



Agilent Technologies

# **Agilent E361xA 60W BENCH SERIES DC POWER SUPPLIES**

## **OPERATING AND SERVICE MANUAL FOR MODELS:**

**Agilent E3614A, Serials KR83503035 and above**  
**Agilent E3615A, Serials KR83506197 and above**  
**Agilent E3616A, Serials KR83502651 and above**  
**Agilent E3617A, Serials KR83502522 and above**

For instruments with higher Serial Numbers than above,  
a change page may be included.

## SAFETY SUMMARY

*The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Agilent Technologies assumes no liability for the customer's failure to comply with these requirements.*

### BEFORE APPLYING POWER.

Verify that the product is set to match the available line voltage and that the correct fuse is installed.

### GROUND THE INSTRUMENT.

This product is a Safety Class I instrument (provided with a protective earth terminal). To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The instrument must be connected to the ac power supply mains through a three-conductor power cable, with the third wire firmly connected to an electrical ground(safety ground) at the power outlet. Any interruption of the protective(grounding) conductor or disconnection of the protective earth terminal will cause a potential shock hazard that could result in personal injury. If the instrument is to be energized via an external autotransformer for voltage reduction, be certain that the autotransformer common terminal is connected to the neutral(earthed pole) of the ac power lines (supply mains).

### DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE.

Do not operate the instrument in the presence of flammable gases or fumes.

### KEEP AWAY FROM LIVE CIRCUITS.

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified service personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power, discharge circuits and remove external voltage sources before touching components.

### DO NOT SERVICE OR ADJUST ALONE.

Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

### SAFETY SYMBOLS



Instruction manual symbol; the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual.



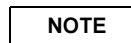
Indicate earth(ground) terminal.



The WARNING sign denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in personal injury. Do not proceed beyond a WARNING sign until the indicated conditions are fully understood and met.



The CAUTION sign denotes a hazard. It calls attention to an operating procedure, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product. Do not proceed beyond CAUTION sign until the indicated conditions are fully understood and met.



The NOTE sign denotes important information. It calls attention to a procedure, practice, condition or the like, which is essential to highlight.

### DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT.

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Agilent Technologies Sales and Service Office for service and repair to ensure that safety features are maintained.

*Instruments that appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel.*

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## GENERAL INFORMATION

### INTRODUCTION

This manual describes all models in the Agilent E361xA 60W Bench Power Supply family and unless stated otherwise, the information in this manual applies to all models.

### SAFETY REQUIREMENTS

This product is a Safety Class I instrument, which means that it is provided with a protective earth ground terminal. This terminal must be connected to an ac source that has a 3-wire ground receptacle. Review the instrument rear panel and this manual for safety markings and instructions before operating the instrument. Refer to the Safety Summary page at the beginning of this manual for a summary of general safety information. Specific safety information is located at the appropriate places in this manual.

This power supply is designed to comply with the following safety and EMC(Electromagnetic Compatibility) requirements:

- IEC 348: Safety Requirements for Electronic Measuring Apparatus
- IEC 1010-1/EN 61010: Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use
- CSA C22.2 No.231: Safety Requirements for Electrical and Electronic Measuring and Test Equipment
- UL 1244: Electrical and Electronic Measuring and Testing Equipment.
- EMC Directive 89/336/EEC: Council Directive entitled Approximation of the Laws of the Member States relating to Electromagnetic Compatibility
- EN 55011(1991) Group 1, Class B/CISPR 11: Limits and Methods of Radio Interference Characteristics of
- Industrial, Scientific, and Medical(ISM) Radio-Frequency Equipment
- EN 50082-1(1991) /
  - IEC 801-2(1991):Electrostatic Discharge Requirements
  - IEC 801-3(1984):Radiated Electromagnetic Field Requirements
  - IEC 801-4(1988):Electrical Fast Transient/Burst Requirements

### INSTRUMENT AND MANUAL IDENTIFICATION

A serial number identifies your power supply. The serial number encodes the country of manufacture, the date of the latest significant design change, and a unique sequential number. As an illustration, a serial number beginning with KR306 denotes a power supply built in 1993 (3=1 993, 4=1994, etc), 6th week manufacture in Korea(KR). The remaining digits of the serial number are a unique, five-digit number assigned sequentially.

If the serial number on your supply differs from that shown on the title page of this manual, a yellow MANUAL CHANGES sheet is supplied with this manual to explain the difference between your instrument and the instrument described by this manual. The change sheet may also contain information for correcting errors in the manual.

### OPTIONS

Options OE3 and OE9 determine which line voltage is selected at the factory. The standard unit is configured for 115 Vac  $\pm$  10%. For information about changing the line voltage setting, see paragraph "INPUT POWER REQUIREMENTS", page 1-6.

OE3:	Input power, 230 Vac $\pm$ 10%, 47-63 Hz
OE9:	Input power, 100 Vac $\pm$ 10%, 47-63 Hz
910:	One additional manual

### ACCESSORY

The accessory listed below may be ordered from your local Agilent Technologies Sales Office either with the power supply or separately. (Refer to the list at the rear of the manual for address.)

#### Agilent Part No. Description

5063-9240	Rack Kit for mounting one or two 3 1/2" high supply in a standard 19" rack
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The rack mount kit is needed for rack mounting of all models in the Agilent E361xA power supply because these supplies have molded feet.

### DESCRIPTION

This power supply is suitable for either bench or rack mounted 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 output can be adjusted both locally from the front panel and remotely by changing the settings of the rear panel switches (See paragraph "REMOTE OPERATING MODES", page 1-9). The models in this family offer up to 60 watts of output power, with voltage up to 60 volts and current up to 6 amps as shown in Table 1.

The front panel VOLTAGE control can be used to establish the voltage limit when the supply is used as a constant current source and the CURRENT control can be used to establish the output current limit when the supply is used as a constant voltage source. The supply will automatically cross over from constant voltage to constant current operation and vice versa if the output current or voltage exceeds these pre-set limits.

The front panel includes an autoranging (E3614A single-range) digital voltmeter and a single-range digital ammeter. Two 3 1/2 digit voltage and current displays accurately show the output voltage and current respectively. The output ratings for each model are shown in the Specifications and Operating Characteristics Table.

The OVP/CC SET switch is used to check the OVP trip voltage and current control set value. When pressing this switch, the voltage display indicates the OVP trip voltage and the current display indicates the current control set value.

The power supply has both front and rear output terminals. Either the positive or negative output terminal may be

be grounded or the power supply can be operated floating at up to a maximum of 240 Volts off ground. Total output voltage to ground must not exceed 240 Vdc.

**LINE FUSE**

Line Voltage	Fuse	Agilent Part No.
100/115 Vac	2.0 AT	2110-0702
230 Vac	1.0 AT	2110-0457

**SPECIFICATIONS**

Detailed specifications for the power supply are given in Table 1. All specifications are at front terminals with a resistive load, and local sensing unless otherwise stated. Operating characteristics provide useful, but non-warranted information in the form of the nominal performance.

**Table 1. Specifications and Operating Characteristics**

<p><b>*AC INPUT</b> An internal switch permits operation from 100, 115, or 230 Vac lines. 100 Vac ± 10%, 47-63 Hz, 163 VA, 125 W 115 Vac ± 10%, 47-63 Hz, 163 VA, 125 W 230 Vac ± 10%, 47-63 Hz, 163 VA, 125 W</p> <p><b>DC OUTPUT</b> Voltage and current can be programmed via front panel control or remote analog control over the following ranges; <u>E3614A</u>: 0 - 8 V, 0 - 6 A <u>E3615A</u>: 0 - 20 V, 0 - 3 A <u>E3616A</u>: 0 - 35 V, 0 - 1.7 A <u>E3617A</u>: 0 - 60 V, 0 - 1 A</p> <p><b>*OUTPUT TERMINALS</b> The output terminals are provided on the front and rear panel. They are isolated from the chassis and either the positive or negative terminal may be connected to the ground terminal.</p> <p><b>LOAD REGULATION</b> <u>Constant Voltage</u> - Less than 0.01% plus 2 mV for a full load to no load change in output current. <u>Constant Current</u> - Less than 0.01% plus 250 µA for a zero to maximum change in output voltage.</p> <p><b>LINE REGULATION</b> <u>Constant Voltage</u> - Less than 0.01% plus 2 mV for any line voltage change within the input rating. <u>Constant Current</u> - Less than 0.01% plus 250 µA for any line voltage change within the input rating.</p> <p><b>PARD (Ripple and Noise)</b> <u>Constant Voltage</u>: Less than 200 µV rms and 1 mV p-p (20 Hz-20 MHz). <u>Constant Current</u>: <u>E3614A</u>: Less than 5 mA rms <u>E3615A</u>: Less than 2 mA rms <u>E3616A</u>: Less than 500 µA rms <u>E3617A</u>: Less than 500 µA rms</p> <p><b>OPERATING TEMPERATURE RANGE</b> 0 to 40°C for full rated output. Maximum current is derated 1% per degree C at 40°C-55°C.</p> <p><b>*TEMPERATURE COEFFICIENT</b> Maximum change in output per °C after a 30-minute warm-up. <u>Constant Voltage</u>: Less than 0.02% plus 500 µV. <u>Constant Current</u>: <u>E3614A</u>: Less than 0.02% plus 3 mA <u>E3615A</u>: Less than 0.02% plus 1.5 mA <u>E3616A</u>: Less than 0.02% plus 1 mA <u>E3617A</u>: Less than 0.02% plus 0.5 mA</p>	<p><b>*STABILITY (OUTPUT DRIFT)</b> Maximum change in output for an 8 hours following a 30 minute warm-up under constant line, load and ambient temperature. <u>Constant Voltage</u>: Less than 0.1% plus 5 mV <u>Constant Current</u>: Less than 0.1% plus 10 mA</p> <p><b>LOAD TRANSIENT RESPONSE TIME</b> Less than 50 µsec for output recovery to within 15 mV following a change in output current from full load to half load, or vice versa.</p> <p><b>METER ACCURACY: ±(0.5% of output + 2 counts) at 25°C ± 5°C</b></p> <p><b>METER (PROGRAMMING) RESOLUTION</b> <u>Voltage</u>: <u>E3614A</u> 10 mV <u>E3615A</u> 10 mV (0 to 20 V), 100 mV (above 20 V) <u>E3616A</u> 10 mV (0 to 20 V), 100 mV (above 20 V) <u>E3617A</u> 10 mV (0 to 20 V), 100 mV (above 20 V) <u>Current</u>: <u>E3614A</u> 10 mA <u>E3615A</u> 10 mA <u>E3616A</u> 1 mA <u>E3617A</u> 1 mA</p> <p><b>*OVERLOAD PROTECTION</b> A continuously acting constant current circuit protects the power supply for all overloads including a direct short placed across the terminals in constant voltage operation. The constant voltage circuit limits the output voltage in the constant current mode of operation.</p> <p><b>*OVERVOLTAGE PROTECTION</b> Trip voltage adjustable via front panel control. <u>E3614A</u> <u>E3615A</u> <u>E3616A</u> <u>E3617A</u> Range: 2.5-10 V 2.5-23 V 2.5-39 V 5-65 V Margin: Minimum setting above output voltage to avoid false tripping: 4% of output + 2 V for all models</p> <p><b>*REMOTE ANALOG VOLTAGE PROGRAMMING (25 ± 5°C)</b> Remotely varied voltage from 0 to 10 V provides zero to maximum rated output voltage or current. <u>Voltage</u>: Linearity 0.5% <u>Current</u>: Linearity 0.5% The programming inputs are protected against input voltages up to ±40 V.</p> <p><b>REMOTE SENSING</b> Meets load-regulation specification when correcting for load-lead drops of up to 0.5 V per lead with sense wire resistance of less than 0.5 ohms per sense lead and lead lengths of less than 5 meters.</p>
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**Table 1. Specifications and Operating Characteristics (Cont'd)**

<b>*REMOTE PROGRAMMING SPEED</b>			<b>DC ISOLATION</b>		
Maximum time required for output voltage to change from initial value to within a tolerance band (0.1%) of the newly programmed value following the onset of a step change in the programming input voltage.			± 240 Vdc maximum between either output terminal and earth ground including the output voltage.		
		<b>Full load</b>		<b>*COOLING:</b>	Convection cooling is employed.
<b>Up:</b>	<u>E3614A:</u>	3 msec	<b>No load</b>	<b>*WEIGHT:</b>	12.1 lbs/5.5 Kg net, 14.9 lbs/6.75 Kg shipping.
	<u>E3615A:</u>	9 msec			
	<u>E3616A:</u>	85 msec			
	<u>E3617A:</u>	200 msec			
<b>Down:</b>	<u>E3614A:</u>	7 msec		<b>* Operating Characteristics</b>	
	<u>E3615A:</u>	13 msec			
	<u>E3616A:</u>	65 msec			
	<u>E3617A:</u>	200 msec			

## INSTALLATION

### INITIAL INSPECTION

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, a claim should be filed with the carrier. The Agilent Technologies Sales and Service office should be notified.

### Mechanical Check

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.

### Electrical Check

The instrument should be checked against its electrical specifications. Paragraph "TURN-ON CHECKOUT PROCEDURE" contains a brief checkout procedure and "PERFORMANCE TEST" in section SERVICE INFORMATION includes an instrument performance check to verify proper instrument operation.

### INSTALLATION DATA

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.

### Location and Cooling

This instrument is air cooled. Sufficient space should be allowed 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 40°C. Maximum current is derated 1% per °C at 40°C-55°C.

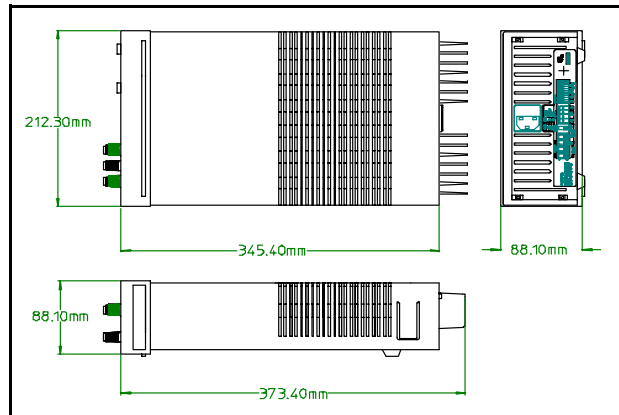
### Outline Diagram

Figure 1 is an outline diagram showing the dimensions of the instrument.

### Rack Mounting

This instrument may be rack mounted in a standard 19-inch rack panel either by itself or alongside a similar unit. Please see ACCESSORY, page 1-4, for available rack mounting accessories. Each rack-mounting kit includes complete installation

instructions.



**Figure 1. Outline Diagram**

### INPUT POWER REQUIREMENTS

This power supply may be operated from nominal 100, 115, or 230 Vac 47-63 Hertz power source. A label on the rear panel shows the nominal input voltage set for the unit at the factory. If necessary, you can convert the supply to another nominal input voltage by following the instructions below

### Line Voltage Option Conversion

Line voltage conversion is accomplished by adjusting two components: the line select switch and the rear panel fuse F1. To convert the supply from one line voltage option to another, proceed as follows:

- Disconnect power cord.
- Turn off the supply and remove the top cover by lifting the cover upwards after taking it off from both sides of the chassis by inserting a flat-blade screwdriver into the gap on the lower rear portion of the cover.
- Set two sections of the line voltage selector switch on the PC board for the desired line voltage (see Figure 2).
- Check the rating of the fuse F1 installed in the rear panel fuse holder and replace with the correct fuse if necessary. For 100 and 115 V operation, use a normal blow 2 A fuse and for 230 V use a time delay 1 A fuse.

- e. Replace the cover and mark the supply clearly with a tag or label indicating the correct line voltage and fuse that is in use.

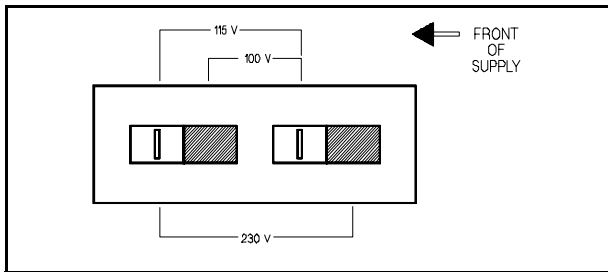


Figure 2. Line Voltage Selector (set for 115 Vac)

### Power Cord

To protect operating personnel, the instrument should be grounded. This instrument is equipped with a three conductor power cord. The third conductor is the ground conductor and when the power cord is plugged into an appropriate receptacle, the supply is grounded.

The power supply was shipped with a power cord for the type of outlet used at your location. If the appropriate cord was not included, contact your nearest Agilent Sales Office to obtain the correct cord.

## OPERATING INSTRUCTIONS

### INTRODUCTION

This section explains the operating controls and indicators and provides information on many operating modes possible with your instrument. The front panel controls and indicators are illustrated in Figure 3.

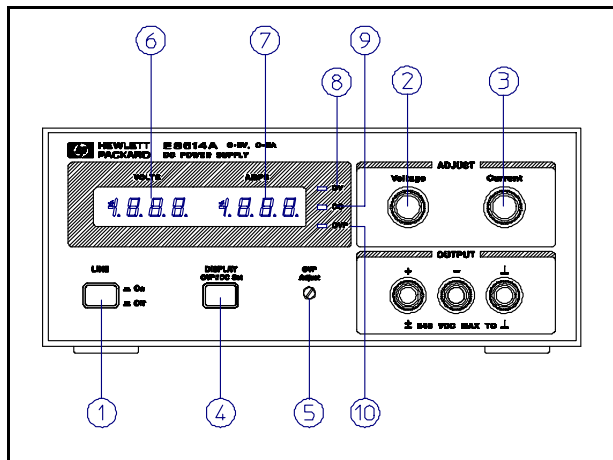


Figure 3. Front-Panel Controls and Indicators

1. **LINE Switch:** Pressing this switch turns the supply on, or off.
2. **VOLTAGE Control:** Clockwise rotation increases output voltage.
3. **CURRENT Control:** Clockwise rotation increases output current.

4. **DISPLAY OVP/CC SET Switch:** Pressing this switch causes the VOLTS display to show voltage setting for overvoltage shutdown (trip voltage) and the AMPS display to show the current control set value. Setting values are either front panel settings or remote voltage programmed settings.
5. **OVP Adjust Screwdriver Control:** While pressing the DISPLAY OVP/CC SET switch, rotating the control clock-wise with a small, flat-blade screwdriver increases the setting for overvoltage shutdown.
6. **VOLTS Display:** Digital display of actual output voltage, or OVP shutdown setting.
7. **AMPS Display:** Digital display of actual output current, or output-current setting.
8. **CV LED Indicator:** Output voltage is regulated when lighted. This means the power supply is operating in the constant voltage mode.
9. **CC LED Indicator:** Output current is regulated when lighted. This means the power supply is operating in the constant current mode.
10. **OVP LED Indicator:** Output is shutdown by the occurrence of an overvoltage when lighted. Removing the cause of overvoltage and turning the power off, then on, resets the power supply.

### TURN-ON CHECKOUT PROCEDURE

The following checkout procedure describes the use of the front panel controls and indicators illustrated in Figure 3 and ensures that the supply is operational:

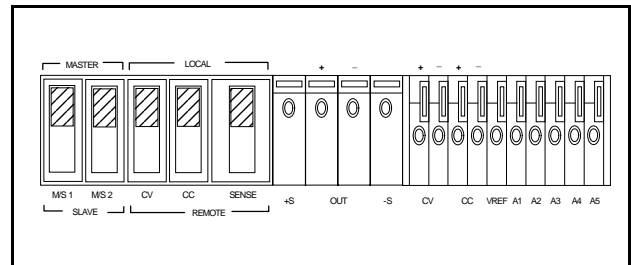


Figure 4. Switch Settings of Rear-Panel Control for Turn-On Checkout

- a. Disconnect power cord.
- b. Check that the rear-panel switch settings are as shown in Figure 4.
- c. Check that the rear panel label indicates that the supply is set to match your input line voltage (If not, refer to "Line Voltage Option Conversion").
- d. Check that the fuse on the rear panel is correct for your line voltage.
- e. Connect the power cord and push the LINE switch to ON.
- f. While pressing OVP/CC SET switch, verify that the OVP shutdown is set above 8.0, 20.0, 35.0, or 60.0 Vdc for E3614A, E3615A, E3616A, or E3617A respectively. If not, turn up OVP Adjust with a small flat-blade screwdriver.
- g. Turn VOLTAGE control fully counter clockwise to ensure that the output of VOLTS display decreases to 0 Vdc, then fully clockwise to ensure that output voltage increases to the maximum output voltage.
- h. While pressing OVP/CC SET switch, turn the CURRENT control fully counter clockwise and then fully clockwise to ensure

that the current limit value can be set from zero to maximum rated value.

## OPERATING MODES

The setting of the rear panel switch determines the operating modes of the power supply. The local operating mode is set so the power supply senses the output voltage directly at the output terminals (local sensing) for operation using the front panel controls (local programming). Other operating modes are: remote voltage sensing and remote programming of output voltage and current using external voltages.

### LOCAL OPERATING MODE

The power supply is shipped from the factory configured in the local operating mode. Local operating mode requires the switch settings of the rear panel, as shown in Figure 4. The power supply provides constant voltage(CV) or constant current(CC) output.

#### Constant Voltage Operation

To set up a power supply for constant voltage operation, proceed as follows:

- Turn on the power supply and adjust 10-turn VOLTAGE control for desired output voltage (output terminals open).
- While depressing DISPLAY OVP/CC SET switch, adjust 10-turn CURRENT control for the desired current limit.
- With power off connect the load to the output terminals.
- Turn on the power supply. Verify that CV LED is lighted. During actual operation, if a load change causes the current limit to be exceeded, the power supply will automatically cross over to constant current mode and the output voltage will drop proportionately.

#### Constant Current Operation

To set up a power supply for constant current operation, proceed as follows:

- Turn on power supply.
- While depressing DISPLAY OVP/CC SET switch, adjust CURRENT control for the desired output current.
- Turn up the VOLTAGE control to the desired voltage limit.
- With power off connect the load to the output terminal.
- Turn on power supply and then verify that CC LED is lighted. (If CV LED is lighted, choose a higher voltage limit. A voltage setting that is greater than the current setting multiplied by the load resistance in ohms is required for CC operation.) During actual operation, if a load change causes the voltage limit to be exceeded, the power supply will automatically cross over to constant voltage operation at the preset voltage limit and output current will drop proportionately.

#### Overvoltage Protection (OVP)

Adjustable overvoltage protection guards your load against overvoltage. When the voltage at the output terminals increases (or is increased by an external source) to the OVP shutdown voltage as set by the OVP ADJUST control, the supply's OVP circuit disables the output causing the output voltage and current to drop to zero. During OVP shutdown the OVP LED lights.

False OVP shutdowns may occur if you set the OVP shutdown too close to the supply's operating voltage. Set the OVP shutdown voltage 4% of output +2.0 V or more above the output voltage to avoid false shutdowns from load-induced transients.

**Adjusting OVP.** Follow this procedure to adjust the OVP shutdown voltage.

- With the VOLTAGE control fully counter clockwise, turn on the power supply.
- While depressing DISPLAY OVP/CC SET switch, adjust the OVP Adjust control to the desired OVP shutdown using a small, flat-blade screwdriver.
- Follow the procedure for CC or CV operation to set the output voltage and current

**Resetting OVP.** If OVP shutdown occurs, reset the supply by turning power off. Wait one or more seconds, and turn power on again. If OVP shutdown continue to occur, check the connections to the load and sense terminals, and check the OVP limit setting..

#### NOTE

*Strong electrostatic discharge to power supply can make OVP trip and eventually crowbar the output, which can effectively protect output loads from the hazardous ESD current.*

### CONNECTING LOADS

The output of the supply is isolated from earth ground. Either output terminal may be grounded or the output can be floated up to 240 volts off ground. Total output voltage to ground must not exceed 240 Vdc.

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 pick-up. (If a shield is used, connect one end to the power supply ground terminal and leave the other end unconnected.)

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 (See paragraph "Remote Voltage Sensing").

### OPERATION BEYOND RATED OUTPUT

The output controls can adjust the voltage or current to values up to 5% over the rated output. Although the supply can be operated in the 5% overrange region without being damaged, it can not be guaranteed to meet all of its performance specifications in this region.



## REMOTE OPERATING MODES

Remote operating modes discussed below are remote voltage sensing and remote voltage programming. You can set up the unit for remote operating modes by changing the settings of the rear panel switch and connecting the leads from the rear panel terminals to the load or the external voltage. Solid conductors of 0.75 to 1.5 mm<sup>2</sup> can be connected to the rear panel terminals by simply push fitting. Thinner wires or conductors are inserted into the connection space after depressing the orange opening lever.

### CAUTION

*Turn off the supply while making changes to rear panel switch settings or connections. This avoids the possibility of damage to the load and OVP shutdown from unintended output.*

### Remote Voltage Sensing

Remote voltage sensing is used to maintain good regulation at the load and reduce the degradation of regulation that would occur due to the voltage drop in the leads between the power supply and the load. By connecting the supply for remote voltage sensing, voltage is sensed at the load rather than at the supply's output terminals. This will allow the supply to automatically compensate for the voltage drop in the load leads and improve regulation.

When the supply is connected for remote sensing, the OVP circuit senses the voltage at the sense leads and not the main output terminals.

### NOTE

*Remote voltage sensing compensates for a voltage drop of up to 0.5 V in each load, and there may be up to a 0.1 V drop between the output terminal and the internal sensing resistor, at which point the OVP circuit is connected. Therefore, the voltage sensed by the OVP circuit could be as much as 1.1 V more than the voltage being regulated at the load. It may be necessary to re-adjust the OVP trip voltage when using remote sensing.*

**CV Regulation.** Notice that any voltage drop in the sense leads adds directly to the CV load regulation. In order to maintain the specified performance, keep the sense lead resistance to 0.5 ohms per lead or less.

**Remote Sensing Connections.** Remote sensing requires changing settings of the rear panel switch and connecting the load leads from + and - output terminals to the load and connecting the sense leads from the +S and -S terminals to the load as shown in Figure 5.

### CAUTION

*Observe polarity when connecting the sensing leads to the load.*

**Output Noise.** Any noise picked up on the sense leads will appear at the supply's output voltage and may degrade CV load regulation. Twist the sense leads to minimize the pickup of external noise and run them parallel and close to the load leads. In noisy environments, it may be necessary to shield the sense leads. Ground the shield at the power supply end only. Do not use the shield as one of the sensing conductors.

**Stability.** When the supply is connected for remote sensing, it is possible for the impedance of the load wires and the capacitance of the load to form a filter, which will become part of the supply's CV feedback loop. The extra phase shift created by this filter can degrade the supply's stability and can result in poor transient response performance or loop stability. In extreme cases, it can cause oscillations. Keep the leads as short as possible and twist the leads of the load to eliminate the load lead inductance and keep the load capacitance as small as possible. The load leads should be of the largest diameter practical, heavy enough to limit the voltage drop in each lead to 0.5 volts.

The sense leads are part of the supply's programming feedback control loop. Accidental open-connections of sense or load leads during remote sensing operation have various unwanted effects. Provide secure, permanent connections-especially for the sense leads.

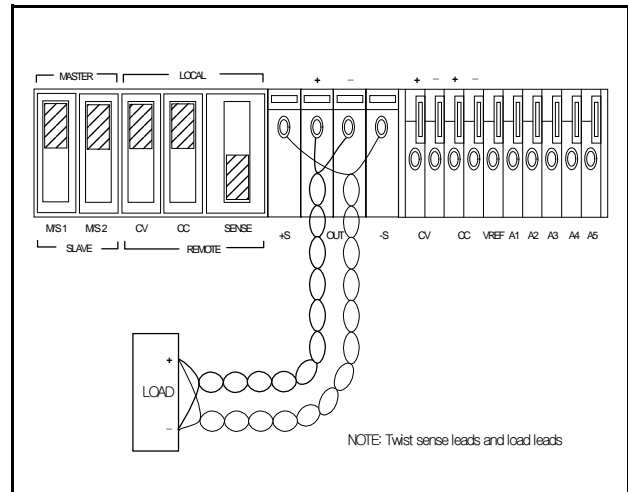


Figure 5. Remote Voltage Sensing

### Remote Analog Voltage Programming

Remote analog voltage programming permits control of the regulated output voltage or current by means of a remotely varied voltage. The programming (external) voltage should not exceed 10 volts. The stability of the programming voltages directly affects the stability of the output. The voltage control on the front panel is disabled during remote analog programming.

### CAUTION

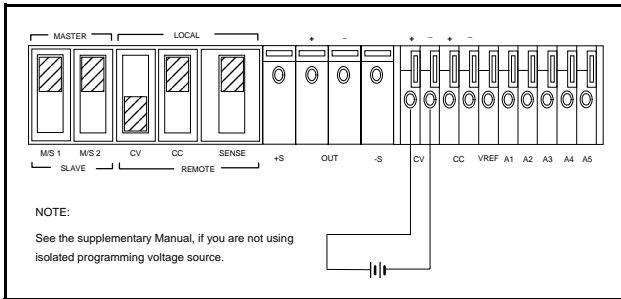
*The supply includes clamp circuits to prevent it from supplying more than about 120% of rated output voltage or current when the remote programming voltage is greater than 10 Vdc. Do not intentionally operate the sup-*

ply above 100% rated output. Limit your programming voltage to 10 Vdc.

**Remote Programming Connections.** Remote programming requires changing settings of the switch and connecting external voltages to + and - terminals of "CV" or "CC" on the rear panel. Any noise picked up on the programming leads will appear on the supply's output and may degrade regulation. To reduce noise pick-up, use a twisted or shielded pair of wires for programming, with the shield grounded at one end only. Do not use the shield as a conductor.

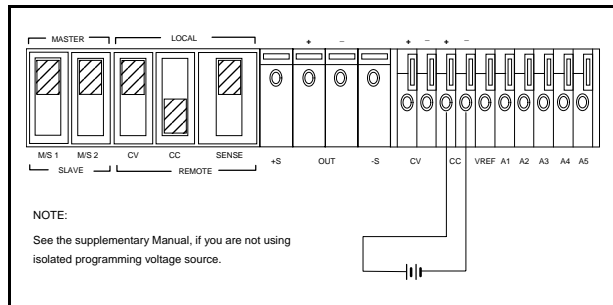
Notice that it is possible to operate a power supply simultaneously in the remote sensing and the remote analog programming modes.

**Remote Programming, Constant Voltage.** Figure 6 shows the rear panel switch settings and terminal connections for remote-voltage control of output voltage. A 1 Vdc change in the remote programming voltage produces a change in output voltage (voltage gain) as follows: E3614A: 0.8 Vdc, E3615A: 2 Vdc, E3616A: 3.5 Vdc, E3617A: 6 Vdc



**Figure 6. Remote Voltage Programming, Constant Voltage**

**Remote Programming, Constant Current.** Figure 7 shows the rear panel switch settings and terminal connections for remote-voltage control of output current. A 1 Vdc change in the remote programming voltage produces a change in output current (current gain) as follows: E3614A: 0.6 Adc, E3615A: 0.3 Adc, E3616A: 0.17 Adc, E3617A: 0.1 Adc



**Figure 7. Remote Voltage Programming, Constant Current**

**Remote Programming Speed.** See the table of Specifications, page 1-5.

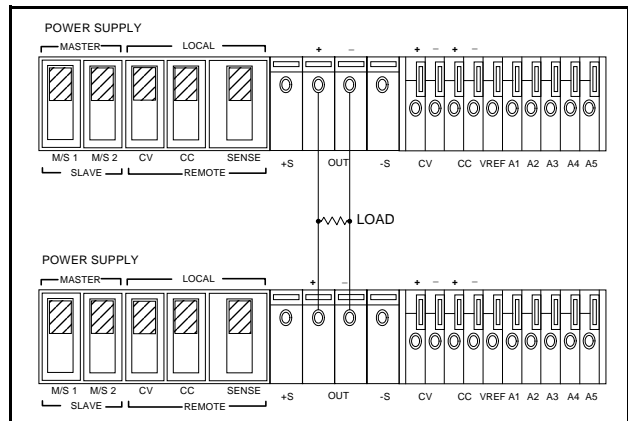
## MULTIPLE-SUPPLY OPERATION

Normal parallel and auto-parallel operation provides increased output current while normal series and auto-series provides increased output voltage. Auto-tracking provides single control of output voltage of more than one supply. You can set up the unit for multiple-supply operation by changing the settings of the rear panel switch and connecting the leads from the rear panel terminals to the load.

Solid conductors of 0.75 to 1.5 mm<sup>2</sup> can be connected to the rear panel terminals by simply push fitting. Thinner wires or conductors are inserted into the connection space after depressing the orange opening lever.

### NORMAL PARALLEL OPERATION

Two or more power supplies being capable of CV/CC automatic cross over operation 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 of each power supply can be set separately. 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 higher output voltage. The supply with the higher output voltage setting will deliver its constant current output, and drop its output voltage until it equals the output of the other supply, and the other supply will remain in constant voltage operation and only deliver that fraction of its rated output current which is necessary to fulfill the total load demand. Figure 8 shows the rear panel switch settings and terminal connections for normal parallel operation of two supplies.



**Figure 8. Normal Parallel Operation of Two Supplies**

### AUTO-PARALLEL OPERATION

Auto-parallel operation permits equal current sharing under all load conditions, and allows complete control of output current from one master supply. The control unit is called the master; the controlled units are called slaves. Normally, only supplies having the same model number should be connected for auto-parallel operation, since the supplies must have the same voltage drop across the current monitoring resistor at full current rating. The output current of each slave is approximately equal to the master's. Figure 9 and Figure 10 show the rear panel switch settings and terminal connections for auto-parallel operation of two supplies and three supplies.

**Setting Voltage and Current.** Turn the slave unit's CURRENT control fully clockwise. Adjust the master unit's controls to set the desired output voltage and current. The master supply operates in a completely normal fashion and may be set up for either constant voltage or constant current operation as required. Verify that the slave is in CV operation.

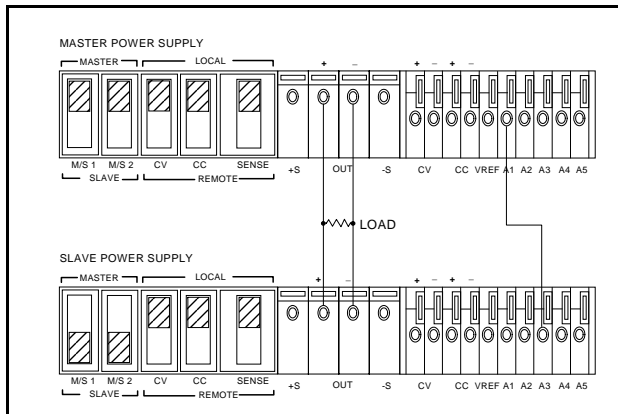
For auto-parallel operation of two supplies, the combined output voltage is the same as the master unit's voltage setting, and the combined output current is two times the master unit's current. In general, for two supplies, the auto-parallel output current( $I_o$ ) is

$$I_o = I_m + I_s = 2I_m$$

where  $I_m$  = master unit's output current  
 $I_s$  = slave unit's output current

**NOTE**

*Proportional currents from auto-parallelled units require equal load-lead voltage drops. Connect each supply to the load using separate pairs of wire with length chosen to provide equal voltage drops from pair to pair. If this is not feasible, connect each supply to a pair of distribution terminals using equal-voltage-drop wire pairs, and then connect the distribution terminals to the load with a single pair of leads.*



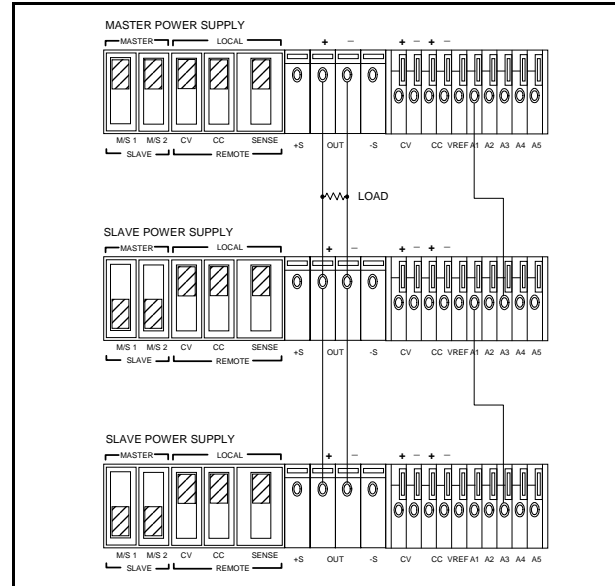
**Figure 9. Auto-Parallel Operation of Two Supplies**

**Overvoltage Protection.** Adjust the desired OVP shutdown limit using the master unit's OVP Adjust control. Set the slave units' OVP limits above the master's. When a master-unit shuts down, the master programs the slave units to zero voltage output. If a slave unit shuts down, it shuts only itself down. If the required current is great enough, the master will switch from CV to CC operation.

**Remote Sensing.** To remote sense with auto-parallel operation, connect remote-sense leads only to the master unit according to the remote-sensing instructions.

**Remote Analog Voltage Programming.** To remote program with auto-parallel operation, set up only the master unit for remote programming according to the remote-programming instructions.

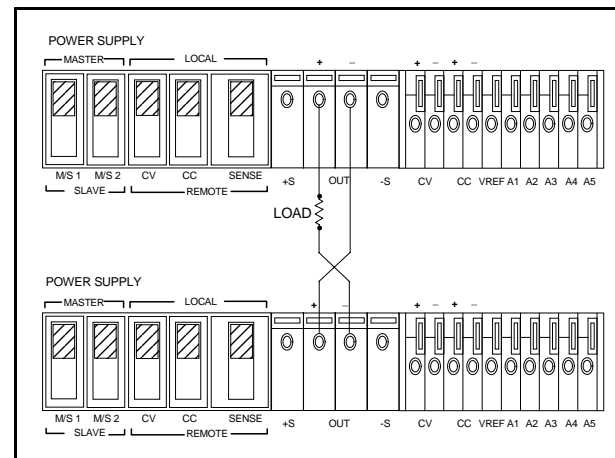
programming according to the remote-programming instructions.



**Figure 10. Auto-Parallel Operation of Three Supplies**

**NORMAL SERIES OPERATION**

Series operation of two or more power supplies can be accomplished up to the output isolation rating of any one supply to obtain a higher voltage than that available from a single supply. Series connected supplies can be operated with one load across both supplies or with a separate load for each supply. These power supplies have a reverse polarity diode connected across the output terminals so that if operated in series with other supplies, damage will not occur if the load is short-circuited or if one supply is turned on separately from its series partners. 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. Figure 11 shows the rear panel switch settings and terminal connections for normal series operation of two supplies.



**Figure 11. Normal Series Operation of Two Supplies**

## AUTO-SERIES OPERATION

Auto-series operation permits equal or proportional voltage sharing, and allows control of output voltage from one master unit. The voltage of the slaves is determined by the setting of the front panel VOLTAGE control on the master and voltage divider resistor. The master unit 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 setting. If any output CURRENT controls are set too low, automatic cross over to constant current operation will occur and the output voltage will drop. Figure 12 and Figure 13 show the rear panel switch settings and terminal connections for Auto-series operation of two supplies and three supplies. This mode can also give  $\pm$ voltage tracking operation of two supplies with two separate loads.

Mixed model numbers may be employed in auto-series combination without restriction, provided that each slave is specified as being capable of auto-series operation. If the master supply is set up for constant current operation, then the master-slave combination will act as a composite constant current source.

### CAUTION

Total output voltage to ground must not exceed 240 Vdc.

**Determining Resistors.** External resistors control the fraction (or multiple) of the master unit's voltage setting that is supplied from the slave unit. Notice that the percentage of the total output voltage contributed by each supply is independent of the magnitude of the total voltage. For two units in auto-series the ratio of R1 to R2 is

$$\begin{aligned} (R1+R2)/R1 &= (Vo/Vm) \\ R2/R1 &= (Vs/Vm) \end{aligned}$$

Where  $V_o$  = auto-series voltage =  $V_s + V_m$   
 $V_m$  = master unit's output voltage  
 $V_s$  = slave unit's output voltage

For example, using the E3617A as a slave unit and putting  $R2=50$  k $\Omega$  (1/4 watt), then from the above equations,  
 $R1 = R2(V_m/V_s) = 50(V_m/V_s)$  k $\Omega$

In order to maintain the temperature coefficient and stability performance of the supply, choose stable, low noise resistors.

### NOTE

It is recommended to connect a 0.1  $\mu$ F capacitor in parallel with R2 in two supplies operation or R2 and R4 in three supplies operation to ensure the stable operation.

**Setting Voltage and Current.** Use the master unit's controls to set the desired output voltage and current. The VOLTAGE control of the slave unit is disabled. Turning the voltage control of the master unit will result in a continuous variation of the output of the series combination, with the contribution of the master's output voltage to that of the slave's voltage always remaining in the ratio of the external resistors. Set the CURRENT control of slave unit

above the master unit's current setting to avoid having the slave switch to CC operation.

When in CC operation the combined output current is the same as the master unit's current setting, and when in CV operation the combined output voltage is the sum of the master unit's and the slave unit's output voltages.

**Overvoltage Protection.** Set the OVP shutdown voltage in each unit so that it shuts down at a voltage higher than its output voltage during auto-series operation. When a master unit shuts down, it programs any slave units to zero output. When a slave unit shuts down, it shuts down only itself (and any slaves below it in the stack). The master (and all slaves above the shut-down slave) continues to supply output voltage.

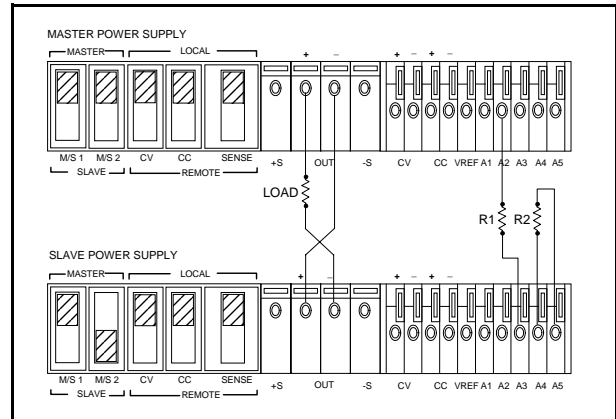


Figure 12. Auto-Series Operation of Two Supplies

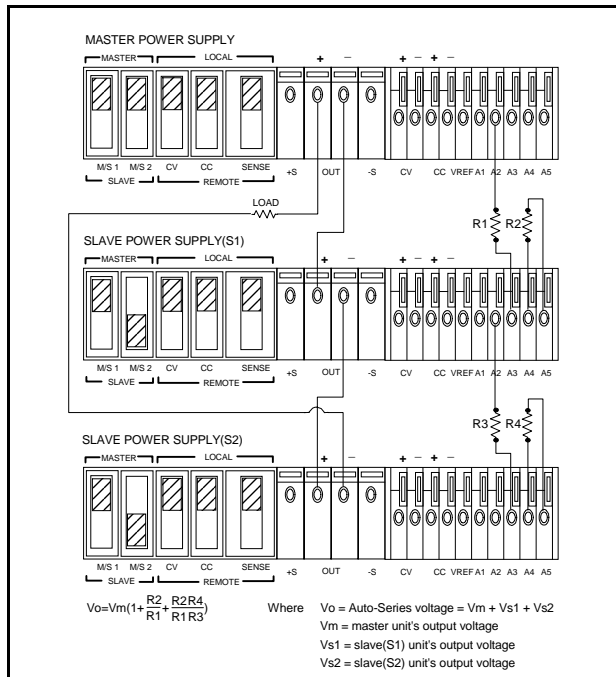


Figure 13. Auto-Series Operation of Three Supplies

**Remote Sensing.** To remote sense with auto-series operation, set SENSE switch of the master unit and set SENSE switch of the slave unit to remote.

**Remote Analog Voltage Programming.** To remote analog program with auto-series operation, connect program (external) voltages to the "CV" or "CC" terminal of the master unit and set "CV" or "CC" switch of the master unit to remote.

**AUTO-TRACKING OPERATON**

Auto-tracking operation of power supplies is similar to auto-series operation except that the master and slave supplies have the same output polarity with respect to a common bus or ground. This operation is useful where simultaneous turn-up, turn-down or proportional control of all power supplies is required.

Figure 14 and Figure 15 show two and three supplies connected in auto-tracking with their negative output terminals connected together as a common or ground point. For two units in auto-tracking a fraction  $R2/(R1+R2)$  of the output of the master supply is provided as one of the inputs to the comparison amplifier of the slave supply, thus controlling the slave's output. The master supply in an auto-tracking operation must be the positive supply having the largest output voltage. Turn-up and turn-down of the power supplies are controlled by the master supply. In order to maintain the temperature coefficient and stability specifications of the power supply, the external resistor should be stable, low noise, low temperature.

**Determining Resistors.** External resistors control the fraction of the master unit's voltage that is supplied from the slave unit. For two units in auto-tracking the ratio  $R1$  and  $R2$  is

$$R2/(R1+R2) = (Vs/Vm)$$

Where  $Vm$  = master output voltage  
 $Vs$  = slave output voltage

**NOTE**

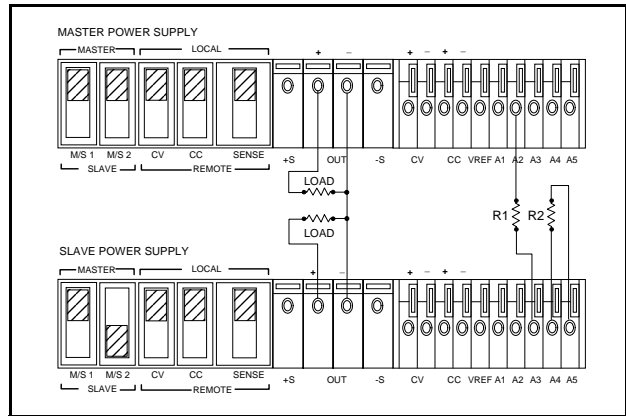
*It is recommended to connect a 0.1 μF capacitor in parallel with R2 in two supplies operation or R2 and R4 in three supplies operation to ensure the stable operation.*

**Setting Voltage and Current.** Use the master unit's VOLTAGE control to set the output voltage from both units. When the master is in CV operation, the master's output voltage ( $Vm$ ) is the same as its voltage setting, and the slave's output voltage for two units operation is  $Vm(R2/(R1+R2))$ . The VOLTAGE control of the slave unit is disabled. Set the CURRENT controls of master and slave units above the required currents to assure CV operation of master and slave units.

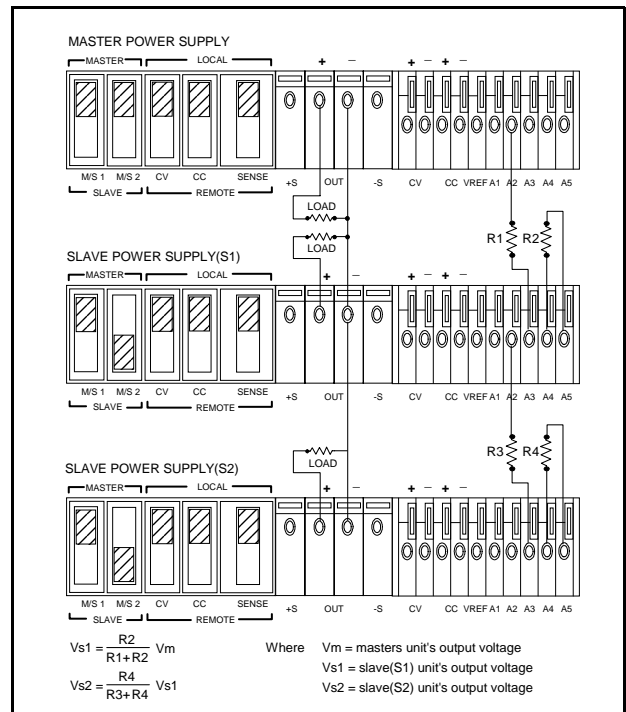
**Overvoltage Protection.** Set the OVP shutdown voltage in each unit so that it shuts down at a voltage higher than its output voltage during auto-tracking operation. When a master unit shuts down, it programs any slave units to zero output. When a slave unit shuts down, it shuts down only itself.

**Remote Sensing.** To include remote sensing with auto-tracking operation independently, set up each unit for remote sensing according to the remote-sensing instructions under previous paragraph.

**Remote Analog Programming.** To simultaneously remote program both units' output voltages, set up only the master unit for remote voltage programming according to the remote programming instructions. To vary the fraction of the output voltage contribution by the slave unit, connect a variable resistor in place of R2 in two units operation. To independently remote program each unit's output current setting, set up each unit for remote control of output current according to the instructions under "Remote Programming, Constant Current" paragraph.



**Figure 14. Auto-Tracking Operation of Two Supplies**



**Figure 15. Auto-Tracking Operation of Three Supplies**

## LOAD CONSIDERATIONS

This section provides information on operating your supply with various types of loads connected to its output.

### PULSE LOADING

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

### REVERSE CURRENT LOADING

An active load 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 can not be allowed to pump current into the supply without loss of regulation and possible damage to the output capacitor of the power supply. 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 devices.

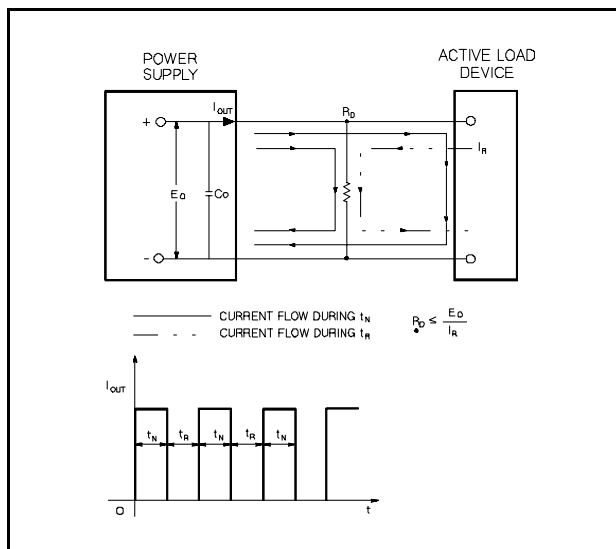


Figure 16. Reverse Current Loading Solution

### OUTPUT CAPACITANCE

An internal capacitor, connected across the output terminals of the power supply, helps to supply 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 current limiting circuit. A high-current pulse may damage load components before the average output current is large enough to cause the current limiting circuit to operate.

The effect of the output capacitor during constant current operation are as follows:

- The output impedance of the power supply decreases with increasing frequency.
- The recovery time of the output voltage is longer for load resistance changes.
- A large surge current causing a high power dissipation in the load occurs when the load resistance is reduced rapidly.

### REVERSE VOLTAGE LOADING

A diode is connected across the output terminals with reverse polarity. This diode protects the output electrolytic capacitors and the series regulator transistors from the effects of a reverse voltage applied across the output terminals. For example, in series operation of two supplies, if the AC is removed from one supply, the diode prevents damage to the unenergized supply which would otherwise result from a reverse polarity voltage.

Since series regulator transistors cannot withstand reverse voltage, another diode is connected across the series transistor. This diode protects the series regulators in parallel or auto-parallel operation if one supply of the parallel combination is turned on before the other.

### BATTERY CHARGING

The power supply's OVP circuit contains a crowbar SCR, which effectively shorts the output of the supply whenever the OVP trips. If an external voltage source such as a battery is connected across the output, and OVP inadvertently triggered, the SCR will continuously sink a large current from the source; possibly damaging the supply. To avoid this a diode must be connected in series with the output as shown in Figure 17.

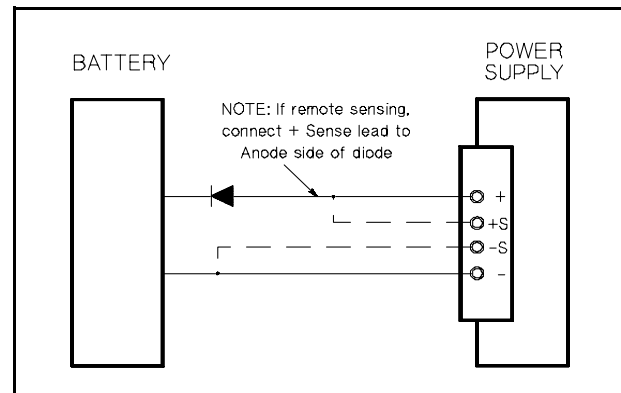
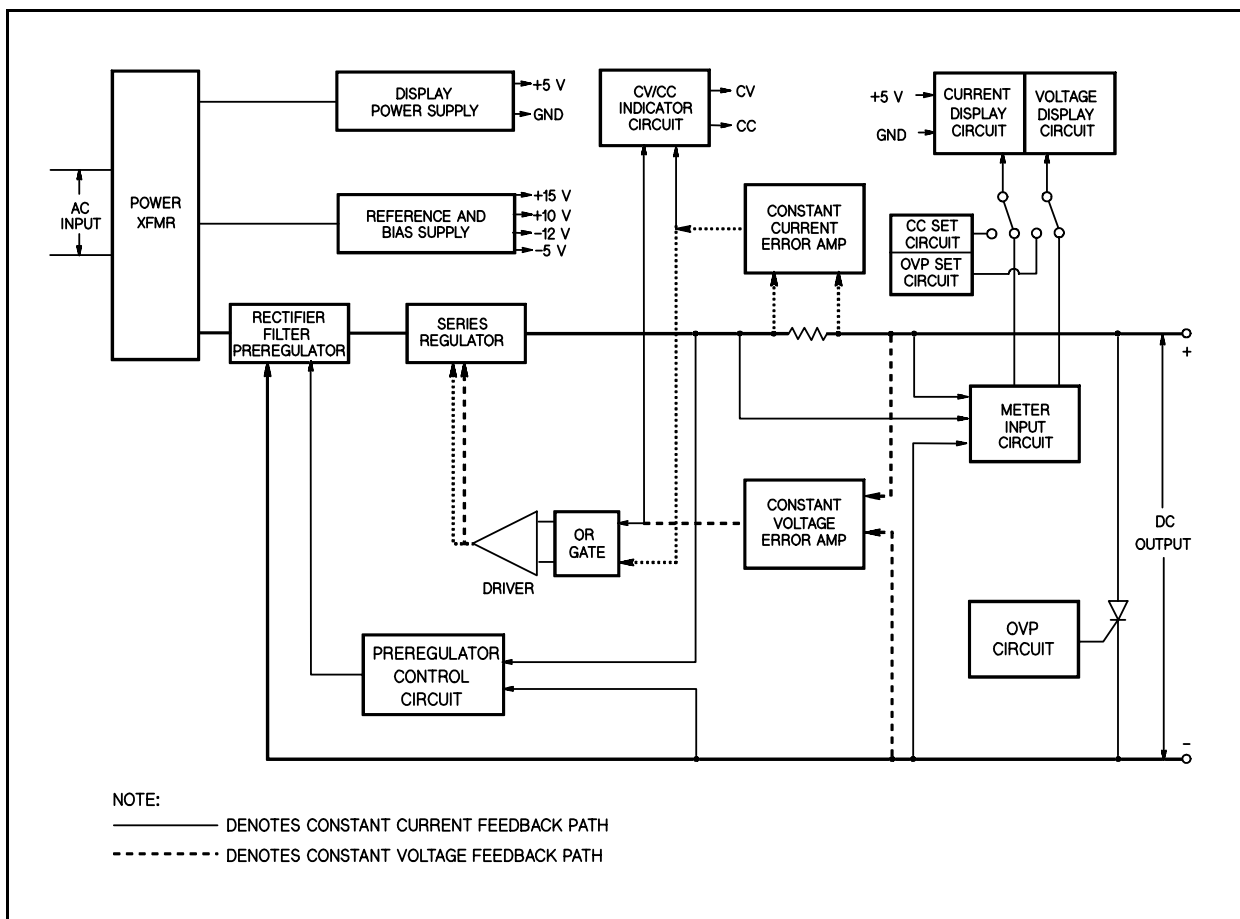


Figure 17. Recommended Protection Circuit for Battery Charging

## SERVICE INFORMATION



**Figure A-1. Block Diagram**

### PRINCIPLES OF OPERATION (Block Diagram Overview)

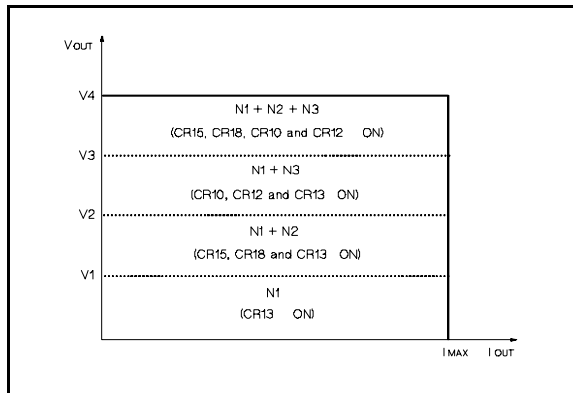
Throughout this discussion, refer to both the block diagram of Figure A-1 and the schematic diagrams at the rear of the manual. The input ac line voltage is first applied to the preregulator which operates in conjunction with the SCR control circuit (preregulator control circuit) to rectify the tap switched AC voltage. This preregulator minimizes the power dissipated in the series regulating elements by controlling the dc level across the input filter capacitor, depending on the output voltage.

To achieve this, tap switching is accomplished by four SCRs and one bridge diode (CR10, CR12, CR15, CR18 and CR13) and the SCR control circuit. By selecting different SCR firing combinations from SCR control circuit, these circuits allow the input capacitors (C7 and C8) to charge to one of four discrete voltage levels, depending on the output voltage required.

The main secondary winding of the power transformer has three sections (N1, N2, and N3), each of which has a different turns ratio with respect to the primary winding. At the beginning of each half-cycle of the input ac, the control circuit determines whether one pair, both or none of the SCR will be fired. If neither SCR is fired, the bridge diode (CR13) receives an ac input voltage that is determined by N1 turns and the input capacitors charge to a corresponding level. If SCR CR15 and CR18 are fired, input capacitors charge to the voltage determined by N1+N2 turns. Similarly, if CR10 and CR12 are fired the capacitors are charged by N1 + N3. Finally, if all SCRs are fired simultaneously, input capacitors charge to its highest voltage level determined by N1 + N2 + N3 turns.

The SCR control circuit determines which SCRs are to be fired by monitoring the output voltage and comparing these values against a set of three internally derived reference levels. These three reference levels are translated into boundary lines to allow the output characteristic to be mapped into four operating regions (Figure A-2). The boundary lines, which are invisible to the user, are divided into four operating regions (V1, V2, V3, and V4) to minimize the power dissipation in the

series pass transistors. Whenever the output voltage is below the sloping V1 line, the control circuit inhibits four SCRs and the input capacitors charge to a voltage determined by N1. Figure A-2 indicates the windings that are connected as a result of the other voltage decisions.



**Figure A-2. Output Power Plot**

The series regulators (Q1 and Q4) are part of a feedback loop which consists of the driver and the Constant Voltage/Constant Current error amplifier. The series regulator feedback loop provides "fine and fast" regulation of the output while the preregulator feedback loop handles large, relatively slow, regulation demands.

The regulator is made to alter its conduction to maintain a constant output voltage or current. The voltage developed across the current sampling resistors (R58 and R59) is the input to the constant current error amplifier. The constant voltage error amplifier obtains its input by sampling the output voltage of the supply.

Any changes in output voltage or current are detected and amplified by the constant voltage or constant current error circuit and applied to the series regulator in the correct phase and amplitude to counteract the change in output voltage or current.

Two error amplifiers are included in a CV/CC supply, one for controlling output voltage, the other for controlling output current. Since the constant voltage amplifier tends to achieve zero output impedance and alters the output current whenever the load resistance changes, while the constant current amplifier causes the output impedance to be infinite and changes the output voltage in response to any load resistance change, it is obvious that the two amplifiers can not operate simultaneously. For any given value of load resistance, the power supply must act either as a constant voltage source or as a constant current source - it can not be both; transfer between these two modes is accomplished at a value of load resistance equal to the ratio of the output voltage control setting to the output current control setting.

Full protection against any overload condition is inherent in the Constant Voltage/Constant Current design principle since there is not any load condition that can cause an output which lies outside the operating region. For either constant voltage or constant current operation, the proper choice of front panel voltage and current control settings insures optimum protection for the load device as well as full protection for the power supply.

The reference and bias circuit provides stable reference voltages which are used by the constant voltage/current error amplifier circuits for comparison purpose. The display circuit provides an indication of output voltage and current for constant voltage or constant current operating modes.

An operator error or a component failure within the regulating feedback loop can drive a power supply's output voltage to many times its preset value. The overvoltage protection circuit is to protect the load against this possibility. The circuit insures that the power supply voltage across the load will never exceed a preset limit.

Diode CR19 is connected across the output terminals in reverse polarity. It protects the output electrolytic capacitor and the series regulator transistors from the effects of a reverse voltage applied across the output terminals.

The display power circuit provides voltage which is used by A/D converter and LED drive.

## MAINTENANCE

### INTRODUCTION

This section provides performance test and calibration procedures and troubleshooting information. The following operation verification tests comprise a short procedure to verify that the power supply is performing properly, without testing all specified parameters.

If a fault is detected in the power supply while making the performance check or during normal operation, proceed to the troubleshooting procedures. After troubleshooting, perform any necessary adjustments and calibrations. 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.

### Test Equipment Required

The following Table A-1 lists the equipment required to perform the tests and adjustments of this section. You can separately identify the equipment for performance tests, calibration, and troubleshooting in the USE column of the table.

### Operation Verification Tests

The following tests assure that the power supply is performing properly. They do not, however, check all the specified parameters tested in the complete performance test described below. Proceed as follows:



- a. Perform turn-on checkout procedure given in page 1-7.
- b. Perform the CV and CC Load Regulation performance tests given in the following paragraphs respectively.

### PERFORMANCE TESTS

The following paragraphs provide test procedures for verifying the power supply's compliance with the specifications of Table 1. Please refer to adjustment and calibration or troubleshooting procedure if you observe any out of specification performance.

#### Measurement Techniques

**Setup for All Tests.** Measure the output voltage directly at the +S and -S terminals on the rear panel; in this way the monitoring device sees the same performance as the feedback amplifier within the power supply. Failure to connect the monitoring device to the proper points shown in Figure A-3 will result in the measurement not of the power supply characteristics, but of the power supply plus the resistance of the leads between its output terminals and the point of connection.

Use separate leads to all measuring devices to avoid the subtle mutual coupling effects that may occur between measuring devices unless all are returned to the low impedance terminals of the power supply. Twisted pairs or shielded cable should be used to avoid pickup on the measuring leads.

**Electronic Load.** The test and calibration procedures use an electronic load to test the supply quickly and accurately. An electronic load is considerably easier to use than load resistor. It eliminates the need for connecting resistors or rheostats in parallel to handle the power, it is much more stable than carbon-pile load, and it makes easy work of switching between load conditions as is required for the load regulation and load transient response tests.

**Current Monitoring Resistor  $R_s$ .** To eliminate output-current measurement error caused by voltage drops in the leads and connections, connect the current monitoring (sampling) resistor between -OUT and the load as a four-terminal device. Figure A-3 shows correct connections. Connect the current monitoring test leads inside the load lead connections directly at the monitoring resistor element. Select a resistor with stable characteristics and lower temperature coefficient (see Table A-1).

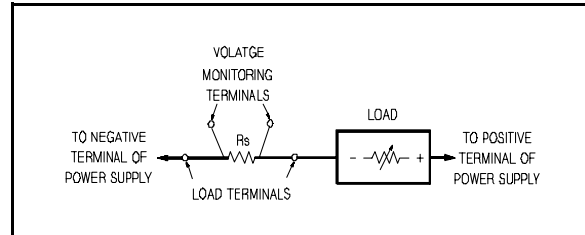


Figure A-3. Current Monitoring Resistor Connections

Table A-1. Test Equipment Required

TYPE	REQUIRED CHARACTERISTICS	USE	RECOMMENDED MODEL
Oscilloscope	Sensitivity : 1 mV Bandwidth : 20 MHz/100 MHz Input : Differential, 50 ohm and 100 ohm	P, T	Agilent 54600A
RMS Voltmeter	True rms, 20 MHz bandwidth Sensitivity : 1 mV Accuracy : 5%	P	
Multimeter	Resolution : 100 nV Accuracy : 0.0035%	P, A, T	Agilent 34401A
Electronic Load	Voltage Range : 240 Vdc Current Range : 10 Adc Open and short switches Transient on/off	P	Agilent 6063A
Load Resistor ( $R_L$ )	1.3 ohm 60 W, 6.6 ohm 60 W, 20.5 ohm 60 W, 60 ohm 60 W	P	
Current Monitoring (Sampling) Resistor ( $R_S$ )	0.1 ohm 0.1% 10 W, 1 ohm 1% 5 W	P, A	
Variable Voltage Auto Transformer	Range : 85-130 and 200-260 Volts	P, T	

\* P = Performance testing A = Calibration adjustments T = Troubleshooting.

## CONSTANT VOLTAGE (CV) TESTS

**CV Setup.** For all CV tests set the output current at full rated output to assure CV operation. The onset of constant current can cause a drop in output voltage, increased ripple, and other performance changes not properly ascribed to the constant voltage operation of the supply.

### Load Regulation (Load Effect)

**Definition:** CV Load regulation is the change in the steady state value of dc output voltage due to a change in load resistance from open circuit to full load or from full load to open circuit.

#### Test Parameters:

Measured Variable: Output Voltage

Expected Results: Less than 0.01% plus 2 mV

#### Test Procedure:

- Connect the test equipment as shown in Figure A-4. Operate the electronic load in constant current mode and set its current to the full rated value of the power supply (6 A for E3614A, 3 A for E3615A, 1.7 A for E3616A and 1 A for E3617A).
- Turn the supply's power on and turn CURRENT control fully clockwise.
- Turn up output voltage to the full rated value (8 V for E3614A, 20 V for E3615A, 35 V for E3616A and 60 V for E3617A) as read on the digital voltmeter.
- Record the output voltage at the digital voltmeter.
- Operate the electronic load in open(input off) mode.
- When the reading settles, record the output voltage on the digital voltmeter again. Check that the two recorded readings differ less than 0.01% of output voltage plus 2 mV.

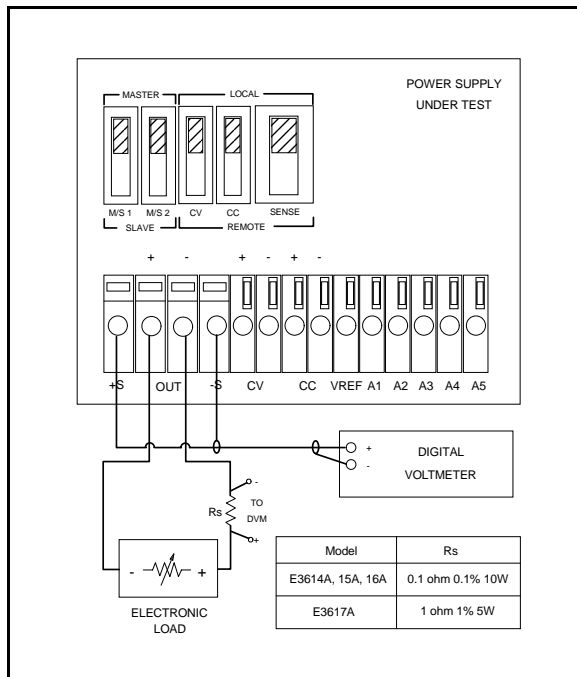


Figure A-4. Basic Test Setup

### Line Regulation (Source Effect)

**Definition:** Line regulation is the change in the steady state value of dc output voltage due to a change in ac input voltage from a minimum to a maximum value ( $\pm 10\%$  of nominal voltage).

#### Test Parameter:

Measured Variable: Output Voltage

Expected Results: Less than 0.01% plus 2 mV

#### Test Procedure:

- Connect the test equipment as shown in Figure A-4. Operate the electronic load in constant current mode and set its current to the full rated value of the power supply.
- Connect the supply to the ac power line through a variable autotransformer which is set for low line voltage (104 Vac for nominal 115 Vac, 90 Vac for nominal 100 Vac, and 207 Vac for nominal 230 Vac).
- Turn the supply's power on and turn CURRENT control fully clockwise.
- Adjust VOLTAGE control until the front panel VOLTS display indicates exactly the maximum rated output voltage.
- Record voltage indicated on the digital voltmeter.
- Adjust autotransformer to high line voltage (127 Vac for nominal 115 Vac, 110 Vac for nominal 100 Vac, and 253 Vac for nominal 230 Vac).
- When the reading settles, record the output voltage again. Check that the two recorded readings differ less than 0.01% of output voltage plus 2 mV.

### Load Transient Response Time

**Definition :** This is the time for the output voltage to return to within a specified band around its voltage following a change from full load to half load or half load to full load.

#### Test Parameter:

Measured Variable: Output Voltage Transients

Expected Results: Less than 50 usec (at 15 mV from base line)

#### Test Procedure:

- Connect the test equipment as shown in Figure A-4, but replace the DVM with the oscilloscope. Operate the electronic load in constant current mode.
- Turn the supply's power on and turn CURRENT control fully clockwise.
- Turn up output voltage to the full rated value.
- Set the electronic load to transient operation mode between one half of supply's full rated value and supply's full rated value at a 1 KHz rate with 50% duty cycle.
- Set the oscilloscope for ac coupling, internal sync and lock on either the positive or negative load transient.
- Adjust the oscilloscope to display transients as in Figure A-5.
- Check that the pulse width of the transients at 15 mV from the base line is no more than 50 usec as shown.

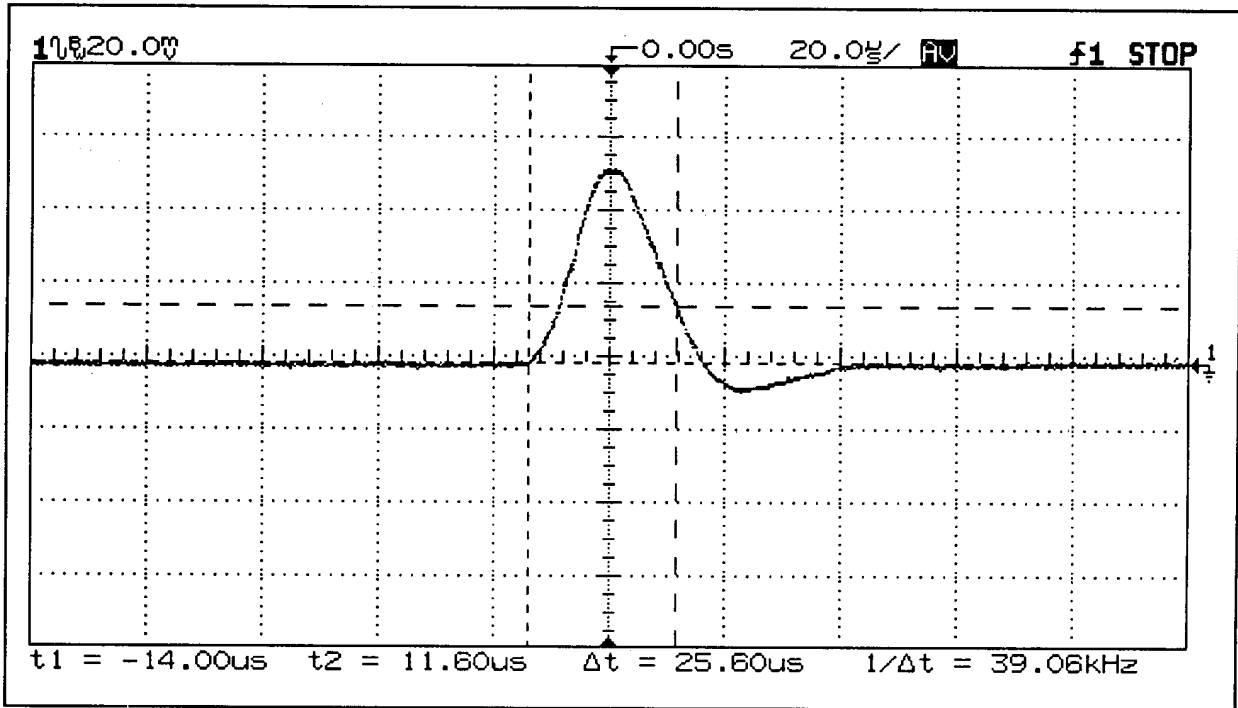


Figure A-5. Load Transient Response Time Waveform

### PARD(Ripple and Noise)

**Definition:** PARD is the Periodic and Random Deviation of the dc output voltage from its average value, over a specified bandwidth and with all other parameters maintained constant. Constant voltage PARD is measured in the root-mean-square(rms) or peak-to-peak(pp) values over a 20 Hz to 20 MHz bandwidth. Fluctuations below the lower frequency limit are treated as drift.

### PARD(RMS) Measurement

The rms measurement is not an ideal representation of the noise, since fairly high output noise spikes of short duration could be present in the ripple and not appreciably increase the rms value.

#### Test Parameter:

Measured Variable: Output Voltage(rms)

Expected Results: Less than 200  $\mu$ V rms

#### Test Procedure:

- Connect the test equipment as shown in Figure A-6.
- Turn the supply's power on and turn CURRENT control fully clockwise.
- Turn up output voltage to the full rated value. Check that the supply's CV indicator remains lighted. Reduce VOLTAGE control if not lighted.
- Check that the rms noise voltage at the true rms voltmeter is less than 200  $\mu$ V.

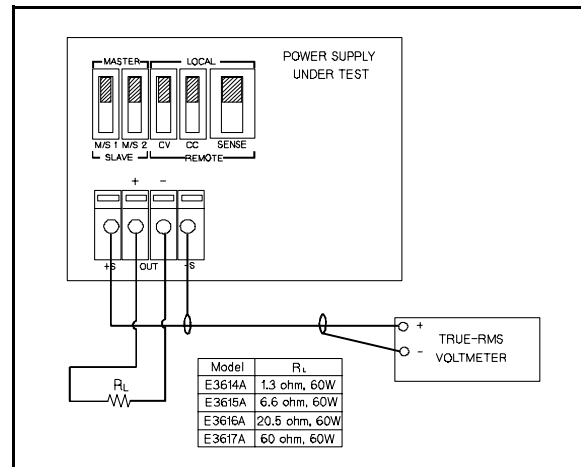


Figure A-6. CV PARD RMS Measurement Test Setup

### PARD(Peak-to-Peak) Measurement

The peak-to-peak measurement is particularly important for applications where noise spikes could be detrimental to a sensitive load, such as logic circuitry.

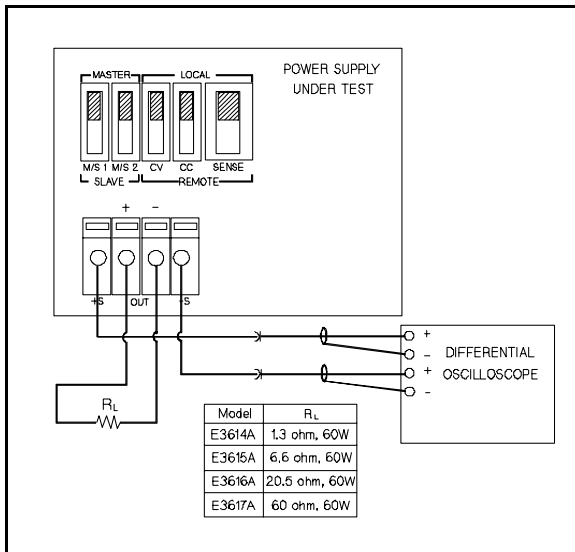
#### Test Parameter:

Measured Variable: Output voltage(peak-to-peak)

Expected Results: Less than 1 mV p-p (20 Hz-20 MHz)

#### Test Procedure:

- Connect the test equipment as shown in Figure A-7.
- Turn the supply's power on and turn CURRENT control fully clockwise.
- Turn up output voltage to the full rated value. Check that the supply's CV indicator remains lighted. Reduce VOLTAGE control if not lighted.
- Set the oscilloscope to AC mode and bandwidth to 20 MHz.
- Check that the peak-to-peak noise is less than 1 mV.



**Figure A-7. CV PARD Peak-to-Peak Measurement Test Setup**

### CV Drift (Stability)

**Definition:** The change in output voltage (dc to 20 Hz) for the first 8 hours following a 30-minute warm-up period with constant input line voltage, constant load resistance and constant ambient temperature.

#### Test Parameter:

Measured Variable: Output Voltage  
Expected Results: Less than 0.1% plus 5 mV

#### Test Procedure:

- Connect the DVM across  $R_s$  in Figure A-4.
- Operate the electronic load in constant current mode and set its current to the full rated value of power supply.
- Turn the supply's power on and turn CURRENT control fully clockwise.
- Turn up output voltage to the full rated value as read on the digital voltmeter.
- After a 30-minute warm-up, note the voltage on DVM.
- The output voltage reading should deviate less than 0.1% plus 5 mV from the reading obtained in step e over a period of 8 hours.

### CONSTANT CURRENT (CC) TESTS

**CC Setup.** Constant current tests are analogous to constant voltage tests, with the supply's output short circuited and the voltage set to full output to assure CC operation. For output current measurements the current monitoring resistor must be treated as a four terminal device. Refer to the "Measurement Techniques" for details. All constant current measurements are made in terms of the change in voltage across this resistor; the current performance is calculated by dividing these voltage changes by ohmic value of  $R_s$ .

### Load Regulation (Load Effect)

**Definition:** CC Load regulation is the change in the steady state value of dc output current due to a change in load resistance from short circuit to full load or from full load to short circuit.

#### Test Parameter:

Measured Variable: Output Current  
Expected Results: Less than 0.01% plus 250  $\mu$ A

#### Test Procedure:

- Connect the DVM across  $R_s$  in Figure A-4. Operate the electronic load in constant voltage mode and set its voltage to the full rated value of power supply.
- Turn the supply's power on and turn VOLTAGE control fully clockwise.
- Turn up output current to the full rated value. Check that the AMPS display reads full rated values and CC indicator remains lighted. Reduce CURRENT control if not lighted.
- Record the voltage across  $R_s$  and convert it to current by dividing this voltage by  $R_s$ .
- Operate the electronic load in short (input short) mode.
- When the reading settles, record voltage across  $R_s$  again and convert it current. Check that the two recorded readings differ less than 0.01% of output current plus 250  $\mu$ A.

### Line Regulation (Source Effect)

**Definition:** Line regulation is the change in the steady state value of dc output current due to a change in ac input voltage from the minimum to maximum value ( $\pm 10\%$  of nominal voltage).

#### Test Parameter:

Measured Variable: Output Current  
Expected Results: Less than 0.01% plus 250  $\mu$ A

#### Test Procedure:

- Connect the DVM across  $R_s$  in Figure A-4. Operate the electronic load in constant voltage mode and set its voltage to the full rated value of power supply.
- Connect the supply to the ac power line through a variable autotransformer that set for low line voltage (104 Vac for nominal 115 Vac, 90 Vac for nominal 100 Vac, and 207 Vac for nominal 230 Vac).
- Turn the supply's power on and turn VOLTAGE control fully clockwise.
- Turn up output current to the full rated value. Check that the AMPS display reads full rated values and CC indicator remains lighted. Reduce CURRENT control if not lighted.

- e. Record output voltage across  $R_s$  and convert it to current by dividing this voltage by  $R_s$ .
- f. Adjust autotransformer to the high line voltage (127 Vac for nominal 115 Vac, 110 Vac for nominal 100 Vac, and 253 Vac for nominal 230 Vac).
- g. When the reading settles, record the voltage across  $R_s$  again and convert it current. Check that the two recorded readings differ less than 0.01% of output current plus 250  $\mu\text{A}$ .

### PARD(Ripple and Noise)

**Definition :** The residual ac current which is superimposed on the dc output current of a power supply. Constant current PARD is specified as the root-mean-square(rms) output current in a frequency range of 20 Hz to 20 MHz with the supply in CC operation.

### PARD(RMS) Measurement

#### Test Parameter:

Measured Variable: Output Current(rms)  
 Expected Results: E3614A: Less than 5 mA rms  
 E3615A: Less than 2 mA rms  
 E3616A: Less than 500  $\mu\text{A}$  rms  
 E3617A: Less than 500  $\mu\text{A}$  rms

#### Test Procedure:

- a. Connect the test equipment as shown in Figure A-8.
- b. Turn the supply's power on and turn VOLTAGE control fully clockwise.
- c. Turn up output current to the full rated value. Check that the CC indicator remains lighted. Reduce CURRENT control if not lighted.
- d. Record rms voltage across  $R_s$  and convert it to current by dividing this voltage by  $R_s$ .
- e. Check that the rms noise current is less than 5 mA rms for E3614A, 2 mA rms for E3615A and 500  $\mu\text{A}$  rms for E3616A and E3617A respectively.

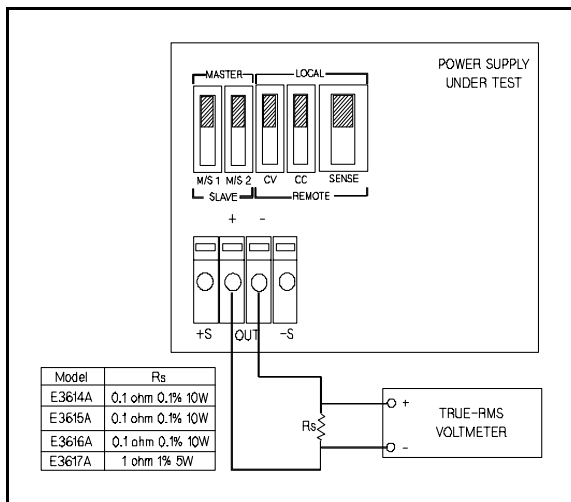


Figure A-8. CC PARD RMS Measurement Test Setup

### CC Drift (Stability)

**Definition:** The change in output current for the first 8 hours following a 30-minute warm-up with constant input line voltage, constant load resistance and constant ambient temperature.

#### Test Parameter:

Measured Variable: Output Current  
 Expected Results: Less than 0.1% plus 10 mA

#### Test Procedure:

- a. Connect the DVM across  $R_s$  in Figure A-4. Operate the electronic load in constant voltage mode and set its voltage to the full rated value of the power supply.
- b. Turn the supply's power on and turn VOLTAGE control fully clockwise.
- c. Turn up output current to the full rated value.
- d. After a 30-minute warm-up, note the voltage on DVM and convert it to current by dividing this voltage by  $R_s$ .
- e. The converted output current should deviate less than 0.1% plus 10 mA from the current obtained in step d over a period of 8 hours.

## ADJUSTMENT AND CALIBRATION PROCEDURE

Adjustment and calibration may be required after performance testing, troubleshooting, or repair and replacement. Perform those adjustments that affect the operation of the faulty circuit and no others. To remove the top cover, refer to "Line Voltage Option Conversion" paragraph.

### WARNING

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

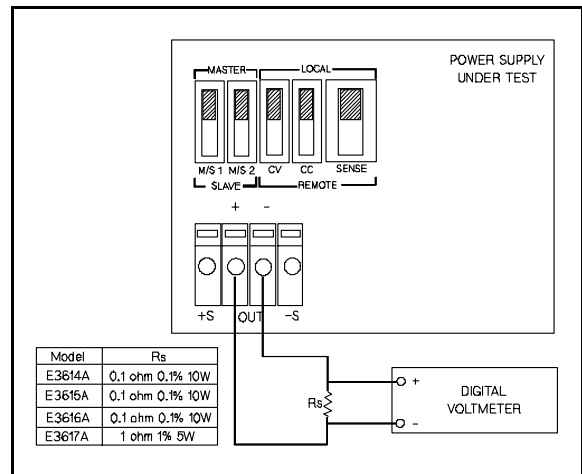


Figure A-9. Calibration Test Setup

### Ammeter and CC Set Calibration

To calibrate ammeter and CC set, proceed as follows:

- a. Connect test setup on Figure A-9.
- b. Turn VOLTAGE and CURRENT control fully clockwise.
- c. Turn on the supply and to calibrate ammeter adjust R5 on the display board until front panel AMPS display reads exactly DVM value divided by Rs.
- d. To calibrate CC Set adjust R69 on the main board until front panel AMPS display reads exactly DVM value divided by Rs while depressing OVP/CC Set switch.

### Voltmeter and OVP Set Calibration

To calibrate voltmeter and OVP set, proceed as follows:

- a. Disconnect Rs from test setup on Figure A-9 and connect DVM across output terminal of the supply.
- b. Turn on the supply.
- c. To calibrate voltmeter for E3614A, adjust R16 on the display board until front panel VOLTS display reads exactly DVM value. To calibrate voltmeter for E3615A, E3616A and E3617A set the output voltage below 18V (ex, 15V), and adjust R16 on the display board until front panel VOLTS display reads exactly DVM value. Next, set the output voltage above 20V (ex, 21V) and adjust R17 on the display board until front panel VOLTS display reads exactly DVM value.
- d. To calibrate OVP Set, turn down the OVP Adjust screwdriver control on the front panel slowly until the OVP circuit trips. Record the output voltage when the OVP trip occurs. Then adjust R97 on the main board until front panel VOLTS display reads exactly OVP trip voltage while depressing OVP/CC Set switch.

## TROUBLESHOOTING

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

### NOTE

*The applicable test points are identified by encircled numbers on the schematic diagrams at the rear of the manual, Figure A-10, Figure A-11, Figure A-12, and Figure 13.*

A good understanding of the principles of operation is a helpful aid in troubleshooting, and it is recommended that principles of operation in this manual be reviewed before attempting to troubleshoot the supply. Once the principles of operation are understood, refer to the overall troubleshooting procedures paragraph to locate the symptom and probable cause.

Once the defective component has been located (by means of visual inspection or trouble analysis) replace it and re-conduct the performance test. After a component is replaced, perform the meter calibration.

### Overall Troubleshooting Procedure

To locate the cause of trouble follow steps 1, 2, and 3 in sequence. Before attempting overall troubleshooting, ensure that the rear-panel switches M/S 1 and M/S 2 be set to MASTER position and CV, CC, and SENSE to LOCAL position.

1. Check that input power is available, and check the power cord and rear panel line fuse. When replacing line fuse, be certain to select fuse of proper rating for line voltage being used.
2. In almost all cases, the trouble source can be caused by the dc bias or reference voltages; thus, it is a good practice to check voltages in Table A-2 before proceeding with step 3.
3. Disconnect the load and examine Table A-3 to determine your symptom, then check the probable cause.

### Reference and Bias Circuit

- a. Make an ohmmeter check to be certain that neither the positive and negative output terminal is grounded.
- b. Turn front panel VOLTAGE and CURRENT controls fully clockwise.
- c. Turn on power supply (no load connected).
- d. Proceed as instructed in Table A-2.

### Regulating Loop Troubles

If the voltages in Table A-2 have been checked to eliminate the reference and bias circuits as a source of trouble; the malfunction is caused by either the series regulator or preregulator feedback loop. Because the interaction between these two loops makes logical troubleshooting difficult, the following steps help you to locate the source of troubles in these two feedback loops. Once the trouble has been located to one of the feedback loops, the operation of either loop can be analyzed independently. This method should be followed whenever a low output voltage condition exists. Notice that troubleshooting can proceed directly as described in Table A-4 whenever a high output voltage condition exists.

1. Turn on the power supply with full load connected and increase output voltage by turning up the front panel voltage control. The output voltage is clamped and CV indicator is turned off at some output voltage (below full rated output voltage). If this is the case, the series regulator feedback loop is operating normally and the trouble condition is probably due to a defect in the preregulator feedback loop (refer to Table A-6). If the output voltage remains in low stage, and varying the front panel voltage control has little or no effect, then the trouble is probably in the series regulator feedback loop. Refer to Table A-5.
2. Measure the voltage between TP2 and TP1 (shown on the schematic diagram at the rear of the manual) with full load with oscilloscope while increasing the output voltage from 0 to full rated voltage. The voltage measured has step changes three times during 0 to full output voltage swing. If this is the case, preregulator feedback loop is operating normally. If this is not the case, the trouble is probably in the preregulator feedback loop. Refer to Table A-6.

After the trouble has been isolated to one of the feedback loops, troubleshooting can proceed as described in Tables A-4, A-5, or A-6.

**Series Regulating Feedback Loop.** When troubleshooting the series regulating loop, it is useful to open the loop since measurements made anywhere within a closed loop may appear abnormal. With a loop closed, it is very difficult to separate cause from effect. As described in Tables A-4 and A-5, the conduction or cutoff capability of each stage is checked by shorting or opening a previous stage, as follows:

1. Shorting the emitter to collector of a transistor simulates saturation, or the full ON condition.
2. Shorting the emitter to base of a transistor cuts it off, and simulates an open circuit between emitter and collector.

Although a logical first choice might be to break the loop somewhere near its mid-point, and then perform successive subdividing tests, it is more useful to trace the loop from the

series regulator backwards a stage at a time, since loop failures occur more often at the higher power levels.

**Preregulator Feedback Loop.** The preregulator feedback loop (SCR control circuit) can be conveniently checked using Table A-6. As indicated in Table A-6, the control circuit is checked by starting with the waveform at point 7 and point 6 (shown on the schematic diagram) and tracing forwards and backwards from this point.

**Overvoltage Protection Circuit Troubles**

When troubleshooting the overvoltage protection circuit, it is useful to check the turn-on overshoot control circuit which includes U20 and Q10. The function of the control circuit is to slow down the rising speed of the +15 V bias the moment the power is turned on. This function prevents the supply from false OVP tripping the moment the power is turned on. After the troubles has been isolated to overvoltage protection circuit, troubleshooting can proceed as described in Table A-7.

**Table A-2. Reference and Bias Circuit Troubleshooting**

METER COMMON	METER POSITIVE	NORMAL INDICATION	NORMAL RIPPLE (p-p)	PROBABLE CAUSE
TP6	point 2	+15.0 +/- 0.3 Vdc	2 mV	Check U13, CR31, and CR32.
TP6	point 4	-12.0 +/- 0.3 Vdc	2 mV	Check +15 V bias or U14.
TP6	TP7	+10.5 +/- 0.2 Vdc	2 mV	Check +15 V bias, U11, and U14.
TP6	point 3	-5.1 +/- 0.5 Vdc	2 mV	Check -12 V bias or VR1.
TP6	point 5	+5.0 +/- 0.3 Vdc	4 mV	Check U1 and CR2.

**Table A-3. Overall Troubleshooting**

SYMPTOM	CHECKS AND PROBABLE CAUSES
High Output Voltage	<ol style="list-style-type: none"> <li>a. Check series regulator feedback loop or preregulator feedback loop.</li> <li>b. Refer to "Regulating Loop Troubles" paragraph or Table A-4 or A-6 as instructed.</li> </ol>
Low and No Output Voltage	<ol style="list-style-type: none"> <li>a. If output is zero, check fuse.</li> <li>b. Check series regulator feedback loop or preregulator loop. Refer to "Regulating Loop Troubles" paragraph or Table A-5 or A-6 as instructed.</li> <li>c. Check CR20 shorted.</li> </ol>
High Ripple	<ol style="list-style-type: none"> <li>a. Check operating setup for ground loops.</li> <li>b. If output floating, connect 1 <math>\mu</math>F capacitor between output and ground.</li> <li>c. Ensure that the supply is not crossing over to constant current mode under loaded conditions.</li> <li>d. Check for low voltage across C7 or Q1 and Q4.</li> <li>e. Check for excessive ripple on reference voltages (Table A-2).</li> </ol>
Poor Line Regulation (Constant Voltage)	<ol style="list-style-type: none"> <li>a. Check +10 V reference voltage.</li> <li>b. Check U9.</li> </ol>

**Table A-3. Overall Troubleshooting (Cont'd)**

<b>SYMPTOM</b>	<b>CHECKS AND PROBABLE CAUSES</b>
Poor Load Regulation (Constant Voltage)	a. Refer to "Measurements Techniques" paragraph. b. Check +10 V reference voltage. c. Ensure that the supply is not going into current limit.
Poor Load Regulation (Constant Current)	a. Check +10 V reference voltage. b. CR1, CR19, CR20, C2, C31 leaky. c. Ensure that the supply is not crossing over to constant voltage operation.
Oscillates (Constant Voltage/ Constant Current)	a. Check C29 and C36 in constant voltage circuit. b. Check C31 and C33 in constant current circuit.
Poor Stability (Constant Voltage)	a. Check +10 V reference voltage. b. CR27, CR28, CR23, and CR26 leaky. c. U9 defective. d. Noisy programming resistor R83.
Poor Stability (Constant Current)	a. Check +10 V reference voltage. b. CR24, CR25, CR29, and CR30 leaky. c. U9 and U10 defective. d. Noisy programming resistor R85.
Excessive heat	a. Check preregulator control circuit. Refer to Table A-6. b. CR10, CR12, CR15, and CR18 short
OVP Shutdown	a. Check that the front panel OVP Adjust screw control is rotated fully clockwise. b. Check the overvoltage protection circuit. Refer to "Overvoltage Protection Circuit Troubles" paragraph or Table A-7.

**Table A-4. High Output Voltage Troubleshooting**

<b>STEP</b>	<b>ACTION</b>	<b>RESPONSE</b>	<b>PROBABLE CAUSE</b>
1	Check turn off of Q1 and Q4 by shorting Q9 emitter to collector.	a. Output voltage remains high. b. Output voltage decreases.	a. Q1 or Q4 shorted. b. Remove short and proceed to step 2.
2	Check turn on of Q9 by shorting point 1 to -12 V.	a. Output voltage remains high. b. Output voltage decreases.	a. Q9 open. b. Remove short and proceed to step 3.
3	Check voltage from pin 5 to pin 6 of U9.	a. Input voltage is positive. b. Input voltage is negative.	a. U9B is defective. b. Turn down the voltage control fully counter clockwise. Check the voltage of U9 pin 1 is 0.

**Table A-5. Low Output Voltage Troubleshooting**

<b>STEP</b>	<b>ACTION</b>	<b>RESPONSE</b>	<b>PROBABLE CAUSE</b>
1	Check turn on of Q1 and Q4 by disconnecting emitter of Q9.	a. Output voltage remains low. b. Output voltage increases.	a. Q1 or Q4 open. b. Reconnect emitter lead and proceed to step 2.
2	Check turn off of Q9 by shorting point 1 to +15 V.	a. Output voltage remains low. b. Output voltage increases.	a. Q9 shorted. b. Remove short and proceed to step 3.
3	Eliminate constant current comparator as a source of trouble by disconnecting anode of CR22.	a. Output voltage is increases. b. Output voltage remains low.	a. Proceed to step 4. b. Reconnect lead and proceed to step 5.



**Table A-5. Low Output Voltage Troubleshooting (Cont'd)**

STEP	ACTION	RESPONSE	PROBABLE CAUSE
4	Check voltage from pin 13 to pin 12 of U9.	a. Measured voltage is positive. b. Measured voltage is negative.	a. Check U9A is defective. b. Check U10 and U9D is defective. Check R85 is open.
5	Check voltage from pin 6 to pin 5 of U9.	a. Measured voltage is positive. b. Measured voltage is negative.	a. U9B is defective. b. Check U9C is defective.

**Table A-6. Preregulator/Control Circuit Troubleshooting**

STEP	MEASURE		RESPONSE	PROBABLE CAUSE
1	Set output voltage to 4.5 V +- 0.5 V for E3614A. Set output voltage to 10 V +- 1 V for E3615A. Set output voltage to 15 V +- 1 V for E3616A. Set output voltage to 26 V +- 5 V for E3617A.			
2	E3614A E3615A	Waveform form from TP6(common) to point 6	a. Normal firing pulse b. No firing pulse	a. Check CR18, CR15, Q7, Q8 for defective. b. Proceed to step 3.
	E3616A	Voltage from TP6 (common) to point 6	a. High voltage (+0.7 V) b. Low voltage (0 V)	a. CR15, CR18, U2, U21 defective b. Proceed to step 3.
3	Voltage from TP6(common) to U4 pin 1		a. Low voltage (-12 V) b. High voltage (+5 V)	a. U3 defective b. Proceed to step 4.
4	Voltage from TP6(common) to U5 pin 1		a. High voltage (+15 V) b. Low voltage (-12 V)	a. U4 defective b. Proceed to step 5.
5	Voltage from pin 6 to pin 7 of U5		a. Measured voltage is positive. b. Measured voltage is negative.	a. U5 defective b. U6 defective
6	Set output voltage to 7 V +- 1 V for E3614A. Set output voltage to 16 V +- 2 V for E3615A. Set output voltage to 25 V +- 2 V for E3616A. Set output voltage to 44 V +- 5 V for E3617A.			
7	Waveform form from TP6 (common) to point 7		a. Normal firing pulse b. No firing pulse	a. CR10, CR12, Q5, Q6 defective b. Proceed to step 8.
8	Voltage from TP6(common) to U4 pin 14		a. Low voltage (-12 V) b. High voltage (+5 V)	a. U3 defective b. Proceed to step 9.
9	Voltage from TP6(common) to U5 pin 14		a. High voltage (+15 V) b. Low voltage (-12 V)	a. U4 defective b. Proceed to step 10.
10	Voltage from pin 8 to pin 9 of U5		a. Measured voltage is positive. b. Measured voltage is negative.	a. U5 defective b. U6 defective

**Table A-7. Overvoltage Protection Circuit Troubleshooting**

STEP	ACTION	RESPONSE	PROBABLE CAUSE
1	Short U19 pin 4 to TP6.	a. Shutdown release (OVP indicator OFF) b. Output voltage remains shutdown(0 V)	a. U20 defective or C57 shorted. b. Proceed to step 2.
2	Measure the voltage from TP6(common) to TP9.	a. High voltage (+5 V) b. Low voltage (0 V)	a. U19 defective or proceed step 3. b. U4D defective.
3	Measure the voltage from TP6(common) to TP8.	a. Below +2.6 V b. Above +2.6 V	a. U12 or U8 defective b. U18 defective

## REPLACEABLE PARTS

### INTRODUCTION

This section contains information for ordering replacement parts. Table A-10 lists parts by reference designators and provides the following information:

- a. Reference designators. Refer to Table A-8.
- b. Agilent Technologies Part Number.
- c. Total quantity used in that assembly.
- d. Description.
- e. Manufacturer's supply code number. Refer to Table A-9 for manufacturer's name and address.
- f. Manufacturer's part number or type.

Mechanical and miscellaneous parts are not identified by reference designator.

**Table A-8. Reference Designators**

A	Assembly
C	Capacitor
CR	Diode
DS	Signaling Device(light)
F	Fuse
G	Pulse Generator
J	Jack
L	Inductor
Q	Transistor
R	Resistor
S	Switch
T	Transformer
TP	Test Point
VR	Zener Diode
U	Integrated Circuit
W	Wire

### ORDERING INFORMATION

To order a replacement part, address order or inquiry to your local Agilent Technologies sales office (see lists at rear of this manual for addresses). Specify the following information for each part: Model, complete serial number of the power supply; Agilent Technologies part number; circuit reference designator; and description.

**Table A-9. Code List of Manufacturers**

CODE	MANUFACTURER	ADDRESS
01295	Texas Instruments Inc, Semicon Comp Div.	Dallas, TX
14936	General Instruments Corp, Semicon Prod	Hicksville, N.Y.
27014	National Semiconductor Corporation	Santa Clara, CA
28480	Agilent Technologies	Palo Alto, CA
04713	Motorola Semiconductor Products	Phoenix, AZ
32997	Bourns Inc.	Riverside, CA
34371	Harris Corp.	Melbourne, FL

Table A-10. Replaceable Parts List

Reference Designator	Agilent Part Number	Q'ty	Description	Model	Mfr. P/N	Mfr. Code
	E3614A	1	60W BENCH POWER SUPPLY - E3614A MODEL			
	E3615A	1	60W BENCH POWER SUPPLY - E3615A MODEL			
	E3616A	1	60W BENCH POWER SUPPLY - E3616A MODEL			
	E3617A	1	60W BENCH POWER SUPPLY - E3617A MODEL			
	E3614-60005	1	<b>MAIN BODY ASSY</b>	14		28480
	E3615-60005	1	<b>MAIN BODY ASSY</b>	15		28480
	E3616-60005	1	<b>MAIN BODY ASSY</b>	16		28480
	E3617-60005	1	<b>MAIN BODY ASSY</b>	17		28480
	0371-3806	1	KEY CAP - WHT	ALL		28480
	0371-8624	1	KEY CAP - GRAY	ALL		28480
	E361X-60003	1	<b>FRONT PANEL ASSY</b>	ALL		28480
	E361X-60009	1	DISPLAY BOARD ASSY	ALL		28480
R84,85	2100-4503	2	RES-VAR 10K 5% 10-TURN WW	ALL	3590S-A17-103	32997
	E3631-20011	1	BINDING POST RED	ALL		28480
	E3631-20012	1	BINDING POST BLACK	ALL		28480
	E3631-20013	1	BINDING POST GREEN	ALL		28480
	2950-0144	3	NUT- BINDING POST	ALL		28480
	5041-8621	2	KNOB	ALL		28480
	E3614-60002	1	<b>MAIN BOARD ASSY</b>	14		28480
	E3615-60002	1	<b>MAIN BOARD ASSY</b>	15		28480
	E3617-60002	1	<b>MAIN BOARD ASSY</b>	16		28480
	E3617-60002	1	<b>MAIN BOARD ASSY</b>	17		28480
	5021-8128	1	PCB MAIN FOR E3614A,E3615A	14,15		28480
	5021-8139	1	PCB MAIN FOR E3616A,E3617A	16,17		28480
C1,3,47	0160-4835	3	CAP-FXD .1UF +-10% 50V CER X7R	ALL		28480
C2	0180-4360	1	CAP-FXD 1000UF 25V +-20% AL-ELECTLT	14		28480
C2	0180-4355	1	CAP-FXD 470UF 50V +-20% AL-ELECTLT	15		28480
C2	0180-4452	1	CAP-FXD 330UF 63V +-20% AL-ELECTLT	16		28480
C2	0180-3595	1	CAP-FXD 220UF 100V +-20% AL-ELECTLT	17		28480
C4,5	0160-0269	2	CAP-FXD 0.1UF +-20% 500V CER Z5U	ALL		28480
C6	0180-3990	1	CAP-FXD 4700UF +-20% 25V AL-ELECTLT	ALL		28480
C7,8	0180-4567	2	CAP-FXD 39000UF 25V +-20% AL-ELECTLT	14		28480
C7,8	0180-4568	2	CAP-FXD 12000UF 63V +-20% AL-ELECTLT	15		28480
C7,8	0180-4607	2	CAP-FXD 5600UF 100V +-20% AL-ELECTLT	16		28480
C7,8	0180-4566	2	CAP-FXD 2700UF 160V +-20% AL-ELECTLT	17		28480
C9,41,42,43,55	0180-3970	5	CAP-FXD 1UF +-20% 50V AL-ELECTLT	ALL		28480
C10,48,49	0160-7449	3	CAP-FXD 0.33UF +-10% 50V POLYE-FL	ALL		28480
C11,16,17,25,26	0160-4832	5	CAP-FXD 0.01UF +-10% 100V CER X7R	14,15		28480
C12	0160-4835	1	CAP-FXD .1UF +-10% 50V CER X7R	14,15		28480
C13,14,15,30,32,34,38,39,50,54	0160-4832	10	CAP-FXD 0.01UF +-10% 100V CER X7R	ALL		28480

Table A-10. Replaceable Parts List (Cont'd)

Reference Designator	Agilent Part Number	Q'ty	Description	Model	Mfr. P/N	Mfr. Code
C18,21,24,27	0160-7077	4	CAP-FXD .1UF +-10% 630V POLYE-FL	14,15		28480
C19,22	0160-4822	2	CAP-FXD 1000PF +-5% 100V CER COG	14,15		28480
C20,23	0180-3970	2	CAP-FXD 1UF +-20% 50V AL-ELECTLT	14,15		28480
C28	0160-6225	1	CAP-FXD 0.33UF +-10% 250V POLYE-MET	ALL		28480
C29	0160-4832	1	CAP-FXD 0.01UF +-10% 100V CER X7R	14,15		28480
C29	0160-7673	1	CAP-FXD .047UF +-10% 100V POLYP-MET	16,17		28480
C31	0160-7075	1	CAP-FXD 4700PF +-2% 50V POLYP-FL	ALL		28480
C33,35,44,45,46- ,56	0160-4822	6	CAP-FXD 1000PF +-5% 100V CER COG	ALL		28480
C36	0160-7548	1	CAP-FXD 2200PF +-10% 50V CER Y5P	ALL		28480
C37	0160-4801	1	CAP-FXD 100PF +-5% 100V CER COG	ALL		28480
C40	0160-7673	1	CAP-FXD .047UF +-10% 100V POLYP-MET	ALL		28480
C52	0180-4085	1	CAP-FXD 330UF +-20% 35V AL-ELECTLT	ALL		28480
C53	0180-4355	1	CAP-FXD 470UF 50V +-20% AL-ELECTLT	ALL		28480
C57	0180-4437	1	CAP-FXD 47UF +-20% 50V AL-ELECTLT	ALL		28480
C58	0160-4065	1	CAP-FXD 0.1UF +-20% 250V PPR-MET	ALL		28480
C59,60	0160-7049	2	CAP-FXD 4700PF +-20% 250V CER X5V	ALL		28480
C61	0160-7363	1	CAP-FXD 1UF +-10% 250V POLYP-MET	16,17		28480
C62	0160-4808	1	CAP-FXD 470PF +-5% 100V CER COG	16,17		28480
C63,64,65,66	0160-0301	4	CAP-FXD 0.012UF +-10% 200V PE-FL	17		28480
R1,2	0811-3478	2	RESISTOR 0.1 +-1% 5W PWN TC=0+-90	14		28480
R1,2	0811-3839	2	RESISTOR 0.2 +-1% 5W PWN TC=0+-90	15		28480
R1,2	0811-3864	2	RESISTOR 0.6 +-5% 5W PWN TC=0+-90	16		28480
R1,2	0811-3861	2	RESISTOR 1.78 +-1% 5W PWN TC=0+-90	17		28480
R3,7,21,22,105,10 6	0698-3160	6	RESISTOR 31.6K +-1% .125W TF TC=0+-100	ALL		28480
R4,71,73,76,112	0757-0465	5	RESISTOR 100K +-1% .125W TF TC=0+-100	ALL		28480
R5,6,80	0757-0401	3	RESISTOR 100 +-1% .125W TF TC=0+-100	ALL		28480
R8,9,12	0757-0280	3	RESISTOR 1K +-1% .125W TF TC=0+-100	14,15		28480
R8,9	0761-0021	2	RESISTOR 1K +-5% 1W TF TC=0+-100	16,17		28480
R10,108	0699-2715	2	RESISTOR-FUSE 10HM +-5%; 0.5W @70	ALL		28480
R11	0811-1806	1	RESISTOR 2K +-5% 3W PWI 20PPM	14		28480
R11	0811-2188	1	RESISTOR 5K +-5% 3W PWI 20PPM	15		28480
R11	0764-0007	1	RESISTOR 27K +-5% 2W MO TC=0+-200PPM	16		28480
R11	0699-3105	1	RESISTOR 45K +-5% 2W MO TC=0+-500PPM	17		28480
R13	0757-0461	1	RESISTOR 68.1K +-1% .125W TF TC=0+-100	14,15		28480
R14,48,52	0698-3157	3	RESISTOR 19.6K +-1% .125W TF TC=0+-100	14,15		28480
R15	0757-0442	1	RESISTOR 10K +-1% .125W TF TC=0+-100	14,15		28480
R16	0757-0465	1	RESISTOR 100K +-1% .125W TF TC=0+-100	14,15		28480
R17,18,66,78,110, 123	0757-0280	6	RESISTOR 1K +-1% .125W TF TC=0+-100	ALL		28480
R19,113	0698-0083	2	RESISTOR 1.96K +-1% .125W TF TC=0+-100	ALL		28480
R20,23	0757-0463	2	RESISTOR 82.5K +-1% .125W TF TC=0+-100	ALL		28480

Table A-10. Replaceable Parts List (Cont'd)

Reference Designator	Agilent Part Number	Q'ty	Description	Model	Mfr. P/N	Mfr. Code
R24,26,27,37,38,64,88,117,120	0757-0442	9	RESISTOR 10K +-1% .125W TF TC=0+-100	ALL		28480
R25,30,33	0698-8824	3	RESISTOR 562K +-1% .125W TF TC=0+-100	ALL		28480
R28,111	0698-3228	2	RESISTOR 49.9K +-1% .125W TF TC=0+-100	ALL		28480
R29,68,86,89,91,9-2,95,96,99,114,121	0698-3162	11	RESISTOR 46.4K +-1% .125W TF TC=0+-100	ALL		28480
R31,32,35	0698-0084	3	RESISTOR 2.15K +-1% .125W TF TC=0+-100	ALL		28480
R34	0757-0288	1	RESISTOR 9.09K +-1% .125W TF TC=0+-100	ALL		28480
R36	0698-3518	1	RESISTOR 7.32K +-1% .125W TF TC=0+-100	14		28480
R36	0757-0439	1	RESISTOR 6.81K +-1% .125W TF TC=0+-100	15		28480
R36	0757-0441	1	RESISTOR 8.25K +-1% .125W TF TC=0+-100	16		28480
R36	0698-8580	1	RESISTOR 9.53K +-1% .125W TF TC=0+-100	17		28480
R39	0757-0440	1	RESISTOR 7.5K +-1% .125W TF TC=0+-100	14		28480
R39	0698-4471	1	RESISTOR 7.15K +-1% .125W TF TC=0+-100	15		28480
R39	0698-3498	1	RESISTOR 8.66K +-1% .125W TF TC=0+-100	16		28480
R39	0757-0442	1	RESISTOR 10K +-1% .125W TF TC=0+-100	17		28480
R40	0757-0431	1	RESISTOR 2.43K +-1% .125W TF TC=0+-100	14		28480
R40	0698-4438	1	RESISTOR 3.09K +-1% .125W TF TC=0+-100	15		28480
R40	0698-0063	1	RESISTOR 5.23K +-1% .125W TF TC=0+-100	16		28480
R40	0757-0439	1	RESISTOR 6.81K +-1% .125W TF TC=0+-100	17		28480
R41	0698-4473	1	RESISTOR 8.06K +-1% .125W TF TC=0+-100	14		28480
R41	0757-0454	1	RESISTOR 33.2K +-1% .125W TF TC=0+-100	15		28480
R41	0698-4503	1	RESISTOR 66.5K +-1% .125W TF TC=0+-100	16		28480
R41	0757-0467	1	RESISTOR 121K +-1% .125W TF TC=0+-100	17		28480
R42,44,54,56	0757-0346	4	RESISTOR 10 +-1% .125W TF TC=0+-100	14,15		28480
R42,44,54,56	0698-3438	4	RESISTOR 147 +-1% .125W TF TC=0+-100	16,17		28480
R43,55	0757-0293	2	RESISTOR 1.96K +-1% .125W TF TC=0+-100	16,17		28480
R43,45,55,57	0757-0401	4	RESISTOR 100 +-1% .125W TF TC=0+-100	14,15		28480
R46,53	0757-0489	2	RESISTOR 10 +-1% .25W TF TC=0+-100	14,15		28480
R47,50	0698-4123	2	RESISTOR 499 +-1% .125W TF TC=0+-100	14,15		28480
R49,51	0757-0293	2	RESISTOR 1.96K +-1% .125W TF TC=0+-100	14,15		28480
R58,59	0811-3909	2	RESISTOR 0.2 +-1% 10W PWN TC=0+-90	14		28480
R58	0811-3909	1	RESISTOR 0.2 +-1% 10W PWN TC=0+-90	15		28480
R58	0811-4118	1	RESISTOR 0.6 +-1% 10W PWN TC=0+-90	16		28480
R58,59	0811-3861	2	RESISTOR 1.78 +-1% 5W PWN TC=0+-90	17		28480
R60	0811-1799	1	RESISTOR 390 +-5% 3W PWI TC=0+-20	14		28480
R60	0813-0001	1	RESISTOR 1K +-5% 3W PWI TC=0+-20	15		28480
R60	0811-0071	1	RESISTOR 1.52K +-5% 3W PWI TC=0+-20	16		28480
R60	0811-1808	1	RESISTOR 2.6K +-5% 3W PWI TC=0+-20	17		28480
R61	0698-0085	1	RESISTOR 2.61K +-1% .125W TF TC=0+-100	ALL		28480
R62	0698-7634	1	RESISTOR 42.2K +-1% .125W TF TC=0+-100	14		28480

R62	0698-4514	1	RESISTOR 105K +-1% .125W TF TC=0+-100	15		28480
R62	0757-0481	1	RESISTOR 475K +-1% .125W TF TC=0+-100	16		28480

Table A-10. Replaceable Parts List (Cont'd)

Reference Designator	Agilent Part Number	Q'ty	Description	Model	Mfr. P/N	Mfr. Code
R62	0698-8826	1	RESISTOR 825K +-1% .125W TF TC=0+-100	17		28480
R63	0698-8827	1	RESISTOR 1M +-1% .125W TF TC=0+-100	ALL		28480
R65	0757-0274	1	RESISTOR 1.21K +-1% .125W TF TC=0+-100	ALL		28480
R67	0757-0438	1	RESISTOR 5.11K +-1% .125W TF TC=0+-100	ALL		28480
R69	2100-4306	1	RESISTOR-TRMR 50K 10% TKF TOP-ADJ 25-T	ALL	3296Y-1-503	32997
R70	0698-3243	1	RESISTOR 178K +-1% .125W TF TC=0+-100	14		28480
R70	0698-3459	1	RESISTOR 383K +-1% .125W TF TC=0+-100	15		28480
R70	0698-3158	1	RESISTOR 23.7K +-1% .125W TF TC=0+-100	16		28480
R70	0757-0465	1	RESISTOR 100K +-1% .125W TF TC=0+-100	17		28480
R72	0757-0289	1	RESISTOR 13.3K +-1% .125W TF TC=0+-100	14		28480
R72	0757-0290	1	RESISTOR 6.19K +-1% .125W TF TC=0+-100	15		28480
R72	0757-0458	1	RESISTOR 51.1K +-1% .125W TF TC=0+-100	16		28480
R72	0698-8123	1	RESISTOR 26.1K +-1% .125W TF TC=0+-100	17		28480
R74,75	0757-0444	2	RESISTOR 12.1K +-1% .125W TF TC=0+-100	14,15		28480
R74,75	0698-3245	2	RESISTOR 20.5K +-1% .125W TF TC=0+-100	16		28480
R74,75	0698-3136	2	RESISTOR 17.8K +-1% .125W TF TC=0+-100	17		28480
R77	0698-3430	1	RESISTOR 21.5 +-1% .125W TF TC=0+-100	14,15		28480
R77	0757-0395	1	RESISTOR 56.2 +-1% .125W TF TC=0+-100	16,17		28480
R79	0698-4767	1	RESISTOR 147K +-1% .125W TF TC=0+-100	14		28480
R79	0698-3460	1	RESISTOR 422K +-1% .125W TF TC=0+-100	15		28480
R79	0698-8825	1	RESISTOR 681K +-1% .125W TF TC=0+-100	16		28480
R79	0698-8827	1	RESISTOR 1M +-1% .125W TF TC=0+-100	17		28480
R81,122	0698-3157	2	RESISTOR 19.6K +-1% .125W TF TC=0+-100	ALL		28480
R82	0698-8123	1	RESISTOR 26.1K +-1% .125W TF TC=0+-100	14,15		28480
R82	0757-0461	1	RESISTOR 68.1K +-1% .125W TF TC=0+-100	16,17		28480
R83,119	0757-0440	2	RESISTOR 7.5K +-1% .125W TF TC=0+-100	ALL		28480
R87	0698-3444	1	RESISTOR 316 +-1% .125W TF TC=0+-100	ALL		28480
R90	0757-0346	1	RESISTOR 10 +-1% .125W TF TC=0+-100	ALL		28480
R93	0698-3581	1	RESISTOR 13.7K +-1% .125W TF TC=0+-100	ALL		28480
R94	2100-4357	1	RESISTOR-VAR 10K +-10%	ALL	52UAL-T22-A15	32997
R97	2100-4305	1	RESISTOR-TRMR 10K 10% TKF TOP-ADJ 25-T	ALL	3296Y-1-103	32997
R98	0698-3455	1	RESISTOR 261K +-1% .125W TF TC=0+-100	14		28480
R98	0757-0465	1	RESISTOR 100K +-1% .125W TF TC=0+-100	15		28480
R98	0757-0461	1	RESISTOR 68.1K +-1% .125W TF TC=0+-100	16		28480
R98	0698-3160	1	RESISTOR 31.6K +-1% .125W TF TC=0+-100	17		28480
R100	0698-4123	1	RESISTOR 499 +-1% .125W TF TC=0+-100	ALL		28480
R101	0698-3441	1	RESISTOR 215 +-1% .125W TF TC=0+-100	ALL		28480
R102	0698-3438	1	RESISTOR 147 +-1% .125W TF TC=0+-100	ALL		28480
R103	0757-0428	1	RESISTOR 1.62K +-1% .125W TF TC=0+-100	ALL		28480
R104,107	0698-3156	2	RESISTOR 14.7K +-1% .125W TF TC=+-100	ALL		28480

R109	0698-3153	1	RESISTOR 3.83K +-1% .125W TF TC=0+-100	ALL		28480
R115	0757-0462	1	RESISTOR 75K +-1% .125W TF TC=0+-100	14		28480

Table A-10. Replaceable Parts List (Cont'd)

Reference Designator	Agilent Part Number	Q'ty	Description	Model	Mfr. P/N	Mfr. Code
R115	0757-0463	1	RESISTOR 82.5K +-1% .125W TF TC=0+-100	15		28480
R115	0757-0462	1	RESISTOR 75K +-1% .125W TF TC=0+-100	16		28480
R115	0757-0461	1	RESISTOR 68.1K +-1% .125W TF TC=0+-100	17		28480
R116	0698-4489	1	RESISTOR 28K +-1% .125W TF TC=0+-100	14		28480
R116	0698-3161	1	RESISTOR 38.3K +-1% .125W TF TC=0+-100	15,16		28480
R116	0698-4494	1	RESISTOR 35.7K +-1% .125W TF TC=0+-100	17		28480
R118	0698-8678	1	RESISTOR 178 +-1% .125W TF TC=0+-100	ALL		28480
R124	0698-8812	1	RESISTOR 1 +-1% .125W TF TC=0+-100	16,17		28480
R125	0698-8825	1	RESISTOR 681K +-1% .125W TF TC=0+-100	16,17		28480
R126	0757-0401	1	RESISTOR 100 +-1% .125W TF TC=0+-100	ALL		28480
U1	1826-0144	1	IC V RGLTR-FXD-POS 4.8/5.2V T0-220 PKG	ALL	MC7805CT	04713
U2	1826-0346	1	IC OP AMP GP DUAL 8 PIN DIP-P	14,15	LM358N	27014
U3,16,20	1826-0412	3	IC COMPARATOR PRCN DUAL 8 PIN DIP-P	ALL	LM393N	27014
U4,5	1826-0138	2	IC COMPARATOR GP QUAD 14 PIN DIP-P	ALL	LM339	27014
U6,9	1826-0665	2	IC OP AMP LOW-BIAS-H-IMPQ QUAD 14 PIN	ALL	LF347BN	27014
U7,15,17	1826-1297	3	IC V RGLTR-V-REF-FXD 4.8/5.2V T0-92 PKG	ALL	LM336BZ-5.0	27014
U8	1990-1659	1	OPTO-ISOLATOR LED-TRIAC IF=100MA-MAX	ALL	MCP3020Z	14936
U10	1826-1702	1	IC OP AMP PRCN 8 PIN DIP-P	ALL		28480
U11	1826-1075	1	IC OP AMP GP DUAL 8 PIN DIP-P	ALL	LF442CN	27014
U12	1826-0468	1	IC V RGLTR-0V-V-SEN 2.3/37.8V 8-DIP-P	ALL	MC3423P1	04713
U13	1826-0393	1	IC V RGLTR-ADJ-POS 1.2/37V T0-220 PKG	ALL	LM317T	27014
U14	1826-0221	1	IC V RGLTR-FXD-NEG -11.5/-12.5V T0-220	ALL	MC7912CT	04713
U18	1826-0346	1	IC OP AMP GP DUAL 8 PIN DIP-P	ALL	LM358N	27014
U19	1820-1197	1	IC GATE TTL/LS NAND QUAD 2-INP	ALL	SN74LS00N	01295
U21,22,23,24	1990-1659	4	OPTO-ISOLATOR LED-TRIAC IF=100MA-MAX	16,17	MCP3020Z	14936
Q1,4	1855-0989	2	TRANSISTOR MOSFET N-CHAN E-MODE T0-247AC	14,15	IRFP044	28480
Q1,4	1855-0536	2	TRANSISTOR MOSFET N-CHAN E-MODE T0-3 SI	16,17		28480
Q2,3,10,11	1854-0477	4	TRANSISTOR NPN 2N2222A SI T0-18 PD=500MW	ALL	2N2222A	04713
Q5,6,7,8	1854-0477	4	TRANSISTOR NPN 2N2222A SI T0-18 PD=500MW	14,15	2N2222A	04713
Q6,7	1853-0281	2	TRANSISTOR PNP 2N2907A SI T0-18 PD=400MW	16,17	2N2907A	04713
Q9	1853-0041	1	TRANSISTOR PNP SI T0-39 PD=1W FT=60MHZ	ALL	MM5007	04713
CR1,19	1901-1273	2	DIODE-PWR RECT 100V 6A 35NS	ALL	FE6B	14936
CR2	1906-0284	1	DIODE-FW BRIDGE 100V 1A	ALL	DF01	14936
CR3,4,5,6,7	1901-0033	5	DIODE-GEN PRP 180V 200MA D0-35	14,15	1N645	27014
CR8,9,16,17,31,32	1901-1149	6	DIODE-PWR RECT 400V 1A 50NS D0-41	ALL	UF4004	14936
CR10,12,15,18,20	1884-0332	5	THRYSTER-SCR T0-220AB VRRM=200V	ALL	MCR264-4	04713
CR11,14	1901-1149	2	DIODE-PWR RECT 400V 1A 50NS D0-41	14,15	UF4004	14936
CR13	1906-0400	1	DIODE-BRIDGE 600V 6A	ALL	GBU8J	14936

Table A-10. Replaceable Parts List (Cont'd)

Reference Designator	Agilent Part Number	Q'ty	Description	Model	Mfr. P/N	Mfr. Code
CR21,22,23,24,25,26,27,28,29,30	1901-0033	10	DIODE-GEN PRP 180V 200MA D0-35	ALL	1N645	27014
VR1,2,3	1902-0579	3	DIODE-ZNR 5.1V 5% PD=1W IR=10UA	ALL	1N4733APL	04713
RT1,2	0837-0261	2	DIODE-VARISTOR	ALL	V275LA20A	34371
C67	0160-0263	1	CAP-FXD 0.22uF +-20% 50V CER	ALL		
			<b>MAGNETIC DEVICE</b>			
T1	9100-5068	1	TRANSFORMER-POWER	14		28480
T1	9100-5069	1	TRANSFORMER-POWER	15		28480
T1	NO P/N	1	TRANSFORMER-POWER	16		28480
T1	9100-5070	1	TRANSFORMER-POWER	17		28480
T2,3	9100-4969	2	TRANSFORMER-PULSE; PRI IND:5MH	14,15		28480
L1	9170-0894	1	CORE-SHIELDING BEAD	ALL		28480
			<b>MISCELLANEOUS</b>			
J1	1252-4159	1	CONNECTOR-POST TYPE 2.5-PIN-SPCG 11-CO-NT	ALL		28480
TP1-16	0360-2359	16	TERMINAL-TEST POINT .230IN ABOVE	ALL		28480
S1,2,3,4	3101-3237	4	SWITCH-SL SPDT SUBMIN 6A 250VAC	ALL		28480
S5	3101-3238	1	SWITCH-SL DPDT SUBMIN 6A 250VAC	ALL		28480
S6	3101-1914	1	SWITCH-SL 2-DPDT STD 1.5A 250VAC PC	ALL		28480
S7	3101-3115	1	SWITCH-PB MOM .5A 250VAC	ALL		28480
S8	3101-3083	1	SWITCH-PB DPSTALTNG 6A 250VAC	ALL		28480
	0360-2548	3	TERMINAL BLOCK	ALL		28480
	0360-2545	1	TERMINAL BLOCK	ALL		28480
	0360-2546	9	TERMINAL BLOCK	ALL		28480
	0360-2547	1	TERMINAL BLOCK	ALL		28480



Table A-11. Component Value

Component	Model			
	E3614A	E3615A	E3616A	E3617A
C2	1000UF 25V +-20% AL-ELECTLT	470UF 50V +-20% AL-ELECTLT	330UF 50V +-20% AL-ELECTLT	220UF 100V +-20% AL-ELECTLT
C7,8	39000UF 25V +-20% AL-ELECTLT	12000UF 63V +-20% AL-ELECTLT	5600UF 100V +-20% AL-ELECTLT	2700UF 160V +-20% AL-ELECTLT
C11,16,17,25,26	0.01UF 100V +-10% CER X7R	0.01UF 100V +-10% CER X7R		
C12	0.1UF 50V +-10% CER X7R	0.1UF 50V +-10% CER X7R		
C18,21,24,27	0.1UF 630V +-10% POLYE-FL	0.1UF 630V +-10% POLYE-FL		
C19,22	1000PF 100V +-5% COG	1000PF 100V +-5% COG		
C20,23	1UF 50V +-20% AL-ELECTLT	1UF 50V +-20% AL-ELECTLT		
C29	0.01UF 100V +-10% CER X7R	0.01UF 100V +-10% CER X7R	0.047UF 100V +-10% POLYP-MET	0.047UF 100V +-10% POLYP-MET
C61			1UF +-10% 250V POLYP-MET	1UF +-10% 250V POLYP-MET
C62			470PF +-5% 100V CER COG	470PF +-5% 100V CER COG
C63,64,65,66				0.012UF +-10% 200V PE-FL
R1,2	0.1 +-1% 5W	0.2 +-1% 5W	0.6 +-5% 5W	1.78 +-1% 5W
R8,9	1K 1% .125W	1K 1% .125W	1K +-5% 1W	1K +-5% 1W
R11	2K +-5% 3W	5K +-5% 3W	27k +-5% 2W	45K +-5% 2W
R12	1K +-1% .125W	1K +-1% .125W		
R13	68.1K +-1% .125W	68.1K +-1% .125W		
R14,48,52	19.6K +-1% .125W	19.6K +-1% .125W		
R15	10K +-1% .125W	10K +-1% .125W		
R16	100K +-1% .125W	100K +-1% .125W		
R36	7.32K +-1% .125W	6.81K +-1% .125W	8.25K +-1% .125W	9.53K +-1% .125W
R39	7.5K +-1% .125W	7.15K +-1% .125W	8.66K +-1% .125W	10K +-1% .125W
R40	2.43K +-1% .125W	3.09K +-1% .125W	5.23K +-1% .125W	6.81K +-1% .125W
R41	8.06K +-1% .125W	33.2K +-1% .125W	66.5K +-1% .125W	121K +-1% .125W
R42,44,54,56	10 +-1% .125W	10 +-1% .125W	147 +-1% .125W	147 +-1% .125W
R43,55	100 +-1% .125W	100 +-1% .125W	1K +-1% .125W	1K +-1% .125W
R45,57	100 +-1% .125W	100 +-1% .125W		
R46,53	10 +-1% .25W	10 +-1% .25W		
R47,50	499 +-1% .125W	499 +-1% .125W		
R49,51	1.96K +-1% .125W	1.96K +-1% .125W		
R58	0.2 +-1% 10W	0.2 +-1% 10W	0.6 +-1% 10W	1.78 +-1% 5W
R59	0.2 +-1% 10W			1.78 +-1% 5W
R60	390 +-5% 3W	1K +-5% 3W	1.52K +-5% 3W	2.6K +-5% 3W
R62	42.2K +-1% .125W	105K +-1% .125W	475K +-1% .125W	825K +-1% .125W
R70	178K +-1% .125W	383K +-1% .125W	23.7K +-1% .125W	100K +-1% .125W
R72	13.3K +-1% .125W	6.19K +-1% .125W	51.1K +-1% .125W	26.1K +-1% .125W
R74,75	12.1K +-1% .125W	12.1K +-1% .125W	20.5 +-1% .125W	17.8K +-1% .125W
R77	21.5 +-1% .125W	21.5 +-1% .125W	56.2 +-1% .125W	56.2 +-1% .125W
R79	147K +-1% .125W	422K +-1% .125W	681K +-1% .125W	1M +-1% .125W
R82	26.1K +-1% .125W	26.1K +-1% .125W	68.1K +-1% .125W	68.1K +-1% .125W
R98	261K +-1% .125W	100K +-1% .125W	68.1K +-1% .125W	31.6K +-1% .125W
R115	75K +-1% .125W	82.5K +-1% .125W	75K +-1% .125W	68.1K +-1% .125W
R116	28K +-1% .125W	38.3K +-1% .125W	38.3K +-1% .125W	35.7K +-1% .125W
R124			1 +-1% .125W	1 +-1% .125W
R125			681K +-1% .125W	681K +-1% .125W
Q1,4	MOSFET N-CHAN E-MODE TO 204AE	MOSFET N-CHAN E-MODE TO 204AE	MOSFET N-CHAN E-MODE TO 3 SI	MOSFET N-CHAN E-MODE TO 3 SI
Q5,8	NPN 2N2222A SI TO-18 PD=500MW2	NPN 2N2222A SI TO-18 PD=500MW		
Q6,7	NPN 2N2222A SI TO-18 PD=500MW2	NPN 2N2222A SI TO-18 PD=500MW2	PNP 2N2907A SI TO-18 PD=400MW	PNP 2N2907A SI TO-18 PD=400MW
U2	IC OP AMP GP DUAL 8 PIN DIP-P	IC OP AMP GP DUAL 8 PIN DIP-P		
U21,22,23,24			OPTO-ISOLATOR LED-TRIAC	OPTO-ISOLATOR LED-TRIAC
CR3,4,5,6,7	DIODE-GEN PRP 180V 200MA DO-35	DIODE-GEN PRP 180V 200MA DO-35		
CR11,14	DIODE-PWR RECT 400V 1A 50NS DO-41	DIODE-PWR RECT 400V 1A 50NS DO-41		
T1	TRANSFORMER-POWER FOR E3614A	TRANSFORMER-POWER FOR E3615A	TRANSFORMER-POWER FOR E3616A	TRANSFORMER-POWER FOR E3617A
T2,3	TRANSFORMER-PULSE; PRI IND:5MH	TRANSFORMER-PULSE; PRI IND:5MH		

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# Manual Supplement

Supplement Agilent Part Number : 5959-5336, Edition 4

Supplement Print Date : 14 April, 2000

This supplement updates the following document:

Agilent E361XA 60W Series Lab Bench DC Power Supplies

Manual Agilent Part Number : 5959-5310

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## **What is a manual supplement?**

A manual supplement keeps your manual up-to-date. The supplement, which consists of additional pages for your manual, is shipped with the manual that it updates. Additional pages have page numbers with a lower-case letter. For example, if one additional page is added between pages 1-10 and 1-11, it will be numbered 1-10-1.

This supplement is new information that was not described in the manual for remote programming of the E3614A/E3615A/E3616A/E3617A with a voltage or current source and resistors.

---

## Voltage and Current Programming of the E3614A/15A/16A/17A with a Voltage and Current Source

Remote analog voltage programming permits control of the regulated output voltage or current by means of a remotely varied voltage or current. The stability of the programming voltages directly affects the stability of the output. The voltage control or current control on the front panel are disabled during analog programming.

---

### NOTE

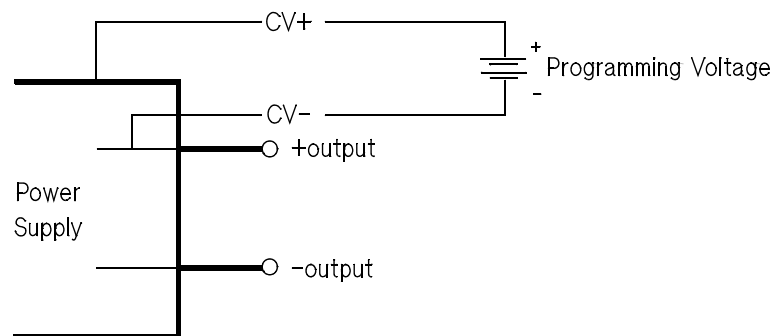
*The CV(-) terminal on the rear panel is internally connected to the plus output terminal. In following connections, it is recommended to use Figure 2, Figure 4, or Figure 6 if the negative terminal of the "Programming Voltage" is not floted from its circuits.*

---

### Constant Voltage Mode

The programming voltage is not isolated from the power supply output. The power supply may be programmed with a voltage that is common to either the plus output, or the minus output.

#### Programming Voltage Common to the Plus output



**Figure 1**

Set the CV switch down on the rear panel, and all others up.

$$V_{in} = 1/A \times V_{out}$$

$$V_{out} = A \times V_{in}$$

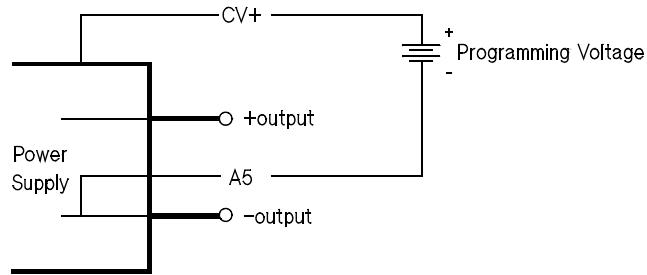
Where  $V_{out}$  is the power supply output voltage.

$V_{in}$  is the programming voltage.

A is the gain factor and the values of each model are as below.

Model	A	1/A
E3614A	0.8	1.25
E3515A	2.0	0.5
E3616A	3.5	0.29
E3617A	6.0	0.17

## Programming Voltage Common to the Minus Output



**Figure 2**

Set the CV switch down on the rear panel, and all others up.

$$V_{in} = 1/A \times V_{out}$$

$$V_{out} = A \times V_{in}$$

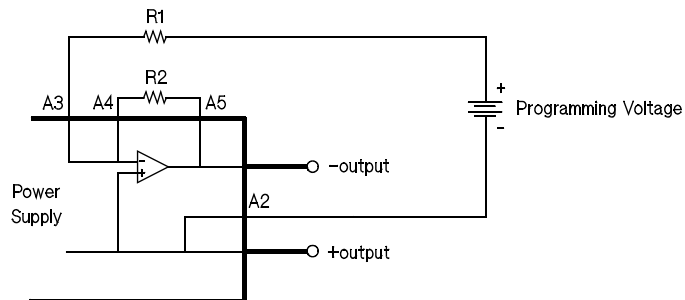
Where  $V_{out}$  is the power supply output voltage.

$V_{in}$  is the programming voltage.

A is the gain factor and the values of each model are as below.

Model	A	1/A
E3614A	0.44	2.25
E3515A	0.67	1.5
E3616A	0.78	1.29
E3617A	0.86	1.17

## Alternative Voltage Programming Using Resistors Programming Voltage Common to the Plus Output



**Figure 3**

The M/S2 switch must be in the down position. For best results, place a 0.1μF capacitor in parallel with R2.

$$V_{in} = (R1/R2) \times V_{out}$$

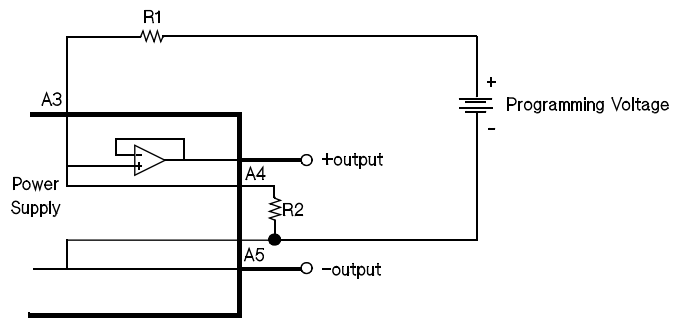
$$V_{out} = (R2/R1) \times V_{in}$$

Where  $V_{out}$  is the power supply output voltage.

$V_{in}$  is the programming voltage.

R1 and R2 should be in the 1KΩ to 100KΩ range.

### Programming Voltage Common to the Minus Output



**Figure 4**

The output will always be the same or less than the programming voltage.

The M/S2 switch must be in the down position. For best results, place a 0.1  $\mu\text{F}$  capacitor in parallel with R2.

$$V_{\text{in}} = (R1 + R2) / R2 \times V_{\text{out}}$$

$$V_{\text{out}} = R2 / (R1 + R2) \times V_{\text{in}}$$

Where  $V_{\text{out}}$  is the power supply output voltage.

$V_{\text{in}}$  is the programming voltage.

R1 and R2 should be in the 1K $\Omega$  to 100K $\Omega$  range.

### Constant Current Mode

The E3614A/15A/16A/17A may be programmed for constant current with an analog voltage or current. Constant current with analog voltage programming can only be achieved with a voltage source that is common with the positive output terminal.

#### Constant Current with Voltage Programming

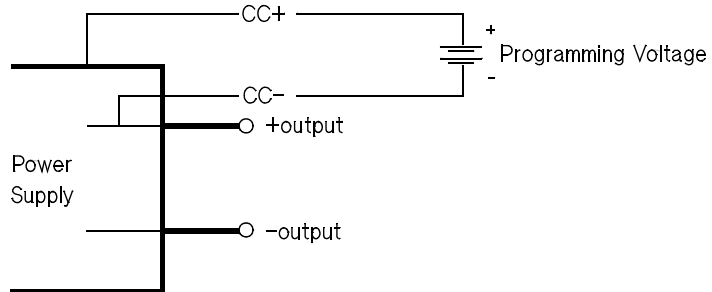


Figure 5

Set the CC switch down the rear panel, and all others up.

$$V_{in} = 1/A \times I_{out}$$

$$I_{out} = A \times V_{in}$$

Where  $I_{out}$  is the power supply output current.

$V_{in}$  is the programming voltage.

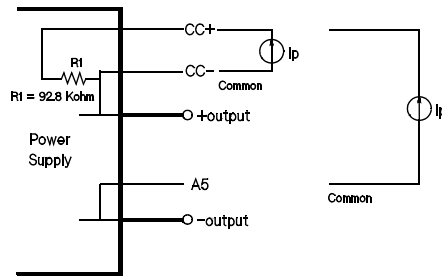
A is the transconductance in Amp/Volt and the values of each model are as below.

Model	A (A/V)	1/A (V/A)
E3614A	0.6	1.67
E3515A	0.3	3.33
E3616A	0.17	6.0
E3617A	0.1	10

#### Constant Current with Current Programming

When using current to program the power supply, the source must have a dynamic range of 10 volts when the programming source is common to the plus output and 10 volts plus the maximum output voltage expected when the programming source is common to the minus output of the power supply.

The load to the power supply must be stable for the constant current output to be accurate. Current transient response is not specified, and depends on the change of the output voltage of the power supply.



**Figure 6**

Set the CC switch down, and all others up.

$$I_{in} = 1/A \times I_{out}$$

$$I_{out} = A \times V_{in}$$

Where  $I_{out}$  is the power supply output current in amps.

$I_{in}$  is the programming current in  $\mu$ amps.

A is the gain.

Model	A (A/ $\mu$ A)	1/A ( $\mu$ V/A)
E3614A	0.055	18
E3515A	0.0278	35.9
E3616A	0.0158	63.4
E3617A	0.00928	108

Programming currents can be increased by adding a resistor across the CC+ and CC-. A 10 volts drop across R1 represents full scale current of the power supply. When a 1 kohm resistor is added across R1, the programming currents are as follows with the programming current in mA.

Model	A (A/mV)	1/A (mA/A)	Parallel resistor required for a 1 amp/mamp value of A (kohm)
E3614A	0.594	1.69	1.7
E3515A	0.297	3.37	3.45
E3616A	0.168	5.95	6.28
E3617A	0.0989	1.01	11.2

### Current Monitoring

Current of the power supply can be monitored across the internal current monitoring resistor. One side of the resistor is at the +output and A3; the other side of the resistor is at A1. The table below shows the resistor value and conversion factors. To obtain the current divide the measured voltage by the resistor value or multiply the amps/V times the voltage measured.

Model	Resistor value ( $\Omega$ )	amps/V
E3614A	0.1	10
E3515A	0.2	5
E3616A	0.6	1.67
E3617A	0.89	1.12

## Voltage and Current Programming of the E3614A/15A/16A/17A with Resistors

Remote programming with resistors permits control of the regulated output or current by means of a remotely varied resistor. The sum of the resistance of external programming resistors ( $R_1 + R_2$ ) should be more than 40 kohm. *To have more precise output voltage, use a variable resistor more than 40 kohm.* The voltage control on the front panel is disabled during remote resistor programming.

### NOTE

*Do not operate the power supply simultaneously in the remote analog voltage programming and in the remote resistor programming.*

### Remote Resistor Programming Connections

Remote resistor programming requires changing the setting of the switches and connecting external resistors between “+” and “-” terminals of “CV” and “VREF” terminal or “+” and “-” terminals of “CC” and “VREF” terminal. Any noise picked up on the programming leads will appear on the power supply's output and may degrade regulation. To reduce noise pickup, use a twisted or shielded pair of wires for programming, with the shield grounded at one end only.

### Remote Resistor Programming, Constant Voltage

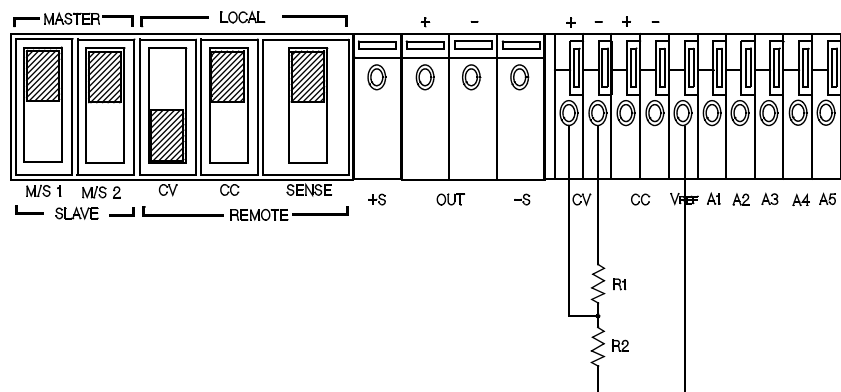


Figure 7

Set the CV switch down on the rear panel, and all others up.

$$V_{\text{out}} = A \times [V_{\text{REF}} \times \{R/(R + R_2 + 100)\}]$$

Where  $V_{\text{out}}$  is the power supply output voltage.

A is the gain factor and the values of each model are as below.

$V_{\text{REF}}$  is between 10.11 V and 11.40 V.

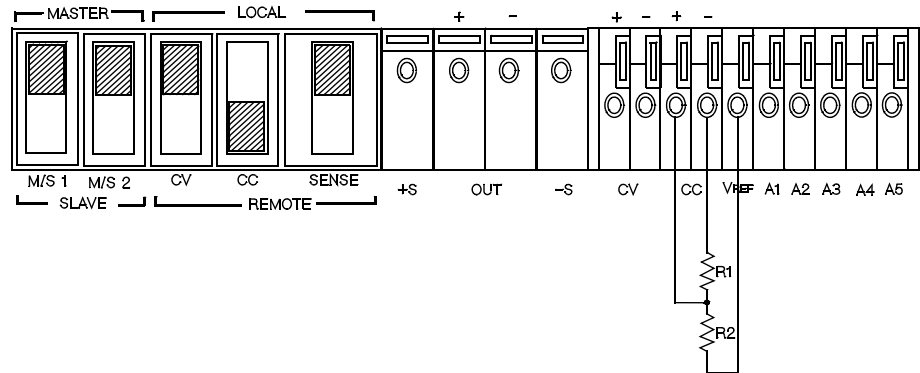
$$R = (92800 \times R_1)/(92800 + R_1)$$

$$R_1 + R_2 > 40 \text{ kohm}$$

Model	A
E3614A	0.8
E3515A	2.0
E3616A	3.5
E3617A	6.0



## Remote Resistor Programming, Constant Current



**Figure 8**

Set the CC switch down on the rear panel, and all others up.

$$I_{\text{out}} = A \times [V_{\text{REF}} \times \{R / (R + R2 + 100)\}]$$

Where  $I_{\text{out}}$  is the power supply output current.

A is the gain factor and the values of each model are as below.

$V_{\text{REF}}$  is between 10.11 V and 11.40 V.

$$R = (92800 \times R1) / (92800 + R1)$$

$$R1 + R2 \gg 40 \text{ kohm}$$

Model	A
E3614A	0.6
E3515A	0.3
E3616A	0.17
E3617A	0.1



## CERTIFICATION

*Agilent Technologies certifies that this product met its published specifications at time of shipment from the factory. Agilent Technologies further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology (formerly National Bureau of Standards), to the extent allowed by that organization's calibration facility, and to the calibration facilities of other International Standards Organization members.*

## WARRANTY

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

For warranty service, with the exception of warranty options, this product must be returned to a service facility designated by Agilent. Return to Englewood Colorado Service Center for repair in United States(1-800-258-5165). Customer shall prepay shipping charges by (and shall pay all duty and taxes) for products returned to Agilent for warranty service. Except for the products returned to Customer from another country, Agilent shall pay for return of products to Customer.

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

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

The warranty period begins on the date of delivery or on the date of installation if installed by Agilent.

## LIMITATION OF WARRANTY

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

*For consumer transactions in Australia and New Zealand:*

The warranty terms contained in this statement, except to the extent lawfully permitted, do not exclude, restrict or modify and are in addition to the mandatory rights applicable to the sale of this product to you.

## EXCLUSIVE REMEDIES

TO THE EXTENT ALLOWED BY LOCAL LAW, THE REMEDIES PROVIDED HEREIN ARE THE CUSTOMER'S SOLE AND EXCLUSIVE REMEDIES. AGILENT SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

## ASSISTANCE

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

# DECLARATION OF CONFORMITY

according to ISO/IEC Guide 22 and EN 45014

**Manufacturer's Name:** Agilent Technologies, Inc.

**Manufacturer's Address:** 345-15, Kasan-dong, Kumchon-ku,  
Seoul 153-023 Korea

**declares, that the products**

Product Name: DC Power Supply

Model Numbers: E3614A, E3615A, E3614A, E3615A, and E3617A

Product Options: All Options

**conforms to the following Product Specifications:**

Safety: IEC 1010-1:1990+A1:1992 / EN 61010-1:1993

EMC: CISPR 11:1990 / EN 55011:1991 - Group 1 Class A<sup>1)</sup>  
EN 50082-1:1992

IEC 801-2 : 1991 - 4KV CD, 8KV AD  
IEC 801-3 : 1984 - 3V/m  
IEC 801-4 : 1988 - 1kV Power Lines  
0.5kV Signal Lines

**Supplementary Information:** The product herewith comply with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC and carry the "CE" mark accordingly.

<sup>1)</sup>The products was tested in a typical configuration with Agilent Technologies Test System.

Seoul, Korea      November 1, 1999



Quality Manager

European Contact for regulatory topics only: Hewlett-Packard GmbH, HQ-TRE, Herrenberger Strabe 110-140,  
D-71034 Böblingen (FAX: +49-7031-143143).