# TEKTRONIX®

## 577-178-D1

# LINEAR IC CURVE TRACER

## INSTRUCTION MANUAL

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97005

Serial Number ____________

070-1474-00

973

## WARRANTY

All TEKTRONIX instruments are warranted against defective materials and workmanship for one year. Any questions with respect to the warranty should be taken up with your TEKTRONIX Field Engineer or representative.

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

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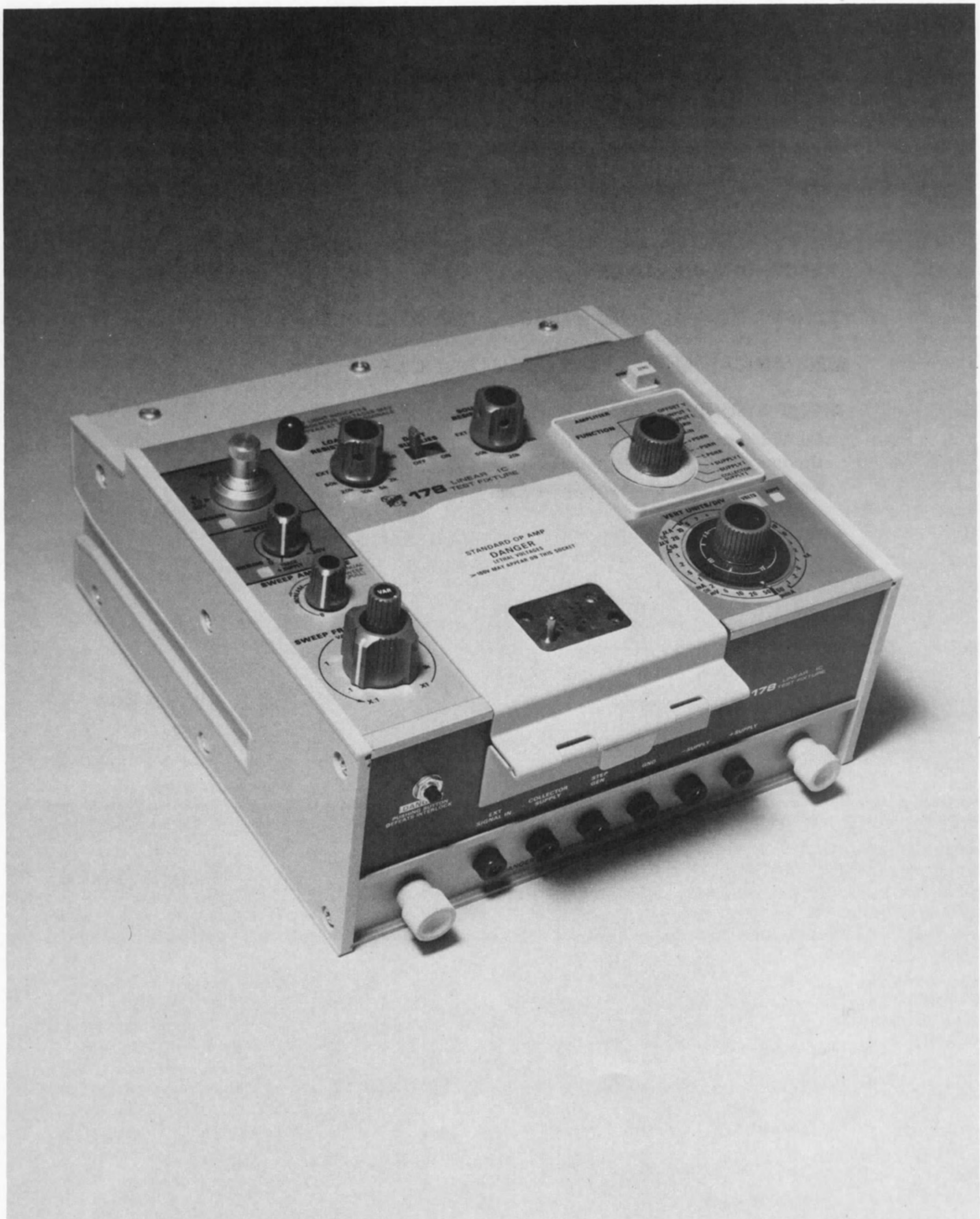



**Fig. 1-1. 178 Linear Integrated Circuit Test Fixture.**

# SPECIFICATION

Introduction

The 178 Linear IC Test Fixture is a plug-in device for use with the 577-D1 or D2 Curve Tracer system. The 577-178 combination, with the D1 Display Unit module, is designed to measure the parameters of operational amplifiers, comparators, differential amplifiers, and regulators.

The D2 Display Unit may be used but the results may not be satisfactory because of the low frequencies necessary to test many devices.

The 178 Linear IC Test Fixture features a sweep generator, positive and negative supplies, part of the vertical measuring system, feedback loop for the Device Under Test (DUT), and switching capabilities to facilitate testing of various parameters under diverse conditions.

The sweep generator provides a sinusoidal output with the frequency variable from 0.0l Hz to 1 kHz. The sweep generator output is used to force the DUT output or the positive or negative supplies (either in phase or out of phase), or to sweep the DUT inputs.

The dc voltage levels of both positive and negative supplies are independently adjustable from 0 to 30 volts. The negative supply can be made to track (have the same absolute amplitude) the positive supply amplitude.

The maximum current capability of the positive and negative supplies can be limited by potentiometers on the DUT card. If the load current attempts to exceed the set limits, the supply current limits and a lamp for each supply indicates the condition.

Any pair, of four pairs, of internal source resistors can be used in series with the amplifier inputs. Any value of external source resistance can be added to the DUT card.

The DUT output can be loaded with one of six values of internal load resistance. Any value of external load resistance can be added to the DUT card.

The vertical measurement system is capable of measuring either voltage or current. The choice of voltage or current measurement is determined by the position of the FUNCTION switch and is indicated by the AMPS or VOLTS lamp.

The vertical deflection factor switch has twenty-eight positions ranging from 50 p/Div to 50 m/Div (unmagnified) in a 1-2-5 sequence.

All of the twenty-eight positions are used for current measurements but only the range from 10 $\mu$/Div to 50 m/Div can be used for voltage measurements.

Any attempt to measure voltage using vertical deflection factors less than 10 μV/Div (unmagnified) causes the VOLTS indicator light to turn off, indicating an unusable switch position.

Vertical deflection factor is increased by a factor of ten when the Vertical POSITION-X10 VERT MAG knob on the 577 is pulled, and is indicated by the lamp behind the VERT UNITS/DIV knob skirt. This lamp also turns off if an unusable switch position is selected.

The FUNCTION selector switch provides eleven test positions. All positions are useful to test operational amplifiers.

Horizontal deflection factors range from 50 mV/DIV to 200 V/DIV (unmagnified) and are selected from the COLLECTOR VOLTS segment of the 577 HORIZ VOLTS/DIV switch.

The Standard Op Amp card can be used to test operational amplifiers (single and dual), comparators, and differential amplifiers.

IC socket-pin configurations are selected by using adapter sockets and patch cords.

An offset ZERO button provides a zero crt-display reference and nulls offset voltage when measuring Δ Input V on the vertical display axis.

Offset is usually reset automatically when the setting of the FUNCTION switch is changed. Offset must be reset manually when switching between 1 and .5 mV/DIV and between .1 mV and 50 μV/DIV.

The stored display on the D1 Display Unit is erased whenever the FUNCTION switch is changed, except between +INPUT I and -INPUT I, +PSRR and -PSRR, and +SUPPLY I and -SUPPLY I.

Regulator cards are used to test IC regulator parameters. These regulator cards are optional accessories and are covered on separate data sheets.

## CHARACTERISTICS

## ELECTRICAL

Vertical Deflection Factors

Input Current: 50 pA/DIV to .2 mA/DIV in a 1-2-5 sequence, unmagnified. 5 pA/DIV to 20 $\mu$A/DIV with 10X magnifier on.

Accuracy[3]: ± 3%, ± 50 pA, unmagnified, ± 4%, ± 50 pA with 10X magnifier on.

Voltage: 10 $\mu$V/DIV to 50 mV/DIV in a 1-2-5 sequence, unmagnified. 1 $\mu$V/DIV to 5 mV/DIV with 10X magnifier on.

Accuracy[3] (in GAIN and OFFSET V functions): ± 3%, unmagnified. ± 4% with 10X magnifier on.

Accuracy (in CMRR function): $3\% + \frac{100\text{ K}}{\text{Gain - K}}\% \pm \frac{150}{\text{K}}\ \mu\text{V}/\text{V}_{cm}$. $4\% + \frac{100\text{ K}}{\text{Gain - K}}\% \pm \frac{150}{\text{K}}\ \mu\text{V}/\text{V}_{cm}$, with 10X magnifier on (1 $\mu$V/DIV to 5 $\mu$V/DIV). See footnotes 1 and 2.

Accuracy (in PSRR functions): $3\% + \frac{100\text{ K}}{\text{Gain - K}}\%$. $4\% + \frac{100\text{ K}}{\text{Gain - K}}\%$, with 10X magnifier on (1 $\mu$V/DIV to 5 $\mu$V/DIV) See footnotes 1 and 2.

Power Supply

Current: 1 nA/DIV to 50 mA/DIV in a 1-2-5 sequence, unmagnified. .1 nA/DIV to 5 mA/DIV with 10X magnifier on.

Accuracy[3]: 3%, ± 1 nA unmagnified. 4%, ± 1 nA with 10X magnifier on.

Collector Supply

Current: 1 nA/DIV to 50 mA/DIV, in a 1-2-5 sequence, unmagnified. .1 nA/DIV to 5 mA/DIV with 10X magnifier on.

Accuracy[3]: 3%, ± 1 nA, unmagnified. 4%, ± 1 nA with 10X magnifier on.

[1] Gain DUT gain with small signal out near zero volts with 50 kΩ load.
K = 10 for 50 mV/DIV to 1 mV/DIV,
K = 100 for .5 mV/DIV to 100 $\mu$V/DIV,
K = 1000 for 50 $\mu$V/DIV to 10 $\mu$V/DIV, and $V_{cm}$ = Common-mode voltage.

[2] Vertical magnification is not recommended for .5 mV/DIV through 50 mV/DIV unmagnified settings.

[3] Accuracies are the highest percentage of on-screen value.

Positive and Negative Supplies

Voltage: Adjustable from 0 to 30 volts.

Both supplies can be adjusted from +SUPPLY control.

Negative supply can be independently adjusted using an uncalibrated -SUPPLY control.

Accuracy: 2%, ± 100 mV. -Supply voltage, ± 1% from the +SUPPLY, in the TRACK +SUPPLY position.

Current: At least 150 mA. Adjustable current limiting.

Sweep Generator

Frequency: .01 Hz to 1 kHz, sinusoidal signal. Five ranges: .1, 1, 10, 100, and 1 kHz with X.1 to X1 variable. Ranges overlap at X.1 end of variable.

Accuracy: 5% in calibrated (X1) position.

Amplitude: Adjustable, depends on function.

Output Voltage (in OFFSET and GAIN functions): 0 to 30 V, ± 3%, maximum peak. Limited to the output capability of the DUT.

Common-Mode Voltage (in INPUT I and CMRR functions): 0 to 30 V, ± 3%, maximum peak. Limited to the power supply voltages (clipped). In the 1 mV/DIV to 50 mV/DIV ranges, the values are 10% lower.

Power Supply Voltage (in PSRR and SUPPLY I functions): See Positive and Negative Supplies.

Manual: Sweep Generator output may be manually set to any dc level (uncalibrated) within its amplitude range (depends on the setting of the FUNCTION switch).

Source Resistance

Resistances: Four pairs, 50 Ω, 10 k, 20 k, and 50 k. When the VERT UNITS/DIV is set to 1 mV/DIV through 50 mV/DIV, the indicated values increase by 500 Ω.

Accuracy: ± 1%, ± 10 Ω.

External resistors may be used.

Load Resistance

Resistances: Seven Resistances, 100 Ω, 1 k, 2 k, 5 k, 10 k, 20 k, and 50 k.

Accuracy: 3%, except when using the 50 mV, 20 mV, and 10 mV positions of the VERT UNITS/DIV switch. The tolerance may then be as large as 50 kΩ, ± 30%; 20 k, ± 14%; 10 k, ± 7% and 5 k, ± 3.5%, when the DUT output voltage swing is 2.5 V or less. The maximum tolerance decreases exponentially as the output swing is increased and is less than 3% when the output is swinging ± 30 volts.

Function Switch

Selects vertical and horizontal deflection signals and connects the test signal to the DUT.

Table 1-1 shows the FUNCTION switch positions and the measurement displayed on the crt when using the Standard Op Amp card.

TABLE 1-1

| Test Number | Functions with Standard Op Amp Card | Vertical Display | Horizontal Display |
|---|---|---|---|
| 1 | OFFSET V | Input V | Output V |
| 2 | +INPUT I | +Input I | Common-mode V |
| 3 | -INPUT I | -Input I | Common-mode V |
| 4 | CMRR | Δ Input V[4] | Common-mode V |
| 5 | GAIN | Δ Input V[4] | Output V |
| 6 | +PSRR | Δ Input V[4] | +Supply V |
| 7 | -PSRR | Δ Input V[4] | -Supply V |
| 8 | ± PSRR | Δ Input V[4] | +Supply V[5] |
| 9 | +SUPPLY I | + Supply I | +Supply V |
| 10 | -SUPPLY I | -Supply I | -Supply V |
| 11 | COLLECTOR SUPPLY I | Collector Supply Current | Collector Supply V[6] |

[4] ΔInput V is the change in differential input voltage and does not include dc offset voltage.

[5] The +Supply and -Supply are swept out of phase at the same amplitude in ± PSRR function. Horizontal display is the +Supply voltage.

[6] The Sweep Generator is not used in COLLECTOR SUPPLY I function.

Display Zero

Provides display zero reference.

In functions four through eight, nulls offset voltage to measure Δ Input V on the vertical display axis.

Collector Supply

The 25 V and 100 V ranges of the Collector Supply (577 mainframe) are available to the 178. Supply output available on the 178 front panel and on the DUT (Device Under Test) card. See Table 1-2.

TABLE 1-2

| Voltage Ranges | 25 V | 100 V |
|---|---|---|
| Max Peak Current | 2.5 A | 0.5 A |
| Peak Current, Pulsed | 5 A | 1.25 A |
| Minimum Series Resistance | 1.9 Ω | 30 Ω |
| Maximum Series Resistance | 120 Ω | 2 MΩ |

Step Generator

Accuracy (current or voltage steps, including offset):

Incremental: The amplitude of any step is 2% of any other step.

Absolute: Within 3% of STEP/OFFSET AMPL switch setting or 3% of total output, whichever is greater. Within 4% of total output when using 10 steps (in STEP X.1).

Offset Mult Range: Continuously variable from 0 to 10 times, or from 0 to 100 times STEP/OFFSET AMPL switch setting, depending on the STEP X.1 setting, either aiding or opposing the Step Generator polarity.

Current Mode

STEP/OFFSET AMPL Switch Range: 200 mA/Step to 50 mA/Step in a 1-2-5 sequence with STEP X.1 knob pushed in (X1 position). 20 mA/Step to 5 nA/Step with STEP X.1 out.

Maximum Current (steps and aiding offset): 20 times STEP AMPL switch setting, except at least 10 times switch setting when switch is set to 200 mA/Step and 15 times switch setting when switch is set to 100 mA/Step.

Maximum Voltage: At least 7 volts, up to 1 A total output and at least 5 volts, up to 2 A total output.

Maximum Opposing Offset Current: 10 times STEP/OFFSET AMPL switch setting, up to 10 mA. Not more than 20 mA.

Maximum Opposing Voltage: Between 1 volt and 5 volts.

Voltage Mode

STEP/OFFSET AMPL Switch Range: 50 V/Step to 2 V/Step in a 1-2-5 sequence with STEP X.1 button pushed in. 5 mV/Step to 200 mV/Step with STEP X.1 knob out (X.1 position).

Maximum Voltage (Steps and Aiding Offset): 20 times STEP/OFFSET AMPL switch setting.

Maximum Current: At least 100 mA.

Short Circuit Current Limiting: Not more than 200 mA.

Maximum Opposing Offset Voltage: 10 times the STEP/OFFSET AMPL switch setting.

Maximum Opposing Offset Current: Limited between 10 mA and 20 mA at zero volts, going down to zero current at 20 volts, opposing.

Pulsed Steps: Pulsed steps, approximately 300 $\mu$s, produced when PULSED 300 $\mu$s button is pushed in.

Number of Steps: Ranges from 1 to 10 as selected by the NUMBER OF STEPS control (STEP X.1 button in). Approximately 1 to 95 steps when STEP X.1 button is released (button out).

Display Amplifiers

Display Accuracies (percent of highest on-screen value):

Horizontal Collector Volts: 3%, unmagnified, and 4% magnified.

Horizontal Base Volts: 3%, unmagnified and 4% magnified.

Horizontal Step Generator: 4%, unmagnified and 5% magnified.

Deflection Factors

Horizontal Collector Volts: 50 mV/DIV to 200 V/DIV in a 1-2-5 sequence, unmagnified. 5 mV/DIV to 20 V/DIV, magnified.

Horizontal Base Volts: 50 mV/DIV to 2 V/DIV in a 1-2-5 sequence, unmagnified. 5 mV/DIV to .2 V/DIV magnified.

Indicator and CRT (Display Module)

Cathode Ray Tube

Type: Electrostatic Deflection

Phosphor

D2 (non-storage): P31 (standard)

D1 (storage): Equivalent to P1

Accelerating Voltage: 3.5 kV

Storage Characteristics

Storage Time: 1 hour

Power Input

Line Voltage

Nominal: 100 V, 110 V, 120 V, or 200 V, 220 V, 240 V, within 10%.

Line Frequency

Range: 50 to 60 Hz.

Maximum Power at 110 V, ac, 60 Hz: 155 W (1.7 A).

ENVIRONMENTAL

Temperature

Specified Operating: +10 °C (+50 °F) to +40 °C (+104°F).

Useful Operating: 0°C (+32 °F) to +50 °C (+120 °F).

Non-operating: -40°C (-40 °F) to +65°C (+149°F).

Altitude

Operating: To 10,000 feet.

Transportation

12-inch package drop: Qualified under the National Safe Transit Committe procedure 1A.

## PHYSICAL

| | | |
|---|---|---|
| **Dimensions:** | | |
| Height | 4.5 in. | 11.4 cm. |
| Width | 7.9 in. | 20.1 cm. |
| Depth | 7.8 in. | 19.8 cm. |
| **Weight** | | |
| Net | 3.3 lb. | 1.5 kg. |

**Standard Accessories**

| | |
|---|---|
| 8-Patch Cords | 012-0200-00 |
| 1-Dual-in-line 16-pin IC socket | 136-0442-00 |
| 1-Standard Op Amp Card (with cover) | 670-2567-00 |
| 1-Interchangeable nomenclature panel | 333-1770-00 |
| 1- 741 IC Op Amp | 156-0067-00 |
| 1-577-178-D1 or D2 Instruction Manual | 070-1474-00 |
| 12-Bifurcated pin terminals | 131-1497-00 |

# OPERATING INFORMATION

Introduction to Curve Tracers

For fifteen years Tektronix Curve Tracers have been used to evaluate discrete semiconductor devices. In this time, the use of curve tracers has grown so that today the curve tracer has become a standard in the field of semiconductor measurements. No other instrument can match its range of measurements and versatility.

New generations of curve tracers employ plug-in test fixtures to expand their versatility. The 178 is such a test fixture. It extends curve tracer measurements to include many of the parameters of linear integrated circuits. It is designed to operate in a 577-D1 (storage) curve tracer mainframe, making the Tektronix 577 family the most versatile of curve tracers ever.

Curves Rather than Numbers. Your ability to plot a characteristic curve rather than obtain a single numerical answer to your measurement is one of the curve tracer's truly unique features. A curve is actually a set of answers plotted over a measurement range, which shows you how and why parameters change throughout a device's operating range. The result is more information and insight. Your curve tracer's crt becomes a window on effects that remain hidden from test sets that provide numerical or go-no go answers.

From Lab to Production Line. The versatile curve tracer finds applications that range from the laboratory to the production line. In the laboratory the curve tracer is really the star among other available instruments for evaluating components. Here, because of the wealth of information a curve tracer reveals about the device-under-test, it has no equal.

The production line also finds the curve tracer an indispensable tool to keep things running smoothly. When automated equipment starts to reject large numbers of components, the curve tracer is immediately brought into action to discover what these rejected components 'look like'. Thus the curve tracer pinpoints the problem area. Small batches and special tests are two other production line applications where the curve tracer finds use beside even the most sophisticated automatic system. Often the curve tracer can be used to test an entire batch to a single, special specification in less time that it would take to program the automatic system to include that test.

Incoming inspection groups often sharpen their pencils when comparing curve tracers to automatic test systems as applied to their particular situation. A high-speed, automatic test set usually looks attractive on first analysis, but allowance for typical real-life situations often tips business analysis in favor of curve tracers. Items sometimes overlooked are allowance for equipment down time (both breakdown and routine maintenance and calibration), and allowance for future testing needs, which are seldom well-defined beforehand. With these two considerations alone, several curve tracers with their higher labor costs often prove to be a wiser investment than a single, high-speed, automatic test set. Why? Equipment failure cannot seriously threaten the capacity of several test stations equipped with rugged curve tracers. Down time on a single station would be a small percentage of total capacity, and even that rare occurence can be avoided at low cost with a spare. As for future capability, few, if any instruments can match the curve tracer's flexibility and measurement range. Added to this, its plug-in versatility permits future expansion to meet the ever-changing requirements of our advancing technology.

## How the 178 Tests Linear ICs

Operational amplifiers make up the greatest single class of linear integrated circuits. In order to test amplifiers, the 178 Linear IC Test Fixture uses a closed-loop technique. This technique is a departure from standard curve tracer techniques where device parameters are obtained in open-loop configurations. The essential difference between the two test configurations is seen by comparing two simplified diagrams, figures 1 and 2. In theory, either configuration could be used to determine DUT (device under test) gain A, where $A = \frac{\Delta \text{ output volts}}{\Delta \text{ input volts}}$.

The 178 uses the closed-loop approach because of its greater inherent stability and ease of operation when testing very high-gain devices.

In the closed-loop test of figure 2-1, a test signal is applied between the DUT's input and output. Because of the DUT's gain, its input voltage changes little compared with its output voltage. The small signal at the input is measured while the generator, in effect, applies an easily controllable signal to the DUT's output. Conversely, in the open-loop test of figure 2-2, a small signal applied to the DUT's input produces a less controllable signal that is measured at its output.

Measuring Parameters. Operational amplifier parameters are obtained from the crt display on the Tektronix 577-178 much as parameters of transistors and diodes are obtained with conventional curve tracers. The operator first reads the crt display and then makes any necessary calculations. In the closed-loop test described above, the DUT's small input signal, or dependent variable, is displayed on the Vertical axis of the crt. The large amplitude test signal at the DUT's output, or independent variable, is displayed on the Horizontal axis. Gain is obtained by dividing a change in output voltage (Horizontal) by the corresponding change in input voltage (Vertical).

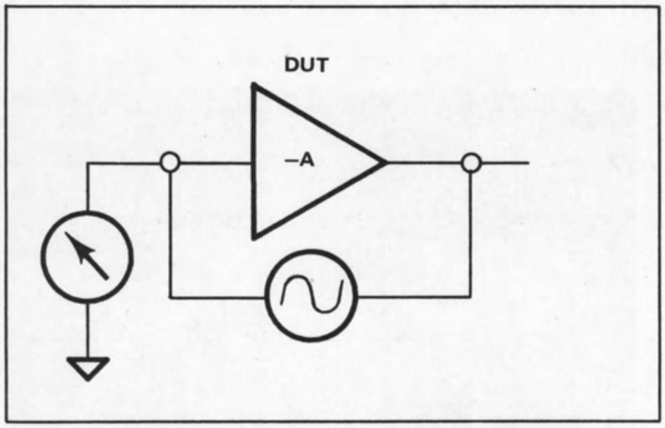



**Fig. 2-1. Simplified closed-loop test of an inverting amplifier.**

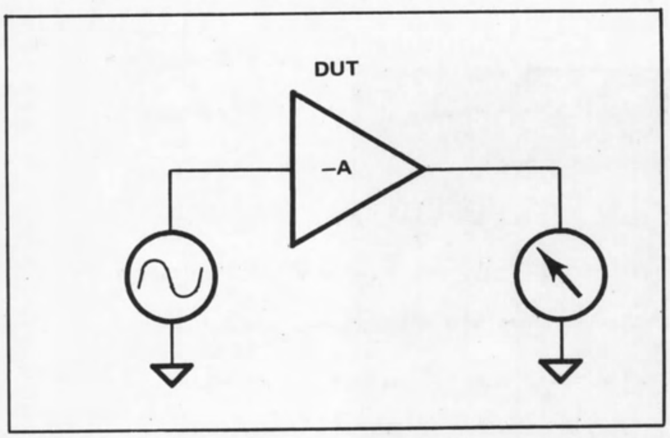



**Fig. 2-2. Hypothetical open-loop test of an inverting amplifier.**

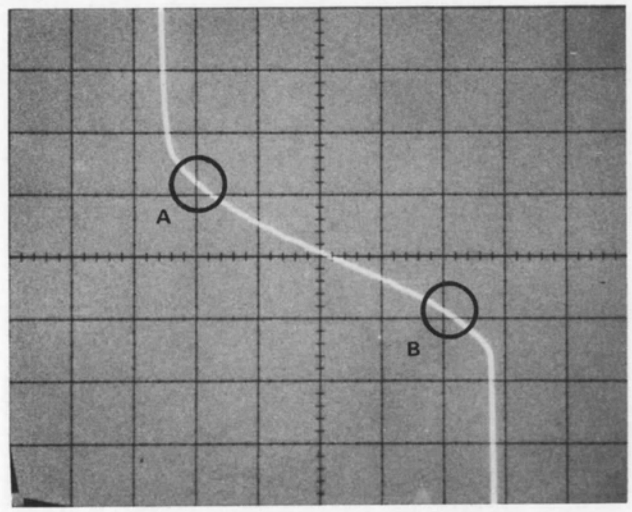



**Fig. 2-3. Typical displays of Op Amp characteristics.**

Figures 3 through 7

Input voltage vs output voltage, or GAIN curves, for five different operational amplifiers. Vertical deflection factor is 0.1 mV/div, horizontal 5V/div. Load resistance is 50K ohms in Figures 3 and 7, 1K ohm in Figures 4, 5 and 6. Supply voltages are plus and minus fifteen volts.

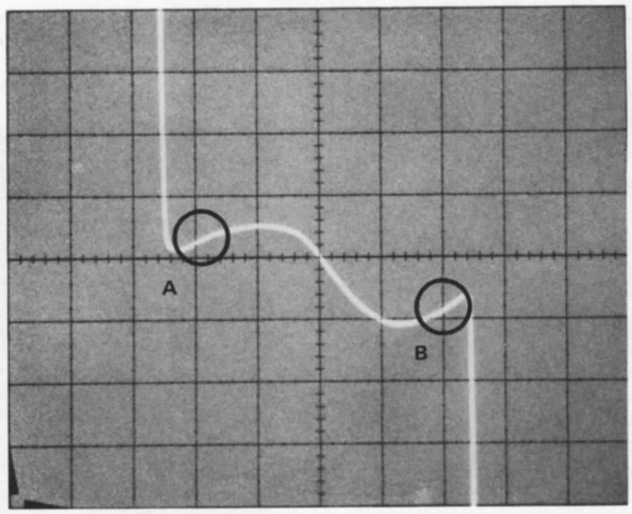



**Fig. 2-4. Typical displays of Op Amp characteristics.**

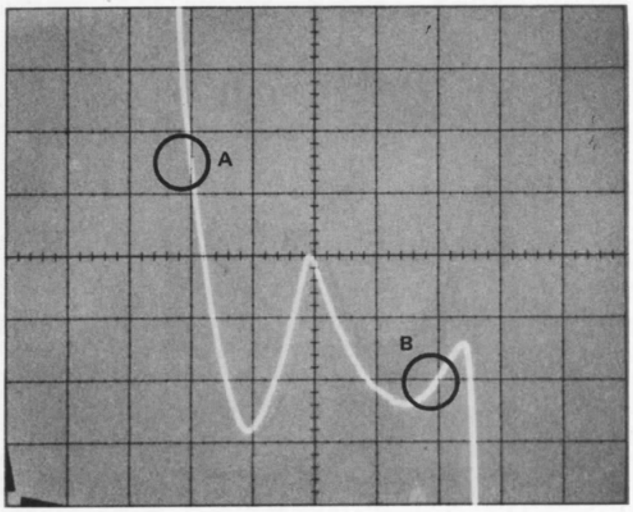



Fig. 2-5. Typical displays of Op Amp characteristics

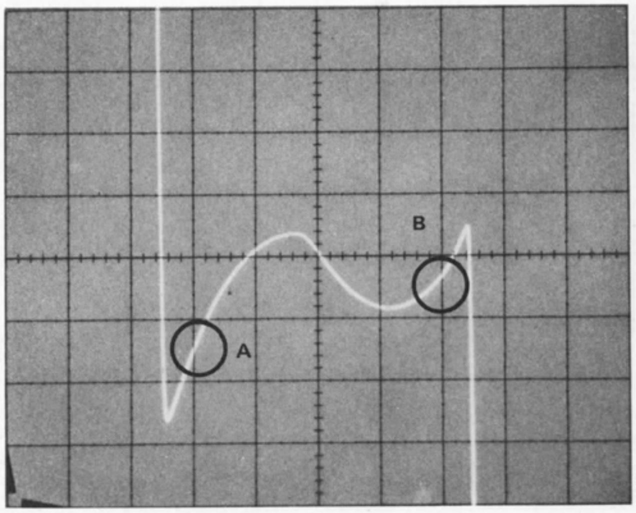



Fig. 2-6. Typical displays of Op Amp characteristics.

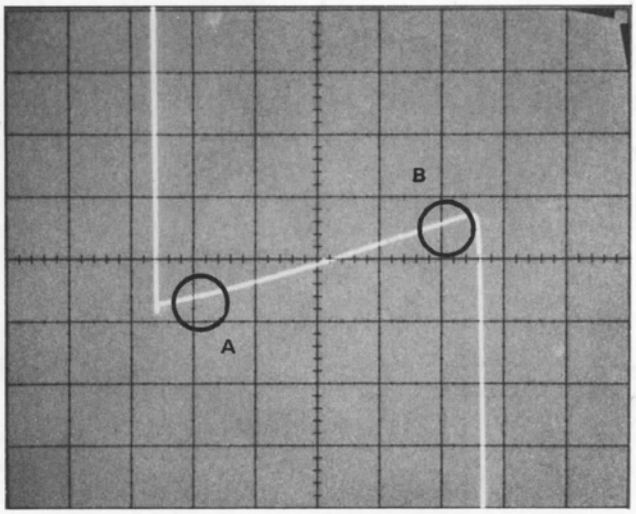



Fig. 2-7. Typical displays of Op Amp characteristics.

Figure 2-3 is such a crt display of an amplifier's gain curve or transfer characteristic measured at essentially dc (actually 0.05 Hz). Zero volts on both axes is at center screen. Considering points A and B, for an output swing from -10 volts to +10 volts, the input voltage is seen to change 200 microvolts. The gain of this amplifier is 100,000 or 100 dB, obtained by dividing output voltage by input voltage.

The vertical deflection is the voltage at the amplifier's inverting input and is therefore positive for negative output voltage. The curve occupies the second and fourth quadrants. The vertical lines going off screen are caused when the output of the operational amplifier (DUT) reaches its limits. At that point the sweep generator's test signal no longer moves the DUT's output, but is applied to the input, causing large, off-screen excursions.

The wealth of Information. The process described above for measuring gain is not as quick as jotting down a number flashed to the operator by a tester's numerical readout. However, it is important to look beyond the test speed and compare the kind of information provided by a Linear IC Curve Tracer and other types of integrated circuit testers.

A tester that provides a numerical answer is likely to measure large signal gain by making two 'point' measurements, for example, from point A and B on figure 2-3. A curve tracer measurement, by contrast, not only shows points A and B, but how the amplifier responds at all points between. It shows how it got from one point to the other.

In figure 2-3, the curve between points A and B contains the information theoretically expected of an ideal amplifier: linear, constant slope with no spurious excursions. It is easy to assume that the expected information, that the input voltage is well behaved, is not important information at all. This misunderstanding can be dispelled by examining four other gain curves.

Figures 2-4 through 2-7 show characteristics that go from point A to point B, but not in the anticipated, ideal manner. These are not unusual amplifiers that were built especially to demonstrate a point, but commonly available integrated circuit amplifiers. The "unusual" response is the ideal curve in figure 2-3. Most devices either do not produce ideal dc transfer characteristics or their application (operating conditions) distorts the characteristics beyond recognition.

Interpreting the Information. Many applications make use of an operational amplifier's extremely high dc gain. Three such uses are transducer amplifiers, voltage regulator amplifiers, and D to A converters. In these applications a high gain is usually relied on to reduce errors and keep the circuit performance dependent mainly upon precise, passive components that make up a feedback network.

One way to evaluate how well an operational amplifier performs in such a dc application is to determine how much its differential input voltage changes during normal operating conditions. To reduce error this change should be small compared to the signal being amplifier; just how small depends upon how much is admissible error. Theoretically, an amplifier's gain determines how much its input changes to produce a given change in putput: $V(in) = \frac{V(out)}{Gain}$. In a world of ideal amplifiers, where all curves look like figure 2-3, knowledge of an amplifier's gain is reasonably adequate for intelligent circuit design or component selection. From gain and the required output voltage change, a circuit designer can determine how much error signal will appear at the amplifier's output.

As figures 2-4 thrugh 2-7 show, however, the real world is seldom ideal. These figures demonstrate that a gain parameter may not always be very meaningful or useful, especially at dc or very low frequencies. Here, thermal effects often mask or completely overshadow changes dur to actual gain. For some of these figures, it would be difficult indeed to communicate how their respective DUT's perform in terms of a gain parameter. It would even be difficult to say what the gain could be. Whatever the definition, a higher gain amplifier would not necessarily perform better or give less dc error than some other lower gain amplifier.

An Example. Consider figure 2-4. Measuring large-signal gain from points A and B tells nothing about how the input changes between these points. The large signal gain of 106 dB (200,000) suggests that the total input voltage excursions over a ± 10 volt operating range is 100 μvolts. However, the 577-178 display clearly shows that the actual excursion is 160 μvolts. More significant may be the voltage excursion for small signals. The gain curve begins to approximate a straight line for small enough signals, making small-signal gain a more meaningful parameter for evaluating amplifier performance in some cases. Consider, for example, a small signal near zero volts output, as in figure 2-4. The input voltage excursion is great for relatively small output voltage changes. The computed dc gain for these small signals is only 50,000, far worse than the large signal gain of 200,000 measured from points A and B. Thus, these examples clearly illustrate the inadequacy of the use of gain for specifying or predicting an amplifier's behavior at or near dc conditions.

Though small-signal gain can be a useful parameter in some applications, it is not a satisfactory substitute for a complete gain curve. For example, finding where the small-signal gain is best or worst would require many measurements over an amplifier's entire range. This information can be determined at a glance from the complete gain curve that is normally traced on the 577-178 crt.

IDENTIFICATION OF CONTROLS

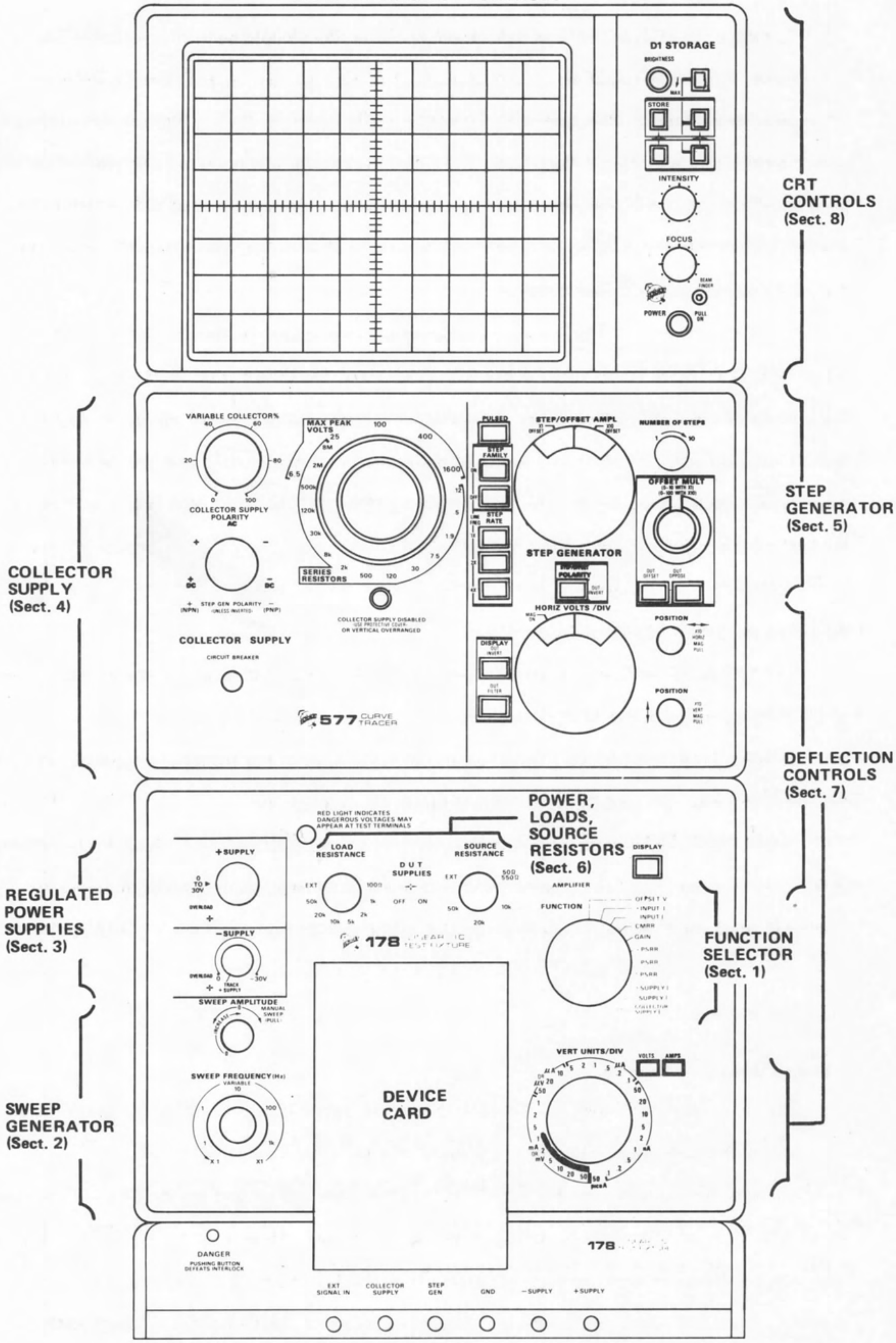



Fig. 2-8. 178 Front-panel controls.

Summary. If all amplifiers had ideal response curves there would be little need for a linear IC curve tracer. But actual responses are seldom ideal. Not only gain curves, but curves presenting other parameters, such as Common-Mode Rejection Ratio or Power Supply Rejection Ratio, show non-linearities that are often unspecified. The 577-178 provides a window on this world that has been largely hidden from engineers designing with op amps. Measurements at only a few points give unrealistic indications of an op amp's true behavior. In contrast, curves provide more complete information, much at just a glance.

The 577-178 takes its place in linear IC testing and evaluation. In the tradition of the conventional laboratory curve tracer (such as the 577-177), the linear IC curve tracer is not only a better but a lower cost solution to the many measurement needs. It should be an especially valuable tool to anyone desiring insight into linear IC behavior: the designer using ICs, the device evaluation engineer, the device designer, and the Q.A. engineer. The 178's low cost also makes it attractive for low volume testing in incoming inspection.

## Operating the Linear IC Curve Tracer

The 178 Linear IC Test Fixture combines with a Tektronix 577 mainframe and a D1 (storage) or D2 (non-storage) Display Module to form a curve tracer system.

This section of the manual gives a functional description of the front-panel controls and connectors of the 577, D1, and D2, and the 178 Linear IC Test Fixture.

Figure 2-8 is provided for rapid location and identification of controls. Each group of controls is numbered and each group number corresponds to the numbered heading under Function of Controls.

Following the Function of Controls section is the section covering First Time Operration.

## Function of Controls

### Function Selector — Group 1

The eleven-position FUNCTION switch selects the points to be monitored by the vertical and horizontal display axes, and selects the point driven by the Sweep Generator.

The specified operation of the FUNCTION switch depends in part on the Device Card used in the 178. Not all of the eleven positions are used with every device card type. Each device card type uses a separate, interchangeable nomenclature panel that shows the functions of each switch position. A detailed description of the functions of each card is included with card specifications.

Sweep Generator — Group 2

The Sweep Generator provides a sinusoidal waveform to various control points to facilitate plotting the characteristic curves of the Device Under Test (DUT). The control points depend on the Device Card selected and the FUNCTION switch setting.

In many test functions, the Sweep Generator varies the output voltage of the DUT. In others, the input common-mode voltage or the regulated supply voltages (+SUPPLY and -SUPPLY) are varied.

Adjusting the Frequency. The SWEEP FREQUENCY control adjusts the Sweep Generator frequency from .01 Hz to 1 kHz. Five calibrated frequency steps, .1, 1, 10, 100, and 1 kHz, are provided. The VARIABLE control provides continuous adjustment from 0.1 to 1.0 times the selected decade value.

Adjusting the Amplitude. The SWEEP AMPLITUDE control adjusts the Sweep Generator amplitude from zero volts to its maximum value (which depends on the function being swept by the Sweep Generator). Amplifier output voltages and input common-mode voltages can be swept up to ± 30 volts or the limits of the DUT, whichever is the smaller. The regulated Power Supplies can be swept from zero volts to the voltage selected by the Power Supply controls (+SUPPLY and -SUPPLY).

Manual Amplitude Control. To manually control the Sweep Generator output, pull the SWEEP AMPLITUDE control. The output may be set anywhere within the voltage range described under Adjusting the Amplitude. The SWEEP FREQUENCY control is inoperative in this mode.

Regulated Power Supplies — Group 3

There are two adjustable, regulated power supplies, one positive and one negative, in the 178. The adjustment range is 0 to 30 volts, with 150 mA current capability. Adjustable current limiting for each supply is provided on the Device Card. Overload lamps in the supply-control area indicate when the current limit is reached.

Adjusting the Voltage. The supply voltages can be adjusted independently or from a single control. When the -SUPPLY control is in the TRACK + SUPPLY position, the voltage of both supplies is controlled by the +SUPPLY control, a three-turn, calibrated dial. Adjustment accuracy is ±2%, ±100 mV. When the -SUPPLY is not in TRACK + SUPPLY, the -Supply is independently adjustable by the -SUPPLY control.

In some positions of the FUNCTION switch, tests six through ten, the supply voltages are also controlled by the Sweep Generator.

Calibrated Adjustment of the Negative Supply. The -Supply output can be calibrated, independent of the +Supply, by proceeding as follows: Put the -SUPPLY control in TRACK +SUPPLY and adjust the +SUPPLY control to the voltage required for the -Supply. Turn the SWEEP AMPLITUDE control fully counterclockwise. Turn the FUNCTION switch to -SUPPLY I (displays the supply voltage on the horizontal axis). See the section on Deflection Factor Adjustment, Group 7, for more information. Note, exactly, the horizontal position of the spot. Now turn the -SUPPLY control clockwise until the spot returns to the same horizontal position (the supply voltage).

Calibrated Adjustment of Current Limiting. Current limiting for the regulated supplies is located on the device card. Calibrated adjustment can be made in the following manner: Turn to the appropriate SUPPLY I function, either plus or minus, that displays the supply current on the vertical axis (see section on adjusting deflection factors, in Group 7, for more information). Ground the supply that you wish to adjust (use a jumper, either on the Device Card or on the 178 front panel). The vertical display indicates the short-circuit current. Turn the appropriate I Limit on the Device Card to set the required limit. See the section on Device Cards for further details.

Collector Supply — Group 4

The Collector Supply is located in the mainframe. Only two voltage ranges are available to the 178, 25 volts or 100 volts (MAX PEAK VOLTS switch positions).

The Collector Supply is not used for most 178 functions. When not in use set the MAX PEAK VOLTS switch to 25 and COLLECTOR SUPPLY POLARITY to either +DC or -DC.

Safety Interlock. A safely interlock helps to protect the operator from dangerous voltages. A pushbutton (Interlock Defeat) on the 178 front panel must be pressed to enable the Collector Supply when the MAX PEAK VOLTS switch is set to 100.

Waveform and Polarity. The COLLECTOR SUPPLY POLARITY switch selects waveform and polarity of the Collector Supply output. The AC position selects line-frequency alternating voltage. The + or — polarities select full-wave rectified line frequency waveform of the polarity indicated.

The +DC and -DC positions add filtering to the rectified waveform, providing dc voltage. The ripple amplitude on the dc voltage depends (in part) on the load current.

Voltage Adjustment. The VARIABLE COLLECTOR % continuously adjusts the Collector Supply voltage from approximately zero volts to the maximum indicated by the MAX PEAK VOLTS switch.

Power Limiting. The SERIES RESISTORS switch selects the Collector-Supply impedance to limit power to the DUT. The maximum peak power that the DUT can dissipate is read from the scale coupled to the MAX PEAK VOLTS and SERIES RESISTORS switches (pull the MAX PEAK POWER-WATTS knob to unlock from the MAX PEAK VOLTS switch).

Maximum peak power also depends on the setting of the VARIABLE COLLECTOR % control (adjusting the VARIABLE COLLECTOR % to 50% voltage reduces the maximum peak power to 25% of the indicated value).

The actual peak power dissipated by the DUT is usually less than the maximum value indicated by the MAX PEAK POWER-WATTS switch.

DUT power dissipation can reach the maximum value indicated only when the DUT static resistance is equal to the series resistance of the Collector Supply. If the DUT voltage drop is either a small or large percentage of the open circuit voltage of the collector supply, the power dissipated by the DUT is less than the maximum value.

The average DUT power dissipation is usually about one-half of its peak power when the waveform is either ac or full-wave rectified line frequency.

SUPPLY DISABLED Indicator Lamp. The yellow lamp in the Collector Supply area of the 577 front panel indicates when the supply is turned off. Several conditions can turn off the Collector Supply:

a. The 178 DUT SUPPLIES switch is turned off.

b. An unusable Collector Supply voltage range is selected: 6.5, 400, or 1600 volts.

c. The 100 V range is selected, but the Safety Interlock Defeat button (178 front panel) is not pressed.

d. The vertical deflection signal is greatly over-range (approximately 20 divisions of deflection). The over-range mode of operation works only when the 178 is in a current-measuring function: Input Current, Supply Current, or Collector Supply Current.

Step Generator — Group 5

The Step Generator, located in the mainframe, is a regulated voltage or current supply having two main modes of operation. In the Stepping mode, the generator provides discrete steps of voltage or current, synchronized with the Collector Supply.

In the Offset mode the generator provides continously variable dc (voltage or current).

The two modes may be selected independently. When operated together, their outputs are additive.

For most 178 functions, the Step Generator is not used. When not in use, press the STEP FAMILY SINGLE button to turn off the stepping function.

Selecting the Mode of Operation. To Select the stepping mode, press the STEP FAMILY REP button. To select the Offset mode, release the OFFSET ZERO button. Successive pressing of the STEP FAMILY SINGLE button triggers a single set of steps.

Voltage-Current Adjustment. The primary voltage or current adjustment is made by turning the STEP/OFFSET AMPL control. The value indicated by the STEP/OFFSET AMPL control is the amplitude of a single step.

Releasing the STEP X.1 button (concentric with the STEP/OFFSET AMPL control) reduces amplitude by a factor of ten. A corresponding scale factor change takes place and is indicated on the STEP/OFFSET AMPL knob skirt.

The STEP/OFFSET AMPL control, with the OFFSET MULT control (a ten-turn calibrated dial) adjusts the amplitude of the ac voltage or current in the offset mode of operation. The OFFSET MULT control varies the dc amplitude from zero to the equivalent of ten normal steps.

Releasing the STEP X.1 button does not affect the Offset voltage or current. However, since the scale factor of the STEP/OFFSET AMPL control changes with the STEP X.1 button position, the maximum dc amplitude of the OFFSET MULT is read as 100 small steps, rather than 10 normal steps.

Polarity. The polarity of the Step Generator is primarily set by the COLLECTOR SUPPLY POLARITY switch. The steps have the same polarity as the Collector Supply (positive steps when AC position is selected).

The polarity of the dc voltage or current in the Offset mode may be the same or of opposite polarity as the steps (aiding offset).

Releasing the AID button selects the polarity opposite the step (opposing offset).

The Aiding polarity mode of operation has greater current capability than opposing polarity. When using the Offset mode alone, the AID button is normally pressed.

The step polarity selected by the COLLECTOR SUPPLY POLARITY can be inverted. Releasing the STEP/OFFSET POLARITY NORM produces steps that have polarity opposite that of the Collector supply (or negative steps when the AC position is selected).

Number of Steps. Turning the NUMBER OF STEPS control selects from one to ten normal amplitude steps. When the STEP X.1 button is released, the NUMBER OF STEPS control selects up to about 95 small-amplitude steps.

Step Rate. The three STEP RATE buttons select the frequency at which the steps change from one level to the next. The normal rate (press NORM button) is twice the line frequency or one change for each full-wave rectified collector sweep.

The change from one step level to the next occurs at the beginning of each collector sweep when the sweep voltage is zero.

Pressing the SLOW button selects line frequency, and pressing the FAST button selects 4X line frequency. At the fast rate, one half the step changes occur at the peak of the collector-sweep waveform.

Pressing both FAST and SLOW buttons produces the normal rate, but all step changes occur at the peak of the collector sweeps. Selecting Pulsed operation, described later, affects the operation of some of the step rates.

Pulsed Operation. Pushing the PULSED 300 μs button selects Pulsed operation of the stepping mode. The Offset mode of operation is unaffected by this selection.

In Pulsed operation, the steps occur as 300 μs duration pulses. The amplitude level is zero except during the pulse. The pulse amplitude is set by the STEP/OFFSET AMPL switch.

In the Offset mode, the dc level (voltage or current) is constant and the 300 μs pulse is added to the dc.

The Collector Supply goes automatically into dc operation when the Pulsed operation is selected, except for two conditions. First, if the FAST Rate button is pushed, the Collector Supply operates with a sweep waveform. The FAST Rate is not available in Pulsed operation and the actual step rate is the normal rate. Second, if the COLLECTOR SUPPLY POLARITY is in the AC position, the Collector Supply does not go into DC operation when the PULSED 300 μs button is pushed.

Power, Loads, and Source Resistances — Group 6

Disconnecting DUT Power Supplies. The DUT SUPPLIES switch disconnects all DUT power sources (in its OFF position), including the +SUPPLY, the -SUPPLY, the Collector Supply, and the Step Generator.

Adjusting the Source Resistance. The SOURCE RESISTANCE control selects one pair of four input resistors pairs: 50 Ω (550 Ω with VERT UNITS/DIV in the 1 mV to 50 mV/DIV range), 10 k, 20 k, or 50 k.

External resistances may be selected in the EXT position. The external resistors must be mounted on the DUT card and are in series with 50 Ω (550 Ω when VERT UNITS/DIV is in the 1 mV to 50 mV/DIV range), which is the minimum resistance available. All input voltage measurements are made on the source side of the input resistance.

Not all Device Cards use external source resistors. Device card specifications indicate when the SOURCE RESISTANCE switch is inoperative.

Adjusting the Load Resistance. The LOAD RESISTANCE control selects one of seven load resistors: 100 Ω, 1 k, 2 k, 5 k, 10 k, 20 k, or 50 k. External resistance may be selected in the EXT position. The external resistance must be mounted on the DUT card and is always in parallel with 50 kΩ, which is the maximum resistance available.

Not all Device Cards use external resistors. The Device Card specifications indicate whenever the LOAD RESISTANCE switch is inoperative.

## Deflection Controls — Group 7

All deflection controls are located on the 577 mainframe except the VERT UNITS/DIV and DISPLAY ZERO, which are located on the 178 Test Fixture.

Positioning. The POSITION controls labeled with a vertical arrow (Vertical POSITION) and a horizontal arrow (Horizontal POSITION) adjust the position of the display on the CRT. If no trace or spot is displayed, the display may be positioned off screen or the intensity may be set too low. See the crt controls Section for use of the BEAM FINDER and INTENSITY controls.

An X10 magnifier is activated on either or both axes by pulling the appropriate POSITION control knob. Magnification changes the deflection factor by ten times.

Adjusting the Vertical Deflection Factor. The VERT UNITS/DIV control on the 178 selects the vertical deflection factor. The deflection factor is either voltage or current per division depending on the FUNCTION switch position. Indicator lamps show either VOLTS or AMPS.

A section of the VERT UNITS/DIV control is devoted to low-current deflection factors only. If this current-only sector is selected when the VOLTS indicator lamp is lighted, the knob skirt lamp automatically turns off.

The voltage measurement range is 10 μV/DIV to 50 mV/DIV (1 μV/DIV with X10 vertical magnifier on). The current measurement range is 50 pA/DIV to 50 mA/DIV (5 pA/DIV with X10 vertical magnifier on).

Not all of the current range is useful on all current measuring positions selectable by the FUNCTION switch. See the functional description for the particular Device Card being used.

When the vertical magnifier is used, the corresponding deflection factor change is indicated on the VERT UNITS/DIV control.

Adjusting the Horizontal Deflection Factor. The HORIZ VOLTS/DIV control (on the 577 mainframe) selects the Horizontal deflection factor. Most measurements require the HORIZ VOLTS/DIV control to be in the COLLECTOR VOLTS segment of its range, unless otherwise stated by the functional description for the Device Card being used.

The voltage measurement range is 50 mV/DIV to 200 V/DIV (from 5 mV/DIV with X10 horizontal magnifier on), although the highest voltage positions are not useful with the 178 Test Fixture.

When the horizontal magnifier is selected, the corresponding deflection factor change is indicated on the HORIZ VOLTS/ DIV control knob skirt.

Inverting the Display. Releasing the upper NORM (DISPLAY INVERT) button inverts the polarity of both vertical and horizontal displays.

Filtering the Vertical Signal. Releasing the lower NORM (DISPLAY FILTER) button adds a low-pass filter to the vertical deflection signal to remove unwanted noise. The pass band of the filter is very low and can add phase shift to the display unless the test frequency approaches dc. Use care when using the filter.

Display Controls — Group 8

The crt controls are located on the D1 or D2 Display Module.

Adjusting the Intensity and Focus Controls. The INTENSITY and FOCUS controls adjust the brightness and spot size (trace width) of the display. Adjust for the best display.

Finding Off-Screen Displays. Press the BEAM FINDER button to provide on-screen display (compresses the display). If no spot or trace is visible, turn the INTENSITY control slowly clockwise while holding the BEAM FINDER button in. The compressed display shows which direction the display is off screen.

Using Storage. Pressing the buttons labeled UPPER and LOWER in the STORE area of the Display Module, selects the Storage mode for the upper and lower halves of the graticule.

Pressing the UPPER and LOWER buttons in the ERASE area selects the half of the graticule to be erased. With both UPPER and LOWER buttons pressed in, the entire screen may be erased.

To erase either the selected half or the entire screen, press the ERASE button.

The brightness of a stored display is controlled by the BRIGHTNESS control. For extended retention of a stored display reduce the brightness to minimum and turn up only for viewing.

For normal operation and retention times, leave the BRIGHTNESS control at MAX.

The BRIGHTNESS control operates only when the VARIABLE COLLECTOR % is turned to zero or the Collector Supply is disabled, as indicated by the yellow lamp.

## DEVICE CARDS

A selection of Device Cards provides test configurations most suited to several classes of devices. Device Cards provide a means of making electrical connections to the DUT (device under test), and in most cases, also provide come circuitry.

Many Device Cards include a universal interconnection system that accepts various DUT sockets. A number of sockets are available from Tektronix, Inc. (see the catalog) to connect to common IC case styles, such as the 16—pin or 14—pin dual in-line package or the 8—pin or 10—pin-round package. These and other sockets are also available directly from Amphenol/Barnes.

Most classes of linear IC devices do not have standard pin configurations. For this reason and for greatest flexibility, most Device Cards employ patch cords to connect DUT terminals to the 178.

The operation of the FUNCTION selector on the 178 front panel depends upon the device card used and the description of each card includes operation of the FUNCTION selector.

Interchangeable nomenclature subpanels permit individual labeling of the FUNCTION selector for each Device Card type.

The Standard Operational Amplifier card (670-2567-00) is included with the 178.

Standard Op Amp Card. The Standard Op Amp Card is designed to test devices that require two power supplies (plus and minus), have two (differential) high impedance inputs, and have a single output. Testing other types of devices is treated in the Applications Section of this manual.

The basic measurements that can be made using the Standard Op Amp card are summarized in Table 2—1. A detailed procedure illustrating measurement technique is available in the 'First Time Operation' section.

TABLE 2-1

| Function | Vertical Display | Horizontal Display and Sweep Generator Controlling Point |
|---|---|---|
| OFFSET V | Differential Input Volts | Output Volts |
| +INPUT I | +Input Bias Current | Common-Mode Volts |
| -INPUT I | -Input Bias Current | Common-Mode Volts |
| CMRR | Δ Differential Input V[1] | Common-Mode Volts |
| GAIN | Δ Differential Input V[1] | Output Volts |
| +PSRR | Δ Differential Input V[1] | +Supply Volts |
| -PSRR | Δ Differential Input V[1] | -Supply Volts |
| ±PSRR | Δ Differential Input V[1] | +Supply Volts and -Supply Volts[2] |
| +SUPPLY I | +Supply Current | +Supply Volts |
| -SUPPLY I | -Supply Current | -Supply Volts |
| COLLECTOR SUPPLY I | Collector Supply Current | Collector Supply Volts |

[1] ΔInput V is the relative change in input voltage only. There is no information about the amount of of dc voltage that exits.

[2] The Sweep Generator controls both the +Supply and -Supply. The horizontal display, however, is only the +Supply.

Offset Voltage. Offset voltage is the differential input voltage required to maintain output voltage at zero. The maximum measurable offset voltage using the Standard Op Amp card is 800 mV. However, this large amount of offset voltage is not fully compatible with other measurement functions when ΔInput V is displayed. In these functions the amount of permitted offset voltage depends upon the vertical deflection factor. See Table 2-2.

TABLE 2-2

| Vertical Deflection Factor Δ Input V | Maximum Permited Offset Voltage |
|---|---|
| 10 μV to 50 μV/Div | 25 mV |
| 100 μV to 500 μV/Div | 200 mV |
| 1 mV to 50 mV/Div | 2 V |

Input I. Input I is the bias current at each of the amplifier input terminals with the amplifier output at zero volts.

Gain. Gain is the change in op amp output voltage divided by the corresponding change in differential input voltage. For an output voltage swing of ±10 volts the measurable range of gain with the Standard Op Amp card is approximately 34 dB (50) to over 126 dB (2 million). Lower gains may be measured at less output voltage change.

CMRR. CMRR (Common-Mode Rejection Ratio) is the change in common-mode voltage divided by the change in differential input voltage while the output voltage is maintained at zero. The measurable range of CMRR is the same as the range for GAIN with the Standard Op Amp card.

PSRR. PSRR (Power Supply Rejection Ratio) is the change in power supply voltage divided by the change in differential input voltage while the output is maintained at zero. For a power supply swing of 5 volts, the measurable range of PSRR with the Standard Op Amp card is approximately 22 dB (12.5) to over 114 dB (500,000).

Supply I. Supply I is the supply current that the DUT draws with its output at zero volts.

Collector Supply I. Collector Supply I is an auxilliary test function. The Collector Supply is not utilized for most op amp measurements.

## Connecting To The DUT

The small sockets in the DUT connection area are labeled from 1 through 16. These sockets connect to corresponding pins of a DUT socket that is plugged into the lower connector block.

## Connecting To The 178

Five small sockets in the 178 connection area are located close to the op amp symbol. These sockets must be connected to the corresponding terminals of the DUT using patch cords. The regulated supplies are labeled V+ and V-. Sockets connecting to the DUT's differential inputs are labeled +IN and -IN. The socket connecting to the DUT's output is labeled OUT.

External resistors, both source ($R_S$) and load ($R_L$), may be installed between the sockets so marked. These resistors remain unconnected until the EXT position of the SOURCE RESISTANCE or LOAD RESISTANCE switches is selected. Use the bifurcated pin terminals for easy placement and removal of external components. Two other resistors shown between the DUT's input and output are for optional external feedback components.

Other 178 connections on the card include:

CS-Collector Supply

STEP-Step Generator

EXT-External signal input (from front panel)

GND-Ground

Kelvin sensing of the Collector Supply voltage (Horizontal display) on the most clockwise position of the FUNCTION switch (COLLECTOR SUPPLY I) is possible by using the terminals indicated in Fig. 2-9. Besides connecting to these indicated terminals, the small foils, that connect to the collector supply and ground, must be cut. See Fig. 2-9.

Compensation and Other External Networks.

External components, for compensation or other purposes, can be conveniently added in the 'network' area shown in Fig. 2-9. Use the included pin terminals for easy installation and removal of components. Once in place, a network may be connected to either the DUT connection area or the 178 area using patch cords.

External Feedback Amplifier

Additional gain may be added to the closed loop test configuration by switching in the External Feedback Amplifier shown in Fig. 2-9. This added gain can be useful for testing low gain amplifiers, for example, in a test function such as CMRR or PSRR, where the DUT's output voltage should be held at zero volts. In these functions, the External Feedback Amplifier maintains the DUT's output closer to zero volts than would be possible if the loop gain were provided by only a low-gain DUT. If the output of a low-gain DUT is not held close to zero volts, an error signal appears at the input. This error signal due to gain adds to the input signal due to CMRR or PSRR and produces an erroneous measurement.

As a rule of thumb, this low-DUT-gain error may be significant whenever gain is more than 20 dB below CMRR or PSRR.

Fig. 2-10 is a simplified block diagram of the Feedback Amplifier with the 178 in the GAIN function. The components are added by the user to tailor gain to his particular needs. Capacitor $C_F$ must be added to prevent loop gain from exceeding unity at high frequencies. Typically the $R_F$ - $C_F$ time constant should be about 0.01 second.

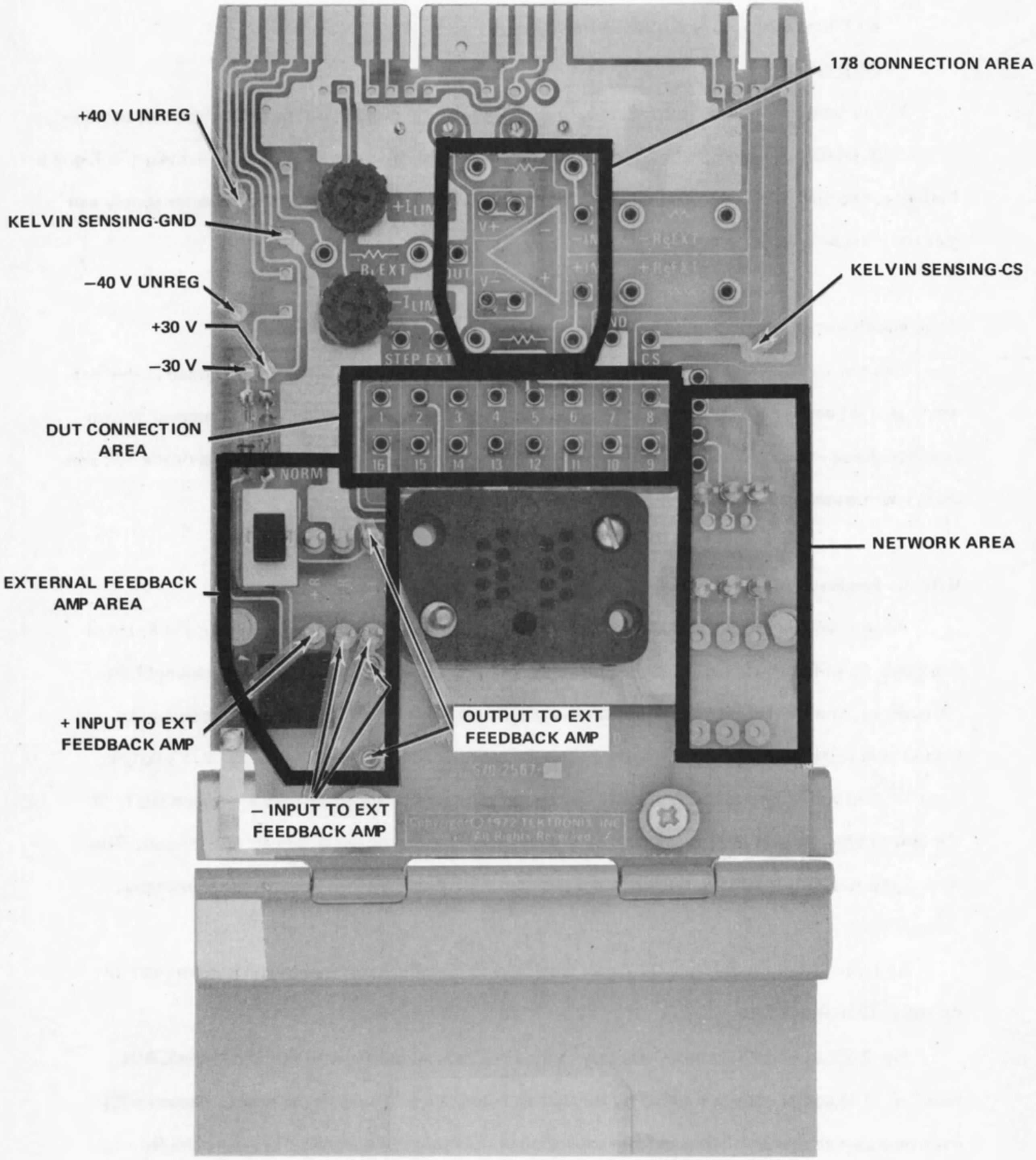



**Fig. 2-9. The Standard Op Amp card.**

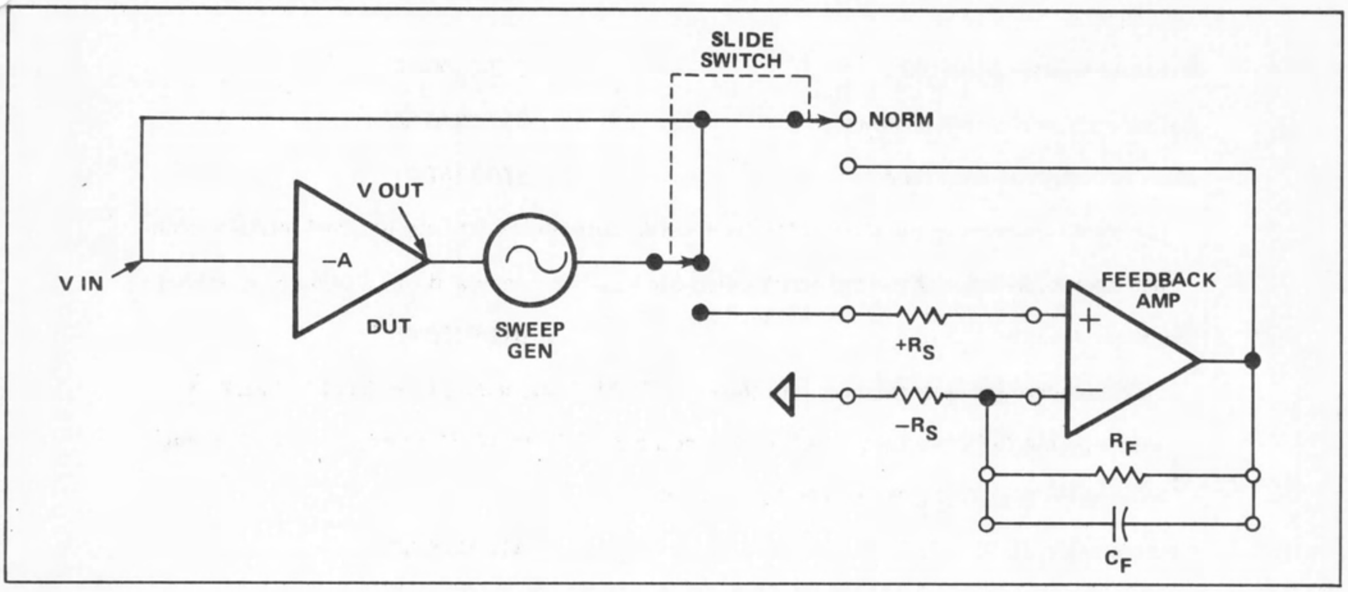



Fig. 2-10. Block diagram of the Feedback Amplifier.

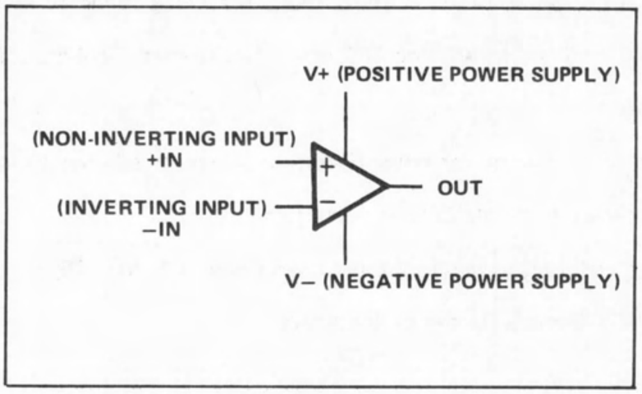



Fig. 2-11. Operational Amplifier symbol.

Useful Accessories

| | |
|---|---|
| 8—two-inch patch cords (red) | 012-0200-00 |
| 8—four-inch patch cords (yellow) | 012-0310-00 |
| Blank Standard Op Amp Card | 670-2567-01 |

Standard card without pin sockets for patch cords, current-limitng pots, external feedback amplifier (socket, switch, and zener diodes), patch cords, pin terminals and two 0.005 μF capacitors.

| | |
|---|---|
| Transistor Adapter | 013-0128-00 |

This three-terminal adapter plugs into the GND, STEP GEN, and COLLECTOR SUPPLY terminals on the 178 front panel. The adapter accepts TO-5 and TO-18 transistor types that may be tested in the COLLECTOR SUPPLY I function.

| | |
|---|---|
| Potentiometer, 50 Ω | 311-1568-00 |

For adjusting current limiting. Two of these pots are included on the Standard Op Amp card.

## FIRST-TIME OPERATION

The most common IC amplifying device is the operational amplifier or Op Amp. The 178 can be used to test a large variety of op amps using the Standard Op Amp card (standard accessory).

The following procedure demonstrates the 178, using the Standard Op Amp card to test a 741 Op Amp (or similar device).

Amplifiers that require compensation for stable operation can be tested once the appropriate external components are added to provide loop stability at unity gain.

The objective of this procedure is to familiarize the operator with 1) the 178, 2) some basic op amp parameters, and 3) how the 178 measures these parameters.

### Op Amp Terminology

The op amp symbol is shown in Fig. 2-11.

Normally, only input and output terminals are shown. The power-supply terminals and the Standard Op Amp terminology are included for convenience.

The minimum number of connections to an op amp is five (multiple op amps in a common package usually share the power-supply connections).

Some op amps require the addition of one or more passive components, often a single capacitor, to achieve stability. Such compensation usually requires connection to one or more terminals in addition to the five mentioned. Internally compensated op amps do not require external compensation.

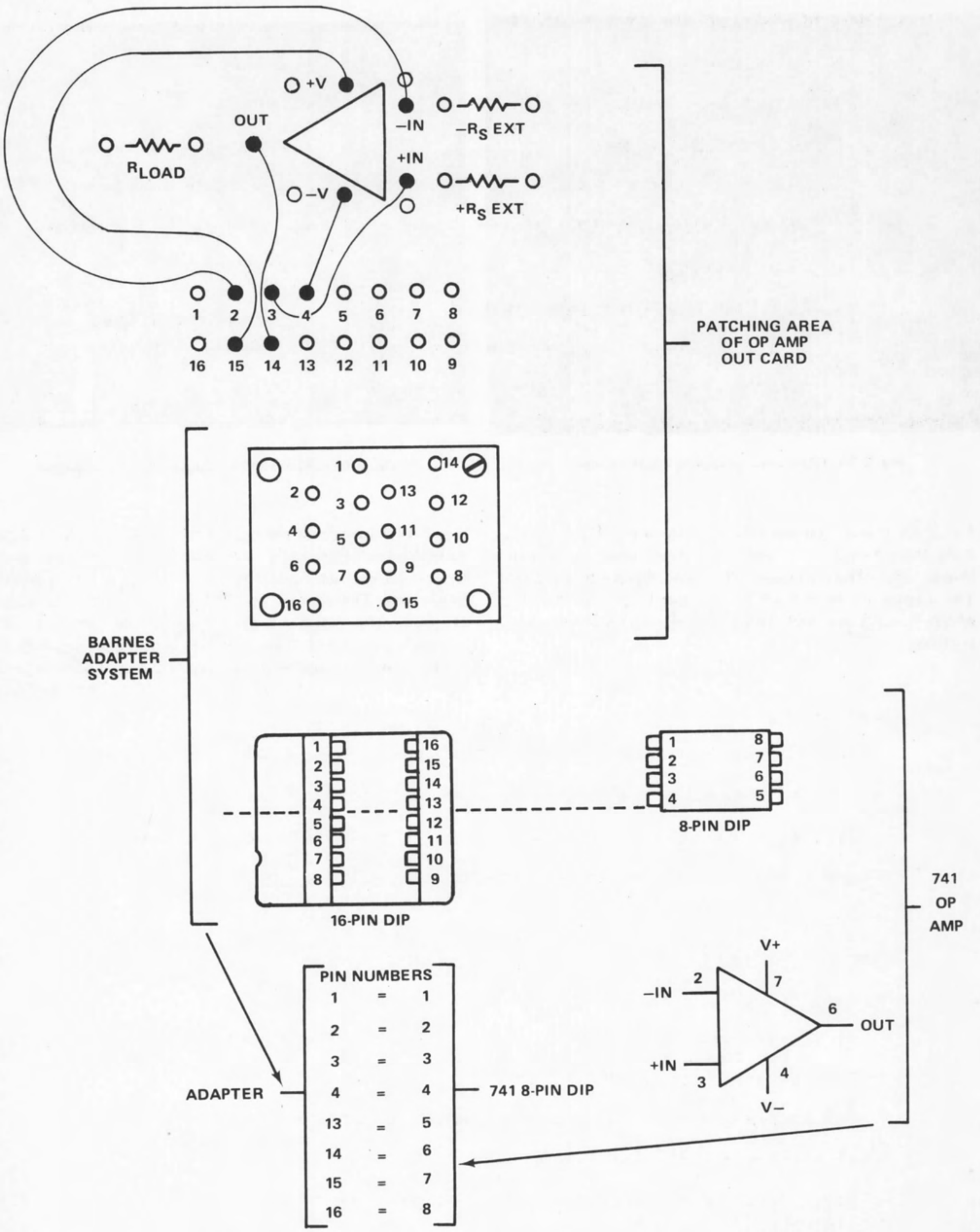



Fig. 2-12. 8-pin DUT plugged into the 16-pin adapter socket.

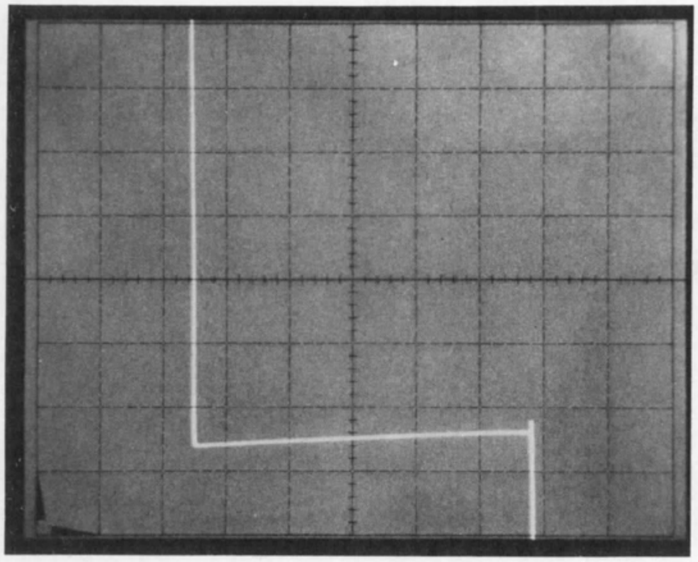


Fig. 2-13. Illustration of typical offset voltage.

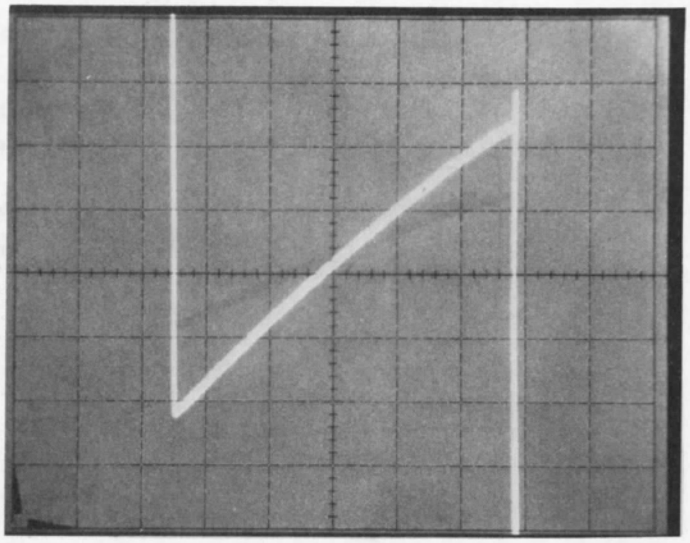


Fig. 2-14. Illustration of Op Amp Gain calculation.

Fig. 2-13. Horizontal deflection factor is 5 V/DIV. Vertical deflection factor is 1 mV/DIV. Zero volts is graticule center. The offset voltage of this 741 Op Amp is 2.5 mV. The display is the voltage at the inverting input terminal, which is −2.5 mV with respect to the non-inverting input terminal.

Fig. 2-14. Horizontal deflection factor is 5 V/DIV. Vertical deflection is 50 $\mu$V/DIV. Vertically, true zero volts (dc) is far off-screen. Horizontally, zero volts is the graticule center line. The gain of this 741 Op Amp is approximately 115,000. The slope of the curve is the opposite of a 'normal' gain curve. The inverting input goes positive for positive output signal. This inverted gain curve suggests internal positive feedback, and is typical of 741 amplifiers.

The supply voltage and output voltage are simply the potentials at the device terminals.

Potentials at the input terminals require more careful definition. The input voltage is the differential voltage at the input terminals. The common-mode voltage is that voltage common to both +IN and -IN terminals.

Characteristically, an op amp's output voltage is extremely sensitive to changes in its input voltage and insensitive to changes in common-mode and power-supply voltages. Parameters that reflect the magnitude of these characteristics are gain, common-mode rejection (CMR), and power-supply rejection ratio (PSRR). These and other characteristics are explained later in greater detail.

Connecting the Device Under Test (DUT)

The Standard Op Amp card is equipped with a two-piece socket system that adapts to several styles of IC packages. The base of the system is a sixteen-pin socket that is permanently attached to the Standard Op Amp card. Sockets for various IC packages plug into this sixteen-pin socket. Standard equipment includes a 16-pin socket for 16-pin dual-in-line packages.

A major benefit of the socket system is uniform pin numbering on the card. The 16 connections on the base socket are numbered on the DUT card and always correspond to the pin numbers of all upper sockets.

To provide the greatest flexibility in connecting to a device under test, patch cords are used on the card. Patch cords permit connecting the DUT terminals to the 178 for any DUT pin arrangement. This capability is especially beneficial when there is little standardization of pin connections.

Patching the DUT card for the 741

Remove the upper socket and swing the card cover away from the card. The card may be removed from the instrument or left plugged in when patching from the device card to the adapter socket. Switch the DUT SUPPLIES switch to OFF before placing or changing patch cords or inserting the card into the 178.

If the DUT has the same number of pins as the upper socket, the patch cord connections may be made directly. If the DUT has fewer pins that the upper socket, the DUT pin numbers do not correspond to the socket pin numbers on the card and pin-number substitution must be made. Fig. 2-12 illustrates an 8—pin DIP device plugged into the 16—pin upper socket, with corresponding pin numbers shown.

Current Limits

Two small potentiometers located on the Standard Op Amp card independently adjust the current limits for the positive and negative regulated supplies. The adjustment range is approximately 10 mA (counterclockwise) to 150 mA (clockwise). The typical setting for a 741 op amp test is one-quarter turn clockwise from the minimum-current position (ccw). This adjustment is not critical.

A method for accurate current limit adjustment is found in the Function of Controls section under Regulated Supplies.

Switch the DUT SUPPLIES switch to OFF and install the op amp card in the 178. Always switch the DUT SUPPLIES to OFF when patching or when removing or replacing the DUT card in the 178.

Initial Setup-Obtaining a Display

For convenience, the controls are grouped as follows: group 1, the unused controls; group 2, the occasionally used controls that may produce difficulties (if not set to their normal position); and group 3, the controls that most directly affect the setup and obtain a display.

Group 1 controls. Though the controls for Collector Supply and Step Generator are not used, proper setting of these controls prevent interference with normal measurements.

Set the MAX PEAK VOLTS switch to 25. At other settings of the MAX PEAK VOLTS switch the yellow light remains lighted. Set the MAX PEAK POWER-WATTS to .15 or .6 (to change power settings, pull the MAX PEAK POWER-WATTS switch and turn while in the pulled position). At .15 and .6 watts settings the Vertical Overrange circuitry will not cause the yellow light to flash under certain conditions (see Operation of Controls, Collector Supply section for more details).

Set the VARIABLE COLLECTOR % fully counterclockwise and COLLECTOR SUPPLY POLARITY to either +DC or -DC to reduce unwanted noise pickup at higher sensitivities.

Additional noise reduction is obtained by setting controls in the Step Generator. Press the STEP FAMILY SINGLE button to turn off the Step Generator and push to release the PULSE 300 μs button to lock out the pulsed mode.

Group 2 Controls. These controls should be set to the normal mode of operation. These controls are occasionally changed from the normal settings, but cause the least difficulty if the initial setup is made as follows:

Pull the POWER switch to ON.

Place the DISPLAY FILTER and DISPLAY INVERT in the normal mode (NORM button in).

The remaining controls in this group are on the display unit module (D1 or D2).

Set the BRIGHTNESS control (located only on the D1 Display Unit module) fully clockwise to the MAX position. If the BRIGHTNESS control is not set to MAX, the display can appear chopped or segmented. Use this control only for long retention of stored displays.

Set the INTENSITY control for a visible spot (push BEAM FINDER button if necessary).

Push the UPPER and LOWER STORE buttons and the UPPER and LOWER Erase selector buttons in. The Erase selectors permit erasing the corresponding areas of the screen.

Group 3. The initial display is obtained in the Offset function (turn FUNCTION switch to OFFSET V). In OFFSET, the Op Amp output voltage is displayed horizontally and the input voltage is displayed vertically. Since measurement is made at the DUT's inverting input terminal (the non-inverting terminal is grounded), the crt display actually shows input voltage inverted. All input voltage measurements in other functions are also inverted.

Set the +SUPPLY control to 15 V (or other specific voltage within the rating of the DUT). Set the -SUPPLY control to TRACK +SUPPLY (fully counterclockwise). Be sure the detent is engaged. In this mode, both supplies are controlled by the +SUPPLY control.

Set the LOAD RESISTANCE to 50 kΩ and the SOURCE RESISTANCE to 50 Ω.

Turn the SWEEP AMPLITUDE control fully counterclockwise (zero amplitude). Be sure that this control is pushed in (not in manual mode). Set the SWEEP FREQUENCY control to 10 Hz with the VARIABLE fully clockwise (X1).

Set the VERT UNITS/DIV to 10 mV/DIV and the HORIZ VOLTS/DIV selector (on the 577 mainframe) to 5 V/DIV, COLLECTOR. Note the lighter shaded arc along a portion of the VERT UNITS/DIV knob skirt. This arc represents the limits of voltage measurements from 10 μV/DIV to 50 mV/DIV. Current measurements use all switch positions. Whether voltage or current is displayed on the Vertical axis depends on the setting of the FUNCTION selector. In the voltage functions, the VOLTS lamp goes out if the VERT UNITS/DIV is not within the lighter-shaded arc.

While holding the DISPLAY ZERO button (on the 178) pressed, adjust the POSITION control to move the spot to the graticule.

The instrument is now ready to obtain an Offset function display. In this display the op amp's differential voltage is displayed on the vertical axis and the output voltage on the horizontal axis.

Install the DUT in the adapter socket and move the DUT SUPPLIES switch to ON. A spot should appear near the center of the graticule. Turn the SWEEP AMPLITUDE control clockwise to increase the Sweep Generator output. The spot should expand to a horizontal trace (adjust for about two divisions of deflection each side of graticule center).

The instrument is now ready to measure Op Amp parameters. If the proper display is not obtained, try the following recheck procedure. If the proper display is obtained, proceed with measuring Offset Voltage.

Troubleshooting the Setup

1. Check the Op Amp connections on the device card to determine:

a. That the proper pin numbers are connected to the five essential 178 terminals (+V, -V, +IN, -IN, and OUT).

b. The DUT is installed properly in the test socket, i.e., DUT pin numbers correspond to socket-pin numbers.

c. Allowance was made for pin number equivalents if the DUT has fewer pins than the test socket.

2. Recheck the group 3 settings with special attention to:

a. HORIZ VOLTS/DIV selector (in COLLECTOR VOLTS segment, not BASE), and the deflection factor is correct (5 volts, not 0.5 volts).

b. SOURCE RESISTANCE is not in EXT. EXT disconnects the inputs unless resistors are added to the device card.

c. VERT UNITS/DIV selector is not in the current only section of its range and the correct sensitivity is selected (go to 50 mV/DIV).

d. DUT SUPPLIES switch is ON.

3. Try another Op Amp.

Measuring Offset Voltage

Offset voltage is defined as the input voltage (differential voltage at the input terminals) required to obtain zero volts at the amplifier output.

The preceding steps prepare the 178 to measure offset voltage. The display shows the amplifier input voltage on the vertical axis (inverted) and the output voltage on the horizontal axis.

Before actually making a measurement from the display, it may be necessary to become familiar with the operation of several controls and their effects on the measurements.

Op Amp's Output Operating Range. In the Offset function,the SWEEP AMPLITUDE control adjust the op amp output voltage excursion. Actually, the Sweep Generator indirectly controls the op amp output by causing the feedback loop (the op amp is a part of the feedback loop) to control the op amp input voltage.

Slowly turn the SWEEP AMPLITUDE control and note the effect on the horizontal display. Increase the SWEEP AMPLITUDE until vertical lines appear at both ends of the horizontal display. These vertical lines mark the limits of the op amp output swing. These vertical lines are produced by the feedback driving the input beyond the op amp operating range or to the point at which the op amp loses gain. This range should be somewhat less than the power-supply voltage.

Reduce the Regulated Supply voltage by slowly turning the +SUPPLY control counterclockwise. Notice that the output operating range decreases. Reset the +SUPPLY control to 15 volts.

Slow Sweep Frequency and Storage. It is quite often necessary to measure op amp parameters at very low frequencies. The convenience of storage becomes apparent at these low frequencies.

Adjust the SWEEP AMPLITUDE control so that the vertical excursion at each end of the horizontal trace (where the op amp reaches its output limits) is small.

Turn the SWEEP FREQUENCY control to .1 Hz with the VARIABLE fully clockwise (X1). Many op amp measurements are made at .1 Hz or lower.

Push both UPPER and LOWER STORE buttons to put the display module in the storage mode. Push the UPPER and LOWER Erase selector buttons and push the ERASE button to prepare the screen for storage.

Note that the storage mode provides a flicker-free, easy-to-view trace from a slow-moving spot.

Use the ERASE button to clear the screen of unwanted displays. The display is automatically erased between some of the FUNCTION switch positions. This procedure leaves the use of the erase and storage function to the operator's discretion.

Manual Operation. Manual Sweep operation is now demonstrated, although this mode of operation is used infrequently.

In manual sweep, the Sweep Generator is replaced with a manually-operated potentiometer. Pull the SWEEP AMPLITUDE control out and rotate the control in both directions. Note that the op amp output can be set to any desired voltage within its operating range. Push the SWEEP AMPLITUDE control in and reset the control to display a small vertical excursion at each end of the trace.

Larger vertical excursions, or overdriving the inputs, does not damage a well-designed op amp. However, large vertical excursions cause the moving spot to spend excessive time off-screen in the more sensitive measurements.

Op Amp Offset Voltage . The display can now be used to measure offset voltage. Increase the vertical sensitivity (turn the VERT UNITS/DIV control clockwise until the largest on-screen vertical deflection is obtained). Offset is measured on the vertical axis where the output voltage passes through zero volts (see Fig. 2-13). The vertical deflection is the differential voltage between the op amp input terminals.

Push the DISPLAY ZERO button to check for zero in the display. Position the spot to graticule center as necessary.

Any trace tilt is due to op amp gain, which is covered in the next step.

A loop may be displayed due to op amp phase shift. The amplitude of the loop can be reduced by either reducing the sweep frequency (turn the SWEEP FREQUENCY VARIABLE counterclockwise), or by reducing the sweep amplitude. To eliminate looping, manually position the op amp output to zero volts in the horizontal axis (see Manual Operation, previously described).

Measuring Gain. Op amp gain is defined as the change in output voltage divided by the change in the differential voltage at the input terminals. Gain is one measure of how faithfully an op amp processes a signal, when operating within a feedback loop. High gain op amps introduce less distortion or error (from ideal response dictated by the feedback network) than do low-gain op amps.

As the output voltage of an op amp changes, the input voltage of a low-gain op amp changes more than the input voltage of a high-gain op amp. The change in input voltage due to feedback ($\Delta$ input V), has the same effect on the overall circuit as an input signal of the same amplitude.

Therefore, the effective input signal is input signal minus $\Delta$ input V. If the change in input voltage is small with respect to the signal (as it should be in a practical circuit), the error introduced due to gain is approximately the ratio of input voltage to signal.

$$\%\ \text{error} \cong \frac{100 \times \Delta\ \text{input V}}{\text{signal}}$$

If the op amp feedback network provides signal amplification, new terms must be substituted into the above ratio from the following relationships, where $\Delta V_O$ is the change in op amp output voltage.

$\Delta V_O$ = Network Gain x Signal, and

$\Delta V_O$ = Op Amp Gain x $\Delta$ Input V

Therefore, by substitution,

$$\%\ \text{error} \cong \frac{100 \times \text{Network Gain}}{\text{Op Amp Gain}}$$

Measurement of op amp gain can be made using the same type display as in the Offset function. However, since the offset voltage of the op amp is usually quite large relative to the input voltage change, the vertical deflection factor cannot be made sensitive enough to measure gain and maintain an on-screen display. This problem is solved by switching the FUNCTION switch to the GAIN position. In the GAIN position, offset voltage is nulled and the vertical deflection factor can be decreased to display the slope of the input voltage curve.

Automatic Offset Null. With the FUNCTION switch in the GAIN position, momentarily press the DISPLAY ZERO button. In the GAIN function, the circuit configuration is essentially the same as in the OFFSET function, except that an electronic sample and hold circuit is added in the op amp feedback loop. When the DISPLAY ZERO button is pressed, the sample and hold circuit detects and nulls any offset voltage in the op amp. When the DISPLAY ZERO button is released, the sample and hold circuit remembers and maintains this offset null. The automatic nulling occurs in the 178 and is not related to any Offset Null terminals on the op amp.

The display in the GAIN function is the same as in OFFSET function except that the trace should pass nearly through graticule center.

The display is uncalibrated in the absolute sense, as the display provides information only about changes in input voltage. The location of zero volts is lost when the sample and hold circuit nulls offset voltage.

Switch the VERT UNITS/DIV to display about three divisions vertically. Press the DISPLAY ZERO button (reset the sample and hold circuit) to maintain the display on screen. Make frequent use of the DISPLAY ZERO button in all functions that measure $\Delta$ Input V (GAIN, CMRR, and all PSRR positions). It is often necessary to reset the sample and hold circuit after changing the VERT UNITS/DIV switch, after changing the FUNCTION, or after prolonged operation in which the sample and hold may drift. Only occasional reminders to reset the DISPLAY ZERO will be made for the remainder of this procedure.

It is not necessary that resetting the sample and hold causes the trace to pass through the screen center. The 178 is designed to provide an on-screen trace for amplifiers with 25 mV or less of offset. Use the vertical POSITION control (on 577) for minor adjustments to facilitate measurement.

Phase Shift. In high-gain op amps, phase shift can occur at extremely low frequencies. Phase shift results in a vertical separation of the positive-going and negative-going traces on the display. At high vertical sensitivities, even small amounts of phase shift become apparent.

With the VERT UNITS/DIV selector set for three or more divisions of deflection and the SWEEP FREQUENCY selector at .1 Hz, some phase shift may be displayed. Increase the frequency to 1 Hz or higher and observe the phase shift. Return to .1 Hz. If excessive phase shift exists at this frequency, use the VARIABLE to further reduce the frequency.

Noise. All operational amplifiers exhibit some degree of noise. At times, this noise is great enough to interfere with gain measurement. Normally, the noise is small enough that the center of the trace can be determined. Occasionally the Display Filter in the 577 Mainframe can be used to reduce trace width. The Display Filter eliminates all but the lowest frequency noise components from the display.

Push the DISPLAY FILTER NORM button to release the button to the out position. The noise reduction in the displayed trace should be noticeable unless the op amp is exceptionally noise free. Notice that some phase shift may be introduced by the filter.

The shift effects of the filter may be easily observed by displaying both the filtered and unfiltered traces by using display storage.

The operator can then decide (from the display) whether the filter aids or hinders measurements for these particular measurement conditions. Reducing the sweep frequency reduces phase shift caused by the display filter.

To prevent the filter from inadvertently causing future erroneous measurements, push the DISPLAY FILTER NORM button in, once a measurement has been made (before proceeding to new functions or operating conditions). Check the effects of the filter on phase shift before each use.

Measuring Op Amp Gain. Set the VERT UNITS/DIV for an on-screen display of three divisions or greater. Set the Sweep Frequency for acceptably small phase shift looping. Select an appropriate change in horizontal deflection and measure the corresponding vertical deflection (see Fig. 2-14). The op amp gain is the change in output voltage (horizontal) divided by the corresponding change in input voltage (vertical). The gain is inversely proportional to the slope of the trace. The flatter the trace, the higher the gain. See the Applications section for additional gain information.

### Measuring Common-Mode Rejection Ratio

Common-mode rejection ratio, CMRR, is a measure of the ability of an op amp to ignore changes in the common-mode voltage at the input. Ideally, an op amp should respond only to the input voltage (differential voltage between the input terminals) and be insensitive to common-mode voltage (average voltage between input terminals). If the common-mode voltage changes on an imperfect (real) op amp, the effect is the same as through a slight change in input voltage occured. CMRR is obtained by dividing the change in common-mode voltage by the change in input voltage required to hold the op amp output voltage constant. In the 178, the op amp output voltage is held at zero volts during CMRR measurements.

Common-Mode Operating Range. Turn the FUNCTION selector to the CMRR position. Set the SWEEP FREQUENCY control to 1 Hz, VARIABLE fully clockwise. Press the DISPLAY ZERO button if the display is off screen. Set the VERT UNITS/DIV so that some portion of the trace is relatively horizontal. In this function, the horizontal deflection is the common-mode voltage (the average voltage between the input terminals). The vertical axis displays the change in input voltage between the input terminals. The Sweep Generator drives the common-mode voltage in CMRR function. Turn the SWEEP AMPLITUDE control counterclockwise and notice the effect on horizontal deflection. Turn the SWEEP AMPLITUDE control clockwise until both ends of the display go off screen.

In CMRR function, the output of the op amp is held at zero volts. The display is less subject to the effects of phase shift noted in the GAIN function. Increase the Sweep Frequency to verify the lower susceptibility to phase shift. Set the frequency low enough to minimize phase shift.

The op amp's common-mode operating range is that range of common-mode voltage at which the op amp is insensitive to changes. The crt graphically displays this range. The flattest portion of the trace indicates the least sensitivity to common-mode voltage (the best CMRR). The display shows relative performance over a range of common-mode voltages. Reduce the power-supply voltages (+SUPPLY control counterclockwise) and notice the decrease in common-mode operating range. Common-mode range, therefore, depends on supply voltage. Return the +SUPPLY to the original setting (15 volts).

Measuring the Op Amp CMRR. Choose an area of interest in the common-mode operating range. Decrease the VERT UNITS/DIV until the trace has an easily measured slope or vertical deflection. CMRR is measured by selecting the appropriate change in horizontal deflection and measuring the corresponding vertical deflection. The op amp CMRR is the change in common-mode voltage (horizontal) divided by the change in input voltage (vertical). CMRR is inversely proportional to the slope of the trace; the flatter the trace, the better or higher the CMRR. CMRR is discussed further in the Applications section.

Measuring Power-Supply Rejection Ratio

Power-Supply Rejection Ratio, PSRR, is a measure of the ability of the op amp to ignore changes in the power supply voltages. An ideal op amp does not respond to changes in the power-supply voltage.

If the power-supply voltage changes in the imperfect op amp, the effect can be related to an equivalent change in the input voltage. PSRR is obtained by dividing the change in power-supply voltage by the change in input voltage required to hold the output voltage constant. In the 178, the op amp output and common-mode voltage are both held at zero during the PSRR measurement.

The 178 provides three PSRR functions. PSRR can be measured from variations in the positive power supply (+PSRR), for variations in the negative power supply (-PSRR), or for output-of-phase variations in both power supplys (± PSRR). In the ± PSRR function, the positive supply voltage increases (more positive) while the negative supply increases (more negative) and vice versa.

In PSRR functions, the horizontal deflection is the power-supply voltage, positive in +PSRR, negative in -PSRR, and positive only in ±PSRR, although both supplies are sweeping. The amplitude and frequency of the power supply variations are controlled by the sweep generator controls. The vertical deflection in all PSRR functions is the change in the op amp input voltage. Because of the similarity of all PSRR functions, only one is presented.

Op Amp PSRR. Turn the FUNCTION selector to ±PSRR. The display shows the input voltage variations (vertical) as a function of the supply voltage (horizontal). Decrease the vertical sensitivity if vertical deflection is excessive. Press DISPLAY ZERO if necessary. Turn the SWEEP AMPLITUDE control fully counterclockwise and note that the horizontal display indicates the supply voltage as set by the +SUPPLY control. Turn the SWEEP AMPLITUDE clockwise enough to conveniently measure horizontal deflection. Increase the vertical sensitivity, if necessary, to measure the corresponding vertical deflection. PSRR is the change in power-supply voltage (horizontal) divided by the change in input voltage. PSRR is inversely proportional to the slope of the trace.

Increase the sweep amplitude until the trace goes off screen near zero volts. At this point the op amp input can no longer hold the output at zero volts.

The power-supply voltage at which the trace goes off screen is the minimum operating supply with both common-mode and output voltages of the op amp held at zero volts. (This operating condition is unrealistic for most applications.)

## Measuring Input Currents

Input bias current is that current flowing into either the +IN or -IN terminals. Input Offset current is the difference in the +IN current and the -IN current. Normally these currents are specified at zero common-mode voltage. The 178 displays input bias current of the op amp (vertical) as a function of common-mode voltage (horizontal), thus permitting input bias-current measurements at zero volts common-mode, or over the common-mode operating range. The op amp output is held at zero volt during bias current measurements.

Op Amp Bias Current. Turn the FUNCTION selector to +INPUT I. Turn the VERT UNITS/DIV switch until sufficient deflection is obtained to make a measurement. In a current-measuring function, all positions of the VERT UNITS/DIV switch are usable (in voltage functions, only those positions in the light-shaded arc are usable). The current measured in this function is the current into the non-inverting (+) input terminal.

Once input-bias current is measured at the desired common-mode voltage, or range of voltages, turn the FUNCTION selector to -INPUT I. Current into the inverting (—) terminals can now be displayed and measured. In the most sensitive positions it is necessary to remove the op amp from the test socket to check zero-current level.

Op Amp Input Offset Current. When the input bias currents have been determined for both input terminals, the input offset current can be obtained by finding the difference.

The display is not automatically erased when the FUNCTION selector is moved from the +INPUT I to -INPUT I position. Both curves can be viewed simultaneously. Better resolution is required to measure input offset current. Use the following procedure:

Turn the FUNCTION switch to +INPUT I. Vertically position the trace to graticule center using the vertical POSITION control. Pull the vertical POSITION control to magnify the vertical display. Note that the deflection factor has changed by a factor of ten and the new deflection factor is indicated on the VERT UNITS/DIV knob skirt.

If necessary, reposition the trace vertically to place the display on screen. Push the ERASE button to clear the storage screen.

Next, switch to the -INPUT I function. If well positioned, both traces of bias current are displayed at ten times the normal resolution. Input offset current, the current represented by the distance between the two traces, is measured at the desired common-mode voltage. If the second trace (-INPUT I) is not displayed on screen, reposition the trace, erase the display and repeat both functions.

If the device has excessively large input offset current, it may be necessary to reduce the vertical sensitivity or make the measurement at the normal (unmagnified) deflection factor.

Measuring Supply Current

Supply current, as measured on the ninth and tenth positions of the FUNCTION selector, is that current in the +V or -V supply terminals of the op amp. The output terminal is held at zero volts for this measurement. Only one of these functions is required for testing op amps. With the amplifier output held at zero volts, and with insignificant current in the input terminal, the currents in the supply terminals have equal magnitude (but opposite sign). The two separate functions are provided for use with device cards other than the Standard Op Amp card. In the supply current functions, the horizontal display is the power-supply voltage and the vertical display, the supply current.

Op Amp Supply Current. Turn the SWEEP AMPLITUDE control fully counterclockwise. Switch the VERT UNITS/DIV selector to about 10 mA/DIV. Turn the FUNCTION selector to +SUPPLY I. The display should be a spot. The horizontal spot deflection is equal to the supply voltage. Decrease the VERT UNITS/DIV to produce an easily measured vertical deflection. The vertical deflection is a point measurement of the supply current.

Decrease the supply voltage using the +SUPPLY voltage control while in stored mode. The stored display shows how supply current varies with supply voltage. Return the +SUPPLY voltage to its original setting and retain the stored display.

Next, slowly turn the SWEEP AMPLITUDE control clockwise to display another trace. This trace probably does not correspond to the stored trace obtained previously. The second trace shows how power-supply current varies while only the positive-supply voltage changes (controlled by the Sweep Generator) while the negative supply remains constant. It is important to keep in mind the difference in these two traces.

# CIRCUIT DESCRIPTION

This section of the manual provides a description of the major circuits in the 178 Linear IC Test Fixture.

## Power Supply

The power supply consists of a sine-wave generator, a sweep amplifier, supply regulators, current-limit adjustment, and current overload indicators.

Sine-Wave Generator. This generator produces a square wave, integrates the square wave, then shapes the triangular waveform (out of the integrator) into a sine wave.

The square-wave generator-integrator circuit is a feedback device consisting of a comparator, Q402 and Q404; a switch, consisting of Q406 and Q408; and an IC integrator, U424-C424-C425. The outputs of U424 and Q408 are summed through R402 and R401 and applied to the input of the comparator. The result is that Q408 emitter swings from approximately -29 volts to approximately +29 volts, which is applied through the frequency selecting resistances (switched and variable) into the input of integrator U424.

The integrator output, a triangular wave, is then applied to the diode shaping circuit, Q442-CR443-CR444-CR445 (for the negative-going excursion) and Q452-CR453-CR454-CR455 (for the positive-going excursion).

The changing load and non-linear characteristics of the diodes shape the triangular input into a sine wave.

The sine wave is then fed into U432A through R449. U432A output, pin 1, swings from 0 to approximately +6 volts when F4 switch contact is closed (to -30 volts) and from -3 volts to +3 volts when F4 is open.

When the SWEEP AMPLITUDE switch is pushed in (the auto sweep position) the sine-wave generator output is applied across R460 to ground. R460 wiper is connected to the sweep amplifier. Thus, the SWEEP AMPLITUDE control sets the amplitude of the sine-wave generator output.

When F4 is open, Q462 is turned off, permitting the voltage at pin 7, U460, to be at the level set by R560. When F4 is closed, applying -30 volts to R461, Q462 saturates, pulling the + Input, pin 5 of U460, to ground. The output of U460 (pin 7) follows. In this mode, (in manual sweep) the bottom of R460 (SWEEP AMPLITUDE) is at ground potential, limiting the maximum voltage across R460 to about 6 volts during PSRR and +SUPPLY I tests and 3 volts for all other tests.

Sweep Amplifier. The sweep amplifier consists of a FET, Q520, an integrated operational amplifier, U540, and four bipolar transistors, Q536, Q538, Q546, and Q548. The amplifier is basically an operational amplifier having a gain of 10. The input resistance is R527 and the feedback resistance is R549.

The input signal from pin 2, P222, is applied to Q520 source. Q520 is quiescently biased on, permitting the signal to be amplified and applied to other circuits (depending on the position of the FUNCTION switch). Q520 can be biased off, inhibiting the input signal to the sweep amplifier. Q520 is biased off when the DISPLAY ZERO is pressed, and between positions on the FUNCTION switch, whenever the Sample and Hold circuit is being reset.

The sweep amplifier output is connected to the DUT power supplies to sweep the supplies in PSRR and SUPPLY I modes; to force the DUT output in OFFSET and GAIN modes; or to sweep the DUT inputs in CMRR and INPUT I modes. The switching for these modes is accomplished by the FUNCTION switch.

Supply Regulators. The signal (sine wave from the sweep amplifier) is applied to the +DUT supply via switch contact F8, divided down by R570-R571, applied to U576, which sets the output voltage of Q584, setting the +DUT voltage out.

In the same manner, the signal (sine wave from the sweep amplifier) is applied to the -DUT supply via switch contact F3, divided down by R551-R552, and applied to U476, which sets the output voltage of Q484, setting the -DUT voltage out.

The +SUPPLY dc level is set by U432B and R560 (the three-turn precision control). This dc level is applied to pin 2, U576. The result of the dc level on pin 2 of U576 and a sine wave on pin 3 is a dc level at the output, pin 6, swept at the sine-wave rate.

The -SUPPLY dc level is set by R565, through switch S565, when out of the detent (fully counterclockwise) position in the same manner as the +SUPPLY dc level is set. The -SUPPLY can be swept by the sweep generator at the sine-wave rate.

When the -SUPPLY control is in the detent position (TRACK +SUPPLY), both -SUPPLY and +SUPPLY have the same absolute value of voltage out, under control of the precision +SUPPLY dial. The DUT supply voltages are, therefore, identical except for polarity.

When the SWEEP AMPLITUDE knob is pulled out, the sweeping of the DUT supplies is done manually.

Pulling the SWEEP AMPLITUDE knob disconnects the sine-wave sweep from the sweep amplifier, and substitutes the output of U460A and B across R460. U460A and B pick off the voltage from the +SUPPLY control. U460A is a non-inverting feedback amplifier and U460B is an inverting feedback amplifier, applying voltages of opposite polarity to the ends of R460. The voltage picked off at R460 wiper is fed to the sweep amplifier to sweep the DUT supplies manually. The sweep amplitude can never be greater than the voltage set from the -SUPPLY and +SUPPLY voltages.

Since each of the output ICs (U476 and U576) is capable of delivering only about 20 mA to the load, Q484 and Q584 act as pass transistors to provide the necessary DUT load current.

Current Limiting and Overload Indication. Current limiting and overload indication are provided for each of the DUT supplies.

I Limit, the limit resistor on the DUT card (the potentiometer for the DUT +SUPPLY limiting), provides the voltage to Q572 to cause current limiting. When the drop across R284 and the I limit resistor in parallel exceeds 0.5 volts, Q572 turns on, pulling the negative output of U576 positive, causing the output to go negative, limiting the output current. At the same time, as Q572 turns on, Q578 is turned on, causing the +OVERLOAD lamp to light, indicating the overload condition.

The same current-limiting action occurs in the negative supply, turning on Q472-Q478, limiting the current and indicating the overload.

Q492-Q592, and associated circuitry are a clipping circuit to ensure that in the common-mode test (CMRR and Input currents) the sweeping voltage can not exceed the DUT supply voltages. If the common-mode voltage exceeds either of the supply voltages, the appropriate transistor turns on, drawing current from the sweep amplifier, limiting the common-mode sweep voltage.

Feedback Amplifier

The feedback amplifier consists of three transistors: an emitter follower, Q214, and a non-inverting feedback amplifier, Q222-Q226. R223 is the input resistor and R227 is the feedback resistor, providing a gain of approximately three.

The principal inputs to the feedback amplifier are: from the DUT via R205, and from the sweep amplifier through contact F9 and R206. In the OFFSET V and GAIN modes of the FUNCTION switch the summing point of the feedback operational amplifier is the base of Q214, the junction of R205-R206.

The feedback amplifier output connects through P235, through the interface board to the DUT card, permitting the addition of an amplifier on the DUT card.

The feedback amplifier output connects to the Sample and Hold circuit, through contact F5, to Q252A gate. This feedback amplifier also drives the DUT input attenuators, R231, R233, R235, and R238.

The feedback amplifier output into the Sample and Hold circuit is controlled by two switches, FUNCTION switch contact F5, and DISPLAY switch (S200) contact D.

Contact F5 closes momentarily between some FUNCTION switch positions, and is closed in some of the FUNCTION switch positions as well.

S200D, the DISPLAY ZERO switch, a spring-return, pushbutton switch, connects the feedback amplifier output to the Sample and Hold input.

The Sample and Hold is basically a dual FET input, Q252, and an IC operational amplifier, U250. The hold configuration is an integrator, using C254 as the integrating capacitor.

The Sample and Hold output is fed to the DUT card through FUNCTION switch contact F7 and feeds half (R232, R234, R236, and R239) of the DUT attenuator. R232, R234, and R236 each has an adjustable resistor in series, to permit this half of the attenuator to be matched exactly to the other half (R231, R233, R235, and R238).

Both sides of the DUT attenuator are switched by the VERT UNITS/DIV switch contacts, V9, V10, V18, V19, V20, and V21. This switching permits attenuation ratios of 1000:1, 100:1, and 10:1.

The DUT attenuator output taps connect through FUNCTION switch contacts to the + and -DUT inputs. The DUT inputs can be switched by FUNCTION switch contacts to insert the vertical current-measuring circuit. In the DUT +Input, this switching is performed by FUNCTION switch contacts F12, F13, and F15. In the -Input the switching is performed by contacts F11, F14, and F16.

FUNCTION switch contacts F9 and F10 determine whether the sweep amplifier forces the DUT output, through R206 (F9), or sweeps the DUT inputs via the common junction of R238-R239 through contact F10.

Transistors Q280, Q284, and Q286 control the VOLTS, AMPS, AND VERT UNITS/DIV MAG ON lamps. When both contacts, F6 and V1 are open, Q280 and Q286 are on and the AMPS and VERT UNITS/DIV MAG ON lamps are lighted. When F6 closes, the +5 volts applied to Q284 base turns Q284 on, and Q286 off (VOLTS lamp lights and AMPS lamp extinguishes). When V1 also closes, the +5 volts applied to Q280 base turns Q280 off, extinguishing all lamps.

### Vertical Preamplifier

The Vertical Preamplifier measures either current or voltage, depending on the setting of the FUNCTION switch.

As a current-measuring circuit, the preamplifier floats with the 0+15 V, 0-15 V, and ØComm Supply from the 577.

As a voltage measuring circuit, the preamplifier reference is ground. When the preamp is connected to measure voltage it always monitors the feedback amplifier via F5, (F3 open), which is the input to the DUT attenuators. Whenever the preamplifier is measuring voltage, the point being measured is the DUT -input.

When the preamplifier is measuring current, the preamp can be inserted in the + or -DUT input leads, + or -power supply leads, or in the Collector Supply.

The Vertical Preamplifier (for current measurements) consists of Q310A and B and U340, and serves as a current to voltage converter. The high sensitivity current switching is in the feedback around Q310A and B and U340. Additional decade switching at lower sensitivities is done at the current amplifier input (R301, R302, and R305).

The 1-2-5 switching for both voltage and current is done around the last stage of the vertical preamplifier (R361, R362, and R363).

Additional decade switching is in the feedback around U340B (R342, R344, and R345).

The DUT attenuator (R231, R233, R235, and R238 on the Feedback Amplifier) also provides decade switching for the voltage modes. The output of the vertical preamp, pin 1 of U350A, is 0.5 V/Div into the 577.

U350B compensates for current in the stray capacitance between U310B gate and chassis ground (causes looping in the display). The voltage between pin 6, U350B and chassis ground is sensed in R316 and R317. The compensating signal at pin 7, U350B, is coupled via C318 to Q310B gate.

R315 adjusts the voltage at pin 7, and C315 is a noise suppressor.

R318 is a surge current limiter.

## Function Switching

Each FUNCTION switch setting changes the circuit configuration. The configuration for each FUNCTION switch position is shown in the series of block diagrams, figures 3-1 through 3-11.

An overall block diagram (SWITCH CONFIG BLOCK DIAGRAM) is provided in the DIAGRAMS section, preceding the FUNCTION/VERTICAL SWITCHES diagram. This block relates the circuits to the FUNCTION and VERT UNITS/DIV switch contact numbers.

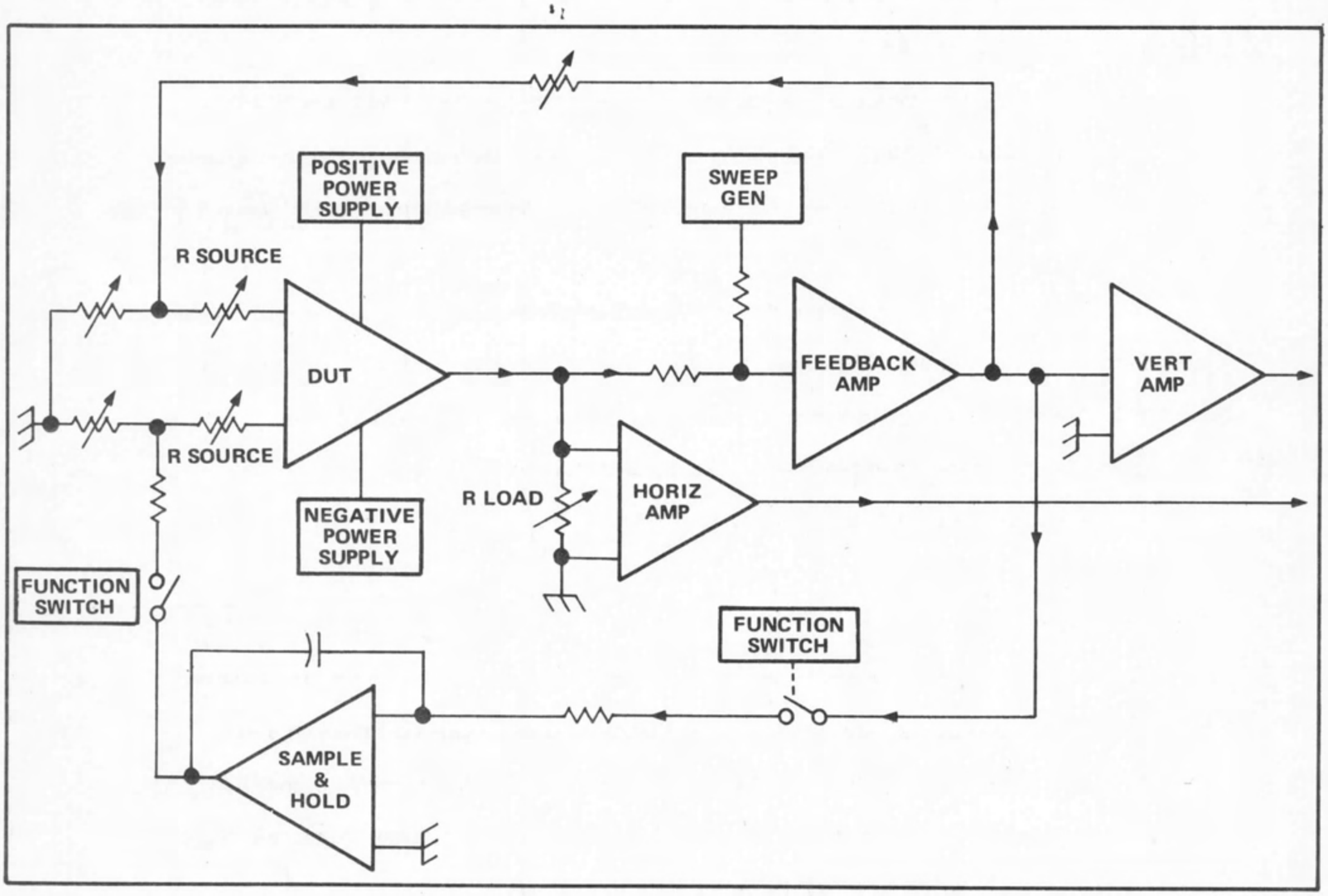



Fig. 3-1. Block diagram OFFSET V Configuration.

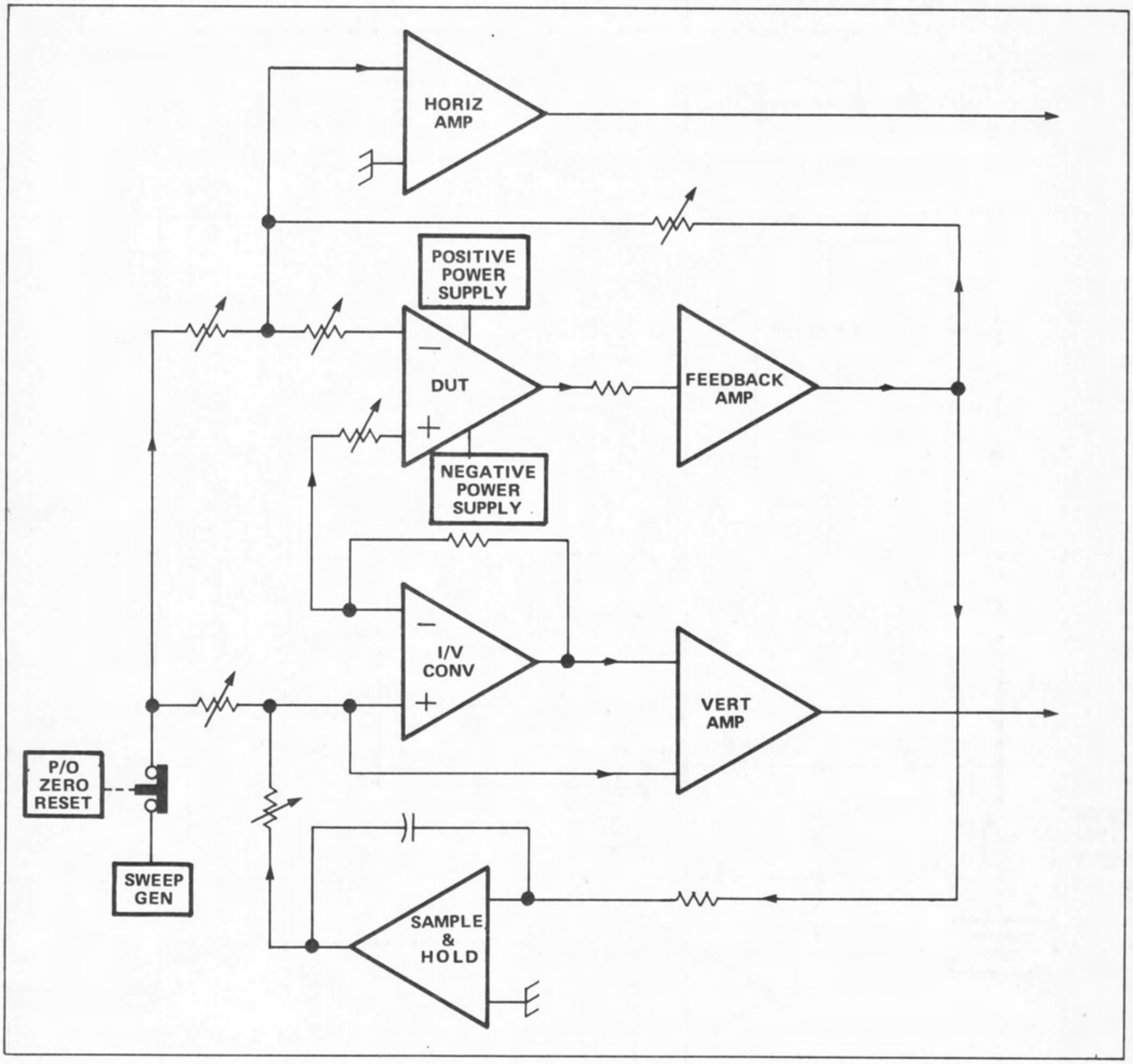



Fig. 3-2. Block diagram + INPUT I Configuration.

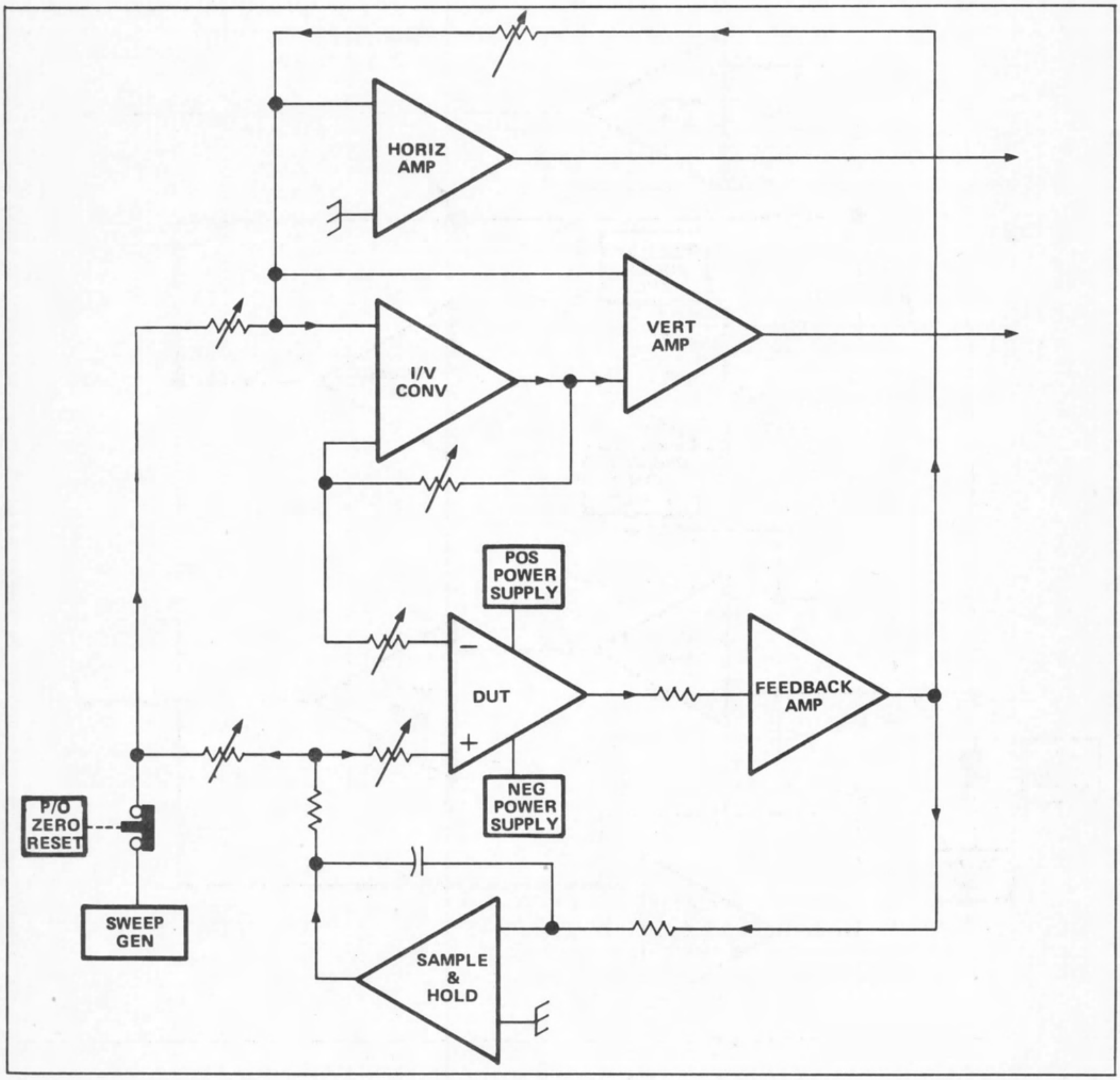



**Fig. 3-3. Block diagram – INPUT I Configuration.**

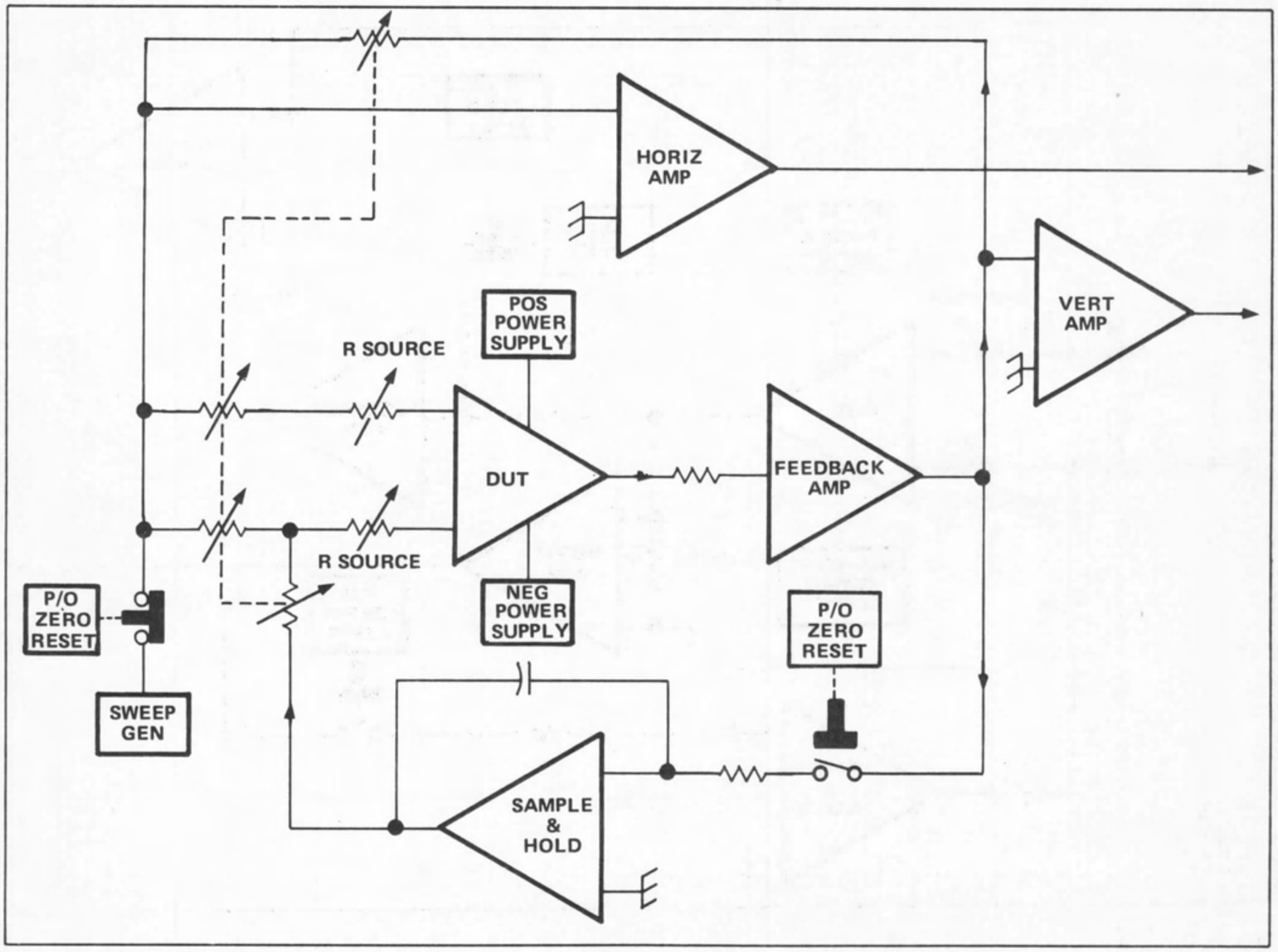



**Fig. 3-4. Block diagram CMRR Configuration.**

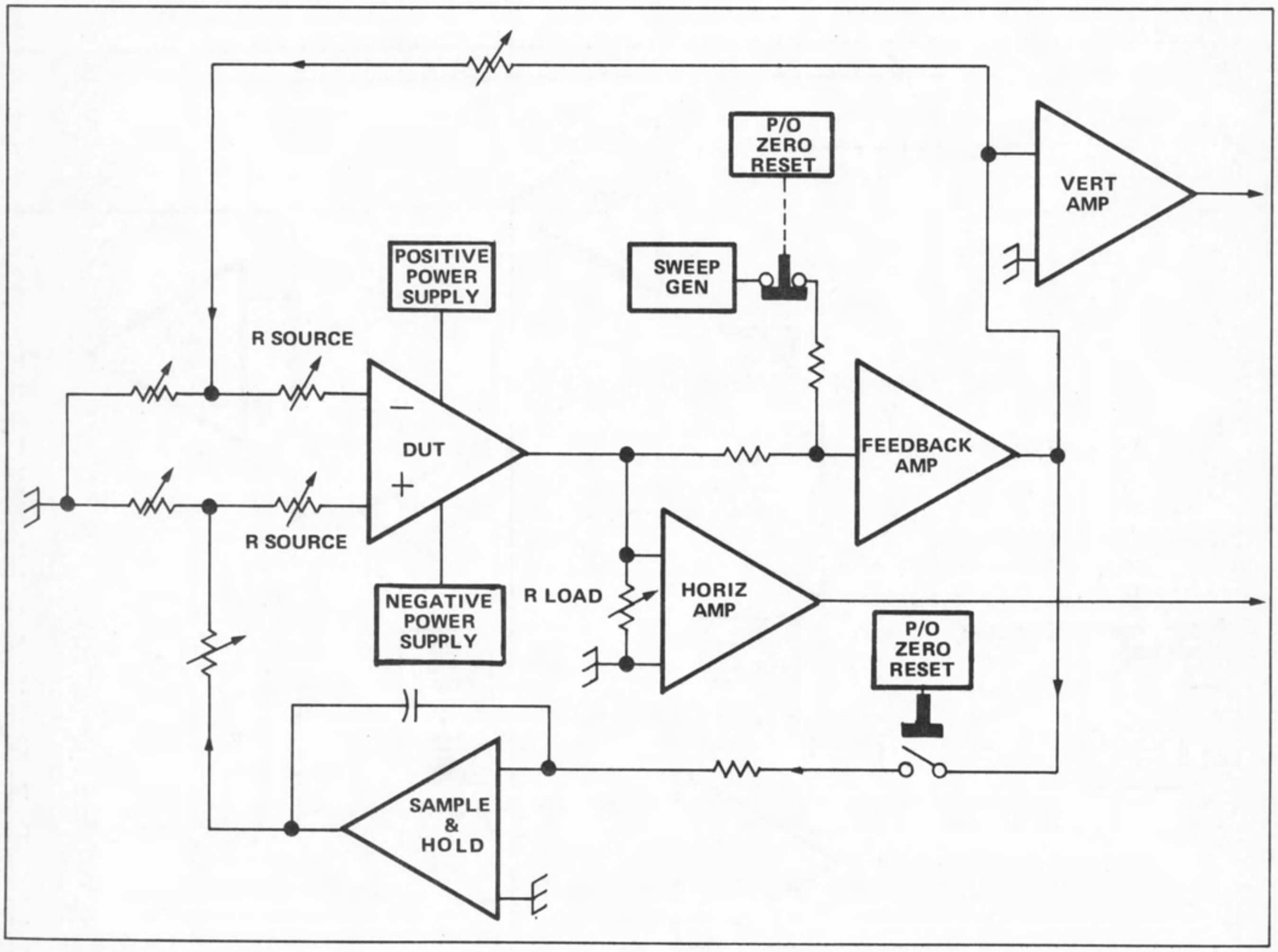



**Fig. 3-5. Block diagram GAIN Configuration.**

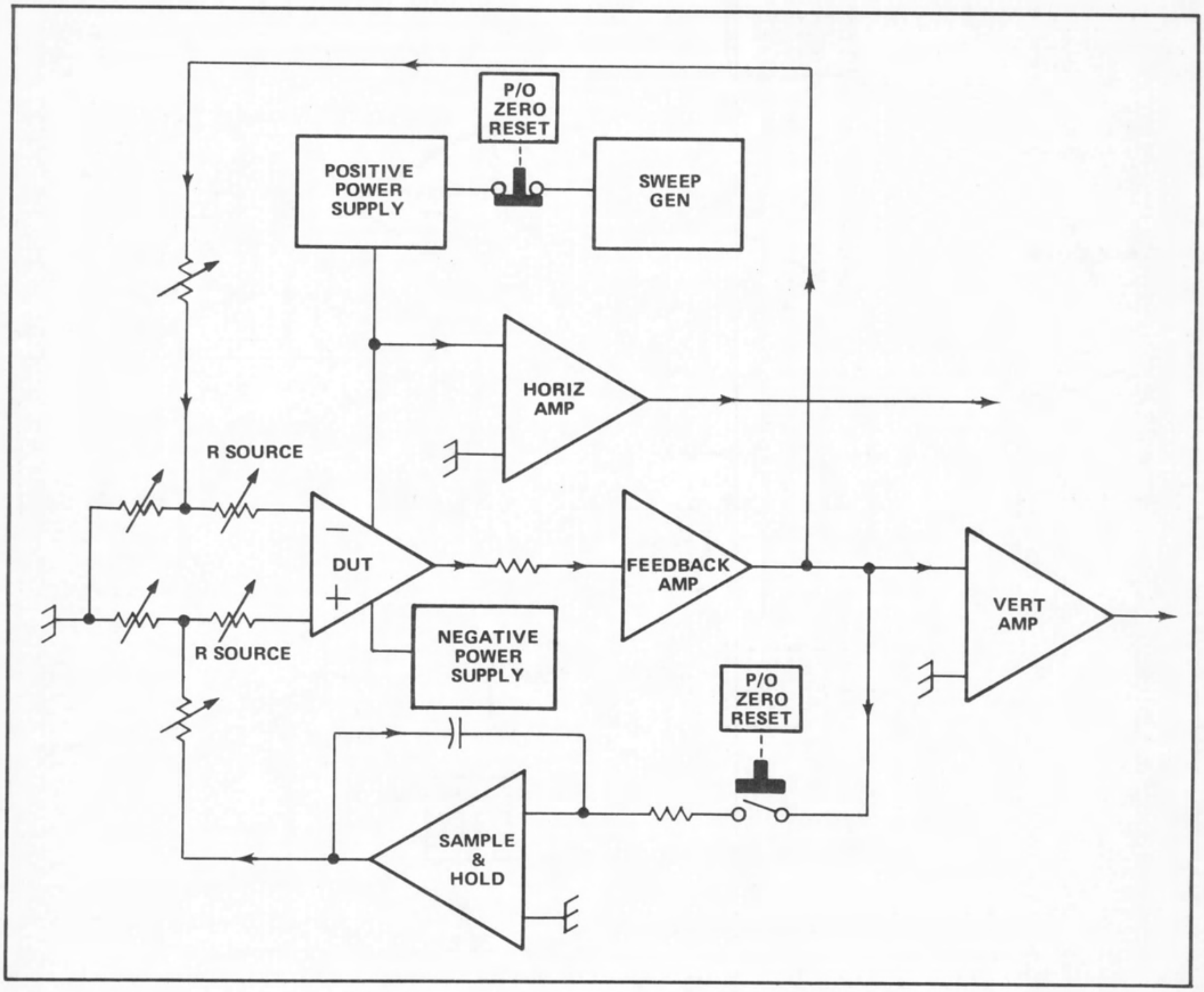



**Fig. 3-6. Block diagram + PSRR Configuration.**

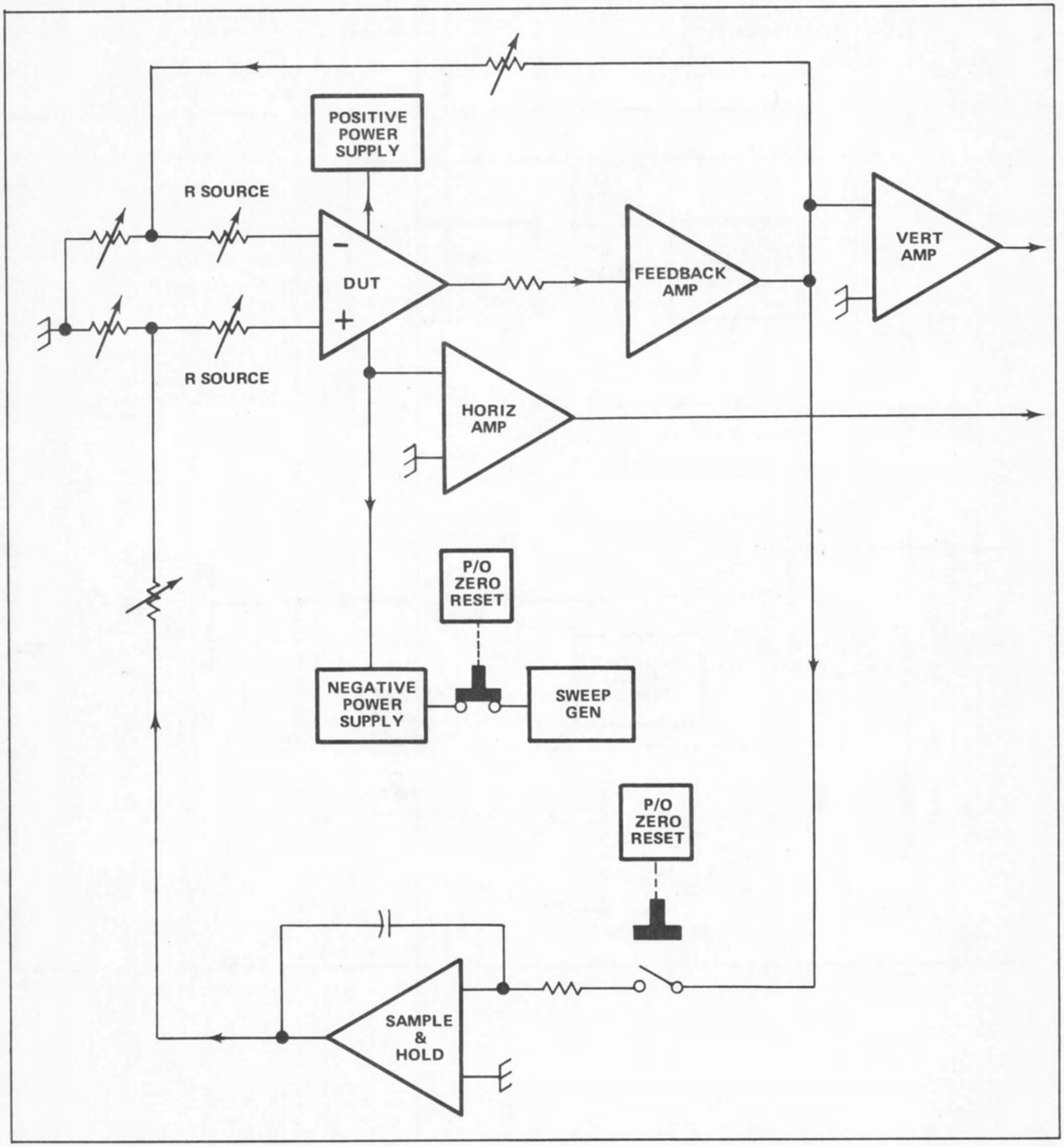



Fig. 3-7. Block diagram – PSRR Configuration.

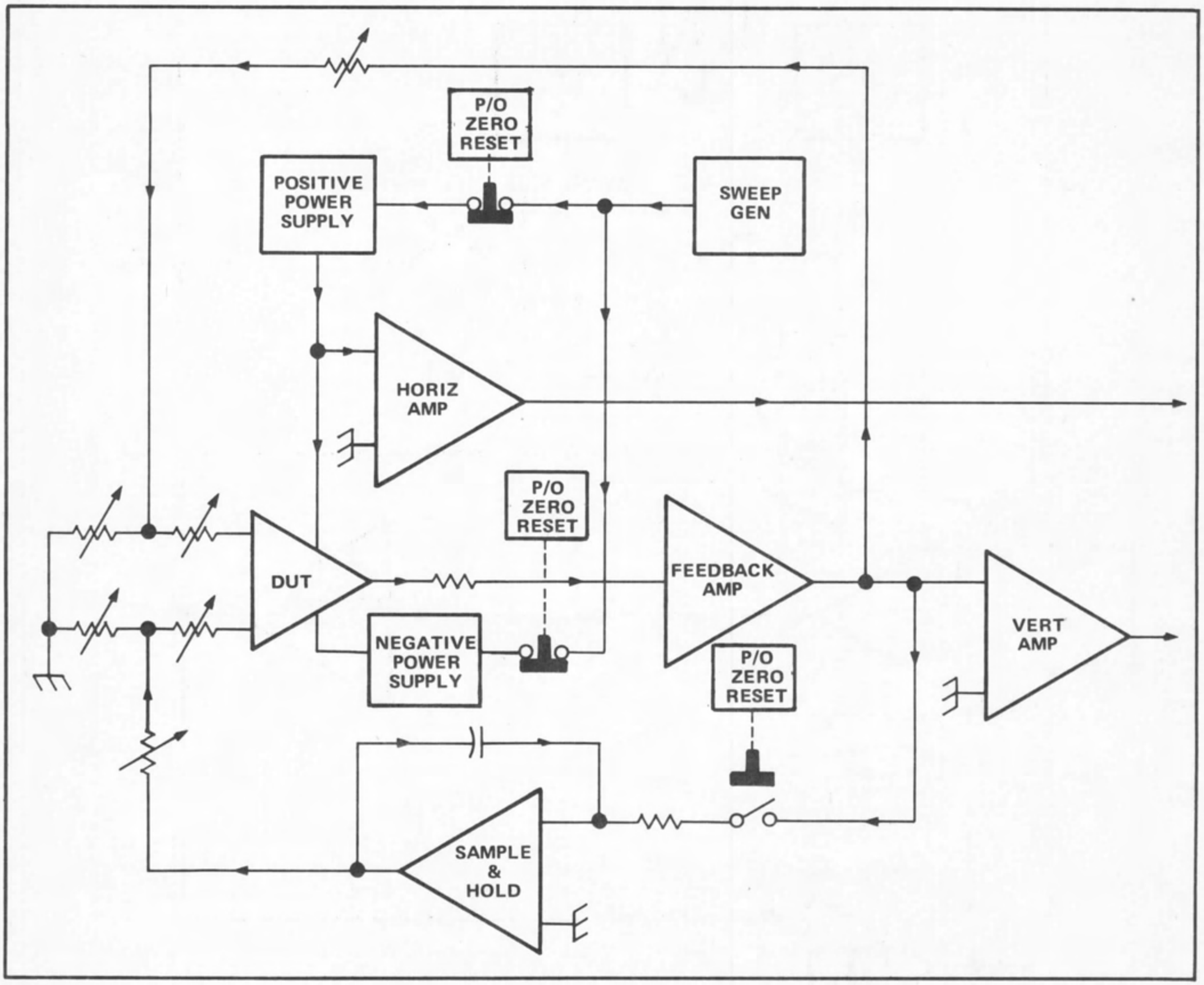



**Fig. 3-8. Block diagram ± PSRR Configuration.**

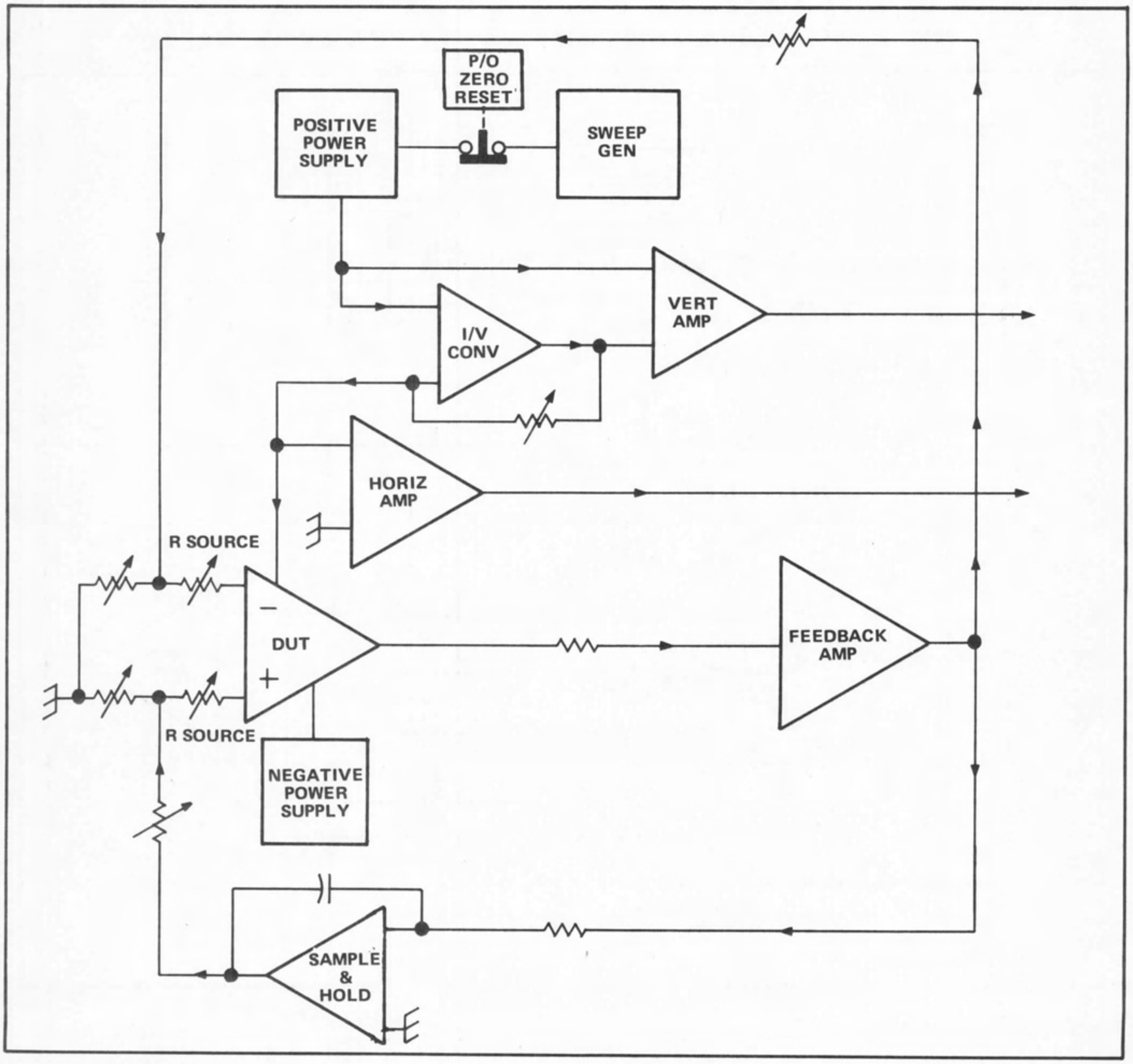



**Fig. 3-9. Block diagram +SUPPLY I Configuration.**

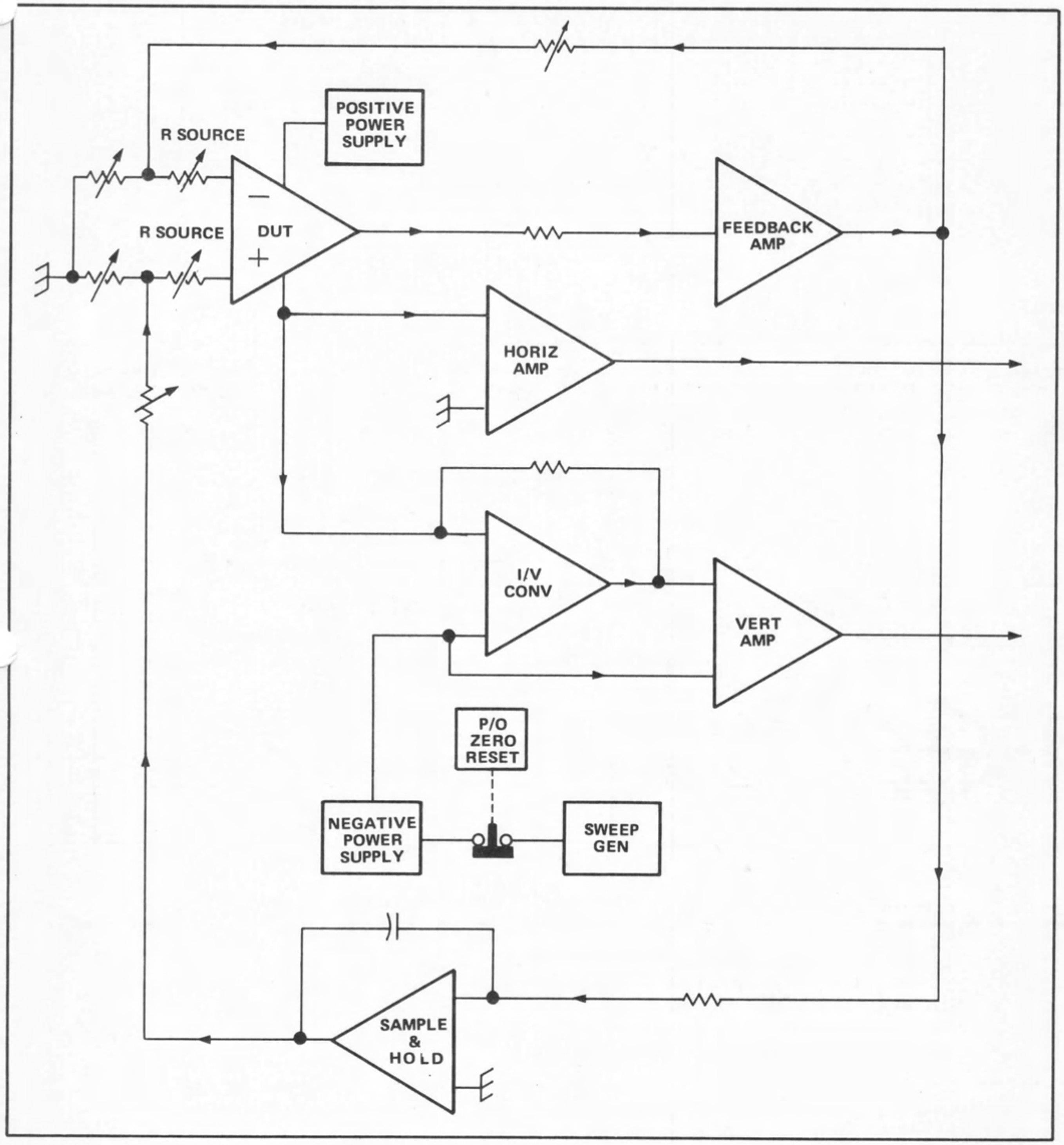



Fig. 3-10. Block diagram —Supply I Configuration.

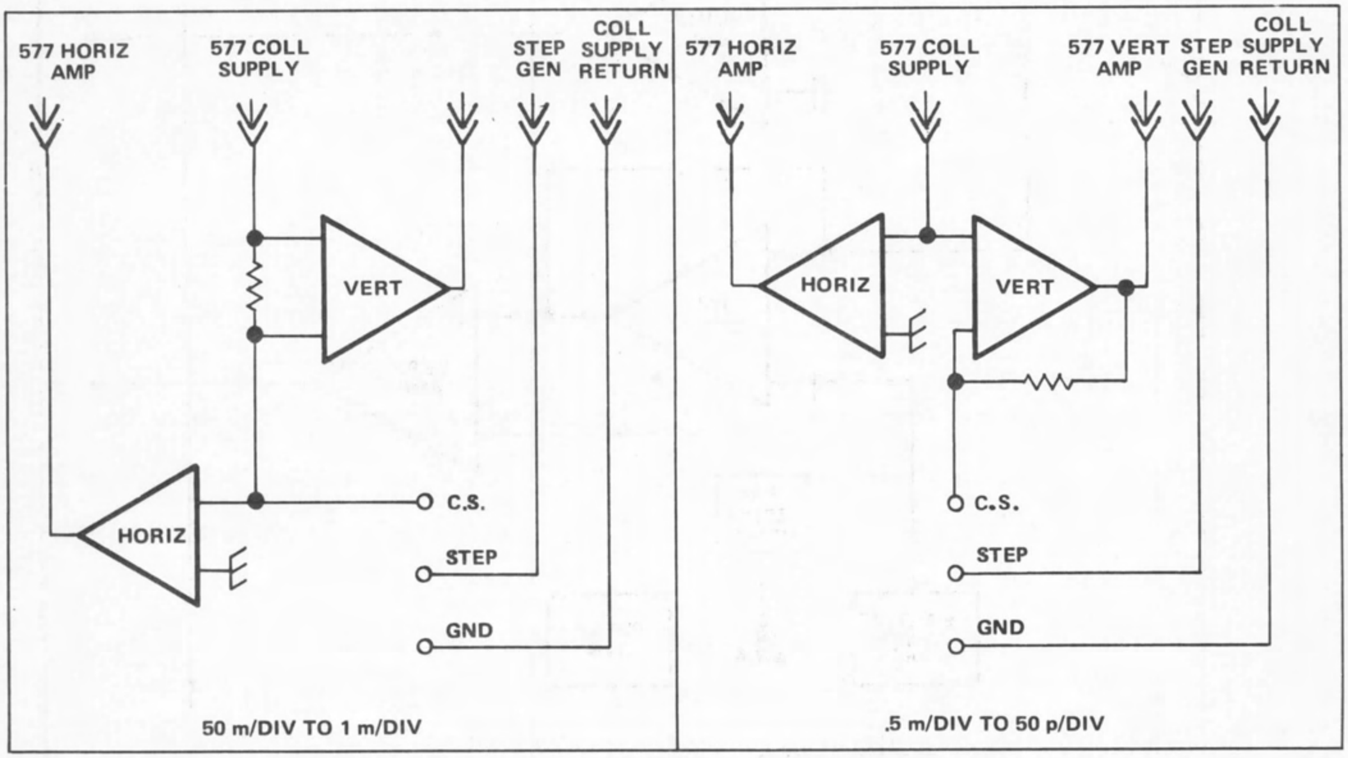



Fig. 3-11. Block diagram COLLECTOR I Configuration.

# MAINTENANCE

Introduction

This section of the manual contains information for use in preventive and corrective maintenance, with some aids to troubleshooting.

## PREVENTIVE MAINTENANCE

General

Preventive maintenance consists of cleaning, visual inspection, lubrication, etc. Preventive maintenance performed on a regular basis improves instrument reliability. The severity of the environment in which the instrument is used determines the frequency of maintenance.

Cleaning

The 178 Test Fixture should be cleaned as often as operating conditions require. Accumulation of dirt in the instrument can cause leakage current and component breakdown, especially in a humid atmosphere.

Exterior. Loose dust accumulated on the outside of the instrument can be removed with a soft cloth or a small paint brush. The paint brush is particularly useful for dislodging loose dust on and around the front-panel controls. Dirt that remains can be removed with a soft cloth dampened in a mild detergent and water solution. Abrasive cleaners should be avoided.

Interior. Dust in the interior of the instrument should be removed occasionally to prevent electrical conduction in high-humidity environments. Blow out accumulated dust using dry, low-velocity air. Remove any remaining dirt with a mild detergent and water solution. A cotton-tipped applicator is useful for cleaning circuit boards.

CAUTION

Avoid the use of chemical cleaning agents that might damage the plastics used in the instrument. Do not use chemicals that contain benzene, toluene, xylene, acetone, or similar solvents.

Lubrication

The reliability of potentiometers, rotary switches, and other moving parts can be maintained if they are kept properly lubricated. Use a cleaning-type lubricant (such as Tektronix Part No. 006-0442-00) on rotary switch contacts. Lubricate switch detents with heavier grease (such as Tektronix Part No. 006-0291-00). Do not lubricate cam switches.

NOTE

Shaft bushings of potentiometers that are not sealed should be lubricated with a lubricant (such as Tektronix Part No. 006-0172-00) that will not affect the electrical characteristics. Do not over-lubricate. A lubrication kit (Tektronix Part No. 003-0342-01) is available.

### Visual Inspection

The 178 Test Fixture should be inspected occasionally for such defects as broken connections, loose pin connections, improperly seated transistors, damaged circuit boards and heat damaged parts.

The corrective procedure for most visible defects in obvious. However, particular care must be taken if heat damaged components are found. Overheating usually indicates other trouble in the instrument. It is, therefore, important that the cause of overheating be corrected to prevent recurrence of the damage.

### Transistors and Integrated Circuits

Periodic checks of individual transistors and integrated circuits are not recommended. The best check is their operation in the equipment as reflected by performance. Sub-standard performance is normally detected during a performance check or calibration procedure.

### Recalibration

To ensure accurate measurements, check the instrument calibration after each 1000 hours (approximately) of operation, or if the instrument is used infrequently, every year. Replacement of components may necessitate recalibration of the affected circuits. Complete calibration instructions are given in the Performance Check/Adjustment section. The Performance Check/Adjustment procedure can also be helpful in locating troubles.

## TROUBLESHOOTING

### Introduction

The following information is provided to facilitate troubleshooting the 178. Information contained in other sections of this manual should be used with the following information to aid in locating circuit defects (see Operating and Circuit Description sections).

### Troubleshooting Equipment

The following equipment is useful for troubleshooting the 178.

1. Semiconductor Tester. Some means of testing the transistors, diodes, FETs, and linear op amps used in the instrument is helpful. A curve tracer, such as the Tektronix 575, 576, or 577-177 (577-178 for linear op amps) gives the most complete information.

2. DC Voltmeter and Ohmmeter. A voltmeter for checking circuit voltages and an ohmmeter for checking resistances and diodes are required. For most applications, a 20,000 ohms/volt VOM can be used if allowances are made for circuit loading when measuring voltage at high impedance points.

3. Test Oscilloscope. An oscilloscope with a DC to 10 MHz bandwidth and 10 mV/Div to 10 V/Div vertical deflection factor is suggested. A 10X probe should be used to reduce circuit loading.

### Troubleshooting Aids

Diagrams. Circuit diagrams are located on foldout pages in the Diagrams section near the rear of the manual. The component number and electrical value of each component is shown. See the first page of the Diagrams section for definition of the symbols used to indentify components.

The circuit configuration for each FUNCTION switch position is shown in the series of block diagrams, Figures 3-1 through 3-11 (Circuit Description section).

An overall block diagram (SWITCH CONFIG BLOCK DIAGRAM) is provided in the DIAGRAMS section preceding the FUNCTION/VERTICAL SWITCHES diagram (number 3). This block relates the circuits to the FUNCTION and VERT UNITS/DIV switch contact numbers.

Switch Wafer Identification. Rotary switch wafers shown on the diagrams are coded to indicate the position of each wafer in the switch assembly. The number portion of the code is the wafer number, counting from the mounting end of the switch. The letters F and R indicate whether the front or rear of the wafer performs the switching function. For example, a wafer designated 2R indicates the rear of the second wafer.

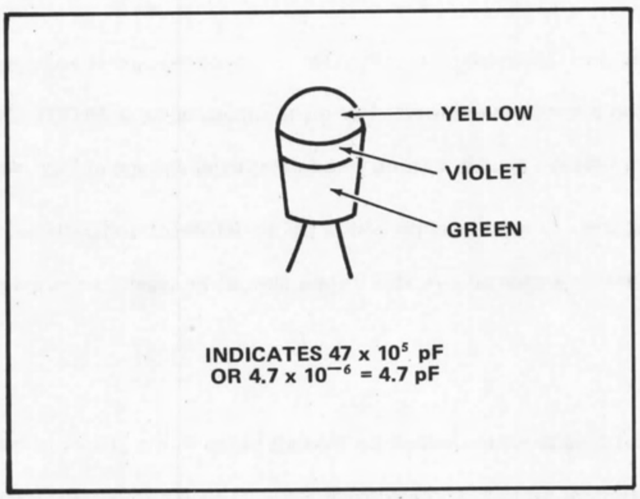



**Fig. 4-1. Electrolytic capacitor color code.**

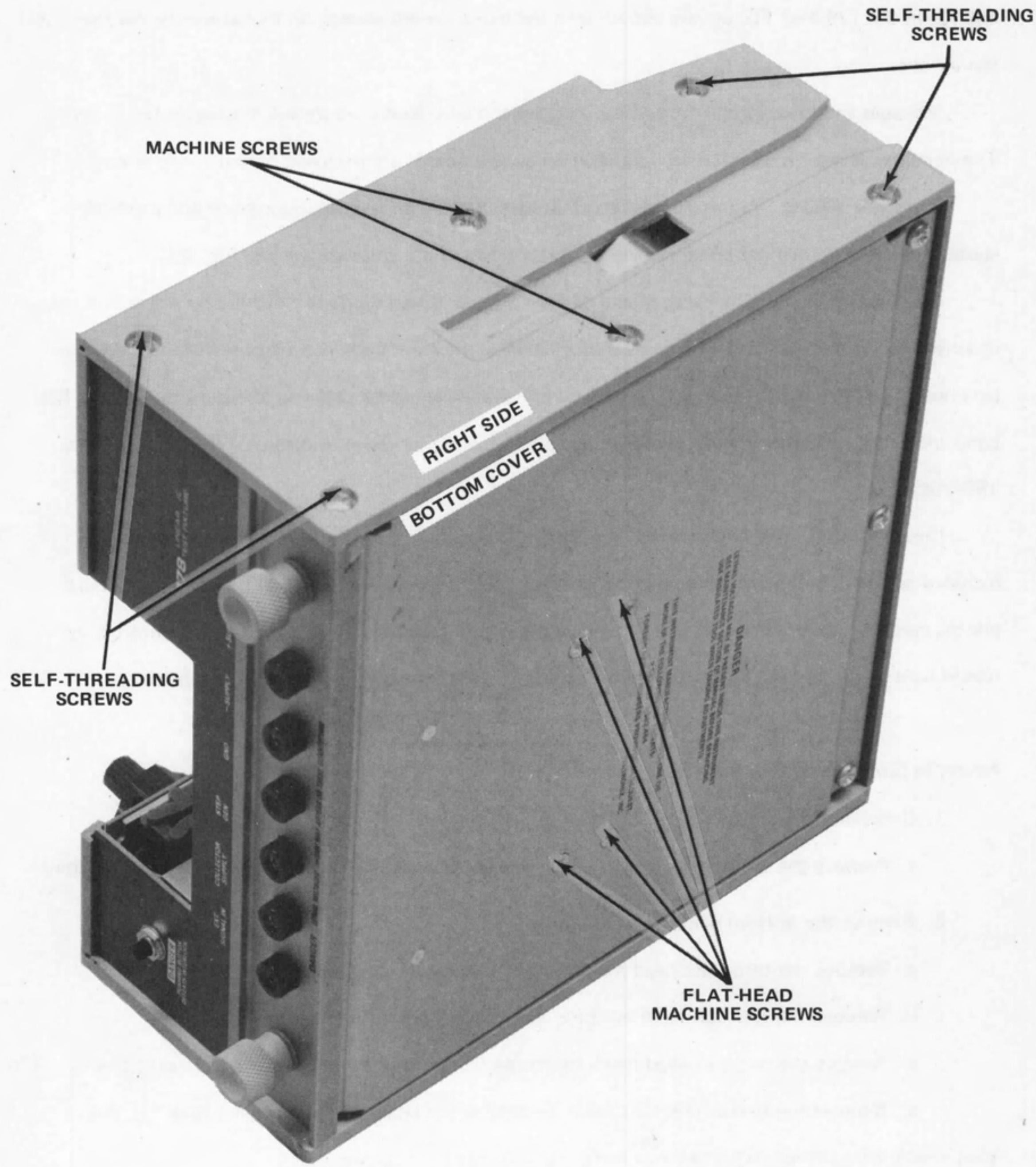



Fig. 4-2. Right-side and bottom panel of the 178.

Circuit Description. The Circuit Description, Section 3, contains a brief description of the theory of circuit operation. Refer to the schematic diagrams in the pullout DIAGRAMS section.

Transistors and Integrated Circuit Lead Configurations. The lead configurations of the transistors and ICs in the 178 Test Fixture are shown with the circuit board photos on the schematic diagram fold-out aprons.

Voltages and Waveforms. Important voltages and waveforms are shown in blue on the diagrams. The portions of the circuits that are mounted on circuit boards are enclosed by blue lines or boxes.

Capacitor Values. Values of disc capacitors are marked on the capacitor body and electrolytic capacitor values are marked either on the capacitor body or are color coded (see Fig. 4-1).

Diode Color Code. The cathode end of each glass enclosed diode is indicated by a stripe, a series of stripes, or a dot. For diodes using a series of stripes, the color code identifies either the Tektronix part number of the JEDEC number. This code follows the standard color code except that a pink first band indicates a Tektronix part number, i.e., pink-brown-gray-green, indicates Tektronix Part No. 152-0185-00.

Circuit Boards. A photograph of each circuit board, with circuit components identified, is included adjacent to the schematic diagram relating most directly to the circuit board. Some board photos may be placed on the back of the preceding circuit diagram. Each circuit board photo is sectioned by a grid system to facilitate rapid location of components by component number.

Access to Circuit Boards in the 178

1. Remove the side panels.

   a. Remove the six screws on each side (note the two screw types: self-threading and machine).

2. Remove the bottom panel.

   a. Remove the three pan-head machine screws from the bottom panel (see Fig. 4-2).

   b. Remove the four flat-head machine screws from the bottom panel.

   c. Remove the two pan-head machine screws from inside the storage compartment (see Fig. 4-3).

   d. Remove the two shields that form the side of the storage compartment. See Fig. 4-3. (The front shield, held in place with two hex nuts, Fig. 4-3, need not be removed).

   e. Remove the three pan-head machine screws (see Fig. 4-2) from the bottom panel.

   f. Remove the bottom panel.

Removing the Vertical Preamplifier and Feedback Amplifier Boards from the 178

1. Remove the Power Supply circuit board as follows:

   a. Remove the eleven multi-pin connectors from the Power Supply circuit board. See Fig. 4-5 for circuit-board location.

NOTE

The last digit in the number of the circuit-board to which the multi-pin connector is mated indicates the color of the connector body. The standard color code is used. Therefore, the connector body color for P473 is orange. An arrow on the circuit board indicates pin number one on the board. Pin number one is marked with an arrow on the plug. Align the arrows for correct position.

   b. Remove the red connector (P222) from the rear of the Feedback Amp board. Lift the pair of wires (attached to the red connector) away from the Power Supply circuit board.

   c. Remove the three round-head machine screws from the top-rear of the instrument (Fig. 4-4).

   d. Slide the Power Supply circuit board and rear-panel assembly away from the instrument far enough to unsolder the two black panel-lamp leads.

   e. Remove the circuit board and rear-panel assembly.

2. Remove the Vertical Preamp, Feedback Amp, and Interface Boards (remove as a unit) as follows:

   a. Remove the six multi-pin connectors (color coded as previously detailed).

   b. Lift the three-lamp holder caps away from the plastic sleeves (see Fig. 4-6).

   c. Note the positions of the VERT UNITS/DIV and FUNCTION switches and remove the switch knobs.

   d. Note the positions of the SOURCE RESISTANCE and LOAD RESISTANCE knobs and remove the knobs.

   e. Remove the hex nut and washer from the SOURCE RESISTANCE, LOAD RESISTANCE, and FUNCTION switch shafts.

   f. Remove the four flat-head screws (visible through the front-panel openings, see Fig. 4-7) at the VERT UNITS/DIV and FUNCTION switches.

   g. Loosen the socket-head screw from the DUT SUPPLIES switch arm (see Fig. 4-8).

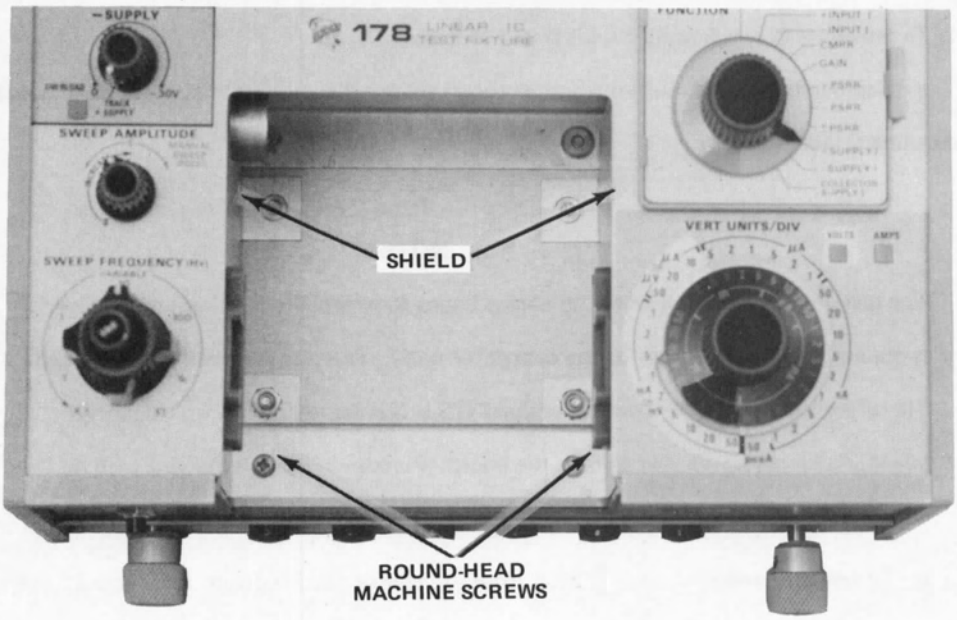



**Fig. 4-3. Top view of the 178 showing storage-compartment shields.**

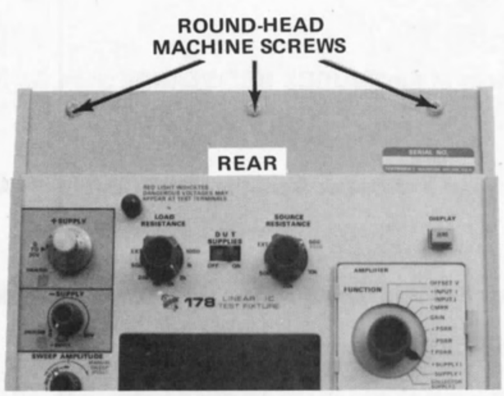



**Fig. 4-4. Top view of the 178.**

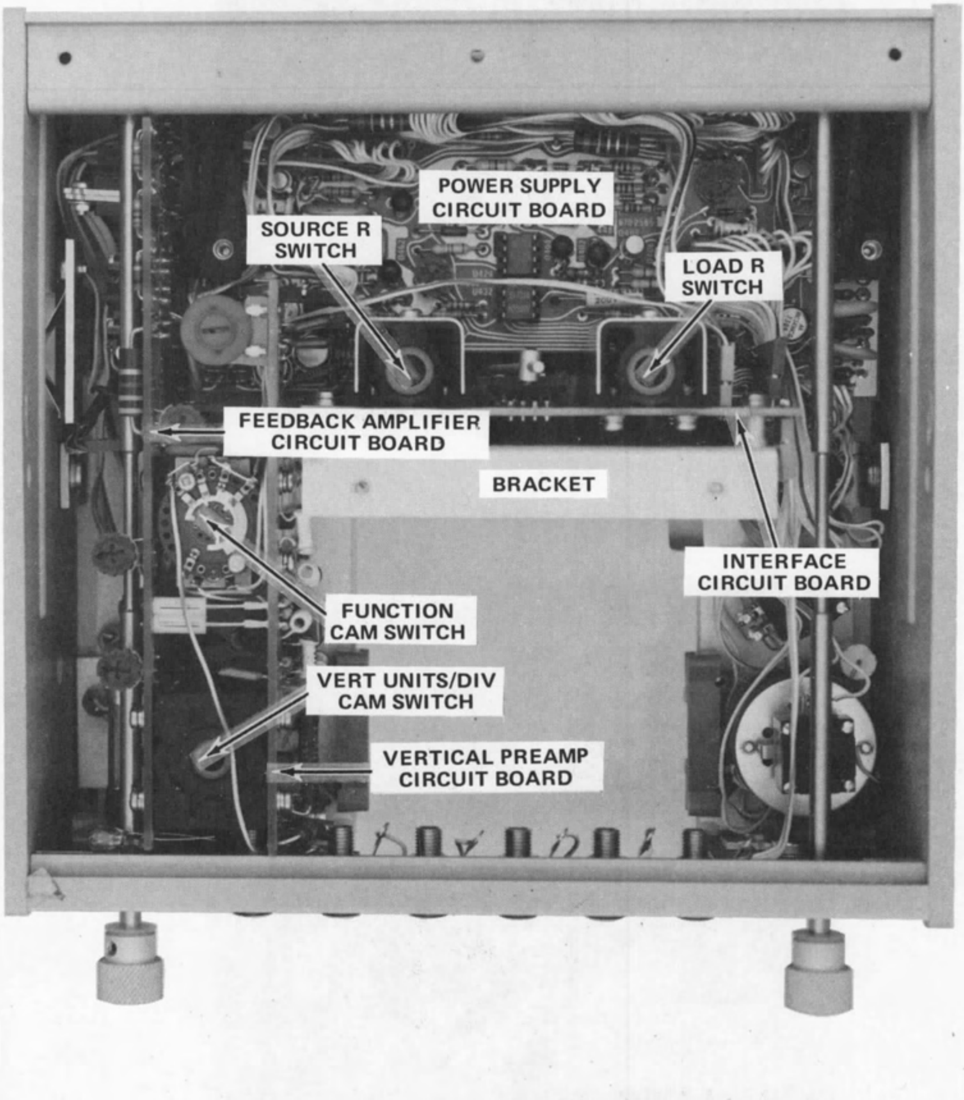



**Fig. 4-5. Location of circuit boards in the 178.**

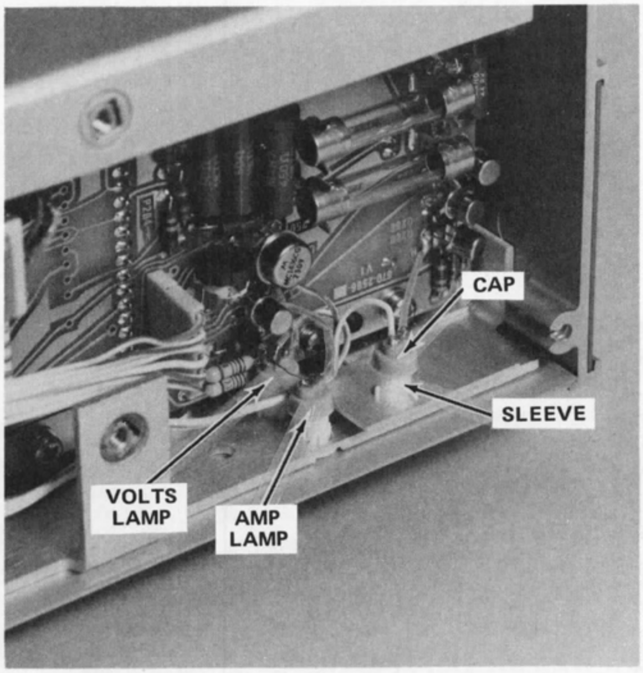



**Fig. 4-6. Location and assembly details of indicator lamps.**

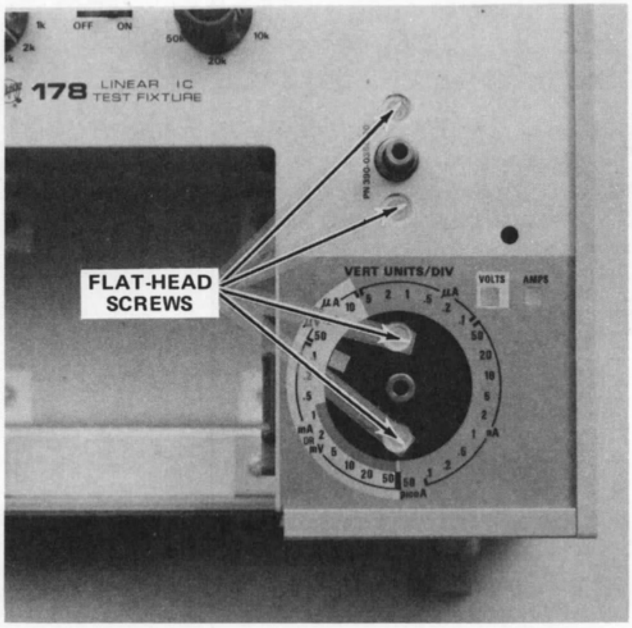



**Fig. 4-7. Location of the flat-head machine screws under FUNCTION and VERT UNITS/DIV switches.**

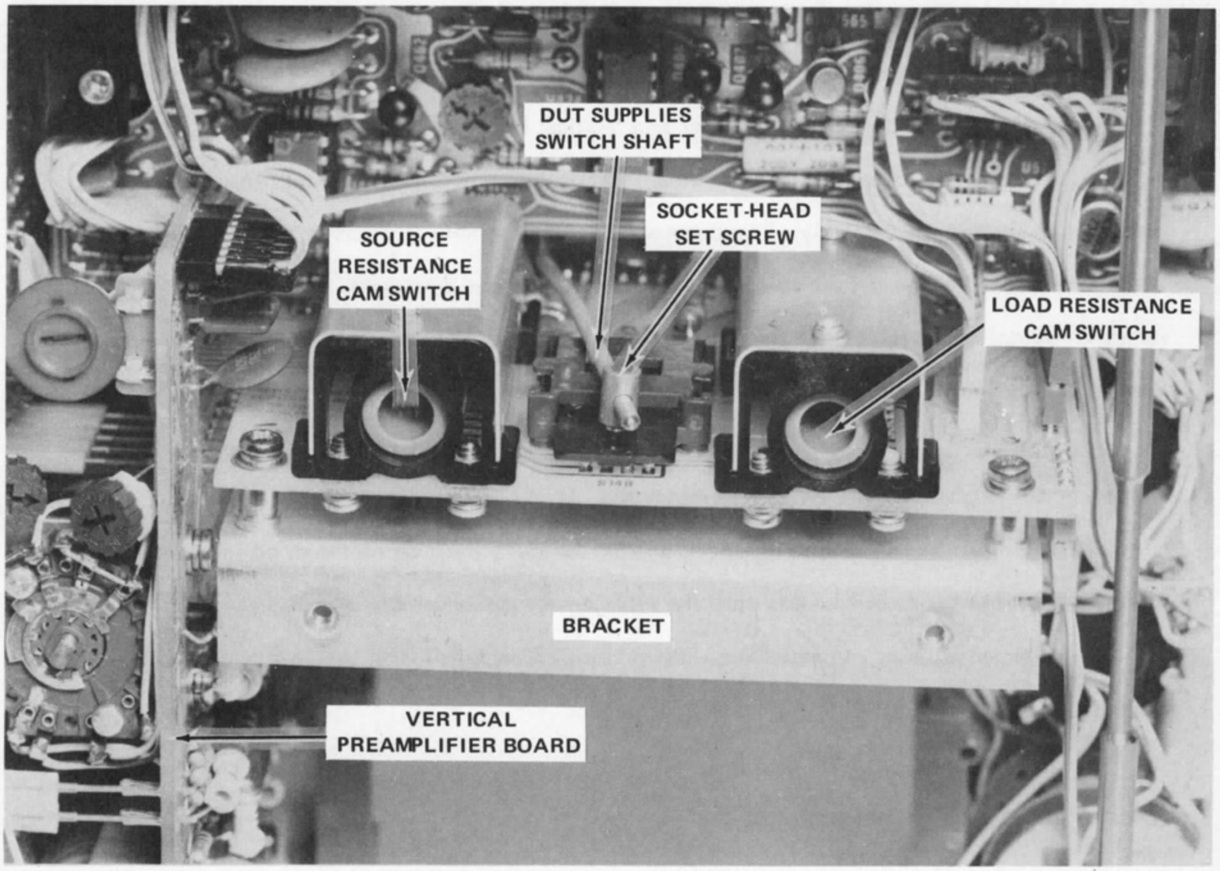



**Fig. 4-8. Location of the DUT SUPPLIES switch arm.**

h. Remove the three multi-pin connectors from the Interface circuit board.

i. Remove the DUT card-grounding clip (see Fig. 4-9).

j. Remove the two hex nuts (that hold the bracket to the main chassis) near the 60-pin interface connector.

k. Lift the Vertical Preamp, Feedback Amp, and Interface circuit boards away from the instrument, as a unit.

l. Separate the two board assemblies lying at right angles by pulling the Interface board away from the double-board assembly.

Removing and Replacing the Feedback and Vert Preamp Boards from the Cam-Switch Assembly

If the two boards (Feedback Amplifier and Vertical Preamp) common to the FUNCTION and VERT UNITS/DIV switches must be separated, remove only one board at a time from the cam switch drum-and-bearing assembly. The drum-and-bearing assembly is precisely aligned at the factory. If both boards are removed from this assembly, the alignment is destroyed. If both boards must be removed, do not disassemble until the replacement boards are obtained. Replace one board at a time to preserve the alignment.

Removing and Replacing the Cam Switch Assembly

If the cam in the cam-switch drum-and-bearing assembly must be replaced, do not remove the assembly from the circuit boards until the replacement cam assembly is obtained.

An alignment fixture and installation instructions are included with the replacement cam assembly.

Removal of Storage Compartment Shields

Preliminary

1. Remove the two flat-head machine screws (Fig. 4-10) from the bottom panel.

2. Remove the two round-head machine screws (Fig. 4-11) at the front of the storage compartment.

Removal-Right Shield

1. Press lightly at the point on the shield indicated in Fig. 4-12.

2. Grasp the upper-right corner of the shield and tilt the top of the shield toward the center of the instrument while lifting the shield upward.

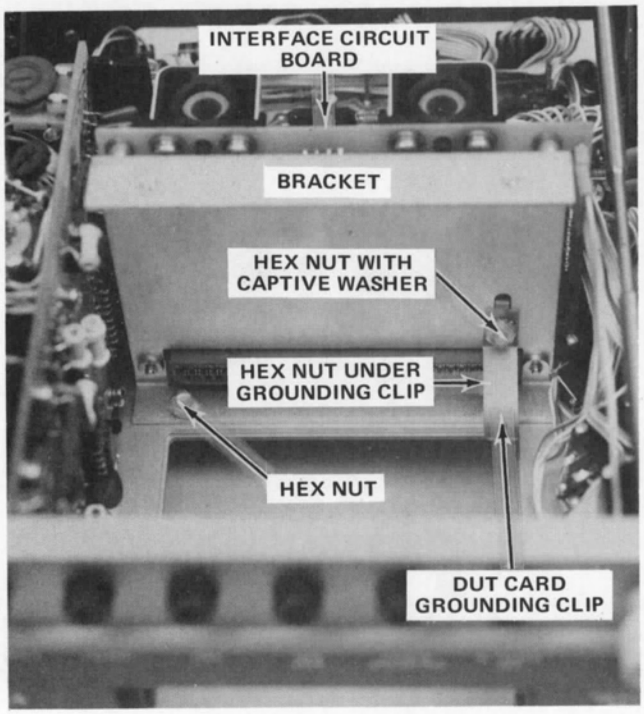



**Fig. 4-9. Location of the DUT card grounding clip.**

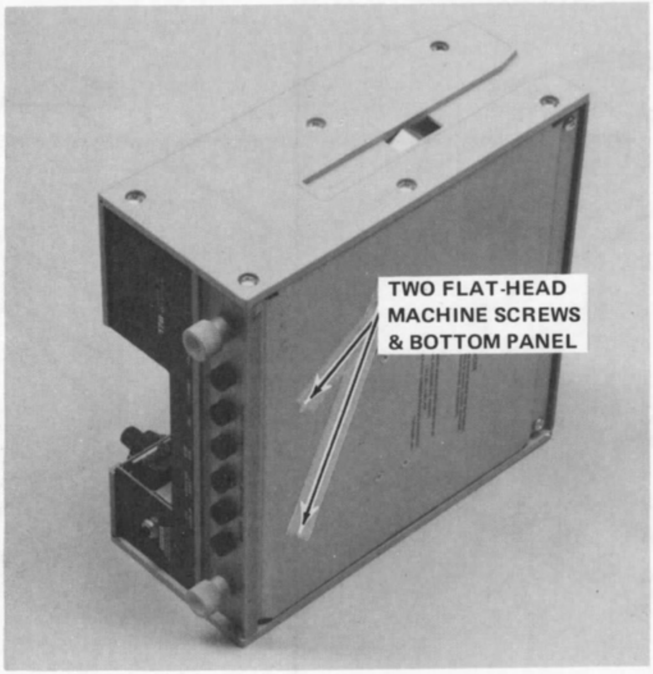



**Fig. 4-10. Location of the screws securing the storage compartment shields.**

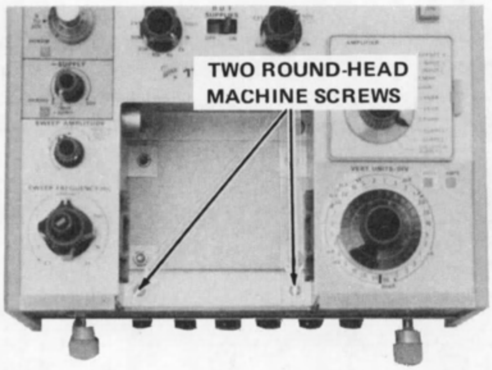



**Fig. 4-11. Location of the screws in the storage compartment.**

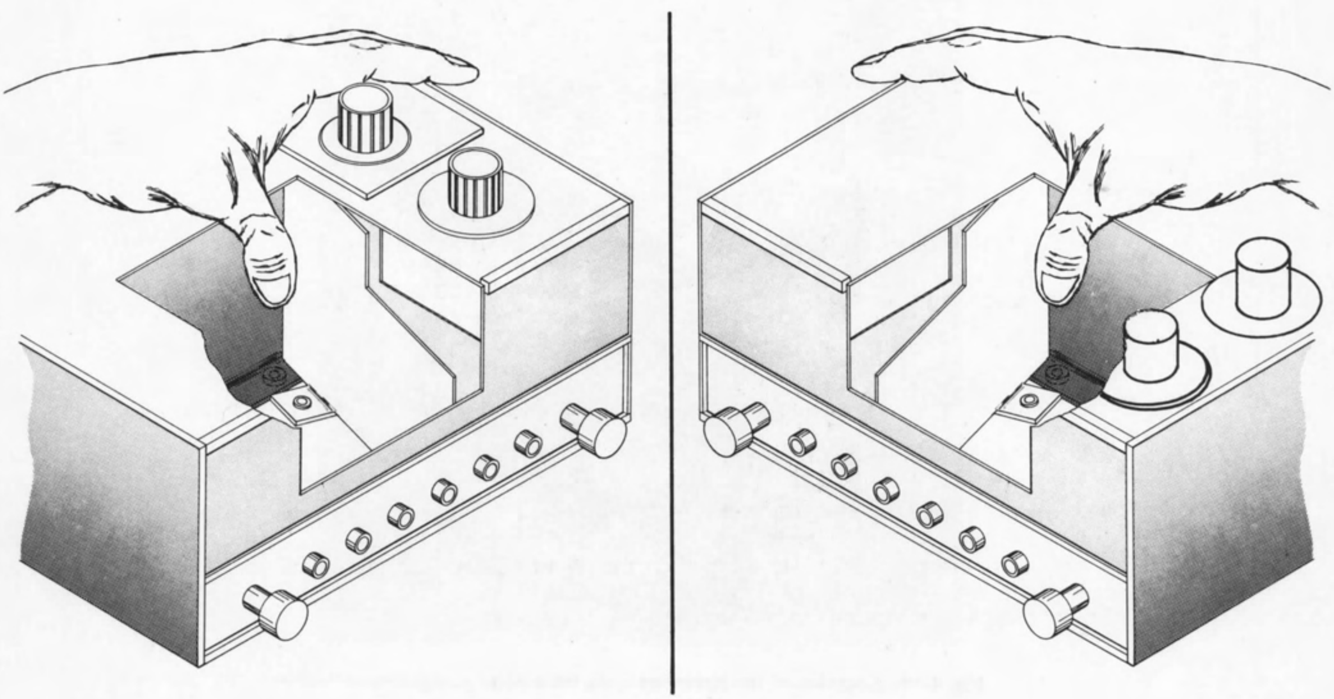


**Fig. 4-12. Removing the storage compartment shields.**

3. When the bottom of the shield clears the hex nut on the bottom panel, swing the front of the shield toward the instrument center, and lift the shield away from the instrument.

Removal-Left Shield

1. Press lightly at the point on the shield indicated in Fig. 4-12.

2. Grasp the upper-left corner of the shield and tilt the top of the shield slightly toward the instrument center while lifting the shield to clear the hex nut on the bottom panel.

3. Swing the front of the shield toward the center while pulling forward on the shield, until the shield clears the grounding clip (Fig. 4-12).

4. Lift the shield from the instrument.

Replacement of Storage Compartment Shield-Left Side

1. Place the shield in the instrument as shown in Fig. 4-13, with the back edge to the left of the grounding clip.

2. Tilt the top of the shield slightly toward the instrument center, while swinging the front of the shield toward its final position.

3. When the bottom of the shield clears the hex nut on the bottom panel, slide the shield into position and place the round-head machine screw through the front tab, but do not tighten.

4. Replace the flat-head screw through the bottom panel into the shield and tighten. Tighten the round-head machine screw at the front of the compartment.

Replacement of Storage Compartment Shield-Right Side

1. Place the shield into the compartment as shown in Fig. 4-13.

2. Grasp the upper-left corner of the shield and tilt the top of the shield slightly toward the instrument center.

3. Keeping the shield tilted, swing the front end of the shield toward its final position, lifting slightly to clear the hex nut on the bottom panel.

4. Place the round-head screw through the front tab, Fig. 4-13, but do not tighten.

5. Replace the flat-head machine screw through the bottom panel into the shield and tighten. Tighten the round-head machine screw at the front of the compartment.

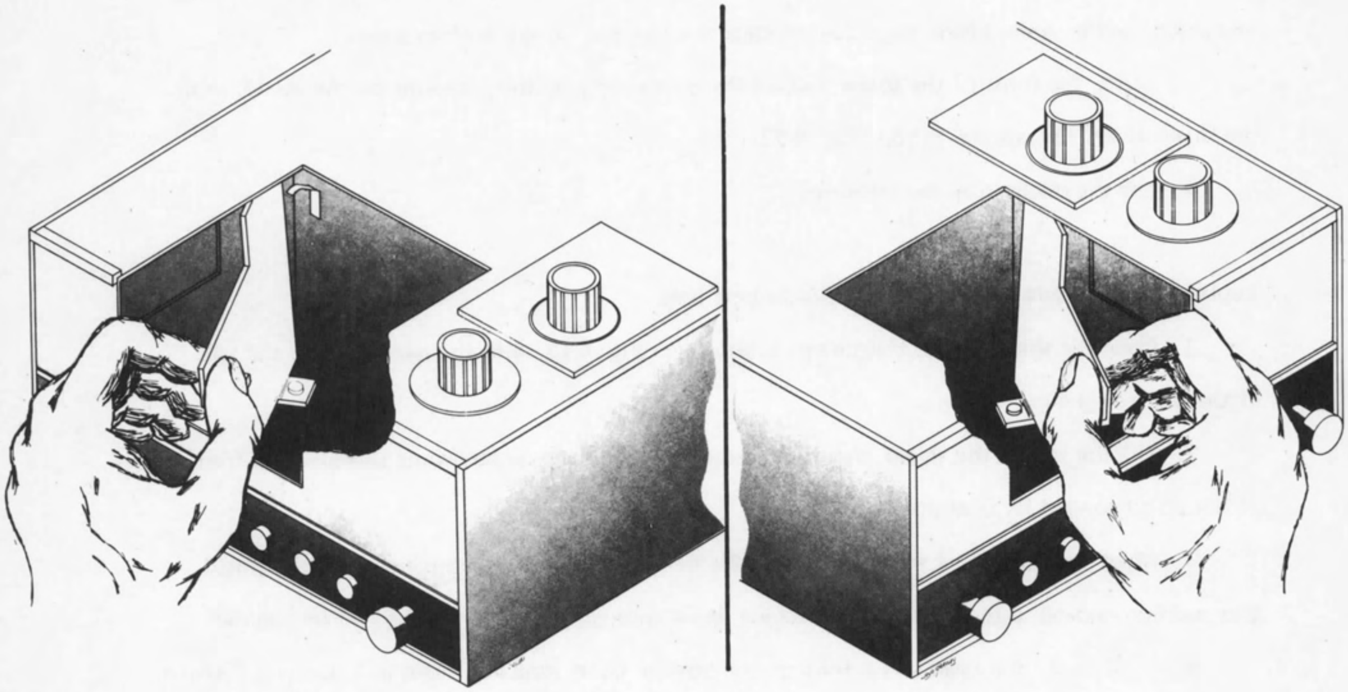


Fig. 4-13. Replacement of the storage compartment shields.

# PERFORMANCE CHECK/ADJUSTMENT PROCEDURE

## Introduction

This section of the manual contains separate check and adjustment procedures. The Check procedure is provided to check the instrument operation against the instrument specifications. The adjustment procedure returns the circuitry to within the design capabilities. Adjustment is generally required after a repair has been made, or after a long time interval in which normal aging of components may affect instrument accuracy.

For initial inspection, using the check procedure, the right-side panel should be removed.

## Services Available

Tektronix, Inc. provides complete instrument repair and calibration service at local field service centers and field offices. Contact your local Tektronix Field Office or representative for further information.

## Test Equipment Required

The following test equipment, or equivalent, is required for complete check and adjustment of the 178 Linear IC Test Fixture. All test equipment is assumed to be correctly calibrated and operating within the listed specifications.

1. Digital Ohmmeter or Resistance Bridge. Range, 50 Ω through 50 kΩ; accuracy, 0.1%.

2. Differential dc Voltmeter. Input resistance, 1000 MΩ[1]; range, through 4 volts; accuracy, 0.1%. A digital voltmeter may be used for some of the measurements in these procedures. Use the differential voltmeter where indicated.

3. Test Oscilloscope. Dual Input, dc coupled; Time/Div, .1 ms through 1 s; Deflection factor, from .5 V/Div. (10 μV/Div, differential input, for CMRR test method 3, optional).

4. Time Mark Generator. Markers at 1 ms, .1 s, 1 s, and 5 s. The Tektronix 184 or 2901 Time Mark Generator is recommended.

5. Test Op Amp. CMRR 150 dB specified minimum or 120 dB measured; noise level less than 2 μV with 50 Ω source resistance. Precision Monolithics SS725 meets the 120 dB requirement. See CMRR test method 1 in the procedure.

[1] See footnote 1, Step 5, Check Vertical Current-Mode Accuracy.

Or, CMRR 110 dB specified minimum; noise level less than 2 μV with 50 Ω source resistance; any op amp meeting or exceeding 114 dB, measured, may be used. The OP-05E is recommended. See CMRR test method 2 in the procedure.

6. Two 741 IC operational amplifiers. One is supplied as a standard accessory.

7. Resistor Kit (Tektronix Calibration Fixture 067-0691-00). Same as the calibration resistor kit for the 177.

| | |
|---|---|
| 1-1 Ω, 3 W, 1/4% | 1-10 kΩ, 1/4 W, 1/4% |
| 1-10 Ω, 3W, 1/4% | 1-100 kΩ, 1/8 W, 1/4% |
| 1-100 Ω, 1/2 W, 1/4% | 1-1 MΩ, 1/8 W, 1/4% |
| 2-200 Ω, 10 W, 1% | 1-10 MΩ, 1/8 W, 1/4% |
| 1-1 kΩ. 1/4 W, 1/4% | |

Plus, for the 178 only, one-100 MΩ, 1 W, 1/4% resistor (Tektronix Calibration Fixture 067-0705-00).

8. Capacitor. 0.22 μF, 50 volts.

9. Other components, for building CMRR test circuit for method 2:

| | |
|---|---|
| 2-50 kΩ, 1/4% | 1-10 kΩ potentiometer |
| 1-40.2 kΩ, 1% | 2-10-volt zener diodes |
| 2-1.5 kΩ, 5% | |

## PERFORMANCE CHECK

1. Check Source Resistance Accuracy

a. With the 178 removed from the 577, set the 178 controls as follows:

| | |
|---|---|
| FUNCTION | OFFSET V |
| VERT UNITS/DIV | 1 m |
| SOURCE RESISTANCE | 50 Ω |

b. Connect an ohmmeter or resistance bridge (accuracy .1%) between the +IN and GND terminals on the Standard Op Amp DUT card. Set the SOURCE RESISTANCE and VERT UNITS/DIV switches to the first settings in Table 5-1.

c. CHECK – The resistance and tolerance should be as shown in the table.

d. Switch to the next settings in Table 5-1.

e. CHECK – The resistance value for each of the SOURCE RESISTANCE and VERT UNITS/DIV setting should be within the tolerances shown.

TABLE 5-1

| SOURCE RESISTANCE | VERT UNITS/DIV[1] | Ohmmeter Reading | Tolerance |
|---|---|---|---|
| 50 Ω | 1 m | 550 Ω | Check for approx value only[2] |
| 50 Ω | .5 m | 50 Ω | |
| 10 k | .5 m | 10 kΩ | ± 1% |
| 20 k | .5 m | 20 kΩ | ± 1% |
| 50 k | .5 m | 50 kΩ | ± 1% |

If a more accurate measurement is required, use the following method:

Connect the points on the DUT card, shown in Fig. 5-1, to GND and slide the Ext Feedback Amp switch away from the NORM position. Measure the resistance as in parts b through e. Return the slide switch to NORM and remove the connecting leads.

f. Connect the ohmmeter or resistance bridge between -IN and GND on the Op Amp card and repeat steps a through e.

g. Connect the ohmmeter between -IN and the left -$R_S$ EXT terminal. Set the SOURCE RESISTANCE switch to EXT.

h. CHECK — The meter should indicate a short circuit.

i. Connect the ohmmeter between GND and the right -$R_S$ EXT terminal.

j. CHECK — The ohmmeter should indicate approximately 50 Ω.

k. Connect the ohmmeter between GND and the right + $R_S$ EXT terminal.

l. CHECK — The ohmmeter should indicate approximately 50 Ω.

m. Connect the ohmmeter between +IN and the left +$R_S$ EXT terminal.

n. CHECK — The ohmmeter should indicate a short circuit.

2. Check Load Resistance Accuracy

a. Set the controls as follows:

| | |
|---|---|
| 577 | |
| POWER | in (off) |
| 178 | |
| FUNCTION | OFFSET V |
| LOAD RESISTANCE | 100 Ω |

[1] When the VERT UNITS/DIV switch is in the 1 m/DIV to 50 m/DIV positions, add 500 Ω to the SOURCE RESISTANCE indicated.

[2] The measured resistance varies, depending upon the ohmmeter and resistance range used, because of the Source Resistance protection circuit in the 178. Use the highest range possible consistent with good resolution.

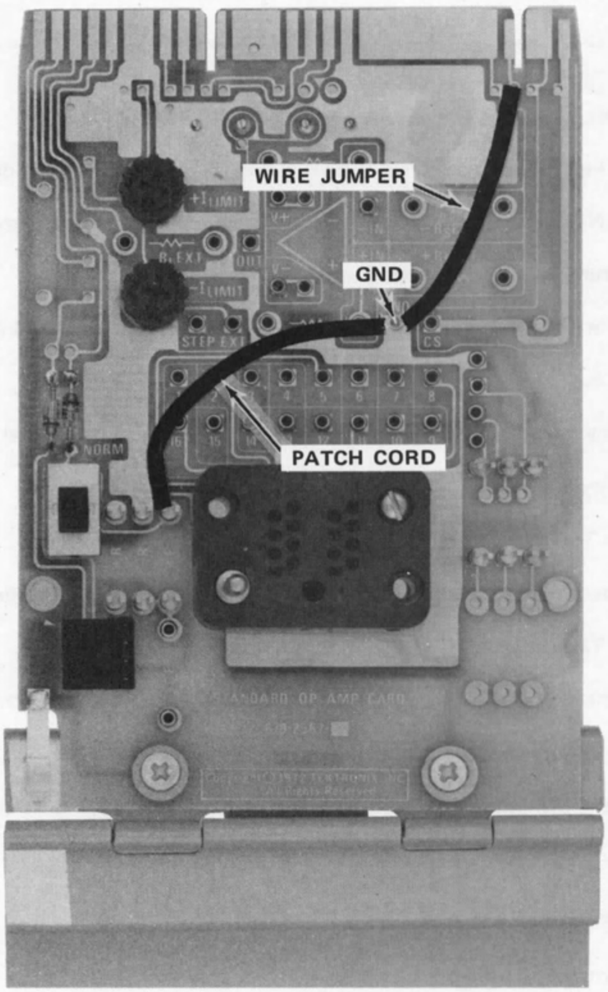



Fig. 5-1. See Table 5-1, footnote 2.

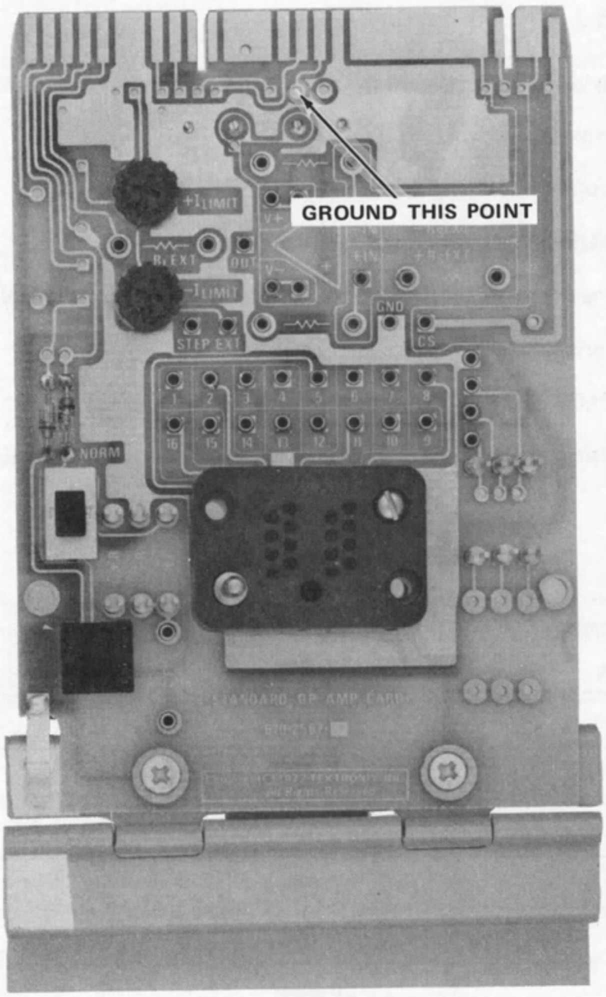



**Fig. 5-2. Location of the point to be grounded in Step 2, part B.**

b. Connect a lead from GND to the sixth hole to the left from the upper-right corner of the Standard Op Amp card. See Fig. 5-2.

NOTE

Grounding this point permits measuring these resistors without removing the right-side cover. The resistance measured is higher (on the higher ranges) than indicated on the LOAD RESISTANCE switch. This difference is reflected in Table 5-2.

c. Place the Standard Op Amp card in the 178 and plug the 178 into the 577. Pull the 577 POWER switch to the on position.

d. Connect the ohmmeter between GND and OUT on the DUT card.

e. Switch the FUNCTION switch to each of its positions.

f. CHECK — The meter reads 100 Ω only on the OFFSET V and GAIN positions. All other positions should read approximately 50 kΩ.

g. Return the FUNCTION switch to OFFSET V.

h. CHECK — Using Table 5-2, read the value of resistance for each setting of the LOAD RESISTANCE switch.

TABLE 5-2

| LOAD RESISTANCE Switch Setting | Resistance in Ohms | Tolerance |
|---|---|---|
| 100 Ω | 100 | ± 3 Ω |
| 1 k | 1.001 k | ± 30 Ω |
| 2 k | 2.006 k | ± 60 Ω |
| 5 k | 5.039 k | ± 150 Ω |
| 10 k | 10.156 k | ± 302 Ω |
| 20 k | 20.60 k | ± 606 Ω |
| 50 k | 54.20 k | ± 1.54 kΩ |
| EXT | 54.20 k | ± 1.54 kΩ |

i. Set the LOAD RESISTANCE switch to EXT.

j. CHECK — With the ohmmeter connected between OUT and the right end of $R_L$ EXT on the DUT card, the meter should read a short circuit.

3. Check Vertical Preamp Balance

a. Set the controls as follows:

| 577 | |
|---|---|
| MAX PEAK VOLTS | 6.5 |
| VARIABLE COLLECTOR % | 0 |
| SERIES RESISTORS | .12 |
| HORIZ VOLTS/DIV | 200 V, COLLECTOR |
| Horizontal POSITION | centered |

All Dark Gray Buttons and Knobs in except:

| | |
|---|---|
| STEP FAMILY | SINGLE |
| DISPLAY FILTER NORM | out |
| Vertical POSITION | pull (MAG ON) centered |

| 178 | |
|---|---|
| FUNCTION | —INPUT I |
| VERT UNITS/DIV | 5 m (magnified) |
| SWEEP FREQUENCY (Hz) | .1 |

b. Press and hold the DISPLAY ZERO button. Position the spot to near the graticule center and note the spot position.

c. Release the DISPLAY ZERO button.

d. CHECK – The spot should shift not more than two divisions, ± 50 pA, from the position noted in part b.

4. Check Vertical Looping

a. Set the controls as follows:

| 577 | |
|---|---|
| MAX PEAK VOLTS | 25 |
| VARIABLE COLLECTOR % | 100 |
| COLLECTOR SUPPLY POLARITY | AC |
| HORIZ VOLTS/DIV | 10 V, COLLECTOR |
| Horizontal POSITION | centered |

All Dark Gray Buttons and Knobs in except:

| | |
|---|---|
| STEP FAMILY | SINGLE |
| Vertical POSITION | pull (magnified) centered |

| 178 | |
|---|---|
| FUNCTION | COLLECTOR SUPPLY I |
| VERT UNITS/DIV | 2 mA (magnified) |
| DUT SUPPLIES Switch | ON |

b. CHECK – Vertical separation (looping) of the trace should be less than one division on the .1 mA to 50 mA ranges.

5. Check Vertical Current-Mode Accuracy

a. Set the controls as follows:

| | |
|---|---|
| **577** | |
| MAX PEAK VOLTS | 6.5 |
| VARIABLE COLLECTOR % | 0 |
| SERIES RESISTORS | .12 |
| HORIZ VOLTS/DIV | 200 V, COLLECTOR |
| COLLECTOR SUPPLY POLARITY | AC |
| All Dark Gray Buttons and Knobs in except: | |
| DISPLAY FILTER | |
| NORM | out |
| STEP FAMILY | SINGLE |
| Horizontal POSITION | centered |
| Vertical POSITION | centered |
| OFFSET MULT | |
| ZERO (button) | in |
| AID (button) | in |
| STEP/OFFSET AMPL | 50 mA |
| OFFSET MULT (dial) | 0.00 |
| **178** | |
| FUNCTION | COLLECTOR SUPPLY I |
| VERT UNITS/DIV | 50 m |
| SWEEP FREQUENCY (Hz) | 1 k |
| SWEEP AMPLITUDE | fully counterclockwise |
| DUT SUPPLIES Switch | ON |

b. Connect the 10 Ω, 1/4%, 3-watt resistor shown in Table 5-3, between STEP and CS terminals on the Op Amp DUT card. Connect a digital dc voltmeter across the 10 Ω resistor. The meter must float (meter common to the STEP terminal).

c. Note the digital voltmeter reading. Vertically and horizontally position the spot to top-center graticule lines.

d. Push to release the OFFSET ZERO button to the out position. Set the OFFSET MULT dial to position the spot to the bottom graticule line.

e. CHECK — The dc voltmeter should indicate with 4.00 volts (± 3%) of the voltage noted in part c.

f. Set the VERT UNITS/DIV and STEP/OFFSET AMPL to the next settings in Table 5-3. Push the OFFSET ZERO button in and repeat steps c and d.

g. CHECK — The voltmeter reading should be within the voltage limits set in column 4 (with the voltage noted in part c as the reference).

h. Continue the tests using Table 5-3, using the resistor values shown in column 3, through 50 nA/DIV.

i. Starting with 20 nA/DIV, use a differential dc voltmeter. Set the FUNCTION Selector to -INPUT I.

TABLE 5-3

| VERT UNITS/DIV | STEP/OFFSET AMPL | Resistor Value | Meter Reading | Limit (3%) |
|---|---|---|---|---|
| 50 mA | 50 mA | 10 Ω | 4.00 V | ±0.12 V |
| 20 mA | 20 mA | | 1.60 V | ±0.048 V |
| 10 mA | 10 mA | | 0.80 V | ±0.024 V |
| 5 mA | 5 mA | 100 Ω | 4.00 V | ±0.I2 V |
| 2 mA | 2 mA | | 1.60 V | ±0.048 V |
| 1 mA | 1 mA | | 0.80 V | ±0.024 V |
| .5 mA | .5 mA | 1 kΩ | 4.00 V | ±0.12 V |
| .2 mA | .2 mA | | 1.60 V | ±0.048 V |
| .1 mA | .1 mA | | 0.80 V | ±0.024 V |
| 50 μA | 50 μA | 10 kΩ | 4.00 V | ±0.12 V |
| 20 μA | 20 μA | | 1.60 V | ±0.048 V |
| 10 μA | 10 μA | | 0.80 V | ±0.024 V |
| 5 μA | 5 μA | 100 kΩ[1] | 4.00 V | ±0.12 V |
| 2 μA | 2 μA | | 1.60 V | ±0.048 V |
| 1 μA | 1 μA | | 0.80 V | ±0.024 V |
| .5 μA | .5 μA | 1 MΩ[1] | 4.00 V | ±0.12 V |
| .2 μA | .2 μA | | 1.60 V | ±0.048 V |
| .1 μA | .1 μA | | 0.80 V | ±0.024 V |
| 50 nA | 50 nA | | 0.40 V | ±0.012 V |

TABLE 5-3 (cont)

Use a differential voltmeter for the remaining measurements
(see part j)

| | | | | |
|---|---|---|---|---|
| 20 nA | .2 V | 10 MΩ[2] | 1.60 V | ±0.048 V |
| 10 nA | .1 V | | 0.80 V | ±0.024 V |
| 5 nA | .05 V | | 0.40 V | ±0.012 V |
| 2 nA | .2 V | 100 MΩ[2] | 1.60 V | ±0.048 V |
| 1 nA | .1 V | | 0.80 V | ±0.024 V |
| .5 nA | .05 V | | 0.40 V | ±0.012 V |
| .2 nA | .05 V | | 0.16 V | ±0.0048 V |
| .1 nA | .05 V | | 0.08 V | ±0.0024 V |
| 50 pA | .05 V | | 0.04 V | ±0.0012 V |

j. Connect the resistor between DUT STEP and -IN terminals. Set the OFFSET MULT dial to 0.00. Zero the differential dc voltmeter.

k. Connect the differential voltmeter common terminal to the DUT STEP terminal and the ± voltmeter terminal to the DUT -IN terminal. This minimizes noise pickup.

l. Adjust the OFFSET MULT dial for a zero-volt reading on the voltmeter. Opposing offset voltage (AID button in the out position may have to be used).

m. Position the spot to the top graticule line.

n. Disconnect the differential voltmeter positive terminal.

o. Adjust the OFFSET MULT dial to position the spot to the bottom graticule line (in OFFSET AID).

[1] If a dc voltmeter having an input impedance of less than 1000 MΩ is used to measure the voltage across the 100 kΩ and 1 MΩ resistors, the reading will be in error depending on the meter impedance. To calculate the correct voltage, use the formula:

$$V_2 = V_1 \frac{R_m}{R_m + R_s}$$

Where,

$V_2$ is actual voltage

$V_1$ is indicated voltage

$R_m$ is meter impedance

$R_s$ is the current-sensing resistor in the table.

[2] A shielded cable can be used to reduce noise on these measurements. Connect the shield to the Step terminal on the DUT card and to the voltmeter common (do not ground).

p. Reconnect the voltmeter and set the meter dials for a meter null.

q. CHECK — The differential meter should read voltage as indicated in Table 5-3.

r. Continue the tests as described in parts j through p for the remainder of the switch positions.

6. Check Vertical Voltage Accuracy

a. Set the controls as follows:

577

| | |
|---|---|
| HORIZ VOLTS/DIV | 5 V, COLLECTOR |
| All Dark Gray Buttons and Knobs in except: | |
| STEP FAMILY | SINGLE |

178

| | |
|---|---|
| SWEEP FREQUENCY (Hz) | .1 |
| SWEEP AMPLITUDE | pull |
| +SUPPLY | 15.0 V |
| -SUPPLY | TRACK +SUPPLY |
| LOAD RESISTANCE | 50 k |
| SOURCE RESISTANCE | 20 k |
| DUT SUPPLIES | OFF |
| FUNCTION | GAIN |
| VERT UNITS/DIV | 50 m |

b. Connect the test socket on the DUT card for an op amp, such as the 741. Place the op amp in the test socket.

c. Connect a 1 MΩ resistor between OUT and -IN. Connect a patch cord between +R, top end, and $R_F$, top end. Set the External Feedback Amplifier switch, the slide switch on the DUT card, away from the NORM position.

d. Connect a DVM or dc bridge between GND and the patch cord between +R and $R_F$. Set the DUT SUPPLIES switch to ON. Press the DISPLAY ZERO button.

e. Turn the MANUAL SWEEP control until the spot on the crt is on the bottom graticule line. Note the meter reading.

f. Turn the MANUAL SWEEP control until the spot is on the top graticule line. Note the meter reading.

g. CHECK — The sum of the readings noted in parts e and f should be as shown in Table 5-4, column 3.

h. Switch the VERT UNITS/DIV switch to 20 m and SOURCE RESISTANCE to 10 k.

i. Press the DISPLAY ZERO button. Turn the MANUAL SWEEP control to set the spot to the bottom graticule line. Note the voltage reading.

j. Turn the MANUAL SWEEP control to set the spot to the top graticule line. Note the voltage reading.

k. CHECK — The sum of the readings noted in parts i and j should be as shown in Table 5-4, column 3.

TABLE 5-4

| VERT UNITS/ DIV | SOURCE RESISTANCE | Sum of the Voltages | Accuracy |
|---|---|---|---|
| 50 m | 20 k | 4.00 V | ± 120 mV |
| 20 m | 10 k | 1.60 V | ± 40 mV |

l. Replace the 1 MΩ resistor on the DUT card with a 10 MΩ resistor.

m. CHECK — Using Table 5-5 and the procedure in parts i and j, check the accuracy at the VERT UNITS/DIV settings in column 1.

TABLE 5-5

| VERT UNITS/ DIV | SOURCE RESISTANCE | Sum of the Voltages | Accuracy |
|---|---|---|---|
| 10 m | 50 k | 0.8 V | ± 24 mV |
| 5 m | 20 k | 0.4 V | ± 12 mV |
| 2 m | 10 k | 0.16 V | ± 4.8 mV |
| 1 m | 10 k | 0.08 V | ± 2.4 mV |

n. Remove the patch cords and set the External Feedback Amplifier switch to NORM.

7. Check Sample and Hold Offset Voltage Range

a. Set the controls as follows:

| 577 | |
|---|---|
| VARIABLE COLLECTOR % | 0 |
| MAX PEAK VOLTS | 100 |
| COLLECTOR SUPPLY POLARITY | AC |
| SERIES RESISTORS | 2 M |
| STEP/OFFSET AMPL | .5 V |
| OFFSET MULT (dial) | 1.00 |
| HORIZ VOLTS/DIV | .1 V, COLLECTOR |
| All Dark Gray Buttons and Knobs in except: | |
| STEP FAMILY | SINGLE |
| OFFSET ZERO | out |
| Horizontal POSITION | pull (X10 MAX) centered |
| PULSED 300 μs | out |
| Vertical POSITION | centered |

| 178 | |
|---|---|
| VERT UNITS/DIV | 10 μA |
| FUNCTION | COLLECTOR SUPPLY I |
| SOURCE RESISTANCE | 50 Ω |
| DUT SUPPLIES | OFF |

b. Connect a patch cord between OUT and STEP on the Standard Op Amp card. Connect a patch cord between +IN and CS.

c. Switch DUT SUPPLIES switch to ON.

d. Press and hold the DISPLAY ZERO button and position the spot approximately to horizontal graticule center. Note the spot position and release the DISPLAY ZERO button.

e. CHECK — The spot should shift ⩾ 2.5 divisions to the left of the position noted in part d.

f. Release the AID button on the 577 to the OPPOSE position.

g. Press the DISPLAY ZERO button.

h. CHECK — The spot should shift ⩾ 2.5 divisions to the right of the position noted in part d.

i. Remove the patch cords from the Op Amp card.

8. Check Power Supplies

a. Set the controls as follows:

| | |
|---|---|
| 577 | |
| HORIZ VOLTS/DIV | 10 V, COLLECTOR |
| Vertical POSITION | centered |
| All Dark Gray Buttons and Knobs in except: | |
| STEP FAMILY | SINGLE |
| 178 | |
| FUNCTION | OFFSET V |
| +SUPPLY | fully counterclockwise |
| -SUPPLY | TRACK +SUPPLY |
| SWEEP AMPLITUDE | fully counterclockwise |
| SWEEP FREQUENCY (Hz) | .1 |
| VERT UNITS/DIV | 50 mV |
| DUT SUPPLIES Switch | ON |
| Standard Op Amp Card | |
| Limits | fully clockwise |

b. Connect the DVM between +SUPPLY and GND on the front panel. Read the voltage on the DVM.

c. CHECK — The +SUPPLY dial should indicate approximately the voltage read on the DVM in part b.

d. Reconnect the DVM between +SUPPLY and -SUPPLY on the front panel. Set +SUPPLY dial to 30.0.

e. CHECK — The voltage should be 60.0 volts, ± 0.6 volts (1%).

f. Set the DUT SUPPLIES switch to OFF. Connect a 200 Ω, 10 watt, 1% resistor from +V to GND on the Standard Op Amp card. Connect the DVM across the 200 Ω resistor and set the DUT SUPPLIES switch to ON.

g. CHECK — For +30 volts, ± 2%, ± 100 mV.

h. Set the DUT SUPPLIES switch to OFF. Reconnect the 200 Ω resistor between -V and GND. Switch the DUT SUPPLIES switch to ON. Read the voltage across the 200 Ω.

i. CHECK — For -30 volts, ± 2%, ± 100 mV.

j. Set the DUT SUPPLIES switch to OFF. Remove the 200 Ω resistor. Patch from +V to GND on the Standard Op Amp card. Set the FUNCTION switch to +SUPPLY I. Set the DUT SUPLIES swith to ON.

k. Press the DISPLAY ZERO button and position the spot to the graticule bottom center (zero reference). Release the DISPLAY ZERO button and set the DUT SUPPLIES switch to ON.

l. CHECK — For approximately four divisions of vertical shift from the zero reference (approximately 200 mA). Note that the +SUPPLY OVERLOAD lamp is lighted.

m. CHECK — That when the +I Limit control (on the Standard Op Amp card) is turned counterclockwise, the +Supply current decreases (spot moves toward the zero reference).

n. Set the DUT SUPPLIES switch to OFF. Move the patch cord from +V to -V. Set the FUNCTION switch to -SUPPLY I.

o. Press the DISPLAY ZERO button and position the spot to the graticule top center (zero reference). Release the DISPLAY ZERO button and set the DUT SUPPLIES switch to ON.

p. CHECK — For approximately four divisions of vertical shift from the zero reference (approximately 200 mA). Note that the -SUPPLY OVERLOAD lamp is lighted.

q. CHECK — That when the -I Limit control is turned counterclockwise, the -Supply current decreases (spot moves toward the zero reference).

9. Check Sweep Generator

a. Set the 577-178 controls as follows:

| 577 | |
|---|---|
| HORIZ VOLTS/DIV | 5 V, COLLECTOR |
| Horizontal POSITION | centered |
| Vertical POSITION | centered |
| All Dark Gray Buttons and Knobs in except: | |
| STEP FAMILY | SINGLE |

| 178 | |
|---|---|
| FUNCTION | +SUPPLY I |
| +SUPPLY | 30.0 |
| -SUPPLY | TRACK +SUPPLY |
| SWEEP AMPLITUDE | midrange |
| SWEEP FREQUENCY (Hz) | 1 k |
| VARIABLE | fully clockwise (X1) |
| DUT SUPPLIES | OFF |
| VERT UNITS/DIV | .5 mA |

9. Check Sweep Generator (cont)

Test Oscilloscope

| | |
|---|---|
| Vert Mode | Alt |
| CH 1 DC | 5 V/Div |
| CH 2 DC | .5 V/Div |
| Position CH 1 and 2 | centered |
| Time/Div | .1 ms |
| Trigger Mode | Norm |
| Slope | + |
| Coupling | DC |

Time Mark Generator

| | |
|---|---|
| Marker Selector | 1 ms |

b. Connect the Time Mark Generator to CH 2 of the Test Scope. Connect +V on the Standard Op Amp card to CH 1 of the Test Scope. Set the DUT SUPPLIES switch to ON. Trigger the Test Scope for a stable display.

c. Position the first time mark to the left graticule line on the Test Scope. Note the point at which the sine wave crosses the time mark.

d. CHECK — That the sine wave crosses the right time mark at the same point as noted in part c, ± 0.5 major horizontal divisions.

e. Set the SWEEP FREQUENCY to 100 Hz and the test scope Horizontal to 1 ms/Div.

f. CHECK — For 1 cycle in 10 time marks, ±0.5 div.

g. Set the SWEEP FREQUENCY to 10 Hz. Set the Time Mark Generator to .1 s. Set the test scope to 10 ms/Div.

h. CHECK — For 1 cycle in 1 time mark, ± 0.5 div.

i. Set the test scope for .1 s/Div[2] and the Time Mark Generator to 1 s. Set the test scope to CH 2 only and check the test scope display for 1 time mark/10 horizontal divisions. If not 1 time mark/10 divisions, adjust the horizontal Variable for 1 mark/10 divisions.

j. Set the test scope vertical to CH 1. Set the 178 SWEEP FREQUENCY control to 1 s.

k. CHECK — For 1 cycle in 10 divisions, ± 0.5 division.

l. Set the test scope to 1 s/Div (use variable if necessary). Switch the test scope vertical to CH 2. Set the Time Mark Generator to 1 s and check the time base for 10 sec in 10 divisions.

m. Set the test scope vertical to CH 1. Set the 178 SWEEP FREQUENCY to .1.

[2] If the test scope goes to only .5 sec, use the Horizontal Variable and the Time Mark Generator at 1 sec and calibrate the crt for 1 time mark/division.

n. CHECK – For 1 cycle in 10 divisions, ± 0.5 division.

o. Set the test scope horizontal to 2 s/Div. Set the SWEEP FREQUENCY VARIABLE to X.1.

p. CHECK – The sine wave on the test scope for 5 divisions, +0.25 to 2 divisions.

q. Set the SWEEP FREQUENCY to 10 Hz. Set the test scope horizontal for .2 s/Div. Set the test scope horizontal variable to Cal.

r. CHECK – Display for 1 cycle in 5 divisions, +0.25 to +2 divisions, minus the test scope accuracy[3].

s. Set the SWEEP FREQUENCY to 100 Hz. Set the test scope horizontal for 20 ms/Div.

t. CHECK – The display for 1 cycle in 5 divisions, +0.25 to +2 divisions, minus the test scope accuracy[3].

u. Set SWEEP FREQUENCY to 1 k and test scope horizontal to 2 ms/Div and repeat part s.

v. Set SWEEP FREQUENCY to .1. Set the Time Mark Generator to 5 s. Disconnect the test scope. Connect the Time Mark Generator through a .22 μF, 50 V capacitor to +V on the Standard Op Amp card. Set the 178 VERT UNITS/DIV to .1 mA. Position the trace on screen[4].

w. Turn on the storage. When the trace is at about midsweep, approximately 15 V, erase the trace, and count the number of time marks in one full sine-wave cycle.

x. CHECK – For 2l pulses, ± 7 pulses in one cycle.

10. Check Common-Mode Rejection Ratio, Method 1[5]

a. Set the controls as follows:

577

| | |
|---|---|
| HORIZ VOLTS/DIV | 2 V, COLLECTOR |

All Dark Gray Buttons and Knobs in except:

| | |
|---|---|
| STEP FAMILY | SINGLE |
| Vertical POSITION | Pull (MAG ON) centered |

[3]Test scope accuracy can be checked with the Time Mark Generator. If the sine wave is off the graticule, to the right, move the right time mark two divisions to the left with the horizontal position control.

[4]Another method of checking part v is to use a stop watch or a watch with a sweep second hand and check for 100 seconds/cycle.

10. Check Common-Mode Rejection Ratio, Method 1[5] (cont)

| 178 | |
|---|---|
| SWEEP FREQUENCY (Hz) | 1 |
| VARIABLE | X1 (clockwise) |
| +SUPPLY | 15.0 V |
| -SUPPLY | TRACK +SUPPLY |
| DUT SUPPLIES Switch | OFF |
| SOURCE RESISTANCE | 50 Ω |
| FUNCTION | CMRR |
| VERT UNITS/DIV | .1 m (magnified) |

b. Using patch cords, connect the test Op Amp[5] on the Standard Op Amp card. Set the DUT SUPPLIES switch to ON. Press the DISPLAY ZERO button.

c. Set the SWEEP AMPLITUDE control for ten divisions of horizontal display.

d. CHECK — Vertical deflection of the horizontal trace should not exceed ± 3 divisions.

e. Set the VERT UNITS/DIV switch to 10 $\mu$V (magnified). Press the DISPLAY ZERO button.

f. CHECK — Vertical deflection of the horizontal trace should not exceed ±3 divisions.

g. Set the VERT UNITS/DIV switch to 1 $\mu$V (magnified). Press the DISPLAY ZERO button.

h. CHECK — Vertical deflection of the horizontal trace should not exceed ± 3 divisions.

Check Common-Mode Rejection Ratio — Method 2

a. Set the controls as follows:

| 577 | |
|---|---|
| HORIZ VOLTS/DIV | 2 V, COLLECTOR |
| Horizontal POSITION | centered |
| POWER Switch | in (off) |
| All Dark Gray Buttons and Knobs in except: | |
| STEP FAMILY | SINGLE |
| Vertical POSITION | pull (MAG ON) centered |

[5]CMRR of the test op amp must be 150 dB, specified minimum, or must be ⩾ 120 dB, measured. The noise level must be less than 2 $\mu$V, using 50 Ω source resistance. Precision Monolithics SS725 meets the 120 dB requirement. Compensate the SS725 for X10 gain according to manufacturers specification.

Check Common-Mode Rejection Ratio — Method 2 (cont)

| 178 | |
|---|---|
| FUNCTION | CMRR |
| SOURCE RESISTANCE | 50 Ω |
| +SUPPLY | 15.0 V |
| -SUPPLY | TRACK +SUPPLY |
| SWEEP AMPLITUDE | fully counterclockwise |
| SWEEP FREQUENCY (Hz) | 10 |
| VARIABLE | X1 (clockwise) |
| VERT UNITS/DIV | .1 m (magnified) |
| DUT SUPPLIES Switch | OFF |

b. Construct the circuit of Fig. 5-3 on the Standard Op Amp card. This method uses an op amp having good CMRR and drives its terminals common mode, thereby improving the op amp CMRR to ≈ 160 to 180 dB.

c. Plug the Standard Op Amp card into the 178. Pull the 577 POWER switch.

d. Set the 178 DUT SUPPLIES switch to ON. Press the DISPLAY ZERO button and position the spot to graticule center. Turn the SWEEP AMPLITUDE control clockwise to display ten divisions of horizontal trace.

e. Adjust the Output Terminal CMRR control (on the test circuit) for no trace looping.

f. CHECK — Vertical deflection of the horizontal trace should not exceed ± 1.5 divisions.

g. Set the VERT UNITS/DIV to 10 μV (MAG ON) and press the DISPLAY ZERO button. Adjust the Output Terminal CMRR control for no trace looping.

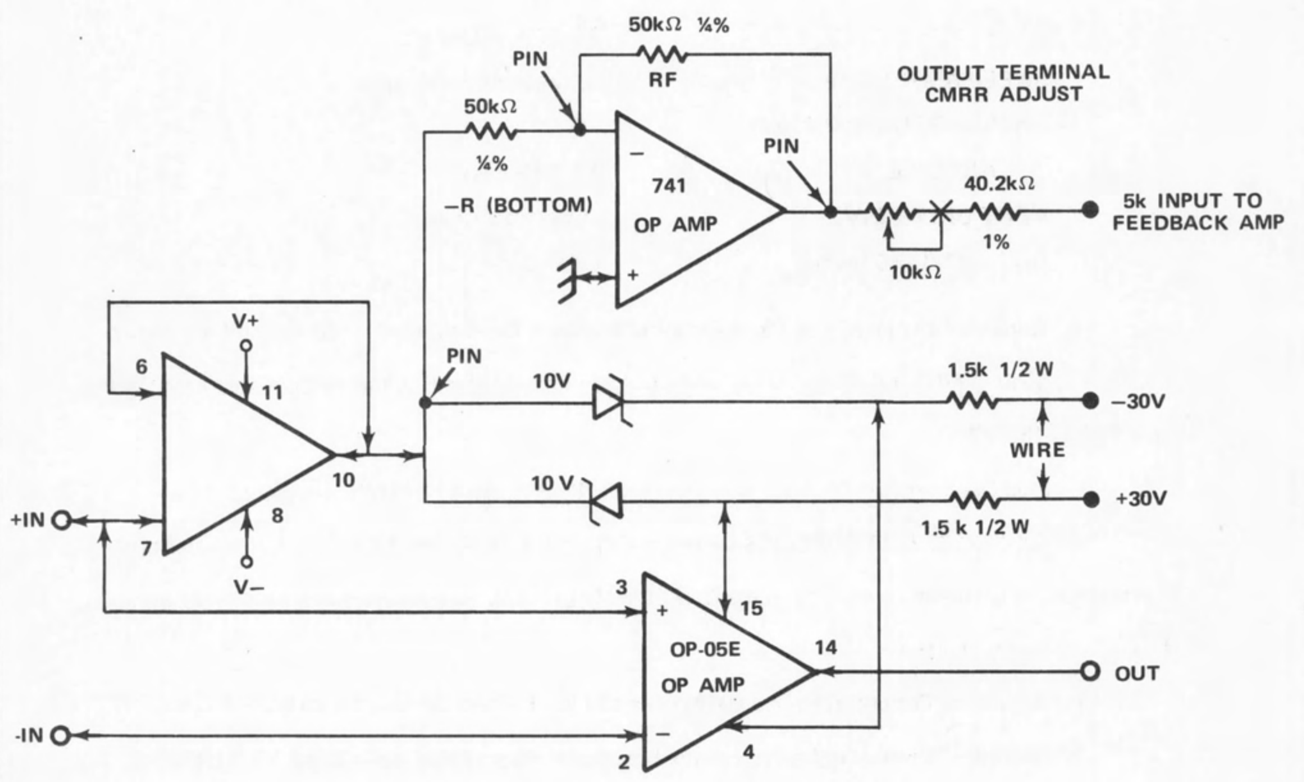
h. CHECK — Vertical deflection of the horizontal trace should not exceed ± 1.5 divisions.

i. Set the VERT UNITS/DIV switch to 1 μV (MAG ON) and press the DISPLAY ZERO button. Adjust the Output Terminal CMRR control for no trace looping.

j. CHECK — Vertical deflection of the horizontal trace should not exceed ± 1.5 divisions.

k. Remove patch cords and components from the Standard Op Amp card.

| | |
|---|---|
| ←→ PATCH CORD<br>● ← PIN BIFURCATED TERMINAL PIN<br>○ HOLE IN CIRCUIT BOARD (SOLDER)<br>× WIRED CONNECTION (SOLDER) | THE SOCKET PIN NUMBERS SHOWN ARE TEST SOCKET NUMBERS FOR THE OP AMPS SHOWN. IF OTHER TYPES ARE USED, THE SOCKET NUMBERS MAY BE DIFFERENT. |




THE OP-05E OP AMP USED IN THIS TEST IS A LOW-NOISE DEVICE HAVING A MINIMUM SPEC OF 110 dB. ANY OP AMP MEETING OR EXCEEDING 114 dB MAY BE USED. ALL WIRING SHOWN IS IN ADDITION TO THAT ON THE STANDARD OP AMP CARD. IF OTHER THAN A LOW NOISE DEVICE IS USED, THERE MAY BE CONSIDERABLE JOHNSON NOISE. THE OP-05E TYPICALLY DISPLAYS 1 TO 2 $\mu$V OF NOISE IN THIS TEST'

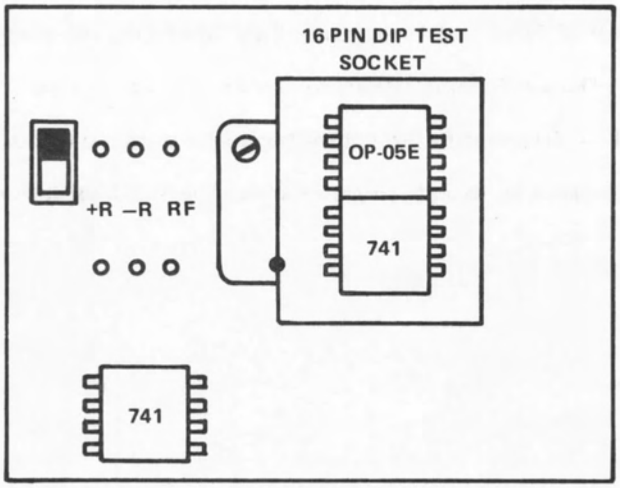



Fig. 5-3. Test circuit for CMRR adjust.

## ADJUSTMENT PROCEDURE

1. Adjust Vertical Preamplifier Balance

a. Set the controls as follows:

| 577 | |
|---|---|
| MAX PEAK VOLTS | 6.5 |
| VARIABLE COLLECTOR % | 0 |
| SERIES RESISTORS | .12 |
| HORIZ VOLTS/DIV | 200 V, COLLECTOR |
| Horizontal POSITION | centered |
| All Dark Gray Buttons and Knobs in except: | |
| STEP FAMILY | SINGLE |
| DISPLAY FILTER NORM | out |
| Vertical POSITION | pull (MAG ON) centered |

| 178 | |
|---|---|
| FUNCTION | -INPUT I |
| VERT UNITS/DIV | 5 m (magnified) |
| SWEEP FREQUENCY (Hz) | .1 |

b. Press and hold the DISPLAY ZERO button. Position the spot to or near to graticule center and note the spot position.

c. Set the VERT UNITS/DIV to 5 pA and press and hold the DISPLAY ZERO button.

d. ADJUST-R340, Vertical Preamp Balance, for no spot movement while switching between 5 mA and 5 pA. See Fig. 5-4 for location of R340.

e. Release the DISPLAY ZERO button. Set the VERT UNITS/DIV switch to 5 pA. Wait 15 seconds.

f. ADJUST-R310, Converter Balance, to position the spot to the point noted in part b.

2. Adjust Vertical Looping

a. Set the controls as follows:

| 577 | |
|---|---|
| MAX PEAK VOLTS | 25 |
| VARIABLE COLLECTOR % | 100 |
| COLLECTOR SUPPLY POLARITY | AC |
| HORIZ VOLTS/DIV | 10 V, COLLECTOR |
| Horizontal POSITION | centered |

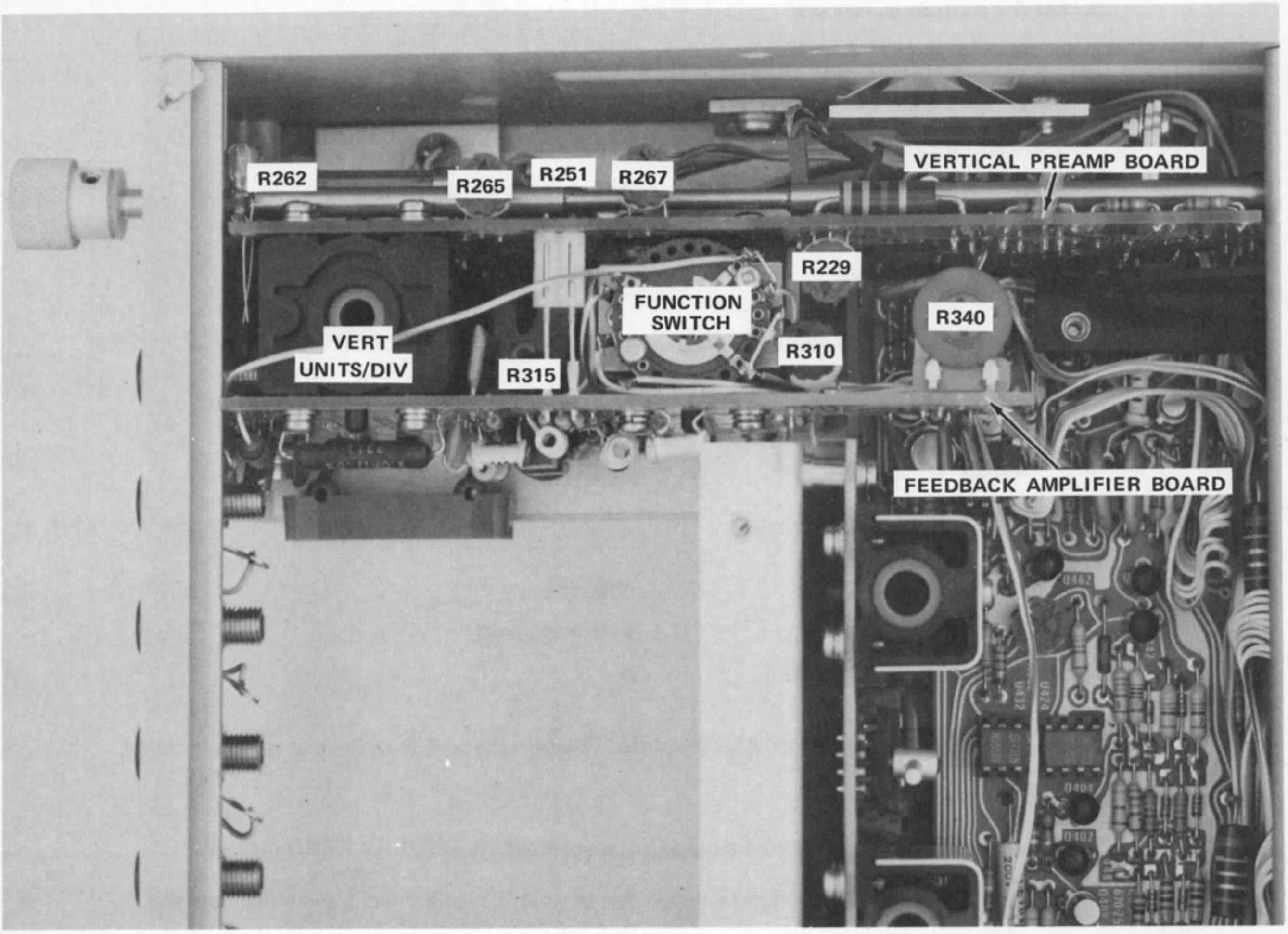



**Fig. 5-4. Location of adjustments on Vertical Preamp and Feedback Amplifier board.**

2. Adjust Vertical Looping (cont)

All Dark Gray Buttons and Knobs in except:

| | |
|---|---|
| STEP FAMILY | SINGLE |
| Vertical POSITION | pull (MAG ON) centered |

178

| | |
|---|---|
| FUNCTION | COLLECTOR SUPPLY I |
| VERT UNITS/DIV | 2 mA (magnified) |
| DUT SUPPLIES Switch | ON |

b. ADJUST-R315, Vertical Looping, for minimum vertical trace separation (looping). See Fig. 5-4 for location of R315.

3. Adjust Feedback Amplifier and Sample and Hold

a. Set the controls as follows:

577

| | |
|---|---|
| HORIZ VOLTS/DIV | 5 V, COLLECTOR |
| Horizontal POSITION | centered |

All Dark Gray Buttons and Knobs in except:

| | |
|---|---|
| STEP FAMILY | SINGLE |
| Vertical POSITION | Pulled and centered |
| DISPLAY FILTER | out |

178

| | |
|---|---|
| FUNCTION | CMRR |
| SOURCE RESISTANCE | 50 Ω |
| +SUPPLY | +15 V |
| -SUPPLY | TRACK +SUPPLY |
| SWEEP AMPLITUDE | fully counterclockwise |
| DUT SUPPLIES Switch | OFF |
| VERT UNITS/DIV | 5 $\mu$ (magnified) |

b. Press and hold the DISPLAY ZERO button. Adjust Vertical POSITION to position the spot to graticule center. Release the DISPLAY ZERO button.

c. Patch GND to OUT on the Standard Op Amp card.

d. ADJUST-R229, Feedback Bal, to position the spot to graticule center.

e. Remove the patch cord from GND. Patch the test socket terminals to the Op Amp terminals on the Standard Op Amp card for a 741 Op Amp. Place the 741 in the test socket.

f. Set the DUT SUPPLIES switch to ON.

g. Press the DISPLAY ZERO button. Note the spot position and release the button.

h. ADJUST-R251, Sample and Hold Bal, to locate the spot to the position noted in part f. Repeat parts g and h until there is no spot movement while pressing and releasing the DISPLAY ZERO button.

i. Remove the patch cords and 741 op amp.

4. Adjust Power Supplies

a. Set the controls as follows:

| | |
|---|---|
| **577** | |
| HORIZ VOLTS/DIV | 10 V, COLLECTOR |
| Vertical POSITION | centered |
| All Dark Gray Buttons and Knobs in except: | |
| STEP FAMILY | SINGLE |
| **178** | |
| FUNCTION | OFFSET V |
| +SUPPLY | fully counterclockwise |
| -SUPPLY | TRACK +SUPPLY |
| SWEEP AMPLITUDE | fully counterclockwise |
| SWEEP FREQUENCY (Hz) | .1 |
| VERT UNITS/DIV | 50 mA |
| DUT SUPPLIES Switch | ON |
| **Standard Op Amp Card** | |
| Limits | fully clockwise |

b. Connect the DVM between +SUPPLY and GND on the front panel. Note the voltage on the DVM, approximately ± 0.1 V or less.

c. Mechanically (loosen +SUPPLY knob set-screw) position the knob to the voltage noted in part b (voltage indicated on knob when the shaft is in the fully counterclockwise position).

d. Reconnect the DVM between +SUPPLY and -SUPPLY on the front panel. Set the +SUPPLY knob to 30.0.

e. ADJUST-R562, Supply Cal, for 60.0 volts. See Fig. 5-5 for location.

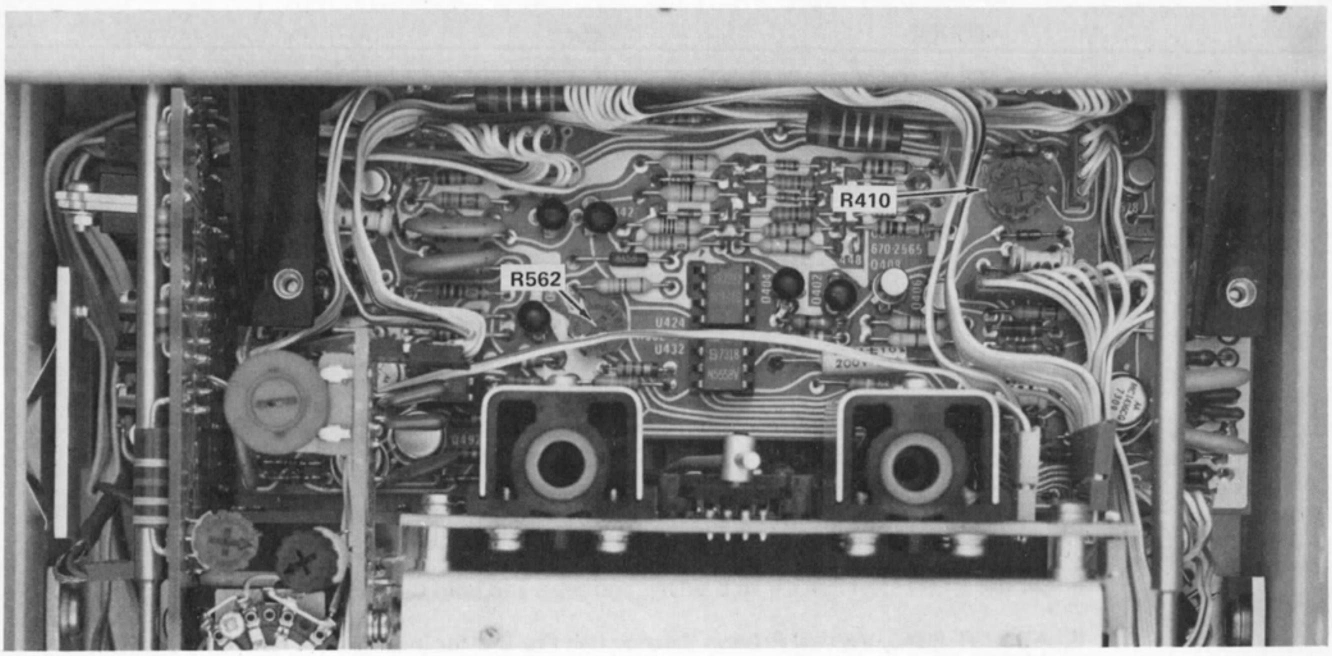



**Fig. 5-5. Location of R562 and R410.**

5. Adjust Preamplifier Balance and Converter Balance

a. Set the controls as follows:

| 577 | |
|---|---|
| MAX PEAK VOLTS | 6.5 |
| VARIABLE COLLECTOR % | 0 |
| SERIES RESISTORS | .12 |
| HORIZ VOLTS/DIV | 200 V, COLLECTOR |
| Horizontal POSITION | centered |
| All Dark Gray Buttons and Knobs in except: | |
| DISPLAY FILTER | |
| NORM | out |
| STEP FAMILY | SINGLE |
| Vertical POSITION Knob (X10 VERT MAG) | pulled and centered |

| 178 | |
|---|---|
| FUNCTION | -INPUT I |
| VERT UNITS/DIV | 5 m/DIV (magnified) |
| SWEEP FREQUENCY (Hz) | .1 |
| VAR | fully clockwise |

b. Press and hold the DISPLAY ZERO button. Vertically and horizontally position the spot to or near to graticule center and note the spot position.

c. Set the VERT UNITS/DIV to 5 p/DIV and press and hold the DISPLAY ZERO button.

d. ADJUST-R340, Vertical Preamp Balance (see Fig. 5-4 for location) for no spot movement while switching between 5 p/DIV and 5 m/DIV.

e. Release the DISPLAY ZERO button and set the VERT UNITS/DIV switch to 5 p/DIV. Wait 15 seconds. Proceed to part f.

f. ADJUST-R310, Converter Balance, to the spot position noted in part b.

6. Adjust Sweep Generator

a. Set the 577-178 controls as follows:

| 577 | |
|---|---|
| HORIZ VOLTS/DIV | 5 V, COLLECTOR |
| Horizontal POSITION | centered |
| Vertical POSITION | centered |

6. Adjust Sweep Generator (cont)

All Dark Gray Buttons and Knobs in except:

| | |
|---|---|
| STEP FAMILY | SINGLE |
| **178** | |
| FUNCTION | +SUPPLY I |
| +SUPPLY | 30.0 |
| -SUPPLY | TRACK +SUPPLY |
| SWEEP AMPLITUDE | midrange |
| SWEEP FREQUENCY (Hz) | 10 |
| VARIABLE | fully clockwise (X1) |
| DUT SUPPLIES | OFF |
| VERT UNITS/DIV | .5 mA |
| **Test Oscilloscope** | |
| Vert Mode | Alt |
| CH 1 DC | 5 V/Div |
| CH 2 DC | .5 V/Div |
| Position CH 1 and 2 | centered |
| Time/Div | 1 ms |
| Triggering Mode | Norm |
| Slope | + |
| Coupling | DC |
| **Time Mark Generator** | |
| Marker Selector | 10 ms |

b. Connect the Time Mark Generator to CH 2 of the Test Scope. Connect the +V on the Standard Op Amp card to CH 1 of the Test Scope. Set the DUT SUPPLIES switch to ON. Trigger the Test Scope for a stable display. Note: CH 1 may have to be readjusted to obtain a better display.

c. Roughly adjust Sweep Freq Adj. R410, for one cycle per time mark. See Fig. 5-5 for location.

d. Turn on the Test Scope Horizontal Magnifier. Position the first time mark on the left graticule line on the Test Scope. Note the point at which the sine wave crosses the time mark.

e. ADJUST-R410, Sweep Freq, so that the sine wave crosses the twentieth time mark at the same point (vertically) as noted in part d.

7. Adjust Common-Mode Rejection Ratio, Method 1[6]

a. Set the controls as follows:

577

| | |
|---|---|
| HORIZ VOLTS/DIV | 2 V, COLLECTOR |
| All Dark Gray Buttons and Knob in except: | |
| Vertical POSITION | pull (MAG ON) centered |

178

| | |
|---|---|
| SWEEP FREQUENCY (Hz) | 1 |
| VARIABLE | X1 (clockwise) |
| +SUPPLY | +15.0 V |
| -SUPPLY | TRACK +SUPPLY |
| DUT SUPPLIES Switch | OFF |
| SOURCE RESISTANCE | 50 Ω |
| FUNCTION | CMRR |
| VERT UNITS/DIV | .1 m (magnified) |

b. Using patch cords, patch the test op amp[6] (test socket terminals) to the op amp terminals on the Standard Op Amp card. Place the test op amp[6] in the test socket. Set the DUT SUPPLIES switch to ON. Press the DISPLAY ZERO button.

c. ADJUST-R267, X10 CMRR (see Fig. 5-4 for location), for no vertical deflection of the horizontal trace.

d. Set the VERT UNITS/DIV switch to 10 μV (MAG ON) and press the DISPLAY ZERO button.

e. ADJUST-R265, X100 CMRR, for no vertical deflection of the horizontal trace.

f. Set the VERT UNITS/DIV to .1 V (MAG ON) and press the DISPLAY ZERO button and repeat parts c through f until there is no vertical deflection of the horizontal trace.

g. Set the VERT UNITS/DIV to 1 μV (MAG ON) and press the DISPLAY ZERO button.

h. ADJUST-R262, X1000 CMRR for no vertical deflection of the horizontal display.

[6] CMRR of the test op amp must be ⩾ 150 dB, minimum, or must be ⩾ 120 dB, measured. The noise level must be less than 2 μV using 50 Ω source resistance. Precision Monolithics SS725 meets the 120 dB specification. Compensate the SS725 for X10 gain according to manufacturers specification.

Adjust Common Mode Rejection Ratio, Method 2

a. Set the controls as follows:

| 577 | |
|---|---|
| HORIZ VOLTS/DIV | 2 V, COLLECTOR |
| Horizontal POSITION | centered |
| POWER Switch | in (off) |
| All Dark Gray Buttons and Knobs in except: | |
| STEP FAMILY | SINGLE |
| Vertical POSITION | pull (MAG ON) centered |

| 178 | |
|---|---|
| FUNCTION | CMRR |
| SOURCE RESISTANCE | 50 Ω |
| +SUPPLY | 15.0 V |
| -SUPPLY | TRACK + SUPPLY |
| SWEEP AMPLITUDE | fully counterclockwise |
| SWEEP FREQUENCY (Hz) | 10 |
| VARIABLE | X1 (clockwise) |
| VERT UNITS/DIV | .1 m (magnified) |
| DUT SUPPLIES Switch | OFF |

b. Construct the circuit of Fig. 5-6 on the Standard Op Amp card. This method uses an op amp having good CMRR and drives its terminals common mode, thereby improving the op amp CMRR to ≈ 160 to 180 dB.

c. Plug the Standard Op Amp card into the 178. Pull the 577 POWER switch.

d. Set the 178 DUT SUPPLIES switch to ON. Press the DISPLAY ZERO button and position the spot to graticule center. Turn the SWEEP AMPLITUDE control clockwise to display ten divisions of horizontal trace.

e. Adjust the Output Terminal CMRR control (on the test circuit) for no trace looping.

f. ADJUST-R267, X10 CMRR (see Fig. 5-4) for no vertical deflection of the horizontal trace.

g. Set the VERT UNITS/DIV to 10 $\mu$V (magnified) and press the DISPLAY ZERO button. Adjust the Output Terminal CMRR control for no trace looping.

h. ADJUST-R265, X100 CMRR, for no vertical deflection of the horizontal trace.

i. Set the VERT UNITS/DIV to .1 mV and press the DISPLAY ZERO button. Repeat parts e through i until there is no vertical deflection.

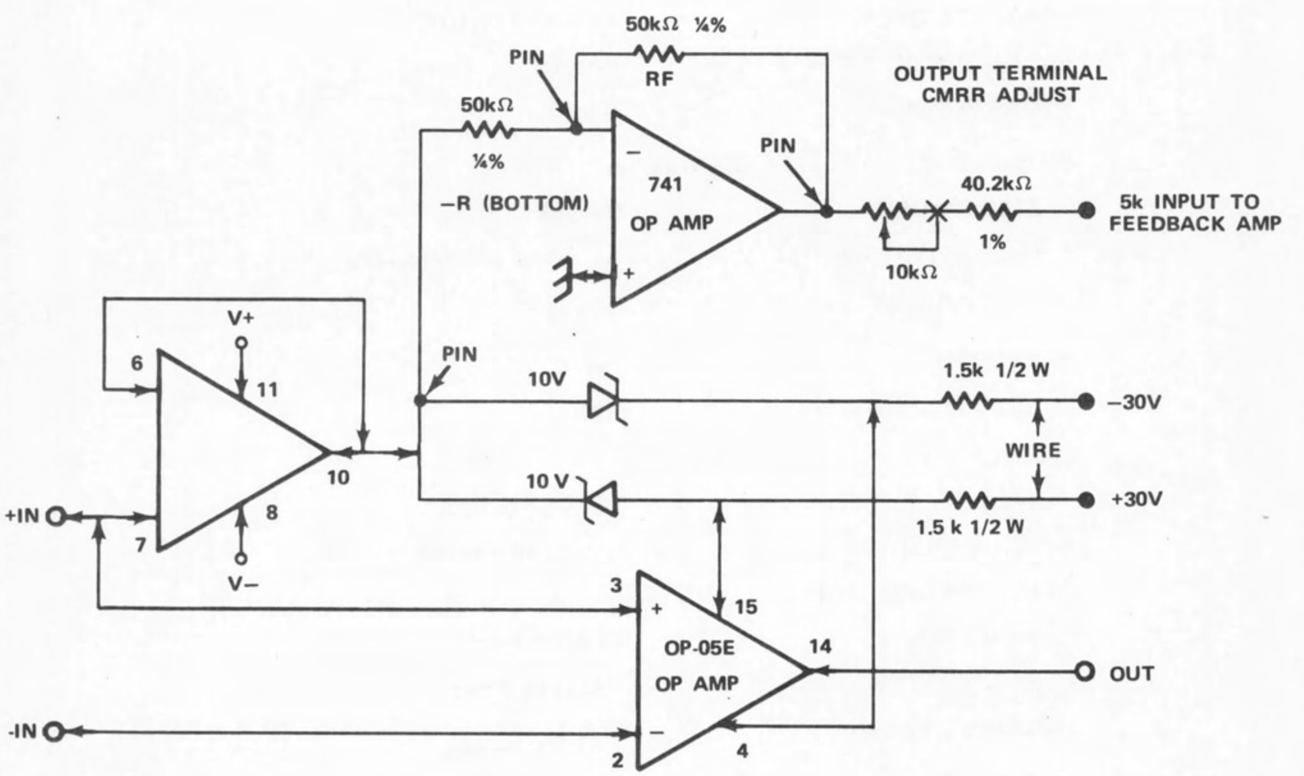
↔ PATCH CORD

● ← PIN BIFURCATED TERMINAL PIN

O HOLE IN CIRCUIT BOARD (SOLDER)

× WIRED CONNECTION (SOLDER)

THE SOCKET PIN NUMBERS SHOWN ARE TEST SOCKET NUMBERS FOR THE OP AMPS SHOWN. IF OTHER TYPES ARE USED, THE SOCKET NUMBERS MAY BE DIFFERENT.




THE OP-05E OP AMP USED IN THIS TEST IS A LOW-NOISE DEVICE HAVING A MINIMUM SPEC OF 110 dB. ANY OP AMP MEETING OR EXCEEDING 114 dB MAY BE USED. ALL WIRING SHOWN IS IN ADDITION TO THAT ON THE STANDARD OP AMP CARD. IF OTHER THAN A LOW NOISE DEVICE IS USED, THERE MAY BE CONSIDERABLE JOHNSON NOISE. THE OP-05E TYPICALLY DISPLAYS 1 TO 2 μV OF NOISE IN THIS TEST'

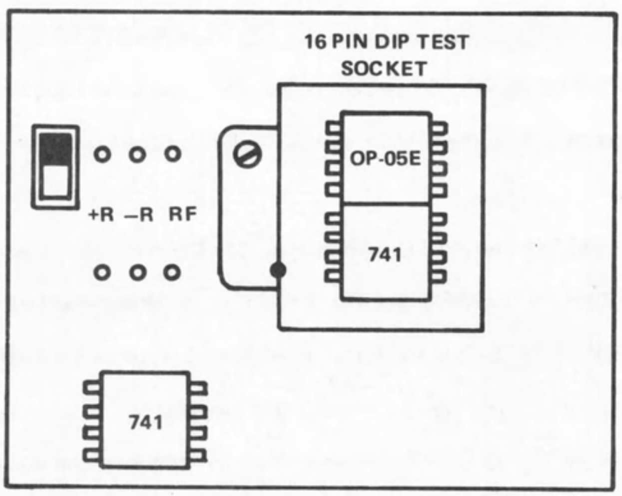



Fig. 5-6. Test circuit for CMRR adjust.

j. Set the VERT UNITS/DIV to 1 μV (magnified) and press the DISPLAY ZERO button. Adjust the Output Terminal CMRR Adjust for no looping.

k. ADJUST-R262, X1000 CMRR, for no vertical deflection of the horizontal trace.

Adjust Common-Mode Rejection Ratio, Method 3

a. Set the controls as follows:

| | |
|---|---|
| **577** | |
| HORIZ VOLTS/DIV | 2 V, COLLECTOR |
| All Dark Gray Buttons and Knobs in except: | |
| STEP FAMILY | SINGLE |
| Vertical POSITION | pull (MAG ON) centered |
| **178** | |
| SWEEP FREQUENCY (Hz) | 1 |
| VARIABLE | X1 (fully clockwise) |
| +SUPPLY | 15.0 V |
| -SUPPLY | TRACK +SUPPLY |
| SOURCE RESISTANCE | 50 Ω |
| FUNCTION | CMRR |
| VERT UNITS/DIV | .1 m (MAG ON) |
| DUT SUPPLIES Switch | OFF |

b. Using patch cords, patch the test op amp (test socket terminals) to the op amp terminals on the Standard Op Amp card. Place the test op amp in the test socket. Set the DUT SUPPLIES switch to ON. Press the DISPLAY ZERO button.

c. Set the SWEEP AMPLITUDE to display ten divisions of horizontal deflection.

d. ADJUST-R267, X10 CMRR (see Fig. 5-4 for location), for no vertical deflection of the horizontal trace.

e. Set the VERT UNITS/DIV switch to 10 μV (MAG ON) and press the DISPLAY ZERO button.

f. ADJUST-R265, X100 CMRR, for no vertical deflection of the horizontal trace.

g. Set the VERT UNITS/DIV switch to .1 mV (MAG ON). Press the DISPLAY ZERO button and repeat parts d through f until there is no vertical deflection of the horizontal trace. If the CMRR is not 120 dB, but is a known (recorded) value, adjust the CMRR to the known value.

h. Remove the test op amp from the Standard Op Amp card.

i. Reset the controls as follows:

| | |
|---|---|
| 178 | |
| VERT UNITS/DIV | 1 μV (MAG ON) |
| FUNCTION | GAIN |
| SWEEP AMPLITUDE | fully counterclockwise |
| Differential Input Test Oscilloscope | |
| Vertical Input | 10 μV, DC |
| Horizontal Time/Div | 5 ms |
| Trigger | Auto |
| Probes | X1, identical lead length |

or

In lieu of a test scope, use a DVM having 1 μV resolution.

j. Connect a lead between the $R_F$ terminal (upper end) and the third hole from the left of the upper-right corner of the DUT card. Keep the lead short.

k. Press the DISPLAY ZERO button. Switch the External Feedback selector (see Fig. 5-6) (to the left of the test socket) away from the NORM position.

l. Connect both test oscilloscopes probes (or the DVM) to -IN on the DUT card, using a bifurcated pin terminal. Twist the probe leads together to minimize noise.

m. Note the dc voltage level. Connect one of the probes (or one of the DVM leads) to the +IN terminal on the DUT card.

n. ADJUST-R262, X1000 CMRR, for the dc level noted in part m.

NOTE

Performing parts i through n calibrate the 50 μV, 20 μV, and 10 μV (5 μV, 2 μV, and 1 μV with magnifier on) ranges. If the X10 CMRR or X100 CMRR controls are re-adjusted, the X1000 range is no longer calibrated and parts i through n must be repeated.

o. To calculate CMRR, plug the test op amp into the test socket on the DUT card and calculate the CMRR, in dB, as follows:

Switch the VERT UNTS/DIV to 1 μV (MAG ON) and measure the vertical deflection. It may be necessary, if the CMRR on the device is low, to switch the VERT UNITS/DIV to the next lower decade (10 μV/DIV).

Divide the horizontal volts (horizontal display) by the vertical deflection in $\mu V$.

Example: $\frac{20\ V\ \text{(horizontal deflection)}}{40\ \mu V\ \text{(vertical deflection)}}$

$$CMRR = \frac{20\ V}{40\ \mu V} = .5 \times 10^6$$

$$CMRR = 5 \times 10^5$$

$$CMRR = 20 \log_{10} 5 \times 10^5$$

$$CMRR = 20 \times 5.69897$$

$$CMRR \cong 114\ dB$$

# ELECTRICAL REPLACEABLE PARTS LIST

## 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 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.

## SPECIAL NOTES AND SYMBOLS

| | |
|---|---|
| X000 | Part first added at this serial number |
| 00X | Part removed after this serial number |

### ITEM NAME

In the Parts List, an Item Name is separated from the description by a colon (:). Because of space limitations, an Item Name may sometimes appear as incomplete. For further Item Name identification, the U.S. Federal Cataloging Handbook H6-1 can be utilized where possible.

## ABBREVIATIONS

| | | | |
|---|---|---|---|
| ACTR | ACTUATOR | PLSTC | PLASTIC |
| ASSY | ASSEMBLY | QTZ | QUARTZ |
| CAP | CAPACITOR | RECP | RECEPTACLE |
| CER | CERAMIC | RES | RESISTOR |
| CKT | CIRCUIT | RF | RADIO FREQUENCY |
| COMP | COMPOSITION | SEL | SELECTED |
| CONN | CONNECTOR | SEMICOND | SEMICONDUCTOR |
| ELCTLT | ELECTROLYTIC | SENS | SENSITIVE |
| ELEC | ELECTRICAL | SEP | SEPARATELY |
| FXD | FIXED | VAR | VARIABLE |
| INCAND | INCANDESCENT | WW | WIREWOUND |
| LED | LIGHT EMITTING DIODE | XFMR | TRANSFORMER |
| NONWIR | NON WIREWOUND | XTAL | CRYSTAL |

# CROSS INDEX MFR. CODE NUMBER TO MANUFACTURER

| MFR.CODE | MANUFACTURER | ADDRESS | CITY,STATE,ZIP |
|---|---|---|---|
| 01121 | Allen-Bradley Co. | 1201 2nd St. | Milwaukee, WI 53212 |
| 04713 | Motorola, Inc., Semiconductor Products Div. | 5005 E. McDowell Rd. | Phoenix, AZ 85008 |
| 07263 | Fairchild Semiconductor, A Div. of Fairchild Camera and Instrument Corp. | 464 Ellis St. | Mountain View, CA 94040 |
| 07910 | Teledyne Semiconductor | 12515 Chadron Ave. | Hawthorne, CA 90250 |
| 08806 | General Electric Co., Miniature Lamp Dept. | Nela PK. | Cleveland, OH 44112 |
| 12040 | National Semiconductor Corp. | Commerce Drive | Danbury, CT 06810 |
| 15818 | Teledyne Semiconductor | 1300 Terra Bella Ave. | Mountain View, CA 94040 |
| 17856 | Siliconix, Inc. | 2201 Laurelwood Rd. | Santa Clara, CA 95050 |
| 18324 | Signetics Corp. | 811 E. Arques | Sunnyvale, CA 94086 |
| 18796 | Erie Technological Products, Inc. State College Division | | State College, PA 16801 |
| 56289 | Sprague Electric Co. | | North Adams, MA 01247 |
| 71400 | Bussman Mfg., Division of McGraw Edison Co. | 2536 W. University St. | St. Louis, MO 63107 |
| 72982 | Erie Technological Products, Inc. | 644 W. 12th St. | Erie, PA 16512 |
| 73138 | Beckman Instruments, Inc., Helipot Div. | 2500 Harbor Blvd. | Fullerton, CA 92634 |
| 75042 | TRW Electronic Components, IRC Philadelphia Div. | 401 N. Broad St. | Philadelphia, PA 19108 |
| 80009 | Tektronix, Inc. | P. O. Box 500 | Beaverton, OR 97005 |
| 81073 | Grayhill, Inc. | 561 Hillgrove Ave. | La Grange, IL 60525 |
| 81483 | International Rectifier Corp. | 9220 Sunset Blvd. | Los Angeles, CA 90069 |
| 91637 | Dale Electronics, Inc. | P. O. Box 609 | Columbus, NB 68601 |

| Ckt No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|
| A1 | 670-2568-00 | | | CKT BOARD ASSY:--INTERFACE | 80009 | 670-2568-00 |
| A2 | 670-2569-00 | | | CKT BOARD ASSY:--VERTICAL PREAMPL | 80009 | 670-2569-00 |
| A3 | 670-2566-00 | | | CKT BOARD ASSY:--FEEDBACK AMPL | 80009 | 670-2566-00 |
| A4 | 670-2565-00 | | | CKT BOARD ASSY:--POWER SUPPLY | 80009 | 670-2565-00 |
| A5 | 670-2567-00 | | | CKT CARD ASSY:--STANDARD OP AMPL | 80009 | 670-2567-00 |
| C23 | 283-0110-00 | | | CAP.,FXD,CER DI:0.005UF,+80-20%,150V | 18796 | 855547Z5U0502Z |
| C25 | 283-0110-00 | | | CAP.,FXD,CER DI:0.005UF,+80-20%,150V | 18796 | 855547Z5U0502Z |
| C131 | 283-0000-00 | | | CAP.,FXD,CER DI:0.001UF,+100-0%,500V | 56289 | 40C626 |
| C141 | 283-0000-00 | | | CAP.,FXD,CER DI:0.001UF,+100-0%,500V | 56289 | 40C626 |
| C205 | 281-0526-00 | | | CAP.,FXD,CER DI:1.5PF,+/-0.5PF,500V | 72982 | 301-000S2K0159D |
| C208 | 283-0003-00 | | | CAP.,FXD,CER DI:0.01UF,+80-20%,150V | 56289 | 20C205A1 |
| C227 | 281-0504-00 | | | CAP.,FXD,CER DI:10PF,+/-1PF,500V | 72982 | 301-000C0G0100F |
| C254 | 285-0898-00 | | | CAP.,FXD,PLSTC:0.47UF,10%,100V | | |
| C263 | 283-0003-00 | | | CAP.,FXD,CER DI:0.01UF,+80-20%,150V | 56289 | 20C205A1 |
| C291 | 283-0081-00 | | | CAP.,FXD,CER DI:0.1UF,+80-20%,25V | 56289 | 36C600 |
| C293 | 283-0081-00 | | | CAP.,FXD,CER DI:0.1UF,+80-20%,25V | 56289 | 36C600 |
| C295 | 283-0081-00 | | | CAP.,FXD,CER DI:0.1UF,+80-20%,25V | 56289 | 36C600 |
| C306 | 283-0000-00 | | | CAP.,FXD,CER DI:0.001UF,+100-0%,500V | 56289 | 40C626 |
| C315 | 283-0119-00 | | | CAP.,FXD,CER DI:2200PF,5%,200V | 72982 | 855-030Y5D00222J |
| C318 | 283-0000-00 | | | CAP.,FXD,CER DI:0.001UF,+100-0%,500V | 56289 | 40C626 |
| C320 | 281-0504-00 | | | CAP.,FXD,CER DI:10PF,+/-1PF,500V | 72982 | 301-000C0G0100F |
| C322 | 281-0536-00 | | | CAP.,FXD,CER DI:100PF,+/-100PF,500V | | |
| C324 | 281-0523-00 | | | CAP.,FXD,CER DI:100PF,+/-20PF,350V | 72982 | 301-000U2M0101M |
| C342 | 281-0512-00 | | | CAP.,FXD,CER DI:27PF,+/-2.7PF,500V | 72982 | 308-000C0G0270K |
| C352 | 281-0504-00 | | | CAP.,FXD,CER DI:10PF,+/-1PF,500V | 72982 | 301-000C0G0100F |
| C359 | 283-0003-00 | | | CAP.,FXD,CER DI:0.01UF,+80-20%,150V | 56289 | 20C205A1 |
| C361 | 281-0546-00 | | | CAP.,FXD,CER DI:330PF,10%,500V | 72982 | 301-000X5P0331K |
| C371 | 283-0059-00 | | | CAP.,FXD,CER DI:1UF,+80-20%,25V | 72982 | 8141N038E105Z |
| C373 | 283-0059-00 | | | CAP.,FXD,CER DI:1UF,+80-20%,25V | 72982 | 8141N038E105Z |
| C406 | 281-0543-00 | | | CAP.,FXD,CER DI:270PF,10%,500V | 72982 | 301-055X5P271K |
| C424, C425 [1] | 295-0158-00 | | | CAP.,SET,MTCHD:0.001UF AND 1UF | | |
| C442 | 283-0081-00 | | | CAP.,FXD,CER DI:0.1UF,+80-20%,25V | 56289 | 36C600 |
| C452 | 283-0081-00 | | | CAP.,FXD,CER DI:0.1UF,+80-20%,25V | 56289 | 36C600 |
| C472 | 281-0549-00 | | | CAP.,FXD,CER DI:68PF,10%,500V | 72982 | 301-000U2J0680K |
| C475 | 290-0522-00 | | | CAP.,FXD,ELCTLT:1UF,20%,50V | 56289 | 196D105X0050HA1 |
| C476 | 283-0111-00 | | | CAP.,FXD,CER DI:0.1UF,20%,50V | 72982 | 8131-050651104M |
| C482 | 283-0010-00 | | | CAP.,FXD,CER DI:0.05UF,+100-20%,50V | 56289 | 273C20 |
| C484 | 290-0522-00 | | | CAP.,FXD,ELCTLT:1UF,20%,50V | 56289 | 196D105X0050HA1 |
| C521 | 281-0580-00 | | | CAP.,FXD,CER DI:470PF,10%,500V | 72982 | 301-000Z5D0471K |
| C542 | 283-0000-00 | | | CAP.,FXD,CER DI:0.001UF,+100-0%,500V | 56289 | 40C626 |
| C562 | 283-0081-00 | | | CAP.,FXD,CER DI:0.1UF,+80-20%,25V | 56289 | 36C600 |
| C566 | 283-0081-00 | | | CAP.,FXD,CER DI:0.1UF,+80-20%,25V | 56289 | 36C600 |
| C574 | 281-0523-00 | | | CAP.,FXD,CER DI:100PF,+/-20PF,350V | 72982 | 301-000U2M0101M |
| C575 | 290-0522-00 | | | CAP.,FXD,ELCTLT:1UF,20%,50V | 56289 | 196D105X0050HA1 |
| C576 | 283-0111-00 | | | CAP.,FXD,CER DI:0.1UF,20%,50V | 72982 | 8131-050651104M |
| C582 | 283-0010-00 | | | CAP.,FXD,CER DI:0.05UF,+100-20%,50V | 56289 | 273C20 |
| C584 | 290-0522-00 | | | CAP.,FXD,ELCTLT:1UF,20%,50V | 56289 | 196D105X0050HA1 |
| CR14 | 152-0243-00 | | | SEMICOND DEVICE:ZENER,0.4W,15V,5% | 81483 | 1N965B |
| CR18 | 152-0243-00 | | | SEMICOND DEVICE:ZENER,0.4W,15V,5% | 81483 | 1N965B |
| CR211 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR226 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR282 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR306 | 152-0367-00 | | | SEMICOND DEVICE:SILICON,20V,20PA | | |
| CR307 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR321 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR322 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR406 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR443 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |

[1]Individual timing capacitors in this assembly must be ordered by the 9 digit part number, letter suffix and tolerance printed on the timing capacitor to be replaced. The letter suffix and the tolerance should be the same for all of the timing capacitors in the assembly. Example:

——| 285-XXXX-XX F- |——

| Ckt No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|
| CR444 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR445 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR453 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR454 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR455 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR472 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR482 | 152-0040-00 | | | SEMICOND DEVICE:SILICON,600V,1A | | |
| CR484 | 152-0040-00 | | | SEMICOND DEVICE:SILICON,600V,1A | | |
| CR492 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR493 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR494 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR520 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR532 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR533 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR572 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR582 | 152-0040-00 | | | SEMICOND DEVICE:SILICON,600V,1A | | |
| CR584 | 152-0040-00 | | | SEMICOND DEVICE:SILICON,600V,1A | | |
| CR592 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR593 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| CR594 | 152-0141-02 | | | SEMICOND DEVICE:SILICON,30V,150MA | 07910 | CD8220 |
| DS236 | 150-0075-00 | | | LAMP,INCAND:T1 3/4 | | |
| DS268 | 150-0075-00 | | | LAMP,INCAND:T1 3/4 | | |
| DS281 | 150-0048-00 | | | LAMP,INCAND:5V,60MA | 08806 | 683 |
| DS284 | 150-0048-00 | | | LAMP,INCAND:5V,60MA | 08806 | 683 |
| DS286 | 150-0048-00 | | | LAMP,INCAND:5V,60MA | 08806 | 683 |
| DS441 | 150-0133-00 | | | LAMP,INCAND:14V,80MA | | |
| DS478 | 150-0048-00 | | | LAMP,INCAND:5V,60MA | 08806 | 683 |
| DS578 | 150-0048-00 | | | LAMP,INCAND:5V,60MA | 08806 | 683 |
| F236 | 159-0083-00 | | | FUSE,CARTRIDGE:0.15A,3AG,FAST-BLOW | 71400 | AGC15-100 |
| F268 | 159-0083-00 | | | FUSE,CARTRIDGE:0.15A,3AG,FAST-BLOW | 71400 | AGC15-100 |
| J40 | 136-0140-00 | | | JACK,TIP: | 80009 | 136-0140-00 |
| J50 | 136-0140-00 | | | JACK,TIP: | 80009 | 136-0140-00 |
| J60 | 136-0140-00 | | | JACK,TIP: | 80009 | 136-0140-00 |
| J70 | 136-0140-00 | | | JACK,TIP: | 80009 | 136-0140-00 |
| J80 | 136-0140-00 | | | JACK,TIP: | 80009 | 136-0140-00 |
| J90 | 136-0140-00 | | | JACK,TIP: | 80009 | 136-0140-00 |
| Q214 | 151-0188-00 | | | TRANSISTOR:SILICON,PNP | 04713 | 2N3906 |
| Q222 | 151-0367-00 | | | TRANSISTOR:SILICON,NPN,SEL FROM 3571TP | 80009 | 151-0367-00 |
| Q226 | 151-0188-00 | | | TRANSISTOR:SILICON,PNP | 04713 | 2N3906 |
| Q252A,B | 151-1049-00 | | | TRANSISTOR:SI,JFE,N-CHAN,SEL FROM 2N3822 | 80009 | 151-1049-00 |
| Q280 | 151-0301-00 | | | TRANSISTOR:SILICON,PNP | 04713 | 2N2907A |
| Q284 | 151-0302-00 | | | TRANSISTOR:SILICON,NPN | 04713 | 2N2222A |
| Q286 | 151-0302-00 | | | TRANSISTOR:SILICON,NPN | 04713 | 2N2222A |
| Q310A,B | 151-1077-00 | | | TRANSISTOR:SILICON,JFE,N CHANNEL,DUAL | 17856 | 2N5908 |
| Q402 | 151-0342-00 | | | TRANSISTOR:SILICON,PNP | 07263 | 2N4249 |
| Q404 | 151-0342-00 | | | TRANSISTOR:SILICON,PNP | 07263 | 2N4249 |
| Q406 | 151-0126-00 | | | TRANSISTOR:SILICON,NPN | 07263 | 2N2484 |
| Q408 | 151-0126-00 | | | TRANSISTOR:SILICON,NPN | 07263 | 2N2484 |
| Q442 | 151-0342-00 | | | TRANSISTOR:SILICON,PNP | 07263 | 2N4249 |
| Q452 | 151-0341-00 | | | TRANSISTOR:SILICON,NPN | 07263 | 2N3565 |
| Q462 | 151-0342-00 | | | TRANSISTOR:SILICON,PNP | 07263 | 2N4249 |
| Q472 | 151-0126-00 | | | TRANSISTOR:SILICON,NPN | 07263 | 2N2484 |
| Q478 | 151-0301-00 | | | TRANSISTOR:SILICON,PNP | 04713 | 2N2907A |
| Q484 | 151-0373-00 | | | TRANSISTOR:SILICON,PNP | 04713 | SJE925 |
| Q492 | 151-0103-00 | | | TRANSISTOR:SILICON,NPN | 04713 | 2N2219A |
| Q520 | 151-1059-00 | | | TRANSISTOR:SILICON,JFE,N CHANNEL | 15818 | U1897E |
| Q536 | 151-0432-00 | | | TRANSISTOR:SILICON,NPN | 12040 | SM07391 |
| Q538 | 151-0342-00 | | | TRANSISTOR:SILICON,PNP | 07263 | 2N4249 |

| Ckt No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|
| Q546 | 151-0462-00 | | | TRANSISTOR:SILICON,PNP | | |
| Q548 | 151-0464-00 | | | TRANSISTOR:SILICON,PNP | | |
| Q572 | 151-0342-00 | | | TRANSISTOR:SILICON,PNP | 07263 | 2N4249 |
| Q578 | 151-0302-00 | | | TRANSISTOR:SILICON,NPN | 04713 | 2N2222A |
| Q584 | 151-0349-00 | | | TRANSISTOR:SILICON,NPN SEL FROM MJE2801 | 80009 | 151-0349-00 |
| Q592 | 151-0235-00 | | | TRANSISTOR:SILICON,PNP | 04713 | 2N4890 |
| R10 | 311-1568-00 | | | RES.,VAR,NONWIR:50 OHM,20%,0.50W | | |
| R20 | 311-1568-00 | | | RES.,VAR,NONWIR:50 OHM,20%,0.50W | | |
| R111 | 308-0545-00 | | | RES.,FXD,WW:100 OHM,0.5%,5W | | |
| R113 | 308-0507-00 | | | RES.,FXD,WW:1K OHM,1%,3W | | |
| R115 | 308-0759-00 | | | RES.,FXD,WW:2.08K OHM,1%,3W | | |
| R116 | 321-0339-00 | | | RES.,FXD,FILM:33.2K OHM,1%,0.125W | 75042 | CEATO-3322F |
| R117 | 322-0264-00 | | | RES.,FXD,FILM:5.49K OHM,1%,0.25W | 75042 | CEBTO-5491F |
| R119 | 321-0298-00 | | | RES.,FXD,FILM:12.4K OHM,1%,0.125W | 75042 | CEATO-1242F |
| R121 | 315-0302-00 | | | RES.,FXD,COMP:3K OHM,5%,0.25W | 01121 | CB3025 |
| R131 | 321-0289-01 | | | RES.,FXD,FILM:10K OHM,0.5%,0.125W | 75042 | CEATO-1002D |
| R132 | 321-0318-02 | | | RES.,FXD,FILM:20K OHM,0.5%,0.125W | | |
| R133 | 321-0756-01 | | | RES.,FXD,FILM:50K OHM,0.5%,0.125W | | |
| R141 | 321-0289-01 | | | RES.,FXD,FILM:10K OHM,0.5%,0.125W | 75042 | CEATO-1002D |
| R142 | 321-0318-02 | | | RES.,FXD,FILM:20K OHM,0.5%,0.125W | | |
| R143 | 321-0756-01 | | | RES.,FXD,FILM:50K OHM,0.5%,0.125W | | |
| R202 | 321-0260-01 | | | RES.,FXD,FILM:4.99K OHM,0.5%,0.125W | 75042 | CEATO-4991D |
| R204 | 321-0692-00 | | | RES.,FXD,FILM:49.9K OHM,0.5%,0.125W | | |
| R205 | 321-0692-00 | | | RES.,FXD,FILM:49.9K OHM,0.5%,0.125W | | |
| R206 | 321-0356-00 | | | RES.,FXD,FILM:49.9K OHM,1%,0.125W | 75042 | CEATO-4992F |
| R208 | 316-0472-00 | | | RES.,FXD,COMP:4.7K OHM,10%,0.25W | 01121 | CB4721 |
| R214 | 315-0512-00 | | | RES.,FXD,COMP:5.1K OHM,5%,0.25W | 01121 | CB5125 |
| R216 | 316-0151-00 | | | RES.,FXD,COMP:150 OHM,10%,0.25W | 01121 | CB1511 |
| R221 | 316-0152-00 | | | RES.,FXD,COMP:1.5K OHM,10%,0.25W | 01121 | CB1521 |
| R223 | 315-0620-00 | | | RES.,FXD,COMP:62 OHM,5%,0.25W | 01121 | CB6205 |
| R224 | 316-0151-00 | | | RES.,FXD,COMP:150 OHM,10%,0.25W | 01121 | CB1511 |
| R226 | 304-0331-00 | | | RES.,FXD,COMP:330 OHM,10%,1W | 01121 | GB3311 |
| R228 | 316-0102-00 | | | RES.,FXD,COMP:1K OHM,10%,0.25W | 01121 | CB1021 |
| R227 | 315-0161-00 | | | RES.,FXD,COMP:160 OHM,5%,0.25W | 01121 | CB1615 |
| R229 | 311-1562-00 | | | RES.,VAR,NONWIR:2K OHM,20%,0.50W | 73138 | 91A-20000M |
| R231, R232 | 325-0162-00 | | | RES.,MATCHED:45K OHM/44.8K OHM,0.1%,0.125W | | |
| R233, R234 | 325-0165-00 | | | RES.,MATCHED:50 OHM/50 OHM,0.1%,0.25W | | |
| R235, R236 | 325-0164-00 | | | RES.,MATCHED:450 OHM/446 OHM,0.1%,0.25W | | |
| R238, R239 | 325-0163-00 | | | RES.,MATCHED:4.5K OHM/4.478K OHM,0.1%,0.25W | | |
| R251 | 311-1566-00 | | | RES.,VAR,NONWIR:200 OHM,20%,0.50W | 73138 | 91A-200R0M |
| R252 | 321-0297-00 | | | RES.,FXD,FILM:12.1K OHM,1%,0.125W | 75042 | CEATO-1212F |
| R253 | 321-0297-00 | | | RES.,FXD,FILM:12.1K OHM,1%,0.125W | 75042 | CEATO-1212F |
| R254 | 321-0097-00 | | | RES.,FXD,FILM:100 OHM,1%,0.125W | 75042 | CEATO-1000F |
| R255 | 316-0102-00 | | | RES.,FXD,COMP:1K OHM,10%,0.25W | 01121 | CB1021 |
| R261 | 316-0103-00 | | | RES.,FXD,COMP:10K OHM,10%,0.25W | 01121 | CB1031 |
| R262 | 311-1564-00 | | | RES.,VAR,NONWIR:500 OHM,20%,0.50W | 73138 | 91A-500R0M |
| R263 | 316-0180-00 | | | RES.,FXD,COMP:18 OHM,10%,0.25W | 01121 | CB1801 |
| R265 | 311-1568-00 | | | RES.,VAR,NONWIR:50 OHM,20%,0.50W | | |
| R267 | 311-1594-00 | | | RES.,VAR,NONWIR:10 OHM,20%,0.50W | | |
| R271 | 315-0226-00 | | | RES.,FXD,COMP:22M OHM,5%,0.25W | 01121 | CB2265 |
| R272 | 315-0335-00 | | | RES.,FXD,COMP:3.3M OHM,5%,0.25W | 01121 | CB3355 |
| R280 | 316-0332-00 | | | RES.,FXD,COMP:3.3K OHM,10%,025W | 01121 | CB3321 |
| R281 | 316-0332-00 | | | RES.,FXD,COMP:3.3K OHM,10%,025W | 01121 | CB3321 |
| R284 | 316-0152-00 | | | RES.,FXD,COMP:1.5K OHM,10%,0.25W | 01121 | CB1521 |
| R286 | 316-0152-00 | | | RES.,FXD,COMP:1.5K OHM,10%,0.25W | 01121 | CB1521 |

| Ckt No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|
| R291 | 307-0107-00 | | | RES.,FXD,COMP:5.6 OHM,5%,0.25W | 01121 | CB56G5 |
| R293 | 307-0107-00 | | | RES.,FXD,COMP:5.6 OHM,5%,0.25W | 01121 | CB56G5 |
| R295 | 307-0107-00 | | | RES.,FXD,COMP:5.6 OHM,5%,0.25W | 01121 | CB56G5 |
| R300 | 315-0201-00 | | | RES.,FXD,COMP:200 OHM,5%,0.25W | 01121 | CB2015 |
| R301 | 308-0754-00 | | | RES.,FXD,WW:5.55 OHM,0.5%,3W | | |
| R302 | 308-0720-01 | | | RES.,FXD,WW:50 OHM,0.5%,3W | | |
| R305 | 321-0756-01 | | | RES.,FXD,FILM:50K OHM,0.5%,0.125W | | |
| R306 | 302-0334-00 | | | RES.,FXD,COMP:330K OHM,10%,0.50W | 01121 | EB3341 |
| R307 | 316-0393-00 | | | RES.,FXD,COMP:39K OHM,10%,0.25W | 01121 | CB3931 |
| R309 | 315-0203-00 | | | RES.,FXD,COMP:20K OHM,5%,0.25W | 01121 | CB2035 |
| R310 | 311-1559-00 | | | RES.,VAR,NONWIR:10K OHM,20%,0.50W | 73138 | 91A-10001M |
| R311 | 321-0995-00 | | | RES.,FXD,FILM:549K OHM,1%,0.125W | | |
| R312 | 321-0995-00 | | | RES.,FXD,FILM:549K OHM,1%,0.125W | | |
| R313 | 321-0260-00 | | | RES.,FXD,FILM:4.99K OHM,1%,0.125W | 75042 | CEAT0-4991F |
| R315 | 311-1554-00 | | | RES.,VAR,NONWIR:200K OHM,20%,0.50W | 73138 | 91A-20002M |
| R316 | 316-0126-00 | | | RES.,FXD,COMP:12M OHM,10%,0.25W | 01121 | CB1261 |
| R317 | 316-0126-00 | | | RES.,FXD,COMP:12M OHM,10%,0.25W | 01121 | CB1261 |
| R318 | 315-0104-00 | | | RES.,FXD,COMP:100K OHM,5%,0.25W | 01121 | CB1045 |
| R321 | 308-0537-00 | | | RES.,FXD,WW:1K OHM,0.5%,5W | | |
| R322 | 322-0707-03 | | | RES.,FXD,FILM:100.1K OHM,0.25%,0.25W | | |
| R323 | 307-0430-00 | | | RES.,FXD,FILM:11.1M OHM,1%,0.5W | | |
| R324 | 307-0429-00 | | | RES.,FXD,FILM:100M OHM,1%,1W | | |
| R329 | 321-0991-03 | | | RES.,FXD,FILM:18K OHM,0.25%,0.125W | | |
| R331 | 321-0222-03 | | | RES.,FXD,FILM:2K OHM,0.25%,0.125W | 91637 | MFF1816D2001C |
| R333 | 315-0107-00 | | | RES.,FXD,COMP:100M OHM,5%,0.25W | 01121 | CB1075 |
| R340 | 311-1136-00 | | | RES.,VAR,NONWIR:100K OHM,30%,0.25W | | |
| R341 | 316-0225-00 | | | RES.,FXD,COMP:2.2M OHM,10%,0.25W | 01121 | CB2251 |
| R342 | 316-0222-00 | | | RES.,FXD,COMP:2.2K OHM,10%,0.25W | 01121 | CB2221 |
| R343 | 321-0414-03 | | | RES.,FXD,FILM:200K OHM,0.25%,0.125W | | |
| R344 | 321-1609-03 | | | RES.,FXD,FILM:2.02K OHM,0.25%,0.125W | | |
| R345 | 321-1610-03 | | | RES.,FXD,FILM:22.22K OHM,0.25%,0.125W | | |
| R351 | 321-0289-03 | | | RES.,FXD,FILM:10K OHM,0.25%,0.125W | 91637 | MFF1816D1002C |
| R352 | 315-0103-00 | | | RES.,FXD,COMP:10K OHM,5%,0.25W | 01121 | CB1035 |
| R361 | 321-0756-01 | | | RES.,FXD,FILM:50K OHM,0.5%,0.125W | | |
| R362 | 321-0756-01 | | | RES.,FXD,FILM:50K OHM,0.5%,0.125W | | |
| R363 | 321-0631-03 | | | RES.,FXD,FILM:12.5K OHM,0.25%,0.125W | | |
| R401 | 321-0334-00 | | | RES.,FXD,FILM:29.4K OHM,1%,0.125W | 75042 | CEAT0-2942F |
| R402 | 321-0260-00 | | | RES.,FXD,FILM:4.99K OHM,1%,0.125W | 75042 | CEAT0-4991F |
| R403 | 316-0102-00 | | | RES.,FXD,COMP:1K OHM,10%,0.25W | 01121 | CB1021 |
| R404 | 315-0303-00 | | | RES.,FXD,COMP:30K OHM,5%,0.25W | 01121 | CB3035 |
| R408 | 316-0103-00 | | | RES.,FXD,COMP:10K OHM,10%,0.25W | 01121 | CB1031 |
| R409 | 321-0287-00 | | | RES.,FXD,FILM:9.53K OHM,1%,0.125W | 75042 | CEAT0-9531F |
| R410 | 311-1558-00 | | | RES.,VAR,NONWIR:20K OHM,20%,0.50W | 73138 | 91A-20001M |
| R411 | 321-0155-00 | | | RES.,FXD,FILM:402 OHM,1%,0.125W | 75042 | CEAT0-4020F |
| R415 | 311-0555-00 | | | RES.,VAR,NONWIR:10K OHM,20% | | |
| R421 | 307-0381-00 | | | RES.,FXD,FILM:4.99M OHM,1%,0.50W | | |
| R422 | 321-0452-00 | | | RES.,FXD,FILM:499K OHM,1%,0.125W | 75042 | CEAT0-4993F |
| R423 | 321-0353-00 | | | RES.,FXD,FILM:46.4K OHM,1%,0.125W | 75042 | CEAT0-4642F |
| R424 | 321-0449-00 | | | RES.,FXD,FILM:464K OHM,1%,0.125W | 75042 | CEAT0-4643F |
| R426 | 321-0260-00 | | | RES.,FXD,FILM:4.99K OHM,1%,0.125W | 75042 | CEAT0-4991F |
| R431 | 321-0463-00 | | | RES.,FXD,FILM:649K OHM,1%,0.125W | | |
| R432 | 321-0367-00 | | | RES.,FXD,FILM:64.9K OHM,1%,0.125W | 75042 | CEAT0-6492F |
| R433 | 316-0333-00 | | | RES.,FXD,COMP:33K OHM,10%,0.25W | 01121 | CB3331 |
| R441 | 321-0196-00 | | | RES.,FXD,FILM:1.07K OHM,1%,0.125W | 75042 | CEAT0-1071F |
| R442 | 321-0284-00 | | | RES.,FXD,FILM:8.87K OHM,1%,0.125W | 75042 | CEAT0-8871F |
| R443 | 321-0160-00 | | | RES.,FXD,FILM:453 OHM,1%,0.125W | 75042 | CEAT0-4530F |
| R444 | 321-0188-00 | | | RES.,FXD,FILM:887 OHM,1%,0.125W | 75042 | CEAT0-8870F |
| R445 | 321-0197-00 | | | RES.,FXD,FILM:1.1K OHM,1%,0.125W | 75042 | CEAT0-1101F |
| R446 | 321-0612-00 | | | RES.,FXD,FILM:500 OHM,1%,0.125W | 91637 | MFF1816D5000F |
| R447 | 321-0263-00 | | | RES.,FXD,FILM:5.36K OHM,1%,0.125W | 75042 | CEAT0-5361F |

| Ckt No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|
| R448 | 321-0320-00 | | | RES.,FXD,FILM:21K OHM,1%,0.125W | 75042 | CEAT0-2102F |
| R449 | 321-0370-00 | | | RES.,FXD,FILM:69.8K OHM,1%,0.125W | 75042 | CEAT0-6982F |
| R451 | 321-0284-00 | | | RES.,FXD,FILM:8.87K OHM,1%,0.125W | 75042 | CEAT0-8871F |
| R452 | 321-0196-00 | | | RES.,FXD,FILM:1.07K OHM,1%,0.125W | 75042 | CEAT0-1071F |
| R453 | 321-0160-00 | | | RES.,FXD,FILM:453 OHM,1%,0.125W | 75042 | CEAT0-4530F |
| R454 | 321-0188-00 | | | RES.,FXD,FILM:887 OHM,1%,0.125W | 75042 | CEAT0-8870F |
| R455 | 321-0197-00 | | | RES.,FXD,FILM:1.1K OHM,1%,0.125W | 75042 | CEAT0-1101F |
| R460[1] | 311-1310-00 | | | RES.,VAR,NONWIR:20K OHM,20%,1W | | |
| R461 | 315-0514-00 | | | RES.,FXD,COMP:510K OHM,5%,0.25W | 01121 | CB5145 |
| R463 | 321-0289-00 | | | RES.,FXD,FILM:10K OHM,1%,0.125W | 75042 | CEAT0-1002F |
| R464 | 321-0306-00 | | | RES.,FXD,FILM:15K OHM,1%,0.125W | 75042 | CEAT0-1502F |
| R467 | 321-0289-00 | | | RES.,FXD,FILM:10K OHM,1%,0.125W | 75042 | CEAT0-1002F |
| R468 | 321-0268-00 | | | RES.,FXD,FILM:6.04K OHM,1%,0.125W | 75042 | CEAT0-6041F |
| R469 | 315-0512-00 | | | RES.,FXD,COMP:5.1K OHM,5%,0.25W | 01121 | CB5125 |
| R471 | 315-0104-00 | | | RES.,FXD,COMP:100K OHM,5%,0.25W | 01121 | CB1045 |
| R472 | 315-0512-00 | | | RES.,FXD,COMP:5.1K OHM,5%,0.25W | 01121 | CB5125 |
| R473 | 308-0291-00 | | | RES.,FXD,WW:2K OHM,5%,3W | | |
| R474 | 316-0822-00 | | | RES.,FXD,COMP:8.2K OHM,10%,0.25W | 01121 | CB8221 |
| R475 | 315-0510-00 | | | RES.,FXD,COMP:51 OHM,5%,0.25W | 01121 | CB5105 |
| R476 | 315-0511-00 | | | RES.,FXD,COMP:510 OHM,5%,0.25W | 01121 | CB5115 |
| R477 | 315-0510-00 | | | RES.,FXD,COMP:51 OHM,5%,0.25W | 01121 | CB5105 |
| R478 | 315-0512-00 | | | RES.,FXD,COMP:5.1K OHM,5%,0.25W | 01121 | CB5125 |
| R479 | 301-0111-00 | | | RES.,FXD,COMP:110 OHM,5%,0.50W | 01121 | EB1115 |
| R481 | 321-0756-03 | | | RES.,FXD,FILM:50K OHM,0.25%,0.125W | 75042 | CEAT2-5002C |
| R482 | 315-0512-00 | | | RES.,FXD,COMP:5.1K OHM,5%,0.25W | 01121 | CB5125 |
| R483 | 315-0150-00 | | | RES.,FXD,COMP:15 OHM,5%,0.25W | 01121 | CB1505 |
| R484 | 315-0201-00 | | | RES.,FXD,COMP:200 OHM,5%,0.25W | 01121 | CB2015 |
| R485 | 315-0101-00 | | | RES.,FXD,COMP:100 OHM,5%,0.25W | 01121 | CB1015 |
| R486 | 308-0764-00 | | | RES.,FXD,WW:2.7 OHM,5%,2W | | |
| R492 | 316-0123-00 | | | RES.,FXD,COMP:12K OHM,10%,0.25W | 01121 | CB1231 |
| R521 | 316-0106-00 | | | RES.,FXD,COMP:10M OHM,10%,0.25W | 01121 | CB1061 |
| R522 | 316-0222-00 | | | RES.,FXD,COMP:2.2K OHM,10%,0.25W | 01121 | CB2221 |
| R526 | 316-0224-00 | | | RES.,FXD,COMP:220K OHM,10%,0.25W | 01121 | CB2241 |
| R527 | 321-0356-00 | | | RES.,FXD,FILM:49.9K OHM,1%,0.125W | 75042 | CEAT0-4992F |
| R531 | 316-0473-00 | | | RES.,FXD,COMP:47K OHM,10%,0.25W | 01121 | CB4731 |
| R533 | 316-0473-00 | | | RES.,FXD,COMP:47K OHM,10%,0.25W | 01121 | CB4731 |
| R535 | 315-0152-00 | | | RES.,FXD,COMP:1.5K OHM,5%,0.25W | 01121 | CB1525 |
| R536 | 315-0101-00 | | | RES.,FXD,COMP:100 OHM,5%,0.25W | 01121 | CB1015 |
| R537 | 315-0101-00 | | | RES.,FXD,COMP:100 OHM,5%,0.25W | 01121 | CB1015 |
| R538 | 315-0152-00 | | | RES.,FXD,COMP:1.5K OHM,5%,0.25W | 01121 | CB1525 |
| R541 | 315-0242-00 | | | RES.,FXD,COMP:2.4 OHM,5%,0.25W | 01121 | CB2425 |
| R542 | 315-0243-00 | | | RES.,FXD,COMP:24K OHM,5%,0.25W | 01121 | CB2435 |
| R546 | 315-0201-00 | | | RES.,FXD,COMP:200 OHM,5%,0.25W | 01121 | CB2015 |
| R548 | 315-0201-00 | | | RES.,FXD,COMP:200 OHM,5%,0.25W | 01121 | CB2015 |
| R549 | 321-0452-00 | | | RES.,FXD,FILM:499K OHM,1%,0.125W | 75042 | CEAT0-4993F |
| R551 | 321-0356-00 | | | RES.,FXD,FILM:49.9K OHM,1%,0.125W | 75042 | CEAT0-4992F |
| R552 | 321-0631-00 | | | RES.,FXD,FILM:12.5K OHM,1%,0.125W | 75042 | CEAT0-1252F |
| R554 | 321-0289-00 | | | RES.,FXD,FILM:10K OHM,1%,0.125W | 75042 | CEAT0-1002F |
| R560 | 311-1150-00 | | | RES.,VAR,WW:10K OHM,5% | | |
| R562 | 311-1559-00 | | | RES.,VAR,NONWIR:10K OHM,20%,0.50W | 73138 | 91A-10001M |
| R563 | 321-0354-00 | | | RES.,FXD,FILM:47.5K OHM,1%,0.125W | 75042 | CEAT0-4752F |
| R565[2] | 311-1518-00 | | | RES.,VAR,NONWIR:10K OHM,20%,1W | | |
| R566 | 321-0198-00 | | | RES.,FXD,FILM:1.13K OHM,1%,0.125W | 75042 | CEAT0-1131F |
| R567 | 321-0260-00 | | | RES.,FXD,FILM:4.99K OHM,1%,0.125W | 75042 | CEAT0-4991F |
| R570 | 321-0364-00 | | | RES.,FXD,FILM:60.4K OHM,1%,0.125W | 75042 | CEAT0-6042F |
| R571 | 321-0289-00 | | | RES.,FXD,FILM:10K OHM,1%,0.125W | 75042 | CEAT0-1002F |
| R572 | 315-0512-00 | | | RES.,FXD,COMP:5.1K OHM,5%,0.25W | 01121 | CB5125 |
| R573 | 308-0291-00 | | | RES.,FXD,WW:2K OHM,5%,3W | | |
| R574 | 321-0289-03 | | | RES.,FXD,FILM:10K OHM,0.25%,0.125W | 91637 | MFF1816D1002C |
| R575 | 315-0510-00 | | | RES.,FXD,COMP:51 OHM,5%,0.25W | 01121 | CB5105 |

[1]Furnished as a unit with S460.
[2]Furnished as a unit with S565.

| Ckt No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|
| R576 | 315-0511-00 | | | RES.,FXD,COMP:510 OHM,5%,0.25W | 01121 | CB5115 |
| R577 | 315-0510-00 | | | RES.,FXD,COMP:51 OHM,5%,0.25W | 01121 | CB5105 |
| R578 | 315-0512-00 | | | RES.,FXD,COMP:5.1K OHM,5%,0.25W | 01121 | CB5125 |
| R579 | 301-0111-00 | | | RES.,FXD,COMP:110 OHM,5%,0.50W | 01121 | EB1115 |
| R581 | 321-0720-03 | | | RES.,FXD,FILM:60K OHM,0.25%,0.125W | 91637 | MFF1816D6002C |
| R582 | 315-0512-00 | | | RES.,FXD,COMP:5.1K OHM,5%,0.25W | 01121 | CB5125 |
| R583 | 315-0150-00 | | | RES.,FXD,COMP:15 OHM,5%,0.25W | 01121 | CB1505 |
| R584 | 315-0201-00 | | | RES.,FXD,COMP:200 OHM,5%,0.25W | 01121 | CB2015 |
| R585 | 315-0101-00 | | | RES.,FXD,COMP:100 OHM,5%,0.25W | 01121 | CB1015 |
| R586 | 308-0764-00 | | | RES.,FXD,WW:2.7 OHM,5%,2W | | |
| R592 | 316-0123-00 | | | RES.,FXD,COMP:12K OHM,10%,0.25W | 01121 | CB1231 |
| S30 | 260-1641-00 | | | SWITCH,SLIDE: | | |
| S120 | 263-1027-00 | | | ACTR ASSY,CAM S:LOAD | 80009 | 263-1027-00 |
| S130 | 263-1026-00 | | | ACTR ASSY,CAM S:SOURCE | 80009 | 105-0467-00 |
| S140 | 105-0467-00 | | | ACTR ASSY,SLIDE S:DUT SUPPLIES | 80009 | 263-1028-00 |
| S200A,B | 260-1310-00 | | | SWITCH,PUSH:DISPLAY | | |
| S300 | 263-1025-00 | | | ACTR ASSY,CAM S:FUNCTION | 80009 | 263-1025-00 |
| S350 | 263-1024-00 | | | ACTR ASSY,CAM S:VERTICAL UNITS/DIV | 80009 | 263-1024-00 |
| S420 | 260-1529-00 | | | SWITCH,ROTARY:SWEEP FREQUENCY | | |
| S441 | 260-0247-00 | | | SWITCH,PUSH:SPST,CS ENABLE | 81073 | 30YY1009 |
| S460[1] | | | | :MANUAL SWEEP | | |
| S565[2] | | | | :TRACK SUPPLY | | |
| U16 | 156-0067-00 | | | INTEGRATED CKT:OPERATIONAL AMPLIFIER | 07263 | UA741 |
| U250 | 156-0400-00 | | | INTEGRATED CKT:OPERATIONAL AMPLIFIER | | |
| U340 | 156-0158-00 | | | INTEGRATED CKT:DUAL OPERATIONAL AMPLIFIER | 18324 | S5558V |
| U350 | 156-0158-00 | | | INTEGRATED CKT:DUAL OPERATIONAL AMPLIFIER | 18324 | S5558V |
| U424 | 156-0200-00 | | | INTEGRATED CKT:LOW INPUT/OFFSET CURRENT | 18324 | N5556V |
| U432 | 156-0158-00 | | | INTEGRATED CKT:DUAL OPERATIONAL AMPLIFIER | 18324 | S5558V |
| U460 | 156-0158-00 | | | INTEGRATED CKT:DUAL OPERATIONAL AMPLIFIER | 18324 | S5558V |
| U476 | 156-0400-00 | | | INTEGRATED CKT:OPERATIONAL AMPLIFIER | | |
| U540 | 156-0067-00 | | | INTEGRATED CKT:OPERATIONAL AMPLIFIER | 07263 | UA741 |
| U576 | 156-0400-00 | | | INTEGRATED CKT:OPERATIONAL AMPLIFIER | | |
| VR121 | 152-0243-00 | | | SEMICOND DEVICE:ZENER,0.4W,15V,5% | 81483 | 1N965B |
| VR238 | 152-0278-00 | | | SEMICOND DEVICE:ZENER,0.4W,7.5V,5% | 07910 | 1N4372A |
| VR239 | 152-0278-00 | | | SEMICOND DEVICE:ZENER,0.4W,7.5V,5% | 07910 | 1N4372A |
| VR268 | 152-0278-00 | | | SEMICOND DEVICE:ZENER,0.4W,7.5V,5% | 07910 | 1N4372A |
| VR269 | 152-0278-00 | | | SEMICOND DEVICE:ZENER,0.4W,7.5V,5% | 07910 | 1N4372A |
| VR281 | 152-0508-00 | | | SEMICOND DEVICE:ZENER,0.4W,12.5V,5% | 80009 | 152-0508-00 |
| VR472 | 152-0280-00 | | | SEMICOND DEVICE:ZENER,0.4W,6.2V,5% | 04713 | 1N753A |
| VR572 | 152-0280-00 | | | SEMICOND DEVICE:ZENER,0.4W,6.2V,5% | 04713 | 1N753A |

[1]Furnished as a unit with R460.
[2]Furnished as a unit with R565.

# DIAGRAMS AND CIRCUIT BOARD ILLUSTRATIONS

## Symbols and Reference Designators

Electrical components shown on the diagrams are in the following units unless noted otherwise:

Capacitors = Values one or greater are in picofarads (pF).
Values less than one are in microfarads (μF).

Resistors = Ohms (Ω).

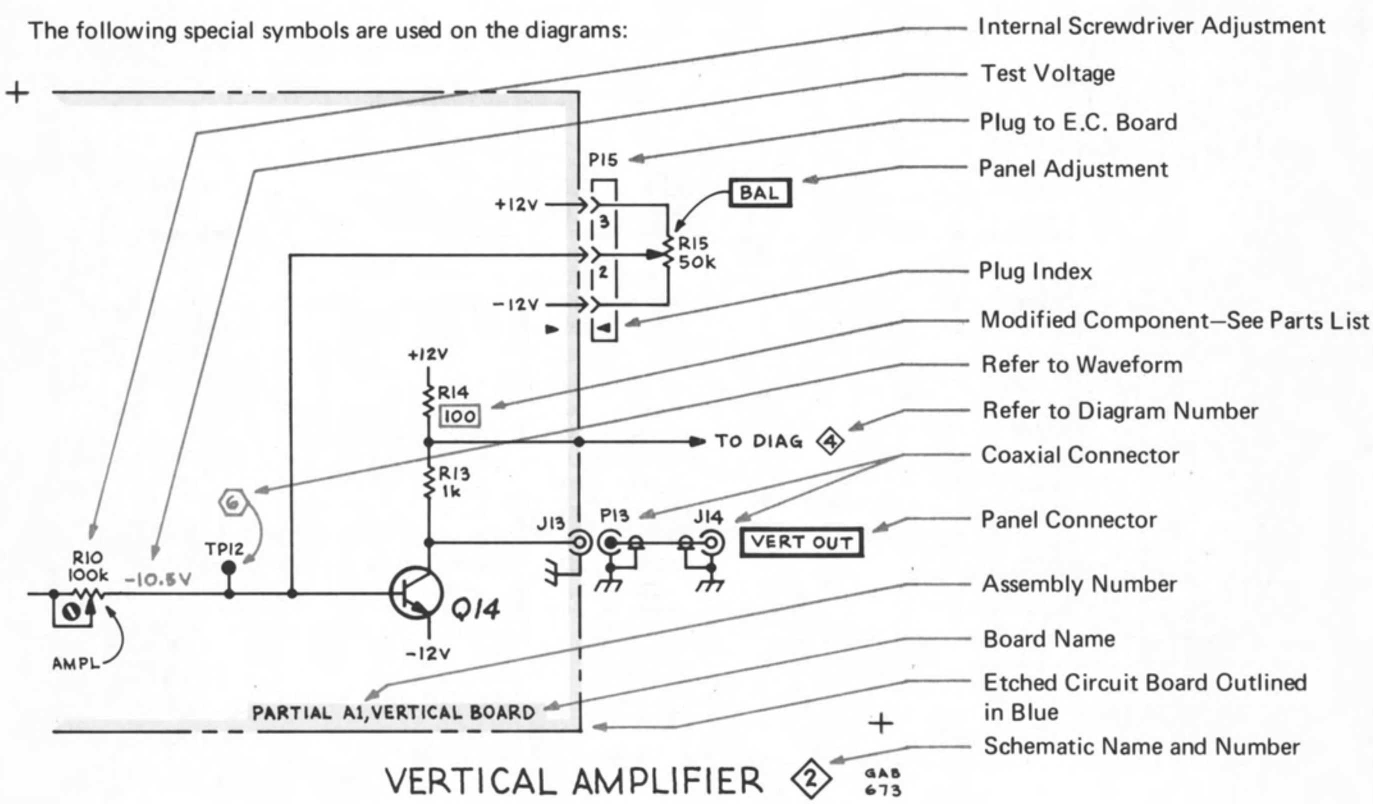
Symbols used on the diagrams are based on USA Standard Y32.2-1967.

Logic symbology is based on MIL-STD-806B in terms of positive logic. Logic symbols depict the logic function performed and may differ from the manufacturer's data.

The following prefix letters are used as reference designators to identify components or assemblies on the diagrams.

| | |
|---|---|
| A | Assembly, separable or repairable (circuit board, etc.) |
| AT | Attenuator, fixed or variable |
| B | Motor |
| BT | Battery |
| C | Capacitor, fixed or variable |
| CB | Circuit breaker |
| CR | Diode, signal or rectifier |
| DL | Delay line |
| DS | Indicating device (lamp) |
| E | Spark Gap |
| F | Fuse |
| FL | Filter |
| H | Heat dissipating device (heat sink, heat radiator, etc.) |
| HR | Heater |
| HY | Hybrid circuit |
| J | Connector, stationary portion |
| K | Relay |
| L | Inductor, fixed or variable |
| LR | Inductor/resistor combination |
| M | Meter |
| P | Connector, movable portion |
| Q | Transistor or silicon-controlled rectifier |
| R | Resistor, fixed or variable |
| RT | Thermistor |
| S | Switch |
| T | Transformer |
| TC | Thermocouple |
| TP | Test point |
| U | Assembly, inseparable or non-repairable (integrated circuit, etc.) |
| V | Electron tube |
| VR | Voltage regulator (zener diode, etc.) |
| Y | Crystal |
| Z | Phase shifter |

The following special symbols are used on the diagrams:



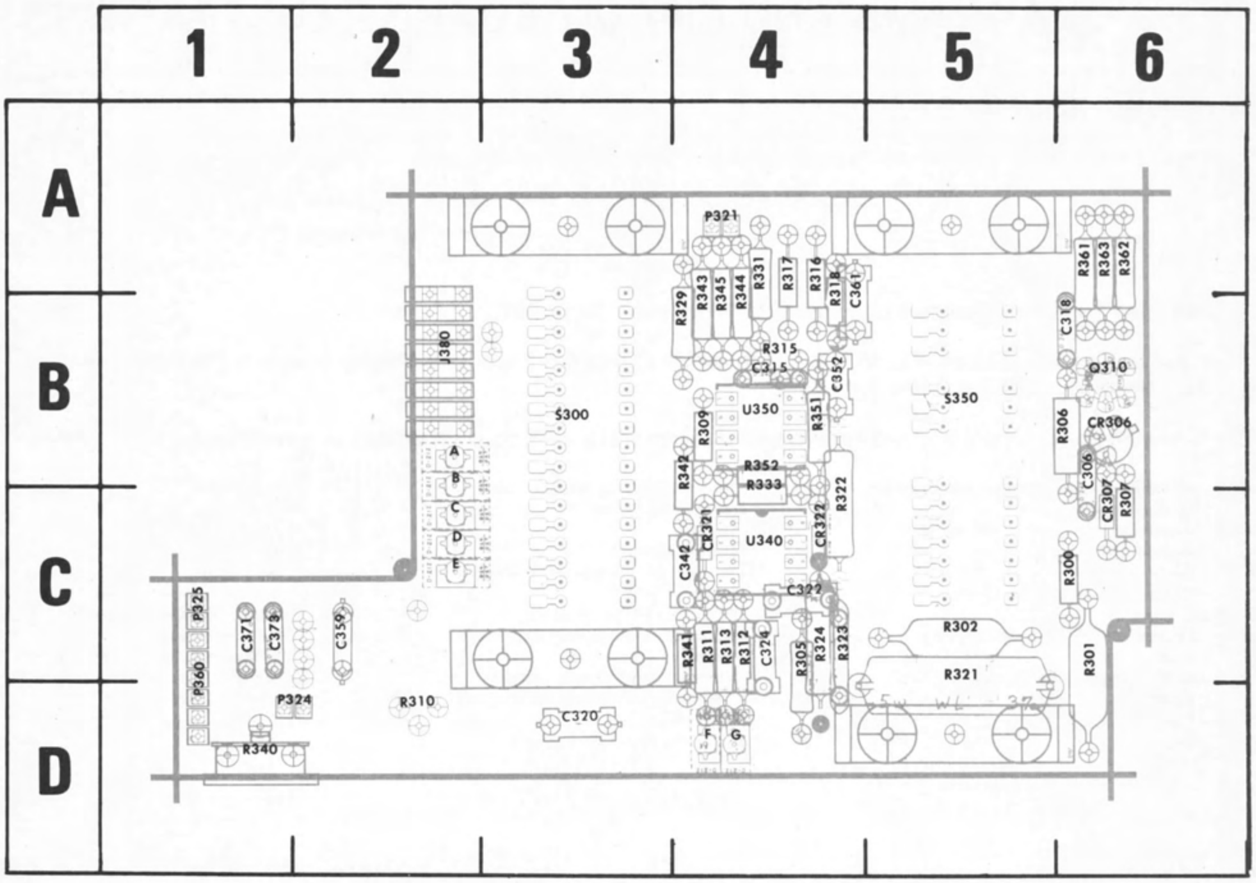



Fig. 7-1. A2—Vertical Preamp circuit board.

| CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC |
|---|---|---|---|---|---|---|---|---|---|
| C306 | 6B | CR306 | 6B | R300 | 6C | R317 | 4A | R344 | 4A |
| C315 | 4B | CR307 | 6C | R301 | 6C | R318 | 4A | R345 | 4A |
| C318 | 6B | CR321 | 4C | R302 | 5C | R321 | 5C | R351 | 4B |
| C322 | 4C | CR322 | 4C | R305 | 4C | R322 | 4C | R352 | 4B |
| C320 | 3D | | | R306 | 6B | R323 | 4C | R361 | 6A |
| C324 | 4C | J380 | 2B | R307 | 6C | R324 | 4C | R363 | 6A |
| C342 | 4C | | | R309 | 4B | R329 | 4B | | |
| C352 | 4B | P321 | 4A | R310 | 2D | R331 | 4A | S300 | 3B |
| C359 | 2C | P324 | 1D | R311 | 4C | R333 | 4B | S350 | 5B |
| C361 | 4A | P325 | 1C | R312 | 4C | R340 | 1D | | |
| C371 | 1C | P360 | 1C | R313 | 4C | R341 | 4C | U340 | 4C |
| C373 | 1C | | | R315 | 4B | R342 | 4B | U350 | 4B |
| | | Q310 | 6B | R316 | 4A | R343 | 4A | | |

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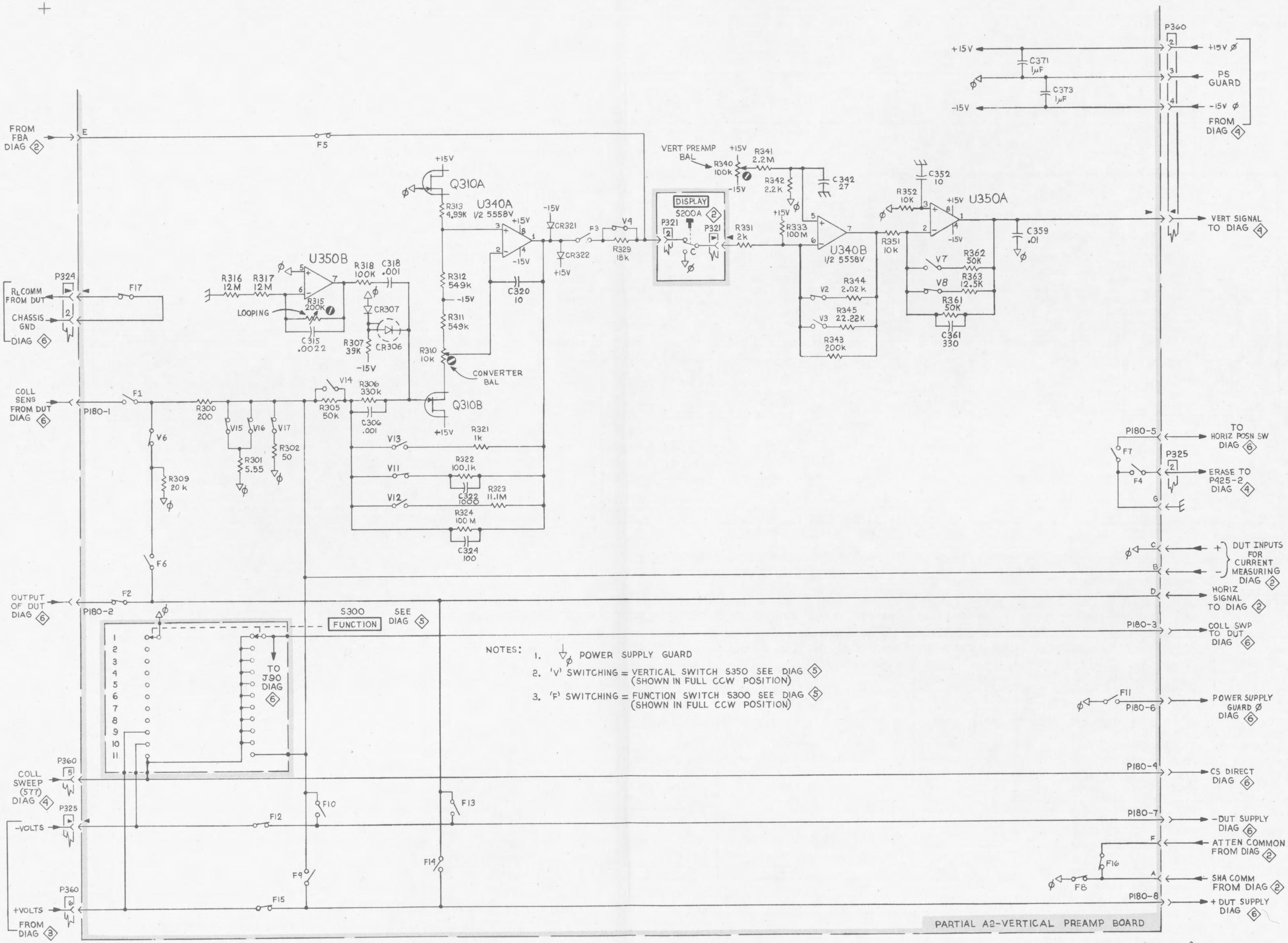


17B LINEAR IC TEST FIXTURE

VERTICAL PREAMP ①

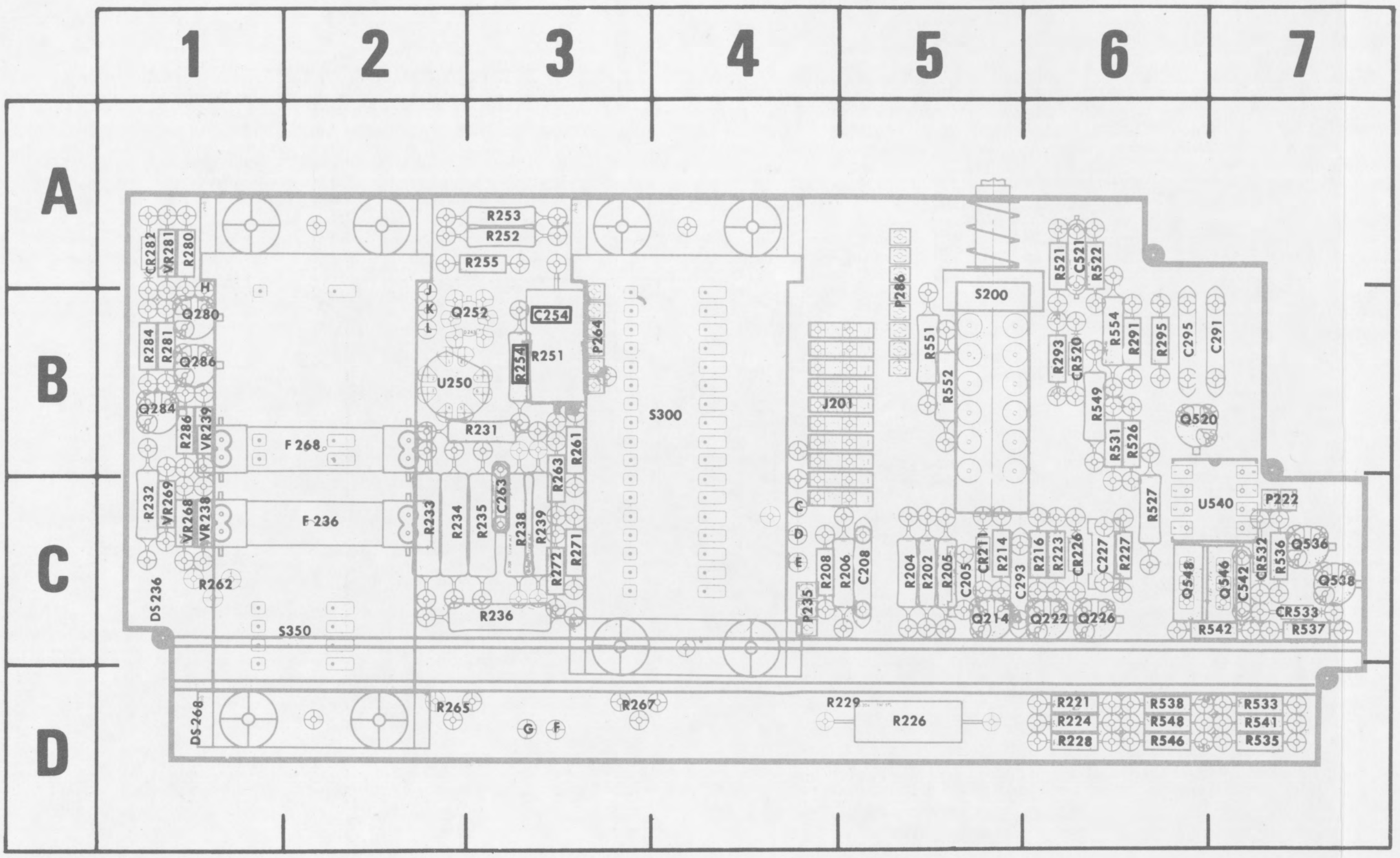


Fig. 7-2. A3—Feedback Amplifier circuit board.

| CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C205 | 5C | DS236 | 1C | Q280 | 1B | R223 | 6C | R254 | 3B | R522 | 6A | S200 | 5B |
| C208 | 5C | DS268 | 1D | Q284 | 1B | R224 | 6D | R255 | 3A | R525 | 5B | S300 | 4B |
| C227 | 6C | | | Q286 | 1B | R226 | 5D | R261 | 3B | R526 | 6B | S350 | 2C |
| C254 | 3B | F236 | 2C | Q520 | 6B | R227 | 6C | R262 | 1C | R527 | 6C | | |
| C263 | 3C | F268 | 2B | Q536 | 7C | R228 | 6D | R263 | 3B | R531 | 6B | U250 | 2B |
| C291 | 7B | | | Q538 | 7C | R229 | 5D | R265 | 2D | R533 | 7D | U540 | 7C |
| C293 | 5C | J201 | 5B | Q546 | 7C | R231 | 3B | R267 | 3D | R535 | 7D | | |
| C295 | 6B | | | Q548 | 6C | R232 | 1C | R271 | 3C | R536 | 7C | VR238 | 1C |
| C521 | 6A | P222 | 7C | | | R233 | 2C | R272 | 3C | R537 | 7C | VR239 | 1B |
| C542 | 7C | P235 | 4C | R202 | 5C | R234 | 2C | R280 | 1A | R538 | 6D | VR268 | 1C |
| | | P264 | 3B | R204 | 5C | R235 | 3C | R281 | 1B | R541 | 7D | VR269 | 1C |
| CR211 | 5C | P286 | 5B | R205 | 5C | R236 | 3C | R284 | 1B | R542 | 7C | VR281 | 1A |
| CR226 | 6C | | | R206 | 5C | R238 | 3C | R286 | 1B | R546 | 6D | | |
| CR250 | 6B | Q214 | 5C | R208 | 4C | R239 | 3C | R291 | 6B | R548 | 6D | | |
| CR282 | 1A | Q222 | 6C | R214 | 5C | R251 | 3B | R293 | 6B | R549 | 6B | | |
| CR532 | 7C | Q226 | 6C | R216 | 6C | R252 | 3A | R295 | 6B | R551 | 5B | | |
| CR533 | 7C | Q252 | 3B | R221 | 6D | R253 | 3A | R521 | 6A | R554 | 6B | | |

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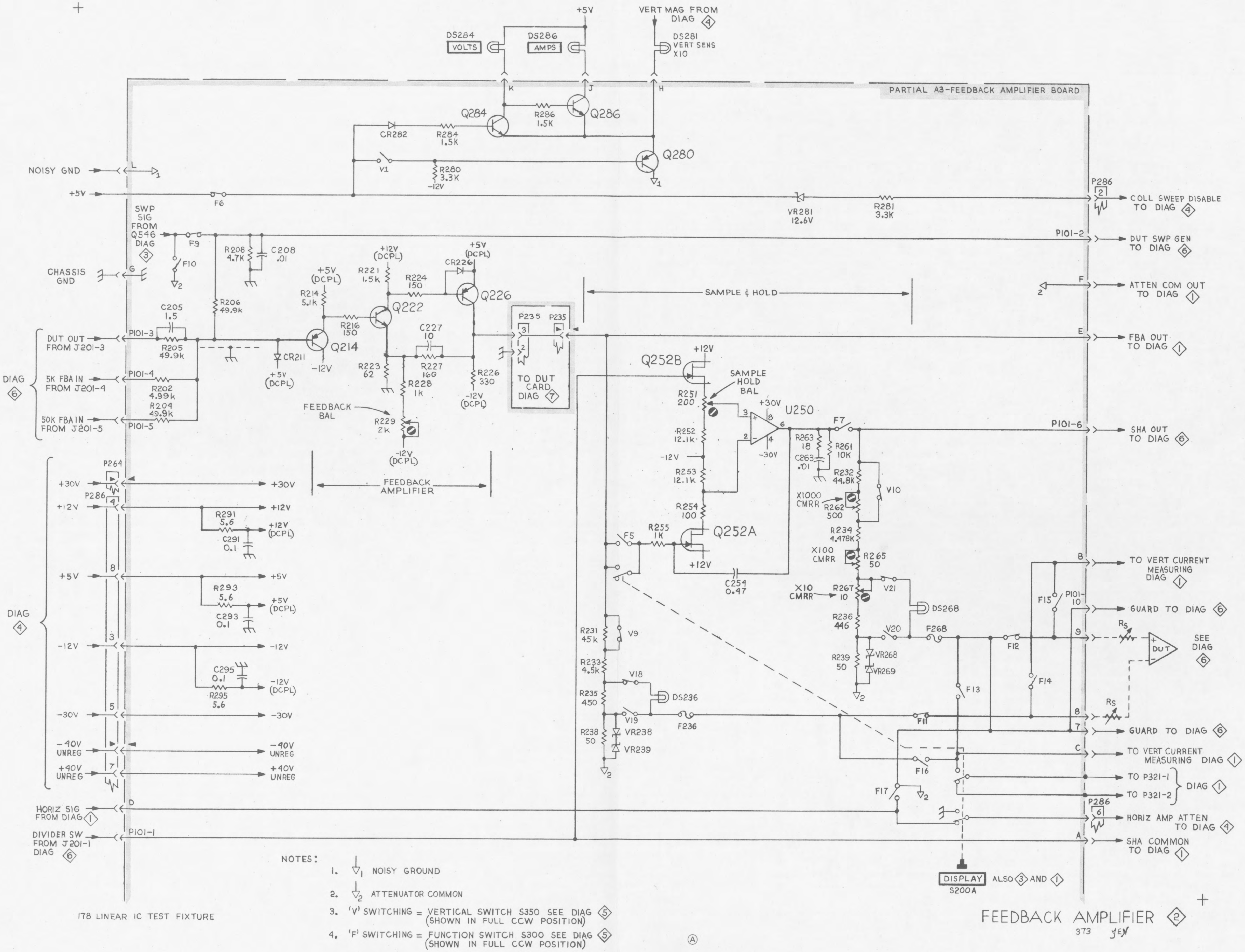


178 LINEAR IC TEST FIXTURE

# FEEDBACK AMPLIFIER ②

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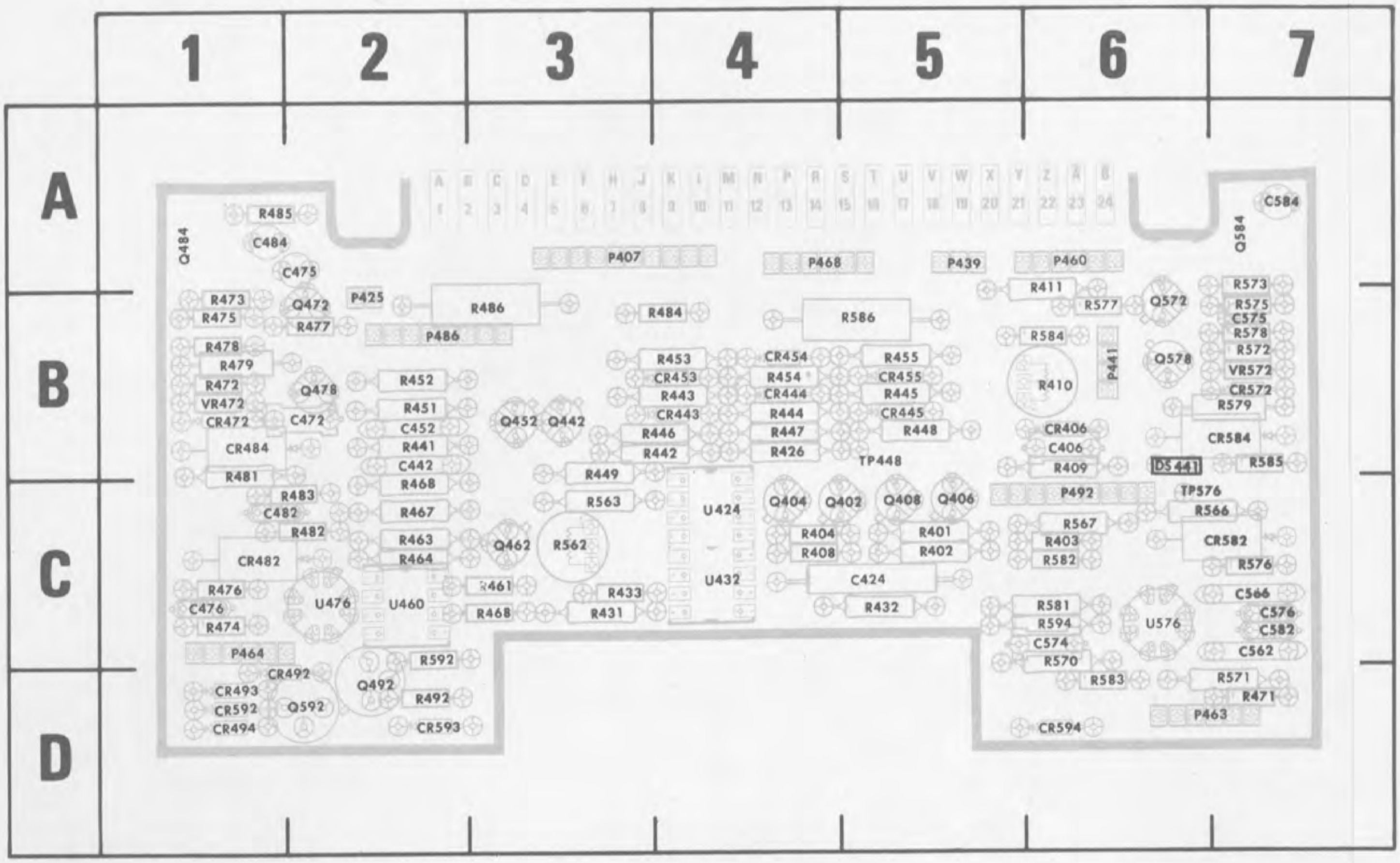


Fig. 7-3. A4—Power Supply circuit board.

| CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC | CKT NO | GRID LOC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C406 | 6B | CR454 | 4B | P463 | 6D | R401 | 5C | R452 | 2B | R484 | 4B | R587 | 5B |
| C424 | 5C | CR455 | 5B | P464 | 1C | R402 | 5C | R453 | 4B | R485 | 1A | R592 | 2C |
| C442 | 2B | CR472 | 1B | P468 | 4A | R403 | 6C | R454 | 4B | R486 | 3B | R594 | 6C |
| C452 | 2B | CR482 | 1C | P486 | 2B | R404 | 4C | R455 | 5B | R492 | 2D | | |
| C472 | 2B | CR484 | 1B | P492 | 6C | R408 | 4C | R461 | 3C | R562 | 3C | TP448 | 5B |
| C475 | 2A | CR492 | 2D | | | R409 | 6B | R463 | 2C | R563 | 3C | TP576 | 6C |
| C476 | 1C | CR494 | 1D | Q402 | 5C | R410 | 6B | R464 | 2C | R566 | 7C | | |
| C482 | 1C | CR572 | 7B | Q404 | 4C | R411 | 6A | R467 | 2C | R567 | 6C | U424 | 4C |
| C484 | 1A | CR582 | 7C | Q406 | 5C | R426 | 4B | R468 | 3C | R570 | 6C | U432 | 4C |
| C562 | 7C | CR584 | 7B | Q408 | 5C | R431 | 3C | R468 | 2C | R571 | 7D | U460 | 2C |
| C566 | 7C | CR593 | 2D | Q442 | 3B | R432 | 5C | R471 | 7D | R572 | 7B | U476 | 2C |
| C574 | 6C | CR592 | 1D | Q452 | 3B | R433 | 3C | R472 | 1B | R573 | 7A | U576 | 6C |
| C575 | 7B | CR493 | 1D | Q462 | 3C | R441 | 2B | R473 | 1B | R575 | 7B | | |
| C576 | 7C | CR594 | 6D | Q472 | 2B | R442 | 4B | R474 | 1C | R576 | 7C | VR472 | 1B |
| C582 | 7C | | | Q478 | 2B | R443 | 4B | R475 | 1B | R577 | 6B | VR572 | 7B |
| C584 | 7A | DS441 | 6B | Q484 | 1A | R444 | 4B | R476 | 1C | R578 | 7B | | |
| | | | | Q492 | 2D | R445 | 5B | R477 | 2B | R579 | 7B | | |
| CR406 | 6B | P407 | 3A | Q572 | 6B | R446 | 4B | R478 | 1B | R581 | 6C | | |
| CR443 | 4B | P425 | 2B | Q578 | 6B | R447 | 4B | R479 | 1B | R582 | 6C | | |
| CR444 | 4B | P439 | 5A | Q584 | 7A | R448 | 5B | R481 | 1B | R583 | 6D | | |
| CR445 | 5B | P441 | 6B | Q592 | 2D | R449 | 3B | R482 | 2C | R584 | 6B | | |
| CR453 | 4B | P460 | 6A | | | R451 | 2B | R483 | 2C | R585 | 7B | | |

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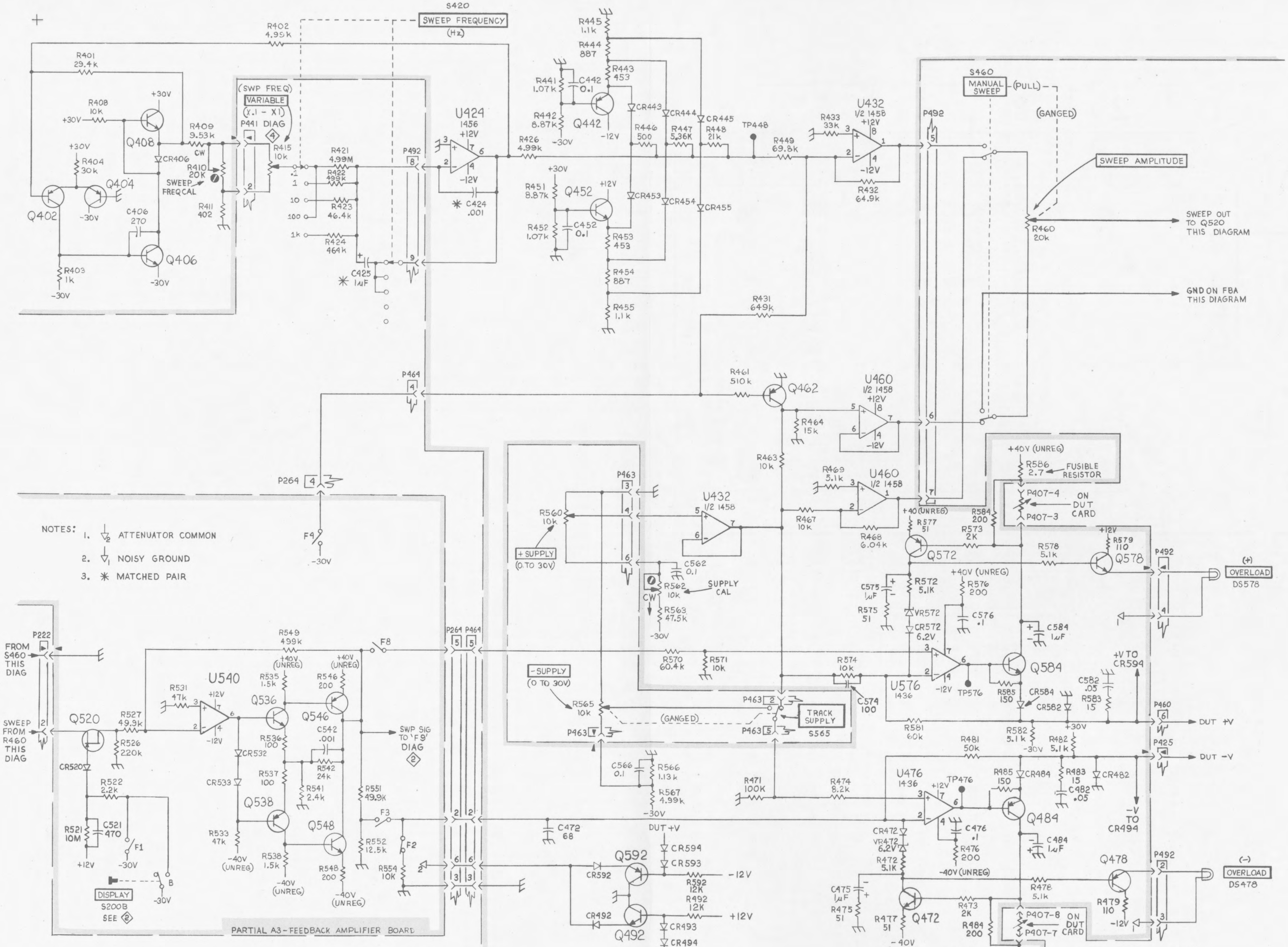
ASSEMBLY A4




178 LINEAR IC TEST FIXTURE

POWER SUPPLY 3

473 JEN

A

POWER SUPPLY

3

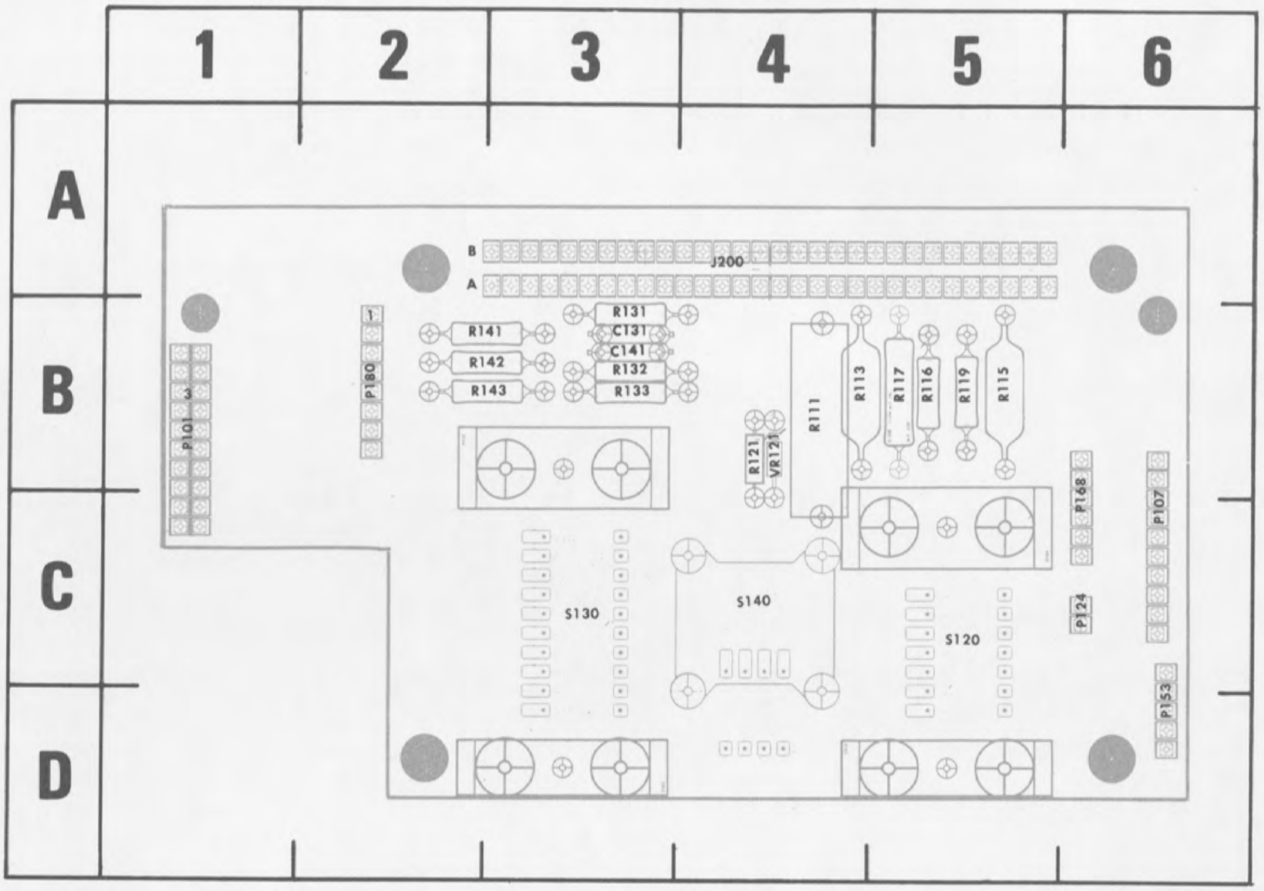



Fig. 7-4. A1—Interface circuit board.

| CKT NO | GRID LOC | CKT NO | GRID LOC |
|---|---|---|---|
| C131 | 3B | R115 | 5B |
| C141 | 3B | R119 | 5B |
| | | R121 | 4B |
| J200 | 4A | R131 | 3B |
| | | R132 | 3B |
| P101 | 1B | R133 | 3B |
| P107 | 6C | R141 | 2B |
| P124 | 6C | R142 | 2B |
| P153 | 6D | R143 | 2B |
| P168 | 6C | | |
| P180 | 2B | S120 | 5C |
| | | S130 | 3C |
| R111 | 4B | S140 | 4C |
| R113 | 4B | | |
| R116 | 5B | VR121 | 4B |
| R117 | 5B | | |

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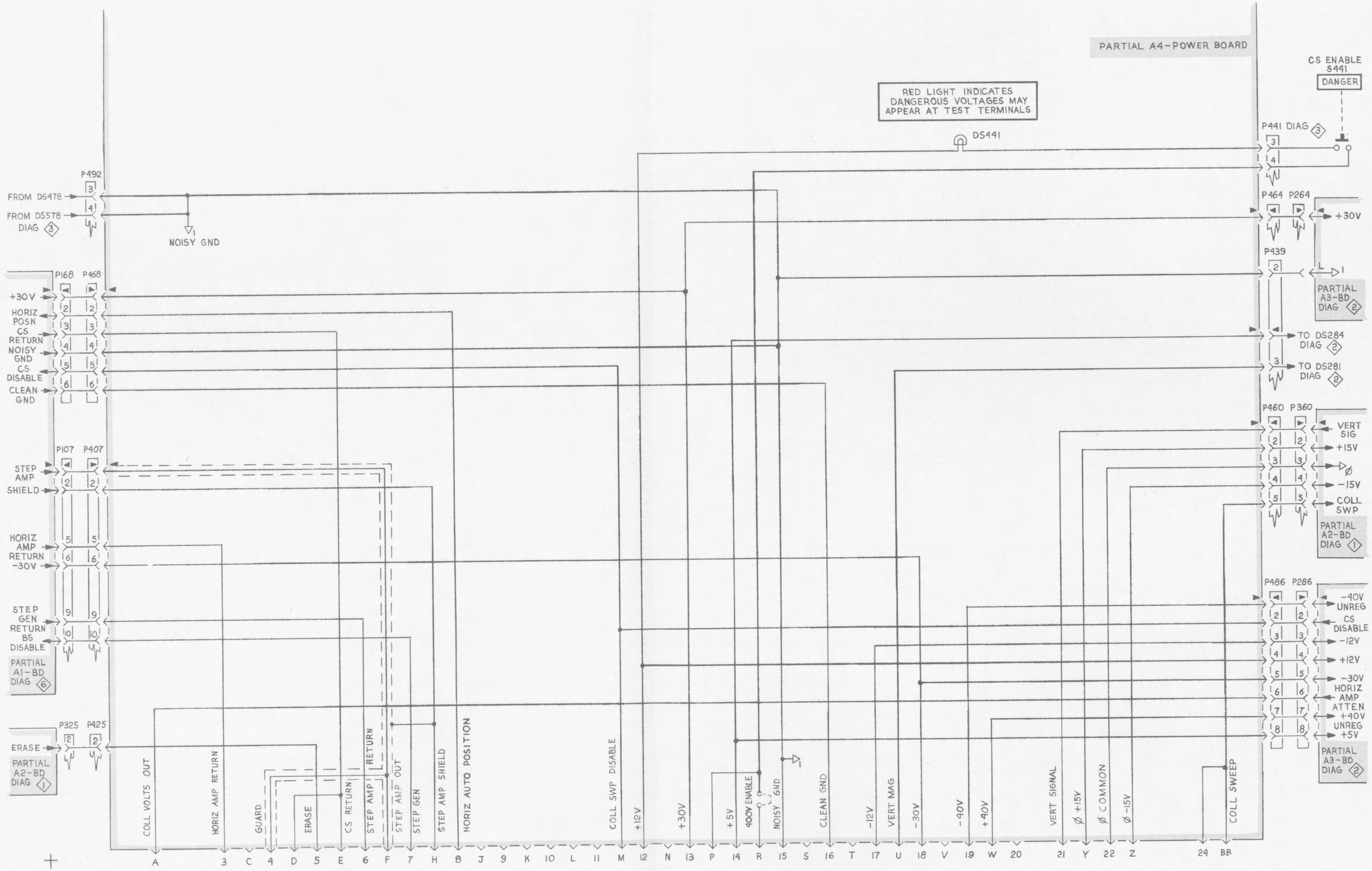
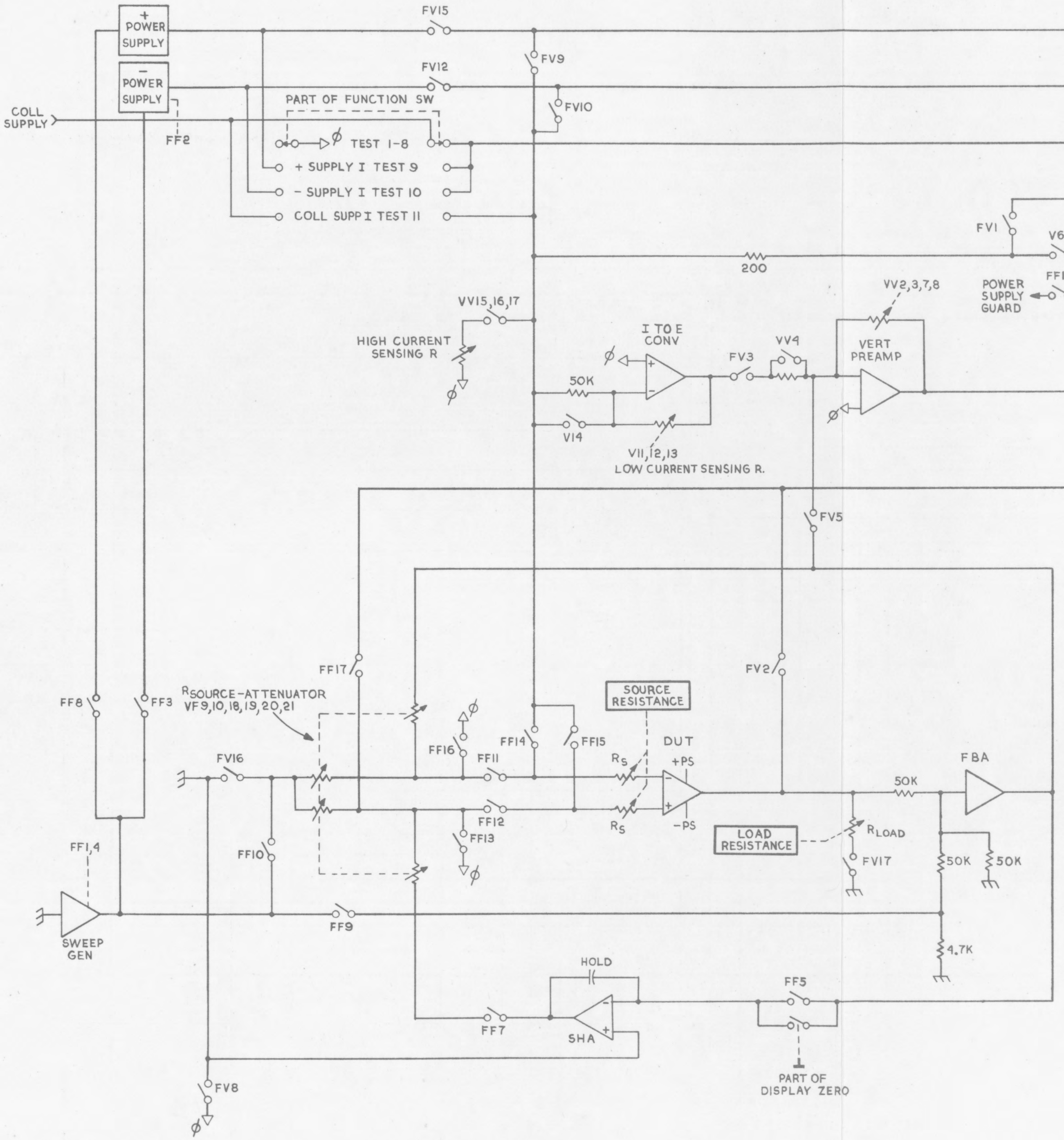
ASSEMBLY A1







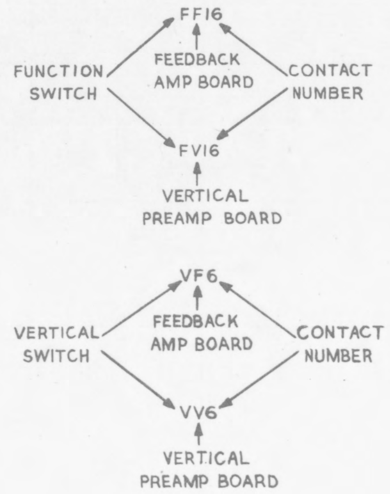

INTERCONNECTING DIAGRAM 4




NOTES:

Ø - FLOATING COMMON
DUT - DEVICE UNDER TEST
FBA - FEEDBACK AMPLIFIER
SHA - SAMPLE & HOLD AMPLIFIER
I TO E CONV - CURRENT TO VOLTAGE CONVERTER

CAM SWITCH CONTACT IDENTIFICATION EXAMPLES




USE WITH FUNCTION/VERTICAL SWICHING DIAGRAM →

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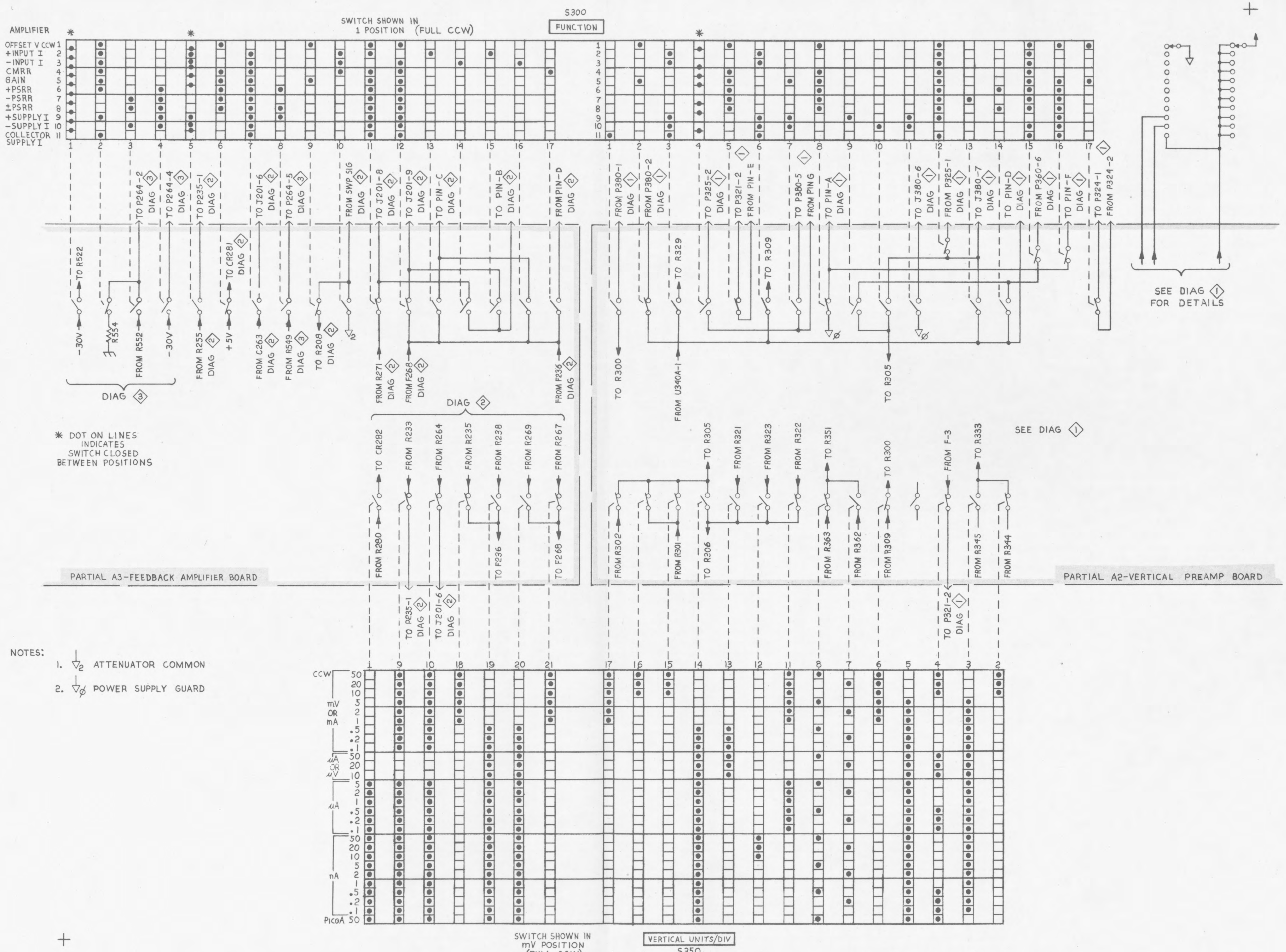
178 LINEAR TEST FIXTURE

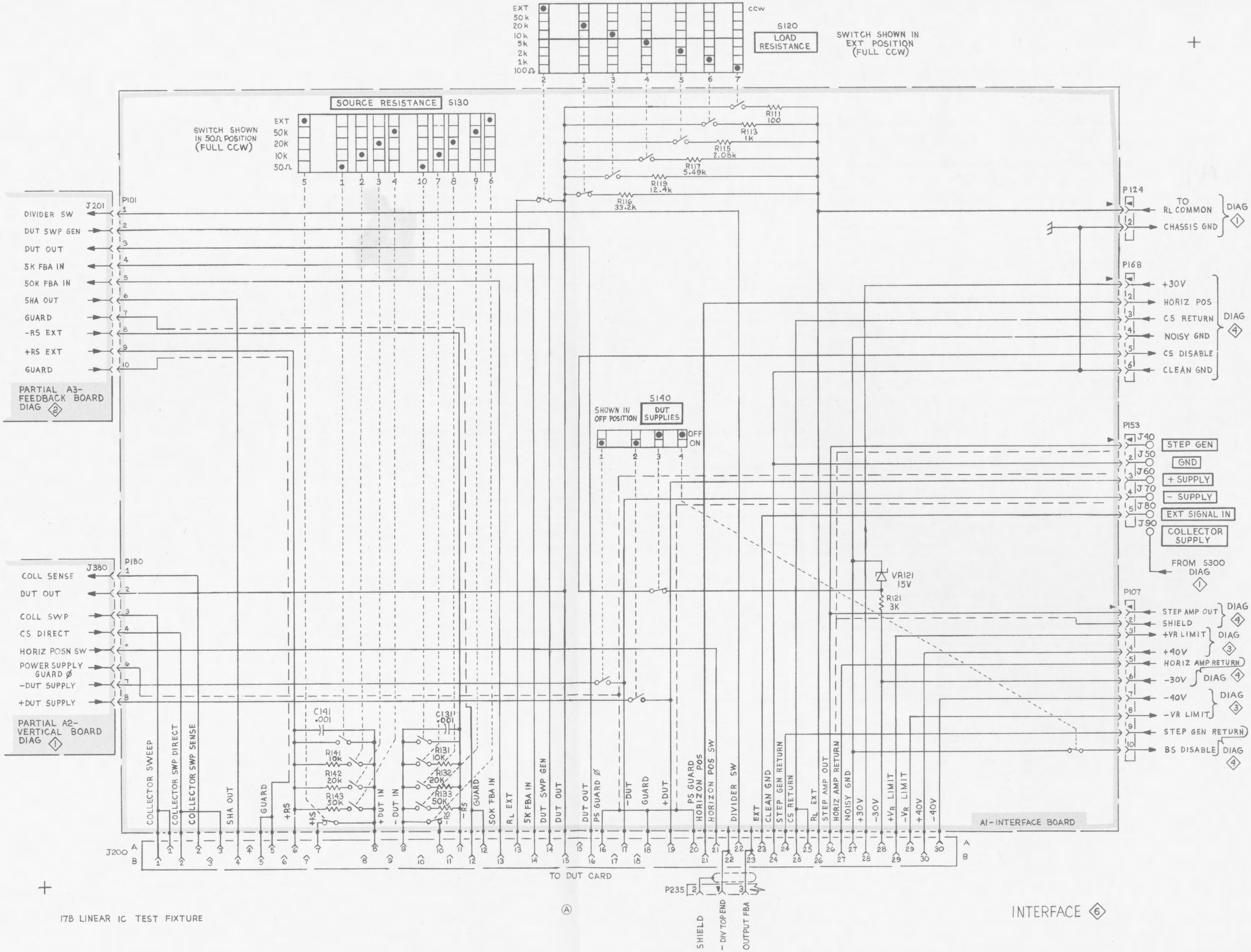
# SWITCHING BLOCK DIAGRAM
(WITH STANDARD OP-AMP CARD)

P.S 8-8-73




# FUNCTION/VERTICAL SWITCHES ⑤

Ⓐ




178 LINEAR IC TEST FIXTURE

Ⓐ

INTERFACE ⑥

DUT INTERFACE

⑥

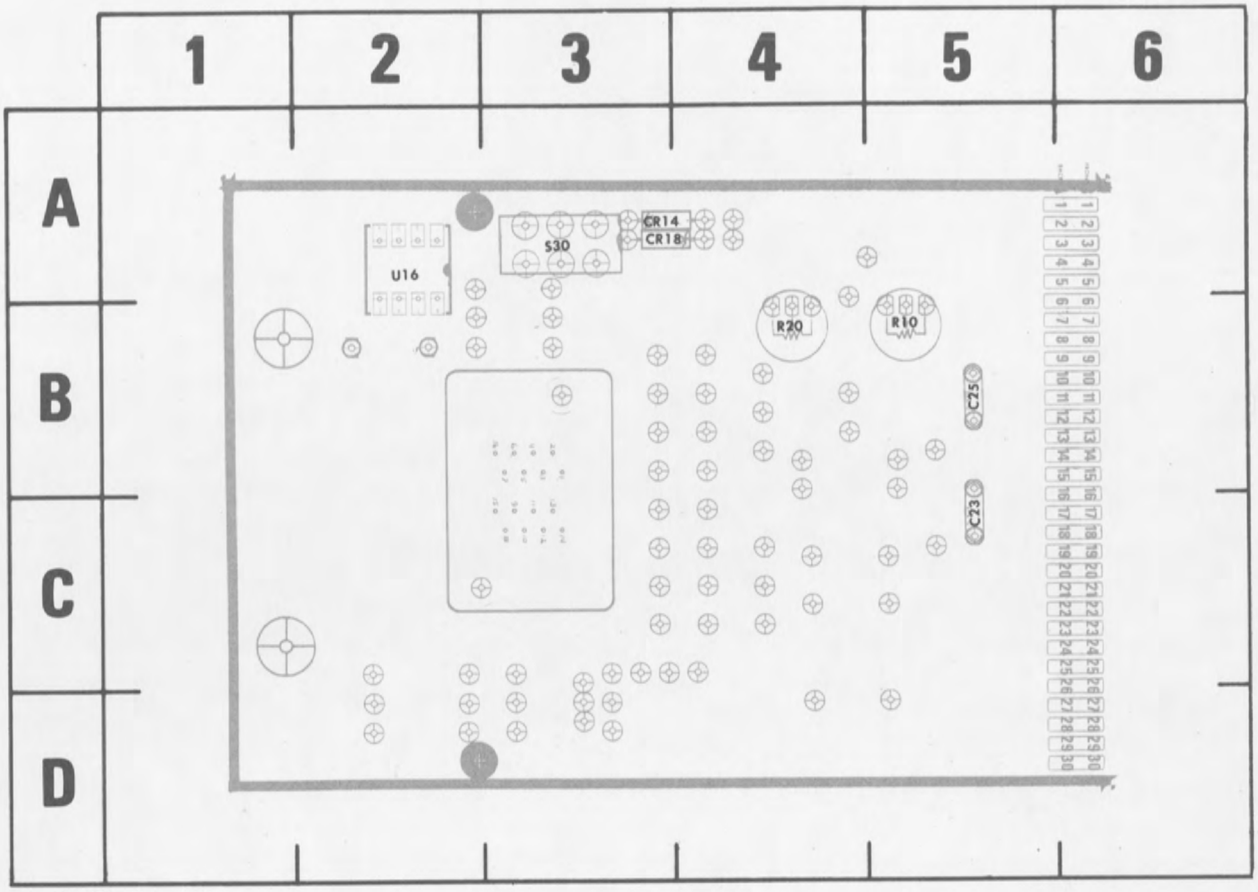
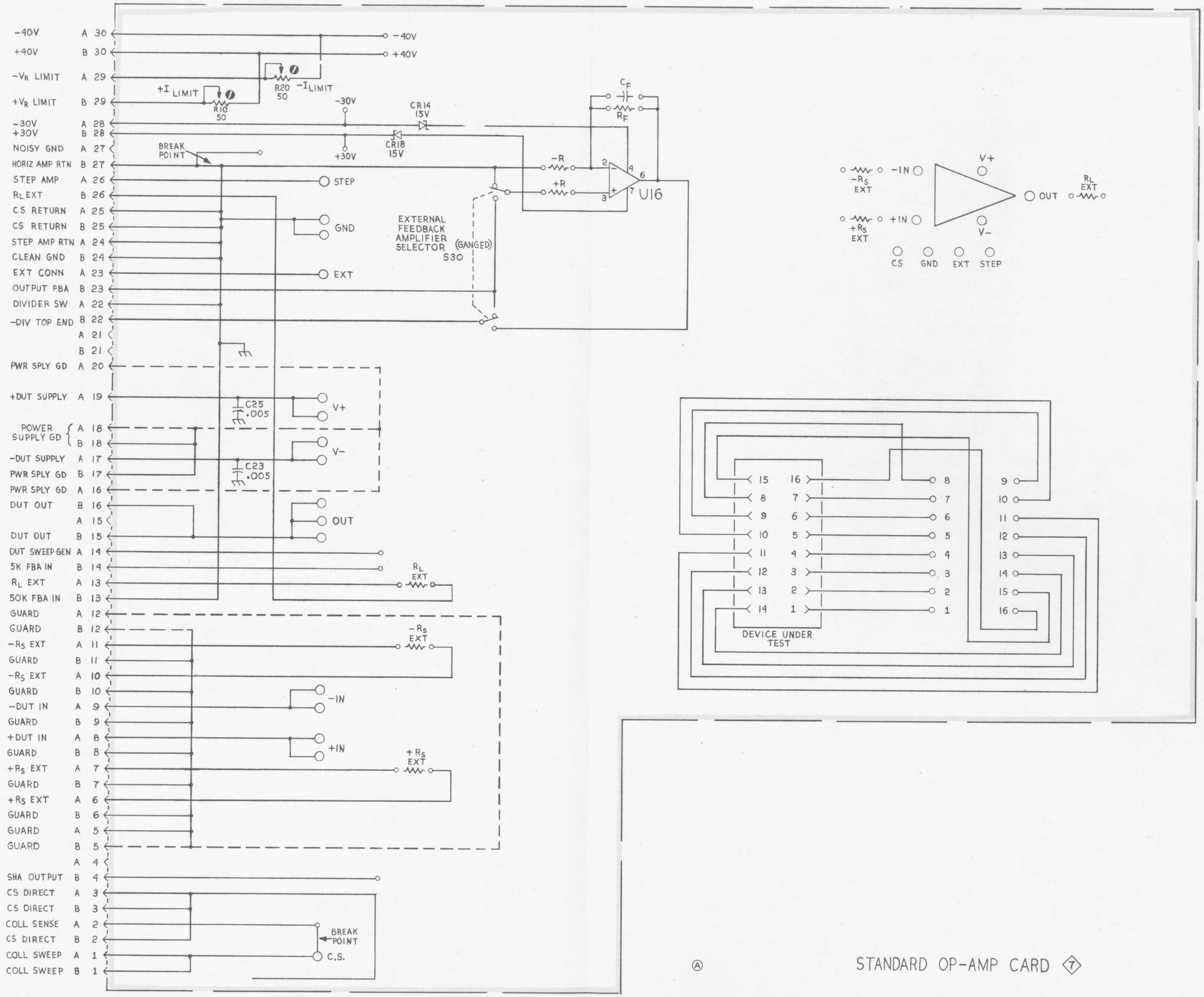



Fig. 7-5. A5—Standard Op Amp Card circuit board.

| CKT NO | GRID LOC |
|---|---|
| C23 | 5C |
| C25 | 5B |
| CR14 | 3A |
| CR18 | 3A |
| R10 | 5B |
| R20 | 4B |
| S30 | 3A |
| U16 | 2A |




Ⓐ STANDARD OP-AMP CARD ⑦

178 LINEAR IC TEST FIXTURE

STANDARD OP AMP CARD

⑦

# MECHANICAL REPLACEABLE PARTS LIST

## 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 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.

## SPECIAL NOTES AND SYMBOLS

X000 Part first added at this serial number

00X Part removed after this serial number

## FIGURE AND INDEX NUMBERS

Items in this section are referenced by figure and index numbers to the illustrations.

## INDENTATION SYSTEM

This mechanical parts list is indented to indicate item relationships. Following is an example of the indentation system used in the description column.

*1 2 3 4 5 Name & Description*

*Assembly and/or Component*
*Attaching parts for Assembly and/or Component*
--- * ---
 *Detail Part of Assembly and/or Component*
 *Attaching parts for Detail Part*
--- * ---
  *Parts of Detail Part*
  *Attaching parts for Parts of Detail Part*
--- * ---

Attaching Parts always appear 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. The separation symbol --- * --- indicates the end of attaching parts.

**Attaching parts must be purchased separately, unless otherwise specified.**

## ITEM NAME

In the Parts List, an Item Name is separated from the description by a colon (:). Because of space limitations, an Item Name may sometimes appear as incomplete. For further Item Name identification, the U.S. Federal Cataloging Handbook H6-1 can be utilized where possible.

# ABBREVIATIONS

| | | | | | |
|---|---|---|---|---|---|
| " | INCH | FLH | FLAT HEAD | PWR | POWER |
| # | NUMBER SIZE | FLTR | FILTER | RCPT | RECEPTACLE |
| ACTR | ACTUATOR | FR | FRAME or FRONT | RES | RESISTOR |
| ADPTR | ADAPTER | FSTNR | FASTENER | RDG | RIGID |
| ALIGN | ALIGNMENT | FT | FOOT | RLF | RELIEF |
| AL | ALUMINUM | FXD | FIXED | RTNR | RETAINER |
| ASSEM | ASSEMBLED | GSKT | GASKET | SCH | SOCKET HEAD |
| ASSY | ASSEMBLY | HDL | HANDLE | SCOPE | OSCILLOSCOPE |
| ATTEN | ATTENUATOR | HEX | HEXAGON | SCR | SCREW |
| AWG | AMERICAN WIRE GAGE | HEX HD | HEXAGONAL HEAD | SE | SINGLE END |
| BD | BOARD | HEX SOC | HEXAGONAL SOCKET | SECT | SECTION |
| BRKT | BRACKET | HLCPS | HELICAL COMPRESSION | SEMICOND | SEMICONDUCTOR |
| BRS | BRASS | HLEXT | HELICAL EXTENSION | SHLD | SHIELD |
| BRZ | BRONZE | HV | HIGH VOLTAGE | SHLDR | SHOULDERED |
| BSHG | BUSHING | IC | INTEGRATED CIRCUIT | SKT | SOCKET |
| CAB | CABINET | ID | INSIDE DIAMETER | SL | SLIDE |
| CAP | CAPACITOR | IDENT | IDENTIFICATION | SLFLKG | SELF-LOCKING |
| CER | CERAMIC | IMPLR | IMPELLER | SLVG | SLEEVING |
| CHAS | CHASSIS | IN | INCH | SPR | SPRING |
| CKT | CIRCUIT | INCAND | INCANDESCENT | SQ | SQUARE |
| COMP | COMPOSITION | INSUL | INSULATOR | SST | STAINLESS STEEL |
| CONN | CONNECTOR | INTL | INTERNAL | STL | STEEL |
| COV | COVER | LPHLDR | LAMPHOLDER | SW | SWITCH |
| CPLG | COUPLING | MACH | MACHINE | T | TUBE |
| CRT | CATHODE RAY TUBE | MECH | MECHANICAL | TERM | TERMINAL |
| DEG | DEGREE | MTG | MOUNTING | THD | THREAD |
| DWR | DRAWER | NIP | NIPPLE | THK | THICK |
| ELCTRN | ELECTRON | NON WIRE | NOT WIRE WOUND | TNSN | TENSION |
| ELEC | ELECTRICAL | OBD | ORDER BY DESCRIPTION | TPG | TAPPING |
| ELCTLT | ELECTROLYTIC | OD | OUTSIDE DIAMETER | TRH | TRUSS HEAD |
| ELEM | ELEMENT | OVH | OVAL HEAD | V | VOLTAGE |
| EPL | ELECTRICAL PARTS LIST | PH BRZ | PHOSPHOR BRONZE | VAR | VARIABLE |
| EQPT | EQUIPMENT | PL | PLAIN or PLATE | W/ | WITH |
| EXT | EXTERNAL | PLSTC | PLASTIC | WSHR | WASHER |
| FIL | FILLISTER HEAD | PN | PART NUMBER | XFMR | TRANSFORMER |
| FLEX | FLEXIBLE | PNH | PAN HEAD | XSTR | TRANSISTOR |

# CROSS INDEX MFR. CODE NUMBER TO MANUFACTURER

| MFR.CODE | MANUFACTURER | ADDRESS | CITY,STATE,ZIP |
|---|---|---|---|
| 00779 | AMP, Inc. | P. O. Box 3608 | Harrisburg, PA 17105 |
| 05129 | Kilo Engineering Co. | 2015 D | La Verne, CA 91750 |
| 05574 | Viking Industries, Inc. | 21001 Nordhoff | Chatsworth, CA 91311 |
| 08261 | Spectra-Strip Corp. | 7100 Lampson Ave. | Garden Grove, CA 92642 |
| 09422 | Plastic Stamping Corp. | 2216 W. Armitage Ave. | Chicago, IL 60647 |
| 12327 | Freeway Washer and Stamping Co. | P. O. Box 05206 | Cleveland, OH 44105 |
| 12360 | Albany Products Co., Div. of Pneumo Dynamics Corp. | 351 Connecticut Ave. | South Norwalk, CT 06856 |
| 22526 | Berg Electronics, Inc. | Youk Expressway | New Cumberland, PA 17070 |
| 23499 | Gavitt Wire and Cable, Division of Amerace Esna Corp. | 455 N. Quince St. | Escondido, CA 92025 |
| 33888 | Fairchild Semiconductor, San Diego Facility, A Div. of Fairchild Camera and Instrument Corp. | 5625 Kearny Villa Rd. | San Diego, CA 92123 |
| 70485 | Atlantic India Rubber Works, Inc. | 571 W. Polk St. | Chicago, IL 60607 |
| 71279 | Cambridge Thermionic Corp. | 445 Concord Ave. | Cambridge, MA 02138 |
| 73743 | Fischer Special Mfg. Co. | 446 Morgan St. | Cincinnati, OH 45206 |
| 74445 | Holo-Krome Co. | 31 Brook St. West | Hartford, CT 06110 |
| 76854 | Oak Mfg. Co., Division of Oak Electro/Netics Corp. | S. Main St. | Crystal Lake, IL 60014 |
| 78189 | Illinois Tool Works, Inc. Shakeproof Division | St. Charles Road | Elgin, IL 60126 |
| 78471 | Tilley Mfg. Co. | 900 Industrial Rd. | San Carlos, CA 94070 |
| 79136 | Waldes, Kohinoor, Inc. | 47-16 Austel Place | Long Island City, NY 11101 |
| 79807 | Wrought Washer Mfg. Co. | 2100 S. O Bay St. | Milwaukee, WI 53207 |
| 80009 | Tektronix, Inc. | P. O. Box 500 | Beaverton, OR 97005 |
| 81073 | Grayhill, Inc. | 561 Hillgrove Ave. | La Grange, IL 60525 |
| 82647 | Texas Instruments, Inc., Control Products Div. | 34 Forest St. | Attleboro, MA 02703 |
| 83385 | Central Screw Co. | 2530 Crescent Dr. | Broadview, IL 60153 |
| 83501 | Gavitt Wire and Cable, Division of Amerace Esna Corp. | Central St. | Brookfield, MA 01506 |
| 88245 | Litton Precision Products, Inc., USECO Div., Litton Industries | 13536 Saticoy St. | Van Nuys, CA 91409 |
| 97464 | Industrial Retaining Ring Co. | 57 Cordier St. | Irvington, NJ 07111 |
| 99779 | Barnes Div., Bunker Ramo Corp. | 24 N. Lansdowne Ave. | Lansdowne, PA 19050 |

FIGURE 1 EXPLODED

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Qty | 1 2 3 4 5 Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|---|
| 1-1 | 390-0359-00 | | | 1 | COVER,OSCP:BOTTOM | 80009 | 390-0359-00 |
| | | | | | (ATTACHING PARTS) | | |
| -2 | 211-0504-00 | | | 3 | SCREW,MACHINE:6-32 X 0.25 INCH,PNH STL | 83385 | OBD |
| -3 | 211-0105-00 | | | 4 | SCREW,MACHINE:4-40 X 0.188"100 DEG,FLH STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| -4 | 390-0227-02 | | | 1 | CAB SIDE,SCOPE:RIGHT | 80009 | 390-0227-02 |
| | | | | | (ATTACHING PARTS) | | |
| -5 | 213-0146-00 | | | 4 | SCR,TPG,THD FOR:6-20 X 0.313 INCH,PNH STL | 83385 | OBD |
| -6 | 211-0504-00 | | | 2 | SCREW,MACHINE:6-32 X 0.25 INCH,PNH STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| -7 | 390-0228-01 | | | 1 | CAB SIDE,SCOPE:LEFT | 80009 | 390-0228-01 |
| | | | | | (ATTACHING PARTS) | | |
| -8 | 213-0146-00 | | | 4 | SCR,TPG,THD FOR:6-20 X 0.313 INCH,PNH STL | 83385 | OBD |
| | 211-0504-00 | | | 2 | SCREW,MACHINE:6-32 X 0.25 INCH,PNH STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| -9 | 260-0247-00 | | | 1 | SWITCH,PUSH:SPST,NORMALLY OPEN | 81073 | 30YY1009 |
| | | | | | (ATTACHING PARTS) | | |
| -10 | 210-0583-00 | | | 1 | NUT,PLAIN,HEX.:0.25-32 X 0.312 INCH,BRS | 73743 | 2X20319-402 |
| -11 | 210-0940-00 | | | 1 | WASHER,FLAT:0.25 ID X 0.375 INCH OD,STL | 79807 | OBD |
| -12 | 210-0046-00 | | | 1 | WASHER,LOCK:INTL,0.26 ID X 0.40" OD,STL | 78189 | 1214-05-00-0541C |
| | | | | | - - - * - - - | | |
| -13 | 333-1731-00 | | | 1 | PANEL,FRONT: | 80009 | 333-1731-00 |
| -14 | 366-0125-00 | | | 2 | KNOB:KNURLED,WITH SETSCREW | 80009 | 366-0125-00 |
| -15 | 210-0894-00 | | | 2 | WASHER,NONMETAL:0.19 ID X 0.438"OD,PLSTC | 09422 | OBD |
| -16 | 384-0900-00 | | | 2 | ROD,SECURING:8.255 INCH LONG | 80009 | 384-0900-00 |
| | | | | | (ATTACHING PARTS FOR EACH) | | |
| -17 | 354-0025-00 | | | 1 | RING,RETAINING:0.181 INCH FREE ID | 79136 | 5555-18 |
| | | | | | - - - * - - - | | |
| -18 | 136-0140-00 | | | 6 | JACK,TIP: | 80009 | 136-0140-00 |
| | | | | | (ATTACHING PARTS FOR EACH) | | |
| -19 | 210-0583-00 | | | 2 | NUT,PLAIN,HEX.:0.25-32 X 0.312 INCH,BRS | 73743 | 2X20319-402 |
| -20 | 210-0223-00 | | | 1 | TERMINAL,LUG:0.25 INCH DIA,SE | 78189 | 2101-14-03-2520N |
| -21 | 210-0895-00 | | | 1 | WASH. SHOULDERED:0.375ODX0.105"THK,NYLON | 80009 | 210-0895-00 |
| | | | | | - - - * - - - | | |
| -22 | 426-1024-00 | | | 1 | FRAME PANEL CAB:FRONT | 80009 | 426-1024-00 |
| | | | | | (ATTACHING PARTS) | | |
| -23 | 211-0541-00 | | | 2 | SCREW,MACHINE:6-32 X 0.25"100 DEG,FLH STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| -24 | 366-1023-02 | | | 1 | KNOB:GRAY,WITH SETSCREW | 80009 | 366-1023-02 |
| -25 | 366-1037-00 | | | 1 | KNOB:GRAY,WITH SETSCREW | 80009 | 366-1037-00 |
| -26 | 366-1207-00 | | | 2 | KNOB:GRAY,WITH SETSCREW | 80009 | 366-1207-00 |
| -27 | 331-0373-00 | | | 1 | DIAL CONTROL: | 05129 | 771-S-6 |
| -28 | 366-1190-00 | | | 2 | KNOB:GRAY,WITH SETSCREW | 80009 | 366-1190-00 |
| -29 | 366-1508-00 | | | 1 | KNOB:GRAY,WITH SKIRT | 80009 | 366-1508-00 |
| -30 | 333-1770-00 | | | 1 | PANEL,FUNCT SW: | 80009 | 333-1770-00 |
| -31 | 352-0251-00 | | | 1 | HOLDER,SCALE:2.14 X 2.14 INCH,PLSTC | 80009 | 352-0251-00 |
| -32 | 366-1501-00 | | | 1 | KNOB:GRAY,WITH SKIRT | 80009 | 366-1501-00 |
| -33 | 260-1529-00 | | | 1 | SWITCH,ROTARY:SWEEP FREQUENCY | 76854 | 5-18252-142 |
| | | | | | (ATTACHING PARTS) | | |
| -34 | 210-0590-00 | | | 1 | NUT,PLAIN,HEX.:0.375 X 0.438INCH,STL | 73743 | 2X28269-402 |
| -35 | 210-0978-00 | | | 1 | WASHER,FLAT:0.375 ID X 0.50 INCH OD STL | 78471 | OBD |
| | | | | | - - - * - - - | | |
| -36 | ----- ----- | | | 1 | RESISTOR,VARIABLE:(SEE R415 EPL) | | |
| | | | | | (ATTACHING PARTS) | | |
| -37 | 210-0590-00 | | | 2 | NUT,PLAIN,HEX.:0.375 X 0.438INCH,STL | 73743 | 2X28269-402 |
| -38 | 210-0012-00 | | | 1 | WASHER,LOCK:INTL,0.375 IDX 0.50" OD STL | 78189 | 1220-02-00-0541C |
| | | | | | - - - * - - - | | |
| -39 | 384-1210-00 | | | 1 | EXTENSION,SHAFT:1.875 INCH LONG | 80009 | 384-1210-00 |
| | | | | | (ATTACHING PARTS) | | |
| -40 | 376-0014-00 | | | 1 | CPLG,SHAFT,FLEX:SST WIRE | 76854 | 22675-001 |
| | | | | | - - - * - - - | | |
| -41 | ----- ----- | | | 2 | RESISTOR,VARIABLE:(SEE R460,R565 EPL) | | |
| | | | | | (ATTACHING PARTS FOR EACH) | | |
| -42 | 210-0583-00 | | | 1 | NUT,PLAIN,HEX.:0.25-32 X 0.312 INCH,BRS | 73743 | 2X20319-402 |
| -43 | 210-0940-00 | | | 1 | WASHER,FLAT:0.25 ID X 0.375 INCH OD,STL | 79807 | OBD |
| | | | | | - - - * - - - | | |
| -44 | ----- ----- | | | 1 | RESISTOR,VARIABLE:(SEE R560 EPL) | | |
| | | | | | (ATTACHING PARTS) | | |
| -45 | 210-0046-00 | | | 1 | WASHER,LOCK:INTL,0.26 ID X 0.40" OD,STL | 78189 | 1214-05-00-0541C |
| | | | | | - - - * - - - | | |

FIGURE 1 EXPLODED (CONT)

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Qty | 1 2 3 4 5 Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|---|
| 1-46 | ----- ----- | | | 1 | LAMP:(SEE DS441 EPL) | | |
| | | | | | (ATTACHING PARTS) | | |
| -47 | 348-0004-00 | | | 1 | GROMMET,RUBBER:0.375 INCH | 70485 | 763-26006 |
| | | | | | - - - * - - - | | |
| -48 | 366-1489-37 | | | 1 | PUSH BUTTON:GRAY PLASTIC | 80009 | 366-1489-37 |
| -49 | 426-0681-00 | | | 1 | FR,PUSH BUTTON:GRAY PLASTIC | 80009 | 426-0681-00 |
| -50 | 358-0029-05 | | | 2 | NUT,PLAIN,HEX:0.274ID X 0.438" LG,BRS | 80009 | 358-0029-05 |
| | | | | | (ATTACHING PARTS FOR EACH) | | |
| -51 | 210-0590-00 | | | 1 | NUT,PLAIN,HEX.:0.375 X 0.438INCH,STL | 73743 | 2X28269-402 |
| -52 | 210-0978-00 | | | 1 | WASHER,FLAT:0.375 ID X 0.50 INCH OD STL | 78471 | OBD |
| -53 | 210-0012-00 | | | 1 | WASHER,LOCK:INTL,0.375 IDX 0.50" OD STL | 78189 | 1220-02-00-0541C |
| | | | | | - - - * - - - | | |
| -54 | 390-0358-00 | | | 1 | COVER,OSCP:TOP | 80009 | 390-0358-00 |
| -55 | 351-0380-00 | | | 2 | GUIDE,CKT CARD: | 80009 | 351-0380-00 |
| | | | | | (ATTACHING PARTS FOR EACH) | | |
| -56 | 211-0038-00 | | | 2 | SCREW,MACHINE:4-40 X 0.312"100 DEG,FLH STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| -57 | 407-1296-00 | | | 1 | BRACKET,ANGLE: | 80009 | 407-1296-00 |
| | | | | | (ATTACHING PARTS) | | |
| -58 | 211-0030-00 | | | 2 | SCREW,MACHINE:2-56X0.250" 82 DEG,FLH STL | 83385 | OBD |
| -59 | 210-0001-00 | | | 2 | WASHER,LOCK:INT,0.092ID X 0.180OD,STL | 78189 | 1216-01-00-0541C |
| -60 | 210-0405-00 | | | 2 | NUT,PLAIN,HEX.:2-56 X 0.188 INCH,BRS | 73743 | 2X12157-402 |
| | | | | | - - - * - - - | | |
| -61 | 386-2569-00 | | | 1 | LIGHT CONDUCTOR:SWITCH ILLUM | 80009 | 386-2569-00 |
| -62 | 352-0157-00 | | | 5 | LAMPHOLDER:WHITE PLASTIC | 80009 | 352-0157-00 |
| -63 | 200-0935-00 | | | 5 | BASE,LAMPHOLDER:0.29 OD X 0.19" L,BK PLSTC | 80009 | 200-0935-00 |
| -64 | 378-0635-00 | | | 5 | LENS,LIGHT:WHITE | 80009 | 378-0635-00 |
| -65 | 386-2658-00 | | | 1 | PLATE,TRIM REAR: | 80009 | 386-2658-00 |
| | | | | | (ATTACHING PARTS) | | |
| -66 | 211-0504-00 | | | 3 | SCREW,MACHINE:6-32 X 0.25 INCH,PNH STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| -67 | 441-1149-00 | | | 1 | CHAS,ELEC EQUIP:MAIN | 80009 | 441-1149-00 |
| -68 | 131-0942-00 | | | 1 | CONTACT ELEC:GROUNDING | 80009 | 131-0942-00 |
| | | | | | (ATTACHING PARTS) | | |
| -69 | 213-0138-00 | | | 1 | SCR,TPG,THD FOR:4-40 X 0.188 INCH,PNH STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| -70 | 426-1023-00 | | | 1 | FRAME PANEL CAB:REAR | 80009 | 426-1023-00 |
| | | | | | (ATTACHING PARTS) | | |
| -71 | 211-0101-00 | | | 4 | SCREW,MACHINE:4-40 X 0.25" 100 DEG,FLH STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| -72 | 166-0353-00 | | | 1 | SLEEVE LOCKING:0.320 DIA X 0.457" LG | 80009 | 166-0353-00 |
| -73 | 337-1963-00 | | | 1 | SHIELD CKT BD: | 80009 | 337-1963-00 |
| | | | | | (ATTACHING PARTS) | | |
| -74 | 211-0007-00 | | | 1 | SCREW,MACHINE:4-40 X 0.188 INCH,PNL STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| -75 | 337-1962-00 | | | 1 | SHIELD CKT BD: | 80009 | 337-1962-00 |
| | | | | | (ATTACHING PARTS) | | |
| | 211-0007-00 | | | 1 | SCREW,MACHINE:4-40 X 0.188 INCH,PNL STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| -76 | 337-1961-00 | | | 1 | SHIELD JACK: | 80009 | 337-1961-00 |
| | | | | | (ATTACHING PARTS) | | |
| -77 | 210-0586-00 | | | 2 | NUT,PLAIN,EXT W:4-40 X 0.25 INCH,STL | 78189 | OBD |
| | | | | | - - - * - - - | | |
| -78 | ----- ----- | | | 2 | TRANSISTOR:(SEE Q484,Q584 EPL) | | |
| | | | | | (ATTACHING PARTS FOR EACH) | | |
| -79 | 211-0510-00 | | | 1 | SCREW,MACHINE:6-32 X 0.375 INCH,PNH STL | 83385 | OBD |
| -80 | 342-0163-00 | | | 1 | INSULATOR,PLATE:XSTR,0.675 X 0.625 X 0.001" | 80009 | 342-0163-00 |
| -81 | 210-0071-00 | | | 1 | WASHER,SPR TNSN: | 80009 | 210-0071-00 |
| -82 | 210-0407-00 | | | 1 | NUT,PLAIN,HEX.:6-32 X 0.25 INCH,BRS | 73743 | 3038-0228-402 |
| | | | | | - - - * - - - | | |
| -83 | 407-1298-00 | | | 2 | BRACKET,ANGLE: | 80009 | 407-1298-00 |
| -84 | 384-1202-00 | | | 1 | EXTENSION,SHAFT:LEVER SWITCH | 80009 | 384-1202-00 |
| -85 | 214-1770-00 | | | 1 | LEVER,SLIDE SW: | 80009 | 214-1770-00 |
| | | | | | (ATTACHING PARTS) | | |
| -86 | 354-0165-00 | | | 1 | RING,RETAINING: | 97464 | 1000-15 |
| | | | | | - - - * - - - | | |
| -87 | 407-1297-00 | | | 1 | BRKT,ELEC SW: | 80009 | 407-1297-00 |
| | | | | | (ATTACHING PARTS) | | |
| -88 | 211-0101-00 | | | 2 | SCREW,MACHINE:4-40 X 0.25" 100 DEG,FLH STL | 83385 | OBD |
| | | | | | - - - * - - - | | |

FIGURE 1 EXPLODED (CONT)

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Qty | 1 2 3 4 5 Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|---|
| 1-89 | 214-0720-01 | | | 1 | SPRING,GROUND: | 80009 | 214-0720-01 |
| | | | | | (ATTACHING PARTS) | | |
| -90 | 210-0586-00 | | | 1 | NUT,PLAIN,EXT W:4-40 X 0.25 INCH,STL | 78189 | OBD |
| | | | | | - - - * - - - | | |
| -91 | 386-2570-00 | | | 1 | SUPPORT,CKT BD:INTERFACE | 80009 | 386-2570-00 |
| | | | | | (ATTACHING PARTS) | | |
| -92 | 210-0586-00 | | | 2 | NUT,PLAIN,EXT W:4-40 X 0.25 INCH,STL | 78189 | OBD |
| | | | | | - - - * - - - | | |
| | 672-0070-00 | | | 1 | CKT BOARD ASSY:WITH CAM SWITCH | 80009 | 672-0070-00 |
| | | | | | (ATTACHING PARTS) | | |
| -93 | 211-0116-00 | | | 2 | SCR,ASSEM WSHR:4-40 X 0.312 INCH,PNH BRS | 83385 | OBD |
| -94 | 211-0154-00 | | | 2 | SCR,ASSEM WSHR:4-40 X 0.562 INCH,PNH BRS | 83385 | OBD |
| | | | | | - - - * - - - | | |
| | ----- ----- | | | - | . CKT BOARD ASSY W/CAM SWITCH INCLUDES: | | |
| -95 | ----- ----- | | | 1 | . CKT BOARD ASSY:--INTERFACE(SEE A1 EPL) | | |
| | ----- ----- | | | - | . . CKT BOARD ASSY INCLUDES: | | |
| -96 | 131-0604-00 | | | 21 | . . CONTACT,ELEC:0.025 SQ X 0.365 INCH LONG | 80009 | 131-0604-00 |
| -97 | 131-0608-00 | | | 23 | . . TERMINAL,PIN:0.365 INCH LONG | 22526 | 47357 |
| | 131-0787-00 | | | 8 | . . TERMINAL,PIN:0.64 INCH LONG | 22526 | 47359 |
| -98 | 131-1228-00 | | | 1 | . . CONN,RCPT,ELEC: | 05574 | 3VH30/1JV5 079 |
| -99 | 131-1261-00 | | | 10 | . . CONTACT,ELEC:F-SHAPED | 00779 | 1-380953 |
| -100 | 214-1458-00 | | | 2 | . . CONNECTOR KEY: | 05574 | 091-0071-00 |
| | 263-1026-00 | | | 1 | . ACTR ASSY,CAM S:SOURCE RESISTANCE | 80009 | 263-1026-00 |
| | | | | | (ATTACHING PARTS) | | |
| -101 | 211-0116-00 | | | 4 | . SCR,ASSEM WSHR:4-40 X 0.312 INCH,PNH BRS | 83385 | OBD |
| | | | | | - - - * - - - | | |
| | ----- ----- | | | - | . . ACTUATOR ASSY INCLUDES: | | |
| -102 | 200-0995-00 | | | 1 | . . COVER,CAM SW: | 80009 | 200-0995-00 |
| | | | | | (ATTACHING PARTS) | | |
| -103 | 211-0022-00 | | | 2 | . . SCREW,MACHINE:2-56 X 0.188",PNH STL | 83385 | OBD |
| -104 | 210-0001-00 | | | 2 | . . WASHER,LOCK:INT,0.092IDX0.180"OD,STL | 78189 | 1216-01-00-0541C |
| | | | | | - - - * - - - | | |
| -105 | 214-1126-00 | | | 1 | . . SPRING,FLAT:GOLD COLORED | 80009 | 214-1126-00 |
| | 214-1126-02 | | | 1 | . . SPRING,FLAT:RED COLORED | 80009 | 214-1126-02 |
| -106 | 214-1127-00 | | | 1 | . . ROLLER,DETENT:0.125 DIA X 0.125 INCH L | 80009 | 214-1127-00 |
| -107 | 354-0219-00 | | | 1 | . . RING,RETAINING:FOR 0.25 INCH SHAFT | 79136 | 5103-25-MD-R |
| -108 | 401-0058-00 | | | 1 | . . BEARING,CAM SW:FRONT | 80009 | 401-0058-00 |
| -109 | 105-0460-00 | | | 1 | . . ACTUATOR,CAM SW: | 80009 | 105-0460-00 |
| -110 | 210-0406-00 | | | 4 | . . NUT,PLAIN,HEX.:4-40 X 0.188 INCH,BRS | 73743 | 2X12161-402 |
| -111 | 210-0405-00 | | | 2 | . . NUT,PLAIN,HEX.:2-56 X 0.188 INCH,BRS | 73743 | 2X12157-402 |
| -112 | 401-0061-00 | | | 1 | . . BEARING,CAM SW:REAR | 80009 | 401-0061-00 |
| | 263-1027-00 | | | 1 | . ACTR ASSY,CAM S:LOAD RESISTANCE | 80009 | 263-1027-00 |
| | | | | | (ATTACHING PARTS) | | |
| -113 | 211-0116-00 | | | 4 | . SCR,ASSEM WSHR:4-40 X 0.312 INCH,PNH BRS | 83385 | OBD |
| | | | | | - - - * - - - | | |
| | ----- ----- | | | - | . . ACTUATOR ASSY INCLUDES: | | |
| -114 | 200-1033-00 | | | 1 | . . COVER,CAM SW: | 80009 | 200-1033-00 |
| | | | | | (ATTACHING PARTS) | | |
| -115 | 211-0022-00 | | | 2 | . . SCREW,MACHINE:2-56X0.188 INCH,PNH STL | 83385 | OBD |
| -116 | 210-0001-00 | | | 2 | . . WASHER,LOCK:INT,0.092IDX0.180" OD,STL | 78189 | 1216-01-00-0541C |
| | | | | | - - - * - - - | | |
| -117 | 214-1126-00 | | | 1 | . . SPRING,FLAT:GOLD COLORED | 80009 | 214-1126-00 |
| | 214-1126-02 | | | 1 | . . SPRING,FLAT:RED COLORED | 80009 | 214-1126-02 |
| -118 | 214-1127-00 | | | 1 | . . ROLLER,DETENT:0.125 DIA X 0.125 INCH L | 80009 | 214-1127-00 |
| -119 | 354-0219-00 | | | 1 | . . RING,RETAINING:FOR 0.25 INCH SHAFT | 79136 | 5103-25-MD-R |
| -120 | 401-0058-00 | | | 1 | . . BEARING,CAM SW:FRONT | 80009 | 401-0058-00 |
| -121 | 105-0459-00 | | | 1 | . . ACTUATOR,CAM SW: | 80009 | 105-0459-00 |
| -122 | 210-0406-00 | | | 4 | . . NUT,PLAIN,HEX.:4-40 X 0.188 INCH,BRS | 73743 | 2X12161-402 |
| -123 | 210-0405-00 | | | 2 | . . NUT,PLAIN,HEX.:2-56 X 0.188 INCH,BRS | 73743 | 2X12157-402 |
| -124 | 401-0061-00 | | | 1 | . . BEARING,CAM SW:REAR | 80009 | 401-0061-00 |
| | 105-0467-00 | | | 1 | . ACTR ASSY,SL SW:DUT SUPPLY ON-OFF | 80009 | 105-0467-00 |
| | ----- ----- | | | - | . . ACTUATOR ASSY INCLUDES: | | |
| -125 | 376-0142-00 | | | 1 | . . ADPT,SHAFT,CPLG:SLIDE TO SHAFT | 80009 | 376-0142-00 |
| | | | | | (ATTACHING PARTS) | | |
| -126 | 213-0048-00 | | | 1 | . . SETSCREW:4-40 X 0.125 INCH HEX SOC STL | 74445 | OBD |
| | | | | | - - - * - - - | | |

FIGURE 1 EXPLODED (CONT)

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Qty | 1 2 3 4 5 Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|---|
| 1-127 | 214-1126-01 | | | 2 | . . SPRING,FLAT:GREEN COLORED | 80009 | 214-1126-01 |
| -128 | 214-1127-00 | | | 2 | . . ROLLER,DETENT:0.125 DIA X 0.125 INCH L | 80009 | 214-1127-00 |
| -129 | 105-0478-00 | | | 1 | . . ACTUATOR,CAM SW: | 80009 | 105-0478-00 |
| -130 | 351-0355-00 | | | 1 | . . GUIDE,SW SLIDE: | 80009 | 351-0355-00 |
| | 672-0413-00 | | | 1 | CKT BOARD ASSY:WITH CAM SWITCH | 80009 | 672-0413-00 |
| | | | | | (ATTACHING PARTS) | | |
| -131 | 211-0030-00 | | | 4 | SCREW,MACHINE:2-56X0.250" 82DEG,FLH STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| | ----- ----- | | | - | . CKT BOARD ASSY W/CAM SWITCH INCLUDES: | | |
| -132 | ----- ----- | | | 1 | . CKT BOARD ASSY:--FEEDBACK AMP(SEE A3 EPL) | | |
| | ----- ----- | | | - | . . CKT BOARD ASSY INCLUDES: | | |
| -133 | 131-0593-00 | | | 7 | . . TERMINAL,PIN:1.15 INCH LONG | 22526 | 47354 |
| -134 | 352-0274-00 | | | 1 | . . HOLDER,TERMINAL:FOR 8 SQUARE PINS | 80009 | 352-0274-00 |
| -135 | 131-0604-00 | | | 24 | . . CONTACT,ELEC:0.025 SQ X 0.365 INCH LONG | 80009 | 131-0604-00 |
| -136 | 131-0608-00 | | | 1 | . . TERMINAL,PIN:0.365 INCH LONG | 22526 | 47357 |
| -137 | 136-0252-04 | | | 41 | . . SOCKET,PIN CONN:0.188 INCH LONG | 22526 | 75060-001 |
| -138 | 136-0499-10 | | | 1 | . . SOCKET,CKT CARD:10 CONTACT | 00779 | 4-380949-0 |
| -139 | 136-0514-00 | | | 1 | . . SOCKET,SEMICOND:INTEGRATED CKT | 82647 | C930802 |
| | ----- ----- | | | 2 | . . TRANSISTOR:(SEE Q546,Q548 EPL) | | |
| | | | | | (ATTACHING PARTS) | | |
| -140 | 210-0406-00 | | | 1 | . . NUT,PLAIN,HEX.:4-40 X 0.188 INCH,BRS | 73743 | 2X12161-402 |
| -141 | 210-0004-00 | | | 1 | . . WASHER,LOCK:INT,0.12 ID X0.26" OD,STL | 78189 | 1204-00-00-0541C |
| -142 | 211-0008-00 | | | 1 | . . SCREW,MACHINE:4-40 X 0.25 INCH,PNH STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| -143 | 344-0154-00 | | | 4 | . . CLIP,ELECTRICAL:FOR 0.25 INCH DIA FUSE | 80009 | 344-0154-00 |
| -144 | 260-1310-00 | | | 1 | . . SWITCH,PUSH:DISPLAY | 80009 | 260-1310-00 |
| -145 | 361-0384-00 | | | 2 | . . SPACER,PB SW:0.133 INCH LONG | 80009 | 361-0384-00 |
| | ----- ----- | | | 1 | . CKT BOARD ASSY:--VERT PREAMP(SEE A2 EPL) | | |
| | ----- ----- | | | - | . . CKT BOARD ASSY INCLUDES: | | |
| -146 | 131-0604-00 | | | 30 | . . CONTACT,ELEC:0.025 SQ X 0.365 INCH LONG | 80009 | 131-0604-00 |
| -147 | 131-0608-00 | | | 10 | . . TERMINAL,PIN:0.365 INCH LONG | 22526 | 47357 |
| -148 | 136-0252-04 | | | 10 | . . SOCKET,PIN CONN:0.188 INCH LONG | 22526 | 75060-001 |
| -149 | 136-0327-01 | | | 7 | . . SOCKET,PIN TERM:0.067 INCH DIA | 00779 | 86281-2 |
| -150 | 136-0499-08 | | | 1 | . . SOCKET,CKT CARD:8 CONTACT | 00779 | 3-380949-8 |
| -151 | 136-0514-00 | | | 2 | . . SOCKET,SEMICOND:INTEGRATED CKT | 82647 | C930802 |
| | 263-1024-00 | | | 1 | . ACTR ASSY,CAM S:VERT UNITS/DIV | | |
| | | | | | (ATTACHING PARTS) | | |
| -152 | 211-0116-00 | | | 8 | . SCR,ASSEM WSHR:4-40 X 0.312 INCH,PNH BRS | 83385 | OBD |
| | | | | | - - - * - - - | | |
| | ----- ----- | | | - | . . ACTUATOR ASSY INCLUDES: | | |
| -153 | 214-1139-02 | | | 1 | . . SPRING,FLAT:GREEN COLORED | 80009 | 214-1139-02 |
| | 214-1139-03 | | | 1 | . . SPRING,FLAT:RED COLORED | 80009 | 214-1139-03 |
| -154 | 214-1127-00 | | | 2 | . . ROLLER,DETENT:0.125 DIA X 0.125 INCH L | 80009 | 214-1127-00 |
| -155 | 354-0391-00 | | | 1 | . . RING,RETAINING:0.395"FREE IDX 0.025"STL | 97464 | 3100-43-CD |
| | 105-0482-00 | | | 1 | . . STOP,DETENT:MOVEABLE(NOT SHOWN) | 80009 | 105-0482-00 |
| -156 | 401-0081-01 | | | 1 | . . BEARING,CAM SW:FRONT | 80009 | 401-0081-01 |
| -157 | 105-0461-00 | | | 1 | . . ACTUATOR,CAM SW: | 80009 | 105-0461-00 |
| -158 | 210-0406-00 | | | 8 | . . NUT,PLAIN,HEX.:4-40 X 0.188 INCH,BRS | 73743 | 2X12161-402 |
| -159 | 401-0115-00 | | | 1 | . . BEARING,CAM SW:CNETER | 80009 | 401-0115-00 |
| | 263-1025-00 | | | 1 | . ACTR ASSY,CAM S:FUNCTION | 80009 | 263-1025-00 |
| | | | | | (ATTACHING PARTS) | | |
| -160 | 211-0116-00 | | | 6 | . SCR,ASSEM WSHR:4-40 X 0.312 INCH,PNH BRS | 83385 | OBD |
| -161 | 211-0168-00 | | | 2 | . SCREW,MACHINE:4-40 X 0.25 INCH,PNH STL | 12360 | OBD |
| -162 | 210-1002-00 | | | 2 | . WASHER,FLAT:0.125 ID X 0.25 INCH OD,BRS | 12327 | OBD |
| | | | | | - - - * - - - | | |
| | ----- ----- | | | - | . . ACTUATOR ASSY INCLUDES: | | |
| -163 | 214-1139-03 | | | 2 | . . SPRING,FLAT:RED COLORED | 80009 | 214-1139-03 |
| -164 | 214-1127-00 | | | 2 | . . ROLLER,DETENT:0.125 DIA X 0.125 INCH L | 80009 | 214-1127-00 |
| -165 | 354-0391-00 | | | 1 | . . RING,RETAINING:0.395"FREE IDX 0.025"STL | 97464 | 3100-43-CD |
| -166 | 401-0081-01 | | | 1 | . . BEARING,CAM SW:FRONT | 80009 | 401-0081-01 |
| -167 | 105-0462-00 | | | 1 | . . ACTUATOR,CAM SW: | 80009 | 105-0462-00 |
| -168 | 263-0519-00 | | | 1 | . . SWITCH,ROTARY:FUNCTION | 76854 | 4-2542-619 |
| | | | | | (ATTACHING PARTS) | | |
| -169 | 386-2877-00 | | | 1 | . . PLATE,SW MTG: | 80009 | 386-2877-00 |
| -170 | 211-0022-00 | | | 2 | . . SCREW,MACHINE:2-56 X 0.188",PNH STL | 83385 | OBD |
| | | | | | - - - * - - - | | |
| -171 | 210-0406-00 | | | 8 | . . NUT,PLAIN,HEX.:4-40 X 0.188 INCH,BRS | 73743 | 2X12161-402 |
| -172 | 401-0146-01 | | | 1 | . . BEARING,CAM SW:CENTER | 80009 | 401-0146-01 |
| -173 | ----- ----- | | | 1 | CKT BOARD ASSY:--POWER SUPPLY(SEE A4 EPL) | | |
| | | | | | (ATTACHING PARTS) | | |
| -174 | 211-0116-00 | | | 4 | SCR,ASSEM WSHR:4-40 X 0.312 INCH,PNH BRS | 83385 | OBD |
| | | | | | - - - * - - - | | |

FIGURE 1 EXPLODED (CONT)

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Qty | 1 2 3 4 5 Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|---|
| 1- | ----- ----- | | | - | . CKT BOARD ASSY INCLUDES: | | |
| -175 | 131-0589-00 | | | 6 | . TERMINAL,PIN:0.46 INCH LONG | 22526 | 47350 |
| | 131-0608-00 | | | 54 | . TERMINAL,PIN:0.365 INCH LONG | 22526 | 47357 |
| -176 | 136-0252-04 | | | 55 | . SOCKET,PIN CONN:0.188 INCH LONG | 22526 | 75060-001 |
| -177 | 136-0514-00 | | | 3 | . SOCKET,SEMICOND:INTEGRATED CKT | 82647 | C930802 |
| -178 | 214-0579-00 | | | 3 | . TERM,TEST PT:0.40 INCH LONG | 80009 | 214-0579-00 |
| -179 | 175-0825-00 | | | FT | WIRE,ELECTRICAL:2 WIRE RIBBON | 23499 | TEK-175-0825-00 |
| -180 | 175-0826-00 | | | FT | WIRE,ELECTRICAL:3 WIRE RIBBON | 08261 | TEK-175-0826-00 |
| -181 | 175-0827-00 | | | FT | WIRE,ELECTRICAL:4 WIRE RIBBON | 08261 | TEK-175-0827-00 |
| -182 | 175-0828-00 | | | FT | WIRE,ELECTRICAL:5 WIRE RIBBON | 23499 | TEK-175-0828-00 |
| -183 | 175-0829-00 | | | FT | WIRE,ELECTRICAL:6 WIRE RIBBON | 83501 | TEK-175-0829-00 |
| -184 | 175-0831-00 | | | FT | WIRE,ELECTRICAL:8 WIRE RIBBON | 08261 | TEK-175-0831-00 |
| -185 | 175-0832-00 | | | FT | WIRE,ELECTRICAL:9 WIRE RIBBON | 83501 | TEK-175-0832-00 |
| -186 | 175-0833-00 | | | 1 | WIRE,ELECTRICAL:10 WIRE RIBBON | 23499 | TEK-175-0833-00 |
| -187 | 131-0707-00 | | | 109 | CONNECTOR TERM.:0.48"L,22-26 AWG WIRE | 22526 | 47439 |
| -188 | 352-0161-09 | | | 1 | HOLDER,TERM.CON:3 WIRE WHITE | 80009 | 352-0161-09 |
| -189 | 352-0162-01 | | | 1 | HOLDER,TERM.CON:4 WIRE BROWN | 80009 | 352-0162-01 |
| -190 | 352-0163-03 | | | 1 | HOLDER,TERM.CON:5 WIRE ORANGE | 80009 | 352-0163-03 |
| -191 | 352-0164-10 | | | 2 | HOLDER,TERM.CON:6 WIRE BLACK | 80009 | 352-0164-10 |
| -192 | 352-0164-03 | | | 2 | HOLDER,TERM.CON:6 WIRE ORANGE | 80009 | 352-0164-03 |
| -193 | 352-0164-04 | | | 2 | HOLDER,TERM.CON:6 WIRE YELLOW | 80009 | 352-0164-04 |
| -194 | 352-0164-08 | | | 2 | HOLDER,TERM.CON:6 WIRE GRAY | 80009 | 352-0164-08 |
| -195 | 352-0166-06 | | | 2 | HOLDER,TERM.CON:8 WIRE BLUE | 80009 | 352-0166-06 |
| -196 | 352-0167-02 | | | 1 | HOLDER,TERM.CON:9 WIRE RED | 80009 | 352-0167-02 |
| -197 | 352-0168-07 | | | 1 | HOLDER,TERM.CON:10 WIRE PURPLE | 80009 | 352-0168-07 |
| -198 | 352-0169-02 | | | 1 | HOLDER,TERM.CON:2 WIRE RED | 80009 | 352-0169-00 |
| -199 | 352-0169-04 | | | 2 | HOLDER,TERM.CON:2 WIRE YELLOW | 80009 | 352-0169-04 |
| -200 | 352-0169-05 | | | 2 | HOLDER,TERM.CON:2 WIRE GREEN | 80009 | 352-0169-05 |

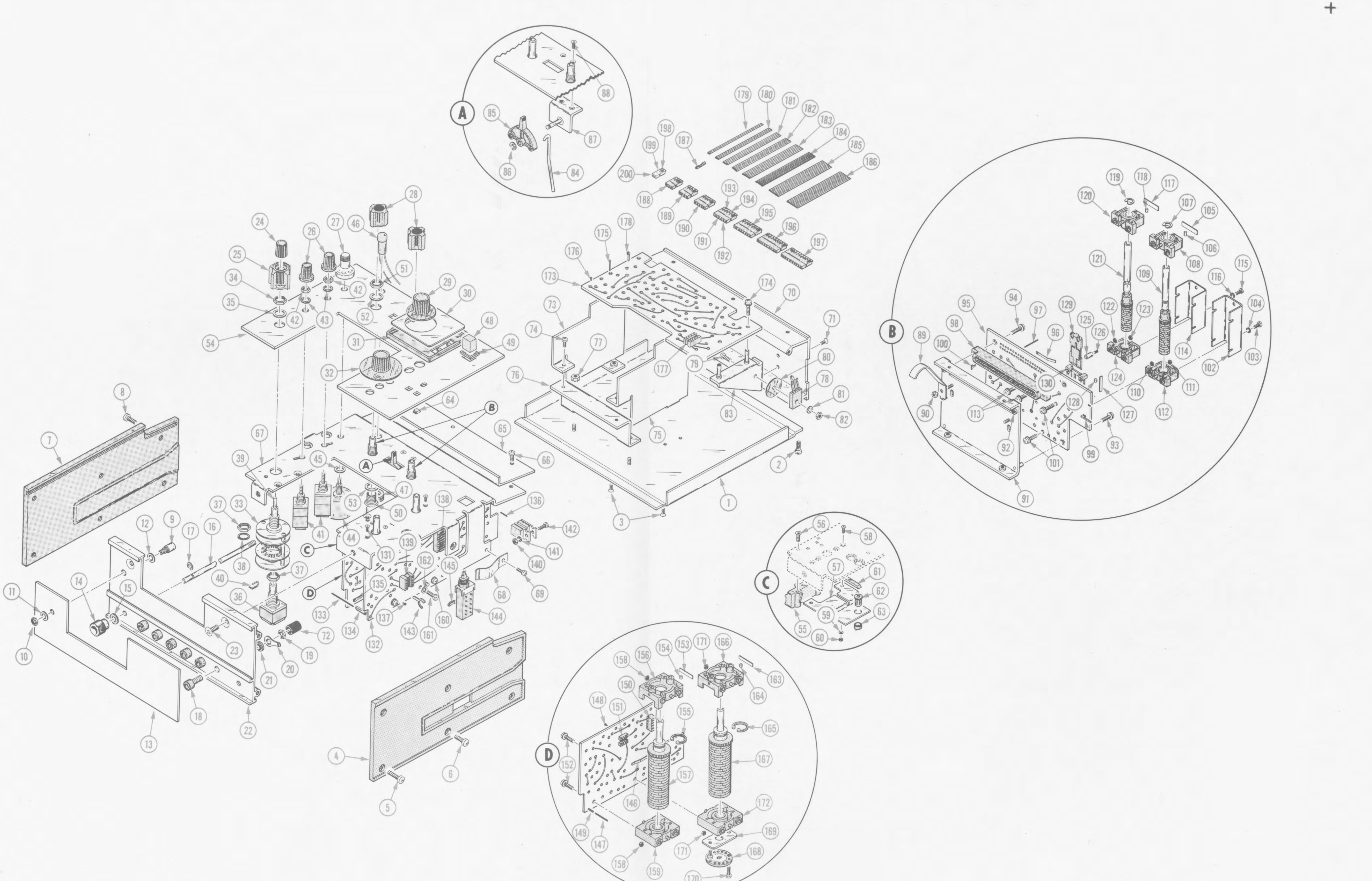
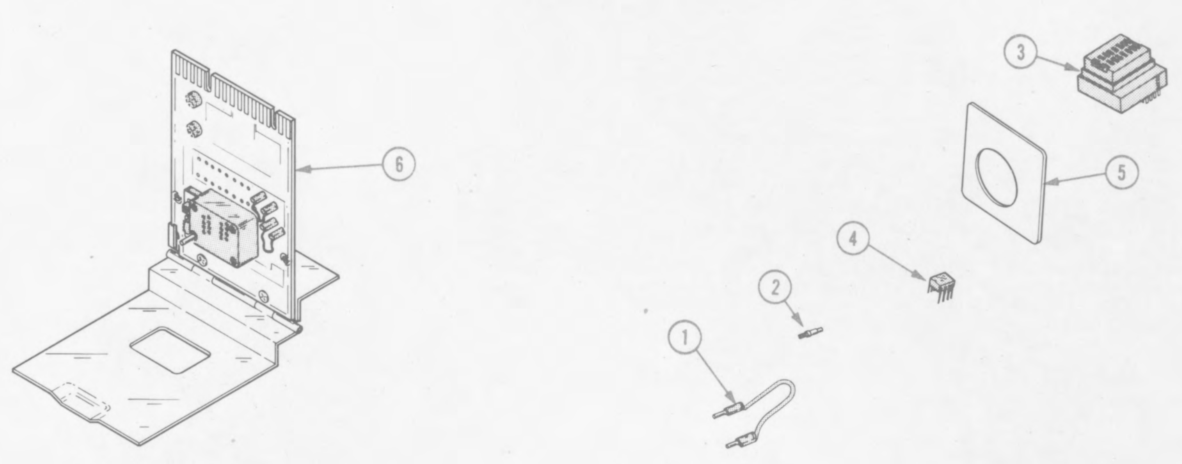


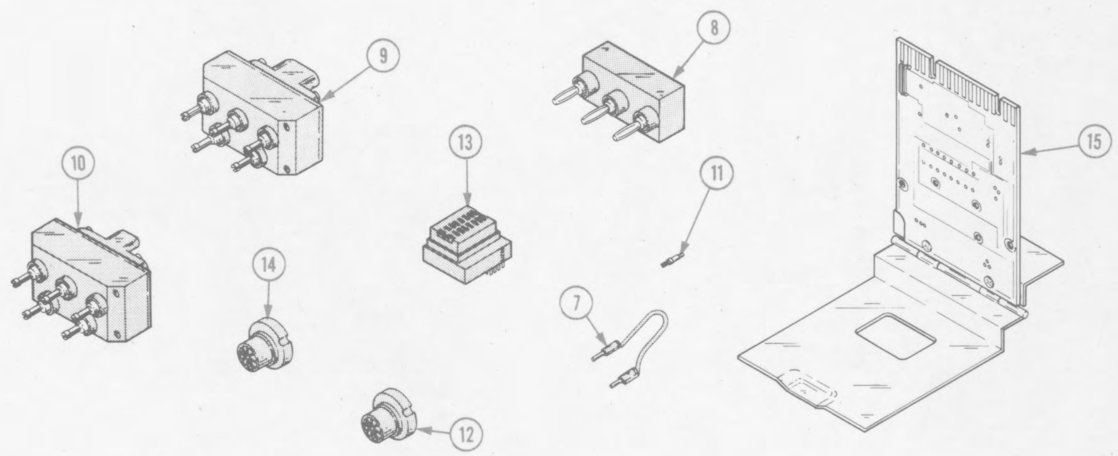

FIG. 1 EXPLODED

## ACCESSORIES



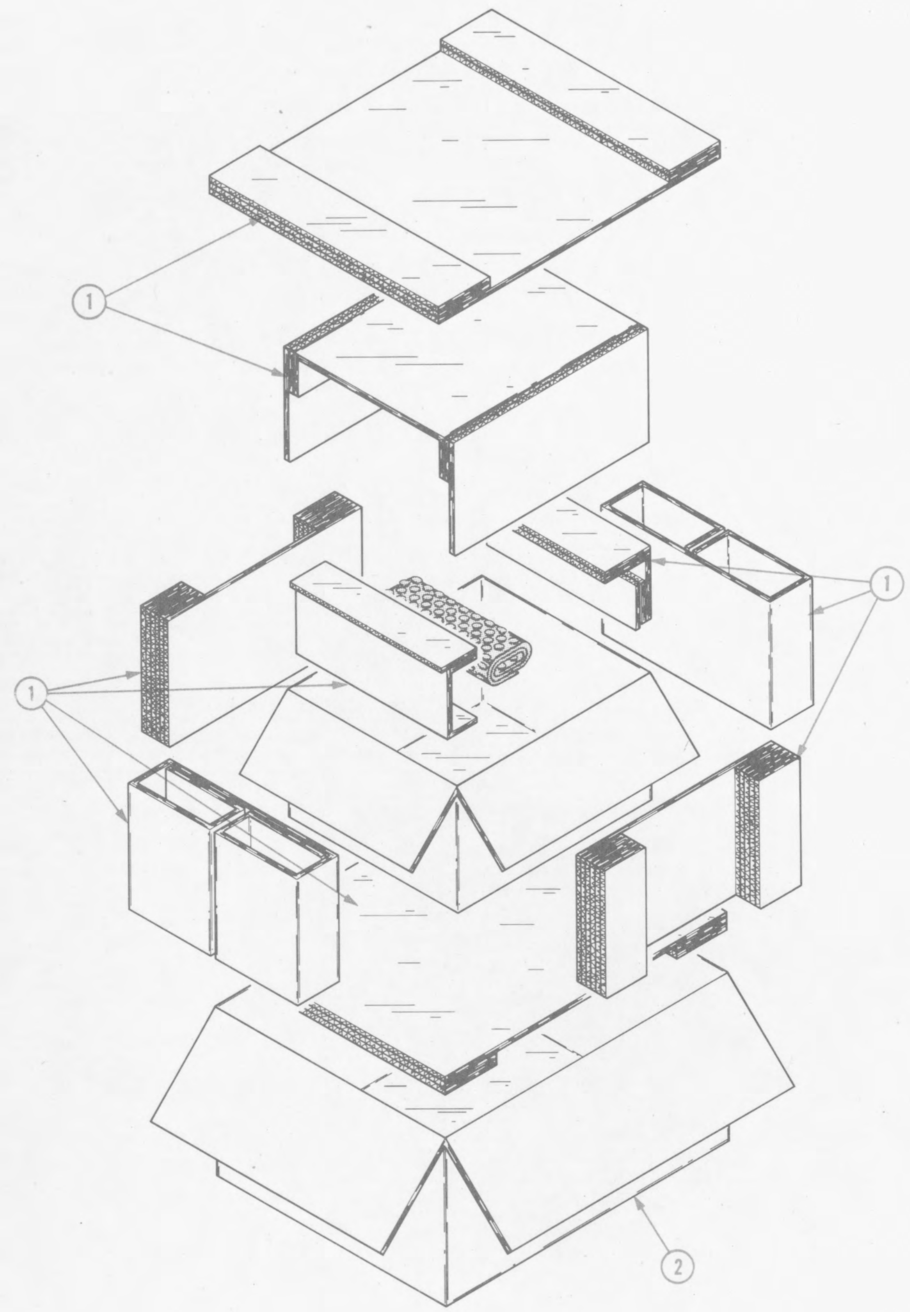

| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Qty | 1 2 3 4 5 Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|---|
| 2-1 | 012-0200-00 | | | 8 | PATCH CORD:2 INCHES LONG | 71279 | 3705-1-0312 |
| -2 | 131-1497-00 | | | 12 | CONTACT,ELEC: | 88245 | 15409 |
| -3 | 136-0442-00 | | | 1 | SOCKET,SEMICOND:INTEGRATED CKT,16 LEAD | 99779 | 029-385-03 |
| -4 | 156-0067-00 | | | 1 | INTEGRATED CKT:UDAL IN-LINE,8 PIN | 33888 | SL21822 |
| -5 | 333-1770-00 | | | 1 | PANEL,FUNCT SW: | 80009 | 333-1770-00 |
| -6 | 670-2567-00 | | | 1 | CKT CARD ASSY:STANDARD OP AMP | 80009 | 670-2567-00 |
| | 070-1474-00 | | | 1 | MANUAL:OPERATORS | 80009 | 070-1474-00 |

## OPTIONAL ACCESSORIES




| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Qty | 1 2 3 4 5 Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|---|
| 2-7 | 012-0200-00 | | | 1 | PATCH CORD:2 INCHES LONG | 71279 | 3705-1-0312 |
| -8 | 013-0070-01 | | | 1 | ADAPTER,TEST:3 TERMINAL,TRANSISTOR | 80009 | 013-0070-01 |
| -9 | 013-0138-00 | | | 1 | ADAPTER,TEST:IN-LINE,LARGE | 80009 | 013-0138-00 |
| -10 | 013-0139-00 | | | 1 | ADAPTER,TEST:IN-LINE,SMALL | 80009 | 013-0139-00 |
| -11 | 131-1497-00 | | | 1 | CONTACT,ELEC: | 88245 | 15409 |
| -12 | 136-0441-00 | | | 1 | SOCKET,SEMICOND:TRANSISTOR,10 LEAD | 99779 | 639-70021-101 |
| -13 | 136-0443-00 | | | 1 | SOCKET,SEMICOND:INTEGRATED CKT,14 LEAD | 99779 | 629-70021-141 |
| -14 | 136-0444-00 | | | 1 | SOCKET,SEMICOND:TRANSISTOR,10 LEAD | 99779 | 639-70021-081 |
| -15 | 670-2567-01 | | | 1 | CKT CARD ASSY:STANDARD OP AMP,W/COVER ONLY | 80009 | 670-2567-01 |

## REPACKAGING




| Fig. & Index No. | Tektronix Part No. | Serial/Model No. Eff | Dscont | Qty | 1 2 3 4 5 Name & Description | Mfr Code | Mfr Part Number |
|---|---|---|---|---|---|---|---|
| 3- | 065-0208-00 | | | 1 | CARTON ASSEMBLY: | 80009 | 065-0208-00 |
| | ----- ----- | | | - | . CARTON ASSEMBLY INCLUDES: | | |
| -1 | 004-1179-00 | | | 1 | . PAD SET: | 80009 | 004-1179-00 |
| -2 | 004-0496-00 | | | 1 | . BOX: | 80009 | 004-0496-00 |

# APPLICATIONS

## Op Amp Gain Error

Certain applications of operational amplifiers require precise signal amplification. Where the circuit gain is determined by precision passive components of a feedback network, one source of error is limited open-loop gain of the op amp. If the op amp gain is considered to be a constant, the error due to limited op amp gain is approximately:

$$\% \text{ error} \cong 100 \frac{\text{Network Gain}}{\text{Op Amp Gain}},$$

where the network gain is the gain determined by the feedback components and op amp gain is the open loop gain of the amplifier.

This commonly-used formula is convenient to use whenever op amp gain is constant (the gain curve is a well-behaved, linear function). However, as shown in the introduction to operational amplifiers, gain curves are not always linear. In these cases, another approach is used to determine error due to limited open-loop gain. One straight-forward approach was suggested in the first-time operation section, where the change in input voltage $\Delta V_{in}$, is compared to the signal being amplified ($V_s$).

Using this approach, the input voltage change due to limited gain is read directly from the curve tracer. This error can be easily grouped with other error sources that are normally already expressed in this manner.

To read the appropriate $\Delta V_{in}$ from the curve tracer, it is necessary to know what output voltage change, $\Delta V_o$, to consider. $\Delta V_o$ is obtained from the relationship:

$$\Delta V_o \cong V_s \times \text{Network Gain}.$$

Using the appropriate $\Delta V_o$, the corresponding value of $\Delta V_{in}$ is determined directly from the display. It is important to select the proper source and load resistances to simulate the circuit environment in which the op amp will be used.

Most irregular gain-curve shapes can be traced to the thermal effects within the op amp IC chip. The heating is produced in the amplifier's output stage and becomes more pronounced as the op amp is required to supply greater load currents. If two gain curves of the same op amp are compared, one using 50 kΩ load resistance, and the other using a lower value, such as a 2 kΩ, the thermal nature of the irregular slope becomes apparent. The points of minimum op amp power dissipation (output voltages near supply voltage zero) change the least. The greatest difference between the two curves usually occurs at the maximum power dissipation points, half way between ground and each supply.

The time constant of these internal thermal effects is usually very short. When operating below the amplifier's first gain-vs-frequency break point, the thermal input voltage changes usually cannot be separated from changes due to limited gain. Therefore, the dc and low-frequency gain of an op amp is, in effect, the composite of both electronic and thermal actions. Using the change in DUT input voltage as a measure of gain-thermal performance, this source of error can be conviently accounted for.

## Op Amp Gain at Higher Frequencies

As the frequency of signals applied to the op amp raises, thermal effects diminish and the effect of amplifier phase shift becomes predominant. Once well beyond the first gain-vs-frequency break point, gain falls at six dB per octave. In addition, the phase shift between input and output is near ninety degrees. The result on the curve tracer display is roughly an ellipse or a circle.

Input voltage is the maximum vertical excursion and output voltage is the maximum horizontal excursion. If the phase shift is ninety degrees, these maximum excursions should occur on the vertical and horizontal center lines of the graticule. The sweep amplitude should not be so high as to cause the DUT to reach its output limits during these measurements.

The Sweep Generator signal (up to 1 kHz) is an approximate sine wave. Higher frequency components are present, which cause larger irregularities in the displayed circles or ellipses. Therefore, gain measurements at higher frequencies are approximate.

## Measurement Restrictions Due to Insufficient DUT Gain

When operating the 178 in the CMRR and PSRR functions, it is possible to have excessive measurement error whenever the op amp (DUT) has insufficient gain. This measurement error can be eliminated by selecting the External Feedback Amp circuit. The procedure that follows reveals whether the External Feedback Amp is needed.

The cause of measurement error due to low gain is found by considering the simplified diagram in Fig. I.

The Op Amp (DUT) is in a feedback loop in which the primary gain source is the DUT. In the CMRR and PSRR functions, the DUT output is held near zero volts by the action of the feedback loop. However, the output must move some small amount in order to supply the $\Delta V_{in}$ for the functional test being performed. The small movement of DUT output voltage, $\Delta V_o$, is accompanied by

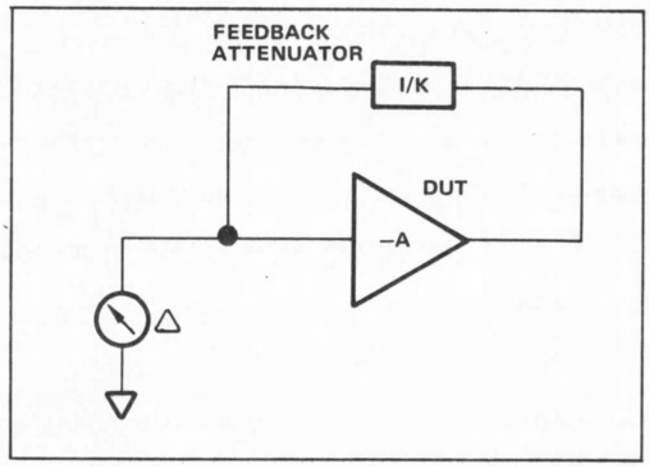



**Fig. 1. Simplified diagram illustrating measurement error due to low voltage.**

an input voltage change, producing some error in the $\Delta V_{in}$ being measured. The vertical deflection factor controls the feedback attenuator shown in Fig. 1, so that the DUT output must change from ten to one thousand times the required input voltage change. The error introduced by this process is:

$$\text{Error, } \Delta V_{in} = \frac{\Delta V_{in} \times K^1}{\text{DUT Gain} - K^1}$$

$$\text{and, \% error} = \frac{100 \times K^1}{\text{DUT Gain} - K^1}$$

[1] where K = 1000 for 10 µV to 50 µV/DIV

K = 100 for 100 µV to .5 mV/DIV

K = 10 for 1 mV to 50 mV/DIV

These results assume that small-signal (0.5 volts, p-p) DUT gain with a 50 kΩ load, is constant. This assumption is usually valid. Gain curve distortion is more pronounced with low value load resistance and large output signals. If the gain is not constant under this condition, the error in $\Delta V_{in}$ can be obtained from the gain curve by considering that portion of the curve around zero volts, where the DUT output voltage is $K^1 \times \Delta V_{in}$.

## MANUAL CHANGE INFORMATION

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

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

A single change may affect several sections. Sections of the manual are often printed at different times, so some of the information on the change pages may already be in your manual. Since the change information sheets are carried in the manual until ALL changes are permanently entered, some duplication may occur. If no such change pages appear in this section, your manual is correct as printed.

178 Linear IC Test Fixture

EFF for ALL SN

TEXT CORRECTION

SPECIFICATION

CHANGE TO:

Power Supply

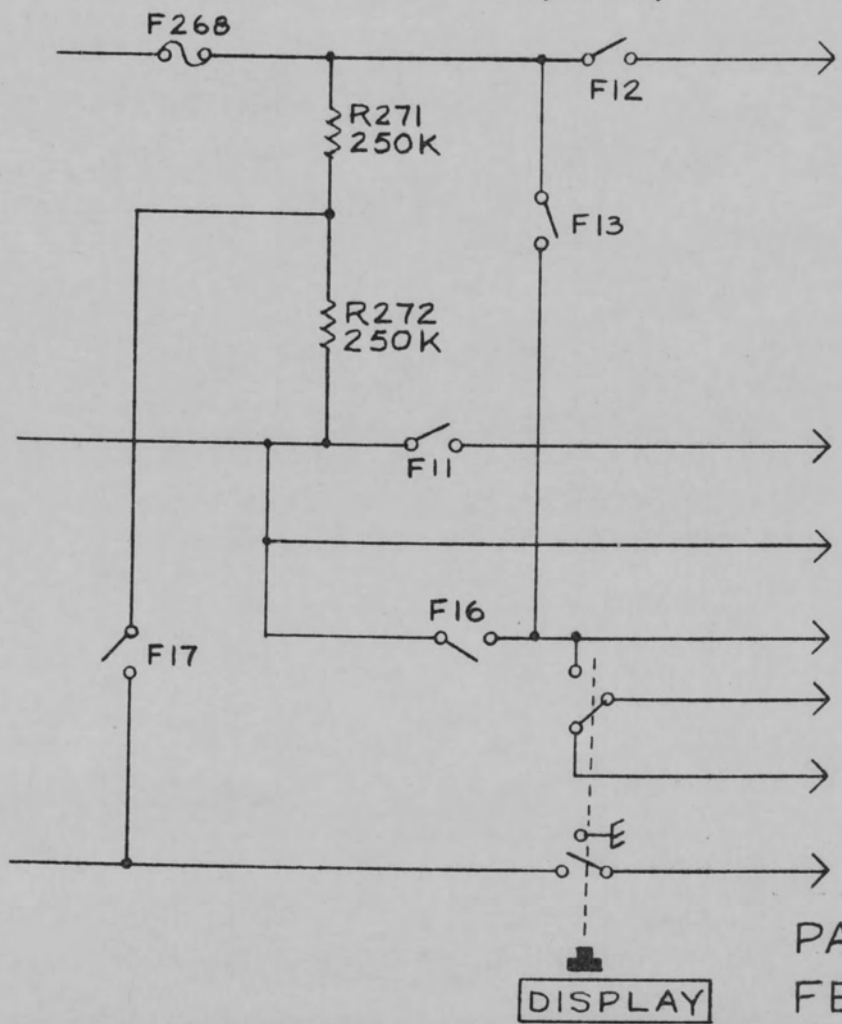
Current: 100 nA/DIV to 50 mA/DIV in a 1-2-5 sequence, unmagnified. 10 nA/DIV to 5 mA/DIV with 10X magnifier on.

Accuracy: ±3%, ±100 nA, unmagnified
±4%, ±100 nA, 10X magnifier on

ELECTRICAL PARTS LIST AND SCHEMATIC CORRECTION

CHANGE TO:

| | | |
|---|---|---|
| R271 | 321-0618-00 | 250 kΩ, 1/8 W, 1% |
| R272 | 321-0618-00 | 250 kΩ, 1/8 W, 1% |
| R476 | 315-0201-00 | 200 Ω, 1/4 W, 5% |
| R485 | 315-0151-00 | 150 Ω, 1/4 W, 5% |
| R576 | 315-0201-00 | 200 Ω, 1/4 W, 5% |
| R585 | 315-0151-00 | 150 Ω, 1/4 W, 5% |




C1/973

PARTIAL-
FEEDBACK AMP.

178 Linear I C Test Fixture

EFF SN B020000-up

ELECTRICAL PARTS LIST AND SCHEMATIC CORRECTION

CHANGE TO:

| | | |
|---|---|---|
| R467 | 321-0288-00 | 9.76 kΩ, 1/8 W, 1% |
| R551 | 321-0756-01 | 50 kΩ, 1/8 W, 1/2% |
| R570 | 321-0720-00 | 60 kΩ, 1/8 W, 1% |

## ELECTRICAL PARTS LIST AND SCHEMATIC CORRECTIONS

ADD:

| | | |
|---|---|---|
| C549 | 281-0518-00 | 47 pF, Cer, 500 V |

(C549 is added parallel to R549)

| | | |
|---|---|---|
| CR151 | 152-0242-00 | Silicon, 1N486A |
| CR152 | 152-0242-00 | Silicon, 1N486A |

CHANGE TO:

| | | |
|---|---|---|
| C320 | 281-0518-00 | 47 pF, Cer, 500 V |
| Q252 | 151-1037-00 | Dual N-Channel FET |

Interface Schematic