OPERATING AND SERVICE MANUAL

EXTENDED RANGE DC POWER SUPPLY HP MODEL 6002A

HP Part No. 06002-90001

HEWLETT PACKARD

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.

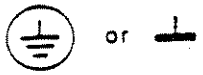
DO NOT EXCEED INPUT RATINGS.

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.



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.

SECTION I
GENERAL INFORMATION

1-1 DESCRIPTION

1-2 This laboratory type power supply employs a unique extended range technique which allows the supply to furnish maximum output power over a wide range of output voltage and current combinations. The supply can provide a full 200 Watts of output from 20V, 10A to 50V, 4A. The output is completely adjustable through the entire operating range of 0 to 50 volts and 0 to 10 amps by front panel voltage and current controls.

1-3 The supply is of the Constant Voltage/Constant Current (CV/CC) type and provides laboratory grade performance. It is fan cooled and packaged in a System II modular enclosure which is sturdy, attractive, and easily accessible for servicing.

1-4 Output voltage and current are continuously indicated on individual front panel meters. Four LED indicators on the front panel provide a convenient means of monitoring the operating status of the supply. They inform the user whether the supply is in the constant voltage or constant current mode; or whether the supply is in an overrange (operating beyond the 200 Watt boundaries) or overvoltage protection condition.

1-5 The overvoltage protection crowbar circuit protects the users load by quickly and automatically shorting the output terminals if a preset trip voltage is exceeded. A screwdriver control on the front panel sets the overvoltage trip point and can be adjusted between 2.5V and 60V. If several of these supplies are installed in the same system their crowbar circuits can be "slaved" together so that all supplies will crowbar if any one of them does.

1-6 Either the positive or negative output terminal of the supply may be grounded or the output may be floated at up to 150 volts above ground.

1-7 Remote programming, remote sensing, and several methods of operating supplies in combination of two or three are made possible by rear panel terminals that allow access to control points within the regulator circuits. These capabilities are described in Section III.

1-8 SPECIFICATIONS

1-9 Detailed specifications for this power supply are given in Table 1-1.

1-10 OPTIONS

1-11 Options are factory modifications of a standard instrument that are requested by the customer. One Option is available for this instrument as indicated below. Detailed coverage of this Option is presented in Appendix A.

OPTION NO.	DESCRIPTION
001	HP-IB Interface: Allows the supply to be digitally controlled via the HP-IB from a calculator, computer, or other controller. This modification involves the changing of internal PC board jumpers and the addition of three PC boards, two switches and an HP-IB connector. Either the output voltage or current can be programmed by the HP-IB controller

1-12 ACCESSORIES

1-13 The System-II cabinet accessories listed below may be ordered with the power supply or separately from your local Hewlett-Packard field sales office (refer to list at rear of manual for addresses). All accessories applicable to System-II modular cabinets are fully described and illustrated in the Hewlett-Packard catalog.

HP Part No.	Description
5061-0090	Two front handles that attach to each side of 7" high cabinets.
5061-0094	Kit of lock link hardware for joining together cabinets of equal depth. Units can be joined side-by-side or vertically. This kit is required whenever two (or more) sub-module units are to be rack mounted side-by-side.
1460-1345	Tilt stand snaps into standard foot supplied with instrument – must be used in pairs.
5061-0060	Rack mounting kit for one half module width unit, 7-inches high. Includes one rack flange (ear) and one half module width extention panel (adapter).
5061-0078	Rack mounting kit for two half module units,

	7" high. Kit includes two rack flanges (ears). Also, lock-together kit (5061-0094) is required for joining the two supplies together. The cabinets must also be of equal depth (17").
5061-0055	Rack mounting kit for two units (one half module width and one quarter module width). Kit includes one rack flange and one quarter width extension adapter. Lock-together kit (5061-0094) is required for joining the two supplies.
5061-0098	Support shelf for mounting one or more 7" high units which are half module or quarter module width. Cabinet depths need not be equal.
5061-2027	Front filler panel (half module width) for 7" high support shelf.
1494-0015	Slide kit for support shelves mounted in HP rack enclosures.

1-14 INSTRUMENT AND MANUAL IDENTIFICATION

1-15 Hewlett-Packard power supplies are identified by a two part serial number. The first part is the serial number prefix, a number-letter combination that denotes the date of a significant design change and the country of manufacture. The first two digits indicate the year (10 = 1970, 11 = 1971, etc.), the second two digits indicate the week, and the letter "A" designates the U. S. A. as the country of manufacture. The second part is the power supply serial number; a different sequential number is assigned to each power supply, starting with 00101.

1-16 If the serial number on your instrument does not agree with those on the title page of the manual, Change Sheets supplied with the manual of Manual Backdating Changes define the difference between your instrument and the instrument described by this manual.

1-17 ORDERING ADDITIONAL MANUALS

1-18 One manual is shipped with each power supply. Additional manuals may be purchased from your local Hewlett-Packard field office (see the list at the rear of this manual for addresses). Specify the model number, serial number prefix, and the HP Part Number provided on the title page.

Table 1-1. Specifications, Model 6002A

INPUT POWER:
Unit has ac power module which is settable to: 100/120/220/240Vac (−13%, +6%), 48-63Hz. A 3-wire detachable line cord is supplied.

DC OUTPUT:
Adjustable from 0-50V and 0-10A. Maximum output power is 200W from 20-50V.

LOAD EFFECT (LOAD REGULATION):
Constant Voltage — Less than 0.01% of output plus 1mV for a load change equal to the maximum current rating of the supply.
Constant Current — Less than 0.01% of output plus 1mA for a load change equal to the maximum voltage rating of the supply.

SOURCE EFFECT (LINE REGULATION):
Constant Voltage — Less than 0.01% of output plus 1mV for any line voltage change within rating.
Constant Current — Less than 0.01% of output plus 1mA for any line voltage change within rating.

PARD (Ripple and Noise):
Constant Voltage — Less than 1mV rms and 10mV p-p (20Hz to 20MHz).
Constant Current — Less than 5mA rms.

TEMPERATURE COEFFICIENT:
Constant Voltage — Less than 0.02% plus 200μV change in output per degree Celsius change in ambient following a 30-minute warmup.
Constant Current — Less than 0.02% plus 5mA change in output per degree Celsius change in ambient following a 30-minute warmup.

DRIFT (STABILITY):
(Change in output over an 8-hour interval under constant line, load, and ambient temperature following a 30-minute warmup).
Constant Voltage — Less than 0.05% of output plus 1mV.
Constant Current — Less than 0.05% of output plus 5mA.

LOAD TRANSIENT RECOVERY TIME:
Less than 100μsec is required for output voltage recovery (in constant voltage operation) to within 15mV of the nominal output following a change in output current from 50% to 100% or 100% to 50% of maximum current rating.

REMOTE RESISTANCE CONTROL:
CV: 1KΩ/V ±7% CC: 100Ω/A±7%

REMOTE VOLTAGE CONTROL:
CV: 1V/V ±20mV (−50mV offset) CC: 50mV/A ±10%

Table 1-1. Specifications, Model 6002A (continued)

RESPONSE TIME:
Maximum time for output voltage to change between 1 to 99.9% or 100% to 0.1% of maximum rated output voltage.

UP:	No Load – 100msec	
	Full Load – 100msec	
DOWN:	No Load – 400msec	
	Full Load – 200msec	

OVERVOLTAGE PROTECTION:
Trip voltage adjustable from 2.5V to 60V. Minimum setting above output voltage to avoid false tripping is 1 volt.

DC OUTPUT ISOLATION:
150Vdc

TEMPERATURE RATINGS:
Operating: 0 to 55°C Storage: –40 to +75°C

RESOLUTION:
(Minimum output voltage or current change that can be obtained using the front panel controls.)
CV: 10mV CC: 10mA

OUTPUT IMPEDANCE:
Typical value is 0.5mΩ in series with 1μH.

OPTIONS:
001 HP-IB Interface – specifications listed in Appendix A.

DIMENSIONS:
(See Figure 2-1)

WEIGHT:
Net: 14.5kg. (32 lb) Shipping: 15.9kg. (35 lb)

SECTION II
INSTALLATION

2-1 INITIAL INSPECTION

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

2-3 Mechanical Check

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

2-5 Electrical Check

2-6 Section V of this manual contains complete verification procedures for this unit. Section III contains an abbreviated check which can be used to quickly place the unit into operation. Refer to the inside front cover of the manual for the Certification and Warranty statements.

2-7 REPACKAGING FOR SHIPMENT

2-8 To insure safe shipment of the instrument, it is recommended that the package designed for the instrument be used. The original packaging material is reusable. If it is not available, contact your local Hewlett-Packard field office to obtain the materials. This office will also furnish the address of the nearest service office to which the instrument can be shipped. 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.

2-9 INSTALLATION DATA

2-10 The instrument is shipped ready for bench operation. Before applying power to the instrument, read paragraph 2-18.

2-11 Location and Cooling

2-12 This instrument is fan cooled and must be installed with sufficient space for cooling air flow between the sides and rear of the unit. It should be used in an area where the ambient temperature does not exceed 55°C.

2-13 Outline Diagram

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

2-15 Rack Mounting

2-16 This supply can be rack mounted in a standard 19-inch rack panel either by itself or alongside another half (or quarter) System-II module of equal height and depth. All rack mounting accessories for this unit are listed in paragraph 1-12. Also, complete installation instructions are included with each rack mounting kit.

2-17 Input Power Requirements and Line Voltage Conversion

2-18 This supply may be operated continuously from a nominal 100V, 120V, 220V, or 240V (48-63Hz) power source. A printed circuit board located within the ac power module on the rear panel must be positioned to match the

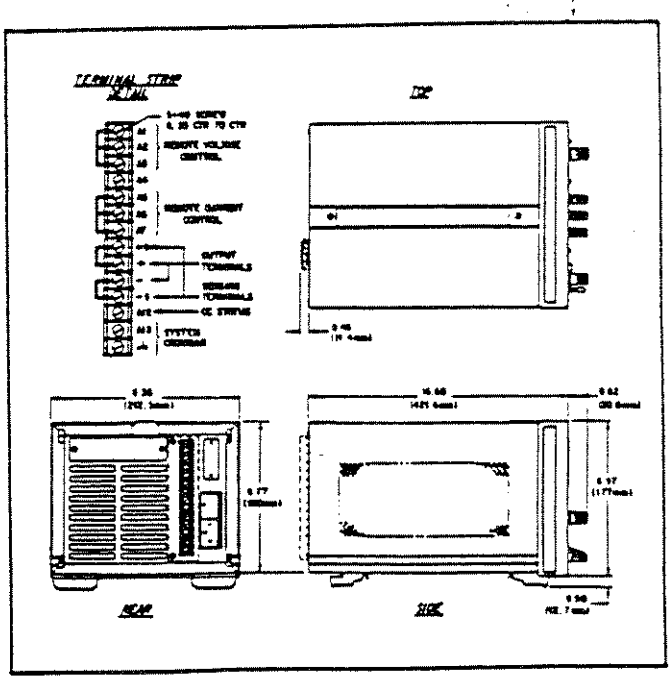


Figure 2-1. Outline Diagram

power source. Voltage choices are available on both sides of the PC board. Before connecting the instrument to the power source, check that the PC board position matches the nominal line voltage of the source. The operating voltage that is selected is the one printed on the lower-left side of the PC board. As shipped from the factory, the PC board in this supply is positioned for 120Vac operation. To select another input voltage proceed as follows:

a. Remove power cable from instrument.

b. Slide down plastic door on power module.

c. Push FUSE PULL down and remove line fuse F1 (Figure 2-2).

d. Remove PC board from slot by inserting pointed object into hole in PC board and gently pulling outward. Select operating voltage by orienting PC board to position the desired voltage on lower-left side of PC board. Push board firmly back into slot.

e. Push FUSE PULL up into normal position and re-insert fuse F1 in holder using caution to select the correct value for F1 (6A for 100V or 120V and 4A for 220V or 240V).

f. Close plastic door and connect power cable.

2-19 When the instrument leaves the factory, the 6A fuse is installed for 120V operation. An envelope containing a 4A fuse for 220V/240V operation is attached to the instrument. Make sure that the correct fuse value for F1 is installed if the position of the PC board is changed.

2-20 The input voltage range and input current required for each of the four nominal input voltages associated with this unit are listed below. The maximum input power required for any of the four inputs is 480 Watts.

Nominal Input Voltage	Maximum Input Range	Maximum Input Current
100Vac	87–106Vac	6.6A
120Vac	104–127Vac	5.6A
220Vac	191–233Vac	3.0A
240Vac	208–250Vac	2.8A

2-21 Power Cable

2-22 This unit is factory equipped with a power cord plug that is the most appropriate for the user's location. The replaceable parts section of this manual lists all of the power cords associated with this unit. If a different power cord is desired, contact your nearest HP Sales Office.

2-23 To protect operating personnel, the National Electrical Manufacturers Association (NEMA) recommends that the instrument panel and cabinet be grounded. This instrument is equipped with a three conductor power cable. The third conductor is the ground conductor and when the cable is plugged into an appropriate receptacle, the instrument is grounded. The offset pin on the power cable three-prong connector is the ground connection. In no event shall this instrument be operated without an adequate cabinet ground connection.

2-24 To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter (if permitted by local regulations) and connect the green lead on the adapter to ground.

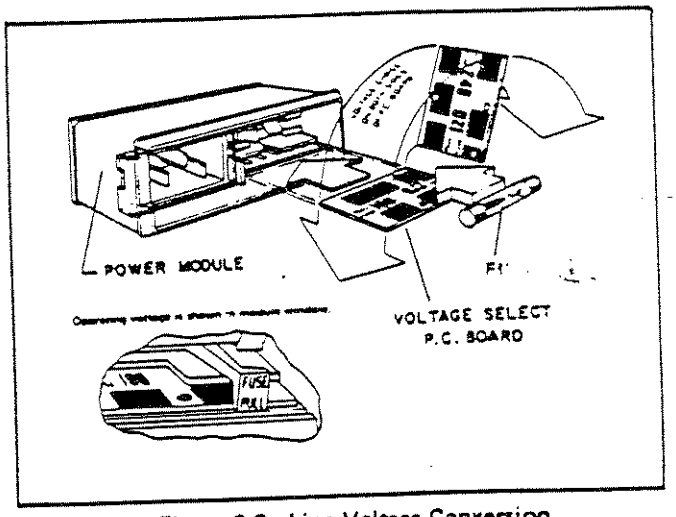


Figure 2-2. Line Voltage Conversion

SECTION III
OPERATING INSTRUCTIONS

3-1 TURN-ON CHECKOUT PROCEDURE

3-2 The following checkout procedure describes the use of the front panel controls and indicators (see Figure 3-1) and ensures that the supply is operational. Either this check or the detailed performance tests of paragraph 5-5 should be performed when the unit is first received. If the supply fails to perform properly, proceed to the trouble-shooting procedures in Section V.

a. Ensure that rear terminal board straps are connected as shown in Figure 3-2, but do not connect load. Ensure that ac power module board matches line voltage to be used as outlined in Section II. If unit is equipped with HP-IB interface (Option 001) ensure that rear panel switch is set to LOCAL before proceeding.

b. Ensure that CURRENT control (5) is rotated clockwise at least two turns and OVERVOLTAGE potentiometer (7) is fully clockwise.

c. Set LINE switch (1) to ON and observe that pilot lamp (2) lights and fan goes on.

d. Turn VOLTAGE control (3) through output voltage span of unit as indicated on voltmeter (4). VOLTAGE MODE light (3) should be lit throughout procedure indicating that supply is in constant voltage mode.

e. Check out overvoltage circuit by turning OVERVOLTAGE control (7) (screwdriver adjust) counterclockwise until unit crowbars. Voltage should drop to near zero and OVERVOLTAGE (8) and OVERRANGE (9) indicators should light.

f. Reset crowbar circuit by returning OVERVOLTAGE control to maximum clockwise position and turning supply off and then back on. Output voltage should return to value set in step d.

g. To check constant current circuit, first turn off supply and connect short across + and − output terminals (front or rear). Ensure that VOLTAGE control is rotated at least two turns clockwise.

h. Next, turn supply back on and rotate CURRENT control (5) through output current span as indicated on ammeter (6). CURRENT MODE light (5) should be on throughout this procedure.

i. Turn off supply, remove short from output, and read remainder of operating instructions before connecting actual load to supply.

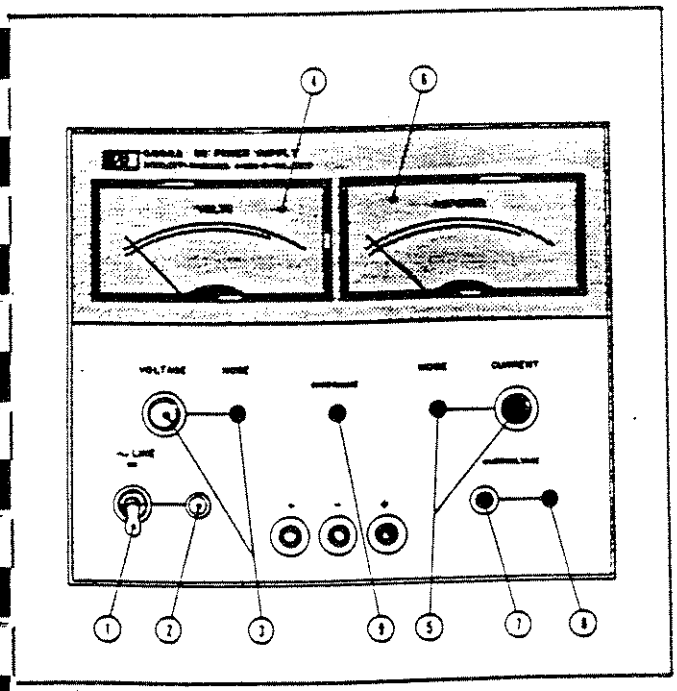


Figure 3-1. Front Panel Controls and Indicators

3-3 OPERATING MODES

3-4 This power supply is designed so that its mode of operation can be selected by making strapping connections between terminals on its rear panel. The following paragraphs first describe normal operation using the normal strapping pattern as it is connected at the factory. Later paragraphs cover some optional operating modes including

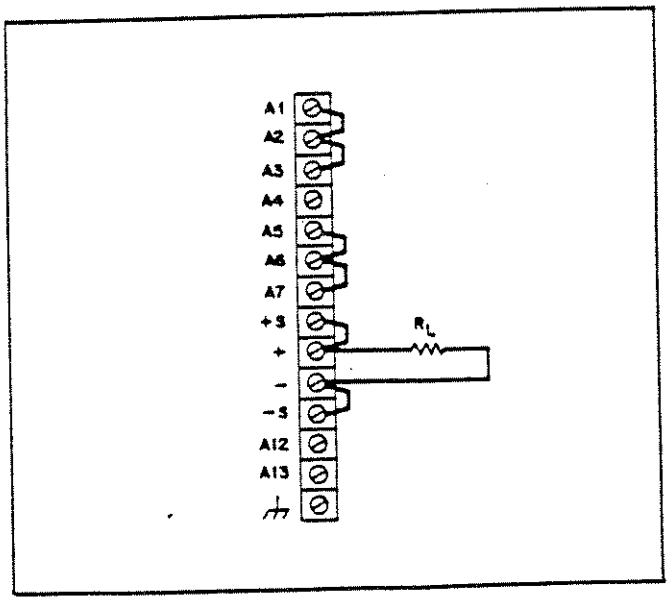


Figure 3-2. Normal Strapping

methods of operating these power supplies in combinations of two or three. More theoretical descriptions regarding the operational features of power supplies in general are given in the DC Power Supply Handbook, Application Note 90A (available at no charge from your local HP Sales Office).

3-5 NORMAL OPERATING MODE

3-6 This power supply was shipped with the proper rear panel strapping connections made for constant-voltage/constant-current operation with local sensing and local programming. This strapping pattern is illustrates in Figure 3-2. By means of the front panel voltage and current controls, the operator selects either a constant-voltage or a constant-current output as described later, in paragraphs 3-10 or 3-12. Whether the supply functions in the constant-voltage or constant-current mode depends on the settings of the VOLTAGE and CURRENT controls and on the value of the load resistance. Figure 3-3 shows the overall characteristic of this supply together with the sample operating locus that is established with voltage and current settings of 40V and 5A respectively. For values of load resistance greater than the sample crossover value of 8 ohms, the supply operates in the constant-voltage mode. With a load resistance smaller than the crossover value, it operates in the constant-current mode. The transition occurs automatically; no switches need to be operated or connections changed. The front panel MODE lights indicate which mode the supply is in. A rectangular operating locus similar to that shown in Figure 3-3 will be established for all voltage and current settings within the 200 Watt output boundaries. However, if the operator sets the voltage or current controls so that the 200 Watt limit can be exceeded, the supply will go into overrange if the load resistance exceeds the 200 Watt value (refer to next paragraph).

3-7 **Overrange.** This supply will be driven into overrange (shaded area of Figure 3-3) if the voltage and current controls are set above the 200W rating and the load resistance exceeds a 200W critical value. For example, assume that the operator sets the VOLTAGE control at 40V and the CURRENT control to 10A (Figure 3-3). For all load resistances above 8 ohms (which is the 200 Watt critical value) the supply would operate normally in the constant voltage mode. If the load resistance were to fall much below 8 ohms, however, the supply would be forced into overrange. If the load resistance continued to decrease to a 2 ohm value, the supply would automatically come out of overrange and into the constant current mode at the 10A, 20V point. (The supply will probably go out of regulation while operating in the overrange region, refer to paragraph 3-9).

3-8 The OVERRANGE indicator on the front panel will light any time that the supply overranges. This indicator also lights if the overvoltage crowbar fires even though the output is reduced to near zero at this time.

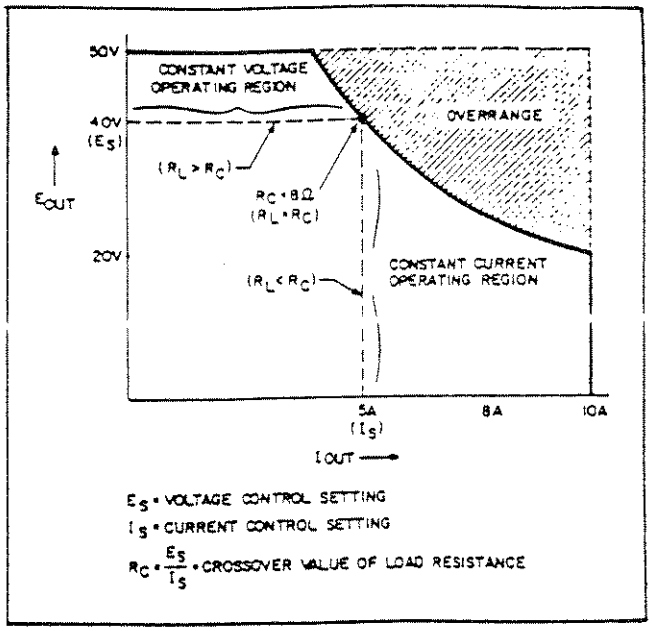


Figure 3-3. Overall Output Characteristic With Sample Operating Locus

3-9 Note that the supply can operate in the overrange region (beyond the 200 Watt limits) for sustained periods without being damaged. However, the supply is not guaranteed to meet specifications in overrange. Output ripple increases substantially and regulation is seriously degraded. As an operator aid, the maximum available load current for each constant voltage setting is indicated on a secondary scale of the voltmeter. Similarly, the maximum available load voltage for each current setting is indicated on the ammeter.

NOTE

Under certain conditions of line and load, it is possible for this supply to provide more than the 200 Watt rating and still maintain regulation. If this occurs, the unit will operate normally and the OVERRANGE indicator will be off. However, the slightest change in either one of the above factors may cause the unit to go out of regulation and it is definitely not recommended to intentionally attempt operation beyond the 200 Watt rating of the unit.

3-10 Constant Voltage Operation

3-11 To adjust the supply for constant voltage operation:

a. Turn on supply and, with output terminals open,

adjust the VOLTAGE control for the desired output voltage. Then turn power off.

b. Connect a short across the front or rear panel output terminals, restore power, and adjust the CURRENT control for the desired maximum output current. Then remove the short. If a load change causes this current limit to be exceeded, the supply automatically crosses over to constant current operation at this preset current limit and the output voltage drops proportionately. In setting the

currents that could cause unwanted crossover.

3-12 Constant Current Operation

3-13 To adjust the supply for constant current operation:

a. Connect a short across the front or rear output terminals, turn the power on, and adjust the CURRENT control for the desired output current.

b. Open the output terminals and adjust the VOLTAGE control for the desired maximum output voltage. If a load change causes this voltage limit to be exceeded, the supply automatically crosses over to constant voltage operation at this preset voltage limit and the output current drops proportionately. In setting the voltage limit, make an adequate allowance for high peak voltages that could cause unwanted crossover.

3-14 Overvoltage Protection

5 **Adjustment.** The crowbar trip voltage is adjusted using the screwdriver control on the front panel. The approximate trip voltage range for this unit is from 2.5V to 60V. When the crowbar trips, an SCR shorts the output and the OVERVOLTAGE indicator on the front panel lights. Rotating the control clockwise sets the trip voltage higher. (It is set to maximum at the factory.)

3-16 When adjusting the crowbar trip point, the possibility of false tripping must be considered. If the trip voltage is set too close to the supply's operating voltage, a transient in the output would falsely trip the crowbar. For this reason it is recommended that the crowbar be set higher than the output voltage by at least one volt. To adjust the crowbar trip voltage, proceed as follows:

a. With OVERVOLTAGE potentiometer fully CW, turn on supply; no load connected.

b. Set output VOLTAGE control to desired trip voltage.

c. Turn OVERVOLTAGE pot CCW until crowbar fires; red indicator lights and voltage falls to zero.

d. Turn off supply and turn down output voltage.

e. Turn supply back on and set desired output voltage.

3-17 **Resetting the Crowbar.** If the crowbar trips during normal operation, the ac LINE switch must be turned off and then back on to reset the circuit. If the crowbar trips continuously check the load and/or the trip point setting. If the supply does not operate properly after the crowbar is reset, proceed to troubleshooting in Section V.

3-18 **System Crowbar Connections.** The crowbar circuit contains an extra winding which is connected across terminals A13 and rtn on the rear terminal board. These terminals

conversely, can receive an external input pulse which can be used to trip the circuit. The correct polarity must be observed in the external circuit with the A13 terminal being positive. If the terminals will be used for input tripping, the external pulse must have the following characteristics:

Input trip pulse:
Amplitude: 5 – 10 Volts
Width: 2 – 5μsec
Source Impedance: 2Ω (maximum)

If the terminals are used to provide an output pulse for a status indication, the output pulse has the following characteristics:

Output pulse:
Amplitude: 4 – 12 Volts
Width: 2 – 7μsec
Load Impedance: 10Ω (minimum)

3-19 Because one of the system crowbar terminals is tied to chassis ground, the user should take precautions against circulating ground currents which could cause false tripping of the crowbar or make external tripping difficult. To help avoid ground loop problems, always run a separate ground terminal wire between the supply and the external source and maintain the above impedances.

3-20 CONNECTING THE LOAD

3-21 To satisfy the requirements of safety, the wires to the load should be at least heavy enough not to overheat while carrying the power supply current that would flow if the load were shorted. Generally, heavier wire than this is required to obtain good regulation at the load. If the load regulation is critical, use remote voltage sensing. (Refer to paragraph 3-27.)

3-22 If multiple loads are connected to one supply, each load should be connected to the supply's output terminals using separate pairs of connecting wires. This minimizes mutual coupling effects between loads and takes full advantage of the supply's low output impedance. Each pair of connecting wires should be as short as possible and twisted or shielded to reduce noice pickup.

3-23 If load considerations require the use of output distribution terminals that are located remotely from the

supply, then the power supply output terminals should be connected to the remote distribution terminals by a pair of twisted or shielded wires and each load should be separately connected to the remote distribution terminals. Remote voltage sensing would be required under these circumstances (paragraph 3-27).

3-24 Either positive or negative voltages can be obtained from this supply by grounding one of the output terminals or one end of the load. Always use two wires to connect the load to the supply regardless of where or how the system is grounded. Never ground the system at more than one point. This supply can be operated up to 150 volts above ground if neither output terminal is grounded.

3-25 OPTIONAL OPERATING MODES

3-26 The optional operating modes discussed in the following paragraphs include: remote voltage sensing, remote programming, auto-parallel operation, auto-series operation, and auto-tracking operation. By changing its rear panel strapping pattern according to the instructions which follow, any of the supplies covered by this manual can be operated in any of the modes listed above.

CAUTION

Disconnect input ac power before changing any rear panel connections and make certain all wires and straps are properly connected and terminal strip screws are securely tightened before reapplying power.

3-27 Remote Voltage Sensing

3-28 Because of the unavoidable voltage drop developed in the load leads, the normal strapping pattern shown in Figure 3-2 will not provide the best possible voltage regulation at the load. The remote sensing connections shown in Figure 3-4 improve the voltage regulation at the load by monitoring the voltage there instead of at the supply's output terminals. (The advantages of remote sensing apply only during constant voltage operation.) The following paragraphs discuss some precautions that should be observed when making a remote sensing installation.

3-29 The load leads should be of the heaviest practicable wire gauge, at least heavy enough to limit the voltage drop in each lead to 0.5 volt. This limitation is mainly dictated by the protection diode connected between the −S and − output terminal. This diode will conduct if it is forward biased by more than 0.5 volts. Note that the transisent recovery time of the supply may be slower than the specified value of 100μsec if remote sensing is used. If this is a factor in your application, check the transient recovery time (see Section V) using the actual lead lengths that will be used in your setup. The inductance of long load leads is not a problem in this supply because it contains an internal compensating network, A2C2-R2.

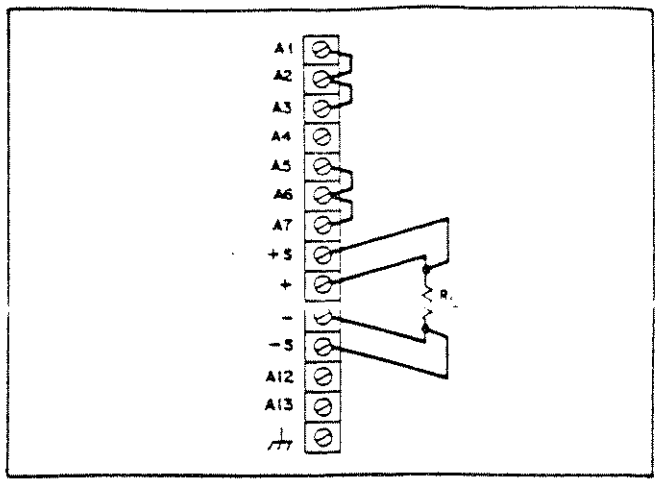


Figure 3-4. Remote Sensing

NOTE

Due to the voltage drop in the load leads, it may be necessary to readjust the overvoltage trip point in the remote sensing mode.

3-30 Since the sensing leads carry only a few milliamps, the wires used for sensing can be much lighter than the load leads (22 AWG is generally adequate), but they should be a shielded, twisted pair to minimize the pickup of external noise. Any noise picked up on the sensing leads will appear at the supply's output. The shield should be grounded at one end only and should not be used as one of the sensing conductors. The sensing leads should be connected as close to the load as possible.

3-31 The sensing leads are part of the supply's programming circuit, so they should be connected in such a way as to make it unlikely that they might inadvertently become open circuited. If the sensing leads open during operation, the output voltage will tend to fall. Although the decay may be limited by protection diodes A2CR9-CR10, it is recommended that no switch, relay, or connector contacts be included in the remote sensing path.

CAUTION

When using remote voltage sensing, it is possible to damage the supply by disconnecting a load lead while the sensing lead is still connected and the supply is energized. If a load lead becomes disconnected, current flows through internal protection diodes CR9 and CR10, the sensing leads, and the load and may burn out the diodes or connecting track on the PC board.

3-32 Remote Programming

3-33 The output voltage or current of this supply can be remotely controlled by analog or digital means. Analog control consists of programming the output by means of an external resistor or voltage source connected to the rear terminals and is the only remote programming method that will be described in this section. Digital control of the output on the Hewlett-Packard Interface Bus (HP-IB, Option 001) is described in Appendix "A" of this manual.

3-34 For resistance programming, a variable resistor can control the output over its entire range. Or, a variable resistor connected in series with a fixed resistor can have its control restricted to a limited portion of the output range. Alternately, a switch can be used to select fixed values of programming resistance to obtain a set of discrete voltages or currents. (The switch must have make-before-break contacts to avoid producing the output voltage transients that momentarily opening the programming terminals would cause.) To maintain the temperature and stability specifications of the supply, programming resistors must be stable, low noise resistors with a temperature coefficient of less than 30ppm per °C and a power rating at least 30 times what they will actually dissipate.

3-35 Both voltage and current outputs can also be controlled by a voltage source. When voltage programming the output voltage, the choice can be made between using a connection that produces a unity gain relationship between input and output or another connection that produces variable voltage gains. The output current can be programmed using a connection that produces a fixed gain.

3-36 Connecting a supply for remote voltage or current programming disables the corresponding front panel controls.

3-37 The following paragraphs discuss in greater detail the methods of remotely programming the output voltage or current using either a resistance or a voltage input. Whichever method is used, the wires connecting the programming terminals of the supply to the remote programming device must be shielded to reduce noise pickup. The outer shield of the cable should not be used as a conductor but should be connected to ground at one end only.

3-38 Although the following connection drawings (Figures 3-5 through 3-7) show the supply strapped for local sensing, it is possible to operate the supply simultaneously in the remote sense and remote constant voltage programming modes.

3-39 **Constant Voltage Output, Resistance Control.** The rear panel connections shown in Figure 3-5 allow the output voltage to be varied by using an external resistor to program the supply. The output voltage varies in accordance with the voltage control coefficient of 1000 ohms per volt. The output voltage will increase by approximately 1 volt for each 1000 ohms added across the programming terminals.) Note that voltage programming current determines the coefficient and that this programming current is factory adjusted to within 7% of 1mA. If a programming accuracy of greater than 7% is required, resistor A1R15 can be adjusted to obtain an accuracy of up to 0.5% (refer to Section V).

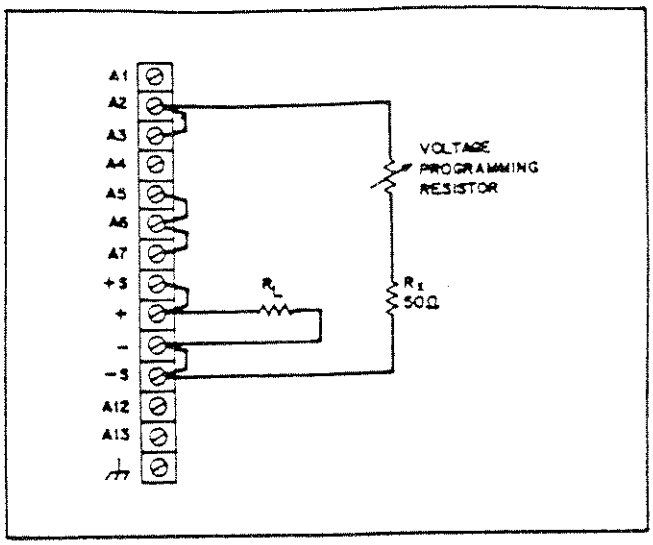


Figure 3-5. Resistance Programming of Output Voltage

3-40 Resistor R_X replaces the internal 50Ω offset resistor (A2R1) that is disconnected (along with the front panel control) by the connections of Figure 3-5. The addition of R_X will bring the output voltage to near zero volts when the external programming resistor is set to minimum. If an output voltage that is closer to zero than this is required, it can be obtained by substituting a 100 ohm potentiometer in place of R_X. This potentiometer can than be adjusted to obtain exactly 0V output when the external programming resistor is set to minimum.

NOTE

If the programming terminals (A2 to −S) become open circuited during resistance programming, the output voltage will tend to rise above rating. The supply will not be damaged if this occurs but the overvoltage trip point should be properly adjusted to protect the users load.

3-41 **Constant Voltage Output, Voltage Control (Unity Gain).** The rear panel connections shown in Figure 3-6 allow the output voltage to be varied by using an external

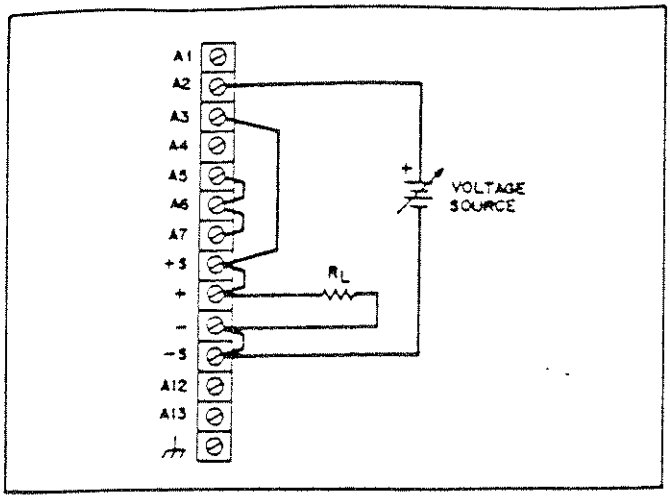


Figure 3-6. Voltage Programming of Output Voltage (Unity Gain)

voltage source to program the supply. In this mode, the output voltage varies in a 1 to 1 ratio with the programming voltage. The load on the programming voltage source is less than 20 microamperes. Note that the voltage control coefficient contains a fixed offset voltage of 50mV in addition to the tolerance of ±20mV. This means that the external voltage source will have to be set slightly higher than the output voltage. For example, to obtain an output of 50V, the external source would have to be set from 30 to 70mV higher than 50V.

3-42 **Constant Voltage Output Voltage Control (Variable Gain).** The arrangement of Figure 3-7 shows a method of programming the supply with gain using a variable voltage source (E_S). Note that this method is no different than the circuit normally used within the supply except that an external reference source (E_S) replaces the +6.2V internal reference and resistor R_X replaces the constant voltage pullout resistors (A1R12-R15). The voltage gain (between E_S and E_{OUT}) is equal to the resistance ratio R_P/R_R.

3-43 Reference resistor R_R must be less than 10k ohms and must be selected so that the programming current flowing through it is at least 1 milliamp when the voltage source (E_S) is set to maximum. Once R_R is selected, multiply it by the maximum voltage gain desired to find R_P. If desired, the power supply's front panel voltage controls can be used in place of external gain control R_P by deleting the external gain control from the circuit and strapping together terminals A1 and A2. Of course, a fixed external resistor can also be used in place of R_P if required. In any event, both R_P and R_R should be precision, wire-wound resistors. Notice that an offset voltage exists in this mode similar to that in unity gain voltage programming (paragraph 3-41). If an external gain control is used, this offset voltage will be 70mV (maximum). If the front panel voltage control is used the offset voltage will be less (20mV, maximum).

3-44 **Constant Current Output, Resistance Control.** The rear panel connections shown in Figure 3-8 allow the output current to be varied by using an external resistor to program the supply. The supply's constant current programming current, which is factory adjusted to 500μA ±7% determines the exact value of its programming coefficient of 100 ohms per Ampere. If the 7% accuracy of this coefficient is not adequate, it may be adjusted to within 0.5% with internal potentiometer A1R1 (refer to Section V).

3-45 Resistor R_X (15 ohms) replaces internal resistor A1R3 which is disconnected, along with the front panel current control, by the connections of Figure 3-8. This resistor provides a small amount of end resistance so that the output current can be adjusted to exactly zero (by A1R6) when the current programming resistor is shorted, or set to minimum. Section V gives the adjustment procedure for zeroing the output current using the internal offset adjust potentiometer, A1R6.

CAUTION

Do not allow programming terminals A4 or A6 to become open-circuited while resistance programming the output current. If they do open, the supply's output current rises to a value that may damage the supply or the load. If in the particular programming configuration used there is a chance that the terminals might open, we suggest that a 1k ohm protection resistor be connected across the programming terminals. Of course, when this resistor is used, the resistance value actually programming the supply is the parallel combination of the remote programming resistance and the resistor across the programming terminals. Like the programming resistor, this resistor should be a low noise, low temperature coefficient type.

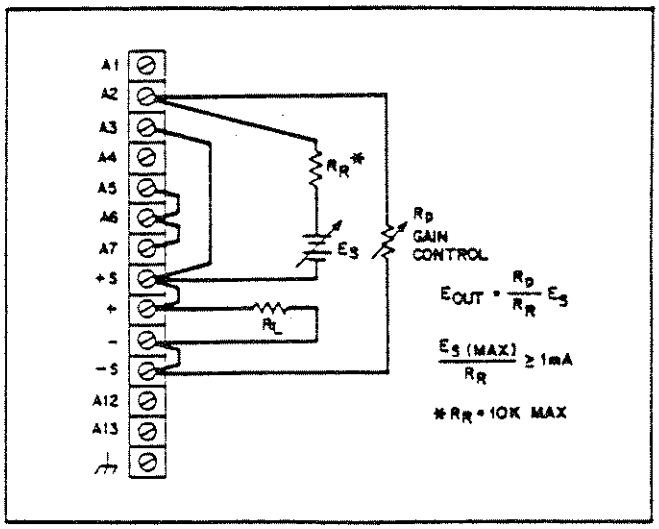


Figure 3-7. Voltage Programming of Output Voltage (Variable Gain)

3-46 **Constant Current Output, Voltage Control.** In this mode (Figure 3-9) the output is varied by the external voltage source at a rate established by the programming coefficient of 50mV/A ±10%. The external voltage required to obtain maximum rated output current from the supply is about 500mV. An input greater than 600mV will cause excessive power dissipation and possible damage to the supply. The load on the external voltage source will be less than 20 microamperes.

3-47 To adjust the output current to exactly zero with a zero programming voltage, adjust A1R6 as outlined in Section V.

3-48 Auto-Parallel Operation

3-49 Figure 3-10 shows the interconnections required to auto-parallel two units. This mode of operation provides a greater current capacity than can be obtained from a single supply while maintaining nearly equal load sharing among the paralleled supplies under all load conditions. Only supplies having the same model numbers can be used in auto-parallel unless the supplies all have equal current ratings and the voltage drop across the monitoring resistor in each supply is equal at maximum rated current.

3-50 **Additional Slave.** One additional slave supply can be added in parallel to the master/slave combination shown in Figure 3-10. All connections between the master and slave number one are duplicated between slave number one and the added supply (slave number two). The remaining terminals on slave number two should be strapped the same as those shown for slave number one on Figure 3-10.

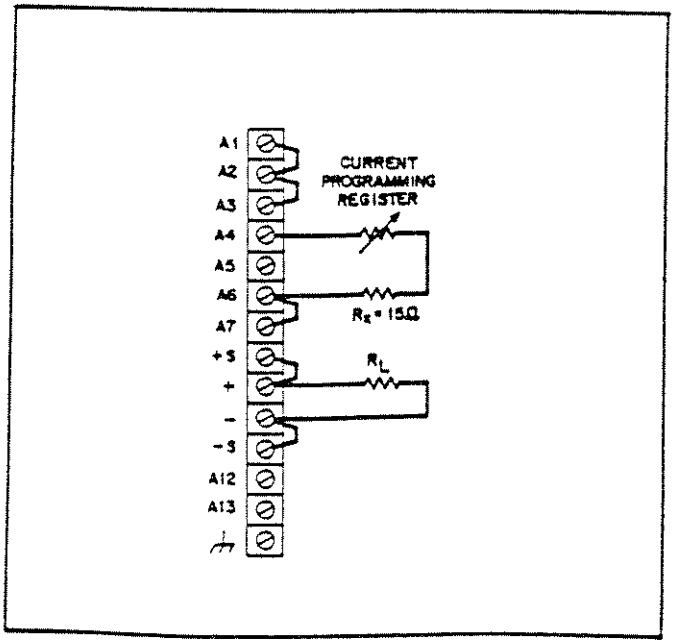


Figure 3-8. Resistance Programming of Output Current

NOTE

Use wires of equal length and gauge to connect each auto-parallel supply to the load. Load sharing will not be equal unless the positive leads connecting each supply to the load are all equal in resistance.

3-51 **Setting the Voltage and Current Controls.** The auto-parallel combination of two or three supplies behaves as if it were a single constant-voltage/constant-current supply controlled by the voltage and current controls of the master supply. The voltage control of the slave(s) is disabled, but its current control remains operative and must be set to maximum to prevent a slave supply from independently reverting to constant current operation as would occur if the output current setting of the master supply exceeded that of the slave.

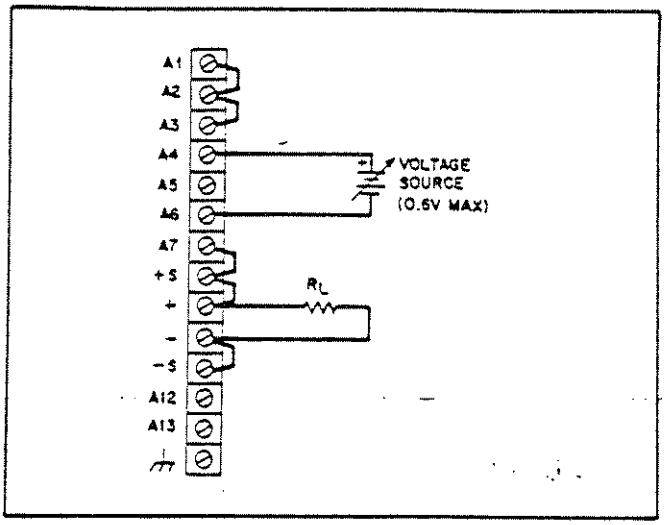


Figure 3-9. Voltage Programming of Output Current

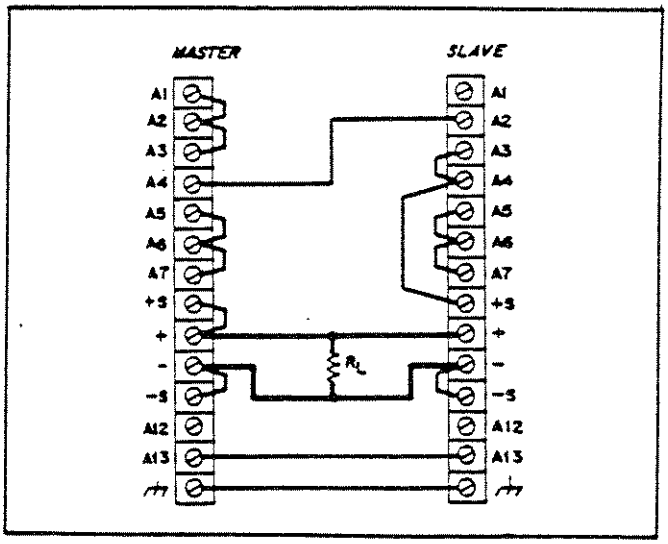


Figure 3-10. Auto-Parallel Operation of Two Units

3-52 **Overvoltage Protection in Auto-Parallel.** The interconnections shown in Figure 3-10 between the external crowbar trigger terminals on the master and on the slave(s) must be made to permit the overvoltage crowbar in the master to fire the SCRs in the master and the slave(s) if an overvoltage condition occurs. Be sure to connect them with the correct polarity shown. Set the slave supply overvoltage control(s) to maximum (clockwise) to disable them, and adjust the overvoltage trip point at the master supply.

3-53 **Auto-Parallel With Remote Sensing.** To combine auto-parallel operation with remote sensing, connect the supplies as described above but remove the +S and −S jumpers from the master supply and connect the +S and −S terminals directly to the (+) and (−) ends of the load. Observe the precautions outlined under paragraph 3-27.

3-54 **Auto-Parallel With Remote Programming.** When two or three supplies are connected in auto-parallel, their combined output voltage, current, or both can also be remotely programmed from the master supply. Observe all precautions outlined in the paragraphs on remote programming. The simultaneous use of remote sensing and remote programming is also possible during auto-parallel operation.

3-55 Auto-Series Operation

3-56 Auto-series operation provides greater output voltage capability than that available from one supply. A maximum of three units can be used in this configuration. Figures 3-11 and 3-12 show the rear panel and circuit board interconnections required to operate two or three supplies in auto-series. This mode of operation allows the series-connected supplies to be simultaneously programmed by the voltage and current controls of a master supply. The master supply must always be the one at the positive end of the series combination. The output voltage of each slave supply varies in direct proportion to that of the master and the ratio of each slave's output voltage to the master's is established by the settings of the slave supplies' voltage controls. The resulting combination of two or three supplies behaves as if it were a single constant-voltage/constant-current supply. The supply with the lowest current setting limits the maximum output current of the combination. Mixed model numbers can be employed in auto-series combination, provided that each slave is capable of auto-series operation. Any well-regulated, variable output supply can be used as the master.

3-57 In applications where coordinated positive and negative voltages are required, grounding the center tap of an auto-series combination of supplies allows simultaneous proportional control of both supply voltages.

3-58 **Value of R_X.** As shown, each slave supply has an external resistor R_X that provides its' voltage programming current. The value of R_X is determined by dividing the constant voltage programming current of the slave supply into the maximum rated output voltage that will be received from the master supply. For two Model 6002A supplies, R_X would be 50V/1mA = 50k ohms. To maintain the temperature coefficient and stability specifications of the supplies, R_X must be a stable, low noise resistor with a temperature coefficient of less than 30ppm per °C and a power rating of at least 30 times what it will actually dissipate.

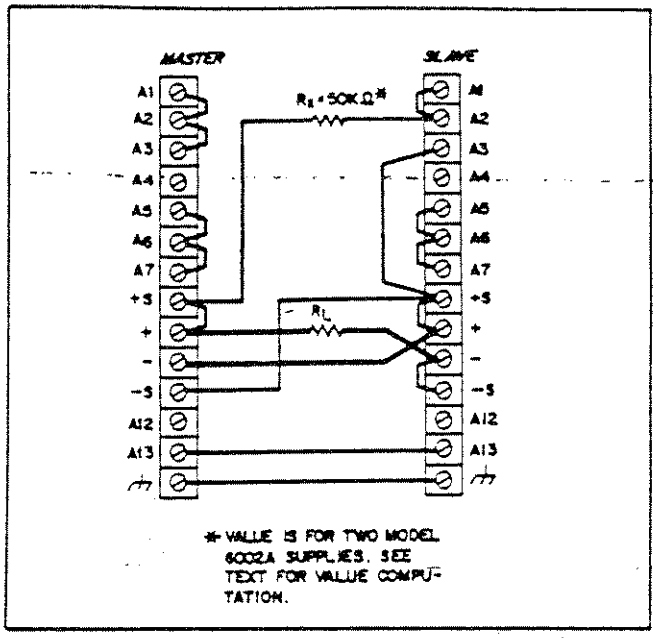


Figure 3-11. Auto-Series Operation of Two Units

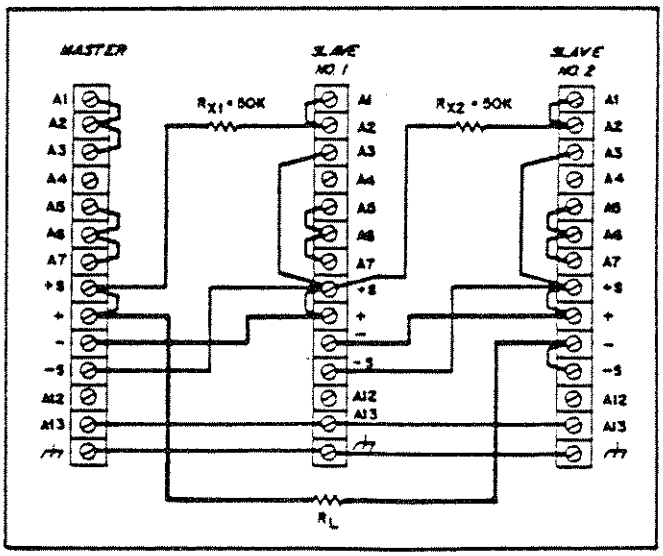


Figure 3-12. Auto-Series Operation of Three Units

3-59 When operating three supplies in auto-series, R_{X2} is found by dividing the voltage programming current of the second slave into the maximum voltage expected from the first slave.

3-60 **Setting the Voltage Controls.** The voltage each slave supply contributes is determined by its voltage control setting. The output voltage of the first slave supply tracks the voltage of the master, and the voltage of the second slave (if used) tracks the voltage of the first slave. For this reason, the voltage of the master must be adjusted to maximum, and then each slave, in turn, must be set to the corresponding voltage desired during initial setup of the auto-series combination. Once this has been done, the total voltage of the combination can be controlled by the voltage controls of the master supply or it can be remotely programmed through the master supply.

3-61 **Setting the Current Controls.** Auto-series operation leaves the current controls of all supplies operative, but the supply whose current control has the lowest setting determines the point at which automatic crossover to constant current operation begins to lower its output voltage and thus that of the series combination. The constant current circuit of a supply has no effect on the outputs of the supplies connected in a more positive position in the series combination, but it does affect its own output and the outputs of the supplies connected in a more negative position. If the current controls of one of the slave supplies are set the lowest, then an overload or short circuit at the output will cause the master supply (or the master and the first slave) to force current through the reverse voltage protection diodes at the outputs of the downstream slaves. Because this current could be excessive either for the diodes or the load, the current controls of the slave supplies should be set to maximum and the master supply's current controls used to establish the output current or current limit.

3-62 **Overvoltage Protection in Auto-Series.** The interconnections shown in Figures 3-11 and 3-12 between the external crowbar trigger terminals on the master and on the slave(s) must be made to permit the overvoltage crowbar in any one of the interconnected supplies to fire the SCRs in all of them if an overvoltage condition occurs. Be sure to connect them with the polarity shown. Set the overvoltage potentiometer in each supply so that it trips at a point slightly above the voltage that supply will contribute.

3-63 **Auto-Series With Remote Sensing.** To combine auto-series operation with remote sensing, connect the supplies as described above but remove the +S jumper from the master supply and the −S jumper from the last slave supply and connect the +S and −S terminals directly to the (+) and (−) ends of the load.

3-64 **Auto-Series With Remote Programming.** When two or three supplies are connected in auto-series, their combined output voltage, current, or both can also be remotely programmed. Refer to the appropriate sections for the additional rear panel connections required and make these connections to the master supply only.

3-65 Auto-Tracking Operation

3-66 Figures 3-13 and 3-14 show the rear panel interconnections required to operate two or three supplies in the auto-tracking mode. This mode of operation allows two or three supplies that share a common negative output bus to power separate loads and have their output voltage simultaneously programmed by the voltage and current controls of a master supply. Unless their outputs are to be equal, the supply that is to have the greatest output voltage must be selected as the master. The output voltage of each slave supply is a constant percentage of the master's with the percentage for each slave established by a voltage divider consisting of R_X and the voltage control of the slave supply. Model numbers can be mixed in an auto-tracking configuration.

3-67 **Value of R_X.** To calculate the proper value of R_X the following information is required:

a. E_M, the maximum voltage desired from the master supply.

b. E_S, the maximum voltage desired from the slave supply.

c. R_P, the resistance of the slave supply's voltage control.

To find R_X use the formula:

$$R_X = (E_M R_P / E_S) - R_P$$

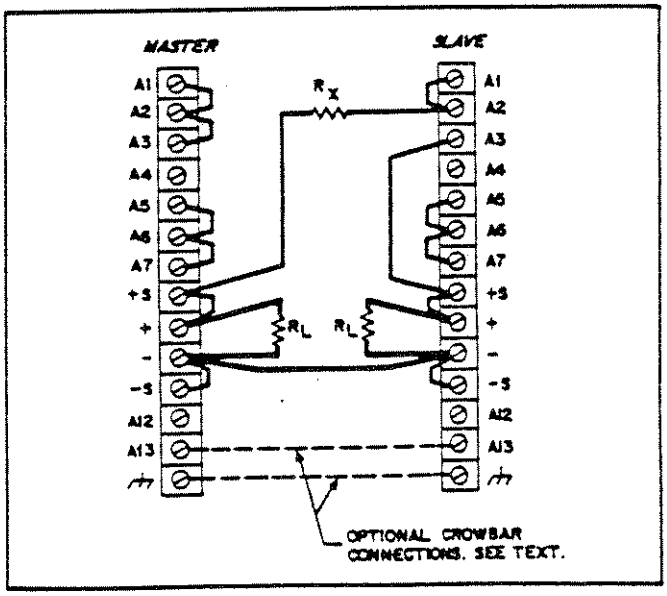


Figure 3-13. Auto-Tracking Operation of Two Units