# Errata

**Title & Document Type:** **6235A Triple Output Power Supply Operating and Service Manual**

**Manual Part Number:** **06235-90001**

**Revision Date:** **January 1978**

## About this Manual

We've added this manual to the Agilent website in an effort to help you support your product. This manual provides the best information we could find. It may be incomplete or contain dated information, and the scan quality may not be ideal. If we find a better copy in the future, we will add it to the Agilent website.

## HP References in this Manual

This manual may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, life sciences, and chemical analysis businesses are now part of Agilent Technologies. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A. We have made no changes to this manual copy.

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Agilent Technologies

# TRIPLE OUTPUT
# POWER SUPPLY
# MODEL 6235A

OPERATING AND SERVICE MANUAL
FOR SERIALS 1752A-00101 AND ABOVE

* For Serials above 1752A-00101,
a change page may be included.

HP Part No. 06235-90001
Microfiche Part No. 06235-90002

Printed: January, 1978

HEWLETT hp PACKARD

## CERTIFICATION

*Hewlett-Packard Company certifies that this instrument met its published specifications at the time of shipment from the factory. Hewlett-Packard Company further certifies that its calibration measurements are traceable to the United States National Bureau of Standards, to the extent allowed by the Bureau's calibration facility, and to the calibration facilities of other International Standards Organization members.*

## WARRANTY AND ASSISTANCE

This Hewlett-Packard product is warranted against defects in materials and workmanship for a period of one year from the date of shipment [, except that in the case of certain components listed in Section I of this manual, the warranty shall be for the specified period]. Hewlett-Packard will, at its option, repair or replace products which prove to be defective during the warranty period provided they are returned to Hewlett-Packard, and provided the preventive maintenance procedures in this manual are followed. Repairs necessitated by misuse of the product are not covered by this warranty. NO OTHER WARRANTIES ARE EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. HEWLETT-PACKARD IS NOT LIABLE FOR CONSEQUENTIAL DAMAGES.

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For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

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# SECTION I
# GENERAL INFORMATION

## 1-1 DESCRIPTION

1-2 The Model 6235A Triple Output Power Supply is a compact general purpose bench supply particularly useful for powering development IC circuits, both linear and digital. This constant-voltage/current-limiting supply combines two 0* to ±18V tracking outputs rated at 0.2A with a single 0* to +6V output rated at 1A. The +18V and −18V tracking outputs can also be used in series as a single 0 to 36V, 0.2A output. Connections to the outputs are made to binding posts on the front panel. The +6V and ±18V outputs share a common output terminal which is isolated from chassis ground. The chassis ground terminal is located on the supply's rear heat sink assembly.

1-3 Each output is protected against overload or short-circuit damage by separate fixed current limit circuits. The +18V and −18V outputs are each limited to 0.255A ±15% and the +6V output is limited to 1.275A ±15%.

1-4 Voltage controls, output terminals, and a combination voltmeter/ammeter are located on the front panel. One voltage control sets the 0 to +6V output and another simultaneously adjusts the 0 to +18V and 0 to −18V dual tracking outputs. A tracking ratio control sets the ratio between the +18V and −18V outputs. It can set the negative supply's output to any value between a minimum that is less than 0.5V and a maximum that is equal to the positive supply's output. A 1:1 ratio is useful when powering operational amplifiers and other circuits that require balanced positive and negative voltages. Once the tracking control has established a voltage ratio between the positive and negative outputs, the ratio remains constant as the ±18V voltage control varies both outputs.

1-5 The front panel also contains a line pushbutton switch with a simulated (non-electrical) on-off indicator, and four meter select pushbutton switches. One meter pushbutton selects either voltage or current monitoring and the remaining three pushbuttons select the output to be monitored and the proper meter range.

1-6 In addition to the standard 104-to-127Vac, 47-to-63Hz input, a 240Vac nominal line voltage option is available. The supply is furnished with a permanently attached 5-foot 3-wire grounding type line cord. The ac line fuse is in an extractor type fuseholder on the rear heatsink.

*Each output has a minimum operating voltage of ≤ 50mV.

## 1-7 SPECIFICATIONS AND SUPPLEMENTAL CHARACTERISTICS

1-8 Table 1-1 provides specifications and supplemental characteristics for Triple Output Power Supply, Model 6235A. Specifications describe the supply's warranted performance characteristics. The supplemental characteristics are typical, but non-warranted, performance characteristics and are intended to provide additional information useful in applying the power supply.

## 1-9 OPTIONS

1-10 Options are factory modifications of a standard instrument that are requested by the customer. The following options are available with this instrument.

| OPTION NO. | DESCRIPTION |
|---|---|
| 028 | Input power: 208-250Vac, 47-63Hz, single phase. |
| 910 | One additional operating and service manual shipped with the power supply. |

1-11 Before the supply is shipped from the factory, an internal line voltage selector switch is set and the proper fuse installed for the line voltage specified on the order. A label on the rear heatsink identifies this line voltage option. The user can convert an instrument from one line voltage option to the other by following the instructions in paragraph 3-13.

## 1-12 SAFETY CONSIDERATIONS

1-13 This product is a Safety Class 1 insturment (provided with a protective earth terminal). The instrument and manual should be reviewed for safety markings and instructions before operation.

## 1-14 ACCESSORIES

1-15 The accessory listed below may be ordered from your local Hewlett-Packard field sales office either with the power supply or separately. (Refer to the list at the rear of the manual for addresses.)

| HP PART NO. | DESCRIPTION |
|---|---|
| 14522A | Rack Mounting Tray for mounting one or two 6235A supplies in a standard 19" relay rack. |

## 1-16 INSTRUMENT AND MANUAL IDENTIFICATION

1-17 Hewlett-Packard power supplies are identified by a two part serial number. The first part is the serial number prefix, a number-letter combination that denotes the date of a significant design change and the country of manufacture. The first two digits indicate the year (10 = 1970, 11 = 1971, etc.) the second two digits indicate the week, and the letter "A" designates the U. S. A. as the country of manufacture. The second part is the power supply serial number. A different sequential number is assigned to each power supply, starting with 00101.

1-18 If the serial number on your instrument does not agree with those on the title page of the manual, Change Sheets supplied with the manual or Manual Backdating Changes define the difference between your instrument and the instrument described by this manual.

## 1-19 ORDERING ADDITIONAL MANUALS

1-20 One manual is shipped with each power supply. (Option 910 is ordered for each extra manual, see paragraph 1-9.) Additional manuals may also be purchased separately from your local Hewlett-Packard field office (see the list at the rear of this manual for addresses). Specify the model number, serial number prefix, and the HP Part Number provided on the title page.

**Table 1-1. Specifications and Supplemental Characteristics**

**SPECIFICATIONS:**
The following specifications describe the 6235A's warranted performance characteristics.

**DC Output:**
Voltage span over which output may be varied using front panel controls.
* Minimum operating voltage for each output is ≤ 50 millivolts.

* 0 to +6V Output. Maximum rated output current is 1A. Short circuit output current is 1.275 ±15% and a fixed current limit circuit limits the output to this maximum at any output voltage setting.

0* to ±18V Output: Maximum rated current is 0.2A for each output. Short circuit output current is 0.255A ±15% and fixed current limit circuits limit the output of each supply to this maximum at any output voltage setting. Unbalanced loads within current rating are permitted.

**Input Power:**
Standard Option: 104-127Vac (120Vac nominal), 47-63Hz, single phase. (240Vac line voltage option available, see paragraph 1-9.)

**Load Effect (Load Regulation):**
Voltage load effect is given for a load current change equal to the current rating of the supply.
0 to +6V Output: 8mV
0 to ±18V Outputs: 10mV

**Source Effect (Line Regulation):**
Given for any line voltage change within rating.
0 to +6V Output: 8mV
0 to ±18V Outputs: 15mV

**PARD (Ripple and Noise):**
All Outputs: Less than 1mV rms and 5mV p-p (20Hz to 20MHz).

**Load Transient Recovery Time:**
All Outputs: Less than 50μsec for output recovery to within 15mV of nominal output voltage following a load change from a full load to half load (or vice versa).

**Temperature Ranges:**
Operating 0 to +40°C ambient. From 40°C to 55°C, output current is derated linearly to 50% at 55°C.
Storage: −40°C to +75°C.

**Meter Ranges:**
0 to +6V Output: 0 to 7V, 0 to 1.2A
0 to +18V Output: 0 to 21V, 0 to 0.24A
0 to −18V Output: 0 to 21V, 0 to 0.24A

**Meter Accuracy:**
Voltmeter: All Outputs: ±3% of full scale
Ammeter: All Outputs: ±4% of full scale

**Weight:**
Net: 5 lb (2.3 kg)
Shipping: 7 lb (3.2 kg)

**Table 1-1. Specifications and Supplemental Characteristics (Continued)**

**SUPPLEMENTAL CHARACTERISTICS:**

The following characteristics are intended to provide information useful in 6235A applications by giving typical, but non-warranted, performance parameters.

**Regulation and Ripple (Typical performance parameters):**

The maximum load regulation, line regulation, and ripple specifications listed on page 1-2 are given for 0 to 40°C temperature range. At an ambient temperature of 25°C, typical performance characteristics are as follows:

Load Regulation:
- 0 to +6V Output: 4mV
- 0 to ±18V Output: 6mV

Line Regulation:
- 0 to +6V Output: 4mV
- 0 to ±18V Output: 6mV

Ripple:
- All outputs: 0.2mV rms.

**Tracking Accuracy (±18V Outputs):**

The output voltage tracking ratio remains constant (within 1%) over the voltage range from 1 to 18 volts for any TRACK control setting.

**Temperature Coefficient:**

All Outputs: Less than 0.04% + 2mV voltage change per degree Celsius over the operating range from 0 to 40°C after 30 minutes warm-up.

**Drift (Stability):**

All Outputs: Less than 0.1% + 10mV (dc to 20Hz) during 8 hours at constant line, load, and ambient after an initial warm-up time of 30 minutes.

SECTION II
INSTALLATION

## 2-1 INITIAL INSPECTION

2-2 Before shipment, this instrument was inspected and found to be free of mechanical and electrical defects. As soon as the instrument is unpacked, inspect for any damage that may have occurred in transit. Save all packing materials until the inspection is completed. If damage is found, file claim with carrier immediately. The Hewlett-Packard Sales and Service office should be notified as soon as possible.

### 2-3 Mechanical Check

2-4 This check should confirm that there are no broken knobs or connectors, that the cabinet and panel surfaces are free of dents and scratches, and that the meter is not scratched or cracked.

### 2-5 Electrical Check

2-6 The instrument should be checked against its electrical specifications. Section V includes an "in-cabinet" performance check to verify proper instrument operation.

## 2-7 INSTALLATION DATA

2-8 The instrument is shipped ready for bench operation. Before applying power to the instrument, see the CAUTION notice in paragraph 3-11.

### 2-9 Location

2-10 This instrument is air cooled. Sufficient space should be allotted so that a free flow of cooling air can reach the rear of the instrument when it is in operation. It should be used in an area where the ambient temperature does not exceed 40°C (up to 55°C with derating).

### 2-11 Outline Diagram

2-12 Figure 2-1 illustrates the outline shape and dimensions of this supply.

### 2-13 Rack Mounting

2-14 One or two 6235A's may be mounted in a standard 19-inch rack panel using rack mounting tray HP Part No. 14522A. Installation consists of bolting the rack mounting tray to the 19-inch rack and sliding the power supply(s) into the slot(s) provided in the tray. The power supply's rubber feet are seated in holes in the bottom of the tray.

### 2-15 Input Power Requirements

2-16 The supply may be operated continuously from a nominal 120V or 240V (47-63Hz) single phase power source. The supply is shipped from the factory ready to be operated from one of these power sources. A label on the rear heatsink identifies the line voltage option of your supply. The input voltage range and input current required for each of the nominal inputs are listed below. The maximum input power (high line, full load conditions) required for either input is 35 watts.

| Option | Line Voltage Range | Maximum Input Current |
|---|---|---|
| Standard (120Vac) | 104-127Vac | .26A |
| 028 (240Vac) | 208-250Vac | .14A |

2-17 If desired, the user can convert the unit from one option to another by following the instructions in paragraph 3-13. A unit is converted by resetting an internal line voltage selector switch, replacing the fuse and line cord plug, and changing the line voltage label.

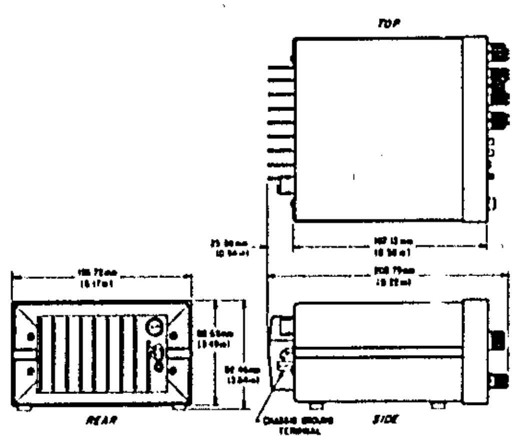



Figure 2-1. Outline Diagram

## 2-18 Power Cable

2-19 To protect operating personnel, the National Electrical Manufacturers Association (NEMA) recommends that the instrument panel and cabinet be grounded. This instrument is equipped with a three conductor power cable. The third conductor is the ground conductor and when the cable is plugged into an appropriate receptacle, the instrument is grounded. The offset pin on the power cable three-prong connector is the ground connection. In no event shall this instrument be operated without an adequate cabinet ground connection.

2-20 To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter (if permitted by local regulations) and connect the green lead on the adapter to ground.

2-21 Model 6235A is equipped at the factory with a power cord plug appropriate for the user's location. Figure 2-2 illustrates the standard configuration of power cord plugs used by HP. Below each drawing is the HP Part Number for a replacement power cord equipped with a plug of that configuration. Notify the nearest HP Sales Office if you require a different power cord.

## 2-22 REPACKAGING FOR SHIPMENT

2-23 To insure safe shipment of the instrument, it is recommended that the package designed for the instrument be used. The original packaging material is reusable. If it is not available, contact your local Hewlett-Packard field office to obtain the materials. This office will also furnish the address of the nearest service office to which the instrument can be shipped and provide the Authorized Return label necessary to expedite the handling of your instrument return. Be sure to attach a tag to the instrument which specifies the owner, model number, full serial number, and service required, or a brief description of the trouble.

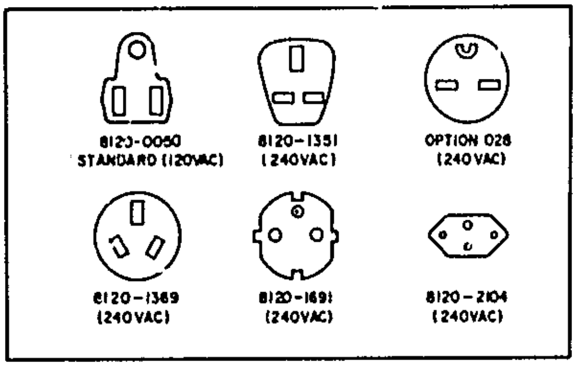



Figure 2-2. Power Cord Plug Configurations

# OPERATION

# THEORY

# SECTION III
# OPERATING INSTRUCTIONS

## 3-1 INTRODUCTION

3-2 This section describes the operating controls and indicators, turn-on checkout procedures, and other operating considerations for the Model 6235A Triple Output Power Supply.

### WARNING

*Before the instrument is switched on, all protective earth terminals, extension cords, auto-transformers and devices connected to it should be connected to a protective earth grounded socket. Any interruption of the protective earth grounding will cause a potential shock hazard that could result in personal injury.*

*Only fuses with the required rated current and specified type should be used. Do not use repaired fuses or short circuited fuseholders. To do so could cause a shock or fire hazard.*

## 3-3 CONTROLS AND INDICATORS

### 3-4 Line Switch

3-5 The LINE pushbutton switch (item (1), Figure 3-1) is pushed-in to turn the supply ON and released (out position) to turn the supply OFF. A simulated (non-electrical) ON indicator (within the pushbutton) "lights" when the button is pushed-in whether or not power is applied to the unit.

### 3-6 Voltage and Current Metering

3-7 Four meter select pushbutton switches (items (2) and (3)) permit the output voltage or current of any one supply (+6V, +18V, or −18V) to be monitored on the VOLTS/AMPS meter (4). The V/A pushbutton (2) selects either voltage (out position) or current (in position). The +6, +18, and −18 output select pushbuttons (3) connect the desired output to the metering circuit when the applicable button is pushed-in. The three output select pushbuttons are mechanically interlocked so that only one can be pushed-in at a time. The voltmeter and ammeter ranges selected by the +6, +18, and −18 pushbuttons are listed below. The shaded areas on the meter scales indicate the amount of output voltage or current that may be available in excess of the normal rating.

| OUTPUT | METER RANGES | |
|---|---|---|
| | VOLTS | AMPS |
| +6V | 0-7 | 0-1.2 |
| +18V | 0-21 | 0-0.24 |
| −18V | 0-21 | 0-0.24 |

### 3-8 Voltage Controls

3-9 The +6 VOLTAGE control (5) sets the output voltage level of the +6V supply and the ±18 control (6) sets the output voltage levels of the dual tracking ±18V supplies. Precise tracking of the +18V and −18V outputs is achieved by controlling the positive output and using it as a reference voltage for the negative supply. The TRACK/VOLTAGE control (7) sets the ratio between the −18V and +18V output voltages. Once the ratio is set, the +18 VOLTAGE control will control both outputs with a constant ratio maintained between the two outputs. The voltage controls (cermet potentiometers) have infinite resolution; thus, the resolution obtained depends only upon the user's care in setting the controls. Greater accuracy in setting the controls can be achieved by using a DVM to measure the outputs.

## 3-10 TURN-ON CHECKOUT PROCEDURES

3-11 The following steps describe the use of the Model 6235A front panel controls and indicators illustrated in Figure 3-1 and serve as a brief check that the supply is operational. Follow this checkout procedure or the more detailed performance test of paragraph 5-6 when the instrument is received and before it is connected to any load equipment. Proceed to the more detailed performance test beginning in paragraph 5-6 if any difficulties are encountered.

### CAUTION

*Before the supply is switched on, check the label on the heat sink to make certain that the supply's line voltage option agrees with the line voltage to be used. The supply will be damaged if its internal switch is set for a 120Vac input and 240Vac input power is applied.*

a. Connect line cord to power source and push LINE switch (1) in.

b. Set meter select switches (2), (3) to monitor

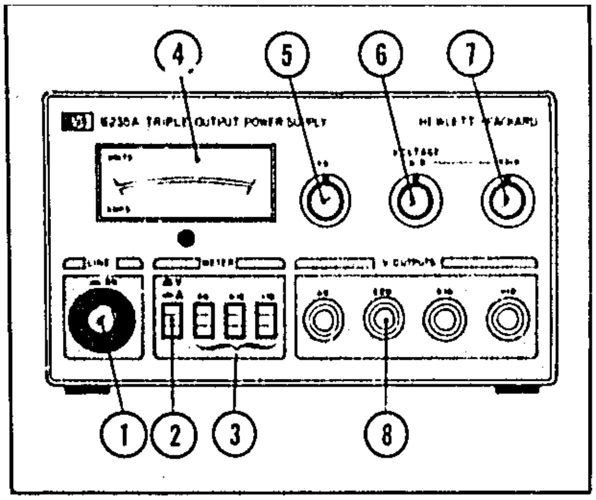



Figure 3-1. Controls and Indicators

+6V supply's output voltage. With no load connected, vary the +6 VOLTAGE control (6) over its range and check that the voltmeter (4) responds to the control setting.

c. Monitor the +18V supply's output voltage. With no load connected, vary the ±18 VOLTAGE control (6) over its range and check that the voltmeter responds to the control setting.

d. Monitor the −18V supply's output voltage. Turn TRACK VOLTAGE (7) control fully clockwise. With no load connected, vary the ±18 VOLTAGE control (6) over its range and check that the voltmeter responds to the control setting.

e. Monitor the +18V output and adjust ±18 VOLTAGE control for +18V indication on voltmeter. Monitor the −18V output and check the effect of the TRACK VOLTAGE control on the voltage of the −18V output. The −18V output should be adjustable from less than 0.5 volts to a maximum of 18 to 21 volts as the TRACK control is rotated from its fully CCW to its fully CW position.

f. Turn the +6, ±18, and TRACK VOLTAGE controls fully CW. Connect ammeter (e. g. Simpson Multimeter, Model 269), in turn, between each output and COM. The internal resistance of the meter is low enough to overload the supply so that the output will current limit. Verify that the current limit circuit in each supply is limiting the output current to:

| Supply | Current Limit |
|---|---|
| +6V | 1.275A ±15% |
| +18V | 0.255A ±15% |
| −18V | 0.255A ±15% |

g. Remove meter and connect loads to the output terminals (see paragraph 3-23).

3-12 If this brief checkout procedure or later use of the supply reveals a possible malfunction, see Section V of this manual for detailed test troubleshooting, and adjustment procedures.

## 3-13 LINE VOLTAGE OPTION CONVERSION

3-14 To convert the supply from one line voltage option to the other, proceed as follows:

1. Disconnect line cord from the power source.
2. Remove top cover from supply by removing 2 screws in rear of supply and sliding cover to the rear. The line voltage selector switch (S2) is mounted on the circuit board behind the meter.
3. Set S2 to the desired position (see Figure 3-2). The forward switch position (toward front panel) selects 120Vac input and the rear switch position (toward heat sink) selects the 240Vac input.
4. Check the rating of the installed fuse and replace it with correct value, if necessary. For 120Vac input, use a 0.4A slo-blow fuse (HP Part No. 2110-0340). For 240Vac input, use a 0.2A slo-blow fuse (HP Part No. 2110-0235).
5. Install proper line cord and plug (see paragraph 2-21).
6. Mark the supply clearly with a tag or label indicating the correct line voltage to be used.

## 3-15 OPERATION

3-16 This power supply can be operated individually or in parallel with another supply (see paragraph 3-27). All output terminals are isolated from chassis ground. The +6V and ±18V outputs use a single common output terminal (8). This common (COM) terminal or any one of the other output terminals may be grounded to the chassis ground terminal which is located on the supply's rear heat sink. All outputs may also be left floating. Loads can be connected separately between each of the 0 to 18V output terminals and the COM terminal, or between the +18V and −18V terminals for a 0 to 36V output. A single load can also be connected between the +6V and −18V terminals for a 0 to 24V output.

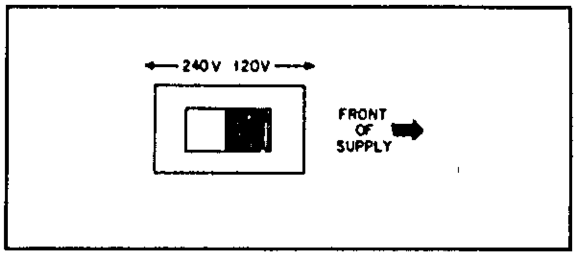



Figure 3-2. Line Voltage Selector (Set For 120Vac)

## 3-17 Tracking Ratio

3-18 The TRACK VOLTAGE control can be used to set a 1:1 ratio so that the voltage of the −18V supply tracks that of the +18V supply within 1% for convenience in varying the symmetrical voltages needed by operational amplifiers and other circuits using balanced positive and negative inputs. The TRACK control can also be used to set the negative supply's output from a minimum of less than 0.5 volts to a maximum equal to the +18V supply's output. Once the ratio is set, the ±18 VOLTAGE control will control both output and maintain a constant ratio between the voltages. To set the ratio between the −18V and +18V outputs, proceed as follows:

**NOTE**

*Any accidental movement or mechanical vibration can vary the tracking ratio setting. Greater accuracy in setting the controls can be achieved by using a DVM to measure the ±18V outputs.*

a. Set the 0 to +18V supply's output to the desired value using the ±18 VOLTAGE control.

b. Set the 0 to −18V supply's output to the desired value (equal to or lower than the magnitude of the +18V supply's output) using the TRACK VOLTAGE control.

## 3-19 Overcurrent Protection

3-20 All three outputs are individually protected against overload or short-circuit damage by separate current limiting circuits. The circuits for the +18V and −18V supplies are factory adjusted to limit the output current to 0.255A ±15%. The circuit for the +6V supply is factory adjusted to limit the output current to 1.275A ±15%. The current limits are set by adjusting resistors R3 in the +18V, R13 in the −18V and R23 in the +6V supply. (See paragraph 5-47 for current limit calibration procedures). No deterioration of a supply's performance occurs if the output current remains below the current limit setting. If a single load is connected between the +18V and −18V outputs, the circuit set for the lesser current limit will limit the output.

## 3-21 Operation Beyond Rated Output

3-22 The supply may be able to provide voltages and currents greater than its rated maximum outputs if the line voltage is at or above its nominal value. Operation can extend into the shaded areas on the meter faces without damage to the supply, but performance specifications cannot be guaranteed.

## 3-23 Connecting Loads

3-24 Connect each load to the power supply output terminals using separate pairs of connecting wires. This minimizes mutual coupling between loads and takes full advantage of the low output impedance of the supply. Load wires must be of adequately heavy gauge to maintain satisfactory regulation at the load. Make each pair of connecting wires as short as possible and twist or shield them to reduce noise pick-up. If shielded wire is used, connect one end of the shield to the power supply ground terminal and leave the other end unconnected. The 6235A's chassis ground terminal is located on the rear of the supply.

3-25 If load considerations require locating output power distribution terminals at a distance from the power supply, then the power supply output terminals should be connected to the remote distribution terminals by a pair of twisted or shielded wires and each load should be connected to the remote distribution terminals separately.

## 3-26 Parallel Operation

3-27 Two or more power supplies can be connected in parallel to obtain a total output current greater than that available from one supply. The total output current is the sum of the output currents of the individual supplies. The output voltage controls of one power supply should be set to the desired output voltage, and the other supply set for a slightly larger output voltage. The supply set to the lower output voltage will act as a constant voltage source, while the supply set to the higher output will act as a current-limited source, dropping its output voltage until it equals that of the other supply. The constant voltage source will deliver only that fraction of its rated output current necessary to fulfill the total current demand.

## 3-28 Special Operating Considerations

3-29 **Pulse Loading.** The power supply will automatically cross over from constant-voltage to current-limit operation in response to an increase in the output current over the preset limit. Although the preset limit may be set higher than the average output current, high peak currents as occur in pulse loading may exceed the preset current limit and cause crossover to occur and degrade performance.

3-30 **Output Capacitance.** An internal capacitor across the output terminals of the power supply helps to supply high-current pulses of short duration during constant-voltage operation. Any capacitance added externally will improve the pulse current capability, but will decrease the load protection provided by the current limiting circuit. A high-current output pulse may damage load components before the average output current is large enough to cause the current limiting circuit to operate.

**3-31 Reverse Current Loading.** An active load connected to the power supply may actually deliver a reverse current to the supply during a portion of its operating cycle. An external source cannot be allowed to pump current into the supply without risking loss of regulation and possible damage to the output capacitor. To avoid these effects, it is necessary to preload the supply with a dummy load resistor so that the power supply delivers current through the entire operating cycle of the load device.

**3-32 Reverse Voltage Protection.** Internal diodes connected with reverse polarity across the output terminals protect the output electrolytic capacitors and the driver transistors from the effects of a reverse voltage applied across a supply output. Since series regulator transistors cannot withstand reverse voltage either, diodes are also connected across them. When operating supplies in parallel, these diodes protect an unenergized supply that is in parallel with an energized supply.

**3-33 Output Voltage Overshoot.** During turn-on or turn-off of ac power, output plus overshoot will not exceed 1V if the output is set for less than 1V. If the control is set for 1V or higher, there is no overshoot.

# SECTION IV
# PRINCIPLES OF OPERATION

## 4-1 OVERALL DESCRIPTION

4-2 This section presents the principles of operation of the Model 6235A Triple Ouptut Power Supply. Throughout this section refer to the schematic diagram of Figure 7-1.

4-3 Two primary windings of the power transformer are connected for either a 120Vac or 240Vac input by setting selector switch S2 mounted on the circuit board to the desired position. The three transformer secondaries provide reduced ac voltages to the rectifiers in each supply. The rectifier-filters in each supply convert the ac to unregulated dc for application to the associated regulator circuit. The bridge rectifier in the +6V supply also provides bias voltages for the ±18V supplies. Each supply contains a series regulator transistor which adjusts its current so that a regulated, constant voltage is available across the output terminals. The 0 to +6V supply is rated at 1A and the 0 to ±18V supplies are each rated at 0.2A. Because of component specifications (principally the specifications for voltage regulator IC's U1 and U11), each supply (0 to +6V, 0 to +18V, 0 to −18V) has a minimum operating voltage of ≤ 50mV (not 0V). The output voltages of the +18V and −18V dual tracking supplies are set by the same front panel control (±18V VOLTAGE control). Precise tracking of the two outputs is achieved by using the regulated positive output as the reference voltage for the negative supply. Each supply has a fixed current limit which is factory set at approximately 130% of its maximum rated output.

4-4 Four meter select pushbutton switches select which of the supplies has its output voltage or current indicated on the combination voltmeter/ammeter. The proper meter range is selected automatically.

## 4-5 0 to +18V REGULATED SUPPLY

4-6 The 0 to +18V regulated supply consists basically of fullwave bridge rectifier (U2), PNP series regulator transistor (Q1), and negative voltage regulator IC (U1). A simplified schematic of the IC is provided on Figure 7-1. Its basic contents include: an error amplifier, driver, current limit circuit, reference supply, and a current source.

4-7 The fullwave bridge rectifier and capacitor filter (C1) provide an unregulated 36Vdc which is connected across the regulator circuit. The PNP series regulator, connected in the negative output line provides the voltage drop that is the difference between the unregulated input voltage and the regulated output voltage. The current through the series regulator is adjusted to maintain the output voltage constant. The series regulator is part of a feedback loop and alters its conduction in accordance with control signals received from the driver. The driver is controlled by feedback signals from the error amplifier during constant voltage operation or the current limit circuit during current limit operation.

### 4-8 Constant Voltage Operation

4-9 The error amplifier continuously compares a stable reference voltage with a portion of the output voltage. The reference voltage applied to the error amplifier is developed across the ±18 VOLTAGE control R1 which is connected between the positive output line and the IC's adjustment terminal (U1-7). If a difference exists between the reference voltage and the output voltage, an error voltage is generated to control the conduction of the series regulator, which, in turn, alters the output voltage so that the difference between the two inputs is reduced to neraly zero volts.

4-10 At the driver output (Booster Output U1, pin 7) a negative voltage change causes an increase in the conduction of Q1. For output voltages greater than 0 volts, the negative booster output is applied to the base of Q1 through diode CR1. For this condition, transistor Q2 is turned off. When the output is set to zero volts, CR1 is turned-off and Q2 is turned-on. With Q2 turned-on, Q1 is turned-off and most of the leakage current is shunted away from the output terminals holding the output near zero volts.

4-11 Besides maintaining the output voltage constant, the error amplifier also originates the control signals necessary to establish output voltage levels in accordance with the settings of the ±18 VOLTAGE control (R1). The voltage control varies the reference voltage supplied to the error amplifier which, in turn, determines the output voltage of the supply. Since the +18V supply's output voltage is used as the reference for the −18V supply (see paragraph 4-16), the ±18 VOLTAGE control simultaneously adjusts the output of both supplies. Clockwise rotation of the ±18 VOLTAGE control (R1) causes the outputs of both supplies to increase. The output voltage scale factor is approximately 2 volts/1000 ohms.

## 4-12 Current Limit Operation

4-13 Current limiting occurs when the current limit transistor in the voltage regulator IC (U1) conducts. This is determined by the voltage drop across current sampling resistor R4 and the adjustment of current limit potentiometer R3. When the output current reaches the limit value (0.255A ±15%), the positive voltage at U1-6 becomes large enough and turns on the current limit transistor. For this condition, the current limit circuit takes control of the regulator's output voltage and reduces it as necessary to keep the output current from exceeding the limit value. Because of the dual tracking interconnection between the positive and negative 18V supplies, the output voltages of both are reduced if the positive output is overloaded. When the overload is removed, the current limit transistor is turned-off returning control of the regulator's output to the error amplifier.

## 4-14 Circuit Protection Components

4-15 Diodes CR5 and CR6 each protect the +18V supply from specific hazards. Output diode CR5 protects the supply's components if a reverse voltage is applied to the output terminals. A common way for this to occur is for an unergized supply to be connected in series with another that is energized. The series regulator diode, CR6, protects the series regulator transistor from reverse voltage. Reverse series regulator voltage could occur if a deenergized supply were connected in parallel with an energized one.

## 4-16 0 to −18V REGULATED SUPPLY

4-17 The 0 to −18V supply consists basically of fullwave bridge rectifier (U12), NPN series regulator transistor (Q11), comparison amplifier (U11), and current limit sensing amplifier (Q12). The NPN series regulator, connected in the supply's positive output line, adjusts the unregulated dc voltage so that a regulated constant voltage is produced across the −18V and COM output terminals. At the output of the comparison amplifier, a positive voltage change causes an increase in the conduction of Q11.

4-18 The −18V supply uses the output of the +18V supply as its reference voltage. As a result, both outputs are set by the ±18V VOLTAGE control and track each other within 1%. Resistor R12 and TRACK VOLTAGE potentiometer R11 are connected in series between the +18V and −18V outputs. The mid-point of this voltage divider is connected to the non-inverting input of the comparison amplifier through R16. The amplifier's inverting input is connected to COM to hold it at zero volts. The amplifier keeps its differential input voltage at zero by matching the output voltage of the −18V supply to that of the +18V supply. The TRACK control sets the ratio between the −18V and +18V outputs. Turning the control counterclockwise reduces the resistance and lowers the voltage of the negative output.

4-19 Current limiting for the −18V supply is effected through terminal 8 of comparison amplifier U11. Current limiting occurs when transistor Q12 conducts. This is determined by the voltage drop across current sampling resistor R14 and the adjustment of current limiting potentiometer R13. When the output current reaches the limit value (0.255A ±15%), Q12 conducts and causes a negative going output change at U11-6 which reduces the output voltage in order to keep the output current from exceeding the limit value.

## 4-20 0 to +6V REGULATED SUPPLY

4-21 The 0 to +6V supply consists basically of fullwave rectifier diodes CR23 and CR24, PNP driver transistor Q22, NPN series regulator transistor Q21, and negative voltage regulator IC (U21).

4-22 Diodes CR23 and CR24 and the center-tapped secondary transformer form a fullwave rectifier circuit. This circuit along with filter capacitor C21B provides an unregulated 16Vdc (nom.) for the 0 to +6V regulator circuit. Diodes CR23 and CR24 are also part of a fullwave bridge rectifier circuit that also includes diodes CR21 and CR22. The fullwave bridge rectifier circuit and filter capacitor C21A provide bias voltage for comparison amplifier U11 in the −18V supply and for transistor Q2 in the +18V supply. Bleed current from the −18V supply flows through R17.

4-23 Except for differing component designations and values, paragraphs 4-8 through 4-15, which describe constant voltage operation, current limit operation, and circuit protection components for the +18V regulator circuit, also apply to the +6V regulation circuit. The only difference in circuit operation is that the +6V supply utilizes a PNP driver transistor (Q22) in conjunction with a NPN series regulator transistor (Q21). Ferrite bead L1, connected between the emitter of Q22 and COM suppresses high frequency oscillations. Also, transistor Q23 is included with VR21 in the +6V supply to improve line regulation. In addition, the +6V supply's current limit is set to 1.275A ±15% whereas the +18V supply has a current limit of 0.255A ±15.

4-24 The output voltage or output current of any one supply can be measured on voltmeter/ammeter (M1). The volts/amps pushbutton (S3) selects either voltage or current and the +6 (S4), +18 (S5), and −18 (S6) pushbuttons connect the desired output to the metering circuit. R36 and R32 are voltage scaling resistors for the +6V and ±18V supplies, respectively. When measuring output current, the meter, in series with ammeter adjust potentiometer (R31), is connected across the applicable current sampling resistor.

# MAINTENANCE

# SECTION V
# MAINTENANCE

## 5-1 INTRODUCTION

5-2 Upon receipt of the power supply, the performance test of paragraph 5-6 can be made. This test is suitable for incoming inspection. Section III contains a quick but less comprehensive checkout procedure that can be used in lieu of the performance test if desired.

5-3 If a fault is detected in the power supply while making the performance test or during normal operation, proceed to the troubleshooting procedure in paragraph 5-32. After troubleshooting and repair, repeat the performance test to ensure that the fault has been properly corrected and that no other faults exist. Before performing any maintenance checks, turn on the power supply and allow a half-hour warm-up.

## 5-4 TEST EQUIPMENT REQUIRED

5-5 Table 5-1 lists the test equipment required to perform the various procedures described in this section.

## 5-6 PERFORMANCE TEST

5-7 The following test can be used as an incoming inspection check and appropriate portions of the test can be repeated to check the operation of the instrument after repairs. If the correct result is not obtained for a particular check, proceed to the troubleshooting procedures of paragraph 5-32.

**CAUTION**

*Before applying power to the supply, check the label on the heat sink to make certain that the supply's line voltage option agrees with the line voltage to be used. The supply will be damaged if its internal switch is set for a 120Vac input and 240Vac input power is applied.*

**Table 5-1. Test Equipment Required**

| TYPE | REQUIRED CHARACTERISTICS | USE | RECOMMENDED MODEL |
|---|---|---|---|
| Digital Voltmeter | Sensitivity: 100mV full scale (min.). Input impedance: 10 megohms (min.). | Measure dc voltages: calibration procedures | HP 3490A |
| Variable Voltage Transformer | Range: 90–130 Vac Equipped with voltmeter accurate within 1 volt | Vary ac input | ...... |
| Oscilloscope | Sensitivity: 100μV/cm. Differential input. | Display transient response and ripple and noise waveforms. | HP 180C with 1821A, and 1801A or 1803A plug-ins. |
| Repetitive Load Sw. | Rate: 60 Hz, 2μs rise and fall time | Measure transient response. | See Figure 5-5. |
| Resistive Loads | Value: See Paragraph 5-11. Tolerance: ±5% | Power supply load resistor (fixed resistor or rheostat). | James G. Biddle ("Lubri-Tact" Rheostat) |
| Current Sampling Resistor (Shunt) | Value: See paragraph 5-13. Accuracy: 1% (minimum) | Measure output current | Simpson Portable Shunt, 06703. |

## 5-8 General Measurement Techniques

5-9 **Connecting Measuring Devices.** To achieve valid results when measuring the load effect, PARD (ripple and noise), and transient recovery time of the supply, measuring devices must be connected as close to the output terminals as possible. A measurement made across the load includes the impedance of the leads to the load. The impedance of the load leads can easily be several orders of magnitude greater than the supply impedance and thus invalidate the measurement. To avoid mutual coupling effects, each measuring device must be connected directly to the output terminals by separate pairs of leads.

5-10 When measurements are made at the front panel terminals, the monitoring leads must be connected at point A, as shown in Figure 5-1, and not at point B. Connecting the measuring device at point B would result in a measurement that includes the resistance of the leads between the output terminals and the point of connection.

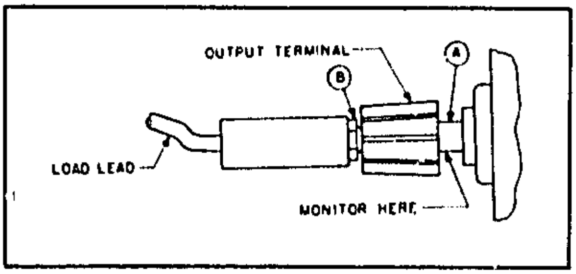



**Figure 5-1. Front Panel Terminal Connections**

5-11 **Selecting Load Resistors.** Power supply specifications are checked with a full load resistance connected across the supply output. The resistance and wattage of the load resistor, therefore, must permit operation of the supply at its rated output voltage and current. For example, a supply rated at 18 volts and 0.2 amperes would require a load resistance of 90 ohms at the rated output. The wattage rating of this resistor would have to be at least 4 watts.

5-12 Either a fixed or variable resistor (rheostat) can be used as the load resistance. Using a rheostat (alone or in series with a fixed resistor) is often more convenient than using fixed resistors as loads because the latter may be more difficult to obtain in the exact resistance required. A supplier of rheostats appropriate for testing these supplies is listed in Table 5-1.

5-13 **Output Current Measurements.** For accurate output current measurements, a current sampling resistor should be inserted between the load resistor and the output of the supply. An accurate voltmeter is then placed across the sampling resistor and the output current calculated by dividing the voltage across the sampling resistor by its ohmic value. The total resistance of the series combination should be equal to the full load resistance as determined in the preceding paragraphs. Of course, if the value of the sampling resistor is very low when compared to the full load resistance, the value of the sampling resistor may be ignored. The meter shunt recommended in Table 5-1, for example, has a resistance of only 1 milliohm and can be neglected when calculating the load resistance of the supply.

5-14 Figure 5-2 shows a four terminal meter shunt. The load current through a shunt must be fed to the extremes of the wire leading to the resistor while the sampling connections are made as close as possible to the resistance portion itself.

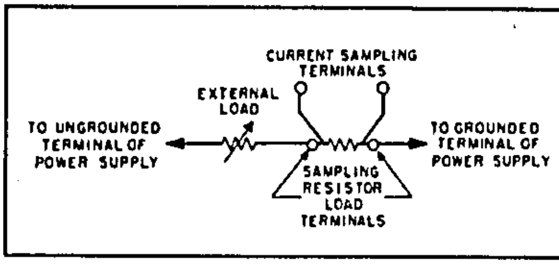



**Figure 5-2. Current Sampling Resistor Connections**

## 5-15 Rated Output, Tracking, Meter Accuracy, and Current Limit

5-16 To check that all supplies will furnish their maximum rated output voltage and current, that the ±18V outputs track each other, that the front panel voltmeter/ammeter is accurate, and that the current limit circuits function, proceed as follows:

**Voltmeter Accuracy**

a. With no loads connected, energize the supply and connect a DVM between the +6V terminal and common (COM). Set the +6 VOLTAGE control so that DVM indication is as near as possible to 6 volts.

b. Set meter select switches to monitor the +6V supply's output voltage. Check that the front panel voltmeter indication is within 3% of the DVM reading.

c. Connect DVM between the +18V terminal and COM. Set the ±18 VOLTAGE control so that DVM indication is as near as possible to 18 volts.

d. Set meter select switches to monitor the +18V supply's output voltage. Check that front panel voltmeter indication is within 3% of the DVM reading.

**NOTE**

*Leave ± 18 VOLTAGE control set as in step (c) when performing steps (e) through (g).*

e. Connect DVM between the −18V terminal and COM. Set the TRACK VOLTAGE control so that DVM indication is as near as possible to −18 volts.

f. Set meter select switches to monitor the −18V supply's output voltage. Check that front panel voltmeter indication is within 3% of the DVM reading.

**Tracking Ratio**

g. Adjust the TRACK VOLTAGE control over its entire range and use DVM to monitor the voltage at the −18V output. The −18V supply should be capable of being adjusted from −0.5 volts to −18 volts. After checking entire range, set TRACK control so that DVM reads −18 volts.

**NOTE**

*Leave TRACK VOLTAGE control set as in step (g) throughout the remainder of the performance test.*

**Rated Output and Ammeter Accuracy**

h. Connect 90Ω 4W load resistors across both the 18V outputs of the supply and set the ±18 VOLTAGE control for ±18V outputs. (All three supplies must be fully loaded while checking the rated output voltage and current of each supply).

i. Connect the test setup shown in Figure 5-3 to the +6V output. Make the total resistance of $R_L$ and the current sampling resistor equal to 6 ohms to permit operating the output at full load. $R_L$ should have a power rating of at least 6 watts.

j. Close the switch and set the +6 VOLTAGE control so that the DVM indicates a voltage drop across the current sampling resistor that corresponds to a current of 1.0 amps.

k. Set meter select switches to monitor the +6V supply's output current and verify that the front panel ammeter indication is within 4% of 1.0 amps.

l. Connect the DVM directly across the output terminals of the +6V supply, record the DVM reading, and then open the switch in the 6V load circuit without disturbing the supply's output terminals. The DVM indication should not change by more than 8mV.

m. Check the rated output and ammeter accuracy of the +18V and −18V supplies similarly by connecting the test setup of Figure 5-3 to each output in turn. For each 18V supply: make the total resistance of $R_L$ and the current sampling resistor 90 ohms, set the ±18 VOLTAGE control for a current indication on the DVM of 0.2A and check that the panel meter indication is within 4% of 0.2A. Connect the DVM to the fully loaded output terminals, and compare the output voltage before and after the load circuit is opened. The voltage should not change by more than 10mV. While checking each supply, the other two must be fully loaded.

**Current Limit**

n. Disconnect all loads from the supply.

o. Connect the test setup shown in Figure 5-3 to the +18V output. Substitute a short for $R_L$ and leave the load circuit switch open.

p. Set the voltage of the ±18V supplies to 18 volts.

q. Close the load switch and determine the current flow through the current sampling resistor (meter shunt) by measuring its voltage drop with the DVM. The current should be 0.255A ±15%.

r. Check the current limit of the −18V supply in the same way. Its short-circuit current should also be 0.255A ±15%.

s. Check the current limit of the +6V supply similarly by setting its output for 6 volts and using a DVM to measure the current that flows through a low-resistance current sampling resistor. The short circuit current of the +6V supply should be 1.275A ±15%.

## 5-17 Load Effect (Load Regulation):

Definition: The change $E_{OUT}$ in the static value of dc output voltage resulting from a change in load resistance from open circuit to the value that yields maximum rated output current (or vice versa).

5-18 To check the load effect:

a. Connect a full load resistance and a digital voltmeter across the output of the +18V supply.

b. Turn on the supply and adjust its voltage to its maximum rated value.

c. Record the voltage indicated on the DVM.

d. Disconnect the load resistance and recheck the DVM indication. It should be within 10mV of the reading in step (c).

e. Repeat steps (a) through (d) for each of the remaining supply outputs. For the 6V output, $E_{OUT}$ should be within 8mV.

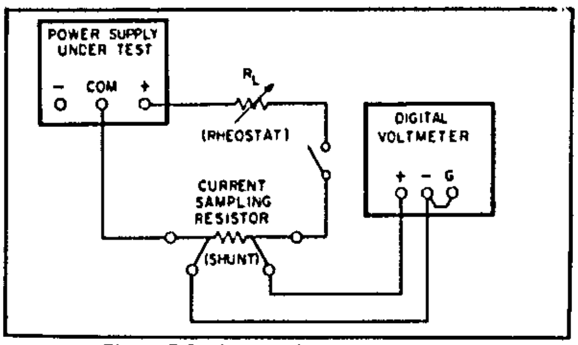



Figure 5-3. Output Current, Test Setup

### 5-19 Source Effect (Line Regulation)

Definition: The change, $\Delta E_{OUT}$, in the static value of dc output voltage resulting from a change in ac input voltage over the specified range from low line (typically 104 Vac) to high line (typically 127 Vac), or from high line to low line.

5-20 To test the source effect:

a. Connect a variable autotransformer between the input power source and the power supply line plug.

b. Connect a full load resistance and a digital voltmeter across the output of the +18V supply.

c. Adjust the autotransformer for a low line input.

d. Turn on the power, adjust the output of the supply to its maximum rated voltage, and record the DVM indication.

e. Adjust the autotransformer for a high line input and recheck the DVM indication. It should be within 15mV of the reading in step (d).

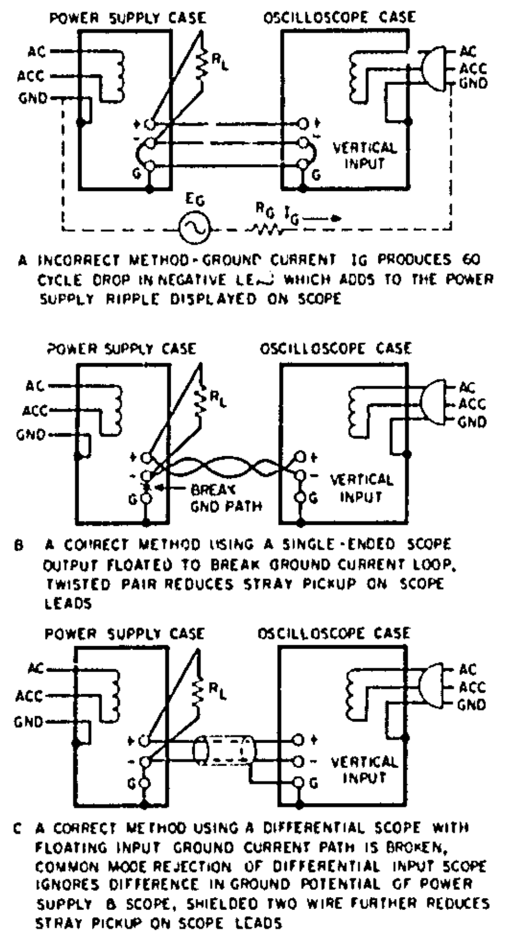
f. Repeat steps (b) through (e) for each of the remaining supply outputs. For the 6V output, $E_{OUT}$ should be within 8mV.

### 5-21 PARD (Ripple and Noise)

Definition: The residual ac voltage that is superimposed on the dc output of a regulated power supply. Ripple and noise may be specified and measured in terms of its rms or peak-to-peak value.

5-22 Measurement Techniques. Figure 5-4A shows an incorrect method of measuring p-p ripple. Note that a continuous ground loop exists from the third wire of the input power cord of the supply to the third wire of the input power cord of the oscilloscope via the grounded power supply case, the wire between the negative output terminal of the power supply and the vertical input of the scope, and the grounded scope case. Any ground current circulating in this loop as a result of the difference in potential $E_G$ between the two ground points causes an IR drop that is in series with the scope input. This IR drop, normally having a 60 Hz line frequency fundamental, plus any pickup on the unshielded leads interconnecting the power supply and scope, appears on the face of the CRT. The magnitude of this resulting signal can easily be much greater than the true ripple developed between the plus and minus output terminals of the power supply and can completely invalidate the measurement.

5-23 The same ground current and pickup problems can exist if an rms voltmeter is substituted in place of the oscilloscope in Figure 5-4. However, the oscilloscope display, unlike the true rms meter reading, tells the observer immediately whether the fundamental period of the signal displayed is 8.3 milliseconds (1/120 Hz) or 16.7 milliseconds (1/60 Hz). Since the fundamental ripple frequency present




A INCORRECT METHOD - GROUND CURRENT IG PRODUCES 60 CYCLE DROP IN NEGATIVE LEAD WHICH ADDS TO THE POWER SUPPLY RIPPLE DISPLAYED ON SCOPE

B A CORRECT METHOD USING A SINGLE-ENDED SCOPE OUTPUT FLOATED TO BREAK GROUND CURRENT LOOP, TWISTED PAIR REDUCES STRAY PICKUP ON SCOPE LEADS

C A CORRECT METHOD USING A DIFFERENTIAL SCOPE WITH FLOATING INPUT GROUND CURRENT PATH IS BROKEN, COMMON MODE REJECTION OF DIFFERENTIAL INPUT SCOPE IGNORES DIFFERENCE IN GROUND POTENTIAL OF POWER SUPPLY & SCOPE, SHIELDED TWO WIRE FURTHER REDUCES STRAY PICKUP ON SCOPE LEADS

**Figure 5-4. Ripple and Noise, Test Setup**

on the output of an HP supply is 120 Hz (due to full-wave rectification), an oscilloscope display showing a 120 Hz fundamental component is indicative of a "clean" measurement setup, while the presence of a 60 Hz fundamental usually means that an improved setup will result in a more accurate (and lower) value of measured ripple.

5-24 Figure 5-4B shows a correct method of measuring the output ripple of a constant voltage power supply using a single-ended scope. The ground loop path is broken by floating the power supply output. To ensure that no potential difference exists between the supply and the oscilloscope, it is recommended that they both be plugged into the same ac power bus. If the same bus cannot be used, both ac grounds must be at earth ground potential.

5-25 Either a twisted pair or, preferably, a shielded two-wire cable should be used to connect the output terminals of the power supply to the vertical input terminals of the scope. When using a twisted pair, care must be taken that one of the two wires is connected to the grounded input terminal of the oscilloscope to ensure that the supply output is safely grounded. When using shielded two-wire, it is essential for the shield to be connected to ground at one end only to prevent ground current flowing through this shield from inducing a signal in the shielded leads.

5-26 To verify that the oscilloscope is not displaying ripple that is induced in the leads or picked up from the grounds, the (+) scope lead should be shorted to the (−) scope lead at the power supply terminals. The ripple value obtained when the leads are shorted should be subtracted from the actual ripple measurement.

5-27 In most cases, the single-ended scope method of Figure 5-4B will be adequate to eliminate extraneous ripple so that a satisfactory measurement may be obtained. However, in more stubborn cases (or if high frequency noise up to 20 MHz must be measured, it may be necessary to use a differential scope with floating input as shown in Figure 5-4C. If desired, two single-conductor shielded cables may be substituted in place of the shielded two-wire cable with equal success. Because of its common mode rejection, a differential oscilloscope displays only the difference in signal between its two vertical input terminals, thus ignoring the effects of any common mode signal produced by the difference in the ac potential between the power supply case and scope case. Before using a differential input scope in this manner, however, it is imperative that the common mode rejection capability of the scope be verified by shorting together its two input leads at the power supply and observing the trace on the CRT. If this trace is a straight line, then the scope is properly ignoring any common mode signal present. If this trace is not a straight line, then the scope is not rejecting the ground signal and must be realigned in accordance with the manufacturer's instructions until proper common mode rejection is attained.

5-28 **Measurement Procedure.** To measure the ripple and noise on each supply output, follow the steps below. If a high frequency noise measurement is desired, an oscilloscope with sufficient bandwidth (20 MHz) must be used. Ripple and noise measurements can be made at any input ac line voltage combined with any dc output voltage and load current within rating.

a. Connect an oscilloscope or rms voltmeter across an output of the supply as shown in Figures 5-4B or 5-4C.

b. Energize the supply and observe the oscilloscope or meter indication. The ripple and noise should not be greater than 1.0mV rms or 5.0mV peak-to-peak.

c. Repeat for the remaining supply outputs.

## 5-29 Load Transient Recovery Time

Definition: The time "X" for output voltage recovery to within "Y" millivolts of the nominal output voltage following a "Z" amp step change in load current, where: "Y" equals 15mV, and "Z" is the specified load current change, equal to half of the current rating of the supply. The nominal output voltage is defined as the dc level halfway between the static output voltage before and after the imposed load change.

5-30 **Measurement Techniques.** Care must be taken in switching the load resistance on and off. A hand-operated switch in series with the load is not adequate since the resulting one-shot displays are difficult to observe on most oscilloscopes and the arc energy occurring during switching completely masks the display with a noise burst. Transistor load switching devices are expensive if reasonably rapid load current changes are to be achieved. Instead, a mercury-wetted relay should be used for loading and unloading the supply. Connect it in the load switching circuit shown in Figure 5-5. When this load switch is connected to a 60 Hz ac input, the mercury-wetted relay will open and close 60 times per second. The 25K control adjusts the duty cycle of the load current switching to reduce jitter in the oscilloscope display. This relay may also be used with a 50 Hz ac input.

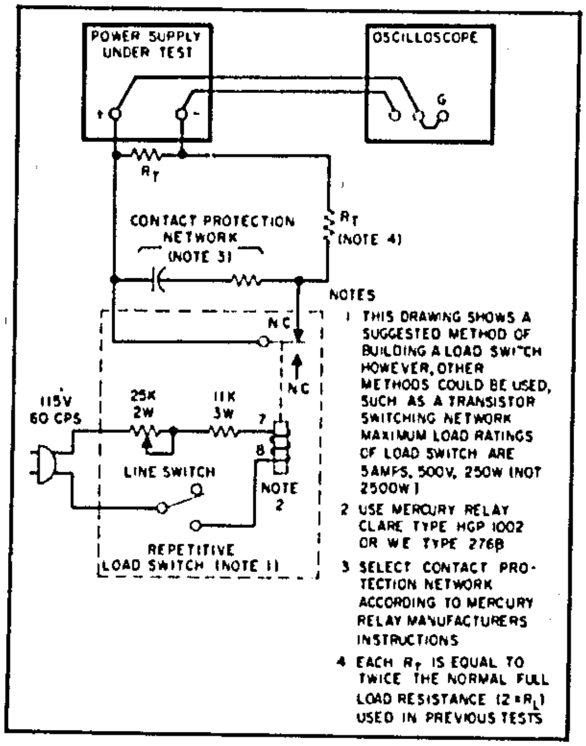



Figure 5-5. Load Transient Recovery Time, Test Setup

5-31 **Measurement Procedure.** To measure the load transient recovery time, follow the steps below for each supply output. Transient recovery time may be measured at any input line voltage and any output voltage within rating. For this supply the specified load change is between half load and full load.

a. Connect the test setup shown in Figure 5-5. Both load resistors ($R_T$) are twice the normal value of a full load resistance.

b. Turn on the supply and close the line switch on the repetitive load switch.

c. Set the oscilloscope for internal sync and lock on either the positive or negative load transient spike.

d. Set the vertical input of the oscilloscope for ac coupling so that small dc level changes in the output voltage of the power supply will not cause the display to shift.

e. Adjust the horizontal positioning control so that the trace starts at a point coincident with a major graticule division. This point then represents time zero.

f. Adjust the vertical centering of the scope so that the tail ends of the no-load and full-load waveforms are symmetrically displaced about the horizontal center line of the oscilloscope. This center line now represents the nominal output voltage defined in the specification.

g. Increase the sweep rate so that a single transient spike can be examined in detail.

h. Adjust the sync controls separately for the positive and negative going transients so that not only the recovery waveshape but also as much as possible of the rise time of the transient is displayed.

i. Starting from the major graticule division representing time zero, count to the right 50μs and vertically 15mV. Recovery should be within these tolerances, as illustrated in Figure 5-6.

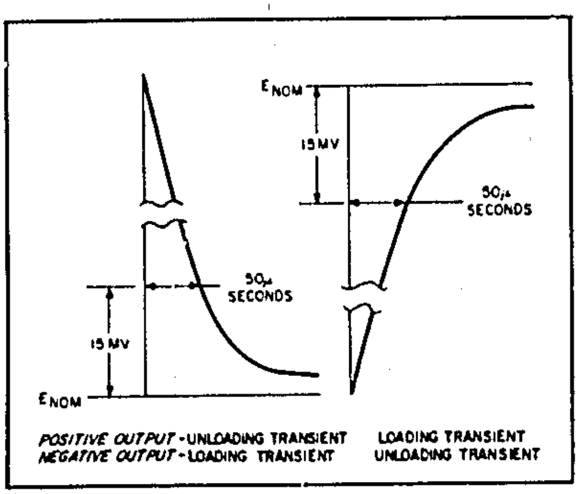



**Figure 5-6. Load Transient Recovery Time Waveforms**

## 5-32 TROUBLESHOOTING

5-33 Before attempting to troubleshoot this instrument, ensure that the fault is in the instrument itself and not in an associated piece of equipment. You can determine this without removing the covers from the instrument by using the appropriate portions of the performance test of paragraph 5-6.

5-34 A good understanding of the principles of operation is a helpful aid in troubleshooting, and the reader is advised to review Section IV of the manual before beginning detailed troubleshooting. Once the principles of operation are understood, proceed to the troubleshooting procedures in paragraph 5-35.

**WARNING**

*Hazardous voltage is present on the circuit board in the area of the LINE switch S1, fuse, and input select switch S2. Exercise care when troubleshooting this unit with protective covers removed.*

### 5-35 Troubleshooting Procedure

5-36 If a malfunction is found, follow the steps below:

a. Disconnect input power from the supply, remove all loads from the output, and remove covers from supply.

b. Table 5-2 lists the symptoms and probable causes of several possible troubles. If the symptom is one of those listed, make the recommended checks.

c. If none of the symptoms of Table 5-2 apply, proceed to the troubleshooting procedures in Table 5-3.

5-37 The numbered test points referred to in the troubleshooting procedures are identified on the circuit schematic and on the component location diagram at the rear of the manual.

### 5-38 Open Fuse Troubleshooting

5-39 Although transients or fatigue can cause a fuse to blow, it is a good idea to inspect the unit for obvious shorts such as damaged wiring, charred components, or extraneous metal parts or wire clippings in contact with circuit board conductors before replacing the fuse. The rating of the correct replacement fuse depends on the line voltage option of the instrument: for 120Vac line voltage, use a slo-blow 0.4 amp fuse (HP Part No. 2110-0340); for 240Vac line voltage, use a slo-blow 0.2 amp fuse (HP Part No. 2110-0235).

## 5-40 REPAIR AND REPLACEMENT

### 5-41 Series Regulator Replacement

5-42 To remove and replace a series regulator transistor:

a. Remove the top and bottom covers from the instrument

b. Remove the collector screws and unsolder the base and emitter leads from the board to remove the transistor.

c. To replace the transistor, follow the below reassembly order, as viewed from the bottom of the heat sink: collector screws, P. C. board, heat sink, two insulating bushings (in collector screw holes in heatsink), silicon grease (Dow DC-5 or HP 8500-0059), mica insulator, another coating of silicon grease, transistor, lock-washers, and hex-nuts.

d. Resolder the emitter and base pins to the circuit board.

### 5-43 Semiconductor Replacement

5-44 Table 6-4 contains replacement data for the semiconductors used in this power supply. When replacing a semiconductor, use the listed Hewlett-Packard or exact commercial replacement if these are available. If neither of these are immediately available and a part is needed without delay for operation or troubleshooting verification, the parts designated Note 1, Alternate Part Number can be tried with a high probability of success.

5-45 Notice that both the commercial and alternate replacements listed in Table 6-4 apply only to the HP power supplies covered by this manual and their use in any other Hewlett-Packard instrument is not necessarily recommended because of inclusion in this table.

## 5-46 ADJUSTMENT AND CALIBRATION

**WARNING**

*Hazardous voltage is present on line switch, fuse, and input select switch. Exercise care when making the following adjustments with protective covers removed from power supply.*

### 5-47 Current Limit Adjustment

5-48 **±18V Supplies.** Perform the following steps to adjust the current limit circuit in the +18V or −18V supply. Potentiometer R3 sets the +18V and R13 the −18V current limit. (See component location diagram in Section VII.)

a. Turn the TRACK VOLTAGE control fully clockwise.

b. Turn the current limit adjustment pot (R3 or R13) to center (approx.) position.

c. Connect the test circuit of Figure 5-3 to the output of the supply to be adjusted. Substitute a short for $R_L$ and leave load circuit switch open.

d. Turn on the supply and set the ±18 VOLTAGE control for maximum output (fully clockwise).

e. Close load switch and adjust the current limit pot (R3 or R13) until the DVM indicates a voltage drop across the shunt corresponding to a current of 0.255A ±15%.

5-49 **+6V Supply.** To adjust the current limit circuit in the +6V supply, proceed as follows:

a. Turn current limit adjustment pot (R23) fully clockwise to its minimum setting.

b. Connect the test circuit of Figure 5-3 to the output of the +6V supply. Substitute a short for $R_L$ and leave load circuit switch open.

c. Turn on the supply and set the +6 VOLTAGE control for maximum output (fully clockwise).

d. Close load switch and adjust the current limit pot (R23) until the DVM indicates a voltage drop across the shunt corresponding to a current of 1.275A ±15%.

### 5-50 Meter Calibration

5-51 **Meter Zero.** The meter pointer must rest on the zero calibration mark on the meter scale when the instrument is at normal operating temperature, resting in its normal operating position, and turned off. To zero set the voltmeter/ammeter, proceed as follows:

a. Turn on the instrument and allow it to come up to normal operating temperature (in about 30 minutes).

b. Turn off instrument and allow 30 seconds for all capacitors to discharge.

c. Insert small screwdriver into the small hole directly below meter face.

d. Rotate zero adjust screw clockwise until meter reads zero, then rotate counterclockwise slightly in order to free adjustment screw from meter suspension. Pointer should not move during latter part of adjustment. If pointer moves, repeat the adjustment.

5-52 **Ammeter.** Check and calibrate the front panel ammeter by following the steps below.

a. Push V/A meter select switch in to monitor output current.

b. Connect the test setup shown in Figure 5-3 to the +6V output. Make the total resistance of $R_L$ and the current sampling resistor 6 ohms to permit operating the supply at its full rated output. $R_L$ should have a power rating of at least 6 watts.

c. Close the switch and set the +6 VOLTAGE control so that the DVM indicates a voltage drop that corresponds to a current of 1.0 amp.

d. Check and record the ammeter accuracy on the +6V range.

e. Check each of the 18-volt ranges similarly, using the same test setup but making $R_L$ 90Ω 4W resistor and setting the voltage control for a 0.2A output current. Record the ammeter accuracy on each 18-volt range.

f. Turn ammeter adjust potentiometer R31 clockwise to increase the indications on all three ranges or counterclockwise to decrease them.

g. If R31 cannot calibrate all three ammeter ranges within specification (±4% for all ranges), check the values of current monitoring resistors R4, R24, and R34.

5-53 **Voltmeter.** Check the accuracy of the front panel voltmeter by performing steps (a) through (f) of the procedure in paragraph 5-16. The accuracy specification is ±3% for the ±18V and +6V ranges. If the ±18V voltmeter ranges are not within specification, check the value of R32 in the meter circuit; if the +6V range is not within specification, check the value of R36.

**Table 5-2. Miscellaneous Troubles**

| SYMPTOM | CHECK – PROBABLE CAUSE |
|---|---|
| High ripple | a. Check operating setup for ground loops (see paragraph 5-22).<br>b. Check main rectifiers (CR21-CR24, U2, U12) for open.<br>c. Supply may be operating in current limit mode. Check current limit adjustment, paragraph 5-16, steps (n) through (s). |
| Will not current limit | Current limit circuit (U1, Q12, U11, U21) probably defective. |
| Poor load or line regulation | a. For poor load regulation, check current limit adjustment, paragraph 5-16, steps (n) through (s).<br>b. For poor line regulation, check main rectifiers and filters, zener diode VR1, VR2, and transistor Q23. |
| Oscillation or poor transient recovery time | a. High frequency oscillations (above 50kHz) can be caused by an open C3, C12, or C24.<br>b. A defective output capacitor (C5, C13, C23) can cause oscillations in one of many frequency ranges.<br>c R8, R18, or R28 open circuited. |
| Transient voltage overshoot at turn-on or turn-off | Defective series regulator transistor. |

**Table 5-3. Troubleshooting Procedures**

| SYMPTOM | STEP – ACTION | RESPONSE – PROBABLE CAUSE |
|---|---|---|
| No outputs (+6V and ±18V outputs measure 0V on front panel meter) with controls turned CW. | 1. Check for obvious troubles such as improper ac input connection or input power failure. | ——— |
| | 2. Remove power and check fuse F1. | a. If blown, check the following components for short circuits: C1, C11, C21, CR21-CR24, U2, U11, U12. Also, see paragraph 5-38.<br>b. If fuse is not blown, proceed to step (3). |
| | 3. Turn +6 VOLTAGE control fully CW. Apply power and measure voltage between +6V and COM terminals on front panel with DVM. | a. If DVM measures > 6V, meter M1 or switch S3 is defective.<br>b. If voltage is 0V, check for defective S1, S2, or T1. |

Table 5-3. Troubleshooting Procedures (Continued)

| SYMPTOM | STEP – ACTION | RESPONSE – PROBABLE CAUSE |
|---|---|---|
| +6V output high (higher than rating) | 1. Turn +6 VOLTAGE control fully CCW and check voltage at TP7 with respect to the +6V output terminal. | a. If TP7 is between 0 and −50mV, proceed to step 2. |
| | | b. If TP7 is more negative than −50mV, check R21, R26, R33. |
| | 2. Attempt to turn off Q21 by shorting Q21 base to emitter. | a. If output remains high, check Q21, Q22, and CR26 for short. |
| | | b. If output voltage falls to near 0V, check Q22. If ok, U21 is defective. |
| +6V output low (lower than rating) | NOTE: If the output is normal unloaded but its voltage falls when loaded, check the current limit adjustment, paragraph 5-49. | |
| | 1. Turn +6 VOLTAGE control fully CW and check unregulated input at U21-5 with respect to the +6V output terminal. | a. If voltage is normal (approx. −16V), proceed to step 2. |
| | | b. If voltage is not normal, check C21B, CR23, CR24, T1. |
| | 2. Check voltage at TP7 with respect to the +6V output terminal. | a. If TP7 is normal (approx. −3.5V), proceed to step (4). |
| | | b. If TP7 is not normal, proceed to step (3). |
| | 3. Check voltage at TP8 with respect to the +6V output terminal. | a. If TP8 is normal (approx. −8V), check R21, R22, R26, R33, C22. If ok, U21 is defective. |
| | | b. If TP8 is not normal, check VR21, Q23, R29. |
| | 4. Check voltage at TP9 with respect to the COM terminal | a. If TP9 is normal (approx. −0.6V), check Q21, Q22. |
| | | b. If TP9 is not normal, U21 is defective. |
| +18V and −18V outputs both high (higher than rating). Since the −18V supply tracks the +18V supply, this symptom indicates a fault in the +18V supply. | 1. Turn ±18 VOLTAGE control fully CCW and check voltage at TP1 with respect to the +18V output terminal. | a. If TP1 is between 0 and −50mV, proceed to step 2. |
| | | b. If TP7 is more negative than −50mV, check R1, R2, R6. |
| | 2. Attempt to turn off Q1 by shorting Q1 base to emitter. | a. If output stays high, check Q1 and CR6 for short. |
| | | b. If output falls to near 0V, check CR1 Q2 for short. If ok, U1 is defective. |

Table 5-3. Troubleshooting Procedures (Continued)

| SYMPTOM | STEP – ACTION | RESPONSE – PROBABLE CAUSE |
|---|---|---|
| +18V and −18V outputs both low (lower than rating). Since the −18V supply tracks the +18V supply, this symptom indicates a fault in the +18V supply. | NOTE: If the +18V and −18V outputs are normal unloaded but fall when the +18V supply is loaded, check the +18V supply's current limit adjustment, see paragraph 5-48. | |
| | 1. Turn ±18 VOLTAGE control fully CW and check unregulated input at U1-5 with respect to the +18V output terminal. | a. If voltage is normal (approx. −36V), proceed to step 2.<br>b. If voltage is not normal, check C1, T1, U2. |
| | 2. Check voltage at TP1 with respect to the +18V output terminal. | a. If TP1 is normal (approx. −9 to −10V), proceed to step (4).<br>b. If TP1 is not normal, check U1, VR1, R1, R2. |
| | 3. Check voltage at TP2 with respect to COM. | a. If TP2 is normal (approx. −1.2V), check Q1 for open.<br>b. If TP2 is not normal, check CR1 for open, Q2 for short. If ok, U1 is defective. |
| −18V output low (lower than rating). The +18V supply operates properly. | NOTE: If the −18V output is normal unloaded but falls when the −18V supply is loaded, check the −18V supply's current limit adjustment, paragraph 5-48. | |
| | 1. Check unregulated input across capacitor C11. | a. If voltage is normal (approx. 36V), proceed to step (2).<br>b. If voltage is not normal, check U12, C11, R19, T1. |
| | 2. Check voltage at TP5 with respect to COM. | a. If TP5 is normal (approx. +0.6V), check Q11.<br>b. If TP5 is not normal, proceed to step (3). |
| | 3. Turn +6 VOLTAGE control fully CW. Check bias voltage at U11-7 with respect to COM. | a. If voltage is normal (approx. 32V), check Q12 and R11 for short, R12 for open. If ok, U11 is defective.<br>b. If voltage is not normal, check C21, CR21, CR22. If ok, U11 is probably shorted. |
| −18V output high (higher than rating). The +18V supply operates properly. | 1. Attempt to turn off Q11 by shorting Q11 base to emitter. | a. If output stays high, check Q11 and CR16 for short.<br>b. If output falls to near zero volts, check R11, R12, U11. |

# PARTS LIST

# SECTION VI
# REPLACEABLE PARTS

## 6-1 INTRODUCTION

6-2 This section contains information for ordering replacement parts. Table 6-4 lists parts in alpha-numeric order by reference designators and provides the following information:

a. Reference Designators Refer to Table 6-1.

b. Description. Refer to Table 6-2 for abreviations.

c. Total Quantity (TQ). Given only the first time the part number is listed except in instruments containing many sub-modular assemblies, in which case the TQ appears the first time the part number is listed in each assembly.

d. Manufacturer's Part Number or Type.

e. Manufacturer's Federal Supply Code Number. Refer to Table 6-3 for manufacturer's name and address.

f. Hewlett-Packard Part Number.

g. Recommended Spare Parts Quantity (RS) for complete maintenance of one instrument during one year of isolated service.

h. Parts not identified by a reference designator are listed at the end of Table 6-4 under Mechanical and/or Miscellaneous. The former consists of parts belonging to and grouped by individual assemblies; the latter consists of all parts not immediately associated with an assembly.

## 6-3 ORDERING INFORMATION

6-4 To order a replacement part, address order or inquiry to your local Hewlett-Packard sales office (see lists at rear of this manual for addresses). Specify the following information for each part: Model, complete serial number, and any Option or special modification (J) numbers of the instrument; Hewlett-Packard part number; circuit reference designator; and description. To order a part not listed in Table 6-4, give a complete description of the part, its function, and its location.

Table 6-1. Reference Designators

| | | | |
|---|---|---|---|
| A | = assembly | E | = miscellaneous electronic part |
| B | = blower (fan) | F | = fuse |
| C | = capacitor | J | = jack, jumper |
| CB | = circuit breaker | K | = relay |
| CR | = diode | L | = inductor |
| DS | = device, signaling (lamp) | M | = meter |

Table 6-1. Reference Designators (Continued)

| | | | |
|---|---|---|---|
| P | = plug | V | = vacuum tube, neon bulb, photocell, etc. |
| Q | = transistor | VR | = zener diode |
| R | = resistor | X | = socket |
| S | = switch | Z | = integrated circuit or network |
| T | = transformer | | |
| TB | = terminal block | | |
| TS | = thermal switch | | |

Table 6-2. Description Abbreviations

| | | | |
|---|---|---|---|
| A | = ampere | mod. | = modular or modified |
| ac | = alternating current | mtg | = mounting |
| assy. | = assembly | n | = nano = $10^{-9}$ |
| bd | = board | NC | = normally closed |
| bkt | = bracket | NO | = normally open |
| °C | = degree Centigrade | NP | = nickel-plated |
| cd | = card | Ω | = ohm |
| coef | = coefficient | obd | = order by description |
| comp | = composition | OD | = outside diameter |
| CRT | = cathode-ray tube | p | = pico = $10^{-12}$ |
| CT | = center-tapped | P.C. | = printed circuit |
| dc | = direct current | pot. | = potentiometer |
| DPDT | = double pole, double throw | p-p | = peak-to-peak |
| DPST | = double pole, single throw | ppm | = parts per million |
| elect | = electrolytic | pvr | = peak reverse voltage |
| encap | = encapsulated | rect | = rectifier |
| F | = farad | rms | = root mean square |
| °F | = degree Farenheit | Si | = silicon |
| fxd | = fixed | SPDT | = single pole, double throw |
| Ge | = germanium | SPST | = single pole, single throw |
| H | = Henry | SS | = small signal |
| Hz | = Hertz | T | = slow-blow |
| IC | = integrated circuit | tan. | = tantulum |
| ID | = inside diameter | Ti | = titanium |
| incnd | = incandescent | V | = volt |
| k | = kilo = $10^3$ | var | = variable |
| m | = milli = $10^{-3}$ | ww | = wirewound |
| M | = mega = $10^6$ | W | = Watt |
| μ | = micro = $10^{-6}$ | | |
| met. | = metal | | |
| mfr | = manufacturer | | |

Table 6-3. Code List of Manufacturers

| CODE | MANUFACTURER | ADDRESS |
|---|---|---|
| 00629 | EBY Sales Co., Inc. | Jamaica, N.Y. |
| 00656 | Aerovox Corp. | New Bedford, Mass. |
| 00853 | Sangamo Electric Co. S. Carolina Div. | Pickens, S.C. |
| 01121 | Allen Bradley Co. | Milwaukee, Wis. |
| 01255 | Litton Ind. | Beverly Hills, Calif. |
| 01281 | TRW Semiconductors, Inc. | Lawndale, Calif. |
| 01295 | Texas Instruments, Inc. | Dallas, Texas |
| 01686 | RCL Electronics, Inc. | Manchester, N.H. |
| 01930 | Amerock Corp. | Rockford, Ill. |
| 02107 | Sparta Mfg. Co. | Dover, Ohio |
| 02114 | Ferroxcube Corp. | Saugerties, N.Y. |
| 02606 | Fenwal Laboratories | Morton Grove, Ill. |
| 02660 | Amphenol Corp. | Broadview, Ill. |
| 02735 | Radio Corp. of America, Solid State and Receiving Tube Div. | Somerville, N.J. |
| 03508 | G.E. Semiconductor Products Dept. | Syracuse, N.Y. |
| 03797 | Eldema Corp. | Compton, Calif. |
| 03877 | Transitron Electronic Corp. | Wakefield, Mass. |
| 03888 | Pyrofilm Resistor Co., Inc. | Cedar Knolls, N.J. |
| 04009 | Arrow, Hart and Hegeman Electric Co. | Hartford, Conn. |
| 04072 | ADC Electronics, Inc. | Harbor City, Calif. |
| 04213 | Caddell & Burns Mfg. Co. Inc. | Mineola, N.Y. |
| 04404 | *Hewlett-Packard Co. Palo Alto Div. | Palo Alto, Calif. |
| 04713 | Motorola Semiconductor Prod. Inc. | Phoenix, Arizona |
| 05277 | Westinghouse Electric Corp. Semiconductor Dept. | Youngwood, Pa. |
| 05347 | Ultronix, Inc. | Grand Junction, Colo. |
| 05820 | Wakefield Engr. Inc. | Wakefield, Mass. |
| 06001 | General Elect. Co. Electronic Capacitor & Battery Dept. | Irmo, S.C. |
| 06004 | Bassik Div, Stewart-Warner Corp. | Bridgeport, Conn. |
| 06486 | IRC Div. of TRW Inc. Semiconductor Plant | Lynn, Mass. |
| 06540 | Amatom Electronic Hardware Co. Inc. | New Rochelle, N.Y. |
| 06555 | Beede Electrical Instrument Co. | Penacook, N.H. |
| 06566 | General Devices Co. | Indianapolis, Ind. |
| 06751 | Semoor Div. Components, Inc. | Phoenix, Arizona |
| 06776 | Robinson Nugent, Inc. | New Albany, N.Y. |
| 06812 | Torrington Mfg. Co. | Van Nuys, Calif. |
| 07137 | Transistor Electronics Corp. | Minneapolis, Minn. |
| 07138 | Westinghouse Electric Corp. | Elmira, N.Y. |
| 07263 | Fairchild Camera and Instrument | Mountain View, Calif. |
| 07387 | Birtcher Corp., The | Los Angeles, Calif. |
| 07397 | Sylvania Electric Prod. Inc. | Mountainview, Calif. |
| 07716 | IRC Div. of TRW Inc. | Burlington, Iowa |
| 07910 | Continental Device Corp. | Hawthorne, Calif. |
| 07933 | Raytheon Co. Components Div. | Mountain View, Calif. |
| 08484 | Breeze Corporations, Inc. | Union, N.J. |
| 08530 | Reliance Mica Corp. | Brooklyn, N.Y. |
| 08717 | Sloan Company, The | Sun Valley, Calif. |
| 08730 | Vemaline Products Co. Inc. | Wyckoff, N.J. |
| 08806 | General Elect. Co. Minature Lamp Dept. | Cleveland, Ohio |
| 08863 | Nylomatic Corp. | Norrisville, Pa. |
| 08919 | RCH Supply Co. | Vernon, Calif. |
| 09021 | Airco Speer Electronic Components | Bradford, Pa. |
| 09182 | *Hewlett-Packard Co. New Jersey Div. | Rockaway, N.J. |
| 09213 | General Elect. Co. Semiconductor Prod. Dept. | Buffalo, N.Y. |
| 09214 | General Elect. Co. Semiconductor Prod. Dept. | Auburn, N.Y. |
| 09353 | C & K Components Inc. | Newton, Mass. |
| 09922 | Burndy Corp. | Norwalk, Conn. |
| 11115 | Wagner Electric Corp. Tung-Sol Div. | Bloomfield, N.J. |
| 11236 | CTS of Berne, Inc. | Berne, Ind. |
| 11237 | Chicago Telephone of Cal. Inc. | So. Pasadena, Calif. |
| 11502 | IRC Div. of TRW Inc. | Boone, N.C. |
| 11711 | General Instrument Corp. | Newark, N.J. |
| 12136 | Philadelphia Handle Co. | Camden, N.J. |
| 12615 | U.S. Terminals, Inc. | Cincinnati, Ohio |
| 12617 | Hamlin Inc. | Lake Mills, Wisconsin |
| 12697 | Clarostat Mfg. Co. Inc. | Dover, N.H. |
| 13103 | Thermalloy Co. | Dallas, Texas |
| 14493 | *Hewlett-Packard Co. | Loveland, Colo. |
| 14655 | Cornell-Dubilier Electronics Div. Federal Pacific Electric Co. | Newark, N.J. |
| 14936 | General Instrument Corp. Semiconductor Prod. Group | Hicksville, N.Y. |
| 15801 | Fenwal Elect. | Framingham, Mass. |
| 16299 | Corning Glass Works | Raleigh, N.C. |

*Use Code 28480 assigned to Hewlett-Packard Co., Palo Alto, California

Table 6-3. Code List of Manufacturers

| CODE | MANUFACTURER | ADDRESS |
|---|---|---|
| 16758 | Delco Radio Div. of General Motors Corp | Kokomo Ind. |
| 17545 | Atlantic Semiconductors, Inc. | Asbury Park, N.J. |
| 17803 | Fairchild Camera and Instrument Corp. | Mountain View, Calif. |
| 17870 | Daven Div. Thomas A. Edison Industries McGraw-Edison Co. | Orange, N.J. |
| 18324 | Signetics Corp. | Sunnyvale, Calif. |
| 19315 | Bendix Corp. The Navigation and Control Div. | Teterboro, N.J. |
| 19701 | Electra/Midland Corp. | Mineral Wells, Texas |
| 21520 | Fansteel Metallurgical Corp. | No. Chicago, Ill. |
| 22229 | Union Carbide Corp. Electronics Div. | Mountain View, Calif. |
| 22753 | UID Electronics Corp. | Hollywood, Fla. |
| 23936 | Pamotor, Inc. | Pampa, Texas |
| 24446 | General Electric Co. | Schenectady, N.Y. |
| 24455 | General Electric Co. | Nela Park, Cleveland, Ohio |
| 24655 | General Radio Co. | West Concord, Mass. |
| 24681 | LTV Electrosystems Inc. Memcor/Components Operations | Huntington, Ind. |
| 26982 | Dynacool Mfg. Co. Inc. | Saugerties, N.Y. |
| 27014 | National Semiconductor Corp. | Santa Clara, Calif. |
| 28480 | Hewlett-Packard Co. | Palo Alto, Calif. |
| 28520 | Heyman Mfg. Co. | Kenilworth, N.J. |
| 28875 | IMC Magnetics Corp. | Rochester, N.H. |
| 31514 | SAE Advance Packaging, Inc. | Santa Ana, Calif. |
| 31827 | Budwig Mfg. Co. | Ramona, Calif. |
| 33173 | G.E. Co. Tube Dept. | Owensboro, Ky. |
| 35434 | Lectrohm, Inc. | Chicago, Ill. |
| 37942 | P.R. Mallory & Co. | Indianapolis, Ind. |
| 42190 | Muter Co. | Chicago, Ill. |
| 43334 | New Departure-Hyatt Bearings Div. General Motors Corp. | Sandusky, Ohio |
| 44655 | Ohmite Manufacturing Co. | Skokie, Ill. |
| 46384 | Penn Engr. and Mfg. Corp. | Doylestown, Pa. |
| 47904 | Polaroid Corp. | Cambridge, Mass. |
| 49956 | Raytheon Co. | Lexington, Mass. |
| 55026 | Simpson Electric Co. Div. of American Gage and Machine Co. | Chicago, Ill. |
| 56289 | Sprague Electric Co. | North Adams, Mass. |
| 58474 | Superior Electric Co. | Bristol, Conn. |
| 58849 | Syntron Div. of FMC Corp. | Homer City, Pa. |
| 59730 | Thomas and Betts Co. | Philadelphia, Pa. |
| 61637 | Union Carbide Corp. | New York, N.Y. |
| 63743 | Ward Leonard Electric Co. | Mt. Vernon, N.Y. |
| 70563 | Amperite Co. Inc. | Union City, N.J. |
| 70901 | Beemer Engrg Co | Fort Washington, Pa. |
| 70903 | Belden Corp. | Chicago, Ill. |
| 71218 | Bud Radio, Inc. | Willoughby, Ohio |
| 71279 | Cambridge Thermionic Corp. | Cambridge, Mass. |
| 71400 | Bussmann Mfg. Div. of McGraw & Edison Co. | St. Louis, Mo. |
| 71450 | CTS Corp. | Elkhart, Ind. |
| 71468 | I.T.T. Cannon Electric Inc. | Los Angeles, Calif. |
| 71590 | Globe-Union Inc. | Milwaukee, Wis. |
| 71700 | General Cable Corp. Cornish Wire Co. Div. | Williamstown, Mass. |
| 71707 | Coto Coil Co. Inc. | Providence, R.I. |
| 71744 | Chicago Miniature Lamp Works | Chicago, Ill. |
| 71785 | Cinch Mfg. Co. and Howard B. Jones Div. | Chicago, Ill. |
| 71984 | Dow Corning Corp. | Midland, Mich. |
| 72136 | Electro Motive Mfg. Co. Inc. | Willimantic, Conn. |
| 72619 | Dialight Corp. | Brooklyn, N.Y. |
| 72699 | General Instrument Corp. | Newark, N.J. |
| 72765 | Drake Mfg. Co. | Harwood Heights, Ill. |
| 72962 | Elastic Stop Nut Div. of Amerace Esna Corp. | Union, N.J. |
| 72982 | Erie Technological Products | Erie, Pa. |
| 73096 | Hart Mfg. Co. | Hartford, Conn. |
| 73138 | Beckman Instruments | Fullerton, Calif. |
| 73168 | Fenwal, Inc. | Ashland, Mass. |
| 73293 | Hughes Aircraft Co. Electron Dynamics Div. | Torrance, Calif. |
| 73445 | Amperex Electronic | Hicksville, N.Y. |
| 73506 | Bradley Semiconductor Corp. | New Haven, Conn. |
| 73559 | Carling Electric, Inc. | Hartford, Conn. |
| 73734 | Federal Screw Products, Inc. | Chicago, Ill. |
| 74193 | Heinemann Electric Co. | Trenton, N.J. |
| 74545 | Hubbell Harvey Inc. | Bridgeport, Conn. |
| 74868 | Amphenol Corp. Amphenol RF Div. | Danbury, Conn. |
| 74970 | E.F. Johnson Co. | Waseca, Minn. |

Table 6-3. Code List of Manufacturers

| CODE | MANUFACTURER | ADDRESS |
|---|---|---|
| 75042 | IRC Div. of TRW, Inc. | Philadelphia, Pa. |
| 75183 | *Howard B. Jones Div. of Cinch Mfg. Corp. | New York, N.Y. |
| 75376 | Kurz and Kasch, Inc. | Dayton, Ohio |
| 75382 | Kilka Electric Corp. | Mt. Vernon, N.Y. |
| 75915 | Littlefuse, Inc. | Des Plaines, Ill. |
| 76381 | Minnesota Mining and Mfg. Co. | St. Paul, Minn. |
| 76385 | Minor Rubber Co. Inc. | Bloomfield, N.J. |
| 76487 | James Millen Mfg. Co. Inc. | Malden, Mass. |
| 76493 | J.W. Miller Co. | Compton, Calif. |
| 76530 | Cinch | City of Industry, Calif. |
| 76854 | Oak Mfg. Co. Div. of Oak Electro/ Netics Corp. | Crystal Lake, Ill. |
| 77068 | Bendix Corp., Electrodynamics Div. | No. Hollywood, Calif. |
| 77122 | Palnut Co. | Mountainside, N.J. |
| 77147 | Patton-MacGuyer Co. | Providence, R.I. |
| 77221 | Phaostron Instrument and Electronic Co. | South Pasadena, Calif. |
| 77252 | Philadelphia Steel and Wire Corp. | Philadelphia, Pa. |
| 77342 | American Machine and Foundry Co. | Princeton, Ind. |
| 77630 | TRW Electronic Components Div. | Camden, N.J. |
| 77764 | Resistance Products Co. | Harrisburg, Pa. |
| 78189 | Illinois Tool Works Inc. | Elgin, Ill. |
| 78452 | Everlook Chicago, Inc. | Chicago, Ill. |
| 78488 | Stackpole Carbon Co. | St. Marys, Pa. |
| 78526 | Stanwyck Winding Div. San Fernando Electric Mfg. Co. Inc. | Newburgh, N.Y. |
| 78553 | Tinnerman Products, Inc. | Cleveland, Ohio |
| 78584 | Stewart Stamping Corp. | Yonkers, N.Y. |
| 79136 | Waldes Kohinoor, Inc. | L.I.C., N.Y. |
| 79307 | Whitehead Metals Inc. | New York, N.Y. |
| 79727 | Continental-Wirt Electronics Corp. | Philadelphia, Pa. |
| 79963 | Zierick Mfg. Co. | Mt. Kisco, N.Y. |
| 80031 | Mepco | Morristown, N.J. |
| 80294 | Bourns, Inc. | Riverside, Calif. |
| 81042 | Howard Industries | Racine, Wisc. |
| 81073 | Grayhill, Inc. | La Grange, Ill. |
| 81483 | International Rectifier | El Segundo, Calif. |
| 81751 | Columbus Electronics | Yonkers, N.Y. |
| 82099 | Goodyear Sundries & Mechanical Co. Inc. | New York, N.Y. |
| 82142 | Airco Speer Electronic Components | Du Bois, Pa. |
| 82219 | Sylvania Electric Products Inc. | Emporium, Pa. |
| 82389 | Switchcraft, Inc. | Chicago, Ill. |
| 82647 | Metals and Controls Inc. | Attleboro, Mass. |
| 82866 | Research Products Corp. | Madison, Wisc. |
| 82877 | Rotron Inc. | Woodstock, N.Y. |
| 82893 | Vector Electronic Co. | Glendale, Calif. |
| 83058 | Carr Fastener Co. | Cambridge, Mass. |
| 83186 | Victory Engineering | Springfield, N.J. |
| 83298 | Bendix Corp. | Eatontown, N.J. |
| 83330 | Herman H. Smith, Inc. | Brooklyn, N.Y. |
| 83385 | Central Screw Co. | Chicago, Ill. |
| 83501 | Gavitt Wire and Cable | Brookfield, Mass. |
| 83508 | Grant Pulley and Hardware Co. | West Nyack, N.Y. |
| 83594 | Burroughs Corp. | Plainfield, N.J. |
| 83835 | U.S. Radium Corp. | Morristown, N.J. |
| 83877 | Yardeny Laboratories | New York, N.Y. |
| 84171 | Arco Electronics, Inc. | Great Neck, N.Y. |
| 84411 | TRW Capacitor Div. | Ogallala, Neb. |
| 86684 | RCA Corp. | Harrison, N.J. |
| 86838 | Rummel Fibre Co. | Newark, N.J. |
| 87034 | Marco & Oak Industries | Anaheim, Calif. |
| 87216 | Philco Corp. | Lansdale, Pa. |
| 87585 | Stockwell Rubber Co. | Philadelphia, Pa. |
| 87929 | Tower-Olschan Corp. | Bridgeport, Conn. |
| 88140 | Cutler-Hammer Inc. | Lincoln, Ill. |
| 88245 | Litton Precision Products Inc, USECO | Van Nuys, Calif. |
| 90634 | Gulton Industries Inc. | Metuchen, N.J. |
| 90763 | United-Car Inc. | Chicago, Ill. |
| 91345 | Miller Dial and Nameplate Co. | El Monte, Calif. |
| 91418 | Radio Materials Co. | Chicago, Ill. |
| 91506 | Augat, Inc. | Attleboro, Mass. |
| 91637 | Dale Electronics, Inc. | Columbus, Neb. |
| 91662 | Elco Corp. | Willow Grove, Pa. |
| 91929 | Honeywell Inc. | Freeport, Ill. |
| 92825 | Whitso, Inc. | Schiller Pk., Ill. |
| 93332 | Sylvania Electric Prod. | Woburn, Mass. |
| 93410 | Essex Wire Corp. | Mansfield, Ohio |
| 94144 | Raytheon Co. | Quincy, Mass. |
| 94154 | Wagner Electric Corp. | Livingston, N.J. |
| 94222 | Southco Inc. | Lester, Pa. |
| 95263 | Leecraft Mfg. Co. Inc. | L.I.C., N.Y. |
| 95354 | Methode Mfg. Co. | Rolling Meadows, Ill. |
| 95712 | Bendix Corp. | Franklin, Ind. |
| 95987 | Weckesser Co. Inc. | Chicago, Ill. |
| 96791 | Amphenol Corp. | Janesville, Wis. |
| 97464 | Industrial Retaining Ring Co. | Irvington, N.J. |
| 97702 | IMC Magnetics Corp. | Westbury, N.Y. |
| 98291 | Sealectro Corp. | Mamaroneck, N.Y. |
| 98410 | ETC Inc. | Cleveland, Ohio |
| 98978 | International Electronic Research Corp. | Burbank, Calif. |
| 99934 | Renbrandt, Inc. | Boston, Mass. |

*Use Code 71785 assigned to Cinch Mfg. Co., Chicago, Ill.

Table 6-4. Replaceable Parts

| REF. DESIG. | DESCRIPTION | TQ. | MFR. PART NO. | MFR. CODE | HP PART NO. | RS |
|---|---|---|---|---|---|---|
| | **Printed Circuit Board Assy.** | | | | | |
| C1, 11 | fxd, elect. 1450µF, 45V | 2 | (Type 68D)D39532 | 56289 | 0180-1893 | 1 |
| C2, 22 | fxd, elect. 1µF, 10%, 35V | 2 | 150D105X9035A2 | 56289 | 0180-0291 | 1 |
| C3, 12, 24 | fxd, mica 470pF, 5%, 300V | 3 | DM15471J0300WV1CR | 72136 | 0140-0149 | 1 |
| C5 | fxd, cer. .22µF, 20%, 50V | 1 | SCZ5U224X005005C | 56289 | 0160-0263 | 1 |
| C13 | fxd, elect. 180µF, 50V | 1 | 672D047 | 56289 | 0180-0634 | 1 |
| C21 | fxd, elect. dual section 6300µF, 20V/47µF, 35V | 1 | | 28480 | 0180-2894 | 1 |
| C23 | fxd, elect. dual section 1000µF, 50V/200µF, 50V | 1 | | 28480 | 0180-2906 | 1 |
| CR1 | diode, general purpose | 1 | 1N485B | 28480 | 1901-0033 | 1 |
| CR5, 6, 15, 16, 21-26 | diode, power rectifier | 10 | 1N5059 | 28480 | 1901-0327 | 5 |
| L1 | inductor, ferrite bead (Q22) | 1 | | 28480 | 9170-0894 | 1 |
| Q2, 12 | SS NPN Si. | 2 | 2N2222A | 28480 | 1854-0477 | 2 |
| Q22 | SS PNP Si. | 1 | 2N4036 | 28480 | 1853-0041 | 1 |
| Q23 | SS PNP Si. | 1 | 2N2907A | 28480 | 1853-0281 | 1 |
| R2 | fxd, film 2.21k, 1%, 1/8W | 1 | C4-1/8-TO-2211-F | 24546 | 0757-0430 | 1 |
| R3, 13, 23 | var, cermet 10, 10% | 3 | 72-99-0 | 73138 | 2100-3345 | 1 |
| R4, 34 | fxd, ww, 4.5 1%, 3W | 2 | T2B-79 | 52750 | 0811-0061 | 1 |
| R5, 16 | fxd, film 28.7k, 1%, 1/8W | 2 | C4-1/8-TO-2872-F | 24546 | 0698-3449 | 1 |
| R6, 7, 26, 35 | fxd, film 10, 1%, 1/8W | 4 | C4-1/8-TO-10R0-F | 24546 | 0757-0346 | 1 |
| R8, 18 | fxd, ww, 0.51, 5%, 2W | 2 | BWH2-R51-J | 75042 | 0811-0929 | 1 |
| R9 | fxd, comp. 1.5k, 5%, 1/2W | 1 | EB-1525 | 01121 | 0686-1525 | 1 |
| R12 | fxd, film 9.31k, 1%, 1/8W | 1 | CMF-1/8-T1-9311-F, | 91637 | 0698-0064 | 1 |
| R14 | fxd, ww, 4.7 5%, 2W | 1 | BWH2-4R7-J | 75042 | 0811-1674 | 1 |
| R15 | fxd, comp. 200 5%, 1/4W | 1 | CB-2015 | 01121 | 0683-2015 | 1 |
| R17 | fxd, ww, 2k, 5%, 3W | 1 | | 28480 | 0811-1806 | 1 |
| R19 | fxd, comp. 6.8k, 5%, 1/2W | 1 | EB-6825 | 01121 | 0686-6825 | 1 |
| R22 | fxd, film 2.49k, 1%, 1/8W | 1 | C4-1/8-TO-2491-F | 24546 | 0698-4435 | 1 |
| R24 | fxd, ww, 0.66, 1%, 3W | 1 | | 28480 | 0811-3522 | 1 |
| R25 | fxd, comp 82, 5%, 1/4W | 1 | CB-8205 | 01121 | 0683-8205 | 1 |
| R27 | fxd, comp. 27, 5%, 1/4W | 1 | CB-2705 | 01121 | 0683-2705 | 1 |
| R28 | fxd, ww, 0.1, 10%, 3W | 1 | | 28480 | 0811-1827 | 1 |
| R29 | fxd, comp. 470, 5%, 1/4W | 1 | CB-4715 | 01121 | 0683-4715 | 1 |
| R31 | var, cermet, 1k, 10% | 1 | 72-105-0 | 73138 | 2100-3211 | 1 |
| R32 | fxd, film, 10.5k, 1%, 1/8W | 1 | C4-1/8-TO-1052-F | 24546 | 0698-4477 | 1 |
| R33 | fxd, film, 21.5k, 1%, 1/8W | 1 | C4-1/8-TO-2152-F | 24546 | 0757-0199 | 1 |
| R36 | fxd, film 3.48k, 1%, 1/8W | 1 | C4-1/8-TO-3481-F | 24546 | 0698-3152 | 1 |
| R37 | fxd, comp. 270, 5%, 1/4W | 1 | CB-2715 | 01121 | 0683-2715 | 1 |
| S1 | switch, line | 1 | | 28480 | 3101-2287 | 1 |
| S2 | slide switch, DPDT (120/240Vac select) | 1 | | 28480 | 3101-2046 | 1 |
| S3-6 | switch, 4 station (meter select: V/A, +6V, ±18V) | 1 | | 28480 | 3101-2286 | |
| U1, 21 | negative voltage reg. IC | 2 | MLM-204G | 04713 | 1826-0016 | 2 |
| U2, 12 | diode, fullwave bridge rect. | 2 | | 28480 | 1906-0006 | 2 |
| U11 | operational amplifier | 1 | CA3140T (Note 1) | 02735 | 1826-0465 | 1 |
| VR1 | diode, zener 16.2V, 5% | 1 | SZ10939-242 | 04713 | 1902-0184 | 1 |
| VR21 | diode, zener 9.09V, 5% | 1 | SZ10939-170 | 04713 | 1902-3149 | 1 |

Note 1: Alternate part number, see paragraph 5-43.

Table 6-4. Replaceable Parts (Continued)

| REF. DESIG. | DESCRIPTION | TQ. | MFR. PART NO. | MFR. CODE | HP PART NO. | RS |
|---|---|---|---|---|---|---|
| | **Front Panel Electrical** | | | | | |
| M1 | Meter, VOLTS/AMPS | 1 | | 28480 | 1120-0433 | 1 |
| R1,11 | var, cermet 10k (±18 and TRACK VOLTAGE controls) | 2 | | 28480 | 2100-3707 | 1 |
| R21 | var, cermet 5k (+6 VOLTAGE control) | 1 | | 28480 | 2100-3708 | 1 |
| | **Rear Heatsink – Electrical** | | | | | |
| F1 | fuse 0.4A 250V slo-blow (120Vac operation) | 1 | 313.400 | 75915 | 2100-0340 | 1 |
| Q1 | power PNP | 1 | SJ1528 (Note 1) | 04713 | 1853-0063 | 1 |
| Q11 | power NPN Si. | 1 | 40250 (Note 1) | 02735 | 1854-0224 | 1 |
| Q21 | power NPN Si. | 1 | 61820 (Note 1) | 02735 | 1854-0563 | 1 |
| T1 | power transformer | 1 | | 28480 | 06235-80090 | 1 |
| | **Mechanical** | | | | | |
| | binding post, red | 4 | | 28480 | 1510-0091 | |
| | binding post, chassis ground | 1 | | 28480 | 1510-0044 | |
| | knob, control (R1, 11, 13) | 3 | | 28480 | 0370-1099 | |
| | knob, pushbutton (S3, 4, 5, 6) | 4 | | 28480 | 0370-2486 | |
| | fuseholder, body | 1 | | 28480 | 2110-0564 | |
| | fuseholder, cap | 1 | | 28480 | 2110-0565 | |
| | fuseholder, nut | 1 | | 28480 | 2110-0569 | |
| | cover, top | 1 | | 28480 | 5000-3137 | |
| | cover, bottom | 1 | | 28480 | 5000-3138 | |
| | frame, front | 1 | | 28480 | 5000-3139 | |
| | front panel | 1 | | 28480 | 06235-00001 | |
| | heat sink | 1 | | 28480 | 5020-2580 | |
| | foot, rubber | 4 | | 28480 | 0403-0266 | |
| | heat dissipator (U1) | 1 | | 28480 | 1205-0336 | |
| | clip, cable | 1 | | 28480 | 1400-0911 | |
| | bracket, meter | 1 | | 28480 | 06235-00002 | |
| | bushing, transistor insulator | 6 | | 28480 | 0340-0168 | |
| | transistor insulator, mica | 2 | | 28480 | 0340-0174 | |
| | transistor insulator, mica | 1 | | 28480 | 0340-0180 | |
| | bushing, insulator | 5 | | 28480 | 0340-0415 | |
| | **Miscellaneous** | | | | | |
| | fuse 0.2A slo-blow (240Vac operation) | 1 | 313.200 | 75915 | 2110-0235 | |
| | line cord | 1 | | 28480 | see para. 2-21 | |
| | line cord strain relief | 1 | | 28480 | 0400-0013 | |
| | packing carton | 1 | | 28480 | 9211-2812 | |
| | floater pad | 4 | | 28480 | 9220-2854 | |
| | filler pad | 4 | | 28480 | 9220-2853 | |

Note 1: Alternate part number. See paragraph 5-43.

# SCHEMATIC DIAGRAMS

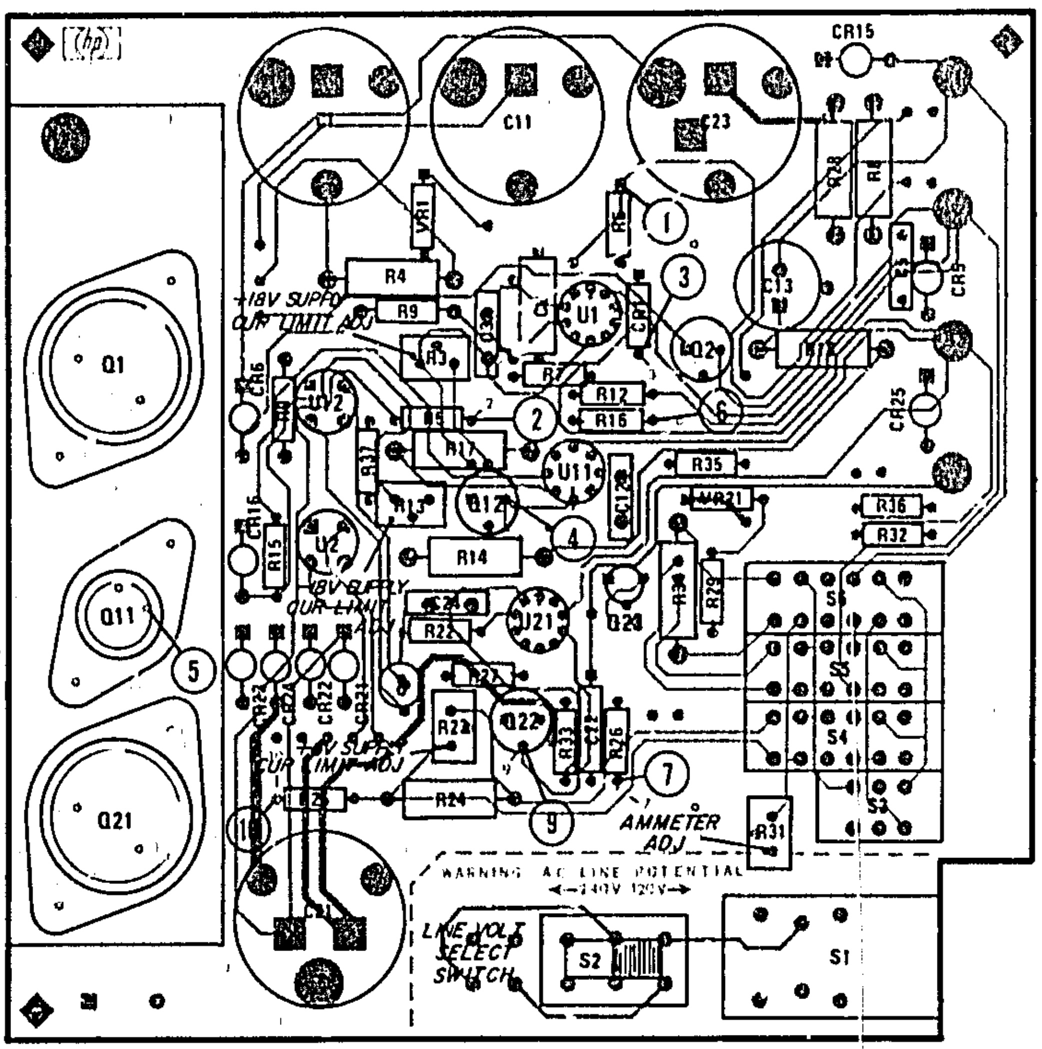
# SECTION VII
# CIRCUIT DIAGRAMS

## 7-1 COMPONENT LOCATION DIAGRAM

7-2 The component location diagram for power supply Model 6235A is given below. The illustration shows the physical locations and reference designations of parts mounted on the printed circuit card.

## 7-3 SCHEMATIC DIAGRAM

7-4 Figure 7-1 is a schematic diagram of the 6235A. The test points (circled numbers) shown on the schematic correspond to those on the component location diagram and in the troubleshooting procedure in Section V.




Model 6235A, Component Locations

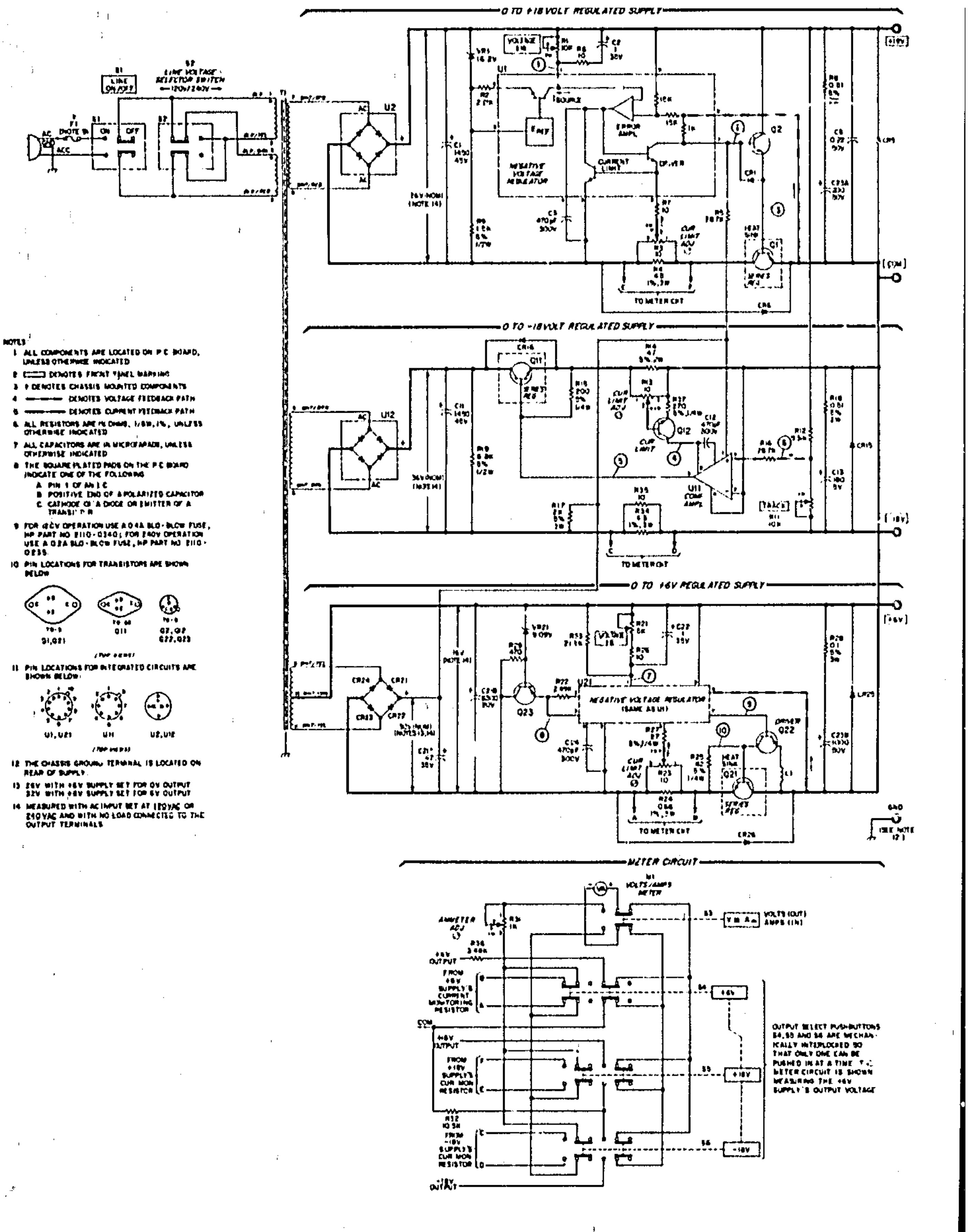



Figure 7-1. Model 6235A, Schematic Diagram

# MANUAL CHANGES

MANUAL CHANGES
6235A Triple Output Power Supply
Manual HP Part No. 06235-90001

Make all corrections in the manual according to errata below, then check the following table for your power supply serial number and enter any listed change(s) in the manual.

| SERIAL | | MAKE CHANGES |
|---|---|---|
| Prefix | Number | |
| All | --- | Errata |
| 1812A | 00201-up | 1 |

ERRATA:

On the title page, change serial number appearing in the title and associated notes to "1803A-00101."

On schematic, connect U1 pin 1 (test point (1)) to $I_{SOURCE}$ transistor within the U1 voltage Reg. I. C. Also change C13 to 180μF, 50V.

On page 7-1, component locations diagram: Change reference designation of resistor located between CR6 and U12 from "R9" to "R19."

Reference designation of component located between C2 and C3 is "R2."

On page 5-7, paragraph 5-42, change the grease speficied in step c from "silicon grease (Dow DC-5 or HP 8500-0059)" to "Heat Sink Compound No. 100 American Oil Co., Part No. PQC2471 (HP 6040-0415)."

CHANGE 1:

The following changes were made to reduce turn-off overshoot at maximum specified operating temperature and maximum specified series pass transistor leakage current.

Make the following changes to the parts list and schematic:

R5: Change to 42.2k, 1/8W, 10%, HP Part No. 0698-3450.

R15: Change to 680Ω, 1/4W, 5%, HP Part No. 0683-6815.

R17: Change to 6.8k, 1/2W, 5%, HP Part No. 0686-6825.

C21: Change to 6300μF/400μF, 35V, HP Part No. 0180-2894 (on schematic change value of C21A to 400μF).

C23: Change to 200μF/1000μF, 50V, HP Part No. 0180-2907 (C23A and C23B values on schematic are correct).

Q11: Change to 2N6261, HP Part No. to 1854-0738.

Make the following additions to the parts list and the schematic.

R38: fxd, comp, 4.7k, 1/4W, 5%, HP Part No. 0683-4725.

R39: fxd, comp. 2k, 1/4W, 5%, HP Part No. 0683-2025.

CR17: diode, silicon, HP Part No. 1901-0327.

Connect R38 between collector and emitter of transistor Q2.

Connect R39 between +6V output terminal and COM.

Connect anode of CR17 to emitter of Q11 and cathode of CR17 to junction of CR16 and R15.

On page 7-1, component locations diagram, position the new components as follows:

CR17: Between CR16 and U2 (R15 is now located between CR16 and CR6).

R38: Directly below C1.

R39: To the immediate left of CR25.

3-22-78