

6024A

AUTORANGING DC POWER SUPPLY



**HEWLETT
PACKARD**



**AUTORANGING
DC POWER SUPPLY
MODEL 6024A**

**OPERATING AND SERVICE MANUAL FOR
SERIALS 1912A-00101 AND ABOVE***

***For Serials above 1912A-00101
a change page may be included.**

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.

GROUND THE INSTRUMENT.

To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The instrument is equipped with a three-conductor ac power cable. The power cable must either be plugged into an approved three-contact electrical outlet or used with a three-contact to two-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet.

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE

Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

KEEP AWAY FROM LIVE CIRCUITS.

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance 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 floating voltages 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.

SAFETY SYMBOLS.



Caution symbol. Advises the operator to refer to the instruction manual for additional information.



Indicates terminal intended to be connected to system ground.

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.

DO NOT EXCEED INPUT RATINGS.

"This instrument is 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 3.5 mA."

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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 20 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 $\pm 15V$ 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).

<u>HP Part No.</u>	<u>Description</u>
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 combination 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).

<u>HP Part No.</u>	<u>Description</u>
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

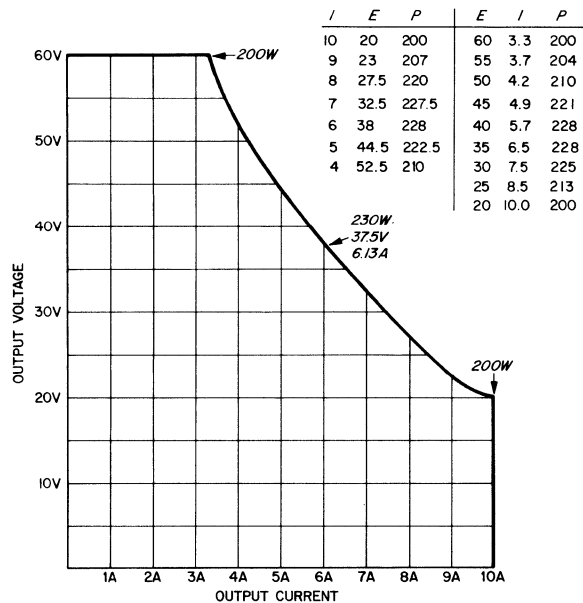
30 seconds after turn-off, 30A

@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:



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:

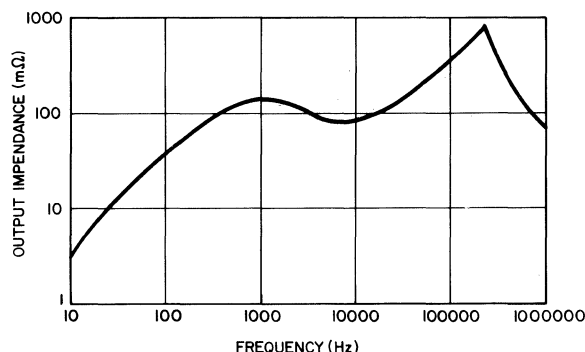
(Minimum output voltage or current change that can be obtained using the 10-turn front-panel controls)

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 $\pm 240\text{Vdc}$ (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 (18 Ω) 200ms

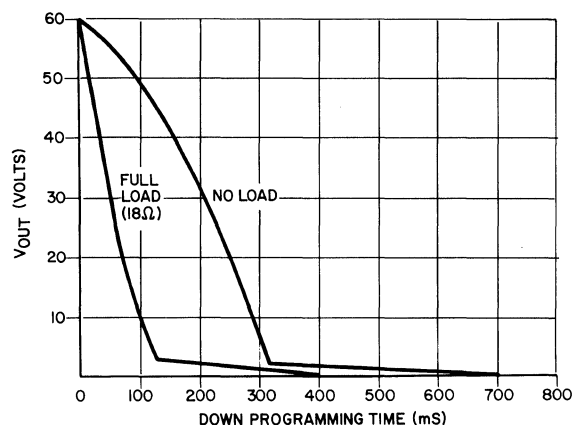
No Load 200ms

Down: Full Load (18 Ω) 300ms

No Load 600ms

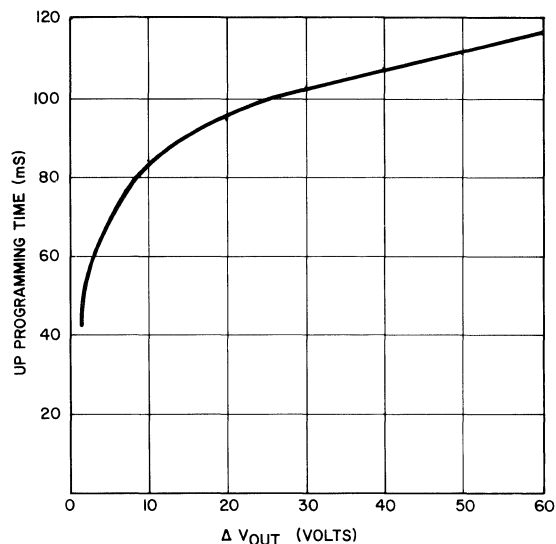
Typical response time, for excursions other than full-scale

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



Plus 125ms if final voltage $\geq 2\text{V}$
or 500ms if final voltage $< 2\text{V}$ 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)

<p>METERS AND INDICATORS:</p> <p><u>Voltmeter</u> - Continuously reading 70V scale with secondary scale indicating amperes available; accuracy, $\pm 3\%$ of full scale.</p> <p><u>Ammeter</u> - Continuously reading 12A scale with secondary scale indicating volts available; accuracy, $\pm 3\%$ of full scale</p> <p><u>VOLTAGE Indicator</u> - Green LED indicates Constant Voltage operation.</p> <p><u>CURRENT Indicator</u> - Green LED indicates Constant Current operation.</p> <p><u>OUTPUT UNREGULATED Indicator</u> - Red LED indicates that output is unregulated because of any of the following conditions: overrange operation, overvoltage, over temperature, or low-input-power shutdown.</p> <p><u>OVP Indicator</u> - Red LED indicates shutdown caused by voltage at output terminals exceeding preset limit.</p> <p>MULTIPLE UNIT OPERATION:</p> <p>Auto-Parallel - Up to eight units may be connected in parallel to increase total output current capability while maintaining control from a single unit.</p> <p>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.</p> <p>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.</p>	<p>TEMPERATURE RATINGS:</p> <p>Operating: 0 to $+55^{\circ}\text{C}$ Storage: -40 to $+75^{\circ}\text{C}$</p> <p>Unit is fan cooled. A thermostat turns off unit if temperature rises above a critical level; resets automatically.</p> <p>OPTIONS:</p> <p>Option 002 (System Interface) specifications are listed in Appendix A.</p> <p>CERTIFICATION:</p> <p>Unit complies with these requirements:</p> <p>IEC 348 - Safety Requirements for Electronic Measuring Apparatus.</p> <p>CSA Electrical Bulletin 556B - Electronic Instruments and Scientific Apparatus for Special Use and Applications.</p> <p>VDE 0871/6.78 Level A - RFI Suppression of Radio Frequency Equipment for Industrial, Scientific, and Medical (ISM) and Similar Purposes.</p> <p>VDE 0411 - Electronic Measuring Instruments and Automatic Controls.</p> <p>DIMENSIONS:</p> <p>See Figure 2-1.</p> <p>WEIGHT:</p> <p>Net: 5.4kg (12 lb) Shipping: 7.3kg (16 lb)</p>
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SECTION II INSTALLATION

2-1 INITIAL INSPECTION

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

2-3 Mechanical Check

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

2-5 Electrical Check

2-6 Section V of this manual contains complete verification procedures for this instrument. Section III contains an abbreviated check which can be used quickly to place the unit into operation. Refer to the inside front cover of the manual for 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 Sales and Service office to obtain the materials. This office will also furnish the address of the nearest service office to which the instrument can be shipped. Be sure to attach a tag to the instrument specifying the owner, model number, full serial number, and service required, or a brief description of the trouble.

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 $+55^{\circ}\text{C}$.

2-13 Outline Diagram

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

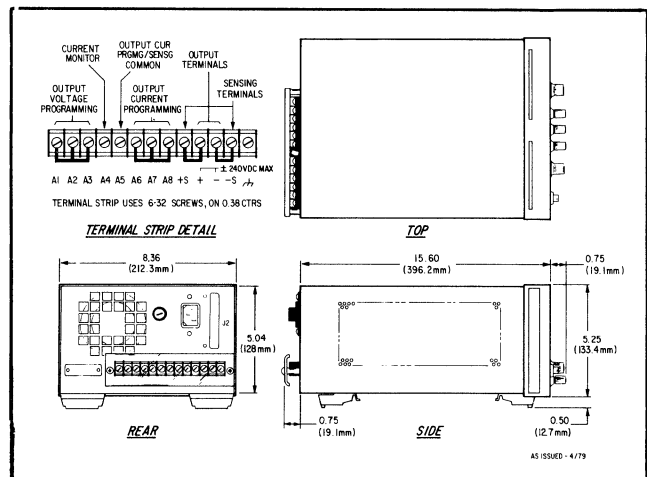


Figure 2-1. Outline Diagram

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) width module. All rack mounting accessories for this unit are listed in paragraph 1-16. Complete installation instructions are included with each rack mounting kit.

2-17 Input Power Requirements

2-18 This supply may be operated from a nominal 120V, 220V or 240V single-phase ac power source (48-63Hz). The input voltage range and input current required for each of the nominal inputs are listed below. The maximum input power (at high line, full load) required for any input is 320 watts. A label on the rear panel indicates the nominal line voltage for which the instrument was set at the factory. If necessary, the user can convert the instrument from one line voltage option to another by following the instructions in paragraph 2-23.

<u>Nominal Voltage</u>	<u>Line Voltage Range</u>	<u>Maximum Input Current</u>
120V	104-127	5.3A rms
220V	191-233	2.9A rms
240V	208-250	2.7A rms

2-19 Power Cable

2-20 Model 6024A is shipped from the factory with a power-cord plug appropriate for the user's location. Figure 2-2 illustrates the standard configuration of power-cord plugs used by Hewlett-Packard. Below each drawing is the HP Part Number for a replacement power cord equipped with a plug of that configuration. If a different power cord is required, contact the nearest Hewlett-Packard Sales and Service office.

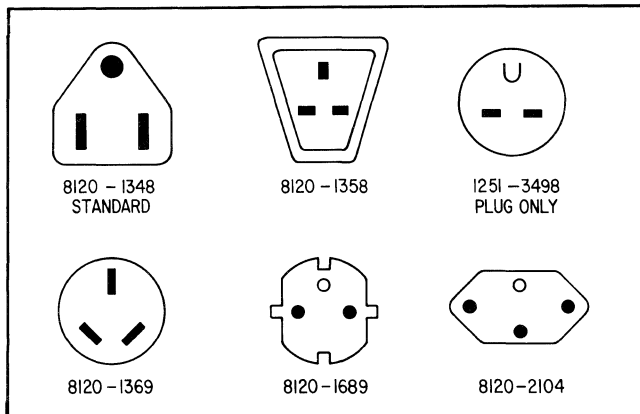


Figure 2-2. Power-Cord Plug Configurations

2-21 To protect operating personnel, the National 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. When the cable is plugged into an appropriate receptacle the instrument is grounded. In no event shall this instrument be operated without an adequate cabinet ground connection.

2-22 The offset pin on the standard power cable three-prong connector is the ground connection. To preserve the protection feature when operating the

instrument from a two-contact outlet, use a parallel-ground adapter (if permitted by local regulations) and connect the green lead on the adapter to ground.

2-23 LINE VOLTAGE OPTION CONVERSION

2-24 Line voltage conversion is accomplished by adjusting three components; the two-section line select switch S2, line-voltage jumper W1, and rear-panel line fuse F1. To convert the supply from one line voltage option to another, proceed as follows:

- Disconnect line cord from power source.
- Remove top cover from instrument by removing four screws from cover (two on each side) and sliding cover to the rear.
- The line voltage select switch is located on left side of main board (as viewed from front) near front of instrument (see Figure 2-3). Use a small-blade screwdriver to set the two switch sections to match the pattern silkscreened on main board as shown in Figure 2-3. For example, to set switches for 120V operation (as illustrated), move forward switch section so that its white slot is toward front of instrument and move rearward switch section so its white slot is toward rear of instrument.
- The line voltage jumper W1 is located on main board near center rear (see Figure 2-4). (A dashed line is silkscreened on main board from vicinity of S2 to W1). Jumper must be soldered in place for 120V operation, and *must be removed for 220V or 240V operation*.
- Check rating of fuse F1 installed in rear-panel fuseholder and replace with correct value if necessary. Do not use slow-blow fuses. For 120V operation, use 6A fuse, HP Part Number 2110-0056. For 220V or 240V operation, use 4A fuse, HP Part Number 2110-0055. Fuse F2 on main board should be 0.5A, HP Part Number 2110-0202, for all input voltages.
- Replace covers and mark the supply clearly with a tag or label indicating correct line voltage to be used.

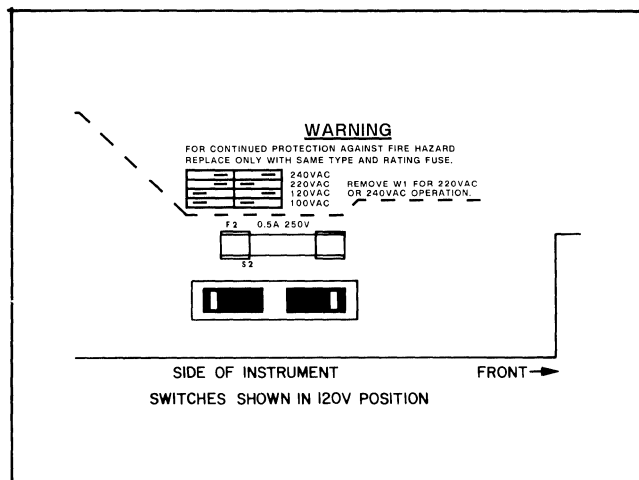


Figure 2-3. Line Voltage Select Switch

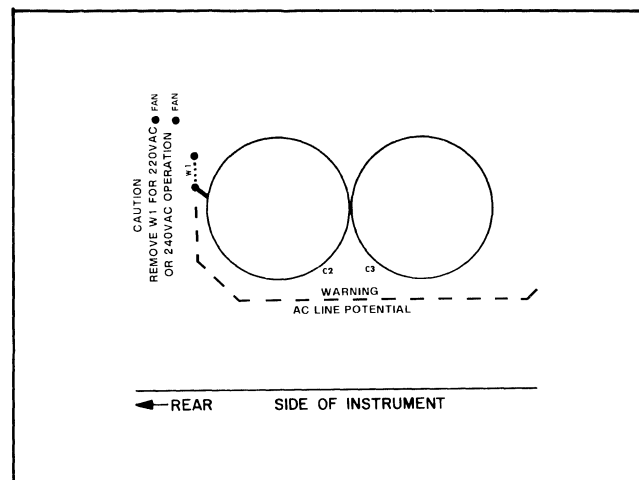


Figure 2-4. Location of Jumper W1

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 voltmeter (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) counter-clockwise 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.

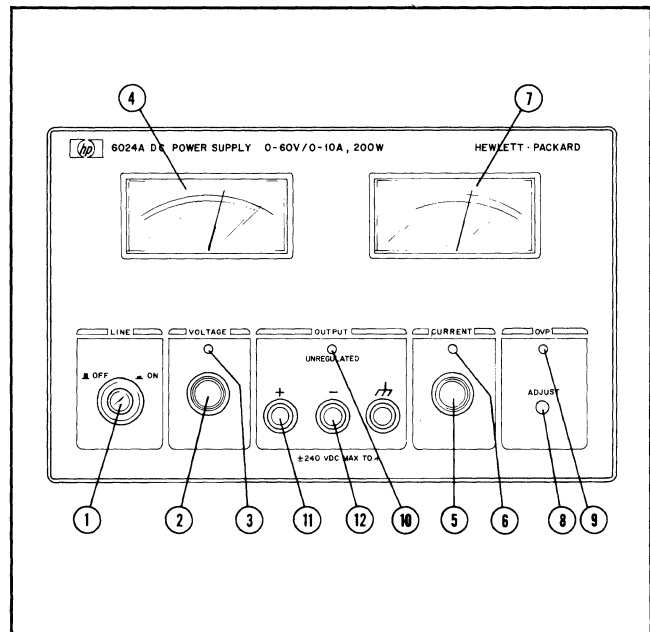


Figure 3-1. Front Panel Controls and Indicators

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.

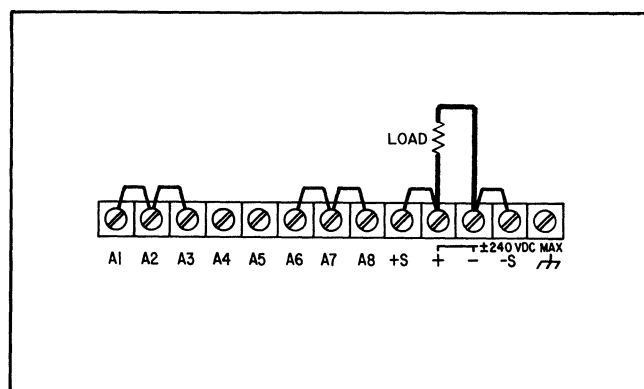


Figure 3-2. Normal Strapping

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.

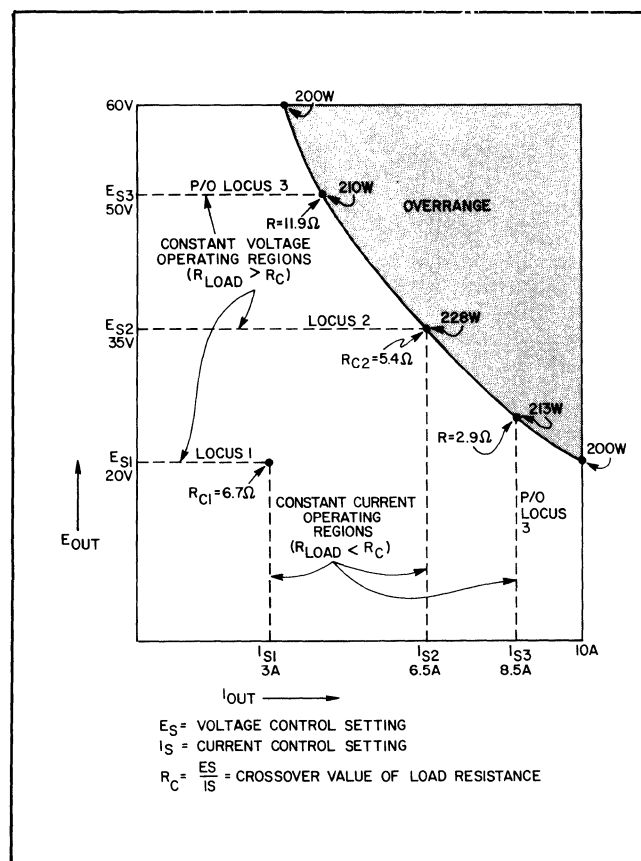


Figure 3-3. Overall Output Range with Three Sample Operating Loci

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 over-heat 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.

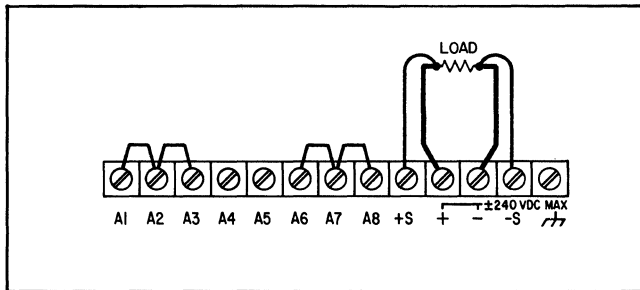


Figure 3-4. Remote Sensing

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 accomplished 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.

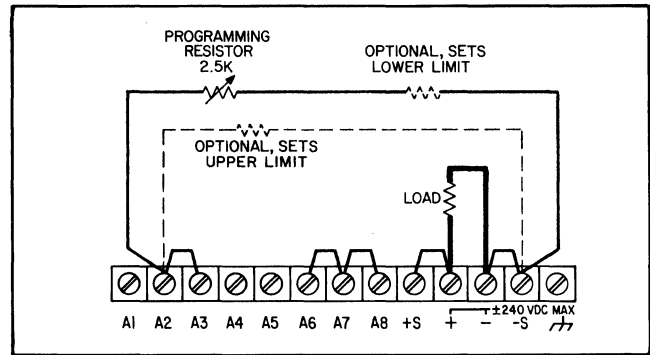


Figure 3-5. Resistance Programming of Output Voltage

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.

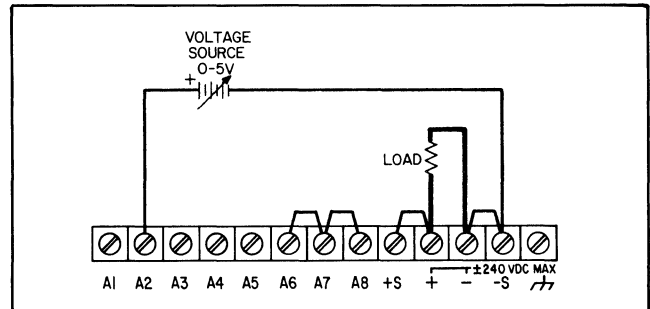


Figure 3-6. Voltage Programming of Output Voltage

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.

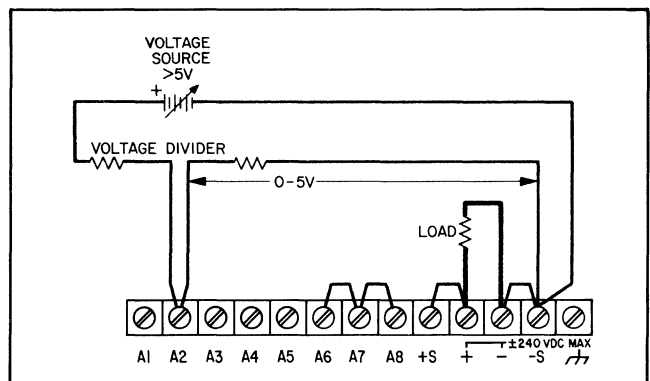


Figure 3-7. Scaled Voltage Programming of Output Voltage

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

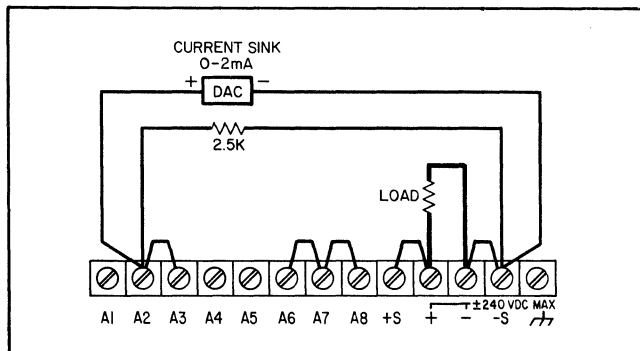


Figure 3-8. Current Programming of Output Voltage

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.

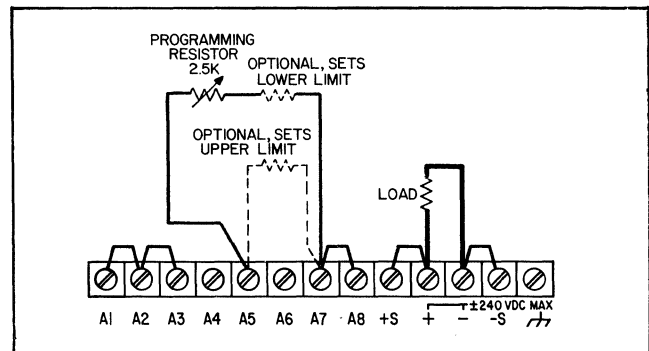


Figure 3-9. Resistance Programming of Output Current

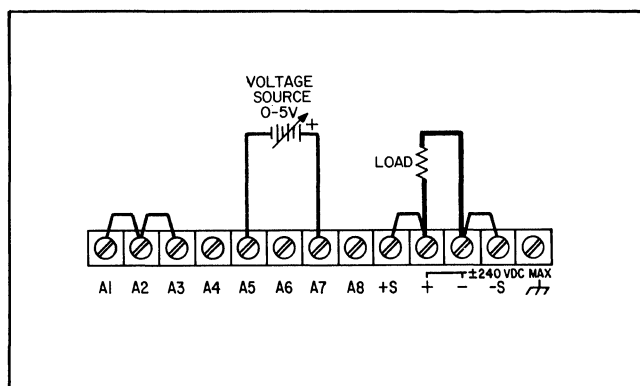


Figure 3-10. Voltage Programming of Output Current

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.

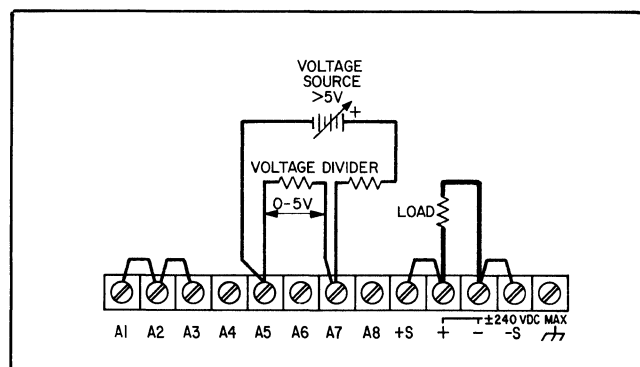


Figure 3-11. Scaled Voltage Programming of Output Current

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.

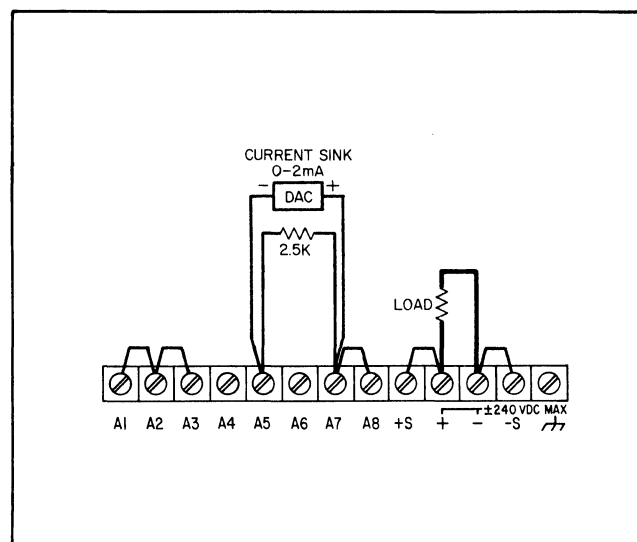


Figure 3-12. Current Programming of Output Current

3-56 Auto-Parallel Operation

3-57 Figure 3-13 shows the rear panel interconnections 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.

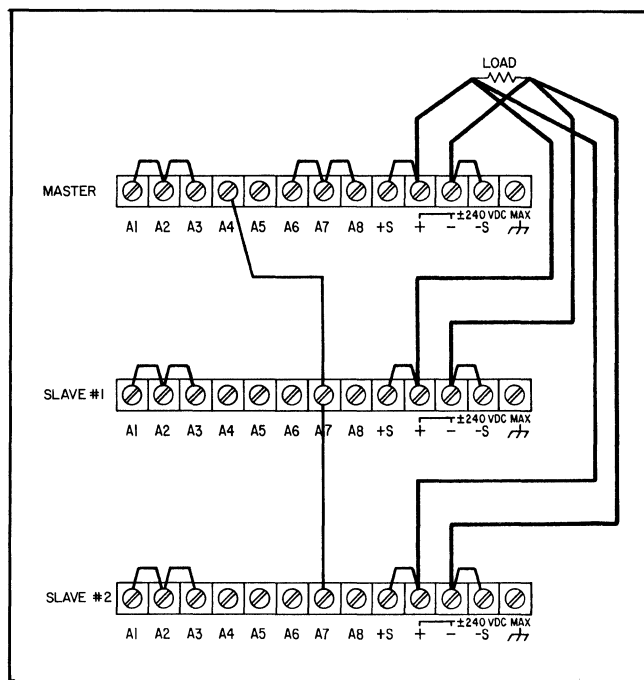


Figure 3-13. Auto-Parallel Operation

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

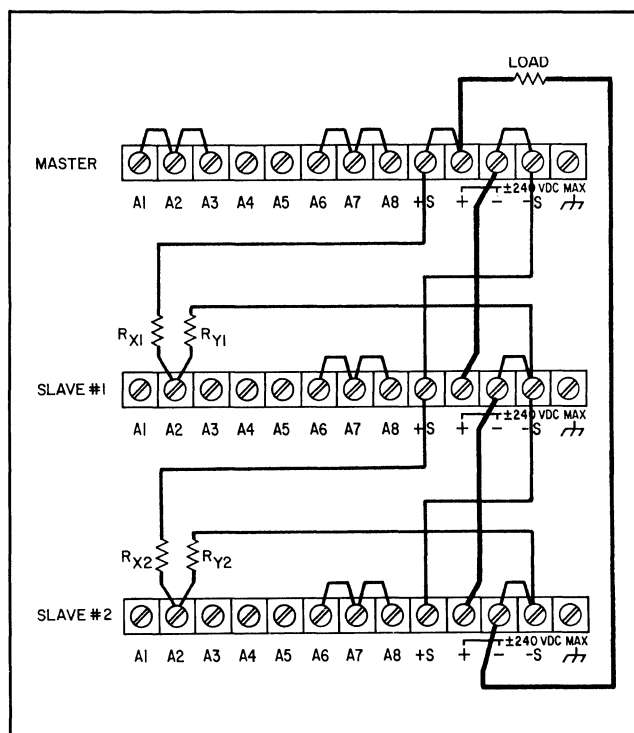


Figure 3-14. Auto-Series Operation

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.

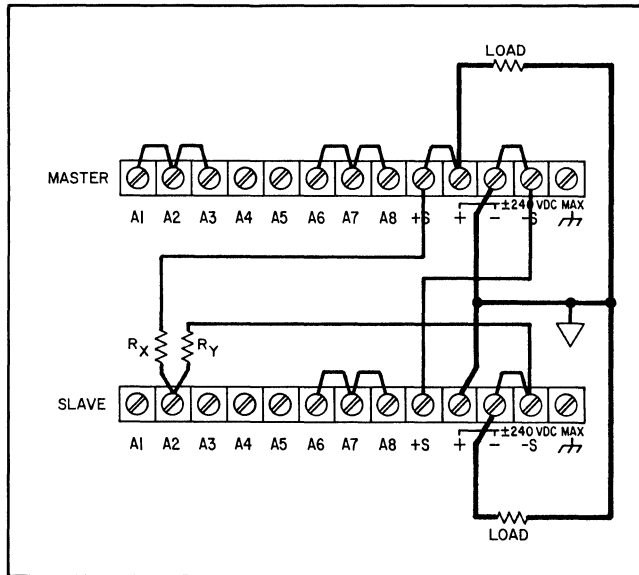


Figure 3-15. Auto-Series Operation, Positive and Negative Outputs

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 ($\frac{V_M}{V_S}$), select a value for R_Y , and then determine the value for R_X by solving this equation: $R_X = 12 (R_Y) (1 + \frac{V_M}{V_S}) - R_Y$. 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:

$$\begin{aligned} R_X &= 12 (1000) (1 + \frac{50}{40}) - 1000 \\ R_X &= 12,000 (2.25) - 1000 \\ R_X &= 26,000 \end{aligned}$$

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.

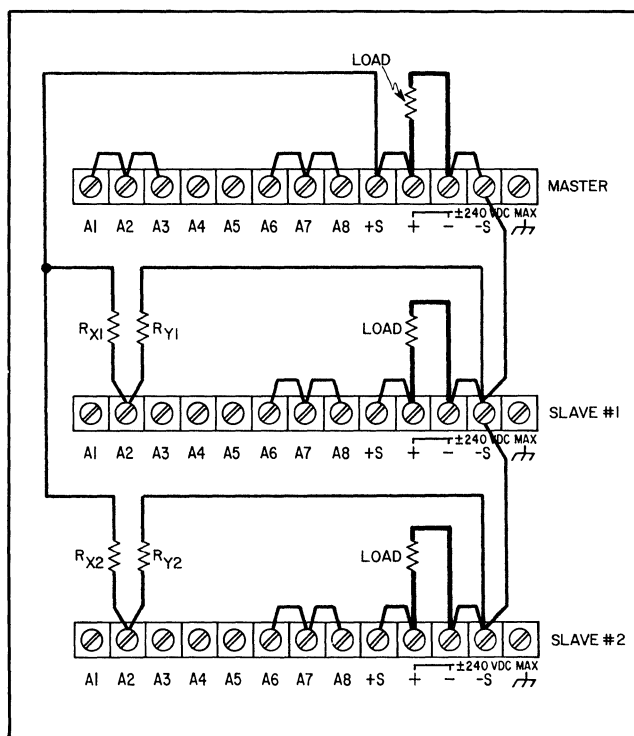


Figure 3-16. Auto-Tracking Operation

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.

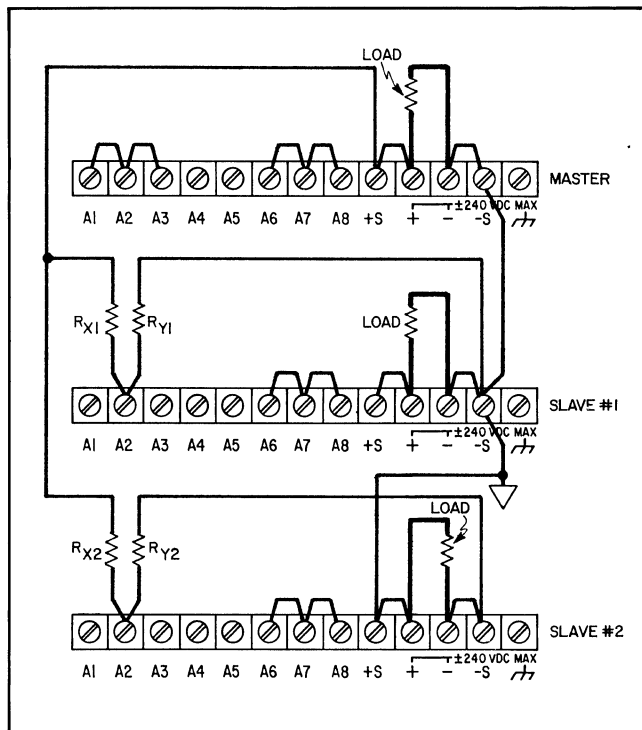


Figure 3-17. Auto-Tracking Operation, Positive and Negative Outputs

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:

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

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:

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

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.

SECTION IV PRINCIPLES OF OPERATION

4-1 DIFFERENCE BETWEEN AN AUTORANGING POWER SUPPLY AND A CONVEN- TIONAL POWER SUPPLY

4-2 The basic difference between an autoranging power supply and conventional types of Constant Voltage/Constant Current (CV/CC) power supplies can be seen by comparing the output characteristics of each. A conventional CV/CC power supply can provide maximum output power at only one combination of output voltage and current, as shown in Figure 4-1A. The range of a power supply can be extended by designing an instrument with two or more switch-selectable voltage/current ranges within the maximum power output capability, as shown in Figure 4-1B. The 6024A autoranging power supply provides maximum output power over a wide and continuous range of voltage and current combinations, as shown in Figure 4-1C, without the operator having to select the proper output range.

4-3 SIMPLIFIED SCHEMATIC DESCRIPTION

4-4 The basic operating concepts of the 6024A are shown on the simplified schematic, Figure 4-2, and described in the following paragraphs. Detailed descrip-

tions are provided only for those individual circuits and components whose operation may not be obvious to the user. The circuit names and layout of the simplified schematic are the same as used on the complete schematic in Section VII; however, some items, such as the LED and meter circuits, are left off the simplified schematic for clarity. The heavy lines represent the input rails and output rails.

4-5 The 6024A is a flyback-type switching power supply, so-called from the flyback technique of generating high voltage in television receivers. In the 6024A, energy is stored in the magnetic field surrounding a transformer while current flows in the primary, and is transferred to the secondary circuit when current flow in the primary is turned off. Current flow in the primary is controlled by a pair of FET switches which are turned on and off at a 20 kHz rate by a pulse width modulator. Regulation is accomplished by controlling the on time of the FET switches. On pulses are generated by a clock circuit. Off pulses are generated when current flow in the primary has stored enough energy for the output circuit, which is determined as follows.

4-6 The output voltage and current are compared to reference voltages set by front panel controls to produce a control voltage. The control voltage indicates the

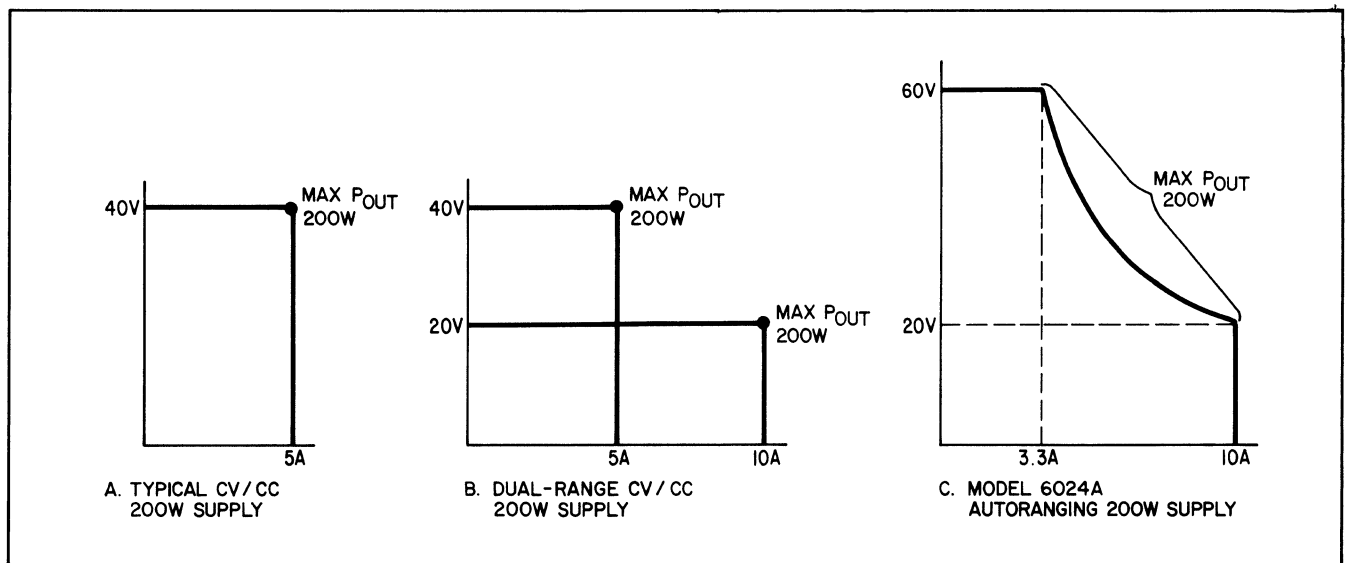


Figure 4-1. Output Characteristics; Typical, Dual-Range, and Auto-Ranging Supplies

Figure 4-2. Simplified Schematic

amount of power required by the output circuit. Current flow in the primary circuit produces a ramp voltage that represents the amount of energy being stored for transfer to the output circuit. An off pulse is generated when the ramp voltage exceeds the control voltage.

4-7 Input AC Circuits

4-8 Primary power is connected to the input rectifier and input filter. Jumper W1 is used only for 100V or 120V operation to connect the input filter as a voltage doubler, so that for any nominal input voltage the input filter charges to approximately 300 volts dc. Thermal resistors RT1 and RT2 have high resistance when cold to limit inrush current when the instrument is first turned on and capacitors in the input filter charge up. When the instrument is turned off, the input filter capacitors discharge slowly and the thermistors cool off. Therefore, if the instrument is turned on again within 30 to 60 seconds of being turned off, inrush current is limited by the combined effects of the remaining charge and thermistor resistance.

4-9 Primary power is also connected through line voltage select switches to the bias power supply circuits. These circuits provide the operating voltages used by the 6024A. The line voltage select switches configure the primary windings of the bias power supply transformer for operation from either a 120V, 220V or 240V line.

4-10 DC TO DC Converter

4-11 Current flow from the input rails through power transformer T1 is controlled by FET switches Q1 and Q2. On and off signals for the FETs are derived from the Pulse Width Modulator, as will be described shortly. The on pulses are applied through diodes CR12 and CR11 to the gates of Q1 and Q2. Although the on pulse is only about 1.5 usec duration, the FETs' input capacitance holds the FETs on after the on pulse has disappeared.

4-12 When the FETs are turned on, current flows through the primaries of power transformer T1 and primary-current monitor transformer T2. The output rectifier CR13 is reverse biased and blocks current flow in the T1 secondary. Consequently, energy is stored in the field that builds around the T1 transformer windings. The longer that voltage is applied to the primary, the more energy is stored. Current flow in the secondary of T2 develops the I_p Ramp voltage across resistor A2R118. The amplitude of this linearly increasing voltage corresponds to the amount of current flow through the T1 primary; therefore, it represents the amount of energy being stored in the field around T1.

It is this I_p Ramp voltage that is compared to a control voltage to determine when the FETs should be turned off.

4-13 When the FETs are turned off, the collapsing magnetic field reverses the polarity across the T1 primary and secondary, and current flows from T1 secondary through output rectifier CR13 to charge output capacitors C16, C17, and C18. The level to which the output capacitors are charged corresponds to the length of time that the FETs are on and current flows in T1 primary. When the FETs turn off, the leakage inductance of T1 develops a small amount of reverse current flow in the primary circuit. Flyback diodes CR5 and CR6 protect the FETs by conducting this current around the FETs and back to the input filter.

4-14 It can be seen that the power available in the output circuit corresponds to the duty cycle of the FET switches. The following paragraphs describe the method by which output voltage and current are sensed to control the FET duty cycle.

4-15 Constant Voltage (CV) Circuit

4-16 The Constant Voltage (CV) Circuit compares a percentage of the output voltage to the CV Programming Voltage set by the VOLTAGE control. Any difference is amplified to establish a control voltage.

4-17 Current from the Constant Current Source flows through VOLTAGE control R1 to develop the CV Programming Voltage at terminal A2. The level of this programming voltage is dependent on the setting of R1. Amplifier A2U13 compares a fraction of the 6024A output voltage at the + Sense terminal to the programming voltage at A2. The output of A2U13 is applied to a second comparison amplifier, A2U14A. This amplifier compares the output of A2U13 to a fraction of the Inboard + Out, which is the + output voltage sensed at the inboard side of the output filter. Use of two comparison amplifier loops provides increased stability for load variations.

4-18 In normal CV mode, the output of A2U14A varies between ≈ -0.5 volts and $\approx +1.0$ volts. It is at its most negative when the load is drawing little or no power from the instrument. Progressively more-positive voltages from A2U14A correspond to increased power demand by the load. The output from the CV Circuit is applied to diode A2CR18.

4-19 Constant Current (CC) Circuit

4-20 Operation of the Constant Current (CC) Circuit

is similar to the CV Circuit. Output current from the 6024A develops a voltage across the current-monitor resistance (R_M) consisting of R28 and R29. This voltage is amplified and buffered by the I-Monitor Amplifier to isolate the output from currents in the CC Circuit. In normal CC mode, the output from the CC Circuit also varies between ≈ -0.5 volts and $\approx +1.0$ volts, and is applied to diode A2CR19.

4-21 Control Voltage

4-22 The outputs of the CV and CC Circuits are applied to diodes that connect to a wired-OR junction. Whichever circuit is requesting less power will forward bias its output diode and determine the voltage at the wired-OR junction. As stated earlier, the outputs vary between -0.5 volts and $+1.0$ volts, with the more negative levels representing lower power demands. The wired-OR junction at the anodes of A2CR18 and A2CR19 is biased to $+1.5$ volts. Therefore, whichever circuit, CV or CC, produces the more negative output will cause its output diode to be forward biased and thereby determine the Control Voltage. This Control Voltage is compared to the I_P Ramp Voltage to determine when the FET switches are turned off.

4-23 For example, assume the output from the CV Circuit (A2U14A) is $+0.2$ volts and the output from the CC Circuit (A2U14C) is $+0.8$ volts. A2CR18 will be forward biased and the wired-OR junction will be held at $+0.8$ volts (includes the 0.6 volt drop across A2CR18). A2CR19 will be reverse biased, so the CC Circuit will have no effect.

4-24 Pulse Width Modulator

4-25 The FET Switches are turned on and off at a 20 KHz rate by signals derived from the Pulse Width Modulator (PWM). On pulses are initiated by the 20 kHz clock signal. Off pulses are initiated when the I_P Ramp Voltage (which indicates the amount of energy being stored for transfer to the output circuit) exceeds the Control Voltage (which indicates the amount of power required by the output circuit). Figure 4-3 is a timing diagram showing the relationship of various signals that control the FET switches.

4-26 The more negative level of the 20 kHz A2U5 output resets both flip flops A2U9A and A2U9B and

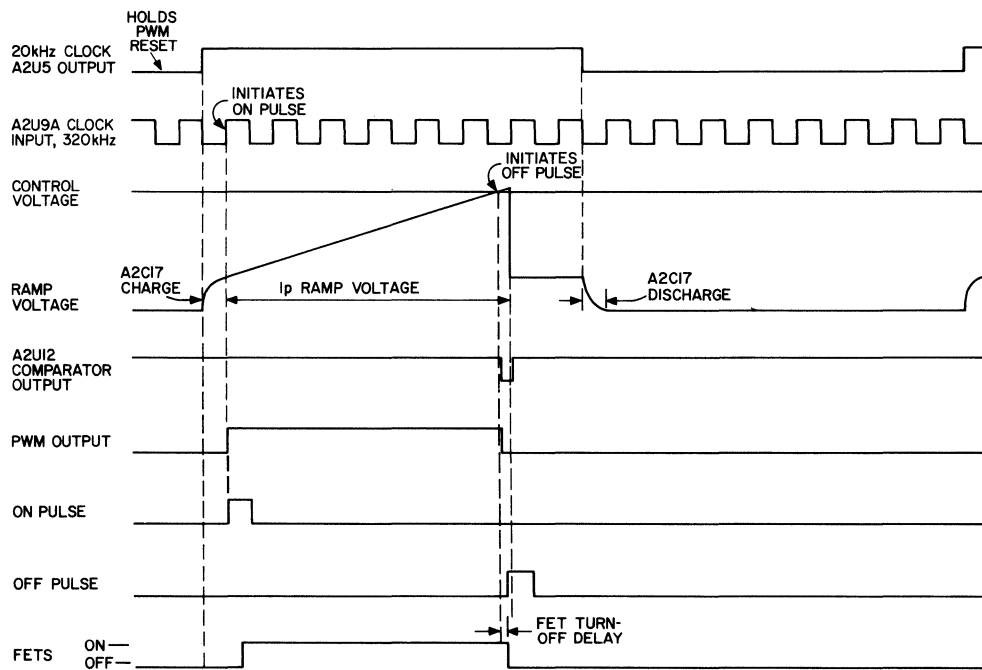


Figure 4-3. FET Control Signals Timing Diagram

holds them reset until the A2U5 output goes positive. Then, the next positive edge from the output of the 320 kHz oscillator triggers A2U9A, triggering A2U9B and one-shot multivibrator A2U10A. The FET switches are turned on, current flows through transformer T2, and I_P Ramp Voltage starts to rise. When I_P Ramp Voltage exceeds the Control Voltage, the output of A2U12 changes state and flip flop A2U9B is reset, triggering one-shot multivibrator A2U10B to produce an off pulse.

4-27 PWM Fast Turn Off

4-28 Figure 4-3 shows that there is a delay between the time when the Control Voltage is exceeded at A2U12 and the time when the FETs turn off. This delay consists of the comparator switching time, gate delays, transformer delay, and FET turn-off time, and it results in a certain amount of power being transferred to the output after the desired off time. If the Control Voltage is at a very low level (unit supplying little or no output power), this power may exceed the amount required by the load. To offset this, the PWM is designed to reduce the minimum on-time of the FETs if necessary to reduce the power transferred to the output circuit. When the 20 kHz clock goes high (allowing the PWM to be triggered by the next 320 kHz signal), A2C17 charges rapidly and exponentially to a low level. If this level exceeds the Control Voltage, the PWM initiates an off pulse, turning off the FETs immediately after they have turned on. Although the charge on A2C17 can exceed the Control Voltage and change the output state of comparator A2U12 even before the FET switches have turned on, circuit delays of the off pulse are such that the FET switches will be turned on each cycle (assuming the PWM is not inhibited by other circuits).

4-29 Primary Current (I_P) Limit

4-30 I_P Ramp Voltage is also compared to a preset I_P Limit at comparison amplifier A2U4B. I_P Limit is a factory-set adjustment that limits the total power output of the instrument. Ordinarily, the PWM generates an off pulse when I_P Ramp exceeds the Control Voltage at A2U12, and I_P Ramp never reaches I_P Limit at A2U4B. However, if the Control Voltage is excessively high (both VOLTAGE and CURRENT controls set to relatively high values), I_P Ramp will exceed I_P Limit. The output of A2U4B changes state, initiating an off pulse.

4-31 As an additional protection feature, if nothing else resets flip flop A2U9B (such as the control circuit, over temperature, dropout, or overvoltage), it will be reset by the next negative level from A2U5, triggering A2U10B to generate an off pulse. Therefore, maximum duty cycle is always less than 50%.

4-32 Bleed Circuit

4-33 This circuit enables the 6024A to regulate properly even at very low output current and/or voltage levels. The circuit conducts approximately 25 milliamperes from the + output line to the -8V supply, thereby ensuring that the FET switches will be turned on each cycle even if the load is drawing little or no power. As the output voltage is increased, R31 becomes the predominate path for bleed current.

4-34 Down Programmer

4-35 This circuit allows the output voltage to be lowered rapidly when required. In order to lower the output voltage it is necessary to discharge the output filter capacitors (typically, through the load). In situations that require the output voltage to drop more rapidly than can be accomplished through the load, the Down Programmer pulls the output line to a low level and discharges the capacitors. This action can be triggered by one of three conditions: The CV Circuit programs a lower output voltage, an overvoltage is detected on the output, or primary power dropout is detected.

4-36 A long-carryover bias supply associated with the Down Programmer stores enough energy to operate the Down Programmer after loss of primary power. This ensures that the Down Programmer will be able to discharge the output circuit completely when primary power is turned off.

4-37 The Down Programmer is disabled by U1A approximately seven seconds after being triggered. This prevents the circuit from trying to sink current continuously from a parallel-connected power supply.

4-38 Overvoltage Protection Circuit

4-39 The Overvoltage Protection Circuit monitors the output voltage across the + Out line and circuit common (- Out Line). If the output voltage exceeds a preset limit, set by the front-panel OVP ADJUST potentiometer, the Overvoltage Protection Circuit inhibits the PWM, triggers the Down Programmer and latches itself until the instrument is turned off.

4-40 The Overvoltage Protection Circuit operates from the long-carryover bias supply associated with the Down Programmer. By ensuring that the bias voltage remains high until after the + Out reaches zero volts when the instrument is turned off, this feature prevents the Overvoltage Protection Circuit from latching if the unit is turned back on again immediately after turn-off.

4-41 AC Dropout Detector

4-42 The AC Dropout Detector operates to shut down the instrument when primary power is turned off or lost. It inhibits the PWM so that the FETs cannot be turned on inadvertently while the control circuits may be dropping out, and it ensures that the output circuit is completely discharged. Power dropout is detected by a ramp circuit that is reset by the rectified ac pulses in the unregulated +5V. If the ramp is not reset within approximately 20 milliseconds of the previous reset, the AC Dropout Detector inhibits the PWM and triggers the Down-Programmer.

4-43 Bias Voltage Detector

4-44 The Bias Voltage Detector inhibits both the PWM and On Driver when the instrument is turned on until the internal +5V supply stabilizes, thus ensuring that the FET switches cannot turn on before the control circuits are able to operate. When the instrument is turned on, the outputs of the bias power supplies begin to rise from 0 volts. When

the output of the +5V Regulated supply reaches approximately 1 volt, transistors in the Bias Voltage Detector turn on and inhibit the PWM and the On Driver. The inhibit signals remain on until the output of the +5V Unregulated supply exceeds approximately +9 volts, at which point the +5V Regulated supply is certain to be stabilized.

4-45 The Bias Voltage Detector also inhibits the PWM and On Driver in "brownout" conditions if the ac line voltage falls below approximately 70% of nominal.

4-46 Over Temperature Detector

4-47 Thermostat TS1 is mounted on the FET heatsink in the fan airflow. If the FET case temperature rises excessively (from high external air temperature and/or internally generated heat) TS1 opens and inhibits the PWM until the temperature drops. The cooling fan continues to operate.

SECTION V MAINTENANCE

5-1 INTRODUCTION

5-2 Upon receipt of the power supply, the performance test (Paragraph 5-5) can be made. This test is suitable for incoming inspection. If a fault is detected in the power supply while making the performance test or during normal operation, proceed to the troubleshooting procedures. After troubleshooting and repair (Paragraph 5-47) perform any necessary adjustments and

calibration (Paragraph 5-74). Before returning the power supply to normal operation, repeat the applicable portions of the performance test to ensure that the fault has been properly corrected and that no other faults exist.

5-3 TEST EQUIPMENT REQUIRED

5-4 Table 5-1 lists the test equipment required to perform the various procedures described in this section.

Table 5-1. Test Equipment Required

TYPE	REQUIRED CHARACTERISTICS	USE	RECOMMENDED MODEL
Digital Voltmeter	Sensitivity: 100 μ V full scale (min) Input impedance: 10M Ω (min)	Measure dc voltages, troubleshooting and calibration procedures	HP 3455
Oscilloscope	Sensitivity: 1mV Band width: 20MHz	Troubleshooting, measure ripple and noise spikes	HP 1740A
Isolation Transformer		Troubleshooting	
RMS Voltmeter	True RMS, 10 MHz bandwidth, 1mV sensitivity	Measure ripple	HP 3400A
Variable Voltage Autotransformer	Voltage range: see paragraph 2-18 Output current: 200% (min) of input current listed in paragraph 2-18	Vary ac input for line regulation measurement	
Multimeter	Sensitivity: 1 μ V Accuracy: 0.02%, 5½ digit	Measure ac and dc voltages, resistance	HP 3455A
Resistive Load	Values: see figures 5-2, 5-3, 5-4, 5-5 and 5-6. Tolerance: 5%	Power supply load resistor (rheostat or fixed resistors)	James G. Biddle non-inductive rheostat 411KN56T
Current-Monitoring Resistor	Value: 100mV @ 10A (10m Ω) Accuracy: 1% minimum	Measure output current, calibration	Weston Instrument Shunt, Model 9992, Cat.# 42210, 100mV @ 10A
Terminating Resistors	Value: 50 Ω ±5%, non-inductive (four required)	Noise spike measurement	— — —
Blocking Capacitors	Value: 0.01 μ F, 100Vdc (two required)	Noise spike measurement	— — —
Switch	SPST, 10A capacity @ 60V	Load effect tests	— — —

5-5 PERFORMANCE TEST

5-6 The following test can be used as an incoming inspection check and appropriate portions of the test can be repeated to check the operation of the instrument after repairs. The tests are performed using the specified nominal input voltage for the unit. If the correct result is not obtained for a particular check, proceed to troubleshooting (Paragraph 5-47).

5-7 Measurement Techniques

5-8 All specifications should be measured at the rear terminals of the power supply. Also, all tests are performed with the supply strapped for local programming and sensing, as shown in Figure 3-2. The wires used to connect the load to the supply should be heavy enough to ensure that they will drop less than 0.5V. If the supply is equipped with System Interface Option 002, remove the Interface Option cable from the rear panel connector and check out the power supply first. Then proceed to the checkout procedure in Appendix A to test the Option 002 components.

5-9 **Selecting A Load Resistor.** Specifications are checked with varying amounts of load resistance connected across the supply. For most of the constant-voltage tests, the value of load resistance must be 2Ω to permit operation of the supply at 20V and its maximum-output-power-rating current of 10A. For the constant-current tests, the load resistance must be approximately 18Ω to permit operation at 3.3A and its maximum-output-power-rating voltage of 60V. The power rating of the load resistance must be at least equal to the maximum output power of the supply: 230 watts.

5-10 Either fixed or variable (rheostat type) load resistors can be used. However, a rheostat is very convenient when changing values and for accurately setting the output current of the supply. Table 5-1 lists a rheostat that is adequate for this supply. For clarity, illustrations in this section show the rheostat as a single resistor, although the recommended unit is a twin resistor model to provide adequate current capacity. If fixed resistors are used, their tolerance must be accounted for when evaluating the test results.

5-11 Connecting A Current-Monitoring Resistor.

To allow precise measurement of output current, a current-monitoring resistor is inserted between the output of the power supply and the load resistance. This resistor must be connected as a four-terminal device in the same manner as a meter shunt would be (see Figure 5-1). The load current is fed to the extremes of the wire leading to the resistor, while the monitoring

terminals are located as close as possible to the resistance element itself. A current-monitoring resistor should have low noise, a low temperature coefficient (less than $30 \text{ ppm}/^\circ\text{C}$), and should be used at no more than 5% of its rated power so that its temperature rise will be minimized.

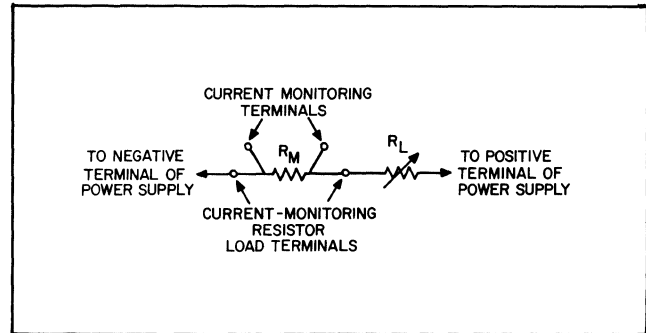


Figure 5-1. Current-Monitoring Resistor Terminals

5-12 Constant Voltage Tests

5-13 Connect all of the measuring devices used in the constant-voltage performance tests directly to the power supply sensing terminals (+S, -S). For best accuracy, the sensing terminals must be used rather than the output terminals, since the measuring instruments must be connected to the same pair of terminals to which the feedback amplifier within the power supply is connected. This is particularly important when measuring the regulation or ripple of the power supply. A measurement made across the load includes the impedance of the leads to the load, and such lead lengths can easily have an impedance several orders of magnitude greater than the supply impedance (typically $<1 \text{ milliohm}$ at dc), thus invalidating the measurement.

5-14 To avoid mutual coupling effects, connect each monitoring device to the sensing terminals by a separate pair of leads. Use twisted pairs or shielded two-wire cables to avoid pickup on the measuring leads. Connect the load resistor across the output terminals as close to the supply as possible. When measuring the constant-voltage performance specifications the current control should be set at least 2% above the output current the load will draw, since the onset of constant-current operation could cause a drop in output voltage, increased ripple and other performance changes not properly ascribed to the constant-voltage operation of the supply.

5-15 Rated Voltage And Voltmeter Accuracy.

To check that the supply will furnish its rated output voltage, proceed as follows:

- Connect test setup shown in Figure 5-2. Set R_L to maximum resistance initially.

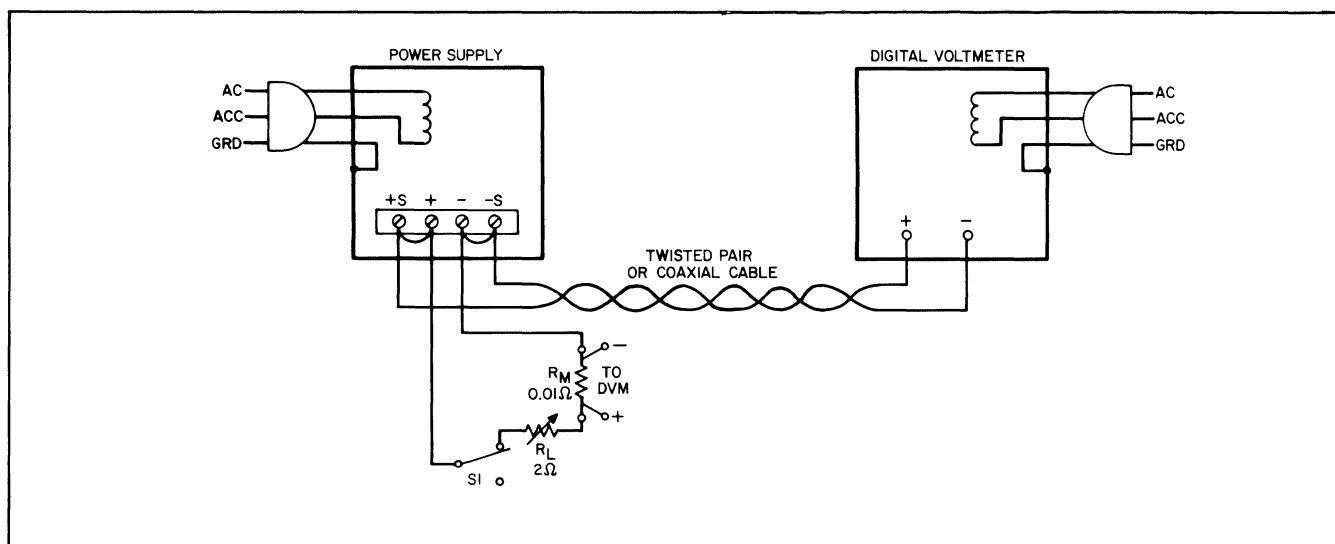


Figure 5-2. Constant-Voltage Test Setup

- b. Turn CURRENT control fully clockwise.
- c. Turn on supply and adjust VOLTAGE control until digital voltmeter (DVM) indicates exactly 60V (maximum rated output voltage).
- d. Front-panel voltmeter should indicate $60V \pm 3\%$.
- e. Disconnect DVM from power supply sense terminals and connect DVM across current-monitoring resistor (R_M).
- f. Reduce resistance of R_L until DVM reads 33mV, indicating that current output is exactly 3.3A (maximum rated power output). Ensure that power supply remains in constant-voltage mode.
- g. Disconnect DVM from R_M and reconnect DVM to power supply sense terminals.
- h. DVM and front-panel voltmeter should both indicate 60V.

5-16 Load Effect (Load Regulation).

Definition: The change in the static value of dc output voltage (ΔE_{OUT}) resulting from a change in load resistance from open circuit to a value which yields maximum rated output current, or from the latter value to open circuit.

5-17 To check the constant-voltage load effect, proceed as follows:

- a. Connect test setup shown in Figure 5-2.
- b. Turn CURRENT control fully clockwise.
- c. Turn on supply and adjust VOLTAGE control until DVM indicates 20V.
- d. Disconnect DVM from power supply sense terminals and connect DVM across R_M .
- e. Adjust resistance of R_L until DVM reads 0.1V, indicating that current output is exactly 10A

(maximum rated output current). Ensure that power supply remains in constant-voltage mode.

- f. Disconnect DVM from R_M and reconnect DVM to power supply sense terminals.
- g. Open switch S1 to disconnect load.
- h. Record voltage indicated on DVM.
- i. Close switch S1 to reconnect load.
- j. Wait a few seconds only to allow DVM to settle. Reading on DVM should not differ from reading of step h by more than 5mV.

5-18 Source Effect (Line Regulation).

Definition: The change in the static value of dc output voltage (ΔE_{OUT}) resulting from a change in ac input voltage over the specified range from low line to high line, or from high line to low line.

5-19 To check the source effect, proceed as follows:

- a. Connect test setup shown in Figure 5-2.
- b. Connect variable autotransformer between input power source and power supply ac power input.
- c. Adjust autotransformer for low line voltage (Paragraph 2-18).
- d. Turn CURRENT control fully clockwise.
- e. Turn on power supply and adjust VOLTAGE control until DVM indicates exactly 60V.
- f. Disconnect DVM from power supply sense terminals and connect DVM across R_M .
- g. Adjust resistance of R_L until DVM reads 33mV, indicating that current output is exactly 3.3A. Ensure that power supply remains in constant-voltage mode.
- h. Disconnect DVM from R_M and reconnect DVM to power supply sense terminals.

- i. Record voltage indicated on DVM.
- j. Adjust autotransformer for high line voltage.
- k. Reading on DVM should not differ from reading of step i by more than 8mV.

5-20 Part (Ripple and Noise).

Definition: The residual ac voltage superimposed on the dc output of a regulated power supply. Ripple and noise measurements may be made at any input ac line voltage combined with any dc output voltage and current within the supply's rating.

5-21 The amount of ripple and noise present on the power supply output is measured either in terms of its rms or (preferably) peak-to-peak value. The peak-to-peak measurement is particularly important for applications where noise spikes could be detrimental to sensitive loads

such as logic circuitry. The rms measurement is not an ideal representation of the noise, because fairly high output noise spikes of short duration can be present in the ripple without appreciably increasing the rms value.

5-22 **Ripple Measurement Techniques.** Figure 5-3A shows a method of measuring ripple using a single-ended true-reading RMS voltmeter or oscilloscope. The power supply output terminals should not be connected to ground at the power supply terminal strip to prevent current from flowing through a ground loop and adding to the measured signal. Also, to ensure that no potential difference exists between the supply and the RMS voltmeter, it is recommended that they both be plugged into the same ac power bus. If the same bus cannot be used, both ac grounds must be at earth ground potential.

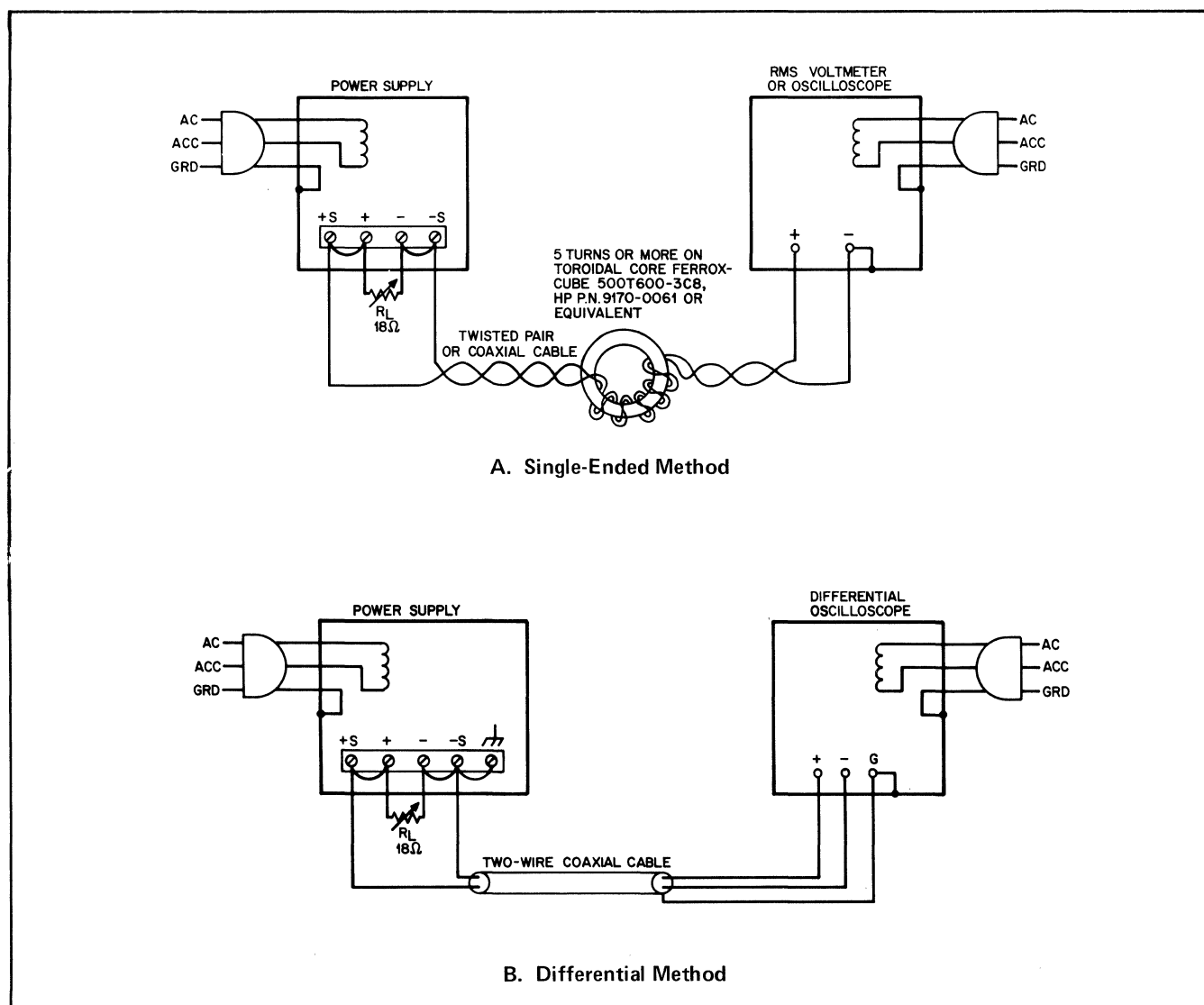


Figure 5-3. Constant-Voltage Ripple Test Setup

5-23 To minimize pickup, a twisted pair or (preferably) a shielded cable should be used to connect the sensing terminals of the power supply to the input of the RMS voltmeter. The common mode choke is recommended to minimize potential interference of common mode noise with the ripple measurement. To verify that the RMS voltmeter is not measuring ripple that is induced in the leads or picked up from ground, short the voltmeter + sense lead to the voltmeter – sense lead at the power supply output terminals. If the test setup is properly configured, the noise value obtained when the leads are shorted should not be significant compared to the measured ripple value.

5-24 In some cases it may be desirable to use a differential oscilloscope to display ripple, as shown in Figure 5-3B. Because of its common-mode rejection, a differential oscilloscope displays only the difference in signal between its two vertical input terminals, thus ignoring the effects of any common-mode signal produced by the difference in the ac potential between the power supply case and the oscilloscope case. Before using a differential-input oscilloscope, however, it is imperative that the common-mode-rejection capability of the oscilloscope be verified by shorting together its two input leads at the power supply and observing the trace on the CRT. If the trace is a straight line, then the oscilloscope is properly ignoring any common-mode signal present. If the trace is not a straight line, then the oscilloscope is not rejecting the ground signal and must be realigned in accordance with the manufacturer's instructions so that proper common-mode rejection is attained.

5-25 **Ripple Measurement Procedure.** To check the ripple output, proceed as follows:

- Connect one of the test setups shown in Figure 5-3.
- Turn CURRENT control fully clockwise.
- Turn on power supply and adjust VOLTAGE control and R_L so that front-panel meters indicate 40V and 5.7A.
- Ripple should be less than 3mV.

5-26 **Noise Spike Measurement Techniques.** An instrument of sufficient bandwidth must be used when making a high-frequency spike measurement. An oscilloscope with a bandwidth of 20MHz or more is adequate. Measuring noise with an instrument that has insufficient bandwidth may conceal high-frequency spikes that could be detrimental to the load.

5-27 A single-ended measurement (replacing rms voltmeter in Figure 5-3A with an oscilloscope) is usually not adequate for measuring spikes; a differential oscilloscope is necessary. The common-mode-rejection capability of the oscilloscope must be verified as described in Paragraph 5-24.

5-28 Figure 5-4 shows the test setup used to measure noise spikes. Two coaxial cables must be used. Impedance-matching resistors must be included to eliminate standing waves and cable ringing, and capacitors must be connected to block dc. The length of the test leads outside the coaxial cable should be kept as short as possible.

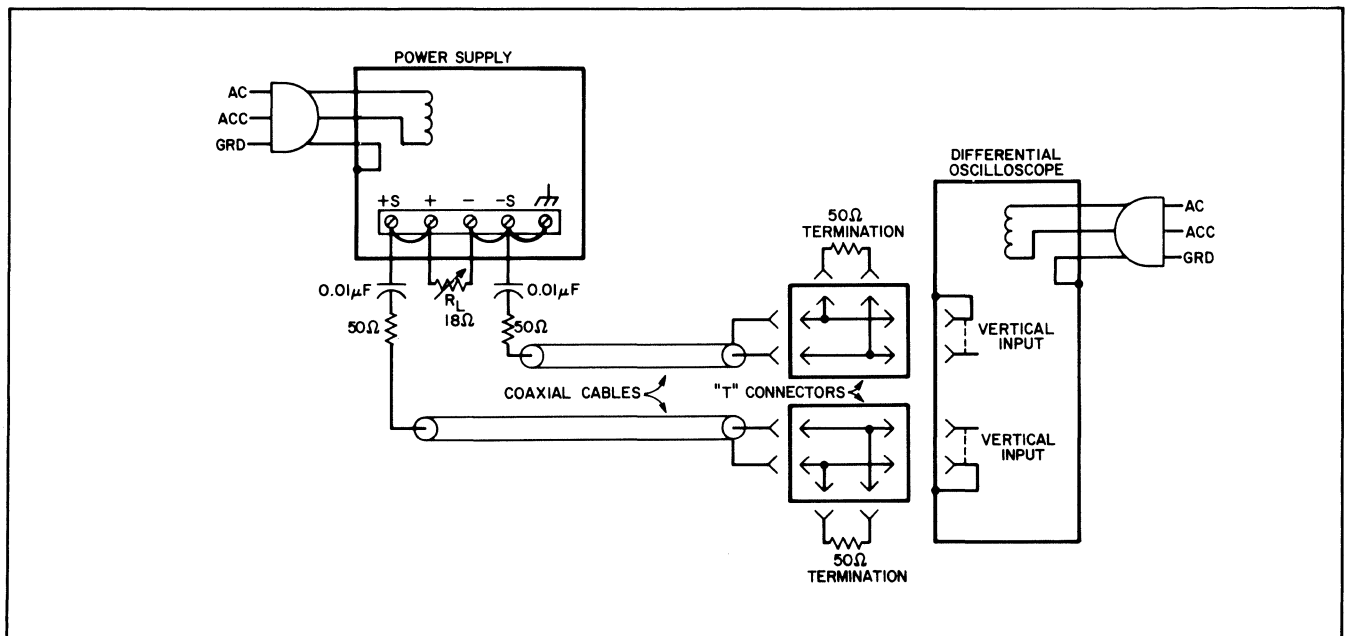


Figure 5-4. Constant-Voltage Noise Spike Measurement Test Setup

The blocking capacitor and impedance-matching resistor should be connected directly from the inner conductor of the cable to the power supply sensing terminal. Notice that the shields of the two coaxial cables are not connected to the power supply, because such a connection would provide a ground current path through the coaxial shield and result in an erroneous measurement.

5-29 Noise Spike Measurement Procedure. To check the noise spikes, proceed as follows:

- Connect the test setup shown in Figure 5-4.
- Turn CURRENT control fully clockwise.
- Turn on power supply and adjust VOLTAGE control and R_L so that the front-panel meters indicate 60V and 3.3A.
- Because the impedance-matching resistors constitute a 2-to-1 attenuator, the noise spikes observed on the oscilloscope should be less than 15mV p-p (instead of 30mV p-p).

5-30 The circuit of Figure 5-4 can also be used for the display of low-frequency ripple. Simply remove the four terminating resistors and the blocking capacitors and substitute a higher-gain vertical plug-in for the wide-band plug-in required for spike measurements.

5-31 Load Transient Recovery Time.

Definition: The time "X" for output voltage recovery to within "Y" millivolts of the nominal output voltage following a "Z" amp step change in load current, where: "Y" is specified as 75mV; the nominal output voltage is defined as the dc level halfway between the static output voltage before and after the imposed load change; and "Z" is the specified load current change of from 90% to 100% (or vice-versa) of maximum current rating.

5-32 Measurement Techniques. Care must be taken in switching the load resistance on and off. A hand-operated switch in series with the load is not adequate since the resulting one-shot displays are difficult to observe on most oscilloscopes and the arc energy occurring during switching completely masks the display with a noise burst. Transistor load switching devices are expensive if reasonably rapid load current changes are to be achieved.

5-33 We suggest that a mercury-wetted relay connected in the load switching circuit shown in Figure 5-5 be used for loading and unloading the supply. When this load switch is connected to a 60Hz ac input, the mercury-wetted relay opens and closes 60 times per second. The 25k control adjusts the duty cycle of the load current switching to reduce jitter in the oscilloscope display. This relay may also be used with a 50Hz ac input.

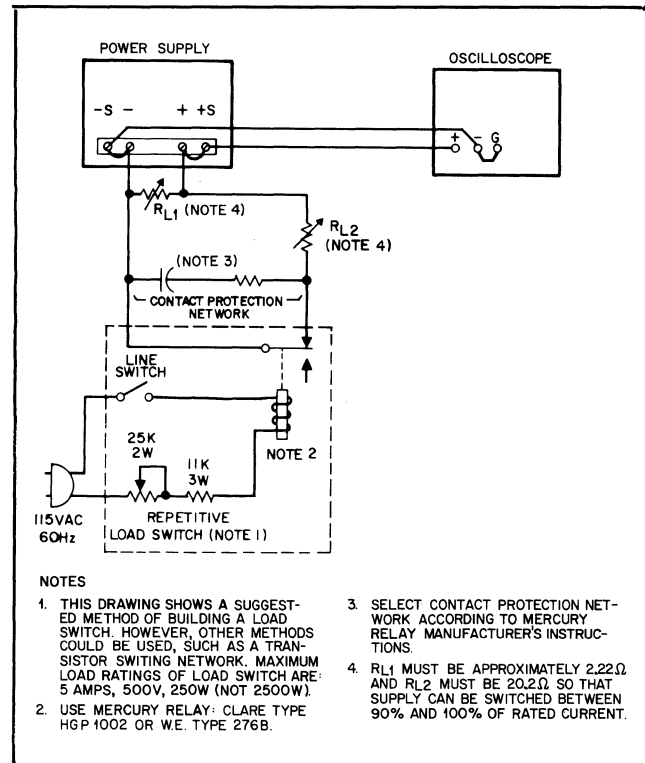


Figure 5-5. Load Transient Recovery Time Test Setup

5-34 Measurement Procedure. To check the load transient recovery time, proceed as follows:

- Connect load resistor R_{L1} (Figure 5-5) across output of supply. Do not connect R_{L2} and load switch at this time.
- Turn CURRENT control fully clockwise and adjust VOLTAGE control for 20V on front panel meter.
- Next, set R_{L1} for approximately 2.22Ω (9A on front panel ammeter). Ensure that supply operates in constant voltage mode.
- Turn off supply and connect R_{L2} , in parallel with R_{L1} . Do not connect load switch yet.
- Turn on supply and set R_{L2} for approximately 20.2Ω (2Ω total resistance across supply) and ensure that supply provides 20V, 10A in the constant voltage mode.
- Turn off supply and connect load switch and load resistors as indicated in Figure 5-5.
- Turn on supply and close line switch on repetitive load switch setup.
- Set oscilloscope for internal sync and lock on either the positive or negative load transient spike.
- Set vertical input of oscilloscope for ac coupling so that small dc level changes in power supply output voltage will not cause display to shift.
- Adjust the vertical centering on the scope so that the tail ends of the low-load and full-load waveforms are

symmetrically displaced about the horizontal centerline of the oscilloscope. This centerline now represents the nominal output voltage defined in the specification.

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

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

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

n. Starting from the major graticule division representing time zero, count to the right 1mS and vertically 75mV, recovery should be within these tolerances as illustrated in Figure 5-6.

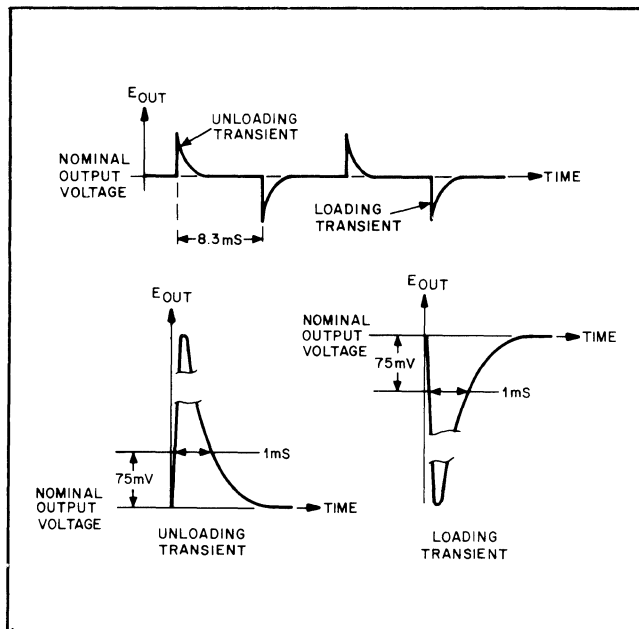


Figure 5-6. Load Transient Recovery Waveforms

5-35 Temperature Coefficient.

Definition: The change in output voltage per degree Celsius change in ambient temperature measured while ac line voltage, output voltage setting, and load resistance are all held constant.

5-36 The temperature coefficient of a power supply is measured by placing the unit in an oven and varying the temperature over any span within the power supply's rating. The power supply temperature must be allowed to stabilize for a sufficient time at each measurement temperature.

5-37 The temperature coefficient given in the specification table is the maximum temperature-dependent output voltage change which will result over any one-degree

interval. The digital voltmeter used to measure the supply's output voltage change should be placed outside the oven and should have a long-term stability adequate to insure that its drift will not affect the overall measurement accuracy.

5-38 To check the temperature coefficient, proceed as follows:

- a. Connect load resistance and digital voltmeter as illustrated in Figure 5-2.
- b. Turn CURRENT control fully clockwise.
- c. Turn on supply and adjust VOLTAGE control until digital voltmeter (DVM) indicates exactly 60V (maximum rated output voltage).
- d. Disconnect DVM from power supply sense terminals and connect DVM across current-monitoring resistor (R_M).
- e. Reduce resistance of R_L until DVM reads 33mV, indicating that current output is exactly 3.3A (maximum rated power output). Ensure that power supply remains in constant-voltage mode.
- f. Disconnect DVM from R_M and reconnect DVM to power supply sense terminals.
- g. Place power supply in temperature-controlled oven (DVM remains outside oven). Set temperature to 30°C and allow 30 minutes warm-up.
- h. Record DVM reading.
- i. Raise temperature to 40°C and allow 30 minutes warm-up.
- j. Observe DVM reading. Difference in voltage reading between steps h and j should be less than 70mVdc.

5-39 Drift (Stability).

Definition: The change in output voltage for the first eight hours following a 30-minute warm-up period. During the interval of measurement, input line voltage, load resistance, and ambient temperature are all held constant.

5-40 This measurement is made by monitoring the output of the power supply on a digital voltmeter over the stated measurement interval. A strip chart recorder can be used to provide a permanent record. Place a thermometer near the supply to verify that the ambient temperature remains constant during the period of measurement. The supply should be located away from any source of stray air current. If possible, place the supply in an oven and hold it at a constant temperature. Take care that the measuring instrument has an eight-hour stability at least an order of magnitude better than the stability specification of the power supply being tested. Typically, a supply will drift less over the eight-hour measurement interval than during the half-hour warm-up period.

5-41 To check the output stability, proceed as follows:

- Connect load resistance and digital voltmeter (DVM) as illustrated in Figure 5-2.
- Turn CURRENT control fully clockwise.
- Turn on supply and adjust VOLTAGE control until DVM indicates exactly 60V (maximum rated output voltage).
- Disconnect DVM from power supply sense terminals and connect DVM across current-monitoring resistor (R_M).
- Reduce resistance of R_L until DVM reads 33mV, indicating that current output is exactly 3.3A (maximum rated power output). Ensure that power supply remains in constant-voltage mode.
- Disconnect DVM from R_M and reconnect DVM to power supply sense terminals.
- Allow 30 minutes warm-up, then record DVM reading.
- After eight hours, DVM reading should not differ from reading of step g by more than 21mVdc.

5-42 Constant-Current Tests

5-43 The instruments, methods, and precautions for the proper measurement of constant-current power supply characteristics are for the most part identical to those already described for the measurement of constant-voltage characteristics. The main difference is that the power supply performance will be checked between short circuit and full load rather than open circuit and full load.

5-44 **Current Output And Ammeter Accuracy.** To check that the supply will furnish its rated output current, proceed as follows:

- Connect test setup shown in Figure 5-7. Set R_L to minimum resistance initially.
- Turn VOLTAGE control fully clockwise.
- Turn on supply and adjust CURRENT control until DVM reads 0.1V, indicating that current output is exactly 10A (maximum rated output current).
- Front-panel ammeter should indicate $10A \pm 3\%$.
- Disconnect DVM from R_M and connect DVM to power supply sense terminals.
- Increase resistance of R_L until DVM reads exactly 20V (maximum rated power output). Ensure that power supply remains in constant-current mode.
- Disconnect DVM from power supply sense terminals and reconnect DVM across R_M .
- DVM should indicate 0.1V; front-panel ammeter should indicate $10A \pm 3\%$.

5-45 Load Effect (Load Regulation).

Definition: The change in the static value of the dc output current (ΔI_{OUT}) resulting from a change in load resistance from short circuit to a value which yields maximum rated output voltage, or from the latter value to short circuit.

5-46 To check the constant-current load effect, proceed as follows:

- Connect test setup shown in Figure 5-7.

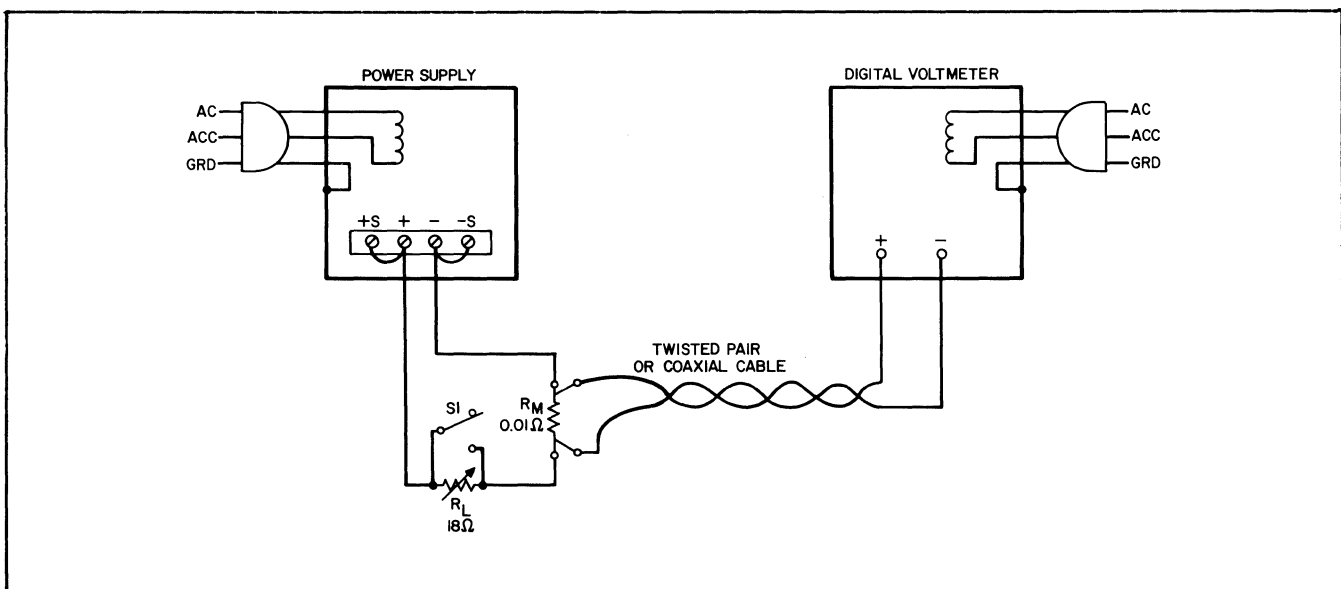


Figure 5-7. Constant-Current Test Setup

- b. Turn VOLTAGE control fully clockwise.
- c. Turn on supply and adjust CURRENT control until DVM reads 33mV, indicating that current output is exactly 3.3A.
- d. Disconnect DVM from R_M and connect DVM to power supply sense terminals.
- e. Adjust resistance of R_L until DVM indicates 60V (maximum rated output voltage). Ensure that power supply remains in constant-current mode.
- f. Disconnect DVM from power supply sense terminals and reconnect DVM to R_M .
- g. Record voltage indicated on DVM.
- h. Close switch to short circuit load.
- i. Wait a few seconds only to allow DVM to settle. Reading on DVM should not differ from reading of step g by more than 33 μ V.

5-47 Source Effect (Line Regulation).

Definition: The change in the static value of dc output current (ΔI_{OUT}) resulting from a change in ac input voltage over the specified range from low line to high line, or from high line to low line.

5-48 To check source effect, proceed as follows:

- a. Connect test setup shown in Figure 5-7.
- b. Connect variable autotransformer between input power source and power supply ac power input.
- c. Adjust autotransformer for low line voltage (Paragraph 2-18).
- d. Turn VOLTAGE control fully clockwise.
- e. Turn on power supply and adjust CURRENT control until DVM reads 0.1V, indicating that current output is exactly 10A (maximum rated output current).
- f. Disconnect DVM from R_M and connect DVM to power supply sense terminals.
- g. Adjust resistance of R_L until DVM reads exactly 20V. Ensure that power supply remains in constant-current mode.
- h. Disconnect DVM from power supply sense terminals and reconnect DVM across R_M .
- i. Record voltage indicated on DVM.
- j. Adjust autotransformer for high line voltage.
- k. Reading on DVM should not differ from reading of step i by more than 30 μ V.

5-49 PARD (Ripple and Noise).

Definition: The residual ac current superimposed on the dc output of a regulated power supply. Ripple and noise measurement may be made at any input ac line voltage combined with any dc output voltage and load current within the supply's rating.

5-50 Most of the instructions pertaining to pickup problems associated with constant-voltage ripple and

noise measurement also apply to the measurement of constant-current ripple and noise. Figure 5-8 shows two test setups that can be used when measuring the ripple and noise of a constant-current supply. Either test setup can be used depending on the availability of an appropriate monitoring resistor.

5-51 The current-monitoring resistor(R_M) in Figure 5-8 can be constructed of parallel-connected resistors. It must have very low inductance to prevent the high frequency components of CC ripple from causing a misleading voltage drop. A current probe/amplifier combination such as Tektronix P6302 probe and AM503 amplifier can be used for the current-monitoring transformer (T1) in Figure 5-8B.

5-52 To check the ripple and noise, proceed as follows:

- a. Connect oscilloscope or rms voltmeter as shown in Figure 5-8.
- b. Rotate VOLTAGE control fully clockwise.
- c. Turn on supply and adjust CURRENT control and R_L so that the front-panel meters indicate 10A and approximately 20V.
- d. The observed ripple and noise should be less than 0.50mV rms (5mA rms).

5-53 TROUBLESHOOTING

WARNING

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

5-54 Before attempting to troubleshoot this instrument, ensure that the fault is with the instrument itself and not with an associated circuit. The performance test enables this to be determined without having to remove the covers from the supply.

5-55 The most important aspect of troubleshooting is the formulation of a logical approach to locating the source of trouble. A good understanding of the principles of operation is particularly helpful, and it is recommended that Section IV of this manual be reviewed before attempting to troubleshoot the unit. Often the user will then be able to isolate a problem simply by using the operating controls and indicators. Once the principles of operation are understood, refer to the following paragraphs.

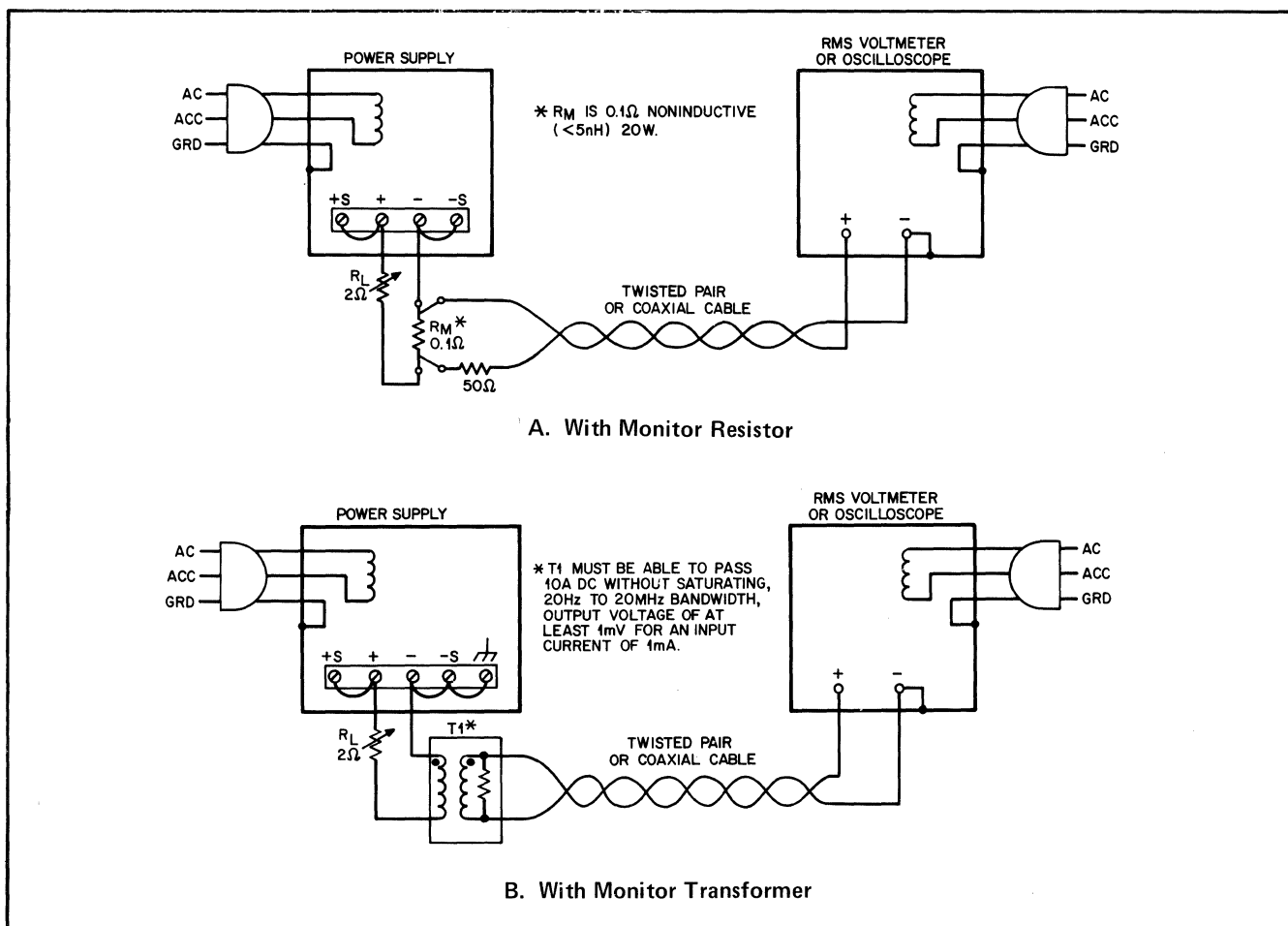


Figure 5-8. Constant-Current Ripple and Noise Measurement Test Setup

5-56 Section VII contains a schematic diagram and information concerning the voltage levels and waveforms at many of the important test points. Section VII also includes component location diagrams to help the user locate the unit's components and test points. Most of the test points used for troubleshooting the supply are located on the control board test "fingers", which are readily accessible at the top of the board.

5-57 If a component is found to be defective, replace it and re-conduct the performance test. When a component is replaced, refer to the repair and adjustment portions of this section. It may be necessary to perform one or more of the adjustment procedures after a component is replaced.

5-58 Initial Troubleshooting Procedures

5-59 If a problem occurs, follow the steps below in sequence:

a. Check that input power is available, and check the power cord and rear-panel line fuse. When replacing line fuse, be certain to select fuse of proper

rating for line voltage being used.

b. Check that straps on the rear-panel terminal strip are properly connected.

c. Check that all connections to the power supply are secure and that circuits between the supply and external devices are not interrupted.

5-60 **Troubleshooting Test Setup.** Before continuing with troubleshooting, proceed as follows:

- Turn off supply and disconnect all loads.
- Connect a 200-ohm 10-watt load resistor across rear output terminals.
- Connect a digital voltmeter (DVM) across rear output terminals to monitor output voltage.
- Turn VOLTAGE and CURRENT controls to mid-range (5 turns), and OVP ADJUST control to maximum (fully CW).
- Remove top cover.
- An extender card, HP Part No. 06024-60024, can be used with the A2 Control Board to allow easy access to components. A test connector, HP Part No. 1251-6016, allows easy connection to the test fingers.

Table 5-2. Bias Voltage Check

(All bias voltages measured at Control Board test fingers with respect to bias common at pin 12 or at A2U1 heatsink. Table 7-2 lists semiconductor components operating on each bias supply.)

Bias Voltage	Measurement Point	Normal Range	Check These Components
+5V Reg	Pin 21	+4.75V to +5.25V	Check for presence of +5V Unreg (+12 to +19V, pin 16). If absent, check A1T5 pins 7 and 9, A1CR22-23, A1C35, A1R61, A1VR5. If present, check A2U1.
+15V Reg	Pin 20	+14.10V to 15.90V	Check for presence of +15V Unreg (+19V to +31V, pin 11). If absent, check A1T5 pins 6 and 10, A1U3, A1C36. If present, check A2Q1, A2U2, A2R2-R7, A2VR1, A2C3.
-12V Reg	Pin 24	-12.96V to -11.04V	Check for presence of -12V Unreg (-19V to -31V, pin 8). If absent, check A1C37. If present check A2Q2, A2U3, A2R8-R11, A2C4.

5-61 Overall Trouble Isolation

5-62 Once the test setup is arranged, proceed to the overall troubleshooting tree in Figure 5-9. This tree will isolate trouble to a particular circuit and direct you to another troubleshooting tree to isolate the trouble within the circuit.

5-63 The following notes apply to the troubleshooting trees.

1. Unless otherwise noted, all troubleshooting procedures should start with test setup of paragraph 5-60.
2. Before removing or replacing fuses or other components turn power off and disconnect input ac power cable.

WARNING

Some circuits on the mainboard are connected directly to the ac power line. Exercise extreme caution when working on energized circuits. Energize the supply through an isolation transformer to avoid shorting ac energized circuits through the test instrument's input leads. (The isolation transformer must have a power rating of at least 1kVA.) During work on energized circuits, the safest practice is to disconnect power, make or change the test connections, and then reapply power.

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

3. Allow input capacitors two minutes to discharge before making resistance checks or removing components in primary circuit.
4. Unless otherwise noted, all voltages measured with respect to bias common (available at A2U1 heat sink).
5. Numbers in brackets refer to waveforms shown in Figure 7-5.
6. Unless arrows point otherwise, flow of troubleshooting trees is down and to the right.
7. The troubleshooting trees provide general guidelines to help isolate trouble. They will not isolate all possible troubles. The user should use signal tracing and other standard troubleshooting techniques to identify faulty components. The user is responsible for connecting and adjusting meters, oscilloscopes, etc. properly. Before replacing a component, check connections to the component and ensure that bias voltages to the component are correct.
8. After isolating and correcting a problem, go back to the beginning of main troubleshooting tree, Figure 5-9, unless otherwise directed.

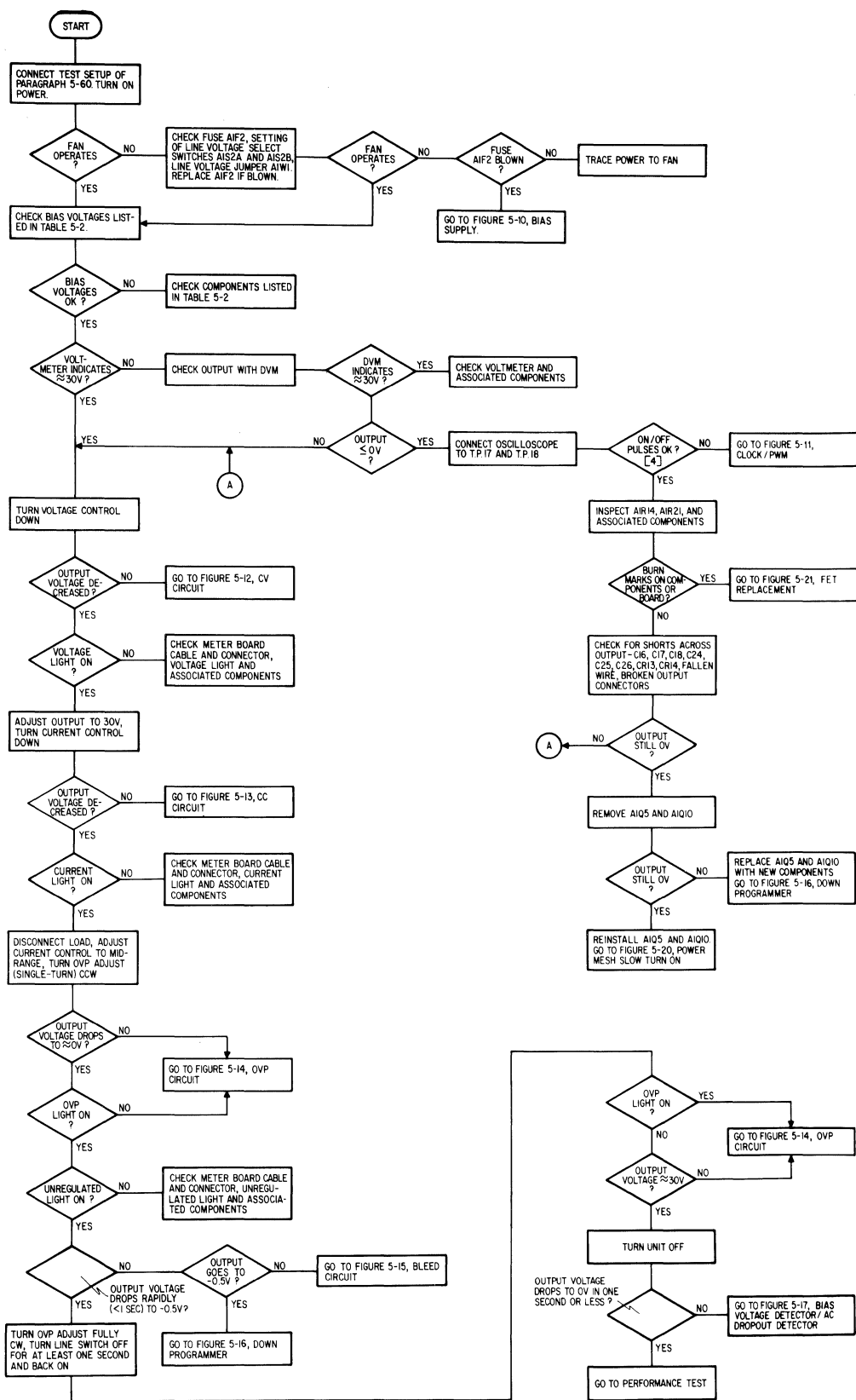


Figure 5-9. Overall Troubleshooting Tree

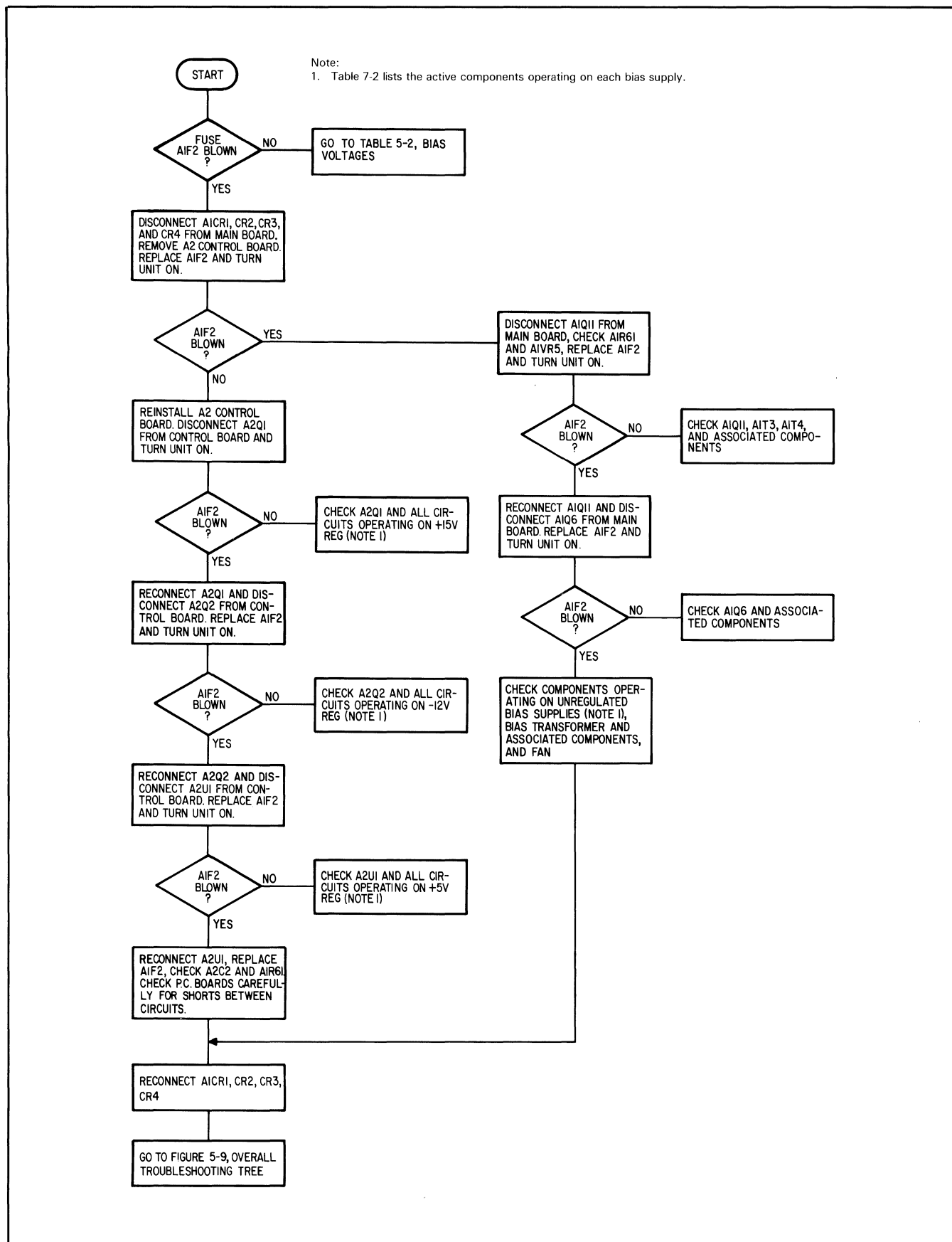


Figure 5-10. Troubleshooting Bias Supply

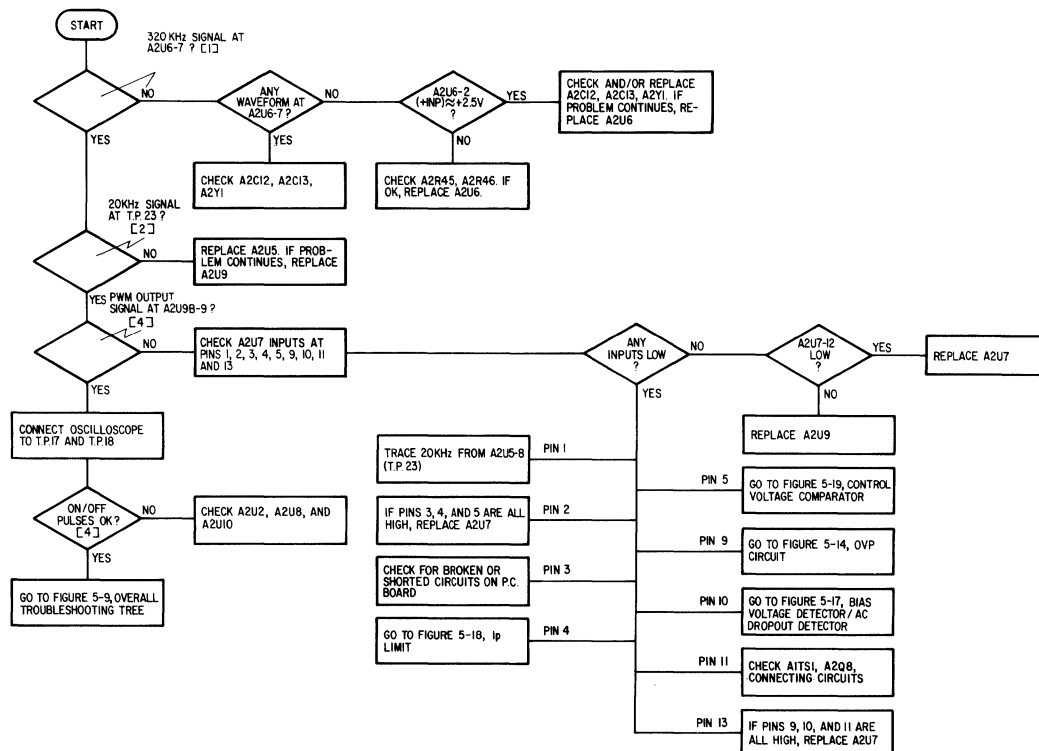


Figure 5-11. Troubleshooting Clock And Pulse Width Modulator

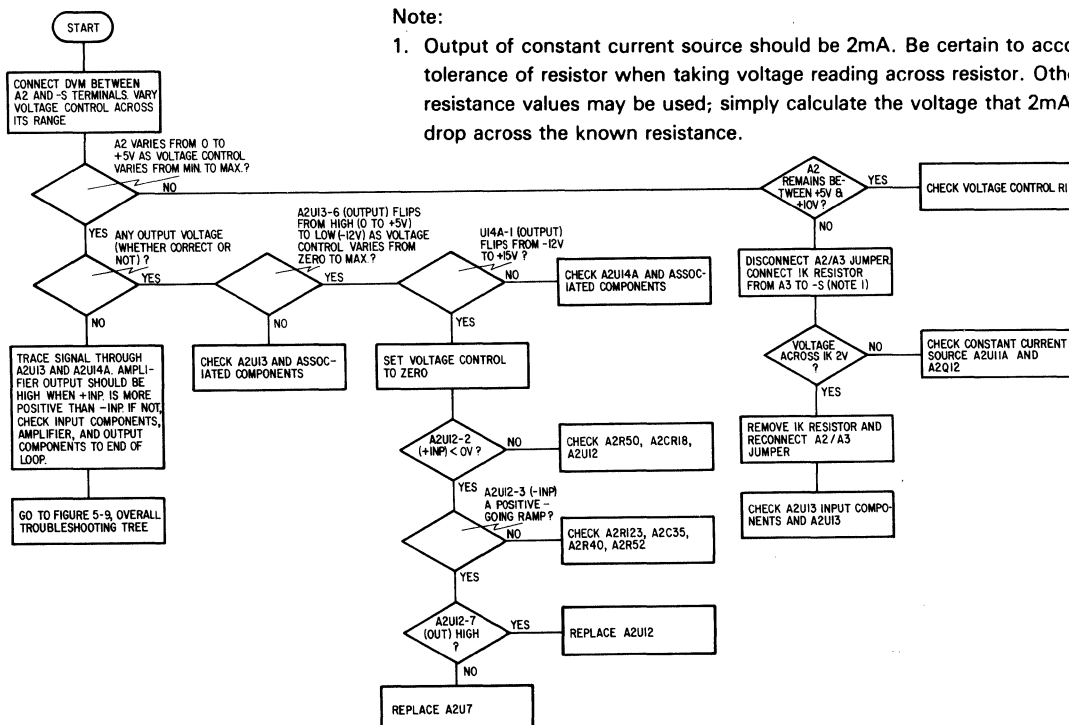


Figure 5-12. Troubleshooting CV Circuit

Note:

1. Output of constant current source should be 2mA. Be certain to account for tolerance of resistor when taking voltage reading across resistor. Other resistance values may be used; simply calculate the voltage that 2mA should drop across the known resistance.

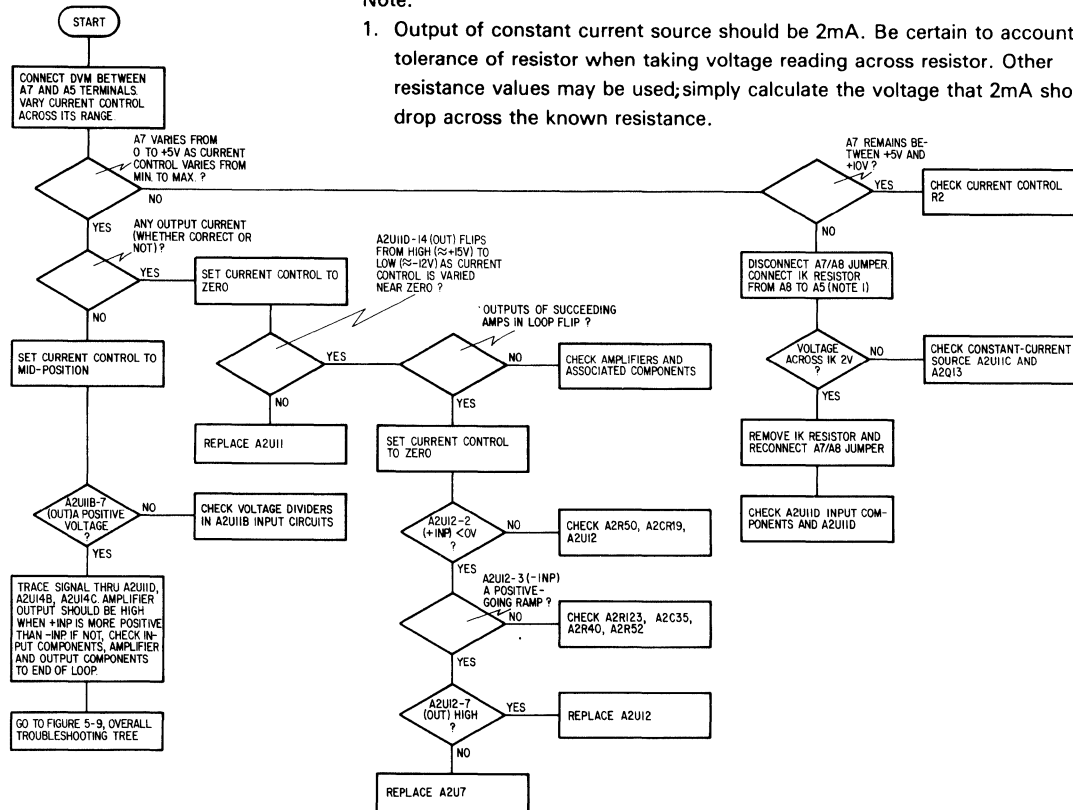


Figure 5-13. Troubleshooting CC Circuit

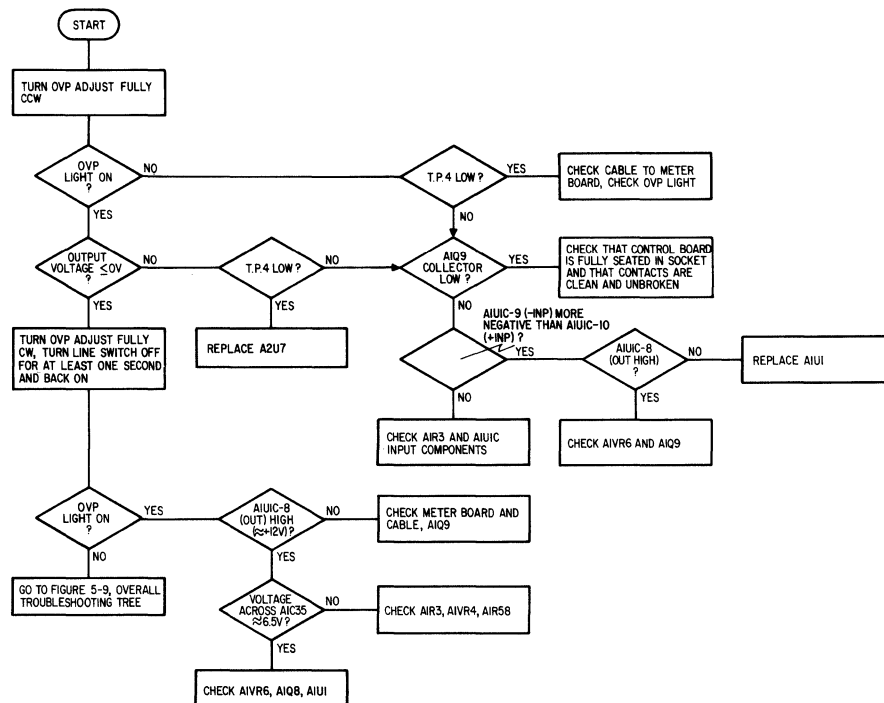


Figure 5-14. Troubleshooting OVP Circuit

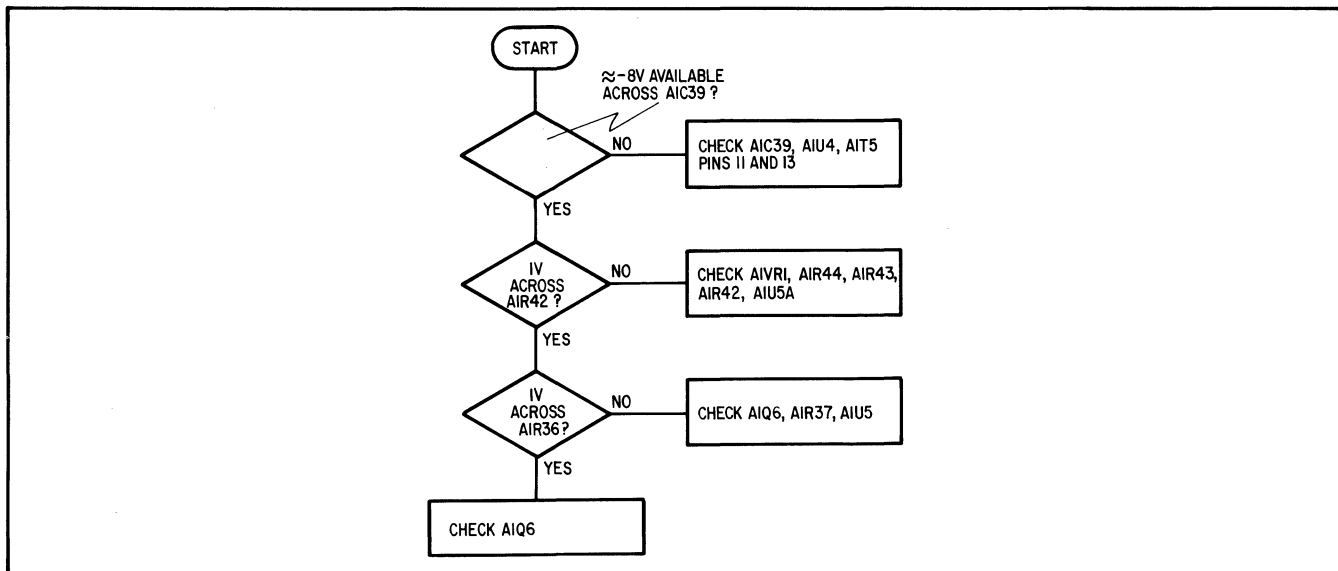


Figure 5-15. Troubleshooting Bleed Circuit

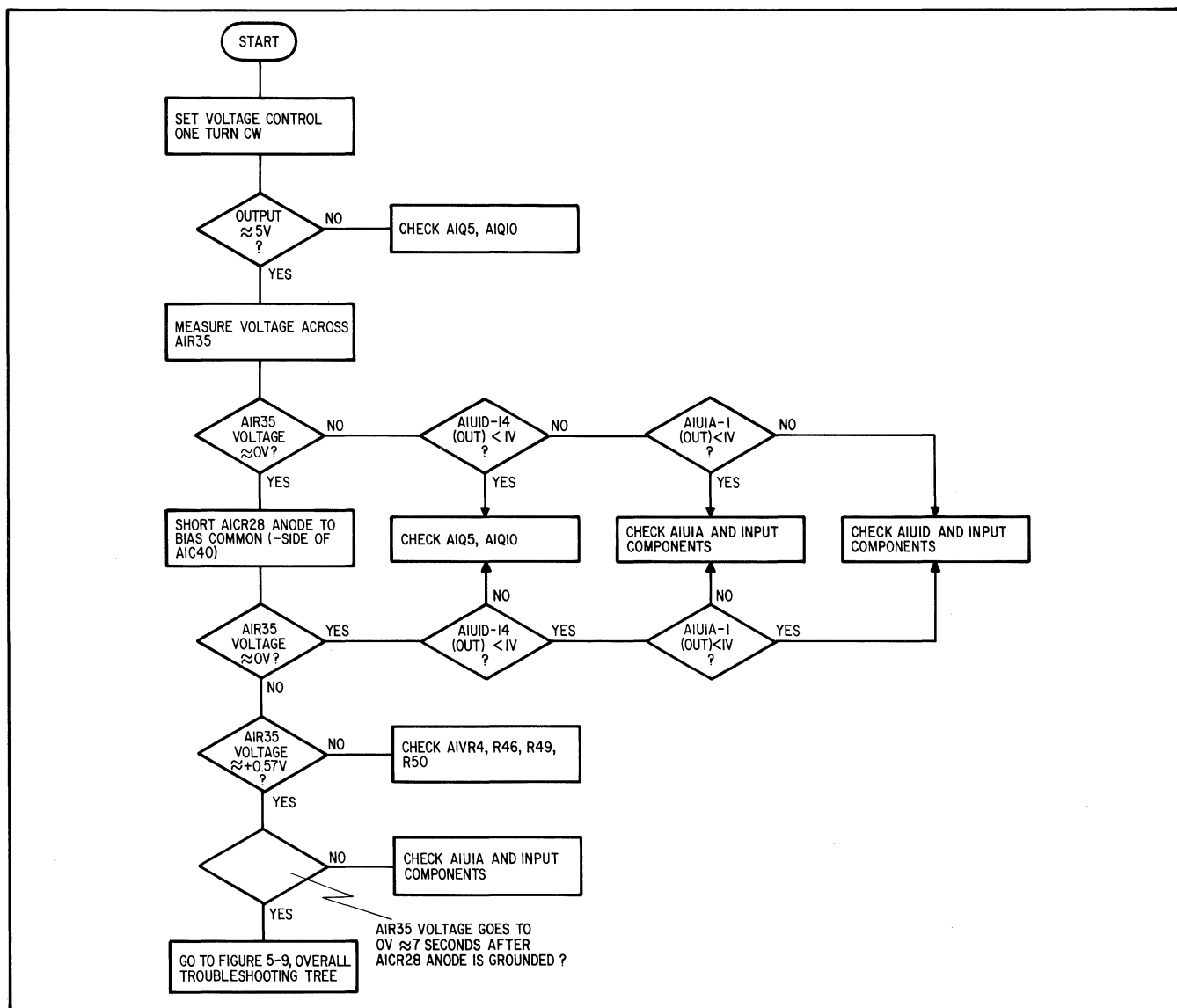


Figure 5-16. Troubleshooting Down Programmer

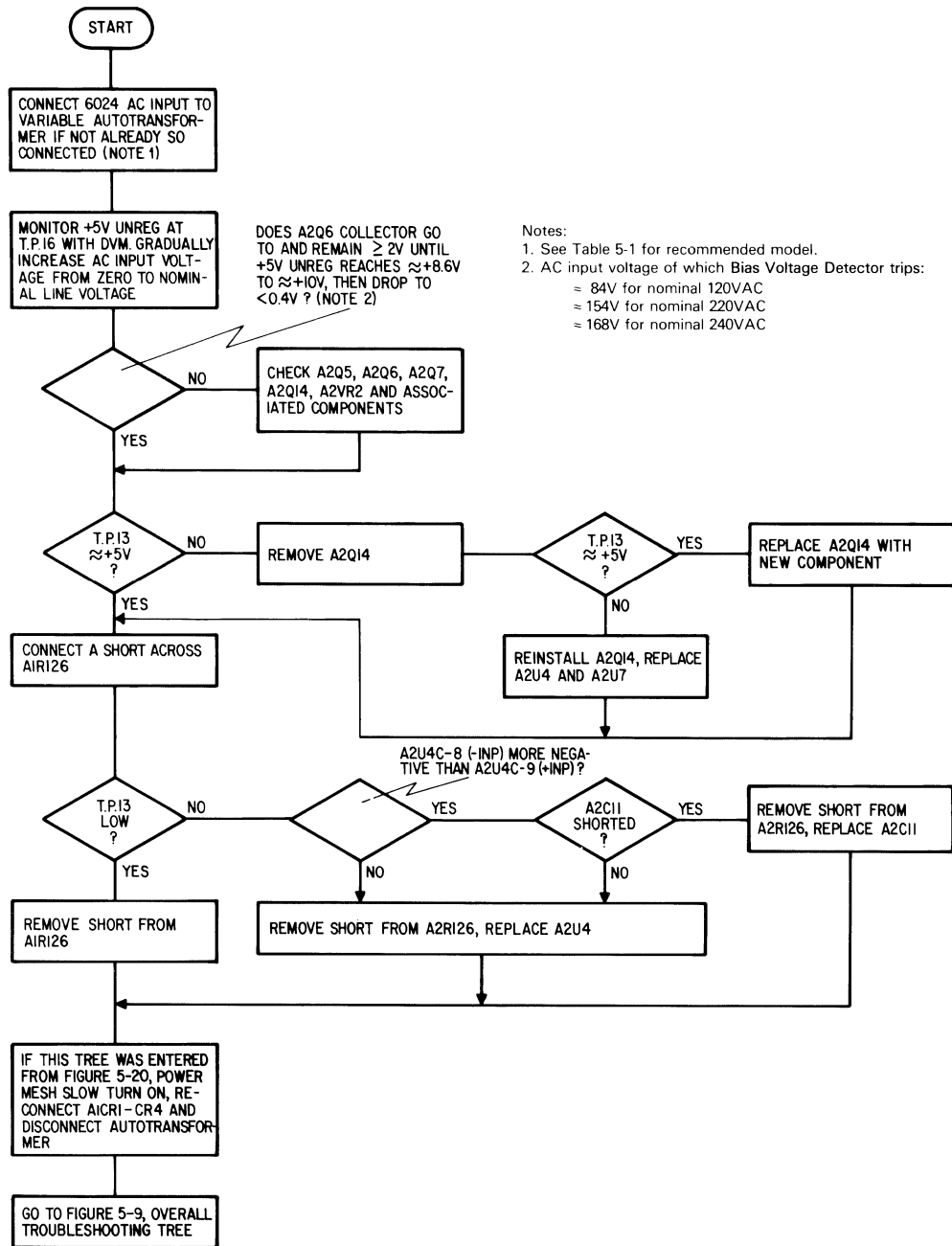


Figure 5-17. Troubleshooting Bias Voltage Detector/AC Dropout Detector

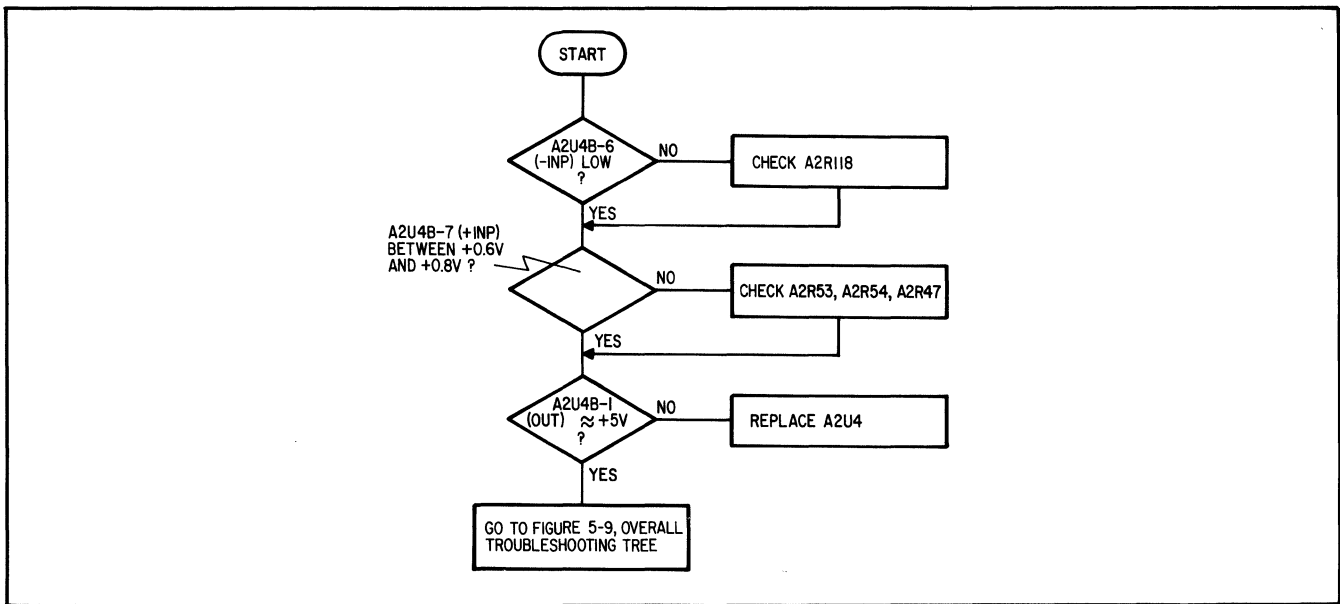


Figure 5-18. Troubleshooting I_p Limit Circuit

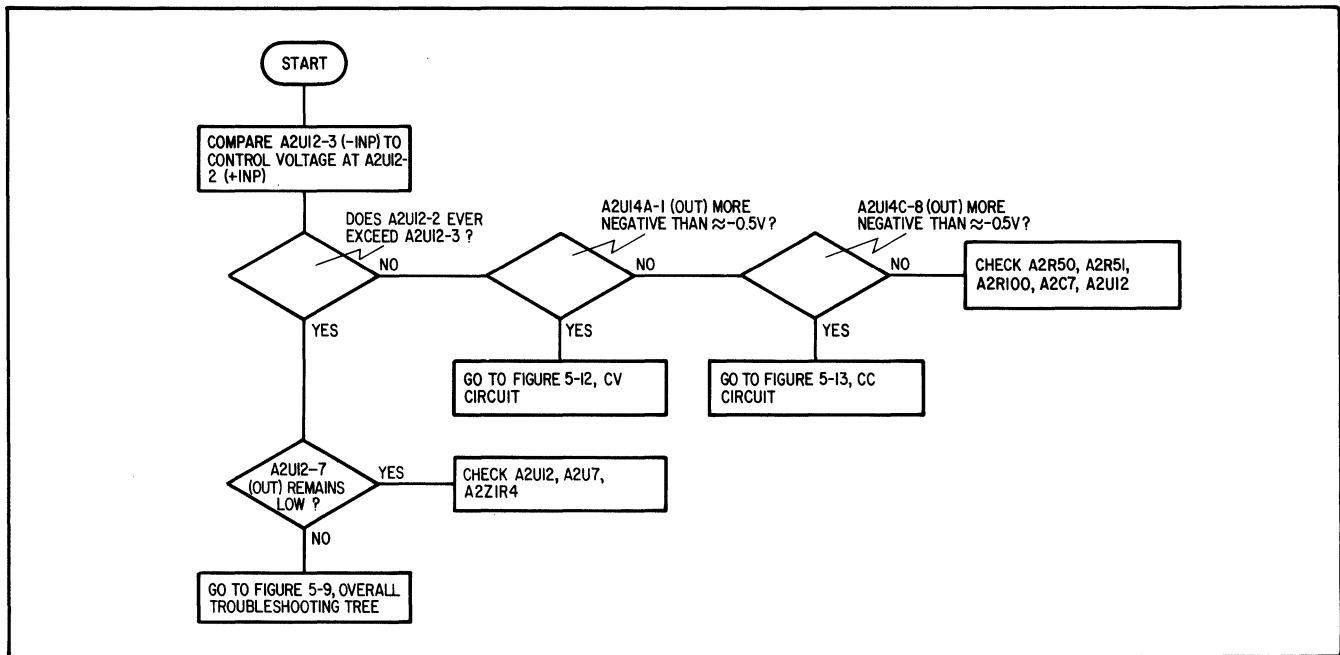


Figure 5-19. Troubleshooting Control Voltage Comparator

Notes:

1. See Table 5-1 for recommended model.
2. Use a dc power supply variable from 0 to at least 40 volts, with current limit set between 0.5A and 2A. The easiest place to connect the external supply is to the two thermistors, RT1 and RT2, on the main board. Make connections to the posts to which thermistors are soldered; do not make connections directly to the thermistor leads. Connect the + output of the external supply to either post of RT1 (closer to side of unit). Connect the - output of the external supply to either post of RT2 (closer to center of unit).
3. AC input voltage at which Level Detector trips:

≈ 70V for nominal 100VAC	≈ 154V for nominal 220VAC
≈ 84V for nominal 120VAC	≈ 168V for nominal 240VAC

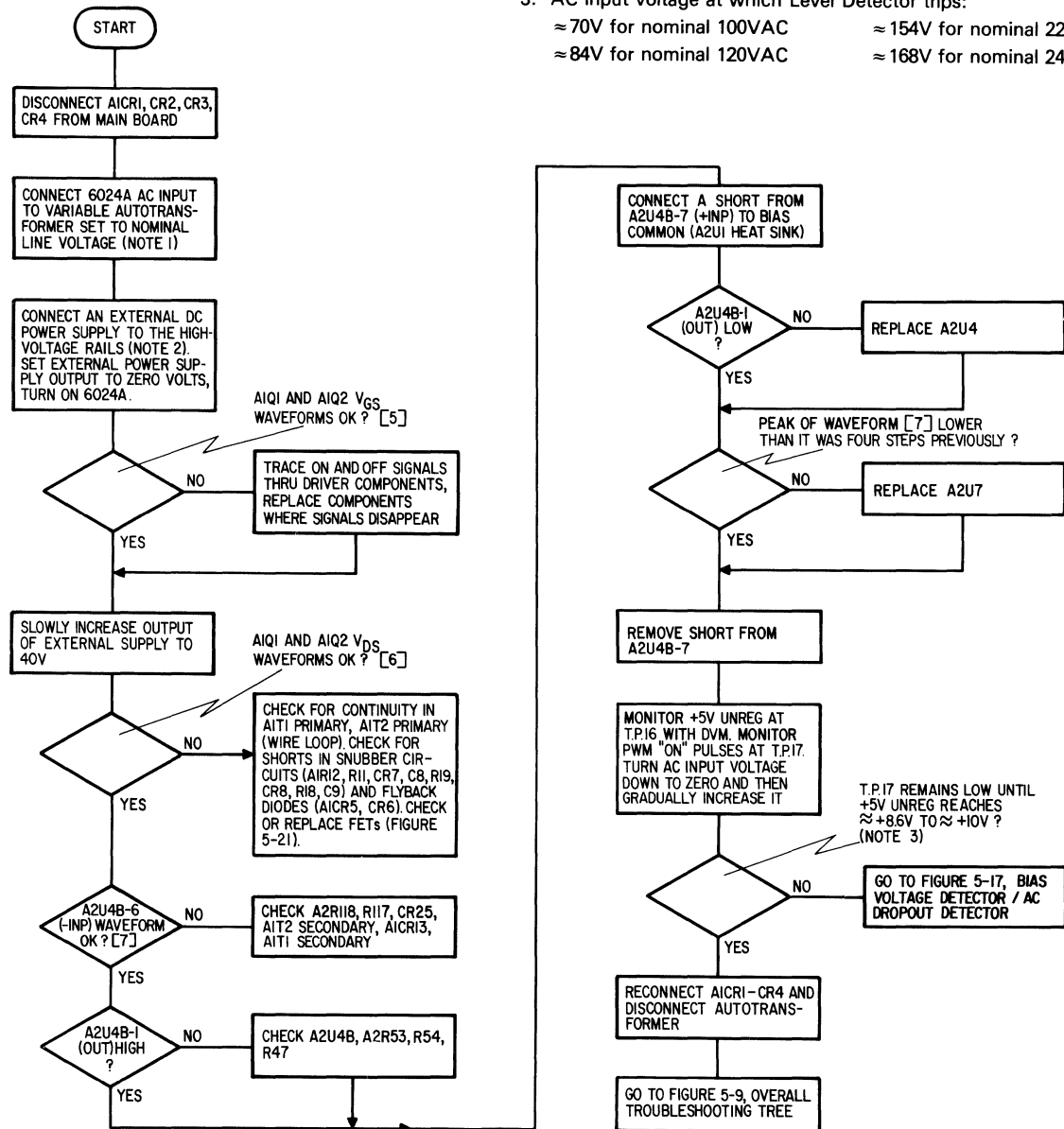
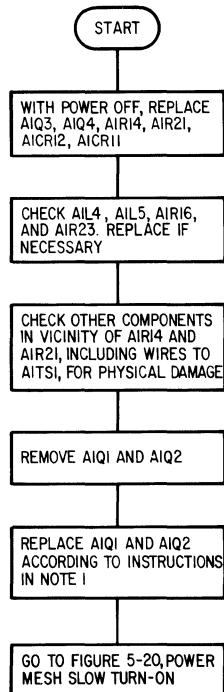


Figure 5-20. Power Mesh Slow Turn-On

In case of damage to FETs or driver circuits, replace both FETs and all other components provided in FET Service Kit, HP Part No. 5080-1953.



Note:

1. Handle FETs with care when out of circuit. Use a grounding strap to avoid static discharge into gate. Avoid touching the gate or source pins. Do not clip the leads too short when replacing FETs; they make good test points. Be certain to replace all washers, spacers, etc. Use a small amount of heat sink compound on both sides of mica insulator when replacing FETs. Do not use any heat sink compound containing silicone. An organic zinc oxide cream, such as American Oil and Supply Company Heat Sink Compound #100, is recommended.

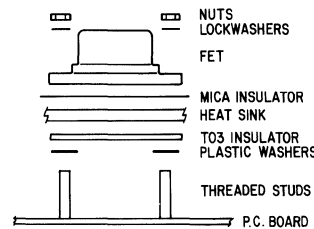


Figure 5-21. FET Replacement

5-64 REPAIR AND REPLACEMENT

5-65 Outside Cover Removal

5-66 To remove the top cover, remove the four screws that secure cover to instrument, slide cover to rear and lift off. When replacing cover, start screws carefully and do not over-tighten.

5-67 To remove the bottom cover, remove the nine screws that secure cover to instrument, slide cover to rear and lift off. It is not necessary to remove instrument feet. When replacing cover, start screws carefully and do not over-tighten.

5-68 A2 Control Board Removal

5-69 The control board is held in place by four retaining screws that pass through keyhole slots in the control board and screw into spacers on the back of the meters. To remove control board, proceed as follows:

- a. Unplug cable from option card (if installed).
- b. Unplug cable from Meter board.

c. Loosen four retaining screws that attach control board to meters on Meter board about one turn (it is not necessary to remove the screws).

d. Grasp control board at top center and pull upward about 3/8 inch to unplug control board from main board. Be careful not to bend any components when gripping board.

e. Tilt control board slightly toward back of instrument to free it from screws loosened in step c.

f. Lift control board carefully up and out of unit; do not bend any components.

g. When replacing control board, lower it carefully into position until larger section of 4 keyhole slots line up with 4 spacers attached to backs of meters.

h. Tilt board toward front of instrument so that screw heads protrude through larger section of keyhole slots.

i. Line up edge connector on bottom of control board with connector on main board; ensure that board is straight up so that keyhole slot will fit between spacers and screw heads.

j. Carefully press control board down into main

board connector. Control board is fully seated when tops of keyhole slots are flush with retaining screws.

k. Tighten retaining screws.

l. Reconnect cable from Meter board. As viewed from front of instrument, brown conductor is to right of instrument and green is to left (marked on Control board).

m. Reconnect cable from option card (if installed). As viewed from front of instrument, red tracer is to right (marked on Control board).

5-70 A3 Meter Board Removal

5-71 The Meter board is attached to the back of the front panel. To remove the Meter board, proceed as follows:

a. Remove the control board per instructions in Paragraph 5-68.

b. Remove the knobs from the VOLTAGE and CURRENT controls using a 0.050" allen wrench (2 set screws per knob).

c. Unscrew the plastic bezel nut that secures the LINE switch to the front panel. Grip the nut only with your fingers; do not use pliers or other tools.

d. Carefully peel the vinyl trim pieces from each side of the sheet-metal bezel that surrounds the front panel.

e. Turn the unit upside down and remove the 4 screws that secure the bezel to the bottom front of the unit.

f. Turn the unit top side up and remove the 2 screws that secure the bezel to the top front of the unit.

g. Slide the bezel off the front of the unit.

h. Remove the 4 screws (2 on each side) that secure the front panel to the sides of the unit.

i. Slide the front panel carefully off the front of the unit.

j. Remove the screw that secures the ground wire to the front panel (right side of front panel as viewed from the rear).

k. Remove the 3 screws (1 top center, 2 bottom sides) that secure the Meter board to the front panel. To avoid damaging the LEDs, do not lay the front panel face down on a hard work surface.

1. To replace the Meter board, reverse the preceding steps. Do not forget to reconnect the ground wire to the front panel.

5-72 Replacement Parts

5-73 Section VI of this manual contains a list of replacement parts. If the part to be replaced does not have a standard manufacturer's part number, it is a

special part and must be obtained directly from Hewlett-Packard. After replacing a component, refer to Table 5-3 for adjustments that may be necessary.

5-74 ADJUSTMENT AND CALIBRATION

5-75 Adjustment and calibration may be required after performance testing, troubleshooting, or repair and replacement. Perform only those adjustments that affect the operation of the faulty circuit. If two or more adjustments will be made, they should be performed in the order in which they are listed in Table 5-3.

5-76 Unless otherwise stated, all adjustments are performed with the power supply strapped as shown in Figure 3-2. The unit should have been turned on for at least 30 minutes before performing any adjustments to allow it to reach normal operating temperature.

WARNING

The power supply should be turned off while making and removing connections to the rear-panel terminals.

5-77 All adjustment potentiometers are located along the top edge of the control board. Figure 5-22 shows the location of the adjustments as viewed from the top front of the instrument.

5-78 Meter Zero Adjustment

5-79 The meter pointers must point to zero on the meter scales when the instrument is at normal operating temperature, in its normal operating position, and turned off. The same procedure is used for both meters. To zero a meter, proceed as follows:

a. After warm-up, turn power supply off and wait two minutes for power supply capacitors to discharge completely.

b. Insert a small-blade screwdriver in meter-adjust screw (about ½ inch below meter face) and turn screw until pointer points to zero mark on scale.

5-80 Constant-Voltage Offset Adjustment

5-81 Proceed as follows:

a. Connect digital voltmeter to rear-panel output terminals.

b. Connect a short between terminals A2 and -S on rear panel.

Table 5-3. Adjustments Required After Component Replacement and Symptoms of Mis-Adjustment

Adjustment	Symptom Indicating Adjustment Necessary	Replaced Components
A2R65 CV Offset	0-volt programming input does not produce 0-volt output	A2U13, A2R63, A2R64, A2R65, A2R6, A2R7
A2R7 CV Full Scale	2.5k resistive programming input does not produce 60-volt output	A2VR1, A2U11, A2R75
A2R99 Voltmeter Adjust	Front-panel voltmeter does not agree with DVM connected to output terminals	Voltmeter (A2M1), A1R45, A2R98, A2R99
A2R91 CC Offset	0-volt programming input does not produce 0-amp output	A2U11, A2R89, A2R90, A2R91
A2R92 CC Full Scale	5-volt programming input does not produce 10-amp output	A2R92, A2R93, A2R94, A1R28, A1R29
A2R87 Ammeter Adjust	Front-panel ammeter does not agree with output current indicated by DVM connected across shunt in series with output	Ammeter (A2M2), A2R86, A2R87
A2R54 I_p Limit	Output unregulated even though operating within power limit (set too low), or provides more than 24V at 10A (set too high).	A2R2, A2R4, A2VR1, A2R53, A2R54, A2R47, A2U4, A2R118, A2T1, A2T2

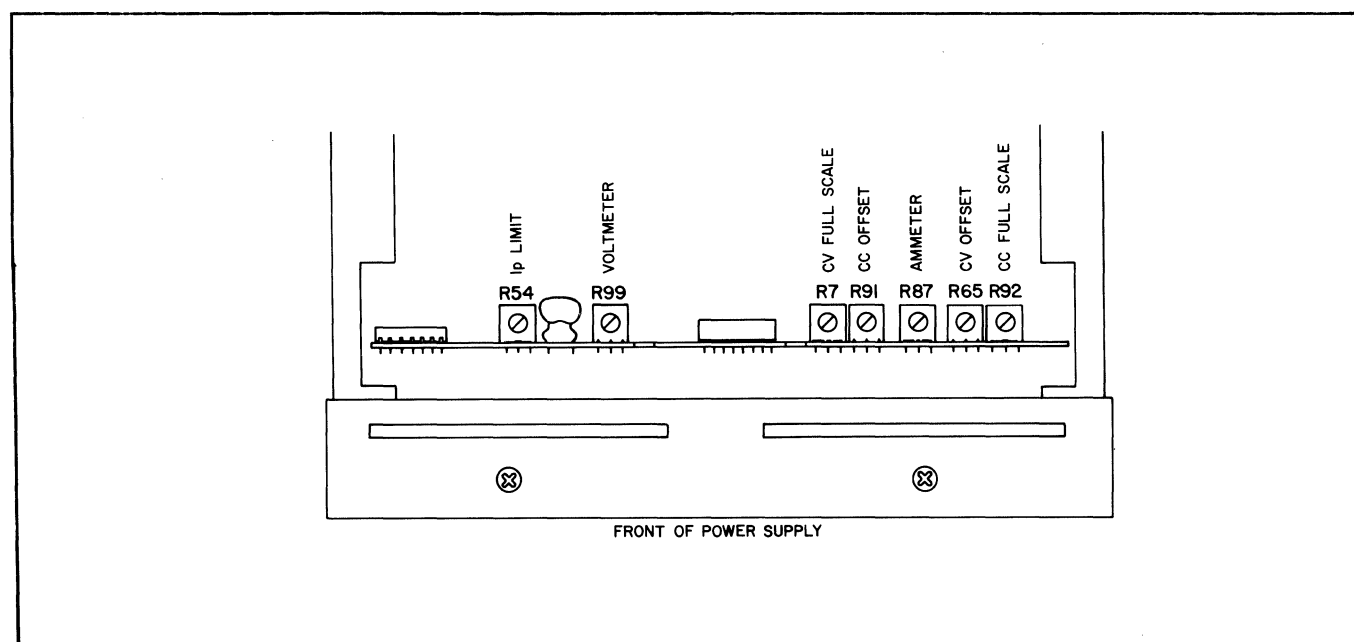


Figure 5-22. Location of Adjustment Potentiometers

- c. Adjust A2R65 for less than $\pm 2\text{mV}$ on DVM.
- d. Remove short between A2 and –S.

5-82 Constant Voltage Full Scale Adjustment

5-83 The CV full scale adjustment is made with a resistor whose value is known within 0.1% connected between terminals A2 and –S on rear panel. The nominal value of the resistor should be between 1k and 2.7k; a value of 1k is recommended for ease of calculating current flow through the resistor. Proceed as follows:

- a. Remove the strap between terminals A1 and A2 on rear panel.
- b. Connect digital voltmeter across resistor connected between terminals A2 and –S.
- c. Adjust A2R7 for $2\text{mA} \pm 0.2\%$ through resistor. (For example, if a 1k resistor is used, DVM reading of 2V indicates 2mA through resistor.)
- d. Disconnect resistor between A2 and –S and reconnect strap between A1 and A2.

5-84 Voltmeter Adjustment

5-85 Proceed as follows:

- a. Connect digital voltmeter to rear-panel output terminals.
- b. Adjust VOLTAGE control for $60\text{V} \pm 0.3\text{V}$ reading on DVM.
- c. Adjust A2R99 for 60V reading on front-panel voltmeter.

5-86 Constant-Current Offset Adjustment

5-87 Proceed as follows:

- a. Connect a 0.01Ω shunt across rear-panel output terminals.
- b. Connect digital voltmeter across shunt.
- c. Connect a short between terminals A7 and A5 on rear panel.
- d. Adjust A2R91 for less than $\pm 0.02\text{mV}$ on DVM (less than 2mA through shunt).
- e. Disconnect short between A7 and A5 and disconnect shunt from output terminals.

5-88 Constant-Current Full Scale Adjustment

5-89 Proceed as follows:

- a. Remove the strap between terminals A6 and

A7 on rear panel.

- b. Connect a 0.01Ω shunt across rear-panel output terminals.
- c. Connect digital voltmeter across shunt.
- d. Connect 5-volt supply ($\pm 5\text{mV}$) between terminals A7 (plus) and A5 (minus) on rear panel.
- e. Adjust A2R92 for $0.1\text{V} \pm 0.2\text{mV}$ on DVM ($10\text{A} \pm 20\text{mA}$ output).
- f. Disconnect 5-volt supply from A7 and A5, disconnect shunt from output terminals, and reconnect strap between A6 and A7.

5-90 Ammeter Adjustment

5-91 Proceed as follows:

- a. Ensure that CC full scale adjustment is set properly (Paragraph 5-82).
- b. Connect a 0.01Ω shunt across rear-panel output terminals.
- c. Connect digital voltmeter across shunt.
- d. Adjust CURRENT control for $0.1\text{V} \pm 0.5\text{mV}$ on DVM ($10\text{A} \pm 50\text{mA}$ output).
- e. Adjust A2R87 for 10A reading on front-panel ammeter.
- f. Disconnect shunt from output terminals.

5-92 I_p Limit Adjustment

5-93 The I_p limit adjustment ensures that the power supply will provide maximum output power under worst-case conditions. Proceed as follows:

- a. Connect power supply ac input to a variable autotransformer set for low-line ac input voltage (see paragraph 2-18).
- b. Adjust A2R54 fully counter clockwise.
- c. Connect DVM across rear-panel output terminals.
- d. With no load connected to 6024A output, adjust VOLTAGE control for 24V output as indicated by DVM.
- e. Connect variable load resistor in series with a 0.01Ω shunt across rear-panel output terminals. Load resistor should be set to less than 1Ω .
- f. Connect DVM across shunt.
- g. Adjust CURRENT control for 100mV reading on DVM (10A output current). CURRENT light should be on.
- h. Adjust A2R54 fully clockwise.
- i. Connect DVM across output terminals.
- j. Adjust variable load resistor for 23V output as indicated on DVM.
- k. *Slowly* adjust A2R54 counter clockwise just until CURRENT light turns off. UNREGULATED light should be on.
- l. Voltage reading on DVM should be $23\text{V} \pm 0.3\text{V}$. If not, repeat procedure with care.

SECTION VI REPLACEABLE PARTS

6-1 INTRODUCTION

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

- a. Reference Designators. Refer to Table 6-1.
- b. Hewlett-Packard Part Number.
- c. Total Quantity (TQ) used in that assembly.
- d. Description. Refer to Table 6-2 for abbreviations.
- e. Manufacturer's Federal Supply Code Number. Refer to Table 6-3 for manufacturer's name and address.
- f. Manufacturer's Part Number or Type.
- g. Parts not identified by a reference designator are listed at the end of Table 6-4 under Mechanical and/or Miscellaneous. The former consists of parts belonging to

Table 6-1 Reference Designators

A	Assembly	R	Resistor
B	Blower (fan)	RT	Thermistor
C	Capacitor	S	Switch
CR	Diode	T	Transformer
DS	Signaling Device (light)	TB	Terminal Block
F	Fuse	TS	Thermostat
FL	Filter	U	Integrated Circuit
J	Jack	VR	Voltage Regulator (zener diode)
L	Inductor	W	Wire (jumper)
M	Meter	X	Socket*
P	Plug	Y	Oscillator
Q	Transistor	Z	Network

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

and grouped by individual assemblies; the latter consists of all parts not immediately associated with an assembly.

6-3 ORDERING INFORMATION

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

Table 6-2. Description Abbreviations

AL	Aluminum	MET POLY	Metallized Poly-
AWG	American Wire Gauge		propylene
CAP	Capacitor	MO	Metal Oxide
CC	Carbon Compo- sition	NO	Normally Open
CER	Ceramic	POLY E	Polyester
C-F	Capacitor	PW	Power Wirewound
CONN	Connector	PWR	Power
DIO	Diode	RECT	Rectifier
DPDT	Double Pole Double Throw	RES	Resistor
F	Film	SI	Silicon
FC	Carbon Film/ Composition	SW-PB	Switch, Push- button
FET	Field Effect Transistor	SW-SL	Switch, Slide
F.S.	Full Scale	SW-THRM	Switch, Thermal
FW BRDG	Full Wave Bridge	TA	Tantalum
GEN PRP	General Purpose	TBAX	Tube Axial
IC	Integrated Circuit	TRMR	Trimmer
		VAR	Variable
		XFMR	Transformer
		XSTR	Transistor
		ZNR	Zener

Table 6-3. Code List of Manufacturers

Code	Manufacturer	Address
00853	Sangamo Electric Company	Pickens, SC
01121	Allen Bradley Company	Milwaukee, WI
01295	Texas Instruments Inc., Semicon Comp. Division	Dallas, TX
01686	RCL Electronics Inc.	Manchester, NH
02111	Spectrol Electronics Corporation	City of Ind, CA
03508	G.E. Company, Semiconductor Products Department	Auburn, NY
04713	Motorola Semiconductor Products	Phoenix, AZ
06776	Robinson Nugent Inc.	New Albany, IN
07263	Fairchild Semiconductor Division	Mountainview, CA
11502	TRW, Inc., Boone Division	Boone, NC
12954	Siemens Corporation Components Group	Scottsdale, AZ
12969	Unitrode Corporation	Watertown, MA
13606	Sprague Electric Company, Semiconductor Division	Concord, NH
14604	Elmwood Sensors, Inc.	Cranston, RI
14936	General Instrument Corporation, Semicon Products	Hicksville, NY
15818	Teledyne Semiconductor	Mountain View, CA
16299	Corning Glass Works, Component Division	Raleigh, NC
19701	Mepco/Electra Corporation	Mineral Wells, TX
20932	Emcon Division ITW	San Diego, CA
24226	Gowanda Electronics Corporation	Gowanda, NY
24546	Corning Glassworks	Bradford, PA
27014	National Semiconductor Corporation	Santa Clara, CA
27167	Corning Glassworks	Wilmington, NC
28480	Hewlett-Packard	Palo Alto, CA
2M627	R-Ohm Corporation	Irvine, CA
31918	ITT Schadow	Minneapolis, MN
32293	Intersil, Inc.	Cupertino, CA
32997	Bourns, Inc.	Riverside, CA
3L585	RCA Corporation, Solid State Division	Somerville, NJ
51167	Aries Electronics, Inc.	Frenchtown, NJ
54473	Matsushita Electric Corporation of America	New York, NY
56289	Sprague Electric Company	North Adams, MA
71400	Bussman Division of McGraw Edison Company	St. Louis, MO
71785	TRW Cinch Division	Elk Grove Village, IL
72982	Erie Technological Products, Inc.	Erie, PA
73138	Beckman Instruments, Inc., Helipot Division	Fullerton, CA
82389	Switchcraft, Inc.	Chicago, IL
82877	Rotron, Inc.	Woodstock, NY
83186	Victory Engineering Corporation	Springfield, NJ
84411	TRW Capacitor Division	Ogallala, NE
90201	Mallory Capacitor Company	Indianapolis, IN
90797	Magnetics Division, Spang Ind., Inc.	Butler, PA
91637	Dale Electronics, Inc.	Columbus, NE
CO633	Rifa	Bromma, Sweden
†	Wima	Mannheim, Germany

Table 6-4. Replaceable Parts

REF. DESIG.	HP PART NO.	TQ.	DESCRIPTION	MFR. CODE	MFR. PART NO.
A1	MAIN BOARD ASSEMBLY				
C1	0160-4962	1	CAP 1.0UF 20% 250 VAC	†	MKS4-R/1.0/250/20%
C2-5	0180-2968	4	C-F 590UF +50-10% 200V AL	56289	68DIO955
C6,7	0160-0269	2	CAP .1UF 20% 500V CER	28480	
C8,9	0160-4960	2	CAP 2200PF 10% 1.6KV	56289	715P222916LD3
C11	0160-3969	1	CAP .015UF ±20PF 250 VAC	C0633	PME271Y515
C12,13,22-25	0150-0012	6	CAP .01UF 20% 1KV CER	56289	CO23A102J103MS38
C15	0160-5022	1	CAP 2200PF 10% 600V POLY D	56289	715P22296JD3
C16-18	0180-2971	3	C-F 1700UF +50-10% 75V AL	00853	Type 101
C21,26	0160-4966	2	CAP 1UF 10% 100V MET-POLY	†	MKC4/1.0/100V/10%
C28	0160-0127	1	CAP 1UF 20% 25V CER	20932	5033ES25RD105M
C31	0140-0149	1	CAP 470PF 5% 300V MICA	28480	
C32	0160-4722	1	CAP .1UF +80 -20% 50V CER	16299	CACO3Z5U104Z050A
C33	0160-2639	1	CAP 5000PF 20% 100V CER	72982	835-100-Z5U-502M
C34	0180-0155	1	C-F 2.2UF 20% 20V TA	56289	150D225X0020A2
C35	0180-0693	1	C-F 1000UF +50%-10% 25V AL	54473	ECE-A25V1000L
C36,37	0180-2628	2	C-F 220UF +50-10% 50V	54473	ECE-A50V220L
C39	0180-0550	1	C-F 330UF +100-10% 25V	54473	ECE-A25V330L
C40	0180-1954	1	C-F 4.7UF ±5% 6V	12954	ST513A475J006N
CR1-4	1901-0759	4	DIO-IN5406	14936	1N5406
CR5,6	1901-1087	2	DIO-PWR RECT 600V 3A	04713	MR856
CR7,8	1901-1065	2	DIO-IN4936	14936	1N4936
*CR11,12	1901-0050	2	DIO-SWITCHING	28480	
CR13	1901-0888	1	DIO-PWR RECT	12969	UTG4008
CR14	1901-0496	1	DIO-PWR RECT 100V 12A	04713	MR1121
CR15,16,21,24-27	1901-0050	2	DIO-SWITCHING	07263	FDH6308
CR22,23	1901-0327	2	DIO-PWR RECT 200V 1A	03508	A14B
CR28	1901-0033	1	DIO-GEN PRP	07263	FDH3369
F2	2110-0202	1	FUSE .5A 250V	71400	MDL-1/2
L1,2		2	CHOKE ASSY, RFI, EACH CONSISTS OF:		
	9170-0721	1	CORE, MAGNETIC	28480	
	06024-80094	1	COIL	28480	
L3	06024-80096	1	INDUCTOR-3A SATURABLE	28480	
L4,5	9140-0179	2	COIL 22UH 10%	24226	15/222
L6	06024-80097	1	INDUCTOR-12A	28480	
L7		1	CHOKE ASSY, 3UH, CONSISTS OF:		
	9170-0707	1	CORE, MAGNETIC	28480	
	06024-80095	1	COIL	28480	
L10	9170-1134	1	CORE-MAGNETIC	28480	
*Q1,2	5080-1925	2	FET-T03	28480	
*Q3,4	1854-0477	2	XSTR NPN 2N2222A	04713	2N2222A
Q5	1854-0755	1	XSTR-NPN 2N6254	3L585	2N6254
Q6	1854-0644	1	XSTR NPN SI	3L585	29C
Q8,9	1854-0823	2	XSTR NPN SI	01295	SKCO221

* These components should all be replaced together. See Service Kit entry in Accessories list, Paragraph 1-16.

Table 6-4. Replaceable Parts

REF. DESIG.	HP PART NO.	TQ.	DESCRIPTION	MFR. CODE	MFR. PART NO.
Q10	1854-0585	1	XSTR NPN SI	04713	MJE182
Q11	1854-0477	1	XSTR NPN 2N2222A	04713	2N2222A
R1,2	2100-3831	2	RES-VAR 2.7K 5% 10-TURN	32997	83A1D-B24-BA0380
R3	2100-3207	1	RES-VAR 5K 10%	02111	63X502T623
R5,6	0811-1867	2	RES 15K 5% 5W PW	91637	RS-5
R7,8	0698-3547	2	RES 1 5% .5W CC	01121	EB-10G5
R11,18	0698-3601	2	RES 10 5% 2W	11502	GS-3
R12,19	0811-1857	2	RES 400 5% 5W PW	91637	RS-5
R13,20,64	0683-1055	3	RES 1M 5% .25W FC	01121	CB-1055
*R14,21	0698-3378	2	RES 51 5% .125W CC	01121	BB-5105
R15,22	0683-3915	2	RES 390 5% .25W FC	01121	CB-3915
*R16,23	0683-1015	2	RES 100 5% .25W FC	01121	CB-1015
R27	0698-3628	1	RES 220 5% 2W MO	27167	FP-42
R28,29	0811-1817	2	RES .4 5% 40W PW	91637	HLW-20-A1Z
R30	0698-3225	1	RES 1.43K 1% .125W F	24546	C4-1/8-TO-1431-F
R31	0811-1865	1	RES 2K1% 5W PW	91637	RS-5
R32	0689-6225	1	RES 6.2K 5% 1W CC	01121	GB6225
R33,37,40,56	0683-1025	4	RES 1K 5% .25W FC	01121	CB-1025
R34	0698-0084	1	RES 2.15K 1% .125W F	24546	C4-1/8-TO-2151-F
R35	0812-0019	1	RES .33 5% 3W PW	01686	T2B-79
R36	0757-0391	1	RES 3.92 1% .125W F	24546	C4-1/8-TO-39R2-F
R38	0683-2725	1	RES 2.7K 5% .25W FC	19701	(CR-25) 1-4-5P-2K7
R39,42,53	0757-0442	3	RES 10K 1% .125W F	24546	C4-1/8-TO-1002-F
R43	0757-0459	1	RES 56.2K 1% .125W F	91637	CMF-55-1,T-1
R44	0757-0317	1	RES 1.33K 1% .125W F	24546	C4-1/8-TO-1331-F
R45	0698-3160	1	RES 31.6K 1% .125W F	24546	C4-1/8-TO-3162-F
R46,47	0757-0472	2	RES 200K 1% .125W F	24546	C4-1/8-TO-2003-F
R48	0757-0473	1	RES 221K 1% .125W F	91637	CMF-55-1, T-1
R49	0757-0123	1	RES 34.8K 1% .125W F	24546	C4,T-O
R50	0698-3496	1	RES 3.57K 1% .125W F	24546	C4-1/8-TO-357R-F
R51	0757-0199	1	RES 21.5K 1% .125W F	24546	C4-1/8-TO2152-F
R52	0757-0410	1	RES 301 1% .125W F	91637	CMF-55-1,T-1
R54,55	0683-1535	2	RES 15K 5% .25W FC	01121	CB -1535
R58	0698-3151	1	RES 2.87K 1% .125W F	91637	CMF-55-1,T-1
R61	0686-4715	1	RES 470 5% .5W CC	01121	EB4715
R62	0683-3305	1	RES 33 5% .25W FC	01121	CB-3305
R63	0683-0275	1	RES 2.7 5% .25W FC	01121	CB-27G5
RT1,2	0839-0006	2	THERMISTOR DISC 10 ohm	03186	11E2/2
S1	3101-0426	1	SW-PB.DPDT-NO	31918	ZFFA-200-WHT-N30TVS
S2	3101-1914	1	SW-SL 2-DPDT	82389	11E-1060
T1	06024-80090	1	XFMR-PWR	28480	
T2	5080-1937	1	XFMR-CURRENT LIM	28480	
T3,4	06024-80092	2	XFMR-DRIVER	28480	
T5	06024-80091	1	XFMR-BIAS	28480	
TB1	0360-1957	1	TERM BLOCK, 13 TERM	28480	
TS1	3103-0017	1	SW-THRM +193F OPN-ON-RISE	14604	2455R-21-582
U1	1826-0161	1	IC 324 QUAD OP AMP	27014	LM324N
U2	1820-1050	1	IC DUAL 2-IN NOR, TTL	01295	SN75454BP
U3,4	1906-0006	2	DIO-FW BRDG 400V 1A	14936	WO4 Special
U5	1826-0346	1	IC OP AMP, DUAL	27014	LM358N

* These components should all be replaced together. See Service Kit entry in Accessories list, Paragraph 1-16.

Table 6-4. Replaceable Parts

REF. DESIG.	HP PART NO.	TQ.	DESCRIPTION	MFR. CODE	MFR. PART NO.
VR1,4	1902-0575	2	DIO-ZNR 6.5V 2%	12954	SZ11594
VR2	1902-3002	1	DIO-ZNR 2.37V 5%	04713	SZ10939-2
VR3	1902-0057	1	DIO-ZNR 6.49V 5%	12954	DZ730821C
VR5	1902-3180	1	DIO-ZNR 11.8V 2%	04713	SZ30016-204
VR6	1902-3092	1	DIO-ZNR 4.99V 2%	12954	DZ730818Z
XA2	1251-1886	1	CONN-PC EDGE 15 CONT/ROW, 2 ROW	71785	252-15-30-341
W1		1	WIRE 18AWG 1 INCH		
A2	CONTROL BOARD ASSEMBLY				
C1,2,11	0180-0291	3	C-F 1UF 10% 35V TA	56289	150D105X9035A2
C3,4	0160-0174	2	CAP .47UF +80-20% 25V CER	20932	5033ES25RD47RZ
C5	0160-2215	1	CAP 750PF 5% 300V MICA	28480	
C6	0140-0200	1	CAP 390PF 5% 300V MICA	28480	
C7,14-16,29	0160-4722	5	CAP .1UF +80-20% 50V CER	16299	CACO3Z5U104Z050A
C9,10	0160-3070	2	CAP 100PF 5% 300V MICA	28480	
C12,13,17,35	0140-0199	4	CAP 240PF 5% 300V MICA	28480	
C18,21	0160-0159	2	CAP 6800PF 10% 200V POLYE	56289	192P68292
C19	0160-0153	1	CAP 1000PF 10% 200V POLYE	56289	192P10292
C20	0170-0040	1	CAP .047UF 10% 200V POLYE	56289	192P47392
C22	0140-0203	1	CAP 30 PF 5% 500V MICA	28480	
C23	0160-0128	1	CAP 2.2UF 20% 50V CER	20932	5043ES50RD225M
C24	0160-0127	1	CAP 1UF 20% 25V CER	20932	5033ES25RD105M
C25	0160-4741	1	CAP .22UF 10% 50V CER	20932	5030EM50RD224M
C26,31,32	0160-4557	3	CAP .1UF 20% 50V CER	16299	CACO4X7R104M050A
C27	0160-0154	1	CAP 2200PF 10% 200V POLYE	56289	192P22292
C28	0180-0550	1	C-F 330UF +100-10% 25V AL	54473	ECE-A25V330L
C30,34	0160-3490	2	CAP 1UF 20% 50V CER	20932	5030ES50RD105M
C33	0160-0162	1	CAP .022UF 10% 200V POLYE	84411	HEW-238M
C36	0160-0161	1	CAP .01UF 10% 200V POLYE	56289	192P10392
CR1,5,6,13,14, 18-20,23,25-27	1901-0050	2	DIO-SWITCHING	07263	FDH 6308
CR7-10,15-17,24, 30,31	1901-0033	10	DIO-GEN PRP	07263	FDH3369
J1	1200-0507	1	CONNECTOR, 16 PIN	06776	0002811
J2	1200-0835	1	CONNECTOR, 5 PIN	51167	5-0513-10
Q1	1854-0448	1	XSTR NPN SI	04713	SS1147
Q2	1853-0041	1	XSTR PNP SI	07263	S21297
Q4-8,14	1854-0823	6	XSTR NPN SI	01295	SKC0221
Q12	1855-0413	1	J-FET P-CHAN D-MODE	28480	
Q13	1853-0086	1	XSTR PNP SI 2N5087	27014	2N5087
R1	0683-2025	1	RES 2K 5% .25W FC	19701	(CR-25) 1-4-5P-2K
R2,110	0757-0436	2	RES 4.32K 1% .125W F	91637	CMF-55-I, T-1
R3	0698-4435	1	RES 2.49K 1% .125W F	24546	C4-1/8-TO-2491-F
R4	0757-0290	1	RES 6.19K 1% .125W F	24546	C4,T-O
R5	0698-4196	1	RES 1.07K 1% .125W F	24546	C4-1/8-TO-1071-F
R6,83,86,102,120, 123	0757-0438	6	RES 5.11K 1% .125W F	24546	C4-1/8-TO-5111-F
R7,87	2100-3273	2	RES-TRMR 2K 10%	73138	72XR2K
R8	0757-0440	1	RES 7.5K 1% .125W F	24546	C4-1/8-TO-7501-F
R9	0698-4484	1	RES 19.1K 1% .125W F	24546	C4-1/8-TO-1912-F
R10	0757-0446	1	RES 15K 1% .125W F	24546	C4-1/8-TO-1502-F
R11	0698-4470	1	RES 6.98K 1% .125W F	91637	CMF-55-1-T-1
R15,20,50,81	0757-0442	4	RES 10K 1% .125W F	24546	C4-1/8-TO-1002-F
R16	0757-0416	1	RES 511 1% .125W F	24546	C4-1/8-TO-511R-F
R17,98	0698-3449	2	RES 28.7K 1% .125W F	91637	CMF-55-1, T-1
R18,23,24,29,34, 49,113,114	0698-0084	8	RES 2.15K 1% .125W F	24546	C4-1/8-TO-2151-F
R19,21,32,33, 69,117	0757-0449	6	RES 20K 1% .125W F	91637	CMF-55-I, T-1

Table 6-4. Replaceable Parts

REF. DESIG.	HP PART NO.	TQ.	DESCRIPTION	MFR. CODE	MFR. PART NO.
R25	0757-0413	1	RES 392 1% .125W F	24546	C4-1/8-TO-392R-F
R26,27	0757-0433	2	RES 3.32K 1% .125W F	24546	C4-1/8-TO-3321-F
R28	0757-0427	1	RES 1.5K 1% .125W F	24546	C4-1/8-TO-1501-F
R35,79	0683-1055	2	RES 1M 5% .25W FC	01121	CB-1055
R36	0683-3335	1	RES 33K 5% .25W FC	01121	CB-3335
R40	0698-3498	1	RES 8.66K 1% .125W F	24546	C4-1/8-TO-866R-F
R43	0683-2225	1	RES 2.2K 5% .25W FC	01121	CB-2225
R44,61,68,124	0683-1045	4	RES 100K 5% .25W FC	01121	CB-1045
R45,46	0683-4725	2	RES 4.7K 5% .25W FC	01121	CB-4725
R47	0757-0418	1	RES 619 1% .125W F	24546	C4-1/8-TO-619R-F
R51	0757-0424	1	RES 1.1K 1% .125W F	24546	C4-1/8-TO-1101-F
R52,89	0757-0280	2	RES 1K 1% .125W F	24546	C4-1/8-TO-1001-F
R53,67	0757-0447	2	RES 16.2K 1% .125W F	91637	CMF-55-1,T-1
R54,92	2100-3351	2	RES-TRMR 500 10%	02111	63X501T623
R55	0757-0270	2	RES 249K 1% .125W F	24546	C4-1/8-TO-2493-F
R56	0757-0473	1	RES 221K 1% .125W F	91637	CMF-55-1, T-1
R58	0698-4536	1	RES 340K 1% .125W F	24546	NA4
R59	0683-6835	1	RES 68K 5% .25W FC	2M627	R-25J
R60	0757-0461	1	RES 68.1K 1% .125W F	14546	C4-1/8-TO-6812-F
R62	0698-3460	1	RES 422K 1% .125W F	24546	NA4
R63	0683-1065	1	RES 10M 5% .25W F	01121	CB1065
R64	0698-5094	1	RES 5.1M 5% .25W F	01121	CB5155
R65,91,99	2100-3353	3	RES-TRMR 20K 10%	02111	63X203T623
R66,126	0757-0278	2	RES 1.78K 1% .125W F	91637	CMF-55-1,T-1
R70	0698-7497	1	RES 100K .1% .25W F	91637	CMF-60-1,T-9
R71	0698-6343	1	RES 9K .1% .125W F	91637	CMF-55-1,T-9
R72	0757-0400	1	RES 90.9 1% .125 W F	24546	C4-1/8-TO-90R9-F
R73,74	0686-1535	2	RES 15K 5% .5W CC	01121	EB1535
R75,76	0698-6631	2	RES 2.5K .1% .125W F	24546	NE55
R77,78,84,85	0686-1035	4	RES 10K 5% .5W CC	01121	EB1035
R80,112	0757-0458	2	RES 51.1K 1% .125W F	24546	C4-1/8-TO-5112-F
R82	0683-1645	1	RES 160K 5% .25W FC	24546	R-25J
R90,95,97	0757-0344	3	RES 1M 1% .25W F	19701	MF52C-1
R93	0698-6341	1	RES 750 1% .125W F	24546	NE55
R94	0698-3274	1	RES 10K 1% .125W F	24546	NE55
R96	0698-3150	1	RES 2.37K 1% .125W F	24546	C4-1/8-TO-2371-F
R100	0683-5105	1	RES 51 5% .25W FC	2M627	R-25J
R101	0683-0275	1	RES 2.7 5% .25W FC	01121	CB-0275
R104,106	0683-1215	2	RES 120 5% .25W FC	2M627	R-25J
R108	0698-4121	1	RES 11.3K 1% .125W F	24546	C4-1/8-TO-1132-F
R109,116	0698-3439	2	RES 178 1% .125W F	24546	C4-1/8-TO-178R-F
R111	0698-4014	1	RES 787 1% .125W F	91637	CMF-55-1,T-1
R118	0698-3430	1	RES 21.5 1% .125W F	24546	C4-TO
R121	0757-0421	1	RES 825 1% .125W F	24546	C4-1/8-TO-825R-F
R122	0757-0282	1	RES 221 1% .125W F	24546	C4-1/8-TO-221R-F
U1	1826-0144	1	IC VOLTAGE REG, +5V	07263	7805UC
U2,3	1820-0493	2	IC OP AMP	27014	LM307N
U4	1826-0138	1	IC COMPARATOR, QUAD	04713	MLM339P
U5	1820-1443	1	IC COUNTER, TTL	04713	SN74LS293N
U6,12	1826-0065	2	IC COMPARATOR	27014	LM311N
U7	1820-1203	1	IC 3-IN AND, TRIPLE	01295	SN74LS11N
U8	1820-1209	1	IC 2-IN NAND, QUAD	01295	SN74LS38N
U9	1820-1112	1	IC D-TYPE FF	27014	SN74LS74N
U10	1820-1437	1	MONO FF, DUAL	01295	SN74LS221N
U11,14	1826-0161	2	IC 324 OP AMP, QUAD	27014	LM324N
U13	1826-0433	1	IC OP AMP	27014	LF3568N
VR1	1902-0777	1	DIO-ZNR 6.2V 5%	04713	IN825
VR2	1902-0575	1	DIO-ZNR 6.5V 2%	12954	SZ11594

Table 6-4. Replaceable Parts

REF. DESIG.	HP PART NO.	TO.	DESCRIPTION	MFR. CODE	MFR. PART NO.
VR3 Y1 Z1 Z2	1902-0057 0960-0586 1810-0231 1810-0279	1 1 1 1	DIO-ZNR 6.49V 5% RESONATOR-CER NETWORK-RES 2.2K X 7 NETWORK-RES 4.7K X 9	12954 28480 91637 91637	DZ730821C CSP08G01-222G/ MSP08A01-222G/ CSP10G01-472G/ MSP10A01-472G
A3	METER BOARD ASSEMBLY				
DS1,2	1990-0486	2	LED-VISIBLE, RED	28480	
DS3,4	1990-0485	2	LED-VISIBLE, GREEN	28480	
M1	1120-1389	1	VOLTMETER, 70V (1mA F.S.)	28480	
M2	1120-1390	1	AMMETER, 12A (1mA F.S.)	28480	
P1	8120-2886	1	CABLE ASSY, 5-WIRE	28480	
	CHASSIS-ELECTRICAL PARTS				
B1	3160-0343	1	FAN-TBAX	82877	SUZA5
F1	2110-0056	1	FUSE 6A 250V (100V OR 120V INPUT)	71400	MTH-6
	2110-0055	1	FUSE 4A 250V (220V OR 240V INPUT)	71400	MTH-4
FL1	9135-0124	1	RFI FILTER	28480	
A1	MAIN BOARD-MECHANICAL				
	1510-0091	2	BINDING POST, RED (+,-)	28480	
	1510-0107	1	BINDING POST, BLACK (GROUND)	28480	
	06024-00012	1	BRACKET ASSY, BINDING POST	28480	
	0370-1091	2	KNOB, ROUND (R1,R2)	28480	
	3131-0419	1	NUT, GRAY PLASTIC	28480	
	06024-00009	2	HEAT SINK, FET (Q1,Q2)	28480	
	0340-0503	2	INSULATOR, TO3, PLASTIC (Q1, Q2)	28480	
	0340-0174	2	INSULATOR, TO3, MICA (Q1,Q2)	28480	
	3050-0311	4	SPACER, PLASTIC (Q1,Q2)	28480	
	06024-00010	1	HEAT SINK (Q5,CR13,CR14)	28480	
	2190-0709	1	INSULATOR,ROUND, MICA (CR13)	28480	
	0340-0171	1	INSULATOR BUSHING (CR13)	28480	
	0340-0170	1	INSULATOR BUSHING (CR14)	28480	
	1205-0282	1	HEAT SINK (Q6)	28480	
	2110-0269	2	FUSEHOLDER, CLIP TYPE (F2)	28480	
	0890-0309	1	TUBING, FLEXIBLE, 1.15FT (AC INPUT)	28480	
	0340-0784	1	INSULATOR BUSHING (T2)	28480	
A2	CONTROL BOARD-MECHANICAL				
	1205-0282	1	HEAT SINK (U1)	28480	
	1200-0181	2	SPACER, ROUND PLASTIC (Q1, Q2)	28480	
A3	METER BOARD-MECHANICAL				
	0380-1184	4	SPACER, ROUND PLASTIC (DS1-DS4)	28480	
	8120-2886	1	CABLE ASSEMBLY, 5-WIRE	28480	
	CHASSIS-MECHANICAL				
	06024-00001	1	OVERLAY, FRONT PANEL (STD)	28480	
	06024-00006	1	CHASSIS ASSY, FRONT	28480	

REF. DESIG.	HP PART NO.	TQ.	DESCRIPTION	MFR. CODE	MFR. PART NO.
	06024-00002	1	BEZEL, FRONT	28480	
	5001-0439	2	TRIM STRIPS, VINYL	28480	
	06024-00003	1	CHASSIS ASSY, REAR PANEL	28480	
	06024-00005	1	CHASSIS ASSY, RIGHT SIDE	28480	
	06024-00004	1	CHASSIS ASSY, LEFT SIDE	28480	
	06024-00008	1	COVER, TOP	28480	
	06024-00007	1	COVER, BOTTOM	28480	
	5040-7201	4	FOOT	28480	
	1390-0481	5	SUPPORT SPACERS, PLASTIC (A1)	28480	
	0590-0052	8	NUT, SHEETMETAL	28480	
	06024-00013	1	BRACKET (A1T5)	28480	
	1400-0332	1	CABLE CLAMP	28480	
	2110-0564	1	FUSEHOLDER BODY (F1)	28480	
	2110-0565	1	FUSEHOLDER CAP (F1)	28480	
	2110-0569	1	FUSEHOLDER NUT (F1)	28480	
	0360-0523	6	JUMPER, TERMINAL BLOCK (TB1)	28480	
	06024-20001	1	COVER, TERMINAL BLOCK (TB1)	28480	
	7120-7659	1	LABEL, 104-127V	28480	
	7120-7661	1	LABEL, 191-233V (OPTION 220)	28480	
	7120-7660	1	LABEL, 208-250V (OPTION 240)	28480	
	MISCELLANEOUS				
	9211-3386	1	PACKING CARTON	28480	
	9220-3278	1	FLOATER PAD FOR PACKING CARTON	28480	

SECTION VII COMPONENT LOCATION ILLUSTRATIONS AND CIRCUIT DIAGRAMS

7-1 This section contains component location diagrams, a schematic diagram, and other drawings and tables useful for maintenance of the 6024A power supply. (Illustrations for Option 002 are given in Appendix A.) Included in this section are:

- a. Component location diagrams (Figures 7-1 through 7-3), showing the physical location and reference designators of almost all electrical parts. (The four front-panel LEDs are mounted on the A3 Meter Board and are identified by lettering on the board and front panel.)
- b. Test point description table (Table 7-1), listing the signals at the 26-pin edge connector (P2) and the 16-pin option-002 jack (J1) at the top of the A2 Control Board.

- c. Bias supplies table (Table 7-2), listing the semiconductor components operating on each bias supply.
- d. Logic symbols diagram (Figure 7-4), illustrating the logic symbols used on the schematic.
- e. Power supply waveforms (Figure 7-5), illustrating waveforms found at key points in the power supply under various conditions.
- f. Schematic diagram (Figure 7-6), including case outline drawings for each of the semiconductor components used in the power supply. The test points shown on the schematic are described in Table 7-1.

WARNING

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

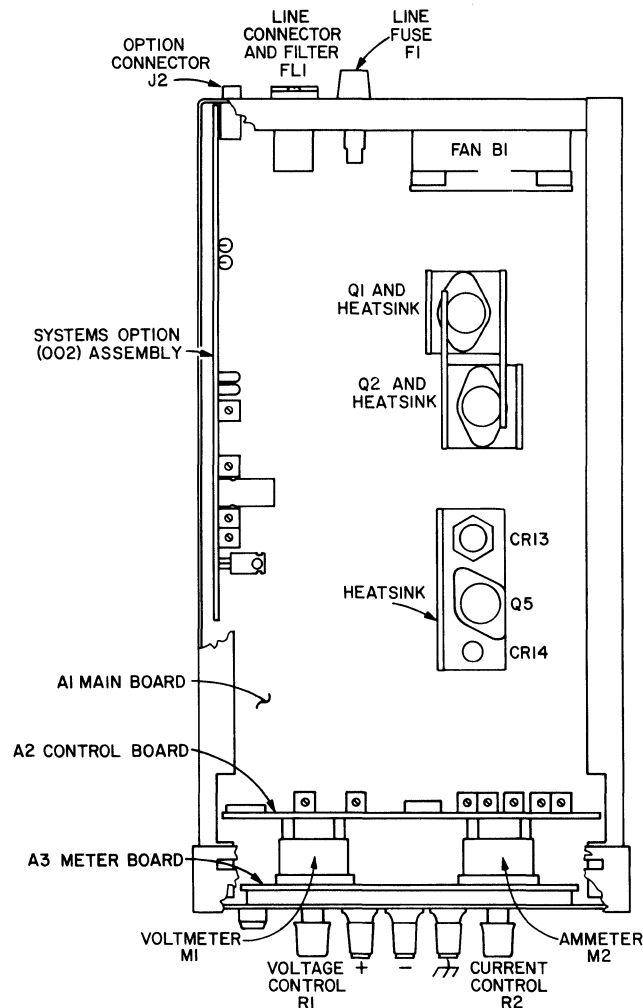


Figure 7-1. Top View, Cover Removed

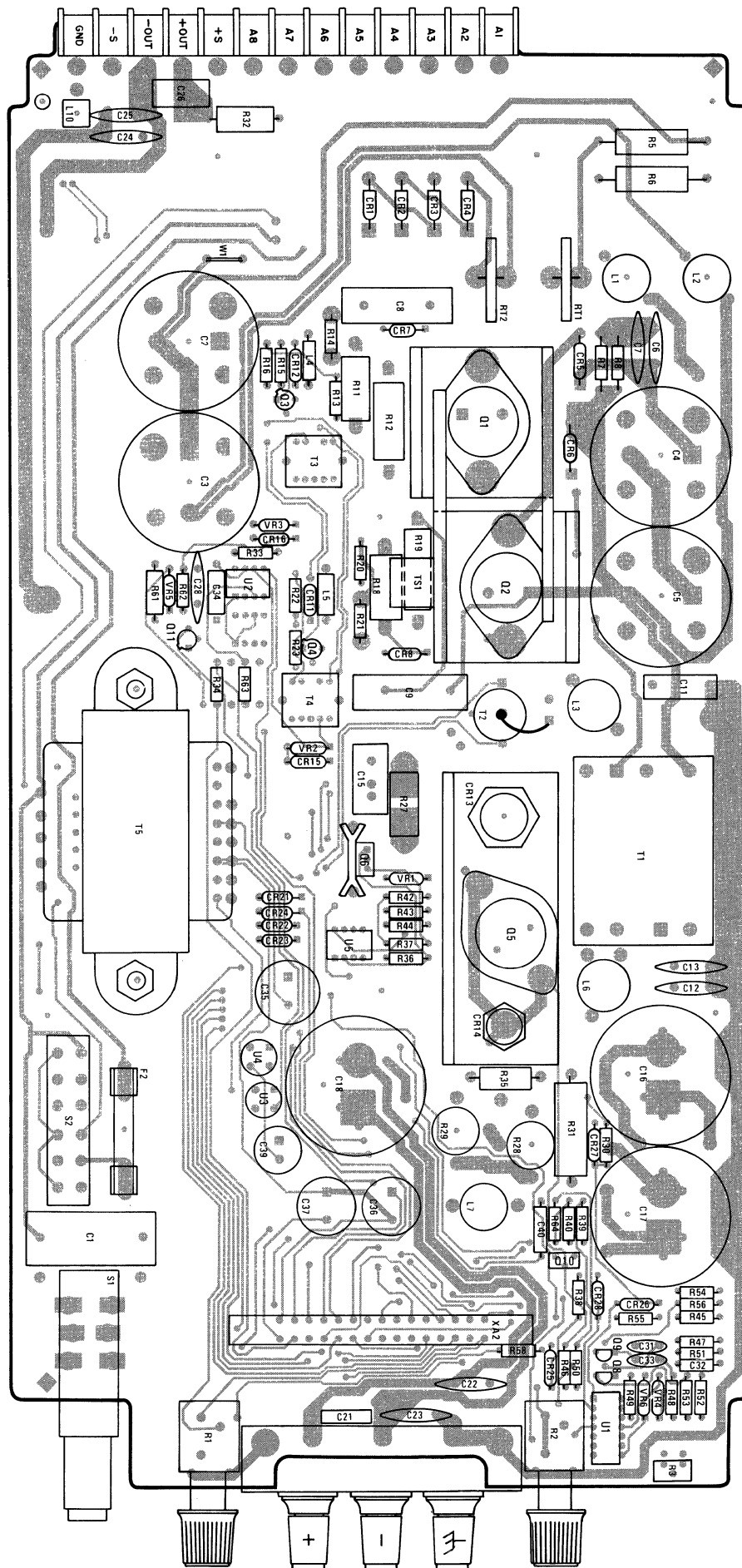


Figure 7-2. Main Board (A1), Component Location

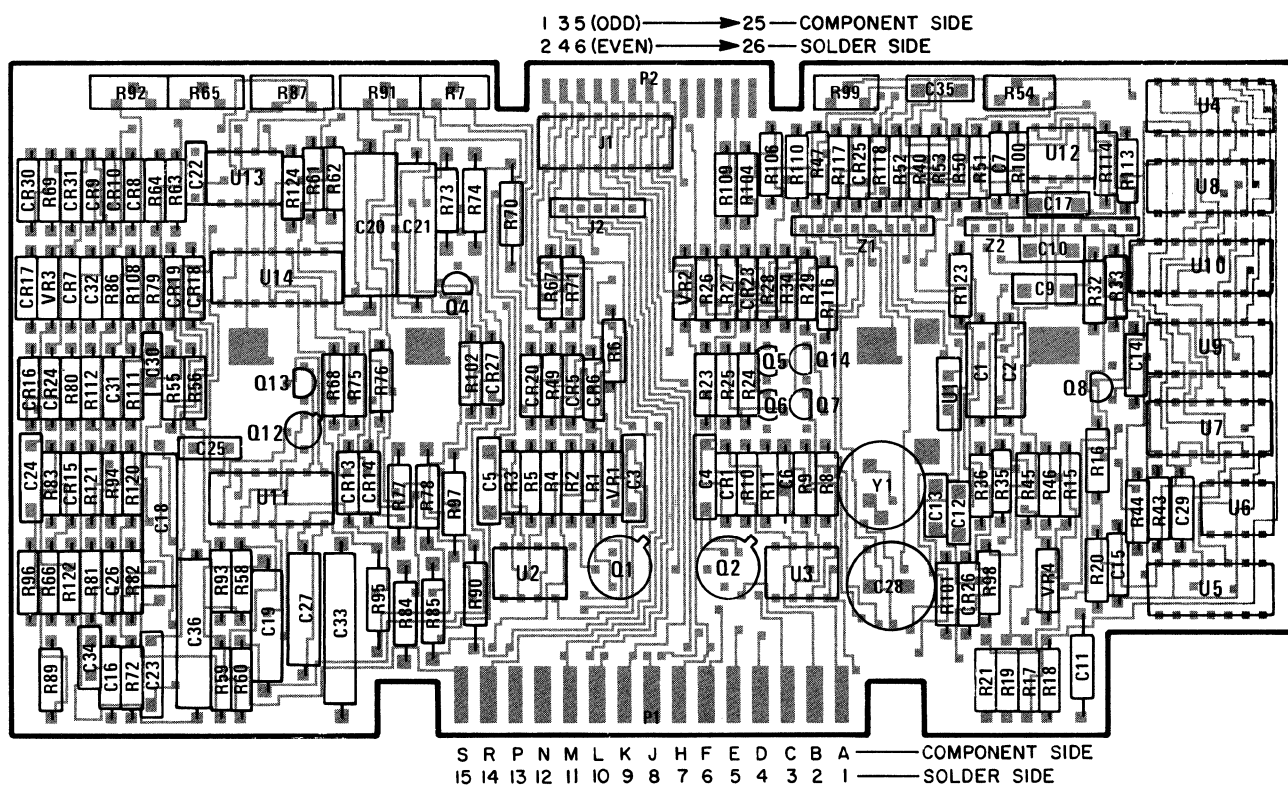


Figure 7-3. Control Board (A2), Component Location

Table 7-1. Test Point Descriptions

Test Point Connector P2 Pin No.	Option 002 Connector J1 Pin No.	Description
1	1	CV Programming Voltage
2	16	–Sense
3	2	I-Monitor Buffer Amplifier Output
4	15	Overvoltage Status (low = overvoltage)
5	3	+ Sense
6	14	Outboard Sense (outboard side of current-monitor resistor)
7	4	CC Programming Voltage
8	13	–12V Unregulated ($\approx -25V$)
9	5	Constant Voltage Mode (low = CV)
10	12	Overvoltage Remote Reset Input
11	6	+15V Unregulated ($\approx +25V$)
12	11	Bias Power Supplies Common
13	7	Low Bias Voltage or AC Dropout (low=low bias or ac dropout)
14	10	Over Temperature Status (low= over temperature)
15	8	Constant Current Mode (low = CC)
16	9	+5V Unregulated ($\approx +16V$)
17	—	Signal To “On” Driver
18	—	Signal To “Off” Driver
19	—	(not used)
20	—	+15V Regulated
21	—	+5V Regulated
22	—	Inboard Sense (inboard side of current-monitor resistor)
23	—	20kHz Clock Signal
24	—	–12V Regulated
25	—	(not used)
26	—	I_P (Primary Current) Ramp Voltage

Table 7-2. Semiconductor Components Operating On Each Bias Supply

+5V REG	+15V REG	–12 REG
A1U2	A1Q8 (+6.5V)	A2U11
A2Q4	A1U1 (+14.5V)	A2U12
A2Q6	A2Q12	A2U13
A2Q7	A2Q13	A2U14
A2Q8	A2U11	
A2Q9	A2U13	
A2Q14	A2U14	
A2U4		
A2U5	+15V UNREG	–12V UNREG
A2U6	A2U2	A2U3
A2U7		
A2U8	+5V UNREG	–8V UNREG
A2U9		
A2U10	A1Q11	A1Q6
A2U12	A2Q5	A1U5
	A2U1	

Figure 7-4. Logic Symbols and Definitions

Definitions

High = more positive
Low = less positive

Indicator And Qualifier Symbols

- ▷ (polarity indicator, shown outside logic symbol) Any marked input or output is active low; any unmarked input or output is active high.
- ▷ (dynamic indicator) Any marked input is edge-triggered, ie, active during transition between states; any unmarked input is level sensitive.
- ◇ open-collector output
- 1┐ monostable (one-shot) multivibrator
- t=xSec indicates pulse width (usually determined by external RC network)
- G gate input (a number following G indicates which inputs are gated)
- C control input (clock)
- R reset (clear)
- S set

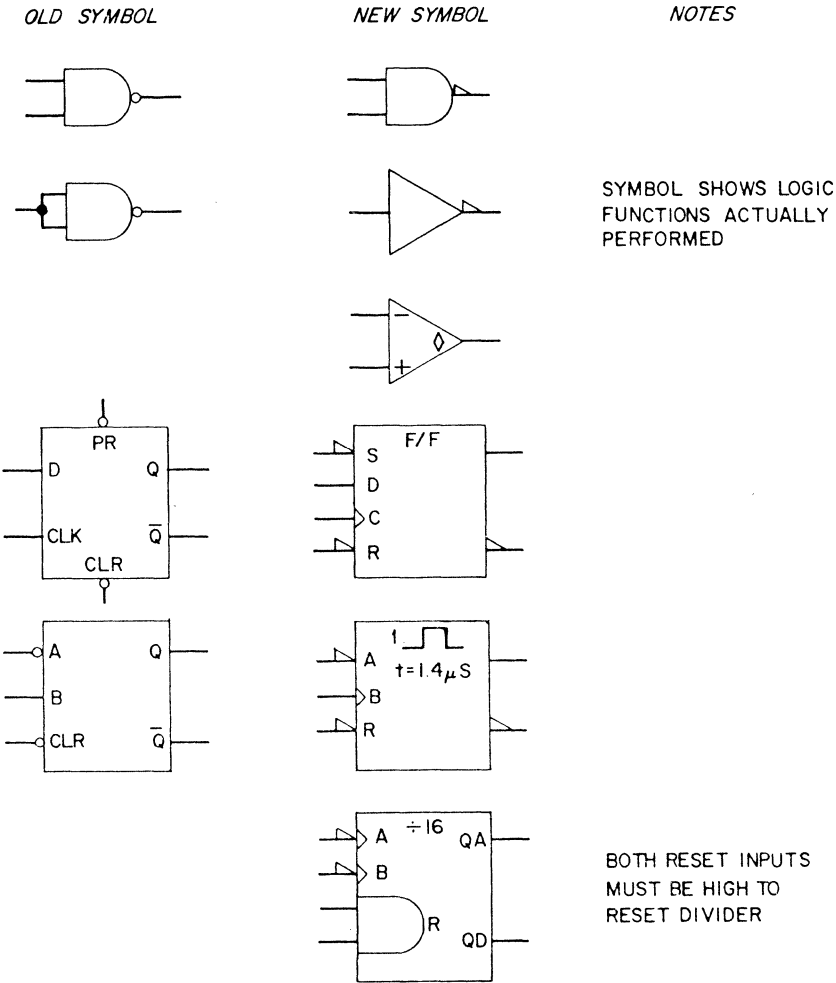


Figure 7-5. Waveforms

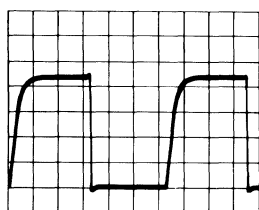
NOTE: Waveforms taken with 200-ohm 10-watt resistor connected across rear output terminals, VOLTAGE and CURRENT controls set to mid-range (5 turns), and OVP ADJUST set to maximum (fully CW). Except for waveforms 5 and 6, oscilloscope probe is grounded at A2U1 heat sink. Waveforms 5, 6, and 7 are taken with reduced voltage on 6024A input rails (see Figure 5-20, note 2).

CAUTION

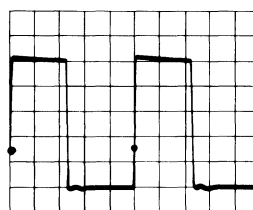
Turn power off while connecting or disconnecting test equipment from 6024A.

WARNING

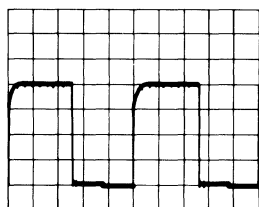
Maintenance described herein is performed with power supplied to the instrument, and protective covers removed. Such maintenance should be performed only by service-trained personnel who are aware of the hazards involved (for example, fire and electrical shock). Where maintenance can be performed without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



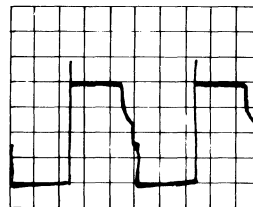
[1]
A2U6-7
320kHz CLOCK
0.5 μ S/DIVISION
1V/DIVISION



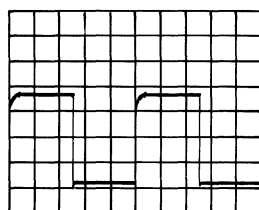
[5]
A1Q1 V_{GS}
A1Q2 V_{GS}
10 μ S/DIVISION
5V/DIVISION



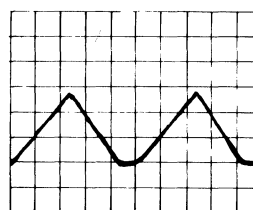
[2]
T. P. 23
20kHz CLOCK
10 μ S/DIVISION
1V/DIVISION



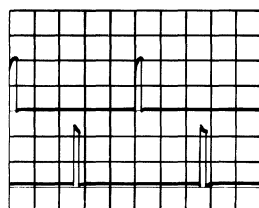
[6]
A1Q1 V_{DS}
A1Q2 V_{DS}
10 μ S/DIVISION
10V/DIVISION



[3]
A2U9-9
PWM OUTPUT
10 μ S/DIVISION
1V/DIVISION



[7]
A2U4B-6
I_p SENSE
10 μ S/DIVISION
0.05V/DIVISION



[4]
T. P. 17
ON PULSE
10 μ S/DIVISION
2V/DIVISION

T. P. 18
OFF PULSE
10 μ S/DIVISION
2V/DIVISION

APPENDIX A

System Option 002

A-1 GENERAL INFORMATION

A-2 This option facilitates the operation of a 6024A power supply in an automated system. Four major circuit blocks provide: 1) remote analog programming of the supply's output by three different control methods; 2) signals indicating the power supply modes and conditions; 3) two different digital methods of remote control; and 4) the outputs of three bias supplies for use with external circuitry.

A-3 A 6024A power supply equipped with this option can be operated from a 6940B Multiprogrammer equipped with a 69520A Power Supply Programming Card. Details are provided in the 69520A Manual.

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

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

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

the power supply for the duration of the low level.

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

A-8 Monitoring of the output voltage and current of the power supply is also possible at the option connector.

A-9 Other modes of operation, such as multiple supply system control, are described in detail in later paragraphs. Modes such as Auto-Series, Auto-Parallel, and Auto-Tracking operation, as described in Section 3 of the main text are also available.

A-10 Specifications

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

A-12 Option 002 Hardware

A-13 The option 002 hardware consists of a single printed-circuit board installed at the left of the 6024A chassis (see Figure 7-1). A cable connects the option board to the A2 control board at A2J1. Connections between the option board and external circuits are made via a 37-pin connector mounted on the option board and available at the rear of the power supply. A mating connector is also included for the user's convenience.

Table A-1. Specifications, Option 002

<p>All 6024A specifications remain the same unless otherwise noted. All specifications are at option board connector J1.</p> <p>REMOTE PROGRAMMING:</p> <p>Resistance Programming - 0 to 2.5 k Ω provides zero to maximum rated voltage or current output. Accuracy @ 25°C: CV; 0.8% + 30 mV CC; 2.5% + 10 mA</p> <p>Voltage Programming - 0 to 5V provides zero to maximum rated voltage or current output. Accuracy @ 25°C: CV; 0.2% + 2 mV CC; 1.0% + 2 mA</p> <p>Current Programming - 0 to 2 mA current sink provides zero to maximum rated voltage or current output. Accuracy @ 25°C: CV; 0.3% + 8 mV CC; 1.1% + 3 mA Input Compliance Voltage: ± 1 V</p>	<p>Current Programming Enable - Relays K1 (CV) and K2 (CC) are biased from the CONTROL ISOLATOR BIAS input (see Remote Shutdown and OVP Clear).</p> <p>Relay bias voltage; + 4 V minimum + 7 V maximum</p> <p>Relay resistance; 500Ω \pm 10%</p> <p>Note: For CONTROL ISOLATOR BIAS voltages greater than 7 V, a series resistor must be used to maintain the relay bias voltage within specified limits.</p> <p>Enabling either relay is accomplished by bringing CV or CC enable line to CONTROL ISOLATOR BIAS common via a suitable driver; maximum driver off-state leakage = 0.5 mA.</p>
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Table A-1. Specifications, Option 002 (cont.)

OUTPUT VOLTAGE MONITOR: 0 to 5 V output indicates zero to maximum rated output voltage.
Accuracy @ 25°C; 0.2% + 1 mV
Output Impedance; 8.3 k Ω
Temperature Coefficient; 0.01% / °C

STATUS INDICATORS:

STATUS ISOLATOR BIAS input (referred to STATUS ISOLATOR COMMON);

Voltage range; +4.75 V to +16 V

Current Drain; 20 mA maximum

Status Indicator outputs;

Open-collector outputs

Maximum output voltage (logic high); +16 V

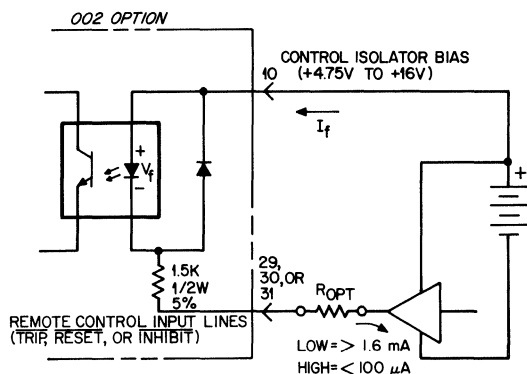
Logic low output; +0.4 V maximum at 8 mA

REMOTE CONTROL (TRIP, RESET, INHIBIT)

CONTROL ISOLATOR BIAS input;

Voltage range; +4.75 V to +16 V

Remote control inputs (REMOTE TRIP, REMOTE RESET, REMOTE INHIBIT);



On state (logic low); Minimum forward current required (I_F): 1.6 mA

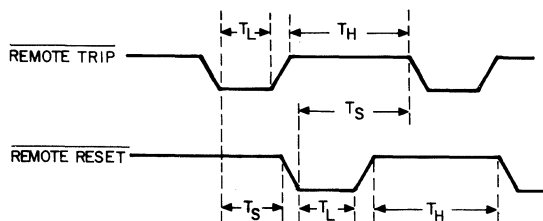
Isolator forward voltage (V_F) at 1.6 mA

I_F : 1.4 V typical, 1.75 V maximum

For CONTROL ISOLATOR BIAS voltage greater than +5 V, an optional resistor (R_{OPT}) may be added to reduce drive current.

Off state (logic high) maximum leakage current; 100 μ A

REMOTE TRIP and REMOTE RESET timing;



Pulse duration (T_L): 15 μ s minimum
Reset time (T_H): 125 μ s minimum
Set-up time (T_S): 25 μ s minimum
OVP Clear delay (to 6024 mainframe); 1 sec. \pm 30%

POWER-ON PRESET:

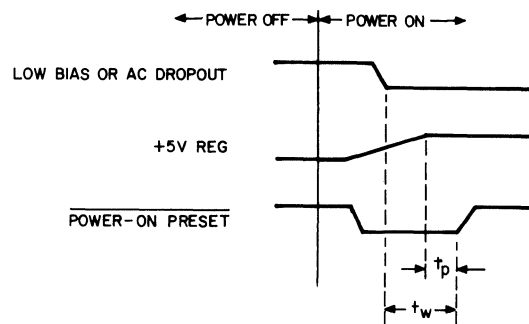
Output ratings;

Open collector output (referred to power supply common)

Maximum output voltage (logic high); +16 V

Logic low output; +0.4 V maximum at 8 mA

POWER-ON PRESET pulse timing;



Wait time after LOW BIAS OR AC DROPOUT indication (T_W): 750 ms maximum

Pulse duration after +5 V REG has stabilized (T_p): 10 ms minimum

BIAS SUPPLIES:

DC output ratings (0 to 55°C);

+ 5 V \pm 1.3% at 100 mA

+ 15 V \pm 1.5% at 75 mA

- 15 V \pm 2.5% at 75 mA

Short circuit output current;

+ 5 V - 170 mA \pm 15%

+ 15 V - 125 mA \pm 15%

- 15 V - 125 mA \pm 20%

Load and Source Effect; Change in output voltage for a load change equal to the maximum available current rating of the supply plus any line voltage change within rating;

+ 5 V - 2.5%

+ 15 V - 3.0%

- 15 V - 1.0%

PARD (typical);

+ 5 V - 1 mV RMS

+ 15 V - 1 mV RMS

- 15 V - 2 mV RMS

ISOLATION:

Status Indicator lines and Remote Control lines may be floated a maximum of 600 VDC from ground, from the power supply output or from each other. These lines may not be connected to any primary circuits.

A-14 INSTALLATION

A-15 The 002 option board can be installed in a 6024A power supply by the user. Proceed as follows:

- a. Turn off power supply and disconnect line cord.
- b. Remove four screws that secure top cover to instrument. Slide cover to rear and lift off.
- c. Remove four screws, one at top and one at bottom on each side, rear of chassis. Pull rear panel away from unit several inches.
- d. Remove and save two screws that secure cover over J2-connector hole in rear panel. Discard J2-connector-hole cover.
- e. Install option board on left side of chassis (see Figure 7-1) with three screws provided.
- f. Replace rear panel and four screws that secure rear panel to instrument.
- g. Using two screws removed in step d, secure option connector (J2) to rear panel.
- h. Connect 16-pin ribbon connector (P1) from option board to connector J1 on control board. Red stripe on ribbon cable should be toward end of J1 marked with "RED" on control board.
- i. Replace top cover.
- j. Read operation section of this appendix before turning on instrument and checking the 002 Option. No preliminary adjustments are required.

A-16 Connector Assembly Procedure

A-17 The following instructions describe assembly of the mating connector provided to interface the user's system with the option connector, J2. Figure A-1 identifies the parts of the mating connector. Proceed as follows:

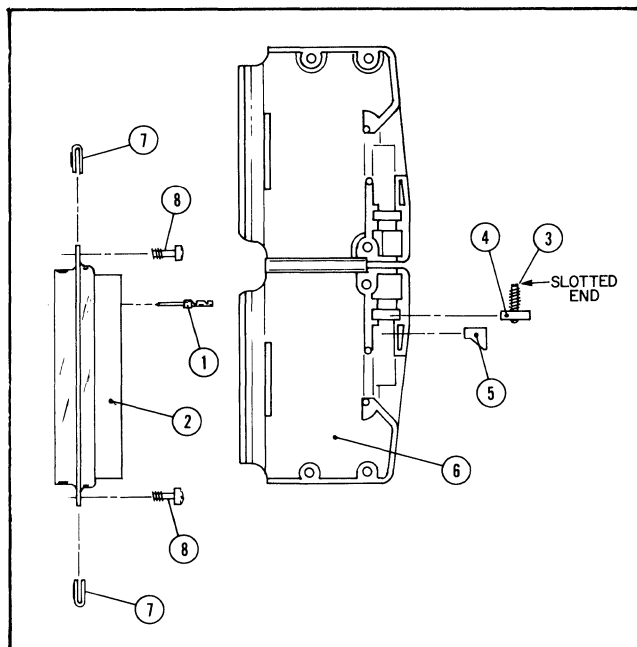


Figure A-1. Mating Connector Assembly

NOTE

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

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

NOTE

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

- e. Screw a slotted set-screw (3) partially into a square nut (4) and place in position in connector shield assembly (6).
- f. Place strain relief (5) in position in connector shield assembly (6), just under set screw (3). Be certain that strain relief is oriented as shown in Figure A-1.
- g. Place connector pin housing (2) in shield assembly (6) and route cable through cable entrance.
- h. Fold connector shield assembly (6) and secure with three screws.
- i. Strain relief set screw (3) can now be adjusted from top of connector to clamp firmly on cable.
- j. Clip fasteners (7) onto ends of connector pin housing (2).
- k. Connector can now be plugged onto option connector J2 and secured with two screws (8) into the threaded stand-offs on either side of J2.

A-18 OPERATION

A-19 The following paragraphs provide the operating instructions necessary to interface an 002-equipped power supply into an automated system. A brief description of the circuits is also provided. All connections are made at the 37-pin rear panel connector, J2 (Figure A-2) and can be wired directly into the mating connector supplied for this purpose.

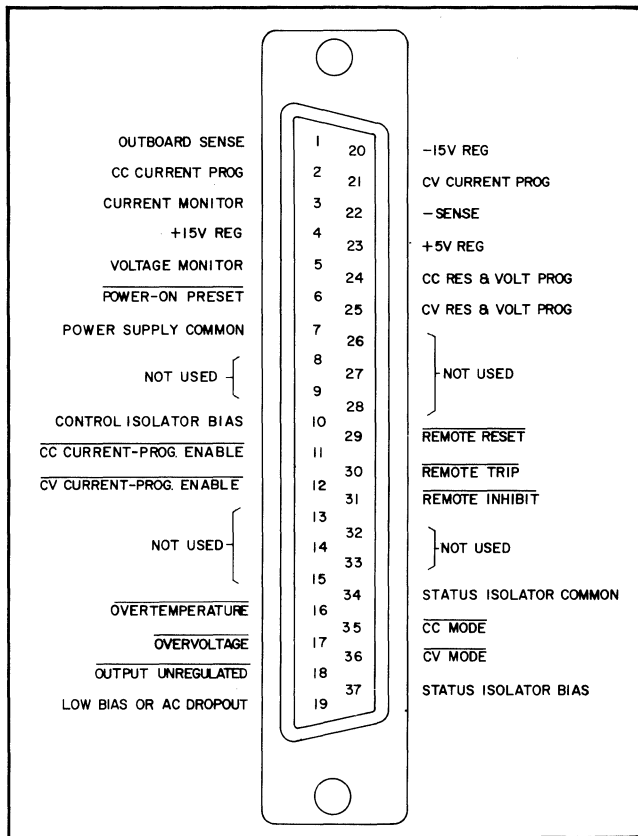


Figure A-2. Rear-Panel Connector J2

A-20 Remote Programming

A-21 Resistance Control (Figure A-3). It is necessary to disable the front panel voltage and current controls during resistance programming. This is accomplished at the rear panel terminal strip by disconnecting the jumper between A6 and A7 (CURRENT control) and the jumper between A1 and A2 (VOLTAGE control).

A-22 A resistance, variable from 0 to 2500 ohms, can be used to program the output voltage or current from 0 to full scale. To program voltage, the variable resistance should be connected from J2-25 (CV RES & VOLT PROG) to J2-22 (- Sense). To program current, the variable resistance should be connected from J2-24 (CC RES & VOLT PROG) to J2-1 (outboard sense). For setting upper and lower limits, refer to paragraphs 3-47 and 3-52.

CAUTION

If the programming lines become open circuited during resistance programming (user's system becomes disconnected from J2), the power supply's output will tend to rise above rating. The supply will not be damaged if this occurs, but the user's load may be damaged. To protect the load, be sure that the overvoltage trip point is properly adjusted and that the CAUTION of paragraph 3-52 is observed.

A-23 Voltage Control (Figure A-4). To program the supply with a voltage source, it is necessary to disable the front panel control pots and disconnect the supply's internal current sources from the programming voltage nodes. This is accomplished at the rear panel terminal strip by disconnecting the jumpers between A1, A2, and A3 for CV, and the jumpers between A6, A7, and A8 for CC.

A-24 A voltage source, variable from 0 to 5 volts, can be used to program the output voltage or current from 0 to full scale. The load on the programming voltage source is less than 5 μ A. To program voltage, the voltage source should be connected from J2-25 (CV RES & VOLT PROG) to J2-22 (- Sense). To program current, the voltage source should be connected from J2-24 (CC RES & VOLT PROG) to J2-1 (outboard sense). A discussion on programming with a voltage greater than 5 volts can be found in paragraphs 3-49 to 3-50.

A-25 If the programming lines become open circuited (user's system become disconnected from J2) during voltage programming, the Programming Protection circuit will reduce the power supply output to zero.

A-26 Current Control (Figure A-5). A current sink, variable from 0 to 2 mA, can be used to program the output voltage or current from 0 to full scale. The following paragraphs provide the necessary instructions for programming with a current sink.

A-27 It is necessary to disable the front panel control pots and disconnect the supply's internal current sources from the programming voltage nodes. This is accomplished at the rear panel terminal strip by disconnecting the jumpers between A1, A2, and A3 for CV, and the jumpers between A6, A7, and A8 for CC.

A-28 Current programming is enabled by relays K1 (for CV) and/or K2 (for CC), which are powered from the CONTROL ISOLATOR BIAS connected to J2-10. Maintaining a low logic level (CONTROL ISOLATOR BIAS supply common) at one or both of the CURRENT PROG. ENABLE inputs, J2-12 (CV) and J2-11 (CC), closes the appropriate relay.

CAUTION

Although CONTROL ISOLATOR BIAS can be +4.75 V to +16 V, a supply voltage of more than 7 V may damage the relays. Therefore, if CONTROL ISOLATOR BIAS exceeds 7 V, it is necessary to use a resistor in series with each of the relay enable lines. Figure A-6 provides a graph and formulas for calculating the proper series resistance value based on the CONTROL ISOLATOR BIAS being used. Be certain to account for the resistor tolerance and CONTROL ISOLATOR BIAS power supply tolerance. The formulas and graph in Figure A-6 account for relay tolerance. Any driver gate voltage drop should be subtracted from the CONTROL ISOLATOR BIAS before using formulas and graph in Figure A-6.

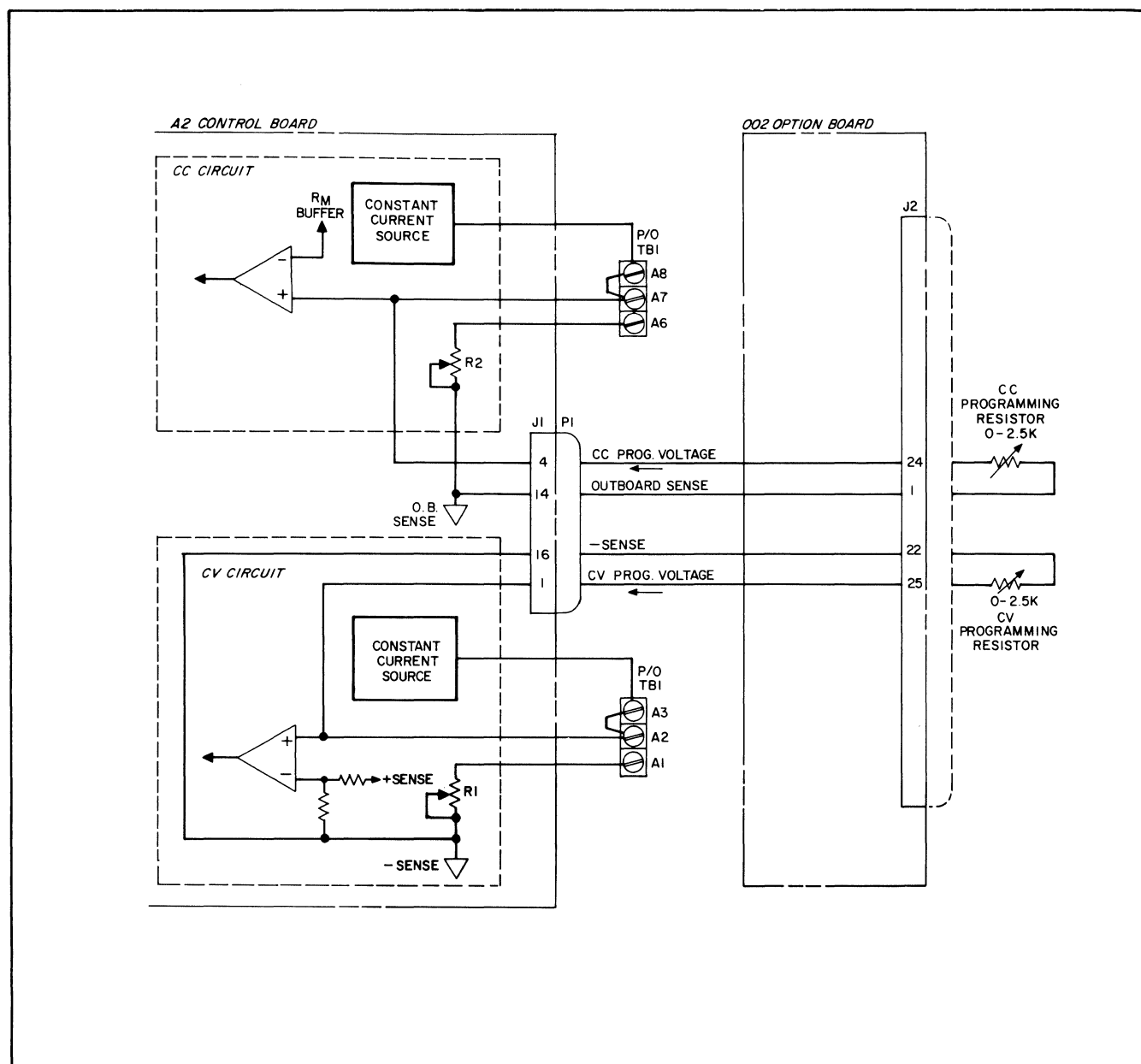


Figure A-3. Resistance Programming of Output Voltage And/Or Current

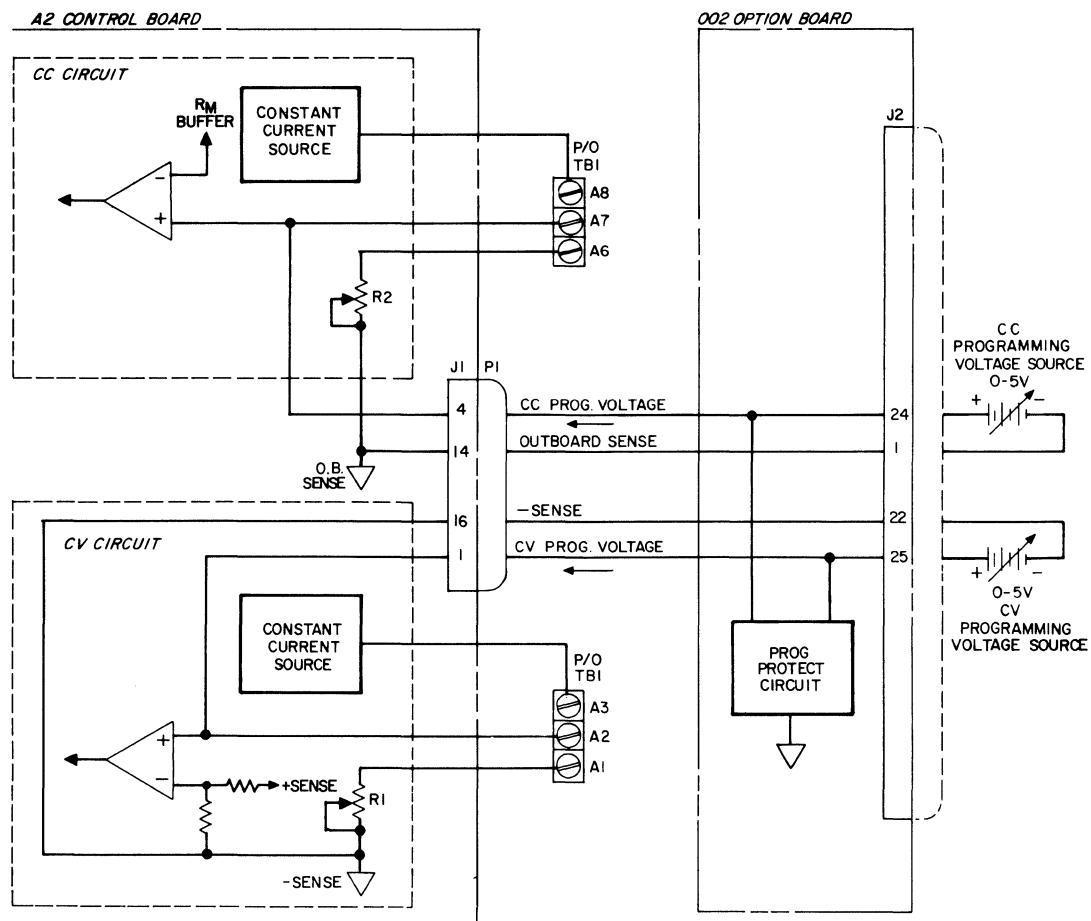


Figure A-4. Voltage Programming of Output Voltage And/Or Current

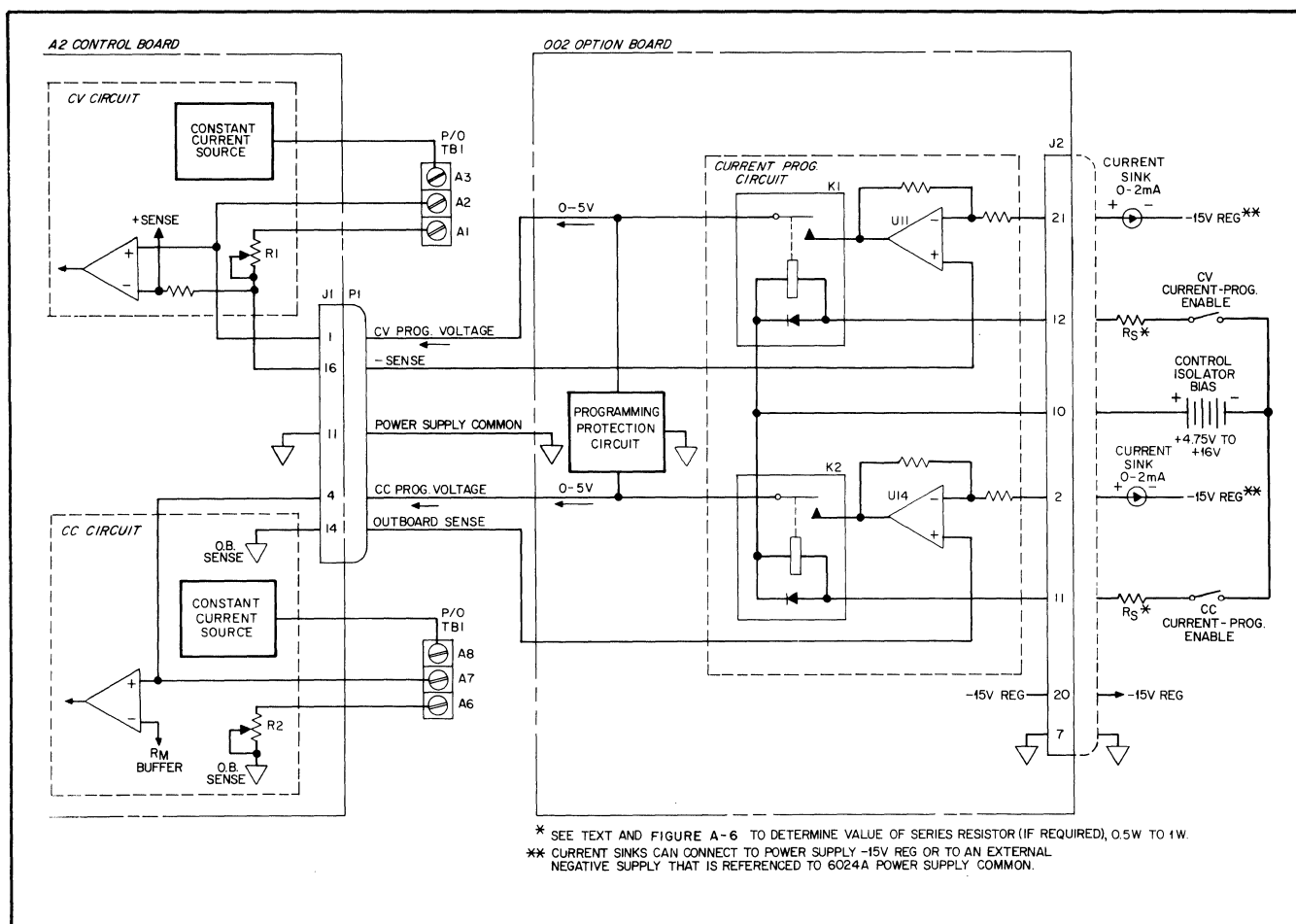


Figure A-5. Current Programming of Output Voltage And/Or Current

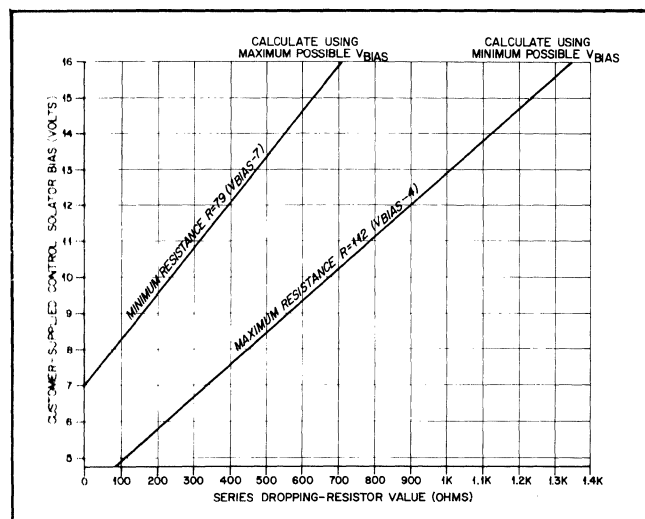


Figure A-6. Calculating Value of Series Dropping Resistor

A-29 To program voltage, the current sink should be connected from J2-21 (CV CURRENT PROG) to J2-20 (-15 V REG). To program current, the current sink should be connected from J2-2 (CC CURRENT PROG) to J2-20.

A-30 The 0 to 2 mA current sink will cause the output of op-amps U11 and U14 to vary proportionally from 0 to 5 volts. With relays K1 and K2 energized, these signals are coupled to the CV and CC circuits (in the main supply) which, in turn, will program the supply's output from 0 to full scale.

A-31 If the programming lines become open circuited (user's system becomes disconnected from J2) during current programming, the Programming Protection circuit will bring the power supply output to zero.

A-32 Remote Monitoring

A-33 The 002 Option board includes a voltage divider to provide a 0 to 5 V output corresponding to a 0 to full scale voltage output. The voltage monitor output is available between pins J2-5 (Voltage Monitor) and J2-22 (- Sense). Output impedance is 8.3 k Ω ; the monitoring device input impedance should be at least 1 M Ω to limit error to 1% plus basic accuracy, 10 M Ω to limit error to 0.1% plus basic accuracy.

A-34 The I-Monitor signal from the mainframe is also brought out through the 002 option board. A 0 to 5 V output corresponds to a 0 to full scale current output. The current-monitor output is available between pins J2-3 (Current

Monitor) and J2-1 (Outboard Sense). Output impedance is 10k Ω ; the monitoring device input impedance should be at least 1 M Ω to limit error to 1% + basic accuracy, 10 M Ω to limit error to 0.1% + basic accuracy.

A-35 In some applications it may be desirable to install a noise-suppression capacitor on these monitor outputs to lessen the effects of noise induced in the monitor leads. The capacitors should be ceramic or tantalum type, from 0.1 to 1 μ F. The capacitor is installed directly across the monitor device input terminals.

A-36 Status Indicators

A-37 Six optically isolated lines provide open collector digital outputs which indicate certain modes and conditions of power supply operation. For proper operation of the opto-isolators, the user must supply the bias voltage, STATUS ISOLATOR BIAS. This voltage can be from +4.75 V to +16 V depending upon the user's interface circuits. Refer to the specification Table A-1. Connect the bias voltage (+) between J2-37, STATUS ISOLATOR BIAS, and J2-34 (STATUS ISOLATOR COMMON). The status indicator outputs are open-collector (referenced to STATUS ISOLATOR COMMON); therefore, it is necessary to connect a pull-up resistor from each output to STATUS ISOLATOR BIAS. When choosing the resistor value, observe the current sink capabilities of these lines as described in the Specifications Table A-1.

A-38 Because of the relatively slow rise and fall times of opto-isolators, Schmitt-triggered devices should be used to interface these output lines to logic circuits.

A-39 The following signals are in active-low form:

- a. CV MODE, J2-36, indicates that the power supply is in constant voltage operation.
- b. CC MODE, J2-35, indicates that the power supply is in constant current operation.
- c. OUTPUT UNREGULATED, J2-18, indicates that the power supply is in neither constant voltage nor constant current operation and cannot be guaranteed to meet specifications.
- d. OVERVOLTAGE, J2-17, indicates power supply shutdown because of: the voltage output exceeding the OVP trip point set at the front panel; or, a system-initiated shutdown as described in Section A-45.
- e. OVERTEMPERATURE, J2-16, indicates power supply shutdown due to an excessive temperature rise on the FET heatsink.

A-40 The LOW BIAS OR AC DROPOUT signal, J2-19, is in active-high form. This signal indicates: loss of primary power, momentary AC dropout, or "brownout" conditions where the AC line voltage drops below approximately 70% nominal.

A-41 Remote Control

A-42 For proper operation of the opto-isolators, the user must supply the bias voltage, CONTROL ISOLATOR BIAS. This voltage can be from +4.75 to +16 V depending on the requirements of the driving circuits. The type of driving logic and resultant bias voltage also determine the amplitude of the "high" and "low" logic levels. Refer to the Specification Table A-1.

A-43 Connect the bias voltage (+) to J2-10, CONTROL ISOLATOR BIAS, and reference the input signals to this bias supply's negative terminal.

A-44 Two optically isolated methods of remote control are available. They are described in the following paragraphs.

A-45 **Remote Trip.** A negative-going edge applied at input J2-30 (REMOTE TRIP) will shut down the power supply, reducing its output voltage to near zero (0 to -0.8 V). For minimum pulse duration and timing considerations with respect to REMOTE RESET, see Table A-1. The following paragraph provides a brief circuit description (see schematic diagram and Figure A-7.)

A-46 A negative-going edge at REMOTE TRIP is coupled through opto-isolator U15 and sets the Trip/Reset latch output "low." This shuts down the supply by pulling down the OV STATUS INHIBIT line (J1-15), which inhibits the Pulse Width Modulator. It also lights the OVP indicator on the front panel and results in the generation of an OVERVOLTAGE status signal from opto-isolator U18. This signal does not affect the state of the power supply's OVP circuit.

A-47 **Remote Reset.** A negative-going edge applied at input J2-29 (REMOTE RESET) will return the supply to its initial state following a system-initiated shutdown (REMOTE TRIP) or an OVP shutdown caused by a temporary over-voltage condition. For minimum pulse duration and timing considerations with respect to REMOTE TRIP, see Table A-1. The following paragraphs provide a brief description of this circuit (see schematic diagram and Figure A-7).

A-48 The negative-going pulse applied at REMOTE RESET is coupled through opto-isolator U17 and resets the Trip/Reset latch output "high". This releases the OV STATUS INHIBIT line and the Pulse Width Modulator.

A-49 The REMOTE RESET pulse will also reset the power supply OVP circuit in the event that an overvoltage condition has shut down the supply. This is accomplished through Q4 after the one-second time delay of one-shot U8. This delay allows the Down Programmer (paragraphs 4-34 to 4-37) to lower the output from its overvoltage condition to zero before the supply can be reactivated.

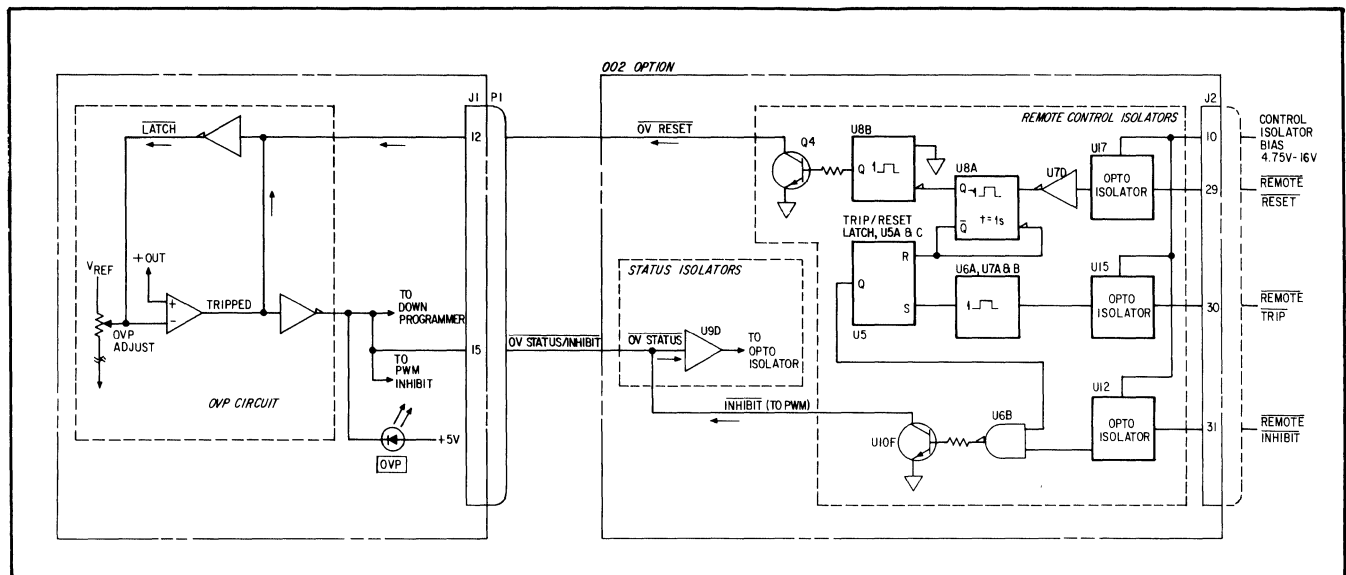


Figure A-7. Remote Control

NOTE

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

A-50 Alternate Method of Remote Control. The REMOTE INHIBIT input, J2-31, provides an alternate method of remote shutdown. By maintaining a low logic level at this input, the supply's output will be inhibited (drop to 0 to -0.8 V) until REMOTE INHIBIT is returned to its initial high state. The following paragraph provides a brief description of this circuit (see schematic diagram and Figure A-7).

A-51 A low logic level at REMOTE INHIBIT is coupled through opto-isolator U12 and causes U10 to inhibit the supply and light the OVP indicator in the same manner as the REMOTE TRIP input of paragraph A-49. Note that this action does not affect the Trip/Reset latch and, therefore, the supply can be returned to its initial state by switching the REMOTE INHIBIT input to a high logic level.

A-52 Power-On Preset

A-53 This open-collector output line, J2-6, provides a logic low pulse (POWER-ON PRESET) that can be used to initialize or delay system operation until the +5 V REG bias supply in the 6024A has stabilized. The pulse is generated after primary power is turned on, and also after resumption of power following momentary ac dropout or brownout conditions in which ac line voltage drops below approximately 70% of nominal. See Table A-1 for POWER-ON PRESET signal specifications.

A-54 Low Bias Or AC Dropout Buffers. These circuits distribute the ORed outputs of the AC Dropout and Bias Voltage Detector circuits in the 6024A mainframe (paragraphs 4-41 through 4-45). The input signal arrives at J1-7 in active-low form and is distributed active-high to opto-isolator U18 and to the Power-On Preset circuit.

A-55 Multiple Supply System Shutdown

A-56 When using more than one 002-equipped power supply in a system, it may be desirable to implement a system shutdown. In this configuration, an OVP trip or remote shutdown of a single unit will cause all of the supplies to shut down.

A-57 Figure A-8 shows one method of system shutdown. The advantages of this method are that one common is used for all status and control lines (useful for controller-operated systems), and the capability of system reset. As shown in Figure A-8, one supply's OVERVOLTAGE line is connected to the next supply's REMOTE TRIP line, and so on in a continuous chain.

NOTE

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

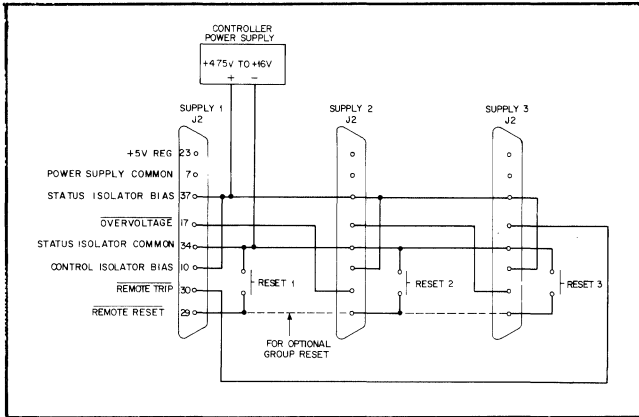


Figure A-8. System Shutdown Using Controller Power Supply

A-58 The note following Paragraph A-49 tells how to determine if a shutdown was initiated by the system controller or by a supply's OVP.

A-59 Following a multiple supply shutdown, each unit can be reset individually or all the REMOTE RESET lines can be tied together for a system reset.

A-60 If it is necessary to have all the supplies come up simultaneously after a system shutdown, follow this procedure:

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

A-61 Figure A-9 shows a second method of system shutdown. This method is appropriate in systems which are not controller-operated and in which more than four supplies must be shutdown simultaneously. Because each supply derives its CONTROL ISOLATOR BIAS from the previous supply's +5V REG, there is no limit to the number of supplies that can be shutdown. Each supply must be reset individually.

A-62 Using either method of system shutdown, LOW BIAS OR AC DROPOUT inhibits the OVERVOLTAGE indicator from going low and shutting down succeeding supplies upon initial turn-on. After the supplies have stabilized, LOW BIAS OR AC DROPOUT returns to a high state.

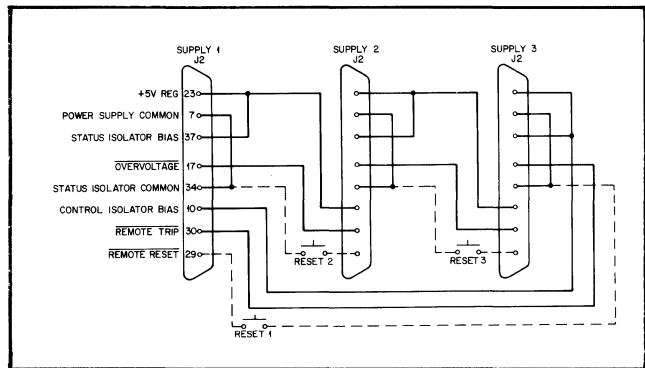


Figure A-9. System Shutdown Using 6024A Bias Supply Output

A-63 Remote/Local Programming

A-64 When using current programming of output voltage and/or current, it is possible to leave the front-panel controls operable. This allows the user to switch back and forth between remote and local programming while initially checking out a current-programming system. For this function, the 6024A rear-panel terminal strip must be strapped as shown in Figure 3-2. The front-panel VOLTAGE and CURRENT controls must be turned fully CW to avoid loading the 002 current-programming circuit. With the CURRENT PROG ENABLE lines (J2-11 and J2-12) low, relays K1 and K2 are closed and remote programming is enabled. Opening the CURRENT PROG ENABLE lines (high logic level) returns control to the front-panel pots.

CAUTION

When switching to local control, output voltage and current will go to full scale. Remember to set the VOLTAGE and CURRENT controls to safe levels before switching to local control, and remember to turn the VOLTAGE and CURRENT controls fully CW after returning to remote control. Once the system has been checked out, remove the straps from A1, A2, and A3 and from A6, A7, and A8, and program the system remotely.

A-65 Bias Supplies

A-66 The outputs of three current-limited bias supplies are available for user-supplied circuitry. These are +15 V @ 75 mA at J2-4, -15 V @ 75 mA at J2-20, and +5 V @ 100 mA at J2-23; all with respect to J2-7, power supply common. Six screwdriver-adjustable pots located at the top of the option board set the output voltages and current limiting points of these supplies (refer to Specification Table A-1).

CAUTION

Although the bias supplies are current limited, it is important to avoid shorting the ± 15 V supplies to common. These supplies are used internally for the current programming circuit. Shorting them could cause improper programming of the power supply and possible damage to the user's load.

A-67 It may be desirable to install noise-suppression capacitors on the bias supply outputs near the load circuits. The capacitors should be ceramic or tantalum type, approximately $0.1\mu\text{F}$ to $10\mu\text{F}$.

A-68 MAINTENANCE

A-69 The following paragraphs provide procedures and set-ups to aid in checking and troubleshooting the 002 option board. This information, used in conjunction with the schematic drawing and the Operation section of this Appendix, will help in the isolation and repair of faulty circuits.

A-70 The adjustments on the option board set the voltage output and current limiting of the three Bias Supplies. Although these potentiometers are set at the factory, calibration procedures are provided for purposes of checking performance and to aid in troubleshooting of these supplies.

A-71 When testing the option, use of the test connector of paragraph A-17 will allow easier access to the J2 contacts.

A-72 Troubleshooting

A-73 Before attempting to troubleshoot the 002 option board, ensure that the fault is with the option itself and not with the main supply. This can be accomplished by removing the top cover, disconnecting ribbon connector P1 from the A2 Control Board and checking the operation of the main supply. If the fault still exists, proceed to the troubleshooting section, paragraph 5-53, in the main text. Otherwise, troubleshoot the option board as described in the following paragraphs.

A-74 Removal of the Option Board. To facilitate troubleshooting of the 002 option, the board can be removed from the power supply and electrically connected via the ribbon cable. To remove the circuit board, proceed as follows:

- a. Turn off and unplug power supply.
- b. Remove the four screws that secure top cover of instrument. Slide cover back and lift off.
- c. Disconnect ribbon connector P1 from A2 Control Board.
- d. Remove two screws on back panel to left of the option connector.
- e. Remove four screws on sides near rear of chassis. Slide rear panel back several inches.
- f. Remove three screws on left side of chassis which attach the option board.

- g. Remove option board. Ribbon connector P1 can now be reconnected to Control Board provided option board is resting on an insulated surface before power is returned to the unit.

A-75 Isolating Faulty Circuit. If it is apparent which function is not operating properly, proceed to the appropriate paragraph. If the problem involves more than one function, check the output voltages of the Bias Supplies. (Table A-1).

A-76 Troubleshooting Resistance and Voltage Programming.

- a. Confirm that problem is on option board by disconnecting P1 from Control Board and attempting to program the supply via the rear panel terminal strip.
- b. Check -15 V and ± 11.8 V supplies.
- c. Check for a problem in the Programming Protection circuit. This circuit should draw about $2\mu\text{A}$ from the programming lines.
- d. Check for shorted relay contacts on K1 and K2.

A-77 Troubleshooting Current Programming.

- a. Check ± 15 V supplies.
- b. Check $+5$ V supply and proceed to the test set-up shown in Figure A-10 and/or A-11.
- c. Disconnect J2-11 and/or J2-12 from J2-7. See if varying the voltage source produces 0 to 5 V at K1, pin 14 and/or K2, pin 14. If not, check op amps and associated circuitry.
- d. Return to original test set-up and see if varying the voltage source produces 0 to 5 V at K1, pin 8 and/or K2, pin 8. If not, check relays for proper operation.
- e. If relays are okay, check for a problem in the Programming Protection circuit. This circuit should draw about $2\mu\text{A}$ from the programming lines.

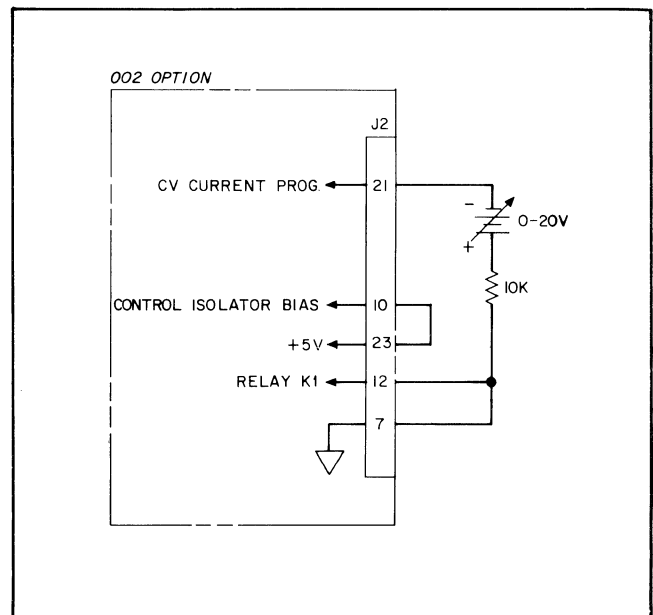


Figure A-10. Troubleshooting Current Programming of CV Mode

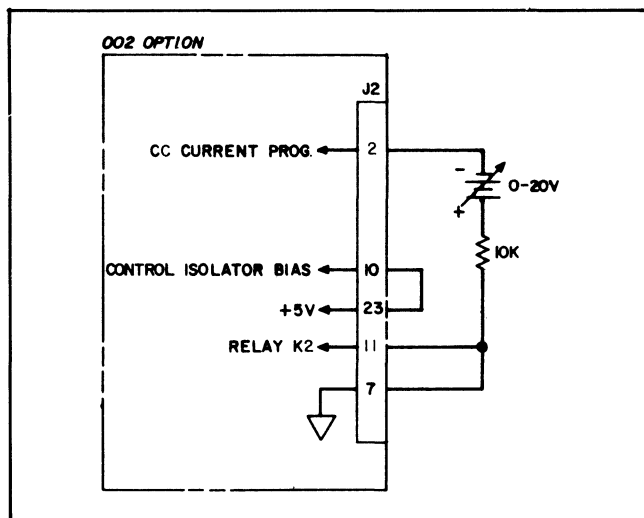


Figure A-11. Troubleshooting Current Programming of CC Mode

A-78 Troubleshooting Status Indicators. The test set-up shown in Figure A-12 can be used to check each of the six status indicators. This set-up, however, will temporarily defeat the isolation of the status lines. Before attempting to troubleshoot a status indicator, check for +5 V at TP1 (+5 V). This voltage must be present for proper operation of the opto-isolators.

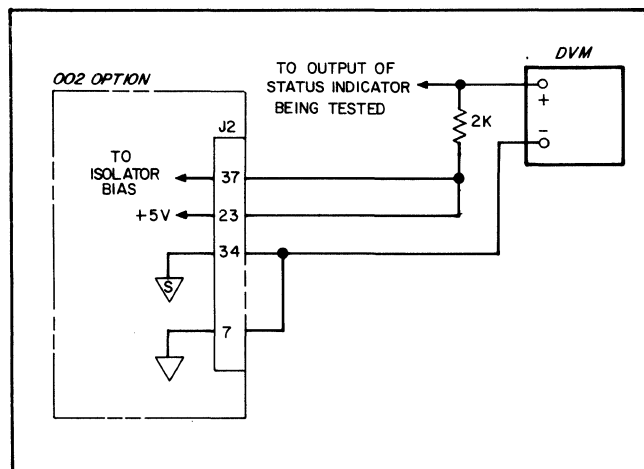


Figure A-12. Troubleshooting Status Indicators

A-79 To check CV MODE, proceed as follows:

- Using test set-up, connect top end of 2 K Ω resistor to J2-36.
- Set CURRENT control one turn clockwise (CW) and VOLTAGE control also one turn CW.
- Turn unit on. DVM should read 0 to .4 V.
- Turn unit off. Short circuit the supply's output.
- Turn unit on. DVM should read about 5 V.

A-80 To check CC MODE, proceed as follows:

- Using test set-up, connect top end of 2 k Ω resistor to J2-35.

- Set CURRENT and VOLTAGE controls one turn CW.
- Turn unit on. DVM should read about 5 V.
- Turn unit off. Short circuit the supply's output.
- Turn unit on. DVM should read 0 to .4 V.

A-81 To check OVERVOLTAGE, proceed as follows:

- Using test set-up, connect top end of 2 k Ω resistor to J2-17.
- With no load on supply, turn OVP ADJUST fully CW and set VOLTAGE control for about 30 volts output. Turn CURRENT control one turn CW.
- Turn OVP ADJUST CCW one-half turn or until the supply goes into overvoltage. DVM should read 0 to .4 V.
- Turn OVP ADJUST fully CW, turn supply off and wait several seconds.
- Turn supply on. DVM should read about 5 volts.

A-82 To check OUTPUT UNREGULATED, proceed as follows:

- Using test set-up, connect top end of 2 k Ω resistor to J2-18.
- With no load on supply, turn OVP ADJUST fully CW and set VOLTAGE control for about 30 volts output. Turn CURRENT control one turn CW.
- Turn OVP ADJUST CCW one-half turn or until the supply goes into overvoltage. DVM should read 0 to .4 V.
- Turn OVP ADJUST fully CW, turn supply off and wait several seconds.
- Turn supply on. DVM should read about 5 volts.

A-83 To check LOW BIAS OR AC DROPOUT, proceed as follows:

- Substitute an oscilloscope in place of DVM in test set-up.
- Connect top end of 2 k Ω resistor to J2-19.
- Turn unit on. Voltage at 2 k Ω resistor should be between 0 and .4 V.
- Turn unit off. Voltage at 2 k Ω resistor should go to about 5 volts before decaying back to OV.

NOTE

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

A-84 To check OVERTEMPERATURE, proceed as follows:

- Using test set-up, connect top end of 2 k Ω resistor to J2-16.
- Disconnect one wire leading to the thermostat, TS1, on FET heatsink, and reconnect the wire to TS1 using a clip-on test lead.
- Turn unit on. DVM should read about 5 volts.
- Disconnect test lead. DVM should read 0 to .4 V.
- Reconnect wire to TS1.

A-85 Troubleshooting Remote Shutdown. The following procedures check the Remote Shutdown features of the option. Troubleshooting can be accomplished by using a logic probe and referring to the schematic and the circuit descriptions in Section A-46. Before attempting to troubleshoot the Remote Shutdown function of the option, check for +5 V at TP1 (+5 V INT.). This voltage must be present for proper operation of these circuits.

A-86 To check REMOTE TRIP and REMOTE RESET, proceed as follows:

- a. Connect +5 V supply, J2-23, to CONTROL ISOLATOR BIAS, J2-10.
- b. Turn unit on and short REMOTE TRIP, J2-30, to power supply common, J2-7, momentarily. Supply should go into overvoltage condition.
- c. Short REMOTE RESET, J2-29, to common momentarily. Supply should return to initial state.

A-87 To check REMOTE INHIBIT, proceed as follows:

- a. Connect ± 5 V supply, J2-23, to CONTROL ISOLATOR BIAS, J2-10.
- b. Turn unit on and short REMOTE INHIBIT, J2-31, to power supply common, J2-7. Supply should go into overvoltage condition.
- c. Remove short from J2-31 to common. Supply should return to its initial state.

A-88 Bias Supply Adjustments

A-89 After troubleshooting and repair of the 002 option, it may be necessary to calibrate the Bias Supplies. The correct calibration procedures are provided in the following paragraphs. Measurements can be taken at the appropriate pins on connector J2 and adjustments are made with the six potentiometers located on the top of the option board.

A-90 To remove the top cover of the power supply, remove the four screws that secure the cover to the instrument. Slide the cover back and lift off.

A-91 +5 V Supply Adjustment. The output voltage and current limiting of the +5 V Bias Supply are adjusted as follows:

- a. Turn off supply and disconnect all loads.

- b. Connect a DVM between J2-23 (+5 V) and J2-7 (power supply common).
- c. Turn on power supply and adjust R20 until DVM reads $+5\text{ V} \pm 25\text{ mV}$.
- d. Turn off power supply and disconnect DVM.
- e. Connect 10 Ω , 5 watt resistor between J2-23 and J2-7. Connect DVM across this resistor.
- f. Turn on power supply and adjust R16 until DVM reads $1.7\text{ V} \pm 50\text{ mV}$. This limits the output current to 170 mA.
- g. Turn off power supply and disconnect DVM and resistor.

A-92 +15 V Supply Adjustment. The output voltage and current limiting of the +15 V Bias Supply are adjusted as follows:

- a. Turn off supply and disconnect all loads.
- b. Connect a DVM between J2-4 (+15 V) and J2-7 (power supply common).
- c. Turn on supply and adjust R15 until DVM reads $+15\text{ V} \pm 75\text{ mV}$.
- d. Turn off power supply and disconnect DVM.
- e. Connect 50 Ω 5 watt resistor between J2-4 and J2-7. Connect DVM across this resistor.
- f. Turn on supply and adjust R8 until DVM reads $\pm 6.25\text{ V} \pm 0.15\text{ V}$. This limits the output current to 125 mA.
- g. Turn off supply and disconnect DVM and resistor.

A-93 -15 V Supply Adjustment. The output voltage and current limiting of the -15 V Bias Supply are adjusted as follows:

- a. Turn off supply and disconnect all loads.
- b. Connect a DVM between J2-20 (-15 V) and J2-7 (power supply common).
- c. Turn on supply and adjust R7 until DVM reads $-15\text{ V} \pm 75\text{ mV}$.
- d. Turn off power supply and disconnect DVM.
- e. Connect 50 Ω 5 watt resistor between J2-20 and J2-7. Connect DVM across this resistor.
- f. Turn on supply and adjust R1 until DVM reads $-6.25\text{ V} \pm 0.15\text{ V}$. This limits the output current to 125 mA.
- g. Turn off supply and disconnect DVM and resistor.

Table A-3. Replaceable Parts

Ref. Desig.	HP Part No.	Qty.	Mfr. Description	Code	Mfr. Part No.
C1, 10	0180-2825	2	cap 22 μ F - 10 + 50% 50 V	28480	
C2, 3	0180-2628	2	cap 220 μ F - 10 + 50% 50 V	28480	
C4	0180-0100	1	cap 4.7 μ F 10% 35 V	56289	150D475X9035B2-DYS
C5	0160-4833	1	cap .022 μ F 10% 100 V cer	16299	CAC04X7R223K100A
C6	0160-4830	1	cap 2200pF 10% 100 V cer	16299	CAC02X7R222K100A
C7, 26	0160-4557	2	cap .1 μ F 20% 50 V cer	16299	CAC04X7R104M050A
C8, 20	0160-4832	2	cap .01 μ F 10% 100 V cer	16299	CAC03X7R103K100A
C9	0180-0693	1	cap 1000 μ F - 10 + 50% 25 V	54473	ECE-A25V19000L
C11	0160-0157	1	cap 4700pF 10% 200 V	56289	192P47292
C12, 16, 18	0180-0405	3	cap 1.8 μ F 10% 20 V	56289	150D185x9020A2
C13	0160-2012	1	cap 330pF 5% 500 V mica	28480	
C14, 23	0160-3070	2	cap 100pF 5% 300 V mica	28480	
C15, 17, 25	0160-4722	3	cap .1 μ F - 20 + 80% 50 V cer	56289	292CZ5U104Z050C
C19	0160-4822	1	cap 1000pF 5% 100 V cer	16299	XX03COG102J100A
C21	0140-0210	1	cap 270pF 5% 300 V mica	28480	
C22	0160-2639	1	cap 5000pF 20% 100 V cer	72982	835-100-Z5U-502M
C24	0140-0149	1	cap 470pF 5% 300V mica	28480	
CR1, 2, 15-17	1901-0327	5	dio-pwr rect. 200 V 1A	03508	A14B
CR3, 4, 8-11, 14	1901-0033	7	dio-gen prp	07263	FDH3369
CR5-7, 12, 13, 18, 19	1901-0050	7	dio-sw 80 V 200 mA	07263	FDH6308
J2	1251-6075	1	connector, F 37-pin	28480	
K1, 2	0490-1277	2	relay, reed	28480	
Q1-3	1853-0234	3	XSTR PNP si	01295	TIP42A
Q4-7	1854-0823	4	XSTR NPN si	01295	SKC0221
R1, 8, 16	2100-0589	3	res var 10 Ω 100% 25W	01121	E4A100
R2, 9	0683-3305	2	res 33 Ω 5% .25W fc	01121	CB3305
R3, 10	0683-0275	2	res 2.7 Ω 5% .25W fc	01121	CB27G5
R4	0683-1525	1	res 1.5k 5% .25W fc	01121	CB1525
R5	0683-3325	1	res 3.3k 5% .25W fc	01121	CB3325
R6	0698-0084	1	res 2.15k 1% .125W f	16299	C4-1/8-TO-215R-F
R7, 15	2100-3274	2	res var 10k 10%	01121	E4A103
R11	0683-6235	1	res 62k 5% .25W fc	01121	CB6235
R12, 19	0683-1025	2	res 1k 5% .25W fc	01121	CB1025
R13	0757-0439	1	res 6.81k 1% .125W f	16299	C4-1/8-TO-6811-F
R14, 24	0757-0438	2	res 5.11k 1% .125W f	16299	C4-1/8-TO-5111-F
R17	0686-1205	1	res 12 Ω 5% .5W fc	01121	EB1205
R18	0683-0335	1	res 3.3 Ω 5% .25W fc	01121	CB33G5
R20	2100-3273	1	res var 2k 10%	01121	E4A202
R21, 44	0757-0427	2	res 1.5k 1% .125W f	16299	C4-1/8-TO-1501-F
R26, 45, 50	0683-1035	3	res 10k 5% .25W fc	01121	CB1035
R22	0683-4735	1	res 47k 5% .25W fc	01121	CB4735
R23, 43	0683-4725	2	res 4.7k 5% .25W fc	01121	CB4725
R25	0686-2225	1	res 2.2k 5% .5W fc	01121	EB2225
R27	0757-0465	1	res 100k 1% .125W f	16299	C4-1/8 -TO-1003-F
R28	0757-0483	1	res 562k 1% .125W f	28480	

Table A-3. Replaceable Parts (cont.)

Ref. Desig.	HP Part No.	Qty.	Mfr. Description	Code	Mfr. Part No.
R29, 51	0813-0001	2	res 1k 5% 3W w	01686	T2B-79
R30, 31	0757-0449	2	res 20k 1% .125W f	91637	CMF-55-1,T-1
R32	0698-4158	1	res 100k .1% .125W f	28480	
R33	0757-0400	1	res 90.9Ω 1% .125W f	16299	C4-1/8-TO-90R9-F
R34	0698-6343	1	res 9k .1% .125 W f	91637	CMF-55-1,T-9
R35	0683-1615	1	res 160 5% .25W fc	01121	CB1615
R36	0683-3335	1	res 33k 5% .25W fc	01121	CB3335
R37, 42	0683-1535	2	res 15k 5% .25W fc	01121	CB1535
R38	0683-2725	1	res 2.7k 5% .25W fc	19701	(CR-25)1-4-5P-2K7
R39	0757-0317	1	res 1.33k 1% .125W f	16299	C4-1/8-TO-1331-F
R40	0683-2745	1	res 270k 5% .25w fc	01121	CXB2745
R41	0683-2715	1	res 270Ω 5% .25W fc	01121	CB2715
R46, 55, 59-61	0683-4715	5	res 470Ω 5% .25W fc	01121	CB4715
R47, 49	0683-4315	2	res 430Ω 5% .25W fc	01121	CB4315
R48, 52	0698-6631	2	res 2.5k .1% .125W f	24546	NE55
R53, 54	0683-1055	2	res 1M 5% .25W fc	01121	CB1055
R56, 58	0683-3355	2	res 3.3m 5% .25W fc	01121	CB3355
R57	0757-0441	1	res 8.25k 1% .125W f	16299	C4-1/8-TO-8251-F
R62-64	0686-1525	3	res 1.5k 5% .5W fc	01121	EB1525
R65-67	0683-2015	3	res 200Ω 5% .25W fc	01121	CB2015
U1	1826-0016	1	IC Voltage Reg., Adj., Neg.	04713	MLM2046
U2, 3	1826-0049	2	IC Voltage Reg., Adj., Pos.	01295	UA723CJ
U4	1826-0144	1	IC Voltage Reg, +5V	07263	7805UC
U5	1820-1961	1	IC-MC14023BCP	04713	SC45010PK
U6	1820-1600	1	IC-MC14093BCP	04713	SC45057PK
U7	1820-2019	1	IC-MC14584BCP	04713	SC45115PK
U8	1820-1932	1	IC-MC14538BCP	04713	SC42853PK
U9	1820-1976	1	IC-MC14050BCP	04713	SC45023PK
U10	1858-0023	1	XSTR Array NPN si	86684	CA3081E
U11, 14	1826-0493	2	IC LM308A	27014	SL35068
U12, 15, 17	1990-0494	3	Opto-Isolator	28480	
U13, 16, 18	1990-0732	3	Opto-Isolator	28480	
VR1, 4, 6, 8-14	1902-0556	10	dio-znr 20 V 5%	04713	SZ11213-227
VR2	1902-0779	1	dio-znr 11.8V 5%	04713	SZ11213-161
VR3	1902-3180	1	dio-znr 11.8 V 2%	04713	SZ30016-204
VR5	1902-0064	1	dio-znr 7.5 V 5%	28480	
VR7	1902-0575	1	dio-znr 6.5 V 2%	12954	SZ11594
Z1	1810-0206	1	res-array 10k 2%	01121	208A103
Z2	1810-0276	1	res array 1.5k 2%	01121	210A152

Table A-3. Replaceable Parts (cont.)

Ref. Desig.	HP Part No.	Qty.	Mfr. Description	Code	Mfr. Part No.
	OPTION BOARD ASSEMBLY				6025D
	06024-60001	1	cable assy, 16 conductor with connectors	28480	
	1251-2615		connector, M 16 pin	28480	
	MECHANICAL				
	1205-0282	3	heat sink al	13103	
	1251-4150	1	connector 37 pin M	28480	
	1251-6069	37	contacts-crimp	28480	
	1251-6070	1	shield and hardware for 37 pin con.	28480	
	06024-00014	1	bracket (J2)	28480	
	1251-5436	1	screwlock F (J2)	28480	
	MISCELLANEOUS				
	06024-90002	1	Option 002 Manual	28480	

Figure A-13. Logic Symbols And Definitions

Definitions

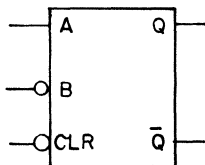
High = more positive

Low = less positive

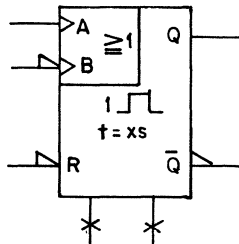
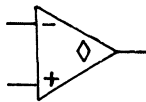
Indicator and Qualifier Symbols

\geq	OR function
∇	(polarity indicator, shown outside logic symbol) Any marked input or output is active low; any unmarked input or output is active high.
\triangleright	(dynamic indicator) Any marked input is edge-triggered, ie, active during transition between states; any unmarked input is level sensitive.
\sqcap	(Schmitt trigger) indicates that hysteresis exists in device.
*	(non-logic indicator) Any marked input or output does not carry logic information.
\diamond	open-collector or open emitter output
$1\sqcap$	monostable (one-shot) multivibrator
$t = x\text{Sec}$	indicates pulse width (usually determined by external RC network)
G	gate input (a number following G indicates which inputs are gated)
C	control input (clock)
R	reset (clear)
S	set

OLD SYMBOL



NEW SYMBOL



NOTES

Output requires external components to achieve logic state

A positive-going transition at A or a negative-going transition at B triggers the one-shot. External timing components connect to non-logic inputs.

Output changes state rapidly regardless of input rate of change.

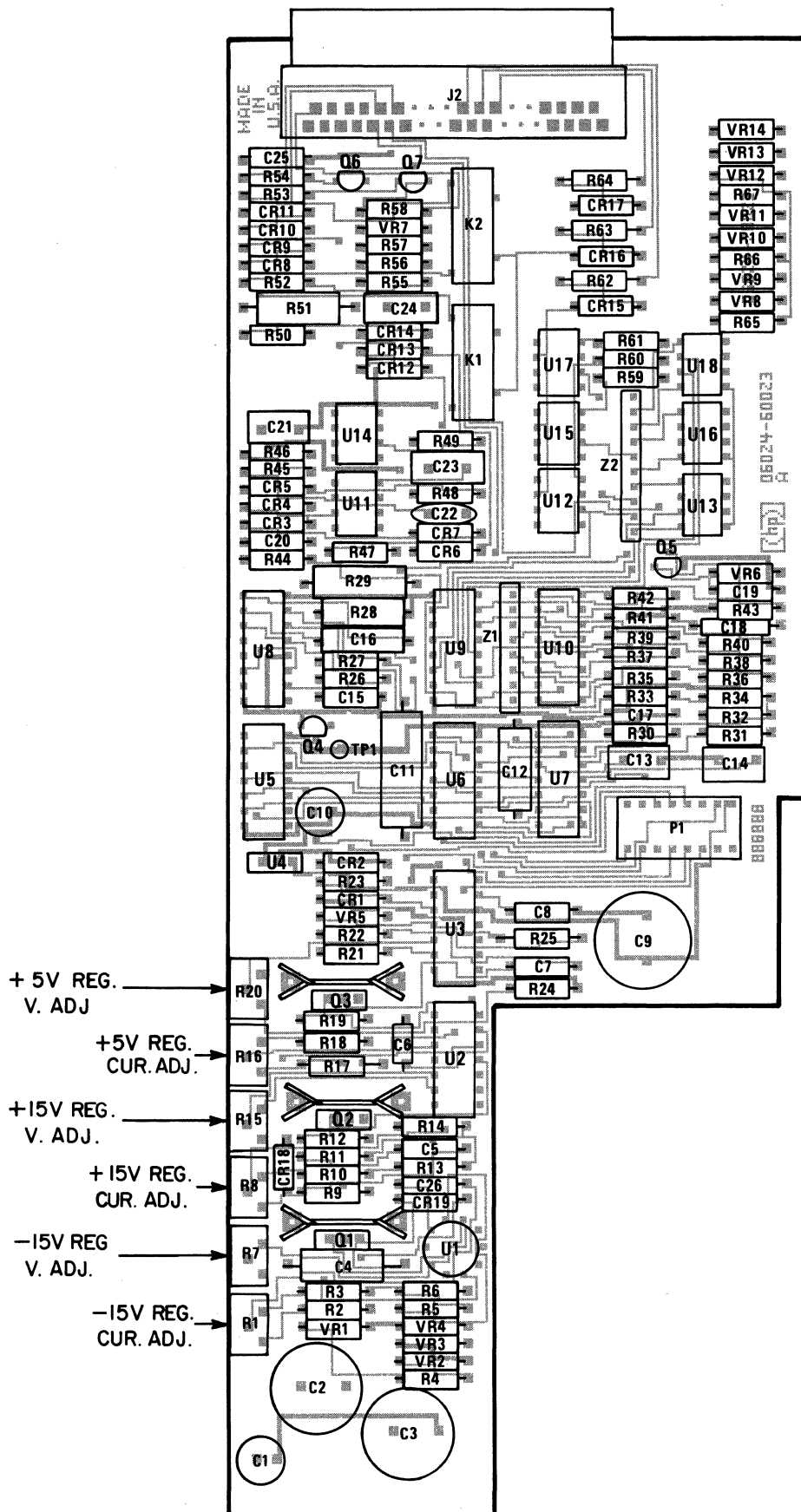
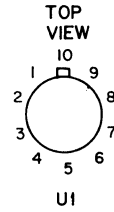
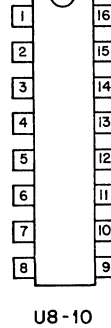
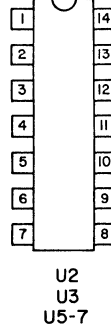
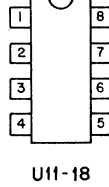
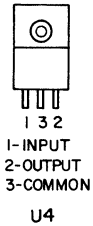
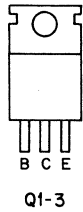


Figure A-14. Option 002 Board Component Location

SCHEMATIC NOTES:

1. ALL RESISTORS ARE IN OHMS, $\pm 5\%$, 1/4W, UNLESS OTHERWISE INDICATED.
2. ALL CAPACITORS ARE IN MICROFARADS, UNLESS OTHERWISE INDICATED.
3. WHITE SILKSCREENED DOTS ON P.C. BOARDS INDICATE ONE OF THE FOLLOWING:
 - A. PIN 1 OF AN I.C. (EXCEPT FOR U1, SEE NOTE 4).
 - B. POSITIVE END OF A POLARIZED CAPACITOR.
 - C. CATHODE OF A DIODE OR THE EMITTER OF A TRANSISTOR.
4. PIN LOCATIONS FOR SEMICONDUCTORS ARE SHOWN BELOW:



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

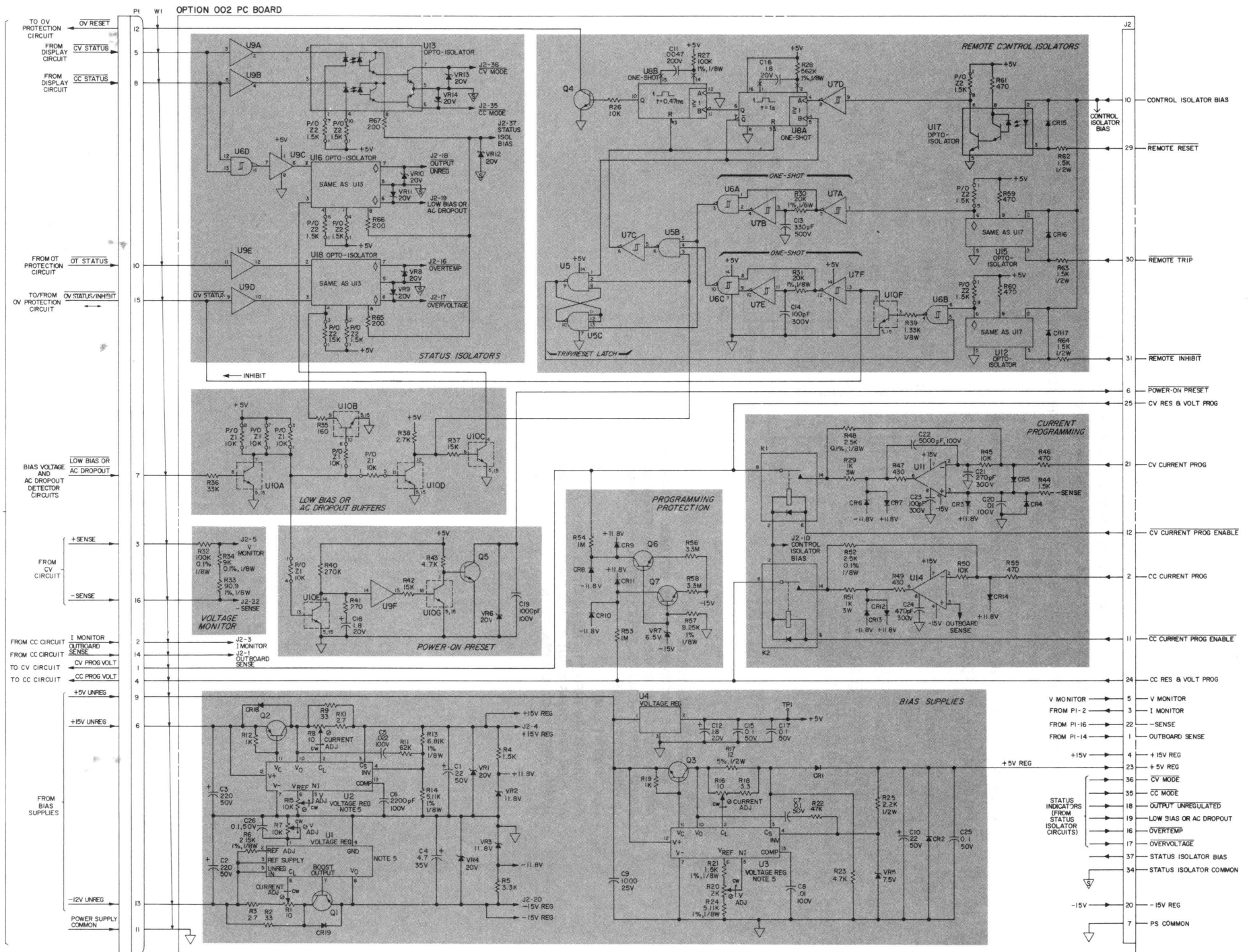
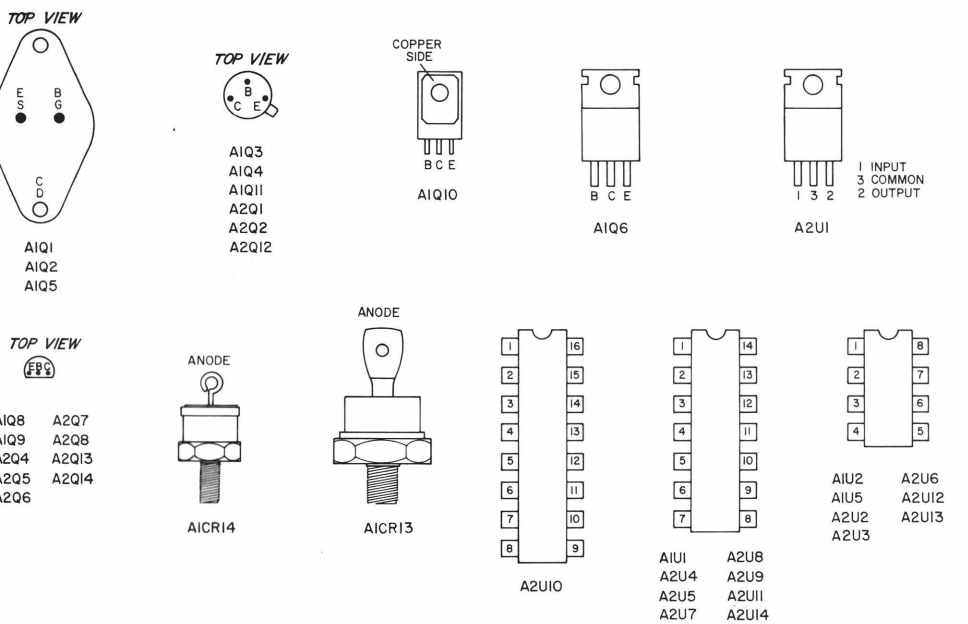


Figure A-15. Model 6024A Option 002, Schematic Diagram



MANUAL CHANGES
Model 6024A Autoranging DC Power Supply
Manual HP Part No. 06024-90001

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

SERIAL		MAKE CHANGES
Prefix	Number	
All		Errata
2126A	0611-0660	1
2129A	0661-1390	1,2
2229A	1391-up	1,2,3

ERRATA:

In Table 1-1, under REMOTE PROGRAMMING, Accuracy specifications should be:

Resistance Programming

CV; 0.8% + 2mV CC; 2.5% +2mA

Voltage Programming

CV; 0.2% + 2mV CC; 1.0% +2mA

Current Programming

CV; 0.2% + 0.36V + accuracy of resistor

CC; 1.0% + 0.15A + 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 (A).

Paragraph 5-44 step a should be:

Connect test setup shown in Figure 5-7.

Set R_L to minimum resistance initially.

Paragraph 5-44 step f should begin:

Increase resistance of R_L until DVM reads exactly 20V (maximum rated power output).

Ensure that power supply remains in constant-current mode.

Paragraph 5-81 step c should be:

Adjust A2R65 for less than $\pm 2\text{mV}$ on DVM.

Paragraph 5-87 step d should be:

Adjust A2R91 for less than $\pm 0.02\text{mV}$ on DVM (less than 2mA through shunt).

Paragraph 5-89 step e should be:

Adjust A2R92 for 0.1V $\pm 0.2\text{mV}$ on DVM (10A $\pm 20\text{mA}$ 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 Part No. 0140-0203, 30pF 5% 500V MICA; R63, HP Part No. 0683-1065, 10M 5% .25W F; R64, HP Part No. 0698-5094, 5.1M 5% .25W F.

CHANGE 1:

In the replaceable parts list, page 6-8 Delete Support Spacers HP Part No. 1390-0481 and Add NUT EXPANSION HP Part No. 0590-1422.

CHANGE 2:

In the replaceable parts list, page 6-5 change C23 to 2.2 μF Polyester, HP Part No. 0160-5377 and C28 to Fixed electrolytic 390 μF , 20Vdc HP Part No. 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 R67,68 62 Ω , 1/8W, HP P/N 0698-4132. R67,68 should have asterisks marked next to them when added to the parts list.

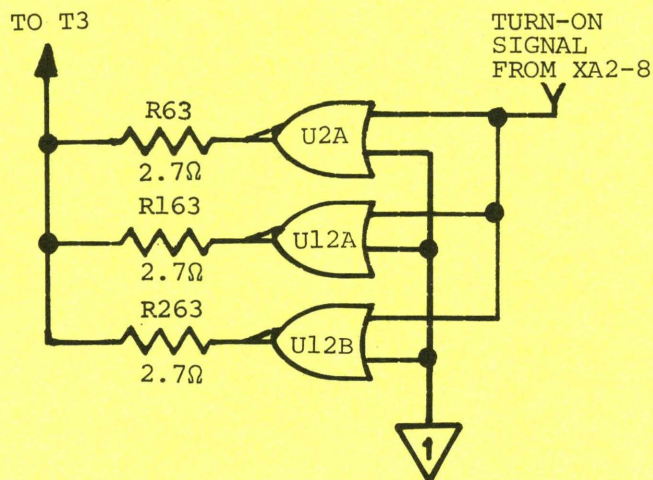
On page 6-4 change T3,4 to HP P/N 5080-2018. Also, T3,4 should have asterisks marked next to them.

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On page 6-4 add U12, IC. driver, HP P/N 1820-1050, qty. 1. and also add R163, 263 Fixed comp., $2.7\Omega \pm 5\%$, 1/4W, HP P/N 0683-0275, qty. 1. When adding these components to the parts list, mark an asterisk next to them.

U12A and U12B, R163, R263 should be added to schematic 7-6 in parallel with U2A as shown below.



On page 6-5 in the replaceable parts list change R32,33 to $24.3K\Omega \pm 1\%$, 1/8W HP P/N 0757-0451, qty.2.

For units with serial numbers up to 2129A-1390, if any parts in service kit have to be replaced, unit must be modified with Service Kit 5080-2021 according to instructions in HP Service Note 6024-1. Make note of units modification so that subsequent repair of A1Q1, A1Q2 and associated components can be done with HP Service Kit 5080-1953.

11-1-82

