HEWLETT PACKARD

Dept. 346

AUTORANGING DC POWER SUPPLY HP MODEL 6010A

SER# 2846A-00599

PRELIMINARY OPERATING AND SERVICE MANUAL FOR INSTRUMENTS WITH SERIAL NUMBERS 2536A-00101 AND ABOVE

For instruments with Serial Numbers above 2536A-00101, a change page may be included.

HP Part No. 06010-90001
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SAFETY SUMMARY

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Hewlett-Packard Company assumes no liability for the customer's failure to comply with these requirements.

BEFORE APPLYING POWER.

Verify that the product is set to match the available line voltage and the correct fuse is installed.

GROUND THE INSTRUMENT.

This product is a Safety Class 1 instrument (provided with a protective earth terminal). To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The instrument must be connected to the ac power supply mains through a three-conductor power cable, with the third wire firmly connected to an electrical ground (safety ground) at the power outlet. For instruments designed to be hard-wired to the ac power lines (supply mains), connect the protective earth terminal to a protective conductor before any other connection is made. Any interruption of the protective (grounding) conductor or disconnection of the protective earth terminal will cause a potential shock hazard that could result in personal injury. If the instrument is to be energized via an external autotransformer for voltage reduction, be certain that the autotransformer common terminal is connected to the neutral (earthed pole) of the ac power lines (supply mains).

INPUT POWER MUST BE SWITCH CONNECTED.

For instruments without a built-in line switch, the input power lines must contain a switch or another adequate means for disconnecting the instrument from the ac power lines (supply mains).

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE.

Do not operate the instrument in the presence of flammable gases or fumes.

KEEP AWAY FROM LIVE CIRCUITS.

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified service personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power, discharge circuits and remove external voltage sources before touching components.

DO NOT SERVICE OR ADJUST ALONE.

Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT EXCEED INPUT RATINGS.

This instrument may be equipped with a line filter to reduce electromagnetic interference and must be connected to a properly grounded receptacle to minimize electric shock hazard. Operation at line voltages or frequencies in excess of those stated on the data plate may cause leakage currents in excess of 5.0 mA peak.

SAFETY SYMBOLS.

Instruction manual symbol: the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual (refer to Table of Contents).

Indicates hazardous voltages.

or Indicate earth (ground) terminal.

WARNING — The WARNING sign denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in personal injury. Do not proceed beyond a WARNING sign until the indicated conditions are fully understood and met.

CAUTION — The CAUTION sign denotes a hazard. It calls attention to an operating procedure, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product. Do not proceed beyond a CAUTION sign until the indicated conditions are fully understood and met.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT.

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Hewlett-Packard Sales and Service Office for service and repair to ensure that safety features are maintained.

Instruments which appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel.

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Section I
GENERAL INFORMATION

1-1 INTRODUCTION

1-2 This Operating and service manual contains a description of the HP Model 6010A System Power Supply, including specifications, installation and operating instructions, theory of operation, maintenance procedures and schematics.

1-3 DESCRIPTION

1-4 The HP 6010A is a 1000 W autoranging power supply with maximum ratings of 200 V and 17 A. It uses power MOSFETs in a 20 kHz switching converter to provide an autoranging output characteristic with laboratory performance. Output voltage and current are continuously indicated on individual meters. LED indicators show the complete operating state of the unit. Front-panel controls allow the user to set output voltage, current and overvoltage protection trip level. Overvoltage protection (OVP) protects the user's load by quickly and automatically interrupting energy transfer if a preset trip voltage is exceeded.

1-5 Output connections are made to rear-panel screw-on terminals. Either the positive or negative output terminal may be grounded or the output may be floated up to +550 Vdc (including output voltage) from chassis ground. Output voltage can be locally or remotely sensed.

1-6 The HP 6010A is considerably smaller, lighter and more efficient than older-design supplies with similar output power capability. The unit is fan cooled and is packaged in a Hewlett-Packard System II-compatible modular enclosure which is sturdy, attractive and provides easy access for servicing.

1-7 SAFETY CONSIDERATIONS

1-8 This product is a Safety Class 1 instrument (provided with a protective earth terminal). The instrument and this manual should be reviewed for safety markings and instructions before operation. Refer to the Safety Summary page at the beginning of this manual for a summary of general safety information. Safety information for specific procedures is located at appropriate places in this manual.

1-9 SPECIFICATIONS

1-10 Instrument specifications are listed in Table 1-1. These specifications are the peformance standards or limits against which the instrument is tested. Supplemental information is also listed in Table 1-1, including typical but non-warranted characteristics.

1-11 OPTIONS

1-12 Options are standard factory modifications or accessories that are delivered with the instrument. The following options are available with the HP 6010A.

Option	Description
002	Systems Option: allows the supply to operate remotely in system applications. It enchances resistance, voltage, and current programming of output voltage and current; and provides for status and isolated control: six isolated status lines; three isolated control lines; +5 V and ±15 bias voltages. This option is mounted on a single additional printed-circuit board, which includes a rear-panel connector.
120	Input power: 120 Vac +6%, −13%. 48-63 Hz single phase.
220	Input Power: 220 Vac +6%, −13%; 48-63 Hz, single phase.
240	Input power: 240 Vac +6%, −13%; 48-63 Hz, single phase.
908	Rack mounting kit.
909	Rack Mounting flange kit.
910	One additional operating and service manual for each Option 910 ordered.

1-13 ACCESSORIES

1-14 The System-II cabinet accessories listed below may be ordered with the power supply or separately from your local Hewlett-Packard Sales and Service Office (see list of addresses at rear of this manual).

HP Part No.	Description
5061-9689	Front handle kit for 5¼ inch high cabinets.
1460-1345	Tilt stand (1) snaps into standard foot on instrument, must be used in pairs.
5061-9677	Rack flange kit for 5¼ inch high cabinet (will be shipped with instrument if ordered as option 908).
5061-9683	Rack mount flange kit with handles.
1494-0060	Rack slide kit, non tilting.
5060-2865	Service kit, includes extenders for control and power mesh boards. Cables allow boards to lie on table outside unit, and control board test connector.
5060-2866	FET service kit, includes FETs and all components that should be replaced with FETs.

1-15 INSTRUMENT AND MANUAL IDENTIFICATION

1-16 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 (23 = 1983, 24 = 1984, etc). The second two digits indicate the week, and "A" designates the U.S.A. The second part of the serial number is a different sequential number assigned to each power supply, starting with 00101.

1-17 If the serial number on your instrument does not agree with those on the title page of this manual, a yellow Manual Changes sheet supplied with the manual defines the difference between your instrument and the instrument described by this manual. The change sheet may also contain information for correcting errors in the manual.

1-18 ORDERING ADDITIONAL MANUALS

1-19 One manual is shipped with each power supply. Additional manuals may be purchased directly from your local Hewlett-Packard Sales office. Specify the model number, instrument serial number prefix, and the manual part number provided on the title page. (When ordered at the same time as the power supply, additional manuals may be puchased by adding Option 910 to the order and specifying the number of additional manuals desired).

Table 1-1. Specifications and Supplementary Characteristics

All performance specifications are at bus bars with a resistive load. All specifications apply over the full operating temperature range unless otherwise specified.

AC Input

Three internal switches and one internal jumper permit operation from 120, 220,or 240 Vac (+6%, −13%; 48-63 Hz).

Input Current (Maximum)

120 Vac: 24 A rms
220 Vac: 15 A rms
240 Vac: 14 A rms

Peak Inrush Current (Maximum)

120 Vac: 32 A
220 Vac: 14 A
240 Vac: 15 A

DC Output

Output is autoranging from 60 to 200 V. Voltage and current can be programmed via front-panel control, or remote analog control over the following ranges:

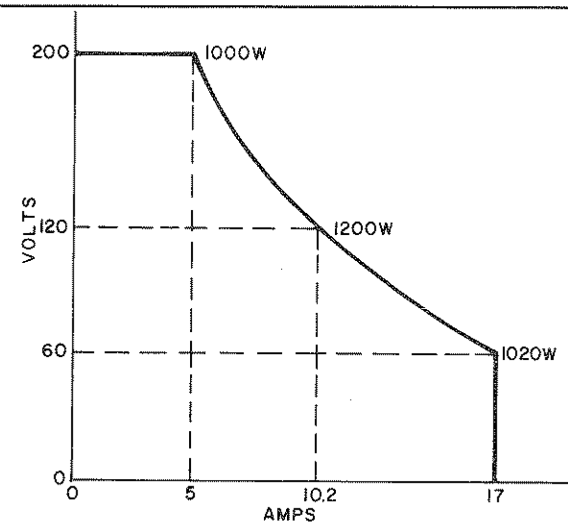
Voltage: 0—200 V **Current:** 0—17 A

Output Boundary Specification

Voltage (V)	Current (A)	Power (W)
60	17	1020
80	13.75	1100
100	11.5	1150
120	10.0	1200
140	8.5	1190
160	7.4	1184
180	6.1	1105
200	5	1000

Efficiency (Typical)

80% on maximum output boundary.



Input Protection

The AC input is protected by a rear panel mounted 25 A single pole circuit breaker and an internal fuse.

Load Effect (Load Regulation)

For a load change equal to the maximum available current rating of the supply at the set voltage (CV) or maximum available voltage at the set current (CC):

Voltage: 0.01% +5 mV **Current:** 0.01% +10 mA

Source Effect (Line Regulation)

For a line change within rating:

Voltage: 0.01% +5 mV **Current:** 0.01% +5 mA

PARD (Ripple and Noise)

	20 Hz—10 MHz
CV 22 mV rms 50 mV p-p	+2.4 mV/°C initially
CC 15 mA rms	+1.4 mV/°V after load is applied for 15 minutes

CC PARD is specified for a 4-foot (1.2 m) length load lead.

Table 1-1. Specifications and Supplementary Characteristics (continued)

DC Output Isolation

Either output terminal may be floated up to ±550 Vdc (including output voltage) from earth ground.

Temperature Coefficient

Change in output per °C after a 30 minute warm-up.

Voltage: 80 ppm + 15 mV **Current:** 100 ppm + 4 mA

DRIFT (Stability)

Change in output over an 8-hour interval under constant line, load, and ambient temperature (after 30 minutes warm-up).

Voltage: 0.03% + 17 mV **Current:** 0.03% + 5 mA

Load Transient Recovery Time

The time required for the output voltage to recover within a band around the nominal value following a change in current.

10% load current change: 2 ms to within 150 mV
50% load current change: 3 ms to within 500 mV

Resolution: (Minimum output voltage or current change that can be obtained using the front panel controls.

Voltage: 70 mV **Current:** 7 mA

Programming Response Time

Maximum time for output voltage to change from 0 V to 200 V or 200 V to 2 V and settle within specified band.

		300 mV
Up:	Full Load (3.4 ohms)	300 ms
	No Load	300 ms
Down:	Full Load (3.4 ohms)	600 s
	No Load	3.5 s

Remote Analog Programming (25 ±5 °C)

Resistance Programming:

0 to 4 k provides 0 to maximum voltage or current output

Accuracy: CV 0.50% ±215 mV
CC 1% ±170 mA

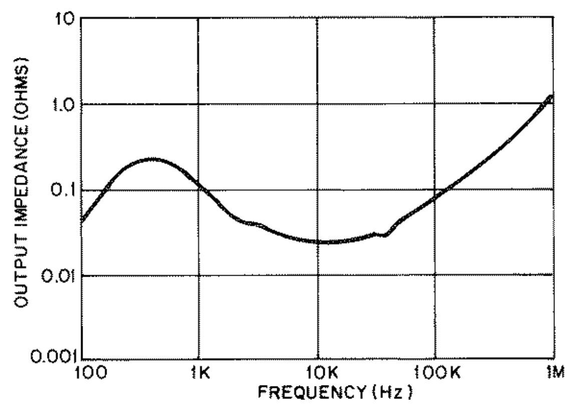
Voltage Programming:

0 to 5 V provides 0 to maximum voltage or current output.

Accuracy: CV 0.3% ±215 mV
CC 0.36% ±170 mA

Output Impedance (Typical)

See graph.



Front Panel Meters (25 ± 5°C)

	Range	Resolution	Accuracy (20-30°C)	Temp. Coeff./°C
Voltage	200 V	100 mV	0.65% + 3.5 counts	1 mV + 80 ppm
	2000 V	1 V	0.65% + 3.5 counts	1 mV + 80 ppm
Current	20 V	10 mA	0.6% + 4 counts	2 mA + 100 ppm
OVP	2000 V	1 V	2.5% + 1.1 V	3 mV + 200 ppm

Remote Sensing

Meets load effect specification at load by correcting for load lead drop of up to 0.5 V per lead with sense wire resistance less than 0.2Ω per lead and sense lead length less than 5 metres. Operation with up to 2 V drop per load lead is possible; however the load effect specification will be degraded and depends upon sense wire resistance.

Overvoltage Protection

Trip voltage adjustable via front panel control.

Range: 0—214 V
Resolution: 600 mV
Accuracy : 0.3% + 1.25 mV

Reverse Voltage Protection

Maximum permissible current caused by reversed voltage impressed across output terminals:

17 A continuous with ac power on
7 A continuous with ac power off

Table 1-1. Specifications and Supplementary Characteristics (continued)

Reactive Loads

Stable with inductive loads up to 100 mH and capacitive loads up to 10 F. CC compensation that provides up to 10 H (with increased settling time) is available on special order.

Voltage Overshoot (Typical)

The output voltage will overshoot its steady state value by less than 250 mV due to any of the following conditions:

1. Up-programming
2. Cross-over from CC to CV mode
3. A step load change of up to 5 A

Monitoring Outputs

0 to 5 V signals from rear-panel terminals indicate 0 to full scale output voltage and current.

Tolerances specified below are referred to actual values of output voltage and current.

Accuracy (25 +5°C): CV 0.3% 60 mV
CC 0.36% +10 mA

Output Impedance: 10 kΩ

Multiple Unit Operations

Up to two units may be connected in series or auto-parallel to provide increased output capability. Other multiple supply combinations including combinations of different model numbers are possible. Contact HP New Jersey Division for application assistance.

Temperature Ratings

Operating: 0 to +50°C (measured at fan intake)
Storage: −40 to +75°C

Certification

The unit is designed to comply with these requirements:

IEC 348—Safety Requirements for Electronic Measuring Apparatus

CSA Electrical Bulletin 556B—Electronic Instruments and Scientific Apparatus for Special Use and Applications.

VDE 0871/6.78 RFI Suppression of Radio Frequency Equipment for Industrial, Scientific, and Medical (ISM) and similar purposes. Conducted is level B. Radiated is level A.

VDE 0411- Electronic Measuring Instruments and Automatic Controls.

UL 1244- Electrical and Electronic Measuring & Testing Equipment.

ANSI C39.5 Part 0 Draft 8—Electrical Testing, Measurement, and Control Equipment.

HP Class B—Environmental Specifications.

CSA 22.2-0-1975—Definitions

Dimensions

See Figure 2-1.

Weight

Net: 15.9 kg. (35 lb.)

Section II
INSTALLATION

2-1 INTRODUCTION

2-2 This section contains instructions for checking and repacking the unit, bench or rack mounting, connecting the unit to ac input power, and converting the unit from one line voltage to another if required. Instructions for connecting the load is given in Section III.

2-3 INITIAL INSPECTION

2-4 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.

2-5 Mechanical Check

2-6 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 face and rear-panel plastic covers are not scratched or cracked.

2-7 Electrical Check

2-8 Section V contains complete verification procedures for this instrument. Section III contains an abbreviated check which can be used quickly to place the unit into operation. Refer to the inside front cover of the manual for Certification and Warranty statements.

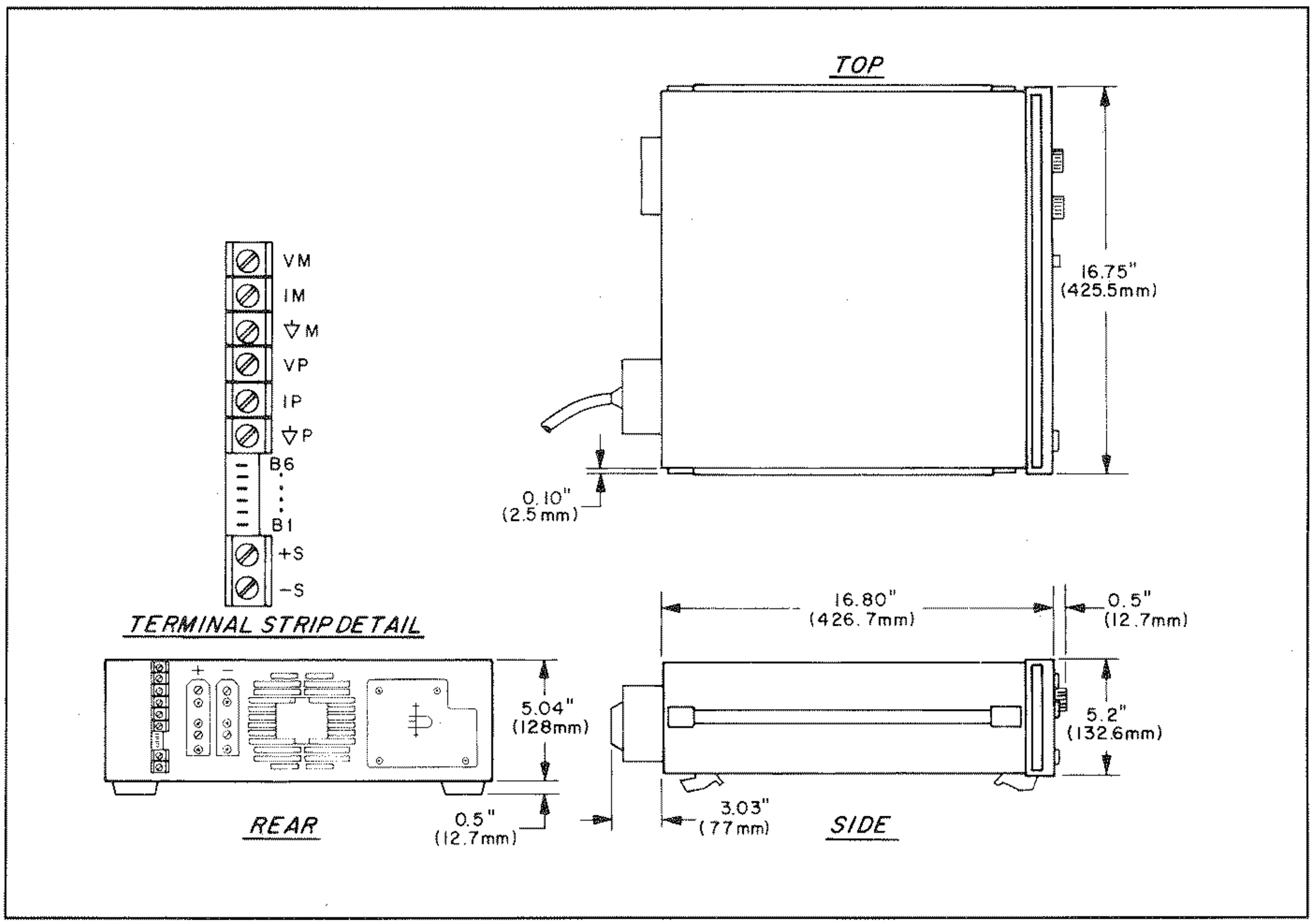


Figure 2-1. Outline Diagram

2-9 PREPARATION FOR USE

2-10 In order to be put into service, the power supply must be connected to an appropriate ac input power source, Also, the line voltage for which the unit is set must be checked. Additional steps may include line voltage conversion and rack mounting. Do not apply power to the instrument before reading paragraph 2-19.

2-11 Location and Cooling

2-12 The instrument is fan cooled and must be installed with sufficient space in the rear and on sides for air flow. It should be used in an area where the ambient temperature does not exceed +50°C.

2-13 Outline Diagram

2-14 Figure 2-1 illustrates the outline shape and dimensions of the cabinet.

2-15 Bench Operation

2-16 The instrument cabinet has plastic feet, which are shaped to ensure self aligning when stacked with other Hewlett-Packard System II cabinets.

2-17 Rack Mounting

2-18 The unit can be mounted in a standard 19-inch rack enclosure. Rack mounting accessories for this unit are listed in the ACCESSORIES paragraph in Section I. Complete installation instructions are included with each rack mounting kit.

2-19 Input Power Requirements

2-20 This supply may be operated from a nominal 120 V, 220 V, or 240 V single-phase ac power source (48-63 Hz). The input voltage range and input current required for each of the nominal inputs are listed below. A label on the rear panel indicates the nominal line voltage for which the instrument was set at the factory. If necessary, the user can convert the instrument from one line voltage option to another by following the instructions in paragraph 2-24.

Nominal Voltage	Line Voltage Range	Maximum Input Current
120 V	120 Vac +6%, −13%	24 A rms
220 V	220 Vac +6%, −13%	15 A rms
240 V	240 Vac +6%, −13%	14 A rms

2-21 Power Connection

CAUTION

Connection of this instrument to an ac power source should be done only by an electrician or other qualified personnel. Before connecting the instrument to the ac power source, check the label on the rear panel to ensure that the instrument is set for the ac voltage to be used. If necessary, the user can convert the instrument from one line voltage option to another by following the instructions in paragraph 2-24.

2-22 Input power is connected to the instrument via the AC Filter Assembly on the rear panel. The power cord must be a three-conductor cord rated for at least 85°C. For 120 V operation, each conductor must be AWG #10 (6mm^2) or larger. For 220 V or 240 V operation, each conductor must be AWG #14 (2.5 mm^2) or larger. Larger wire sizes may be required to prevent excessive voltage drop in the ac input.

WARNING

Do not use three individual wires to connect power to the instrument. The strain relief on the rear panel is designed for use only with a single three-conductor cord.

2-23 To connect input power to the instrument proceed as follows:

a. Remove the AC filter assembly cover by unscrewing the four locating screws.

b. Prepare the power cord as shown in Figure 2-2 and insert it through the strain relief clamp located on the cover.

c. Connect the wires to the terminal block in accordance with the prevailing color codes.
   Green or green/yellow to the terminal labelled "⏚"
   White or blue wire to the terminal labelled "N"
   Black or brown wire to the terminal labelled "L"

d. Replace the cover, tighten all the screws and tighten the strain relief clamp. To ensure good radio frequency grounding of the AC filler Assembly, make certain that all four screws are properly tightened.

e. Connect the other end of the power cord to an appropriate power source.

NOTE

Connections to the ac power line must be made in accordance with applicable electrical codes. The international color code for identifying mains supply conductors is green/yellow, blue, and brown for earth, neutral, and line respectively. Corresponding USA/Canadian codes are green, white, and black.

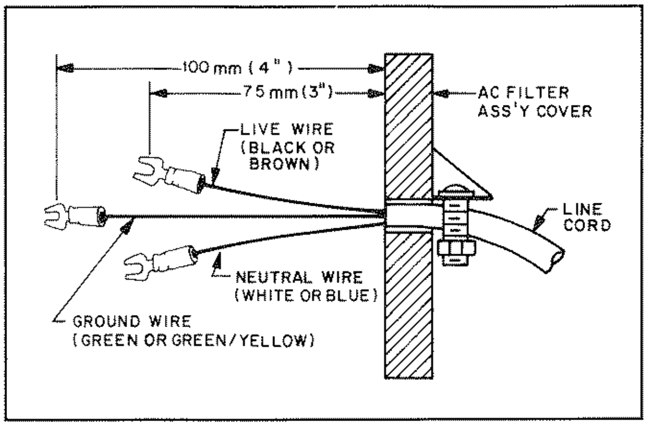


Figure 2-2. Power Cord Preparation

WARNING

For proper protection by the instrument circuit breaker, the wire connected to the "L" terminal on the instrument must be connected to the "L" side of the line (hot); the wire connected to the "N" terminal must be connected to the "N" side of the line (neutral or common).

To protect operating personnel, the wire connected to the ⏚ terminal must be connected to earth ground. In no event shall this instrument be operated without an adequate ground connection.

CAUTION

Before applying power to the instrument, check to see that the rear-panel circuit breaker CB1 is on (breaker may trip because of rough handling during transit). If the breaker trips while power is on, or if the breaker is found to be tripped at any time for unknown reasons, refer to troubleshooting procedures in Section V.

2-24 LINE VOLTAGE OPTION CONVERSION

2-25 Line voltage conversion is accomplished by adjusting three components: the two-section line select switch A1S2, A1S1, and line-voltage jumper A1W1. To convert the supply from one line voltage option to another, proceed as follows:

WARNING

Some components and circuits are at ac line voltage even with the LINE switch off. To avoid electric shock hazard, disconnect line cord and load, and wait two minutes before removing cover.

a. Remove the top cover from the instrument by removing the two screws that secure the cover to the rear panel, and carefully slide the cover to the rear of the instrument until it is clear. Next remove the top inside cover by removing the nine screws, four on top, three on right side, and two on left side, which connect the top inside cover to the instrument chassis.

b. Remove the FET board to reach the line-voltage jumper (W1) terminals.

CAUTION

FETs are static sensitive.

c. Switches A1S2 and A1S1 are located at the front of the instrument. In front of the power transformer T3. Consider switch A1S2, let the section closer to the front of the instrument be called the upper half and the other section the lower half.

d. To select a line voltage setting, switch A1S1 is set identically with the setting of the lower half of A1S2 at all times. The settings of the upper and lower halves of A1S2 are selected to match the pattern silk-screened on the A1 board as shown in Figure 2-3. Use a small blade screw driver to set the switch positions of A1S2.

e. One end of W1 is soldered to the main board; the other end has a female quick-connect terminal that fits onto one of two terminals soldered to the main board. For 120 V operation, W1 must be connected to terminal J9; for 220 V or 240 V operation, W1 must be connected to terminal J10. Be certain that jumper is firmly mated with connector on main board. Do not grip jumper insulation with pliers; either grip jumper wire by hand or grip jumper terminal with pliers.

f. Replace FET board, inside top cover and outside top cover. Mark the unit clearly with a tag or label indicating correct line voltage to be used.

g. Change line label.

2-26 AC LINE IMPEDANCE CHECK

2-27 The power supply is designed for proper operation with line impedance typically found in ac power lines. However, if the supply is connected to an ac power line having high impedance combined with line voltage near the minimum specified value, (e.g., 104 Vac for nominal 120 Vac), the supply will go out of regulation, if the unit is asked to provide full rated output power. Such a situation might occur if the supply is connected to ac power an extended distance from the main ac distribution terminals and/or if the ac power wires from the main ac distribution terminals are of relatively small gauge.

2-29 Measurement of ac line voltage at the supply input terminals typically is not a reliable indication of the actual ac line voltage because of the peak clipping effect of the power sup-

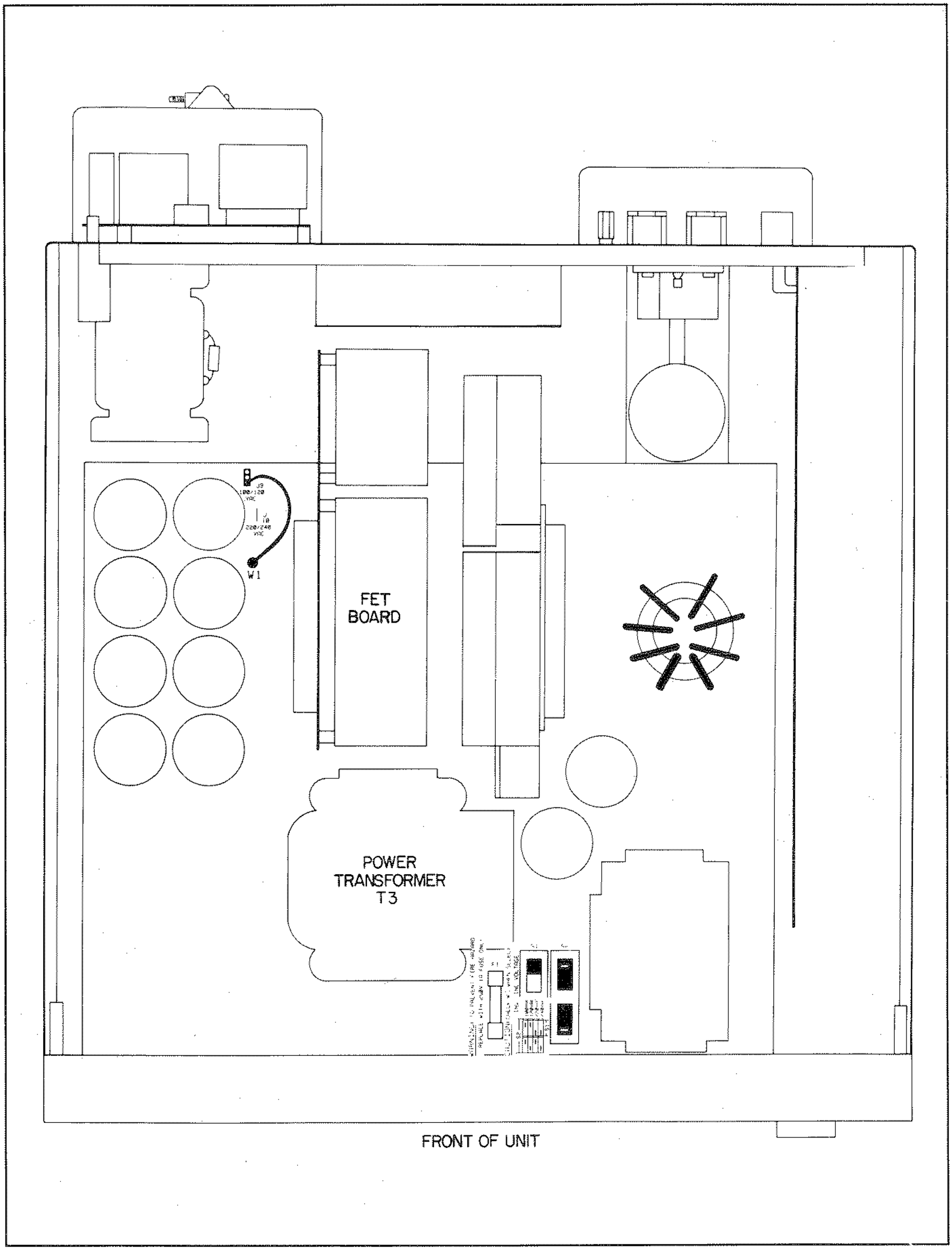


Figure 2-3. Line Voltage Conversion Components

ply and the averaging effect of the voltmeter. Symptoms of excessive line impedance may include erratic or no output from the supply and/or inability of the supply to provide full output power. If there is reason to suspect the ac power lines to the supply may have high impedance, perform the following check:

WARNING

This check should be performed only by service-trained personnel who are aware of the hazards involved (for example, fire and electrical shock). Turn power supply off and disconnect line cord. Wait for two minutes. Hazardous voltages are present within the unit even when power switch is turned off.

a. Connect variable load (Table 5-1 lists recommended load) to the supply. Using the Voltage, and Current controls, and DISPLAY SETTINGS switch, set voltage and current (see Section III for detailed description) to maximum rating. Set the load to 17 A. The unit's output voltage should be greater than or equal to 65 V. If this is not so, proceed to power limit calibration in Section V. If the latter is correct, but the unit still does not provide the required output, then the instrument is not receiving adequate ac line input.

2-30 REPACKAGING FOR SHIPMENT

2-31 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 Sales and Service office to obtain the materials. This office will also furnish the address of the nearest service office to which the instrument can be shipped. Be sure to attach a tag to the instrument specifying the owner, model number, full serial number, and service required or a brief description of the trouble.

Section III
OPERATING INSTRUCTIONS

3-1 INTRODUCTION

3-2 This section explains the operating controls and indicators and provides information on the many operating modes possible with your unit. WARNINGs give information for your safety; CAUTIONs give information to protect the unit or other equipment, and NOTEs highlight important operating information.

WARNING

If the unit is operated without connection to earth ground through its mains cord and a grounded power outlet, a hazardous fault voltage may exist on the unit's cabinet. The fault voltage can be a shock hazard and can cause personal injury. Before operating verify that the unit has a solid connection to earth ground not compromised by extension cord, auto transformer, or other device connected with it.

Defective fuses can cause a shock or fire hazard. Replace fuses only with 250 V fuses of the required current rating. Do not use slow-blow fuses.

3-3 CONTROLS AND INDICATORS

3-4 The following numbers are for front-panel controls and indicators, and they refer to Figure 3-1.

1. **LINE Switch:** Pressing at top of switch applies ac mains voltage to unit's bias and power circuits. Unit is operational 3 seconds after power on.
2. **VOLTAGE Control:** Clockwise rotation increases output voltage, 0 to 200 Vdc range.
3. **CURRENT Control:** Clockwise rotation increases output current, 0 to 17 Adc range.
4. **OVP ADJUST Screwdriver Control:** Clockwise rotation with a small, flat-blade screwdriver increases setting for overvoltage shutdown, 0 to 214 Vdc range.
5. **VOLTS Display:** Digital display of actual output voltage, output-voltage setting, or OVP shutdown setting.
6. **AMPS Display:** Digital display of actual output current or output-current setting.
7. **DISPLAY SETTINGS Switch:** Pressing causes VOLTS Display to show programmed output voltage and causes the AMPS Display to show programmed output current. Programmed values are front-panel settings or settings from remote voltage, or resistance programming.
8. **DISPLAY OVP Switch:** Pressing causes VOLTS Display to show voltage setting for overvoltage shutdown.
9. **CV LED Indicator:** Shows output voltage is regulated when lighted.
10. **CC LED Indicator:** Shows output current is regulated when lighted. (Both CV and CC LEDs light when the unit is crossing over from constant voltage to constant current or the reverse.)

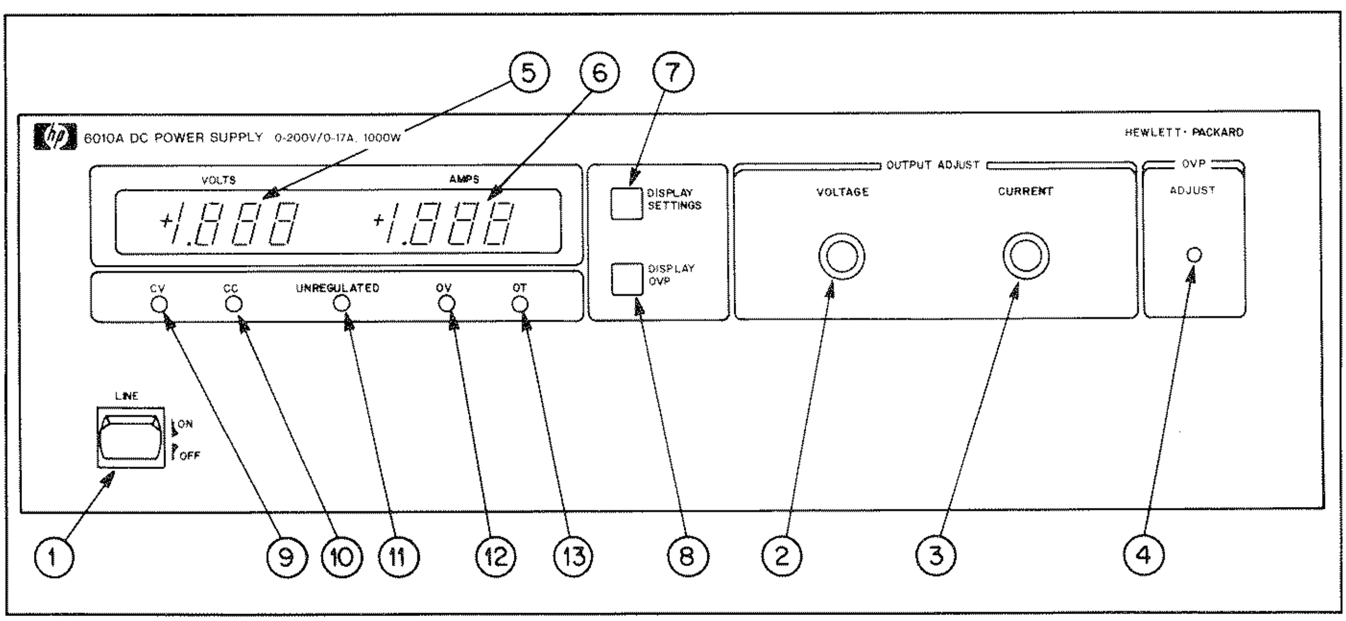


Figure 3-1. Front-Panel Controls and Indicators

11. **UNREGULATED LED Indicator**: Shows that neither output voltage nor current are regulated when lighted. This occurs when output is power limited or shutdown by a protective circuit.
12. **OV LED Indicator**: Shows that output is shutdown by occurrence of overvoltage. Removing the cause of overvoltage and switching the power off and then on resets the unit.
13. **OVERTEMPERATURE LED INDICATOR**: Shows an overheating condition in either the diode or FET Board when it is lighted.

3-5 TURN-ON CHECKOUT PROCEDURE

3-6 This procedure checks that the unit provides constant voltage operation and can be used as an incoming inspection check. Section V contains more extensive checks that determine whether the supply meets all specifications.

a. Check that the rear-panel, MODE switch settings are as shown in Figure 3-2.
b. Check that the + OUT terminal is jumpered to the + S terminal, and the − OUT terminal is jumpered to the − S terminal.
c. Check that the rear-panel label indicates that the unit is set for the mains voltage to be used. (If not, refer to MAINS VOLTAGE CONVERSION in Section II.)
d. If unit is furnished with System Option 002, disconnect the option cable from the rear-panel option connector.
e. Plug the unit into an appropriate ac power outlet, turn the VOLTAGE control all the way down, and turn the CURRENT control up slightly—to assure CV operation.
f. Switch on power; turn up output voltage slightly (about a quarter turn) and verify that the VOLTS display, the AMPS display and CV LED are lighted.
g. Press the DISPLAY OVP switch, and verify that the OVP shutdown is set above 200 Vdc. If not, turn up OVP AJDUST with a small flat-blade screwdriver.
h. Turn up the output voltage; verify that the VOLTS display can increase to 200 Vdc, and check that the CC LED lights while voltage is adjusted quickly.
i. Verify that the VOLTS display does not change when DISPLAY SETTINGS is pressed.
j. With DISPLAY SETTINGS depressed turn the CURRENT control up, and verify that the AMPS display can increase to 17 Adc.

3-7 CONNECTING THE LOAD

WARNING

Turn off input ac power before changing any rear panel connection and make certain all wires and straps are properly connected and terminal block screws are securely tightened before reapplying power. Be certain to replace both terminal block covers before reapplying power. Wires must be properly terminated with connectors securely attached. Do not connect unterminated wires to the power supply.

3-8 Load connections to the power supply are made at the + and − terminals on the rear panel. Two factors must be considered when selecting wire size for load connections, conductor temperature and voltage drop.

3-9 To satisfy safety requirements, the wires to the load should be at least heavy enough not to overheat while carrying the power supply output current that would flow if the load were shorted. Stranded AWG #16 copper wire (1.5 mm^2 cross section area) is rated for 18 amps at 105°C conductor temperature. (The maximum allowable conductor temperature is based on the +60°C ambient temperature plus 45°C temperature rise because of continuous dc current). This rating is based on use of a twisted pair to connect the load to the supply. If the wire insulation is rated for less than 105°C or if the wires are located such that heat build up is a factor, then larger wires must be used. The minimum load wire size is AWG #16 (1.5 mm^2).

3-10 The minimum wire size required to prevent overheating will not usually be large enough to provide good voltage regulation at the load. For proper regulation the load wires should be large enough to limit the voltage drop to no more than 0.5 volts per lead, Table 3-1 lists resistivity for various wire sizes and the maximum lengths that may be used to limit voltage drop to 0.5 V for various currents. Lengths listed are the sum of the (+) and (−) load wires.

3-11 To determine maximum lengths for the current listed, use the formula

$$\text{Maximum Length} = \frac{500}{I * R}$$

where I = Current in amps.
R = Resistivity in ohms/1000 ft or ohms/km.

If load regulation is critical , use remote voltage sensing.

3-12 OVERVOLTAGE PROTECTION (OVP)

3-13 When the voltage at the output terminals increases (or is increased by an external source) to the OVP shutdown voltage set by the the OVP ADJUST control, the unit's OVP circuit inhibits the output, and the output voltage and current drop to zero. During OVP shutdown the OV and UNREGULATED LEDs light.

3-14 False OVP shutdowns may occur if you set the OVP shut-down too close to the unit's operating voltage. Set the OVP shutdown voltage at about + 1.0 V or more times the output voltage to avoid false shutdowns from load-induced transients.

Table 3-1. Maximum Wire Lengths To Limit Voltage Drops

Wire Size		Resistivity		Maximum Length In Metres (Feet)To Limit Voltage Drop To 0.5V		
AWG	Cross-Section Area (sq. mm)	Ω/kft	Ω/km	5 A	10 A	17 A
4		0.2486		(405)	(205)	(135)
	25.0		0.795	126	63	42
2		0.1564		(640)	(320)	(214)
	35		0.565	177	89	59
	50		0.393	255	127	85
0		0.09832		(1020)	(505)	(340)

Table 3-2. Maximum Wire Lengths

Wire Size		Resistivity		Maximum Length in Meters (feet) to limit Resistance to 0.2Ω or less (Sense Leads)
AWG	Cross-Section Area (sq. mm)	Ω/k ft	Ω/km	
22		16.15		(12.0)
	0.5		40.1	5.0
20		10.16		(19.0)
	0.75		26.7	7.5
18		63.88		(31.0)
	1.0		20.0	10.0
16		4.018		(47.0)
	1.5		13.7	14.5
14		2.526		(79.0)
	2.5		8.21	24.0
12		1.589		(125.0)

3-15 **Adjusting OVP.** Follow this procedure to adjust the OVP shutdown voltage.

a. With the VOLTAGE control all the way down switch on the power.

b. Depress DISPLAY OVP, and adjust the OVP ADJUST control to the desired OVP shutdown using a small, flat-blade screwdriver.

c. Follow the procedure for CV or CC operation to set the output voltage and current.

3-16 **Resetting OVP.** If OVP shutdown occurs, reset the unit by switching power off. Wait one or more seconds, and switch power on again. If OVP shutdowns continue to occur, check the connections to the load and sense terminals, and check the OVP limit setting.

3-17 PROTECTIVE SHUTDOWN

3-18 The unit includes protection circuits which inhibit the output when required to protect the unit or the load. The output shuts down when any of three conditions occurs: an overvoltage at the output, an overtemperature inside the unit, or a low or high ac mains input voltage. When an overvoltage occurs reset the unit after eliminating the cause of shutdown by switching the power off for one second and then back on. In the other cases the supply resets automatically.

3-19 Front-panel LEDs indicate that a protective shutdown has occurred. During an overvoltage shutdown CV and CC LEDs are out and the OV and UNREGULATED LEDs light. During overtemperature or ac mains shutdown only the UNREGULATED LED lights.

3-20 OPERATING MODES

3-21 Settings of the rear-panel MODE switch determine the operating modes of the unit. The Normal Operating Mode is with the unit set up for sensing of output voltage directly at the output terminals—local sensing—and set up for operation using the front-panel controls—local programming. Figure 3-2 shows the MODE switch settings for the normal operating mode. Other operating modes covered in this section are remote voltage sensing, remote programming of output voltage and current using external voltages or resistances, and multiple supply operation in auto-parallel, auto-series, and auto-tracking operating modes.

3-22 Even if you plan to use one of the unit's other modes of operation, read the NORMAL OPERATING MODE section on next page first. The operating considerations described apply to the other modes as well. If you desire a more thorough explanation of power-supply operating modes and application possibilities, ask your local HP Sales office for a free copy of the DC Power Supply Handbook, Application Note AN90B.

3-23 NORMAL OPERATING MODE

3-24 The unit is shipped from the factory configured in the normal operating mode—local sensing and programming. Besides jumpers between output and sense terminals, normal operating mode requires the MODE switch settings shown in Figure 3-2.

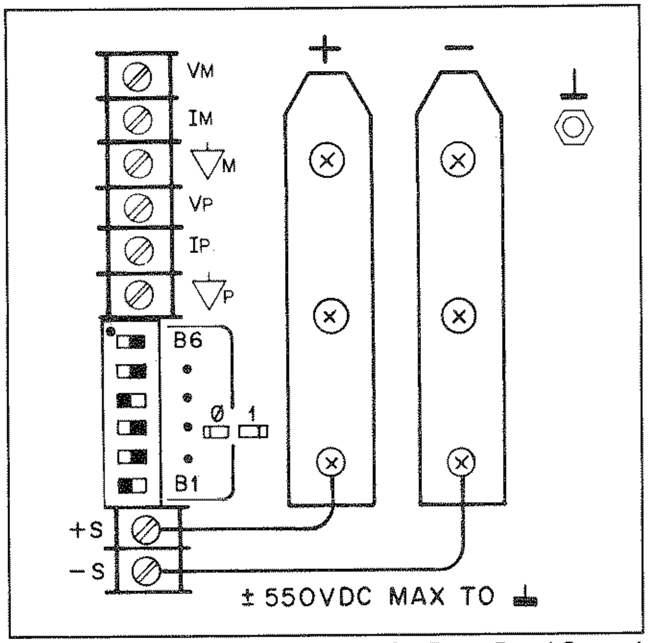


Figure 3-2. MODE-Switch Settings for Front-Panel Control

3-25 The unit provides constant-voltage (CV) or constant-current (CC) output. For CV operation set the output voltage with the VOLTAGE control, and set a current limit by setting the CURRENT control to a value of current higher than the load current at the selected voltage. For CC operation set the output current with the CURRENT control, and set a voltage limit by setting the VOLTAGE control to a voltage higher than the load voltage with the selected output current flowing through the load.

3-26 The settings of the VOLTAGE and CURRENT controls and the load resistance jointly determine whether the unit supplies constant voltage, constant current, or unregulated (power-limited) output. For all rated combinations of output voltage and current the unit is in CV or CC operation: CV if the selected voltage can be applied to the load with less than the selected current, and CC if the selected current can flow with less than the selected voltage across the load.

3-27 Figure 3-3A shows a rectangular operating locus that is defined by voltage and current settings of the power supply. The point on that locus at which the power supply actually operates is determined by the load resistance. Three load resistance lines are shown. The line representing load resistance A, crosses the operating locus at 1. Point 1 is on the part of the operating locus defined by the voltage setting, so the power supply operates in CV mode. Similarly, the line representing load resistance C, crosses the locus at 3. Point 3 is on that part of the operating locus defined by the current setting, so the power supply operates in CC mode.

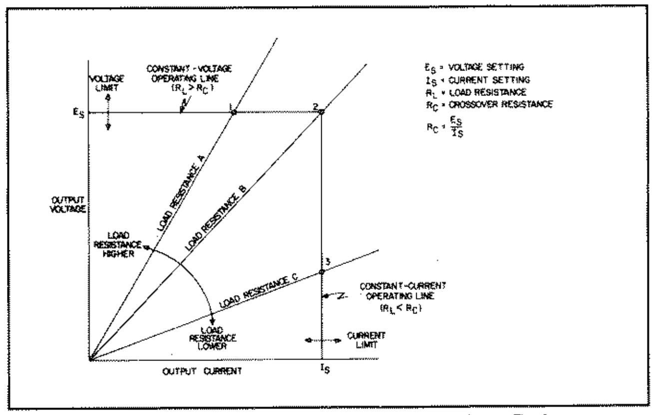


Figure 3-3A Determining Operating Point

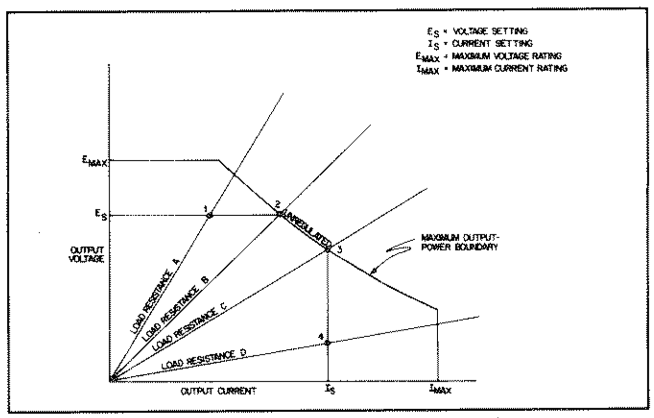


Figure 3-3B. Unregulated Operation

3-28 Load resistance B equals the cross over resistance for the particular combination of voltage and current settings shown in the graph. Either the CV or CC LED or both will light. If any of the following conditions is true, the power supply will operate in CV mode: increasing resistance; decreasing voltage setting; increasing current setting. Conversely, if the above conditions are reversed, then the power supply will operate in CC mode.

3-29 The voltage and current settings in Figure 3-3B are high enough that the rectangular operating locus is cut off by the maximum output boundary of the supply. For load resistance A, the supply operates in CV mode at the voltage and current values for point 1. Similarly, for load resistance D, the power supply operates in CC mode at point 4. For load resistances between B and C, the operating point will be on the maximum output-power boundary between points 2 and 3, and the UNREGULATED LED will be on.

3-30 The VOLTS and AMPS displays will indicate the voltage and current being supplied to the output. (The product of the two readings will exceed the rated output power of the supply.) Note that the actual boundary is beyond the specified minimum boundary. The UNREGULATED LED will light only if the actual boundary is exceeded. The supply can operate in the unregulated region for sustained periods without being damaged. However, the supply is not guaranteed to meet specifications in unregulated mode. Output ripple increases substantially and regulation is seriously degraded.

NOTE

Under certain conditions of line and load, it is possible for the supply to provide more than rated output power and still maintain regulation. If this occurs, the unit will operate normally and the UNREGULATED indicator will be off. However, the slightest change in either line or load may cause the unit to go out of regulation. Operation of the unit beyond the rated output power boundary is not recommended under any circumstances.

3-31 Constant-Voltage Operation

3-32 This procedure sets up the unit to supply a selected, constant voltage to the load.

a. With power off, connect the load to the rear-panel output terminals.
b. With the VOLTAGE control all the way down, switch on the power.
c. With DISPLAY SETTINGS depressed, adjust CURRENT control for the desired current limit.
d. Turn up the VOLTAGE control to the desired output voltage. Verify that the CV LED is lighted. (If the CC LED is lighted, choose a higher current limit. A current setting greater than the voltage setting divided by the load resistance in ohms is required for CV operation. If the UNREGULATED LED is lighted, the voltage cannot be supplied to your load within the unit's rated power. Consider Auto-Series operation if two units are available.)

3-33 Constant-Current Operation

3-34 This procedure sets up the unit to supply a selected, constant current through the load.

a. With power off, connect the load to the rear-panel output terminals.
b. With the VOLTAGE control all the way down, switch on the power.
c. With DISPLAY SETTINGS depressed, adjust CURRENT control for the desired output current.
d. Turn up the VOLTAGE control to the desired voltage limit. Verify that the CC LED is lighted. (If the CV LED is lighted, choose a higher voltage limit. A voltage setting more than the current setting times the load resistance in ohms is required for CC operation. If the UNREGULATED LED is lighted, the current cannot be supplied to your load within the unit's rated power. Consider Auto-Parallel operation if two units are available.)

3-35 OTHER OPERATING MODES

3-36 Other operating modes discussed below are remote voltage sensing, remote voltage programming and remote resistance programming. You can set up the unit for remote sensing by reconnecting the leads between output and sense terminals, and you can set up the unit for the other modes by changing the settings of the rear-panel MODE switch. Procedures follow.

CAUTION

Switch off ac power while making changes to MODE switch settings or rear-panel connections. This avoids the possibility of damage to the load and OVP shutdown from unintended output from the unit.

3-37 Remote Voltage Sensing

3-38 Remote voltage sensing of the output voltage at the load allows the unit to automatically increase the output voltage and compensate for the voltage drops in the load leads. This improves the voltage regulation at the load, and is especially useful for CV operation with loads that vary and have significant load-lead resistance. Remote sensing has no effect during CC operation.

3-39 Connect the unit for remote voltage sensing by connecting load leads from the +OUT and −OUT terminals to the load, and sense leads from the +S and −S terminals to the load as shown in Figure 3-4.

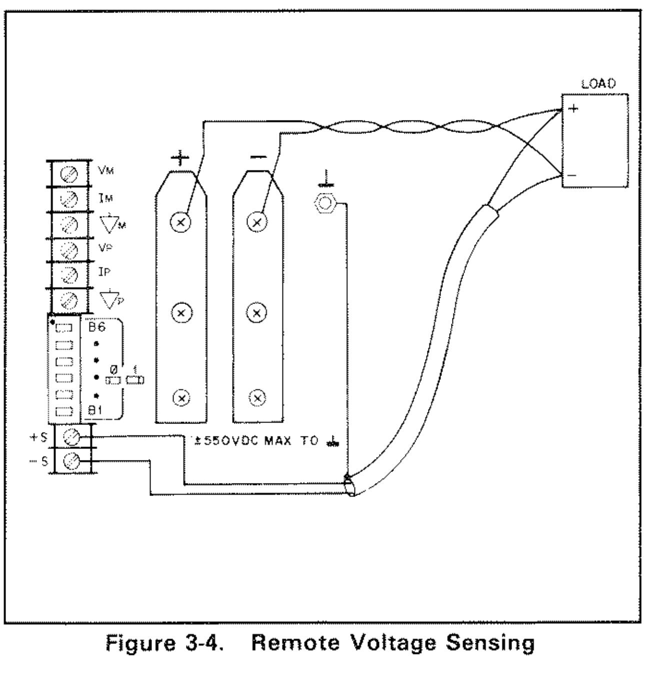


Figure 3-4. Remote Voltage Sensing

3-40 With slightly degraded CV load regulation performance, the unit will provide remote voltage sensing with up to 2 Vdc in each load lead and with more than 0.2 ohms in each sense lead. As the voltage drop in the load leads increases, the load voltage error due to the sense lead resistance increases according to the formula

$$\frac{(2Rs + 1)\ VI}{1000}$$

where Rs is the resistance in ohms of each sense lead and VI is the voltage drop in each load lead. For example, if the voltage drop in each load lead is 2 Vdc and the resistance in each sense lead is 1 ohm, the load voltage is about [2(1) + 1.0]2/1000 = 6 mVdc less than with no sense-lead resistance.

NOTE

During remote sensing the load-lead voltage drops cause the voltage at the output terminals to increase beyond the set value. Re-adjust the OVP shutdown voltage as required to avoid nusiance OVP shutdowns.

3-41 Any noise picked up on the sense leads will appear on the unit's output voltage and may degrade voltage regulation. To reduce noise pick up use a twisted pair or shielded pair with the shield grounded at one end only. Connect the sense leads as close to the load as possible. It is best to avoid grounding the output at any point other than the power supply output terminals to avoid noise problems. Always use two wires to connect the load to the supply regardless of where or how the system is grounded.

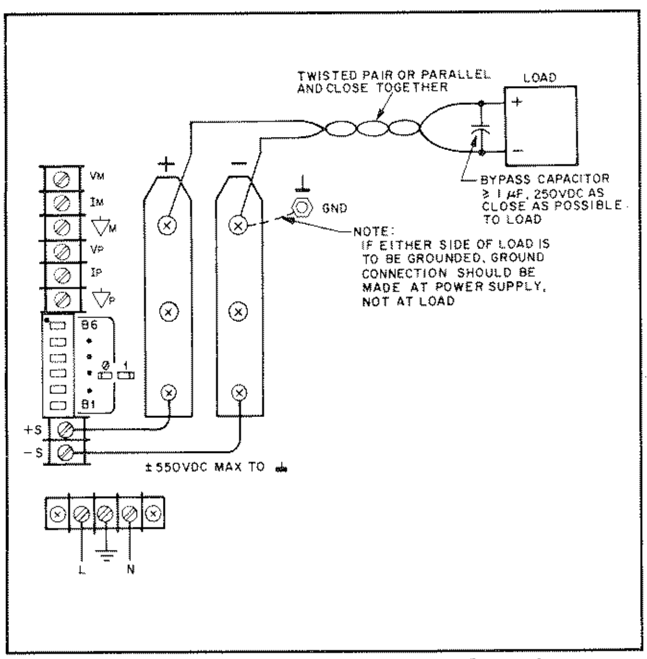


Figure 3-5. Connecting a Bypass Capacitor

3-42 The PARD specifications in Table 1-1 apply at the power supply output terminals. However, noise spikes induced in the load leads at or near the load may affect the load although the spikes are inductively isolated from the power supply. To minimize voltage spikes at the load, connect a bypass capacitor as shown in Figure 3-5. With this setup, peak-to-peak noise at the load can actually be reduced to a level below the value specified at the power supply output terminals.

3-43 The bus bars are protected by an impact resistant plastic cover, which is secured to the unit with four M4 x 8 screws. Be certain to replace the cover after making connections.

3-44 Accidental open-connections of sense or load leads during remote-sensing operation produces undesireable effects. Provide secure, permanent connections—especially for the sense leads. The sense leads are part of the unit's programming feedback control loop.

NOTE

The power supply includes protection resistors which reduce the effect of open sense leads. With local sensing if the +S sense lead opens, the output voltage increases about 1.6%. If the −S sense lead opens the output voltage decreases about 0.1% . If both sense leads open, the output voltage increases about 1.5%.

3-45 Remote Programming

3-46 This section describes programming the output voltage or output current from zero to full output using either 0-5 Vdc voltages or 0-4 k ohm resistances. Remote programming requires changing settings of the MODE switch and connecting external voltages or resistors to screw terminals VP, IP and ▽P on the rear-panel barrier strip.

3-47 The stability of the external voltages or resistances directly affects the stability of the output. Low noise, ½ watt resistors with a temperature coefficient of 25 ppm/°C are suitable. If external switches are used to interchange resistors for different fixed outputs, use make-before-break contacts to avoid output transients during program switching.

3-48 A 1.0 Vdc change in the remote programming voltage produces a 40 Vdc change in output voltage or a 3.4 Adc change in output current. During remote resistance programming internal CV and CC current sources force a 1.25 mA current through the remote programming resistors to create programming voltages for the unit. The 1.25 mA current allow a 1 k ohm change in remote programming resistance to produce a 50 Vdc change in output voltage or a 4.25 Adc change in output current.

CAUTION

The unit includes clamp circuits to prevent it from supplying more than about 120% of rated output voltage or current when the remote programming voltage is greater than 5 Vdc or remote programming resistance is greater than 4 k ohm. Do not intentionally operate the unit above 100% rated output. Limit your programming voltage to 5 Vdc and programming resistance to 4 k ohm to assure reliable operation.

NOTE

When external resistors are used to limit the the remote-programming voltage to 5 Vdc, the resulting high programming-source resistance can degrade the unit's programming speed, offset and drift performance. Limit the equivalent source resistance to 10 k ohm maximum. Figure 3-6 shows a convenient way of calculating suitable voltage-divider resistance values for a 5 k ohm source resistance.

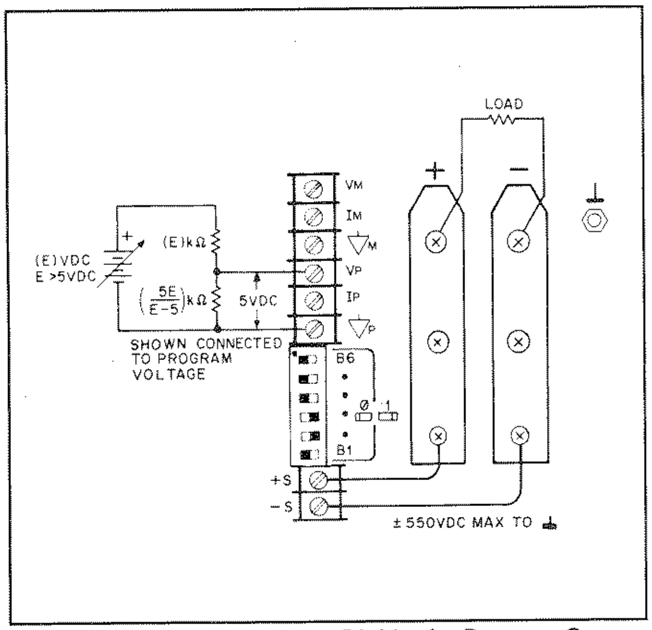


Figure 3-6. Optional Voltage Divider for Program Source

3-49 Any noise picked up on the programming leads will appear on the unit's output and may degrade regulation. To reduce noise pickup, use a shielded pair of wires for programming with the shield grounded at one end only. Do not use the shield as a conductor.

3-50 CV Output, Remote Voltage Control

3-51 Figure 3-7 shows the rear-panel MODE switch settings and terminal connections for remote-voltage control of output voltage. A 0 to 5 Vdc programming voltage produces a 0 to 200 Vdc output voltage. The output voltage is 40 times the input. The load on the programming voltage source is less than 5 μA.

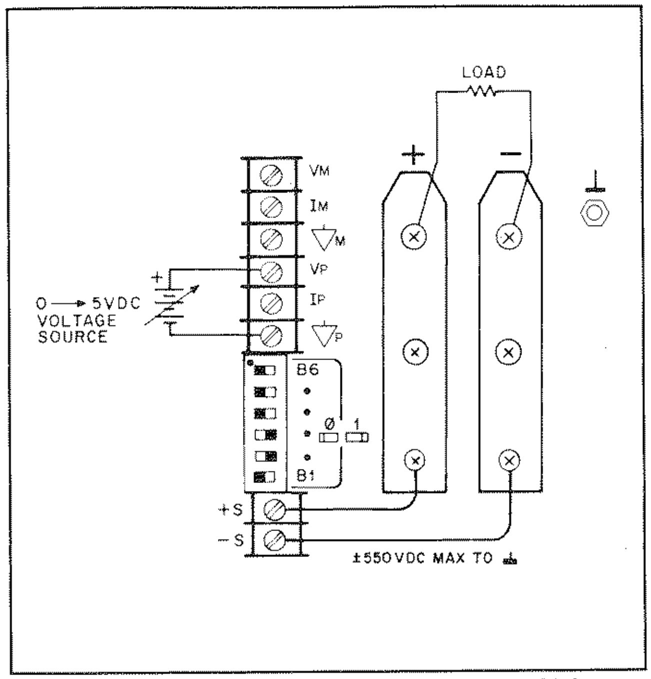


Figure 3-7. Voltage Programming of Output Voltage

3-52 CC Output, Remote Voltage Control

3-53 Figure 3-8 shows the rear-panel MODE switch settings and terminal connections for remote-voltage control of output current. A 0 to 5 Vdc programming produces a 0 to 17 Adc output current. The output current is 3.4 times the input. The load on the programming voltage source is less than 5 μA.

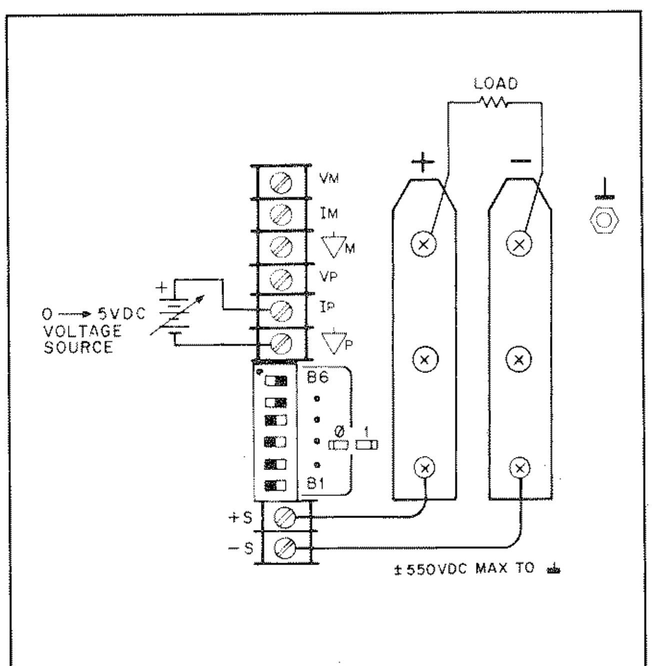


Figure 3-8. Voltage Programming of Output Current

3-54 CV Output, Remote Resistance Control

3-55 Figure 3-9 shows the rear-panel MODE switch settings and terminal connections for remote-resistance control of output voltage. A 0 to 4 k ohms external programming resistance will produce a 0 to 200 Vdc output. The resistance programming coefficient is nominally 20 ohms/volt.

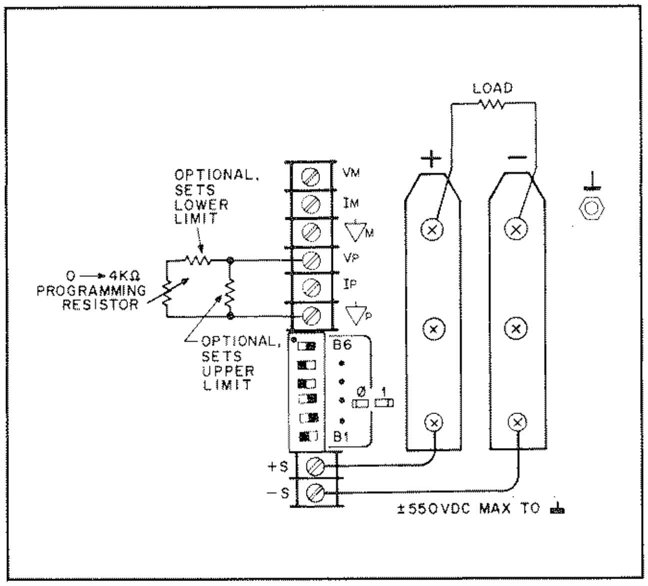


Figure 3-9. Resistance Programming of Output Voltage

3-56 CC Output, Remote Resistance Control

3-57 Figure 3-10 shows the rear-panel MODE switch settings and terminal connections for remote-resistance control of output current. A 0 to 4 k ohms external programming resistance produces a 0 to 17 Adc output current. The resistance programming coefficient is nominally 235.3 ohms/amp.

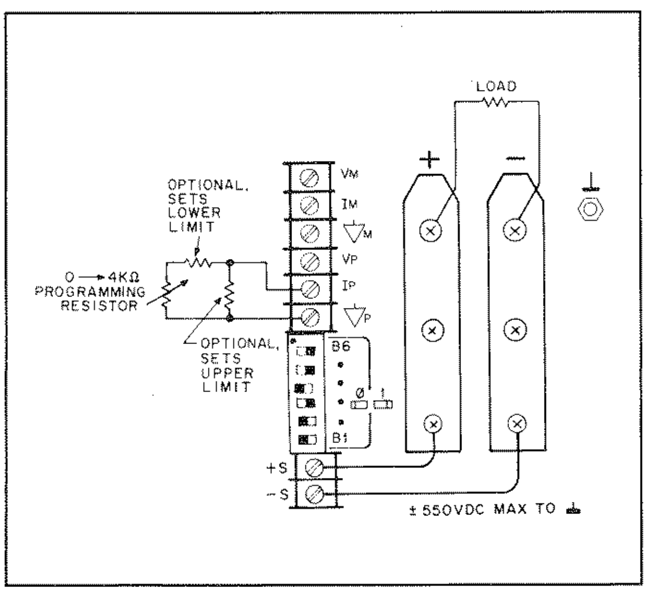


Figure 3-10. Resistance Programming of Output Current

CAUTION

If a programming resistor to a programming terminal opens during resistive programming, the output voltage or current will rise. If CV programming is interrupted, the units voltage will rise to the O.V. setting and shut down. If CC programming is interrupted, the units output current will rise to approximately 19 amps. The user should be sure that these two conditions will not damage the load. To protect against OVP shutdown when switching CV programming resistors, and to protect the load against over current when switching CC programming resistors, connect a parallel, resistor directly to the programming terminals as shown in Figures 3-9 and 3-10 to set an upper limit on output voltage and current. (The resistance value which determines the output is the parallel combination.)

3-58 MULTIPLE-SUPPLY OPERATION

3-59 This section includes procedures for interconnecting two units in master/slave configuration. To connect the unit as a master or slave with other HP autoranging power supplies, use the information here to help develop interconnection diagrams which accomodate the different rear-panel terminal strips on other supplies. Auto-Parallel operation provides increased output current; Auto-Series provides increased output voltage.

3-60 Auto-Parallel Operation

3-61 Figure 3-11 shows the rear-panel MODE switch settings and terminal connections for Auto-Parallel operation of two units. The master regulates the output and the slave—operating in CC mode—contributes proportionally to the load current. This configuration provides 0 to 200 Vdc at an output current of up to 34 Adc for two units. You can Auto-Parallel the unit with other HP autoranging power supplies.

3-62 Setting Voltage and Current. Set the slave unit's output voltages above the master's to avoid interference with master-unit CV control. Adjust the master unit's controls to set the desired output voltage and current. Verify that the slave is in CC operation.

3-63 In CV operation the output voltage is the same as the master unit's voltage setting, and the output current is two times the master unit's current if the master and slave units have the same rated current. In general, for two units or for units with different full-rated currents, the Auto-Parallel output current (Io) is

$$Io = Im[1 + j1 + j2 + \ldots + jn]$$

Im = master unit's output current
j1...n = ratio of slave unit's rated current to master unit's
n = number of slave units

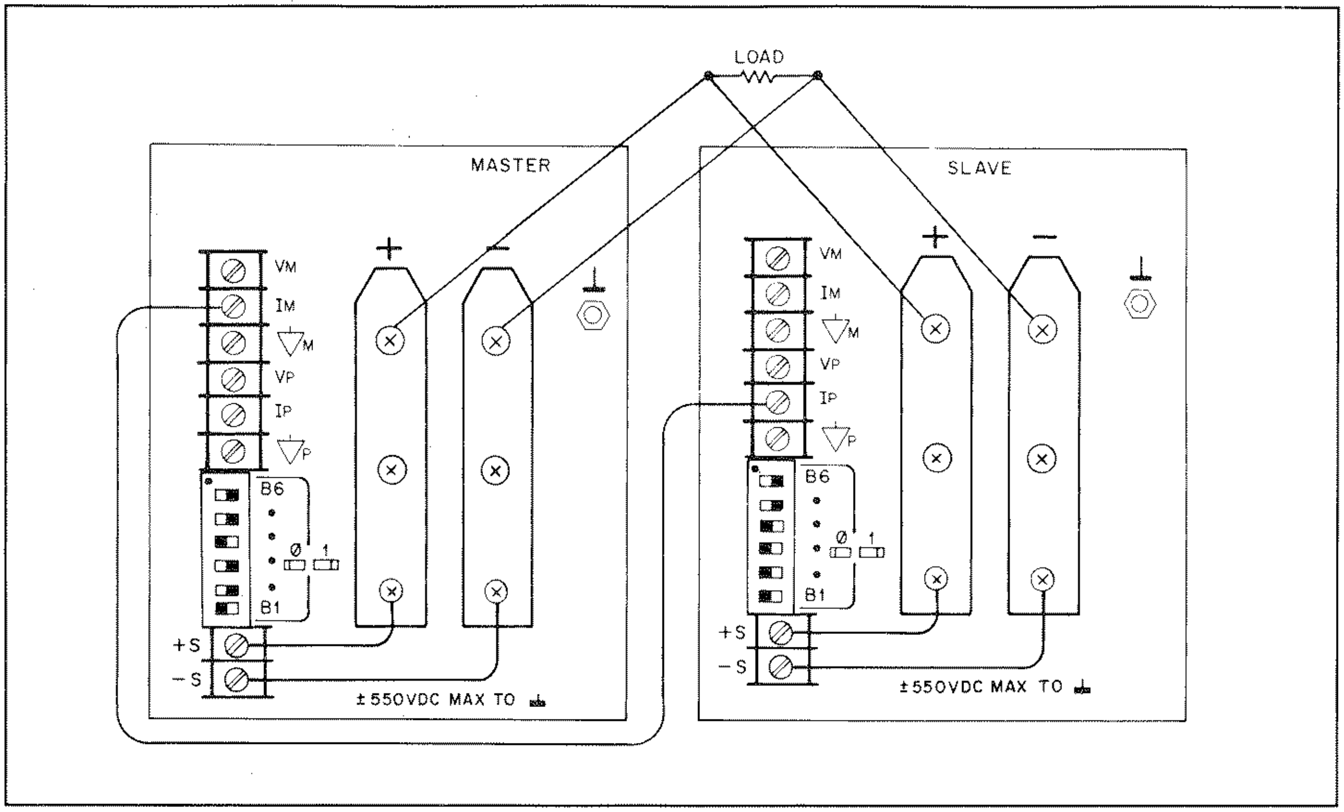


Figure 3-11. Auto-Parallel Operation

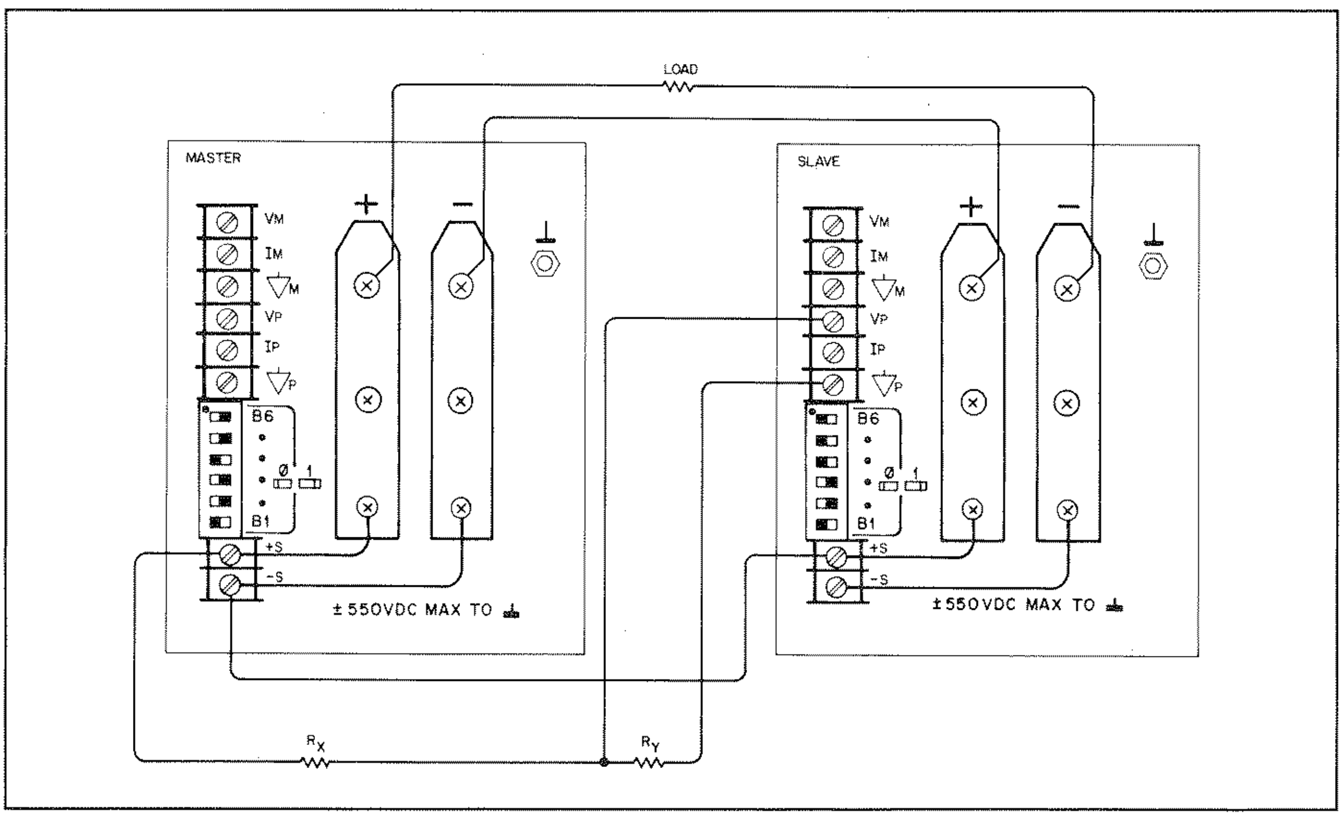


Figure 3-12. Auto-Series Operation

NOTE

Proportional currents from Auto-Paralleled units requires equal load-lead voltage drops. Connect each unit to the load using separate pairs of wire with length and gauge chosen to provide equal voltage drops from pair to pair. If this is not feasible, connect each unit to a pair of distribution terminals using equal-voltage-drop wire pairs, and then connect the distribution terminals to the load with a single pair of leads.

3-64 You may connect two units in Auto-Parallel. The output current is the sum of both units' rated output current.

3-65 Overvoltage Protection. Adjust the desired OVP shutdown limit using the master unit's OVP ADJUST control. Set the slave units' OVP limits above the master's. When a master-unit shuts down, the master programs the slave units to zero voltage output. If a slave unit shuts down (because its OVP shutdown limit is set lower than the master's), it shuts down only itself, and the other units supply all the load current plus 1 to 4 Adc of current to the shut-down slave. If the required current is great enough, the master will switch from CV to CC operation.

3-66 Remote Sensing. To remote sense with Auto-Parallel operation, connect remote-sense leads only to the master unit and according to the remote-sensing instructions given in paragraph 3-39.

3-67 Remote Programming. To remote program with Auto-Parallel operation, set up only the master unit for remote programming and follow the remote-programming instructions described earlier in this section.

NOTE

No load Down-Programming speed is slower with Auto-Parallel operation because only the master unit's Down-Programmer operates.

3-68 Auto-Series Operation

3-69 Figure 3-12 shows the rear-panel MODE switch settings and terminal connections for Auto-Series operation of two units. +OUT of the master unit connects directly to the load. This configuration provides 0 to 17 Adc of output current at an output voltage of up to 400 Vdc (1000 W max) for two units. (In general, the output voltage is up to the sum of both units' full output.)

3-70 To provide positive and negative tracking outputs, connect two units in Auto-Series, and provide separate loads as shown in Figure 3-13. Connect to ground at one point, either at the master unit's -S terminal or at a common connection between the loads. The master unit has a positive output and controls a negative output voltage from the slave unit. Ground any one output terminal as required to achieve the desired range of positive and negative outputs.

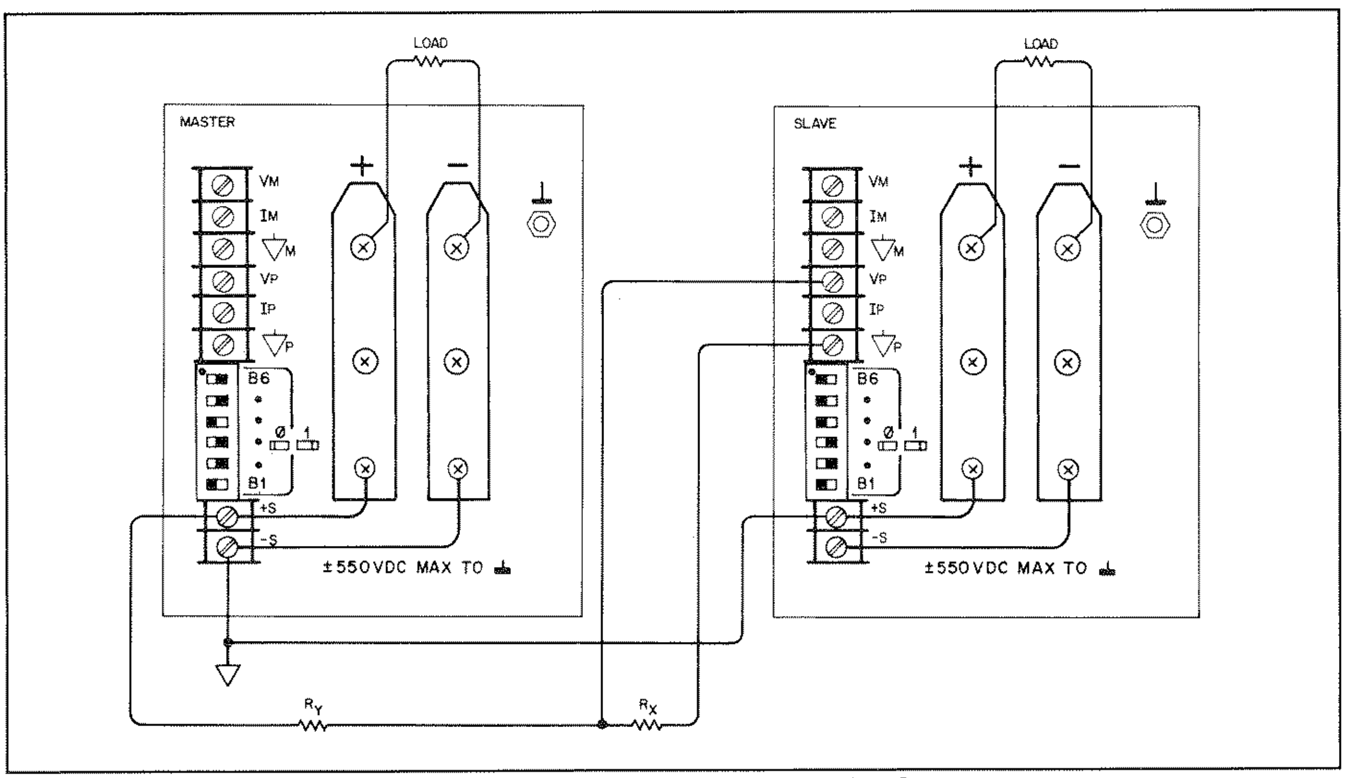


Figure 3-13. Positive and Negative Tracking Output

3-71 Connect two units in Auto-Series. No output terminal can be more than 550 volts from ground. Duplicate the connections shown in Figure 3-12 and determine values for new resistors Rx and Ry by considering the most-negative unit as the master unit for the unit to be added.

3-72 Connect the unit in Auto-Series with any slave unit designed for Auto-Series operation, or use any well-regulated supply as the master unit. The supply with the lower current rating sets the maximum current for the Auto-Series combination. Determine values of resistors Rx and Ry for slave unit as required to provide the needed remote programming voltage. The method of paragraph 3-74 assumes a 5 Vdc programming voltage produces 200 Vdc output (k=40).

3-73 Determining Resistors. Resistors Rx and Ry control the fraction (or multiple) of the master unit's voltage setting that is supplied from the slave unit. For two units in Auto-Series the ratio of Rx to Ry is

$$Rx/Ry = k(Vo/Vs) - 1$$
$$= k(Vm/Vs) + (k - 1)$$

Vo = Auto-Series voltage = Vs + Vm

Vs = slave output voltage

Vm = master output voltage

k = ratio of slave output voltage to slave program voltage

3-74 Set the value of Ry to 10 k ohms and calculate the value of Rx from either equation above. For the 6010A the constant k equals 40, so when using a 6010A as the slave unit and with Ry set to 10 k ohms the equations reduce to

$$Rx/Ry = k\,(Vm/Vs) + (k - 1)$$
where Ry = 10 k ohms; Vo = Vs = 1; k = 40
$$Rx/Ry = 40\,(1/1) + (40 - 1)$$
$$Rx/Ry = 40 + 39$$
$$Rx/Ry = 79$$
$$Rx = 79\,(Ry)$$
$$Rx = 79\,(10\text{ k ohms})$$
Rx = 790 k 1 watt

3-75 To maintain the temperature coefficient and stability performance of the units, choose low noise resistors with temperature coefficients of less than 25 ppm°C. When Ry is 10 k ohms, appropriate power ratings are ¼ W for Ry and 1 W for Rx. In general, set Ry to 10 k ohms or less and use power ratings 30-times actual to avoid degrading program speed, offset and drift performance. Lower resistance values allow faster programming but dissipate more power.

3-76 Setting Voltage and Current. Use the master unit's controls to set the desired output voltage and current. The VOLTAGE control of the slave unit is disabled. Set the CURRENT control of slave unit above the master unit's current setting to avoid having the slave switch to CC operation.

3-77 When in CC operation the output current is the same as the master unit's current setting, and when in CV operation the output voltage is the sum of the master unit's and the slave unit's output voltages. Read the output voltage by adding the voltages displayed on the master and slave units. For two 6010A's the Auto-Series output voltage (Vo) is equal to Vo = ((Vs) (Rx + Ry)/Rx)(K). If Rx is 790 k ohms and Ry is 10 k ohms, Vm and Vs are equal and the output voltage is 2 Vm.

3-78 Overvoltage Protection. Set the OVP shutdown voltage in each unit so that it shuts down at a voltage higher than its output voltage during Auto-Series operation. When a master unit shuts down, it programs the slave(s) to zero output. When a slave shuts down, it only shuts down itself (and any slaves below it in the stack). The master (and all slaves above the shut-down slave) continues to supply output voltage.

3-79 Remote Programming. To remote program with Auto-Series operation, set up only the master unit for remote programming and according to the remote-programming instructions discussed earlier in this section. To vary the fraction of the output voltage contributed by the slave unit, connect a variable resistor in place of Ry.

3-80 OUTPUT MONITORS: V-MON & I-MON

3-81 The unit provides two dc output signals at rear-panel terminals which monitor the output voltage and current. Both are referenced to the unit's monitor common. V-MON varies from 0 to 5 Vdc as the voltage between +S and −S varies from 0 to 200 Vdc. V-MON is connected + to Voltage-Monitor terminal VM and − to monitor-common terminal M. I-MON varies from 0 to 5 Vdc as the current into −OUT varies from 0 to 17 Adc. I-MON is connected + to current-monitor terminal IM and − to monitor-common ⏚M.

3-82 To monitor output voltage or current with a remote voltmeter, simply connect a dc voltmeter to V-MON and multiply the voltage reading by 12 to obtain the output voltage, or connect a dc voltmeter to I-MON and multiply the reading by 10 to obtain the output current. Use at least a 20,000 ohms per voltmeter or 1 megohm impedance electronic meter to avoid significant error caused by the monitor signals' 10.2 k ohm output impedances.

Section IV
PRINCIPLES OF OPERATION

4-1 AUTORANGING POWER

4-2 Autoranging allows the unit to be compact and light weight and yet to deliver a range of output voltage/current combinations which would otherwise require the use of more than one supply or a higher rated power supply. Autoranging is a name for circuitry which automatically makes full power available at all but low rated output voltages and currents. By comparison, a conventional constant voltage/constant current (CV/CC) power supply can provide full output power only at maximum rated output voltage and current. Refer to Operating Modes in Section III for a more detailed discussion of the autoranging characteristic.

4-3 OVERVIEW

4-4 The Simplified Schematic, Figure 4-1, shows how the major circuits are connected. Segmenting the Simplified schematic into functional circuit blocks will highlight how these blocks work and illustrate overall system function.

4-5 Table 4-1 briefly describes the major circuits employed in the design of this unit. When used in conjunction with the Simplified Schematic, the reader is provided with a quick overall appreciation of the unit's operation.

4-6 Power flows from the ac mains at the left of the schematic through circuit blocks connected by heavy lines to the output terminals at the right. Follow the schematic from right to left to see how the output voltage is regulated during CV mode of operation, The output voltage is monitored both at the output sense terminals +S and −S; OVS (Outerloop Voltage Sense) and also before the two stages of output filter IVS (InnerLoop Voltage Sense).

4-7 Sensing with output sense terminals provides accurate load-voltage control and sensing before the output filter stabilizes the supply and permits it to power reactive loads. The CV monitor amplifier buffers the OVS voltage to produce the V-MON output monitoring voltage. A buffer amplifier monitors the voltage before the output filter to produce the IVS voltage.

4-8 When in CC operation, the output current is regulated in a similar mannner. Output current is sensed as the OCS outerloop voltage across a current monitoring resistor. OCS is buffered to produce I-MON. IVS is differentiated to produce an innerloop current sensing voltage.

4-9 SYSTEM DESCRIPTION

4-10 The HP 6010A is a power supply which utilizes the principle of switching to achieve regulation. Basically, the power supply employs five major functional sub-systems together with the Front Panel to achieve its overall objective of delivering a maximum of 17 A or 200 V at the power output of 1000 W. These sub-systems are
1. Regulation & Control
2. Protection
3. Input Power
4. DC Power Conversion
5. Output

4-11 REGULATION & CONTROL SUBSYSTEM

4-12 This sub-system may be considered to be the brains of the unit. It provides the control pulses to open and close the switching elements which deliver power to the output. This section also regulates the output to ensure that the unit is delivering a constant power at either a constant voltage or constant current setting. In the event that this cannot be achieved, then the protection subsystem is employed to limit the power to the output.

4-13 To understand how this control is achieved, consider Figure 4-1, the simplified schematic. Power from the output is sampled and attenuated before it is fed-back to the Constant Voltage Error Amplifier. Another input to this amplifier is the Program Voltage which the user sets via the Front Panel. The difference between these two voltages is amplified and becomes the CV Error Signal. The output of the supply is also sampled by the CC Monitor Amp. This sample voltage is fed into the Constant Current Error Amp. The other input to the Constant Current Error Amp is the program current which the user sets via the front panel. The difference between these two voltages is amplified and becomes the Constant Current Error Signal. These two signals are connected in a wired-OR configuration and fed into the Constant Voltage Comparator.

4-14 The control mechanism which the unit employs to regulate its output comprises the Primary Current Monitor Transformer, the Control Voltage Comparator and the Pulse Width Modulator. The Primary Current Monitor Transformer senses the power transferred by the FETs and generates the Ip Ramp Voltage which continues to build up as the output increases. This Ramp Voltage and the Control Voltage are used as inputs to the CONTROL VOLTAGE COMPARATOR. If the Ramp Voltage exceeds the Control Voltage, the output of the comparator goes low and resets the Pulse Width Modulator in the process. If the unit develops power in excess of its requirements, the POWER LIMIT COMPARATOR effectively monitors this condition and returns a low signal which disables the Pulse Width Modulator and prevents any further power development.

4-15 The PULSE WIDTH MODULATOR (PWM) is the device which the unit employs to constantly alter the duty cycle of the switching waveform produced by the FETs. Once reset, it triggers the off-pulse one-shot which turns off the FETs

Table 4-1. Quick Reference Guide to Major Circuits

Circuit	Major Function	Dependent Circuits Input from	Dependent Circuits Output to	Operation
Bias Power Supply (BPS)	Provides Bias and Reference Voltage.	Mains	Control Circuits	Mains voltage at BVS input is converted to lower voltage levels to provide the internal operating voltages for the various circuits.
Bias Voltage Detector (BVD)	Delays the unit's operation at power on.	BVS	Delay Circuit, OVP	Holds all circuits reset until all internal voltages are at acceptable levels.
Timed Delay Circuit (TDC)	Enables power circuits.	BVD; DOD	PWM; Relay	Waits for 3 seconds after power on and then shuts out inrush current limiting resistor. The circuit is triggered by the BVD when the + VDC is stable.
Power Limit Comparator (PLC)	Determines maximum primary current.	BVS; Ramp	PWM	Compares $V_{IP\ RAMP}$ with V_{REF} and produces a signal to inhibit the PWM when $V_{IP\ RAMP} > V_{REF}$.
Control Voltage Comparator (CVC)	Regulates the operation of the PWM.	$V_{IP\ RAMP}$ Control Port Voltage (V_{CP})	PWM	Compares $V_{IP\ RAMP}$, and V_{CP} and produces a signal to inhibit the PWM when $V_{IP\ RAMP} > V_{CP}$.
Constant Voltage Circuit (CV)	Produces CV Control Voltage.	Outer Voltage Sense (OVS) Innerloop Voltage Sense (IVS) CV Program Voltage	CVC, Display Circuits	Monitors OVS signals from which V-MON is derived. Combines OVS and IVS to give CV Control Voltage.
Constant Current Circuit (CC)	Produces CC Control Voltage	Outer Current Sense (OCS), CC Program Voltage	CVC; Display Circuits	Monitors OCS signals from which I-MON is derived. Combines OCS and; differentiated IVS to give the CC control voltage.
Pulse Width Modulator (PWM)	Switches FETs.	Master Enable; PLC, CVC	FETs	Switching action achieved at 20 kHz rate with on-pulse activated by 20 kHz clock; and off-pulse by CVC, PLC, 20 kHz clock or shutdown circuits.
Primary Current Monitor Transformer	Generates Ip Ramp Voltage.	FETs	CVC; PLC	Senses Ip current build-up while FETs are on.
Power Transformer	Stores and transfers output power.	FETs	Output Rectifier	When FETs are on, the primary windings of the transformer store energy until the FETs are switched off when the energy is transferred to the secondary for output circuits.
A4 Q1,2,3,4	Control gating of current in power, and Sense Transformers.	PWM	Sensing Transformer	FETs open and close in response to pulses from the PWM. The length of its on/off time depends on the duration of the PWM on or off pulse.
Down Programmer (DP)	Rapidly lowers output voltage.	CV Circuit, OVP, DOD	Output Rail	Output filter capacitor are rapidly discharged at varying ampere rates depending on output voltage. Circuit activated under condition of ac power loss, shut down or low voltage.
Drop out Dectector (DOD)	Shuts down output power when line drops out for more than one cycle.	Bias Transformer	PWM; DP	If no ac pulse is detected after 20 ms, the circuit inhibits the PWM and triggers the Down Programmer.
Over Voltage Protection (OVP) Circuit	Limits maximum output voltage.	+ Out Sense	DP; PWM	Senses Output Voltage and compares with a preset limit set by its reference circuit. It triggers the Down Programmer in extreme situations.

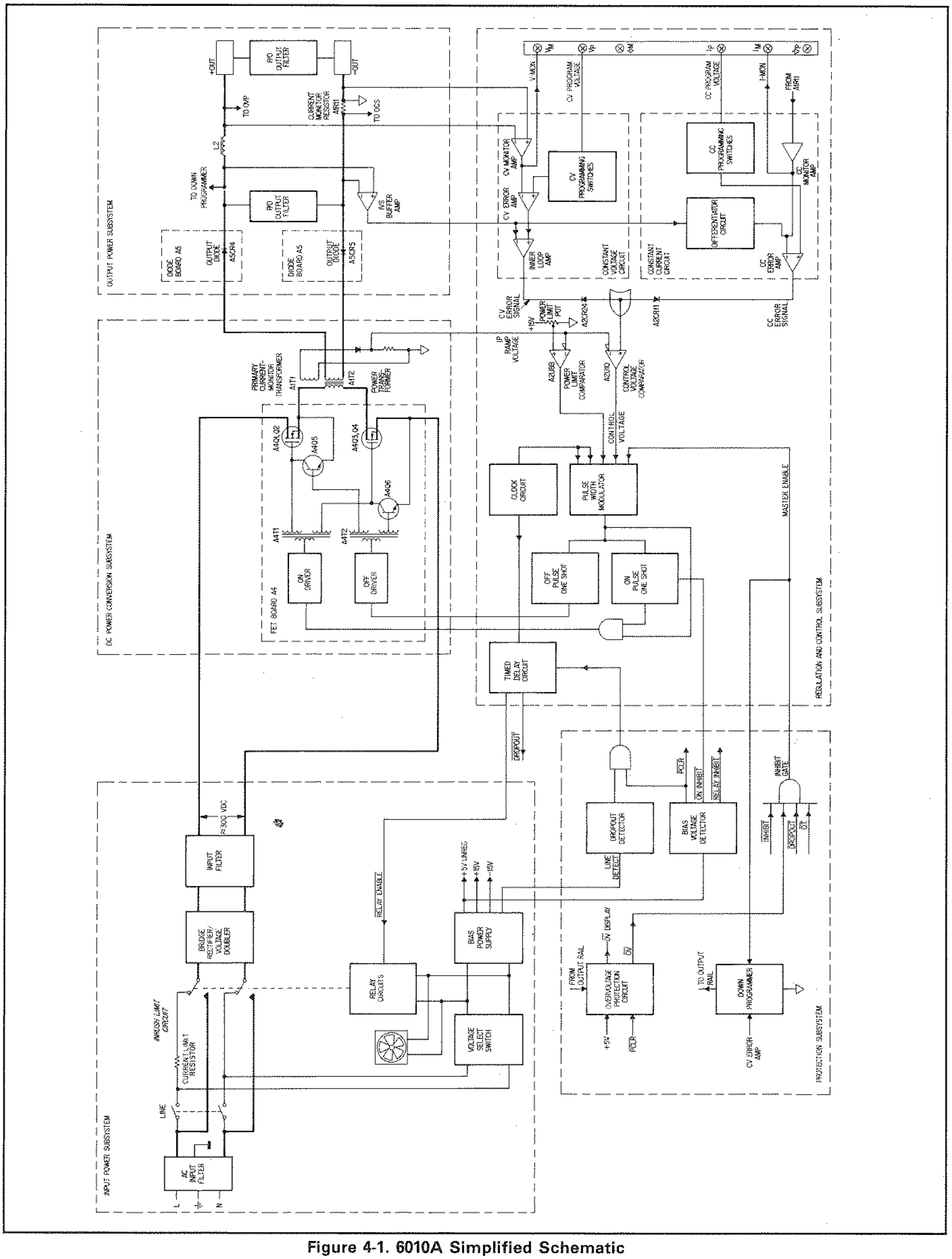


Figure 4-1. 6010A Simplified Schematic

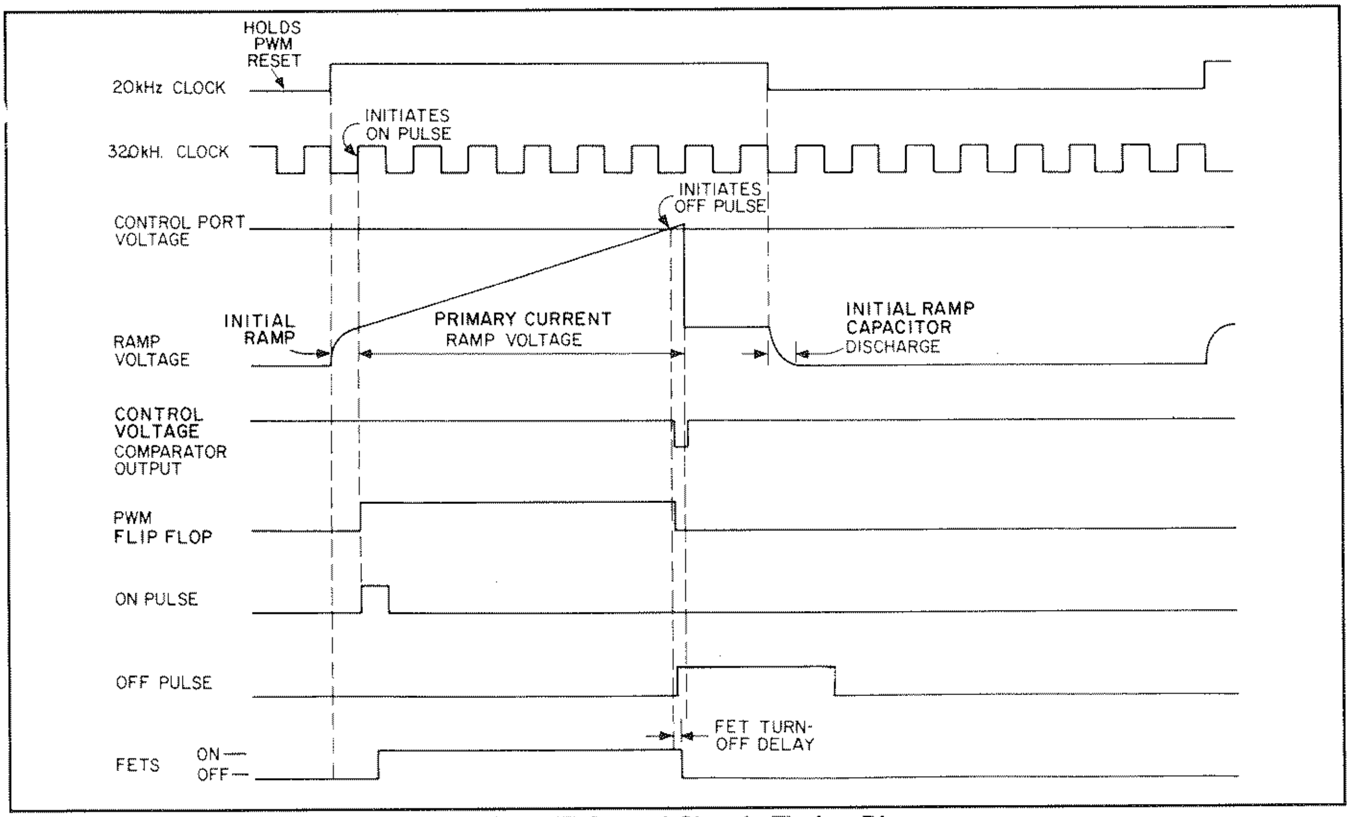


Figure 4-2. FET Control Signals Timing Diagram

via the off-pulse driver. The 20 kHz entering the PWM holds it reset for 1.5 μs and on the next clock pulse from the oscillator the output is clocked high. This in turn triggers the on-pulse one-shot which enables the FETs. Other inputs which can disable the PWM are the outputs from the Power Limit Comparator, the Master Enable, the CV and CC loop.

4-16 Figure 4-2 shows the timing diagram of the signals which control the FETs. Notice that on the rising edge of the on-pulse, the PWM is activated and remains on until the off-pulse is sent. There is a slight delay in the time the off-pulse is sent and the time the FETs are actually turned off. This turn-off delay results in greater power being generated than is required as shown by the Ramp Voltage exceeding the Control Voltage. To prevent this situation, there is an Initial Ramp Circuit which increases the Ramp Voltage and enables the voltage to ramp up to the Control Voltage level earlier.

4-17 The sampled output voltage is fed-back through the Constant Voltage Circuit and the Constant Current Circuit before it becomes the Control Voltage. The CV and CC circuits provide the means for the instrument to deliver power at either constant voltage or constant current.

4-18 The CONSTANT VOLTAGE circuit takes its input from two positions on the output voltage rail: the Innerloop Voltage Sense (IVS), and the Outerloop Voltage Sense (OVS) at the +S and −S terminals. The CV Monitor Amplifier attenuates the OVS in the ratio of 1:40 and produces the Voltage Monitor(V-MON) signal. This signal connects through protective circuitry to the rear panel and display circuits on the front panel,and also forms the input to the CV Error Amplifier. The Program Voltage which the user sets at the front panel voltage control is also an input to this amplifier. The output is the error signal which together with the output from the Innerloop Voltage Sense (IVS) generates the CV Control Voltage.

4-19 In addition to the Front Panel settings, the CV Program Voltage can be set from an external voltage applied between rear panel terminals VP and ⏚P, or from an external resistor between these same terminals.

4-20 The CONSTANT CURRENT CIRCUIT also produces a control voltage. The outerloop current sense (OCS) is taken across the current monitoring resistor and the combined signal is amplified by the CC Monitor amplifier to give the Outerloop Current-Sense Voltage, I-MON. This signal is then diverted along two paths: one terminating at the barrier strip while along the other path the signal combines with the differentiated output of the Innerloop Voltage Sense (IVS). The CC error amplifier compares this combined output with the user-set CC Program Voltage to produce the CC Control Voltage.

4-21 The Control Voltage used to regulate the unit may be derived from either the CV or CC circuit. These circuits are connected via a wired-OR connection to the CV or CC circuit. If the CV Control Voltage exceeds the CC Control Voltage then diode A2CR24 is reversed biased but diode A2CR11 is forward biased and the CC Circuit provides the controlling signal. Similarly when CC Control Voltage exceeds CV Control Voltage, the CV circuit provides the regulating control voltage.

4-22 When the unit is operating in CV mode, the CV Control Voltage varies between −0.5 Vdc and −0.5 Vdc. It is most negative when the load is drawing no power but as power output increases the voltage becomes more positive.

4-23 PROTECTION SUBSYSTEM

4-24 The diverse system configurations and operating environments under which the unit will be required to operate, will certainly require it to be adequately protected if it must function reliably. The protection circuits of the unit offer protection at turn-on and also during operation.

4-25 The CURRENT LIMIT RESISTORS is the first protection along the power rail which the unit utilizes. This circuit prevents any surges of AC input to the input filter by limiting the inrush current. After a predetermined elapsed time the resistor is bypassed and the unit is ready to deliver power. The circuit which carries out this function is the TIMED DELAY CIRCUIT. When both the Dropout Detector and the PCLR are high, this delay circuit is enabled and counting at the clock frequency of 1.25 kHz begins. After 3 seconds, DROPOUT goes high and enables the PWM.

4-26 Turn-On protection is also offered by the BIAS VOLTAGE DETECTOR (BVD) which prevents spurious operation that may occur at power on of the unit if circuits attempt to operate before the +5 Vdc bias voltage is at the clock,PWM,and logic circuits. After power-on, as the output of the +5 Vdc bias power supply rises the BVD is turned on inhibiting the Relay Driver and the On-Pulse Driver and creating the power clear signal PCLR . The latter signal is held low until the unregulated input to the +5 Vdc bias supply is greater than an input voltage sufficient to assure a +5 Vdc output

4-27 Certain circuits also give the unit on-going protection during its operation The AC SURGE AND DROPOUT DETECTOR is such a circuit. This circuit protects the unit from damage from AC mains voltage surges. It shuts down the unit when there is either a 40% overvoltage or a 20 ms voltage interruption in the ac mains voltage. The mains detect signal senses the ac mains voltage and pulls the DROPOUT signal low thereby inhibiting the PWM and shutting off the power.

4-28 During conditions of overvoltage when a monitored fraction of the output voltage exceeds the limit set by the front panel OVP Adjust, the OVER VOLTAGE PROTECTION circuit inhibits the the PWM and triggers the Down Programmer. This condition persists until the unit is turned off. At power-on, the Bias Voltage Detector resets the OVP.

4-29 The DOWN PROGRAMMER is another protection circuit which is activated when any of the following adverse operating conditions occurs: over voltage; over temperature; primary power failure; and programming of a lower output voltage. Under these conditions, the Down Programmer lowers the output voltage by rapidly discharging the output filter capacitors. The Down Programmer takes its input from the Master Enable and the CV Error Amplifier. When either of these signals is low, it is activated. The +8.9 Vdc bias supply provide enough energy to the Down Programmer to discharge the output circuit even when primary power is lost.

4-30 The TEMPERATURE PROTECTION circuit protects the FETs from excessive temperature gradients. A thermostat mounted on the FET heat sink monitors the temperature build up of the FETs and disables the PWM when the temperature exceeds a predetermined limit.

4-31 In addition to an over-temperature protection, there is also an OVERVOLTAGE PROTECTION circuit. When the FETs turn off, the leakage inductance of the power transformer forces current to continue to flow in the primary. Clamp diodes are employed to protect the FETs from excessive reverse voltage by bypassing the FETs and conducting the current to the input filter.

4-32 INPUT POWER SUBSYSTEM

4-33 This subsystem forms the interface between the ac mains supply and the switching elements of the unit. It takes ac power from the mains, converts it to dc and delivers this unregulated dc to the switching elements and internal control circuitry. Input power takes two distinct pathways to carry out the above function: mains -rectifier/filter—switching elements and mains—bias supply—control circuits.

4-34 If the first pathway is taken, it is seen that primary power from the ac mains enters the INPUT RECTIFIER via the inrush current limiting resistor. The rectifier converts the ac voltage to dc voltage and passes its output to the input filter. The unit has a feature which allows it to operate either at 110/120 or 220/240 Vac mains voltage. The voltage doubling capability as it is called is effected by connecting jumper A1W1 between the rectifier and filter. When the mains voltage is 220/240 Vac, the jumper is open permitting the filter to develop a typical bus voltage of about 300 Vdc. However, when the mains voltage is 110/120 Vac, the jumper terminals are connected and the rectifier/filter combination now behaves as a voltage doubler enabling a bus voltage of 300 Vdc to be developed.

4-35 For the second pathway, primary power passes the Mains Voltage Select Switches to the BIAS POWER SUPPLIES which provide the operating voltages for the internal circuits. The Mains Voltage Select Switches connect the primary windings of the Bias-Supplies' transformer for operation at 120, 220, or 240 Vdc.

4-36 The unit checks that the +5 Vdc bias voltage and the ac mains voltage are within acceptable limits as part of its turn-on sequence.

4-37 DC POWER CONVERSION SUBSYSTEM

4-38 The current available at the input rails after rectification enters the power transformer A1T2 and Primary Current Monitor Transformer A1T1. This current flow is controlled by the FETs which act as high frequency switches. The FETs driver circuits are under the control of the Pulse Width Modulator where the On/Off pulses originate.

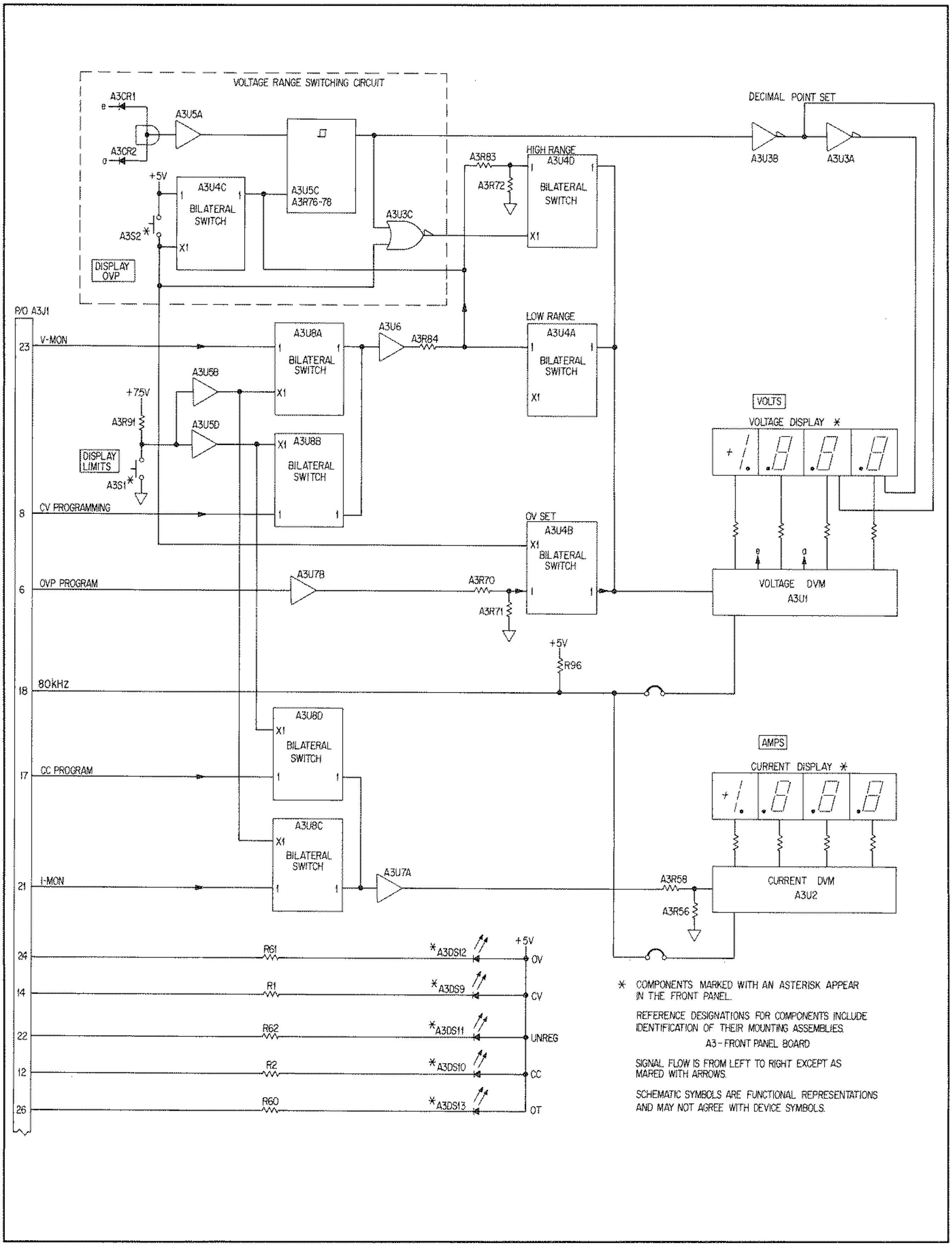


Figure 4-3. 6010A Simplified Front-Panel Schematic

4-39 During the on-pulse the FETs are turned on and current enters the primaries of transformers A1T1 and A1T2 as described above. The output rectifiers A5CR4 and A5CR5 being reversed biased block the flow of current from the secondary of A1T2 to the output. There is therefore a current build up and the secondary windings of A1T2 act as a storage device. Meanwhile the current in the secondary of current transformer A1T1 develops a linearly increasing voltage waveform across resistors A2R116 and A2R117. This waveform is the Ip Ramp Voltage and corresponds to the energy build up in the secondary of the power transformer.

4-40 When the FETs are turned off, the collapsing magnetic field reverses the polarity across the power transformer causing the output rectifiers to be forward biased. Current therefore flows from the secondary windings to the output filters.

4-41 OUTPUT SUBSYSTEM

4-42 As discussed above, power reaches the output rail when the FETs are turned off and the output diodes are forward biased. The signal is first passed through the first stage of the output filter network where most of its 20 kHz ripple derived from the switching FETs are attenuated. Part of the signal leaving the first stage filter is fed back to the CV and CC Circuits as the Innerloop Voltage Sense and becomes part of the inner control loop. The primary purpose of these feed-back loops is to impart sufficient stability to the power supply and enable it to cope with a variety of loads.

4-43 The signal from the first stage filter also becomes the input to the second stage capacitor filter which provides the additional filtering necessary for the unit to meet its specifications. This filter is close to +S and −S output terminals thereby ensuring that the filter is as close to the user's load as possible. The output from the +S and −S terminals is also fed back to the CV and CC Circuits and forms part of the outer feedback loop.

4-44 THE FRONT PANEL BOARD

4-45 Figure 4-3 is a simplified schematic of the front panel board. The V-MON, I-MON, and OVP signals are passed to the front panel board from the A2 Control Board. The V-MON and I-MON signals are then amplified by buffer amplifiers before they are directed to their respective digital voltmeters for display. As an intermediate step before display, the V-MON signal passes through a pair of bilateral range switches A3U4 & U4D which determine the resolution of the voltage display. When the voltage to be displayed is below a certain value, the unit selects the low-range bilateral switch A3U4 which enables the voltage to be displayed to an accuracy of two decimal places; however above this critical output voltage value, the high-range switch A3U4D assumes control and the voltage displayed is accurate to one decimal place.

4-46 In addition to providing the display voltage, the V-MON and I-MON signals are used to generate the CV and CC control voltages respectively. When the CV control voltage is found to be more negative than the Control Port Voltage, the power supply is operating in the CV Mode and the CV LED lights. Similarly the CC LED lights when the CC Control Voltage is below the Control Port Voltage confirming that the power supply is operating in CC Mode. When both CV and CC Control Voltages exceed the Control Port Voltage, the power supply becomes unregulated and the unregulated LED lights.

4-47 The CV of CC Program voltages are obtained by depressing the "DISPLAY SETTINGS" switch and reading the respective display. By depressing this switch and turning the Voltage or Current control,the technician can set the program voltage or current. If the instrument is operating in CV Mode for example, then the display voltage and the CV Program Voltage are identical but the display current may vary with the CC Program Voltage. This condition is reversed when the unit is under CC Mode.

4-48 The OVP set potentiometer is also located on the front panel. By depressing the "OVP DISPLAY" switch and adjusting the pot with a small flat screw-driver, the OVP limit can be set. When the output voltage exceeds this pre-set limit, the unit is disabled and the OVP LED lights.

SECTION V
MAINTENANCE

5-1 INTRODUCTION

5-2 This section provides test and calibration procedures, and troubleshooting and repair information. The operation-verification tests comprise a short procedure to verify that the unit is performing properly, without testing all specified parameters.

5-3 After troubleshooting and repair of a defective power supply you can usually verify proper operation with the functional test procedure in Section III. Repairs to the A1 main board, and the A2 control board can involve circuits which, although functional, may prevent the unit from performing within specified limits. So, after A1 or A2 board repair, decide if recalibration and operation verification tests are needed according to the faults you discover. Use the calibration procedure both to check repairs and for regular maintenance.

5-4 TEST EQUIPMENT REQUIRED

5-5 Table 5-1 lists the equipment required to perform the tests and adjustments of this section. You can separately identify the equipment for performance tests, calibration, and troubleshooting in the USE column of the table.

5-6 OPERATION VERIFICATION TESTS

5-7 The following tests determine that the unit is performing properly to within a confidence level of approximately 90%. They do not, however, check all the specified parameters tested in the complete Performance Test described below. Proceed as follows:

a. Perform turn-on checkout procedure given in paragraph 3-5.
b. Perform the CV & CC Load Effect Performance Tests, given in paragraphs 5-17 and 5-26 respectively.

5-8 PERFORMANCE TESTS

5-9 The following paragraphs provide test procedures for verifying the unit's compliance with the specifications of Table 1-1. Please refer to CALIBRATION PROCEDURE or TROUBLESHOOTING if you observe any out-of-specification performance.

5-10 Measurement Techniques

5-11 Setup For All Tests. Measure the DC output voltage directly at the +S and −S terminals. Connect unit for local sensing, and ensure that MODE switches are set as shown in Figure 3-2. Select an adequate wire gauge for load leads using the procedures given in paragraph 3-7 for connecting the load.

5-12 Electronic Load. The test and calibration procedures use an electronic load to test the unit quickly and accurately. If an electronic load is not available, you may substitute a 3.5 Ω load resistor, capable of safely dissipating > 1000 watts, for the electronic load in these tests:

CV Source Effect (Line Regulation)
CC Load Effect (Load Regulation)

You may substitute a 40 Ω, 1000 W or more, load resistor in these tests:

CV Load Effect (Load Regulation)
CV PARD (Ripple and Noise)
CC Source Effect (Line Regulation)
CC PARD (Ripple and Noise)

The substitution of the load resistor requires adding a load switch to open and short the load in the CC or CV load regulation tests. The load transient recovery time test procedure cannot be performed using load resistors.

5-13 An electronic load is considerably easier to use than a load resistor. It eliminates the need for connecting resistors or rheostats in parallel to handle the power, it is much more stable than a carbon-pile load, and it makes easy work of switching between load conditions as is required for the load regulation and load transient-response tests.

5-14 Current-Monitoring Resistor Rm. To eliminate output-current measurement error caused by voltage drops in the leads and connections, connect the current-monitoring resistor between −OUT and the load as a four-terminal device. Figure 5-1 shows correct connections. Select a resistor with stable characteristics: 0.010, 0.02% accuracy, 30 ppm/°C or lower temperature coefficient and a current rating of 17 A.

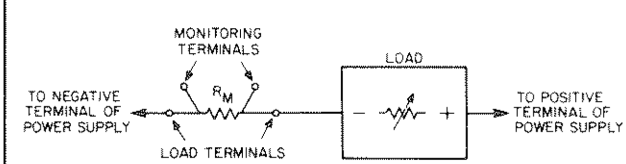


Figure 5-1. Current Monitoring Resistor Connections

Table 5-1. Test Equipment Required

TYPE	REQUIRED CHARACTERISTICS	USE	RECOMMENDED MODEL
Oscilloscope	Sensitivity: 1 mV Bandwidth: 20 MHz & 100 Mhz Input: differential, 50 Ω & 10 MΩ	P,T	HP1740A
Isolation Transformers	100 VA, 4 kVA	T	
RMS Voltmeter	True rms, 10 MHz bandwidth Sensitivity: 1 mV Accuracy: 5%	P	HP3400A
Logic pulser	4.5 to 5.5Vdc @ 35 mA	T	HP546A
Multimeter	Resolution: 100 nV Accuracy: 0.0035%, 6½ digit	P,A,T	HP3456A
CC PARD Test Current Probe	No saturation at 20 Adc Bandwidth: 20 Hz to 20 MHz	P	Tektronix P6303 Probe/AM503 Amp/ TM500 Power Module
Electronic Load*	Voltage range: 200 Vdc Current range: 20 Adc Power range: 1000 watts Open and short switches	P,A	Transistor Devices, Model DLP 130-50-2500 DLR-400-15-2500
CC PARD Test Resistive Load	Value: 0.4 ohms >1000 W Accuracy: 1% Rheostat or Resistor Bank	P,A	
Current-Monitoring Resistors	Value: 100 mV @ 10 A (10 mΩ must be capable of 20 Amps) Accuracy: 0.02% ** TC: 10 ppm/°C	P,A	
Calibration and Test Resistors	Value: 50 Ω, 5%, 40 W 2 kΩ, 0.01%, ¼ W	A,T	
Terminating Resistors (4)	Value: 50 Ω ±5%, noninductive	P	
Blocking Capacitors (2)	Value: 0.01 μF, 400 Vdc	P	
Common-mode Toroidal Core	$\geq 3.7\mu H/turn^2$ ≈23mm I.D.	P	Ferrox-Cube 500T600-3C8, HP 9170-0061
DC Power Supply	Voltage range: 0-60 Vdc Current range: 0–50 Adc	T,P	HP6012B
Variable Voltage Auto transformer	Range greater than −13% to +6% of nominal input AC Voltage 4 k VA	P,A	

P = performance testing A = calibration adjustments T = troubleshooting

*3.5Ω, 3.8Ω, 38Ω, and 40Ω resistors may be substituted for test where an electronic load is not available

**Less accurate, and less expensive, current-monitoring resistors can be used, but the accuracy to which current programming and current meter reading can be checked must be reduced accordingly.

5-15 Constant Voltage (CV) Tests

5-16 CV Setup. If more than one meter or a meter and an oscilloscope are used, connect each to the +S and −S terminals by a separate pair of leads to avoid mutual coupling effects. Connect only to +S and −S (except for peak-to-peak PARD) because the unit regulates the output voltage between +S and −S, not between +OUT and -OUT. Use coaxial cable or shielded 2-wire cable to avoid pickup on test leads. For all CV tests set the output current at full rated output to assure CV operation.

5-17 Load Effect (Load Regulation)

Definition: CV Load Effect is the change in dc output voltage when load resistance changes from open circuit to full load or from full load to open circuit.

Test Parameters: Measured Variable: Output Voltage

Test Points: See Figure 5-2

Expected Results: Recorded readings must be within 0.011 Vdc

Test Procedure:

a. Connect the test equipment as shown in Figure 5-2. Operate the electronic load in constant resistance mode (Amps/Volt) and set resistance to maximum.
b. Turn the unit's power on, and turn up current setting to full output.
c. Turn up output voltage to 60 Vdc as read on the digital voltmeter.

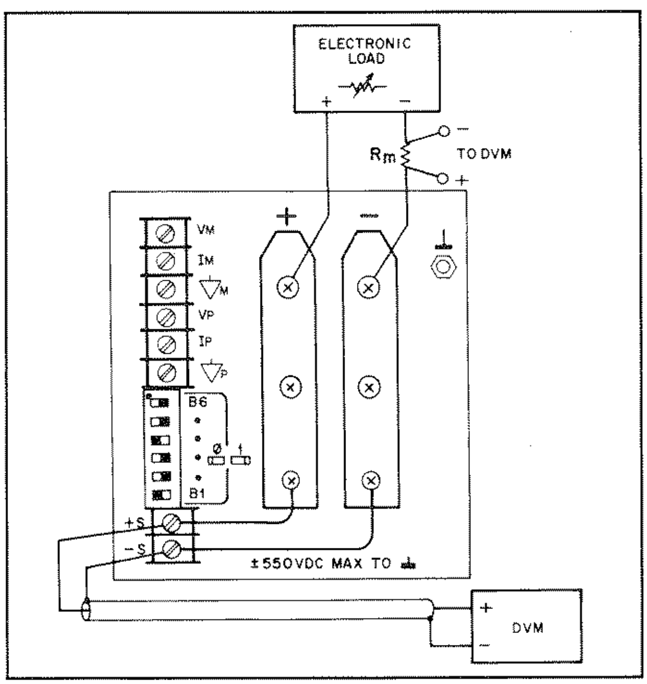


Figure 5-2. Basic Test Setup

d. Reduce the resistance of the load to draw an output current of 17 Adc (0.170 Vdc across Rm). Check that the unit's CV LED remains lighted.
e. Record the output voltage at the digital voltmeter.
f. Open circuit the load.
g. When the reading settles, record the output voltage again. Check that the two recorded readings differ no more than ±0.011 Vdc.

5-18 Source Effect (Line Regulation)

Definition: Source effect is the change in dc output voltage when the ac input voltage changes from a minimum to a maximum value.

Test Parameters: Measured variable: Output Voltage

Test Points: See Figure 5-2

Expected Results: Recorded readings must be within a ±0.011 Vdc range

Test Procedure:

a. Connect the test equipment as shown in Figure 5-2. Operate the electronic load in constant resistance mode (Amps/Volt) and set resistance to maximum.
b. Connect the unit to the ac power line through a variable autotransformer which is set for low line voltage (104 Vac for 120 Vac).
c. Turn the unit's power on, and turn up current setting to full output.
d. Turn up output voltage to 60 Vdc as read on the digital voltmeter.
e. Reduce the resistance of the load to draw an output current of 17 Adc (0.170 Vdc across Rm). Check that the unit's CV LED remains lighted.
f. Record the output voltage at the digital voltmeter.
g. Adjust autotransformer to the maximum for your line voltage.
h. When the reading settles record the output voltage again. Check that the two recorded readings differ no more than ±0.011 Vdc.

5-19 PARD (Ripple & Noise)

Definition: Periodic and random deviations (PARD) in the unit's output ripple and noise combine to produce a residual ac voltage superimposed on the dc output voltage. Constant voltage PARD is specified as the root-mean-square (rms) or peak-to-peak (pp) output voltage in a frequency range of 20 Hz to 20 MHz.

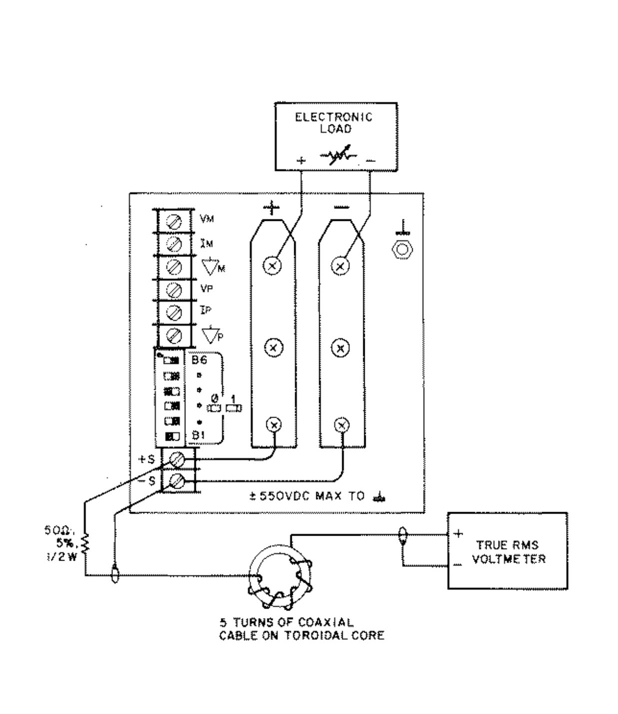


Figure 5-3. RMS Measurement Test Setup, CV PARD

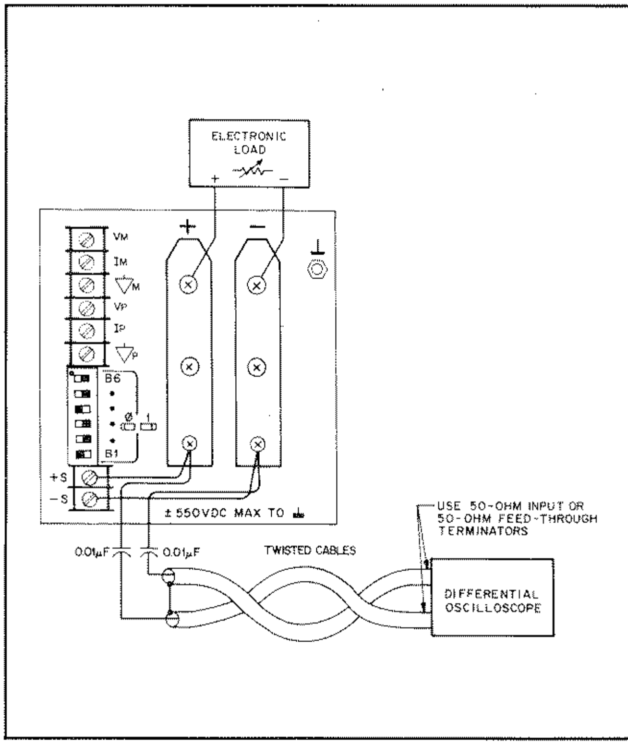


Figure 5-4. Peak-to-Peak Measurement Test Setup, CV PARD Test

PARD RMS Measurement:

Test Parameters: Measured Variable: Output Voltage (rms)

Test Points: See Figure 5-3

Expected Results: Noise Voltage (rms) < 22 mV rms

Test Procedure:

a. Connect the test equipment as shown in Figure 5-3. Operate the electronic load in constant resistance mode (Amps/Volt) and set resistance to maximum.
b. Turn the unit's power on and turn up current setting to full output.
c. Turn up output voltage to 60 Vdc.
d. Reduce the resistance of the load to draw an output current of 17 Adc. Check that the unit's CV LED remains lighted.
e. Check that the rms noise voltage at the true rms voltmeter is no more than 22 mV rms.

NOTE

To ensure that no potential difference exists between the voltmeter and the case of the unit, either connect both to the same ac power outlet or check that the ac outlets have the same earth ground.

Use common mode choke as in Figure 5-3 to reduce ground loop currents from interfering with measurement. Reduce noise pickup on the test leads by using 50 Ω coaxial cable, and wind it 5 turns through the magnetic core to form the common-mode choke.

5-20 PARD (Peak-to-Peak) Measurement:

Test Parameters: Measured Variable: Output Voltage Peak-to-Peak

Test Points: See Figure 5-4

Expected Results: Peak-to-Peak noise voltage < 50 mV

Test Procedure:

a. Connect the test equipment as shown in Figure 5-4. Operate the electronic load in constant resistance mode (Amps/Volt) and set resistance to maximum.
b. Turn the unit's power on and turn up current setting to full output.
c. Turn up output voltage to 60 Vdc.
d. Reduce the resistance of the load to draw an output current of 17 Adc. Check that the unit's CV LED remains lighted.
e. Set the oscilloscope's input impedance to 50 Ω and bandwidth to 20 MHz. Adjust the

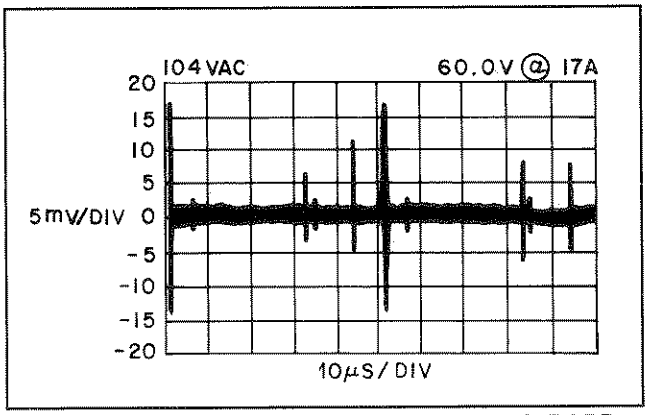


Figure 5-5. 20 kHz Noise, CV Peak-to-Peak PARD

controls to show the 20 kHz and higher frequency output-noise waveform of Figure 5-5.

f. Check that the peak-to-peak noise is no more than 50 mV.

NOTE

The equipment grounding and power connection remain the same as in the PARD rms test.

Connect the oscilloscope to the + OUT and − OUT terminals through 0.01 µF blocking capacitor to protect the oscilloscope's input from the unit's output voltage.

To reduce common-mode noise pick-up, set up the oscilloscope for a differential, two-channel voltage measurement.

To reduce normal mode pick-up, use twisted, 1 metre or shorter 50 ohm coaxial cable with shields connected to the oscilloscope case and to each other at the other ends.

5-21 Load Transient Recovery Time

Definition: This is the time for the output voltage to return to within a specified band around its voltage following a step change in load.

Test Parameters:

Measured Variable: Output Voltage Transients

Test Set-up: See Figure 5-2

Expected Results: Pulse width < 2 ms (at 150 mV from base line)

Test Procedure:

a. Connect the test equipment as shown in Figure 5-2. Operate the electronic load in constant-current mode and set for minimum current.

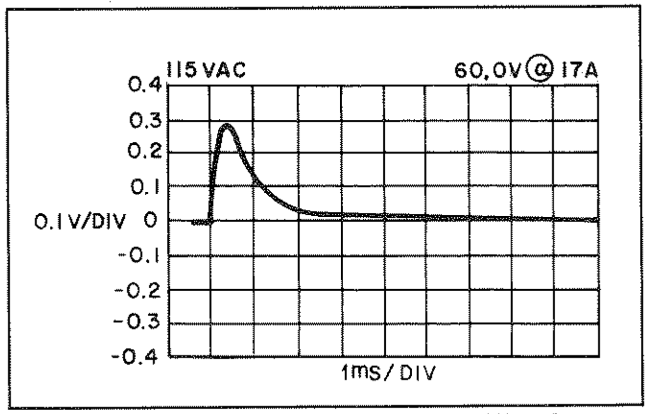


Figure 5-6. Load Transient Recovery Waveform

b. Turn the unit's power on and turn up current setting to full output.

c. Turn up output voltage to 60 Vdc as read on the digital voltmeter.

d. Set the load to vary the load current between 15 Adc and 17 Adc at a 30 Hz rate.

e. Set the oscilloscope for ac coupling, internal sync and lock on either the positive or negative load transient.

f. Adjust the oscilloscope to display transients as in Figure 5-6.

g. Check that the pulse width of the transients at 150 mV from the base line is no more than 2 ms as shown.

NOTE

While performming this test, it is important to adhere to the requirements that the change in current must be no greater than 10% of the set current, and that the total current must be no more than the rated current at the set voltage.

5-22 Temperature Coefficient

Definition: Temperature coefficient (TC) is the change in output voltage for each °C change in ambient temperature with constant ac line voltage, constant output voltage setting and constant load resistance.

Test Parameters:

Measured Variable(s): Output Voltage

Test Points: +S and −S

Expected Results: Output Voltage change < 620 mV

Test Procedure:

a. Connect DVM between +S and −S.

b. Place power supply in oven, and set temperature to 30°C.

c. Turn the unit's power on and turn up current setting to full output.
d. Turn up output voltage to 200 Vdc as read on the DVM
e. After 30 minutes stabilization record the temperature to the nearest 0.1 °C. Record the output voltage at the DVM.
f. Set oven temperature to 50 °C.
g. After 30 minutes stabilization, record the temperature to the nearest 0.1 °C. Record output voltage.
h. Check that the magnitude of the output-voltage change is no greater than 620 mV.

NOTE

Measure temperature coefficient by placing the unit in an oven, varying the temperature over a range within the unit's operating temperature range, and measuring the change in output voltage. Use a large, forced air oven for even temperature distribution. Leave the unit at each temperature measurement for half hour to ensure stability in the measured variable. Measure the output voltage with a stable DVM located outside the oven so voltmeter drift does not affect the measurement accuracy. To measure offset TC, repeat the procedure with output voltage set to 0.10 Vdc.

5-23 Drift (Stability)

Definition: Drift is the change in output voltage beginning after a 30-minute warm-up during 8 hours operation with constant ac input line voltage, constant load resistance and constant ambient temperature.

Test Parameters: Measured Variable: Output Voltage

Test Points: +S and −S

Expected Results: Output Voltage ±75 mV from reading taken after 30-minute warm-up

Test Procedure:

a. Connect DVM between +S and −S.
b. Turn the unit's power on and turn up current setting to full output.
c. Turn up output voltage to 200 Vdc as read on the digital voltmeter.
d. After a 30-minute warmup, note reading on DVM.
e. The output voltage should not deviate more than 77 mV from the reading obtained in step d over a period of 8 hours.

NOTE

Use a DVM and record the output at intervals, or use a strip-chart recorder to provide a continuous record. Check that the DVM's or recorder's specified drift during the 8 hours will be no more than 0.001%. Place the unit in a location with constant air temperature preferably a large forced-air oven set to 30°C and verify that the ambient temperature does not change by monitoring with a thermometer near the unit. Typically the drift during 30-minute warm-up exceeds the drift during the 8-hour test. To measure offset drift, repeat the procedure with output voltage set to 0.10 Vdc.

5-24 Constant Current (CC) Tests

5-25 CC Setup. Constant-current tests are analogous to constant-voltage tests, with the voltage set to full output to assure CC operation. Follow the general setup instructions of paragraphs 5-9 through 5-14.

5-26 Load Effect (Load Regulation)

Definition: CC Load Effect is the change in dc output current when load resistance changes from short circuit to full load or from full load to short circuit.

Test Parameters: Measured Variable: Output Current

Test Points: See Figure 5-2

Expected Results: Recorded readings must be within ±0.105 mVdc range

Test Procedure:

a. Connect the test equipment as shown in Figure 5-2. Operate the electronic load in constant resistance mode (Amps/Volt) and set resistance to minimum.
b. Turn the unit's power on and turn up voltage setting to full output.
c. Turn up output current to 5 Adc(0.050 Vdc across Rm). Check that the AMPS display reads about 5 amps.
d. Increase the load resistance until the output voltage at +S and −S increases to 200 Vdc. Check that the CC LED is lighted and AMPS display reads ~5 A.
e. Record voltage across Rm.
f. Short circuit the load.
g. When the reading settles, record the voltage across Rm again. Check that the two recorded readings differ no more than ±0.105 mVdc.
h. Disconnect the short across the load.

5-27 Source Effect (Line Regulation)

Definition: Source effect is the change in dc output current when the ac input voltage changes from the minimum to the maximum value as listed in the Specifications Table.

Test Parameters: Measured Variable: Output Current

Test Points: See Figure 5-2

Expected Results: Recorded readings must be within a ±0.067 mVdc range.

Test Procedure:

a. Connect the test equipment as shown in Figure 5-2. Operate the load in constant resistance mode (Amps/Volt) and set resistance to minimum.
b. Connect the unit to the ac power line through a variable autotransformer set for low line voltage (eg. 104 Vac for 120 Vac)
c. Turn the unit's power on and turn up output voltage setting to full output.
d. Turn up output current to 17 Adc (0.170 Vdc across Rm). Check that the AMPS display reads 17 A.
e. Increase the load resistance until the output voltage between +S and −S increases to 60.0 Vdc. Check that the CC LED is on and the AMPS display still reads 17 A.
f. Record the output voltage across Rm.
g. Adjust autotransformer to the maximum for your line voltage.
h. When the reading settles record the voltage across Rm again. Check that the two recorded readings differ no more than ±0.067 m Vdc.

5-28 PARD (Ripple & Noise)

Definition: Periodic and random deviations (PARD) in the unit's output ripple and noise combine to produce a residual ac current as well as an ac voltage superimposed on the dc output. The ac voltage is measured as CV (PARD) paragraph 5-20. Constant current PARD is specified as the root-mean-square (rms) output current in a frequency range of 20 Hz to 10 MHz with the unit in CC operation.

Test Parameters: Measured Variable: Output Current (rms)

Test Points: See Figure 5-7

Expected Results: Noise Current (rms) <15 mA rms

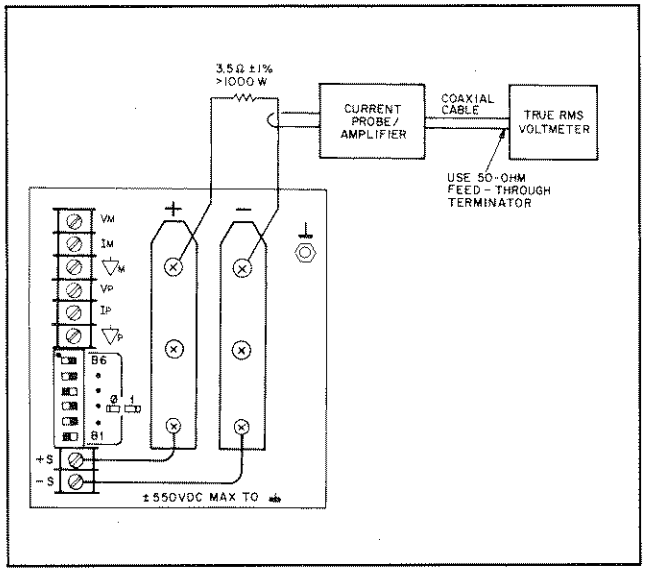


Figure 5-7. CC PARD Test Setup

NOTE

To avoid incorrect measurements caused by the impedance of the electronic load at noise frequencies,use a 0.4 Ω load resistor that is capable of safely dissipating 1000 watts.

Test Procedure:

a. Connect the test equipment as shown in Figure 5-7.
b. Turn the unit's power on and turn the output voltage all the way up.
c. Turn up output current to 17 Adc. Check that the CC LED remains lighted.
d. Check that the rms noise current measured by the current probe and rms voltmeter is no more than 15 mA rms.

5-29 CALIBRATION PROCEDURE

5-30 Calibrate the unit twice per year and when required during repair. The calibration procedures which follow should be performed in the sequence given. Table 5-2 describes in detail these calibration procedures and lists the expected results to which each adjustment must be made. Some of the calibration procedures for this instrument can be performed independently and some must be performed together and/or in the prescribed order. If a procedure makes no cross-references to other procedures then it can be assumed that procedure can be independently calibrated.

5-31 To return a serviced unit to specifications as quickly as possible with minimal calibration, the technician need only perform calibration procedures that affect the repaired circuit. Table 5-3 lists various power supply circuits with calibration procedures that should be performed after those circuits are serviced. Circuits are identifed by schematic designators; either

Table 5-2. Calibration Procedure

TEST	TESTED VARIABLE	TEST POINTS	TEST SEQUENCE AND ADJUSTMENTS	EXPECTED RESULTS
Meter F/S Adjust.	Meter Ref. Voltage	A2J3 pin 7 (+) A2J3 pin 10(−)	a. Connect DVM across test points and turn on ac power. b. Adjust A2R24 to obtain the voltage range specified in the results.	0.5 V ± 50μV
Resistance Programming F/S Adjust.	Prog. Voltage	VP(+) ⏚P(−)	a. Connect a 2 kΩ 0.01%, ¼ W programming resistor and DVM between test points. b. Set MODE switch as in Figure 3-8 and turn on ac power. c. Adjust A2R23 to obtain the voltage range specified in the results.	2.5 V ±4 mV
V-MON Zero Adjust.	V-MON	VM(+) ⏚M(−)	a. Set voltage and current controls to minimum settings. b. Disable power supply as in paragraph 5-32(k) c. Short circuit output terminals and connect the DVM between test points. Turn on power supply. d. Adjust V-MON Zero trim pot A2R22 to voltage range specified in the results.	0 ± 80μV
Common Mode Adjust.	Residual Output Voltage VM(+)	VM (+) ⏚M(−)	a. Set voltage and current controls to minimum and short the unit's sense terminals (+S & −S) b. Attach the DVM across test points and disable power supply as in paragraph 5-32 (k) c. Turn on ac power and record the initial voltage (IR) with DVM across test points. d. Remove the local sensing straps and connect a 1 Vdc power supply between −S(+) and −OUT(−). See Figure 5-8. e. Adjust A2R21 to the voltage range specified. f. Remove the 1 V supply and replace jumpers.	IR* ± 80μV
I-MON Zero Adjust.	I-MON	IM (+) ⏚M(−)	a. Set voltage and current controls to minimum. b. Disable power supply as in paragraph 5-32 (k) and short output terminals. Turn on ac power. c. Connect DVM across test points and adjust I-MON Zero trim pot A2R8 as shown in results.	0 ± 100μV

*IR = Initial Reading

Table 5-2. Calibration Procedure (continued)

TEST	TESTED VARIABLE	TEST POINTS	TEST SEQUENCE AND ADJUSTMENTS	EXPECTED RESULTS
I-MON F/S Adjust.	I-MON	IM (+) ⏚M (−)	a. Perform I-MON Zero Adjust before proceeding. b. Connect a 0.010Ω, current monitoring resistor Rm across the output terminals. c. Turn on ac power and using the "Display Settings", set current control to 17 A and voltage control to 5 V. d. Connect DVM across test points and take an initial reading (IR).	IR*
		Rm (+) Rm (−)	e. Connect DVM across Rm monitoring terminals and adjust A2R9 as shown in the results.	0.034 IR* ±33.5μV
Power Limit Adjust.	V(OUT) I(OUT)		a. Perform I-MON F/S Adjust before proceeding. b. Connect the unit to the ac powerline via a variable transformer. Set input power rail to 240 Vdc; DVM (+) on rear of A1R3 and DVM (−) to rear of A1R1. Note that power rail must be maintained at 240 Vdc during calibration. **WARNING** *The inner cover must be removed to connect the voltmeter. Disconnect the power line and wait two minutes before connecting or disconnecting the voltmeter.* c. Connect a 3.8 Ω, resistor or an electronic load across the unit's output terminals. d. Set the load for 18 A in CC mode, and turn A2R25 (lower knee) fully counter clockwise e. Turn on power supply and set voltage at 65 V and current at 17.5 A using DISPLAY SETTINGS. f. Turn A2R25 clockwise until CV LED lights. Output should be 65 V ±0.6 V and 17 A in CV mode. g. Turn off ac power and replace the 3.8 Ω resistor with a 38Ω resistor or reset electronic load for 5.5 A in CC mode. h. Turn A2R26 (upper knee) fully counter clockwise. Turn on the supply and set voltage at 200 V and current at 5.25 A using DISPLAY SETTINGS. i. Turn A2R26 (upper knee) clockwise until CV LED lights. Output should be 200 ±2 V and 5.25 A in CV mode.	

*IR = Initial Reading

Table 5-3. Guide to Recalibration after Repair

Printed Circuit Board	Block Name	Circuit Within	Reference Designator	Perform These Procedures *
A1 Main Board			R11	3, then 4
A1 Main Board			T1, T2	5
A5 Diode Board			CR4	5
A2 Control Board	Constant Voltage (CV) Circuit	All Except Current Source	All	1 then 2
A2 Control Board	Constant Voltage (CV) Circuit	Current Source	All	6
A2 Control Board	Constant Current (CC) Circuit		All	3 then 4
A2 Control Board	Power Limit Comparator		All	5
A2 Control Board	Bias Power Supplies	±15 V Supplies	All	All
A2 Control Board			U7, R84 R85, R24	7

* Code To Calibration Procedures To Be Performed

1. V-MON Zero Calibration
2. Common-Mode Calibration
3. I-MON Zero Calibration
4. I-MON Full Scale (F/S) Calibration
5. Power Limit Calibration
6. Resistance Programming Full Scale (F/S) Calibration
7. Meter Full Scale (F/S) Calibration

the tinted block and/or specific circuit area within a tint block, or the reference designator of specific components. In both cases, the printed circuit board containing the circuit is also listed.

5-32 Initial Setup

WARNING

Maintenance described herein is performed with power supplied to the instrument, and protective covers removed. Such maintenance should be performed only by service trained personnel who are aware of the hazards involved (for example, fire and electrical shock). Turn off ac power when making or removing connections to the power supply.

a. Unplug the line cable and remove the top cover by removing two screws.
b. Slide the cover to the rear.
c. Plug a control board test connector A2P7 onto the A2J7 card-edge fingers.
d. Turn OVERVOLTAGE ADJUST control A3R97 fully clockwise.
e. Disconnect all loads from output terminals.
f. Connect power supply for local sensing, and ensure that MODE switches are set as shown in Figure 3-2.
g. Reconnect line cable and turn on ac power.
h. Allow unit to warm up for 30 minutes.
i. At the beginning of each calibration procedure, the power supply should be in its power-off state, with no external circuitry connected except as instructed.

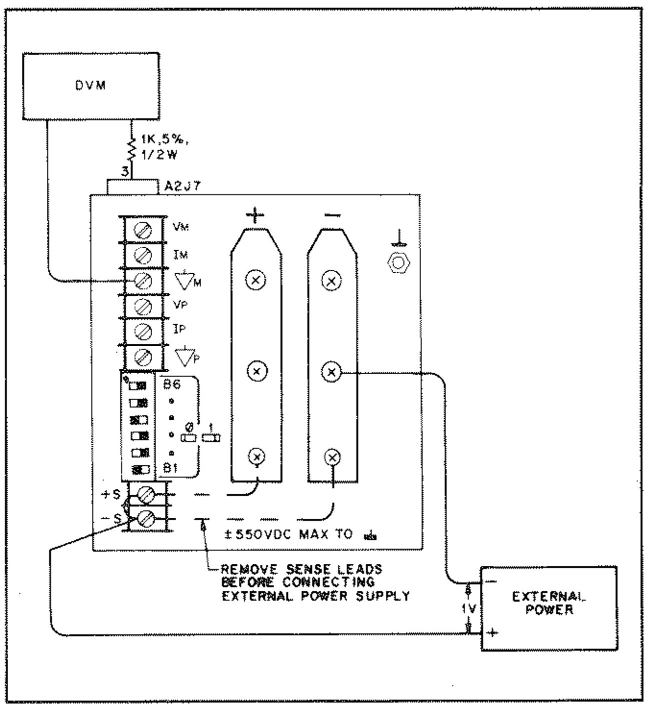
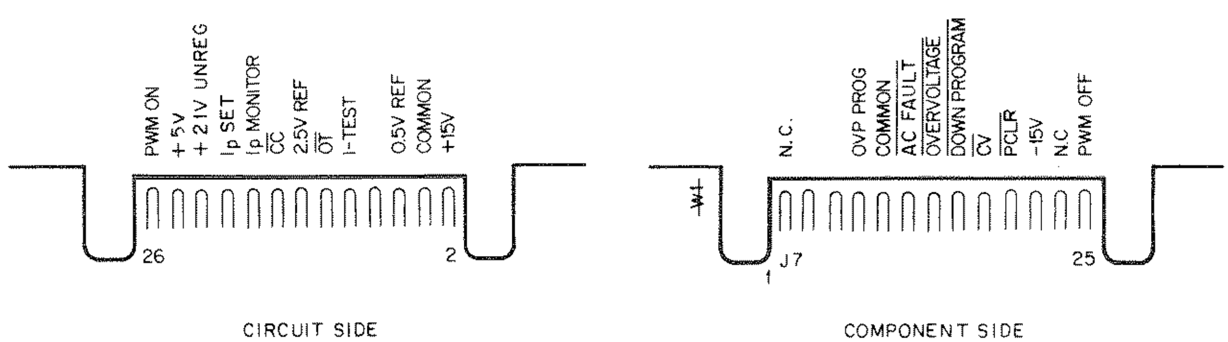


Figure 5-8. Common Mode Setup

Table 5-4. Control Board Test Connector, A2J7

PIN NO.	SIGNAL NAME	VDC	WAVEFORM/CONDITIONS	SOURCE
Digital-Circuits Bias & Reference Voltages				
24	+5 V	5.0		A2Q9 (emitter)
22	+20 V (5 V UNREG)	20.0	with 120 Hz & 40 kHz ripple	A1CR2, A1CR5
14	2.5 V ref.	2.50		A2U7 (OUT)
6	0.5 V ref.	0.50		A2R84, A2R85, A2R24
Analog-Circuits Bias Voltages				
2	+15 V	15.0		A2U11 (OUT)
21	−15.0	−15.0		A2U12 (OUT)
Status Signals				
17	CV	TTL lo	If in CV operation	A2Q2 (collector)
16	CC	TTL lo	if in CC operation	A2Q1 (collector)
13	OV	TTL hi	if not OVP shutdown	A2U15-13
11	DROPOUT	TTL hi	if ac mains okay	A2U15-10
12	OT	TTL hi	if not overtemp shutdown	A4TS1, A5TS1
Control Signals				
25	PWM OFF		10 μs TTL pulses, 20 kHz	A2U16-5
26	PWM ON		1.7 μs TTL pulses, 20 kHz	A2U15-1
18	Ip MONITOR		½ sawtooth, 20 kHz	A2CR27 (cathode)
15	DOWN PROGRAM	TTL HI	while not down programming	A2CR17, CR31 (anode)
7	OVP PROGRAM	1/100 OVP	e.g: 2 Vdc if OVP set to 200	A3R97 (wiper)
19	PCLR	TTL hi	if +5 V bias is OK	A2UQ11-4
Commons & Current Monitor				
4	L COMMON		common return for all bias voltages and status and control signals	
9	M COMMON	0.0	common return for 2.5 V ref. and 0.5 V ref.	
10	I-TEST	≈0.0017 (Iout)	inboard-side monitoring res.	A1R11
3	NOT USED			
20	Ip-SET	≈0.9		A2R25 wiper



j. The POWER LIMIT adjustment (A2R25) must be adjusted at least coarsely before many of the calibration procedures can be performed. If you have no reason to suspect that the Power Limit circuit is out of adjustment, do not disturb its setting. Otherwise, center A2R25 before you begin to calibrate the power supply.

5-33 TROUBLESHOOTING-GENERAL

WARNING

Maintenance described herein is performed with power supplied to the instrument, and protective covers removed. Such maintenance should be performed only by service-trained personnel who are aware of the hazards involved (for example, fire and electrical shock). Where maintenance can be performed without power applied, the power should be removed.

5-34 Before attempting to troubleshoot this instrument, ensure that the fault is with the instrument itself and not with an associated circuit. The performance test enables this to be determined without having to remove the covers from the supply.

5-35 The most important aspect of troubleshooting is the formulation of a logical approach to locating the source of trouble. A good understanding of the principles of operation is particularly helpful, and it is recommended that Section IV of this manual be reviewed before attempting to troubleshoot the unit. Often the user will then be able to isolate a problem simply by using the operating controls and indicators. Once the principles of operation are understood, refer to the following paragraph.

5-36 Section V contains schematic diagrams and information concerning the voltage levels and waveforms at many of the important test points. Most of the test points used for troubleshooting the supply are located on the control board test "fingers", which are accessible close to the top of the board, see Table 5-4. If a component is found to be defective, replace it and re-conduct the performance test. When a component is replaced, refer to the Calibration Procedure of this section. It maybe necessary to perform one or more of the adjustment procedures after a component is replaced.

5-37 Initial Troubleshooting Procedures

5-38 If a problem occurs, follow these steps in sequence:

a. Check that input power is available, and check the power cord and rear-panel circuit breaker.
b. Check that the settings of MODE switch A2S1 are correct for the desired mode of operation (See Table 3-4).
c. Check that all connections to the power supply are secure and that circuits between the supply and external devices are not interrupted.

WARNING

Some circuits on the power mesh are connected directly to the ac power line. Exercise extreme caution when working on energized circuits. Energize the supply through an isolation transformer to avoid shorting ac energized circuits through the test instrument's input leads. The isolation transformer must have a power rating of at least 4 k VA. During work on energized circuits, the safest practice is to disconnect power, make or change the test connections, and then re-apply power.

Make certain that the supply's ground terminal ( ) is securely connected to an earth ground before applying power. Failure to do so will cause a potential shock hazard that could result in personal injury.

5-39 Electrostatic Protection

5-40 The following caution outlines important precautions which should be observed when working with static sensitive components in the power supply.

CAUTION

This instrument uses components which can be damaged by static charges. Most semiconductors can suffer serious performance degradation as a result of static charges, even though complete failure may not occur. The following precautions should be observed when handling static-sensitive devices.

a. Always turn power off before removing or installing printed-circuit boards.
b. Always store or transport static-sensitive devices (all semiconductors and thin-film devices) in conductive material. Attach warning labels to the container or bag enclosing the device.
c. Handle static-sensitive devices only at static-free work stations. These work stations should include special conductive work surfaces (such as HP Part No. 9300-0797) grounded through a one-megohm resistor. Note that metal table tops and highly conductive carbon-impregnated plastic surfaces are too conductive; they can act as large capacitors and shunt charges too quickly. The work surface should have distributed resistance of between 10^6 and 10^{12} Ω per square.
d. Ground all conductive equipment or devices that may come in contact with static-sensitive devices or subassemblies containing same.
e. Where direct grounding of objects in the work area is impractical, a static neutralizer should be used (ionized-air blower directed at work). Note that this method is considerably less effective than direct grounding and provides less protection for static-sensitive devices.
f. While working with equipment on which no point exceeds 500 volts, use a conductive wrist strap in contact with skin. The wrist strap should be connected to ground through a one-megohm resistor. A wrist strap with insulated cord and built-in resistor is recommended, such as 3M Co. No. 1066 (HP Part No. 9300-0969 [small] and 9300-0970 [large]).

WARNING

Do not wear a conductive wrist strap when working with potentials in excess of 500 volts; the one-megohm resistor will provide insufficient current limiting for personal safety.

g. All grounding (device being repaired, test equipment, soldering iron, work surface, wrist strap, etc.) should be done to the same point.
h. Do not wear nylon clothing. Keep clothing of any kind from coming within 12 inches of static-sensitive devices.
i. Low-impedance test equipment (signal generators, logic pulsers, etc.) should be connected to static-sensitive inputs only while the components are powered.
j. Use a mildly activated rosin core solder (such as Alpha Metal Reliacor No. 1, HP Part No. 8090-0098) for repair. The flux residue of this type of solder can be left on the printed-circuit board. Generally, it is safer not to clean the printed-circuit board after repair. Do not use Freon or other types of spray cleaners. If necessary, the printed-circuit board can be brushed using a natural-bristle brush only. Do not use nylon-bristle or other synthetic-bristle brushes. Do not use high-velocity air blowers (unless ionized).
k. Keep the work area free of non-conductive objects such as Styrofoam-type cups, polystyrene foam, polyethylene bags, and plastic wrappers. Non-conductive devices that are necesary in the area can be kept from building up a static charge by spraying them with an anti-static chemical (HP Part No. 8500-3397).
l. Do not allow long hair to come in contact with static-sensitive assemblies.
m. Do not exceed the maximum rated voltages specified for the device.

5-41 Repair And Replacement

5-42 Repair and replacement of most components in the power supply require only standard techniques that should be apparent to the technician. The following paragraphs provide instructions for removing certain assemblies and components for which the procedure may not be obvious upon inspection.

WARNING

To avoid the possibility of personal injury, remove the power supply from operation before opening the cabinet. Turn off ac power and disconnect the line cord, load, and remote sense leads before attempting any repair or replacement.

CAUTION

When replacing any heatsink-mounted components except thermostat, smear a thin coating of heatsink compound between the component and heatsink.

Do not use any heatsink compound containing silicone, which can migrate and foul electrical contacts elsewhere in the system. An organic zinc oxide cream, such as American Oil And Supply Company Heatsink Compound #100, is recommended.

CAUTION

Most of the attaching hardware in this unit is metric. The only non-metric (sometimes called English or inch) fittings are listed below. Be careful when both types of screws are removed not to get them mixed up.

a. screws that secure the input and output capacitors to A1 Board and output bus.
b. rear-panel circuit breaker
c. rear-panel ground binding post

5-43 **Top Outside Cover Removal.** Remove the two top-rear screws using a Size 2, Pozidriv screwdriver. A phillips head screwdriver does not fully seat into Pozidriv screws and risks stripping the heads. Remove the top cover by sliding it back and lifting up.

5-44 **Bottom Cover Removal.** Remove the handles from both sides of the unit and remove the bottom cover by sliding it to the rear. Use a phillips head #2 screwdriver to remove the handle screws. You do not need to remove the unit's feet.

5-45 **Inside Top Cover Removal.** The unit includes an inside cover which secures the vertical board assemblies. Remove the inside cover for repair but be certain not to do so for the instrument calibration. Remove the nine mounting screws (Pozidriv, M4x.7)—two on the left side, three on the right side, and four on top. Remove the inside cover by lifting at the front edge.

5-46 When installing the inside cover, insert it first at the right side. While holding it tilted up at the left, reach through the cutouts in the cover and fit the top tabs of the A2 control board into the mating slots in the cover. Then repeat the process for the A4 FET board, and the A5 Diode board. Press the inside cover down firmly while tightening screws that secure cover to chassis. Be careful when replacing printed-circuit assemblies and covers not to bend any boards or components.

5-47 A2 Control Board Removal

5-48 After removing the inside cover, unplug the W1 ribbon cable at the front edge of the A2 control board and unplug the W7 and W8 ribbon cables from the lower center of the A2 control board. Remove the A2 board by lifting first at the front edge and then pulling it up and out of the unit.

5-49 When installing the A2 board, insert it first at the rear of the unit. While holding it tilted up at the front fit the A2TB1 terminal strip into the mating cutout in the rear panel. Then lower the A2 board's bottom tabs into the mating slots on the chassis. Re-install the W1,W7,W8 ribbon cables.

5-50 A4 FET Board Removal

5-51 After removing the inside cover, remove the A4 FET board by lifting, using the large aluminum heatsink as a handle. One connector and one tab hold the A4 board at its bottom edge.

5-52 When installing the A4 FET board, lower it vertically placing its tab into the A1 board slot first, align the connector and press in place.

5-53 A5 Diode Board Removal

5-54 After removing the cover, remove the A5 Diode board by first removing the two cover screws (pozidriv) that hold the heatsinks to the A1 board, then lift vertically to remove the A5 Diode board from the connector.

5-55 When installing the A5 Diode board, lower it into the mating connector on the A1 board, then install a screw between each heatsink and the A1 board.

5-56 A3 Front-Panel Board Removal

5-57 Remove the A3 front-panel board by first removing the entire front panel assembly. You do not need to remove the top cover. Follow this procedure:

a. Remove the top plastic insert from the front frame by prying up with a flat-blade screwdriver.
b. Remove the four front-panel assembly mounting screws (Phillips 6-32) two on top and two on the bottom.
c. Gently pull the front-panel assembly away from the unit as far as permitted by the connecting cables.
d. Note the locations of the four power-wire connections to the power switch, and then unplug the quick-connect plugs.
e. Unplug the W1 ribbon cable from connector A2J3 on the A2 Control board.
f. Remove the A3 board from the front-panel assembly by removing the six mounting screws (Pozidriv, M4x.7).

5-58 Install the A3 Board by reversing the above steps. Connect the power switch wires in the exact locations from which they were removed. See paragraph 5-60 (d).

5-59 A1 Main Board Removal

5-60 Removing the A1 main board requires removing all the vertical boards except the A3 front-panel board, 17 A1 board mounting screws, four stand offs, and two bus-bar mounting screws. Component-access cutouts in the bottom inside cover allow unsoldering most A1-board components for repair without removing the A1 board.

To remove the A1 board proceed as follows:

a. Remove the A2, A4, and A5, boards according to the previous instructions.
b. Remove the AC power cord from the cooling fan and the four AC Input Power wires.

AC Input Wire		Terminal Destination	
from	color	designator	location
L6 (chassis)	white	P	left rear
RFI filter	white/gray	N	behind A1K1
Circuit breaker	white/brown/gray	L	behind A1K1
L6 (chassis)	white		A1K1 front armature

c. Remove the following mounting screws:
   2 (1 each) from the output bus bars
   7 from the A1 board
   4 from transformer A1T2
   4 from transformer A1T3
   2 from relay A1K1
   4 inside-cover mounting posts 5/16 hex
d. Lift the A1 board up and toward the rear, then remove the wires from the front panel switch A3S1.

A1 Designator	Wire color	A3S1 Position (Rear View)
A	white/gray	Upper right
B	gray	Upper left
C	white/brown/gray	Lower left
D	white/red/gray	Lower right

A3 FRONT PANEL ASSEMBLY

REAR VIEW

S1
B—| —A
C—| —D

Install the A1 board by reversing the above steps. Be careful to follow the wire color code mentioned above.

5-61 TROUBLESHOOTING PROCEDURE

WARNING

Perform the troubleshooting and repair procedures which follow only if you are trained in equipment service and are aware of the danger from fire and electrical-shock hazards. Some of the procedures include removing the unit's protective covers which may expose you to potentially lethal electrical shock. Whenever possible, make test connections and perform service with the power removed.

5-62 After performing the Initial Troubleshooting Procedures paragraph 5-37, focus on developing a logical approach to locating the source of the trouble. The underlying strategy for the troubleshooting procedures here is to guide you to the faulty circuit nodes which have improper signals or voltages. It relies on you to identify the particular functional circuit to troubleshoot from symptom tables and by understanding how the unit works. It then relies on you to discover the defective component or components which cause the faulty circuit nodes. So, read the BLOCK DIAGRAM OVERVIEW under paragraph 4-3 and read the functional circuit descriptions for the circuits that you suspect may be defective. (Functional circuit descriptions begin at paragraph 4-12.) Then return to this section for help finding the faulty circuit nodes.

5-63 Table 5-4 gives the signals for each of the test points on the control board test connector. This connector is provided in service kit P/N 5060-2865. The measurements given here include bias and reference voltages as well as power supply status signals and waveform information. To troubleshoot the power supply the A4 power FET board and A2 control board can be raised out of the unit using extender boards and cables provided in service kit P/N 5060-2865.

WARNING

The A4 power FET board should only be raised on its extender when using the Main Troubleshooting Setup; ***NEVER when the unit is operated with its normal*** *(≈300 Vdc) bus voltage. To do so can cause damage to the unit and is a shock hazard.*

5-64 Table 5-5 provides troubleshooting information based on the status of the PWM-ON and PWM-OFF signals which drive the PFETs. This table is used for no-output failures.

5-65 Tables 5-6 and 5-7 give measurements for the test points on the A3 front panel board and possible failure symptoms respectively.

5-66 Table 5-8 describes possible symptoms for overall performance failures of the power supply. It is necessary to have a properly working front panel before using this table.

5-67 Section VII contains schematic diagrams and voltage levels, and component location diagrams to help you locate components and test points.

5-68 Make most voltage measurements (except DC-to-DC Converter and ac mains-connected circuits) referenced to the unit's output common which is accessible at rear-panel terminal ∇M. All voltages are ±5% unless a range is given.

5-69 Using the Tables

5-70 Typically there will be two types of power supply failures; no-output and performance failures.

1. NO-OUTPUT FAILURE: Start with the TROUBLESHOOTING NO-OUTPUT FAILURES section at paragraph 5-77 which references Tables 5-4 and 5-6.
2. PERFORMANCE FAILURE: If the power supply produces an output but does not perform to specifications, begin by verifying the measurements at the A2J7 test connector using Table 5-4. Next, verify the front panel by doing the procedure outlined in the FRONT PANEL TROUBLESHOOTING section starting at paragraph 5-79. After the front panel has been verified consult Table 5-8 for the performance failure symptom which seems closest to the one observed and proceed to the functional circuit given for that failure.

5-71 The circuits referenced in Tables 5-5 and 5-8 are derived from functional blocks of circuits in the power supply. These blocks are given in the Power Supply Blocks section starting in Paragraph 5-102. Troubleshooting information for each block will include a brief description of the circuit involved. The columns provided in each block are as follows:

NODE:	This column lists the nodes where the measurements should be taken. In some cases this will be stated as NODE(+) and NODE(−) where the first is the test node and the second is the reference.
SETUP:	If a certain setup is required for the measurement, it will be given in this column.
MEASUREMENT:	This column indicates what the expected measurement is for the given node.
SOURCE:	If applicable, the components which generate the signal will be provided in this column.

5-72 Some blocks will have Input and Output sections. The input section will have a source column to indicate which components generated the measured signal. The output section will list all the important output signals from that block. However, because the outputs of one block are the inputs to another, the schematic should be consulted if an output measurement is incorrect. This will indicate the next circuit block to be trouble shot.

5-73 Main Troubleshooting Setup

5-74 Figure 5-9 shows the troubleshooting setup for trouble shooting all of the unit except the front panel and initial no-output failures (see paragraph 5-77). The external power supply provides the unit's internal bus voltage. The ac mains cord connects to the unit's A1T3 bias transformer via an isolation transformer, thereby energizing the bias supplies, but it does not connect to the input rectifier and filter because that would create the bus voltage. With the external supply the unit operates as a dc-to-dc converter. The supply biases the A4Q1, A4Q2, A4Q3 and A4Q4 PFETs with a low voltage rather than the 320 Vdc bus voltage. This protects the PFETs from failure from excess power dissipation if the power-limit comparator or the off-pulse circuitry are defective. It also reduces the possibility of electrical shock to the troubleshooter.

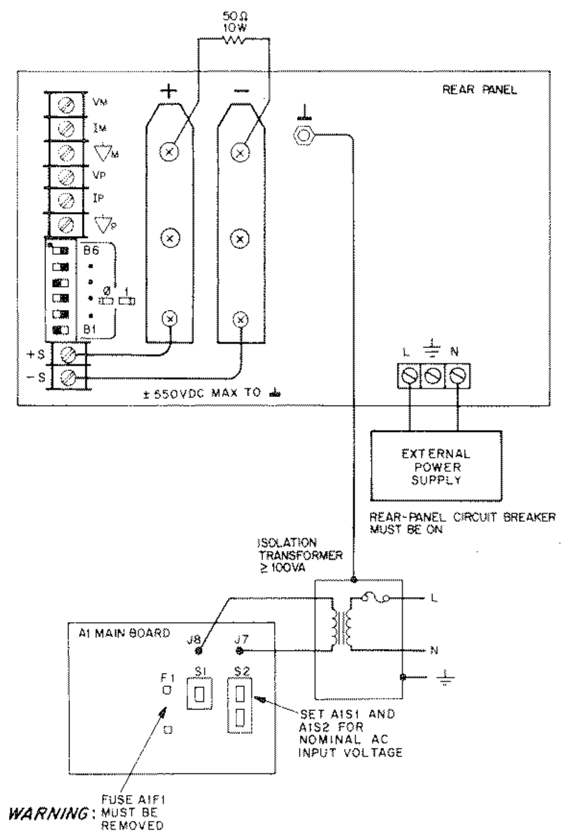


Figure 5-9. Main Troubleshooting Setup

WARNING

An isolation transfomer provides ac voltage that is not referenced to earth ground, thereby reducing the possibility of accidently touching two points having high ac potential between them. Failure to use an isolation transformer as shown in Figure 5-9 will cause the ac mains voltage to be connected directly to many components and circuits within the power supply, including the FET heatsinks, as well as to the terminals of the external dc power supply. Failure to use an isolation transformer is a definite personal-injury hazard.

The troubleshooting setup of Figure 5-9 connects high ac voltage to relay K1, fan B1, fuseholder A1F1, and other components and circuits along the front of the A1 main board.

5-75 As a convenience in implementing the troubleshooting setup, prepare cord sets as shown in Figure 5-10. This facilitates connecting the unit's input power rail to the external supply and connecting the bias transformer to the isolation transformer.

5-76 With the mains cord unplugged proceed as follows:

a. Remove the top cover and the inside cover as in paragraphs 5-43 and 5-45. Remove fuse A1F1.

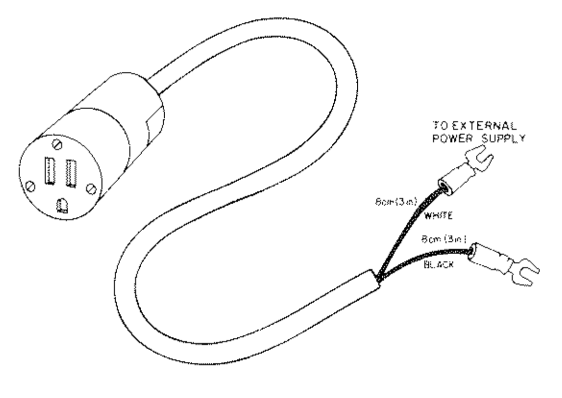


Figure 5-10a

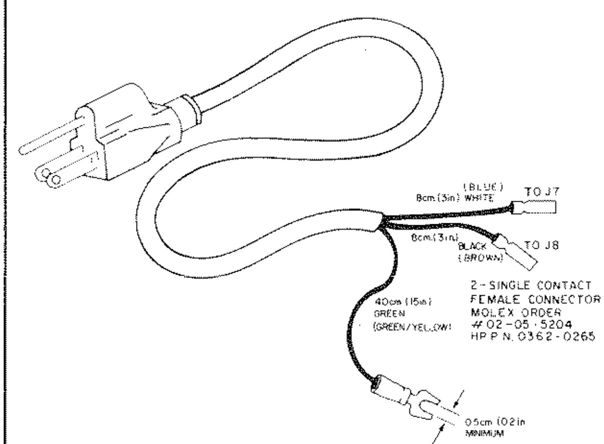


Figure 5-10b

Figure 5-10. Modified Mains Cord Set For Troubleshooting

WARNING

Failure to remove fuse A1F1 will result in damage to the 6010A; damage to the external DC supply and a shock hazard to you.

b. Install control board test connector onto the A2J7 card-edge fingers.
c. Connect a 50 Ω, 40 W, load resistor to the unit's output terminals.
d. Place the front panel power-on switch in the off position. Remove the ac input cover from the rear panel and connect the "L" and "N" screws on the barrier block to the output of the external DC supply. If a line cord is already connected to these terminals, construct an adapter as shown in Figure 5-10 (a), which allows you

Table 5-5. No-Output Failures
(Bias supplies and AC turn-on circuit functioning)

Status of PFET on/Off-Pulses

PWM-ON A2J7-26	PWM-OFF A2J7-25	DEFECTIVE BOARD	CHECK FUNCTIONAL CIRCUITS
lo	lo	A2	Control ckts: CV & CC thru On- & Off-Pulse Oneshots *
lo	hi	A2&A4	PWM and DC-to-DC Converter: A4Q1, A4Q2, A4Q3 and A4Q4 probably failed
hi	lo	A2&A4	PWM and DC-to-DC Converter: A4Q1, A4Q2, A4Q3 and A4Q4 probably failed
hi	hi	A2&A4	PWM and DC-to-DC Converter: A4Q1, A4Q2, A4Q3 and A4Q4 probably failed
lo	N	A2	A2U15A,On-Pulse Oneshot and A2Q11
N	lo	A2&A4	Off-Pulse Oneshot and DC-to-DC: A4Q1, A4Q2, A4Q3 and A4Q4 probably failed
hi	N	A2&A4	A2U15A, On-Pulse Oneshot & DC-to-DC: A4Q1, A4Q2, A4Q3, and A4Q4 probably failed
N	hi	A2&A4	Off-Pulse Oneshot and DC-to-DC: A4Q1, Q4Q2, A4Q3 and A4Q4 probably failed
N	N	A2&A4	Power-Limit Comparator and DC-to-DC: A4Q1, Q4Q2,A4Q3 and A4Q4 probably failed

lo= TTL low hi= TTL high N= normal 20 kHz pulse train, TTL levels

* Decide which to troubleshoot—the CV Circuit, the CC Circuit, or the PWM and Off-Pulse & On-Pulse Oneshots—by measuring the CV CONTROL (A2CR24, cathode) and the CC CONTROL (A2CR11 cathode) voltages. Troubleshoot whichever is negative, and if neither is negative, troubleshoot the PWM. Make these voltage measurements after you have implemented the Main Troubleshooting Setup.

Table 5-6. Front Panel Board Tests

Pin No.	Signal Name	Measurement	Description	Source
1	+7.5 V	7.5 V	derived from +15 V bias	A3VR2, A3R93
2	−1 V	−1.0 V	derived from −15 V bias	A3R89, A3R94, A3C17
3	CV VOLTAGE	0-5 V	for 0 to full scale output voltage	A3U6-6, A3R88, A3CR3
4	CC VOLTAGE	0-5 V	for 0 to full scale output current	A3U7-1, A3R58
5	VOLTS test	−1888 on volts display	jumper to +5 V on A3 board	A3U1-37
6	AMPS test	−1888 on amps display	jumper to +5 V on A3 board	A3U2-37
7	VOLTS input	0-1 V	for 0 to full scale output voltage	A3U4-2,3,10
8	VOLTS lowrange	TTL high	if VOLTS display is below 20 volts (press DISPLAY SETTINGS)	A3U5-13
9	DISPLAY SETTINGS	TTL lo	if DISPLAY SETTINGS switch on front panel is depressed	A3S1,A3R85
10	DISPLAY OVP	TTL high	if DISPLAY OVP switchon front panel is depressed	A3S2,A3R64
11	AMPS input	0-600 mV	for 0 to full scale output current	A3R56,A3R58
12	−5 V	−5.0 V	derived from −15 V bias	A3VR1, A3R90
13	buffered OVP	0-2.2 V	1/30 of OVP voltage setting when DISPLAY OVP switch is depressed. Varies with OVP ADJUST pot	A3U7-7,A3CR5,

to connect the cord to the DC supply. In either case ignore polarity as the unit's rectifying diodes steer the dc power to the correct nodes.

e. Complete the setup of Figure 5-9 by attaching an ac mains cord to test points J8 (L, black wire) and J7 (N, white wire) and connect the green ground wire to the unit's case ground terminal or a suitably grounded cabinet screw. See Figure 5-10 (b). Plus the mains cord into an isolation transformer.

5-77 Troubleshooting No-Output Failures

NOTE

The main troubleshooting setup is not used for the No Output Failures and Front Panel troubleshooting tests.

5-78 No-output failures often include failure of the A4Q1 through A4Q4 PFETs and their fuses, A4F1 and A4F2. When either the off-pulses or the power-limit comparator fails, the PFETs can fail from excessive power dissipation. The strategy for localizing no-output failures is to check the voltages and waveforms at the control board test connector to predict if that circuit failure would cause the the PFETs to fail. This makes it possible to develop your troubleshooting approach without an extensive equipment setup. Proceed as follows:

a. With the mains cord unplugged remove the A4 FET Driver board per paragraph 5-50. Plug in the mains cord and switch on power.
b. Using Table 5-4 check the bias voltages, the PWM-OFF, PWM-ON and Ip MONITOR Control signals and other signals of interest at the A2 control board test fingers, A2J7.
c. Check for the presence of program voltages, VP and IP, at the rear panel.
d. Check for presence of the 320 Vdc rail voltage between the rear facing end of A1R3 and the rear facing end of A1R1. If there is no rail voltage, check diode Assembly A1U1.

WARNING

A1R1, A1R3, and A1U1 connect to the ac mains voltage. Use a voltmeter with both input terminals floating to measure the rail voltage.

e. Select the functional circuit for troubleshooting based on your measurements and Table 5-5, which provides direction based on the status of the PWM OFF and PWM ON signals.

5-79 Front-Panel Troubleshooting

5-80 The A3 front panel board can be troubleshot by first doing the following setup.

a. Remove the top plastic insert from the front frame by prying up with a flat-blade screwdriver.
b. Remove the 4 front-panel assembly mounting screws (Phillips 6-32), two on top and two on the bottom.
c. Detach the A3 board from the front panel assembly by removing the 6 mounting screws (Pozidriv, M4x7).
d. Place the A3 board vertically against the supply with a piece of insulating material between. The test connector can then be attached to the A3 board. The rest of the front panel assembly can stand vertically so that the pots and the switches can be accessed while troubleshooting.
e. Plug in the mains cord and switch on power.

WARNING

The ac mains voltage connects directly to the LINE switch and to components and traces at the front of the A1 main board. Be extremely careful to avoid touching the ac mains voltage.

5-81 Start troubleshooting by performing the tests given in Table 5-6. This table provides the measurements for the test points on the test connector as well as the source components for that measurement. Table 5-7 gives front panel symptoms as well as the circuits or components that may cause the supply to exhibit those symptoms. Both Table 5-6 and 5-7 should be used to check out and troubleshoot the front panel.

5-82 Troubleshooting Bias Supplies

5-83 +5 V On A2 Control Board. The PWM A2U22 includes a clock generator (40 kHz set by A2R170, A2C79, and A2Q10), and a current limit (2 Adc set by 0.15 Vdc across A2R172). It turns off each output pulse using the difference between the voltage at voltage divider A2R161-A2R163 and the 2.5 Vdc set by voltage regulator A2U21.

5-84 Circuit Included. +5 Vdc bias supply circuitry from connector pin A1J5-1,3 (1,3 both pins) through jumper A2W3 on A2 control board.

5-85 Setup. The Main Troubleshooting Setup, paragraph 5-73. Apply the ac mains voltage to the isolation transformer, and set the external supply to 0 Vdc.

5-86 Input:

NODE +	NODE −	MEASUREMENT	SOURCE
A2J7-22	A2J7-4	~20 Vdc	A1CR2,A1CR5

5-87 Outputs:

NODE	MEASUREMENT
A2U22-6	~2 to 4 Vdc sawtooth, 40 kHz
A2U22-12,13	~19 Vpk, 15 μs pulses, 40 kHz
A2Q9 (emit.)	~20 Vpk, 5 μs pulses, 40 kHz
A2U21 − 2	2.5 Vdc
A2R161, A2R163	2.5 Vdc

5-88 To check if load on +5 V is shorted, remove jumper A2W3.

Table 5-7. A3 Front Panel Board Failure Symptoms

SYMPTOMS	DEFECTIVE CIRCUIT	CHECK COMPONENTS
Error when pressing DISPLAY SETTINGS	limits display	A3U5, A3U8
error in VOLTS or AMPS	input ranging or DVMS	A3U8,A3U6,A3U4,A3U1,A3U2, A3U7
* one or more display digits out	display LEDs	A3DS1 through A3DS8
unable to adjust VOLTAGE or CURRENT or always max	potentiometers	A3R99, A3R100
VOLTS decimal point error	decimal drivers	A3U3

*Note that the Volts and Amps tests (Table 5-6 pins 5 and 6) verify that all the current and voltage display segments light except for the decimal points.

Table 5-8. Performance Failure Symptoms

SYMPTOMS	DEFECTIVE BOARD	CHECK FUNCTIONAL CIRCUITS
unexplained OVP shutdowns	A2	OVP Circuit, CV Circuit
no current limit	A2	CC Circuit
max current < 17 Adc	A2	CC Clamp, CC Circuit
max power < specified	A2, A1	Power Limit, 20 kHz clock, transformer A1T2
max voltage < 200 Vdc	A2, A1	CV Circuit, diodes A1U1, mains voltage select jumper A1W1
cycles on & off randomly	A2, A1	AC-Surge-&-Dropout Detector, Mains Voltage Select switch A1S2,
CV overshoots	A2	A2U5A, A2CR19, A2R62
output noise (< 1 kHz)	A2, A1	CV Circuit, Input Filter
output noise (>1 kHz)	A1, A4	transformer A1T2, Output Filter, snubbers A4R1 to A4R11, A4R13 to A4R19, A4C1 to A4C4, A4CR1 to A4CR4
CV regulation, transient response, programming time	A2, A1	wrong sensing (paragraph 3-40), low ac mains voltage, CV Circuit
CC regulation	A2	low ac mains voltage, CC circuit
CV oscillates with capacitive loads	A2	A2R61, A2R60, A2R58, A2R59, A2C33, A2R64, A2R68, A2C36, A2C37, A2U5, A2R65
CC oscillates with inductive loads	A2	A2R61, A2R60, A2R58, A2R57, A2C33, A2R19, A2C11, A2R58, A2C12, A2U4, A2R35, A2C20, A2R37, A2C17, A2R29, A2C18, A2R31

5-89 +15 V On A2 Control Board. Voltage regulator A2U11 regulates the voltage across resistor A2R99 to be 1.25 Vdc. That sets the current through zener diode A2VR3 at 7.5 mAdc. The output voltage is 1.25 Vdc plus 11.7 Vdc across A2VR3 plus the voltage across A2R100.

5-90 Circuit Included. +15 Vdc bias supply circuitry from connector pin A2J5-5 through test point A2J7-2 on A2 control board.

5-91 Setup. The Main Troubleshooting Setup, paragraph 5-73. Apply the ac mains voltage to the isolation transformer, and set the external supply to 0 Vdc.

5-92 Input:

NODE(+)	NODE(−)	MEASUREMENT	SOURCE
A2C52(+)	A252(−)	~27 Vdc	A1U4, A1C15 (+)

5-93 Outputs:

NODE (+)	NODE (−)	MEASUREMENT
A2J7-2	A2U11(ADJ)	1.25 Vdc
A2J7-2	A2VR3(Anode)	12.9 Vdc
A2J7-2	A2 VR2(Anode)	6.2 Vdc
A2C50(+)	A2 C50(−)	13.8 Vdc

5-94 To check if load on +15 V is shorted, remove jumper A2W1.

5-95 −15 V On A2 Control Board. Voltage regulator A2U12 regulates the voltage across resistor A2R103 to be 1.25 Vdc.

5-96 Circuit Included. −15 Vdc bias supply circuitry from connector pin A2J5-6 through test point A2J7-21 on A2 control board.

5-97 Setup. The Main Troubleshooting Setup, paragraph 5-73. Apply the ac mains voltage to the isolation transformer, and set the external supply to 0 Vdc.

5-98 Input:

NODE (+)	NODE (−)	MEASUREMENT	SOURCE
A2C55(+)	A2C55(−)	~27 Vdc	A1U4, A1C16(−)

* NODE (−)= A2J7-4

5-99 Outputs:

NODE(+)	NODE(−)	MEASUREMENT
A2J7-21	A2U12-3(ADJ.)	−1.25 Vdc
A2J7-21	A2VR4 (cath.)	−12.9 Vdc
A2C54 (+)	A2C54 (−)	13.8 Vdc

5-100 To check if load on −15 V is shorted, remove jumper A2W3.

5-101 Refer to Down Programmer, paragraph 5-123, for the +10.6 V bias supply, and refer to OVP Circuit, paragraph 5-141, for the +2.5 V bias supply.

5-102 Power Section Blocks

5-103 This section contains the blocks referenced in Tables 5-5 and 5-8.

5-104 Troubleshooting AC-Turn-On Circuits

5-105 Relay A1K1 closes at 2.5 seconds and DROPOUT goes high at 2.9 seconds after 20 V (5V UNREG) reaches about 13 Vdc. DROPOUT high enables the PWM if OVERVOLTAGE, and OVERTEMPERATURE are also high.

5-106 Circuits Included. AC-Surge-&-Dropout Detector, Bias Voltage Detector, Delay Circuits, and Relay Driver—all on A2 control board.

5-107 Setup. The Main Troubleshooting Setup, paragraph 5-73. Apply the ac mains voltage to the isolation transformer, and set the external supply to 0 Vdc.

5-108 Inputs:

NODE (+) *	SETUP	MEASUREMENT	SOURCE
A2J7-24		5.0 Vdc	A2Q9 (emit.)
A2J7-22		≈ 21 Vdc	A1CR2,A1CR5
A2U11-16		f.w.rect.,0.8 V pk	A1CR3,A1CR4
A2U20-13		TTL sq wave,20 kHz	A2U20-6

5-109 Outputs:

NODE (+) *	SETUP	MEASUREMENT
A2U17-9	cycle power	≈ 13.5 Vdc
A2U17-14	cycle power	≈ 1.4 Vdc
A2Q11-14	cycle power	transition 0 to 5 Vdc at 2.5 sec
A2Q11-4		hi (5 Vdc)
A2U9-10	cycle power	2.9 s burst 1.25 kHz sq. wave
A2U9-15	cycle power	one 840 ms pulse then hi at 2.5 sec
A2U9-14	cycle power	three 420 ms pulses then hi at 2.9 sec
A2U9-1	cycle power	transition lo to hi at 1.7 sec.
A2U15-10 (AC FAULT)	cycle power	transition lo to hi at 2.9 sec.
A2Q7-C (RELAY ENABLE)	cycle power	transition 5.0 to 0.3 Vdc at 2.5 sec

5-110 Troubleshooting PWM & Clock

5-111 The inputs to inhibit Gate A2U18A and PWM gate A2U18B are the keys to PWM troubleshooting. The 20 kHz clock starts each PWM output pulse, and the pulse stops when any of the inputs to A2U18A or A2U18B goes low. The PWM is inhibited and prevented from initiating output pulses as long as any of the seven inputs is low.

5-112 Circuit Included. Pulse Width Modulator (PWM), Off-Pulse Oneshot, On-Pulse One-Shot, 20 kHz Clock.

5-113 Setup. The Main Troubleshooting Setup, paragraph 5-73. Apply the ac mains voltage to the isolation transformer. Adjust the units current setting above 1.0 Adc. Set the external supply (EXTERNAL) and adjust the unit's voltage setting (INTERNAL) as instructed below. Use the "DISPLAY SETTINGS" switch to make adjustments to the unit's current or voltage setting.

5-114 Inputs:

NODE (−) = A2J7-4

NODE (+)	SETUP	MEASUREMENT	SOURCE
A2J7-24		5.0 Vdc	A2Q9, A2W3
A2U18-10		hi	A2U15-10
A2U18-12		hi	A2U15-13
A2U18-13		hi	A5TS1,A4TS1
A2U18-5		hi	A2U18-8
A2U18-2		hi	A2U8-2
A2U18-1	set OUTPUT ADJUST for 1 Vdc	hi	A2U10-7

5-115 Outputs:

	SET VOLTAGE (Vdc)		
NODE (+)	EXTERNAL	INTERNAL	MEASUREMENT
A2U20-1	0	0	TTL sq wave, 320 kHz
A2U20-5	0	0	TTL sq wave, 40 kHz
A2U20-6	0	0	TTL sq wave, 20 kHz
A2U19-5	0	2	20 kHz
A2U19-6	0	2	20 kHz
A2U16-5	40	2	10μs pulse, 20 kHz
A2U16-5	40	0	lo
A2U16-4	40	20	48μs pulse, 20 kHz
A2U16-4	40	0	hi
A2U15-1	40	20	1.7μs pulse, 20kHz
A2U15-1	40	0	lo
+OUT	40	20	≈ 40 Vdc (UNREGULATED)
+OUT	40	2	20 Vdc (CV)

5-116 Troubleshooting DC-To-DC Converter

5-117 Parallel NOR gates A4U1, A4U2 and A4U3A act as drivers and switch on FETs A4Q1,Q2,Q3 and Q4 through pulse transformer A4T1. NOR gate A4U3B turns off the FETs through pulse transformer A4T2 and transistors A4Q5 and A4Q6.

5-118 Circuits Included. On-Pulse Driver, Off-Pulse Driver, FET Switches and Drivers on A4 FET board.

5-119 Setup. The Main Troubleshooting Setup, paragraph 5-73. Apply the ac mains voltage to the isolation transformer, and set the external supply to 40 Vdc. Set the unit's output voltage to 20 Vdc and current to above 1 Adc using "DISPLAY SETTINGS" switch. Verify that the UNREGULATED LED lights. See Figure 5-11 for waveforms.

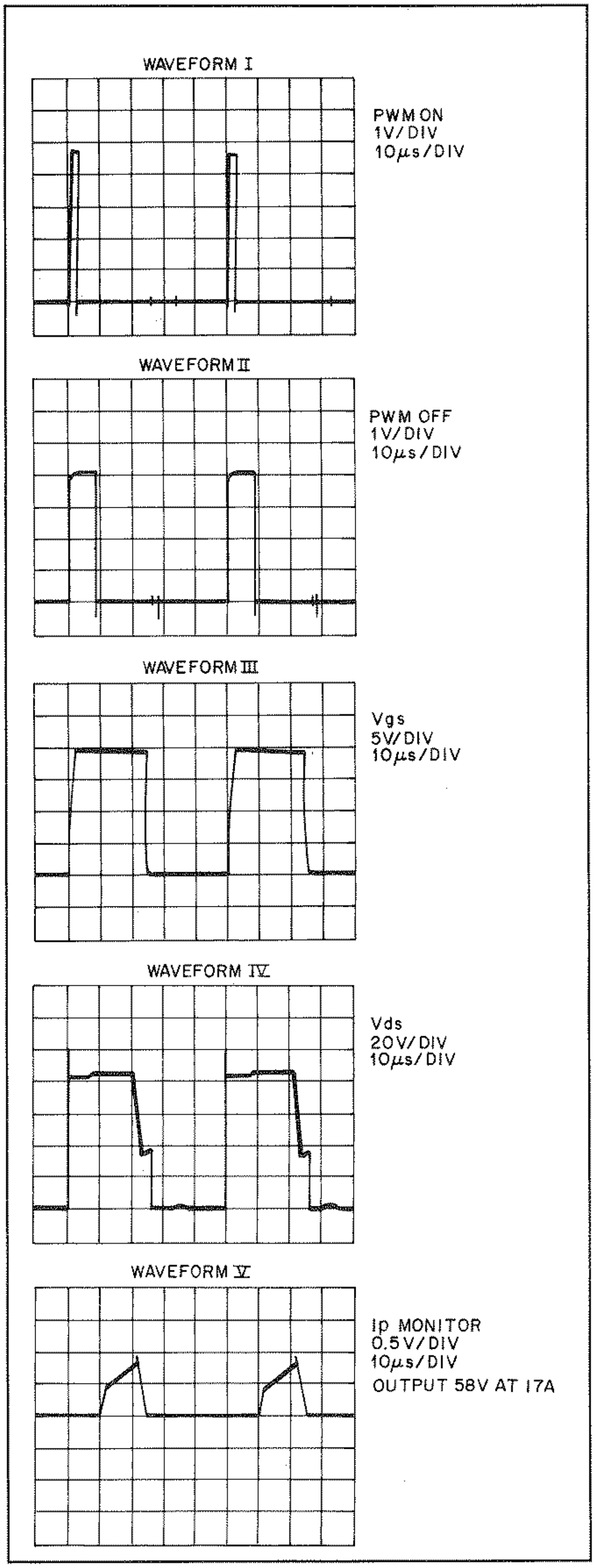


Figure 5-11. Waveforms

5-120 **Inputs:**

NODE (+)	NODE (−)	MEASUREMENT	SOURCE
A2J7-26 (PWM-ON)	∇M	1.7μs, 20 kHz pulse (see Waveform 1)	A2J5-11,A2U15-1, A4P1-A3
A2J7-25 (PWM-OFF)	∇M	10μs, 20 kHz pulse (see Waveform 2)	A2U16-5,A2J5-13, A4P1-A2
A4P1-C1	∇M	10.6 Vdc	A1U3-2
A4Q2-D	A4Q4-S	39 Vdc	A1C5(+),A4P1-22 to 25 A1C1(−),A4P1-16 to 18

5-121 **Outputs:**

NODE (+)	NODE (−)	MEASUREMENT
A4Q1/Q2-G	A4Q2-S	(see Waveform 3)
A4Q3/Q4-G	A4Q4-S	(see Waveform 3)
A4Q2-S	A4Q4-D	(see Waveform 4)
A2J7-18	A2J7-4	(see Waveform 5)

5-122 If you replace the FETs, replace both the FETs and associated drive components as furnished in FET Service Kit, HP Part No. 5060-2866.

CAUTION

The FETs are static sensitive and can be destroyed by relatively low levels of electrostatic voltage. Handle the A4 FET board and the FETs only after you, your work surface and your equipment are properly grounded with appropriate resistive grounding straps. Avoid touching the FET's gate and source pins.

5-123 Troubleshooting Down Programmer

5-124 The down programmer discharges the output when either PWM OFF is generated or CV ERROR is more negative than about −3 Vdc. Comparator A5U1 triggers down programming when the voltage at A5U1-5 is less than about 4 Vdc.

5-125 **Circuit Included.** Down programmer and 10.6 V bias supply on A1 main board.

5-126 **Setup.** The Main Troubleshooting Setup, Paragraph 5-73, except connect the external supply to the unit's +OUT (+) and −OUT (−) terminals. Apply the ac mains voltage to the isolation transformer. Set the external supply for an output voltage of 10 Vdc and set current limit for 2.5 Amps. Set the power supply under test for a voltage setting of 8.0 Vdc and current setting of 2.0 Adc using "DISPLAY SETTINGS".

5-127 **Outputs:**

NODE (+)	EXTERNAL SUPPLY	MEASUREMENT
A5C3(+)	ON/OFF	10 Vdc
A5VR1(K)	ON/OFF	6.5 Vdc
A5U1-3	ON /OFF	0.2 Vdc
A5CR2(K)	OFF	1.8 Vdc
A5CR2(K)	ON	0.2 Vdc
A5U1-1	OFF	0.5 Vdc
A5U1-1	ON	5.0 Vdc
+R20	OFF	< .001 Vdc
+R20	ON	1.5 Vdc

NODE (−) = A2J7-4

5-128 Troubleshooting CV Circuit

5-129 V-MON, the output of CV Monitor Amp A2U2, is 1/40 the voltage between +S and −S. CV Error Amp A2U3 compares V-MON to CV PROGRAM. Innerloop Amp A2U5A stabilizes the CV loop with input from A2U5B. The measurements below verify that the operational amplifier circuits provide expected positive and negative dc voltage excursion when the CV loop is open and the power mesh shut down.

5-130 **Circuits Included.** Constant Voltage (CV) Circuit and buffer amplifier A2U5B.

5-131 **Setup.** The Main Troubleshooting Setup, paragraph 5-73. Apply the ac mains voltage to the isolation transformer, and disconnect the external supply. Remove the +S jumper and connect A2J7-2 (+15 V) to +S. Set mode switch settings B4, B5 and B6 all to 0. Set VP to 0 Vdc by connecting to ∇P or set VP to +5 Vdc by connecting to A2J7-24 according to SETUP below. VP and ∇P are on rear-panel terminal block.

5-132 **Outputs:**

NODE (+)	NODE (−)	SETUP	MEASUREMENT
VM	A2J7-4		3.75 Vdc
A2U5-1	"	VP = 0	− 14 Vdc
A2U3-6	"	VP = 0	− 14 Vdc
A2U5-1	"	VP = 5	13 Vdc
A2U3-6	"	VP = 5	≈0 Vdc
A2U5-7	"	short A2J7-24 to A2U5-5	+ 7.5 Vdc

5-133 If the failure symptoms include output voltage oscillation, check if the CV Error Amp circuit is at fault by shorting A2U3-6 to A2U3-2. If oscillations stop, the CV Error Amp circuit is probably at fault.

5-134 Troubleshooting CC Circuit

5-135 I-MON, the output of CC Monitor Amp A2U1, in volts is ≈1/3 the output current in amperes. CC Error Amp A2U4C compares I-MON to CC PROGRAM. Differentiator circuit A2U4A differentiates the inboard voltage sense to stablize the CC loop. Its output is summed with I-MON at CC Error Amp A2U4C.

5-136 The measurements below verify that the operational amplifier circuits provide expected positive and negative dc voltage gain when the CC loop is open and the power mesh shut down.

5-137 Circuits Included. Constant Current (CC) Circuit on A2 control board.

5-138 Setup. The Main Troubleshooting Setup, Paragraph 5-73, except connect the external supply with polarity reversed to the unit's +OUT (−) and −OUT (+) terminals. Apply the ac mains voltage to the isolation transformer. Set the external supply to 3.0 Adc constant current with a voltage limit in the range 5 to 20 Vdc. Set mode switches B1, B2 and B3 to 0. Set IP to 0 Vdc by connecting to ▽P or set IP to +5 Vdc by connecting to A2J7-24 according to SETUP below.

5-139 Outputs:

NODE (+)	NODE (−)	SETUP	MEASUREMENT
IM	A2J7-4		0.125 Vdc
A2U4-8	"	IP=0	−14 Vdc
A2U4-8	"	IP=5	+14 Vdc

5-140 If the failure symptoms include output current oscillation, check if the differentiator circuit is at fault by removing resistor A2R35 (1 M ohm). If oscillations stop, the differentiator is probably at fault.

5-141 Troubleshooting OVP Circuit

5-142 Flip-flop A2U8A-A2U8D is set by comparator A2U8C and reset by PCLR. TTL low at A2U18-12 inhibits the PWM. OVP Program Voltage on A2J7-7 is equal to Eout/10.

5-143 Circuit included. OVP Circuit and 2.5V bias supply on A2 control board.

5-144 Setup. The Main Troubleshooting Setup, Paragraph 5-173, except connect the external supply to the unit's +OUT (+) and −OUT (−) terminals. Apply the ac mains voltage to the isolation transformer. Adjust the unit's OVP limit to 10 Vdc. Set the external supply (EXTERNAL) as instructed below.

5-145 Outputs:

NODE (−) = A2J7-4

NODE (+)	SET VOLTAGE EXTERNAL(Vdc)	SETUP	MEASUREMENT
A2U7-2	−		2.5 Vdc
A2J7-7	−		1.0 Vdc
A2J7-13	5		hi
A2J7-13	15		lo
A2J7-13	5		lo
A2J7-13	5	cycle power	hi

NOTE

Connecting a test probe to either input of either comparator in the OV Flip Flop (pins A2U8-1,6,7,10,11 or 13) may cause the flip flop to change states and cause the probed input to be low.

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. Hewlett-Packard Part Number.
c. Total Quantity (TQ) used in that assembly (given the first time the particular part number appears).
d. Description. Refer to Table 6-2 for abbreviations.
e. Manufacturer's Federal Supply Code Number. Refer to Table 6-3 for manufacturer's name and address.
f. Manufacturer's Part Number or Type.

6-3 Parts not identified by reference designator are listed at the end of Table 6-4 under Mechanical and/or Miscellaneous.

Table 6-1. Reference Designators

A	Assembly
B	Blower
C	Capacitor
CR	Diode
DS	Signaling Device (light)
F	Fuse
FL	Filter
G	Pulse Generator
J	Jack
K	Relay
L	Inductor
Q	Transistor
R	Resistor
RT	Thermistor Disc
S	Switch
T	Transformer
TB	Terminal Block
TS	Thermal Switch
U	Integrated Circuit
VR	Voltage Regulator (Zener diode)
W	Wire (Jumper)
X	Socket*
Y	Oscillator

*Reference designator following "X" (e.g. XA2) indicates assembly or device mounted in socket.

6-4 ORDERING INFORMATION

6-5 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 6-2. Description Abbreviations

ADDR	Addressable
ASSY	Assembly
AWG	American Wire Gauge
BUFF	Buffer
CER	Ceramic
COMP	Carbon Film Composition
CONV	Converter
DECODER/DEMULTI	Decoder/Demultiplexer
ELECT	Electrolytic
EPROM	Eraseable Programmable Read-Only Memory
FET	Field Effect Transistor
FF	Flip-Flop
FXD	Fixed
IC	Integrated Circuit
INP	Input
LED	Light Emmiting Diode
MET	Metalized
MOS	Metal-Oxide Silicon
OP AMP	Operational Amplifier
OPTO	Optical
OVP	Over Voltage Protection
PCB	Printed Circuit Board
PORC	Porcelain
POS	Positive
PRIOR	Priority
ROM	Read-Only Memory
RAM	Random Access Memory
RECT	Rectifier
REGIS	Register
RES	Resistor
TBAX	Tube Axial
TRIG	Triggered
UNI	Universal
VAR	Variable
VLTG REG	Voltage Regulator
WW	Wire Wound

Table 6-3. Code List of Manufacturers

CODE	Manufacturer	Address
56289	Sprague Electric Company	North Adams, MA
04713	Motorola Semiconductor Products	Phoenix, AZ
01121	Allen Bradley Company	Milwaukee, WI
24546	Corning Glass Works	Bradford, PA
28480	Hewlett Packard	Palo Alto, CA
01295	Texas Instruments Inc, Semicon Comp Div.	Dallas, TX
27014	National Semiconductor Corporation	Santa Clara,CA
34333	Silicon General Inc.	Westminster, CA
32293	Intersil Inc.	Cupertino, CA
34333	Silicon General Inc.	Westminster, CA

Table 6-4. Replacement Parts List

DESG.	HP PART NO.	TQ	DESCRIPTION	MFR. CODE	MFR. PART NO.
A1	06030-60021	1	MAIN BOARD ASSEMBLY	28480	
B1			See Chassis Electrical		
C1-8	0180-3460	8	fxd elect 1400uf 200V	28480	
C9	0160-5932	1	fxd poly 0.47uf 250V	28480	
C10	0180-3696	1	fxd elect 22uf 250V	28480	
C11,12	0160-6392	2	fxd poly .047uf 20%	28480	
C13,14	0180-3702	2	fxd elect 1600uf 125V -10% +50%	28480	
C15,16	0180-3693	2	fxd elect 1000uf 20%	28480	
C17,18	0180-0291	2	fxd elect 1uf 35V	56289	0150D105X9035A2
*C19	0160-0260	4	fxd cer .047uf 20%	28480	
*C20-23	0160-6392	4	fxd poly .047uf 20%	28480	
C24			NOT USED		
*C25	0160-0269		fxd cer .047uf 20%	28480	
C26			NOT USED		
C27			See Chassis Electrical		
C28			See Chassis Electrical		
C29	0160-4323	1	fxd met .047uf 20% 250VAC	28480	
C30			See Chassis Electrical	28480	
CB1			See Chassis Electrical		
CR1	1901-0028	1	power rect. 400V	28480	
CR2	1901-0731	2	power rect. 400V 1A	28480	
CR3,4	1901-0050	2	diode-switching 80V 200ma	04713	1N4150
CR5	1901-0731		power rect. 400V	28480	
DS1	1990-0325	1	display, single digit	28480	
F1	2110-0001	1	fuse 1A 250V	28480	
F2	2110-0671	1	fuse .125A 125V	28480	
K1	0490-1457	1	Relay DPDT 30A	28480	
K2	0490-1341	1	Relay 1A 6VDC-coil 10A, 240VAC	28480	
L1	06012-80003	1	snubber wire	28480	
	9170-0707	2	ferrite core, (ref. L1)	28480	
L2	9170-1267	1	magnetic core	28480	
	5080-2040	6	jumper for L2	28480	
L3	9140-1064	1	Output Choke	28480	
L4			See Chassis Electrical		
Q1	1855-0456	1	MOSFET N-Chan	28480	
R1-4	0811-1866	4	fxd ww 10k 1% 5W	28480	
R5	0686-3015	1	fxd comp 300 5% 1/2W	01121	EB3015
R6	0811-1803	1	fxd ww 1.3k 5% 3W	28480	
R7	0686-1005	1	fxd comp 10 5%& 1/2W	56289	EB1005
R8	0686-3335	1	fxd comp 33k 5% 1/2W	56289	EB3335
R9	0811-3700	1	fxd ww 20 10% 20W	28480	
R10	0811-3699	1	fxd ww 6 10% 20W	28480	
R11	5080-2079	1	current sensing resistor	28480	
R12,13	0699-0188	2	fxd film 2.2 5% 1/4W	28480	
R14,15			NOT USED		
R16,17	0683-1065	2	fxd comp 10M 5% 1/2W	28480	
R18	0757-0422	1	fxd film 909 1% 1/8W	28480	
R19	0757-0403	1	fxd film 121 1% 1/8W	28480	
R20-23			NOT USED		
R24			See Chassis Electrical		

* Part of output filter, which is mounted on the output buss bars.

Table 6-4. Replacement Parts List (Cont.)

REF. DESG.	HP PART NO.	TQ	DESCRIPTION	MFR. CODE	MFR. PART NO.
R25-R28			Not Used		
R29,30	0811-1909	2	fxd ww .05 5% 10W	28480	
R31	0757-0367	1	fxd film 100k 1% 1/2W	28480	
R32	0686-7535	1	fxd comp 75k 5% 1/2W	01121	EB7535
R33	0757-0451	1	fxd film 24.3k 1% 1/8W	24546	CT4-1/8-TO-2432-F
R34	0757-0438	1	fxd film 5.11k 1% 1/8W	24546	CT4-1/8-TO-5111-F
R35	0698-8827	1	fxd film 1M 1% 1/8W	28480	
R36,37	0811-1909	2	fxd ww 500 5% 10W	28480	
R38,39	0757-0467	2	fxd film 121K 1% 1/8W	24546	CT4-1/8-TO-1213-F
R40			NOT USED		
R41	0811-1869	1	fxd ww 30 3% 3W	28480	
S1	3101-2046	1	switch, DPDT slide	28480	
S2	3101-1914	1	switch, 2-DPDT slide	28480	
S3			See Chassis Electrical		
T1	9100-4350	1	current transformer	28480	
T2	06030-80090	1	power transformer	28480	
T3	5080-1982	1	bias transformer	28480	
U1	1906-0218	1	diode bridge	28480	
U2	1906-0006	2	diode bridge 400	28480	
U3	1826-0393		IC, volt-reg, 1.2/37V	28480	
U4	1906-0006	1	diode bridge 400V	28480	
U5	1826-0643	1	IC, switched-mode ckt	28480	
			A1 MECHANICAL		
	1205-0282	1	heatsink (ref. U3)	28480	
	1205-0562	1	heatsink (ref. U1)	28480	
	2110-0269	2	fuse clip (ref F1)	28480	
	0403-0086	2	bummper foot (ref R9,10)	28480	
	06032-60010	2	output buss bar	28480	
	0340-1095	4	insulator for buss bar	28480	
J1			Not Used		
J2	1251-5384	1	Post-Type Connector,3pin	28480	
J3,4			Not Used		
J5	5060-2877	1	ribbon cable(2inch)(ref.W8)	28480	
J6	5060-2878	1	ribbon cable(4inch)(ref.W7)	28480	
J7,8	1251-0600	6	connector, single contact	28480	
J9,10, L,N,P	1251-5613	5	connector, single contact	28480	
J11-14	1251-0600		connector, single contact	28480	
XA4,5	1252-1052	2	connector 64pin		
A2	06030-60022	1	Control Board Assembly	28480	
C1-4	0160-5422	27	fxd cer .047uf 20% 50V	28480	
C5	0160-4801	3	fxd cer 100pf 5% 100V	28480	
C6-7	0160-5422		fxd cer .047uf 20% 50V	28480	
C8	0160-5892	5	fxd poly .22uf 10%	28480	
C9	0160-5422		fxd cer .047 20% 50V	28480	
C10	0160-4807	3	fxd cer 33pf 5% 100V	28480	
C11	0160-5892		fxd poly .22uf 10%	28480	
C12	0160-4830	2	fxd cer 2200pf 10% 100V	28480	
C13-16	0160-5422		fxd cer .047uf 20% 50V	28480	
C17	0160-4833	2	fxd cer .022uf 10% 100V	28480	
C18	0160-5892		fxd poly .22uf 10%	28480	

Table 6-4. Replacement Parts List (Cont.)

REF. DESG.	HP PART NO.	TQ	DESCRIPTION	MFR. CODE	MFR. PART NO.
C19	0160-5469	1	fxd met 1uf 10% 50V	28480	
C20	0160-5892		fxd poly .22uf 10%.	28480	
C21,22	0160-5422		fxd cer .047uf 20% 50V	28480	
C23			NOT USED	28480	
C24	0160-0162	1	fxd poly .022uf 10% 200V	28480	
C25	0160-4812	7	fxd cer 220pf 5% 100V	28480	
C26	0160-4807		fxd cer 33pf 5% 100V	28480	
C27	0160-5892		fxd poly .22uf 10%	28480	
C28	0160-4834	1	fxd cer .047uf 10% 100V	28480	
C29	0160-5422		fxd cer .047uf 20% 50V	28480	
C30	0160-4807		fxd cer 33pf 5% 100V	28480	
C31	0160-5422		fxd cer .047uf 20% 50V	28480	
C32	0160-5644	1	fxd cer .033uf 10% 50V	28480	
C33	0160-4822	2	fxd cer 1000pf 5% 100V	28480	
C34			NOT USED		
C35	0160-5422		fxd cer .047uf 20% 50V	28480	
C36	0160-4812		fxd cer 220pf 5% 100V	28480	
C37			NOT USED		
C38-40	0160-5422		fxd cer .047uf 20% 50V	28480	
C41	0160-4831	1	fxd cer 4700pf 10% 100V	28480	
C42	0160-4812		fxd cer 220pf 5% 100V	28480	
C43	0160-4831		fxd cer 4700pf 10% 100V	28480	
C44	0160-5422		fxd cer .047uf 20% 50V	28480	
C45	0160-4812		fxd cer 220pf 5% 100V	28480	
C46	0160-5166	1	fxd cer .015uf 20% 100V	28480	
C47	0160-5422		fxd cer .047uf 20% 50V	28480	
C48,49	0160-4835	5	fxd cer .1uf 10% 50V	28480	
C50	0180-0291	2	fxd elect 1uf 10% 35V	56289	150D105X9035A2
C51	0180-1731	2	fxd cer 4.7uf 100V	28480	
C52	0180-0230	2	fxd elect 1uf 20% 50V	56289	150D105X9035A2
C53	0180-1731		fxd cer 4.7uf 100V	28480	
C54	0180-0291		fxd elect 1uf 10% 35V	56289	150D105X9035A2
C55	0180-0230		fxd elect 1uf 20% 50V	56289	150D105X0050A2
C56,57	0160-5422		fxd cer .047uf 20% 50V	28480	
C58	0160-4801		fxd cer 100pf 5% 100V	28480	
C59	0160-4835		fxd cer .1uf 10% 50V	28480	
C60	0160-5422		fxd cer .047uf 20% 50V	28480	
C61	0160-4812		fxd cer 220pf 5% 100V	28480	
C62	0160-4835		fxd cer .1uf 10% 50V	28480	
C63	0180-1980	1	fxd elect 1uf 5% 35V	56289	0150D105X5035A2
C64	0180-0116	1	fxd elect 6.8uf 10% 35V	56289	0150D685X9035B2
C65	0160-5422		fxd cer .047uf 20% 50V	28480	
C66	0160-4801		fxd cer 100pf 5% 100V	28480	
C67	0160-5422		fxd cer .047uf 20% 50V	28480	
C68	0160-4822	1	fxd cer 1000pf 5% 100V	28480	
C69,70	0160-5422		fxd cer .047uf 20% 50V	28480	
C71	0180-0376	1	fxd elect .47uf 10% 35V	56289	150D474X9035A2
C72	0180-2624	1	fxd elect 2000uf 10V	28480	
C73	0180-3407	1	fxd elect 2200uf 35V	28480	
C74,75	0160-5098	2	fxd cer .22uf 10% 50V	28480	
C76	0160-4835		fxd cer .1uf 10% 50V	28480	
C77	0160-4833		fxd cer .022uf 10% 100V	28480	
C78	0160-4832	2	fxd cer .01uf 10% 100V	28480	
C79	0160-4830		fxd cer 2200pf 10% 100V	28480	

Table 6-4. Replacement Parts List (Cont.)

REF. DESG.	HP PART NO.	TQ	DESCRIPTION	MFR. CODE	MFR. PART NO.
C80	0160-4813	1	fxd cer 180pf 5% 100V	28480	
C81	0160-5422		fxd cer .o47uf 20% 50V	28480	
C82	0160-4812		fxd cer 220pf 5% 100V	28480	
C83	0160-5422		fxd cer .047uf 20% 50V	28480	
C84	0160-4812		fxd cer 220pf 5% 100V	28480	
C85	0160-4832		fxd cer .01uf 10% 100V	28480	
CR1-6	1901-0033	12	gen prp 180V 200ma	04713	1N645
CR7,8	1901-0050	19	switching 80V 200ma	04713	1N4150
CR9,10	1901-0033		gen prp 180V 200ma	04713	1N645
CR11	1901-0050		switching 80V 200ma	04713	1N4150
CR12	1901-0033		gen prp 180V 200ma	04713	1N645
CR13,14	1901-0050		switching 80V 200ma	04713	1N4150
CR15,16	1901-0033		gen prp 180V 200ma	04713	1N645
CR17,18	1901-0050		switching 80V 200ma	04713	1N4150
CR19	1901-0033		gen prp 180V 200ma	04713	1N645
CR20-31	1901-0050		switching 80V 200ma	04713	1N4150
CR32	1901-0992	1	schottky 40V 3A	28480	
L1	06023-80090	1	choke	28480	
Q1-3	1854-0823	4	NPN Si	28480	
Q4-6	1855-0413	3	J-FET P-chan Si	28480	
Q7	1854-0823		NPN Si	28480	
Q8	1853-0012	1	PNP Si	28480	
Q9	1854-0635	1	NPN Si	28480	
Q10	1853-0036	1	PNP Si	28480	
Q11	1858-0023	1	transistor array	28480	
R1,2	0686-5125	4	fxd comp 5.1K 5% 1/2W	01121	EB525
R3	0683-5125	2	fxd film 5.1K 5% 1/4W	01121	CB5125
R4	0757-0483	1	fxd film 562K 1% 1/8W	28480	
R5	0683-2015	2	fxd film 200 5% 1/4W	01121	CB2015
R6	0698-6615	1	fxd film 3.75K .1%	28480	
R7	0683-5125		fxd film 5.1K 5% 1/4W	01121	CB5125
R8	2100-3353	2	trimmer 20K 10%	28480	
R9	2100-3352	1	trimmer 1K 10%	28480	
R10	0698-3433	1	fxd film 28.7 1% 1/8W	28480	
R11,12	0757-0465	4	fxd film 100K 1% 1/8W	24546	CT4-1/8-TO-1003-F
R13	0698-3430	1	fxd film 21.5 1% 1/8W	28480	
R14,15	0686-5125		fxd comp 5.1K 1/2W	01121	EB5125
R16	0683-2015		fxd film 200 5% 1/4W	01121	CB2015
R17	0698-7082	1	fxd film 100K 1% 1/8W	28480	
R18	0683-1025	3	fxd film 1K 5% 1/4W	01121	CB1025
R19	0757-0442	5	fxd film 10K 1% 1/8W	24546	CT4-1/8-TO-1002-F
R20	0686-5135	2	fxd comp 51K 5% 1/2W	01121	EB5135
R21	2100-3274	2	trimmer 10K 10%	28480	
R22	2100-3353	1	trimmer 20K 10%	28480	
R23	2100-3273	2	trimmer 2K 10%	28480	
R24	2100-3350	1	trimmer 200 10%	28480	
R25	2100-3273		trimmer 2K 10%	28480	
R26	2100-3274		trimmer 10K 10%	28480	
R27	0757-0470	2	fxd film 162K 1% 1/8W	28480	
R28	0757-0464	2	fxd film 90.9K 1% 1/8W	24546	CT4-1/8-TO-9092-F
R29	0698-4509	1	fxd film 80.6K 1% 1/8W	24546	CT4-1/8-TO-8062-F
R30	0757-0280	3	fxd film 1K 1% 1/8W	24546	CT4-1/8-TO-1001-F
R31	0698-3260	1	fxd film 464K 1% 1/8W	28480	
R32	0698-8827	2	fxd film 1M 1% 1/8W	28480	

Table 6-4. Replacement Parts List (Cont.)

REF. DESG.	HP PART NO.	TQ	DESCRIPTION	MFR. CODE	MFR. PART NO.
R33	0698-3449	1	fxd film 28.7K 1% 1/8W	24546	CT4-1/8-T0-2872-F
R34	0757-0458	2	fxd film 51.1K 1% 1/8W	24546	CT4-1/8-T0-5112-F
R35	0683-1055	1	fxd film 1M 5% 1/4W	01121	CB1055
R36	0698-3455	2	fxd film 261K 1% 1/8W	24546	CT4-1/8-T0-2613-F
R37,38	0698-4536	2	fxd film 340K 1% 1/8W	28480	
R39	0683-4725	8	fxd film 4.7K 5% 1/4W	01121	CB4725
R40	0699-1210	1	fxd film 80K .1% .1W	28480	
R41	0699-1744	1	fxd film 280K 1% .1W	28480	
R42	0699-1742	2	fxd film 70K .1% .1W	28480	
R43	0699-1743	1	fxd film 345K .1% .1W	28480	
R44	0757-0199	4	fxd film 21.5K 1% 1/8W	24546	CT4-1/8-T0-2152-F
R45	0698-8816	1	fxd film 2.15 1% 1/8W	28480	
R46	0683-1255	1	fxd film 1.2M 5% 1/4W	01121	CB1255
R47	0757-0470		fxd film 162K 1% 1/8W	28480	
R48	0757-0458		fxd film 51.1K 1%	24546	CT4-1/8-T0-5112-F
R49	0699-1745	2	fxd film 560K .1% 1/4W	28480	
R50	0686-5135	3	fxd film 51K 5% 1/2W	01121	EB5135
R51			jumper (see W1-3)		
R52	0699-1742	1	fxd film 70K .1% .1W	28480	
R53	0757-0451	3	fxd film 24.3K 1% 1/8W	24546	CT4-1/8-T0-2432-F
R54	0698-3450	1	fxd film 42.2K 1% 1/8W	24546	CT4-1/8-T0-4222-F
R55	0757-0451		fxd film 24.3K 1% 1/8W	24546	CT4-1/8-T0-2432-F
R56	0757-0199		fxd film 21.5K 1% 1/8W	24546	CT4-1/8-T0-2152-F
R57	0698-3155	1	fxd film 4.64K 1% 1/8W	24546	CT4-1/8-T0-4641-F
R58	0757-0344	2	fxd film 1M 1% 1/4W	24546	NA5-1/4-T0-1004-F
R59,60	0698-4486	1	fxd film 24.9K 1% 1/8W	24546	CT4-1/8-T0-2492-F
R61	0757-0344		fxd film 1M 1% 1/4W	24546	NA5-1/4-T0-1004-F
R62	0757-0124	3	fxd film 39.2K 1% 1/8W	28480	
R63	0683-1015	2	fxd film 100 5% 1/4W	01121	CB1015
R64	0757-0124		fxd film 39.2K 1% 1/8W	28480	
R65			NOT USED		
R66	0683-4725		fxd film 4.7K 5% 1/4w	01121	CB4725
R67			NOT USED		
R68	0757-0270	1	fxd film 249K 1% 1/8W	24546	CT4-1/8-T0-2493-F
R69	0683-1015		fxd film 100 5% 1/4W	01121	CB1015
R70	0757-0449	1	fxd film 20K 1% 1/8W	24546	CT4-1/8-T0-2002-F
R71	0698-0085	1	fxd film 2.61K 1% 1/8W	24546	CT4-1/8-T0 2611-F
R72	0757-0452	1	fxd film 27.4K 1% 1/8W	24546	CT4-1/8-T0-2742-F
R73	0757-0289	1	fxd film 13.3K 1% 1/8W	28480	
R74	0757-0460	1	fxd film 61.9K 1% 1/8W	24546	CT4-1/8W-T0-6192-
R75	0698-8827		fxd film 1M 1% 1/8W	28480	
R76	0757-0438		fxd film 5.11K 1% 1/8W	24546	CT4-1/8-T0-5111-F
R77	0683-4715	3	fxd film 470 5% 1/4W	01121	CB4715
R78	0698-6322	2	fxd film 4K 1% 1/8W	28480	
R79,80	0683-2035	3	fxd film 20K 5% 1/4W	01121	CB2035
R81	0757-0419	1	fxd film 681 1% 1/8W	24546	CT4-1/8-T0-681R-F
R82	0683-4715		fxd film 470 5% 1/4W	01121	CB4715
R83	0698-6322		fxd film 4K 1% 1/8W	28480	
R84	0698-6320	1	fxd film 5K .1% 1/8W	28480	
R85	0698-6983	1	fxd film 20.4K .1% 1/8W	28480	
R86	0757-0465		fxd film 100K 1% 1/8W	24546	CT4-1/8-T0-1003-F
R87	0698-7933	1	fxd film 3.83K .1% 1/8W	28480	
R88	0699-1745		fxd film 500 .1% 1/8W	28480	
R89-91	0683-2225	8	fxd film 2.2K 5% 1/4W	01121	CB2225

Table 6-4. Replacement Parts List (Cont.)

REF. DESG.	HP PART NO.	TQ	DESCRIPTION	MFR. CODE	MFR. PART NO.
R92	0898-4480		fxd film 15.8K 1% 1/8W	24546	CT4-1/8-T0-1582-F
R93	0683-3325	1	fxd film 3.3K 5% 1/4W	01121	CB3325
R94,95	0683-2225		fxd film 2.2K 5% 1/4W	01121	CB2225
R96	0757-0481	1	fxd film 475K 1% 1/8W	28480	
R97	0757-0290	1	fxd film 6.19K 1% 1/8W	28480	
R98	0757-0444	2	fxd film 12.1K 1% 1/8W	24546	CT4-1/8-T0-1212-F
R99	0698-4416	5	fxd film 169 1% 1/8W	24546	CT4-1/8-T0-169R-F
R100	0757-0404	5	fxd film 130 1% 1/8W	24546	CT4-1/8-T0-131-F
R101	0698-4608	1	fxd film 806 1% 1/4W	24546	CT4-1/4-T0-806R-F
R102	0698-4447	1	fxd film 280 1% 1/8W	24546	CT4-1/8-T0-280R-F
R103	0698-4416		fxd film 169 1% 1/8W	24546	CT4-1/8-T0-169R-F
R104,105	0683-4725		fxd film 4.7K 5% 1/4W	01121	CB1025
R106-109	0757-0404		fxd film 130 5% 1/4W	24546	CT4-1/8-T0-131-F
R107	0683-1815	2	fxd film 180 5% 1/4W	01121	CB1815
R108	0683-2715		fxd film 270 5% 1/4W	01121	CB2715
R109	0683-1815		fxd film 180 5% 1/4W	01121	CB1815
R110	0683-5105	1	fxd film 51 5% 1/4W	01121	CB5105
R111	0683-2035		fxd film 20K 5% 1/4W	01121	CB2035
R112	0757-0199		fxd film 21.5K 1% 1/8W	24546	CT4-1/8-T0-2152-F
R113	0757-0283	3	fxd film 2K 1% 1/8W	24546	CT4-1/8-T0-2001-F
R114	0683-2225		fxd film 2.2K 5% 1/4W	01121	CB2225
R115	0757-0280		fxd film 1K 1% 1/8W	24546	CT4-1/8-T0-1001-F
R116,117	0757-0346	2	fxd film 10 1% 1/8W	28480	
R118	0698-3498	1	fxd film 8.66K 1% 1/8W	24546	CT4-1/8-T0-866R-F
R119	0757-0438		fxd film 5.11K 1% 1/8W	24546	CT4-1/8-T0-5111-F
R120	0683-4725		fxd film 4.7K 5% 1/4W	01121	CB4725
R121	0683-2025	3	fxd film 2K 5% 1/4W	01121	CB2025
R122	0683-1025		fxd film 1K 5% 1/4W	01121	CB1025
R123	0683-4715		fxd film 470 5% 1/4W	01121	CB4715
R124	0757-0442		fxd film 10K 1% 1/8W	24546	CT4-1/8-T0-1002-F
R125	0757-0465		fxd film 100K 1% 1/8W	24546	CT4-1/8-T0-1003-F
R126	0757-0442		fxd film 10K 1% 1/8W	24546	CT4-1/8-T0-1002-F
R127	0698-8827	1	fxd film 1M 1% 1/8W	28480	
R128	0698-3136	2	fxd film 17.8k 1% 1/8W	24546	CT4-1/8-T0-1782-F
R129	0698-4121	1	fxd film 11.3K 1% 1/8W	28480	
R130			NOT USED		
R131	0757-0449		fxd film 20K 1% 1/8W	24546	CT4-1/8-T0-2002-F
R132	1810-0205		resistor network	28480	
R133	0683-5625	1	fxd film 5.6K 5% 1/4W	01121	CB5625
R134	0683-1025		fxd film 1K 5% 1/4W	01121	CB1025
R135	0683-1855	1	fxd film 1.8M 5% 1/4W	01121	CB1855
R136	0757-0420	1	fxd film 750 1% 1/4W	24546	CT4-1/8-T0-751-F
R137	0698-4435	1	fxd film 2.49K 1% 1/8W	24546	CT4-1/8-T0-2491-F
R138	0757-0199		fxd film 21.5K 1% 1/8W	24546	CT4-1/8-T0-2152-F
R139	0683-4725		fxd film 4.7K 5% 1/4W	01121	CB4725
R140	0683-2025		fxd film 2K 5% 1/4W	01121	CB2025
R141	0683-5135		fxd film 51K 5% 1/4W	01121	CB5135
R142	0683-6835	1	fxd film 68K 5% 1/4W	01121	CB6835
R143	0683-4725		fxd film 4.7K 5% 1/4W	01121	CB4725
R144	0757-0415	1	fxd film 475 1% 1/8W	24546	CT4-1/8-T0-475R-F
R145	0683-1005	2	fxd film 10 5% 1/4W	01121	CB1005
R146	0683-1035	2	fxd film 10K 5% 1/4W	01121	CB1035
R147	0683-5115		fxd film 510 5% 1/4W	01121	CB5115
R148	0757-0422	1	fxd film 909 1% 1/8W	01121	CT4-1/8-T0-909R-F

Table 6-4. Replacement Parts List (Cont.)

REF. DESG.	HP PART NO.	TQ	DESCRIPTION	MFR. CODE	MFR. PART NO.
R149	0683-2025		fxd film 2K 5% 1/4W	01121	CB2025
R150	0754-0404		fxd film 130 5% 1/4W	24546	CT4-1/8-T0-131-F
R151	0683-4725		fxd film 4.7K 5% 1/4W	01121	CB4725
R152	0757-0442		fxd film 10K 1% 1/8W	24546	CT4-1/8-T0-1002-F
R153	0757-0443	1	fxd film 11K 1% 1/8W	24546	CT4-1/8-T0-1102-F
R154	0757-0451	1	fxd film 24.3K 1% 1/8W	24546	CT4-1/8-T0-2432-F
R155	0757-0444		fxd film 12.1K 1% 1/8W	24546	CT4-1/8-T0-1212-F
R156	0683-4725		fxd film 4.7K 5% 1/4W	01121	CB4725
R157	0683-1005	1	fxd film 10 5% 1/4W	01121	CB1005
R158	0686-2005	1	fxd comp 20 5% 1/2W	01121	EB2005
R159,160	0686-6215	2	fxd comp 620 5% 1/2W	01121	EB6215
R161	0757-0283		fxd film 2K 1% 1/8W	24546	CT4-1/8-T0-2001-F
R162	0757-0442		fxd film 10K 1% 1/8W	24546	CT4-1/8-T0-909R-F
R163	0757-0283		fxd film 2K 1% 1/8W	24546	CT4-1/8-T0-2001-F
R164	0757-0434	1	fxd film 3.65K 1% 1/8W	24546	CT4-1/8-T0-3651-F
R165	0683-1035		fxd film 10K 5% 1/4W	01121	CB1035
R166,167	0686-1315	2	fxd comp 130 5% 1/2W	01121	EB1315
R168	0683-1515	1	fxd comp 150 5% 1/4W	01121	EB1515
R169	0757-0124		fxd film 39.2K 1% 1/8W	28480	
R170	0698-3136		fxd film 17.8K 1% 1/8W	24546	CT4-1/8-T0-1782-F
R171	0757-0280		fxd film 1K 1% 1/8W	24546	CT4-1/8-T0-1001-F
R172	0811-3174	1	fxd WW .07 5% 5W	28480	
R173	0683-2225		fxd film 2.2K 5% 1/4W	01121	CB2225
R174	0683-3625	1	fxd film 3.6K 5% 1/4W	01121	CB3625
R175	0683-1525	1	fxd film 1.5K 55 1/4W	01121	CB1525
R176	0683-2225		fxd film 2.2K 5% 1/4W	01121	CB2225
R177	0683-0335	1	fxd film 3.3 5% 1/4W	01121	CB33G5
R178,179	0683-4725		fxd film 4.7K 5% 1/4W	01121	CB4725
R180	0683-1045	1	fxd film 100K 5% 1/4W	01121	CB1045
R181	0683-3335	1	fxd film 33K 5% 1/4W	01121	CB3335
R182	0698-8827		fxd film 1M 1% 1/8W	28480	
S1	3101-2097	1	switch (6) 1A	28480	
U1-3	1826-0493	3	IC op-amp	27014	LM308AN
U4,5	1826-0161	2	IC op-amp	32293	8007C
U6	1826-0346	1	IC op-amp	27014	LM358N
U7	1826-0544	2	IC voltage regulator	34333	SG3503Y
U8	1826-0138	2	IC voltage reg. dual trkg.	34333	SG1468J
U9	1820-0935	1	IC counter CMOS	04713	MC14020BCP
U10	1826-0065	2	IC comparator	27014	LM311N
U11	1826-0393	1	IC voltage regulator	27014	LM317T
U12	1826-0527	1	IC voltage regulator	27014	LM337T
U13	1820-1287	1	IC buffer TTL LS	01295	SN74LS37N
U14			NOT USED		
U15	1820-1272	1	IC buffer TTL LS	01295	SN74LS33N
U16	1820-1437	1	IC multivibrator TTL LS	01295	SN74LS221N
U17	1826-0138		IC comparator	01295	LM339N
U18	1820-1205	1	IC gate TTL LS	01295	SN74LS21N
U19	1820-1112	1	IC flip flop D-type	01295	SN74LS74AN
U20	1820-2096	1	IC counter TTL LS	01295	SN74LS393N
U21	1826-0544		IC voltage reg	34333	SG3503Y
U22	1826-0428	1	IC voltage regulator	34333	SG3524J
U23	1826-0065		IC comparator	27014	LM311N
VR1	1902-3110		zener 5.9V 2%	28480	
VR2	1902-0777	1	zener 6.2V	04713	1N825

Table 6-4. Replacement Parts List (Cont.)

REF. DESG.	HP PART NO.	TQ	DESCRIPTION	MFR. CODE	MFR. PART NO.
VR3,4	1902-0018	2	zener 6.8V	28480	
VR5	1902-0575	1	zener 6.5V 2%	28480	
VR6			jumper (see W1-3)	28480	
W1-3, R51,VR6	7175-0057	3	jumper	28480	
Y1	0960-0586	1	resonator- cer	28480	
			A2 MECHANICAL		
	1205-0282	3	heat sink (Q9,U11,U12)	28480	
	1200-0485	1	IC socket (S1)	28480	
	1200-0181	1	insulator, (Q8)	28480	
J1,2	1251-8417	2	connector 16-pin	28480	
J3	1251-7743	1	connector 26-pin	28480	
J4	1251-8676	1	connector 5-pin	28480	
J5,6	1251-5240	2	connector 20-pin	28480	
J15	1251-0600	1	connector 1-pin	28480	
TB1	0360-2195	1	barrier block 6-pos.	28480	
TB2	0360-2192	1	barrier block 2-pos.	28480	
A3	06010-60020	1	Front Panel Board	28480	
C1	0160-5893	2	fxd plyprpln .047uf 10% 100V	28480	
C2	0160-0168	2	fxd poly 0.1uf 10% 200V	28480	
C3	0160-4835	3	fxd cer 0.1uf 10% 50V	28480	
C4-6	0160-5422	8	fxd cer .047uf 20% 50V	28480	
C7			NOT USED		
C8	0160-5893		fxd plyprpln .047uf 10% 100V	28480	
C9	0160-0168		fxd poly 0.1uf 10% 100V	28480	
C10	0160-4835		fxd cer 0.1uf 10% 50V	28480	
C11	0160-5422		fxd cer .047uf 20% 50V	28480	
C12			NOT USED		
C13	0160-4835		fxd cer 0.1uf 10% 50V	28480	
C14	0160-5422		fxd cer .047uf 20% 50V	28480	
C15	0160-4831	1	fxd cer 4700pf 10% 100V	28480	
C16	0160-4807	1	fxd cer 33pf 5% 100V	28480	
C17-19	0160-5422		fxd cer .047uf 20% 50V	28480	
CR1,2	1901-0050	2	photoswitch IF=350ma VAX=15V	12969	5015
CR3-5	1901-0033	3	diode gen prp 180V 200ma	12969	1N645
DS1-8	1990-0985	1	display kit	28480	
DS9,10	1990-0995	2	led green IF=30ma BVR=5V	28480	
DS11-13	1990-0895	3	led yellow IF=20ma BVR=5V	28480	
R1-17	0683-2015	53	fxd film 200 5% 1/4W	01121	CB2015
R18	0698-3456	2	fxd film 287K 1% 1/8W	24546	CT4-1/8-TO-2873-F
R19-37	0683-2015		fxd film 200 5% 1/4W	01121	CB2015
R38	0683-1045	2	fxd film 100K 5% 1/4W	01121	CB1045
R39			NOT USED		
R40-44	0683-2015		fxd film 200 5% 1/4W	01121	CB2015
R45	0698-3456		fxd film 287K 1% 1/8W	01121	CB2015
R46-54	0683-2015		fxd film 200 5% 1/4W	24546	CT4-1/8-TO-2873-F
R55	0683-1045		fxd film 100K 5% 1/4W	01121	CB1045
R56	0698-8871	1	fxd film 953 1% 1/8W	28480	

Table 6-4. Replacement Parts List (Cont.)

REF. DESG.	HP PART NO.	TQ.	DESCRIPTION	MFR. CODE	MFR. PART NO.
R57			NOT USED		
R58	0698-0533	1	fxd film 4.64K 0.1% 1/8W	28480	
R59	0683-6215	1	fxd film 620 5% 1/4W	01121	CB6215
R60-62	0683-2015		fxd film 200 5% 1/4W	01121	CB2015
R63	0683-5125	2	fxd film 5.1K 5% 1/4W	28480	
R64	0683-1025	3	fxd film 1K 5% 1/4W	01121	CB1025
R65,66	0683-5615	2	fxd film 560 5% 1/4W	01121	CB5615
R67	0757-0449	1	fxd film 20K 1% 1/8W	24546	CT4-1/8-TO-2002-F
R68	0698-3201	1	fxd film 80K 1% 1/8W	24546	CT4-1/8-TO-8002-F
R69	0757-0442	1	fxd film 10K 1% 1/8W	24546	CT4-1/8-TO-1002-F
R70	0698-7353	1	fxd film 19K 1% 1/8W	24546	CT4-1/8-TO-1902-F
R71	0757-0280	1	fxd film 1K 1% 1/8W	28480	
R72	0698-6362	1	fxd film 1K 0.1% 1/8W	28480	
R73	0757-0452	2	fxd film 27.4K 1% 1/8W	24546	CT4-1/8-TO-2742-F
R74			NOT USED		
R75	0683-5135	3	fxd film 51K 5% 1/4W	28480	
R76	0757-0441	1	fxd film 8.25K 1% 1/8W	24546	CT4-1/8-TO-8251-F
R77	0698-3159	1	fxd film 26.1K 1% 1/8W	24546	CT4-1/8-TO-2612-F
R78	0757-0458	1	fxd film 51.1K 1% 1/8W	24546	CT4-1/8-TO-5112-F
R79	0683-1025		fxd film 1K 5% 1/4W	01121	CB1025
R80	0683-5135		fxd film 51K 5% 1/4W	01121	CB5135
R81	0683-3025	1	fxd film 3K 5% 1/4W	01121	CB3025
R82	0683-1025		fxd film 1K 5% 1/4W	01121	CB1025
R83	0698-6363	1	fxd film 9K 0.1% 1/8W	28480	
R84	0698-6563	1	fxd film 40K 0.1% 1/8W	28480	
R85	0757-0438	1	fxd film 5.11K 1% 1/8W	24546	CT4-1/8-TO-5111-F
R86	0683-5135		fxd film 51K 5% 1/4W	01121	CB5135
R87	0757-0199	1	fxd film 21.5K 1% 1/8W	24546	CT4-1/8-TO-2152-F
R88	0683-3925	1	fxd film 3.9K 5% 1/4W	01121	CB3925
R89	0698-5808	1	fxd film 4K 1% 1/8W	24546	CT4-1/8-TO-4001-F
R90	0686-6815	1	fxd comp 680 5% 1/2W	01121	EB6815
R91	0757-0452		fxd film 27.4K 1% 1/8W	24546	CT4-1/8-TO-2742-F
R92			NOT USED		
R93	0683-2025	1	fxd film 2K 5% 1/4W	01121	CB2025
R94	0757-0280	1	fxd film 1K 1% 1/8W	24546	CT4-1/8-TO-1001-F
R95	0683-1035	1	fxd film 10K 5% 1/4W	01121	CB1035
R96	0683-5125		fxd film 5.1K 5% 1/4W	01121	CB5125
R97	2100-1775	1	var. ww. trimmer 5K 5%	28480	
R98	0698-4457	1	fxd film 576 ohms 1% 1/8W	28480	
R99,100			See Chassis Electrical		
S1,2	5060-9436	2	switch, rockerarm	28480	
U1,2	1826-0876	2	IC Converter A/D CMOS	32293	ICL7107CPL
U3	1820-1144	1	IC NOR Gate TTL LS Quad	01295	SN74LS02N
U4	1826-0502	2	Analog Switch,4SPST,14pin dip	04713	MC14066BCP
U5	1826-0138	1	IC Comparator,quad,14pin dip	27014	LM339N
U6	1826-0493	1	IC Op Amp,Low-Bias-Hi-Impd.	27014	LM308AN
U7	1826-0346	1	IC Op Amp, gen. purpose	27014	LM358N
U8	1826-0502		Analog Switch,4SPST,14pin dip	04713	MC14066BCP
VR1	1902-3092	1	diode, zener, 4.99V 2%	28480	
VR2	1902-0064	1	diode, zener, 7.5V 5%	28480	
W1	8159-0005	1	res. 0 ohms	28480	
W2,4	7175-0057	3	jumper, solid tinned copper	28480	
W3,5-7			NOT USED	28480	
W8	7175-0057		jumper, solid tinned copper	28480	

Table 6-4. Replacement Parts List (Cont.)

REF. DESG.	HP PART NO.	TQ	DESCRIPTION	MFR. CODE	MFR. PART NO.
			A3 MECHANICAL		
J3	1251-5055	1	Connector Post Type	28480	
	5041-0309	2	key cap (ref. S1,S2)	28480	
A4	06011-60023		FET Board		
C1	0160-4569	2	fxd poly .01uf 10% 800Vdc	28480	
C2	0160-5981	2	fxd poly .047uf 10% 630Vdc	28480	
C3	0160-4569		fxd poly .01uf 10% 800Vdc	28480	
C4	0160-5981		fxd poly .047uf 10% 630Vdc	28480	
C5,6	0160-4835	2	fxd cer .1uf 10% 50V	28480	
C7	0180-0116	1	fxd elect 6.8uf 10% 35V	56289	150D685X9035B2X
C8	0180-0228	1	fxd elect 22uf 10% 15V	56289	150D226X9015B2
CR1	1901-1137	2	pwr rect. 600V	28480	
CR2,3	1901-1087	2	pwr rect. 600V	04713	MR856
CR4	1901-1137		pwr rect. 600V		
CR5-11	1901-0050	7	diode-switching 80V 200ma	04713	1N4150
F1,2	2110-0671	2	fuse .125A 125V	28480	
L1-4	9100-1610	4	coil 150uH 20%	28480	
Q1-4	1855-0473	4	MOS FET N chan.	28480	
Q5,6	1854-0585	2	NPN Si	04713	MJE182
R1-4	0811-1065	4	fxd ww 0.2 5% 1/2W	28480	
R5-8	0698-3609	8	fxd met 22 5% 2W	27167	FP42-2-T00-22R0-J
R9-11	0698-5139	5	fxd comp 3.9 5% 5W	01121	EB39G5
R12	0757-0466	2	fxd film 110K 1% 1/8W	24546	CT4-1/8-T0-1103-F
R13-16	0698-3609		fxd met 22 5% 2W	27167	FP42-2-T00-22R0-J
R17-19	0698-5139		fxd comp 3.9 5% .5W	01121	EB39G5
R20	0757-0379	2	fxd film 12.1 1% 1/8W	28480	
R21	0683-1505	2	fxd film 15 5% 1/4W	01121	EB1505
R22	0683-1815	2	fxd film 180 5% 1/4W	01121	EB1815
R23,24	0686-2005	2	fxd comp 20 5% 1/2W	01121	EB2005
R25	0757-0466		fxd film 110K 1% 1/8W	24546	CT4-1/8-T0-1103-F
R26	0683-1815		fxd film 180 5% 1/4W	01121	EB1815
R27	0757-0379		fxd film 12.1 1% 1/8W	28480	
R28	0683-1505		fxd film 5% 1/4W	01121	EB1505
R29-33	0683-0475	5	fxd film 4.7 5% 1/4W	01121	CB47G5
R34	0683-0275	1	fxd film 2.7 5% 1/4W	01121	CB27G5
TS1	3103-0081	1	switch-therm +202F	28480	
T1	06011-80091	1	transformer	28480	
T2	06011-80095	1	transformer	28480	
U1-3	1820-1050	3	DRVR TTL NOR DUAL	01295	SN75454BP
VR1,2	1902-0779	2	zener 11.8V 5%	28480	
			A4 MECHANICAL		
	1205-0398	2	heatsink (ref CR1,4)	28480	
	1252-0093	8	socket pin (ref Q1-4)	28480	
	06032-20001	2	heatsink (ref Q1,Q2)	28480	
	06032-20002	2	heatsink (ref Q3,Q4)	28480	
	0380-1524	7	standoff (8mm)	28480	
P1	1252-1053	1	connector 64-pin	28480	

Table 6-4. Replacement Parts List (Cont.)

REF. DESG.	HP PART NO.	TQ	DESCRIPTION	MFR. CODE	MFR. PART NO.
A5	06030-60024		Diode Board		
C1	0180-3167	1	fxd elect 1000uf 20% 25V	28480	
C2	0160-5464	2	fxd poly .01uf 5% 1.5KVdc	28480	
C3	0160-5422	1	fxd cer .047uf 20% 50Vdc	28480	
C4	0160-4832	1	fxd cer .01uf 10% 100Vdc	28480	
C5	0160-5464		fxd poly .o1uf 5% 1.5KVdc	28480	
C6			see chassis electrical		
CR1	1901-0050	2	diode-switching 80V 200ma	28480	
CR2	1901-0731	1	pwr rectifer 400V 1A	28480	
CR3	1901-0050		diode-switching 80V 200ma	28480	
CR4,5	1901-1182	2	pwr rectifier 400V 50A	28480	
F1			NOT USED		
Q1	1855-0486	1	MOS FET N chan	28480	
L1,2	9170-1334	2	ferrite core for L1,2	28480	
R1	0683-1855	1	fxd film 1.8M 5% 1/4W	01121	CB1855
R2	0698-4444	1	fxd film 1% 1/8W	24546	CT4-1/8-T0-4871-F
R3	0757-0459	1	fxd film 56.2K 1% 1/8W	24546	CT4-1/8-T0-5622-F
R4	0698-3202	1	fxd film 1.74K 1% 1/8W	24546	CT4-1/8-T0-1741-F
R5	0757-0317	1	fxd film 1.33K 1% 1/8W	24546	CT4-1/8-T0-1331-F
R6	0683-1045	1	fxd film 100K 5% 1/4W	01121	CB1045
R7	0683-2735	1	fxd film 5% 1/4W	01121	CB2735
R8	0698-7332	1	fxd film 1M 1% 1/8W	28480	
R9	0698-8144	2	fxd film 787K 1% 1/8W	28480	
R10	0698-3512	1	fxd film 1.18K 1% 1/8W	24546	CT4-1/8-T0-1181-F
R11			NOT USED		
R12	0757-0447	1	fxd film 16.2K 1% 1/8W	24546	CT4-1/8-T0-1622-f
R13	0683-1005	1	fxd film 10 5% 1/4W	01121	CB1005
R14	0811-1746	1	fxd ww .36 5% 2W	28480	
R15-18	0811-3729	4	fxd ww 250 5% 10W	28480	
R19	0689-8144		fxd film 787K 1% 1/8W	28480	
R20	0811-3731	1	fxd ww 1.2 5% 2W	28480	
TS1	3103-0082	1	switch-thermal 200 degree/C	28480	
U1	1826-0346	1	IC OP-Amp	28480	
VR1	1902-0575	1	zener 6.5V 2%	28480	
			A5 MECHANICAL		
	1205-0398	1	heatsink (ref Q1)	28480	
	1251-7600	2	connector sgl. cont. skt.	28480	
	06030-00003	1	front heatsink (ref CR5)	28480	
	06030-00004	1	rear heatsink (ref CR4)	28480	
P1	1251-1053	1	connector 64-pin	28480	
	0340-1123	6	Insulator (ref L1,2)	28480	
	5080-2065	6	Jumper (ref L1,2)	28480	

Table 6-4. Replacement Parts List (Cont.)

REF. DESG.	HP PART NO.	TQ	DESCRIPTION	MFR. CODE	MFR. PART NO.
A6	06011-60025		AC Input Filter		
C1	0160-4355	2	fxd met .01uf 10% 250Vac	28480	
C2	0160-4281	2	fxd met 2200pf 20% 250Vac	28480	
C3	0160-4355		fxd met .01uf 10% 250Vac	28480	
C4	0160-4281		fxd met 2200pf 20% 250Vac	28480	
C5	0160-4962	3	fxd poly 1uf 20% 250Vac	28480	
C6,7	0160-4183	2	fxd met 1000pf 20% 250Vac	28480	
C8,9	0160-4962		fxd poly 1uf 20% 250V	28480	
L1	06011-80094	1	choke, input	28480	
R1	0686-3945	1	fxd comp 390K 5% .5W	01121	EB3545
			A6 MECHANICAL		
TB1	0360-2217	1	Barrier Block 3-pos	28480	
			CABLING		
W1	06011-60001	1	ribbon cable (A2 to A3)		
			CHASSIS MECHANICAL		
	5021-5803	1	front frame casting	28480	
	5040-7202	1	top trim strip	28480	
	5001-0439	2	side trim strip	28480	
	06032-00015	1	front sub-panel	28480	
	06010-00008	1	lettered front panel	28480	
	0370-1091	2	knobs (ref. volt/current)	28480	
	5041-0309	2	plain key cap (ref. front panel)	28480	
	4040-1954	1	display window	28480	
	06032-00016	1	chassis	28480	
	06032-00005	1	internal cover (under top cover, lettered)	28480	
	06032-00011	1	air baffel (ref. fan, attached to rear panel, sheet metal)	28480	
	06032-00012	1	DC output mounting plate	28480	
	0380-1362	2	standoff (12mm)	28480	
	1510-0044	1	binding post,single,(ref rear panel ground)	28480	
	0400-0086	1	insulated bushing (ref. rear panel AC Input Board	28480	
	0380-1692	4	standoff (109.4mm)	28480	
	06032-60002	1	top cover	28480	
	06032-60003	1	bottom cover	28480	
	5040-1626	1	DC output cover (ref. Barrier BlocK	28480	
	5040-1627	1	AC Input cover (ref. AC line cord)	28480	
	5040-1625	1	strain relief (power cord)	28480	
	5060-9803	2	strap handle	28480	
	5041-6819	2	handle retainer (front)	28480	
	5041-6820	2	handle retainer (back)	28480	

Table 6-4. Replacement Parts List (Cont.)

REF. DESG.	HP PART NO.	TQ	DESCRIPTION	MFR. CODE	MFR. PART NO.
	5040-7201	4	foot	28480	
	06032-00010	2	bus bar-output	28480	
			CHASSIS ELECTRICAL		
B1	3160-0097	1	fan		
C6	0160-2569	1	fxd cer 0.02uf 20% 2KVdc	28480	
C27	0160-0381	1	fxd poly .01uf 10% 400V	56289	426P22F
C28	0180-3703	1	fxd elect 1500uf 250V	28480	
C30	0160-4962	1	fxd poly 1.0 uf 20%	28480	
CB1	3105-0126	1	Circuit Breaker 4A 65Vdc	28480	
L4	06011-80093	1	choke (input line)	28480	
R24	0686-2015	1	fxd comp 200 5% 1/2W	01121	EB2015
S3	3101-0402	1	switch DPST (on/off)	28480	
R99, 100	2100-4060	2	5K pot. (ref. Frt. Panel)	28480	

Section VII
COMPONENT LOCATION ILLUSTRATIONS AND CIRCUIT DIAGRAMS

7-1 This section contains component location diagrams, schematics, and other drawings useful for maintenance of the power supply. Included in this section are:

a. Component location illustrations (Figures 7-1 through 7-8), showing the physical location and reference designators of almost all electrical parts. Components mounted on the A6 AC Input Board and on the output filter board mounted on the output bus bars are easily identified by reference designators silkscreened on the boards.

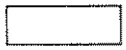
b. Notes (Table 7-1) that apply to all schematic diagrams.

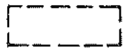
c. Schematic diagrams (Figures 7-9 through 7-13). Logic symbols used on the schematics are described in Appendix B.

WARNING

AC line voltage is present on the A1 Main Board Assembly whenever the power cord is connected to an ac power source.

Table 7-1. Schematic Diagram Notes

1.  denotes front-panel marking.

2.  denotes rear-panel marking.

3. Complete reference designator consists of component reference designator prefixed with assembly number (e.g.: A2R14).

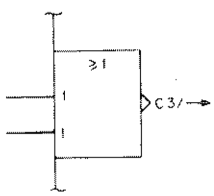
4. Resistor values are in ohms. Unless otherwise noted, resistors are either 1/4 W, 5% or 1/8 W, 1%. Parts list provides power rating and tolerance for all resistors.

5. Unless otherwise noted, capacitor values are in microfarads.

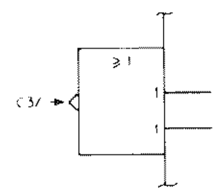
6. Square p.c. pads indicate one of the following:
   a. pin 1 of an integrated circuit.
   b. the cathode of a diode or emitter of a transistor.
   c. the positive end of a polarized capacitor.

7. In schematic symbols drawn to show right-to-left signal flow, blocks of information are still read left to right. For example:

left to right



right to left



→ indicates shift away from control block (normally down and to right), ← indicates shift toward control block (normally up and to left).

8.  indicates multiple paths represented by only one line. Reference designators with pin numbers indicate destination, or signal names identify individual paths. Numbers indicate number of paths represented by the line.

9. For single in-line resistor packages, pin 1 is marked with a dot. For dual in-line integrated circuit packages, pin 1 is either marked with a dot, or pin 1 is to the left (as viewed from top) of indentation at end of integrated circuit package, e.g.:

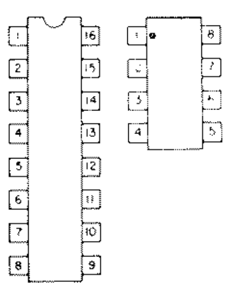
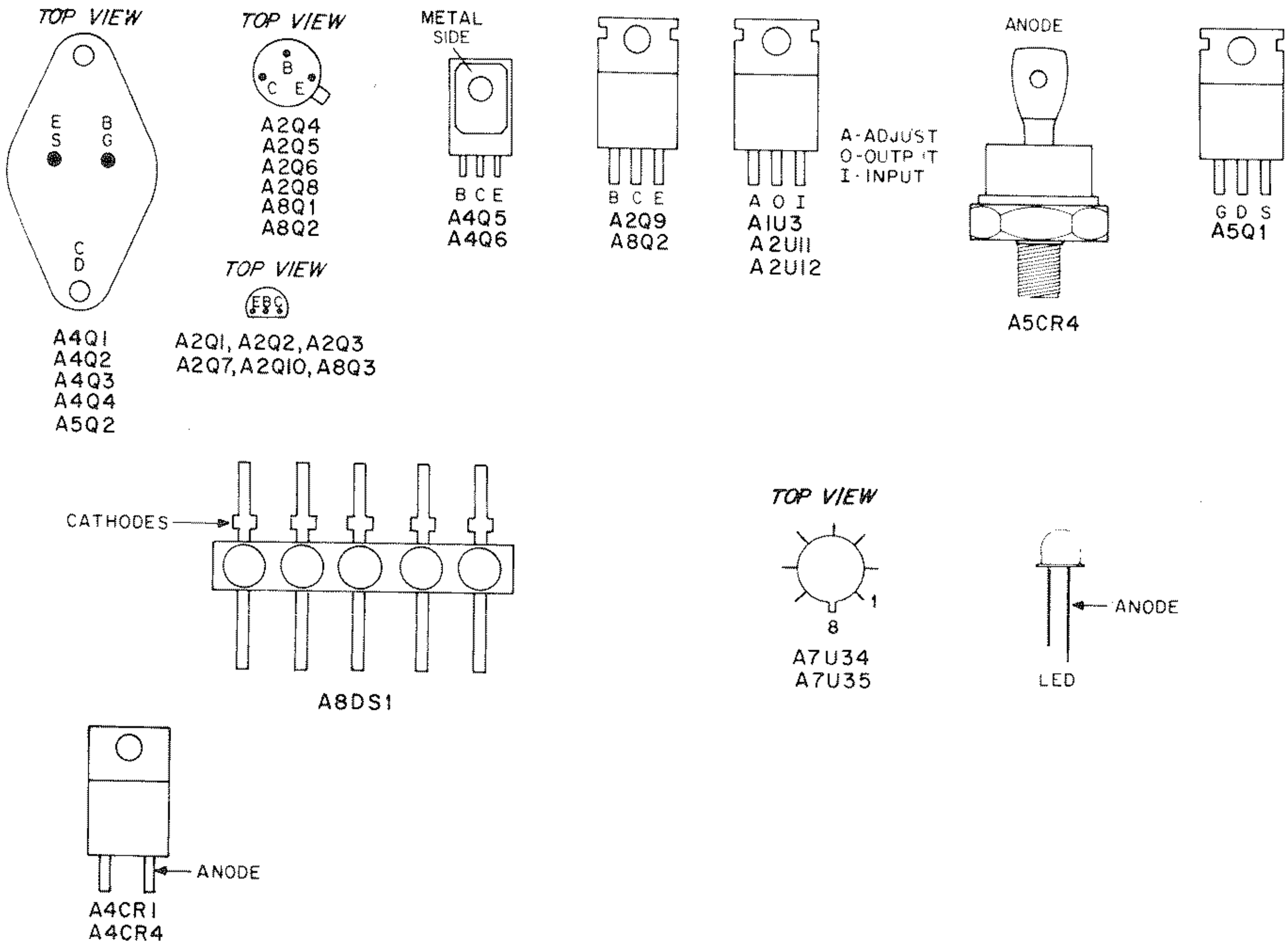


Table 7-1. Schematic Diagram Notes (cont.)

Pin locations for other semi-conductors are shown below:



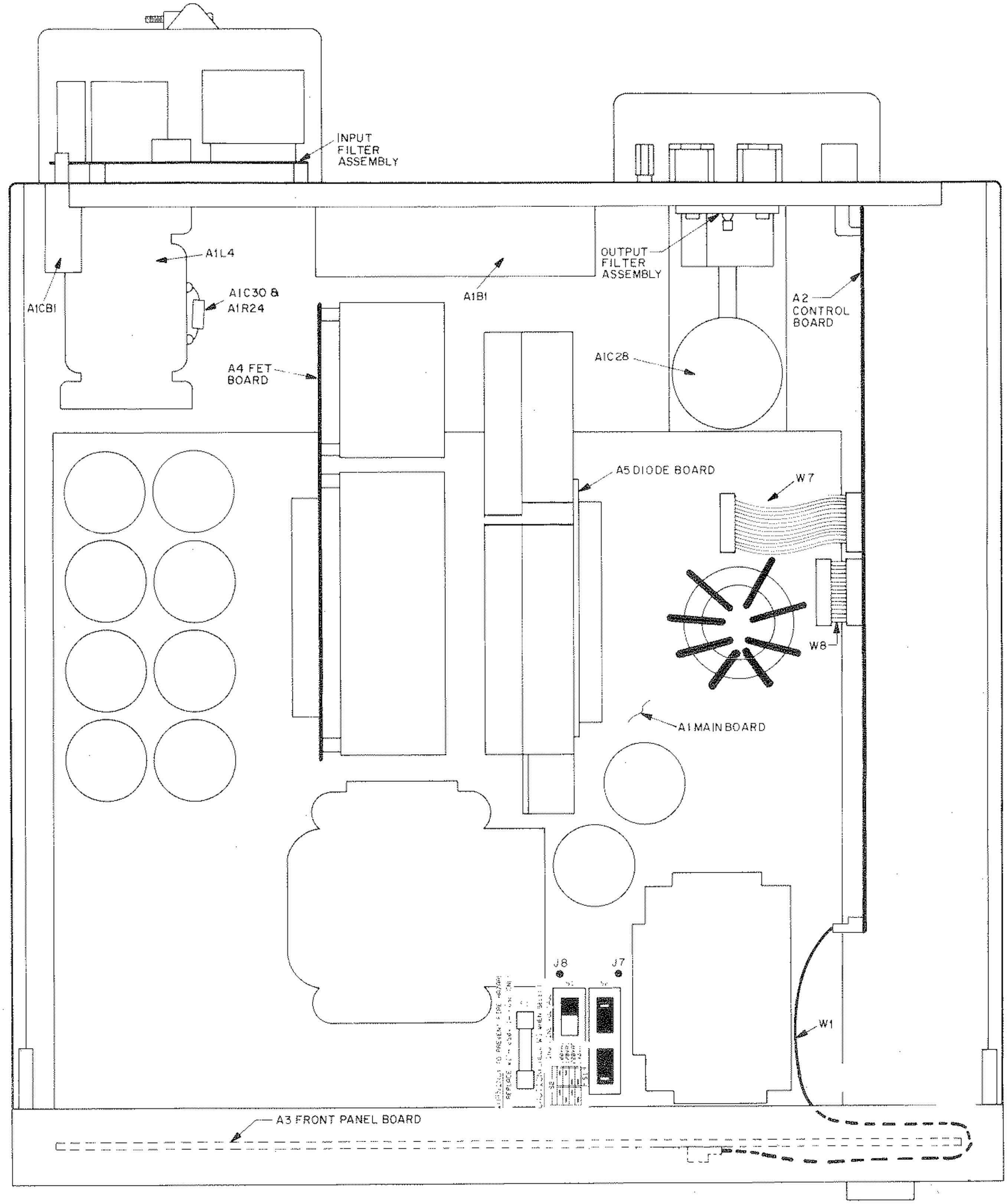


Figure 7-1. Top View, Top Covers Removed

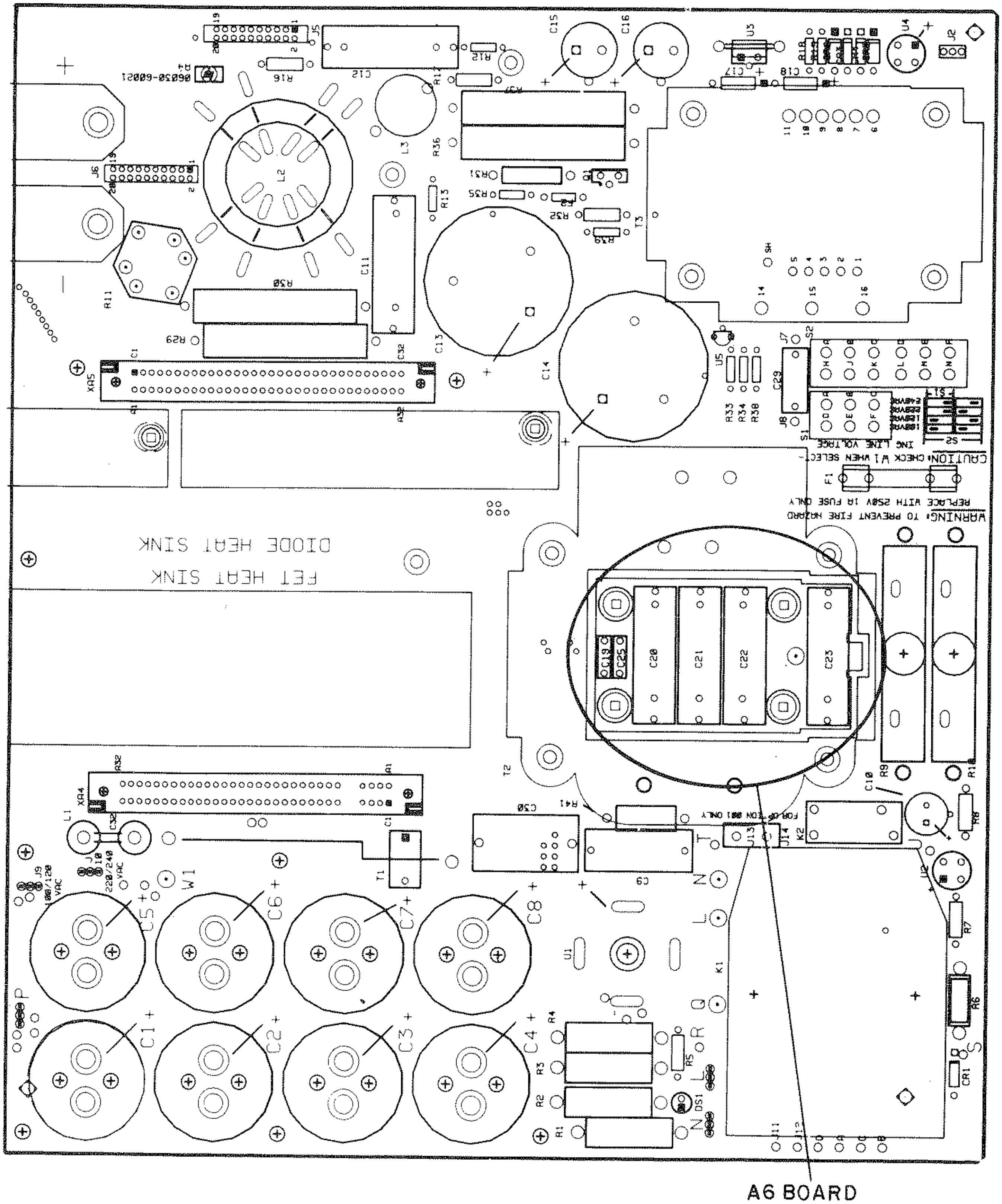


Figure 7.2 Main Board (A1) and Input Filter Board (A6) Component Location

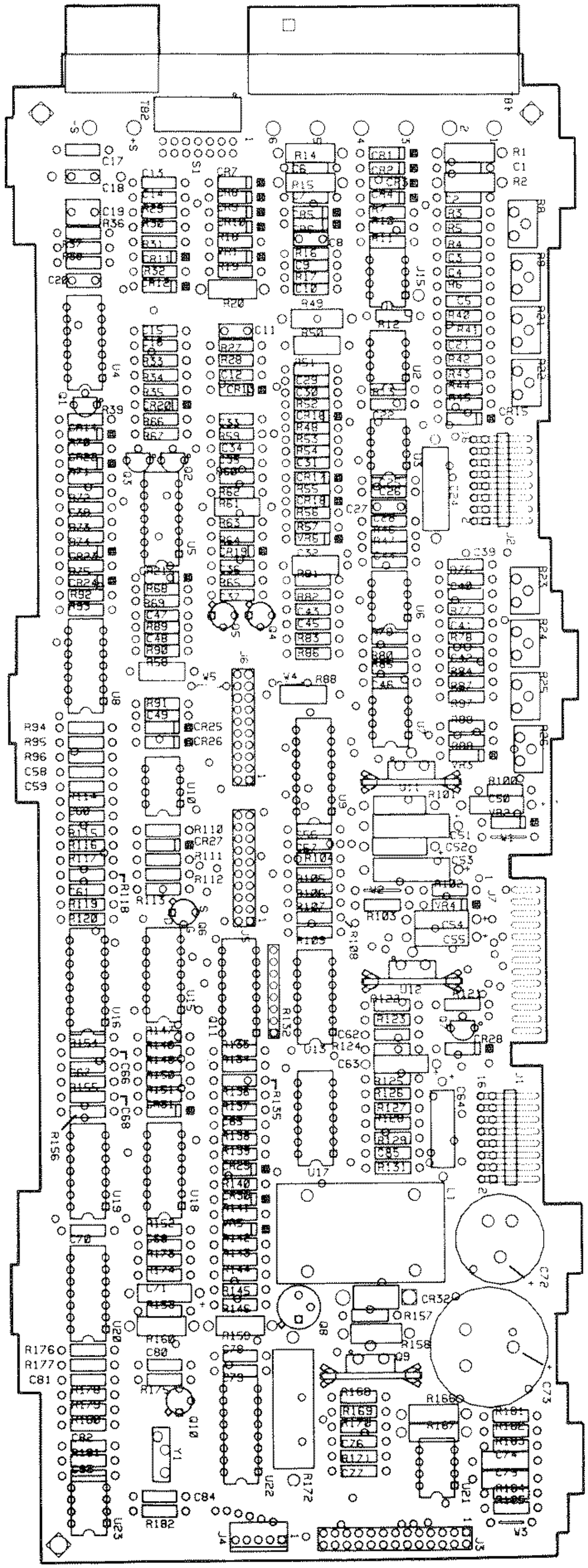


Figure 7-3. Control Board (A2) Component Location

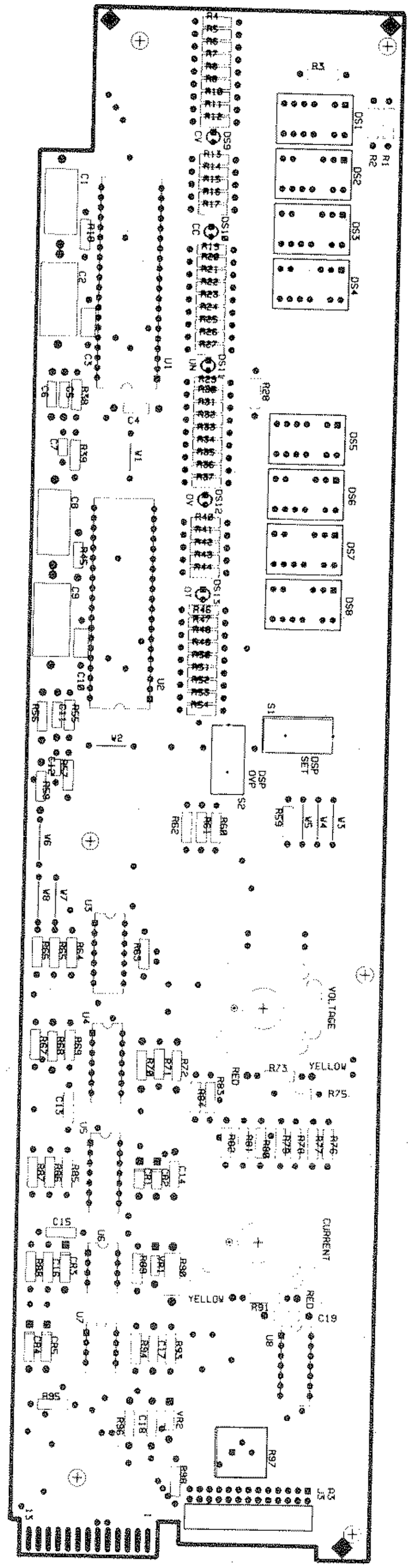


Figure 7-4. Front Panel Board (A3) Component Location

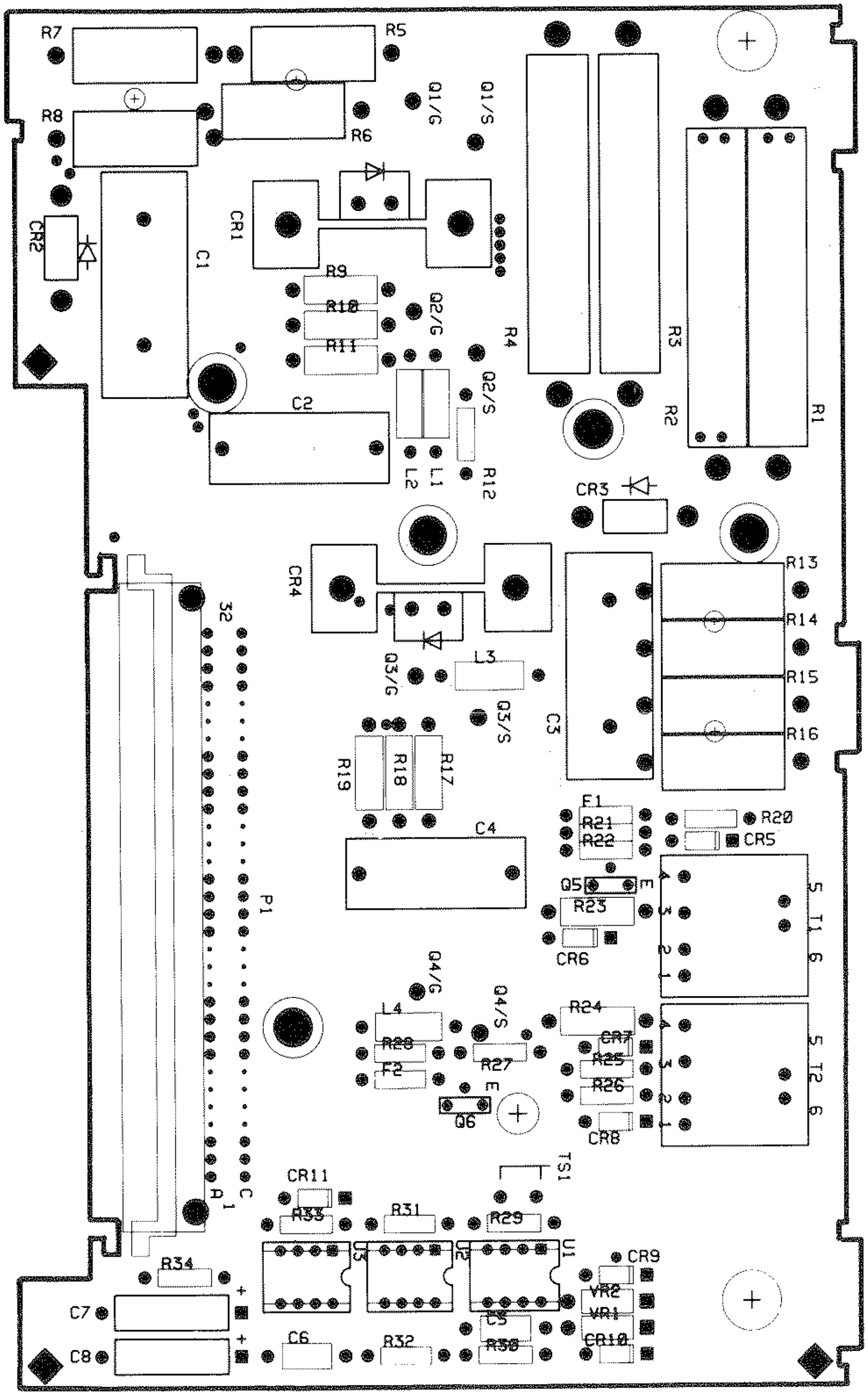


Figure 7-5. FET Board (A4) Component Location

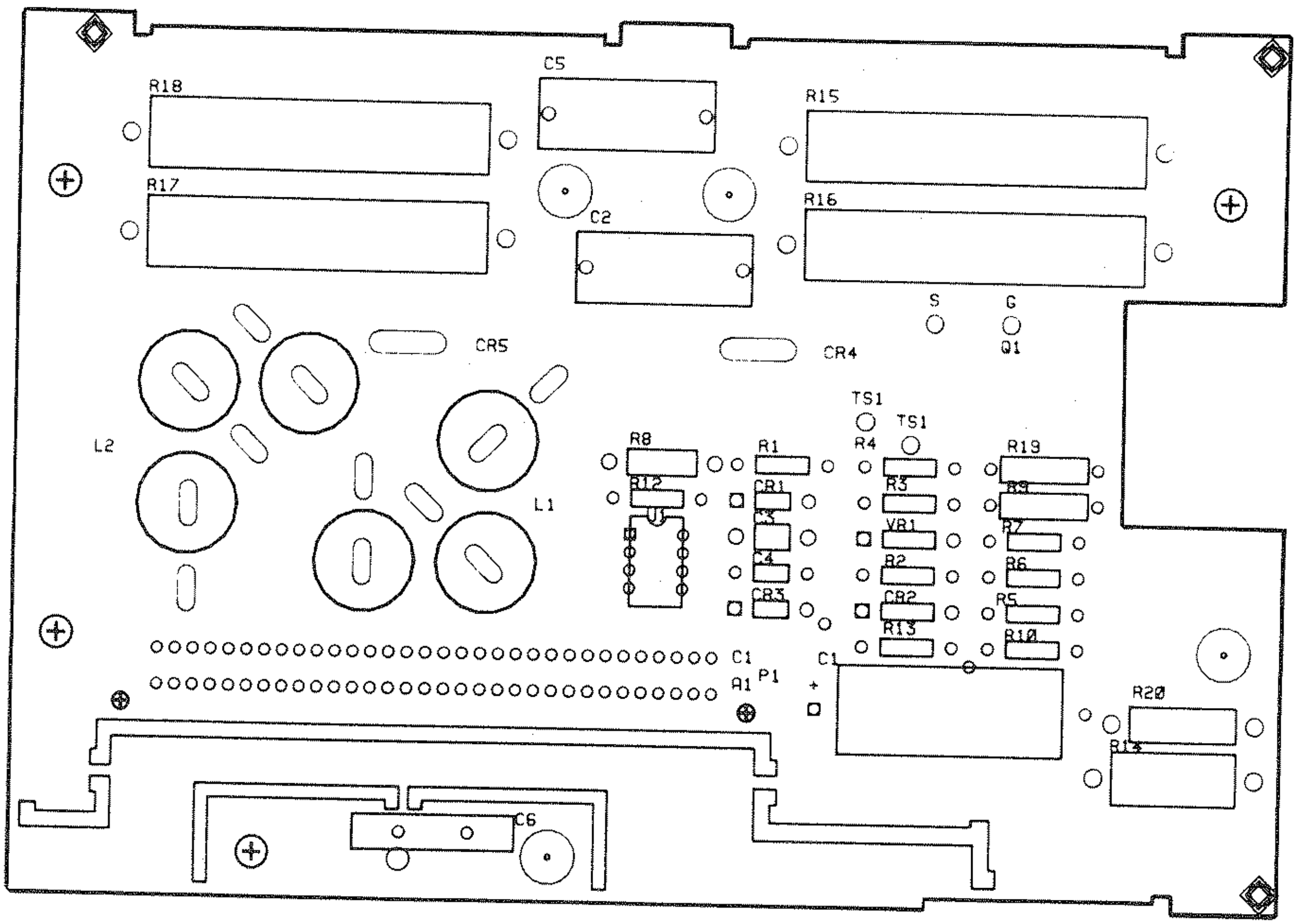


Figure 7-6. Diode Board (A5) Component Location

Appendix A
SYSTEM OPTION 002

A-1 GENERAL INFORMATION

A-2 This option facilitates the operation of the power supply in an automated system. Four major circuit blocks provide: 1) remote analog programming of the supply's output by three different control methods; 2) signals indicating the power supply modes and conditions; 3) two different digital methods of remote control; and 4) the outputs of three bias supplies for use with external circuitry.

A-3 The power supply equipped with this option can be operated from either a 6940B Multiprogrammer equipped with a 69520A power supply programming card or a 6942A Multiprogrammer equipped with a 69709A power supply programming card.

A-4 **Remote Programming.** Through this interface both the output voltage and current can be remote programmed by either an external voltage source, resistance, or a current sink.

A-5 **Status Indicators.** Six optically isolated lines provide open-collector digital outputs which indicate the following states: constant voltage mode, constant current mode, output unregulated, ac dropout, overvoltage, and overtemperature.

A-6 **Remote Control.** Two optically isolated methods of remote control are available. One method requires a negative going edge, which sets a latch on the 002 card to inhibit the power supply. The latch and OVP are reset by a negative-going pulse on another input line. The second method of remote control requires a low logic level to inhibit the power supply for the duration of the low level.

A-7 **Bias Supplies.** The outputs of three bias supplies are also available at the option connector. These outputs are +15 V, −15 V, and +5 V.

A-8 **Monitoring.** The 002 Option Board provides two monitoring outputs (I.MON. and V.MON) available at the option connector. They both vary from 0 to 5 V corresponding to a 0 to full scale output.

A-9 Other modes of operation, such as multiple supply system control, are described in detail in later paragraphs. Modes such as Auto series, Auto Parallel, and Auto tracking operation are described in section three of the main text.

A-10 Specifications

A-11 Table A-1 provides specifications for the Option 002. This table is referred to periodically throughout the text of this Appendix.

A-12 Option 002 Hardware

A-13 The Option 002 hardware consists of a single printed circuit board installed at the right side (facing the front panel) of the 6010A chassis. Two cables connect the option board to the A2 control board at A2J1 and A2J2. Connections between the option board and external circuits are made via the 37-pin connector mounted on the option board and available at the rear of the power supply. A mating connector is also included for the user's convenience.

Table A-1. Specifications, Option 002

Remote Programming

Resistance Programming: 0 to 4 k ohm provides 0 to maximum rated voltage or current output.

Accuracy: @25°C ±5°C
CV: 0.5% ± 235 mV
CC: 1.0% ±170 mA

Voltage Programming: 0 to 5 V provides 0 to maximum rated voltage or current output.

Accuracy: @25°C ±5°C
CV: 0.3% ±235 mV
CC: 0.36% ±170 mA

Current Programming: 0 to 2 mA current sink provides 0 to maximum rated voltage or current output.

Accuracy: @25°C ±5°C
CV: 0.43% ±235 mV
CC: 0.50% ±170 mA

Input Compliance Voltage: ±1 V

Current Programming Enable:

Relays K2 (CV) and K1 (CC) are biased from the Control Isolator Bias input (see Remote Shutdown and OVP Clear)

Relay Bias Voltage: +4 V minimum
+7 V maximum

Relay Resistance: 500Ω ± 10%

NOTE

For Control Isolator Bias voltages greater than 7 V, a series resistor must be used to maintain the relay bias voltage within specified limits.

Enabling either relay is accomplished by bringing CV or CC enable line to Control Isolator Bias common via a suitable driver; maximum driver off-state leakage =0.5 mA.

Table A-1. Specifications, Option 002 (cont.)

Output Voltage and Current Monitor: 0 to 5 V output indicates 0 to maximum rated output voltage or current.

Accuracy: @ 25 ±5° C:

CV: 0.3% +60 mV
CC: 0.36% +10 mA

Output Impedance: 10.2 k ohm ±5%

Temperature Coefficient:

CV: 12.5 ppm/°C +2.4 mV/°C
CC: 47 ppm/°C +0.54 mA/°C

Status Indicators:

Status Isolator Bias input (referred to Status Isolator Common)

Voltage Range: +4.75 V to 16 V

Current Drain: 20 mA maximum

Status Indicator output:

Open collector output:

Maximum Output Voltage (logic high): +16 V

Logic Low Output: + 0.4 V maximum at 8 mA

Remote Control (Trip, Reset, Inhibit) Control Isolator Bias Input

Voltage Range: +4.75 V to 16 V

Remote Control Inputs (Remote Trip , Remote Reset) Remote Inhibit

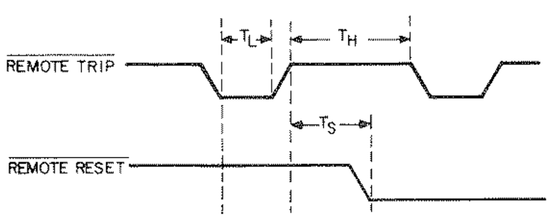
On State (logic low):

Minimum forward current required (I_f): 1.6 mA Isolator forward voltage (V_f) at 1.6 mA (I_f): 1.4 V typical, 1.75 maximum.

For Control Isolator Bias voltage greater than +5 V, an optional resistor (Ropt) may be added to reduce drive current.

Off state (logic high) maximum leakage current: 100 μA.

REMOTE TRIP and REMOTE RESET Timing:



Pulse duration (T_L): 15 μs minimum
Reset time (T_H): 125 μs minimum
Set-up time (T_S): 25 μs minimum
OVP clear delay: 1 sec ±30%

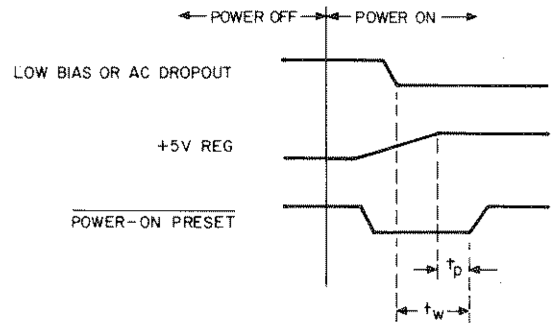
Power-On Preset

Output Ratings: open collector output (referred to power supply common)

Maximum output voltage (logic high): +16 V

Logic low output: +0.4 V maximum at 8 mA

Pulse Timing



Low Bias or AC DROPOUT will go false after 5V supply stabilises.

Bias Supplies

DC Output Ratings: (25°C ± 5)

No Load to Full Load 104 V to 127 V line

+5 V ±3% at 100 mA
+15 V ±3% at 75 mA
−15 V ±4% at 75 mA

Short Circuit Output Current:

+5 V	125 mA ±6%
+15 V	103 mA ±6%
−15 V	103 mA ±6%

PARD (Typical):

+5 V	25 mV pk-pk	1.5 mV Rms
+15 V	Same	Same
−15 V	Same	Same

Isolation:

Status Indicator lines and Remote Control lines may be floated a maximum of 240 Vdc from ground from the power supply or from each other. These lines may not be connected to any primary circuits.

Jumpers Designation

W1—jumpered:	OV indication @ A7J3-17 is active (lo) if OVP; Remote Trip or Remote Inhibit is active.
W1—open:	OV indication is active (lo) if OVP or Remote Trip is active.
Normal Operation as shipped:	W3 and W4 jumpered W2 and W5 open.

A-14 INSTALLATION

A-15 When installing the board, perform the following steps:

a. Remove the top and inner cover of the power supply as discussed in Section 5 under Repair and Replacement.
b. Remove the plate next to the barrier strip on the rear panel of the supply by unscrewing the 2 M3 screws.
c. Insert the already prepared 002 board in the slot closest to the right side (looking from the front panel) of the supply.
d. Use the two M3 screws to connect the rear end of the 002 board to the rear panel of the supply.
e. Attach ribbon cables from the A2 Control Board A2J1 to A7J1 and A2J2 to A7J2.
f. Replace the inner and outer cover of the supply.
g. Remove 550 V label from rear of unit.

A-16 Connector Assembly Procedure

A-17 The following instructions decribe assembly of the mating connector provided to interface the user's system with the option connector, J3. Figure A-1 identifies the parts of the mating connector.

Proceed as follows:

NOTE

It may be desireable to set up a test interface before final assemble of the mating connector to allow checkout of the system. A mating connector with pins accessible for temporary wiring is available from Hewlett-Packard, HP part number 1251-4464.

If the cable assembly presents RFI or ESD problems, a shielded cable assembly accessory HP part number 5060-2890 can be ordered.

a. If a multi-wire cable is being used (as opposed to individual wires), remove approximately 1 ½ inches of cable insulation from the end. Be careful not to cut the insulation on the Individual wires.
b. Strip 3/16 inch of insulation from the end of each wire to be used.
c. Insert each wire into a contact pin (1) and crimp firmly.
d. Insert each pin into a proper hole in connector-pin house (2) from rear. Pins will lock into housing when fully inserted.

NOTE

Once the pins are locked into the connector-pin housing, they are extremely difficult to remove. Therefore, be certain pin is in proper hole before inserting fully.

e. *Screw a slotted set-screw (3) partially into a square nut (4) and place in position in connector shield assembly (6).*
f. Place strain relief (5) in position in connector shield assembly (6), just under set screw (3). Be certain that strain relief is oriented as shown in Figure A-1.
g. Place connector pin housing (2) in shield assembly (6) and route cable through cable entrance.
h. Fold connector assembly (6) and secure with three screws.
i. Strain relief set screw (3) can now be adjusted from top of connector to clamp firmly on cable.
j. Clip fasteners (7) onto ends of connector pin housing (2).
k. Connector can now be plugged onto option connector J3 and secured with two screws (8) into the threaded stand-offs on either side of J3.

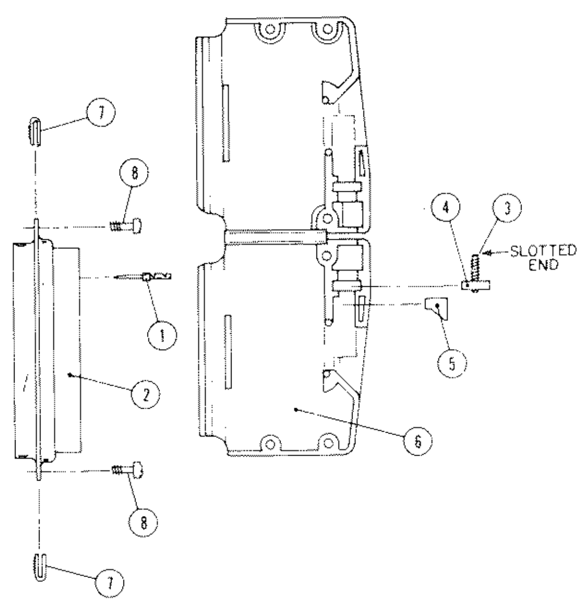


Figure A-1. Mating Connector Assembly

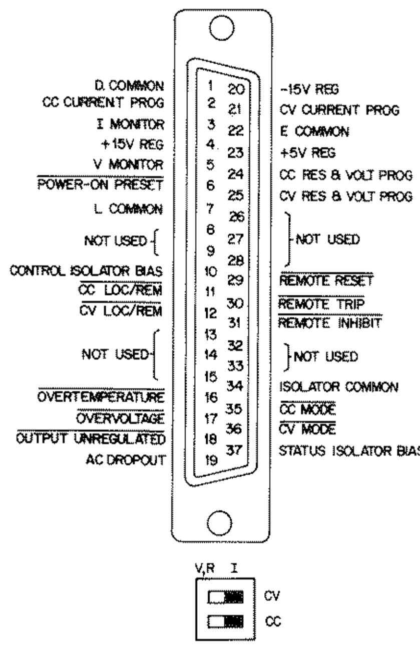
A-18 OPERATION

A-19 The following paragraphs provide the operating instructions necessary to interface a 002-equipped power supply into an automated system. A brief description of some circuits is also provided. The unit is shipped for front panel operation with mode switch settings as follows:

B1	B2	B3	B4	B5	B6
0	1	1	0	1	1

Before beginning, switch the power supply's rear panel MODE switches B1 thru B6 to their correct positions for the programming source being used, (see Table A-2).

Next switch A1 and A2 also on the rear panel, to the correct program source function, see Figure A-2. All connections are made at the 37-pin rear panel connector J3, and can be wired directly into the mating connector supplied for this purpose.



PROGRAM SOURCE FUNCTION	SWITCH POLE CV	CC
CV AND CC CURRENT PROGRAMMING	1	1
CV AND CC RES. & VOLT PROGRAMMING	0	0

Figure A-2. 002 Option Rear Panel Connector J3 and Switches A1 and A2.

A-20 Local/Remote Programming

WARNING

When switching to local control, remember to set Front Panel Voltage and Current Control to safe levels.

A-21 Local Programming (Figure A-3). The supply can be switched back and forth between remote and local programming while initially checking out a remote programming circuit. For proper operation of local programming, the user must supply the bias voltage (CONTROL ISOLATOR BIAS). The Control Isolator Bias voltage can range from +4.75 V to +16 V depending upon the user's interface circuits. Refer to Specifications Table A-1. For local programming, take the Control Isolator Bias common and connect it to both of the LOC/REM terminals, and position mode switch as indicated in paragraph A-19.

CAUTION

Although CONTROL ISOLATOR BIAS can be +4.75 V to +16 V, a supply voltage of more than 7 V may damage the relays. Therefore, if CONTROL ISOLATOR BIAS exceeds 7 V it is necessary to use a resistor in series with each of the LOC/REM terminals. Figure A-4 provides a graph from which the proper series resistance value can be determined. Note that the tolerances of both the Control Isolator Bias and the resistor must be taken into account. The actual Control Bias used in Figure A-4 is obtained after subtracting any driver gate voltage drop.

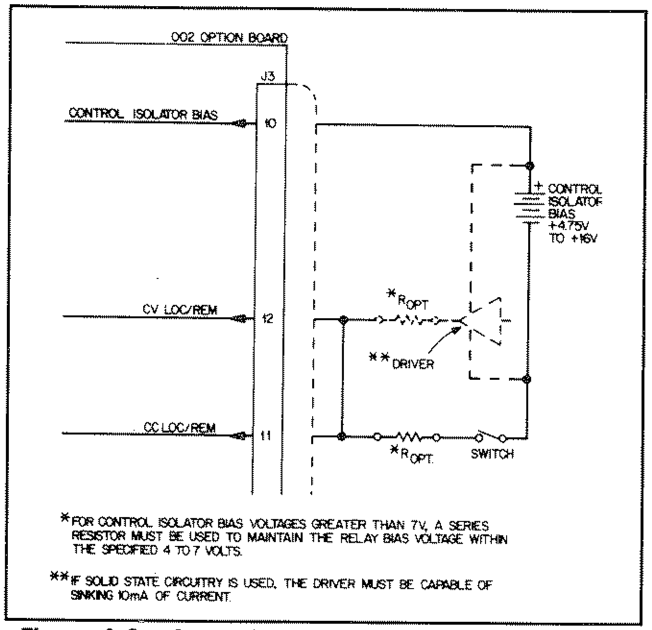


Figure A-3. Accessing Local Programming while in Remote Programming Mode

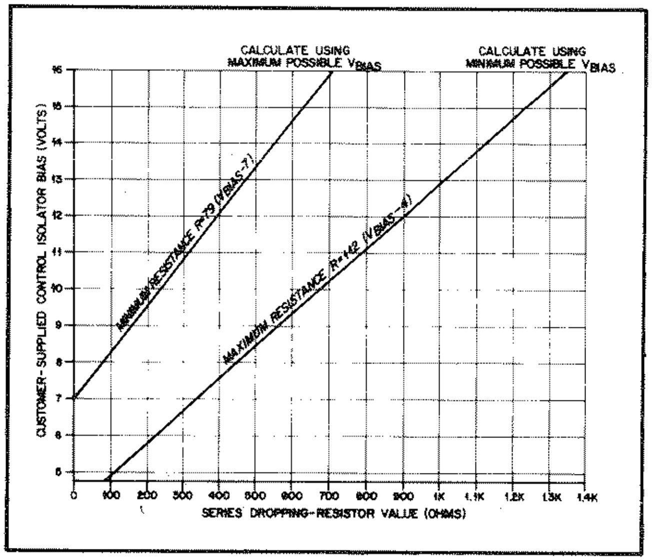


Figure A-4. Calculating Value of Series Dropping Resistor

If solid state circuitry is used, connect the Control Isolator Bias to a driver capable of sinking 10 mA of current, then connect the driver's output to both of the LOC/REM terminals. Refer to figure A-3. Either method will enable relays K1 (CV) and K2 (CC) to switch regulation to the front panel VOLTAGE and CURRENT controls. For Control Isolator Bias voltages greater than 7 V, a resistor (Ropt) must be used in series with the Control Isolator Bias common or the Driver's output. Figure A-4 provides a graph for determining the proper series resistance value depending on the Control Isolator Bias voltage being used.

A-22 The supply can be returned to the remote programming mode by switching off the Control Isolator Bias common or by increasing the Driver's output signal to within 1 V of the Control Isolator Bias voltage. If remote programming is solely desired, leave the LOC/REM terminals open and make the proper connections to the RESISTOR/VOLTAGE PROG. or CURRENT PROG. terminals (see Figures A-5,A-6, A-7).

Table A-2. Mode Switch settings for enabling different Programming Sources

Program Source	Switch Pole Settings					
	Mode					
	B1	B2	B3	B4	B5	B6
Resistance	0	0	1	0	0	1
Voltage or Current	0	1	0	0	1	0

A-23 Remote Resistance Programming

A-24 Check switches A1 and A2 on the rear panel, they must be in their correct positions for CV and CC resistance/voltage programming (see figure A-2). A resistance variable from 0 to 4 K ohms can be used to program the output voltage or current from 0 to full scale. To program the output voltage, connect the variable resistance between J3-25 (CV RES/VOLT PROG.) and J3-22 (E COM.). To program the output current, connect the variable resistance from J3-24 (CC RES/VOLT PROG.) to J3-22 (E COM).

CAUTION

If the programming lines become open circuited during resistance programming (user's system becomes disconnected from J3), the power supply's output will tend to rise above rating. The supply will not be damaged if this occurs, but the user's load may be damaged. To protect the load, be sure that the overvoltage trip point is properly adjusted and that the CAUTION of paragraph 3-48 is observed.

A-25 Remote Voltage Programming (Figure A-6). Check switches A1 and A2 on the rear panel, they must be in the correct positions for CV and CC resistance/ voltage programming (see figure A-2). A voltage source variable from 0 to 5 volts, can be used to program the output voltage or current from 0 to full scale. The load on the programming source is less than 1 mA. To program voltage, the voltage source should be connected from J3-25 (CV RES & VOLT PROG) to J3-22 (E COM). To program current, the voltage source should be connected from J3-24 (CC RES & VOLT PROG) to J3-22 (E. COMMON). If the programming lines become open circuited (user's system becomes disconnected from J3) during voltage programming, the Programming Protection circuit will reduce the power supply output to zero.

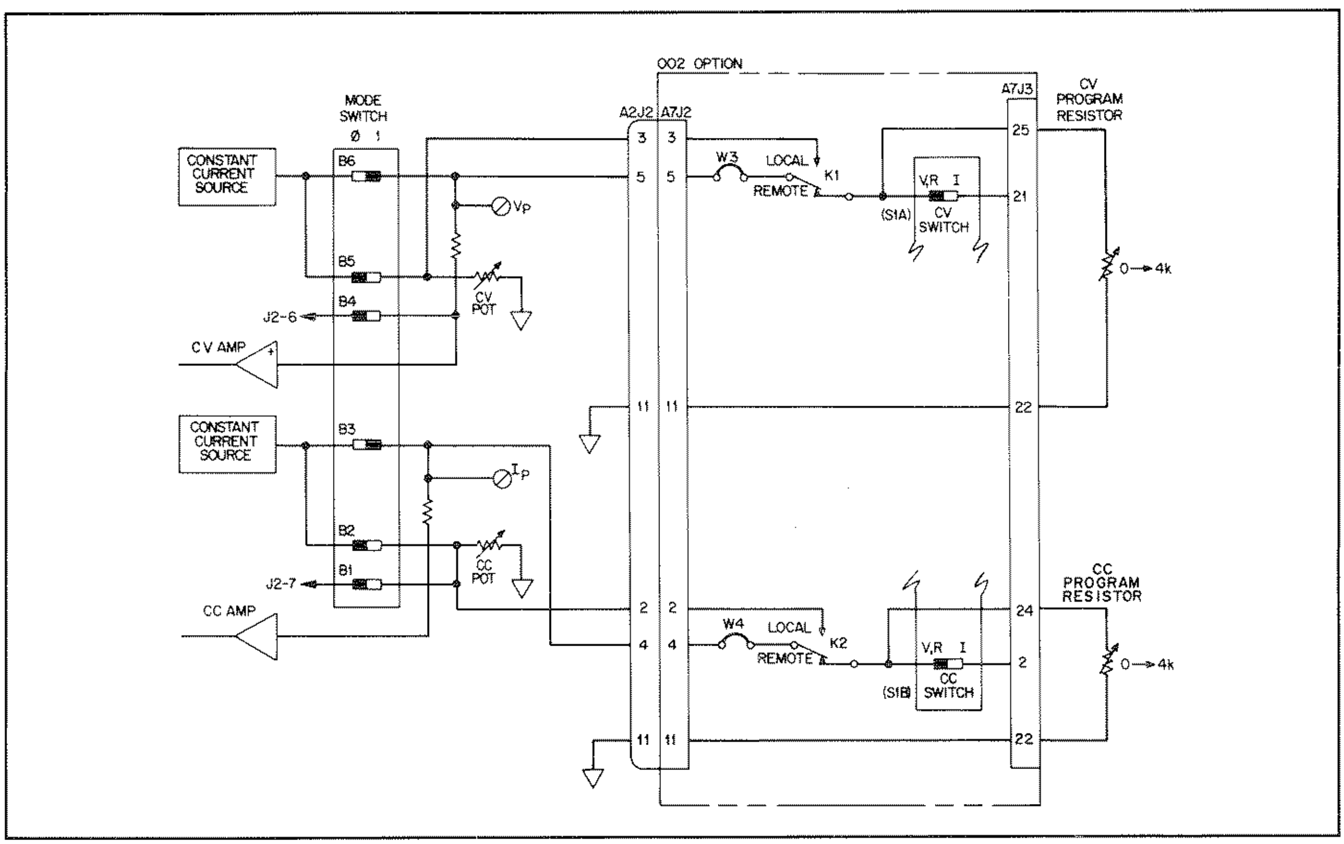


Figure A-5. Remote Resistance Programming

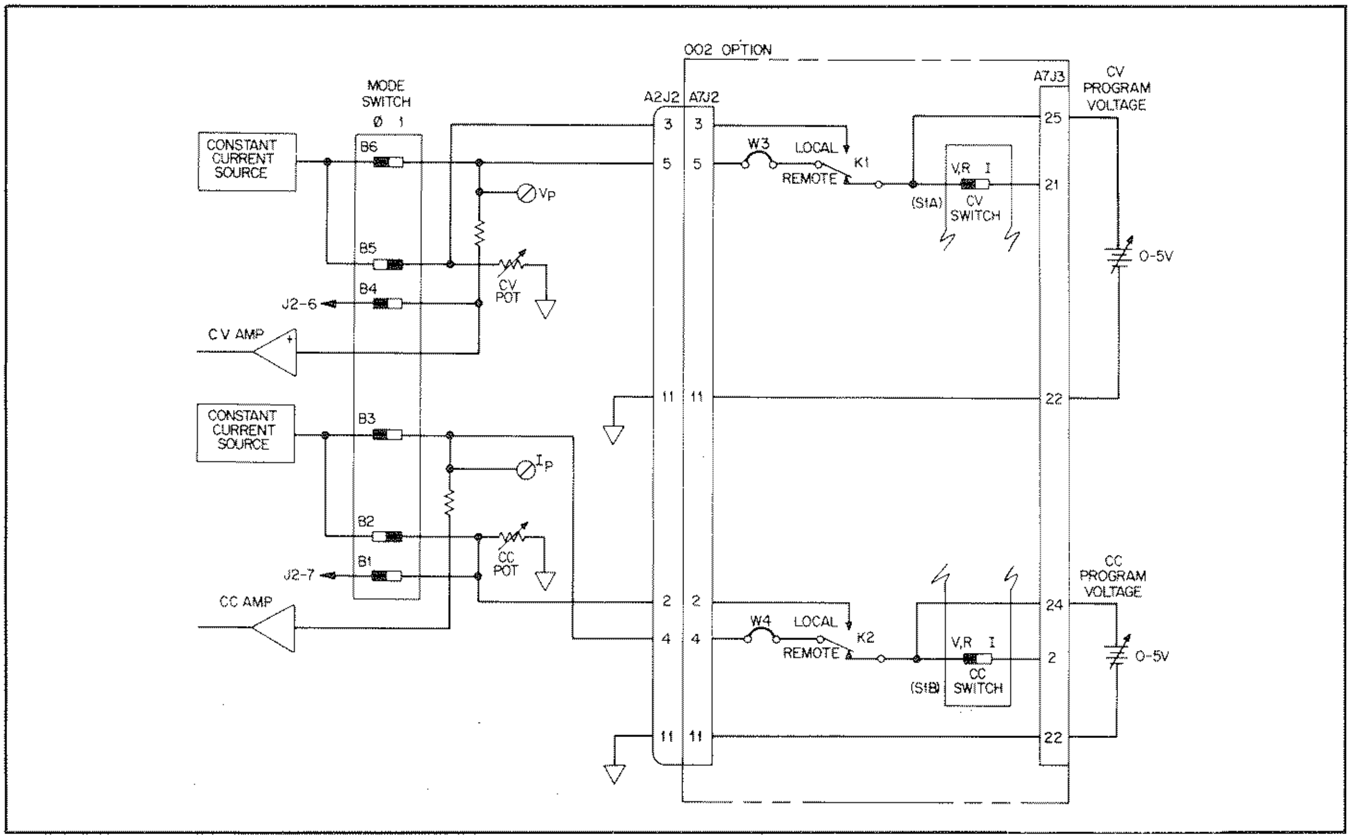


Figure A-6. Voltage Programming of Output Voltage and Current

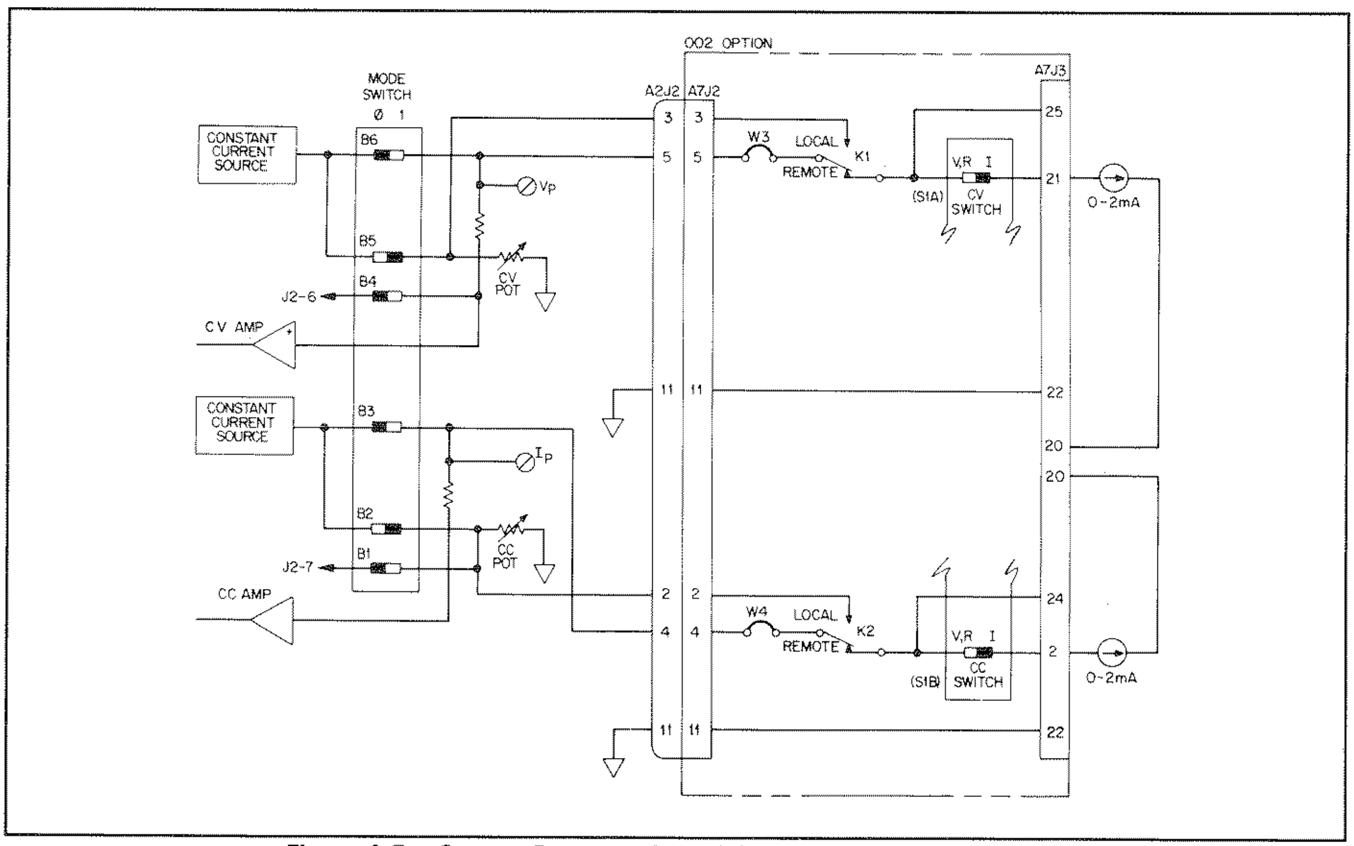


Figure A-7. Current Programming of Output Voltage and Current

A-26 **Current Programming (Figure A-7).** Check switches A1 and A2 on the rear panel, they must be in the correct positions for CV and CC current programming (see Figure A-2). A current sink variable from 0 to 2mA, can be used to program the output voltage or current from 0 to full scale (see Figure A-7). The following paragraph provides a brief circuit description, refer to schematic diagram.

A-27 To program voltage, the current sink can be connected from J3-21 (CV CURRENT PROG) to J3-20 (−15 V). To program current, the current sink can be connected from J3-2 (CC CURRENT PROG) to J3-20 (−15 V). Current sinks can either be connected to the power supply (−15 V) or to an external negative supply that is referenced to the L. COMMON of the power supply.

A-28 The 0 to 2mA current sink will cause the output signal of op-amps U17 and U18 to vary proportionally from 0 to 5 volts. These signals are then coupled through relays K1 and K2 and then on to the A2 Board's CV and CC circuits which, in-turn, will program the supply's output from 0 to full scale. If the programming lines become open circuited (user's system becomes disconnected from J3) during current programming, the Programming Protection circuit will bring the power supply output to zero.

A-29 Remote Monitoring

A-30 The 002 Option board provides a protected 0 to 5 V output corresponding to a full scale voltage output. The voltage monitor output is available between pins J3-5 (V. Monitor) and J3-1 (D COMMON).

CAUTION

Observe the caution described in paragraph A-21.

Output impedance is 10 k ohm; the monitoring device input impedance should be at least 1 M ohm to limit error to 1% + basic accuracy; 10 M ohm to limit error to 0.1% + basic accuracy.

A-31 The I. MON signal from the mainframe is also brought out through the 002 Option board. A 0 to full scale current-monitor output is available between pins J3-3 (I. MON) and J3-1 (D COMMON). Output impedance is 10 k ohms; the monitoring device input impedance should be at least 1 M ohm to limit error to 1% + basic accuracy.

A-32 In some applications it may be desirable to install a noise-suppression capacitor on these monitor outputs to lessen the effects of noise induced in the monitor leads. The capacitors should be ceramic or tantalum type, from 0.1 to 1 uf. The capacitor is installed directly across the monitor device input terminals.

A-33 Status Indicators

A-34 Six optically isolated lines provide open collector digital outputs which indicate certain modes and conditions of power supply operation. For proper supply operation of the opto-isolators, the user must supply the bias voltage, (ISOLATOR BIAS). This voltage can be from +4.75 V to +16 V depending upon the user's interface circuits, refer to the specifications Table A-1. Connect the bias voltage (+) between J3-37, (ISOLATOR BIAS) and J3-34 (ISOLATOR COMMON). The status indicator outputs are open collector (referenced to ISOLATOR COMMON); therefore, it is necessary to connect a pull-up resistor from each output to ISOLATOR BIAS. When choosing the resistor value observe the current sink capabilities of these lines as decribed in the Specifications Table A-1.

A-35 Because of the relatively slow rise and fall times of opto-isolators, Schmitt-triggered devices should be used to interface these output lines to logic circuits.

A-36 The following signals are in active low-form:

a. CV MODE, J3-36, indicates that the power supply is in constant voltage operation.
b. CC MODE, J3-35, indicates that the power supply is in constant current operation.
c. OUTPUT UNREGULATED, J3-18, indicates that the power supply is in neither constant voltage nor constant current operation and cannot be guaranteed to meet specifications.
d. OVERVOLTAGE, J3-17, Indicates power supply shutdown because of: the voltage output exceeding the OV trip point set at the front panel; or, a system-initiated shutdown as decribed in Section A-60.
e. OVERTEMPERATURE, J3-16, indicates power supply shutdown due to an excessive temperature rise on the FET or output diode heatsink.

A-37 The Low Bias AC DROPOUT signal, J3-19, is in active high form. This signal indicates: loss of primary power, momentary AC dropout, or "brownout" conditions where the AC line voltage drops below approximately 70% nominal.

A-38 Remote Control

A-39 For operation of the opto-isolators, the user must supply the bias voltage (CONTROL ISOLATOR BIAS). This voltage can be from +4.75 V to +16 V depending on the requirements of the driving circuits. The type of driving logic and bias voltage will determine the amplitude of the high and low logic levels, refer to the Specification Table A-1 under Remote Control.

A-40 Connect the bias voltage (+) to J3-10 CONTROL ISOLATOR BIAS, and reference the input signals to this bias supply's negative terminal.

A-41 Two optically isolated methods of remote control are available. They are described in the following paragraphs.

A-42 **Remote Trip.** A negative-going edge applied to terminal J3-30 (REMOTE TRIP) will shut down the power supply, reducing the output voltage to near zero. For minimum pulse duration and timing considerations with respect to REMOTE RESET , see Table A-1. The following paragraph provides a brief circuit description (see schematic diagram and Figure A-8).

A-43 A negative going edge at REMOTE TRIP coupled through opto-isolator (U9) causes one-shot U13B to set the TRIP/RESET latch (U5A) low. This sets terminal J1-13 (INHIBIT) low, thus inhibiting the Pulse Width Modulator of the power supply. It also lights the unregulated indicator on the front panel and generates an unregulated signal from the opto-isolator U3.

A-44 The low signal generated by the Trip/Reset Latch is also coupled through opto-isolator U2 and appears at J3-17 as an OVERVOLTAGE status signal. This signal does not affect The state of the power supply's OVP circuit.

A-45 Remote Reset. A negative-going edge applied to terminal J3-29 (REMOTE RESET) will return the supply to its initial state following a system-initiated shutdown or an OVP shutdown caused by a temporary over voltage condition. For minimum pulse duration and timing considerations with respect to REMOTE TRIP see Table A-1 under Remote Control. The following paragraphs provide a brief discription of this circuit (see schematic diagram and Figure A-8).

A-46 A negative-going pulse applied to terminal J3-29 (REMOTE RESET) is coupled through opto-isolator U10. One-Shot U13A then triggers and resets the TRIP/RESET latch output high. This sets terminal J1-13 (INHIBIT) high, thus enabling the power supply's Pulse Width Modulator.

A-47 The REMOTE RESET signal will also reset the power supply OVP circuit in the event that an overvoltage condition has shut down the supply. When a REMOTE RESET signal is present, ONE SHOT U13A goes low, this will produce an OV CLEAR pulse at terminal J1-12. The OV CLEAR pulse will cause the output of A2U2 to go low thus, resetting the OV FLIP FLOP. When this occurs the output of A2U24D goes high and simultaneously causes the front panel OV LED to turn off and the OV signal (J1-6) to go high. The OVERVOLTAGE signal to U4B also goes high and enables the PWM of the power supply.

NOTE

By observing the OVERVOLTAGE status indicator or the power supply's output while applying a reset pulse to REMOTE RESET, the user can determine the cause of shutdown. If the output returns and OVERVOLTAGE goes high immediately, this indicates a controller-initiated shutdown. If the output takes about one second to return, this indicates that the output voltage had exceeded the OVP trip point. If the OVP circuit trips continually, check the load and/or the trip point setting.

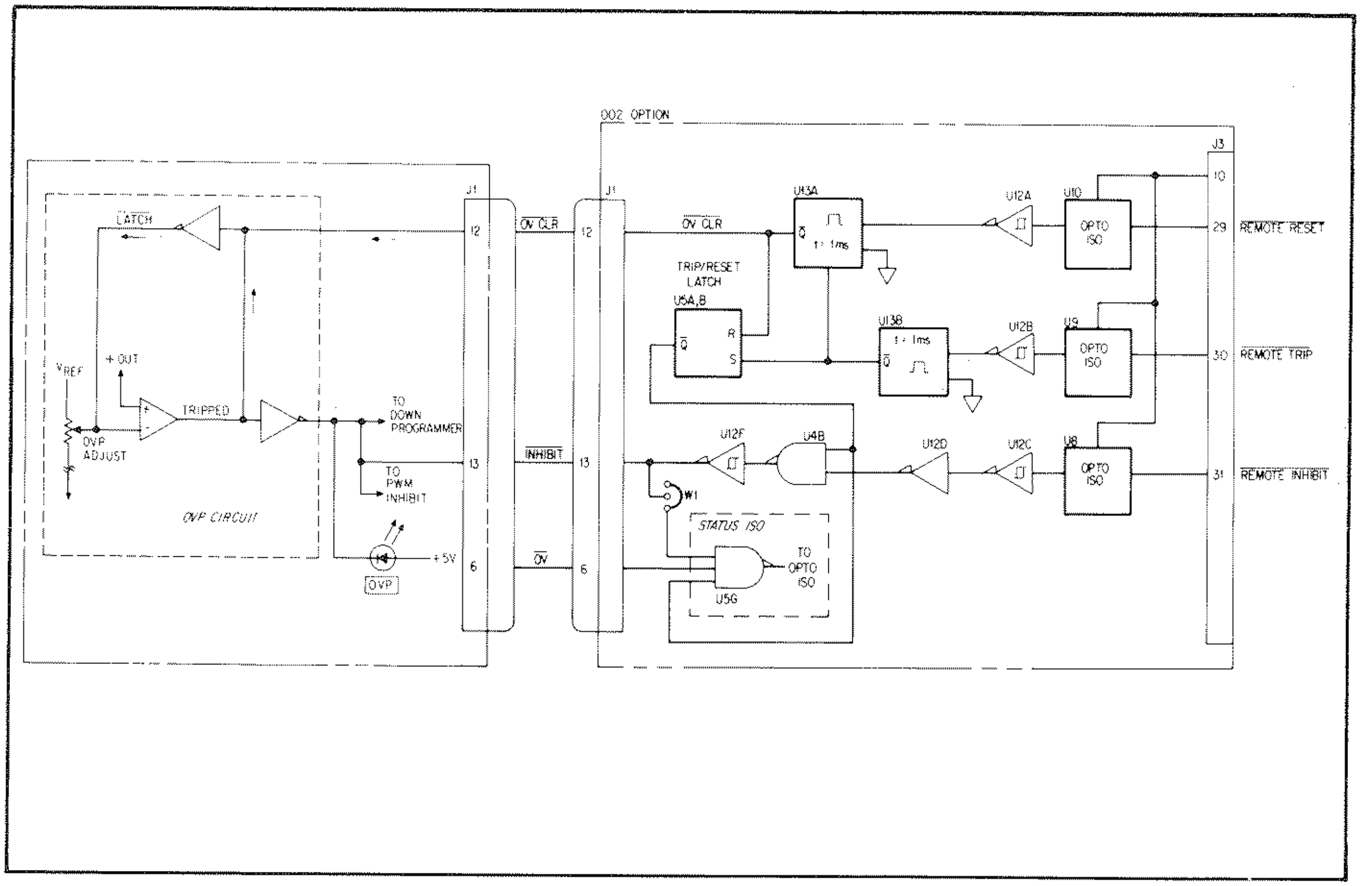


Figure A-8. Remote Control

A-48 Alternate Method of Remote Control. The REMOTE INHIBIT input, J3-31, provides an alternate method of remote shutdown. By maintaining a low logic level at this input, the supply's output will be inhibited until REMOTE INHIBIT is returned to its initial high state. The following paragraph provides a brief description of this circuit (see schematic diagram and Figure A-8).

A-49 A low logic level applied to terminal J3-31 (REMOTE (INHIBIT) is coupled through opto-isolator U8 and causes U4B to inhibit the power supply's (PWM) Pulse Width Modulator. If jumper W1 is used (see Figure A-8) while a REMOTE INHIBIT signal is applied, an OVERVOLTAGE signal will appear at terminal J3-17 OVERVOLTAGE thus, indicating the power supply shut down.

A-50 POWER-ON PRESET

A-51 This open collector output line J3-6, provides a logic low pulse (Power-On-Preset) to the user that can be used to initialize or delay a system's operation until +5 V Reg. supply has stabilized. The pulse is generated after primary power is turned on and also after resumption of power following momentary ac dropout or conditions in which line voltage drops below approximately 70% of the nominal. See Table AI for Power-On Preset signal specifications.

A-52 The Power-On-Preset circuit also ensures that terminal J3-17 (OVERVOLTAGE) will be high when the supply is turned on. This protects against unwanted Multiple Supply System Shutdowns when using J3-17 (OVERVOLTAGE) to remote trip additional power supplies.

A-53 The following paragraphs provide a brief description of the power-on preset circuit, refer to schematic diagram

A-54 Circuits on the Power Supply's A2 Control Board produce a power-clear signal, (PCLR), when the supply is turned on. These circuits hold PCLR low until the unregulated input to the A2 Board's +5 Vdc bias supply is greater than about 11Vdc, an input voltage sufficient to assure +5 Vdc bias output.

A-55 This PCLR signal is coupled through terminal J1-15 to the 002 Option board's power-on preset circuit. When the power-on preset circuit receives the PCLR signal, transistors U14A and U14C turn off.

A-56 Turning U14A off causes a DROPOUT signal to appear at terminal J3-19 (DROPOUT). Turning U14C off causes U14B and U14D to turn on. When U14B is on, it holds output J3-17 (OVERVOLTAGE) high. Holding J3-17 high will prevents any unwanted Multiple Supply Shutdown's from occurring when the supply is wired for such an application. When U10D is on, it causes J3-6 (Power-On-Preset) to be low thus, if used, can initialize or delay a customer's system operation.

A-57 AC Dropout Buffer Circuit

A-58 This circuit couples, inverts and isolates the DROPOUT signal (received from the A2 Control Board) of status output terminal J3-19 (DROPOUT). The dropout signal indicates loss of primary power, momentary AC dropout, or "brownout" conditions where the AC line voltage drops below approximately 70% normal. The following paragraph provides a brief description of the AC Dropout Buffer circuit, refer to the Schematic Diagram.

A-59 The AC Dropout Buffer Circuit receives a DROPOUT signal from the 6010A A2 Control Board. This causes the bias voltage supplied to the Dropout Buffer U14A to be pulled down through diode CR4 thus, turning U14A off. This in turn will cause Opto-Isolator U3 to turn off. Since external pull up resistors are used, terminal J3-19 (DROPOUT) will go high and remain high until the DROPOUT signal from the A2 Control Board is removed.

A-60 Multiple Supply System Shutdown

A-61 When using more than one 002 Option equipped power supply in a system, it may be desirable to implement a system shutdown. In this configuration, an OVP trip or remote shutdown of a single unit will cause all of the supplies to shut down.

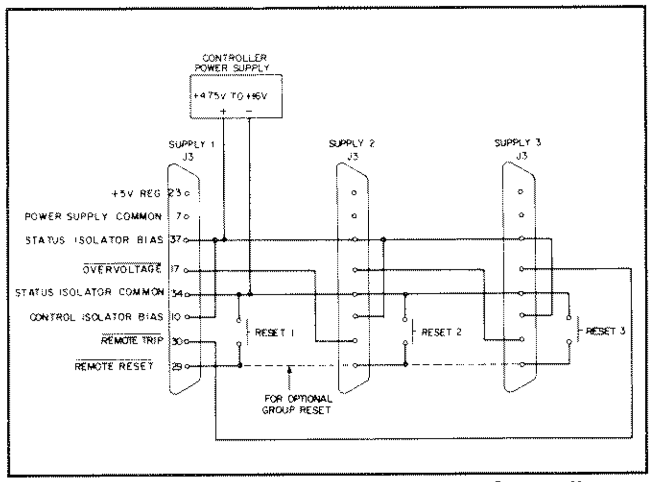


Figure A-9. System Shutdown using Controller Power Supply

A-62 Figure A-9 shows one method of system shutdown. The advantages of this method are that one common is used for all status and control lines (useful for controller-operated systems), and the capability of system reset. As shown in Figure A-9, one supply's OVERVOLTAGE line is connected to the next supply's REMOTE TRIP line, and so on in a continuous chain.

NOTE

+5 V REG/POWER SUPPLY COMMON from Supply 1 can be used instead of the bias voltage from the controller. However, because of current limits of the +5 V REG, no more than four units can be connected together in this configuration. To prevent ground loops, do not parallel connect +5 V REG from more than one supply.

A-63 The note following paragraph A-47 tells how to determine if a shutdown was inititated through the remote trip line or by a supply's OVP. This allows the controller to determine which supply initiated the shutdown.

A-64 Following a multiple supply shutdown, each unit can be reset individually or all the REMOTE RESET lines can be tied together for a system reset.

A-65 If it is necessary to have all the supplies come up simultaneously after a system shutdown, follow this procedure:

a. First bring the REMOTE INHIBIT line low.
b. Provide a negative-going pulse to the REMOTE RESET
c. After at least one second, return REMOTE INHIBIT to a high level.

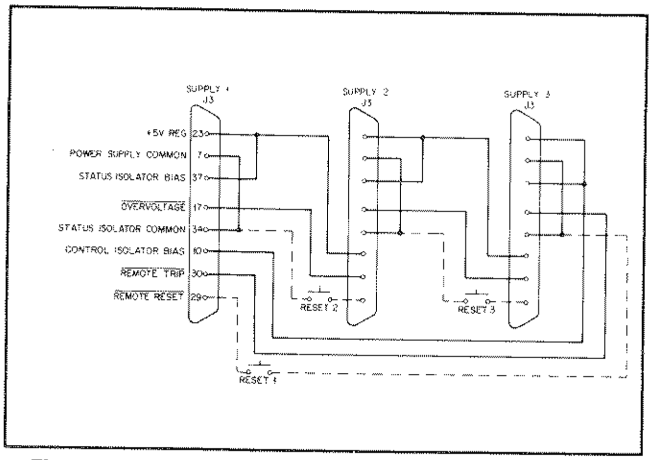


Figure A-10. System Shutdown Using 6010A Bias Supply Output

A-66 Figure A-10 shows a second method of system shutdown. This method is appropriate in systems which are not controller-operated and in which more than four supplies must be shutdown simultaneously. Because each supply derives its CONTROL ISOLATOR BIAS from the previous supply's +5 V REG, there is no limit to the number of supplies that can be shutdown. Each supply must be reset individually.

A-67 Using either method of system shutdown, PCLR inhibits the OVERVOLTAGE indicator from going low and shutting down succeeding supplies upon initial turn-on. After the supplies have stablized, PCLR returns to a high state.

A-68 Bias Supplies

A-69 The outputs of three current-limited bias supplies are available for user-supplied circuitry. These are +15 V @ 75mA at J3-4, −15 V @ 75 mA at J3-20, and +5 V @ 100 mA at J3-23; all with respect to J3-7, L Common.

A-70 It may be desirable to install noise-suppression capacitors on the bias supply outputs near the load circuits. The capacitors should be ceramic or tantalum type, approximately 0.1 μf to 10μf.

A-71 MAINTENANCE

A-72 The following paragraphs provide procedures and setups to aid in checking and troubleshooting the 002 Option Board. This information, used in conjunction with the schematic drawing and the Operation section of this Appendix, will help in the isolation and repair of faulty circuits.

A-73 When testing the option, use of the test connector of paragraph A-17 will allow easier access to the J3 contacts.

A-74 Troubleshooting

A-75 Before attempting to troubleshoot the 002 Option Board, ensure that the fault is with the option itself and not with the main power supply. This can be accomplished by removing the top cover, inside cover and disconnecting the two ribbon cables from the A2 Control board and checking the operation of the main supply. Otherwise troubleshoot the option board as described in the following paragraphs.

A-76 Removal of the Option Board. To facilitate troubleshooting the 002 Option the board can be removed from the power supply and electrically connected via the ribbon cables from Service Kit's 06033-60005 or 5060-2665. To remove the circuit board proceed as follows:

a. Turn off power supply and disconnect line cord.
b. Disconnect option I/O cable from J3 on rear panel and remove the two screws that secure option board to rear panel.
c. Disconnect the ribbon cables from the A2 Control board.
d. Remove option board by lifting the board by the front edge and sliding the board toward the front of the power supply.
e. Reconnect the option board to the A2 Control board using the extended ribbon cables from the Service Kit, and place the option board on an insulated surface next to the power supply.
f. Be careful that the option board lies securely on insulating material and does not touch any part of the main power supply.

A-77 Isolating Faulty Circuit. It is apparent which function is not operating properly, proceed to the appropriate paragraph. If the problem involves more than one function check the bias voltages from connectors J1 and J2 and the ±11.8 V on the option board.

A-78 Troubleshooting Resistance and Voltage Programming

a. Confirm that the problem is on the option board by disconnecting the ribbon cables from the A2 Control Board and attempting to program the supply via the rear panel terminal strip.
b. Check ±15 V and ±11.8 V supplies.
c. Check for a problem in the programming protection circuit. This circuit should draw about 2μA from the programming lines.

d. Check that W3 and W4 are installed and S1 is in proper position.

A-79 Troubleshooting Current Programming

a. Check ±15 V and ±11.8 V supplies.
b. Proceed to test set-up shown in Figure A-11 and/or A-12.
c. Put S1 in V, R position and see if varying the 0-20 V voltage source produces a 0-5 volt DC level across R44 or R39. If not, check op-amps and associated circuitry.
d. Put S1 in I position and see if varying voltage source from 0 to 20 volts produces a 0-5 VDC level at W3 or W4. If not check relay and programming protection circuit.

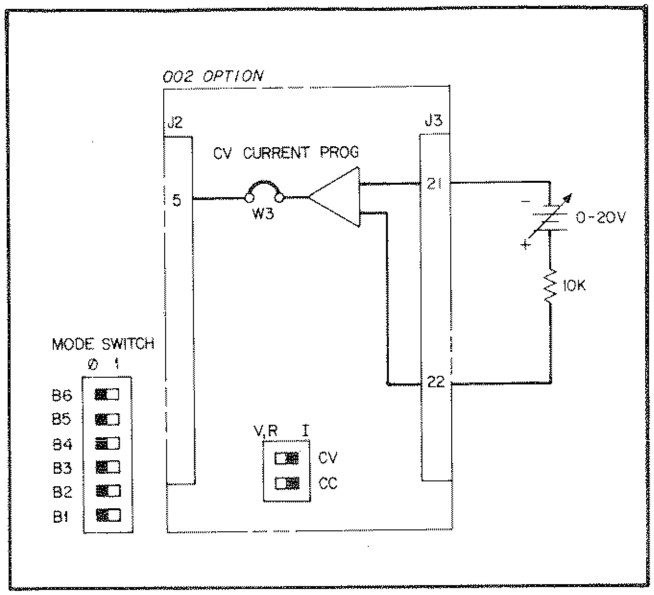


Figure A-11. Troubleshooting Current Programming of CV Mode

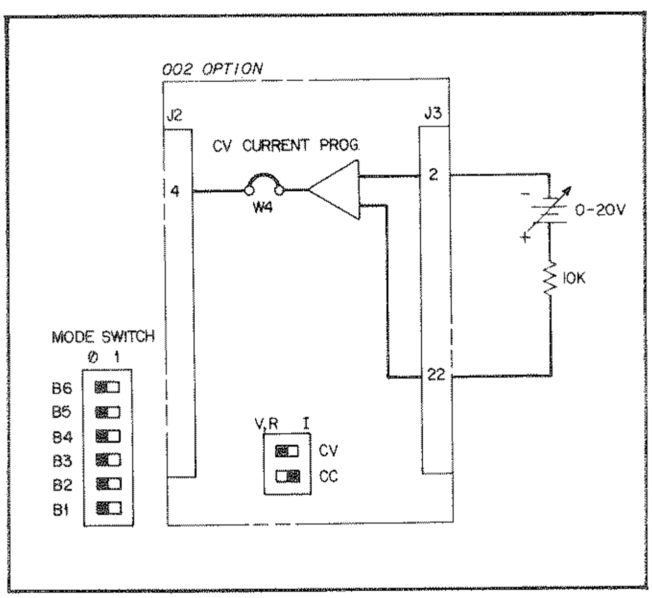


Figure A-12. Troubleshooting Current Programming of CC Mode

A-80 Troubleshooting Status Indicators. The test set-up shown in Figure A-13 can be used to check each of the six status indicators. This set-up will temporarily defeat the isolation of the status lines. Before attempting to troubleshoot a status indicator, check for +5 V Bias for proper operation of the opto-couplers.

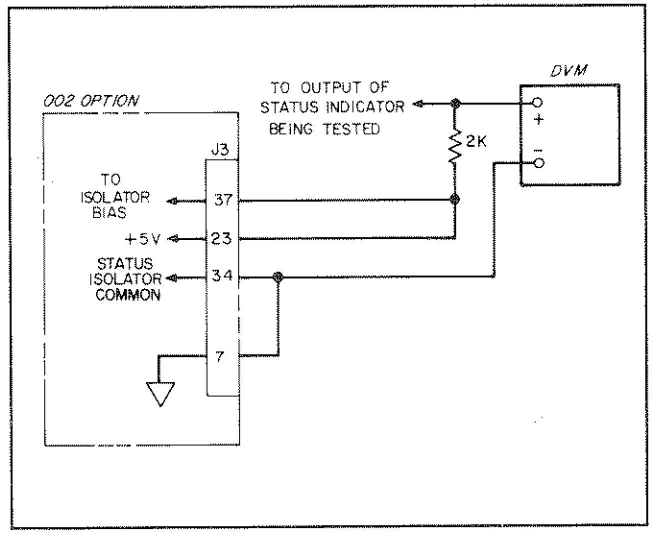


Figure A-13. Troubleshooting Status Indicators

A-81 To check CV Mode proceed as follows:
a. Using test set-up, Figure A-13, connect to end of 2 kΩ resistor to J3-36.
b. Turn on power supply.
c. Using "Display Setting" set voltage and current or power supply for 1 volt and 1 amp.
d. DVM should read between 0 to 0.4 volts.
e. Turn off power supply and short to output terminals.
f. Turn on power supply.
g. DVM should read appoximately 5 Vdc.

A-82 To check CC Mode proceed as follows:
a. Using test set-up, Figure A-13, connect top end of 2 kΩ resistor to J3-35.
b. Turn on power supply.
c. Using "Display Settings" set voltage for 1 volt and current for 1 Amp.
d. DVM should read ≈ 5 Vdc.
e. Turn off power supply and short the output terminals.
f. Turn on power supply.
g. DVM should read between 0 to 0.4 volts DC.

A-83 To check OVERVOLTAGE proceed as follows:
a. Using test set-up, Figure A-13, connect top end of 2 kΩ resistor to J3-17.
b. Turn "OVP Adjust" fully clockwise and voltage control fully counter clockwise.
c. Open power supply output terminals and turn on power.
d. DVM should read approximately 5 Vdc.
e. Press 'Display Settings" and increase voltage control for 15 Vdc output.

f. Turn OVP Adjust" counterclockwise until supply goes into overvoltage.
g. DVM should read between 0 and 0.4 Vdc.
h. Turn "OVP Adjust" fully clockwise and turn off input power for 5 seconds.
i. Turn on input power and DVM should read approximately 5 Vdc.

A-84 To check OUTPUT UNREGULATED proceed as follows:

a. Using test set-up, Figure A-13, connect to end of 2 kΩ to J3-18.
b. Connect output terminals of power supply to an electronic load capable of exceed the power supplies output power rating by 50%.
c. Turn on power supply.
d. DVM should read approximately 5 Vdc.
e. Set voltage and current controls of power supply to maximum.
f. Decrease resistance of electronic load until "UNREGULATED" LED on front panel lights.
g. DVM should now read between 0 to 0.4 VDC.

A-85 To check LOW BIAS or AC Dropout proceed as follows:

a. Using test set-up, Figure A-13, connect top end of 2 KΩ resistor to J3-19.
b. Substitute an oscilloscope in place of DVM. Set vertical deflection for 1 volt/div on the DC input.
c. Turn power on and observe oscilloscope trace. Voltage should increase to 5 V at power-on and drop to between 0 to 0.4 Vac approximately 3 sec.
d. Turn power off. Voltage should go to about 5 Vdc before decaying back to 0 V.

NOTE

In this test, the LOW BIAS or AC Dropout signal decays to 0 V only because of loss of power to the +5 V REG Bias Supply used in the test set-up. If in doubt, use an external +5 V supply for this test.

A-86 To check OVERTEMPERATURE proceed as follows:

a. Turn off power supply and disconnect line cord.
b. Wait at least two minutes for input capacitors to discharge.
c. Remove top cover and inside cover.
d. Using test set-up, Figure A-13, connect top end of 2 kΩ resistor to J3-16.
e. Turn on power supply.
f. DVM should read approximately 5 VAC.
g. Turn off power and wait two mintues.
h. Remove the A4 FET Assembly from the unit.
i. Turn on power supply.
j. DVM should read between 0 to 0.4 VDC.

NOTE

The FET heatsinks are connected to the primary circuit and hazardous voltage (up to between 300 to 400 V) exists between the heatsinks and the heatsink and the chassis. These potentials remain for up to 2 minutes if the power supply is turned off. Do not touch the heatsinks or any components on the heatsink assemlies while the power supply is turned on or for at least two minutes after primary power is removed.. Do not place any of the heatsink assemblies on extender boards.

A-87 Troubleshooting Remote Shutdown. The following procedures check the Remote Shutdown features of 002 Option. Troubleshooting can be accomplished by using a logic probe and referring to the schematic and the circuit description in paragraph A-60. Before attempting to troubleshoot the Remote Shutdown section of the option, check for +5 Vdc internal bias. This voltage must be present for proper operation of these circuits.

A-88 To check the REMOTE TRIP and REMOTE RESET proceed as follows:

a. Connect +5 V (J3-23) to Control Isolator bias (J3-10).
b. Turn unit on and short REMOTE TRIP (J3-30) to +5 V common (J3-7) momentarily. Output should go into unregulated condition with output off.
c. Short REMOTE RESET (J3-29) to +5 V common (J3-7) momentarily and OUTPUT should return to its initial state.

A-89 To check REMOTE INHIBIT proceed as follows:

a. Connect +5 V (J3-23) to control isolator bias (J3-10).
b. Turn unit on and short REMOTE INHIBIT (J3-31) to +5 V common (J3-7). Ouptut should go to an unregulated output off condition.
c . Remove short between REMOTE INHIBIT (J3-31) and +5 V common (J3-7) and output should return to its initial state.

Table A-3. Replacement Parts

REF. DESG.	HP PART NO.	TQ.	DESCRIPTION	MFR. CODE	MFR. PART NO.
A7	5060-2854	1	Opt. 002 Interface Board	28480	
C1,2	0180-0230	6	fxd elect. 1uf 20% 50V	56289	150D105X0050A2
C3	0180-2825	3	fxd elect. 22uf 50V	28480	
C4	0160-4835	2	fxd cer. 0.1uf 10% 50V	28480	
C5	0160-4554	2	fxd cer. 0.01uf 20% 50V	28480	
C6	0160-4835		fxd cer. 0.1uf 10% 50V	28480	
C7	0160-4554		fxd cer. 0.01uf 20% 50V	28480	
C8,9	0180-0230		fxd elect. 1uf 20% 50V	56289	150D105X0050A2
C10	0180-2825		fxd elect. 22uf 50V	28480	
C11	0160-4801	2	fxd cer. 100pf 5% 100V	28480	
C12,13	0160-5422	4	fxd cer. 0.047uf 20% 50V	28480	
C14	0160-4801	2	fxd cer. 100pf 5% 100V	28480	
C15	0160-5422		fxd cer. 0.047uf 20% 50V	28480	
C16	0160-5422		fxd cer. 0.047uf 20% 50V	28480	
C17,18	0180-0230		fxd elect. 1uf 20% 50V	28480	
C19	0180-2825		fxd elect. 22uf 50V	28480	
C20-22	0160-0128	3	fxd cer. 2.2uf 20% 50V		
CR1-4	1901-0050	10	switching 80V 200ma	28480	
CR5-10	1901-0327	8	pwr. rect. 300V 40A	05277	1N1187AR
CR11-14	1901-0033	10	gen. prp. 180V 200ma	12969	1N645
CR15	1901-0327	2	zener 9.09V 10% PD=1.5W	28480	
CR16,17			NOT USED		
CR18,19	1901-0050		switching 80V 200ma	28480	
CR20	1901-0033		gen. prp. 180V 200ma	12969	1N645
CR21,22	1901-0050		switching 80V 200ma	28480	
CR23	1901-0033		gen. prp. 180V 200ma	12969	1N645
CR24,25	1901-0050		switching 80V 200ma	28480	
CR26-29	1901-0033		gen. prp. 180V 200ma	12969	1N645
CR30	1901-0327		zenar 9.09V 10% PD=1.5W	28480	
K1,2	0490-1418	2	relay 250ma 28V,5V-coil 3VA	28480	
L1-3	9170-1223	3	core shielding bead	28480	
Q1,2	1854-0823	2	NPN SI PD=300mW FT=200MHZ	28480	
R1-3	0683-2015	3	fxd. film 200 5% 1/4W	01121	CB2015
R4	0683-3925	1	fxd. film 3.9K 5% 1/4W	01121	CB3925
R5	0683-2035	1	fxd. film 20K 5% 1/4W	01121	CB2035
R6	0683-3035	1	fxd. film 30K 5% 1/4W	01121	CB3035
R7	0683-6225		fxd. film 6.2K 5% 1/4W	01121	CB6225
R8,9	0683-2035		fxd. film 20K 5% 1/4W	01121	CB2035
R10	0683-1035	3	fxd. film 10K 5% 1/4W	01121	CB1035
R11	0683-5125	3	fxd. film 5.1K 5% 1/4W	01121	CB5125
R12	0757-0984	1	fxd. film 10 1% 1/2W	28480	
R13	0683-1615	1	fxd. film 160 5% 1/4W	01121	CB1615
R14	0683-4715	7	fxd. film 470 5% 1/4W	01121	CB4715
R15,16	0683-1235	6	fxd. film 12K 5% 1/4W	01121	CB1235
R17	0686-1525	3	fxd. film 1.5K 5% 1/4W	01121	CB1525
R18	0683-1535	3	fxd. film 15K 5% 1/4W	01121	CB1535
R19	0683-4715		fxd. film 470 5% 1/4W	01121	CB4715
R20,21	0683-1235		fxd. film 12K 5% 1/4W	01121	CB1235
R22	0686-1525		fxd. film 1.5K 5% 1/4W	01121	CB1525
R23	0683-1535		fxd. film 15K 5% 1/4W	01121	CB1535
R24	0683-4715		fxd. film 470 5% 1/4W	01121	CB4715
R25,26	0683-1235		fxd. film 12K 5% 1/4W	01121	CB1235
R27	0686-1525		fxd. film 1.5K 5% 1/4W	01121	CB1525
R28	0683-1535		fxd. film 15K 5% 1/4W	01121	CB1535

Table A-3. Replacement Parts (cont.)

REF. DESG.	HP PART NO.	TQ.	DESCRIPTION	MFR. CODE	MFR. PART NO.
R29,30	0698-4479	2	fxd. film 14K 1% 1/8W	24546	CT4-1/8-TO-1402-F
R31	0686-5125	2	fxd. comp. 5.1K 5% 1/2W	01121	EB5125
R32	0683-5125		fxd. film 5.1K 5% 1/4W	01121	CB5125
R33	0686-5125		fxd. comp. 5.1K 5% 1/4W	01121	EB5125
R34	0683-5125		fxd. film 5.1K 5% 1/4W	01121	CB5125
R35	0757-0986	2	fxd. film 12.1K 1% 1/2W	28480	
R36	0757-0269	2	fxd. film 270 1% 1/8W	24546	CT4-1/8-TO-271-F
R37	0683-4715		fxd. film 470 5% 1/4W	01121	CB4715
R38	0683-1035		fxd. film 10K 5% 1/4W	01121	CB1035
R39	0698-6631	2	fxd. film 2.5K .1% 1/8W	28480	
R40	0683-4715		fxd. film 470 5% 1/4W	01121	CB4715
R41	0813-0001	2	fxd. ww. 1K 5% 3W	28480	
R42	0683-4715		fxd. film 470 5% 1/4W	01121	CB4715
R43	0683-1035		fxd. film 10K 5% 1/4W	01121	CB1035
R44	0698-6631	1	fxd. film 2.5K .1% 1/8W	28480	
R45	0683-4715		fxd. film 470 5% 1/4W	01121	CB4715
R46	0813-0001		fxd. ww. 1K 5% 3W	28480	
R47	0683-1525	1	fxd. film 1.5K 5% 1/4W	01121	CB1525
R48	0683-3325	1	fxd. film 3.3K 5% 1/4W	01121	CB3325
R49	0683-2225	1	fxd. film 2.2K 5% 1/4W	01121	CB2225
R50,51	0683-3355	2	fxd. film 3.3M 5% 1/4W	01121	CB3335
R52,53	0683-1055	1	fxd. film 1M 5% 1/4W	01121	CB1055
R54	0757-0441	1	fxd. film 8.25K 1% 1/8W	24546	CT4-1/8-TO-8251-F
R55	0757-0986		fxd. film 12.1K 1% 1/2W	28480	
R56	0757-0269		fxd. film 270 1% 1/8W	24546	CT4-1/8-TO-271-F
S1	3101-2715	1	Switch-Slide 2-1A .1A 50V	28480	
U1-3	1990-0732	3	Opto-Isolator IF=20mA max.	28480	
U4	1820-1197	1	IC NAND gate TTL LS quad	01295	SN74LS00N
U5	1820-1202	1	IC NAND gate TTL LS	01295	SN74LS10N
U6	5060-2942	2	IC Voltage Reg.heatsink assy.	28480	
U7	5060-2945	1	IC Voltage Reg.heat sink assy.	28480	
U8-10	1990-0494	3	Opto-Isolator IF=20mA max.	28480	
U11	1820-1491	1	IC Buffer TTL LS, hex	01295	SN74LS367AN
U12	1820-1416	1	IC Schmitt-Trig. TTL LS, hex	01295	SN74LS14N
U13	1820-1437	1	IC Multi. Vib. TTL LS	01295	SN74LS221N
U14	1858-0023	1	Trans. Array 16-pin	28480	
U15	5060-2943	2	IC Voltage Reg.heatsink assy.	28480	
U16	5060-2950	1	IC Voltage Reg.heatsink assy.	28480	
U17,18	1826-0493	2	IC Op Amp Low-bias-High-Impd.	04713	LM308AN
U19	5060-2942		IC Voltage Reg.heatsink assy.	28480	
U20	5060-2946	1	IC Voltage Reg.heatsink assy.	28480	
VR1-8	1902-0556	10	zener 20V 5% PD=1W IR=5uA	28480	
VR9	1902-3185	1	zener 12.4V 5% PD=.4W	28480	
VR10	1902-0556		zener 20V 5% PD=1W IR=5uA	28480	
VR11	1902-3256	2	zener 23.7V 5% PD=.4W	28480	
VR12	1902-0779	1	zener 11.8V 5% PD=.4W	28480	
VR13	1902-3180	1	zener 11.8V 2% PD=.4W	28480	
VR14	1902-3110	1	zener 5.9V 2% PD=.4W	28480	
VR15	1902-0575	1	zener 6.5V 2% PD=.4W	28480	
VR16	1902-0556		zener 20V 5% PD=.4W IR=5uA	28480	
VR17	1902-3256		zener 23.7V 5% PD=.4W	28480	
Z1	1810-0276	1	network res. 1.5K x 9	01121	210A152

Table A-3. Replacement Parts (cont.)

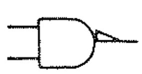
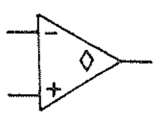
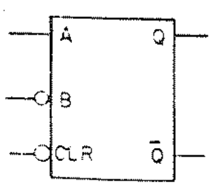
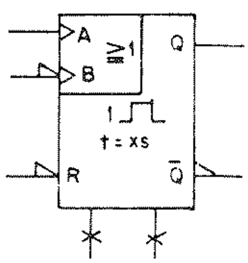
REF. DESG.	HP PART NO.	TQ.	DESCRIPTION	MFR. CODE	MFR. PART NO.
			Mechanical		
	06023-00013	1	plate (ref. A7J3)	28480	
A7J3	1251-6075	1	connector 37-pin	28480	
	1205-0282	6	heatsink (ref. U6,7,15, 16,19,20)	28480	
W1	1258-0189	1	jumper	28480	
W2			NOT USED		
W3,4	7175-0057	2	jumper,solid tinned copper	28480	
W5,6	8120-4356	2	ribbon cable, 16 cond.	28480	
	1251-8417	2	post type header(ref. J1, J2)	28480	

Definitions

High = more positive
Low = less positive

Indicator and Qualifier Symbols

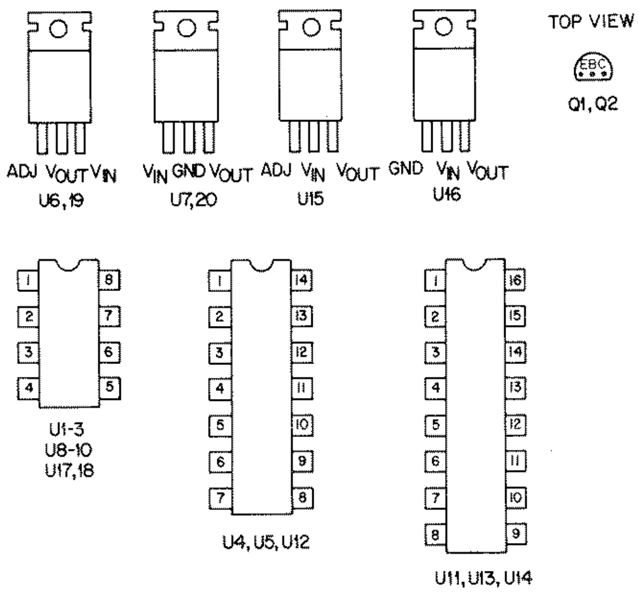
≧	OR function
◺	(polarity indicator, shown outside logic symbol) Any marked input or output is active low; any unmarked input or output is active high.
▷	(dynamic indicator) Any market input is edge-triggered, ie, active during transition between states; any unmarked input is level sensitive.
⎍	(Schmitt trigger) indicates that hysteresis exists in device.
✶	(non-logic indicator) Any marked input or output does not carry logic information.
◊	open-collector or open emitter output
1⎍	monostable (one-shot) multivibrator
t = xSec	indicates pulse width (usually determined by external RC network)
G	gate input (a number following G indicates which inputs are gated)
C	control input (clock)
R	reset (clear)
S	set

OLD SYMBOL	*NEW SYMBOL*	*NOTES*
		
		Output requires external components to achieve logic state
		A positive-going transition at A or a negative-going transition at B triggers the one-shot. External timing components connect to non-logic inputs.
		Output changes state rapidly regardless of input rate of change.

Logic Symbols and Definitions

SCHEMATIC NOTES:

1. ALL RESISTORS ARE IN OHMS, ±5%, 1/4W, UNLESS OTHERWISE INDICATED.
2. ALL CAPACITORS ARE IN MICROFARADS, UNLESS OTHERWISE INDICATED
3. WHITE SILKSCREENED DOTS ON P.C. BOARDS INDICATE ONE OF THE FOLLOWING:
   A. PIN 1 OF AN I.C. (EXCEPT FOR U18, SEE NOTE 4).
   B. POSITIVE END OF A POLARIZED CAPACITOR.
   C. CATHODE OF A DIODE OR THE EMITTER OF A TRANSISTOR.
4. PIN LOCATIONS FOR SEMICONDUCTORS ARE SHOWN BELOW:



5. ON VOLTAGE REGULATOR DEVICES,
   REF SUPPLY = BIAS FOR REGULATOR'S INTERNAL REFERENCE.
   REF = OUTPUT FROM REGULATOR'S INTERNAL REFERENCE.
   BOOST OUTPUT = CONTROL FOR EXTERNAL PASS TRANSISTOR.
   C_S = CURRENT SENSE
   C_L = CURRENT LIMIT
   INV = INVERTING INPUT TO REGULATOR'S ERROR AMPLIFIER.
   NI = NON-INVERTING INPUT TO REGULATOR'S ERROR AMPLIFIER.
   COMP = FREQUENCY COMPENSATION.

Schematic Notes

1. W1 in normally open position.
2. W3 & W4 jumpered.
3. Relays K1, K2 normally closed.
4. S1A and S1B are located at the rear panel.

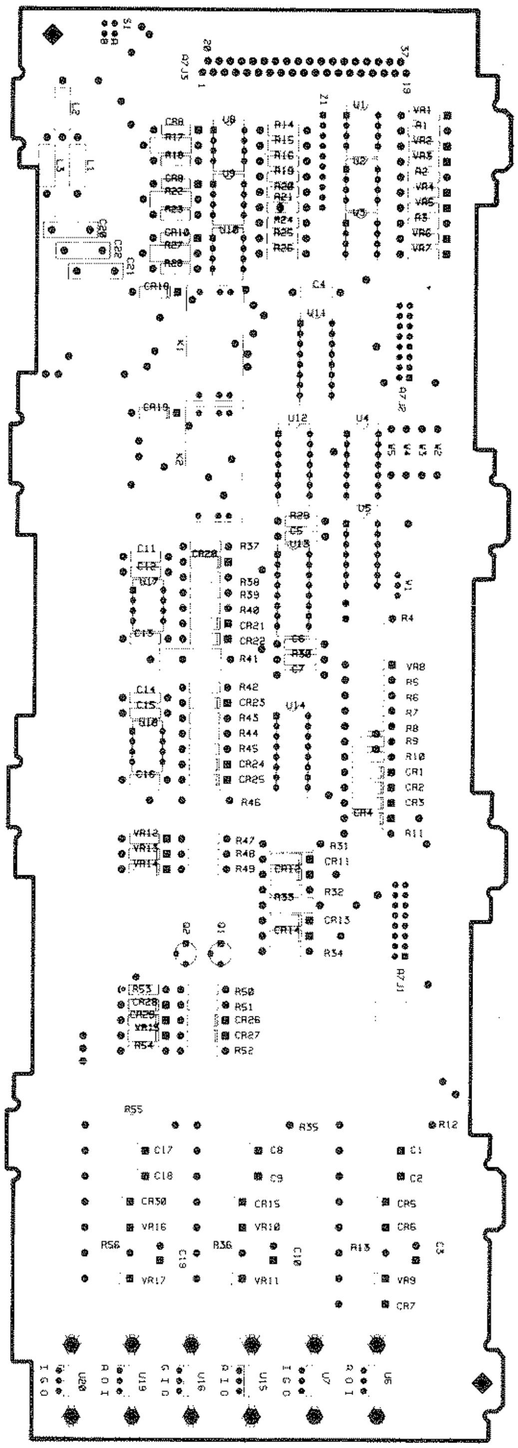


Figure A-15. Option 002 Board. Component Location

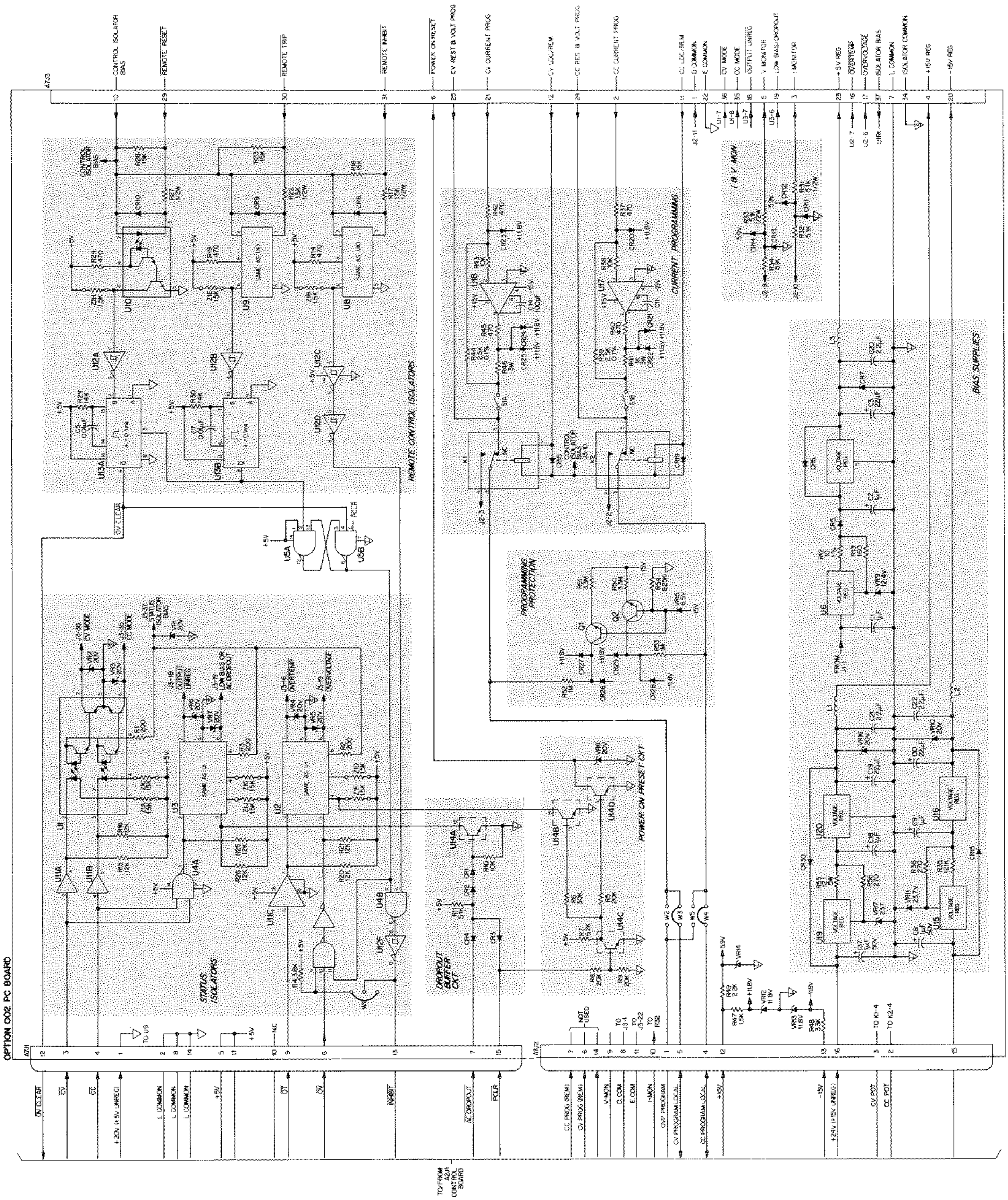


Figure A-16. Option 002 Board Schematic Diagram