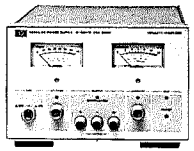
POWER SUPPLIES

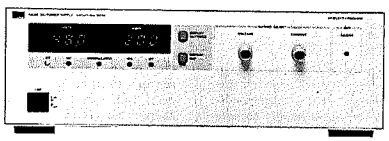
Autoranging Power Supplies

Models 6010A, 6011A, 6012B, 6023A, and 6024A

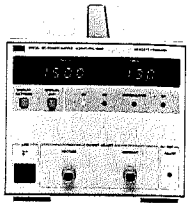
- Complete front panel control/display
- Constant voltage/constant current operation
- Remote programming and sensing
- Autoranging output
- High efficiency, compact, and light weight
- Ten-turn voltage and current controls



HP 6024A



HP 6010A, 6011A, 6012B



HP 6023A

Description

HP Models 6010A, 6011A, 6012B, and 6023A

This versatile family of dc power supplies provides laboratory grade performance along with many features to meet both laboratory and system needs.

Ten-turn front panel controls provide the means to precisely adjust the output voltage and current. The settings of these controls can be observed on the front panel meters by pressing the Display Settings button. This allows the current limit to be set when operating in the CV mode without shorting the output terminals and the voltage limit to be set when operating in the CC mode without opening the load leads.

Three and one-half digit front panel meters provide a convenient means for monitoring the output voltage and current. The accuracy of these meters allow them to replace external DVMs and monitor resistors in many applications that require monitoring of the power supply output.

The overvoltage protection (OVP) trip level can also be displayed on the front panel meters, allowing the trip level to be accurately adjusted without actually activating the OVP circuitry or disconnecting loads. In addition to the protection provided to the power supply and load by the OVP, these supplies also have protection against operating under excessive ac line or thermal conditions.

As autoranging power supplies, these units can operate at their maximum rated power over a wide and continuous range of voltage and current combinations. This often allows both present and future requirements to be satisfied with fewer supplies.

Special modifications are available to extend the output ratings even further. For example, the HP 6010A with Special Option V05 can provide up to 500 volts. See page 454 for more details.

HP Model 6023A is stable when operating in the CC mode into inductive loads up to one henry. HP Models 6010A, 6011A and 6012B are stable when operating in the CC mode into inductive loads up to 100 mH, and a special modification is available for these three models to assure stability with loads up to ten henries.

System Features

The output voltage and current of these supplies can be remotely controlled with either 0-5 volt or 0-4000 ohm analog programming signals. The actual output levels can be monitored without complicated external circuitry by connecting DVMs to the buffered 0-5 volt monitor outputs. All programming and monitoring signals are referenced to the same common and are accessed through the rear panel barrier strip.

Either terminal may be grounded, or floated up to ± 240 volts from chassis ground for the HP 6011A, 6012B and 6023A, and ±550 volts for the HP 6010A.

If more output voltage or current is needed than a single unit can provide, auto-series or auto-parallel configurations can be used. Up to four 1000-watt units, or up to two 200-watt units can be connected in auto-parallel, and any combination can be used in auto-series providing up to 240 volts total (550 Vdc for HP 6010A) from chassis ground including output voltage. Remote sensing can be used to maintain the CV load effect specification at the load with up to 0.5 volt drop per load lead and sense wires that are less than 0.2 ohm per lead. Operation is possible with up to 2.0 volts per lead; however, load effect specification may be degraded. For more system control and monitoring capabilities, see Option 002.

Specifications

Ratings*									Regulation				10% Change Transient Recovery
		Autoranging Output*							Load Effect		Source Effect		
Volts	Amperes	V_1	P_1	V_2	P_2	V_3	P_3	HP Model	Voltage	Current	Voltage	Current	Time / Level
0-20	0-30	20V	200W	14V	242W	6.7V	200W	6023A	0.01% +2mV	0.01% +9mA	0.01% +1mV	0.01% +6mA	1ms / 50mV
0-20	0-120	20V	1000W	14V	1064W	7V	840W	6011A	0.01% +3mV	0.01% +15mA	0.01% +2mV	0.01% +25mA	2ms / 100mV
0-60	0-10	60V	200W	40V	240W	20V	200W	6024A	0.01% +3mV	0.01% +3mA	0.01% +5mV	0.01% +5mA	1ms / 75mV
0-60	0-50	60V	1000W	40V	1200W	20V	1000W	6012B	0.01% +5mV	0.01% +10mA	0.01% +3mV	0.01% +10mA	2ms / 100mV
0-200**	0-17	200V	1000W	120V	1200W	60V	1020W	6010A	0.01% +5mV	0.01% +10mA	0.01% +5mV	0.01% +5mA	2ms / 150mV

*See the generalized autoranging output characteristic curve.
**HP Model 6010A with Special Option V05 can provide up to 500 volts. See page 454 for more details.

HP Model 6024A

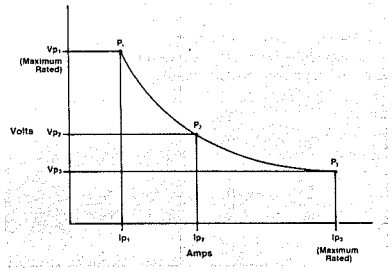
As an autoranging dc power supply, the HP 6024A can provide 200 watts over a wide and continuous range of voltage and current combinations, with maximums of 60 volts and 10 amperes. This provides greater flexibility than traditional power supplies that have only one maximum power point.

Ten-turn potentiometers provide precise control of the output voltage and current. The output levels can be observed on the separate front panel voltage and current meters. Terminals are available on both the front and rear panel for load connections.

The built-in OVP is adjustable from the front panel. Other protection features include over-temperature and high ac line detection.

The HP 6024A has many system oriented features. It can be remotely programmed with 0-5 volt or 0-2500 ohm analog signals. The output current can be easily monitored without an external shunt with the proportional 0-5 volt buffered monitor output. Remote sensing can be used to eliminate the effects of voltage drops in the load leads, and either terminal may be floated up to ±240 volts from chassis ground. Several units can be combined in auto-series, auto-parallel, and auto-tracking configurations, further increasing the HP 6024A's flexibility.

For more system features, see Option 002.



Generalized autoranging output characteristic curve

General Specifications

Dimensions

HP 6010A, 6011A and 6012B: 132.6 mm H x 425.5 mm W x 516.4 mm D (5.2″ x 16.75″ x 20.33″).
HP 6023A: 177.0 mm H x 212.3 mm W x 443.6 mm D (6.97″ x 8.36″ x 17.872″).
HP 6024A: 133.4 mm H x 212.3 mm W x 415.33 D (5.25″ x 8.36″ x 16.35″).

Ordering Information

Price

Option Descriptions

002: provides extra programming and monitoring capabilities for system use. A card inserted into the power supply is accessible through a 37-pin connector on the rear panel. It provides easy access to the control and monitor signals available on standard units, as well as these additional features: $345.00

- OVP trip and reset
- power supply inhibit
- status bits indicating CV mode, CC mode, unregulated output, OVP tripped, overtemperature condition, and ac line drop-out
- remote programming via a 0-2 mA current sink
- bias supplies for your circuitry: +5 volts at 100 mA, +15 volts at 75 mA, and −15 volts at 75 mA.
- buffered 0-5 volt outputs representing both the output voltage and output current. (HP 6010A, 6011A, 6012B, and 6023A provide this feature standard, but HP 6024A only provides a scaled 0-5 volt output to represent the output current, not the output voltage.)
- programmable remote/local for use when programming with a current sink.

These features can all be taken advantage of with an HP 6940B or 6942A Multiprogrammer instrument sub-system configured with an HP 69520A or 69709A Power Supply Programming Card. The Multiprogrammer provides a cost-effective solution for controlling a group of power supplies, and also can provide many other digital and analog monitoring and control functions, all on the HP-IB. The voltage and current programming resolution available with either card is 1/1000th of full scale.

The features available with Option 002 can also be interfaced to your own external circuitry rather than an HP Multiprogrammer.

100: 87-106 Vac, 48-63 Hz. HP 6024A Only! This option is for use in Japan only. The power supply output power is 75% of the output power available with the other line voltage options. For HP 6024A only. N/C
220: 191 to 233 Vac, 48-63 Hz. N/C
240: 208 to 250 Vac, 48-63 Hz. N/C
800: Rack-mount kit for two units side by side. This applies to HP 6023A and 6024A only.
HP 6023A $63.00
HP 6024A $69.00
908: Rack-mount kit for a single unit. A blank filler panel is supplied when ordered for half rack width units.
HP 6010A, 6011A, 6012B $36.00
HP 6023A $84.00
HP 6024A $64.00
909: Rack-mount kit with handles for HP Models 6010A, 6011A, and 6012B $85.00
910: One extra operating and service manual shipped with each power supply.
HP 6024A $10.00
HP 6010A, 6011A, 6012B, 6023A $21.00

PARD (rms/p-p) 20Hz-20MHz		Programming Response Time							General*						
		UP			DOWN				AC Input Current				Weight kg (lbs)		
Voltage	Current	Settling Band	Full Load	No Load	Full Load	Light Load Time	Light Load Load	100 Vac	120 Vac	220 Vac	240 Vac	Net	Shipping	Price
3 mV / 30 mV	15 mA / —	5 mV	100 ms	100 ms	200 ms	500 ms	50 Ω	—	6.5 A	3.8 A	3.6 A	8.6 (19)	10.5 (23)	$2010
8 mV / 50 mV	120 mA / —	30 mV	300 ms	300 ms	500 ms	1.5 sec	50 Ω	—	24 A	15 A	14 A	16.8 (37)	22.2 (49)	$2935
3 mV / 30 mV	5 mA / —	60 mV	200 ms	200 ms	300 ms	600 ms	Open	5.3 A	5.3 A	2.9 A	2.7 A	5.4 (12)	7.3 (16)	$1800
8 mV / 40 mV	25 mA / —	90 mV	300 ms	300 ms	2.0 sec	3.0 sec	100 Ω	—	24 A	15 A	14 A	15.9 (35)	21.3 (47)	$2935
22mV / 50mV	15mA / —	300mV	300ms	300ms	600ms	3.5 sec	Open	—	24 A	15 A	14 A	16.3 (36)	21.7 (48)	$2935

* An ac input option must be specified when ordering.

POWER SUPPLY HP 6024A

HP 6024 A

SECTION I
GENERAL INFORMATION

1-1 DESCRIPTION

1-2 The Model 6024A is an autoranging 200-watt power supply providing laboratory-grade performance with the high efficiency of switching regulation techniques. Autoranging allows the supply to furnish 200 watts output power over a wide range of output voltage and current combinations without the user having to select the proper output range. The output is adjustable through the entire operating range of 0 to 60 volts and 0 to 10 amperes by 10-turn front-panel controls.

1-3 The supply is of the Constant Voltage/Constant Current (CV/CC) type with front-panel LEDs to indicate whether the unit is operating in CV or CC mode. Output voltage and current are continuously indicated on individual front-panel meters. A red LED indicates an overvoltage condition. The overvoltage protection (OVP) circuit protects the user's load by quickly and automatically interrupting energy transfer if a preset trip voltage is exceeded. A screwdriver control on the front panel sets the overvoltage trip point between 2V and 64V.

1-4 Connections to the output are made either to front-panel binding posts or rear-panel screw-on terminals. Either the positive or negative output terminal may be grounded, or the output may be floated at up to 240 volts DC from ground.

1-5 Remote programming, remote sensing, and several methods of operating multiple supply combinations are possible by making connections to rear-panel terminals. These capabilities are more fully described in Section III.

1-6 The unit is fan cooled and is packaged in an 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 I instrument (provided with a protective earth terminal). The instrument and this manual should be reviewed for safety markings and instructions before operation.

1-9 SPECIFICATIONS

1-10 Detailed specifications for the power supply are given in Table 1-1.

1-11 INSTRUMENT AND MANUAL IDENTIFICATION

1-12 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 of the prefix indicate the year (19 = 1979, 20 = 1980, etc), the second two digits indicate the week, and the letter "A" designates the USA as the country of manufacture. The second part of the serial number is a different sequential number assigned to each power supply, starting with 00101.

1-13 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.

1-14 OPTIONS

1-15 Options are standard factory modifications that are requested by the customer. The following options are available with this instrument. Option 002 is described in Appendix A.

OPTION NO.	DESCRIPTION
002	Systems Option: allows the supply to operate automatically in system applications. Provides resistance, voltage, and current programming of voltage and current; six isolated status lines; three isolated control lines; +5V and ±15V bias voltages. This option is mounted on a single additional printed-circuit board, which includes a rear-panel connector.

OPTION NO.	DESCRIPTION
220	Input Power: 191 to 233Vac, 48 to 63 Hz, single phase.
240	Input Power: 208 to 250Vac, 48 to 63 Hz, single phase.
910	One additional operating and service manual shipped with the power supply.

1-16 ACCESSORIES

1-17 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 the rear of this manual).

HP Part No.	Description
5061-0089	Front handle kit for 5-1/4 inch high cabinets.
5061-2002	Bail handle kit for 5-1/4 inch high, half-module width cabinets.
1460-1345	Tilt stand snaps into standard foot supplied with unit, must be used in pairs.
5061-0077	Rack flange kit for 5-1/4 inch high cabinets (must be used with another half-module width instrument of same depth and with lock-together kit #5061-0094).
5061-0083	Rack flange and front handle comination kit for 5-1/4 inch high cabinets (must be used with another half-module width instrument of same depth and with lock-together kit #5061-0094).

HP Part No.	Description
5061-0094	Lock-together kit for cabinets of equal depth, enough links for three side-by-side joints (over-under connections are not possible).
5061-0057	Rack mounting adapter kit for 5-1/4 inch high cabinets, includes one rack flange and one half-module width extension adapter.
5061-0071	Rack mounting adapter kit for center mounting one 5-1/4 inch high cabinet, includes one rack flange and one quarter-module width extension adapter; two kits required.
5061-0097	Support shelf for mounting 5-1/4 inch high cabinets of different depths.
1494-0015	Slide kit for support shelf.
5061-2025	Front filler panel; 5-1/4 inch high, half-module width extender card for servicing control board.
5080-1953	FET Service Kit; includes components that should be replaced when FETs are replaced.
06024-60024	Control Board Extender.
1251-6016	Control Board Test Connector.

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 purchased by adding Option 910 to the order and specifying the number of additional manuals desired.)

Table 1-1. Specifications, Model 6024A

All performance specifications are at rear terminals with a resistive load.

INPUT POWER:

Two internal switches and one internal jumper permit operation from 120, 220, or 240Vac (−13%, +6%); 48-63Hz; 320W maximum. Maximum input current is 5.3A rms for 120Vac, 2.9A rms for 220Vac, and 2.7A rms for 240Vac. A three-wire detachable line cord is supplied.

INPUT PROTECTION:

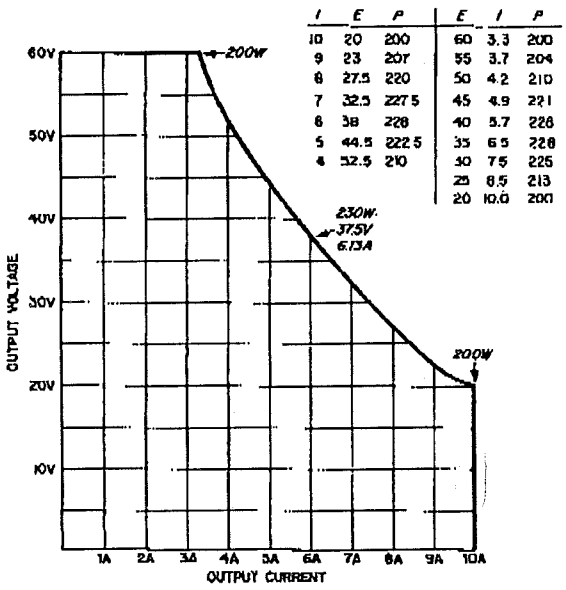
The ac input is protected by a rear-panel mounted fuse; 6A for 120Vac, 4A for 220Vac and 240Vac.

PEAK INRUSH CURRENT:
(typical values)

@25°C ambient, 25A
30 seconds after turn-off, 30A
@55°C ambient, 50A
30 seconds after turn-off, 60A

DC OUTPUT:

Adjustable from 0 to 60V and 0 to 10A. Maximum output power is 200W at extremes of voltage and current, increases to approximately 230W at mid-range. (This power is available at load with up to 0.5V drop in each load lead.) See graph:



I	E	P	E	I	P
10	20	200	60	3.3	200
9	23	207	55	3.7	204
8	27.5	220	50	4.2	210
7	32.5	227.5	45	4.9	221
6	38	228	40	5.7	228
5	44.5	222.5	35	6.5	228
4	52.5	210	30	7.5	225
			25	8.5	213
			20	10.0	200

LOAD EFFECT (LOAD REGULATION):

Constant Voltage - Less than 0.01% of output voltage plus 3mV for a load change equal to the maximum available current rating of the supply at the set voltage.

Constant Current - Less than 0.01% of output current plus 3mA for a load change equal to the maximum available voltage rating of the supply at the set current.

SOURCE EFFECT (LINE REGULATION):

Constant Voltage - Less than 0.01% of output voltage plus 2mV for any line voltage change within rating.

Constant Current - Less than 0.01% of output current plus 2mA for any line voltage change within rating.

PARD (Ripple and Noise), 20Hz to 20MHz:

Constant Voltage - Less than 3mV rms and 30mV p-p.

Constant Current - Less than 5mA rms.

TEMPERATURE COEFFICIENT:

Constant Voltage - Less than 0.01% plus 1mV change in output per degree Celsius change in ambient after 30-minute warmup.

Constant Current - Less than 0.03% plus 1mA change in output per degree Celsius change in ambient after 30-minute warmup.

DRIFT (Stability):

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

Constant Voltage - Less than 0.03% of output plus 3mV.

Constant Current - Less than 0.03% of output plus 3mA.

LOAD TRANSIENT RECOVERY TIME:

Less than 1ms is required for output voltage recovery (in constant voltage operation) to within 75mV of the nominal output following a change in output current from 90% to 100% or 100% to 90% of maximum current rating.

RESOLUTION:

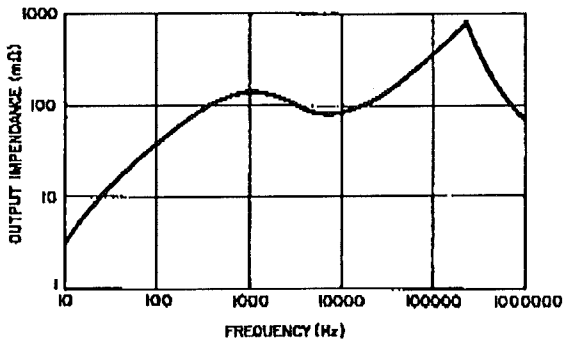
(Minimum output voltage or current change that can be obtained using the 10-turn front-panel controls)

Constant Voltage - 20mV

Constant Current - 5mA

Table 1-1. Specifications, Model 6024A (continued)

OUTPUT IMPEDANCE (Typical):



DC OUTPUT ISOLATION:

Either output terminal may be floated up to ±240Vdc (including output voltage) from earth ground.

OVERVOLTAGE PROTECTION:

Trip voltage adjustable from 2V to 64V. Minimum setting above output voltage to avoid false tripping is 1.5V.

REVERSE VOLTAGE PROTECTION:

(Maximum permissible reverse current caused by reverse voltage impressed across output terminals) 10A continuous.

REMOTE SENSING:

Maintains nominal voltage at load by correcting for load-lead voltage drop of up to 0.5V per lead.

REMOTE PROGRAMMING:

Resistance Programming - 0 to 2.5K provides zero to maximum rated voltage or current output.
Accuracy: CV; 0.8% + 2mV CC; 2.5% + 1mA

Voltage Programming - 0 to 5V provides zero to maximum rated voltage or current output.
Accuracy: CV; 0.2% + 2mV CC; 1.0% + 2mA

Current Programming - 2mA to 0mA current sink provides zero to maximum rated voltage or current output (with user-provided 2.5k resistor).
Accuracy: CV; 0.2% + 0.36V + accuracy of resistor
CC; 1.0% + 0.15A + accuracy of resistor

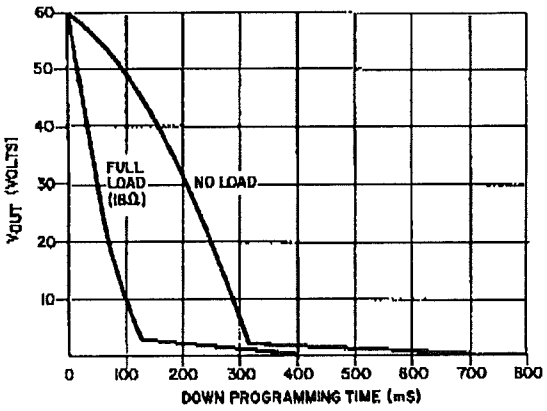
PROGRAMMING RESPONSE TIME:

Maximum time for output voltage to change from 0V to 60V or 60V to 2V and settle within 60mV band (0.1% of maximum rated output).

Up:	Full Load (18Ω)	200mS
	No Load	200mS
Down:	Full Load (18Ω)	300mS
	No Load	600mS

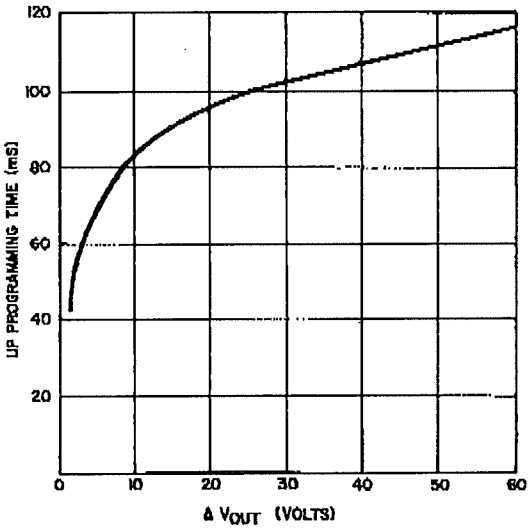
Typical response time, for excursions other than full-scale

Down: On graph, read difference in time between initial output voltage and final output voltage; add settling time



Plus 125ms if final voltage ≥ 2V
or 500ms if final voltage < 2V to settle within 60mV band (0.1% of maximum rated output)

Up: On graph, read time for change in output voltage



CURRENT MONITORING OUTPUT:

0 to 5V output from rear-panel terminal indicates zero to maximum rated current output; accuracy, 0.9% + 7mV output impedance, 10k.

Table 1-1. Specifications, Model 6024A (continued)

METERS AND INDICATORS:

Voltmeter - Continuously reading 70V scale with secondary scale indicating amperes available; accuracy, ±3% of full scale.

Ammeter - Continuously reading 12A scale with secondary scale indicating volts available; accuracy, ±3% of full scale

VOLTAGE Indicator - Green LED indicates Constant Voltage operation.

CURRENT Indicator - Green LED indicates Constant Current operation.

OUTPUT UNREGULATED Indicator - Red LED indicates that output is unregulated because of any of the following conditions: overrange operation, overvoltage, over temperature, or low-input-power shutdown.

OVP Indicator - Red LED indicates shutdown caused by voltage at output terminals exceeding preset limit.

MULTIPLE UNIT OPERATION:

Auto-Parallel - Up to eight units may be connected in parallel to increase total output current capability while maintaining control from a single unit.

Auto-Series - Up to four units (eight if center-tapped to ground) may be connected in series to increase total output voltage to 240Vdc (480Vdc if center-tapped to ground) while maintaining control from a single unit.

Auto-Tracking - Any number of units may have either one of their output terminals connected to a common bus so that all outputs track, at some fraction, the output of a single, controlled, unit.

TEMPERATURE RATINGS:

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

Unit is fan cooled. A termostat turns off unit if temperature rises above a critical level; resets automatically.

OPTIONS:

Option 002 (System Interface) specifications are listed in Appendix A.

CERTIFICATION:

Unit complies 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 Level A - RFI Suppression of Radio Frequency Equipment for Industrial, Scientific, and Medical (ISM) and Similar Purposes.

VDE 0411 - Electronic Measuring Instruments and Automatic Controls.

DIMENSIONS:

See Figure 2-1.

WEIGHT:

Net: 5.4kg (12 lb) Shipping: 7.3kg (16 lb)

SECTION III
OPERATING INSTRUCTIONS

3-1 INTRODUCTION

3-2 This section describes the operating controls and indicators, turn-on check-out procedures, and operating procedures and considerations for the Model 6024A.

WARNING

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

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

3-4 TURN-ON CHECKOUT PROCEDURE

3-5 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. This check should be performed when the unit is first received. If the supply fails to perform properly, proceed to the troubleshooting procedures in Section V.

a. Ensure that rear terminal board straps are connected as shown in Figure 3-2, but do not connect load. Check that rear-panel label indicates unit is set for line voltage to be used. If it is not, refer to paragraph 2-23. If unit is equipped with System Option 002 ensure that option cable is disconnected from rear panel option connector before proceeding.

b. Ensure that CURRENT control (5) is rotated clockwise at least two turns and OVP ADJUST potentiometer (8) is fully clockwise.

c. Press pushbutton LINE switch (1) to ON (pushbutton in) and observe that reflective indicator shows in the LINE switch and that fan operates.

d. Turn VOLTAGE control (2) through output voltage range of unit as indicated on volmeter (4). VOLTAGE light (3) should be lit across entire range indicating that supply is in constant voltage mode.

e. Check out overvoltage circuit by turning OVP ADJUST control (8) (screwdriver adjust) counterclockwise until unit shuts down. Output voltage should drop to –0.6 to 0 volts and OVP (9) and UNREGULATED (10) indicators should light.

f. Reset overvoltage circuit by returning OVP control to maximum clockwise position and turning supply off for at least one second and then back on. Output voltage should return to value set in step d.

g. To check constant current circuit, turn off supply and connect short (AWG #18 or larger) across + and – output terminals ((11) and (12) on front panel or + and – on rear panel). Ensure that VOLTAGE control is rotated at least two turns clockwise.

h. Turn supply back on and rotate CURRENT control (5) through output current range of unit as indicated on ammeter (7). CURRENT light (6) should be on across entire range indicating that supply is in constant current mode.

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

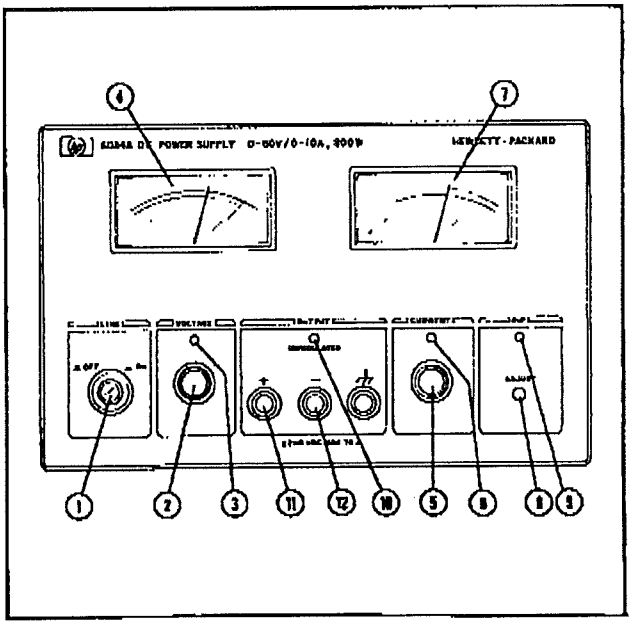


Figure 3-1. Front Panel Controls and Indicators

3-6 OPERATING MODES

3-7 This power supply is designed so that its mode of operation can be selected by making strapping connections on its rear panel. Normal operating mode for this power supply uses local programming of the output voltage and current via the front panel VOLTAGE and CURRENT controls, and local sensing of the output voltage. Alternate operating modes allow use of remote programming, remote sensing, and multiple power supply combinations.

3-8 The following paragraphs first describe operating considerations with the normal operating mode, using the strapping pattern as it is connected at the factory. Later paragraphs cover alternate operating modes. The operating considerations described with normal mode, such as constant voltage/constant current crossover, overrange, constant voltage and constant current operation, overvoltage protection, protective circuits, and load connections, apply to the alternate modes as well as to normal mode. More theoretical descriptions regarding the operational features of power supplies in general are given in the DC Power Supply Handbook, Application Note 90B (available at no charge from your local Hewlett-Packard Sales Office).

3-9 NORMAL OPERATING MODE

3-10 The 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 illustrated 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 in paragraphs 3-17 or 3-19. 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.

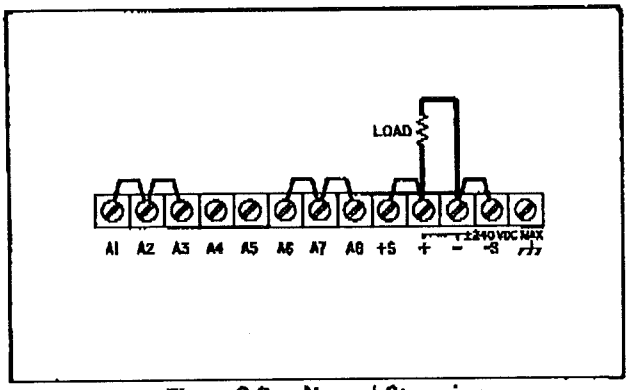


Figure 3-2. Normal Strapping

3-11 Figure 3-3 shows the overall output range of the supply, with three sample operating loci. Locus 1 is established with a VOLTAGE setting of 20V and a CURRENT setting of 3A. For any values of load resistance greater than the crossover value of 6.7 ohms, the supply operates in constant voltage mode. For values of load resistance less than the crossover value, the supply operates in constant current mode. The transition occurs smoothly and automatically; no switches need be operated or connections changed. The front panel VOLTAGE and CURRENT lights indicate which mode is operating.

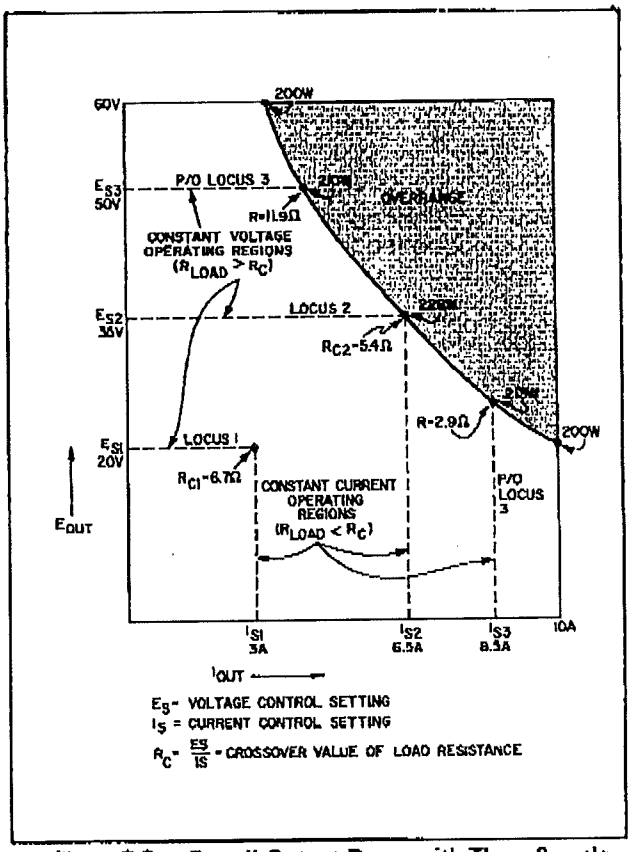


Figure 3-3. Overall Output Range with Three Sample Operating Loci

3-12 Locus 2 is established with a VOLTAGE setting of 35V and a CURRENT setting of 6.5A. Its crossover load resistance is 5.4 ohms, and lies on the rated-output-power boundary.

3-13 A rectangular operating locus will be established for all voltage and current settings within the rated-output-power boundary. However, if the VOLTAGE and CURRENT controls are set so that the boundary can be exceeded, as in locus 3, the supply will go into overrange if the load resistance falls within a critical band (refer to next paragraph).

3-14 **Overrange.** The supply will be driven into overrange (shaded area of Figure 3-3) if the VOLTAGE and CURRENT controls are set above the output power rating and the load resistance falls within a critical band. For example, assume that the operator sets the VOLTAGE control at 50V and the CURRENT control at 8.5A, as in locus 3 on Figure 3-3. For all load resistances above 11.9 ohms (which is the critical value) the supply would operate normally in the constant voltage mode. If the load resistance were to fall much below 11.9 ohms, however, the supply would be forced into overrange. If the load resistance continued to decrease to a 2.9 ohm value, the supply would automatically come out of overrange and into the constant current mode at the 8.5A, 25V point. (The supply will probably go out of regulation while operating in the overrange region, refer to paragraph 3-16.)

3-15 Anytime the supply operates in overrange, the VOLTAGE and CURRENT indicators turn off and the UNREGULATED indicator lights. The VOLTS and AMPERES meters indicate the voltage and current being supplied to the output. (The product of the two readings will exceed 200 watts.) Paragraph 3-30 identifies conditions other than overrange which cause the UNREGULATED indicator to light.

3-16 The supply can operate in the overrange region (beyond the rated-output-power boundary) 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 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.

3-17 Constant Voltage Operation

3-18 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 + and — output terminals, restore power, and adjust the CURRENT control for the desired maximum output current. Then turn power off and 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 current limit, make an adequate allowance for high peak currents that could cause unwanted crossover.

3-19 Constant Current Operation

3-20 To adjust the supply for constant current operation, with supply turned off:

a. Connect a short across the front or rear panel + and — 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.

3-21 Overvoltage Protection

3-22 **Adjustment.** The overvoltage trip point is adjusted with the OVP ADJUST screwdriver control on the front panel. The approximate trip voltage range for this unit is from two volts to 64V. When the overvoltage protection (OVP) circuit trips, the supply is inhibited and delivers no output power; the OVP and UNREGULATED indicators on the front panel light. Rotating the control clockwise sets the trip voltage higher. (It is set to maximum at the factory.)

3-23 When adjusting the OVP 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 OVP. For this reason it is recommended that the OVP trip voltage be set higher than the output voltage by at

least 1.5 volts. To adjust the OVP trip voltage, proceed as follows:

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

b. Set output VOLTAGE control to desired trip voltage.

c. Turn OVP ADJUST pot CCW until OVP circuit fires; red OVP indicator lights and output voltage falls to zero.

d. Turn off supply and turn down output voltage.

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

3-24 Resetting the OVP Circuit. If the OVP circuit trips during normal operation, the ac LINE switch must be turned off for at least one second and then back on to reset the circuit. If the OVP circuit trips continuously check the load and/or the trip point setting. If the supply does not operate properly after the OVP circuit is reset, proceed to troubleshooting in Section V.

3-25 CONNECTING THE LOAD

3-26 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. Stranded AWG#16 wire is rated for 12.7A at 105°C conductor temperature (45°C rise above 60°C ambient temperature). Stranded AWG #14 wire is rated for 14.8A at 80°C conductor temperature (20°C rise above 60°C ambient temperature). These ratings are based on use of a twisted pair to connect the load to the supply. *Generally, heavier wire is required to obtain good regulation at the load.* If the load regulation is critical, use remote voltage sensing. (Refer to paragraph 3-34).

3-27 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 noise pickup.

3-28 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 is required under these circumstances (paragraph 3-34).

3-29 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 with either output terminal up to ±240 volts dc from ground.

3-30 PROTECTIVE CIRCUITS

3-31 Protective circuits within the instrument may limit or turn off the output in case of abnormal conditions. The cause for the protective action can be determined by observing the front panel indicators (lights and meters). An overrange condition is indicated by the UNREGULATED indicator on, the VOLTS and AMPERES meters reading relatively high, and the VOLTAGE, CURRENT, and OVP indicators off. An overvoltage condition is indicated by both the OVP and UNREGULATED indicators on, the meters reading near zero, and the VOLTAGE and CURRENT indicators off. An overtemperature condition is indicated by the UNREGULATED indicator on, the VOLTAGE, CURRENT, and OVP indicators off, and the meters dropping toward zero from the readings that existed when the overtemperature condition occurred. If the primary power voltage drops below approximately 70% of nominal, the level detector will shut down the instrument. In this case, the UNREGULATED indicator is on, the VOLTAGE, CURRENT, and OVP indicators are off, and the meters read zero immediately.

3-32 ALTERNATE OPERATING MODES

3-33 The alternate 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 the rear panel strapping pattern according to the instructions which follow, the supply can be operated in any of the modes listed above.

WARNING

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.

3-34 Remote Voltage Sensing

3-35 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.) When using remote sensing, turn off the power supply before changing the rear panel straps, sense leads, or load leads. The following paragraphs discuss some precautions that should be observed when making a remote sensing installation.

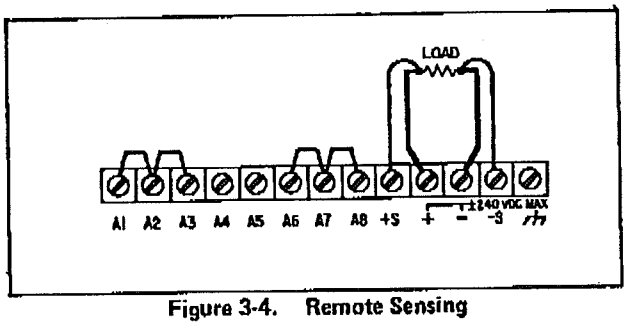


Figure 3-4. Remote Sensing

3-36 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 volts. The power supply has been designed to minimize the effects of long load lead inductance, but best results will be obtained by using the shortest load leads practical.

NOTE

Because the OVP circuit monitors voltage at the rear terminals and there is an unavoidable voltage drop in the load leads, it may be necessary to readjust the OVP trip point in remote sensing mode.

3-37 Since the sensing leads carry only a few milliamperes, the wires used for sensing can be much lighter than the load leads (AWG#22 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, and CV load regulation may be adversely affected. 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.

3-38 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. It is recommended that no switch, relay, or connector contacts be included in the remote sensing path.

NOTE

If the + output lead opens, the load voltage (+ sense to – output) will remain regulated at the set value, but the output voltage of the supply will rise to some high value dependent on the control settings and the load. If this voltage exceeds the OVP voltage, the OVP trips and down-programs the output voltage to zero volts. Whether or not the OVP trips, neither the supply nor the load will be damaged by excessive voltage.

If the – output lead opens, the load voltage (+ output to – sense) will drop to some low value and the output voltage of the supply operates at some value between zero and seven volts, both depending on the control settings and the load.

3-39 Remote Programming

3-40 The output voltage and/or current of the power supply can be remotely controlled by external resistance, voltage, or current sink. Programming can be accomplisht via the standard rear-panel screw-on terminals or via the option connector on units equipped with System Option 002. Standard programming is described in this section; programming with System Option 002 is described in Appendix A.

3-41 For resistance programming, a variable resistor can control the output over its entire range. Or, a variable resistor connected in series and/or parallel 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 switching configuration used may require make-before-break contacts to avoid producing the output voltage transients caused by momentarily opening the programming terminals.) To maintain the temperature and stability specifications of the supply, any resistors used for programming must be stable, low-noise resistors with a temperature coefficient of less than 25ppm per °C and a power rating at least 30 times what they will actually dissipate.

3-42 Both voltage and current outputs can also be controlled by a voltage source. A voltage source of 0 to 5 volts programs the output from zero to full scale.

Voltage sources of more than 5 volts can be scaled down to the proper range.

3-43 Current programming of both voltage and current outputs is possible also. With current programming, the supply's own constant current sources are used to provide current through an external resistance. A controllable current sink, such as a DAC, in parallel with the external resistor sinks a controllable percentage of the current around the resistance. The remaining current flows through the external resistance and develops a voltage that programs the power supply.

3-44 Connecting a supply for remote voltage or current programming disables the corresponding front-panel controls.

3-45 The following paragraphs discuss in greater detail the methods of remotely programming the output voltage or current using either a resistance, voltage, or current 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, and should be connected to ground at one end only.

3-46 Although the following connection drawings (Figures 3-5 through 3-12) show the supply strapped for local sensing, remote programming and remote voltage sensing do not interact and may be used simultaneously.

3-47 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. A programming resistor variable from 0 to 2500 ohms produces a proportional output voltage from zero to full scale. Note that fixed resistors may be connected in series and/or in parallel with the variable programming resistor to set lower and/or upper output voltage limits. The resultant programming resistance is the sum of the series/parallel resistor combination, and must be between 0 and 2500 ohms. For example, a 1250 ohm resistor connected in series with the variable programming resistor will set the lower limit for output voltage at one-half full scale, i.e., 30 volts.

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 over-voltage trip point should be properly adjusted to protect the user's load.

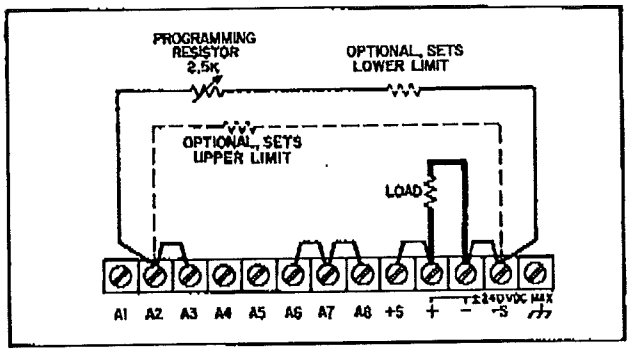


Figure 3-5. Resistance Programming of Output Voltage

3-48 Constant Voltage Output, Voltage Control. The rear panel connections shown in Figure 3-6 allow the output voltage to be varied by using an external voltage source to program the supply. A voltage source variable from 0 to +5 volts produces a proportional output voltage from zero to full scale. The load on the programming voltage source is less than 5μA.

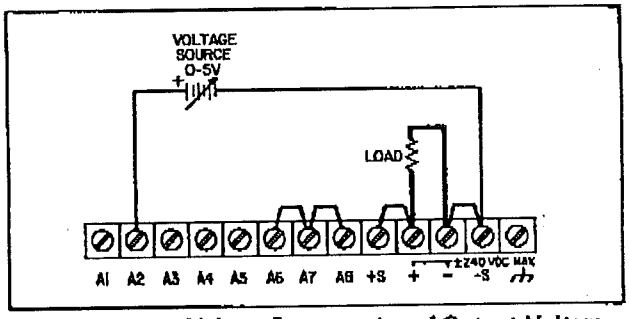


Figure 3-6. Voltage Programming of Output Voltage

3-49 Constant Voltage Output, Scaled Voltage Control. The rear panel connections shown in Figure 3-7 allow the output voltage to be varied by using an external voltage source of more than 5 volts to program the supply. The ratio of the resistance values in the voltage divider must be selected so that the voltage at the center tap of the divider, A2, varies from 0 to 5 volts as the programming voltage source varies from zero to maximum.

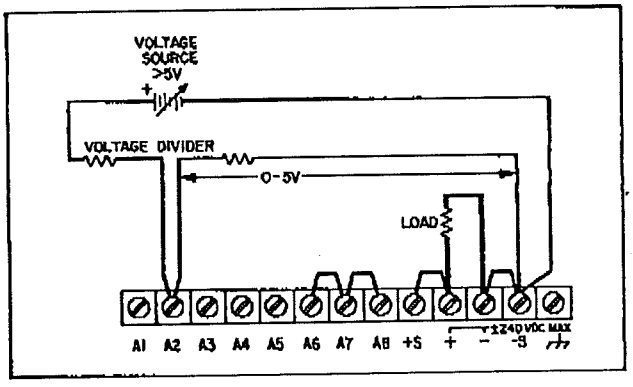


Figure 3-7. Scaled Voltage Programming of Output Voltage

3-50 The total resistance of the voltage divider should be as small as practical without excessively loading the external voltage source. This minimizes degrading the programming speed, offset, and drift specifications. For example, a total resistance of 7.5K will approximately double the up-programming time. A total resistance of less than 5K will make the degradation unnoticeable in most applications.

3-51 Constant Voltage Output, Current Control. The rear panel connections shown in Figure 3-8 allow the output voltage to be varied by using an external current sink to program the supply. In this configuration the supply's own constant current source is used to develop a voltage across a resistor. A current sink, such as a DAC, connected in parallel with the resistor sinks part or all of the current, and thereby determines the voltage developed across the resistor. A current sink variable from 2 mA to 0 mA produces an inversely proportional output voltage from zero to full scale. Many DACs include a sign-change bit, so that a zero digital input to the DAC will produce a 0 volt output from the power supply, and a maximum digital input to the DAC will produce a full scale output from the power supply. Note that the VOLTAGE control potentiometer can be used in place of the external resistor by connecting A1 to A2 in addition to the connections shown in Figure 3-8.

CAUTION

If the DAC is turned off or the program leads open, 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 user's load.

3-52 Constant Current Output, Resistance Control. The rear panel connections shown in Figure 3-9 allow the output current to be varied by using an external resistor to program the supply. The discussion in paragraph 3-47 for constant voltage operation also applies for constant current operation.

CAUTION

If the programming terminals (A7 to A5) become open circuited during resistance programming, the output current will tend to rise above rating. The supply will not be damaged if this occurs, but the user's load may be damaged. If there is a possibility that the programming leads may be opened, it is suggested that the optional resistor be connected directly across terminals A5 and A7, as shown in Figure 3-9. The value of this resistor should be selected to limit the output current to the maximum that the load can handle without damage. For example, if the load can handle 5 amperes (one-half of full scale), a 1250 ohm resistor should be connected from A5 to A7. Of course, if this resistor is used, the resistance value actually programming the supply is the parallel combination of the programming resistor and the optional resistor.

3-53 Constant Current Output, Voltage Control. The rear panel connections shown in Figure 3-10 allow the output current to be varied by using an external voltage source to program the supply. The discussion in paragraph 3-48 for constant voltage operation also applies for constant current operation.

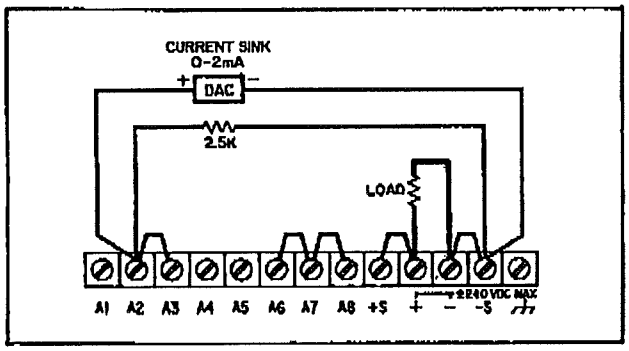


Figure 3-8. Current Programming of Output Voltage

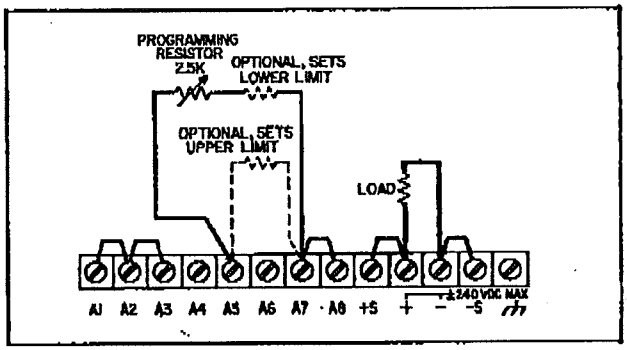


Figure 3-9. Resistance Programming of Output Current

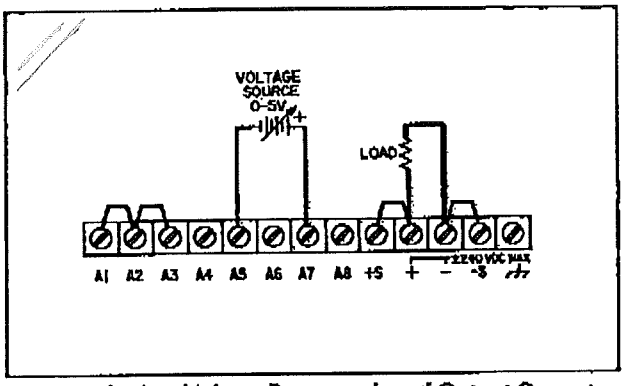


Figure 3-10. Voltage Programming of Output Current

3-54 **Constant Current Output, Scaled Voltage Control.** The rear panel connections shown in Figure 3-11 allow the output current to be varied by using an external voltage source of more than 5 volts to program the supply. The discussion in paragraphs 3-49 and 3-50 for constant voltage operation also applies for constant current operation.

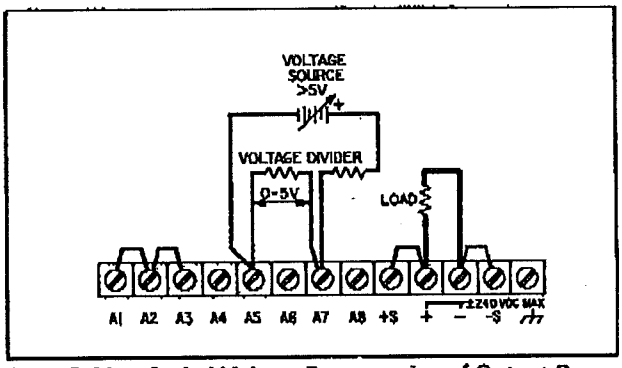


Figure 3-11. Scaled Voltage Programming of Output Current

3-55 **Constant Current Output, Current Control.** The rear panel connections shown in Figure 3-12 allow the output current to be varied by using an external current sink to program the supply. The discussion in paragraph 3-51 for constant voltage operation also applies for constant current operation, except that the CURRENT control can be used in place of the external resistor by connecting A6 to A7 in addition to the connections shown in Figure 3-12.

CAUTION

If the DAC is turned off or the program leads open, the output current will tend to rise above rating. The supply will not be damaged if this occurs, but the VOLTAGE control should be adjusted such that the supply will switch to CV mode once the output current reaches the highest level the load can absorb and/or the OVP ADJUST should be set to shut down the supply.

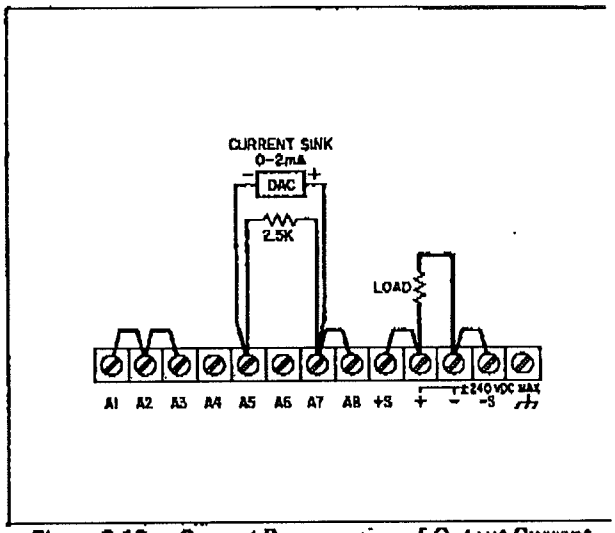


Figure 3-12. Current Programming of Output Current

3-56 Auto-Parallel Operation

3-57 Figure 3-13 shows the rear panel interconnection required to auto-parallel two or more units. This mode of operation provides a greater current capability than can be obtained from a single supply, while ensuring that each supply will share the load proportionally to its own total power capability under all load conditions. For example, if a 200W supply and a 1000W supply were auto-paralleled, the 200W supply would provide 1/6 the total current and the 1000W supply would provide 5/6 the total current. The 6024 can be auto-paralleled only with other autoranging units, or with units that have current-monitoring output signals that are internally referenced to the –output and equal to 5V at maximum rated current output. Up to eight supplies may be connected in auto-parallel.

NOTE

Use wires of equal length and gauge to connect each auto-paralleled supply to the load. Load sharing will not be equal unless the leads connecting each supply to the load are equal in resistance. If it is impractical to run leads from each supply to the load because of distance between the supplies and the load, leads of equal length should be run from each supply to common distribution terminals, with a single pair of leads run from the distribution terminals to the load.

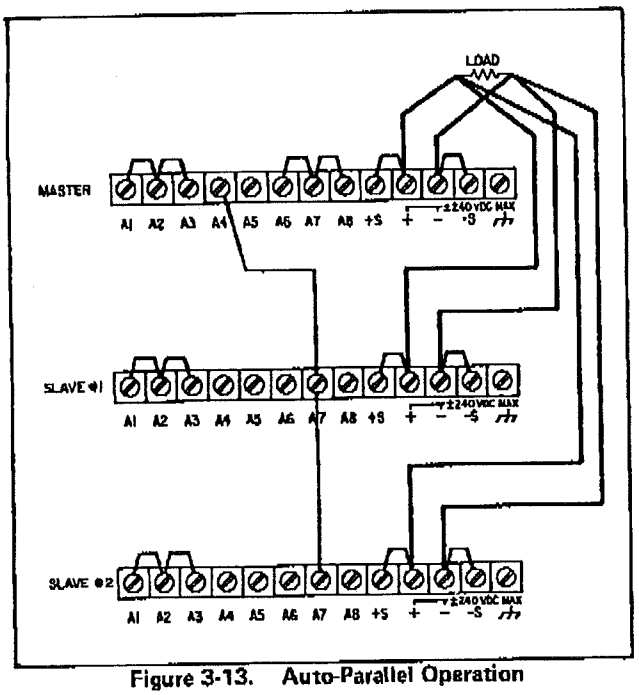


Figure 3-13. Auto-Parallel Operation

3-58 Setting the Voltage and Current Controls. The auto-parallel combination of 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 current controls of the slaves are disabled. The voltage controls of the slaves should be set above the desired output voltage to avoid interference with the master.

NOTE

The voltage controls of the slave supplies can be disabled by disconnecting the straps between the A1 and A2 terminals and connecting a resistor between A2 and −S on each slave. The resistor value should be chosen to program a voltage higher than the desired output voltage. (See paragraph 3-47.)

3-59 Overvoltage Protection in Auto-Parallel. Adjust the OVP trip point at the master supply. The slave supply OVP control(s) may be set to the same level or to maximum (fully clockwise) to disable them. If the master supply OVP trips, the master will program the slaves to zero output. If a slave OVP trips, it shuts down only that slave; the other units supply more current until the master switches to CC mode.

3-60 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 3-34.

3-61 Auto-Parallel with Remote Programming. The output voltage and/or current of an auto-parallel combination can be remotely programmed. Remote programming connections are made to the master supply. Observe all precautions outlined in the remote programming paragraphs. Simultaneous use of remote sensing and remote programming is also possible during auto-parallel operation.

NOTE

Because only the master can down-program the output of an auto-parallel combination, down-programming speed will be reduced under no-load conditions.

3-62 Auto-Series Operation

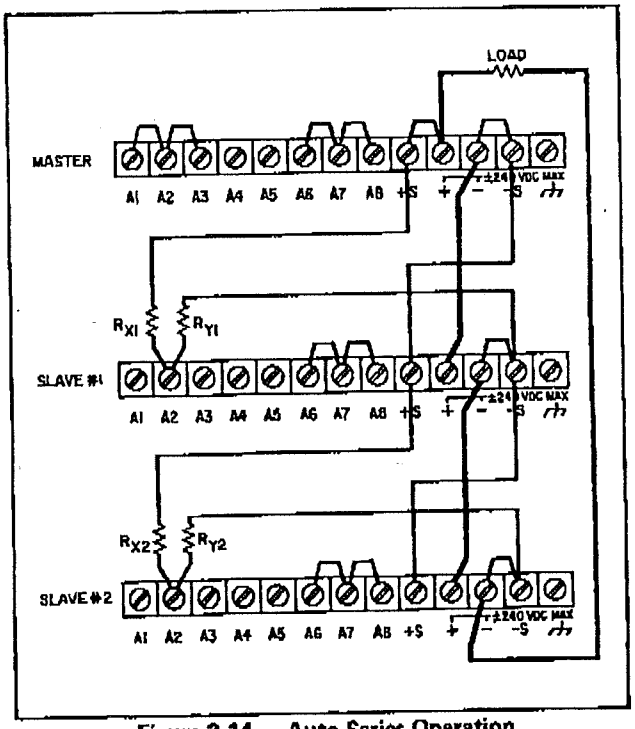


Figure 3-14. Auto-Series Operation

3-63 Figures 3-14 and 3-15 show the rear-panel interconnections required to operate two or more supplies in auto-series. This mode of operation provides a greater voltage capability than can be obtained from a single supply. As many as four supplies can be

connected in auto-series in the configuration shown in Figure 3-14, and as many as eight supplies can be connected if the power supply combination and load are center-tapped as in Figure 3-15 (with no more than four supplies on each side of the center tap). Either configuration allows all the supplies to be programmed simultaneously by the voltage and current controls of the master supply. The master supply must always be the one at the positive end of the series combination Any point of the output can be grounded if desired, as long as no other point in the output is more than 240 volts from ground.

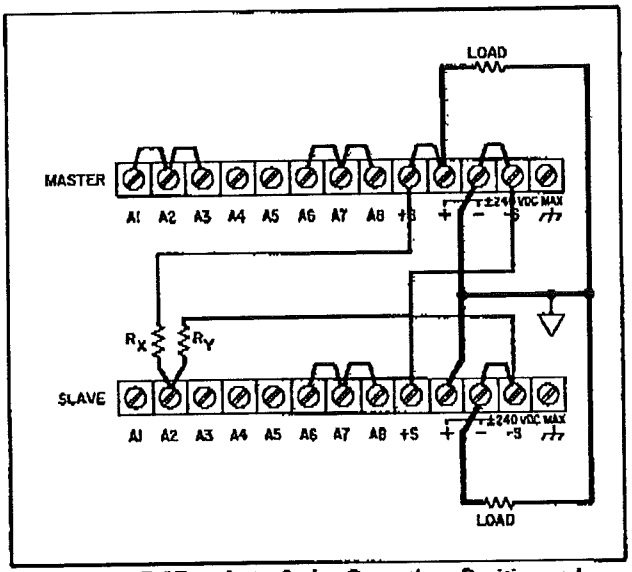


Figure 3-15. Auto-Series Operation, Positive and Negative Outputs

3-64 The output voltage of each slave supply varies in direct proportion to that of the master. The ratio of each slave's output voltage to the master's is established by the ratio of the resistors in the voltage divider connected between the + Sense of the master and the −Sense of the slave.

3-65 Any power supply capable of auto-series operation can be used in the auto-series combination. The supply with the lowest current rating limits the maximum output current of the combination. Any well-regulated, variable-output supply can be used as the master.

3-66 In applications in which coordinated positive and negative voltages are required, center tapping the supply combination and load as shown in Figure 3-15 allows simultaneous proportional control of both supply voltages.

CAUTION

If more than four supplies are connected together in an auto-series combination, be certain that neither the more positive end nor the more negative end of the auto-series combination is more than 240 volts from ground.

3-67 Setting the Voltage and Current Controls. The auto-series combination of 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 controls of the slaves are disabled. The current controls of the slaves should be set above the desired output current to avoid having a slave switch to CC mode.

NOTE

The current controls of the slave supplies can be disabled by disconnecting the straps between the A6 and A7 terminals and connecting a resistor between A7 and A5 on each slave. The resistor value should be chosen to program a current greater than the desired output current. (See paragraph 3-52.)

3-68 Resistor Values. As shown, each slave has an external voltage divider, R_X and R_Y, that determines its programming voltage. The ratio of R_Y to R_X determines the ratio of the slave output voltage to the master output voltage. To determine the values of R_Y and R_X, first choose the ratio of the slave output voltage to the master output voltage ($\frac{VM}{VS}$), select a value for R_Y, and then determine the value for R_X by solving this equation: $R_X = 12\,(R_Y)\,(1 + \frac{VM}{VS}) - R_Y$. For example, assume a two-supply combination that is to provide 90 volts, 50 volts from the master and 40 volts from the slave. If we select a value of 1k for R_Y, the equation becomes:

$$R_X = 12\,(1000)\,(1 + \tfrac{50}{40}) - 1000$$
$$R_X = 12{,}000\,(2.25) - 1000$$
$$R_X = 26{,}000$$

3-69 Note that the slave output voltage may be lower than, equal to, or higher than the master output voltage.

3-70 Two factors must be considered when selecting the resistance value of R_Y: the effect on programming specifications, particularly speed, and the power that the resistor will have to dissipate. In the previous example, with a total resistance of 27k across an output of 90 volts, R_X will have to dissipate 290 milliwatts and R_Y will have to dissipate slightly more than 11 milliwatts. Lower resistance values of R_X and R_Y will increase programming speed while increasing the amount of power that R_X and R_Y will have to dissipate.

3-71 To maintain the temperature coefficient and stability specifications of the supplies, R_X and R_Y must be stable, low-noise resistors with temperature coefficients of less than 25 ppm per °C and power ratings of at least 30 times what they will actually dissipate.

3-72 The front-panel VOLTAGE control of the slave can be used in place of R_Y by connecting a strap from A2 of the slave to A1 of the slave. This enables the user to vary the percentage of the total voltage contributed by the slave. For calculation purposes, use a resistance value of 2.7k for the VOLTAGE control when it is set to maximum.

3-73 **Overvoltage Protection in Auto-Series.** Set the OVP in each supply so that it trips at a level higher than the voltage that supply will contribute. If the master supply OVP trips, the master will program the slaves to zero output. If a slave OVP trips, that slave and all slaves between it and the negative end of the series will go to zero output; all units more positive than the tripped slave (which includes the master) will continue to supply their set output voltage. Therefore, the total output voltage of the auto-series combination will be the sum of the outputs from the master plus any slaves between the master and the tripped slave. For maximum protection against overvoltage, set each unit's OVP slightly higher (≈1.5 volts) than the voltage it will contribute. For maximum protection against false tripping, set the slave OVPs to maximum and adjust OVP at the master.

3-74 **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 most negative supply, and connect the +S and the —S terminals directly to the + and — ends of the load.

3-75 The output voltage and/or current of an auto-series combination can be remotely programmed. Remote programming connections are made to the master supply. The percentage of the total voltage contributed by a slave can also be remotely programmed by connecting a variable resistor to the slave in place of R_Y. Observe all precautions outlined in the remote programming paragraphs. Simultaneous use of remote sensing and remote programming is also possible during auto-series operation.

3-76 Auto-Tracking Operation

3-77 Figure 3-16 shows the interconnections required to operate two or more units in auto-tracking mode. This mode of operation allows multiple supplies that share a common negative (or positive) output bus to power separate loads and have their output voltages simultaneously programmed by the voltage and current controls of the master supply. The output voltage of each slave supply varies in direct proportion to that of the master. The ratio of each slave's output voltage to the master's is established by the ratio of the resistors in the voltage divider connected between the +S of the master and the —S of the slave.

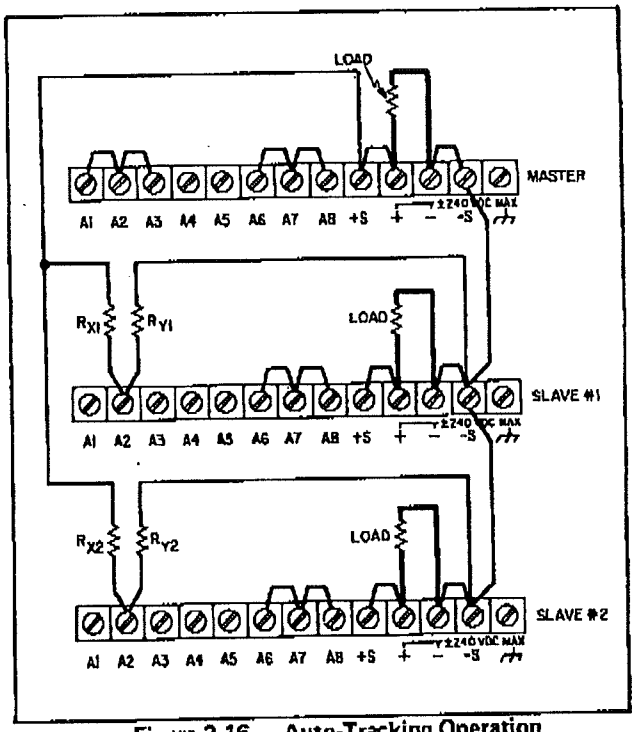


Figure 3-16. Auto-Tracking Operation

3-78 Figure 3-17 shows the interconnections required to provide both positive and negative outputs from an auto-tracking combination. As can be seen, the only difference from standard auto-tracking operation is that the + Out terminal of slave #2 instead of the — Out terminal is connected to the common bus. There is no limit to the number of supplies that can be operated in either auto-tracking configuration.

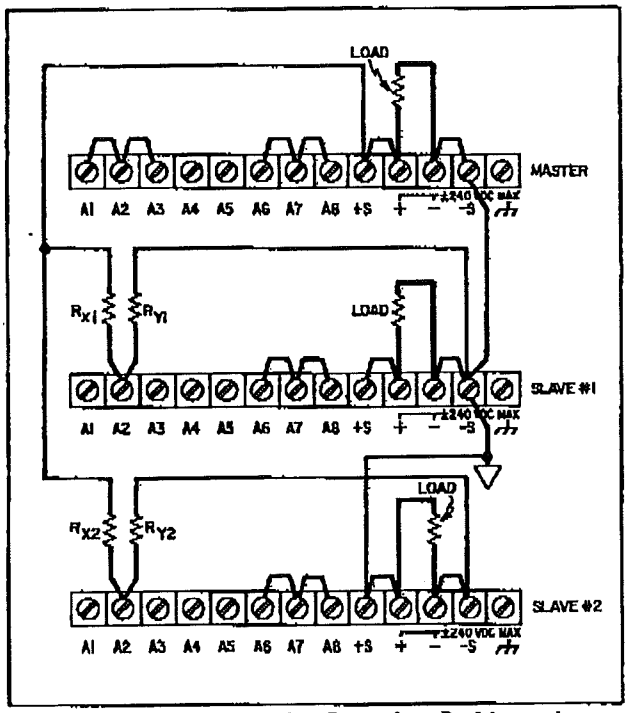


Figure 3-17. Auto-Tracking Operation, Positive and Negative Outputs

3-79 **Resistor Values.** The method for determining the values of R_X and R_Y in Figure 3-16 is similar to that given in paragraph 3-68 for auto-series mode. First choose the ratio of the slave output voltage to the master output voltage, select a value for R_Y, and then determine the value for R_X by solving the equation:

$$R_X = R_Y \left[\left(12 \frac{VM}{VS}\right) - 1 \right]$$

3-80 For example, assume a two-supply configuration in which the slave output is to vary from 0 to 50 volts while the master output varies from 0 to 30 volts. If we select a value of 1k for R_Y, the equation becomes:

$$R_X = 1000 \left[\left(12 \frac{30}{50}\right) - 1 \right]$$
$$R_X = 1000 \left[7.2 - 1\right]$$
$$R_X = 6200$$

3-81 The same factors that govern the choice of R_Y in auto-series mode apply in auto-tracking mode.

3-82 Repeat the process for each slave, with each slave referenced to the same (master) supply (unlike auto-series mode). Note that the slave output voltage may be lower than, equal to , or higher than the master output voltage.

3-83 For auto-tracking operation with both positive and negative outputs, as shown in Figure 3-17, the equation in Paragraph 3-79 is used to determine the values of R_X and R_Y for the slaves providing positive outputs, and the equation in Paragraph 3-68 is used to determine the values of R_X and R_Y for the slaves providing negative outputs.

3-84 To maintain the temperature coefficient and stability specifications of the supplies, R_X and R_Y must be stable, low-noise resistors with temperature coefficients of less than 25 ppm per °C and power ratings at least 30 times what they will actually dissipate.

3-85 The front panel VOLTAGE control of the slave can be used in place of R_Y by connecting a strap from A2 of the slave to A1 of the slave. This enables the user to vary the ratio of the slave output voltage to the master output voltage. For calculation purposes, use a resistance value of 2.7k for the VOLTAGE control when it is set to maximum.

3-86 **Setting the Current Controls.** The current controls of all supplies in an auto-tracking combination are independently operative and can be used to set current limits for each individual load. If the master supply goes into the constant current mode, the output voltages of the slaves continue to track that of the master. If a slave supply goes into constant current mode, however, no other supply is affected.

3-87 **Overvoltage Protection in Auto-Tracking** Set the OVP of each supply as appropriate for the load connected to that supply. If the master supply OVP trips, the master will program the slaves to zero output. If a slave OVP trips, only that slave and its load will be affected.

3-88 **Auto-Tracking with Remote Sensing.** To combine auto-tracking operation with remote sensing, connect the supplies as described above but remove the +S and −S jumpers from each supply and connect the +S and −S terminals directly to the + and − ends of its load.

3-89 **Auto-Tracking with Remote Programming.** The output voltages of an auto-tracking combination can be remotely programmed by programming connections made to the master supply. In addition, the ratio of each slave's output to the master's output can be remotely programmed by connecting a variable resistor to the slave in place of R_Y. The output currents of the individual supplies can also be remotely programmed. Observe all precautions outlined in the remote programming paragraphs. Simultaneous use of remote sensing and remote programming is also possible during auto-tracking operation.

3-90 I-MONITOR OUTPUT SIGNAL

3-91 An amplified and buffered output signal from the current-monitoring resistance (R_M) is available between terminals A4 and A5 on the rear panel. This signal can be connected to a remote voltmeter to indicate the amount of output current. The signal varies from 0 to 5 volts to indicate a zero to full scale (10A) current output. The – terminal of the voltmeter should be connected to terminal A5. Output impedance at terminal A4 is 10k; a load of 1 megohm will maintain 1% reading accuracy.

MANUAL CHANGES
Model 6024A DC Power Supply
Manual HP P/N 06024-90001

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

SERIAL		MAKE CHANGES
Prefix	Number	
All	---	Errata
2126A	00611-00660	1
2129A	00661-01390	1,2
2229A	01391-02290	1,2,3
2332A	02291-up	1,2,3,4

ERRATA:

In Table 1-1, under REMOTE PROGRAMMING, Accuracy specifications should be:
Resistance Programming
CV; 0.8% + 12 mV CC; 2.5% + 2mA
Voltage Programming
CV; 0.2% +2 mV CC; 1.0% +2mA
Current Programming
CV; 0.2% +0.36 V + accuracy of resistor CC; 1.0% + 0.15 A + accuracy of resistor

On Figure 5-3 and 5-4, the power supply - and -S terminals should be connected to the power supply frame ground terminal ( ).

Paragraph 5-44 step (a.) should be: Connect test setup shown in Figure 5-7. Set RL to minimum resistance initially. Paragraph 5-44 step (f.) should begin: Increase resistance of RL until DVM reads exactly 20 V (maximum rated power output Ensure that power supply remains in constant-current mode.

Paragraph 5-81 step (c.) should be: Adjust A2R65 less than +/-2mV on DVM. Paragraph 5-87 step (d.) should be: Adjust A2R91 for less than +/-0.2 mV on DVM (less than 2 mA through shunt). Paragraph 5-89 step e should be: Adjust A2R92 for 0.1 V +/-0.2 mV on DVM (10 A +/-20 mA output).

In Table A-1, under REMOTE PROGRAMMING, Accuracy specifications should be: CV; 0.8% + 30mV CC; 2.5% + 10mA.

In the replaceable parts list for A2 Control Board Assembly, add: C22, HP P/N 0140-0203, 30pF 5% 500 V MICA; R63, HP P/N 0683-1065, 10 M 5% .25 W F; R64, HP P/N 0698-5094, 5.1 M 5% .25 W F.

CHANGE 1:

In the replaceable parts list, page 6-8 Delete Support Spacers HP P/N 1390-0481 and Add NUT EXPANSION HP P/N 0590-1422.

CHANGE 2:

In the replaceable parts list, page 6-5 change C23 to 2.2 uF Polyester, HP P/N 0160-5377 and C28 to Fixed electrolytic 390 uF, 20 Vdc HP P/N 0180-3056.

CHANGE 3

On page 6-3 change Q1,2 to HP P/N 5080-2017.

Delete inductors L4,5 HP P/N 9140-0179 from the replaceable parts list and the schematic diagram. Replace L4,5 with R67, R68, 62 ohm, 1/8 W, HP P/N 0698-4132. R67,68 should have asterisks marked next to them when added to the parts list.

On page 6-4 change T3,4 to HP P/N 5080-2018. Also, T3, 4 should have asterisks marked next to them.