DC POWER SUPPLY

SCR-3 SERIES, MODEL 6456B

SERIAL NUMBER PREFIX 5H

hp Stock Number: 06456-90001
Printed: May, 1967

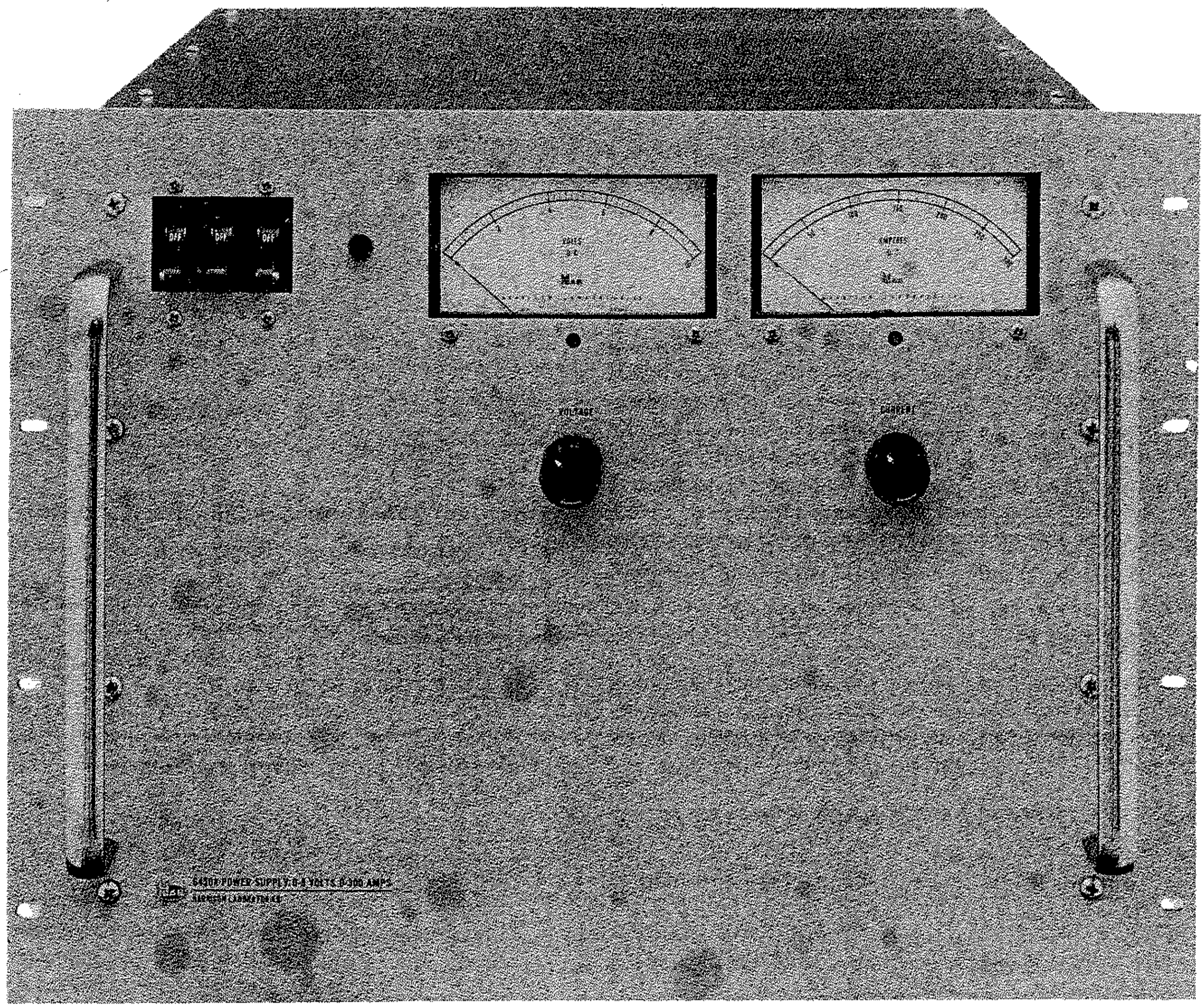


Figure 1-1. DC Power Supply, SCR-3 Series

SECTION I
GENERAL INFORMATION

1-1 DESCRIPTION

1-2 This power supply, Figure 1-1, is a completely transistorized, well-regulated, Constant Voltage/ Constant Current supply that will furnish full rated output voltage at the maximum rated output current or can be continuously adjusted throughout the output range. The front panel CURRENT controls can be used to establish the output current limit (overload or short circuit) when the supply is used as a constant voltage source and the VOLTAGE controls can be used to establish the voltage limit (ceiling) when the supply is used as a constant current source.

1-3 Two meters measure load current and load voltage at the output terminals of the supply. Protection circuits incorporated in this supply are designed to protect the unit against overload conditions generated by the load device and failures in the input power line, while protection against failures in the internal main power mesh is accomplished by means of the three phase circuit breaker on the front panel. The breaker also serves as the on-off switch for the supply.

1-4 Input power is connected by means of a four-prong lock type connector at the rear of the unit. Output power connections and programming connections for the various modes of operation are also made at rear of the unit. The output terminals consist of heavy bus bar connected directly to the output capacitors for improved high frequency performance.

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

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

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

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

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

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

1-6 COOLING EQUIPMENT

1-7 The operation of this unit under high load conditions requires that air be circulated through a compartment containing the heat-producing elements in the circuit. This circulation is by means of fans located in the compartment with air flowing from one side of the unit to the other. Maintenance procedures concerning this cooling system will be found in the maintenance section.

1-8 Detailed Specifications for the power supply are given in Table 1-1.

1-9 INSTRUMENT IDENTIFICATION

1-10 Hewlett-Packard power supplies are identified by a three-part serial number tag. The first part is the power supply model number. The second part is the serial number prefix, which consists of a number-letter combination that denotes the date of a significant design change. The number designates the year, and the letter A through L designates the month, January through December respectively. The third part is the power supply serial number.

1-11 If the serial number prefix on your power supply does not agree with the prefix on the title page of this manual, change sheets are included to update the manual. Where applicable, backdating information is given in an appendix at the rear of the manual.

1-12 ORDERING ADDITIONAL MANUALS

1-13 One manual is shipped with each power supply. Additional manuals may be purchased from your local Hewlett-Packard field office (see list at rear of this manual for addresses). Specify the model number, serial number prefix, and ⓗⓟ stock number provided on the title page.

Table 1-1. Specifications

INPUT:
208/230/460Vac ±10%, 60Hz, three phase. (Instructions are included for wiring for 230 or 208Vac, or unit may be ordered in original purchase contract to be wired for 460Vac.)

OUTPUT: 0-36Vdc, 0-100Adc.

COMBINED LINE AND LOAD REGULATION:
Constant Voltage - Less than 0.2% plus 10mV for a full load to no load change in output current combined with a ±10% change in line voltage.
Constant Current - Less than 1% or 1 amp whichever is greater for a full change in output voltage combined with a ±10% change in line voltage.

RIPPLE AND NOISE:
Less than ½% rms of maximum output voltage for any combination of line voltage, output voltage, and load current.

TRANSIENT RECOVERY TIME:
Less than 50 milliseconds is required for output voltage recovery to within 300 millivolts of the nominal output voltage following a load change from full load to half load or half load to full load.

OPERATING TEMPERATURE RANGE: 0 to 50°C.

TEMPERATURE COEFFICIENT:
Output voltage change per degree Centigrade is less than 0.05% plus 2 millivolts.

STABILITY:
As a constant voltage source the total drift for 8 hours (after 30 minutes warm-up) at a constant ambient is less than 0.25% plus 10 millivolts.

OVERLOAD PROTECTION:
The supply is protected for all overload conditions, including a short circuit at the output terminals. This protection is inherent in the constant voltage/constant current automatic crossover operation. The current control acts as a continuously acting limit in constant voltage operation and the voltage control acts as a voltage limit in constant current operation.

AC LINE DROPOUT PROTECTION:
Protection is provided against an input ac line phase dropout. The supply senses the reduction of input voltage, turns off the rectifiers, and opens a power relay which isolates the output power bus. When the input returns to normal, output power is automatically reapplied to the load.

CONTROLS:
A single control makes possible continuous adjustment of the output voltage over the entire range from 0 to 32 volts. The current control knob permits adjustment for maximum output current to the optimum value for protection of the load device. In addition, this latter control serves as the output control for constant current operation. The three phase circuit breaker serves as the ON-OFF control and as secondary protection to the instrument.

METERS:
A 0-40V voltmeter and 0-100A ammeter are provided on the front panel. Internal meter calibration potentiometers are provided.

TERMINALS:
Output power connections are made on two tapped rectangular bus bars located at the rear of the supply. Both power supply output terminals are isolated from the chassis and either the positive or negative terminal may be connected to chassis ground. The upper bus bar is positive.

ERROR SENSING:
Remote error sensing can be accomplished from the rear programming strip.

REMOTE PROGRAMMING:
Remote programming terminals make possible external control of the output voltage or current by resistance programming or voltage programming. Resistance programming in constant voltage is approximately 200 ohms per volt. Resistance programming in constant current is approximately two ohms per ampere.

COOLING:
Internal fans provide forced air cooling of heat producing components.

SIZE:
14" H x 18¼" D x 19" W (standard relay rack mounting).

WEIGHT: 238 lbs. net, 275 lbs. shipping.

FINISH: Light gray front panel with dark gray case.

SECTION II
INSTALLATION

2-1 INITIAL INSPECTION

2-2 Inspect the instrument for signs of damage incurred in shipment. This instrument should be tested as soon as it is received. If it fails to operate properly or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent and this report should be forwarded to your local ⓗⓟ Sales Office (refer to list at rear of manual). The sales office will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument.

2-3 Hewlett-Packard warrants each instrument to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing and adjusting any instrument returned to the factory for that purpose and to replacing any defective parts thereof. Any damage to the instrument upon receipt is due to the carrier. File a claim with the carrier as instructed in the preceding paragraph.

2-4 INCOMING INSPECTION AND PERFORMANCE TEST

2-5 This instrument should be checked as soon as it is received to determine that its electrical characteristics have not been damaged in shipment. Refer to Section V for the performance test.

2-6 LOCATION

2-7 The SCR-3 Series should be mounted securely in a rack. In environments of vibration the rear of the chassis should also be fastened securely. There should be sufficient space along the sides of the instrument to permit free flow of cooling air. This instrument will fit any standard 19 inch rack. If the rack is not accessible from the rear, plug the power cable into the input power receptacle, connect the load leads to the output terminals, and make any changes in the programming terminal strip that may be necessary before sliding the instrument into the rack. (If the rack is accessible from the rear, these connections may be made at any time.) Secure the instrument to the rack with screws and cup washers. Connect the power cable to the power source.

2-8 LINE POWER

2-9 Because of the variety of line power connectors for three phase power sources, a power cord is not supplied but a twist lock type of connector that mates to the input power receptacle on the unit will be shipped with each new unit. The power cord and the plug for connection to the power source will be supplied by the buyer. Input line current is 15A maximum for a 208Vac line, dictating each conductor be at least number 14 gauge wire.

2-10 The ac power source to this supply may be either delta or wye with isolated neutral.

2-11 The SCR-3 Series as shipped, are wired for 230 volts ac ±10%, three phase, 60Hz. 208Vac ±10%, three phase, 60Hz may be accommodated by changing the strapping configuration on the input transformer. Refer to Section V for details on this change. The unit can be wired by the factory for 208Vac, or 460Vac ±10% 60Hz, when specifically requested by the buyer in his original purchase contract.

2-12 REPACKAGING FOR SHIPMENT

2-13 The best method of packing the instrument is in the original shipping carton with the original fillers packed in the same manner as received from the factory. Therefore, when unpacking note carefully the method of packing and save the original packing material for possible future reuse.

2-14 If the original packing material is not available and it is desired to pack the instrument for storage or shipment, first wrap the instrument in heavy kraft paper to avoid scratching the paint, then pack the instrument in a cardboard carton with a bursting strength of at least 150 pounds per square inch. Pad the instrument on all sides with at least two inches of rubberized hair. Enclose the cardboard carton in a floating base type wooden carton and strap the carton securely to the base. Provide at least two inches of rubberized hair around the four sides of the box and between the box and the top of the crate.

2-15 STORAGE

2-16 No special precautions are necessary in storage of this unit except the usual protection against mechanical damage, salt air, etc.

SECTION III
OPERATING INSTRUCTIONS

3-1 PRELIMINARY CONSIDERATIONS

3-2 Check the strapping pattern on the rear terminals for the proper connection of the rear. Make **sure that all binding head machine screws on the rear barrier strip are tight. Many troubles can arise if these straps are not making connection.** Determine the type of operation as shown in Figures 3-1 through 3-12 and make certain that the rear barrier strip straps are connected for the operation desired. The power supply as furnished from the factory has a strapping arrangement as shown in Figure 3-1.

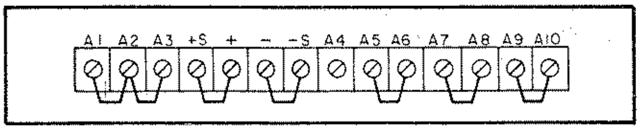


Figure 3-1. Normal Strapping Pattern

3-3 CONNECTIONS TO LOAD

3-4 Load is applied to rectangular bus bars at the rear. The upper bus is positive.

3-5 Sensing is accomplished at rear terminals of the power supply as shipped from the factory. The user should be cognizant of the voltage drop which will occur in load leads, and minimize the drop by using large size cable and minimizing the lead length to the load. Regulation at the load can be maintained within the specifications of the power supply by using remote sensing as described in this section of the manual.

3-6 CONSTANT CURRENT

3-7 The constant current circuit in the SCR-3 series serves two purposes. It protects the power supply and load, and it allows the supply to act as a constant current power source. If only a coarse current limit is required, the current control knob can be set somewhat above the point at which the supply will switch into constant current operation and be controlled by the current knob. In instances where the current limit need be set more precisely, the following procedure should be followed:

a. Turn the VOLTAGE and CURRENT controls full counterclockwise.

b. Place a short circuit across the output terminals of the supply.

c. Slowly rotate the VOLTAGE control clockwise about one-half turn.

d. Bring up the CURRENT control until the output current as read on the front panel meter reads the desired value of current.

e. Rotate the VOLTAGE control counterclockwise, remove the short circuit, reapply the normal load, and adjust the output voltage to the desired setting.

3-8 When operating in the constant current mode, the voltage control can be adjusted for overvoltage protection.

3-9 REMOTE SENSING (See Figure 3-2)

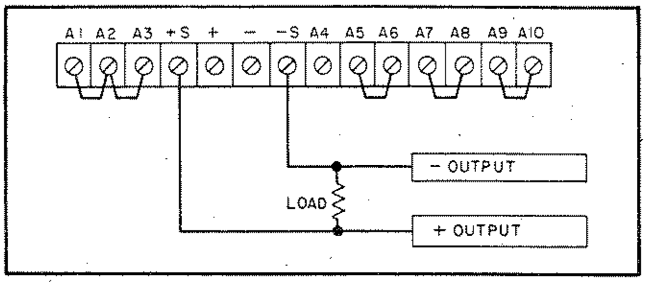


Figure 3-2. Remote Sensing

3-10 In cases where the load device is remote from the power supply, resulting in poor load regulation at the load terminals, remote sensing can be used. As shipped, the power supply senses the output voltage at the output terminals of the supply and any IR drop in the leads between the power supply and the load causes a consequent degradation of the regulation at the load terminals. By sensing the output voltage at the load device terminals, these IR drops are effectively eliminated. The procedure for sensing the load at a remote location is as follows:

a. Turn off the front panel circuit breaker and remove the power cord from the power source.

b. On the barrier terminal strip on the rear of the unit remove jumpers (+S to +) and (-S to -).

c. Connect a pair of leads (#20 gauge wire) between +S and the positive terminal of the remote load and between the -S terminal of the supply and the negative terminal of the remote load.

d. Reconnect the ac power and turn on the power supply.

NOTE

The maximum IR drop that can be contained in the negative bus by means of remote sensing is one volt.

3-11 Although the use of remote sensing improves the dc load regulation at the load, it is important to note that the ac impedance at the load terminals is no better than it was with local sensing. In order to bring about an improvement in the ac impedance, it is advisable to place a large electrolytic capacitor across the terminals of the remote load.

3-12 REMOTE PROGRAMMING-CONSTANT VOLTAGE

3-13 The power supply may be programmed from a remote location by means of an external resistance or an external voltage. It is necessary to change the strapping pattern on the barrier strip at the rear.

3-14 Resistance Programming (See Figure 3-3).

a. A stable, low noise, low temperature coefficient programming resistor is recommended.

b. The programming resistor takes the place of the front panel potentiometer.

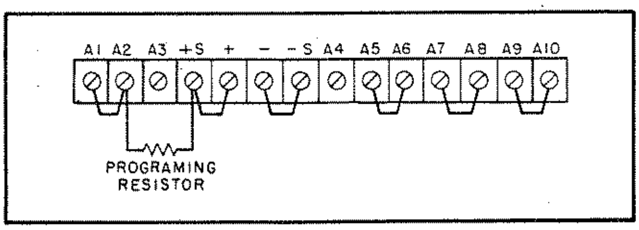


Figure 3-3. Remote Resistance Programming (Constant Voltage)

c. The output voltage will vary at a rate determined by the programming coefficient - 200 ohms per volt (i.e., the output voltage will vary 1 volt for each 200 ohms connected across the programming terminals). The programming coefficient is determined by the programming current. The current is adjusted to within 0.5% of 5.0 milliamperes at the factory. If greater programming accuracy is required, it may be achieved by changing the shunt resistor, R8.

3-15 Voltage Programming (See Figure 3-4).

a. A stable, low noise, low temperature coefficient programming resistor is recommended.

b. R_r = 1.2K. Resistor Rp need not be used if the front panel C.V. potentiometer is left connected and set as follows:

Model	6450A	6453A	6456B	6459A
R_p	1.6K	3K	6.8K	1.2K

c. The output voltage will vary linearly as

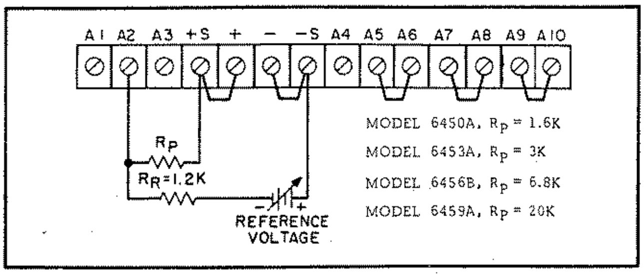


Figure 3-4. Remote Voltage Programming (Constant Voltage)

the reference voltage is changed.

d. The reference voltage in going from zero to -6 volts will change the supply output voltage from zero to the maximum rated output voltage. The maximum load on the reference voltage will be 5mA.

3-16 REMOTE PROGRAMMING-CONSTANT CURRENT

3-17 The power supply may be programmed from a remote location by means of an external resistance or an external voltage. It is necessary to change the strapping pattern on the barrier strip at the rear.

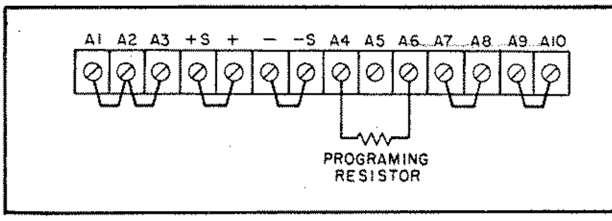


Figure 3-5. Remote Resistance Programming (Constant Current)

3-18 Resistance Programming (See Figure 3-5).

a. A stable, low noise, low temperature coefficient programming resistor is recommended.

b. The programming resistor takes the place of the front panel potentiometer.

c. The output current will vary at a rate determined by the programming coefficient-approximately two ohms per ampere (i.e., the output current will vary one amp for each two ohms connected across the programming terminals). The programming coefficient is determined by the programming current. As a protection feature, the actual programming current has been set by the factory by turning the front panel current control potentiometer (250Ω) full cw and adjusting shunt R22 for a maximum current limit of 10% over the maximum rated output current. This ratio, taking into account the offset voltage of the constant current differential amplifier, sets the coefficient at approximately two ohms per amp. If greater programming accuracy is required, it may be achieved by reshunting R22 terminals.

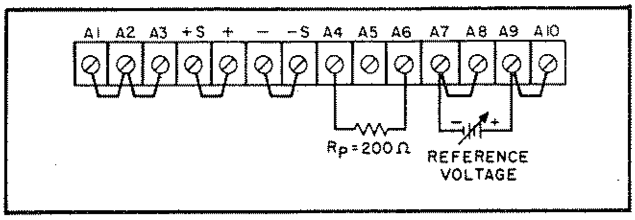


Figure 3-6. Remote Voltage Programming (Constant Current)

3-19 Voltage Programming (See Figure 3-6).

a. A stable, low noise, low temperature coefficient programming resistor is recommended.

b. Rp = 200 ohms or this resistor need not be used if the front panel current potentiometer is left connected and set maximum cw.

c. The output current will vary linearly as the reference voltage is changed.

d. For Rp = 200 ohms; the reference voltage in going from zero to +6 volts will change the supply output current from zero to the maximum rated output current. The maximum load on the reference voltage will be 1.8 milliamperes.

3-20 AUTO-SERIES

3-21 For higher voltages, two or more SCR-3's may be stacked with the positive bus of one tied to the negative bus of the next. Control of all supplies by a single voltage control is enabled by the addition of one control lead, as shown in Figure 3-7.

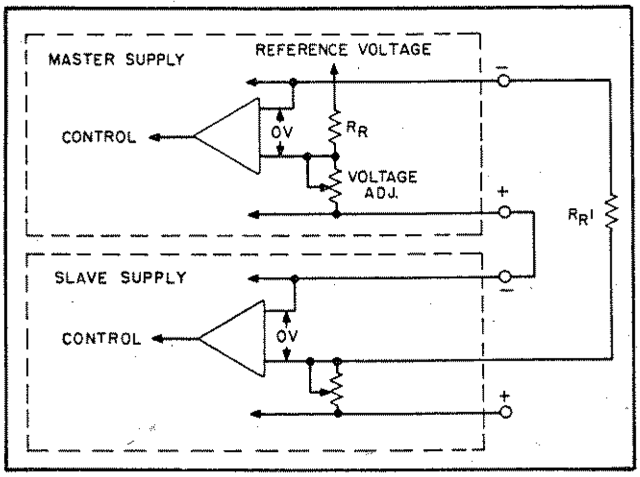


Figure 3-7. Auto-Series Schematic Diagram

With this connection, the "master" supply becomes the reference voltage for the others, which have had their internal voltage references disconnected (a new fixed resistor is added). The slave supplies, set individually to any voltage, will track the master voltage proportionally.

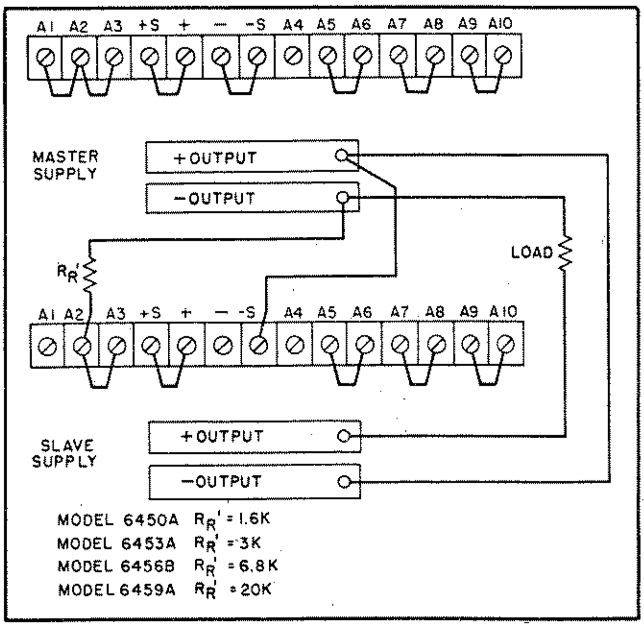


Figure 3-8. Auto-Series Connection Diagram

3-22 Wiring instructions for the connection of two supplies are illustrated in Figure 3-8. The VOLTAGE control of the slave must be set off zero at all times.

3-23 Where one load is connected across the out put of series connected units (either end of the ensemble grounded), the current limit of the master should be used to control the current limit point of the ensemble. With the configuration providing dual voltages to independent loads, each unit has its own current limit point as programmed at the front panel CURRENT control but the output voltage of the slave will be proportional to the master output voltage.

3-24 The load regulation and line regulation characteristics of two or more supplies connected in series will be approximately the sum of the figures for each unit in the ensemble. Transient response should be approximately that of a single unit (50 milliseconds for a change in load from one half to full load).

3-25 AUTO-PARALLEL

3-26 Two or more power supplies may be connected in parallel for higher load current requirements with control of the output voltage and current retained in one of the units (master). In this configuration the maximum current capabilities of the ensemble is within 10% of the sum of the maximum current capabilities of the units so connected. The constant current differential amplifiers of the slave supplies are disconnected from their own references and re-

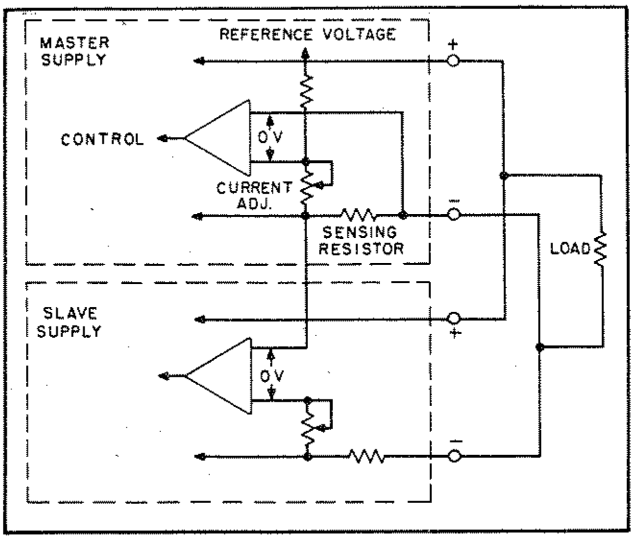


Figure 3-9. Auto-Parallel Schematic Diagram

connected as shown in Figure 3-9. Each slave differential amplifier adjusts its current output so the voltage drop across its current monitoring resistor matches that across the current monitoring resistor of the master supply. Wiring instructions for the connection of two supplies are illustrated in Figure 3-10.

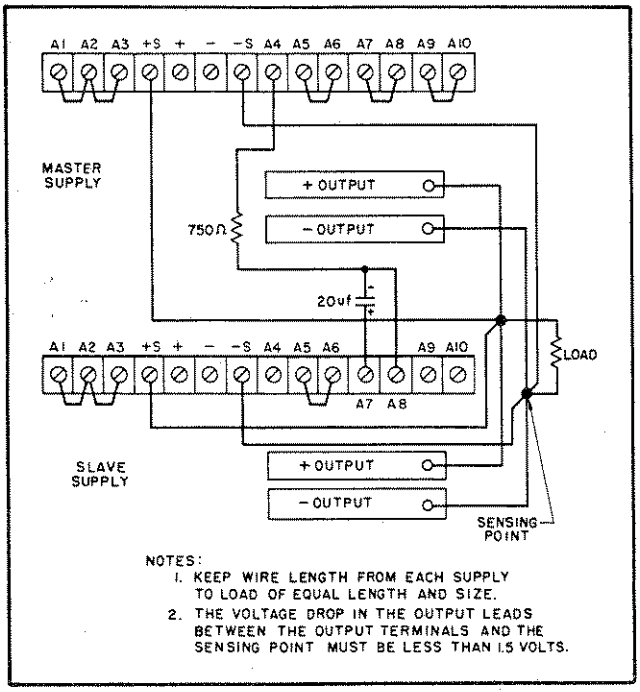


Figure 3-10. Auto-Parallel Connection Diagram

3-27 BATTERY CHARGING

3-28 The automatic transition between constant voltage and constant current displayed by the SCR-3 Series makes it an ideal supply for battery charging applications. Using this feature, a battery may be charged at a constant current until the maximum charge voltage is reached at which point the supply will revert to constant voltage and continue to supply a trickle charge current sufficient to maintain full charge (see Figure 3-11). Thus, the charging operation can be unattended after properly setting the charging rate and the maximum charge voltage and connecting the battery to the output terminals of the supply.

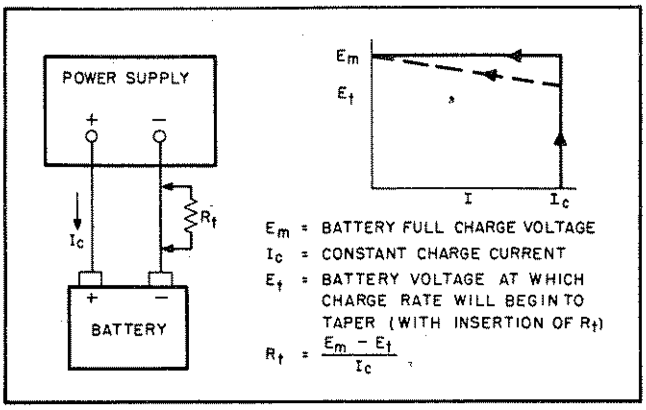


Figure 3-11. Battery Charging Connections

3-29 The procedure for setting the charging rate and full charge voltage on the SCR-3 Series is as follows:

a. Turn both the VOLTAGE and CURRENT controls fully counterclockwise.

b. Place a short circuit across the output terminals and rotate the VOLTAGE control one half turn clockwise.

c. Rotate the CURRENT control to the desired charging rate as read on the front panel ammeter.

d. Rotate the VOLTAGE control fully counterclockwise and remove the short circuit.

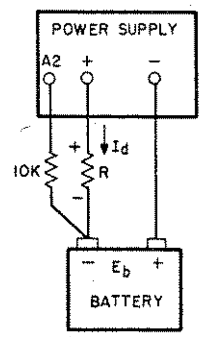
e. Rotate the VOLTAGE control to the desired full charge voltage as read on either the front panel voltmeter or a more precise voltage standard. The unit may then be connected to the battery terminals, positive to positive and negative to negative.

3-30 By inserting a small resistance in series with one of the load leads from the supply to the battery, it is possible to alter the normally rectangular charging plot (Figure 3-12) in such a manner as to provide a taper charge for the last portion of the charge cycle. The value of this resistance is the difference between the full charge voltage and the voltage at which the tapering is to start, divided by the maximum charging current.

3-31 A large battery connected across the supply, presents a very large capacitance at the output. This can cause oscillation in the feedback loop; particularly if remote sensing is employed. To stabilize the feedback loop, adjust potentiometer R10 so as to increase its resistance. If this does not suffice, a resistance must be inserted in series with R10. Further details concerning battery charging applications can be obtained by contacting the factory.

3-32 <u>BATTERY DISCHARGING</u>

3-33 Automatic constant current, unattended discharging of a battery using the SCR-3 Series requires certain changes in the strapping configuration on the rear barrier strip as illustrated in Figure 3-12.



REMOVE JUMPERS A1 TO A2, A2 TO A3

I_d = DISCHARGE CURRENT

$R = \frac{E_b}{I_d}$ BUT $RI_d \leq$ "X"

MODEL	"X"
6450A	8V
6453A	15V
6456B	32V
6459A	64V

Figure 3-12. Battery Discharging Connections

These changes are the removal of the jumpers from A1 to A2 and from A2 to A3 and the connection of A2 to the negative terminal of the battery through a 10K resistor. Make sure that the interconnecting leads between supply and battery are secure and cannot become opened.

3-34 The supply initially operates in constant current mode at the value set by the current control. When the battery voltage is high the supply output voltage will be low, and as the battery discharges the supply output voltage increases. A constant voltage is maintained across R (constant current through R). This condition will prevail until the battery voltage drops to zero. At this point, the supply will switch off and no more current will flow through R.

3-35 The procedure for the connection of the components in this configuration is as follows:

a. De-energize the power supply and rotate the current control fully counterclockwise. (The voltage control will be disconnected by step b.)

b. Remove the designated jumpers (A1 to A2, A2 to A3) and connect A2 to the negative terminal of the battery.

c. Connect the negative terminal of the supply to the positive terminal of the battery.

d. Insert R between the positive terminal of the supply and the negative terminal of the battery, energize the supply and rotate the current control to the desired discharge current as read on the front panel meter.

3-36 <u>MULTIPLE LOADING OF A POWER SUPPLY</u>

3-37 It is imperative that each load have two separate leads brought directly back to the power supply terminal when connecting several pieces of equipment or subassemblies to the same power supply if full advantage is to be taken of the low impedance of the supply and mutual coupling effects between the equipment being powered are to be avoided.

3-38 <u>AUTOMATIC CROSSOVER</u>

3-39 There will be a time during which both the constant voltage input transistor and the constant current input transistor will be conducting. This will occur when the power supply has been operating in the constant voltage mode of operation and is overloaded or when the power supply has been operating in the constant current mode and the load is changed so that the output voltage reaches the voltage ceiling threshold. When operating in this crossover region, the regulation of the principal mode can be degraded. To prevent this, the control should be set to provide a margin of operation.

3-40 The current threshold should be greater than the maximum load current when operating in the constant voltage mode of operation as follows:

<u>Model</u>	6450A	6453A	6456B	6459A
Amperes	25	15	10	5

3-41 The voltage threshold (open circuit voltage) should be greater than the maximum operating output voltage when operating in the constant current mode of operation as follows:

<u>Model</u>	6450A	6453A	6456B	6459A
Volts	0.5	1	2	4

3-42 <u>MEASURING THE PERFORMANCE OF THE POWER SUPPLY</u>

3-43 The measuring device (differential voltmeter, digital voltmeter, or oscilloscope) must be connected to the output terminals as close as possible to the supply when measuring the output impedance, transient response, regulation, or ripple of the power supply in order to achieve valid measurements. It is important that none of the output current flows through the lead lengths in series with the monitoring device since such lead lengths can easily have an impedance of the same order of magnitude as the supply impedance and thus effectively invalidate the measurement.

3-44 Connect either the positive or negative terminal of the supply to the chassis ground and the scope case to the same point, making certain that the scope case is not also grounded by some other means such as the power cord when measuring the power supply ripple. Connect both scope leads simultaneously to the power supply ground terminal to be doubly certain that the scope is not exhibiting a ripple or transient spike that is not coming from the power supply.

3-45 It is recommended that a four-terminal resistor be used to make constant current measurements.

SECTION IV
PRINCIPLES OF OPERATION

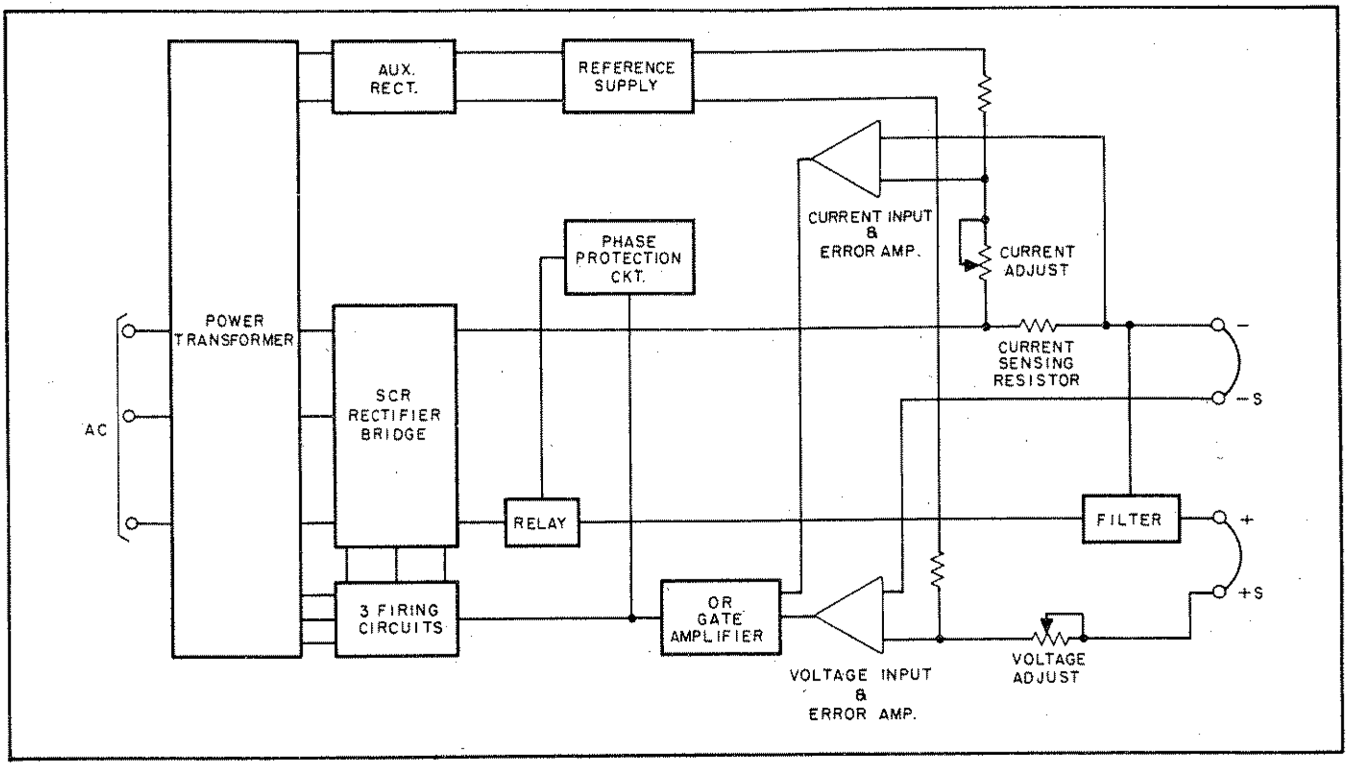


Figure 4-1. Overall Block Diagram

4-1 BLOCK DIAGRAM

4-2 The block diagram, Figure 4-1, shows the basic parts of the power supply. The line voltage is transformed by the three phase power transformer to the bridge rectifier circuit containing both fixed rectifiers and silicon-controlled rectifiers. The SCR turn-on firings are controlled in such a manner as to supply the desired output voltage and current. Separate windings on the power transformer furnish three phase voltage to the auxiliary rectifier for the bias supply and furnish three phase voltage for the three firing circuits to operate on.

4-3 The dc current passes through the current sensing resistor connected in the negative bus. The voltage developed across the sensing resistor is the input to the current input amplifier. The output voltage of the power supply is monitored by the voltage input amplifier through the sensing terminals (+S and -S). Any changes in output voltage/current are detected in the constant voltage/current input amplifier, passed through the "OR" gate, and applied to the firing circuits. The firing circuits control the SCR firing to counteract the change.

4-4 The "OR" gate implements the constant voltage/constant current crossover operation of the supply. It allows one or the other amplifier signal to pass and control the loop but not both at once. The more restrictive signal, demanding less power output, is the controlling signal.

4-5 SIMPLIFIED SCHEMATIC

4-6 The simplified schematic, Figure 4-2, shows the various voltages used throughout the supply. The ammeter location, across the current sensing resistor R96, and the voltmeter location, across the output terminals of the power supply are shown. C12-C17, across the output, are the filter capacitors and, together with choke L1, form the power filter. CR10 is a (F.W.D.) free wheeling diode acting in conjunction with the choke. Also, it protects the power supply if a reverse voltage is applied across the output terminals.

4-7 R97, R98, and CR61 function as a voltage ceiling circuit. When the output voltage at the positive terminal reaches the ceiling level, CR61 turns on, introducing a positive hold signal to the

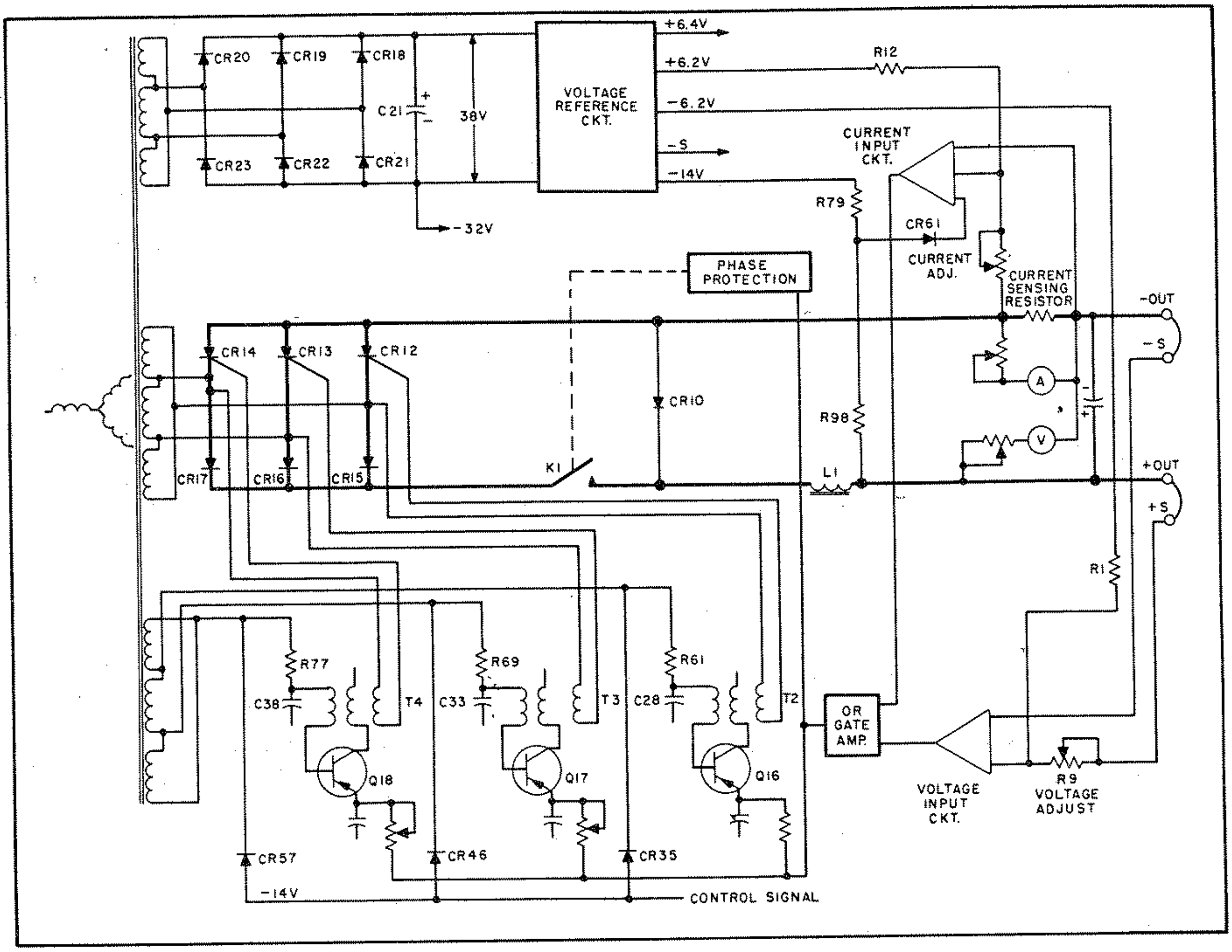


Figure 4-2. Simplified Schematic

current input amplifier. Another protection feature is the phase protection circuit which stops operation if an input ac line phase opens or the line voltage drops below normal. The circuit samples the three input phases (from three diodes not shown in the simplified schematic) and in the event of failure turns off the control signal to the firing circuits and then opens power relay K1. When the input returns to normal, the relay is closed and firing pulses resume.

4-8 The function of the constant voltage input differential amplifier is to compare the reference voltage with the output voltage and to generate a correction signal if the output deviates from its prescribed value. One input to the amplifier is grounded to the negative output terminal -S while the other input is the summing point of output voltage and the -6.2Vdc reference voltage. When no error exists zero volts is maintained between the amplifier input terminals. Any change in output voltage, whether it is due to a change in the setting of the front panel potentiometer or perhaps due to a change in load current tends to produce a voltage other than zero at this second input terminal. Feedback loop action thereafter is such as to reduce this error to zero.

4-9 The action of the constant current input amplifier is similar to the constant voltage amplifier. The current sensing resistor, which monitors the output current, is a strip resistor located in the air blast alongside the main heat sink. Four terminal connections are made to it, one sensing terminal constituting the reference for the constant current loop, the other the signal terminal going to the amplifier.

4-10 The three firing circuits receive the output of the OR-gate amplifier, mix this with an ac bias provided by the bias transformer windings, (this allows instantaneous correction for changes in line voltage) and generate firing pulses that turn on the silicon-controlled rectifiers in their respective phases at the precise time necessary to fulfill the feedback loop requirements. As can be seen in

Figure 4-2, everything is done in triplicate. For each phase there is a transistor blocking oscillator with the third winding of the blocking oscillator transformer providing the gate pulse to the SCR gate leads. The three bias transformer windings are delta connected and the leads brought out to diodes CR35, CR46, and CR57. These diodes perform half wave rectification of the ac voltage. Thus, the voltage waveforms to input resistors R61, R69, and R77 are the same phase and shape as the waveforms across the SCR's in the main rectifying bridge.

4-11 MAIN RECTIFYING AND FILTERING CIRCUITS (See schematic at rear of manual)

4-12 Three phase 230Vac, 60Hz line voltage is connected to the primary of transformer T1 through a three phase common trip type circuit breaker which serves the dual function of ON/OFF control and protection against failure in the main power mesh. The wiring on the primary of the transformer may be changed to accommodate three phase 208Vac, or 460Vac as outlined in the maintenance section. The primary is Wye connected with isolated neutral. The 208Vac taps to neutral are used to power the fans and the front panel power indicator light. The three main secondary windings are delta connected to a three phase fullwave bridge consisting of three SCR's (CR12,13,14) and three fixed rectifiers (CR15, 16,17). The positive dc output side is the rectifier heat sink. The heat sink is cabled to the relay, then choke, and then to the filter capacitor bank + (C12-C17). The negative dc output side is the SCR heat sink. The sensing resistor is located on the heat sink as its output terminal, and from it cabling connects to -(C12-17). The firing angle of each SCR is controlled in such a manner as to fulfill the load conditions on the output terminals of the supply dictated by the output voltage/current setting and the load resistor. Resistor R60 provides a bleed path for the discharge of the filter capacitors at no load.

4-13 CR10 is the free wheeling diode (F. W. D.) rectifier. It has a reverse polarity rectifier case and is located in the SCR heat sink so its cathode can be connected after the relay on the positive output.

WARNING

Make sure replacement for CR10 is a **reverse polarity** rectifier.

4-14 The F. W. D. conducts, carrying the choke current, for the parts of each cycle when no SCR is conducting, and therefore conducts under every condition except full power output. Due to the action of choke and F. W. D., the SCR conduction angle, at short circuit full current output, is small and the input acrms line current is approximately one half that at full power. Also, CR10 protects the output capacitors in case a reverse voltage is applied on the output terminals. (Such a case can occur in auto-series operation when the slave unit is de-energized while the master unit is energized.)

4-15 REFERENCE CIRCUIT (See schematic at rear of manual)

4-16 Three phase fullwave bridge windings 3, 4 of transformer T1 provide power for the auxiliary and reference voltages. Diodes CR18 through CR23 and capacitor C21 provide an unregulated -32Vdc (test point 20). All voltages are measured with respect to -S. The positive side of this unregulated auxiliary voltage is returned to +6.4Vdc.

4-17 Resistors R49, R50, R51, Zener diode VR3 and transistor Q14 form a shunt regulator whose output is a -14Vdc (T. P. 12). In this configuration resistor R49 provides a constant bias current for VR3 (a 20 volt zener diode). Any voltage variation across the shunt regulator is transmitted via the low impedance of VR3 to the base of the transistor. Q14 changes its collector current which is reflected in a voltage change across R51, reducing the variation. R50 reduces the power dissipation of Q14. C20 reduces ripple and causes a slow buildup of the -14 volts at turn-on. The line regulation of this -14 volt source is approximately ±100 millivolts for an input line change of ±10%.

4-18 R48, two 6.2 volt zener diodes VR1 and VR2, and Q13 are connected in series from -14Vdc to +6.4Vdc. VR1 and VR2 produce the two reference voltages +6.2Vdc and -6.2Vdc. Any changes in the -14Vdc source are attenuated by the ratio of R48 to the forward impedance of the two diodes in series. Q13 acts as a shunt regulator for VR1, the base to emitter voltage and R47 determing the zener bias current. There is a large variation in the current returning through +6.4Vdc to -S from other parts of the circuit and this bypasses VR1 through Q13.

4-19 CONSTANT VOLTAGE INPUT AMPLIFIER (See schematic at rear of manual)

4-20 Transistors Q1 and Q2 form a differential amplifier for the purpose of error detection and amplification in the voltage mode. The inputs of this amplifier are the bases of the two transistors. The output is the collector of Q1. The base of Q2 is considered the reference base and is connected to -S through R5 to achieve good thermal compensation. R6, from the base to the -6.2Vdc reference voltage, provides a slight negative bias voltage at the base to insure that the output of the power supply is adjustable to zero volts. The base of Q1 is connected to summing point A2, which is the junction of current pullout resistor R1 and the front panel potentiometer R9. The control action continuously adjusts the output voltage on the positive bus to bring the voltage at A2 to the -S potential. With A2 held at the -S bus voltage, the voltage drop drop across R1 is the same as the reference voltage, and this voltage drop remains constant during operation. The current through R1, and thus through R9, likewise is held constant so that the IR voltage drop across R9 is determined solely by the resistance value of R9. Thus, the power supply output voltage is a linear function of the resistance of R9.

4-21 R2 in the base lead of Q1 limits the current through the programming resistance (pot) under conditions of rapid voltage turndown, and also isolates input and base for stabilizing the feedback loop. Diodes CR1 and CR2 limit voltage excursions on the base of Q1. Capacitor C1 bypasses the pot making the high frequency gain of the input circuit insensitive to pot setting. Capacitor C2 and adjustment pot R10 are located around the amplifier for loop stability.

4-22 <u>CONSTANT CURRENT INPUT AMPLIFIER</u>

4-23 Transistors Q4 and Q5 form a differential amplifier for the purpose of error detection and amplification in the current mode. The basic operation is the same as the constant voltage input amplifier. However, in the current case reference is with respect to the sensing terminal A7 of the sensing resistor R96. R20 at the base of Q5 is normally connected to this reference. The resistor R96 requires four terminals to keep the voltage drop along the internal connections of the power supply from the sensing resistor to (-) from contributing to the input signal. The following components of the constant current input amplifier have functions as described for the voltage input amplifier:

R19 - Positive offset bias to base of Q5.
CR5, CR6 - Protection diodes.
R13 - Current limiting.
C5 - Stability.
R24 - Stability adjustment.
R23 - Front panel current control pot.
R12 - Current pullout resistor; sets programming current.
R22 - Shunts R12; used for trimming adjustment.

4-24 Additional components are C4, CR4, and R14, and those associated with Q6. C4 reduces ripple voltage entering the amplifier. CR4 and R14 come from the Phase Protection Cutoff Circuit. Normally, the cathode of CR4 is +5.5Vdc so the diode is cut off. Upon a phase failure, however, the voltage drops to approximately -28Vdc at R14, CR4 turns on, and CR6 is clamped on by the 1mA current. This negative signal shunts the supply off via the constant current loop. Q6 supplies 1mA bias collector current to Q5 without shunting down the 47K load resistor R18. In this way, the dc gain of the constant current loop is increased. The bias current is fixed by the ratio of the forward voltage drop of CR7 and R17.

4-25 <u>"OR" GATE AMPLIFIER (See schematic at rear of manual)</u>

4-26 The OR gate receives signals from the two input amplifiers at the bases of Q8 and Q9. The most negative base signal tends to turn its transistor on harder. At the same time, the negative voltage is transmitted to the emitter and so to the emitter of the other transistor, turning it off. When the signal to either input amplifier increases above the level set by the control pot, the amplifier output moves negatively. This switches the OR gate and that amplifier controls the loop at its voltage/current setting.

4-27 The output of Q8/Q9 is amplified by Q10 to a suitable voltage level for controlling the firing circuits (T. P. 15):

Power supply OFF signal: Q10 saturated, -13Vdc
Power supply just ON: -10Vdc
Maximum power: +2Vdc

4-28 Diode CR9 at the emitter of Q10 provides 0.7Vdc bias voltage for the stage. Q11 is an emitter follower which transforms impedance so the firing circuit is driven from a voltage source.

4-29 An auxiliary feedback signal is connected from the input side of choke L1 (T. P. 14) to the base of Q10 via R28 and C8. Capacitor C9, to reference A7, performs three functions:

1. C9 reduces ripple appearing from the input L1;
2. C9 provides a frequency cutoff slope;
3. C9 causes a slow turn-on signal buildup to the firing circuits.

4-30 <u>SILICON-CONTROLLED RECTIFIER FIRING CIRCUITS (See schematic at rear of manual)</u>

4-31 GENERAL

4-32 The SCR is a solid state device which displays high impedance characteristics with either positive or negative voltage on its anode but which may be switched into a high conductance state when positive voltage is supplied to the anode simultaneously with a gate signal application between its gate lead and its cathode. The gate signal that is used to turn on the device in the SCR-3 Series is a positive going pulse of about 50μsec duration and whose amplitude is approximately 3.5 volts, this being the output of the blocking oscillator.