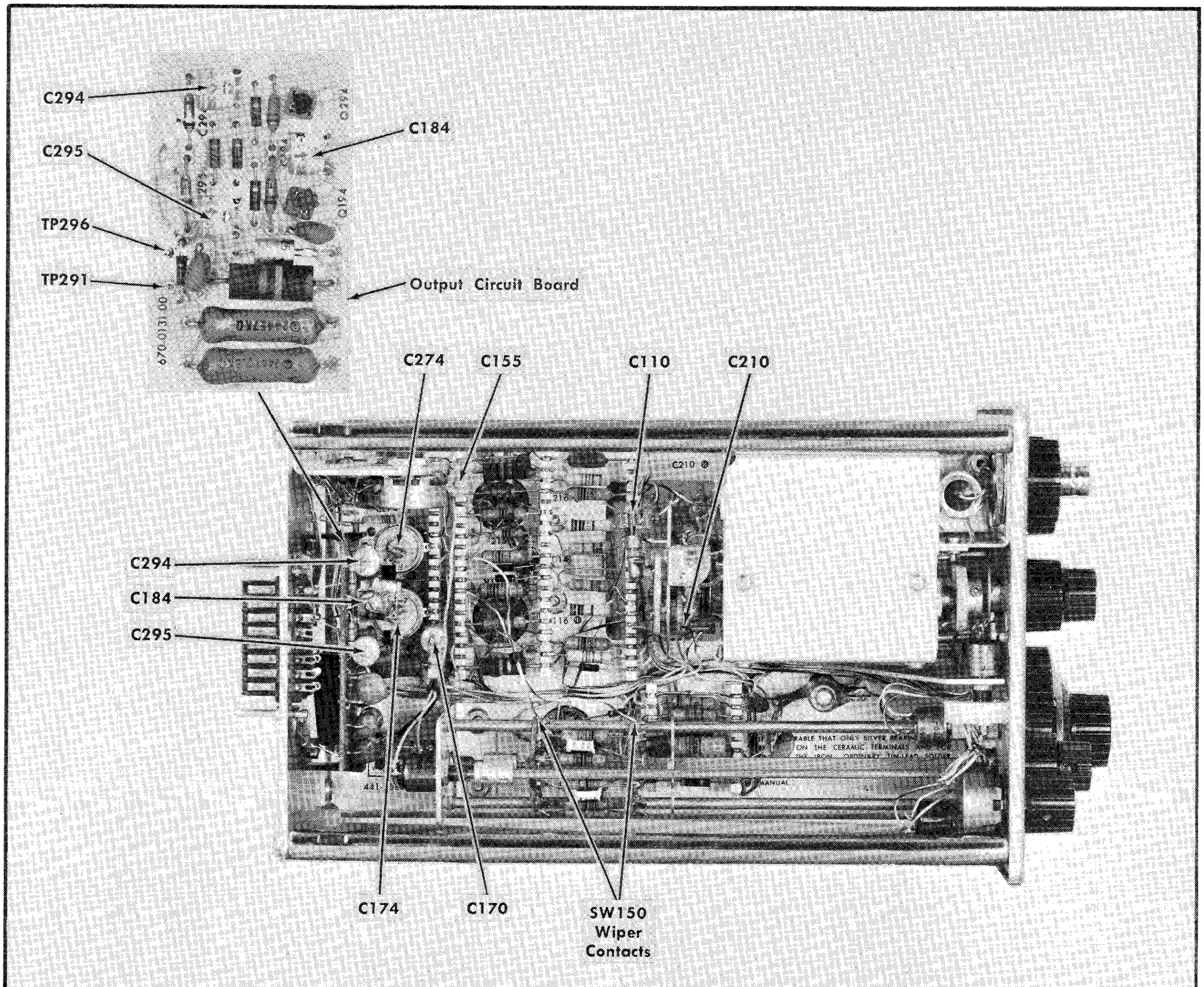



Fig. 5-2. Location of the calibration adjustments and test points (bottom view). Securing rod removed for the illustration.

b. Adjust the DC LEVEL control R280 (see Fig. 5-1) to obtain a reading of +6 volts (within a tolerance of ±0.5 volt) on the VOM.

c. Check that the trace coincides with graticule center. If trace is centered, proceed to step 6-d. If trace is not centered, readjust the POSITION RANGE control to center the trace. If necessary, repeat steps 6-b and 6-c to obtain a 6-volt reading and a centered trace.

d. Turn the oscilloscope power off, remove the jumper clip lead and disconnect the VOM.

e. Turn the oscilloscope on and allow it to warm up.

## 7. Adjust DC BAL R127

a. Preset the VAR BAL and DC BAL front-panel controls to midrange.

b. Set the MILLIVOLTS/CM switch to 1.

c. Adjust the DC BAL control so there is minimum trace shift as the VARIABLE (MILLIVOLTS/CM) control is rotated back and forth.

*NOTE*

*If necessary, use the front panel VAR BAL (R161) control as a positioning control to keep the trace on the CRT.*

d. Check that the VARIABLE control is set to CALIB.

## 8. Adjust VAR BAL (R161)

a. Adjust the VAR BAL control so the trace coincides with graticule center.

b. Repeats steps 7-c and 8-a to obtain minimum trace shift and a centered trace as the VARIABLE control is rotated back and forth.

c. Check that the VARIABLE control is set to CALIB.

## 9. Adjust GAIN (R157)

a. Apply a 0.2-volt peak-to-peak calibrator signal through a coaxial cable to the A input connector.

b. Set input A AC-DC-GND switch to DC and the MILLIVOLTS/CM switch to 50.

c. Set the oscilloscope triggering controls for automatic (Auto) +Int triggering on the calibrator signal.

d. Using the W Unit POSITION control, center the display on the CRT.

e. Adjust the front-panel GAIN control so the vertical deflection of the display is exactly 4 cm peak-to-peak.

## 10. Check MILLIVOLTS/CM Switch

Using Table 5-1 as a guide, check the remaining MILLIVOLTS/CM switch positions for proper calibrated vertical deflection factors. Amplitude tolerance of the display should be within ±3% plus the tolerance of the amplitude calibrator output.

*NOTE*

*If the oscilloscope has a 4 X 10 cm viewing area, check the deflection factors by using calibrator signal amplitudes that do not overscan the screen.*

**TABLE 5-1**

| MILLIVOLTS/CM Switch Position | Amplitude Calibrator Output | Vertical Deflection in cm |
|---|---|---|
| 20 | 0.1 V | 5 |
| 10 | 50 mV | 5 |
| 5 | 20 mV | 4 |
| 2 | 10 mV | 5 |
| 1 | 5 mV | 5 |

## 11. Check VARIABLE (MILLIVOLTS/CM) Control

a. Set the MILLIVOLTS/CM switch to 50.

b. Set the amplitude calibrator for an output of 0.2 volt.

c. Turn the VARIABLE control slowly counterclockwise. As the control is turned, the amplitude of the display should increase 4 mm or more and then decrease. Check for smooth electrical and mechanical operation as the control is turned counterclockwise from the point where the amplitude of the display decreases from 4 cm to 1.6 cm. At 1.6

cm the range of the control is 2.5 to 1 with respect to the 4-cm level.

d. Set the VARIABLE control to CALIB.

e. Disconnect the calibrator signal.

## 12. Check INPUT Source Follower Gate Current

a. Set the oscilloscope Time/Cm switch to 0.5 ms.

b. Set both AC-DC-GND switches to GND and the MILLIVOLTS/CM switch to 1. Connect a 50 ohm termination to input B.

c. Using the POSITION control, position the trace to coincide with the center graticule line.

d. Set the input B AC-DC-GND switch to DC and note the amount of trace shift.

e. Remove the 50 ohm termination from input B and connect it to input A. Set the input B AC-DC-GND switch to GND, and input A AC-DC-GND switch to DC. Note the amount of trace shift.

f. When performing steps 12-d and 12-e, the amount of trace shift should be less than 2 cm., which is 2 nanoamperes or less (2 mV divided by 1 megohm equals 2 nanoamperes). Remove the 50 ohm termination.

## 13. Adjust DIFF BAL (R233) ❶

a. Set the W Unit front-panel controls to these settings:

| | |
|---|---|
| AC-DC-GND (Input B) | DC |
| INPUT ATTEN | 1000 |
| MILLIVOLTS/CM | 10 |

b. Set the oscilloscope Time/Cm switch to 10 ms. Check that the remaining controls are set to the following positions:

**W Unit**

| | |
|---|---|
| Vc Range | 0 |
| COMPARISON VOLTAGE | 10-10-0 |
| AC-DC-GND (Input A) | DC |
| DISPLAY | A—Vc |
| VARIABLE (MILLIVOLTS/CM) | CALIB |
| POSITION | Midrange |
| DC BAL | Adjusted for minimum trace shift as VARIABLE control is rotated. |

**Oscilloscope**

| | |
|---|---|
| Triggering Controls | Auto, +Int |

c. Apply a 30-volt peak-to-peak (15-volt peak referenced to ground) 60 Hz sine-wave signal from an audio generator to the A and B input connectors. (Use two 50 ohm cables and a T connector).

*NOTE*

*The generator is set for proper output when the display amplitude is 3 cm for a 30-volt signal. (The W Unit is set for a deflection factor of 10 volts/cm.)*

d. Set the W Unit controls as follows:

| | |
|---|---|
| DISPLAY | A—B |
| INPUT ATTEN | 1 |
| MILLIVOLTS/CM | 1 |

e. Adjust the front-panel DIFF BAL control to obtain minimum display amplitude. When the control is properly adjusted, the display should be 1.5 cm or less in amplitude. This is equal to a common-mode rejection ratio of 20,000-to-1 or better (30 volts divided by 1.5 mV equals 20,000).

f. Disconnect the audio generator.

## 14. Check Noise

a. Set the Type W controls as follows:

| | |
|---|---|
| INPUT ATTEN | 1000 |
| AC-DC-GND (input A) | DC |
| AC-DC-GND (input B) | GND |
| DISPLAY | A—B |
| MILLIVOLTS/CM | 1 |
| VARIABLE | CALIB |
| POSITION | MIDRANGE |
| DC BAL | Per Step 7 |

b. Set the Square-Wave Generator controls as follows:

| | |
|---|---|
| Repetition Rate | 1 kHz |
| Symmetry | For Symmetrical Output |
| Hi Amplitude/Fast Rise | Fast Rise |
| Power | On |

c. Set the triggering controls on the oscilloscope to produce a free running trace.

d. Apply a 1 kHz signal from the Square Wave Generator + Output connector through a 50 ohm cable, and a 50 ohm termination (in that order), to the A input connector of the Type W. If necessary to reduce the amplitude of the generator signal, add one or more 10X attenuators at the generator + Output connector.

e. Adjust the generator Amplitude control to provide two separate traces on the CRT. These traces represent the upper and lower excursions of the square waves being presented on the free running sweep.

f. Rotate the generator Amplitude control slowly counterclockwise to just eliminate the dark line between the two traces (refer to Fig. 5-3).

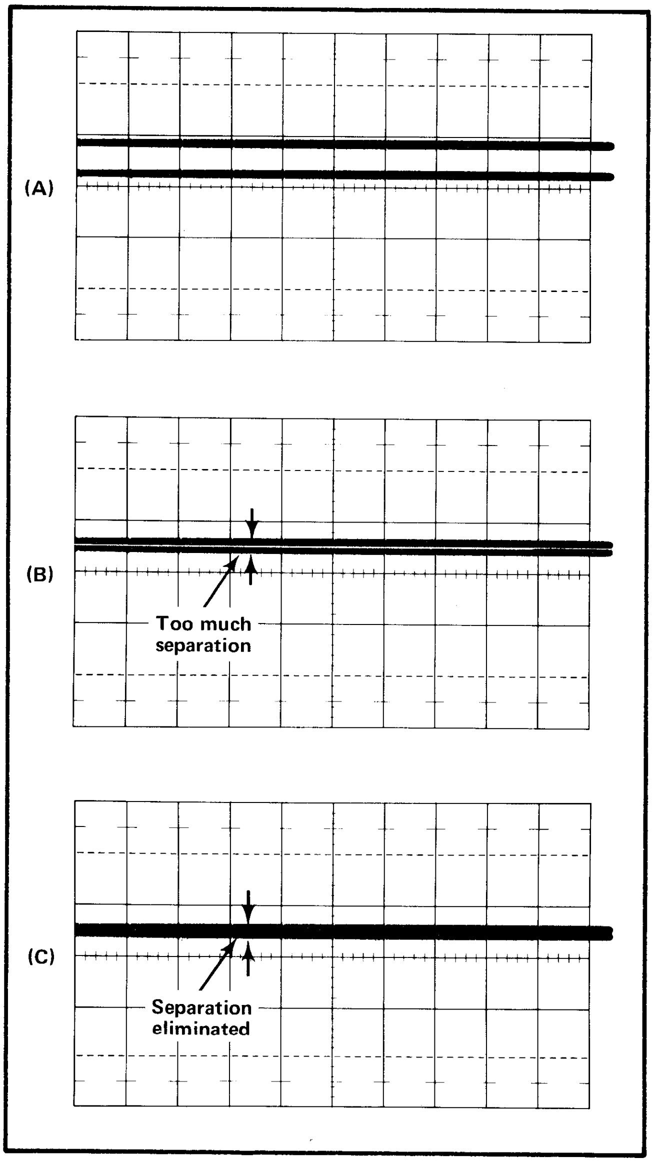



**Fig. 5-3. (A) Initial waveform for noise measurement, (B) Too much separation between traces, (C) Desired waveform (Sweep rate 10 $\mu$s/cm, free running.**

g. Set the MILLIVOLTS/CM switch to 10 mV and the INPUT ATTEN switch to 100.

h. Measure the noise amplitude between trace centers in mV. Divide the amplitude in mV by 100 to determine the noise level in microvolts.

## 15. Adjust Output Amplifier High-Frequency Compensation ◐

*NOTE*

*Perform steps 15 and 16 if the W Unit is being calibrated in an oscilloscope which has a vertical-amplifier risetime of 10 ns or faster. As a suggestion when performing step 15, follow the procedure but do not make any adjustments until the A-input and B-input waveforms have been examined. The adjustments in this procedure interact and therefore they are set to obtain the best compromise results between the two displays.*

a. Set the oscilloscope Time/Cm switch to 1 $\mu$s. Set the triggering controls for + Int, AC, triggered-sweep mode of operation.

b. Set the W Unit controls as follows:

| | |
|---|---|
| DISPLAY | A—Vc |
| MILLIVOLTS/CM | 50 |

At this point in the procedure, check that the remaining W-Unit controls are set to these positions:

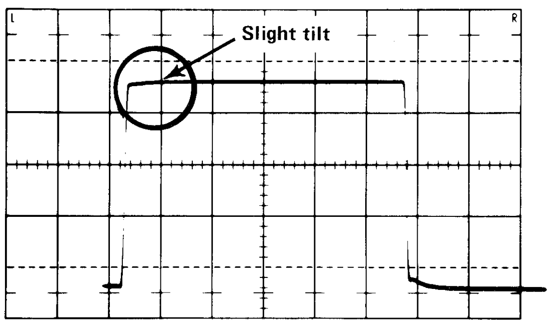
| | |
|---|---|
| Vc RANGE | 0 |
| COMPARISON VOLTAGE | 10-10-0 |
| AC-DC-GND (both inputs) | DC |
| INPUT ATTEN | 1 |
| VARIABLE (MILLIVOLTS/CM) | CALIB |
| POSITION | Midrange |

c. Apply a 100 kHz Fast Rise signal from the square-wave generator, through a coaxial cable and 50-ohm termination (in that order) to the A input connector.

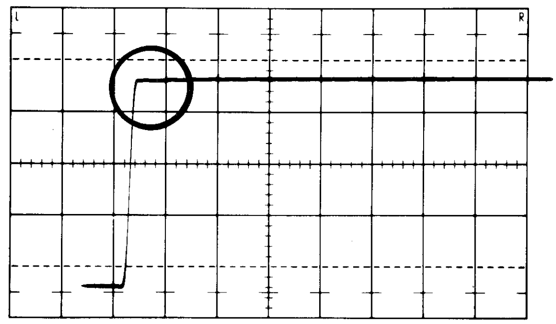
d. Set the generator output amplitude so the display is 4 cm in amplitude. Use the W-Unit POSITION control to center the display.

e. Set the oscilloscope Time/Cm to 0.2 $\mu$s. Adjust the oscilloscope triggering controls to obtain a stable display.

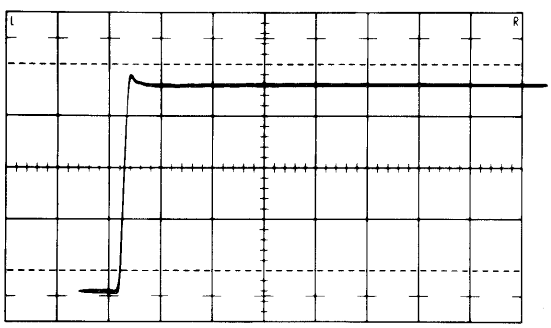
The leading upper corner of the display should have a square corner with minimum abberations (see Fig. 5-4A), abberations should not exceed ±1 mm. To check on the appearance of the waveform at a faster sweep rate and to perform the adjustments, set the oscilloscope Time/Cm switch to 0.1 $\mu$s. Adjust the oscilloscope triggering controls so the entire rising portion of the square wave is displayed (see Fig. 5-4B).



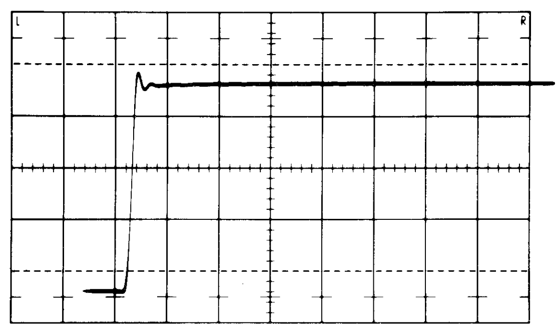

**(A) Input A waveform. Sweep rate: 0.2 $\mu$s/cm.**



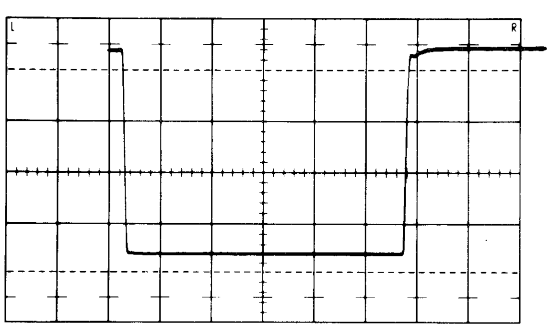
**(B) Input A waveform. Sweep rate: 0.1 $\mu$s/cm.**



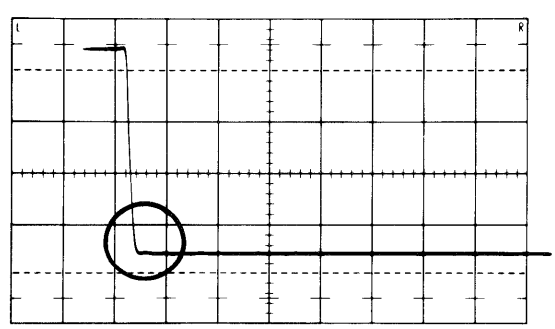
**(C) Input A waveform. C294 and C295 incorrectly adjusted. Sweep rate: 0.1 $\mu$s/cm.**



**(D) Input A waveform. C174 and C184 are incorrectly adjusted. Sweep rate: 0.1 $\mu$s/cm.**



**(E) Input B waveform. Sweep rate: 0.2 $\mu$s/cm.**



**(F) Input B waveform. Sweep rate: 0.1 $\mu$s/cm.**

**Fig. 5-4. Illustrations (A), (B), (E), and (F) are typical waveforms obtained when C174, C184, C274, C294, and C295 are properly adjusted. Waveforms (C) and (D) show results obtained when the indicated adjustments are set incorrectly. Vertical deflection factor 50 mV/cm.**

*NOTE*

*Waveforms shown in Fig. 5-4 are typical, but may vary slightly with the type of oscilloscope and square-wave generator being used.*

f. Adjust C294 (relatively long time constant, about 60 ns), C295 (relatively short time constant, about 20 ns), and C170 (about 25 ns time constant) to obtain the best flat top near the upper front corner of the waveform. If the waveform has a slight tilt or slope (about 250 ns) on the flat portion of the waveform (see Fig. 5-4A) then the contour of the waveform should be followed to obtain best flat top. See Fig. 5-2 for location of these adjustments. Fig. 5-4C shows one form of aberration obtained when C294 and C295 are set incorrectly.

g. Adjust C174 and C184 (see Fig. 5-2) to obtain a fast rise and square corner on the waveform with no ringing or excessive overshoot (see Fig. 5-4B). Fig. 5-4D shows one form of distortion obtained when C174 and C184 are set incorrectly.

Some hints that could be helpful are as follows: Set C174 to midrange and check that C274 (see Fig. 5-2) is near its midrange position. Then, adjust C184 for best square-wave response. Next, adjust C174. If necessary, slight adjustment of C274 can be made to check if the transient response can be improved. Use the 0.2 μs/cm and 0.1 μs/cm sweep rates to check the appearance of the waveform. Make slight adjustments of C170, C294, C295, C184, C174, and C274 as required, to obtain best square-wave response. (If difficulty is encountered, check adjustment of C155 in step 16, then repeat this step.)

h. Apply the signal to input B and set the DISPLAY switch to Vc—B. Set the oscilloscope for —Int triggering.

i. Adjust C274 for best lower leading corner on the negative-going square-wave display (see Fig. 5-4E and 5-4F). If necessary, slightly readjust C170, C174, C184, C274, C294, and C295 to obtain the best compromise waveform. The aberrations should not exceed ±1 mm.

j. Apply the 100 kHz signal to input A and set the DISPLAY switch to A—Vc.

k. Set the oscilloscope triggering control to +Int.

l. If there is too much ringing on the waveform, increase the ringing slightly by adjusting C184. Then, reduce the ringing by adjusting C174 and C274 equally. The overall effect will reduce ringing. If there is front-corner rolloff, reverse the adjustment procedure by rolling off the waveform slightly with C184 and then repeak the waveform by adjusting C174 and C274.

m. Repeat steps 15-e through 15-l to check the A and B displays. Make the necessary adjustments to obtain the best compromise of transient response and risetime. Front corner aberrations should not exceed ±1 mm.

## 16. Check Overdrive Recovery— Adjust Common-Mode Rejection at 20 kHz (C155)

a. Set the W-Unit INPUT ATTEN switch to 100 and the oscilloscope Time/Cm switch to 50 μs. Check that the W-Unit DISPLAY switch is set to A—Vc.

The remaining controls should be at the following positions:

**W Unit**

| | |
|---|---|
| Vc RANGE | 0 |
| COMPARISON VOLTAGE | 10-10-0 |
| AC-DC-GND (both inputs) | DC |
| MILLIVOLTS/CM | 50 |
| VARIABLE (MILLIVOLTS/CM) | CALIB |
| POSITION | Midrange |

**Oscilloscope**

| | |
|---|---|
| Triggering Controls | +Int, AC, Triggered-Sweep Mode |

b. Apply a 10 kHz Hi Amplitude signal from the square-wave generator through a coaxial cable and 50-ohm termination to the input A connector on the W Unit.

c. Adjust the square-wave generator Output Amplitude control so the display amplitude is 2 cm (10 volts peak to peak), measured from flat portion to flat portion, ignore any overshoot. Use the Triggering Level control to obtain a stable display.

d. Set the INPUT ATTEN switch to 1 and the MILLIVOLTS/CM switch to 10.

e. Set the oscilloscope Time/Cm switch to 20 μs/cm. Position the display so the trailing (flat) portion of the overdriven waveform coincides with graticule center (see Fig. 5-5A). This location is used as a reference.

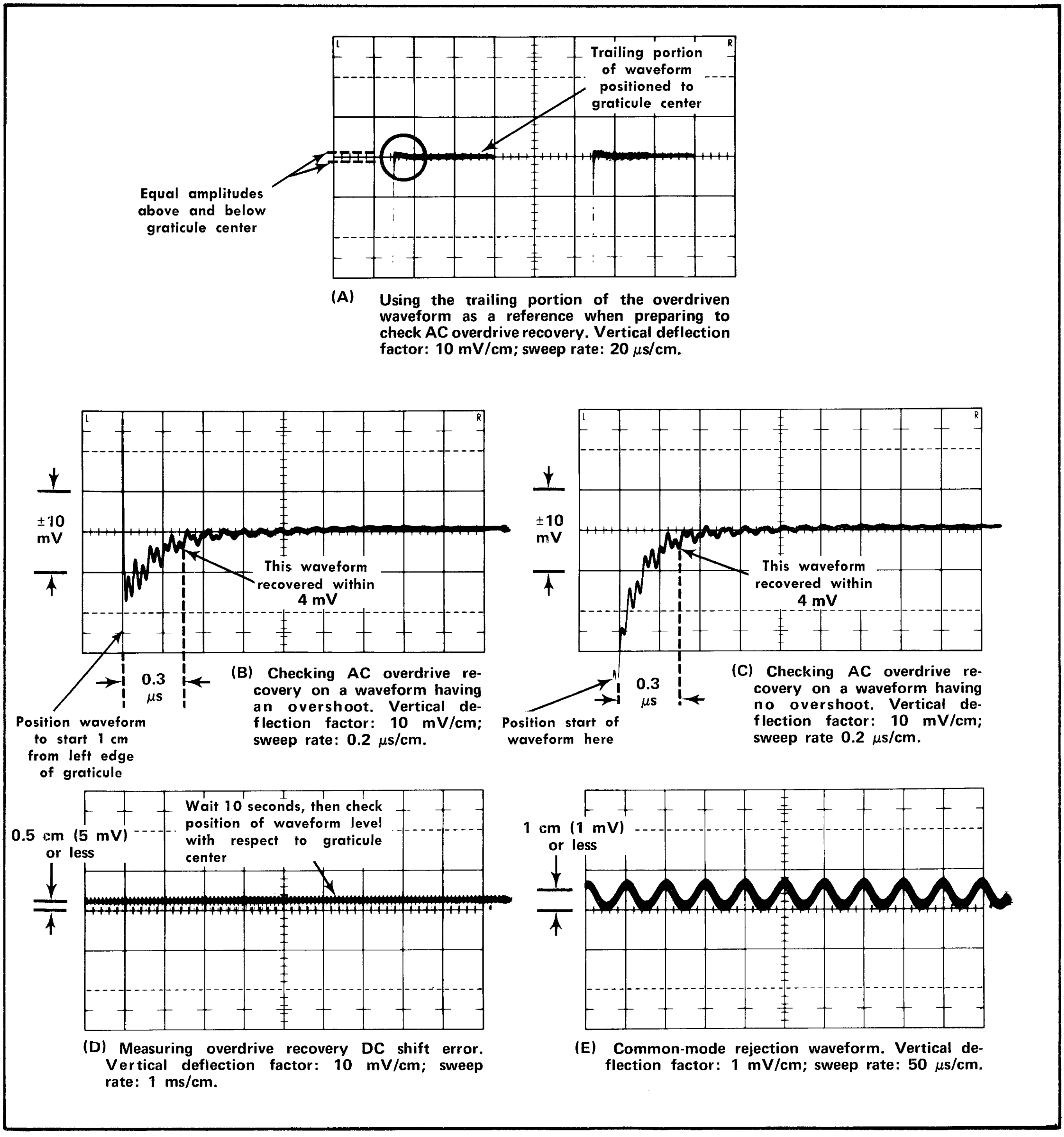



**Fig. 5-5. Typical waveforms obtained when performing step 16.**

*NOTE*

*Do not move the W-Unit POSITION control until the AC Overdrive Recovery check, described in the following portion of this step, has been completed.*

f. Set the oscilloscope Time/Cm switch to 0.2 μs/Cm. Using the oscilloscope Horizontal Position control, position the display so the rising portion of the waveform starts at a point one cm from the left edge of the graticule as illustrated in Figs. 5-5B and 5-5C. Fig. 5-5B shows a waveform that has a very fast overshoot and Fig. 5-5C shows a waveform without overshoot. Both waveforms are typical displays that may be encountered. Check AC overdrive recovery by observing that the waveform recovers to within ±10 mV of the reference level (graticule center) within 0.3 μs (see Fig. 5-5B and 5-5C).

If overdrive recovery is greater than ±10 mV, repeat steps 16-e and f.

g. Set the W-Unit input A AC-DC-GND switch to GND.

h. Set the oscilloscope Time/Cm switch to 1 ms and free run the sweep.

i. Position the trace to coincide with graticule center. Set the input A AC-DC-GND switch to DC. Wait 10 seconds and check the position of the trace. The trace should be within 0.5 cm or less from graticule center (see Fig. 5-5D).

j. Using the same setup as described in step 16-b, disconnect the signal from input A and apply the signal to input B. Set the DISPLAY switch to Vc—B.

k. Repeat steps 16-c through 16-i with these exceptions: Use —Int triggering. When performing steps 16-c and 16-f check AC Overdrive Recovery on the inverted waveform. (For this step, where steps 16-g and 16-i refer to "A input", substitute "B input".)

l. After completing the procedure for input B, disconnect the square-wave generator.

m. Set the INPUT ATTEN switch to 1000 and the MILLIVOLTS/CM switch to 10. Apply a 30 volt peak to peak (15 volts peak referenced to ground) 20 kHz sine-wave signal from the audio generator to the input A and B connectors. Use a 42-inch coaxial cable to connect the signal from the audio generator to a BNC T connector (item 13). Connect the BNC T connector to input B. Connect a short jumper coaxial cable from the BNC T connector to input A.

n. Set the oscilloscope Time/Cm switch to 50 μs and adjust the triggering controls to obtain a stable display. The display should be 3 cm (30 volts) in amplitude when the audio generator output amplitude control is set correctly.

o. Set the W Unit controls as follows:

| | |
|---|---|
| DISPLAY | A—B |
| INPUT ATTEN | 1 |
| MILLIVOLTS/CM | 1 |

p. Adjust the oscilloscope triggering controls to obtain a stable display. Use the W Unit POSITION control to position the display near graticule center. If the display is more than 1.5 cm in amplitude, adjust C155 (see Fig. 5-2) slightly in a direction that reduces the amplitude to meet the 1.5 cm requirement. An amplitude of 1.5-cm or less is a common-mode rejection ratio of 20,000-to-1 or better. If C155 requires considerable readjustment, repeat all of steps 15 and 16.

q. Set the oscilloscope in an upright position.

## 17. Check Common-Mode Rejection at 60 Hz AC coupled and DC coupled

a. Set the oscilloscope Time/Cm switch to 10 ms.

b. Set the Triggering controls to +Int and Automatic.

c. Set the audio generator for a 60 Hz 30-volt peak to peak output signal. (Verify the generator output amplitude using the procedure described in step 16-n.)

d. Set the AC-DC-GND switches to AC and the MILLIVOLTS/CM switch to 10.

e. The display should be 3 cm or less in amplitude. This is a common-mode rejection ratio of 1,000-to-1 or better.

f. Set the AC-DC-GND switches to DC and repeat step 17C. Set the MILLIVOLTS/CM switch to 1. The display amplitude should be 1.5 cm or less for a 60 Hz DC coupled Common-mode Rejection Ratio of 20,000 to 1.

g. Disconnect the audio generator, but leave the short coaxial cable and BNC T connector connected to the A and B input connectors.

## 18. Check DC Common-Mode Rejection Ratio

a. Set the oscilloscope Time/Cm switch to .5 ms.

b. Connect the Vc OUTPUT connector to both A and B input connectors (use the jumper lead with tip plug and a

BNC to binding post connector adapter to complete the interconnections).

c. Set the W Unit front-panel controls as follows:

| | |
|---|---|
| AC-DC-GND (both inputs) | DC |
| MILLIVOLTS/CM | 1 |
| Vc RANGE | +11 |
| COMPARISON VOLTAGE | 10.00 (9-10-0) |
| INPUT ATTEN | 1 |

d. Note the position of the trace and then set the Vc RANGE switch to 0. Again, note the position of the trace. The difference between trace positions should not be any greater than 0.5 cm to obtain a DC common-mode rejection ratio of 20,000-to-1.

*NOTE*

*If oscillations occur, connect a 47-ohm resistor between the Vc OUTPUT connector and interconnecting lead. Disregard slow trace drift. To double-check the trace positions, set the Vc Range switch to +11 and then back to 0. Note the amount of trace shift.*

e. After completing the previous step, note the position of the trace and then set the Vc RANGE switch to −11. Again, note the position of the trace. The difference between the position of the trace when the Vc RANGE switch is set to 0 and when it is set to −11 should not be greater than 0.5 cm.

f. Set the Vc RANGE switch to 0. Remove the lead and 47-ohm resistor which connect between the Vc OUTPUT connector and the A and B input connectors. Remove the connector adapter.

## 19. Check Common-Mode Rejection Ratio at 500 kHz

a. Set the oscilloscope Time/Cm switch to 2 μs.

b. Set the W Unit MILLIVOLTS/CM control to 20.

c. Apply a 500 kHz, 30-volt peak to peak signal (verify the amplitude as in step 16-n) from the audio generator to the A and B input connectors of the W Unit.

d. The display amplitude should be 3 cm or less in amplitude. This indicates a common-mode rejection ratio of 500 to 1 or better.

e. Disconnect the audio generator and interconnecting leads.

## 20. Adjust R106E (Input A 10X Attenuator

a. Set the W Unit front-panel controls as follows:

| | |
|---|---|
| AC-DC-GND (both inputs) | DC |
| INPUT ATTEN | 10 |
| DISPLAY | A−Vc |
| MILLIVOLTS/CM | 1 |
| COMPARISON VOLTAGE | Fully clockwise (10-10-past 0) |

b. Check that the oscilloscope Time/Cm switch is set to 0.5 ms and the triggering controls are set to +Int and Automatic.

c. Connect a short jumper lead from the A input connector to the junction of R310 (Vc CAL) and the wiper contact of SW310 (see Fig. 5-1). Use a connector adapter on the A input connector. Fig. 5-6 shows the complete setup to use as a guide.

d. Connect a short jumper lead (item 15) from the A input connector to the Precision DC Divider Voltage Input connector (item 17).

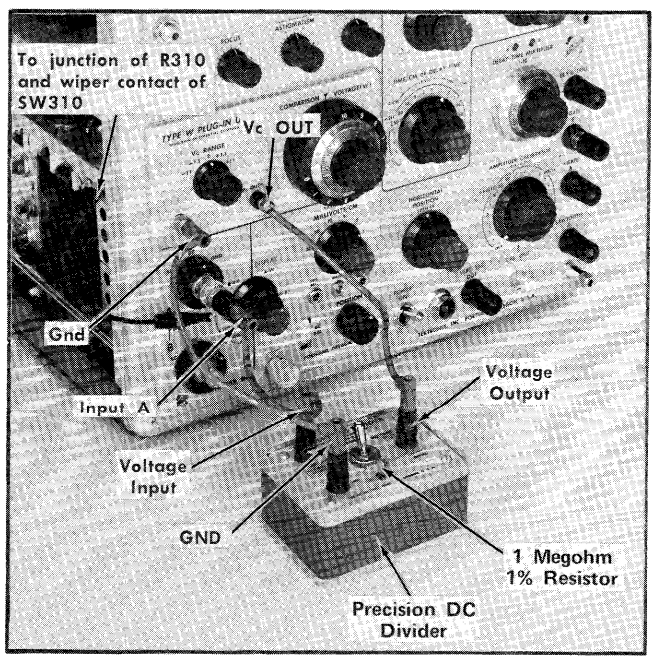



Fig. 5-6. Initial test equipment setup for step 20.

e. Connect a 1 meg (1%) resistor from the Precision DC Divider Voltage Output connector to the Gnd connector.

f. Connect a short jumper lead from the Precision DC Divider Gnd connector to the W Unit ground binding post.

g. Connect a short jumper lead with a tip plug from the Precision DC divider Voltage Output connector to the Vc OUTPUT connector and set the 10:1-100:1 switch to 10:1.

h. Using the POSITION control, position the trace to coincide with graticule center.

*NOTE*

*From time to time it may be necessary to check the DC balance of the W Unit by checking the DC BAL adjustment. If necessary, readjust the DC BAL control to obtain minimum trace shift as the MILLIVOLTS/CM switch position is changed and then returned to its former position.*

i. Set the COMPARISON VOLTAGE control outer (switch) knob to a position between 10 and 9 detent positions to internally disconnect the comparison voltage from the Vc OUTPUT connector. (However, externally the divider voltage will be applied via the jumper to the Vc OUTPUT connector. This voltage is then internally applied from the connector through the DISPLAY switch to the B input grid side of the W Unit amplifier.)

j. Set the Vc RANGE switch to +11.

k. Adjust R106E (see Fig. 5-1) to return the trace to graticule center.

## 21. Adjust R108B (Input A 100X Attenuator)

a. Set the Vc RANGE switch to 0 and COMPARISON VOLTAGE control outer knob to 10.

b. Set the INPUT ATTEN switch to 100.

c. Set the Precision DC Divider 10:1-100:1 switch to 100:1.

d. Check that the trace is centered. If necessary, use the DC BAL control to position the trace to coincide with graticule center.

e. Set the COMPARISON VOLTAGE control outer knob between the 10 and 9 detent positions; set the Vc RANGE switch to +11.

f. Adjust R108G (see Fig. 5-1) to position the trace to coincide with graticule center.

g. Set the Vc RANGE switch to 0 and the COMPARISON VOLTAGE control outer knob to 10.

h. Leave the jumper connected to the junction of R310 and the wiper contact of SW310. Disconnect all other jumpers and connections to disconnect the Precision DC Divider from the W Unit.

## 22. Adjust R105B (Input A 1X Attenuator)

a. Insert a 1 meg (1%) resistor between the jumper and the A input connector.

b. Set the W Unit controls as follows:

| | |
|---|---|
| INPUT ATTEN | 10 |
| Vc RANGE | +1.1 |

c. Rotate the COMPARISON VOLTAGE control to position the trace to graticule center. The control setting will be near +0.55 V (5-5-0). Leave the control at this setting until step 22-g is completed.

d. Connect a non-loading voltmeter between input A connector and ground.

e. Set the non-loading voltmeter to obtain a null reading (at about 5.5 volts).

f. Set the INPUT ATTEN switch to 1 and Vc RANGE switch to +11.

g. Adjust R105B (see Fig. 5-1) to obtain a null reading on the non-loading voltmeter.

h. Disconnect the voltmeter.

### 23. Adjust R206E (Input B 10X Attenuator

a. Set the W Unit controls as follows:

| | |
|---|---|
| Vc RANGE | 0 |
| COMPARISON VOLTAGE | Fully clockwise (10-10-past 0) |
| INPUT ATTEN | 10 |
| DISPLAY | Vc—B |

b. Remove the 1-meg resistor and connect the jumper lead to the B input connector. The jumper lead now connects between the B input connector and the junction of R310 and the wiper contact of SW310.

c. Connect a short jumper lead from the B input connector to the Precision DC Divider Voltage Input connector.

d. Repeat steps 20-e through 20-j. (The divider voltage is now applied via the Vc OUTPUT connector to the A input grid side of the W Unit amplifier. Use Fig. 5-6 as a guide when making the connections.)

e. Adjust R206E (see Fig. 5-1) to return the trace to graticule center.

### 24. Adjust R208G (Input B 100X Attenuator)

a. Repeat steps 21-a through 21-d.

b. With all connections remaining as in step 23, check that the trace is centered. If necessary, use the DC BAL control to position the trace to coincide with graticule center.

c. Set the COMPARISON VOLTAGE control outer knob between the 10 and 9 detent positions; set the Vc RANGE switch to +11.

d. Adjust R208G (see Fig. 5-1) to center the trace.

e. Set the Vc RANGE switch to 0 and the COMPARISON VOLTAGE outer knob to 10.

f. Leave the jumper connected that connects from the B input connector to the junction of R310 and the wiper contact of SW310. Disconnect all other jumpers and connections to disconnect the Precision DC Divider from the W Unit.

### 25. Adjust R205B (Input B 1X Attenuator)

a. Insert the 1-meg resistor between the jumper lead and the B input connector.

b. Set the W Unit controls as follows:

| | |
|---|---|
| COMPARISON VOLTAGE | 5-5-0 |
| INPUT ATTEN | 10 |

c. Check that the trace is centered. If necessary use the DC BAL control to center the trace.

d. Set the Vc RANGE switch to +1.1.

e. Set the COMPARISON VOLTAGE control to center the trace. Leave the COMPARISON VOLTAGE control at this setting until step 25-i is completed.

f. Connect the non-loading voltmeter between the B input connector and ground.

g. Set the non-loading voltmeter to obtain a null reading (about 5.5 volts).

h. Set the INPUT ATTEN switch to 1 and Vc RANGE switch to +11.

i. Adjust R205B (see Fig. 5-1) to obtain a null reading on the non-loading voltmeter.

j. Set the Vc RANGE switch to 0.

k. Disconnect the voltmeter, resistor, and jumper lead.

### 26. Check Input A 1000X Attenuator

a. Set the DISPLAY switch to A—Vc.

The remaining controls should be at the following positions:

**W Unit**

| | |
|---|---|
| Vc RANGE | 0 |
| COMPARISON VOLTAGE | Not applicable |
| AC-DC-GND (both inputs) | DC |
| INPUT ATTEN | 1 |
| MILLIVOLTS/CM | 1 |
| VARIABLE (MILLIVOLTS/CM) | CALIB |
| POSITION | Midrange |
| DC BAL | Properly adjusted |

**Oscilloscope**

| | |
|---|---|
| Time/Cm | .5 ms |
| Triggering Controls | +Int, Auto |

b. Apply a 5 mV peak to peak signal from an amplitude calibrator through a coaxial cable to the A input connector.

c. Note the amplitude of the display because this will be used as a reference when checking the displayed amplitude in step 26-f.

d. Set the INPUT ATTEN switch to 1000.

e. Set the Amplitude Calibrator switch to 5 Volts.

f. Check that the amplitude of the display is within ±1.5 mm (±3%) of the display amplitude noted in step 26-c. (Take into consideration the accuracy of the signal source when performing step 26-c and 26-f or use item 2 in the Equipment Required list).

## 27. Check Input B 1000X Attenuator

a. Set the Amplitude Calibrator switch to 5 mVolts.

b. Disconnect the signal from Input A and apply the signal to Input B.

c. Set the W Unit controls as follows:

| | |
|---|---|
| INPUT ATTEN | 1 |
| DISPLAY | Vc—B |

d. Note the amplitude of the display to use as a reference.

e. Set the INPUT ATTEN switch to 1000.

f. Set the Amplitude Calibrator switch to 5 Volts.

g. Check that the amplitude of the display is within ±1.5 mm (±3%) of the display amplitude noted in step 27-d. (Take into consideration the accuracy of the signal source when performing steps 26-d and 26-g or use item 2 in the Equipment Required list.)

h. Disconnect the calibrator signal.

## 28. Adjust C210 (Input B 1X Input Time Constant Normalization)

a. Set the W Unit controls as follows:

| | |
|---|---|
| INPUT ATTEN | 1 |
| MILLIVOLTS/CM | 50 |

At this point in the procedure, the remaining controls should be at the following positions:

**W Unit**

| | |
|---|---|
| Vc RANGE | 0 |
| COMPARISON VOLTAGE | Not applicable |
| AC-DC-GND (both inputs) | DC |
| DISPLAY | Vc—B |
| VARIABLE (MILLIVOLTS/CM) | CALIB |
| POSITION | Near midrange |

**Oscilloscope**

| | |
|---|---|
| Time/Cm | .1 ms |
| Triggering Controls | +Int, Auto |

b. Apply a 1 kHz Hi Amplitude signal from the square-wave generator, through a coaxial cable, a 50-ohm termination, and a 1-meg X 20-pF input time constant normalizer (in that order) to the B input connector (see Fig. 5-7).

c. Set the square-wave generator output amplitude so the display is about 4 cm in amplitude.

d. Set the oscilloscope triggering controls for —Int stable triggering on the signal.

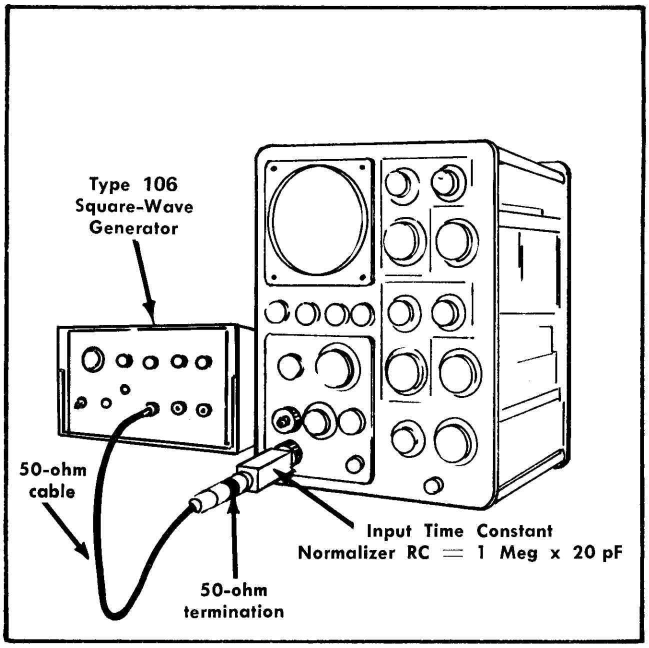



**Fig. 5-7. Setup for performing step 28.**

*NOTE*

*Use the W Unit POSITION control in this and succeeding steps for centering the display for best viewing.*

e. Lay the oscilloscope on its side; adjust C210 (see Fig. 5-1) for best lower front corner on the square-wave display (see Fig. 5-8A). Figs. 5-8B and 5-8C show the effect obtained when C210 is incorrectly adjusted. Return the oscilloscope to its upright position.

## 29. Adjust C110 (Input A 1X Input Time Constant Normalization)

a. Disconnect the signal from input B and apply it to the A input connector.

b. Set the DISPLAY switch to A—Vc.

c. Set the oscilloscope triggering controls for +Int triggering on the signal.

d. Adjust C110 (see Fig. 5-1) for best upper front corner on the square-wave display (waveforms will be inverted from those shown in Fig. 5-8).

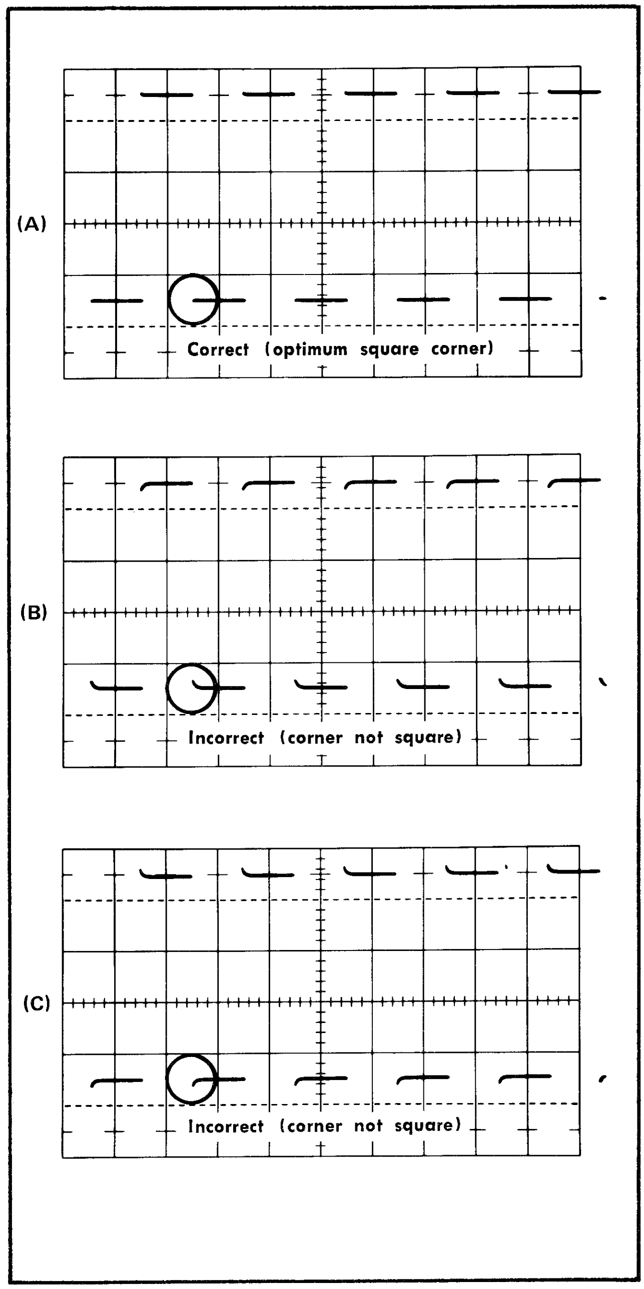



**Fig. 5-8. Normalizing the 1X input time constant of input B.**

## 30. Adjust Input Attenuator High-Frequency Compensation

a. Remove the input time-constant normalizer.

b. Connect the square-wave generator signal through the cable, termination, and a BNC T connector (in that order) to the A input connector.

c. Connect a short coax jumper cable from the BNC T connector to the B input connector.

d. Using Table 5-2 as a guide, perform the adjustments listed in the table from input A; that is, C106C, C106E, C108C, and C109C. Use the generator amplitude control to maintain 4 cm of deflection for the display. Fig. 5-9A shows the correct display; Fig. 5-9B and 5-9C show incorrect displays.

TABLE 5-2

Attenuator High-Frequency Compensation

| INPUT ATTEN Switch Setting | MILLI-VOLTS/CM Switch Setting | Adjustment (See Fig. 5-8) | Adjust For |
|---|---|---|---|
| 10 | 50 | C106C first, then C106E* | Best upper front corner (see Fig. 5-9A). |
| 100 | 20 | C108C | |
| 1000 | 2 | C109C | |
| 1000 | 2 | C209C | Best lower front corner. Similar display to that obtained through input A |
| 100 | 20 | C208C | |
| 10 | 50 | C206C first, then C260E* | |

*If C106C or C206E do not have sufficient range or proper adjustment, repeat the procedure.

e. After completing the adjustments for input A set the DISPLAY switch to Vc—B.

f. Using Table 5-2 as a guide, adjust C209C, C208C, C206C, and C206E. When making the adjustments, set the DISPLAY switch to A—Vc to compare the display obtained for input B to the display obtained for input A. When the adjustments are properly made, the displays for the two inputs should appear very similar to each other.

## 31. Adjust Input Attenuator Time Constant ◐

a. Check that the DISPLAY switch is set to A—Vc.

b. Remove the BNC T connector and short coax jumper cable. In their place insert the input time constant normalizer and apply the signal to input A.

c. Adjust the square-wave generator output amplitude to maintain a display of 4 cm in amplitude.

d. Using Table 5-3 as a guide, adjust C106B, C108B, and C109B. Maintain 4 cm of deflection.

e. After completing the input A adjustments, set the DISPLAY switch to Vc-B.

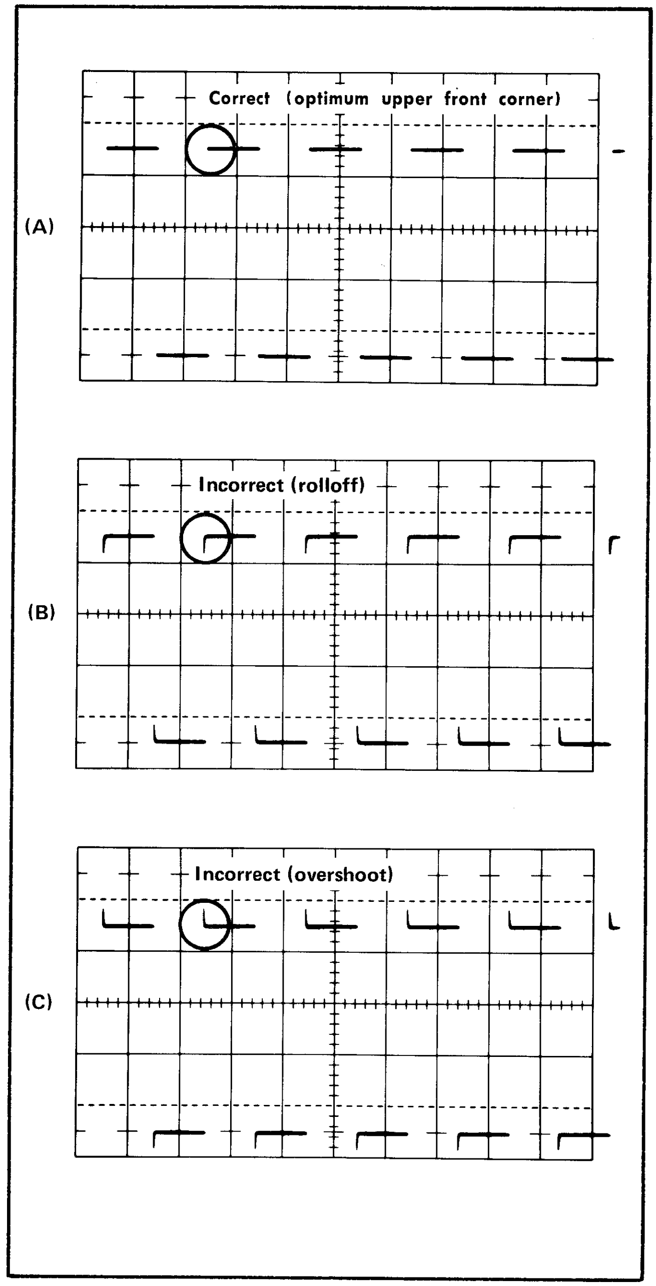



Fig. 5-9. Frequency-compensating the attenuators.

f. Disconnect the signal from input A and apply the signal to input B.

g. Using Table 5-3 as a guide, adjust C209B, C208B, and C206B.

h. Disconnect the signal from input B and turn off the square-wave generator.

TABLE 5-3

**Attenuator Time-Constant Normalization**

| INPUT ATTEN Switch Setting | MILLI-VOLTS/CM Switch Setting | Adjustments (See Fig. 5-1) | Adjust For |
|---|---|---|---|
| 10 | 50 | C106B | Best upper front |
| 100 | 10 | C108B | corner similar to |
| 1000 | 1 | C109B | Fig. 5-8A (inverted). |
| 1000 | 1 | C209B | Best lower front |
| 100 | 10 | C208B | corner similar to |
| 10 | 50 | C206B | Fig. 5-8A. |

## 32. Check Frequency Response

a. Set the INPUT ATTEN switch to 1.

b. Set the oscilloscope Time/Cm switch to 0.1 ms and free run the sweep.

At this point in the procedure, the remaining controls should be at the following positions:

**W Unit**

| | |
|---|---|
| Vc RANGE | 0 |
| COMPARISON VOLTAGE | Not applicable |
| AC-DC-GND (both inputs) | DC |
| DISPLAY | Vc—B |
| MILLIVOLTS/CM | 50 |
| VARIABLE (MILLIVOLTS/CM) | CALIB |
| POSITION | Near Midrange |
| DC BAL | Properly adjusted |

Apply a 50-kHz signal from the constant-amplitude sine-wave generator through a 50 ohm cable, and a 50 ohm termination (in that order), to the B input of the W-Unit. (Use the cable and termination supplied with the generator, or procure suitable adapters to match the W-Unit to the generator, cable, and termination being used.)

d. Adjust the generator amplitude control to obtain 4 cm of vertical deflection as a reference. If the amplitude of the generator signal cannot be reduced sufficiently by means of the attenuator controls on the generator, one or more 50 ohm 10:1 attenuators (with appropriate fittings or adapters) may be inserted at the generator end of the cable.

e. Set the generator output frequency to the frequency which is the 30% down point for the oscilloscope/W-Unit combination. Refer to the Specification section to find the bandwidth of the system.

*NOTE*

*The Type 191 generator maintains a constant-amplitude output signal automatically. If the generator you are using does not maintain a constant amplitude output, the generator output should be monitored and adjusted to the correct output level used as the reference. To monitor the output, use a wide-band test oscilloscope having a flat frequency response equal to or better than the frequency response (includes 30% down point) of the oscilloscope/W-Unit combination under test.*

f. At the frequency used in the previous step, check for at least 2.8 cm of vertical deflection on the oscilloscope used with the W Unit.

g. Check frequency response of each MILLIVOLTS/CM switch position. Compare your results with those listed in the Specification section.

h. Set the DISPLAY switch to A—Vc.

i. Apply the signal to input A and check the frequency response for each MILLIVOLTS/CM switch position in the same manner as was done for input B.

j. Disconnect the generator.

# PARTS LIST ABBREVIATIONS

| | |
|---|---|
| BHB | binding head brass |
| BHS | binding head steel |
| cap. | capacitor |
| cer | ceramic |
| comp | composition |
| conn | connector |
| CRT | cathode-ray tube |
| csk | countersunk |
| DE | double end |
| dia | diameter |
| div | division |
| elect. | electrolytic |
| EMC | electrolytic, metal cased |
| EMT | electrolytic, metal tubular |
| ext | external |
| F & I | focus and intensity |
| FHB | flat head brass |
| FHS | flat head steel |
| Fil HB | fillister head brass |
| Fil HS | fillister head steel |
| h | height or high |
| hex. | hexagonal |
| HHB | hex head brass |
| HHS | hex head steel |
| HSB | hex socket brass |
| HSS | hex socket steel |
| ID | inside diameter |
| inc | incandescent |
| int | internal |
| lg | length or long |
| met. | metal |
| mtg hdw | mounting hardware |
| OD | outside diameter |
| OHB | oval head brass |
| OHS | oval head steel |
| P/O | part of |
| PHB | pan head brass |
| PHS | pan head steel |
| plstc | plastic |
| PMC | paper, metal cased |
| poly | polystyrene |
| prec | precision |
| PT | paper, tubular |
| PTM | paper or plastic, tubular, molded |
| RHB | round head brass |
| RHS | round head steel |
| SE | single end |
| SN or S/N | serial number |
| S or SW | switch |
| TC | temperature compensated |
| THB | truss head brass |
| thk | thick |
| THS | truss head steel |
| tub. | tubular |
| var | variable |
| w | wide or width |
| WW | wire-wound |

## PARTS ORDERING INFORMATION

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

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

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

## SPECIAL NOTES AND SYMBOLS

| | |
|---|---|
| ×000 | Part first added at this serial number |
| 00× | Part removed after this serial number |
| *000-0000-00 | Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, Inc., or reworked or checked components. |
| Use 000-0000-00 | Part number indicated is direct replacement. |

# SECTION 6
# ELECTRICAL PARTS LIST

Values are fixed unless marked Variable.

## CHASSIS

### Capacitors

Tolerance ±20% unless otherwise indicated.

| Ckt. No. | Tektronix Part No. | Serial/Model No. Eff | Disc | Description | | | |
|---|---|---|---|---|---|---|---|
| C101 | 281-0625-00 | | | 35 pF | Cer | 500 V | 5% |
| C102[1] | *295-0105-01 | | | 0.1 μF | PTM | 600 V | +5%—15% |
| C106B | 281-0102-00 | | | 1.7-11 pF, Var | Air | | |
| C106C | 281-0102-00 | | | 1.7-11 pF, Var | Air | | |
| C106D | 283-0109-00 | | | 27 pF | Cer | 1000 V | 5% |
| C106E | 281-0098-00 | | | 1.2-3.5 pF, Var | Air | | |
| C106F | 281-0613-00 | | | 10 pF | Cer | 200 V | 10% |
| C108B | 281-0103-00 | | | 1.8-13 pF, Var | Air | | |
| C108C | 281-0098-00 | | | 1.2-3.5 pF, Var | Air | | |
| C108E | 283-0108-00 | | | 220 pF | Cer | 200 V | 10% |
| C109B | 281-0102-00 | | | 1.7-11 pF, Var | Air | | |
| C109C | 281-0098-00 | | | 1.2-3.5 pF, Var | Air | | |
| C109D | 283-0607-00 | | | 0.002 μF | Mica | 500 V | 10% |
| C110 | 281-0037-00 | | | 0.7-3 pF, Var | Air | | |
| C111 | 283-0059-00 | | | 1 μF | Cer | 25 V | +80%-20% |
| C112[2] | 295-0135-00 | | | 0.0068 μF | PTM | 600 V | 5% |
| C114 | 283-0000-00 | | | 0.001 μF | Cer | 500 V | |
| C120 | 290-0267-00 | | | 1 μF | Elect. | 35 V | |
| C130 | 290-0267-00 | | | 1 μF | Elect. | 35 V | |
| C155 | 281-0061-00 | | | 5.5-18 pF, Var | Cer | | |
| C166 | 281-0534-00 | | | 3.3 pF | Cer | 500 V | ±0.25 pF |
| C167 | 281-0593-00 | | | 3.9 pF | Cer | | 10% |
| C170 | 281-0060-00 | | | 2-8 pF, Var | Cer | | |
| C174 | 281-0005-00 | | | 1.5-7 pF, Var | Cer | | |
| C185 | 281-0611-00 | | | 2.7 pF | Cer | 200 V | ±0.25 pF |
| C190 | 283-0001-00 | | | 0.005 μF | Cer | 500 V | |
| C192 | 283-0001-00 | | | 0.005 μF | Cer | 500 V | |
| C195 | 283-0001-00 | | | 0.005 μF | Cer | 500 V | |
| C201 | 281-0625-00 | | | 35 pF | Cer | 500 V | 5% |
| C202[3] | *295-0105-01 | | | 0.1 μF | PTM | 600 V | +5%—15% |

[1]C102 and C202 matched to within ±1% of each other, furnished as a unit.

[2]C112 and C212 matched to within ±1% of each other, furnished as a unit.

[3]C202 and C102 matched to within ±1% of each other, furnished as a unit.

## CHASSIS (cont)

| Ckt. No. | Tektronix Part No. | Serial/Model No. Eff | Disc | Description | | | |
|---|---|---|---|---|---|---|---|
| | | | | **Capacitors (cont)** | | | |
| C206B | 281-0102-00 | | | 1.7-11 pF, Var | Air | | |
| C206C | 281-0102-00 | | | 1.7-11 pF, Var | Air | | |
| C206D | 283-0109-00 | | | 27 pF | Cer | 1000 V | 5% |
| C206E | 281-0098-00 | | | 1.2-3.5 pF, Var | Air | | |
| C206F | 281-0613-00 | | | 10 pF | Cer | 200 V | 10% |
| C208B | 281-0103-00 | | | 1.8-13 pF, Var | Air | | |
| C208C | 281-0098-00 | | | 1.2-3.5 pF, Var | Air | | |
| C208E | 283-0108-00 | | | 220 pF | Cer | 200 V | 10% |
| C209B | 281-0102-00 | | | 1.7-11 pF, Var | Air | | |
| C209C | 281-0098-00 | | | 1.2-3.5 pF, Var | Air | | |
| C209D | 283-0607-00 | | | 0.002 $\mu$F | Mica | 500 V | 10% |
| C210 | 281-0037-00 | | | 0.7-3 pF, Var | Air | | |
| C212[4] | 295-0135-00 | | | 0.0068 $\mu$F | PTM | 600 V | 5% |
| C214 | 283-0000-00 | | | 0.001 $\mu$F | Cer | 500 V | |
| C274 | 281-0005-00 | | | 1.5-7 pF, Var | Cer | | |
| C285 | 281-0611-00 | | | 2.7 pF | Cer | 200 V | $\pm$0.25 pF |
| C286 | 285-0555-00 | | | 0.1 pF | PTM | 100 V | |
| | | | | **Semiconductor Device, Diodes** | | | |
| D120 | 152-0405-00 | | | Zener | 1 W, 15 V, 5% | | |
| D121 | *152-0185-00 | | | Silicon | Replaceable by 1N4152 | | |
| D122 | *152-0185-00 | | | Silicon | Replaceable by 1N4152 | | |
| D130 | 152-0405-00 | | | Zener | 1 W, 15 V, 5% | | |
| D131 | *152-0185-00 | | | Silicon | Replaceable by 1N4152 | | |
| D132 | *152-0185-00 | | | Silicon | Replaceable by 1N4152 | | |
| D140 | *152-0107-00 | | | Silicon | Replaceable by 1N647 | | |
| D142A, B | *152-0178-00 | | | Silicon | Assembly, Tek Spec | | |
| D175 | 152-0281-00 | | | Zener | 1N969B, 400 mW, 22 V, 5% | | |
| D193 | 152-0265-00 | | | Zener | 1N970B, 400 mW, 24 V, 5% | | |
| D195 | 152-0279-00 | X7390 | | Zener | 1N751A, 5.1 V | | |
| D301 | 152-0171-00 | | | Zener | 1N944, 11.7 V, 5% | | |
| | | | | **Inductors** | | | |
| LR106B | *108-0332-00 | | | 0.75 $\mu$H | (wound on a 130 $\Omega$ resistor) | | |
| LR106G | *108-0270-00 | | | 0.25 $\mu$H | (wound on a 62 $\Omega$ resistor) | | |
| LR108B | *108-0298-00 | | | 0.25 $\mu$H | (wound on a 36 $\Omega$ resistor) | | |
| LR108D | *108-0271-00 | | | 0.25 $\mu$H | (wound on a 51 $\Omega$ resistor) | | |
| LR206B | *108-0332-00 | | | 0.75 $\mu$H | (wound on a 130 $\Omega$ resistor) | | |
| LR206G | *108-0270-00 | | | 0.25 $\mu$H | (wound on a 62 $\Omega$ resistor) | | |
| LR208B | *108-0298-00 | | | 0.25 $\mu$H | (wound on a 36 $\Omega$ resistor) | | |
| LR208D | *108-0271-00 | | | 0.25 $\mu$H | (wound on a 51 $\Omega$ resistor) | | |

[4]C212 and C112 matched to within $\pm$1% of each other, furnished as a unit.

## CHASSIS (cont)

| Ckt. No. | Tektronix Part No. | Serial/Model No. Eff | Disc | Description | | | |
|---|---|---|---|---|---|---|---|

### Transistors

| Ckt. No. | Tektronix Part No. | Eff | Disc | Description | | | |
|---|---|---|---|---|---|---|---|
| Q134 | *151-0150-00 | | | Silicon | NPN | TO-5 | Selected from 2N3440 |
| Q154A, B | *151-0139-00 | | | Silicon | NPN | TO-5 | Tek Spec, Dual |
| Q174 | 151-0188-00 | | | Silicon | PNP | TO-92 | 2N3906 |
| Q184 | *151-0195-00 | | | Silicon | NPN | TO-92 | Replaceable by MPS 6515 |
| Q274 | 151-0188-00 | | | Silicon | PNP | TO-92 | 2N3906 |
| Q284 | *151-0195-00 | | | Silicon | NPN | TO-92 | Replaceable by MPS 6515 |

### Resistors

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

| Ckt. No. | Tektronix Part No. | Eff | Disc | Description | | | |
|---|---|---|---|---|---|---|---|
| R101 | 321-0138-00 | | | 267 Ω | ⅛ W | Prec | 1% |
| R105A | 323-0680-00 | | | 988 kΩ | ½ W | Prec | 1% |
| R105B | 311-0487-00 | | | 30 kΩ, Var | | | |
| R106A[5] | 325-0004-00 | | | 900 kΩ | ¼ W | Prec | 1/10% |
| R106C[6] | 325-0003-00 | | | 99.8 kΩ | ⅛ W | Prec | 1/10% |
| R106E | 311-0486-00 | | | 500 Ω, Var | | | |
| R106F | 316-0101-00 | | | 100 Ω | ¼ W | | |
| R108A | 323-0681-00 | | | 990 kΩ | ½ W | Prec | 1% |
| R108F | 321-0637-00 | | | 9.9 kΩ | ⅛ W | Prec | ½% |
| R108G | 311-0485-00 | | | 250 Ω, Var | | | |
| R109A | 323-0623-00 | | | 999 kΩ | ½ W | Prec | 1% |
| R109B | 316-0101-00 | | | 100 Ω | ¼ W | | |
| R109D | 316-0470-00 | | | 47 Ω | ¼ W | | |
| R109F | 321-0193-00 | | | 1 kΩ | ⅛ W | Prec | 1% |
| R110 | 321-1449-00 | | | 470 kΩ | ⅛ W | Prec | 1% |
| R111 | 316-0470-00 | | | 47 Ω | ¼ W | | |
| R116 | 316-0101-00 | | | 100 Ω | ¼ W | | |
| R118 | 323-0320-00 | | | 21 kΩ | ½ W | Prec | 1% |
| R119 | 323-0469-00 | | | 750 kΩ | ½ W | Prec | 1% |
| R120 | 303-0183-00 | | | 18 kΩ | 1 W | | 5% |
| R122 | 323-0281-00 | | | 8.25 kΩ | ½ W | Prec | 1% |
| R124 | 316-0101-00 | | | 100 Ω | ¼ W | | |
| R126 | 323-0302-00 | | | 13.7 kΩ | ½ W | Prec | 1% |
| R127 | 311-0310-00 | | | 5 kΩ, Var | | DC BAL | |
| R128 | 323-0302-00 | | | 13.7 kΩ | ½ W | Prec | 1% |
| R130 | 316-0101-00 | | | 100 Ω | ¼ W | | |
| R133 | 323-0312-00 | | | 17.4 kΩ | ½ W | Prec | 1% |
| R134 | 323-0278-00 | | | 7.68 kΩ | ½ W | Prec | 1% |
| R136 | 316-0470-00 | | | 47 Ω | ¼ W | | |
| R139 | 324-0605-00 | | | 3.33 kΩ | 1 W | Prec | 1% |

[5] **R106A and R206A furnished as a unit.**

[6] **R106C and R206C furnished as a unit.**

## CHASSIS (cont)

| Ckt. No. | Tektronix Part No. | Serial/Model No. Eff | Disc | Description | | | |
|---|---|---|---|---|---|---|---|
| | | | | **Resistors (cont)** | | | |
| R143 | 323-0360-00 | | | 54.9 kΩ | 1/2 W | Prec | 1% |
| R144 | 321-0405-00 | | | 162 kΩ | 1/8 W | Prec | 1% |
| R149 | 323-0210-00 | | | 1.5 kΩ | 1/2 W | Prec | 1% |
| R150 | 315-0820-00 | | | 82 Ω | 1/4 W | | 5% |
| R152 | 316-0101-00 | | | 100 Ω | 1/4 W | | |
| R154 | 321-0091-00 | 7000 | 7219 | 86.6 Ω | 1/8 W | Prec | 1% |
| R154 | 321-0097-00 | 7220 | | 100 Ω | 1/8 W | Prec | 1% |
| R155[7] | 311-0630-00 | 7000 | 7091 | 500 Ω, Var | | VARIABLE (mV/cm) | |
| R155[7] | 311-0422-00 | 7092 | | 500 Ω, Var | | VARIABLE (mV/cm) | |
| R157 | 311-0169-00 | | | 100 Ω, Var | | | |
| R158 | 321-0091-00 | 7000 | 7219 | 86.6 Ω | 1/8 W | Prec | 1% |
| R158 | 321-0097-00 | 7220 | | 100 Ω | 1/8 W | Prec | 1% |
| R160 | 323-0318-00 | | | 20 kΩ | 1/2 W | Prec | 1% |
| R161 | 311-0086-00 | | | 2.5 kΩ, Var | | VAR BAL | |
| R163 | 323-0318-00 | | | 20 kΩ | 1/2 W | Prec | 1% |
| R164 | 315-0271-00 | X7490 | | 270 Ω | 1/4 W | | 5% |
| R165 | 323-0239-00 | | | 3.01 kΩ | 1/2 W | Prec | 1% |
| R166 | 323-0181-00 | | | 750 Ω | 1/2 W | Prec | 1% |
| R167 | 323-0147-00 | | | 332 Ω | 1/2 W | Prec | 1% |
| R168 | 323-0116-00 | | | 158 Ω | 1/2 W | Prec | 1% |
| R169 | 323-0647-00 | | | 61.4 Ω | 1/2 W | Prec | 1% |
| R170 | 315-0271-00 | X7490 | | 270 Ω | 1/4 W | | 5% |
| R172 | 323-0197-00 | | | 1.1 kΩ | 1/2 W | Prec | 1% |
| R173 | 316-0470-00 | | | 47 Ω | 1/4 W | | |
| R174 | 323-0176-00 | | | 665 Ω | 1/2 W | Prec | 1% |
| R175 | 322-0654-00 | | | 920 Ω | 1/4 W | Prec | 1% |
| R176 | 311-0181-00 | | | 250 Ω, Var | | POSITION RANGE | |
| R178 | 308-0286-00 | | | 8.2 kΩ | 3 W | WW | 5% |
| R179 | 321-0145-00 | | | 316 Ω | 1/8 W | Prec | 1% |
| R180 | 315-0102-00 | | | 1 kΩ | 1/4 W | | 5% |
| R185 | 315-0472-00 | | | 4.7 kΩ | 1/4 W | | 5% |
| R190 | 302-0470-00 | | | 47 Ω | 1/2 W | | |
| R192 | 302-0470-00 | | | 47 Ω | 1/2 W | | |
| R193 | 304-0273-00 | | | 27 kΩ | 1 W | | |
| R195 | 302-0470-00 | | | 47 Ω | 1/2 W | | |
| R201 | 321-0138-00 | | | 267 Ω | 1/8 W | Prec | 1% |
| R205A | 323-0680-00 | | | 988 kΩ | 1/2 W | Prec | 1% |
| R205B | 311-0487-00 | | | 30 kΩ, Var | | | |
| R206A[8] | 325-0004-00 | | | 900 kΩ | 1/4 W | Prec | 1/10% |
| R206C[9] | 325-0003-00 | | | 99.8 kΩ | 1/8 W | Prec | 1/10% |
| R206E | 311-0486-00 | | | 500 Ω, Var | | | |
| R206F | 316-0101-00 | | | 100 Ω | 1/4 W | | |

[7]R155 and S155 furnished as a unit.
[8]R206A and R106A furnished as a unit.
[9]R206C and R106C furnished as a unit.

## CHASSIS (cont)

| Ckt. No. | Tektronix Part No. | Serial/Model No. Eff | Disc | Description | | | |
|---|---|---|---|---|---|---|---|
| | | | | **Resistors** (cont) | | | |
| R208A | 323-0681-00 | | | 990 kΩ | ½ W | Prec | ½% |
| R208F | 321-0637-00 | | | 9.9 kΩ | ⅛ W | Prec | ½% |
| R208G | 311-0485-00 | | | 250 Ω, Var | | | |
| R209A | 323-0623-00 | | | 999 kΩ | ½ W | Prec | 1% |
| R209B | 316-0101-00 | | | 100 Ω | ¼ W | | |
| R209D | 316-0470-00 | | | 47 Ω | ¼ W | | |
| R209F | 321-0193-00 | | | 1 kΩ | ⅛ W | Prec | 1% |
| R210 | 321-1449-00 | | | 470 kΩ | ⅛ W | Prec | 1% |
| R216 | 316-0101-00 | | | 100 Ω | ¼ W | | |
| R218 | 323-0320-00 | | | 21 kΩ | ½ W | Prec | 1% |
| R219 | 323-0469-00 | | | 750 kΩ | ½ W | Prec | 1% |
| R222 | 323-0281-00 | | | 8.25 kΩ | ½ W | Prec | 1% |
| R223 | 311-0329-00 | | | 50 kΩ, Var | | DIFF BAL | |
| R243 | 323-0360-00 | | | 54.9 kΩ | ½ W | Prec | 1% |
| R244 | 321-0405-00 | | | 162 kΩ | ⅛ W | Prec | 1% |
| R249 | 323-0210-00 | | | 1.5 kΩ | ½ W | Prec | 1% |
| R250 | 315-0820-00 | | | 82 Ω | ¼ W | | 5% |
| R252 | 316-0101-00 | | | 100 Ω | ¼ W | | |
| R272 | 323-0197-00 | | | 1.1 kΩ | ½ W | Prec | 1% |
| R273 | 316-0470-00 | | | 47 Ω | ¼ W | | |
| R274 | 323-0176-00 | | | 665 Ω | ½ W | Prec | 1% |
| R278 | 308-0286-00 | | | 8.2 kΩ | 3 W | WW | 5% |
| R279 | 311-0005-00 | | | 500 Ω, Var | | POSITION | |
| R280 | 311-0474-00 | | | 2 kΩ, Var | | DC LEVEL | |
| R281 | 323-0166-00 | | | 523 Ω | ½ W | Prec | 1% |
| R282 | 302-0473-00 | | | 47 kΩ | (nominal value) | Selected | |
| R283 | 308-0003-00 | | | 2 kΩ | 5 W | WW | 5% |
| R285 | 315-0472-00 | | | 4.7 kΩ | ¼ W | | 5% |
| R286 | 308-0071-00 | | | 500 Ω | 5 W | WW | 5% |
| R290 | 308-0315-00 | | | 150 Ω | 10 W | WW | 5% |
| R292 | 308-0405-00 | | | 70 Ω | 3 W | WW | 5% |
| R301 | 308-0321-00 | | | 24.4 kΩ | 5 W | WW | 1% |
| R303 | 308-0320-00 | | | 15.6 kΩ | 3 W | WW | 1% |
| R306 | 301-0113-00 | | | 11 kΩ | ½ W | | 5% |
| R308 | 308-0330-00 | | | 300 Ω | (nominal value) | Selected | |
| R310 | 311-0484-00 | | | 500 Ω, Var | | Vc CAL | |
| R313 | 308-0326-00 | | | 9.9 kΩ | ½ W | WW | 0.01% |
| R315 | 308-0324-00 | | | 1.222 kΩ | ½ W | WW | 0.01% |
| R322 | 308-0316-00 | | | 3.1 kΩ | 5 W | WW | 1% |
| R323 | 311-0484-00 | | | 500 Ω, Var | | TRACKING | |

## CHASSIS (cont)

| Ckt. No. | Tektronix Part No. | Serial/Model No. Eff | Disc | Description | |
|---|---|---|---|---|---|
| | | | | **Resistors (cont)** | |
| R325 | 311-0360-00 | | | 5 kΩ, Var | VARIABLE Vc |
| R327 | 302-0102-00 | | | 1 kΩ | ¼ W |
| R330 thru R341 | 308-0323-00 | | | 1 kΩ | ½ W WW Matched set (within .02% of each other) |
| | | | | **Switches** | |
| Wired or Unwired | | | | | |
| S101 | 260-0603-00 | | | Rotary | AC-DC-GND A |
| S105 } S205 } wired | *262-0680-01 | | | Rotary | INPUT ATTEN |
| S105 } S205 } | 260-0634-00 | | | Rotary | INPUT ATTEN |
| S110 wired | *262-0679-01 | | | Rotary | DISPLAY |
| S110 | 260-0635-00 | | | Rotary | DISPLAY |
| S150 } S155 } | *262-0676-00 | | | Rotary | MILLIVOLTS/CM CALIB |
| S150 | 260-0632-00 | | | Rotary | MILLIVOLTS/CM |
| S155[10] | 311-0630-00 | 7000 | 7091 | | CALIB |
| S155[10] | 311-0422-00 | 7092 | | | CALIB |
| S201 | 260-0603-00 | | | Rotary | AC-DC-GND B |
| S310 wired | *262-0678-00 | | | Rotary | Vc RANGE |
| S310 | 260-0633-00 | | | Rotary | Vc RANGE |
| S320 wired | *262-0677-00 | | | Rotary | COMPARISON VOLTAGE (Vc) |
| S320 | 260-0777-00 | | | Rotary | COMPARISON VOLTAGE (Vc) |
| | | | | **Transformers** | |
| T150 | 276-0541-00 | | | Core, ferrite | |
| T155 | 276-0541-00 | | | Core, ferrite | |
| | | | | **Electron Tubes** | |
| V114A,B | 154-0413-00 | | | 8416 | |
| V124A,B | 154-0413-00 | | | 8416 | |
| V214A,B | 154-0413-00 | | | 8416 | |

[10]S155 and R155 furnished as a unit.

## OUTPUT Circuit Board Assembly

| Ckt. No. | Tektronix Part No. | Serial/Model No. Eff | Disc | Description |
|---|---|---|---|---|
| | *670-0131-01 | | | Complete Board |

### Capacitors

Tolerance ±20% unless otherwise indicated.

| | | | | | | |
|---|---|---|---|---|---|---|
| C184 | 281-0097-00 | | | 9-35 pF, Var | Cer | |
| C292 | 281-0618-00 | | | 4.7 pF | (nominal value) | Selected |
| C293 | 283-0068-00 | | | 0.01 μF | Cer | 500 V |
| C294 | 281-0097-00 | | | 9-35 pF, Var | Cer | |
| C295 | 281-0097-00 | | | 9-35 pF, Var | Cer | |
| C296 | 283-0068-00 | | | 0.01 μF | Cer | 500 V |

### Semiconductor Device, Diode

| | | | | | |
|---|---|---|---|---|---|
| D293 | 152-0022-00 | | | Zener | 1M25Z5 1 W, 25 V, 5% |

### Transistors

| | | | | | | |
|---|---|---|---|---|---|---|
| Q194 | 151-0199-00 | | | Silicon | PNP | TO-92 Replaceable by MOT MPS 3640 |
| Q294 | 151-0199-00 | | | Silicon | PNP | TO-92 Replaceable by MOT MPS 3640 |

### Resistors

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| R191 | 306-0153-00 | | | 15 kΩ | 2 W | | |
| R196 | 315-0201-00 | | | 200 Ω | ¼ W | | 5% |
| R197 | 321-0076-00 | | | 60.4 Ω | ⅛ W | Prec | 1% |
| R198 | 321-0047-00 | | | 30.1 Ω | ⅛ W | Prec | 1% |
| R200 | 315-0203-00 | | | 20 kΩ | ¼ W | (nominal value) Selected | |
| R287 | 315-0271-00 | | | 270 Ω | ¼ W | | 5% |
| R288 | 308-0127-00 | | | 2.5 kΩ | 5 W | WW | 5% |
| R289 | 315-0121-00 | | | 120 Ω | ¼ W | | 5% |
| R291 | 308-0335-00 | | | 7 kΩ | 7 W | WW | 5% |
| R294 | 315-0511-00 | | | 510 Ω | ¼ W | | 5% |
| R296 | 315-0201-00 | | | 200 Ω | ¼ W | | 5% |
| R297 | 321-0076-00 | | | 60.4 Ω | ⅛ W | Prec | 1% |
| R298 | 321-0047-00 | | | 30.1 Ω | ⅛ W | Prec | 1% |

## FET INPUT Circuit Board Assembly

| Ckt. No. | Tektronix Part No. | Serial/Model No. Eff | Disc | Description | | | |
|---|---|---|---|---|---|---|---|
| | *670-1168-00 | | | Complete Board | | | |

### Capacitor

Tolerance ±20% unless otherwise indicated.

| Ckt. No. | Tektronix Part No. | Eff | Disc | Description | | |
|---|---|---|---|---|---|---|
| C196 | 290-0168-00 | | | 100 μF | Elect. | 6 V |

### Semiconductor Device, Diodes

| Ckt. No. | Tektronix Part No. | Eff | Disc | Description | |
|---|---|---|---|---|---|
| D113 | *152-0321-00 | | | Silicon | Dual, Tek Spec |
| D213 | *152-0321-00 | | | Silicon | Dual, Tek Spec |

### Transistors

| Ckt. No. | Tektronix Part No. | Eff | Disc | Description | | |
|---|---|---|---|---|---|---|
| Q104 | *151-0190-01 | | | Silicon | NPN | TO-106 Tek Spec |
| Q113A,B | 151-1011-00 | | | Silicon | FET | TO-71 N channel Junction type, Dual |
| Q195 | *151-0190-01 | | | Silicon | NPN | TO-106 Tek Spec |
| Q196 | *151-0190-01 | | | Silicon | NPN | TO-106 Tek Spec |
| Q204 | *151-0190-01 | | | Silicon | NPN | TO-106 Tek Spec |

### Resistors

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

| Ckt. No. | Tektronix Part No. | Eff | Disc | Description | | | |
|---|---|---|---|---|---|---|---|
| R112 | 321-0177-00 | | | 681 Ω | 1/8 W | Prec | 1% |
| R114 | 315-0470-00 | | | 47 Ω | 1/4 W | | 5% |
| R194 | 315-0274-00 | | | 270 kΩ | 1/4 W | | 5% |
| R199 | 315-0205-00 | | | 2 MΩ | 1/4 W | | 5% |
| R212 | 321-0177-00 | | | 681 Ω | 1/8 W | Prec | 1% |
| R214 | 315-0470-00 | | | 47 Ω | 1/4 W | | 5% |

## FIGURE AND INDEX NUMBERS

Items in this section are referenced by figure and index numbers to the illustrations which appear either on the back of the diagrams or on pullout pages immediately following the diagrams of the instruction manual.

## INDENTATION SYSTEM

This mechanical parts list is indented to indicated 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.

# SECTION 7
# MECHANICAL PARTS LIST

## FIGURE 1 EXPLODED

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Disc | Qty | Description 1 2 3 4 5 |
|---|---|---|---|---|---|
| 1-1 | 366-0173-00 | | | 1 | KNOB, charcoal—Vc RANGE |
| | - - - - - - | | | - | knob includes: |
| | 213-0004-00 | | | 1 | SETSCREW, 6-32 x 0.188 inch, HSS |
| -2 | 331-0091-00 | | | 1 | DIAL, w/charcoal knob |
| -3 | 366-0279-00 | | | 1 | KNOB, charcoal—COMPARISON VOLTAGE (Vc) |
| | - - - - - - | | | - | knob includes: |
| | 213-0020-00 | | | 2 | SETSCREW, 6-32 x 0.125 inch, HSS |
| -4 | 366-0031-00 | | | 1 | KNOB, red—DISPLAY |
| | - - - - - - | | | - | knob includes: |
| | 213-0004-00 | | | 1 | SETSCREW, 6-32 x 0.188 inch |
| -5 | 366-0142-00 | | | 1 | KNOB, charcoal—INPUT ATTEN |
| | - - - - - - | | | - | knob includes: |
| | 213-0004-00 | | | 1 | SETSCREW, 6-32 x 0.188 inch, HSS |
| -6 | 366-0031-00 | | | 1 | KNOB, red—VARIABLE |
| | - - - - - - | | | - | knob includes: |
| | 213-0004-00 | | | 1 | SETSCREW, 6-32 x 0.188 inch, HSS |
| -7 | 366-0142-00 | | | 1 | KNOB, charcoal—MILLIVOLTS/CM |
| | - - - - - - | | | - | knob includes: |
| | 213-0004-00 | | | 1 | SETSCREW, 6-32 x 0.188 inch, HSS |
| -8 | 366-0113-00 | | | 1 | KNOB, charcoal—POSITION |
| | - - - - - - | | | - | knob includes: |
| | 213-0004-00 | | | 1 | SETSCREW, 6-32 x 0.188 inch, HSS |
| -9 | 366-0125-00 | | | 1 | KNOB, latch |
| | - - - - - - | | | - | knob includes: |
| | 213-0004-00 | | | 1 | SETSCREW, 6-32 x 0.188 inch, HSS |
| -10 | 210-0894-00 | | | 1 | WASHER, plastic, 0.19 ID x 0.438 inch OD |
| -11 | 136-0098-00 | | | 1 | SOCKET, tip jack, w/hardware |
| -12 | 129-0035-00 | | | 1 | BINDING POST ASSEMBLY |
| | - - - - - - | | | - | binding post assembly includes: |
| | 355-0507-00 | | | 1 | STEM, binding post |
| | 200-0103-00 | | | 1 | CAP |
| -13 | 210-0455-00 | | | 1 | NUT, hex., 0.25-28 x 0.375 inch |
| -14 | 210-0046-00 | | | 1 | WASHER, lock, internal, 0.261 ID x 0.40 inch OD |

## FIGURE 1 EXPLODED (cont)

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Serial/Model No. Disc | Qty | Description 1 2 3 4 5 |
|---|---|---|---|---|---|
| -15 | 260-0603-00 | | | 2 | SWITCH, rotary—AC-DC-GND, unwired |
| | - - - - - - | | | - | each switch includes: |
| -16 | 366-0274-00 | | | 1 | KNOB, charcoal—AC-DC-GND |
| -17 | 210-0951-00 | | | 1 | WASHER, locating |
| -18 | 354-0179-00 | | | 1 | RING, retaining |
| | 214-0240-00 | | | 1 | SPRING, compression (not shown) |
| | 214-0274-00 | | | 1 | BALL, detent (not shown) |
| | - - - - - - | | | - | mounting hardware for each: (not included w/switch) |
| | 210-0568-00 | | | 1 | NUT, hex., 0.875-32 x 1.125 inches |
| | 210-0047-00 | | | 1 | WASHER, lock, internal, 0.88 ID x 1.11 inches OD |
| -19 | 333-0834-00 | | | 1 | PANEL, front |
| -20 | 262-0677-00 | | | 1 | SWITCH, rotary—COMPARISON VOLTAGE (Vc), wired |
| | - - - - - - | | | - | switch includes: |
| | 260-0777-00 | | | 1 | SWITCH, rotary, unwired |
| -21 | - - - - - - | | | 1 | RESISTOR, variable |
| | - - - - - - | | | - | mounting hardware: (not included w/resistor) |
| -22 | 211-0008-00 | | | 2 | SCREW, 4-40 x 0.25 inch, PHS |
| -23 | 210-0801-00 | | | 2 | WASHER, flat, 0.14 ID x 0.281 inch OD |
| -24 | 426-0289-00 | | | 1 | MOUNT, plastic |
| -25 | 210-0413-00 | | | 1 | NUT, hex., 0.375-32 x 0.50 inch |
| | 210-0012-00 | | | 1 | WASHER, lock, internal, 0.375 ID x 0.50 inch OD |
| -26 | 384-0320-00 | | | 1 | ROD, shaft |
| | - - - - - - | | | - | mounting hardware: (not included w/switch) |
| -27 | 210-0579-00 | | | 1 | NUT, hex., 0.625-24 x 0.75 inch |
| -28 | 210-0049-00 | | | 1 | WASHER, lock, internal, 0.625 inch ID |
| -29 | 262-0678-00 | | | 1 | SWITCH, rotary—Vc RANGE, wired |
| | - - - - - - | | | - | switch includes: |
| | 260-0633-00 | | | 2 | SWITCH, rotary, unwired |
| -30 | - - - - - - | | | 2 | RESISTOR, variable |
| | - - - - - - | | | - | mounting hardware for each: (not included w/resistor) |
| -31 | 211-0089-00 | | | 2 | SCREW, 2-56 x 0.375 inch, PHS |
| -32 | 210-0001-00 | | | 2 | WASHER, lock, internal, #2 |
| -33 | 210-0405-00 | | | 2 | NUT, hex., 2-56 x 0.188 inch |
| | - - - - - - | | | - | mounting hardware: (not included w/switch) |
| -34 | 210-0413-00 | | | 1 | NUT, hex., 0.375-32 x 0.50 inch |
| -35 | 210-0840-00 | | | 1 | WASHER, flat, 0.39 ID x 0.562 inchOD |
| -36 | 210-0012-00 | | | 1 | WASHER, lock, internal, 0.375 ID x 0.50 inch OD |

## FIGURE 1 EXPLODED (cont)

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Serial/Model No. Disc | Qty | Description 1 2 3 4 5 |
|---|---|---|---|---|---|
| -37 | 262-0676-00 | | | 1 | SWITCH, rotary—MILLIVOLTS/CM |
| | - - - - - - | | | - | switch includes: |
| | 260-0632-00 | | | 1 | SWITCH, rotary, unwired |
| | - - - - - - | | | - | mounting hardware: (not included w/switch) |
| -38 | 210-0406-00 | | | 2 | NUT, hex., 4-40 x 0.188 inch |
| -39 | 210-0004-00 | | | 2 | WASHER, lock, internal, #4 |
| -40 | 384-0409-00 | | | 1 | ROD, extension |
| -41 | 376-0029-00 | | | 1 | COUPLING, shaft |
| | - - - - - - | | | - | coupling includes: |
| | 213-0075-00 | | | 2 | SETSCREW, 4-40 x 0.094 inch, HSS |
| -42 | - - - - - - | | | 2 | RESISTOR, variable |
| | - - - - - - | | | - | mounting hardware for each: (not included w/resistor) |
| -43 | 210-0562-00 | | | 1 | NUT, hex., 0.25-40 x 0.312 inch |
| -44 | 210-0940-00 | | | 1 | WASHER, flat, 0.25 ID x 0.375 inch OD |
| -45 | 407-0065-00 | | | 1 | BRACKET |
| -46 | 376-0039-00 | | | 1 | COUPLING, shaft |
| | - - - - - - | | | - | coupling includes: |
| | 213-0075-00 | | | 2 | SETSCREW, 4-40 x 0.094 inch, HSS |
| | - - - - - - | | | - | mounting hardware: (not included w/switch) |
| -47 | 211-0504-00 | | | 2 | SCREW, 6-32 x 0.25 inch, PHS |
| -48 | 210-0413-00 | | | 1 | NUT, hex., 0.375-32 x 0.50 inch |
| | 210-0840-00 | | | 1 | WASHER, flat 0.39 ID x 0.562 inch OD |
| -49 | 210-0012-00 | | | 1 | WASHER, lock, internal, 0.375 ID x 0.50 inch OD |
| -50 | 384-0319-00 | | | 1 | ROD, extension |
| | 644-0009-01 | | | 1 | ATTENUATOR SWITCH ASSEMBLY |
| | - - - - - - | | | - | attenuator switch assembly includes: |
| -51 | 610-0130-00 | | | 1 | ATTENUATOR CHASSIS ASSEMBLY |
| | - - - - - - | | | - | attenuator chassis includes: |
| | 441-0586-00 | | | 1 | CHASSIS |
| -52 | - - - - - - | | | 14 | CAPACITOR |
| | - - - - - - | | | - | mounting hardware for each: (not included w/capacitor) |
| -53 | 214-0456-00 | | | 1 | FASTENER, plastic |
| -54 | - - - - - - | | | 6 | RESISTOR, variable |
| | - - - - - - | | | - | mounting hardware for each: (not included w/resistor) |
| -55 | 210-0562-00 | | | 1 | NUT, hex., 0.25-40 x 0.312 inch |
| -56 | 210-0940-00 | | | 1 | WASHER, flat, 0.25 ID x 0.375 inch OD |
| | 210-0223-00 | | | 1 | LUG, solder, 0.25 ID x 0.437 inch OD, SE |
| -57 | 358-0136-00 | | | 10 | BUSHING, plastic |
| | 262-0680-01 | | | 1 | SWITCH, rotary—INPUT ATTEN |
| | - - - - - - | | | - | switch includes: |
| -58 | 260-0634-00 | | | 2 | SWITCH, rotary, unwired |
| | - - - - - - | | | - | mounting hardware for each: (not included w/switch) |
| -59 | 210-0413-00 | | | 1 | NUT, hex., 0.375-32 x 0.50 inch |

## FIGURE 1 EXPLODED (cont)

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Serial/Model No. Disc | Qty | Description 1 2 3 4 5 |
|---|---|---|---|---|---|
| -60 | 337-0671-00 | | | 1 | SHIELD, switch mounting |
| -61 | 214-0461-00 | | | 3 | GEAR ASSEMBLY |
| | - - - - - - | | | - | each gear assembly includes: |
| | 213-0020-00 | | | 1 | SETSCREW, 6-32 x 0.125 inch, HSS |
| -62 | 210-0913-00 | | | 1 | WASHER, flat, 0.25 ID x 0.625 inch OD |
| -63 | 387-0985-00 | | | 1 | PLATE, switch, front |
| | - - - - - - | | | - | mounting hardware: (not included w/plate) |
| -64 | 211-0018-00 | | | 2 | SCREW, 4-40 x 0.875 inch, RHS |
| | 166-0106-00 | | | 2 | TUBE, spacing |
| -65 | 210-0586-00 | | | 2 | NUT, keps, 4-40 x 0.25 inch |
| -66 | 384-0325-00 | | | 1 | ROD, shaft drive gear |
| | - - - - - - | | | - | mounting hardware: (not included w/attenuator switch assembly) |
| -67 | 210-0413-00 | | | 1 | NUT, hex., 0.375-32 x 0.50 inch |
| -68 | 210-0840-00 | | | 1 | WASHER, flat, 0.39 ID x 0.562 inch OD |
| -69 | 211-0008-00 | | | 2 | SCREW, 4-40 x 0.25 inch, PHS |
| -70 | 262-0679-01 | | | 1 | SWITCH, rotary—DISPLAY, wired |
| | - - - - - - | | | - | switch includes: |
| | 260-0635-00 | | | 1 | SWITCH, rotary, unwired |
| -71 | 337-0670-00 | | | 1 | SHIELD, switch mounting |
| | - - - - - - | | | - | mounting hardware: (not included w/switch) |
| -72 | 210-0413-00 | | | 1 | NUT, hex., 0.375-32 x 0.50 inch |
| -73 | 210-0012-00 | | | 1 | WASHER, lock, internal, 0.375 ID x 0.50 inch OD |
| | 211-0008-00 | | | 2 | SCREW, 4-40 x 0.25 inch, PHS |
| -74 | 200-0588-00 | | | 1 | COVER, attenuator |
| | - - - - - - | | | - | mounting hardware: (not included w/cover) |
| -75 | 211-0007-00 | | | 2 | SCREW, 4-40 x 0.188 inch, PHS |
| -76 | 200-0593-00 | | | 1 | COVER, attenuator |
| | - - - - - - | | | - | mounting hardware: (not included w/cover) |
| -77 | 211-0007-00 | | | 4 | SCREW, 4-40 x 0.188 inch, PHS |
| -78 | 200-0589-00 | | | 1 | COVER, attenuator |
| | - - - - - - | | | - | mounting hardware: (not included w/cover) |
| | 211-0007-00 | | | 4 | SCREW, 4-40 x 0.188 inch, PHS |
| -79 | - - - - - - | | | 2 | RESISTOR, variable |
| | - - - - - - | | | - | mounting hardware for each: (not included w/resistor) |
| -80 | 358-0054-00 | | | 1 | BUSHING |
| -81 | 210-0046-00 | | | 1 | WASHER, lock, internal, 0.261 ID x 0.40 inch OD |
| -82 | 210-0471-00 | | | 1 | NUT, hex., 0.25-32 x 0.312 x 0.594 inch long |

## FIGURE 1 EXPLODED (cont)

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Disc | Qty | Description 1 2 3 4 5 |
|---|---|---|---|---|---|
| -83 | 358-0054-00 | | | 1 | BUSHING |
| | - - - - - - | | | - | mounting hardware: (not included w/bushing) |
| -84 | 210-0583-00 | | | 1 | NUT, hex., 0.25-32 x 0.312 inch |
| -85 | 210-0046-00 | | | 1 | WASHER, lock, internal, 0.261 ID x 0.40 inch OD |
| | | | | | |
| -86 | - - - - - - | | | 1 | RESISTOR, variable |
| | - - - - - - | | | - | mounting hardware: (not included w/resistor) |
| -87 | 210-0413-00 | | | 1 | NUT, hex., 0.375-32 x 0.50 inch |
| -88 | 210-0840-00 | | | 1 | WASHER, flat, 0.39 ID x 0.562 inch OD |
| -89 | 210-0012-00 | | | 1 | WASHER, lock, internal, 0.375 ID x 0.50 inch OD |
| | | | | | |
| -90 | 384-0510-00 | | | 1 | ROD, securing |
| | - - - - - - | | | - | rod includes: |
| -91 | 354-0025-00 | | | 1 | RING, retaining |
| -92 | 387-0979-00 | | | 1 | SUBPANEL, front |
| -93 | 348-0055-00 | | | 2 | GROMMET, plastic, 0.25 inch diameter |
| -94 | 366-0128-00 | | | 1 | KNOB, plastic—DC BAL |
| | - - - - - - | | | - | knob includes: |
| | 213-0076-00 | | | 1 | SETSCREW, 2-56 x 0.125 inch |
| -95 | - - - - - - | | | 1 | RESISTOR, variable |
| | - - - - - - | | | - | mounting hardware: (not included w/resistor) |
| -96 | 210-0562-00 | | | 1 | NUT, hex., 0.25-40 x 0.312 inch |
| -97 | 210-0046-00 | | | 1 | WASHER, lock, internal, 0.261 ID x 0.40 inch OD |
| | | | | | |
| -98 | 407-0067-00 | | | 1 | BRACKET, gusset |
| | - - - - - - | | | - | mounting hardware: (not included w/bracket) |
| -99 | 211-0559-00 | | | 2 | SCREW, 6-32 x 0.375 inch, 100° csk, FHS |
| -100 | 210-0457-00 | | | 2 | NUT, keps, 6-32 x 0.312 inch |
| -101 | 211-0504-00 | | | 2 | SCREW, 6-32 x 0.25 inch, PHS |
| | | | | | |
| -102 | 179-0931-01 | | | 1 | CABLE HARNESS |
| -103 | 124-0145-00 | | | 5 | TERMINAL STRIP, ceramic, 0.438 inch h, w/20 notches |
| | - - - - - - | | | - | each terminal strip includes: |
| | 355-0046-00 | | | 2 | STUD, plastic |
| | - - - - - - | | | - | mounting hardware for each: (not included w/terminal strip) |
| | 361-0009-00 | | | 2 | SPACER, plastic, 0.313 inch |
| | | | | | |
| -104 | 124-0148-00 | | | 2 | TERMINAL STRIP, ceramic, 0.438 inch h, w/9 notches |
| | - - - - - - | | | - | each terminal strip includes: |
| | 355-0046-00 | | | 2 | STUD, plastic |
| | - - - - - - | | | - | mounting hardware for each: (not included w/terminal strip) |
| | 361-0009-00 | | | 2 | SPACER, plastic, 0.313 inch |

## FIGURE 1 EXPLODED (cont)

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Disc | Qty | Description 1 2 3 4 5 |
|---|---|---|---|---|---|
| -105 | - - - - - - | | | 1 | RESISTOR |
| | - - - - - - | | | - | mounting hardware: (not included w/resistor) |
| -106 | 211-0553-00 | | | 1 | SCREW, 6-32 x 1.50 inches, RHS |
| -107 | 210-0601-00 | | | 1 | EYELET |
| -108 | 210-0478-00 | | | 1 | NUT, hex., resistor mounting |
| -109 | 210-0206-00 | | | 1 | LUG, solder, SE #10 |
| -110 | 211-0507-00 | | | 1 | SCREW, 6-32 x 0.312 inch, PHS |
| -111 | - - - - - - | | | 1 | RESISTOR |
| | - - - - - - | | | - | mounting hardware: (not included w/resistor) |
| -112 | 211-0544-00 | | | 1 | SCREW, 6-32 x 0.75 inch, THS |
| -113 | 210-0478-00 | | | 1 | NUT, hex., resistor mounting |
| -114 | 210-0206-00 | | | 1 | LUG, solder, SE #10 |
| -115 | 211-0507-00 | | | 1 | SCREW, 6-32 x 0.312 inch, PHS |
| -116 | 136-0181-00 | | | 5 | SOCKET, transistor, 3 pin |
| | - - - - - - | | | - | mounting hardware for each: (not included w/socket) |
| -117 | 354-0234-00 | | | 1 | RING, locking, transistor socket |
| -118 | 136-0014-00 | | | 3 | SOCKET, tube, 9 pin |
| | - - - - - - | | | - | mounting hardware for each: (not included w/socket) |
| -119 | 213-0044-00 | | | 2 | SCREW, thread cutting, 5-32 x 0.188 inch, PHS |
| -120 | 136-0235-00 | | | 1 | SOCKET, transistor, 6 pin |
| | - - - - - - | | | - | mounting hardware: (not included w/socket) |
| -121 | 354-0234-00 | | | 1 | RING, locking, transistor socket |
| -122 | 210-0201-00 | | | 3 | LUG, solder, SE #4 |
| | - - - - - - | | | - | mounting hardware for each: (not included w/lug) |
| -123 | 213-0044-00 | | | 1 | SCREW, thread cutting, 5-32 x 0.188 inch, PHS |
| -124 | 670-1168-00 | | | 1 | CIRCUIT BOARD ASSEMBLY—FET INPUT |
| | - - - - - - | | | - | circuit board assembly includes: |
| | 388-1462-00 | | | 1 | CIRCUIT BOARD |
| -125 | 131-0589-00 | | | 10 | TERMINAL, pin, 0.50 inch long |
| -126 | 131-0161-00 | | | 2 | CONNECTOR, terminal, feed-thru |
| -127 | 136-0350-00 | | | 2 | SOCKET, transistor, 3 pin, low profile |
| -128 | 136-0220-00 | | | 4 | SOCKET, transistor, 3 pin, square |
| -129 | 136-0235-00 | | | 1 | SOCKET, transistor, 6 pin |
| | - - - - - - | | | - | mounting hardware: (not included w/circuit board assembly) |
| -130 | 211-0602-00 | | | 4 | SCREW, sems, 6-32 x 0.438 inch, PHB |
| -131 | 166-0029-00 | | | 4 | TUBE, spacer, 0.18 ID x 0.25 OD x 0.125 inch long |
| -132 | 352-0200-00 | | | 1 | HOLDER, terminal connector, 4 wire (black) |
| -133 | 131-0621-00 | | | 10 | CONNECTOR, terminal |

**FIGURE 1 EXPLODED (cont)**

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Disc | Qty | Description 1 2 3 4 5 |
|---|---|---|---|---|---|
| -134 | 441-0583-01 | | | 1 | CHASSIS |
| | - - - - - - | | | - | mounting hardware: (not included w/chassis) |
| -135 | 211-0559-00 | | | 2 | SCREW, 6-32 x 0.375 inch, 100° csk, FHS |
| -136 | 210-0457-00 | | | 2 | NUT, keps, 6-32 x 0.312 inch |
| -137 | 211-0504-00 | | | 2 | SCREW, 6-32 x 0.25 inch, PHS |
| -138 | - - - - - - | | | 1 | RESISTOR, variable |
| | - - - - - - | | | - | mounting hardware: (not included w/resistor) |
| -139 | 210-0413-00 | | | 1 | NUT, hex., 0.375-32 x 0.50 inch |
| -140 | 210-0840-00 | | | 1 | WASHER, flat, 0.39 ID x 0.562 inch OD |
| -141 | 210-0013-00 | | | 1 | WASHER, lock, internal, 0.375 ID x 0.688 inch OD |
| -142 | - - - - - - | | | 1 | RESISTOR, variable |
| | - - - - - - | | | - | mounting hardware: (not included w/resistor) |
| -143 | 210-0413-00 | | | 1 | NUT, hex., 0.375-32 x 0.50 inch |
| -144 | 210-0840-00 | | | 1 | WASHER, flat, 0.39 ID x 0.562 inch OD |
| -145 | 407-0064-01 | | | 1 | BRACKET, variable resistor |
| | - - - - - - | | | - | mounting hardware: (not included w/bracket) |
| -146 | 211-0507-00 | | | 2 | SCREW, 6-32 x 0.312 inch, PHS |
| -147 | 210-0457-00 | | | 2 | NUT, keps, 6-32 x 0.312 inch |
| -148 | 348-0031-00 | | | 1 | GROMMET, plastic, 0.094 inch diameter |
| -149 | 670-0131-01 | | | 1 | CIRCUIT BOARD ASSEMBLY—OUTPUT AMPLIFIER |
| | - - - - - - | | | - | circuit board assembly includes: |
| | 388-0812-00 | | | 1 | CIRCUIT BOARD |
| -150 | 136-0220-00 | | | 2 | SOCKET, transistor, 3 pin, square |
| -151 | 214-0579-00 | | | 2 | PIN, test point |
| | - - - - - - | | | - | mounting hardware: (not included w/circuit board assembly) |
| -152 | 344-0132-00 | | | 2 | CLIP, circuit board |
| -153 | 210-0586-00 | | | 2 | NUT, keps, 4-40 x 0.25 inch |
| -154 | 210-0994-00 | | | 2 | WASHER, flat, 0.125 ID x 0.25 inch OD |
| -155 | 211-0097-00 | | | 2 | SCREW, 4-40 x 0.312 inch, PHS |
| -156 | 131-0017-00 | | | 1 | CONNECTOR, chassis mounted, 16-pin |
| | - - - - - - | | | - | mounting hardware: (not included w/connector) |
| -157 | 211-0008-00 | | | 2 | SCREW, 4-40 x 0.25 inch, PHS |
| -158 | 210-0201-00 | | | 2 | LUG, solder, SE #4 |
| -159 | 210-0406-00 | | | 2 | NUT, hex., 4-40 x 0.188 inch |
| -160 | 387-0980-00 | | | 1 | SUBPANEL, rear |
| -161 | 384-0631-00 | | | 4 | ROD, spacer, plug-in |
| | - - - - - - | | | - | mounting hardware for each: (not included w/rod) |
| -162 | 212-0044-00 | | | 4 | SCREW, 8-32 x 0.50 inch, RHS |

**STANDARD ACCESSORIES**

| | | | | | |
|---|---|---|---|---|---|
| | 070-1109-00 | | | 1 | MANUAL, instruction (not shown) |

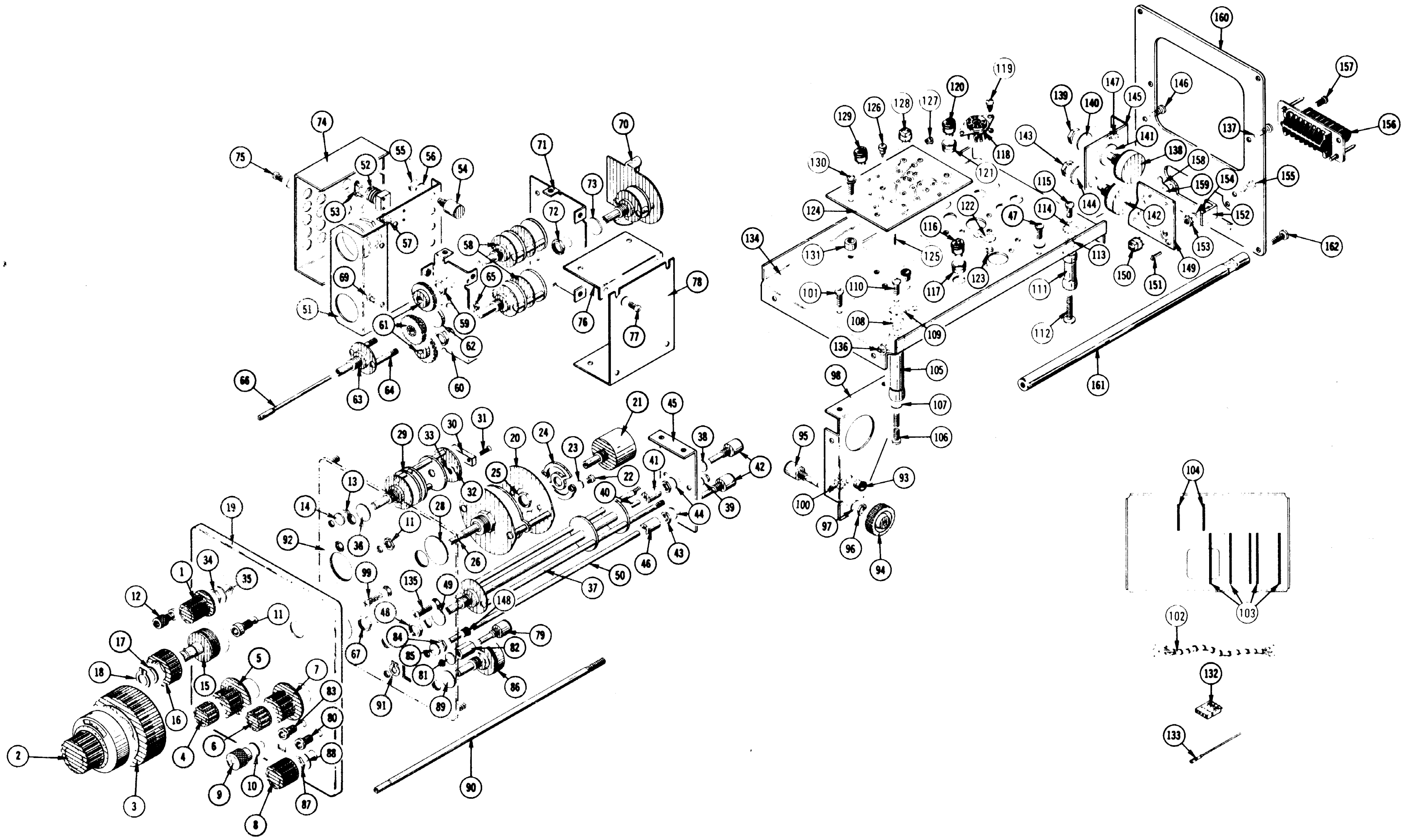


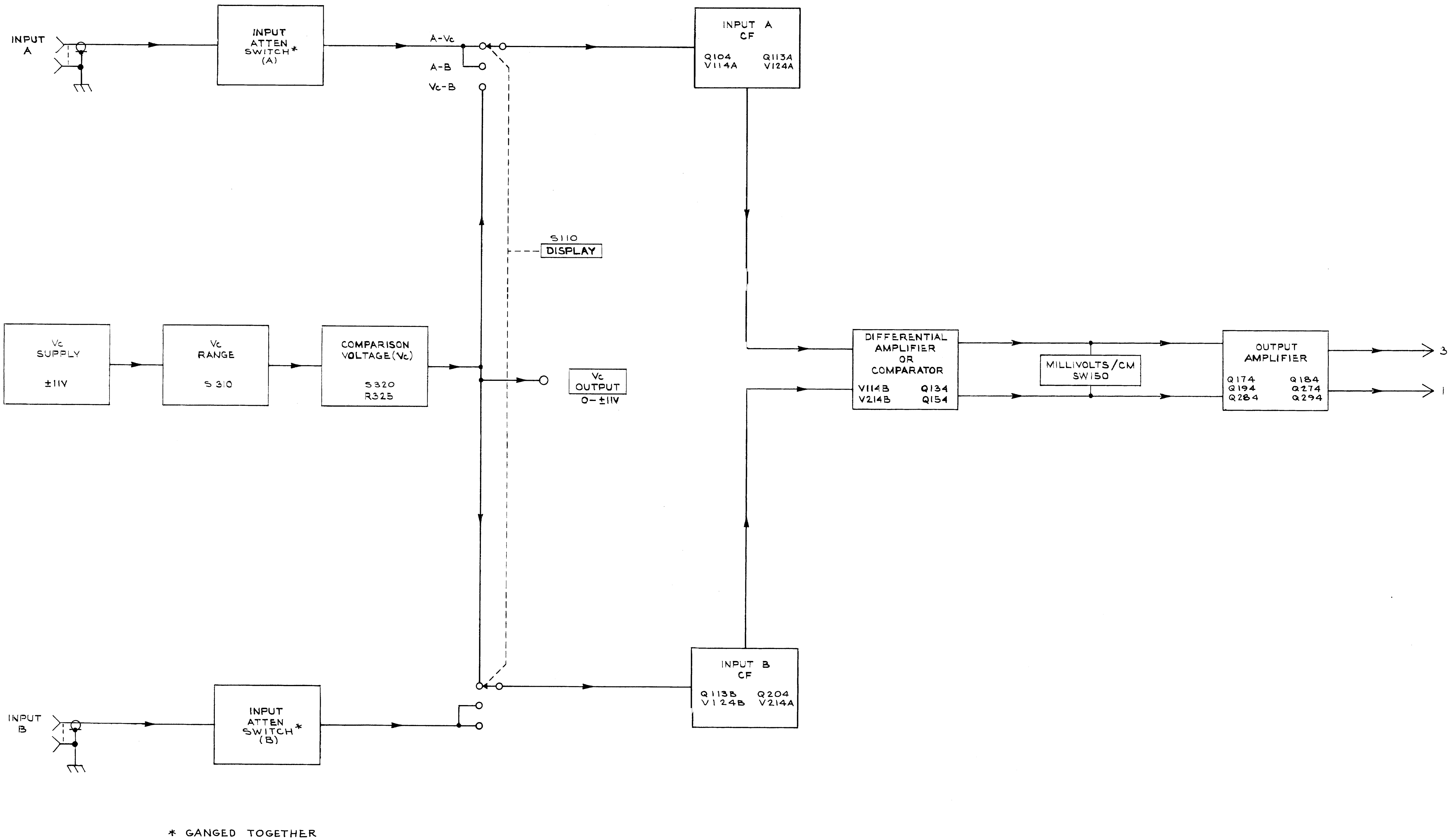
**Fig. 7-1. Exploded.**

## IMPORTANT

Circuit voltages were obtained with a 20,000 Ω/Volt VOM. All readings are in volts.

Voltage and waveform amplitude measurements are not absolute and may vary from unit to unit. For these measurements, a 30" flexible cable plug-in extension (012-0038-00) was used to operate the W Unit out of the oscilloscope plug-in compartment.

Actual waveform photographs are shown with the test oscilloscope set for +Ext triggering on the same signal applied to the W Unit.




TYPE W PLUG-IN

A

hq
1070

BLOCK DIAGRAM
SN 7000-UP

**VOLTAGE AND WAVEFORM READINGS** were obtained under the following common conditions:

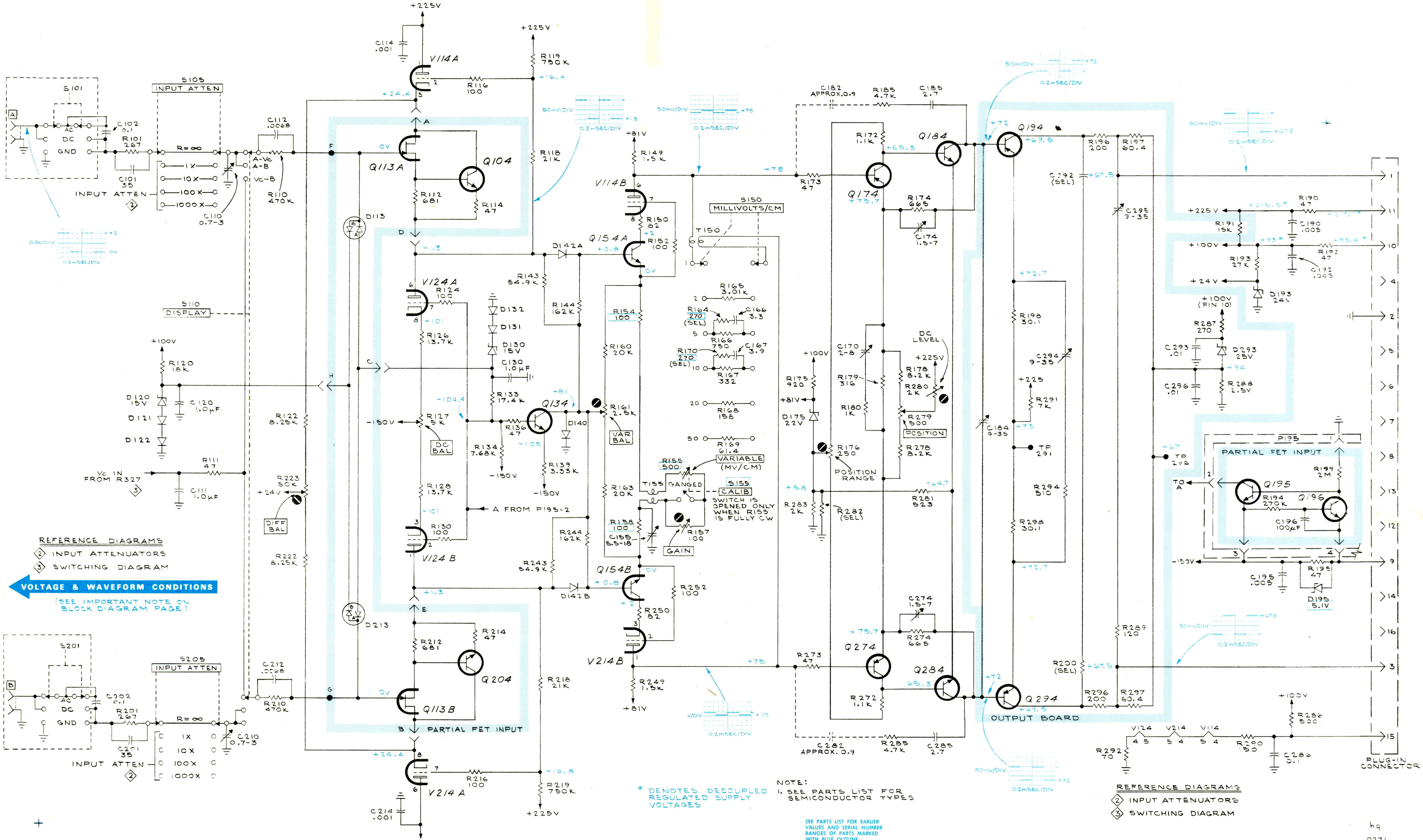
| | |
|---|---|
| $V_C$ RANGE | +11 |
| COMPARISON VOLTAGE | 11 (10-10-0) |
| AC-DC-GND (Channel A) | DC |
| AC-DC-GND (Channel B) | GND |
| INPUT ATTEN | 10 |
| DISPLAY | A–B |
| MILLIVOLTS/CM | 50 |
| VARIABLE | CALIB |
| POSITION | Centered |

**QUIESCENT VOLTAGE READINGS:**

| | |
|---|---|
| Input signal to channel A | None |

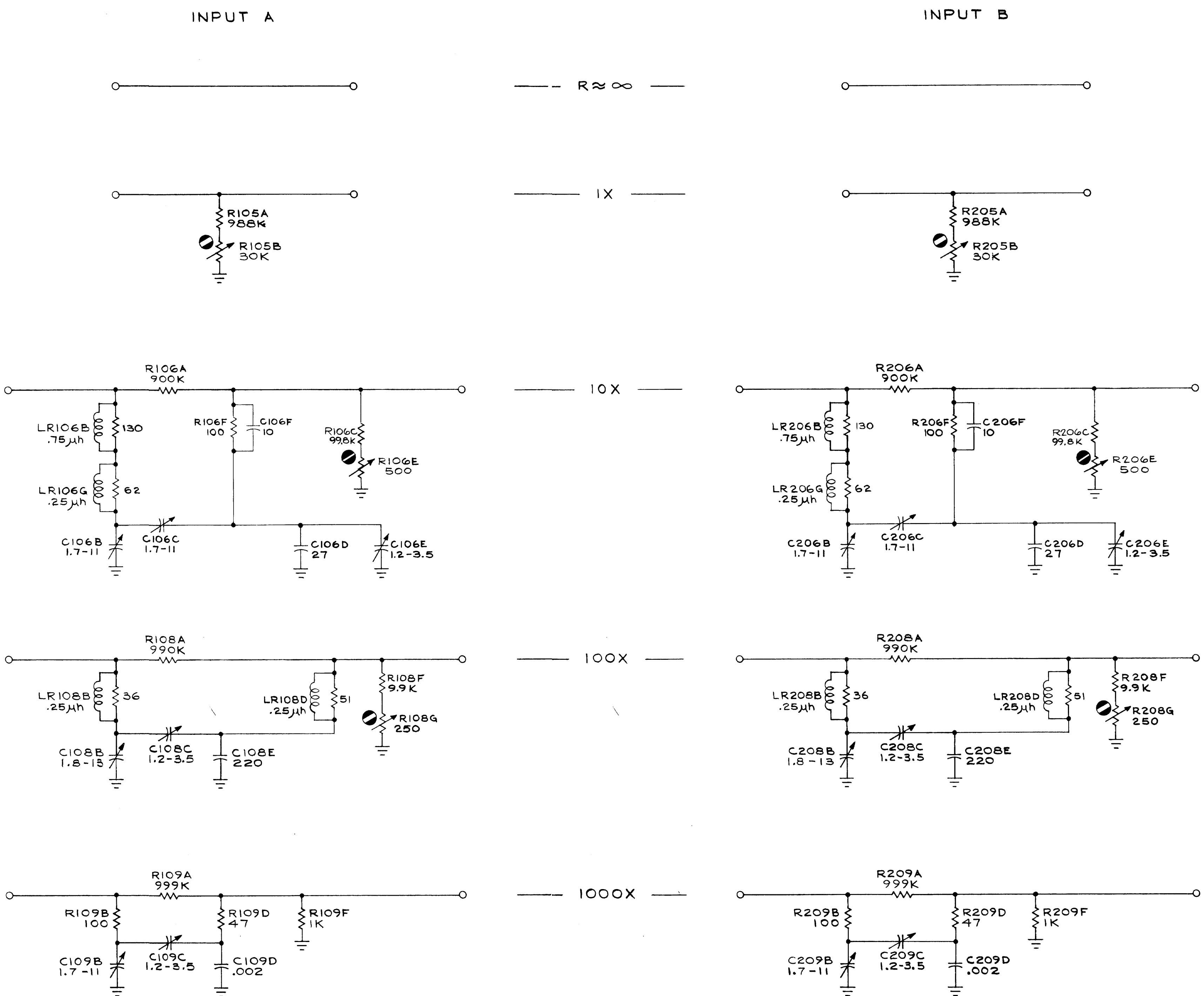
**WAVEFORMS:**

| | |
|---|---|
| Input signal to channel A | 2-Volt 1-kHz Oscilloscope Calibrator Signal |




TYPE W PLUG-IN

HIGH-GAIN DIFFERENTIAL COMPARATOR ①
SN 7000-UP

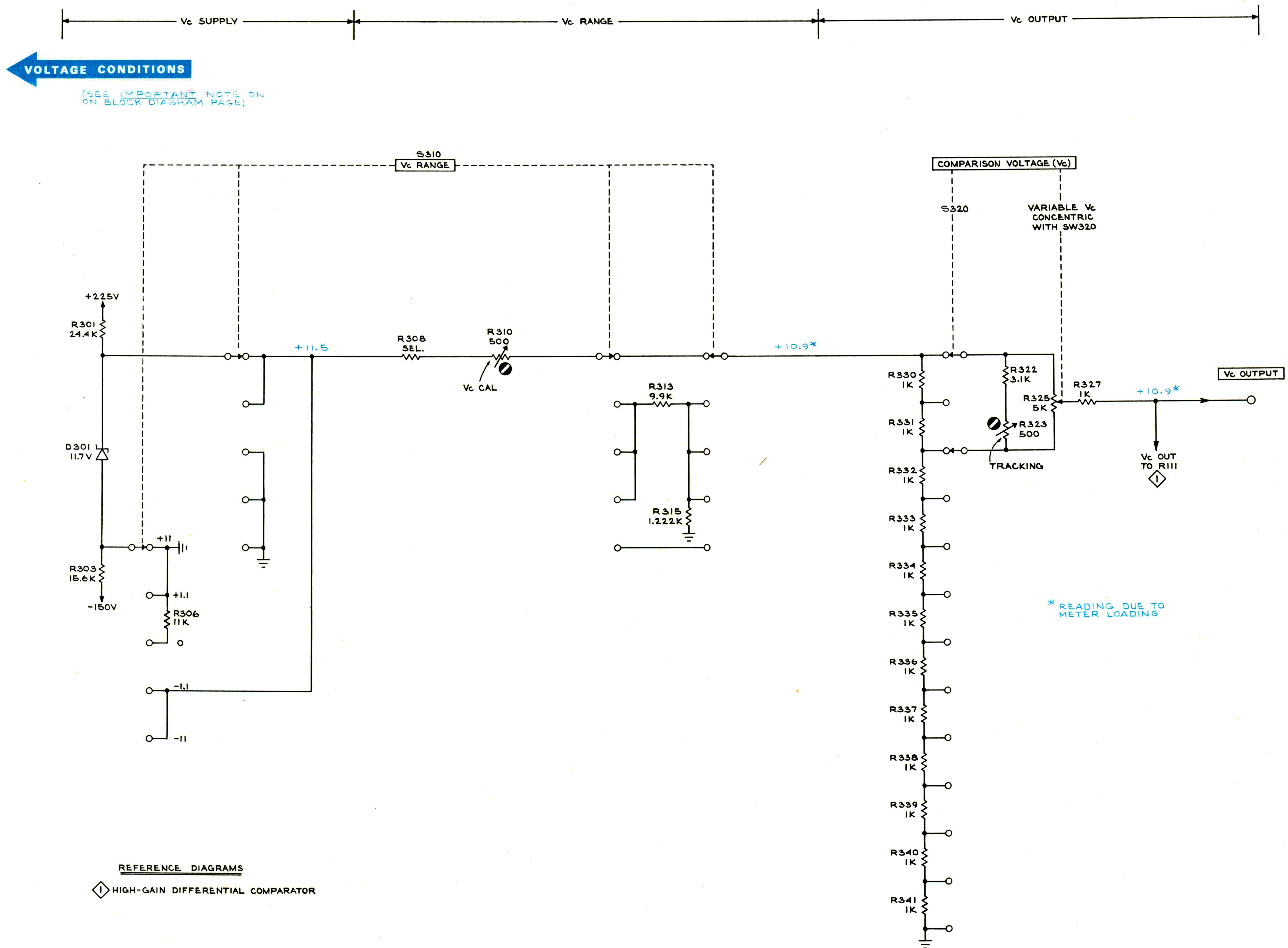



INPUT ATTENUATORS ⟨2⟩

hq
1070

VOLTAGE READINGS were obtained under the following conditions:

| | |
|---|---|
| Vc RANGE | +11 |
| COMPARISON VOLTAGE | 10.00 |




REFERENCE DIAGRAMS

1 HIGH-GAIN DIFFERENTIAL COMPARATOR

TYPE W PLUG-IN

A

SWITCHING DIAGRAM
SN 7000-UP

hq 1070

3

SWITCHING DIAGRAM 3

## MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Since the change information sheets are carried in the manual until all changes are permanently entered, some duplication may occur. If no such change pages appear following this page, your manual is correct as printed.

## SERVICE NOTE

Because of the universal parts procurement problem, some electrical parts in your instrument may be different from those described in the Replaceable Electrical Parts List. The parts used will in no way alter or compromise the performance or reliability of this instrument. They are installed when necessary to ensure prompt delivery to the customer. Order replacement parts from the Replaceable Electrical Parts List.

# CALIBRATION TEST EQUIPMENT REPLACEMENT

**Calibration Test Equipment Chart**

This chart compares TM 500 product performance to that of older Tektronix equipment. Only those characteristics where significant specification differences occur, are listed. In some cases the new instrument may not be a total functional replacement. Additional support instrumentation may be needed or a change in calibration procedure may be necessary.

**Comparison of Main Characteristics**

| | | |
|---|---|---|
| DM 501 replaces 7D13 | | |
| PG 501 replaces 107 | PG 501 - Risetime less than 3.5 ns into 50 Ω. | 107 - Risetime less than 3.0 ns into 50 Ω. |
| 108 | PG 501 - 5 V output pulse; 3.5 ns Risetime. | 108 - 10 V output pulse; 1 ns Risetime. |
| 111 | PG 501 - Risetime less than 3.5 ns; 8 ns Pretrigger pulse delay. | 111 - Risetime 0.5 ns; 30 to 250 ns Pretrigger Pulse delay. |
| 114 | PG 501 - ±5 V output. | 114 - ±10 V output. Short proof output. |
| 115 | PG 501 - Does not have Paired, Burst, Gated, or Delayed pulse mode; ±5 V dc Offset. Has ±5 V output. | 115 - Paired, Burst, Gated, and Delayed pulse mode; ±10 V output. Short-proof output. |
| PG 502 replaces 107 | | |
| 108 | PG 502 - 5 V output | 108 - 10 V output. |
| 111 | PG 502 - Risetime less than 1 ns; 10 ns Pretrigger pulse delay. | 111 - Risetime 0.5 ns; 30 to 250 ns Pretrigger pulse delay. |
| 114 | PG 502 - ±5 V output | 114 - ±10 V output. Short proof output. |
| 115 | PG 502 - Does not have Paired, Burst, Gated, Delayed & Undelayed pulse mode; Has ±5 V output. | 115 - Paired, Burst, Gated, Delayed & Undelayed pulse mode; ±10 V output. Short-proof output. |
| 2101 | PG 502 - Does not have Paired or Delayed pulse. Has ±5 V output. | 2101 - Paired and Delayed pulse; 10 V output. |
| PG 506 replaces 106 | PG 506 - Positive-going trigger output signal at least 1 V; High Amplitude output, 60 V. | 106 - Positive and Negative-going trigger output signal, 50 ns and 1 V; High Amplitude output, 100 V. |
| 067-0502-01 | PG 506 - Does not have chopped feature. | 0502-01 - Comparator output can be alternately chopped to a reference voltage. |
| SG 503 replaces 190, | | |
| 190A, 190B | SG 503 - Amplitude range 5 mV to 5.5 V p-p. | 190B - Amplitude range 40 mV to 10 V p-p. |
| 191 | SG 503 - Frequency range 250 kHz to 250 MHz. | 191 - Frequency range 350 kHz to 100 MHz. |
| 067-0532-01 | SG 503 - Frequency range 250 kHz to 250 MHz. | 0532-01 - Frequency range 65 MHz to 500 MHz. |
| TG 501 replaces 180, | | |
| 180A | TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. Trigger output - slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time. | 180A - Marker outputs, 5 sec to 1 μs. Sinewave available at 20, 10, and 2 ns. Trigger pulses 1, 10, 100 Hz; 1, 10, and 100 kHz. Multiple time-marks can be generated simultaneously. |
| 181 | TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. | 181 - Marker outputs, 1, 10, 100, 1000, and 10,000 μs, plus 10 ns sinewave. |
| 184 | TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. Trigger output - slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time. | 184 - Marker outputs, 5 sec to 2 ns. Sinewave available at 50, 20, 10, 5, and 2 ns. Separate trigger pulses of 1 and .1 sec; 10, 1, and .1 ms; 10 and 1 μs. Marker amplifier provides positive or negative time marks of 25 V min. Marker intervals of 1 and .1 sec; 10, 1, and .1 ms; 10 and 1 μs. |
| 2901 | TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. Trigger output - slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time. | 2901 - Marker outputs, 5 sec to 0.1 μs. Sinewave available to 50, 10, and 5 ns. Separate trigger pulses, from 5 sec to 0.1 μs. Multiple time-marks can be generated simultaneously. |

**NOTE: All TM 500 generator outputs are short-proof. All TM 500 plug-in instruments require TM 500-Series Power Module.**