HEWLETT PACKARD

Operating and Service Manual

Autoranging DC Power Supply HP Model 6012B

HP Part No 06012-90004

For Instruments with Serial Numbers
2428A-00101 and Above

For instruments with Serial Numbers abvove
2428A-00101, a change page may be included.

Microfiche Part No. 06012-90005

Printed in USA: August, 1984

CERTIFICATION

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

WARRANTY

This Hewlett-Packard hardware product is warranted against defects in material and workmanship for a period of one year from date of delivery. HP software and firmware products, which are designated by HP for use with a hardware product and when properly installed on that hardware product, are warranted not to fail to execute their programming instructions due to defects in material and workmanship for a period of 90 days from date of delivery. During the warranty period Hewlett-Packard Company will, at its option, either repair or replace products which prove to be defective. HP does not warrant that the operation for the software firmware, or hardware shall be uninterrupted or error free.

For warranty service, with the exception of warranty options, this product must be returned to a service facility designated by HP. Customer shall prepay shipping charges by (and shall pay all duty and taxes) for products returned to HP for warranty service. Except for products returned to Customer from another country, HP shall pay for return of products to Customer.

Warranty services outside the country of initial purchase are included in HP's product price only if Customer pays HP international prices (defined as destination local currency price, or U.S. or Geneva Export price).

If HP is unable, within a reasonable time, to repair or replace any product to a condition as warranted, the Customer shall be entitled to a refund of the purchase price upon return of the product to HP.

LIMITATION OF WARRANTY

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by the Customer, Customer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation and maintenance. NO OTHER WARRANTY IS EXPRESSED OR IMPLIED. HP SPECIFCALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

EXCLUSIVE REMEDIES

THE REMEDIES PROVIDED HEREIN ARE THE CUSTOMER'S SOLE AND EXLCUSIVE REMEDIES. HP SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

ASSISTANCE

The above statements apply only to the standard product warranty. Warranty options, extended support contracts, product maintenance agreements and customer assistance agreements are also available. Contact your nearest Hewlett-Packard Sales and Service office for further information on HP's full line of Support Programs.

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.

Herstellerbescheinigung

Hiermit wird bescheinigt, daß das Gerät in Übereinstimmung mit den Bestimmungen der Postverfügung 1046/84 funkentstört ist. Der Deutschen Bundespost wurde das Inverkehrbringen dieses Gerätes/Systems angezeigt und die Berechtigung zur Überprüfung der Serie auf Einhaltung der Bestimmungen eingeräumt.

Zusatzinformation für Meß- und Testgeräte

Werden Meß- und Testgeräte mit ungeschirmten Kabeln und/oder in offenen Meßaufbauten verwendet, so ist vom Betreiber sicherzustellen, daß die Funk-Entstörbestimmungen unter Betriebsbedingungen an seiner Grundstücksgrenze eingehalten werden.

Manufacturer's Declaration

This is to certify that this equipment is in accordance with the Radio Interference Requirements of Directive FTZ 1046/84. The German Bundespost was notified that this equipment was put into circulation; the right to check the series for compliance with the requirements was granted.

Additional Information for Test and Measurement Equipment

If Test and Measurement Equipment is operated with unscreened cables and/or used for measurements on open set-ups, the user has to assure that under operating conditions the Radio Interference Limits are still met at the border of his premises.

Herstellerbescheinigung

Diese Information steht im Zusammenhang mit den Anforderungen der Maschinenlärminformationsverordnung vom 18 Januar 1991.

* Schalldruckpegel Lp < 70 dB(A) * Am Arbeitsplatz * Normaler Betrieb * Nach DIN 45635 T. 19 (Typprüfung)

Manufacturer's Declaration

This statement is provided to comply with the requirements of the German Sound Emission Directive, from 18 January 1991. This product has a sound pressure emission (at the operator position) < 70 dB.

* Sound Pressure Lp < 70 dB(A) * At Operator Position * Normal Operation * According to ISO 7779 (Type Test).

Section I
GENERAL INFORMATION

1-1 INTRODUCTION

1-2 This Operating and service manual contains a description of the HP Model 6012B System Power Supply, including specifications, installation and operating instructions, theory of operation, maintenance procedures and schematics.

1-3 DESCRIPTION

1-4 The HP 6012B is a 1000 W autoranging power supply with maximum ratings of 60 V and 50 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 +240 Vdc (including output voltage) from chassis ground. Output voltage can be locally or remotely sensed.

1-6 The HP 6012B 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 6012B.

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 V 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.
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
5061-0089	Front handle kit for 5¼ inch high cabinets.
1460-1345	Tilt stand (1) snaps into standard foot on instrument, must be used in pairs.
5061-0077	Rack flange kit for 5¼ inch high cabinet (will be shipped with instrument if ordered as option 908).
5061-0083	Rack mount flange kit with handles.
1494-0018	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

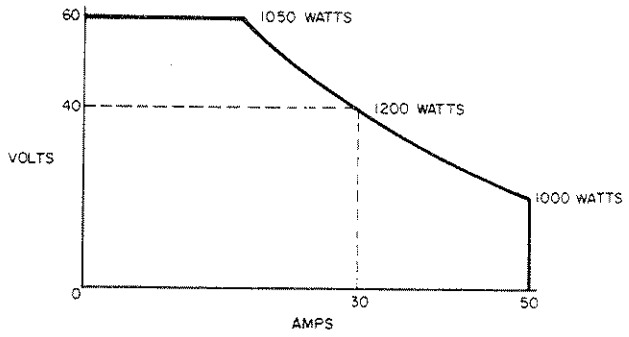
DC Output

Output is autoranging from 20 to 50 V. Voltage and current can be programmed via front-panel control, or remote analog control over the following ranges:

Voltage: 0—60 V **Current:** 0—50 A

Output Boundary Specification

Voltage (V)	Current (A)	Power (W)
20	50.0	1000
25	44.0	1100
30	38.5	1155
35	34.0	1190
40	30.0	1200
45	26.5	1193
50	23.0	1150
55	20.0	1100
60	17.5	1050



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% +3 mV **Current:** 0.01% +10 mA

PARD (Ripple and Noise)

	20 Hz—10 MHz	20 Hz—100 MHz
CV	5 mV rms +0.005% Vout	5 mV rms +0.005% Vout
	40 mV p-p	75 mV p-p
CC	25 mA rms	25 mA rms

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 ±240 Vdc (including output voltage) from earth ground.

Temperature Coefficient

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

Voltage: 80 ppm +4 mV **Current:** 100 ppm +8 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% +5 mV **Current:** 0.03% +10 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 100 mV
50% load current change: 3 ms to within 300 mV

Resolution

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

Voltage: 20 mV **Current:** 20 mA

Programming Response Time

Maximum time for output voltage to change from 0 V to 60 V or 60 V to 2 V and settle within specified band.

		90 mV	200 mV
Up:	Full Load (3.4 ohms)	300 ms	120 ms
	No Load	300 ms	120 ms
Down:	Full Load (3.4 ohms)	2 s	400 ms
	Light Load (100 ohms)	3 s	3 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% ±70 mV
CC 1% ±500 mA

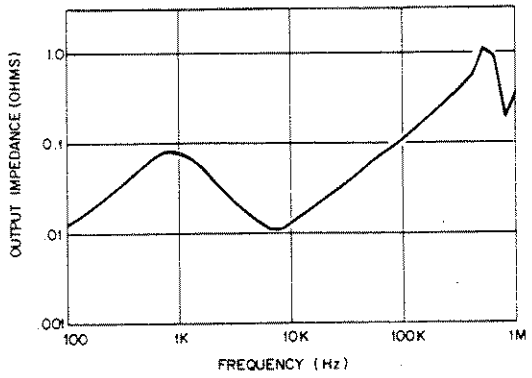
Voltage Programming:

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

Accuracy: CV 0.3% ±70 mV
CC 0.36% ±500 mA

Output Impedance (Typical)

See graph.



Front Panel Meters (25 ± 5°C)

	Range	Resolution	Accuracy	Temp. Coeff.
Voltage	20 V	10 mV	0.65% +3.5 counts	80 ppm +1 mV/°C
	200 V	100 mV	same	same
Current	200 A	100 mA	0.6% +4 counts	100 ppm +2 mA/°C
OVP	200 V	100 mV	2.5% +550 mV	200 ppm +3 mV/°C

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—64 V
Resolution: 200 mV
Accuracy : 2.5% +550 mV

Reverse Voltage Protection

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

50 A continuous with ac power on
20 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. AC power on
2. Up-programming
3. Cross-over from CC to CV mode
4. 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% + 15 mV
CC 0.36% + 20 mA

Output Impedance: 10 kΩ

Multiple Unit Operations

Up to four 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.

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.

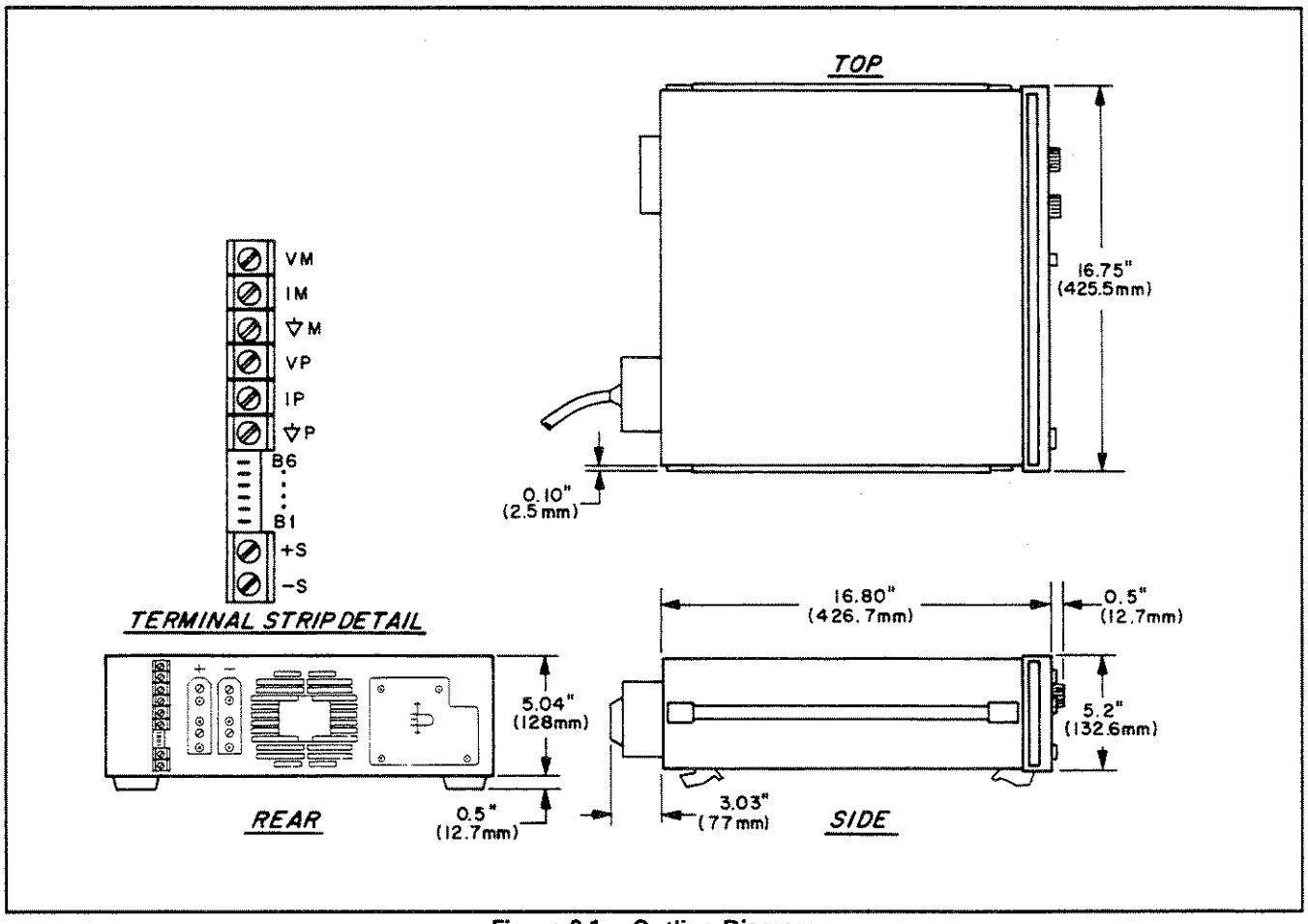


Figure 2-1. Outline Diagram

2-9 PREPARATION FOR USE

2-10 In order to be put into service, the power 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 (4 mm^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.

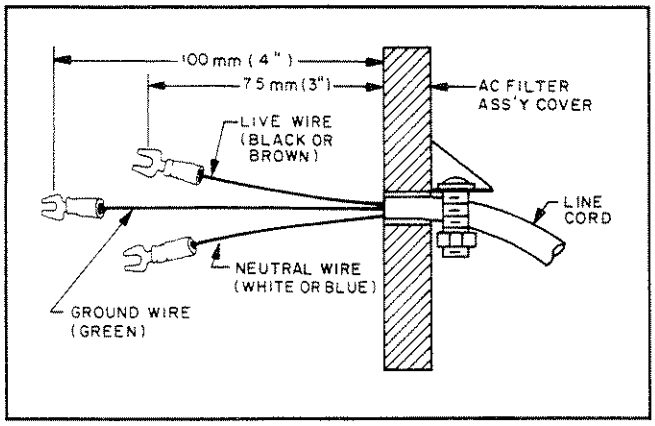


Figure 2-2. Power Cord Preparation

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.

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), some components may overheat 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-

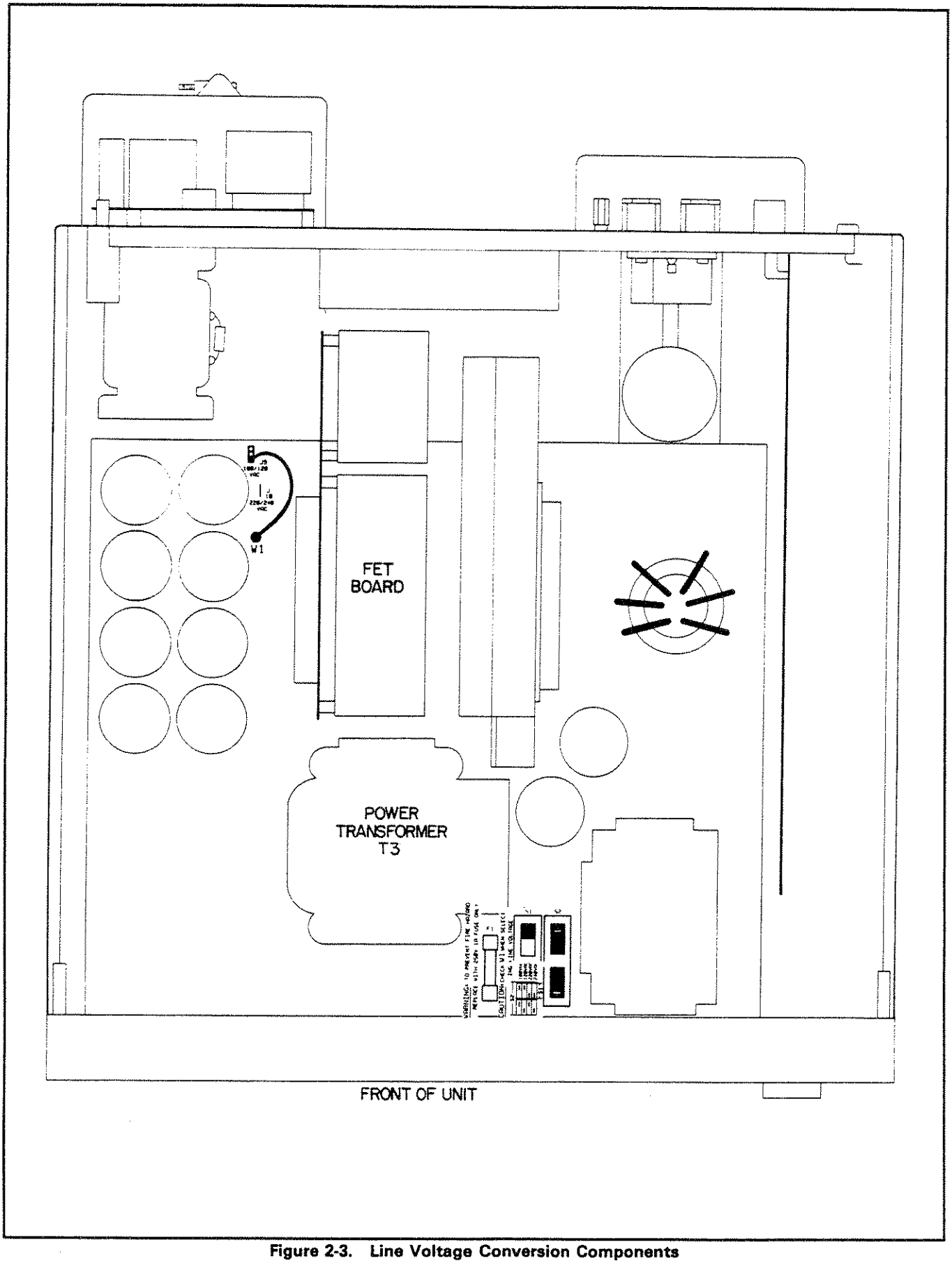


Figure 2-3. Line Voltage Conversion Components

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-strained 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 a 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 50 A. The unit's output voltage should be greater than or equal to 22 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 60 Vdc range.
3. **CURRENT Control:** Clockwise rotation increases output current, 0 to 50 Adc range.
4. **OVP ADJUST Screwdriver Control:** Clockwise rotation with a small, flat-blade screwdriver increases setting for overvoltage shutdown, 0 to 66 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 current 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.)

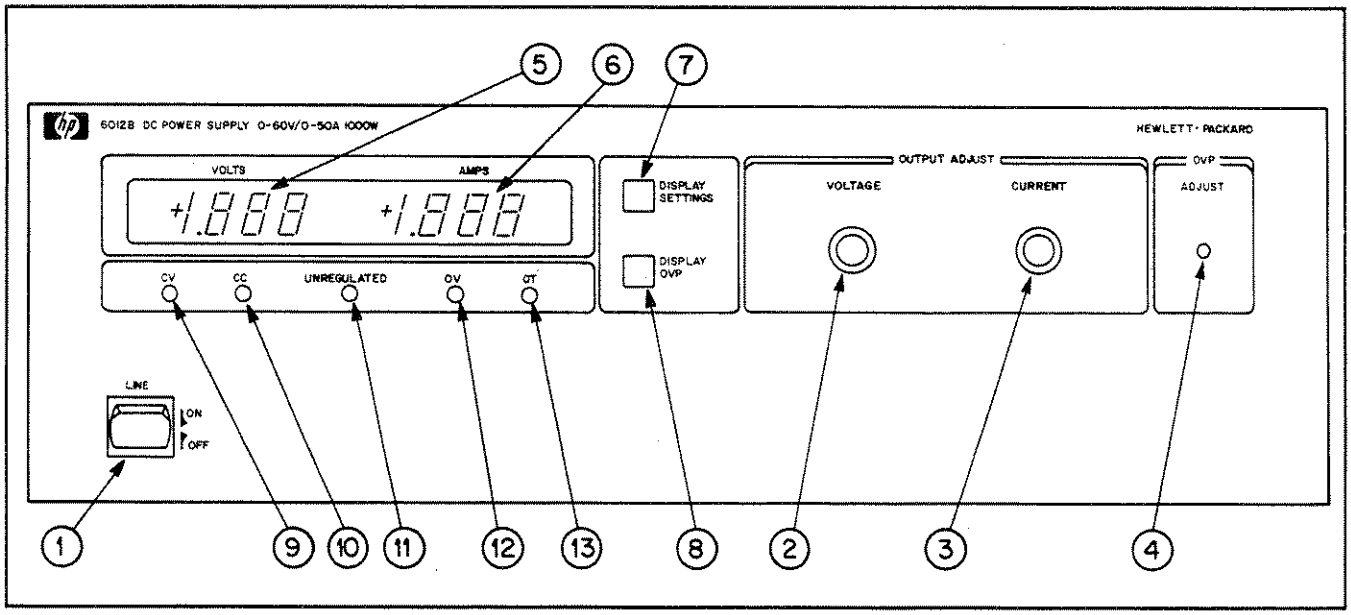


Figure 3-1. Front-Panel Controls and Indicators

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 60 Vdc. If not, turn up OVP ADJUST with a small flat-blade screwdriver.
h. Turn up the output voltage; verify that the VOLTS display can increase to 60 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 50.

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 #10 copper wire (6 sq. mm cross section area) is rated for 54.6 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 #10 (6 sq. mm).

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.

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	20 A	30 A	50 A	120 A
4	25.0	0.2486	0.795	(100) 31.0	(68) 20.0	(40.23) 12.58	(16.76) 5.24
2	35	0.1564	0.565	(159) 44.0	(108) 29.0	(68.94) 17.70	(26.64) 7.34
	50		0.393	63.0	42.0	25.45	1060
0		0.09832		(254)	(173)	(101.71)	(42.38)

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	0.5	16.15	40.1	(12.0) 5.0
20	0.75	10.16	26.7	(19.0) 7.5
18	1.0	63.88	20.0	(31.0) 10.0
16	1.5	4.018	13.7	(47.0) 14.5
14	2.5	2.526	8.21	(79.0) 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 ac mains input voltage. Reset the unit after eliminating the cause of shutdown by switching the power off for one second and then back on.

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.

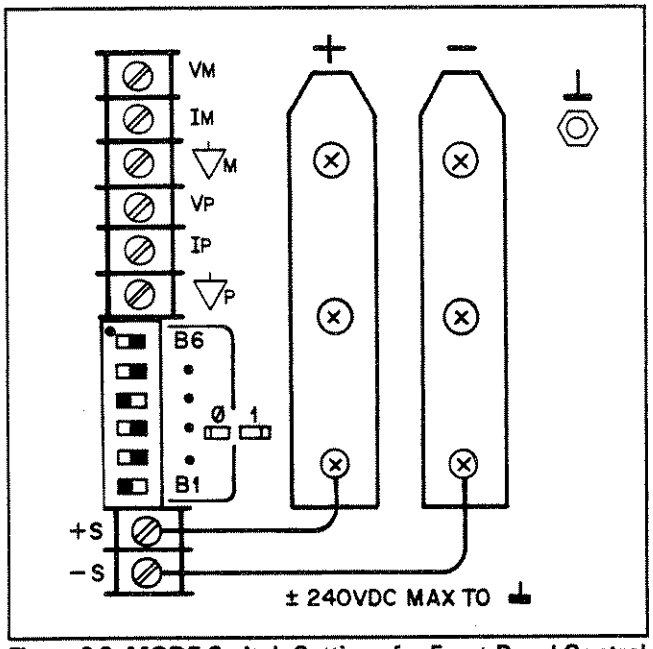


Figure 3-2. MODE-Switch Settings for Front-Panel Control

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.

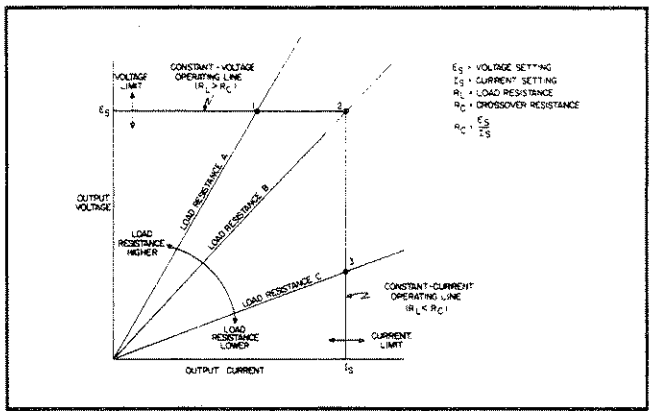


Figure 3-3A Determining Operating Point

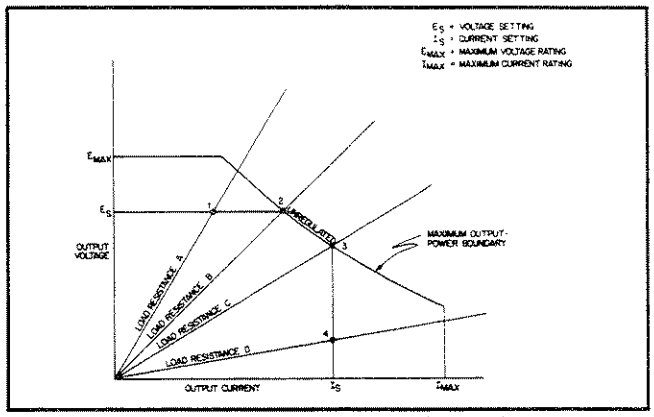


Figure 3-3B. Unregulated Operation

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.

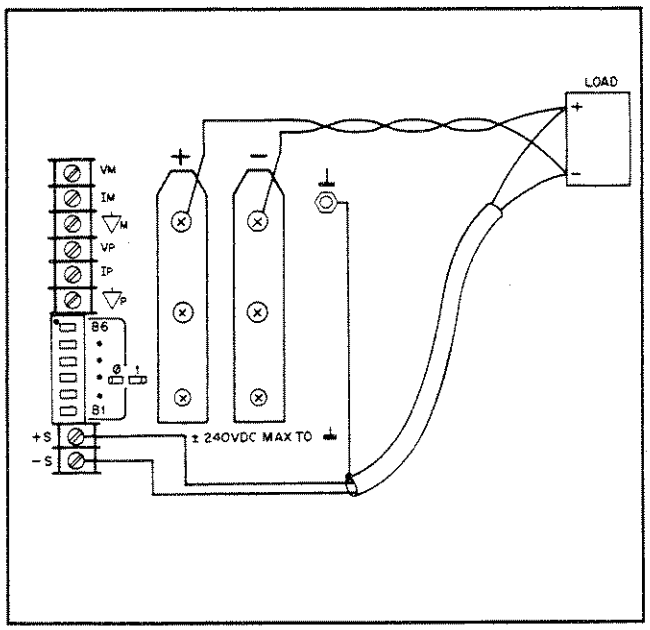


Figure 3-4. Remote Voltage Sensing

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.

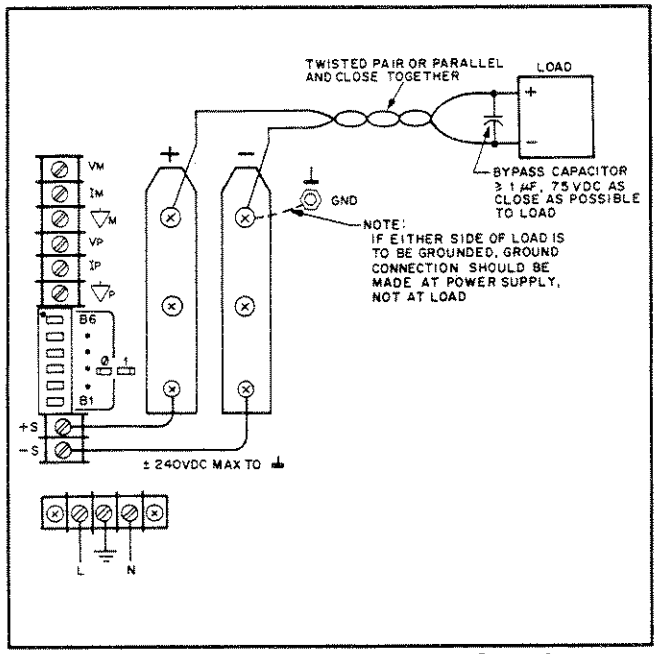


Figure 3-5. Connecting a Bypass Capacitor

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 12 Vdc change in output voltage or a 10 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 15 Vdc change in output voltage or a 12.5 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.

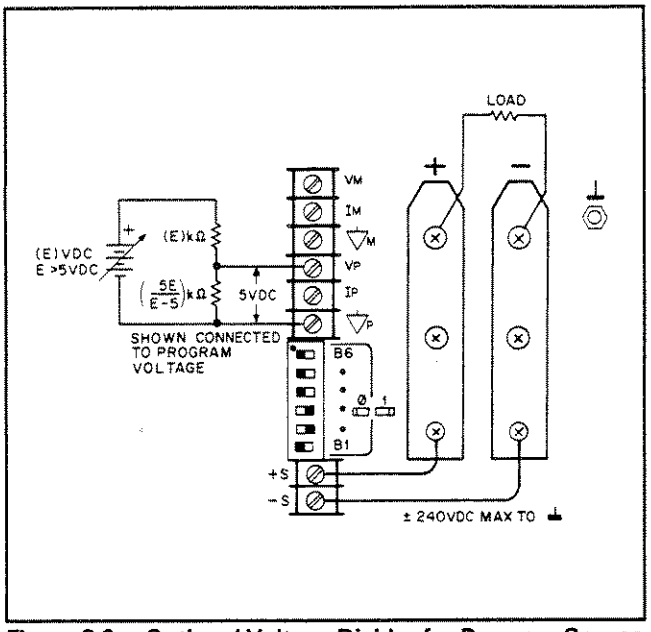


Figure 3-6. Optional Voltage Divider for Program Source

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 60 Vdc output voltage. The output voltage is 12 times the input. The load on the programming voltage source is less than 5 μA.

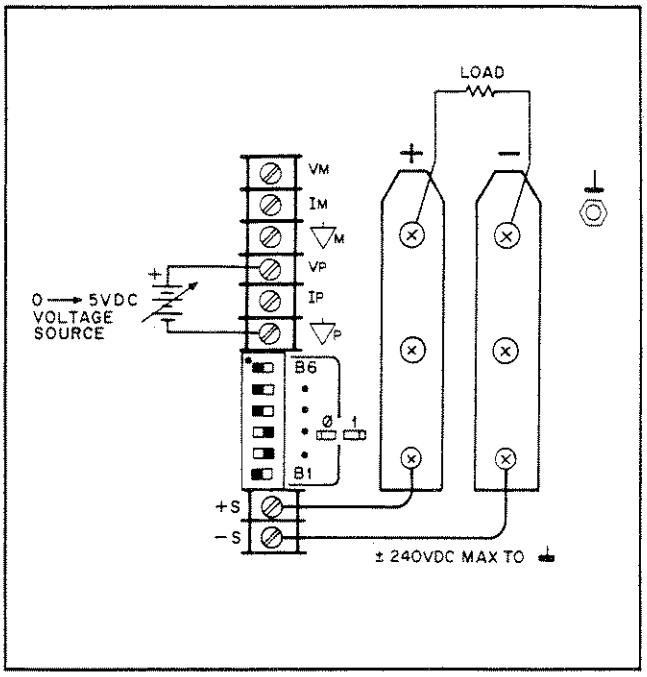


Figure 3-7. Voltage Programming of Output Voltage

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 50 Adc output current. The output current is 10 times the input. The load on the programming voltage source is less than 5 μA.

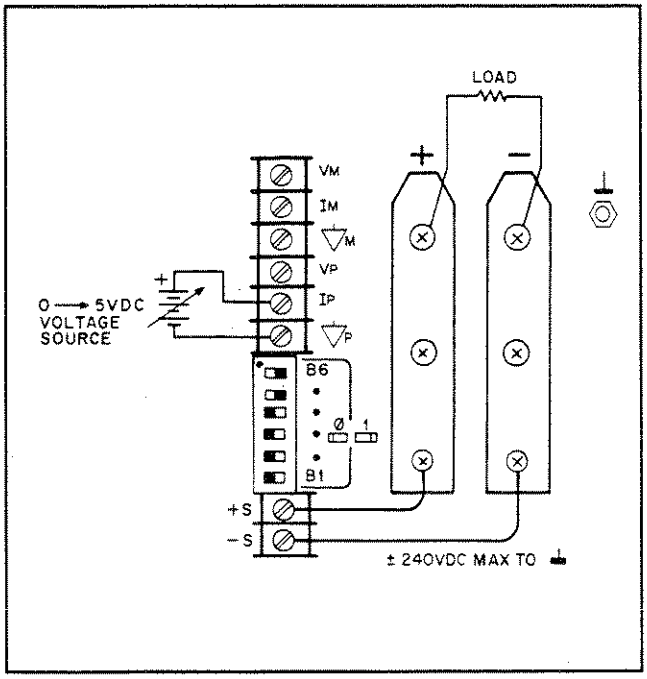


Figure 3-8. Voltage Programming of Output Current

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 60 Vdc output. The resistance programming coefficient is nominally 66.67 ohms/volt.

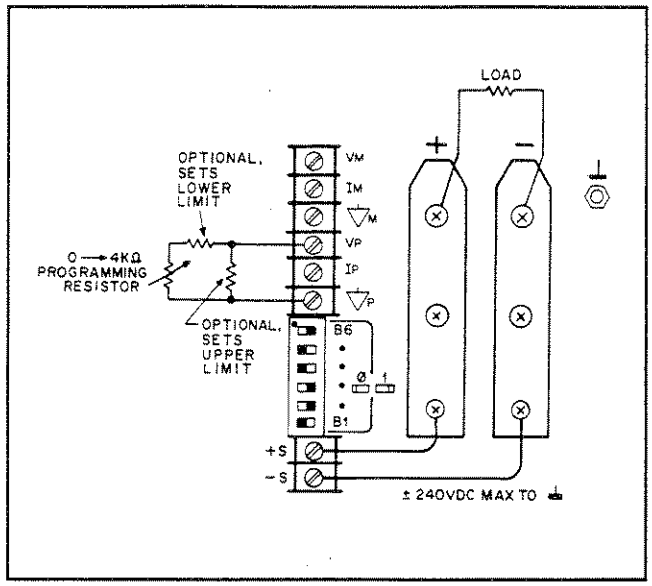


Figure 3-9. Resistance Programming of Output Voltage

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 50 Adc output current. The resistance programming coefficient is nominally 80 ohms/amp.

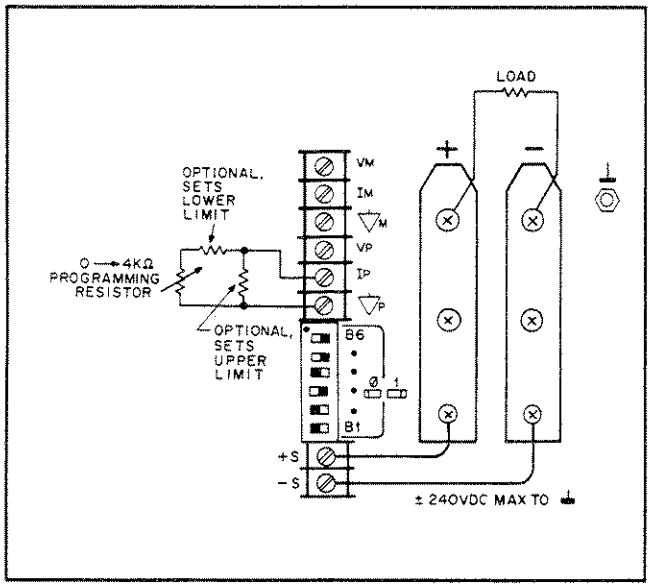


Figure 3-10. Resistance Programming of Output Current

CAUTION

If the connection of a programming resistor to a programming terminal opens during resistance programming, the output of the unit goes to about 66 Vdc or 58 Adc depending on whether CV or CC programming is interrupted. OVP shutdown prevents operation at 66 Vdc, and operation with 58 Adc of output current does not damage the unit but it may 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 or more units and then controlling all from one—the master. 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 60 Vdc at an output current of up to 100 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 more than 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

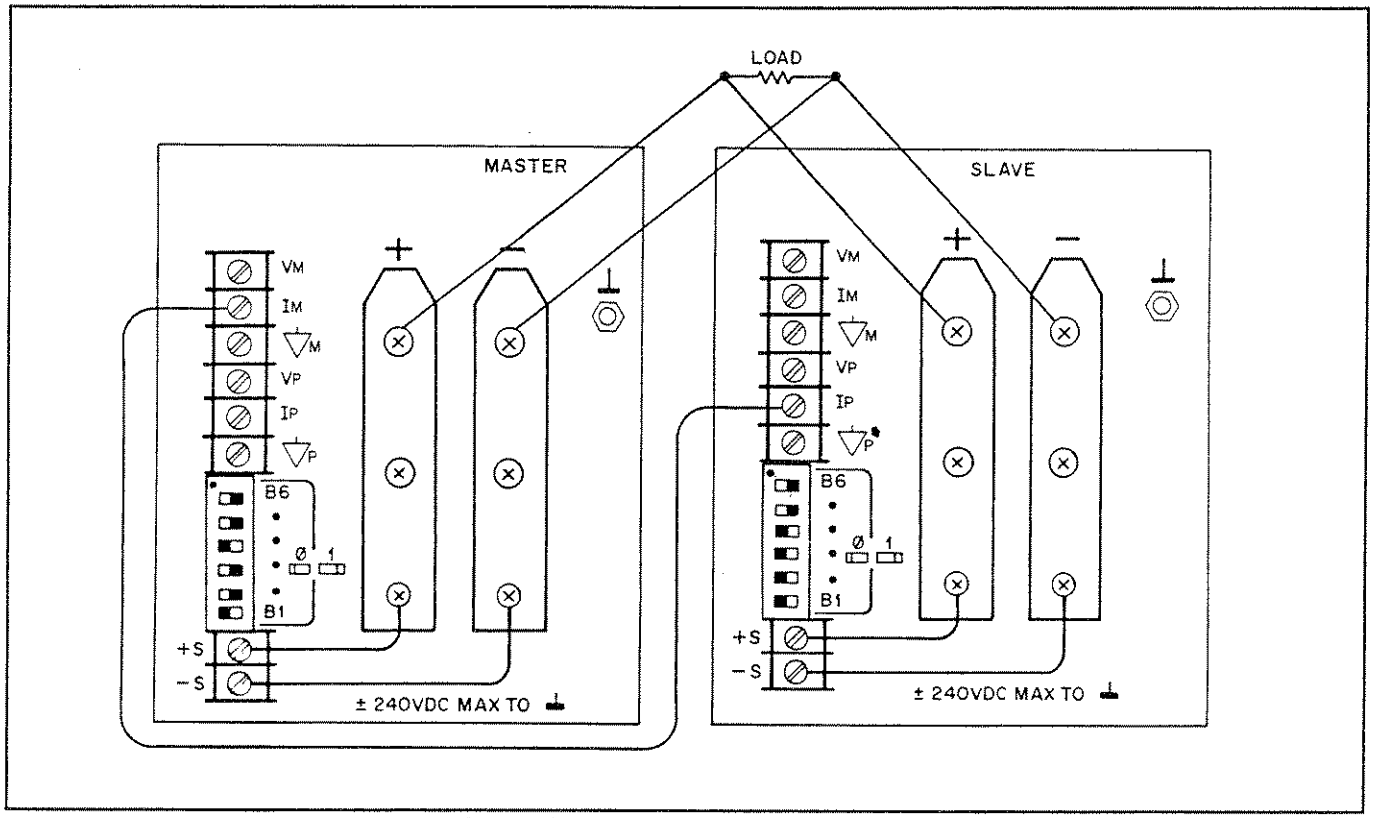


Figure 3-11. Auto-Parallel Operation

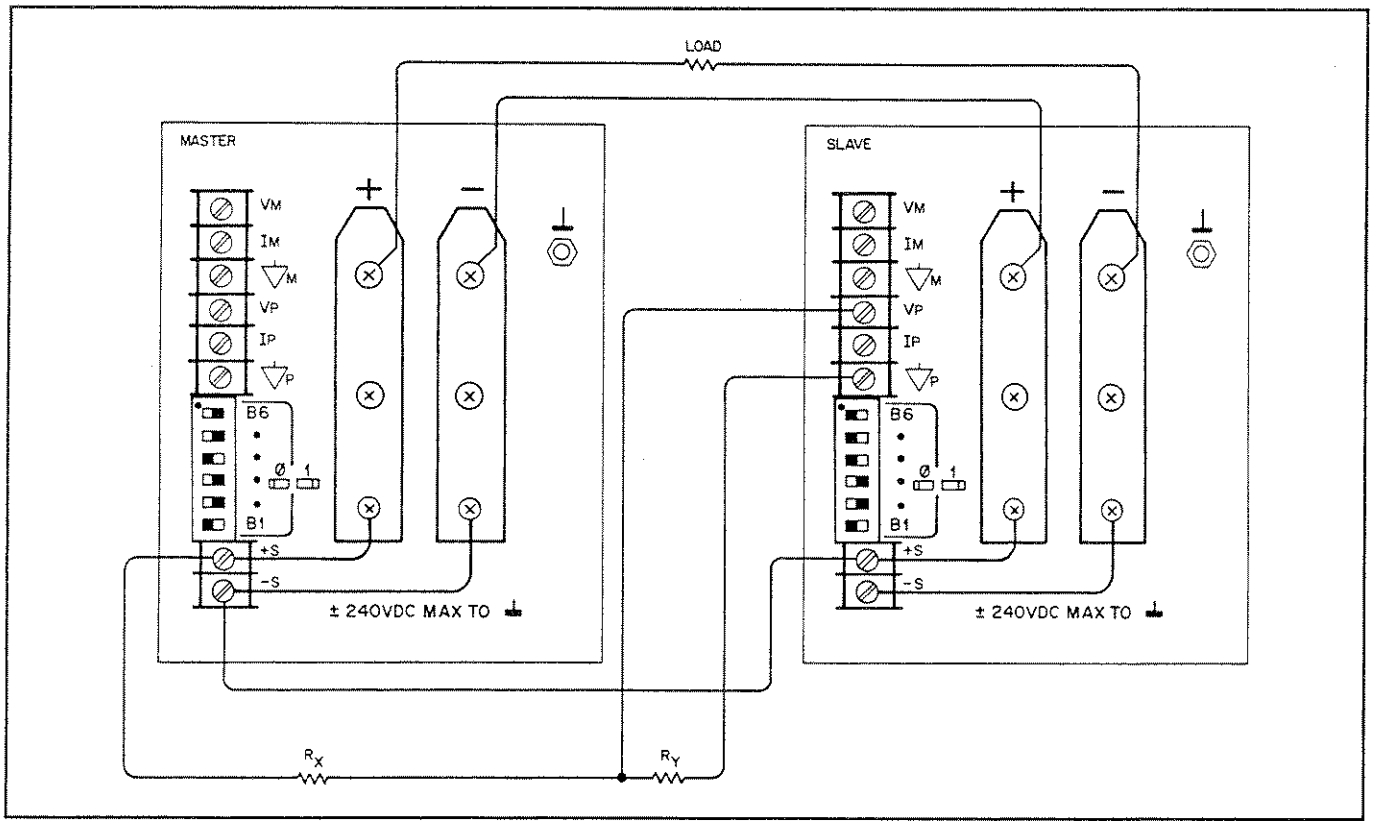


Figure 3-12. Auto-Series Operation

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 up to four units in Auto-Parallel. Add each slave unit to the parallel-output array by duplicating the connections to the master and the load ignoring the other slave units. The output current is the sum of all 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 50 Adc of output current at an output voltage of up to 120 Vdc for two units. (In general, the output voltage is up to the sum of all 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. The positive and negative tracking outputs can include more than one unit. For example, if in a 5-unit Auto-series chain the + OUT of the second unit from the bottom is grounded, the sum of the bottom-2 units' outputs is the negative output, and the sum of the top-3 units' outputs is the positive output. Ground any one output terminal as required to achieve the desired range of positive and negative outputs.

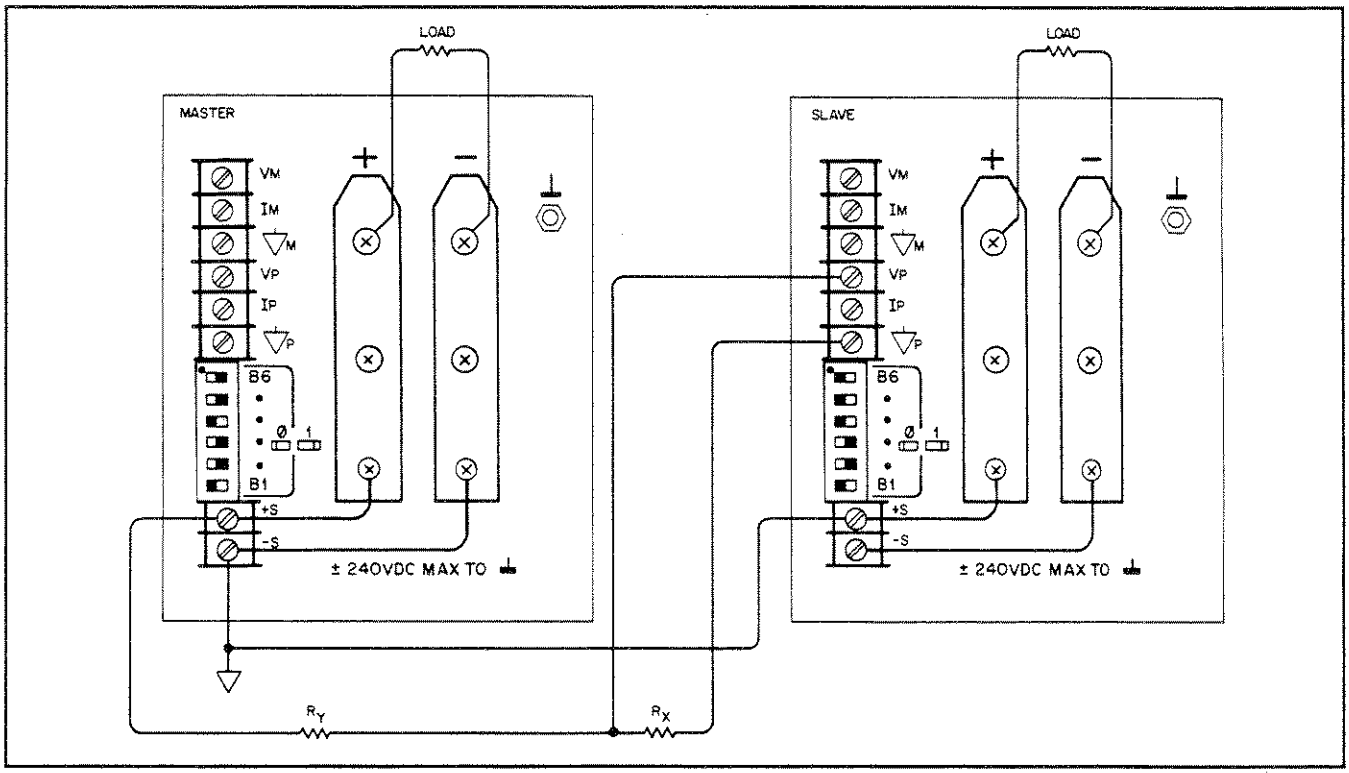


Figure 3-13. Positive and Negative Tracking Output

3-71 Connect up to eight units in Auto-Series so long as no output terminal is more than 240 volts from ground. Add each unit to the Auto-Series stack by considering the bottom unit as the master. 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 60 Vdc output (k = 12).

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 6012B the constant k equals 12, so when using a 6012B as the slave unit and with Ry set to 10 k ohms the equations reduce to

$$Rx = 120\ k/Vo/Vs \text{ wf } 10\ k \text{ ohms, } 1 \text{ watt}$$
$$= 120\ k\ (Vm/Vs) + 110\ k \text{ ohms, } 1 \text{ watt}$$

Ry = 10 k ohms, ¼ 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.

NOTE

To disable the slave unit's CURRENT control and set its current limit to about 140 Adc, change the slave unit's B2 MODE switch setting from mode 1 to mode 0.

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 6012B's the Auto-Series output voltage (Vo) is equal to Vm (Rx + Ry)/(Rx − 11 Ry). If Rx is 230 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 60 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 50 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 volt meter or 1 megohm impedance electronic meter to avoid significant error caused by the monitor signals' 10.2 k ohm output impedances.