

DC POWER SUPPLY

MPB-3 SERIES, MODEL 6299A

SERIAL NUMBER PREFIX 5K

Printed: September, 1966  
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Make all corrections in the manual according to errata below. then check the following table for your power supply serial number and enter any listed change(s) in the manual.

MAKE	SERIAL	
	Prefix	Number
CHANGES	ALL	-
	5K	0421 - 0480
	7M	0481 - 0690
	7M	0691 - 0780
	7M	0781 - 1100
	7M	1101 - 1220
	7M	1 thru 5
	7M	1 thru 6
	1144A	1341 - up
	Errata	1
		1, 2
		1, 2, 3
		1, 2, 3, 4
		1 thru 8

ERRATA:

Change Q8, 10, 12, 14, 15; to 2N2907A, Sprague, HP Part No. 1853-0099.

On Page 3-3, Figure 3-4, unstrap terminals A6 and A7. Positive end of voltage source should be connected to A6; A7 should be connected to +S. On Figure 3-6, disconnect strap between A4 and A5 and connect A4 to +S. On Page 3-4, Figure 3-7, connect A10 to +S.

In the specifications table on Page 1-3, change the "Internal Impedance as a Constant Voltage Source" Specification to:  
 16 milliohms in series with 1 microhenry.

CHANGE 1:

In the replaceable parts table, make the following change:

- R40: Delete resistor R40.
- R62: Change to 750 $\Omega$ , 1/8W, HP Part No. 0757-0420.
- R63: Change to 5k $\Omega$  potentiometer, HP Part No. 2100-1824.
- R64, 65: Change to 12k $\Omega$ , 1/8W, HP Part No. 0698-5088.
- VR3: Add new zener diode, (4.22V) HP Part No. 1902-3070.

The Serial Number Prefix of the instrument has

CHANGE 2:

On the schematic, delete resistor R40 in the meter circuit and connect VR3 in its place. Anode of VR3 to base of Q15 and cathode to +12.4V

been changed from "5K" to "7M."

In the replaceable parts table, make the following

changes:

Q11, Q13: Delete these two transistors and re-

place with new single differential amplifier

(HP Part No. 1854-0229). Circuit connections

on schematic remain the same with Q11 serving

as the "A" side and Q13 the "B" side of the new

transistor.

R48: Change to 1.8k $\Omega$ , 1/2W, HP Part No.

0686-1825.

On the schematic, delete R48 in the reference reg-

ulator circuit, and connect new R48 between emit-

ter of Q6 (TP23) and -6.2Vdc (TP31).

CHANGE 3:

In the replaceable parts table make the following

changes:

Q3 and Q9: Change to NPN, SS, St. (Selected

HP Part No. 1854-0071.

Q11: Change to 2N4045, Union Carbide, HP

Part No. 1854-0221.

CHANGE 4:

In the replaceable parts table, add Guard, Termin-

al Strip, HP Part No. 5060-6181.

CHANGE 5:

In the replaceable parts list, make the following

changes:

S1: Change to HP Part No. 3101-1248.

Terminal Strip: Add, HP Part No. 0360-0417,

Quantity 1.

CHANGE 6:

In the replaceable parts table, change power trans-

former T1 to HP Part No. 06299-80091.

CHANGE 7:

The Serial Prefix of this unit has been changed to

1144A. This is the only change.

ERRATA:

The first sentence of paragraph 3-29 should read:  
 "The output current will be the programming volt-

age divided by 1.33 ohms."

► CHANGE 8:

In Appendix A, Option 11 Replaceable Parts Table  
A-1, change CR4 from HP Part No. 1884-0058 to  
1884-0032.

5-14-73

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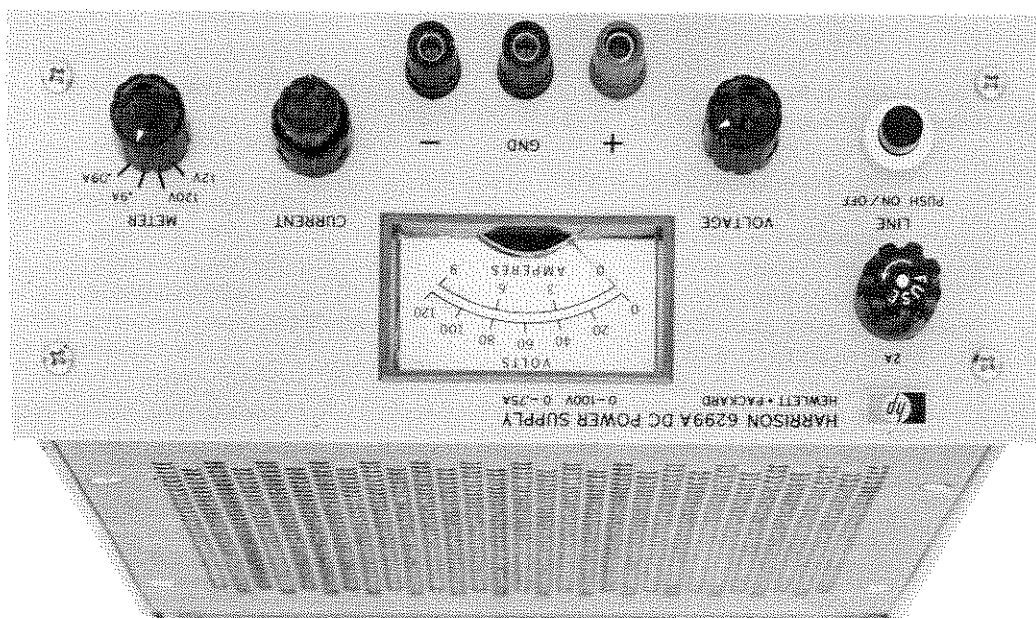
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Figure 1-1. DC Power Supply, Model 6299A



SECTION I  
GENERAL INFORMATION

1-1 DESCRIPTION

1-2 This power supply, Figure 1-1, is completely transistorized and suitable for either bench or relay rack operation. It is a compact, well-regulated, Constant Voltage/Constant Current supply that will furnish full rated output voltage at the maximum rated output current or can be continuously adjusted throughout the output range. The front panel CURRENT controls can be used to establish the output current limit (overload or short circuit) when the supply is used as a constant voltage source and the VOLTAGE controls can be used to establish the voltage limit (ceiling) when the supply is used as a constant current source. The supply will automatically crossover from constant voltage to constant current operation and vice versa if the output current or voltage exceeds these preset limits.

1-3 The power supply has both front and rear terminals. Either the positive or negative output terminal may be grounded or the power supply can be operated floating at up to a maximum of 300 volts off ground.

1-4 A single meter is used to measure either output voltage or output current in one of two ranges. The voltage or current ranges are selected by a METER switch on the front panel.

1-5 The programming terminals located at the rear of the unit allow ease in adapting to the many operational capabilities of the power supply. A brief description of these capabilities is given below:

a. Remote Programming  
The power supply may be programmed from a remote location by means of an external voltage source or resistance.

b. Remote Sensing  
The degradation in regulation which occurs at the load because of the voltage drop in the load leads can be reduced by using the power supply in the remote sensing mode of operation.

c. Series and Auto-Series Operation  
Power supplies may be used in series when a higher output voltage is required in the constant voltage mode of operation or when greater voltage compliance is required in the constant current mode of operation. Auto-Series operation permits one knob control of the total output voltage

d. Parallel and Auto-Parallel Operation  
The power supply may be operated in parallel with a similar unit when greater output current capability is required. Auto-Parallel operation permits one knob control of the total output current from a "master" supply.

e. Auto-Tracking  
The power supply may be used as a "master" supply, having control over one (or more) "slave" supplies that furnish various voltages for a system.

1-6 SPECIFICATIONS

1-7 Detailed specifications for the power supply are given in Table 1-1.

1-8 OPTIONS

1-9 Options are factory modifications of a standard instrument that are requested by the customer. The following options are available for the instrument covered by this manual. Where necessary, detailed coverage of the options is included throughout the manual.

Option No.	Description
06	Overvoltage Protection "Crowbar": A completely separate circuit for protecting delicate loads against power supply failure or operator error. This independent device monitors the output voltage and within 10µsec imposes a virtual short-circuit (crowbar) across the power supply output if the preset overvoltage margin is exceeded. When Option 06 is requested by the customer the device is attached to the rear of the power supply at the factory. This option is not available for Model 6281A supplies.
	Overvoltage Margin: 1 to 4 volts, screwdriver adjustable.
	Power Requirement: 15ma continuous drain from power supply being protected.
	Size: Add 5 inches to power supply depth dimension.

Option No. Description  
 arately from your local Hewlett-Packard field sales office. (refer to list at rear of manual for addresses).

Weight: Add 2 lbs. net.

NOTE

-hp- Part No.	Description
C05	8" Black Handle that can be attached to side of supply.
14513A	Rack Kit for mounting one 3 1/2" -high supply. (Refer to Section II for details.)
14523A	Rack Kit for mounting two 3 1/2" -high supplies. (Refer to Section II for details.)

Detailed coverage of Option 06 is included in an addendum at the rear of manuals that support power supplies containing Option 06.

Voltage 10-Turn Pot: A single control that replaces both coarse and fine voltage controls and improves output settable.

Current 10-Turn Pot: A single control that replaces both coarse and fine current controls and improves output settable.

Voltage and Current 10-Turn Pots: Consists of options 07 and 08 on the same instrument.

Three Digit Graduated Decadal Current Control: Control that replaces coarse and fine current controls permitting accurate resettable.

Three Digit Graduated Decadal Current Control: Control that replaces coarse and fine current controls permitting accurate resettable.

Rewire for 230V AC Input: Supply as normally shipped is wired for 115 Vac input. Option 19 consists of re-connecting the input transformer for 230 Vac operation.

1-16 One manual is shipped with each power supply. Additional manuals may be purchased from your local Hewlett-Packard field office (see list at rear of this manual for addresses). Specify the model number, serial number prefix, and -hp- stock number provided on the title page.

1-11 The accessories listed in the following chart may be ordered with the power supply or separately.

1-10 ACCESSORIES

1-15 ORDERING ADDITIONAL MANUALS

1-14 If the serial number prefix on your power supply does not agree with the prefix on the title page of this manual, change sheets are included to update the manual. Where applicable, backdating information is given in an appendix at the rear of the manual.

1-13 Hewlett-Packard power supplies are identified by a three-part serial number tag. The first part is the power supply model number. The second part is the serial number prefix, which consists of a number-letter combination that denotes the date of a significant design change. The number designates the year, and the letter A through L designates the month, January through December respectively. The third part is the power supply serial number.

1-12 INSTRUMENT IDENTIFICATION



Table 1-1. Specifications

<p><b>INPUT:</b> 105-125/210-250VAC, single phase, 50-400 Hz.</p> <p><b>OUTPUT:</b> 0-100 volts @ 0.75 amps.</p> <p><b>LOAD REGULATION:</b> Constant Voltage--Less than 0.01% plus 2mv for a full load to no load change in output current. Constant Current--Less than 0.01% plus 250µa for a zero to maximum change in output voltage.</p> <p><b>LINE REGULATION:</b> Constant Voltage--Less than 0.01% plus 2 mv for any line voltage change within the input rating. Constant Current--Less than 0.01% plus 250µa for any line voltage change within the input rating.</p> <p><b>RIPPLE AND NOISE:</b> Constant Voltage--Less than 200µv rms. Constant Current--Less than 500µa rms.</p> <p><b>TEMPERATURE RANGES:</b> Operating: 0 to 50°C. Storage: -20 to +85°C.</p> <p><b>TEMPERATURE COEFFICIENT:</b> Constant Voltage--Less than 0.02% plus 500µv per degree Centigrade. Constant Current--Less than 0.02% plus 0.4ma per degree Centigrade.</p> <p><b>STABILITY:</b> Constant Voltage--Less than 0.10% plus 2.5mv total drift for 8 hours after an initial warm-up time of 30 minutes at constant ambient, constant line voltage, and constant load. Constant Current--Less than 0.10% plus 2ma total drift for 8 hours after an initial warm-up time of 30 minutes at constant ambient, constant line voltage, and constant load.</p> <p><b>INTERNAL IMPEDANCE AS A CONSTANT VOLTAGE SOURCE:</b> Less than 0.001 ohm from DC to 100Hz. Less than 0.01 ohm from 100Hz to 1KHz. Less than 0.2 ohm from 1KHz to 100KHz. Less than 2.0 ohms from 100KHz to 1MHz.</p> <p><b>TRANSIENT RECOVERY TIME:</b> Less than 50µsec for output recovery to within 15mv following a full load current change in the output.</p> <p><b>OVERLOAD PROTECTION:</b> A continuously acting constant current circuit protects the power supply for all overloads.</p>	<p><b>INCLUDING A DIRECT SHORT PLACED ACROSS THE TERMINALS IN CONSTANT VOLTAGE OPERATION.</b> The constant voltage circuit limits the output voltage in the constant current mode of operation.</p> <p><b>METER:</b> The front panel meter can be used as either a 0-120 or 0-12 volt voltmeter or as a 0-1 amp or 0-0.1 amp ammeter.</p> <p><b>OUTPUT CONTROLS:</b> Ten-turn voltage control and coarse and fine current controls set desired output voltage or current.</p> <p><b>OUTPUT TERMINALS:</b> Three "five-way" output posts are provided on the front panel and an output terminal strip is located on the rear of the chassis. All power supply output terminals are isolated from the chassis and either the positive or negative terminal may be connected to the chassis through a separate ground terminal located on the output terminal strip.</p> <p><b>ERROR SENSING:</b> Error sensing is normally accomplished at the front terminals if the load is attached to the front or at the rear terminals if the load is attached to the rear terminals. Also, provision is included on the rear terminal strip for remote sensing.</p> <p><b>REMOTE PROGRAMMING:</b> Remote programming of the supply output at approximately 300 ohms per volt in constant voltage is made available at the rear terminals. In constant current mode of operation, the current can be remotely programmed at approximately 1000 ohms per ampere.</p> <p><b>COOLING:</b> Convection cooling is employed. The supply has no moving parts.</p> <p><b>SIZE:</b> 3½" H x 14½" D x 8½" W. Two of the units can be mounted side by side in a standard 19" relay rack.</p> <p><b>WEIGHT:</b> 15 lbs. net, 20 lbs. shipping.</p> <p><b>FINISH:</b> Light gray front panel with dark gray case.</p> <p><b>POWER CORD:</b> A three-wire, five-foot power cord is provided with each unit.</p>
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SECTION II  
INSTALLATION

"In-cabinet" performance check to verify proper instrument operation.

2-7 INSTALLATION DATA

2-8 The instrument is shipped ready for bench operation. It is necessary only to connect the instrument to a source of power and it is ready for operation.

2-9 LOCATION

2-10 This instrument is air cooled. Sufficient space should be allotted so that a free flow of cooling air can reach the sides and rear of the instrument when it is in operation. It should be used in an area where the ambient temperature does not exceed 50°C.

2-11 RACK MOUNTING

2-12 This instrument may be rack mounted in a standard 19" rack panel either alongside a similar

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, proceed as described in the Claim for Damage in Shipment section of the warranty page at the rear of this manual.

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 meter is not scratched or cracked.

2-5 ELECTRICAL CHECK

2-6 The instrument should be checked against its electrical specifications. Section V includes an

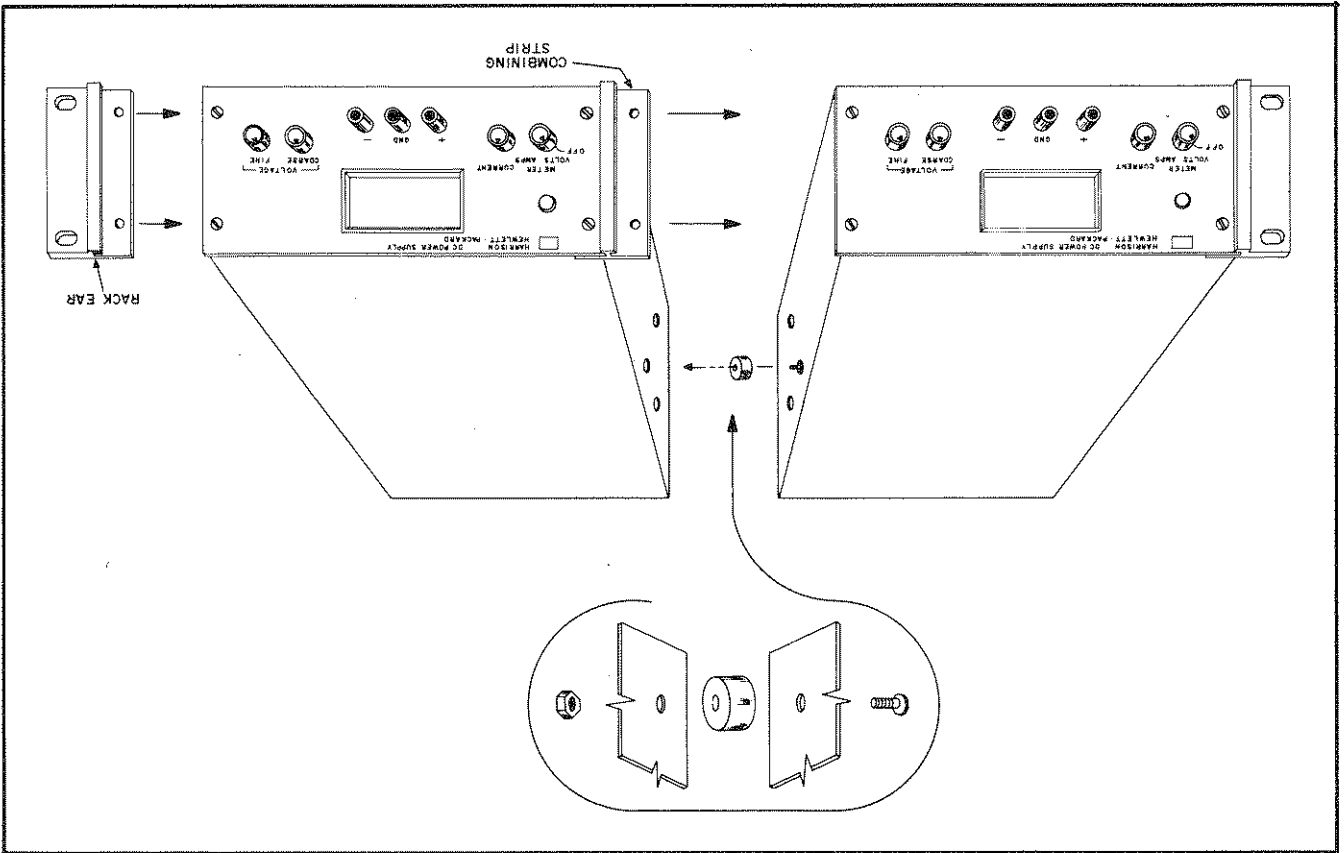


Figure 2-1. Rack Mounting, Two Units

2-18 Normally, the two primary windings of the input transformer are connected in parallel for operation from 115 Volt source. To convert the power supply to operation from a 230 Volt source, the power transformer windings are connected in series as follows:

2-17 CONNECTIONS FOR 230 VOLT OPERATION (See Figure 2-3)

Figure 2-3. Primary Connections

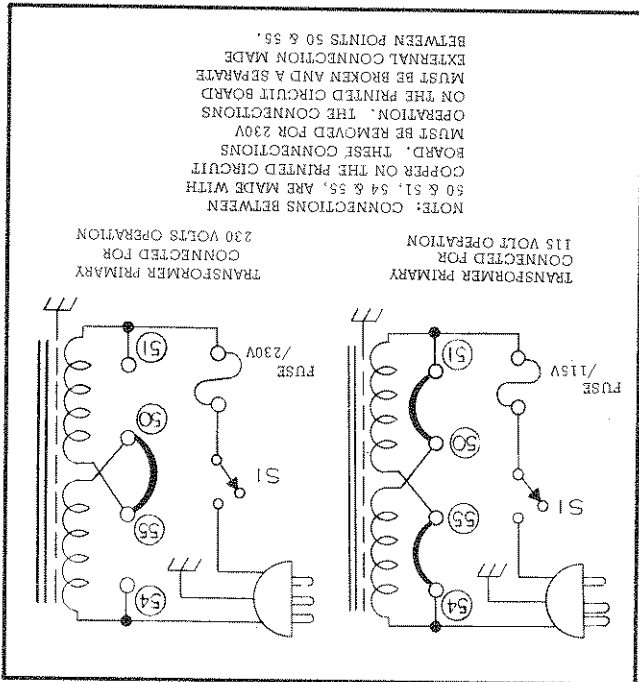
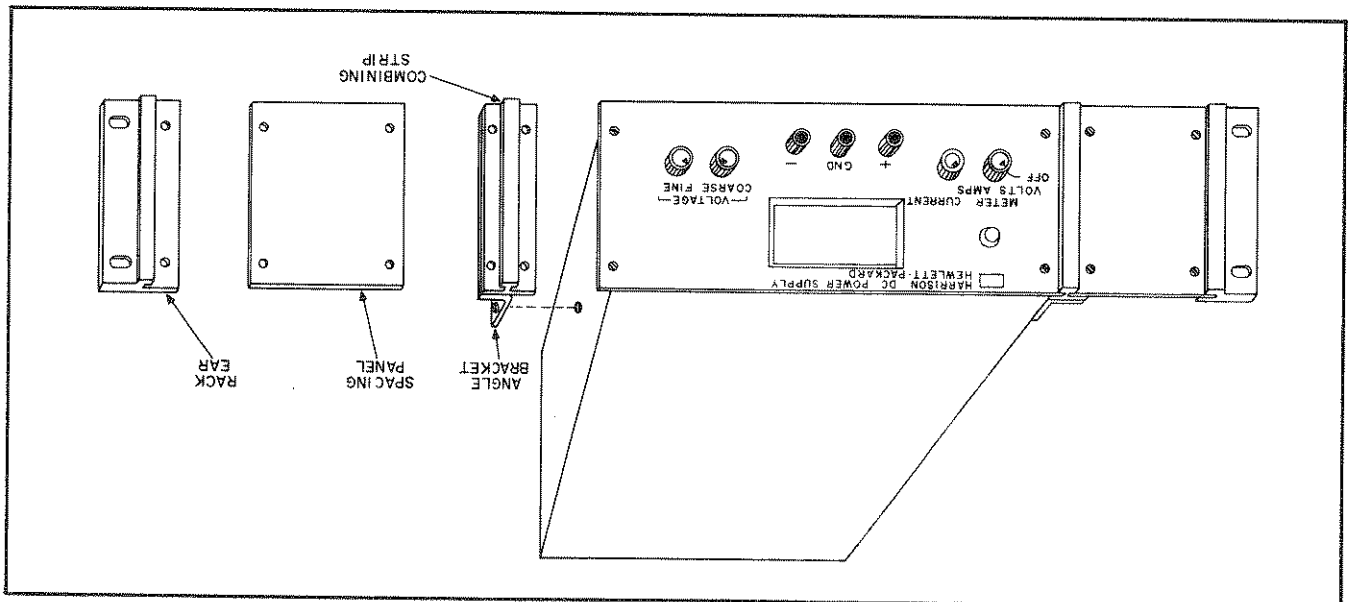


Figure 2-2. Rack Mounting, One Unit



- unit or by itself. Figures 2-1 and 2-2 show how both types of installations are accomplished.
- 2-13 To mount two units side-by-side, proceed as follows:
- Remove the four screws from the front panels of both units.
  - Slide rack mounting ears between the front panel and case of each unit.
  - Slide combining strip between the front panels and cases of the two units.
  - After fastening rear portions of units together using the bolt, nut, and spacer, replace panel screws.
- 2-14 To mount a single unit in the rack panel, proceed as follows:
- Bolt rack mounting ears, combining straps, and angle brackets to each side of center spacing panels. Angle brackets are placed behind combining straps as shown in Figure 2-2.
  - Remove four screws from front panel of unit.
  - Slide combining strips between front panel and case of unit.
  - Bolt angle brackets to front sides of case and replace front panel screws.
- 2-15 INPUT POWER REQUIREMENTS
- 2-16 This power supply may be operated from either a nominal 115V or 230V, 48-440Hz power source. The unit, as shipped from the factory, is wired for 115V operation. The input power source at full load is: 6281A, 6289A, 6294A 118W, 1.5A  
6284A 135W, 1.5A

2-21 To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green lead on the adapter to ground.

2-22 REPACKAGING FOR SHIPMENT

2-23 To insure safe shipment of the instrument, it is recommended that the package designed for the instrument be used. The original packaging material is reusable. If it is not available, contact your local Hewlett-Packard field office to obtain the materials. This office will also furnish the address of the nearest service office to which the instrument can be shipped. Be sure to attach a tag to the instrument which specifies the owner, model number, full serial number, and service required, or a brief description of the trouble.

a. Unplug the line cord and remove the unit from case.

b. Break the copper between 54 and 55 and also between 50 and 51 on the printed circuit board. These are shown in Figure 2-3, and are labeled on copper side of printed circuit board.

c. Add strap between 50 and 55.

d. Replace existing fuse with 1 Ampere, 230 Volt fuse. Return unit to case and operate normally.

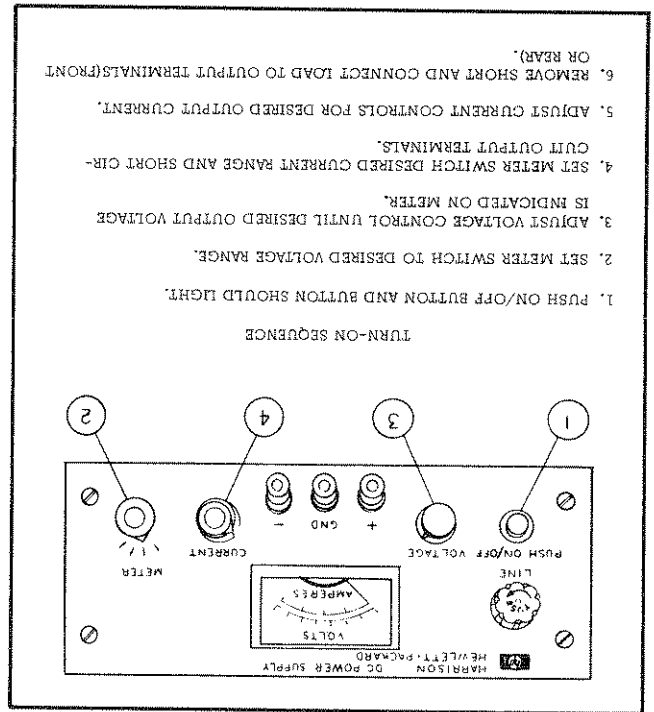
2-19 POWER CABLE

2-20 To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. This instrument is equipped with a three conductor power cable. The third conductor is the ground conductor and when the cable is plugged into an appropriate receptacle, the instrument is grounded. The offset pin on the power cable three-

SECTION III  
OPERATING INSTRUCTIONS

3-1 OPERATING CONTROLS AND INDICATORS

3-2 The front panel controls and indicators, together with the normal turn-on sequence, are shown in Figure 3-1.



3-3 OPERATING MODES

3-4 The power supply is designed so that its mode of operation can be selected by making strapping connections between particular terminals on the terminal strip at the rear of the power supply. The terminal designations are stenciled in white on the power supply above their respective terminals. Although the strapping patterns illustrated in this section show the positive terminal grounded, the operator can ground either terminal or operate the power supply up to 300Vdc off ground (floating). The following paragraphs describe the procedures for utilizing the various operational capabilities of the power supply. A more theoretical description concerning the operational features of this supply is contained in Application Note 90, DC Power Supply Handbook, which may be obtained from your local Hewlett-Packard field sales office.

3-5 NORMAL OPERATING MODE

3-6 The power supply is normally shipped with its rear terminal strapping connections arranged for Constant Voltage/Constant Current, local sensing, local programming, single unit mode of operation. This strapping pattern is illustrated in Figure 3-2. The operator selects either a constant voltage or a constant current output using the front panel controls (local programming, no strapping changes are necessary).

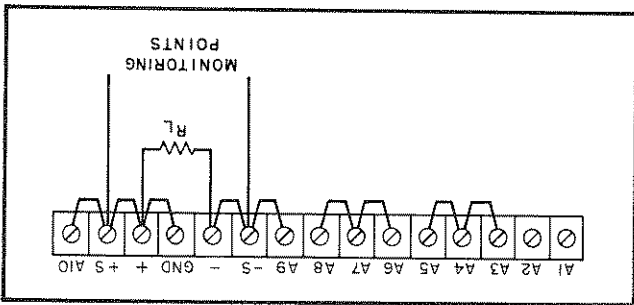


Figure 3-2. Normal Strapping Pattern

3-7 CONSTANT VOLTAGE

3-8 To select a constant voltage output, proceed as follows:

- a. Turn-on power supply and adjust VOLTAGE controls for desired output voltage (output terminals open).

- b. Short output terminals and adjust CURRENT controls for maximum output current allowable (current limit), as determined by load conditions.

If a load change causes the current limit to be exceeded, the power supply will automatically cross-over to constant output at the present current limit and the output voltage will drop proportionately. In setting the current limit, allowance must be made for high peak current which can cause unwanted cross-over. (Refer to Paragraph 3-46.)

3-9 CONSTANT CURRENT

3-10 To select a constant current output, proceed as follows:

- a. Short output terminals and adjust CURRENT controls for desired output current.

b. Open output terminals and adjust VOLTAGE controls for maximum output voltage allowable (voltage limit), as determined by load conditions. If a

3-19 Resistance Programming (Figure 3-3). In this mode, the output voltage will vary at a rate determined by the programming coefficient (200 ohms per Volt for Models 6253A, 6255A, 6281A, 6284A, and 6289A or 300 ohms per Volt for Models 6294A and

3-18 The constant voltage output of the power supply can be programmed (controlled) from a remote location if required. Either a resistance or voltage source can be used for the programming device. The wires connecting the programming terminals of the supply to the remote programming device should be twisted or shielded to reduce noise pick-up. The VOLTAGE controls on the front panel are disabled according to the following procedures.

3-17 REMOTE PROGRAMMING, CONSTANT VOLTAGE

3-16 OPTIONAL OPERATING MODES

3-15 The shaded area on the front panel meter face indicates the amount of output voltage or current that is available in excess of the normal rated output. Although the supply can be operated in this shaded region without being damaged, it cannot be guaranteed to meet all of its performance specifications. However, if the line voltage is maintained above 115 Vac, the supply will probably operate within its specifications.

3-14 OPERATION OF SUPPLY BEYOND RATED OUTPUT

3-13 If load considerations require that the output power distribution terminals be remotely located from the power supply, then the power supply output terminals should be connected to the remote distribution terminals via a pair of twisted or shielded wires and each load separately connected to the remote distribution terminals. For this case, remote sensing should be used (Paragraph 3-20).

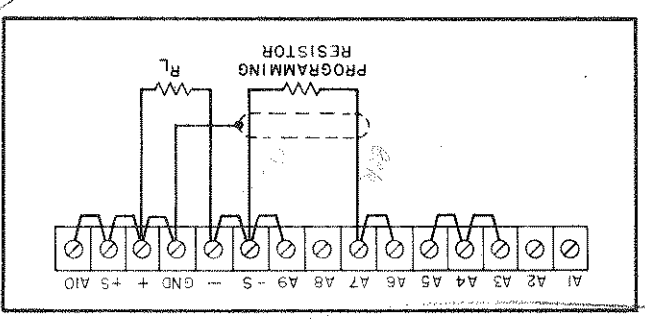
3-12 Each load should be connected to the power supply output terminals using separate pairs of connecting wires. This will minimize mutual coupling effects between loads and will retain full advantage of the low output impedance of the power supply. Each pair of connecting wires should be as short as possible and twisted or shielded to reduce noise pickup. (If shield is used, connect one end to power supply ground terminal and leave the other end unconnected.)

3-11 CONNECTING LOAD

load change causes the voltage limit to be exceeded, the power supply will automatically crossover to constant voltage output at the preset voltage limit and the output current will drop proportionately. In setting the voltage limit, allowance must be made for high peak voltages which can cause unwanted crossover. (Refer to Paragraph 3-46.)

6294A). The output voltage will increase 1 Volt for each 200 ohms (or 300 ohms) added in series with the programming terminals. The programming coefficient is determined by the programming current. This current is factory adjusted to within 2% of 5mA for Models 6253A, 6255A, 6281A, 6284A, and 6289A or 2% of 3.3mA for Models 6294A and 6299A. If greater programming accuracy is required, it may be achieved by changing resistor R13.

Figure 3-3. Remote Resistance Programming (Constant Voltage)



3-20 The output voltage of the power supply should be zero Volts  $\pm 20$  millivolts when zero ohms is connected across the programming terminals. If a zero ohm voltage closer than this is required, it may be achieved by changing resistor R6 or R8 as described in Paragraph 5-59.

3-21 To maintain the stability and temperature coefficient of the power supply, use programming resistors that have stable, low noise, and low temperature (less than 30 ppm per degree Centigrade) characteristics. A switch can be used in conjunction with various resistance values in order to obtain discrete output voltages. The switch should have make-before-break contacts to avoid momentarily opening the programming terminals during the switching interval.

3-22 Voltage Programming (Figure 3-4). Employ the strapping pattern shown on Figure 3-4 for

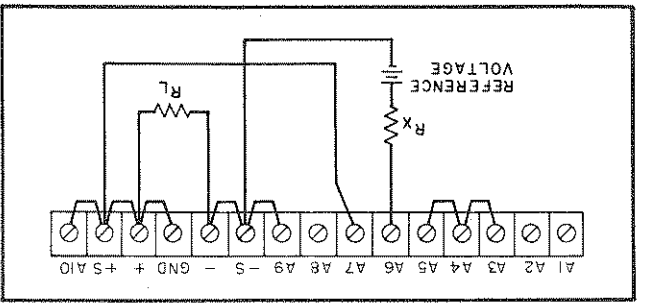


Figure 3-4. Remote Voltage Programming (Constant Voltage)

3-23 The impedance matching resistor (RX) for the programming voltage source should be approximately 500 ohms to maintain the temperature and stability specifications of the power supply.

### 3-24 REMOTE PROGRAMMING, CONSTANT CURRENT

3-25 Either a resistance or a voltage source can be used to control the constant current output of the supply. The CURRENT controls on the front panel are disabled according to the following procedures.

3-26 Resistance Programming (Figure 3-5). In this mode, the output current varies at a rate determined by the programming coefficient—200 ohms per Ampere for Models 6294A and 6299A. The programming coefficient is determined by the Constant Current programming current (2mA for Models 6253A, 6255A, 6284A, and 6289A, 5mA for Model 6281A, 1mA for Model 6294A and 1.3mA for Model 6299A). This current is adjusted to within 10% at the factory. If greater programming accuracy is required, it may be achieved by changing resistor R19 as outlined in Section V.

3-27 Use stable, low noise, low temperature coefficient (less than 30ppm/°C) programming resistors to maintain the power supply temperature coefficient and stability specifications. A switch may be used to set discrete values of output current. A make-before-break type of switch should be used since the output current will exceed the maximum rating of the power supply if the switch contacts open during the switching interval.

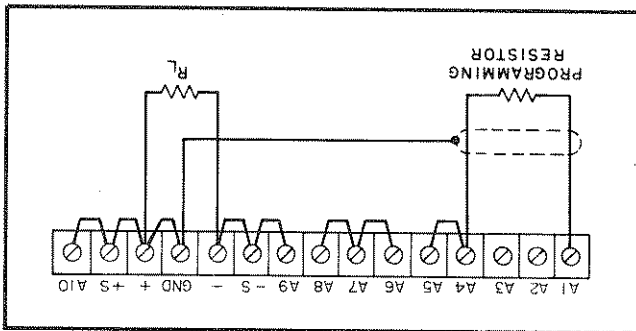


Figure 3-5. Remote Resistance Programming (Constant Current)

3-28 Voltage Programming (Figure 3-6). In this mode, the output current will vary linearly with changes in the programming voltage. The programming voltage should not exceed 1.2 Volts. Voltage in excess of 1.2 Volts will result in excessive power dissipation in the instrument and possible damage.

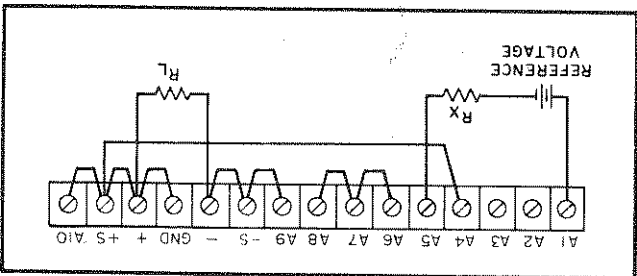


Figure 3-6. Remote Voltage Programming (Constant Current)

If the programming terminals (A1 and A5) should open at any time during this mode, the output current will rise to a value that may damage the power supply and/or the load. To avoid this possibility, connect a resistor across the programming terminals having the value listed below. Like the programming resistor, this resistor should be of the low noise, low temperature coefficient type.

Model	Resistance
6253A, 6284A, 6255A, 6289A, 6299A	1.5k $\Omega$
6281A, 6294A	1k $\Omega$

3-29 The output current will be the programming voltage divided by 1 ohm. The current required from the voltage source will be less than 25 microamperes. The impedance matching resistor (RX) should be approximately 500 ohms if the temperature coefficient and stability specifications of the power supply are to be maintained.

### 3-30 REMOTE SENSING (See Figure 3-7)

3-31 Remote sensing is used to maintain good regulation at the load and reduce the degradation of regulation which would occur due to the voltage drop in the leads between the power supply and the load. Remote sensing is accomplished by utilizing the strapping pattern shown in Figure 3-7. The power supply should be turned off before changing strap-

3-27 Use stable, low noise, low temperature coefficient (less than 30ppm/°C) programming resistors to maintain the power supply temperature coefficient and stability specifications. A switch may be used to set discrete values of output current. A make-before-break type of switch should be used since the output current will exceed the maximum rating of the power supply if the switch contacts open during the switching interval.

3-38 In order to maintain the temperature coefficient and stability specifications of the power supply, the external resistors (Rx) shown in Figure 3-9 should be stable, low noise, low temperature coefficient (less than 30 ppm per degree Centigrade) resistors. The value of each resistor is dependant on the maximum voltage of the "master" supply. The value of Rx is this voltage divided by the voltage programming current of the slave supply ( $1/K_p$  where  $K_p$  is the voltage programming coefficient). The voltage contribution of the slave is determined by its voltage control setting.

3-37 Auto-Series Connections (Figure 3-9). The Auto-Series configuration is used when it is desirable to have the output voltage of each of the series connected supplies vary in accordance with the setting of a control unit. The control unit is called the master; the controlled units are called slaves. At maximum output voltage, the voltage of the front slaves is determined by the setting of the front panel VOLTAGE control on the master. The master supply must be the most positive supply of the series. The output CURRENT controls of all series units are operative and the current limit is equal to the lowest control setting. If any output CURRENT controls are set too low, automatic crossover to constant current operation will occur and the output voltage will drop. Remote sensing and programming can be used; however, the strapping arrangements shown in the applicable figures show local sensing and programming.

3-36 Normal Series Connections (Figure 3-8). Two

3-35 SERIES OPERATION

3-34 Although the strapping patterns shown in Figures 3-3 through 3-6 employ local sensing, note that it is possible to operate a power supply simultaneously in the remote sensing and Constant Voltage/Constant Current remote programming modes.

3-33 The procedure just described will result in a low dc output impedance at the load. If a low ac impedance is required, it is recommended that the following precautions be taken:

a. Disconnect output capacitor C20 by disconnecting the strap between A9 and -S.

b. Connect a capacitor having similar characteristics (approximately same capacitance, same voltage rating or greater, and having good high frequency characteristics) across the load using short leads.

Due to the voltage drop in the load leads, it may be necessary to readjust the current limit in the remote sensing mode.

**NOTE**

3-32 Note that it is desirable to minimize the drop in the load leads and it is recommended that the drop not exceed 1 Volt per lead if the power supply is to meet its dc specifications. If a larger drop must be tolerated, please consult a Hewlett-Packard field representative.

Figure 3-8. Normal Series Connections

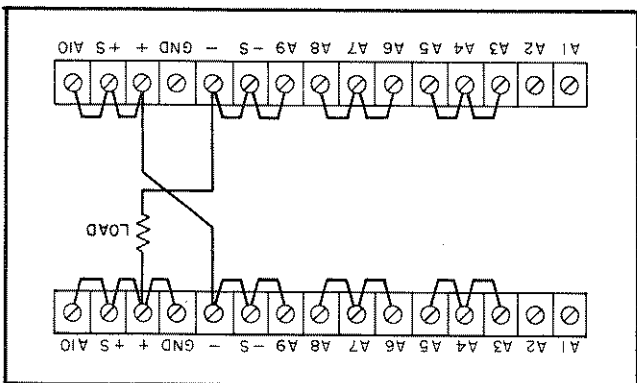
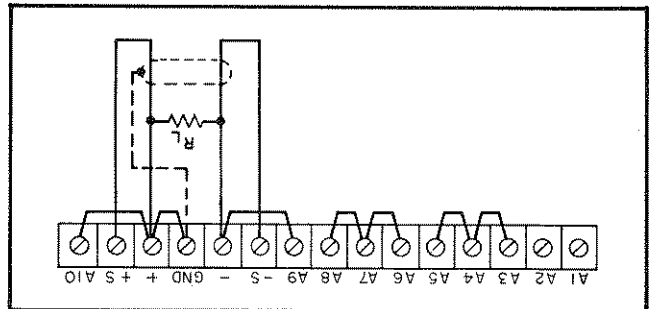


Figure 3-7. Remote Sensing



Observe polarity when connecting the sensing leads to the load.

**CAUTION**

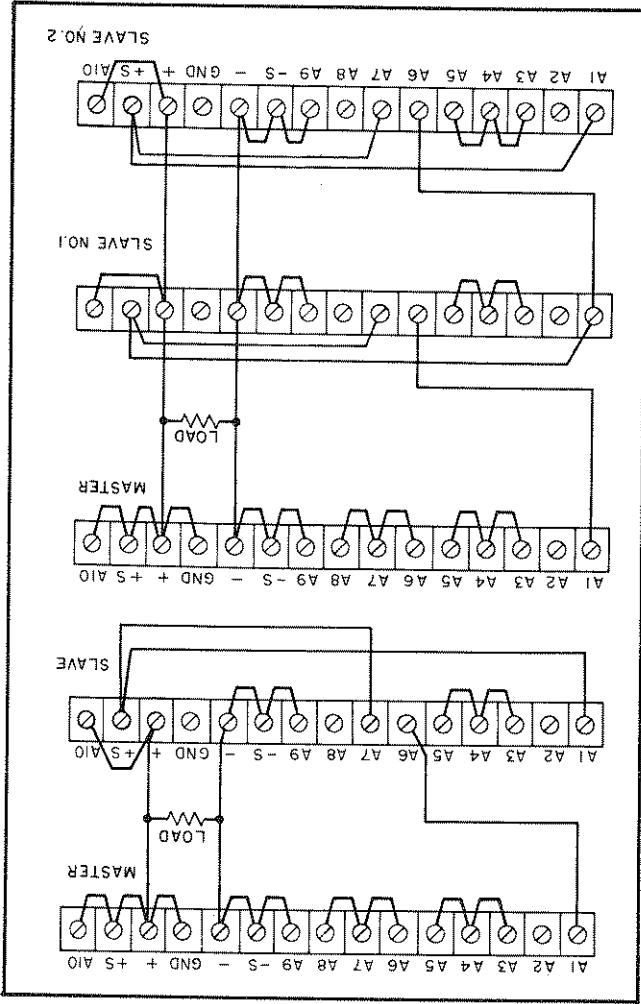
The leads from the +S terminals to the load will carry less than 10mA of current, and it is not required that these leads be as heavy as the load leads. However, they must be twisted or shielded to minimize noise pick-up.

or more power supplies can be operated in series to obtain a higher voltage than that available from a single supply. When this connection is used, the output voltage is the sum of the voltages of the individual supplies. Each of the individual supplies must be adjusted in order to obtain the total output voltage. The power supply contains a protective diode connected internally across the output which protects the supply if one power supply is turned off while its series partner(s) is on.



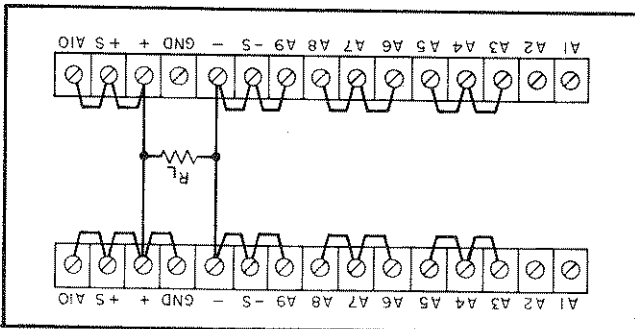
3-41 Auto-Parallel. The strapping patterns for Auto-Parallel operation of two power supplies are shown in Figure 3-11. Auto-Parallel operation permits equal current sharing under all load con-

Figure 3-11. Auto-Parallel, Two and Three Units



voltage until it equals that of the other supply. The constant voltage source will deliver only that fraction of its total rated output current which is necessary to fulfill the total current demand.

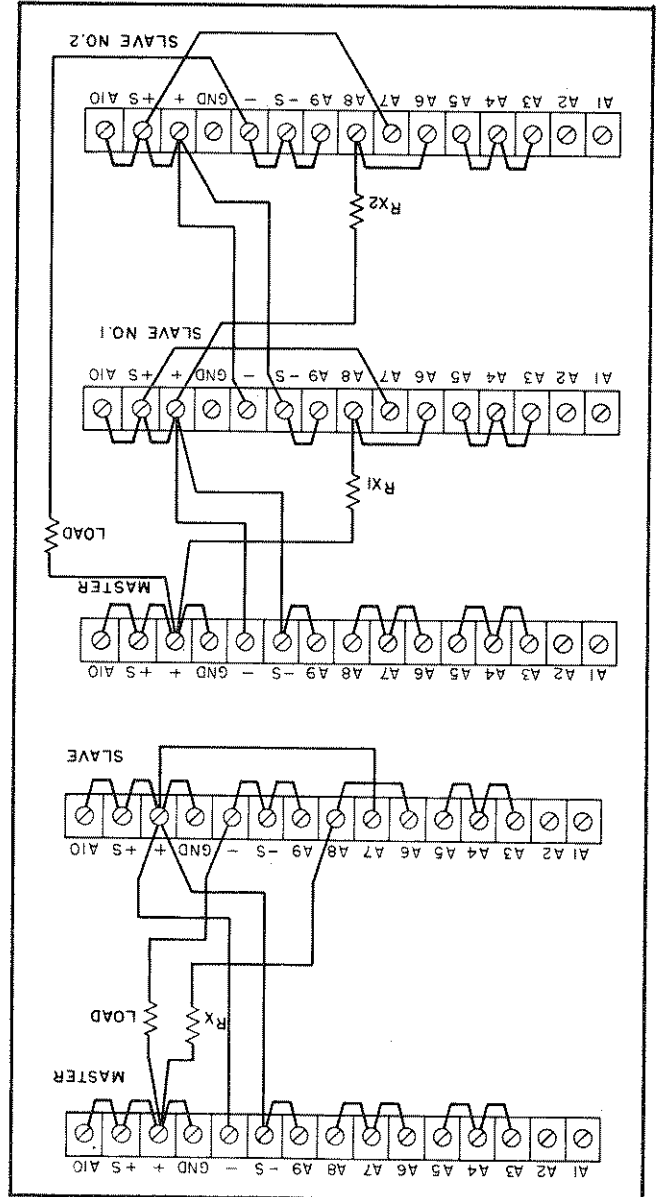
Figure 3-10. Normal Parallel Connections



3-40 Normal Parallel Connections (Figure 3-10). Two or more power supplies can be connected in parallel to obtain a total output current greater than that available from one power supply. The total output current is the sum of the output currents of the individual power supplies. The output CURRENT controls of each power supply can be separately set. The output voltage controls of one power supply should be set to the desired output voltage; the other power supply should be set for a slightly larger output voltage. The supply set to the lower output voltage will act as a constant voltage source; the supply set to the higher output will act as a constant current source, dropping its output

3-39 PARALLEL OPERATION

Figure 3-9. Auto-Series, Two and Three Units



ditions, and allows complete control of output current from one master power supply. The output current of each slave will be approximately equal to the master's regardless of the load conditions. Because the output current controls of each slave are operative, they should be set to maximum to avoid having the slave revert to constant current operation; this would occur if the master output current setting exceeded the slave's.

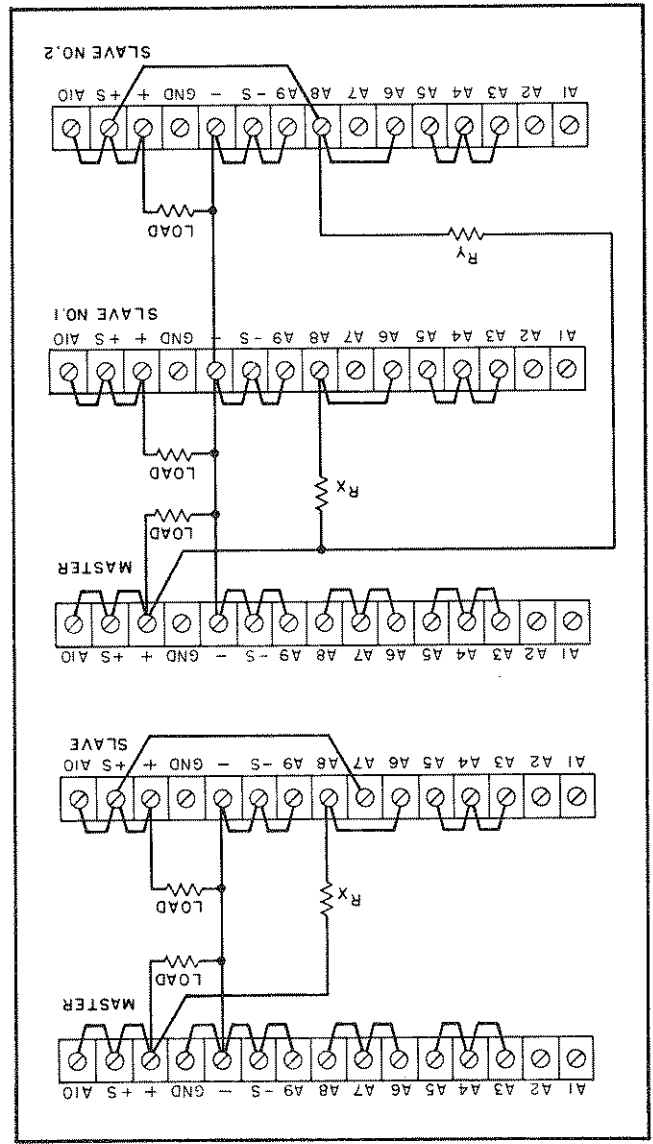


Figure 3-12. Auto-Tracking, Two and Three Units

3-42 AUTO-TRACKING OPERATION (See Figure 3-12)  
 3-43 The Auto-Tracking configuration is used when it is necessary that several different voltages referred to a common bus, vary in proportion to the setting of a particular instrument (the control or

3-44 The output voltage of the slave is a percentage of the master's output voltage, and is determined by the voltage divider consisting of  $R_X$  (or  $R_Y$ ) and the voltage control of the slave supply,  $R_p$ , where:  $E_s = E_m R_p / (R_X + R_p)$ . Turn-on and turn-off of the power supplies is controlled by the master. Remote sensing and programming can be used; although the strapping patterns for these modes show only local sensing and programming. In order to maintain the temperature coefficient and stability specifications of the power supply, the external resistors should be stable, low noise, low temperature (less than 30ppm per °C) resistors.

3-45 SPECIAL OPERATING CONSIDERATIONS

3-46 PULSE LOADING

3-47 The power supply will automatically crossover from constant voltage to constant current operation, or the reverse, in response to an increase (over the preset limit) in the output current or voltage, respectively. Although the preset limit may be set higher than the average output current or voltage, high peak currents or voltages (as occur in pulse loading) may exceed the preset limit and cause crossover to occur. If this crossover limiting is not desired, set the preset limit for the peak requirement and not the average.

3-48 OUTPUT CAPACITANCE

3-49 An internal capacitor, connected across the output terminals of the power supply, helps to suppress high-current pulses of short duration during constant voltage operation. Any capacitance added externally will improve the pulse current capability, but will decrease the safety provided by the constant current circuit. A high-current pulse may damage load components before the average output current is large enough to cause the constant current circuit to operate.

3-50 The effects of the output capacitor during constant current operation are as follows:  
 a. The output impedance of the power supply decreases with increasing frequency.  
 b. The recovery time of the output voltage is longer for load resistance changes.  
 c. A large surge current causing a high power dissipation in the load occurs when the load resistance is reduced rapidly.

### 3-51 REVERSE VOLTAGE LOADING

3-52 A diode is connected across the output terminals. Under normal operating conditions, the diode is reverse biased (anode connected to negative terminal). If a reverse voltage is applied to the output terminals (positive voltage is applied to negative terminal), the diode will conduct, shunting current across the output terminals and limiting the voltage to the forward voltage drop of the diode. This diode protects the series transistors and the output electrolytic capacitor.

### 3-53 REVERSE CURRENT LOADING

3-54 Active loads connected to the power supply may actually deliver a reverse current to the power supply during a portion of its operating cycle. An external source cannot be allowed to pump current into the supply without loss of regulation and possible damage to the output capacitor. To avoid these effects, it is necessary to preload the supply with a dummy load resistor so that the power supply delivers current through the entire operating cycle of the load device.

SECTION IV  
PRINCIPLES OF OPERATION

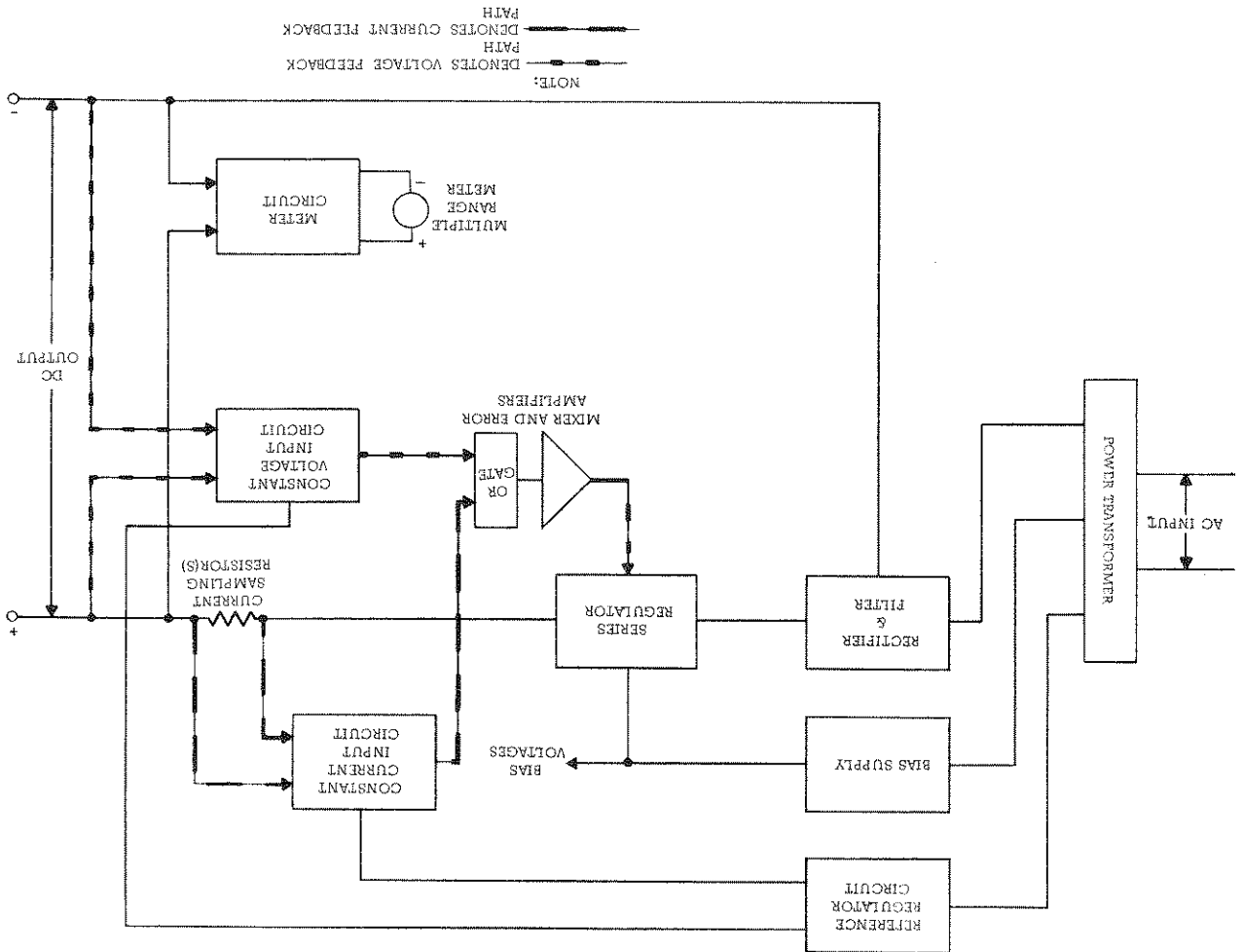


Figure 4-1. Overall Block Diagram

4-1 OVERALL BLOCK DISCUSSION

4-2 The power supply, as shown on the overall block diagram on Figure 4-1, consists of a power transformer, a rectifier and filter, a series regulator, the mixer and error amplifiers, an "OR" gate, a constant voltage input circuit, a constant current input circuit, a reference regulator circuit, a bias supply, and a metering circuit.

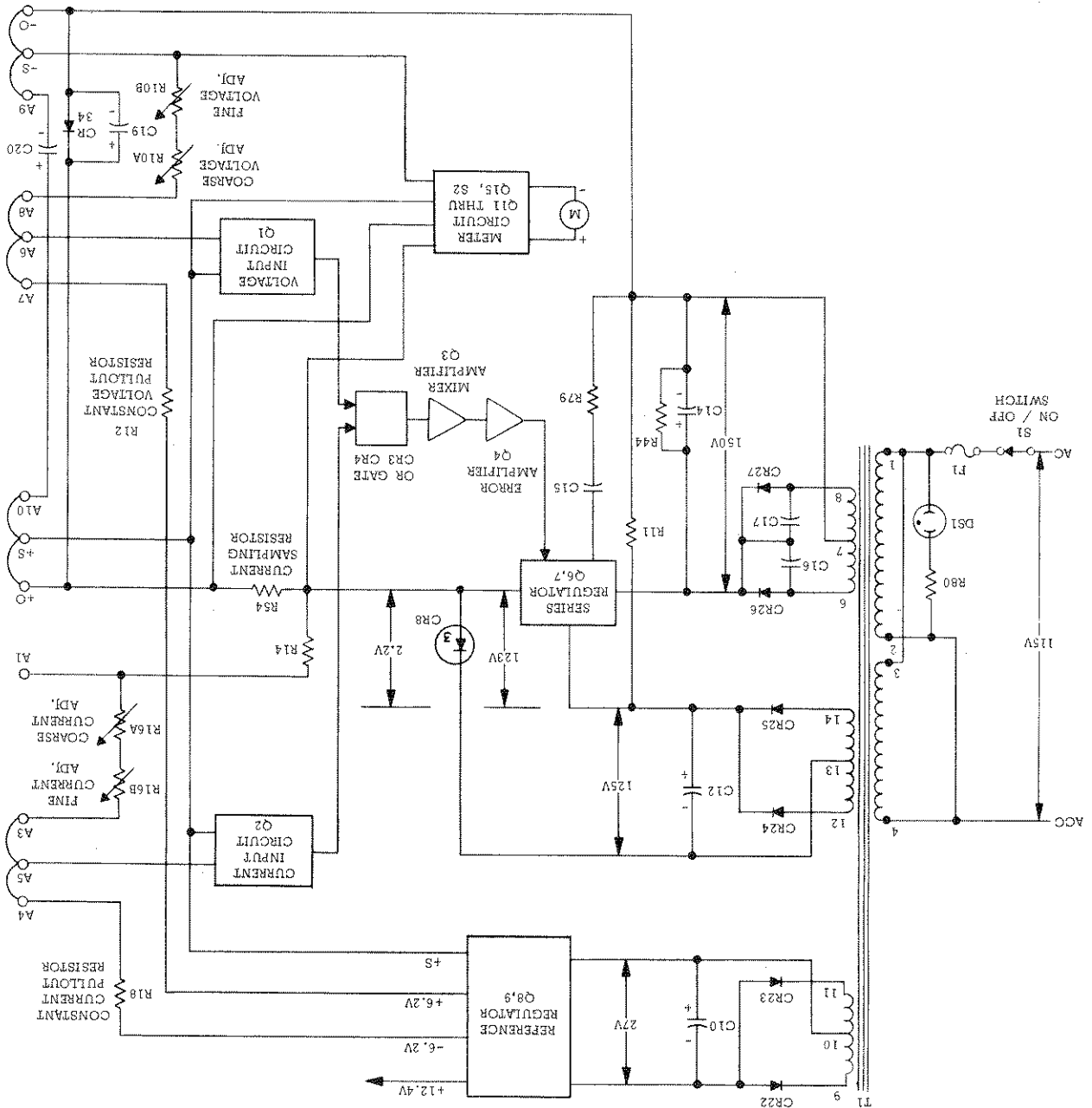
4-3 The input line voltage passes through the power transformer to the rectifier and filter where it is converted to raw DC. The DC current passes through the series regulator to the positive output terminal via the current sampling resistor(s). The regulator, part of the feedback loop, is made to alter its conduction to maintain a constant output

voltage or current. The voltage developed across the current sampling resistor(s) is the input to the constant current input circuit. The output voltage of the power supply is sampled by the voltage input circuit by means of the sensing terminals (±S). Any changes in output voltage/current are detected in the constant voltage/current input circuit, for comparison purposes. The bias supply furnishes voltage through the series regulator in the correct phase and amplitude to counteract any change in output voltage/output current. The reference current provides stable reference voltages which are used by the constant voltage/current input circuits for comparison purposes. The bias supply furnishes voltages which are used throughout the instrument for biasing purposes. The meter circuit provides an indication of output voltage or current.

4-4 SIMPLIFIED SCHEMATIC

4-5 A simplified schematic of the power supply is shown in Figure 4-2. It shows the operating controls; the ON-off switch, the voltage programming controls (R10A and R10B), and the current programming controls (R16A and R16B). The METER switch, included in the meter circuit block on Figure 4-2, allows the meter to read output voltage or current in either of two ranges. Figure 4-2 also shows the internal sources of bias and reference voltages and their nominal magnitudes with an input of 115Vac and no load connected. Diode CR34, connected across the output terminals of the power supply, is a protective device which prevents internal damage

Figure 4-2. Simplified Schematic



4-6 SERIES REGULATOR

4-7 The series regulator consists of transistor stages Q6 and Q7 (see schematic at rear of manual). Transistor Q6 is the series element, or pass transistor, which controls the output. Transistor Q7, together with shunt resistors R81, R82, and R83, are

Under these conditions, capacitor C19 serves to insure loop stability. Note that this capacitor can be removed if an increase in the programming speed is desired. The normal strapping pattern shown on Figure 4-2 is also connected across the output terminals when that might occur if a reverse voltage were applied across the output terminals. Output capacitor, C20, is also connected across the output terminals.

4-10 The constant voltage input circuit continuously compares a fixed reference voltage with a portion of the output voltage and, if a difference exists, produces an error voltage whose amplitude and phase is proportional to the difference. The error output is fed back to the series regulator, through OR gate diode CR3 and the mixer/error amplifiers. The error voltage changes the conduction of the series regulator which, in turn, alters the output voltage so that the difference between the two input voltages applied to the differential amplifier is reduced to zero. This action maintains the output voltage constant.

4-11 Stage Q1B of the differential amplifier is connected to a common (+S) potential through impedance equalizing resistor R5. Resistor R6 and R8 are used to zero bias the input stage, offsetting minor base to emitter voltage differences in Q1. The base of Q1A is connected to a summing point at the junction of the programming resistors and the current pullout resistor R12. Instantaneous changes in output voltage result in an increase or decrease in the summing point potential. Q1A is then made to conduct more

connected in a manner which minimizes the power dissipated in series transistor Q6. The bias voltage for Q7 is developed across a series diode network (CR12 through CR15 for Models 6281A and 6284A or CR12 and CR13 for the remaining Models). The conduction of Q7 will decrease as the collector-to-emitter voltage of Q6 approaches the voltage developed across the biasing diodes. At low output voltages Q7 is completely cutoff and all of the load current flows through the shunt resistors. The voltage that is dropped across Q7 and the shunt resistors reduces the voltage dropped across Q6, thus diminishing its power dissipation. The reliability of the regulator is further increased by mounting the shunt resistors outside the rear of the cabinet so that the internal components are operated under lower temperature conditions. Diode CR11, connected across Q6, protects it from reverse voltages that could develop across it during parallel or auto-parallel operation if one supply is turned on before the other. Diodes CR18 and CR19 perform a similar function for Q7.

#### 4-8 CONSTANT VOLTAGE INPUT CIRCUIT

(Figure 4-3)

4-9 The circuit consists of the coarse and fine programming resistors (R10A and R10B), and a differential amplifier stage (Q1 and associated components). Transistor Q1 consists of two silicon transistors housed in a single package. The transistors

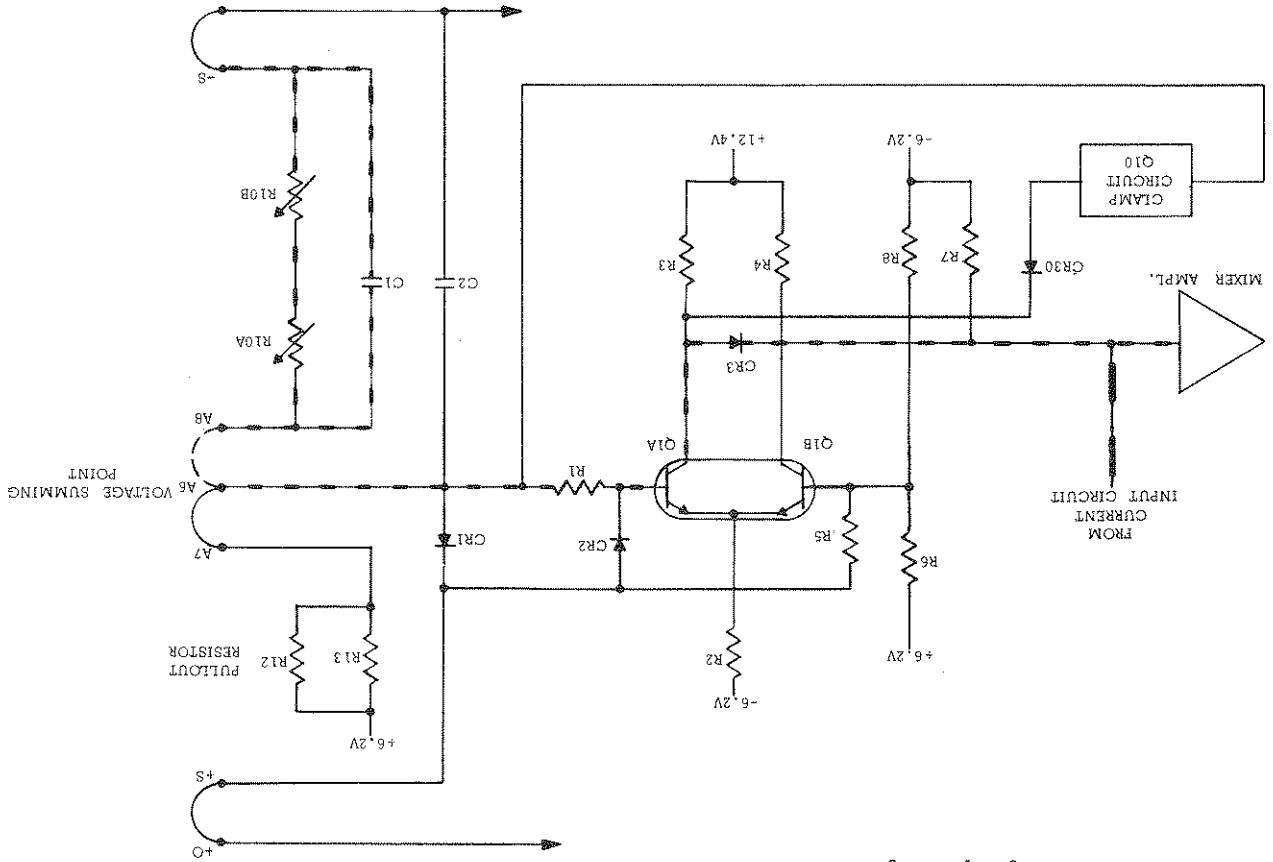


Figure 4-3. Constant Voltage Input Circuit, Simplified Schematic

or less, in accordance with summing point voltage change. The resultant output error voltage is fed back to the series regulator via the remaining components of the feedback loop. Resistor R1, in series with the base Q1A, limits the current through the programming resistors during rapid voltage turn-down. Diodes CR1 and CR2 form a limiting network which prevent excessive voltage excursions from over driving stage Q1A. Capacitors C1 and C2, shunting the programming resistors, increase the high frequency gain of the input amplifier. Resistor R3, shunting pullout resistor R2, serves as a trimming adjustment for the programming current.

#### 4-12 CONSTANT CURRENT INPUT CIRCUIT

(Figure 4-4)

4-13 This circuit is similar in appearance and operation to the constant voltage input circuit. It consists of the coarse and fine current programming resistors (R16A and R16B), and a differential amplifier stage (Q2 and associated components). Like transistor Q1 in the voltage input circuit, Q2 consists of two transistors, having matched characteristics, that are housed in a single package.

4-14 The constant current input circuit continuously compares a fixed reference voltage with the voltage drop across current sampling resistor(s). If a difference exists, the differential amplifier produces an

error voltage which is proportional to this difference. The remaining components in the feedback loop (amplifiers and series regulator) function to maintain the drop across the current sampling resistor, and consequently the output current, at a constant value.

4-15 Stage Q2B is connected to the +S through impedance equalizing resistor R26. Resistors R25 and R28 are used to zero bias the input stage, offsetting minor base to emitter voltage differences in Q2. Instantaneous changes in output current on the positive line are felt at the current summing point and, hence, the base of Q2A. Stage Q2A varies its conduction in accordance with the polarity of the change at the summing point. The change in Q2A's conduction also varies the conduction of Q2B due to the coupling effects of the common emitter resistor, R22. The error voltage is taken from the collector of Q2B and fed back to the series regulator through OR-gate diode CR4 and the remaining components of the feedback loop. The error voltage then varies the conduction of the regulator so that the output current is maintained at the proper level.

4-16 Resistor R20, in conjunction with R21 and C3, helps stabilize the feedback loop. Diode CR5 limits voltage excursions on the base of Q2A. Resistor R19, shunting the pullout resistor, serves as a trimming adjustment for the programming current flowing through R16A and B.

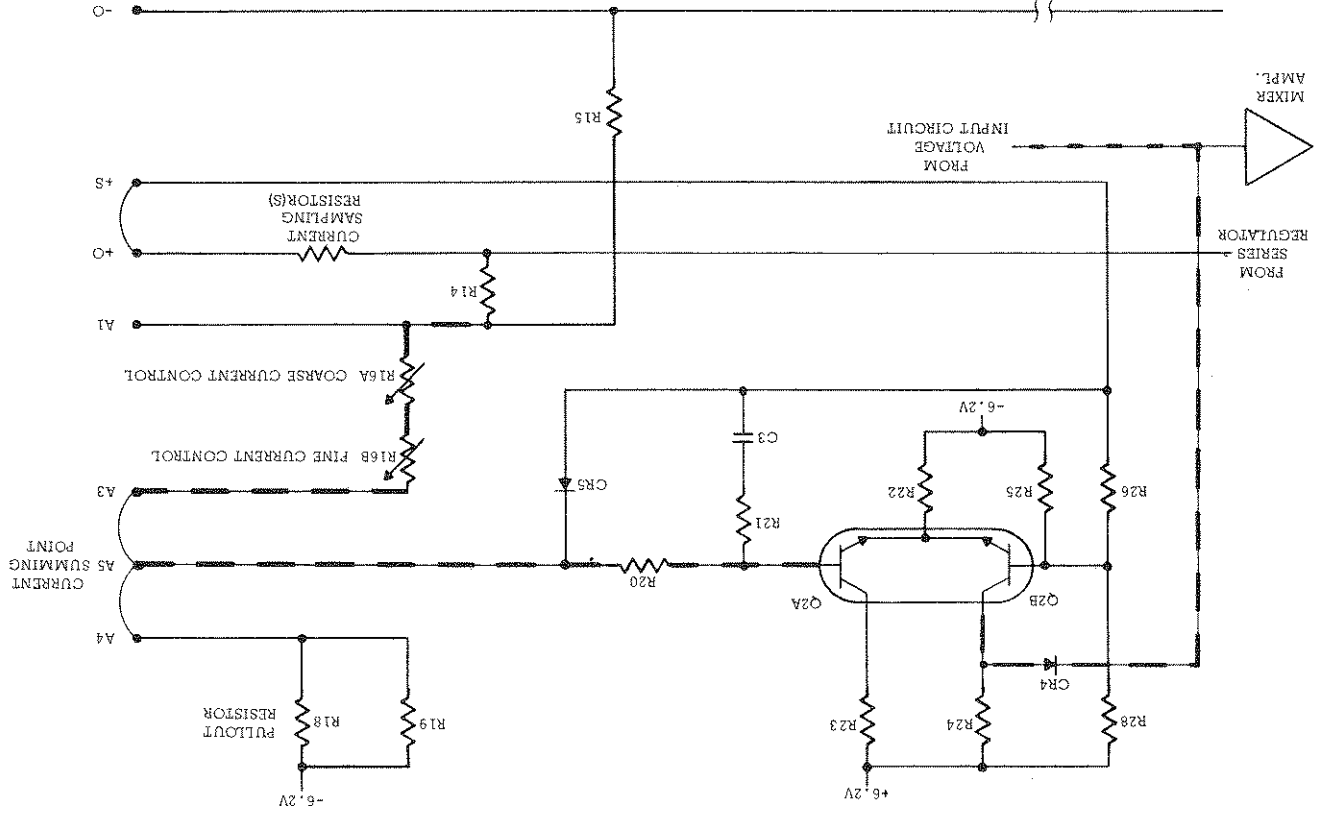


Figure 4-4. Constant Current Input Circuit, Simplified Schematic

4-18 The voltage clamp circuit keeps the constant voltage programming current relatively constant when the power supply is operating in the constant current mode. This is accomplished by clamping terminal A6, the voltage summing point, to a fixed bias voltage. During constant current operation the constant voltage programming resistors are a shunt load across the output terminals of the power supply. When the output voltage changes, the current through these resistors also tends to change. Since this programming current flows through the current sampling resistor(s) it is erroneously interpreted as a load change by the current input circuit. The clamp circuit eliminates this undesirable effect by maintaining the constant voltage programming current constant.

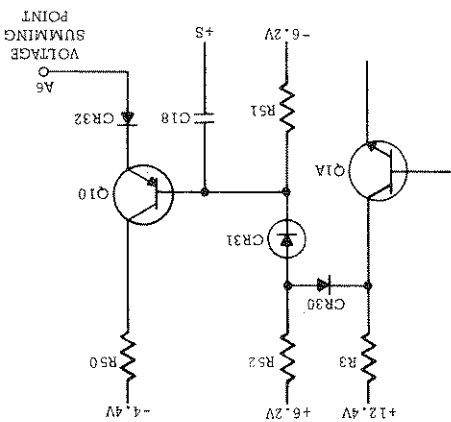


Figure 4-5. Voltage Clamp Circuit

4-19 The voltage divider, R51, R52, and CR31, back biases CR30 and Q10 during constant voltage operation. When the power supply goes into constant current operation, CR30 becomes forward biased by the collector voltage of Q1A. This results in conduction of Q10 and the clamping of the summing point at a potential only slightly more negative than the normal constant voltage potential. Clamping this voltage at approximately the same potential that exists in constant voltage operation, results in a constant voltage across, and consequently a constant current through, the current pullout resistor (R12).

4-20 MIXER AND ERROR AMPLIFIERS (Figure 4-6)

4-21 The mixer and error amplifiers amplify the error signal from the constant voltage or constant current input circuit to a level sufficient to drive the series regulator transistors. Transistor Q3 receives the error voltage input from either the constant voltage or constant current circuit via the OR-gate diode (CR3 or CR4) that is conducting at the time. Diode CR3 is forward biased, and CR4 reversed biased, during constant voltage operation. The reverse is true during constant current operation.

4-22 The RC network, composed of C5 and R30, is an equalizing network which provides for high frequency roll off in the loop gain response in order to stabilize the feedback loop. Error amplifier Q4 serves as the driver element for the series regulator.

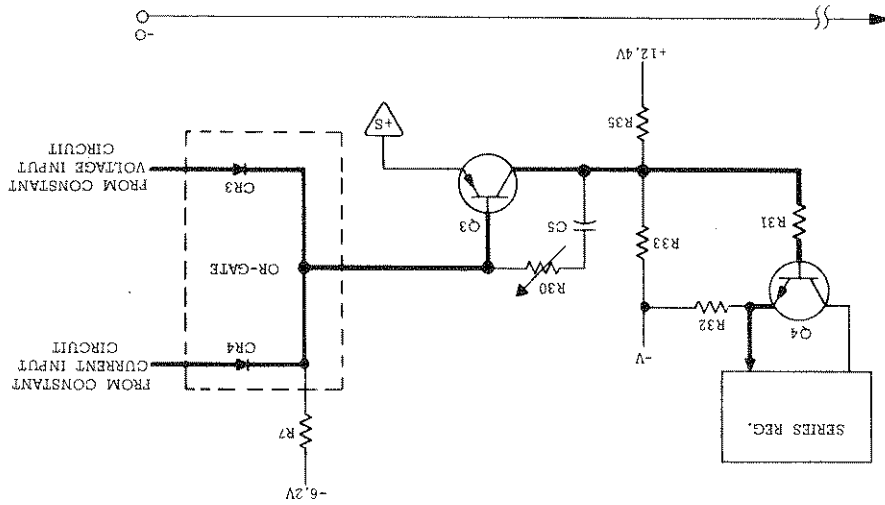


Figure 4-6. Mixer and Error Amplifiers, Simplified Schematic



4-23 REFERENCE CIRCUIT

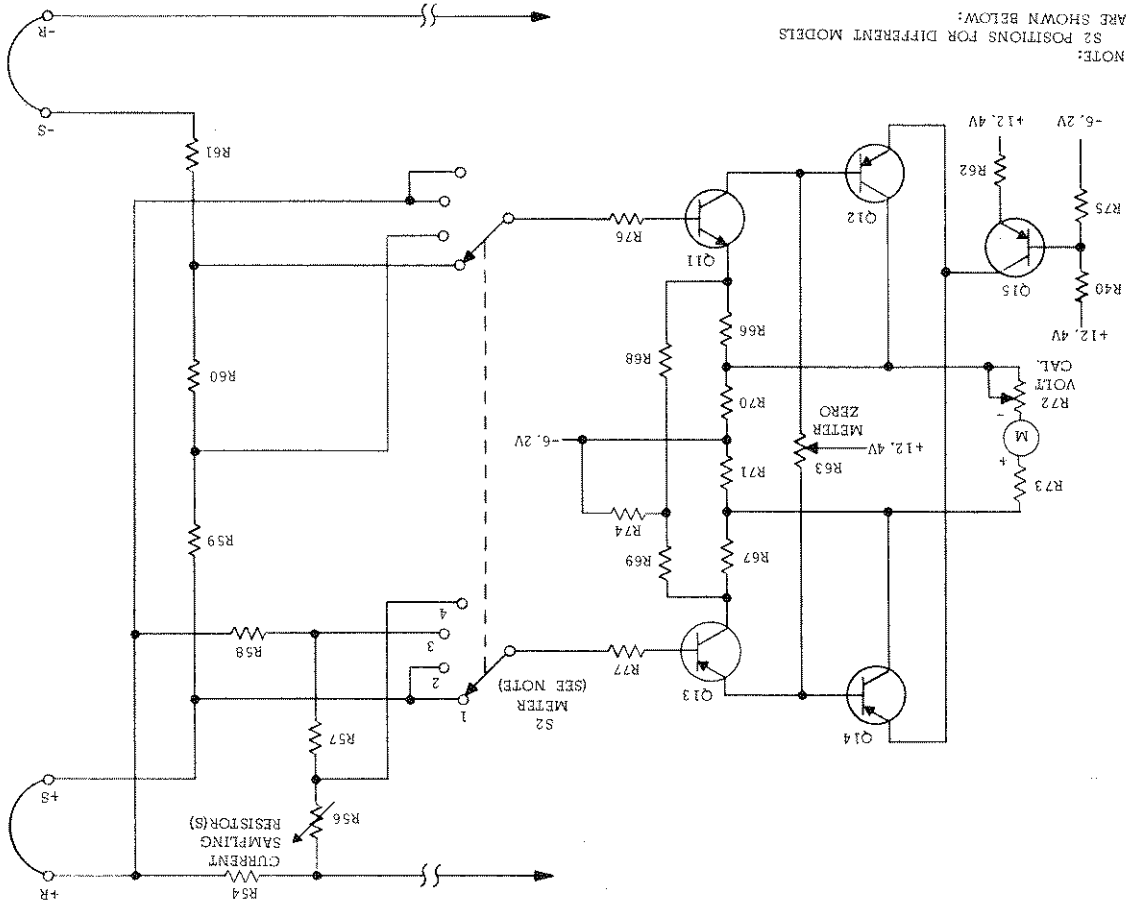
4-24 The reference circuit (see schematic) is a feedback power supply similar to the main supply. It provides stable reference voltages which are used throughout the unit. The reference voltages are all derived from smoothed dc obtained from the full wave rectifier (CR22 and CR23) and filter capacitor C10. The +6.2 and -6.2 voltages, which are used in the constant voltage and current input circuits for comparison purposes, are developed across temperature compensated Zener diodes VR1 and VR2. Resistor R43 limits the current through the Zener diodes to establish an optimum bias level.

4-25 The regulating circuit consists of series regulating transistor Q9 and error amplifier Q8. Output voltage changes are detected by Q8 whose base is

connected to the junction of a voltage divider (R41, R42) connected directly across the supply. Any error signals are amplified and inverted by Q8 and applied to the base of series transistor Q9. The series element then alters its conduction in the direction and by the amount necessary to maintain the voltage across VR1 and VR2 constant. Resistor R46, the emitter resistor for Q8, is connected in a manner which minimizes changes in the reference voltage caused by variations in the input line. Output capacitor C9 stabilizes the regulator loop.

4-26 METER CIRCUIT (Figure 4-7)

4-27 The meter circuit provides continuous indications of output voltage or current on a single multiple range meter. The meter can be used either as a voltmeter or an ammeter depending upon the position of METER switch S2 on the front panel of the supply.



NOTE:  
S2 POSITIONS FOR DIFFERENT MODELS  
ARE SHOWN BELOW:

MODEL	S2 TERMINAL NOS.
6201B	1 2 3 4
6202B	1 2 3 4
6203B	1 2 3 4
6281A	1 2 3 4
6282A	1 2 3 4
6283A	1 2 3 4
6284A	1 2 3 4
6285A	1 2 3 4
6286A	1 2 3 4
6287A	1 2 3 4
6288A	1 2 3 4
6289A	1 2 3 4
6290A	1 2 3 4
6291A	1 2 3 4
6292A	1 2 3 4
6293A	1 2 3 4
6294A	1 2 3 4
6295A	1 2 3 4
6296A	1 2 3 4
6297A	1 2 3 4
6298A	1 2 3 4
6299A	1 2 3 4
6300A	1 2 3 4

Figure 4-7. Meter Circuit, Simplified Schematic

4-28 The selection circuit determines which voltage divider is connected to the differential amplifier input. When S2 is in one of the voltage positions, the voltage across divider R59, R60, and R61 connected across the output of the supply) is the input to the differential amplifier. When S2 is in one of the current positions, the voltage across divider R56, R57, and R58 (connected across the sampling resistor network) is the input to the differential amplifier. The amplified output of the differential amplifier is used to deflect the meter.

4-29 The differential amplifier is a stable device having a fixed gain of ten. Stage Q11 of the differential amplifier receives a negative voltage from the applicable voltage divider when S2 is in one of the voltage positions while stage Q13 is connected to the +S (common) terminal. With S2 in a current position, stage Q13 receives a positive voltage from the applicable voltage divider while stage Q11 is connected to the +S terminal. The differential output of the amplifier is taken from the collectors of Q12 and Q14. Transistor Q15 is a constant current source which sets up the proper bias current for the amplifier. Potentiometer R63 permits zeroing of the meter. The meter amplifier stage contains an inherent current limiting feature which protects the meter movement against overloads. For example, if METER switch S2 is placed in position 4, (low current range) when the power supply is actually delivering a higher amperage output, the differential amplifiers are quickly driven into saturation limiting the current through the meter to a safe value.

4-30 Figures 4-8 and 4-9 show the meter connections when S2 is in the higher voltage and current positions, respectively. For the sake of simplicity, some of the actual circuit components are not shown on these drawings. With METER switch S2 in the higher voltage range, position (2), the voltage drop across R59 is the input to the meter amplifier and the meter indicates the output voltage across the +S and -S terminals. For low output voltages, S2 can be switched to position 1 resulting in the application of a larger percentage of the output voltage (drop across R59 and R60) to the meter amplifier.

4-31 With S2 in the higher current range position (Figure 4-9) the voltage drop across R58 is applied to the meter amplifier and the meter indicates the output current which flows through R54. For low values of output current, S2 can be switched to

4-32 OPERATION OF REGULATING FEEDBACK LOOP

4-33 The feedback loop functions continuously to keep the output voltage constant, during constant voltage operation, and the output current constant, during constant current operation. For purposes of this discussion, assume that the unit is in constant voltage operation and that the programming resistors have been adjusted so that the supply is yielding the desired output voltage. Further assume that the output voltage instantaneously rises (goes positive) due to a variation in the external load circuit.

4-34 Note that the change may be in the form of a slow rise in the output voltage or a positive going ac signal. An ac signal is coupled to summing point A6 through capacitor C1 and a dc voltage is coupled to A6 through R10.

4-35 The rise in output voltage causes the voltage at A6 and thus the base of Q1A to decrease (go negative). Q1A now decreases its conduction and its collector voltage rises. The positive going error voltage is amplified and inverted by Q3 and fed to

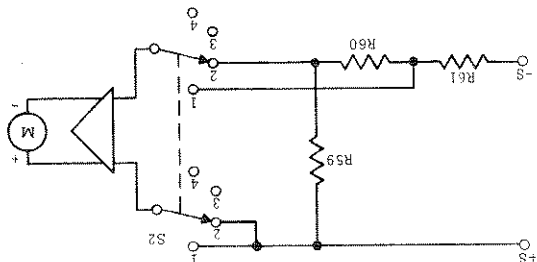


Figure 4-8. Voltmeter Connections, Simplified Schematic

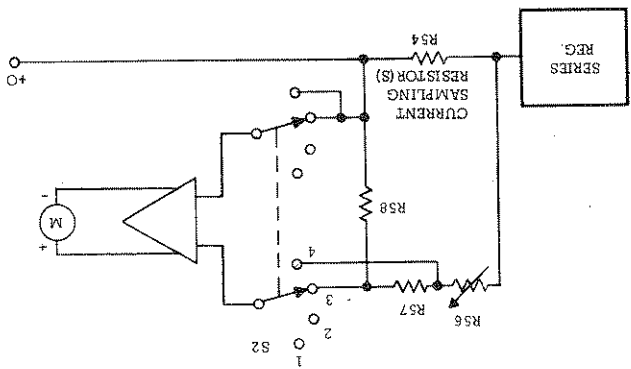


Figure 4-9. Ammeter Connections, Simplified Schematic

its collector voltage decreases by the amount necessary to back bias OR gate diode CR3 and the supply is now in the constant current mode of operation. The crossover point at which constant current operation commences is determined by the setting of CURRENT control R16. The operation of the feedback loop during the constant current operating mode is similar to that during constant voltage operation except that the input to the differential amplifier comparison circuit is obtained from the current sampling resistor(s).

the base of series transistor Q6 via the emitter follower(s). The negative going input causes Q6 to decrease its conduction so that it drops more of the line voltage, and reduces the output voltage to its original level.

4-36 If the external load resistance is decreased to a certain crossover point, the output current increases until transistor Q2A begins to conduct. During this time, the output voltage has also decreased to a level so that the base of Q1A is at a high positive potential. With Q1A in full conduction,

5-1 INTRODUCTION

5-2 Upon receipt of the power supply, the performance check (Paragraph 5-10) should be made. This check is suitable for incoming inspection. If a fault is detected in the power supply while making the performance check or during normal operation, proceed to the troubleshooting procedure (Paragraph 5-25). After troubleshooting and repair (Paragraph 5-35), perform any necessary adjustments and calibrations (Paragraph 5-37).

Before returning the power supply to normal operation, repeat the performance check to ensure that the fault has been properly corrected and that no other faults exist. Before doing any maintenance checks, turn-on power supply, allow a half-hour warm-up, and read the general information regarding measurement techniques (Paragraph 5-3).

5-3 GENERAL MEASUREMENT TECHNIQUES

5-4 The measuring device must be connected across the sensing leads of the supply or as close to the output terminals as possible when measuring the output impedance, transient response, regulation, or ripple of the power supply in order to achieve valid measurements. 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, thus invalidating the measurement.

5-5 The monitoring device should be connected to the +S and -S terminals (see Figure 3-2) or as shown in Figure 5-1. The performance characteristics should never be measured on the front terminals if the load is connected across the rear terminals. Note that when measurements are made at the front terminals, the monitoring leads are connected at A, not B, as shown in Figure 5-1. Failure to connect the measuring device at A will result in a measurement that includes the resistance of the leads between the output terminals and the point of connection.

5-6 For output current measurements, the current sampling resistor should be a four-terminal resistor. The four terminals are connected as shown in Figure 5-2. In addition, the resistor should be of the low noise, low temperature coefficient (less than 30 ppm/°C) type and should be used at no more than 5% of its rated power so that its temperature rise will be minimized.

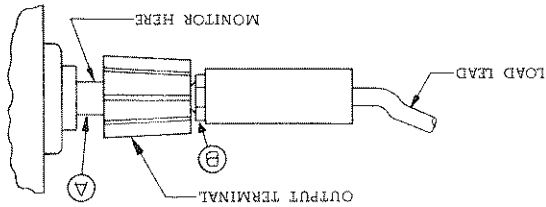


Figure 5-1. Front Panel Terminal Connections

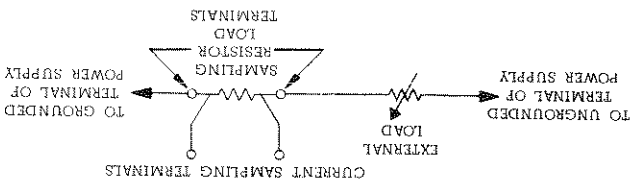


Figure 5-2. Output Current Measurement Technique

5-7 When using an oscilloscope, ground one terminal of the power supply and then ground the case of the oscilloscope to this same point. Make certain that the case is not also grounded by some other means (power line). Connect both oscilloscope input leads to the power supply ground terminal and check that the oscilloscope is not exhibiting a ripple or transient due to ground loops, pick-up, or other means.

5-8 TEST EQUIPMENT REQUIRED

5-9 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
Differential Voltmeter	Sensitivity: 1 mv/full scale (min.). Input impedance: 10 megohms (min.).	Measure DC voltages; calibration procedures	Φ 3420 (See Note)
Variable Voltage Transformer	Range: 90-130 volts. Equipped with voltmeter accurate within 1 volt.	Vary AC input	-----
AC Voltmeter	Accuracy: 2%. Sensitivity: 1 mv full scale deflection (min.).	Measure AC voltages and ripple.	Φ 403 B
Oscilloscope	Sensitivity: 100 μv/cm. Differential input.	Display transient response waveforms	Φ 140 A plus 1400A plug in.
Oscillator	Range: 5 cps to 600 Kc. Accuracy: 2%.	Impedance checks	Φ 200 CD
DC Voltmeter	Accuracy: 1%. Input resistance: 20,000 ohms/volt (min.).	Measure DC voltages	Φ 412A
Repetitive Load Switch	Rate: 60 - 400 Hz, 2μsec rise and fall time.	Measure transient response.	See Figure 5-7
Resistive Loads	Values: See Paragraph 5-14 and Figure 5-4. ±5%, 75 watts.	Power supply load resistors	-----
Current Sampling Resistor	Value: See Figure 5-4. 1%, 40 watts, 20ppm, 4-Terminal	Measure current; calibrate meter	-----
Resistor	1K <sub>Ω</sub> ±1%, 2 watt non-inductive	Measure impedance	-----
Resistor	100 ohms, ±5%, 10 watt	Measure impedance	-----
Resistor	Value: See Paragraph 5-47. ±0.1%, ½ watt.	Calibrate programming current	-----
Resistor	Value: See Paragraph 5-50. ±0.1%, ½ watt.	Calibrate programming current	-----
Capacitor	500μf, 50 wvdc	Measure impedance.	-----
Decade Resistance Box	Range: 0-500K. Accuracy: 0.1% plus 1 ohm Make-before-break contacts.	Measure programming coefficients.	-----

Type	Required Characteristics	Use	Recommended Model
Capacitor	500µf, 50 wvdc	Measure impedance.	-----
Decade Resistance Box	Range: 0-150K (min.). Accuracy: 0.1% plus 1 ohm Make-before-break contacts.	Measure programming coefficients.	-----

NOTE

A satisfactory substitute for a differential voltmeter is to arrange a reference voltage source and null detector as shown in Figure 5-3. The reference voltage source is adjusted so that the voltage difference between the supply being measured and the reference voltage will have the required resolution for the measurement being made. The voltage difference will be a function of the null detector that is used. Examples of satisfactory null detectors are: a 419 A null detector, a DC coupled oscilloscope utilizing differential input, or a 50 mv meter movement with a 100 division scale. For the latter, a 2 mv change in voltage will result in a meter deflection of four divisions.

CAUTION

Care must be exercised when using an electronic null detector in which one input terminal is grounded to avoid ground loops and circulating currents.

5-10 PERFORMANCE TEST

5-11 The following test can be used as an incoming inspection check and appropriate portions of the test can be repeated either to check the operation of the instrument after repairs or for periodic maintenance tests. The tests are performed using a 115-VAC 60 cps, single phase input power source. If the correct result is not obtained for a particular check, do not adjust any controls; proceed to troubleshooting (Paragraph 5-28).

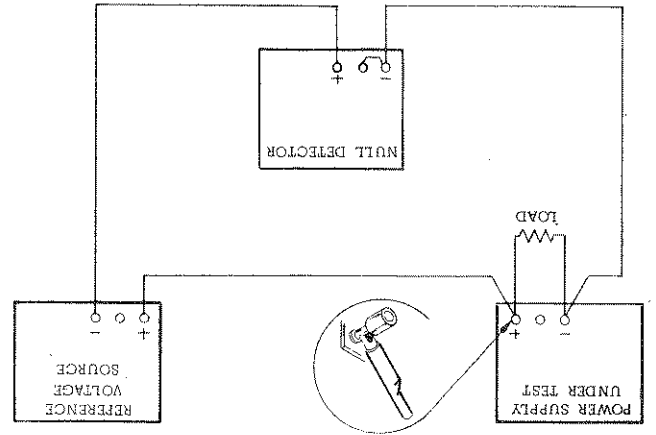


Figure 5-3. Differential Voltmeter Substitute, Test Setup

5-12 CONSTANT VOLTAGE TESTS

5-13 Rated Output and Meter Accuracy.

5-14 Voltage. Proceed as follows:

- Connect load resistor across rear output terminals of supply. Resistor value to be as follows:
- Connect differential voltmeter across +S and -S terminals of supply observing correct polarity.
- Set METER switch to highest voltage range and turn on supply.
- Adjust VOLTAGE control(s) until front panel meter indicates exactly the maximum rated output voltage.
- Differential voltmeter should indicate maximum rated output voltage within  $\pm 2\%$ .

5-15 Current. Proceed as follows:

- Connect test setup shown in Figure 5-4 leaving switch S1 open.
- Turn CURRENT controls fully clockwise.
- Set METER switch to highest current range and turn on supply.
- Adjust VOLTAGE control(s) until front panel meter indicates exactly the maximum rated output current.
- Differential voltmeter should read 1.0  $\pm$  0.02 Vdc.

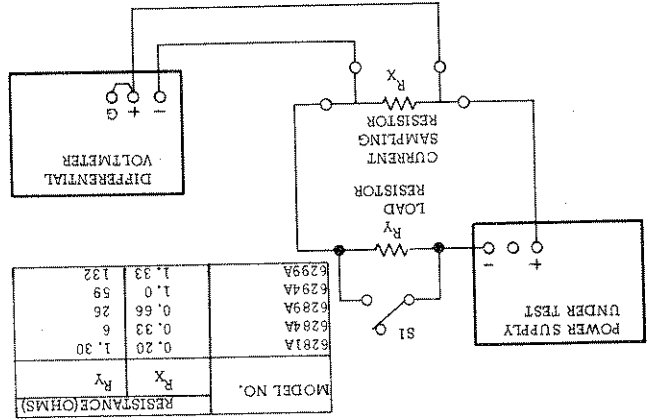
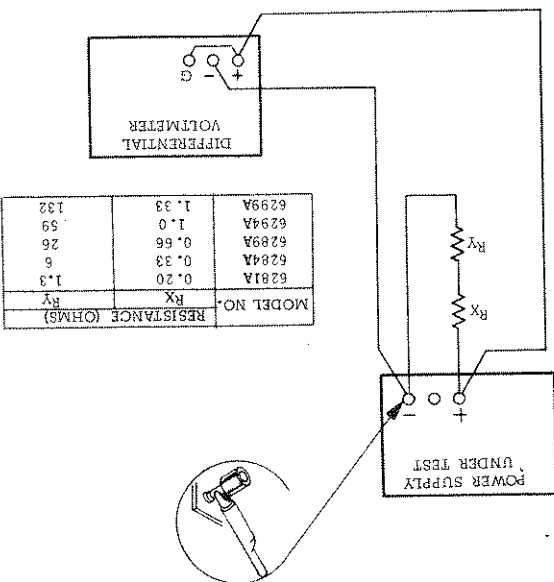


Figure 5-4. Output Current, Test Setup

5-16 Load Regulation. To check constant voltage load regulation, proceed as follows:

- Connect test setup as shown in Figure 5-5.
- Turn CURRENT controls fully clockwise.
- Connect test setup shown in Figure 5-5.
- Adjust variable auto transformer for 105 VAC input.
- Set METER switch to highest voltage range and turn on supply.
- Adjust VOLTAGE control(s) until front panel meter indicates exactly the maximum rated output voltage.
- Read and record voltage indicated on differential voltmeter.
- Adjust variable auto transformer for 125 VAC input.

Figure 5-5. Load Regulation, Constant Voltage



1. Reading on differential voltmeter should not vary from reading recorded in step g by more than the following:  

Model No.	6281A	6284A	6289A	6294A	6299A
Variation (mVdc)	±2.75	±4	±6	±8	±12

5-18 Ripple and Noise. To check the ripple and noise, proceed as follows:

- a. Retain test setup used for previous line output terminals as shown in Figure 5-6.
- b. Adjust variable auto transformer for 125 VAC input.
- c. Set METER switch to highest current range.
- d. Turn CURRENT controls fully clockwise and adjust VOLTAGE control(s) until front panel meter indicates exactly the maximum rated output voltage.
- e. AC voltmeter should read less than 0.20mvrms.

- a. Retain test setup shown in Figure 5-7.
- b. Turn CURRENT controls fully clockwise.
- c. Set METER switch to highest current range and turn on supply.
- d. Adjust VOLTAGE control(s) until front panel meter indicates exactly the maximum rated output voltage.

Figure 5-6. Ripple and Noise, Constant Voltage

5-19 Transient Recovery Time. To check the transient recovery time proceed as follows:

- a. Connect test setup shown in Figure 5-7.
- b. Turn CURRENT controls fully clockwise.
- c. Set METER switch to highest current range and turn on supply.
- d. Adjust VOLTAGE control(s) until front panel meter indicates exactly the maximum rated output voltage.

Figure 5-8. Transient Response, Waveforms

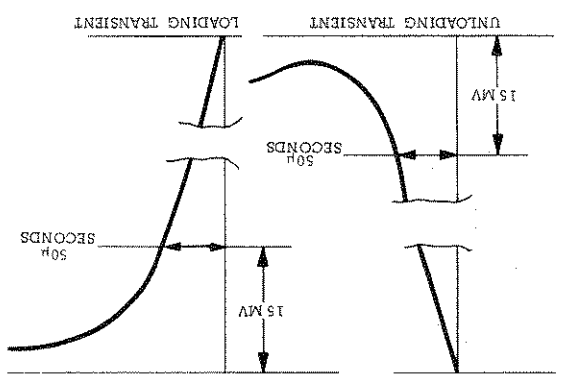
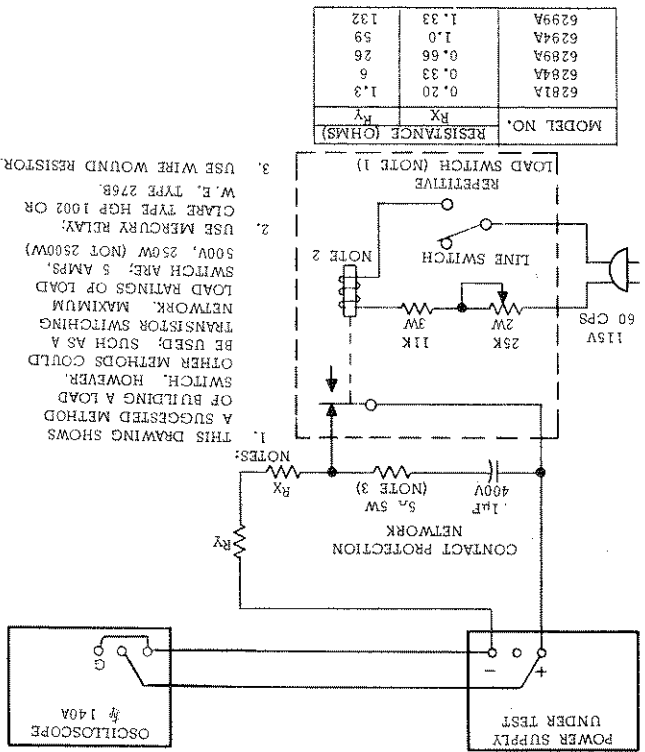
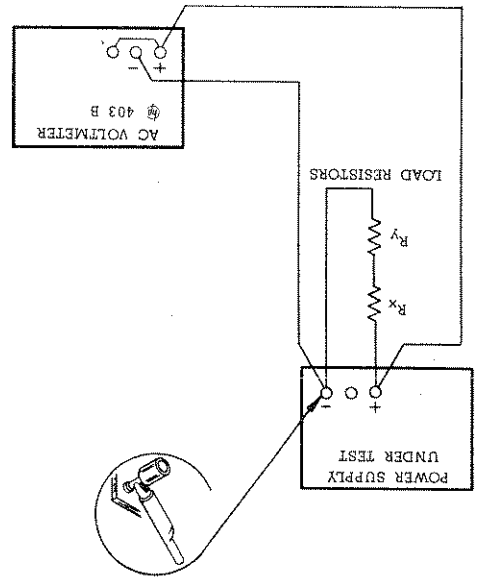


Figure 5-7. Transient Response, Test Setup



- e. Close line switch on repetitive load switch setup.
- f. Adjust 25K potentiometer until a stable display is obtained on oscilloscope. Waveform should be within the tolerances shown in Figure 5-8 (output should return to within 15 mv of original value in less than 50 microseconds).





5-20 Output Impedance. To check the output im-

pedance, proceed as follows:

- Connect test setup as shown in Figure 5-9.
- Set METER switch to highest voltage range
- Turn CURRENT controls fully clockwise, and turn on supply.

- Adjust VOLTAGE control(s) until front panel meter reads 20 volts (5 volts for Model 6281A supplies).
- Set AMPLITUDE control on Oscillator to 10 volts ( $E_{in}$ ), and FREQUENCY control to 10 cps.
- Record voltage across output terminals of the power supply ( $E_0$ ) as indicated on AC voltmeter.
- Calculate the output impedance by the following formula:

$$Z_{out} = \frac{E_{in} - E_0}{E_{OR}}$$

$E_0$  = rms voltage across power supply output terminals.

$R = 1000$   
 $E_{in} = 10$  volts

g. The output impedance ( $Z_{out}$ ) should be less than 0.001 ohm.

- Using formula of step f, calculate output impedance at frequencies of 100cps, 1Kc, and 500Kc. Values should be less than 0.01 ohm, 0.2 ohm, and 2 ohms, respectively.

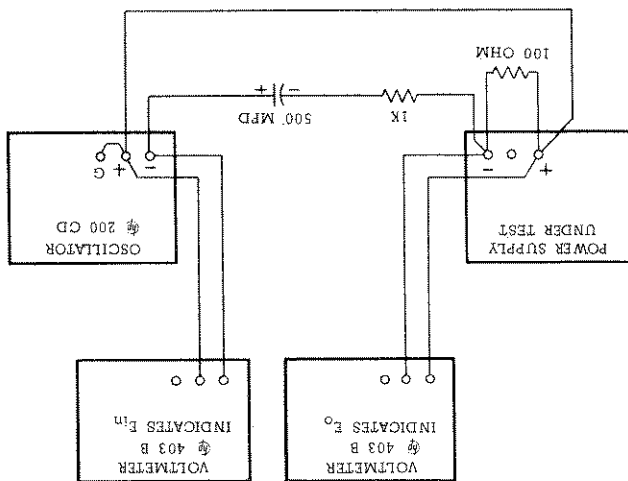


Figure 5-9. Output Impedance, Test Setup

5-21 CONSTANT CURRENT TESTS

5-22 Load Regulation. To check the constant current load regulation, proceed as follows:

- Connect test setup as shown in Figure 5-4.
- Turn VOLTAGE control(s) fully clockwise.

f. The AC voltmeter should read as follows:  
 Model No. 6281A 6284A 6289A 6294A 6299A  
 Reading (mvac) 0.80 0.66 0.33 0.50 0.665

- Use test setup shown in Figure 5-4, except connect AC voltmeter across sampling resistor instead of differential voltmeter.
- Rotate VOLTAGE control(s) fully clockwise.
- Set METER switch to highest current range and turn on supply.
- Adjust CURRENT controls until front panel meter indicates exactly the maximum rated output current.
- Turn range switch on AC voltmeter to 1 mv position.

5-24 Ripple and Noise. To check the ripple and noise, proceed as follows:

Model No. 6281A 6284A 6289A 6294A 6299A  
 Variation (mvd)  $\pm 0.150 \pm 0.183 \pm 0.265 \pm 0.350 \pm 0.433$

- Reading on differential voltmeter should not vary from reading recorded in step g by more than the following:  
 Model No. 6281A 6284A 6289A 6294A 6299A  
 Variation (mvd)  $\pm 0.150 \pm 0.183 \pm 0.265 \pm 0.350 \pm 0.433$
- Reading on differential voltmeter should not vary from reading recorded in step g by more than the following:
- Read and record voltage indicated on differential voltmeter.
- Adjust variable auto transformer for 125 VAC input.

- Utilize test setup shown in Figure 5-4 leaving switch S1 open throughout test.
- Connect variable auto transformer between input power source and power supply power input.
- Adjust auto transformer for 105 VAC input.
- Turn VOLTAGE control(s) fully clockwise.
- Set METER switch to highest current range and turn on supply.
- Adjust CURRENT controls until front panel meter reads exactly the maximum rated output current.
- Read and record voltage indicated on differential voltmeter.

5-23 Line Regulation. To check the line regulation proceed as follows:

Model No. 6281A 6284A 6289A 6294A 6299A  
 Variation (mvd)  $\pm 0.150 \pm 0.183 \pm 0.265 \pm 0.350 \pm 0.433$

- Reading on differential voltmeter should not vary from reading recorded in step e by more than the following:  
 Model No. 6281A 6284A 6289A 6294A 6299A  
 Variation (mvd)  $\pm 0.150 \pm 0.183 \pm 0.265 \pm 0.350 \pm 0.433$
- Adjust CURRENT control until front panel meter reads exactly the maximum rated output current.
- Read and record voltage indicated on differential voltmeter.
- Short out load resistor ( $R_L$ ) by closing switch S1.
- Reading on differential voltmeter should not vary from reading recorded in step e by more than the following:

5-25 TROUBLESHOOTING

readings shown on the schematic and the additional procedures given in the following paragraphs should suffice to isolate a fault to a component or small group of components. The normal voltages shown on the schematic are positioned adjacent to the applicable test points (identified by encircled numbers on the schematic and printed wiring boards). Additional test procedures that will aid in isolating troubles are as follows:

a. Reference circuit check (Paragraph 5-32). This circuit provides critical operating voltages for the supply and faults in the circuit could affect the overall operation in many ways.

b. Feedback loop checks (Paragraph 5-33).

c. Procedures for dealing with common troubles (Paragraph 5-34).

5-31 The test points referred to throughout the following procedures are identified on the schematic diagram by encircled numbers.

5-32 Reference Circuit.

a. Make an ohmmeter check to be certain that neither the positive nor negative output terminal is grounded.  
 b. Turn front-panel VOLTAGE and CURRENT controls fully clockwise (maximum).  
 c. Turn-on power supply (no load connected).  
 d. Proceed as instructed in Table 5-2.

5-33 Feedback Circuit. Generally, malfunction of the feedback circuit is indicated by high or low output voltages. If one of these situations occur, disconnect the load and proceed as instructed in Table 5-3 or Table 5-4.

5-34 Common Troubles. Table 5-5 lists the symptoms, checks, and probable causes for common troubles.

5-26 Components within Hewlett-Packard power supplies are conservatively operated to provide maximum reliability. In spite of this, parts within a supply may fail. Usually the instrument must be immediately repaired with a minimum of "down time" and a systematic approach as outlined in succeeding paragraphs can greatly simplify and speed up the repair.

5-27 TROUBLE ANALYSIS

5-28 General. Before attempting to trouble shoot this instrument, ensure that the fault is with the instrument and not with an associated circuit. The performance test (Paragraph 5-10) enables this to be determined without having to remove the instrument from the cabinet.

5-29 Once it is determined that the power supply is at fault, check for obvious troubles such as open fuse, a defective power cable, or an input power failure. Next, remove the top and bottom covers (each held by four retaining screws) and inspect for open connections, charred components, etc. If the trouble source cannot be detected by visual inspection, follow the detailed procedure outlined in succeeding paragraphs. Once the defective component has been located (by means of visual inspection or trouble analysis) correct it and re-conduct the performance test. If a component is replaced, refer to the repair and replacement and adjustment and calibration paragraphs in this section.

5-30 A good understanding of the principles of operation is a helpful aid in troubleshooting, and it is recommended that the reader review Section IV of the manual before attempting to troubleshoot the unit in detail. Once the principles of operation are understood, logical application of this knowledge used in conjunction with the normal voltage

Table 5-2. Reference Circuit Troubleshooting

Step	Meter Common	Meter Positive	Normal Indication	If Indication Abnormal, Take This Action
1	+S	33	6.2 ± 0.3vdc	Check 12.4 volt bias or VR1
2	31	+S	6.2 ± 0.3vdc	Check 12.4 volt bias or VR2
3	+S	37	12.4 ± 1.0vdc	Check Q8, Q9, CR22, CR23, C10, T1

Table 5-4. Low Output Voltage Troubleshooting

Step	Measure	Response	Probable Cause
1	Disable Q2 by disconnecting CR4.	Normal Output Voltage.	a. Constant current circuit faulty, check CR4, Q2A, and R16 for short. b. Q2B open.
2	Voltage between +S and A6.	More negative than 0V. 0V to +0.8V	a. Open strap A6 - A7. a. Check R10, C1, or C2 for short. b. Proceed to Step 3.
3	Voltage between +S and I2.	More positive than +1.5V. +0.8V to +1.5V.	a. Q1A open. b. Q1B or R3 shorted. Proceed to Step 4.
4	Voltage between +S and I9.	Less positive than +1.2V. More positive than +1.2V.	a. Q3 shorted. b. R33 shorted or low. Proceed to Step 5.
5	Voltage between Z2 and Z3.	More negative than 0V. More positive than 0V.	a. R32 shorted. b. Q4 open. a. Q6 or Q7 open.

Table 5-3. High Output Voltage Troubleshooting

Step	Measure	Response	Probable Cause
1	Voltage between +S and A6	0V to +0.8V More negative than 0V	a. Open strap between A7 and A8 b. R10 open Proceed to Step 2.
2	Voltage between +S and I2	Less positive than +0.8V +0.8V to +1.5V	a. Q1A shorted b. Q1B open c. R3 open Proceed to Step 3.
3	Voltage between +S and I9	More positive than +1.2V Less positive than +1.2V	a. Q3 open b. R35 shorted c. R33 open Proceed to Step 4.
4	Voltage between Z2 and Z3	0V or negative More positive than 0V	a. Q6 or Q7 shorted b. CR11 shorted a. Q4 shorted.

Symptom	Probable Cause
High Ripple	<p>a. Check operating setup for ground loops.</p> <p>b. If output floating, connect 1µf capacitor between output and ground.</p> <p>c. Ensure that supply is not crossing over to constant current mode under loaded conditions. Check for low voltage across C14 or Q6.</p>
Poor line regulation	<p>a. Check reference circuit (Paragraph 5-32).</p> <p>b. Check reference circuit adjustment (Paragraph 5-51).</p>
Poor load regulation (Constant Voltage)	<p>a. Improper measuring technique; refer to Paragraph 5-16.</p> <p>b. Check the regulation characteristics of Zener diode VR1 as follows:</p> <p>(1) Connect differential voltmeter across VR1</p> <p>(2) Connect appropriate load resistor (Ry), given in Figure 5-4, across (+) and (-) output terminals</p> <p>(3) Perform steps b through f of Paragraph 5-32</p> <p>(4) If the differential voltmeter reading varies by more than 0.5mV, replace VR1.</p> <p>c. Ensure that supply is not going into current limit. Check constant current input circuit.</p>
Poor load regulation (Constant Current)	<p>a. Improper measuring technique; refer to Paragraph 5-16.</p> <p>b. Check the regulation characteristics of Zener diode VR2 as follows:</p> <p>(1) Connect differential voltmeter across VR2</p> <p>(2) Connect appropriate load resistor (Ry), given in Figure 5-4, across (+) and (-) output terminals</p> <p>(3) Perform steps b through f of Paragraph 5-51</p> <p>(4) If the differential voltmeter reading varies by more than 0.5mV, replace VR2.</p> <p>c. Check clamp circuit Q10, CR30, CR31 and CR32.</p> <p>d. Ensure that supply is not crossing over to constant voltage operation. Check constant voltage input circuit.</p>
Oscillates (Constant Voltage/ Constant Current)	<p>a. Check C5 for open, adjustment of R30 (Paragraph 5-53).</p> <p>b. Check R20, C3 in constant current input circuit.</p>
Poor stability (Constant Voltage)	<p>a. Check ±6.2Vdc reference voltages (Paragraph 5-32).</p> <p>b. Noisy programming resistor R10.</p> <p>c. CR1, CR2 leaky.</p> <p>d. Check R1, R12, R13, C2 for noise or drift.</p> <p>e. Stage Q1 defective.</p>
Poor stability (Constant Current)	<p>a. Check ±6.2Vdc reference voltages (Paragraph 5-32).</p> <p>b. Noisy programming resistor R16.</p> <p>c. CR5, CR34, C20, C3 leaky.</p> <p>d. Check R18, R19, R20, R21, R54, for noise or drift.</p> <p>e. Stage Q2 defective.</p>

Table 5-5. Common Troubles

Reference	Function	Check	Adjust
Q1	Constant voltage differential amplifier	Constant Voltage (CV) line and load regulation. Zero volt output.	R6 or R8
Q2	Constant current differential amplifier	Constant current (CC) line and load regulation. Zero current output.	R25 or R28
Q3, Q4(Q5)	Mixer and error amplifier(s)	CV/CC load regulation. CV transient response.	R30
Q6, Q7	Series regulator	Reference circuit line regulation.	R46
Q8, Q9	Reference regulator	Reference circuit line regulation.	R46
Q10	Clamp circuit	CC load regulation.	R63, R72, R56
Q11-Q15	Meter circuit	Meter zero. Voltmeter/ammeter tracking.	R63, R72, R56
CR1, CR2	Limiting diodes	CV load regulation.	
CR3-CR5	OR-gate diodes and limiting diode	CV/CC load regulation.	
CR8(CR9)	Forward bias regulator	Voltage across each diode 2.0 to 2.4 volts.	
CR22-CR29	Rectifier diodes	Voltage across appropriate filter capacitor.	
CR34	Protection diode	Output voltage	

Table 5-7. Checks and Adjustments After Replacement of Semiconductor Devices

Reference Designator	Characteristics	Stock No.	Suggested Replacement
Q1, 2	Matched differential amplifier. NPN Si Planar. $I_{c} = 1\text{ma}$ , $V_{CE} = 5\text{V}$ , $I_{co} = 0.01\mu\text{a}$ @ $V_{cbo} = 5\text{V}$ . NPN Power hFE = 35 (min.) @ $I_{c} = 1\text{A}$ ; $V_{CE} = 4\text{V}$ , $V_{CE(sat)} = 1\text{Vmax}$ @ $I_{c} = 1\text{A}$ ; $V_{CE} = 4\text{V}$ .	1854-0229	2N2917 G.E.
Q6, 7(16)	NPN Power hFE = 35 (min.) @ $I_{c} = 1\text{A}$ ; $V_{CE} = 4\text{V}$ , $V_{CE(sat)} = 1\text{Vmax}$ @ $I_{c} = 1\text{A}$ ; $V_{CE} = 4\text{V}$ .	1854-0250	2N3442 R.C.A.
CR1-5, 19, 20, 30, 32	Si. rectifier, 200ma, 200prv	1901-0033	1N485B Sylvania
CR8, 12, 31	Si. diode, 2.4V @ 100ma	1901-0460	1N4830 G.E.
CR13, 33	Si. Stabistor, 200ma, 10prv	1901-0461	1N4828 G.E.
CR22-25	Si. rectifier, 500ma, 200prv	1901-0026	1N3253 R.C.A.

Table 5-6. Selected Semiconductor Characteristics

5-36 Before servicing a printed wiring board, refer to Figure 5-10, Section VI of this manual contains a list of replaceable parts. Before replacing a semiconductor device, refer to Table 5-6 which lists the special characteristics of selected semiconductors. If the device to be replaced is not listed in Table 5-6, the standard manufacturers part number listed in Section VI is applicable. After replacing a semiconductor device, refer to Table 5-7 for checks and adjustments that may be necessary.

Excessive heat or pressure can lift the copper strip from the board. Avoid damage by using a low power soldering iron (50 watts maximum) and following these instructions. Copper that lifts off the board should be cemented in place with a quick drying acetate base cement having good electrical insulating properties.

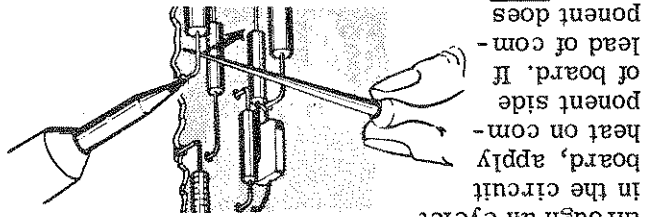
A break in the copper should be repaired by soldering a short length of tinned copper wire across the break.

Use only high quality rosin core solder when repairing etched circuit boards. NEVER USE PASTE FLUX. After soldering, clean off any excess flux and coat the repaired area with a high quality electrical varnish or lacquer.

When replacing components with multiple mounting pins such as tube sockets, electrolytic capacitors, and potentiometers, it will be necessary to lift each pin slightly, working around the components several times until it is free.

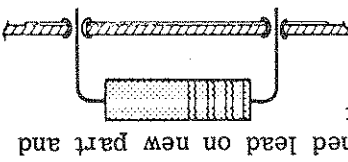
WARNING: If the specific instructions outlined in the steps below regarding etched circuit boards without eyelets are not followed, extensive damage to the etched circuit board will result.

1. Apply heat sparingly to lead of component to be replaced. If lead of component passes through an eyelet

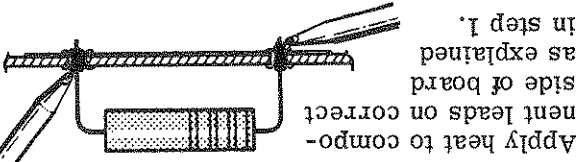


in the circuit board, apply heat on component side of board. If component does not pass through an eyelet, apply heat to conductor side of board.

3. Bend clean tinned lead on new part and carefully insert through eyelets or holes in board.

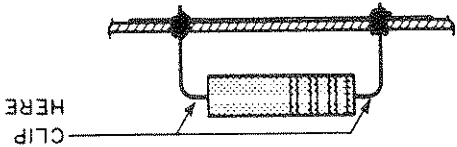


4. Hold part against board (avoid overheating) and solder leads. Apply heat to component leads on correct side of board as explained in step 1.

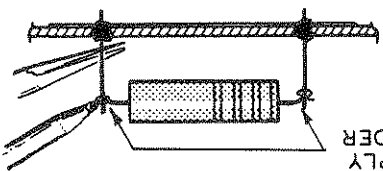


In the event that either the circuit board has been damaged or the conventional method is impractical, use method shown below. This is especially applicable for circuit boards without eyelets.

1. Clip lead as shown below.



2. Bend protruding leads upward. Bend lead of new component around protruding lead. Apply solder using a pair of long nose pliers as a heat sink.



This procedure is used in the field only as an alternate means of repair. It is not used within the factory.

Figure 5-10. Servicing Printed Wiring Boards

Table 5-7. Checks and Adjustments After Replacement of Semiconductor Devices (Continued)

Reference	Function	Check	Adjust
VR1	Positive reference voltage	Positive reference voltage (+6.2V).	
VR2	Negative reference voltage	Negative reference voltage (-6.2V).	

Table 5-8. Calibration Adjustment Summary

Adjustment or Calibration	Paragraph	Control Device
Meter Zero	5-39	Pointer
Voltmeter Tracking	5-41	R63 and R72
Ammeter Tracking	5-43	R56
"Zero" Volt Output	5-46	R6 or R8
"Voltage" Programming Current	5-47	R13
"Zero" Current Output	5-49	R25 or R28
"Current" Programming Current	5-50	R19
Reference Circuit Line Voltage Adjustment	5-52	R46
Transient Response	5-53	R30

5-37 ADJUSTMENT AND CALIBRATION

5-38 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 and no others. Table 5-8 summarizes the adjustments and calibrations contained in the following paragraphs.

5-39 METER ZERO

5-40 Proceed as follows to zero meter:

- Turn off instrument (after it has reached normal operating temperature) and allow 30 seconds for all capacitors to discharge.
- Insert sharp pointed object (pen point orawl) into the small indentation near top of round black plastic disc located directly below meter face.
- Rotate plastic disc clockwise (cw) until meter reads zero, then rotate ccw slightly in order to free adjustment screw from meter suspension. If pointer moves, repeat steps b and c.

5-41 VOLTMETER TRACKING

5-42 To calibrate voltmeter tracking, proceed as follows:

- To electrically zero meter, set METER switch to highest current position and, with supply on and no load connected, adjust R63 until front panel meter reads zero.
  - Connect differential voltmeter across supply, observing correct polarity.
  - Set METER switch to highest voltage range and turn on supply. Adjust VOLTAGE control until differential voltmeter reads exactly the maximum rated output voltage.
  - Adjust R72 until front panel meter also indicates maximum rated output voltage.
- 5-43 AMMETER TRACKING
- 5-44 To calibrate ammeter tracking proceed as follows:
- Connect test setup shown on Figure 5-4, leaving switch S1 open.
  - Turn VOLTAGE control fully clockwise and set METER switch to highest current range.
  - Turn on supply and adjust CURRENT controls until differential voltmeter reads 1.0Vdc.
  - Adjust R56 until front panel meter indicates exactly the maximum rated output current.

5-45 CONSTANT VOLTAGE PROGRAMMING CURRENT

5-46 To calibrate the zero volt programming accuracy, proceed as follows:

- Connect differential voltmeter between +S and -S terminals.
- Short out voltage controls by connecting jumper between terminals A6 and -S.
- Rotate CURRENT controls fully clockwise and turn on supply.
- Observe reading on differential voltmeter. If it is more positive than 0 volts, shunt resistor R6 with decade resistance box.
- Adjust decade resistance until differential voltmeter reads zero, then shunt R6 with resistance value equal to that of the decade resistance.
- If reading of step d is more negative than 0 volts, shunt resistor R8 with the decade resistance box.
- Adjust decade resistance until differential voltmeter reads zero then shunt R8 with resistance value equal to that of the decade box.

5-47 To calibrate the constant voltage programming current, proceed as follows:

- Connect a 0.1%, 1/2 watt resistor between terminals -S and A6 on rear barrier strip. Resistor value to be as follows:

Model No.	6281A	6284A	6289A	6294A	6299A
Resistance	1.5K $\Omega$	4K $\Omega$	8K $\Omega$	18K $\Omega$	30K $\Omega$

- Disconnect jumper between A7 and A8 (leaving A6 and A7 jumpered) on rear terminal barrier strip.
- Connect a decade resistance in place of R13

- Connect a differential voltmeter between +S and -S and turn on supply.
  - Adjust decade resistance box so that differential voltmeter indicates maximum rated output voltage within the following tolerances:
- |                 |  |       |       |       |       |
|-----------------|--|-------|-------|-------|-------|
| Model No.       | 6281A                                      | 6284A | 6289A | 6294A | 6299A |
| Tolerance (Vdc) | $\pm 0.15 \pm 0.4 \pm 0.8 \pm 1.2 \pm 2.0$ |       |       |       |       |
- Replace decade resistance with resistor of appropriate value in R13 position.

5-48 CONSTANT CURRENT PROGRAMMING

5-49 To calibrate the zero current programming accuracy proceed as follows:

- Connect differential voltmeter between +S and -S terminals.
- Short out current controls by connecting jumper between terminals A1 and A5.
- Rotate VOLTAGE control(s) fully clockwise and turn on supply.
- Observe reading on differential voltmeter. If it is more positive than 0 volts, shunt resistor R30 so that the transient response is as shown in Figure 5-8.

5-51 REFERENCE CIRCUIT ADJUSTMENTS

5-52 Line Regulation. To adjust the line regulation capabilities of the instrument proceed as follows:

- Connect the differential voltmeter between +S (common) and 33 (positive).
- Connect variable voltage transformer between supply and input power source.
- Adjust line to 105 VAC.
- Connect decade resistance in place of R46 control(s) for maximum rated output voltage.
- Turn on supply and adjust VOLTAGE control(s) for maximum rated output voltage.
- Adjust decade resistance so that voltage indicated by differential voltmeter does not change more than the following as input line voltage is varied from 105 to 125 VAC:

Model No.	6281A	6284A	6289A	6294A	6299A
Variation (mVdc)	1.24	0.946	0.806	0.750	0.701

- Replace decade resistance with appropriate value resistor in R19 position.
- Set METER switch to highest current range of R19.
- Adjust the decade resistance so that the differential voltmeter indicates  $1.0 \pm 0.02$  Vdc.
- Replace decade resistance with appropriate value resistor in R19 position.

5-53 CONSTANT VOLTAGE TRANSIENT RESPONSE

5-54 To adjust the transient response, proceed as follows:

- Connect test setup as shown in Figure 5-7.
- Repeat steps a through e as outlined in Paragraph 5-19.
- Adjust R30 so that the transient response is as shown in Figure 5-8.

5-55 CONSTANT VOLTAGE TRANSIENT RESPONSE

- Connect test setup as shown in Figure 5-7.
- Repeat steps a through e as outlined in Paragraph 5-19.
- Adjust R30 so that the transient response is as shown in Figure 5-8.



# 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:

- Reference Designators. Refer to Table 6-1.
- Description. Refer to Table 6-2 for abbreviations.
- Total Quantity (TQ). Given only the first time the part number is listed except in instruments containing many sub-modular assemblies, in which case the TQ appears the first time the part number is listed in each assembly.
- Manufacturer's Part Number or Type.
- Manufacturer's Federal Supply Code Number.
- Hewlett-Packard Part Number.
- Recommended Spare Parts Quantity (RS).
- For complete maintenance of one instrument during one year of isolated service.
- Parts not identified by a reference designator are listed at the end of Table 6-4 under Miscellaneous and/or Miscellaneous. The former consists of parts belonging to 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 (O) 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.

A	= assembly	E	= miscellaneous electronic part
B	= blower (fan)	F	= fuse
CB	= circuit breaker	J	= jack, jumper
CR	= diode	K	= relay
DS	= device, signaling (lamp)	I	= inductor
		M	= meter

Table 6-1. Reference Designators

Table 6-1. Reference Designators (Continued)

V	= vacuum tube,	P	= plug
VR	= zener diode	Q	= transistor
X	= socket	R	= resistor
Z	= integrated circuit or network	S	= switch
		T	= transformer
		TB	= terminal block
		TS	= thermal switch

Table 6-2. Description Abbreviations

mfr	= manufacturer	A	= ampere
mod.	= modular or modified	ac	= alternating current
mtg	= mounting	assy.	= assembly
n	= nano = 10 <sup>-9</sup>	bd	= board
NC	= normally closed	bkt	= bracket
NO	= normally open	OC	= degree
NP	= nickel-plated	OC	= degree
ohm	= ohm	cd	= card
obd	= order by description	coef	= coefficient
OD	= outside diameter	comp	= composition
p	= pico = 10 <sup>-12</sup>	CRT	= cathode-ray tube
P.C.	= printed circuit	CT	= center-tapped
pot.	= potentiometer	dc	= direct current
p-p	= peak-to-peak	DPDT	= double pole, double throw
ppm	= parts per million	DPST	= double pole, single throw
pvr	= peak reverse voltage	elect	= electrolytic
rect	= rectifier	encap	= encapsulated
rms	= root mean square	F	= farad
SI	= silicon	of	= degree
SPT	= single pole, double throw	Fahrenheit	
SPST	= single pole, single throw	fxd	= fixed
SS	= small signal	Ge	= germanium
T	= slow-blow	H	= Henry
Tan.	= tantalum	Hz	= Hertz
Ti	= titanium	IC	= integrated circuit
V	= volt	ID	= inside diameter
var	= variable	incnd	= incandescent
vw	= wirewound	k	= kilo = 10 <sup>3</sup>
W	= Watt	m	= milli = 10 <sup>-3</sup>
		M	= mega = 10 <sup>6</sup>
		μ	= micro = 10 <sup>-6</sup>
		met.	= metal

Table 6-3. Code List of Manufacturers

CODE	MANUFACTURER	ADDRESS
00629	EBY Sales Co., Inc.	Jamaica, N.Y.
00656	Aerovox Corp.	New Bedford, Mass.
00853	Sangamo Electric Co.	New Bedford, Mass.
01121	s. Carolina Div. Allen Bradley Co.	Pickens, S.C. Milwaukee, Wis.
01255	Liton Industries, Inc.	Beverly Hills, Calif.
01281	TRW Semiconductors, Inc.	Lawndale, Calif.
01295	Texas Instruments, Inc.	Semiconductor-Components Div. Dallas, Texas
01686	RCL Electronics, Inc.	Manchester, N.H.
01930	Amerock Corp.	Rockford, Ill.
02107	Sparta Mfg. Co.	Dover, Ohio
02114	Ferrocube Corp.	Saugerties, N.Y.
02606	Fenwal Laboratories	Morton Grove, Ill.
02660	Amphenol Corp.	Broadview, Ill.
02735	Radio Corp. of America, Solid State and Receiving Tube Div.	Somerville, N.J.
03508	G.E. Semiconductor Products Dept.	Syracuse, N.Y.
03797	Eldema Corp.	Compton, Calif.
03877	Transitron Electronic Corp.	Wakelield, Mass.
03888	Pyrofilm Resistor Co. Inc.	Cedar Knolls, N.J.
04009	Arrow, Hart and Hegeman Electric Co.	Hartford, Conn.
04072	ADC Electronics, Inc.	Harbor City, Calif.
04213	Caddell & Burns Mfg. Co. Inc.	Mineola, N.Y.
04404	*Hewlett-Packard Co.	Palo Alto Div. Palo Alto, Calif.
04713	Motorola Semiconductor Prod. Inc.	Phoenix, Arizona
05277	Westinghouse Electric Corp.	Youngwood, Pa.
05347	Semiconductor Dept.	Grand Junction, Colo.
05820	Wakelield Engr. Inc.	Wakelield, Mass.
06001	General Elect. Co. Electronic	Irmo, S.C.
06004	Capacitor & Battery Dept.	Stewart-Warner Corp.
06486	IRC Div. of TRW Inc.	Lynn, Mass.
06540	Semiconductor Plant	Lynn, Mass.
06540	Amatom Electronic Hardware Co. Inc.	New Rochelle, N.Y.
06555	Beede Electrical Instrument Co.	Penacook, N.H.
06666	General Devices Co. Inc.	Indianapolis, Ind.
06751	Semcor Div. Components, Inc.	Phoenix, Arizona
06776	Robinson Nugent, Inc.	New Albany, Ind.
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.
07137	Transistor Electronics Corp.	Minneapolis, Minn.
07138	Westinghouse Electric Corp.	Mountain View, Calif.
07263	Patrichild Camera and Instrument Electronic Tube Div.	Elmtra, N.Y.
07387	Bircher Corp., The	Los Angeles, Calif.
07397	Sylvania Electric Prod. Inc.	Sylvania Electronic Systems Western Div. Mountain View, Calif.
07716	IRC Div. of TRW Inc.	Burlington Plant Burlington, Iowa
07910	Continental Device Corp.	Hawthorne, Calif.
07933	Raytheon Co. Components Div.	Semiconductor Operation Mountain View, Calif.
08484	Breeze Corporations, Inc.	Union, N.J.
08530	Reliance Mica Corp.	Brooklyn, N.Y.
08717	Sloan Company, The	Sun Valley, Calif.
08730	Vemaline Products Co. Inc.	Wyckoff, N.J.
08806	General Elect. Co. Minia- ture Lamp Dept.	Cleveland, Ohio
08863	Nylomatic Corp.	Norristown, Pa.
08919	RCH Supply Co.	Vernon, Calif.
09021	Atrco Speer Electronic Components	Bradford, Pa.
09182	*Hewlett-Packard Co.	New Jersey Div. Berkeley Heights, N.J.
09213	General Elect. Co. Semiconductor	Buffalo, N.Y.
09214	General Elect. Co. Semiconductor	Auburn, N.Y.
09353	C & K Components Inc.	Newton, Mass.
09922	Bundy Corp.	Norwalk, Conn.
11115	Wagner Electric Corp.	Tung-Sol Div. Bloomfield, N.J.
11236	CTS of Berne, Inc.	Berne, Ind.
11237	Chicago Telephone of Cal. Inc.	So. Pasadena, Calif.
11502	IRC Div. of TRW Inc.	Boone Plant Boone, N.C.
11711	General Instrument Corp	Rectifier Div. Newark, N.J.
12136	Philadelphia Handle Co. Inc.	Camden, N.J.
12615	U.S. Terminals, Inc.	Cincinnati, Ohio
12617	Hamlin Inc.	Lake Mills, Wisconsin
12697	Clarostat Mfg. Co. Inc.	Dover, N.H.
13103	Thermalloy Co.	Dallas, Texas
14493	*Hewlett-Packard Co.	Loveland Div. Loveland, Colo.
14655	Cornell-Dubilier Electronics Div.	Federal Pacific Electric Co. Newark, N.J.
14936	General Instrument Corp.	Semicon- ductor Prod. Group Hicksville, N.Y.
15801	Fenwal Elect.	Framingham, Mass.
16299	Corning Glass Works, Electronic	Components Div. Raleigh, N.C.

\*Use Code 28480 assigned to Hewlett-Packard Co., Palo Alto, California

Table 6-3. Code List of Manufacturers (Continued)

CODE NO.	ADDRESS	MANUFACTURER	CODE NO.	ADDRESS	MANUFACTURER
16758	Delco Radio Div. of General Motors Corp.	Kokomo, Ind.	70563	Amperte Co. Inc.	Union City, N.J.
17545	Atlantic Semiconductors, Inc.	Asbury Park, N.J.	71218	Bud Radio, Inc.	Willoughby, Ohio
17803	Fathchild Camera and Instrument Corp	Semiconductor Div. Transducer Plant	71279	Cambridge Thermionic Corp.	Cambridge, Mass.
17870	Daven Div. Thomas A. Edison Industries	Mountain View, Calif.	71400	Bussmann Mfg. Div. of McGraw & Edison Co.	St. Louis, Mo.
18324	Signetics Corp.	Sunnyvale, Calif.	71450	CTS Corp.	Eikhardt, Ind.
19315	Bendix Corp. The Navigation and Control Div.	Teterboro, N.J.	71590	Globe-Union Inc.	Los Angeles, Calif.
19701	Electra/Midland Corp.	Mineral Wells, Texas	71700	General Cable Corp. Cornish Wire Co. Div.	Williamstown, Mass.
21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.	71707	Coto Coil Co. Inc.	Providence, R.I.
22229	Union Carbide Corp. Electronics Div.	Mountain View, Calif.	71744	Chicago Miniature Lamp Works	Chicago, Ill.
22753	UID Electronics Corp.	Hollywood, Fla.	71785	Cinch Mfg. Co. and Howard B. Jones Div.	Chicago, Ill.
23936	Pamator, Inc.	Pampa, Texas	71984	Dow Corning Corp.	Midland, Mich.
24446	General Electric Co. Schenectady, N.Y.	Schenectady, N.Y.	72136	Electro Motive Mfg. Co. Inc.	Willimantic, Conn.
24455	General Electric Co. Lamp Div. of Con-	sumer Prod. Group	72619	Dialight Corp.	Brooklyn, N.Y.
24655	General Radio Co. West Concord, Mass.	Nela Park, Cleveland, Ohio	72699	General Instrument Corp.	Newark, N.J.
24681	LTV Electrosystems Inc Memcor/Com-	Huntington, Ind.	72765	Drake Mfg. Co.	Harwood Heights, Ill.
26982	Dynacool Mfg. Co. Inc. Saugerties, N.Y.	Huntington, Ind.	72982	Erie Technological Products Inc.	Erie, Pa.
27014	National Semiconductor Corp.	Santa Clara, Calif.	73096	Hart Mfg. Co.	Hartford, Conn.
28480	Hewlett-Packard Co.	Palo Alto, Calif.	73138	Beckman Instruments Inc.	Pullerton, Calif.
28520	Heyman Mfg. Co.	Kentworth, N.J.	73168	Fenwal, Inc.	Ashland, Mass.
28875	IMC Magnetics Corp.	Rochester, N.H.	73293	Hughes Aircraft Co. Electron Dynamics Div.	Torrance, Calif.
31514	SAE Advance Packaging, Inc.	Santa Ana, Calif.	73445	Amperelex Electronic Corp.	Hicksville, N.Y.
31827	Budwig Mfg. Co.	Ramona, Calif.	73506	Bradley Semiconductor Corp.	New Haven, Conn.
33173	G. E. Co. Tube Dept.	Owensboro, Ky.	73559	Carling Electric, Inc.	Hartford, Conn.
35434	Lectrom, Inc.	Chicago, Ill.	73734	Federal Screw Products, Inc.	Chicago, Ill.
37942	P. R. Mallory & Co. Inc.	Indianapolis, Ind.	74193	Heinemann Electric Co.	Trenton, N.J.
42190	Muter Co.	Chicago, Ill.	74545	Hubbell Harvey Inc.	Bridgeport, Conn.
43334	New Departure-Hyatt Bearings Div.	Sandusky, Ohio	74868	Amphenol Corp. Amphenol RF Div.	Danbury, Conn.
44655	Omrite Manufacturing Co.	Skokie, Ill.	74970	E. F. Johnson Co.	Waseca, Minn.
46384	Penn Engr. and Mfg. Corp.	Doylestown, Pa.	75042	IRC Div. of TRW, Inc.	Philadelphia, Pa.
47904	Polaroid Corp.	Cambridge, Mass.	75183	*Howard B. Jones Div. of Cinch Mfg. Corp.	New York, N.Y.
49956	Raytheon Co.	Lexington, Mass.	75376	Kurz and Kasch, Inc.	Dayton, Ohio
55026	Stimpson Electric Co. Div. of American	Chicago, Ill.	75382	Kiika Electric Corp.	Mt. Vernon, N.Y.
56289	Sprague Electric Co. North Adams, Mass.	Bristol, Conn.	75915	Littlefuse, Inc.	Des Plaines, Ill.
58474	Superior Electric Co.	Chicago, Ill.	76381	Minnesota Mining and Mfg. Co.	St. Paul, Minn.
58849	Syntron Div. of FMC Corp.	Homer City, Pa.	76385	Minor Rubber Co. Inc.	Bloomfield, N.J.
59730	Thomas and Betts Co.	Philadelphia, Pa.	76487	James Millen Mfg. Co. Inc.	Malden, Mass.
61637	Union Carbide Corp.	New York, N.Y.	76493	J. W. Miller Co.	Compton, Calif.
63743	Ward Leonard Electric Co.	Mt. Vernon, N.Y.			

\*Use Code 71785 assigned to Cinch Mfg. Co., Chicago, Ill.

Table 6-3. Code List of Manufacturers (Continued)

CODE NO.	MANUFACTURER	ADDRESS
83508	Grant Pulley and Hardware Co.	West Nyack, N. Y.
83594	Burroughs Corp. Electronic Components Div.	Plainfield, N. J.
83835	U. S. Radium Corp.	Morristown, N. J.
83877	Yardeny Laboratories, Inc.	New York, N. Y.
84171	Arco Electronics, Inc.	Great Neck, N. Y.
84411	TRW Capacitor Div.	Ogallala, Neb.
86684	RCA Corp. Electronic Components	Harrison, N. J.
86838	Rummel Fibre Co.	Newark, N. J.
87034	Marco & Oak Industries a Div. of Oak Electro/hetics Corp.	Anahem, Calif.
87216	Philco Corp. Lansdale Div.	Lansdale, Pa.
87585	Stockwell Rubber Co. Inc.	Philadelphia, Pa.
87929	Tower-Olschan Corp.	Bridgport, Conn.
88140	Cutler-Hammer Inc. Power Distribution and Control Div.	Lincoln Plant Lincoln, Ill.
88245	Litton Precision Products Inc. USOCO Div.	Litton Industries Van Nuys, Calif.
90634	Gulton Industries Inc.	Metuchen, N. J.
90763	United-Car Inc.	Chicago, Ill.
91345	Miller Dial and Nameplate Co.	El Monte, Calif.
91418	Radio Materials Co.	Chicago, Ill.
91506	Augat, Inc.	Attleboro, Mass.
91637	Dale Electronics, Inc.	Columbus, Neb.
91662	Elco Corp.	Willow Grove, Pa.
91929	Honeywell Inc. Div. Micro Switch	Freeport, Ill.
92825	Whitso, Inc.	Schiller Pk., Ill.
93332	Sylvania Electric Prod. Inc. Semi-conductor Prod. Div.	Woburn, Mass.
93410	Essex Wire Corp. Stenco Controls Div.	Mansfield, Ohio
94144	Raytheon Co. Components Div.	Quincy, Mass.
94154	Wagner Electric Corp.	Livingston, N. J.
94222	Tung-Sol Div.	Lester, Pa.
95263	Leecraft Mfg. Co. Inc.	L. I. C., N. Y.
95354	Method Mfg. Co. Rolling Meadows, Ill.	
95712	Bendix Corp. Microwave Devices Div.	Franklin, Ind.
95987	Weckesser Co. Inc.	Chicago, Ill.
96791	Amphenol Corp. Amphenol Controls Div.	Janesville, Wis.
97464	Industrial Retaining Ring Co.	Irvington, N. J.
97702	IMC Magnetics Corp. Eastern Div.	Westbury, N. Y.
98291	Seallectro Corp.	Mamaroneck, N. Y.
98410	ETC Inc.	Cleveland, Ohio
98978	International Electronic Research Corp.	Burbank, Calif.
99934	Renbrandt, Inc.	Boston, Mass.

CODE NO.	MANUFACTURER	ADDRESS
76530	Cinch	City of Industry, Calif.
76854	Oak Mfg. Co. Div. of Oak Electro/Netics Corp.	Crystal Lake, Ill.
77068	Bendix Corp., Electrodynamics Div.	No. Hollywood, Calif.
77122	Palnut Co.	Mountainside, N. J.
77147	Patton-MacGoyer Co.	Providence, R. I.
77221	Phaestron Instrument and Electronic Co.	South Pasadena, Calif.
77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
77342	American Machine and Foundry Co.	Princeton, Ind.
77630	TRW Electronic Components Div.	Camden, N. J.
77764	Resistance Products Co.	Harrisburg, Pa.
78189	Illinois Tool Works Inc. Shakeproof Div.	Elgin, Ill.
78452	Everlock Chicago, Inc.	Chicago, Ill.
78488	Stackpole Carbon Co.	St. Marys, Pa.
78526	Stanwyck Winding Div.	San Fernando
78553	Electric Mfg. Co. Inc.	Newburgh, N. Y.
78584	Tinnerman Products, Inc.	Cleveland, Ohio
79136	Waldes Kohinor, Inc.	L. I. C., N. Y.
79307	Whitehead Metals Inc.	New York, N. Y.
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
79663	Zerick Mfg. Co.	Mt. Kisco, N. Y.
80031	Mepco Div. of Sessions Clock Co.	Morristown, N. J.
80294	Bourns, Inc.	Riverside, Calif.
81042	Howard Industries Div. of Msl Ind. Inc.	Racine, Wisc.
81073	Grayhill, Inc.	La Grange, Ill.
81483	International Rectifier Corp.	El Segundo, Calif.
81751	Columbus Electronics Corp.	Yonkers, N. Y.
82099	Goodyear Sundries & Mechanical Co. Inc.	New York, N. Y.
82142	Airco Speer Electronic Components	Du Bois, Pa.
82219	Sylvania Electric Products Inc.	Chicago, Ill.
82389	Switchcraft, Inc.	Chicago, Ill.
82647	Metals and Controls Inc. Control Products Group	Attleboro, Mass.
82866	Research Products Corp.	Madison, Wis.
82877	Rotron Inc.	Woodstock, N. Y.
82893	Vector Electronic Co.	Glendale, Calif.
83058	Carr Fastener Co.	Cambridge, Mass.
83186	Victory Engineering Corp.	Springfield, N. J.
83298	Bendix Corp. Electric Power Div.	Eatonown, N. J.
83330	Herman H. Smith, Inc.	Brooklyn, N. Y.
83385	Central Screw Co.	Chicago, Ill.
83501	Gavit Wire and Cable Div. of Amerace Esna Corp.	Brookfield, Mass.

Reference Designator Description Quantity Mfr. Part # or Type Mfr. Code Mtr. Stock No. RS

C1, 15	fxd, elect 5µf 150vdc	2	40D505F150DD4	Sprague	56289	0180-1841	1
C2, 18	fxd, film .01µf 200vdc	2	192P10392	Sprague	56289	0160-0161	1
C3	fxd, film 0.1µf 200vdc	1	192P10492	Sprague	56289	0160-0168	1
C4, 7, 8, 11,	NOT ASSIGNED	-	-	-	-	-	-
I3	NOT ASSIGNED	-	-	-	-	-	-
C5	fxd, film .001µf 200vdc	1	192P10292	Sprague	56289	0160-0153	1
C6	fxd, elect 20µf 15vdc	1	30D206G015BB4	Sprague	56289	0180-0300	1
C9	fxd, elect 4.7µf 35vdc	1	150D475X9035B2	Sprague	56289	0180-0100	1
C10	fxd, elect 100µf 50vdc	1	D32218	HIAB	09182	0180-1852	1
C12, 20	fxd, elect 200µf 150vdc	2	D40700	HIAB	09182	0180-1885	1
C14	fxd, elect 710µf 200vdc	1	D42344	HIAB	09182	0180-1878	1
C16, 17	fxd, ceramic .05µf 500V	2	33C17A	Sprague	56289	0150-0052	1
C19	fxd, elect 20µf 200vdc	1	34D206F200F4	Sprague	56289	0180-0367	1
CRI, 2, 3, 4,	Rect, st. 200ma 180prv	9		HIAB	09182	1901-0033	6
CR6, 7, 9,							
10, 14, 15,							
16, 17, 21,							
28, 29, 35	NOT ASSIGNED	-	-	-	-	-	-
CR8, 12, 31	Diode, st. 2.4V @ 100ma	3		HIAB	09182	1901-0460	3
CRI1, 18, 34	Rect, st. 3A 200prv	3	MR1032B	Motorola	04713	1901-0416	3
CR13, 33	Rect, st. 200ma 10prv	2		HIAB	09182	1901-0461	2
CR22, 23, 24,							
25	Rect, st. 500ma 200prv	4	IN3253	R. C. A.	02735	1901-0389	4
CR26, 27	Rect, st. 1A 400prv	2	IN5060	G. E.	03508	1901-0328	2
DS1	Lamp, Neon part of SI ass'y ref			HIAB	09182	2140-0244	2
F1	Fuse Cartridge 2A @ 250V 3AG 1	1	312002	Littlefuse	75915	2110-0002	5
Q1, 2	SS NPN diff. amp. st.	2		HIAB	09182	1854-0229	2
Q3, 9, 11, 13	SS NPN st.	4	47X16A1014	G. E.	03508	1854-0371	4
Q4	SS NPN st.	1	2N3417	G. E.	03508	1854-0087	1
Q5	NOT ASSIGNED	-	-	-	-	-	-
Q6, 7	Power NPN st.	2		HIAB	09182	1854-0250	2
Q8, 10, 12,							
14, 15	SS PNP st.	5	2N2907A	Sprague	56289	1853-0099	5
R1, 12	fxd, ww 2K $\Omega$ $\pm$ 5% 3w	2	242E2025	Sprague	56289	0811-1806	1
R2, 22	fxd, met, film 6.2K $\pm$ 1% 1/8w	2	Type CEA T-O	I. R. C.	07716	0698-5087	1
R3, 4, 64, 65	fxd, met, film 20K $\pm$ 1% 1/8w	4	Type CEA T-O	I. R. C.	07716	0757-0449	1
R5, 26, 48,							
76, 77	fxd, met, film 1.5K $\pm$ 1% 1/8w	5	Type CEA T-O	I. R. C.	07716	0757-0427	1
R6, 25	fxd, comp 360K $\Omega$ $\pm$ 5% $\frac{1}{2}$ w	2	EB-3645	A. B.	01121	0686-3645	1
R7	fxd, met, film 100K $\Omega$ $\pm$ 1% 1/8w	1	Type CEA T-O	I. R. C.	07716	0757-0465	1
R8, 28	fxd, comp 560K $\Omega$ $\pm$ 5% $\frac{1}{2}$ w	2	EB-5645	A. B.	01121	0686-5645	1
R9, 17, 27,							
29, 34, 38,							
39, 53,							
55, 78	NOT ASSIGNED	-	-	-	-	-	-
R10	var, ww 40K $\Omega$ $\pm$ 5% 2w @ 25 $^{\circ}$ C (10 turn)	1		HIAB	09182	2100-1868	1
R11	fxd, ww 5K $\Omega$ C. T. $\pm$ 5% 20w	1		HIAB	09182	0811-1825	1
R13, 19	fxd, comp SELECTED $\pm$ 5% $\frac{1}{2}$ w	2	Type EB	A. B.	01121		1
R14	fxd, comp 3.3 $\Omega$ $\pm$ 5% $\frac{1}{2}$ w	1	EB-0335	A. B.	01121	0686-0335	1

Reference	Designator	Description	Quantity	Mfr. Part #	Mfr.	Code	Stock No.
R15		fxd, comp $K_n \pm 5\% \frac{2}{2}w$	1	EB-3045	A. B.	01121	0686-3045
R16		var. wv DUAL 900 - 10 $\mu$	1		HLAB	09182	2100-0994
R18		fxd, wv $5K_n \pm 5\% 3w$	1	Type 3SX	W. L.	63743	0811-1832
R20		fxd, met. film $1K_n \pm 1\% \frac{1}{2}w$	1	Type CEB T-O	I. R. C.	07716	0757-0338
R21		fxd, comp $39\mu \pm 5\% \frac{2}{2}w$	1	EB-3905	A. B.	01121	0686-3905
R23, 74		fxd, met. film $9.09K_n \pm 1\% 1/8w$	2	Type CEA T-O	I. R. C.	07716	0757-0288
R24		fxd, met. film $8.25K_n \pm 1\% 1/8w$	1	Type CEA T-O	I. R. C.	07716	0757-0441
R30		var. wv $5K_n$ (Modify)	1	Type 110-F4	C. T. S.	11236	2100-1824
R31		fxd, comp $1K_n \pm 5\% \frac{2}{2}w$	1	EB-1025	A. B.	01121	0686-1025
R32		fxd, comp $510\mu \pm 5\% \frac{2}{2}w$	1	EB-5115	A. B.	01121	0686-5115
R33		fxd, comp $20K_n \pm 5\% \frac{2}{2}w$	1	EB-2035	A. B.	01121	0686-2035
R35		fxd, comp $11K_n \pm 5\% \frac{2}{2}w$	1	EB-1135	A. B.	01121	0686-1135
R36, 49		fxd, wv $2.2K_n \pm 5\% 20w$	1		HLAB	09182	0818-0058
R37, 80		fxd, comp $33K_n \pm 5\% \frac{2}{2}w$	2	EB-3335	A. B.	01121	0686-3335
R40, 62		fxd, met. film $619\mu \pm 1\% \frac{1}{2}w$	2	Type CEB T-O	I. R. C.	07716	0757-0728
R41		fxd, comp $12K_n \pm 5\% \frac{2}{2}w$	1	EB-1235	A. B.	01121	0686-1235
R42		fxd, comp $6.8K_n \pm 5\% \frac{2}{2}w$	1	EB-6825	A. B.	01121	0686-6825
R43		fxd, met. film $510\mu \pm 1\% \frac{1}{2}w$	1	Type CEB T-O	I. R. C.	07716	0698-5145
R44		fxd, comp $47K_n \pm 5\% \frac{2}{2}w$	1	EB-4735	A. B.	01121	0686-4735
R45		fxd, comp $5.1K_n \pm 5\% \frac{2}{2}w$	1	EB-5125	A. B.	01121	0686-5125
R46		fxd, comp $100K_n \pm 5\% \frac{2}{2}w$	1	EB-1045	A. B.	01121	0686-1045
R47		fxd, comp $470\mu \pm 5\% \frac{2}{2}w$	1	EB-4715	A. B.	01121	0686-4715
R50		fxd, comp $10\mu \pm 5\% \frac{2}{2}w$	1	EB-1005	A. B.	01121	0686-1005
R51		fxd, met. film $33K_n \pm 1\% 1/8w$	1	Type CEA T-O	I. R. C.	07716	0698-5089
R52		fxd, met. film $27.4K_n \pm 1\% 1/8w$	1	Type CEA T-O	I. R. C.	07716	0757-0452
R54		fxd, wv $1.33\mu$ C. T. $\pm 5\% 20w$	1		HLAB	09182	0811-1820
R56, 72		var. wv $250\mu$ (Modify)	2	Type 110-F4	C. T. S.	11236	2100-0439
R57, 60		fxd, met. film $900\mu \pm 1\% 1/8w$	2	Type CEA T-O	I. R. C.	07716	0757-1099
R58, 59		fxd, met. film $100\mu \pm 1\% 1/8w$	2	Type CEA T-O	I. R. C.	07716	0757-0401
R61		fxd, met. film $118K_n \pm 1\% 1/8w$	1	Type CEA T-O	I. R. C.	07716	0698-3265
R63		var. wv $10K_n$	1	Type 110-F4	C. T. S.	11236	2100-0396
R66, 67		fxd, met. film $3.40K_n \pm 1\% \frac{1}{2}w$	2	Type CEB T-O	I. R. C.	07716	0698-4642
R68, 69		fxd, met. film $365\mu \pm 1\% \frac{1}{2}w$	2	Type CEB T-O	I. R. C.	07716	0757-0723
R70, 71, 75		fxd, met. film $3K_n \pm 1\% 1/8w$	3	Type CEA T-O	I. R. C.	07716	0757-1093
R73		fxd, met. film $750\mu \pm 1\% 1/8w$	1	Type CEA T-O	I. R. C.	07716	0757-0420
R79		fxd, comp $3.3\mu \pm 5\% 1w$	1	GB-0335	A. B.	01121	0689-0335
R81, 82, 83		fxd, wv $540\mu \pm 5\% 75w$	3	Type 6-BR-37	H. H.	73978	0811-1974
S1		Switch, PL, LT (red)	1	54-61681 - 26 A1H	Oak	87034	3101-0100
S2		Meter Switch, w/ater	1		HLAB	09182	3100-1910
T1		Power Transformer	1		HLAB	09182	9100-1840
VR1, 2		Diode, zener 6.2V	2	IN821	N. A. Elect.	06486	1902-0761
		5 Way binding post (maroon)	1	DF21Mn	HLAB	09182	1510-0040
		5 Way binding post (black)	2	DF21BC	Superior	58474	1510-0039
		Angle, plastic extrusion	1		HLAB	09182	4040-0062
		7.875LG	1		HLAB	09182	4040-0062
		Cable clamp $\frac{1}{2}$ I. D.	1	T4-4	Whitehead	79307	1400-0330
		Line cord plug PH151 $7\frac{1}{2}$ ft.	1	KH-4096	Beldon	70903	8120-0050
		Strain relief bushing	1	SR-5P-1	Heyco	28520	0400-0013
		Knob 17/64 insert pointer	1		HLAB	09182	0370-0101
		Knob 3/16 insert	1		HLAB	09182	0370-0179
		Knob $\frac{1}{4}$ insert pointer	1		HLAB	09182	0370-0084

Reference Designator Description Quantity or Type Mfr. Part # Mfr. Code Stock No. RS

1	Knob 5/8 DIA	1	HIAB	09182	0370-0137	1
1	Barrier strip	1	HIAB	09182	0360-1234	1
8	Jumper	8	Cinch	71785	0360-1274	2
4	Rubber bumper	4	Stockwell	87575	0403-0088	1
1	Fuse Holder	1	Littlefuse	75915	1400-0084	1
2	Mica insulator	2	Reliance	08530	0340-0174	1
1	Meter, 2 1/4" size DUAL scale 0-120V 0-.9A	1	HIAB	09182	1120-1149	1
1	Bezel 1/6 MOD	1	HIAB	09182	4040-0295	1
4	Spring	4	HIAB	09182	1460-0720	1
4	Insulator, transistor pin	4	HIAB	09182	0340-0166	1
4	Insulator	4	HIAB	09182	0340-0168	1
3	Rubber bumper	3	Stockwell	87575	0403-0086	1

OPTION 06:

Overvoltage Crowbar

1	HIAB	09182	Model 6916A	1
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OPTION 08:

Current 10-Turn Potentiometer

1	I. R. C.	07716	2100-1864	1
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OPTION 13:

Voltage Decadal Control

Decadal Control

1	(Includes:)	RD-411		1
1	I. R. C.	07716	1140-0020	1

OPTION 14:

Current Decadal Control

Current 10-Turn Potentiometer

Decadal Control

1	(Includes:)	RD-411		1
1	I. R. C.	07716	2100-1864	1
1	I. R. C.	07716	1140-0020	1





APPENDIX A  
Option 11, Overvoltage Protection "Crowbar"

DESCRIPTION:

This option is installed in DC Power Supplies, 6253A, 6255A, 6281A, 6284A, 6289A, 6294A, and 6299A and tested at the factory. It consists of a printed circuit board, screwdriver-type front panel potentiometer, and six wires that are soldered to the main power supply board.

The crowbar monitors the output voltage of the power supply and fires an SCR that effectively shorts the output when it exceeds the preset trip voltage. The trip voltage is determined by the setting of the CROWBAR ADJUST control on the front panel. The trip voltage range is as follows:

Model	Trip Voltage Range
6253A	2.5-23V
6255A	2.5-44V
6281A	2.5-10V
6284A	2.5-23V
6289A	2.5-44V
6294A	2.5-65V
6299A	30-106V

To prevent transients from falsely tripping the crowbar, the trip voltage must be set higher than the power supply output voltage by the following margin: 4% of the output voltage plus 2V. The margin represents the minimum crowbar trip setting for a given output voltage; the trip voltage can always be set higher than this margin.

OPERATION:

1. Turn the CROWBAR ADJUST fully clockwise to set the trip voltage to maximum.
2. Set the power supply VOLTAGE control for the desired crowbar trip voltage. To prevent false crowbar tripping, the trip voltage should exceed the desired output voltage by the following amount: 4% of the output voltage plus 2V.
3. Slowly turn the CROWBAR ADJUST ccw until the crowbar trips, output goes to 0V or a small positive voltage.
4. The crowbar will remain activated and the output shorted until the supply is turned off. To reset the crowbar, turn the supply off, then on.
5. If the CROWBAR must be completely disabled, remove the lead attached to the CROWBAR ADJUST potentiometer R5.

Table A-1. Replaceable Parts

REF. DESIG.	DESCRIPTION	QTY	MFR. PART NO.	MFR. CODE	HP PART NO.	RS
C1	fxd, elect 1 $\mu$ F 50Vdc	1	30D105G050BA2	56289	0180-0108	1
C2	fxd, mica 510pF 500Vdc	1	RCM15E51J	04062	0140-0047	1
CRI-CR3	Diode, SI, 200mA 200prv	3		09182	1901-0033	3
CR4	SCR 35A 400prv	1	38639	02735	1884-0058	1
Q1, 2	SS NPN SI.	2	2N3417	03508	1854-0087	2
R1	fxd, met, film 10 $\Omega$ $\pm$ 1% 1/8W	1	Type CEA T-O	07716	0757-0346	1
R2	fxd, comp 24K $\Omega$ $\pm$ 5% 2W	1	Type C42S	16299	0763-0021	1
R3	fxd, met, film 1.21K $\Omega$ $\pm$ 1% 1/8W	1	Type CEA T-O	07716	0757-0274	1
R4	fxd, met, film 7.5K $\Omega$ $\pm$ 1% 1/8W	1	Type CEA T-O	07716	0757-0440	1
R5	var, ww 20K $\Omega$ $\pm$ 5%	1		09182	2100-1855	1
R6	fxd, ww 3.3K $\Omega$ $\pm$ 5% 3W	1	24ZE332S	56289	0811-1809	1
R7	fxd, comp 10 $\Omega$ $\pm$ 5% $\frac{1}{2}$ W	1	EB-1005	01121	0686-1005	1
R8	fxd, met, film 750 $\Omega$ $\pm$ 1% 1/8W	1	Type CEA T-O	07716	0757-0420	1
R9	fxd, ww .25 $\Omega$ $\pm$ 5% 3W	1	CW2B-1	91637	0811-1829	1
T1	Transformer, Pulse	1		09182	5080-7122	1
VR1	Diode, zener 12.4V $\pm$ 5%	1		09182	1902-3185	1
VR2	Diode, zener 16.2V $\pm$ 5%	1		09182	1902-0184	1
	MISCELLANEOUS					
	Heat Sink, CR4	1		09182	5000-6229	1
	Insulator, CR4	1		09182	0340-0462	1
	Mica Washer, CR4	1		09182	2190-0709	1
	Cable Clamp	1	T4-4	79307	1400-0330	
	Bushing, Potentiometer, R5	1		09182	1410-0052	
	Nut, Shaft Lock, R5	1	181	83330	0590-0457	
	Label, Information, (Crowbar Adj.)	1		09182	7124-0389	1
	Solder Stud Terminal	1	7A1-A6	92825	0360-1449	
	Modified Front Panel, Includes Components	1		09182	06299-60003	
	Printed Circuit Board Assembly, Includes Components	1		09182	06299-60021	





- REVISIONS:**
- 1 - 12V
  - 2 - 120V
  - 3 - '94
  - 4 - '09A

**NOTES:**

1. ALL RESISTORS ARE 1/2 WATT, 5% UNLESS OTHERWISE NOTED.
2. ALL 1/8 W AND 1/4 W RESISTORS ARE 1% IN TOLERANCE.
3. \* DENOTES NOMINAL VALUE, COMPONENTS SELECTED FOR OPTIMUM PERFORMANCE.
4. \* DENOTES 20 PPM WIRE TEMPERATURE COEFFICIENT.
5. REAR TERMINALS ARE SHOWN IN NORMAL STRAPPING FOR USE OF FRONT PANEL CONTROLS.
6. --- DENOTES VOLTAGE SIGNAL.
7. --- DENOTES CURRENT SIGNAL.
8. POTENTIOMETER R16A,B IS A DIAL SAFETY FRONT PANEL CONTROL.
9. TRANSFORMER SHOWN STRAPPED FOR 115 WAC OPERATION. SEE INSTRUCTION MANUAL FOR 220 VAC.

**NOTES (CON'T)**

10. VOLTAGES WERE MEASURED UNDER THE FOLLOWING CONDITIONS:
  - a. SIMULON MODEL, E.G., OR EQUIVALENT.
  - b. 115 VAC INPUT.
  - c. VOLTAGES REFERENCED TO +5 UNLESS OTHERWISE INDICATED.
  - d. VOLTAGES ARE TYPICAL, ±10% UNLESS OTHERWISE INDICATED.
  - e. ALL READINGS TAKEN WITH SUPPLY IN CONSTANT VOLTAGE OPERATION AT MAXIMUM RATED OUTPUT WITH NO LOAD CONNECTED CURRENT CONTROLS SHOULD BE TURNED FULLY CLOCKWISE.

CIRCUIT PATENTS APPLIED FOR. LICENSE TO USE MUST BE OBTAINED IN WRITING FROM HARRISON LABORATORIES.

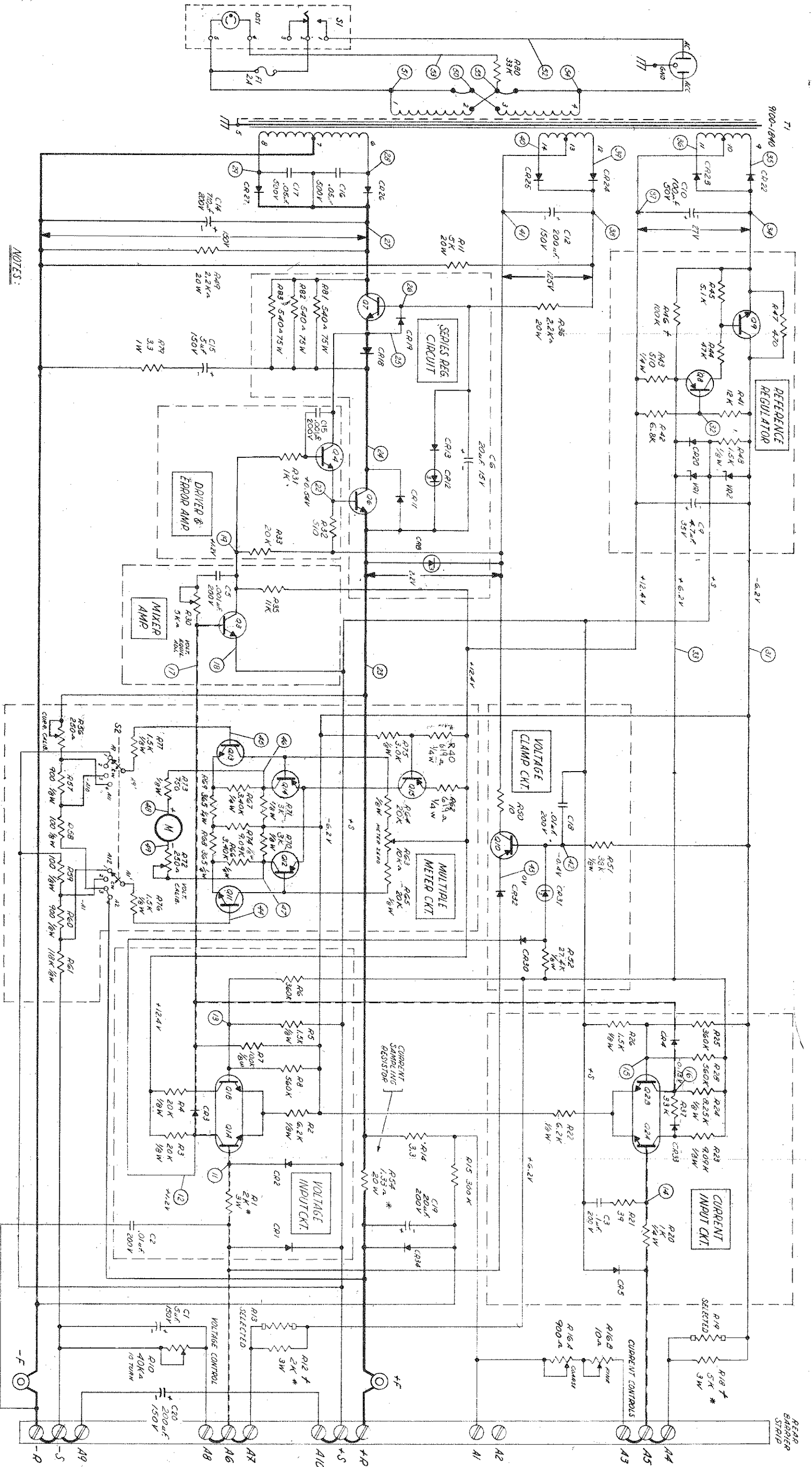
PART NO. 6299A-91001

TYPE

6299A SCHEMATIC

HARRISON LABORATORIES  
DIV. OF HENWETT PACKARD  
BERKELEY HEIGHTS, N. J.

JOB NO.	6299A
REV. B 10-7-65	REV. REV. 2
REV. A 11-12-65	REV. REV. 1
REV. D 11-12-65	REV. REV. 3
REV. C 11-12-65	REV. REV. 4
REV. E 11-12-65	REV. REV. 5
REV. F 11-12-65	REV. REV. 6
REV. G 11-12-65	REV. REV. 7
REV. H 11-12-65	REV. REV. 8
REV. I 11-12-65	REV. REV. 9
REV. J 11-12-65	REV. REV. 10





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CHILE	Santiago	1100 North Dearborn St.	56-2-252-1152	
	Valparaiso	1100 North Dearborn St.	56-3-252-1152	
COLOMBIA	Bogota	1100 North Dearborn St.	57-1-252-1152	
	Medellin	1100 North Dearborn St.	57-2-252-1152	
ECUADOR	Quito	1100 North Dearborn St.	59-1-252-1152	
	Cuenca	1100 North Dearborn St.	59-2-252-1152	
GUATEMALA	Guatemala City	1100 North Dearborn St.	502-252-1152	
	Antigua	1100 North Dearborn St.	502-252-1152	
MEXICO	Mexico City	1100 North Dearborn St.	52-1-252-1152	
	Puerto Vallarta	1100 North Dearborn St.	52-3-252-1152	
PARAGUAY	Asuncion	1100 North Dearborn St.	595-252-1152	
	Encarnacion	1100 North Dearborn St.	595-252-1152	
PERU	Lima	1100 North Dearborn St.	51-1-252-1152	
	Cuzco	1100 North Dearborn St.	51-2-252-1152	
VENEZUELA	Caracas	1100 North Dearborn St.	58-2-252-1152	
	Maracaibo	1100 North Dearborn St.	58-3-252-1152	

