

OPERATING AND SERVICE MANUAL

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MODEL 6269A

DC POWER SUPPLY

MANUFACTURING CODE 6A



SPECIFICATIONS

Input: 187-230/207-253 VAC, single phase, 50-60 cps., line current 21/18 amperes.

Output: 0-40 volts @ 0-50 amperes.

Load Regulation: Constant Voltage -- Less than 0.01% plus 200 μ v for a full load change.

Constant Current -- Less than 0.02% plus 3 ma for a full load change.

Line Regulation: Constant Voltage -- Less than 0.01% plus 200 μ v for a change in line voltage from 187 to 230 volts (or 207 to 253 volts).

Constant Current -- Less than .02% plus 3 ma for a change in line voltage from 187 to 230 volts (or 207 to 253 volts).

Ripple and Noise: Constant Voltage -- Less than 1 mv rms.

Constant Current -- Less than 30 ma rms.

Maximum Operating Temperature: 50°C.

Temperature Coefficient: Output voltage change per degree Centigrade is less than .01% plus 200 μ v. Output current change per degree Centigrade is less than .01% plus 4 ma.

Stability: As a constant voltage source, the total drift for 8 hours (after a one hour warm-up) at a constant ambient is less than 0.03% plus 2 mv. As a constant current source, the total drift for 8 hours (after a one hour warm-up) at a constant ambient is less than .03% plus 10 ma.

Internal Impedance as a Constant Voltage Source:

Less than .001 ohms from DC to 100 cycles.

Less than .01 ohms from 100 cycles to 1 Kc.

Less than .2 ohms from 1 Kc to 100 Kc.

Less than 2 ohms from 100 Kc to 1 Mc.

Transient Recovery Time: Less than 150 microseconds is required for output voltage recovery (in constant voltage operation) to within 20 millivolts of the nominal output voltage following a half load change in output current. For this measurement, the nominal output voltage is defined as the mean between the no load and full load voltages.

Overload Protection: An all-electronic, continuously acting constant current circuit protects the power supply for all overloads, including a direct short placed across the output terminals. A front panel control permits continuous adjustment of the constant current value from 0 amps to 50 amps.

Controls: A single control makes possible continuous adjustment of the output voltage over the entire range from 0 to 40 volts. A vernier control is also provided. The current control permits adjustment of the output current to the optimum value for protection of the load device and serves as the output current control when the supply is used as a constant current source. A vernier current control is also provided.

Meters: A 50V voltmeter and a 0-60 ammeter are provided.

Output Terminals: The output terminal strip is located on the rear of the chassis. All power supply output terminals are isolated from the chassis, and either the positive or negative terminal must be connected to the chassis through a separate ground terminal located adjacent to the output terminals.

Remote Error Sensing: Error sensing is normally accomplished at the rear terminals if the load is attached to the rear terminals. Also, provision is included on the rear terminal strip for remote error sensing.

Remote Programming: Remote programming of the output voltage at 200 ohms/volts is made available on the rear terminal strip. Also, the output current may be remotely programmed at 4 ohms/amp.

Cooling: Forced air cooling is employed.

Size: 7" H x 16-3/4" D x 19" W (Standard Relay Rack Mounting).

Weight: 93 pounds net: shipping weight, 120 pounds.

Finish: Light gray front panel with dark gray case.

SECTION I.

1-1 GENERAL INFORMATION

1-2 The Harrison Division LVR Series are regulated constant voltage/constant current DC power supplies suitable for relay rack operation. These power supplies are completely transistorized general purpose power supplies. They are useful wherever continuously variable well-regulated DC power sources are required. The continuously variable current control may be used to set the maximum output current (overload or shortcircuit current) when the supply is used as a constant voltage source; or the voltage control may be used to set the maximum output voltage (voltage ceiling) when the power supply is used as a constant current source.

1-3 Front panel meters indicate the output current and voltage.

1-4 The power supply has rear output terminals. Power supply insulation permits it to be operated as high as 400 volts off ground, and either output terminal may be grounded.

1-5 There are a number of optional modes in which the power supply may be operated:

- A. Remote Programming
The power supply may be programmed from a remote location by means of an external voltage source of resistance.
- B. Remote Sensing
The degradation in regulation which will occur at the load because of the voltage drop occurring in the load may be ameliorated by using the power supply in the remote sensing mode of operation.
- C. Series Operation
Power supplies are used in series when a higher output voltage than the maximum output voltage of the power supply is required or greater voltage compliance is required when the power supply is used as a constant current source.
- D. Parallel Operation
This power supply may be operated in parallel with similar power supplies when a greater output current is required.

1-6 INSTRUMENT IDENTIFICATION

1-7 Harrison Division 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 power supply serial number; the third part is the Manufacturing Code Letter. The manual applies directly to all instruments which carry the same Manufacturing Code Letter as appears on the instruments which carry the same Manufacturing Code Letter as

appears on the Title Page of this manual. Revision Sheets will be supplied with this manual which will specify changes required to make the manual apply to units having a Manufacturing Code Letter other than that appearing on the Title Page.

1-8 COOLING SYSTEM

1-9 This power supply uses forced air cooling and requires no maintenance except for an occasional dusting. There should be sufficient space to the rear and along the sides of the instrument to permit free flow of cooling air.

SECTION II

2-1. INCOMING INSPECTION

2-2. The instrument should be unpacked and inspected both mechanically and electrically upon receipt. Observe packing method and retain packing materials until unit has been inspected. Mechanical inspection involves checking for signs of physical damage such as scratched panel surfaces, broken knobs, etc. If damage is apparent, file a claim with the carrier. The electrical inspection involves checking the instrument against its specifications. Section V includes a performance check which is an "in-cabinet" check to verify proper instrument operation (see paragraph 5-55). It is recommended as an incoming inspection test. Refer to the warranty page if there is an electrical malfunction.

2-3 INSTALLATION

2-4 The LVR series are shipped ready for relay rack mounting. It is necessary to connect the power cable to the POWER input barrier strip and the instrument is ready for operation.

2-5 This instrument uses force air cooling. Sufficient space to permit the flow of cooling air along the sides and to the rear of the instrument should be considered when installing. It should be used in an area where the ambient temperature does not exceed 50°C. (122°F).

2-6 POWER REQUIREMENTS

2-7 The all silicon LVR series can be operated from nominal 115V or 208/230 volts AC, 48 to 63 cps source. Units having a volt-ampere rating greater than 2,000 are operated from 208/230 volts AC. The power input requirements are given in the specification sheet. Units having a capacity greater than 2,000 VA are shipped from the factory normally wired for 230 volt operation. If the instrument is to be used on a 208 volt line, the following changes must be made.

- a. Unplug the line cord and remove top cover.
- b. Remove the hardware and wire from Tap 3 on the power transformer (T1).
- c. Reconnect hardware and wire to Tap 2 on transformer (T1).
- d. Change from Tap 4 to Tap 3 on transformer (T2).
- e. Replace top cover. Turn on instrument and operate normally.

2-8 Instruments which are not fan cooled and operating at frequencies other than 57-63 cycles have the following options:

- a. The instrument can be operated at frequencies ranging from 48 to 63 cycles without internal adjustment at a maximum ambient of 35°C.
- B. In order to maintain operation at a maximum ambient of 50°C, the internal adjustments outlined in Section 5-29 must be followed.

2-9 THREE-CONDUCTOR POWER CABLE

2-10 For the protection of operating personnel, the National Electrical Manufacturer's Association (NEMA) recommends that the instrument panel and cabinet be grounded. This instrument should be equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument.

2-11 REPACKAGING FOR SHIPMENT

2-12 The following list is a general guide for repackaging an instrument for shipment. If you have any questions, contact your local Hewlett-Packard field office (see list at rear of this manual for addresses).

- a. Use the original container designed for the instrument. If a new container is required, a foam pack and container can be ordered from Harrison Division. The stock number is given in the table of replaceable parts under miscellaneous.
- b. Wrap the instrument in heavy paper or plastic before placing it in the shipping container.
- c. Use plenty of packing material around all sides of the instrument and protect the panel with cardboard strips.
- d. Use heavy cardboard carton or wooden box to house the instrument and use heavy tape or metal bands to seal the container.
- e. Mark the packing box with "Fragile--Delicate Instrument," etc.

NOTE

If the instrument is to be shipped to Hewlett-Packard for service or repair, attach to the instrument a tag identifying the owner and indicating the service or repair to be accomplished. In any correspondence be sure to identify the instrument by model number and serial number.

SECTION III.

OPERATION

3-1 OPERATING CONTROLS

3-2 Controls and indicators and their functions are shown in Figure 3-1.

3-3 PRELIMINARY CONSIDERATIONS

3-4 Check strapping pattern on rear terminals of the unit. (See Figure 3-2.) The power supply as shipped from the factory is strapped for local programming, local sensing as indicated on the rear of the unit. It will be necessary to change the strapping pattern if the power supply is used in some other mode. Wiring instructions for other operating configurations are outlined later in this section.

3-5 CONNECTIONS TO LOAD

3-6 The load is connected to the rear output terminals of the power supply. The leads should be twisted or shielded if they are run past a source of interference.

3-7 Sensing is automatically accomplished at the rear terminals of the power supply as shipped from the factory. The user should realize that the specifications describing the electrical characteristics of the power supply are written for measurements made on the sensing terminals of the power supply. The user should be cognizant of the voltage drop which will occur in the load leads. For example, if two amperes flows through #16 stranded wire, the drop in the leads will be approximately 8 mv per foot. This drop can be minimized by using a larger size wire 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.

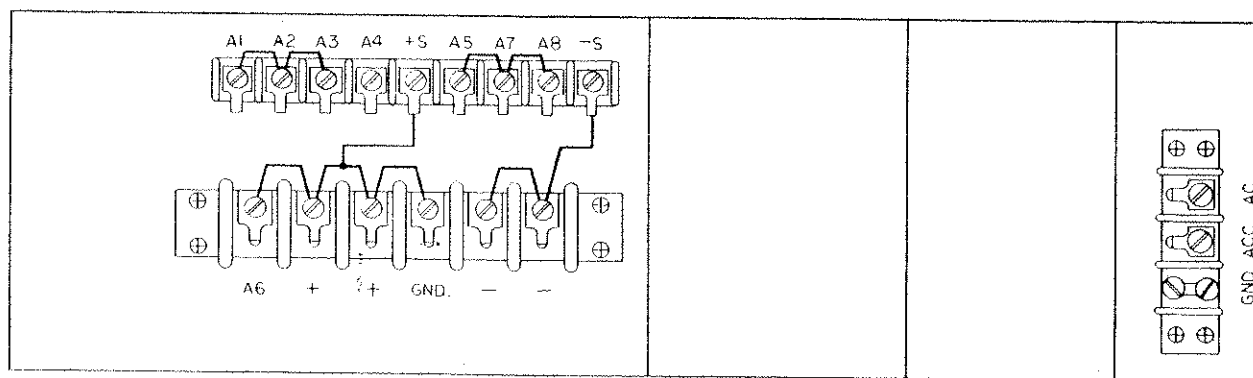
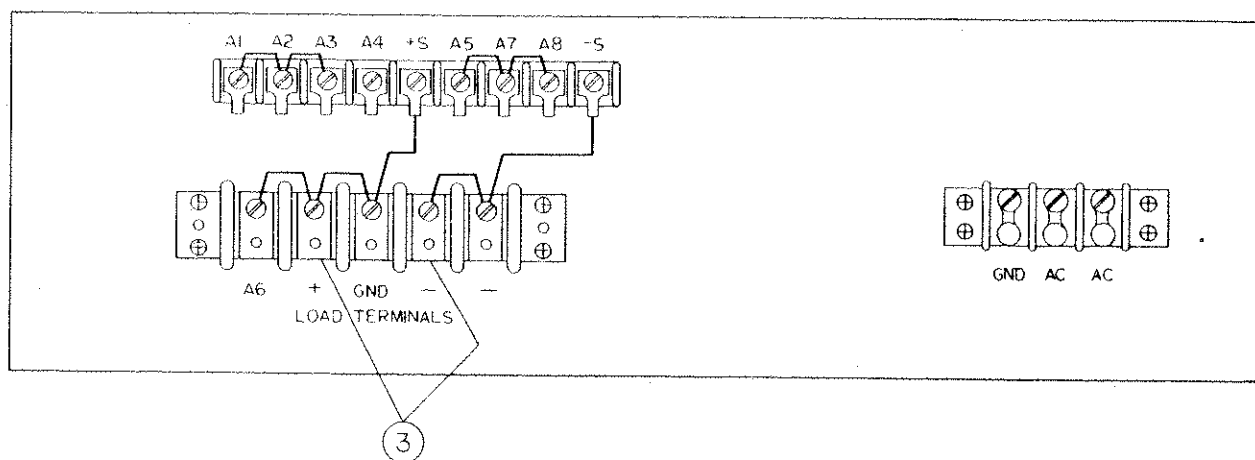
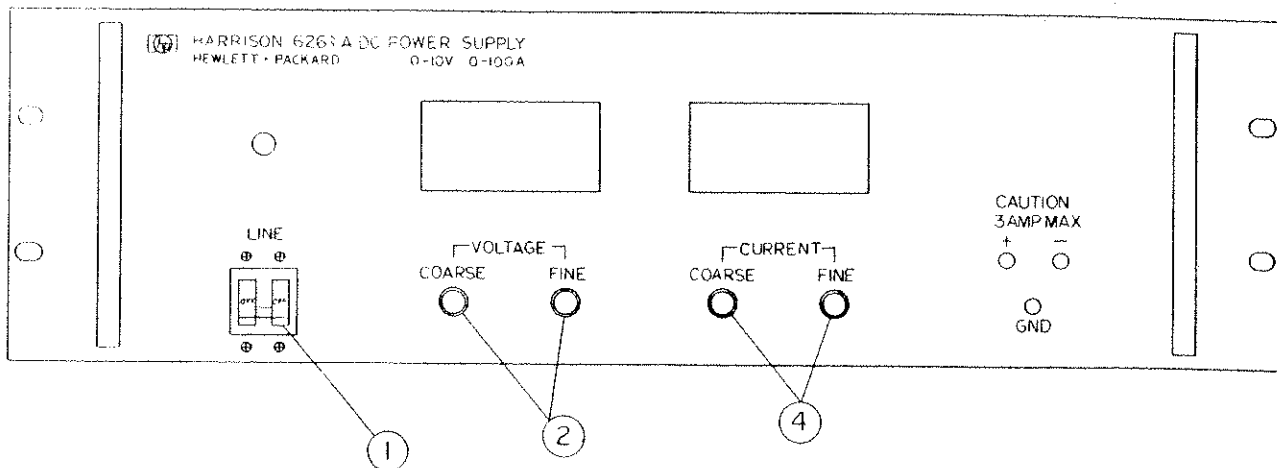
3-8 OPERATING PROCEDURE

3-9 The step-by-step operating procedure for the instrument is outlined in Figure 3-1. The steps are keyed to controls and indicators on the figure.

3-10 REMOTE PROGRAMMING -- CONSTANT VOLTAGE

3-11 The power supply may be programmed from the remote location by means of an external voltage source or a resistance. It is necessary to change the strapping pattern on the barrier strip on the rear panel. The front panel is disabled when the following remote programming procedures are followed.

- a. Resistance Programming (See Figure 3-5A)
 - (1) Stable, low noise, low temperature coefficient (less than 30 ppm per degree Centigrade) programming resistors should be used.



1. TURN AC POWER ON.
2. ADJUST COARSE AND FINE VOLTAGE CONTROLS UNTIL THE VOLTAGE ON THE OUTPUT VOLTAGE METER IS OF DESIRED VALUE.
3. SHORT CIRCUIT THE OUTPUT TERMINALS

4. ADJUST COARSE AND FINE CURRENT CONTROLS UNTIL THE CURRENT ON THE OUTPUT CURRENT METER IS OF DESIRED VALUE.
5. REMOVE SHORT AND CONNECT LOAD.

OPERATING PROCEDURE
FIG 3-1

(2) 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 current is adjusted to within 2% of 5 milliamperes at the factory for the models having a maximum rated output less than 60V and 3.33 milliamperes for models with a capability equal to or greater than 60V. If greater programming accuracy is required, it may be achieved by changing the shunt resistor. SEE NOTE:

b. Voltage Programming (See Figure 3-5B)

- (1) The output voltage will vary in a one to one ratio with the external programming voltage.
- (2) The maximum load on the programming voltage will be approximately 25 microamperes.
- (3) The impedance looking into the external programming voltage should be approximately 1000 ohms.

c. Voltage-Resistance Programming (See Figure 3-5C)

- (1) Stable, low noise, low temperature coefficient (less than 30 ppm per degree Centigrade) programming resistors should be used.
- (2) R_r and R_p should be selected so that the impedance looking into their junction is a maximum of 1000 ohms.
- (3) The power supply may be programmed by varying the reference voltage, by varying resistor R_r or by varying resistor R_p .
- (4) The output voltage will vary linearly as the reference voltage is changed.
- (5) The output voltage will vary as the ratio of R_p to R_r when R_p is varied.
- (6) The output voltage will vary in accordance with the following equation when R_r is varied.

$$V_O = V_{REF} \times \frac{R_p}{R_r}$$

NOTE: 3.33 milliamperes corresponds to 300 ohms per volt.

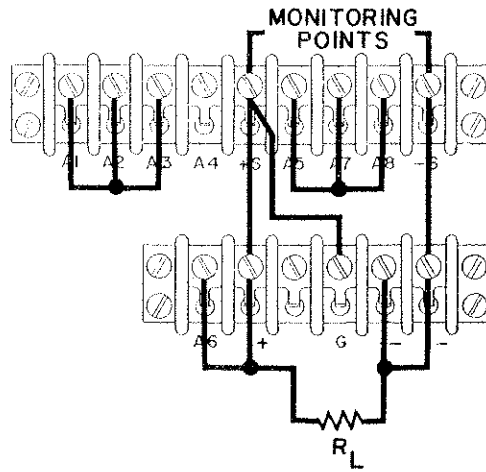


FIG. 3-2 NORMAL.

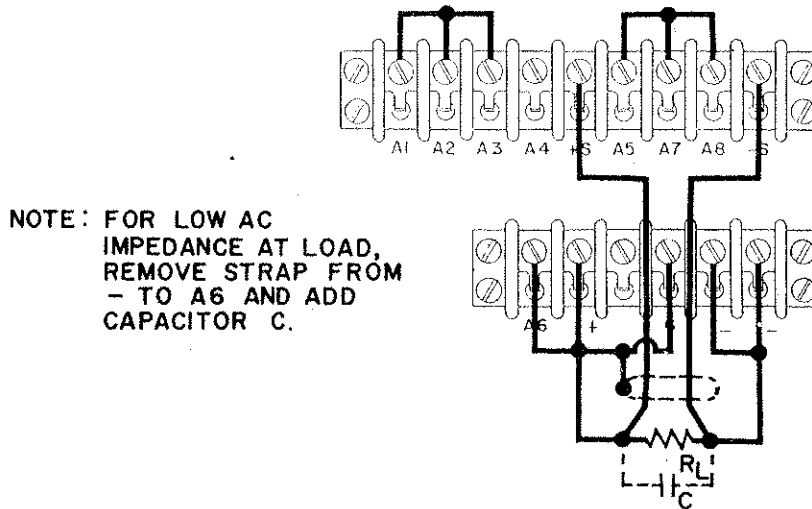


FIG. 3-3 REMOTE SENSING.

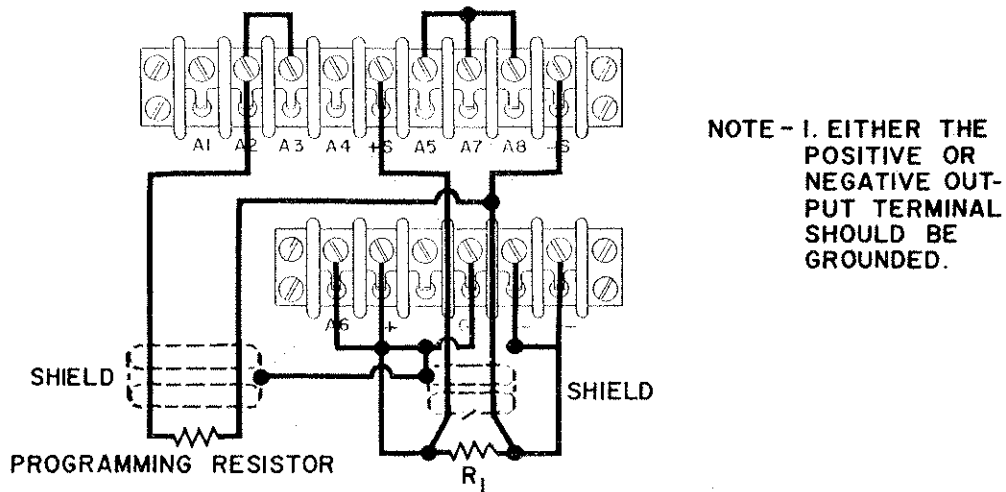


FIG. 3-4 REMOTE SENSING & REMOTE PROGRAMMING.

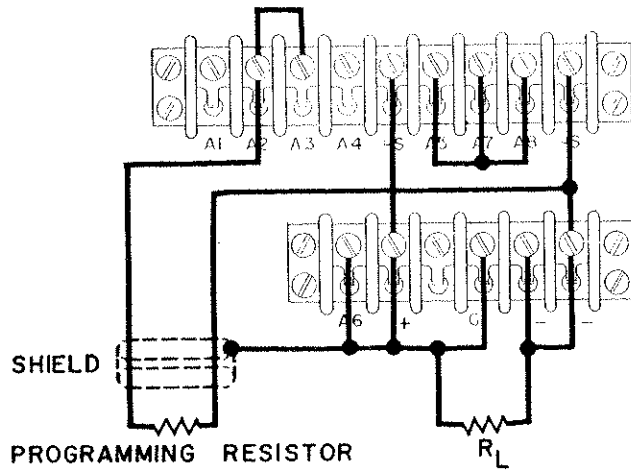


FIG. 3-5 A (RESISTANCE PROGRAMMING) REMOTE PROGRAMMING CONSTANT VOLTAGE

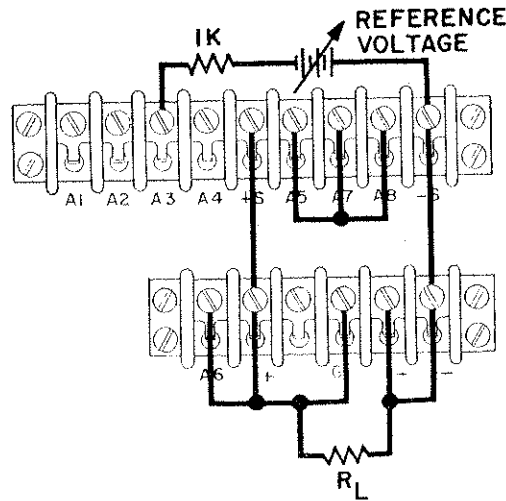


FIG. 3-5 B (VOLTAGE PROGRAMMING) REMOTE PROGRAMMING CONSTANT VOLTAGE

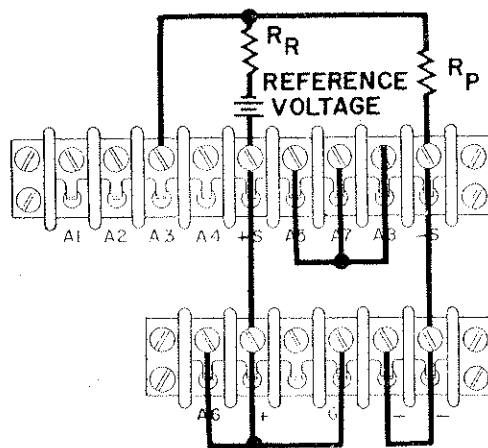


FIG. 3-5 C (VOLTAGE-RESISTANCE PROGRAMMING) REMOTE PROGRAMMING CONSTANT VOLTAGE

3-12 REMOTE PROGRAMMING -- CONSTANT CURRENT

- a. Resistance Programming (See Figure 3-6A)
- (1) Stable, low noise, low temperature coefficient (less than 30 ppm per degree Centigrade) programming resistors should be used.
 - (2) The output current will vary at a rate determined by the programming coefficient. (See Remote Programming in Specifications). The programming coefficient is determined by the programming current which can be varied by means of an internal adjustment.
- b. Voltage Programming (See Figure 3-6B)
- (1) The output current will vary in the following manner:
$$I_O = \frac{V_R}{R_M} \text{ Amps}$$

$V_R =$ Reference Voltage
 $R_M =$ Internal Monitoring Resistor
 - (2) The maximum load on the reference voltage is approximately 10 microamperes.
 - (3) The impedance looking into the external programming voltage should be approximately 1000 ohms.
- c. Voltage Resistance Programming (See Figure 3-6C)
- (1) Stable, low noise, low temperature coefficient (less than 30 ppm per degree Centigrade) programming resistors should be used.
 - (2) R_A and R_B should be selected so that the impedance looking into their junction is a maximum of 1000 ohms.
 - (3) The output current will vary linearly as a function of V_{REF} , R_A , and R_B . The equation for the output current is given by the following:

$$I_O = \frac{V_{REF}}{R_M} \frac{R_A}{R_B}$$

3-13 REMOTE SENSING

3-14 Remote sensing is used to maintain good regulation at the load and ameliorate the degradation of regulation which will occur due to the voltage drop in the leads between the power supply and the load. Remote sensing is accomplished as follows: (See Figure 3-3).

- a. Disconnect the jumper between -S and - and +S and +.
- b. Run a separate pair of leads from -S to the negative load terminal and +S to the positive load terminal.
CAUTION: Polarity must be observed.
- c. It is not required that these leads be as heavy as the load leads. However, it is recommended that they be twisted or shielded to minimize hum pickup.

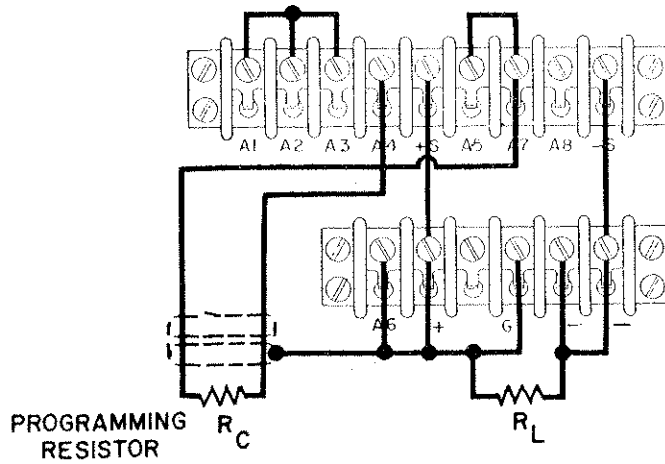


FIG. 3-6A REMOTE RESISTANCE PROGRAMMING CONSTANT CURRENT

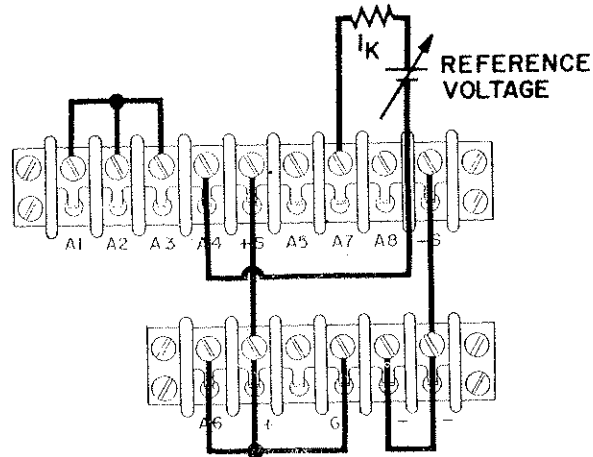


FIG. 3-6B (VOLTAGE PROGRAMMING) REMOTE PROGRAMMING CONSTANT CURRENT

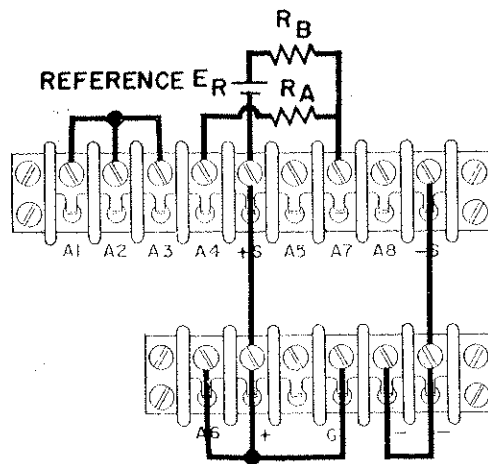


FIG. 3-6C (VOLTAGE & RESISTANCE PROGRAMMING) REMOTE PROGRAMMING CONSTANT CURRENT

3-15 The above precautions will result in a low DC output impedance at the load. However, if a low AC impedance is required, it is recommended that the following precautions be taken.

- a. Remove the strap between A6 and +.
- b. Reconnect the output capacitor or an equivalent capacitor across the load using a separate pair of leads and being careful to minimize the length of these leads.

3-16 A combination of remote programming and remote sensing may be used. The wiring for this combination is shown in Figure 3-4.

3-17 CONSTANT VOLTAGE SERIES OPERATION

3-18 Two or more supplies may be operated in series to obtain a higher voltage (the 6260A Series may be operated as much as 400 volts above ground) than that obtainable from a single supply. Power supplies are operated in series by connecting the positive terminal of one of the power supplies to the negative terminal of the second supply. The load is then taken across the two unconnected output terminals.

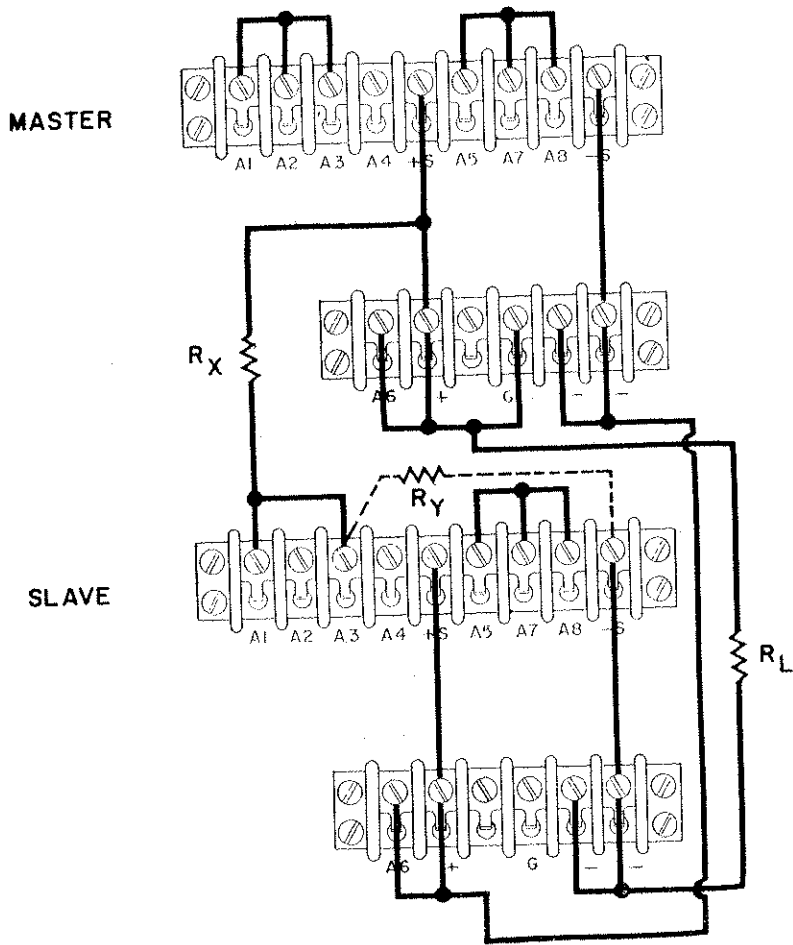
3-19 The power supplies should be connected in the Auto-Series configuration if it is desirable to have the voltage of two or more power supplies, connected in series, track each other or vary proportionally. (See Figures 3-7A and 3-7B for wiring diagrams). See note.

- NOTE:
- a. Stable, low noise, low temperature coefficient (less than 30 ppm per degree Centigrade) resistors should be used for R_x R_y .
 - b. R_x and R_y should be selected so that a current equal to the programming current flows at maximum output voltage. The voltage across R_x will be equal to the output voltage of the master unit. The voltage across R_y will equal the output voltage of slave unit one.
 - c. The most positive supply must be selected as the master or control unit.

3-20 AUTO-TRACKING OPERATION

3-21 Auto-tracking is useful when it is desirable to have several power supplies referenced to a common bus vary proportionally. The connections are made in accordance with Figure 3-8.

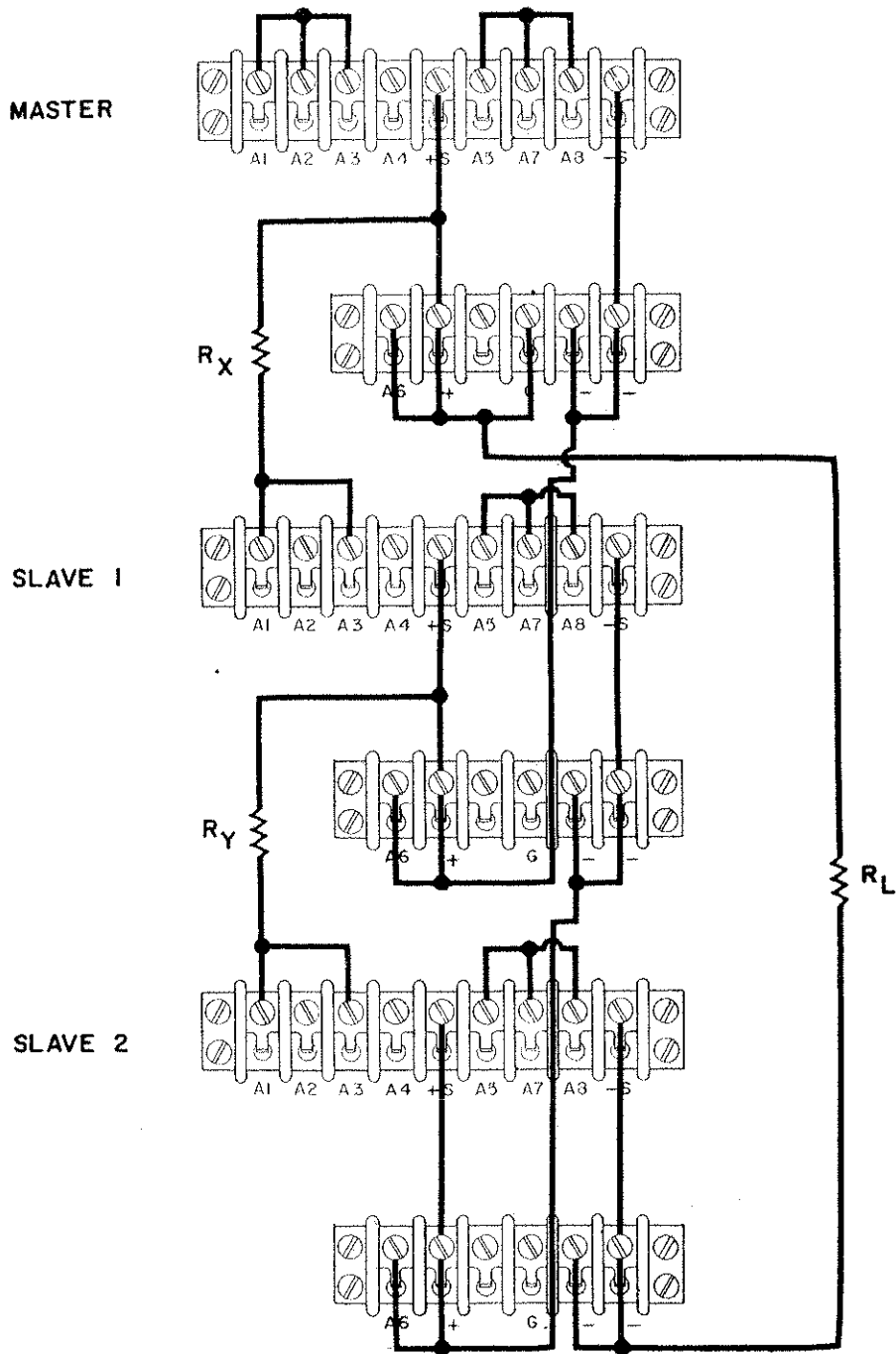
- a. The most positive power supply must be selected as the master or control unit.



NOTE: FOR EXTERNAL PROGRAMMING
OF SLAVE SUPPLY, ADD R_Y ,
REMOVE STRAP FROM A1
TO A2 ON SLAVE UNIT.

(2 UNITS)
FIG. 3-7A AUTO SERIES

NOTE - 1. EITHER THE POSITIVE OR
NEGATIVE OUTPUT TERMINAL
SHOULD BE GROUNDED.



(3 UNITS)
 FIG. 3-7B AUTO SERIES

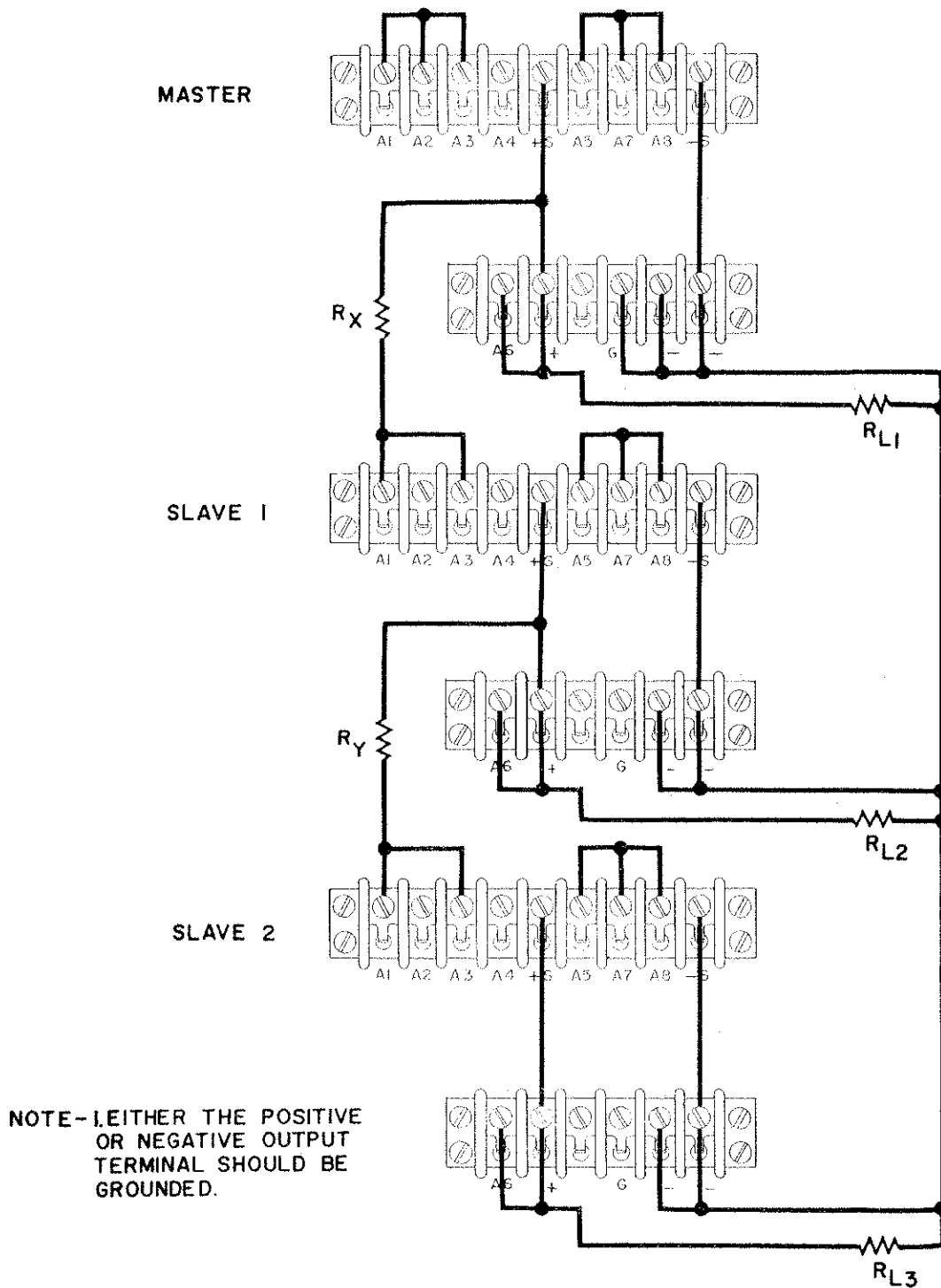


FIG. 3-8 AUTO TRACKING

- b. Resistors R_x and R_y are selected so that the current through the resistors is approximately equal to the programming current at maximum output voltage.
- c. Either the positive or negative output terminal of the slave units may be connected to the common bus.

3-22 PARALLEL OPERATION

3-23 Auto-Parallel operation is used when it is desirable to have a larger current than is available from a single supply.

3-24 Power supplies are connected in Auto-Parallel in accordance with Figure 3-9. R_x and R_y are stable, low noise, and low temperature coefficient (less than 30 ppm per °C) and selected such that the individual slave output currents equal ($\pm 10\%$) the master output current (approximately 10% of the maximum value of the current programming network). R_x sets maximum current limit to compensate for voltage drop in + output voltage lead.

3-25 INCREASING SENSITIVITY OF THE POWER SUPPLY IN CONSTANT CURRENT OPERATION

3-26 The operation of the power supply may be improved in the constant current mode of operation when operating at reduced current levels by increasing the size of the current sensing resistors. The resistor should be selected so that at maximum operating current, the voltage drop across the resistor will now be a percent of maximum operating current rather than a percent of rated output current. The resistor used to replace the current sensing resistor (s) should be a low noise, low temperature coefficient (less than 30 ppm/°C) resistor. It should be selected so that at maximum operating current, it dissipates no more than 5% of its rated power.

3-27 MULTIPLE POWER SUPPLY LOADING

3-28 It is imperative that each load taken from the power supply have two separate leads brought back to the power supply terminals if full advantage is to be taken of the low output impedance of the power supply and mutual coupling effects between equipments being powered from the same supply are to be avoided.

3-29 NEGATIVE CURRENT LOADING

3-30 A load on the power supply may cause current to flow into the positive terminal of the power supply rather than out of the positive terminal as in normal operation, i.e., the power supply may be subjected to negative current loading. The series regulating transistors are unilateral devices and must always conduct in the forward direction if the output regulation of the power supply is to be maintained; therefore, an external source cannot be allowed to pump current into the supply such that the direction of current flow in the series transistors will be reversed. It is necessary to load the supply with a dummy load so that the direction of current flow in the supply does not change if the power supply is to be subjected to negative current loading.

A diode is connected across the output terminals of the power supply so that in the event a negative voltage is applied to the power supply, the current will be shunted across the output terminals by the protective diode. This diode is used to protect the series transistors and the electrolytic capacitor connected across the output terminals of the power supply.

3-31 OVERLOAD PROTECTION CIRCUIT

3-32 Special notice should be taken of the action of the current regulating circuit. The power supply will automatically switch to constant current operation when the power supply is overloaded in the constant voltage mode of operation. The constant current regulating circuit will limit the output current to the magnitude established by the current control setting. Since the protection circuit must necessarily be a fast-acting circuit, it follows that the power supply will not perform properly if the current threshold is exceeded in constant voltage operation. For example, if the load on the power supply consists of a class B amplifier which is drawing peak currents in excess of the threshold current, the protection circuit will begin to limit the output current even though the ammeter (which reads only the average current) indicates a current considerably less than the threshold value.

3-33 When the supply is used in the constant current mode of operation, a voltage ceiling or threshold is established by the output voltage control. That is, if the IR product of the load and the constant current exceeds the threshold as established by the constant voltage control, the supply will operate as a constant voltage supply.

3-34 AUTOMATIC CROSSOVER

3-35 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 of operation and the load is changed so that the output voltage increases and exceeds the voltage ceiling threshold. The transition during which both transistors are conducting is called the crossover region.

3-36 The current threshold should be set at a minimum of 5 percent greater than the maximum load current when operating in the constant voltage mode of operation.

3-37 The voltage threshold (open circuit voltage) should be set a minimum of 2.0 volts greater than the maximum operating voltage when operating in the constant current mode of operation.

3-38 MEASURING THE PERFORMANCE OF THE POWER SUPPLY

3-39 The measuring device (differential voltmeter, digital voltmeter, or oscilloscope) must be connected across the sensing leads of the supply or as close to the output terminals as possible when measuring the output impedance, transient response, regulation, or ripple of the power supply in order to achieve valid measurements. 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.

3-40 Connect either the positive or negative terminals 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.

3-41 The monitoring device should be connected to the +S and -S terminals (See Figure 3-2) not on the load terminals when conducting performance checks.

3-42 It is recommended that a four-terminal resistor be used to make constant current measurements. The resistor should be a low noise, low temperature coefficient (less than 30 ppm/°C) resistor and should be used at no more than 5% of its rating power.

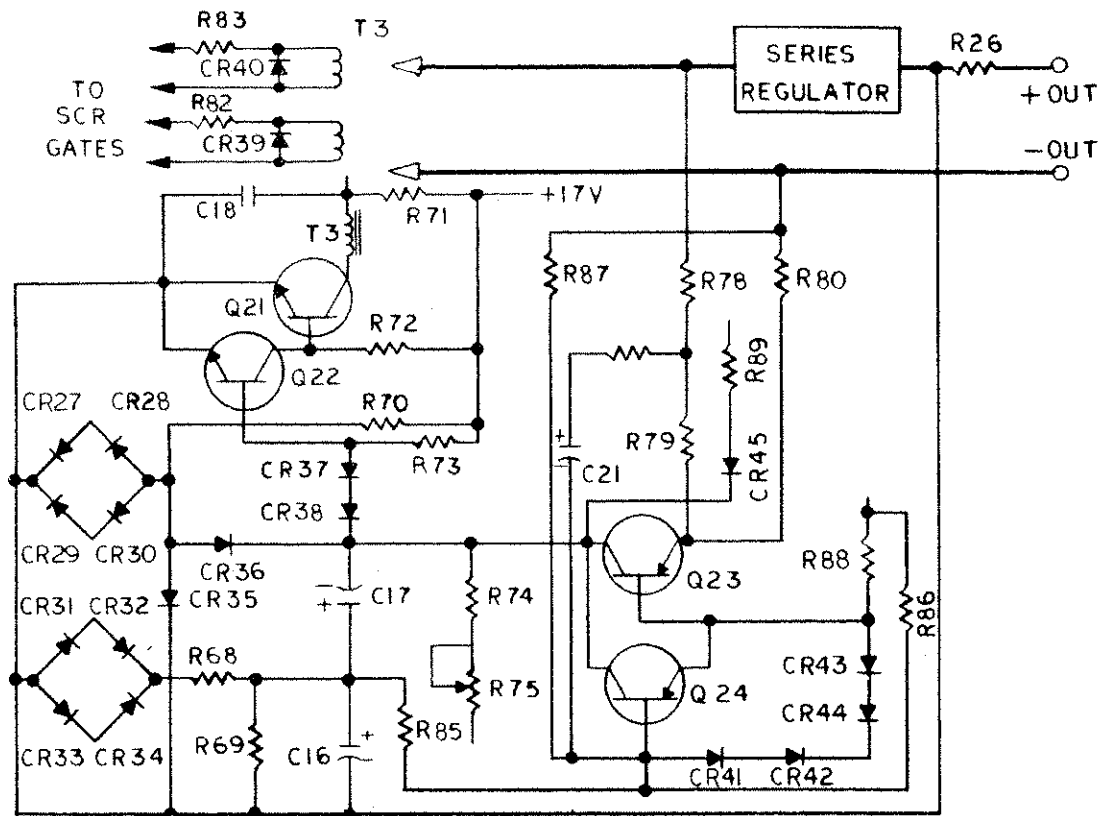


FIG. 4-3 PREREGULATOR

4-5 PREREGULATOR CIRCUIT (Figure 4-3)

4-6 By minimizing the losses in the control element, the preregulator maintains a high efficiency for all output conditions. The operation of the preregulator circuit is outlined in the following paragraphs.

4-7 The collector of Q24 serves the summing point for all signal inputs to the preregulator control circuit. The composite waveform and the individual components of the summing point waveform are shown in Figure 4-4. The presentation will be simplified by examining each signal component separately, followed by the algebraic summation of the signal components (composite waveform). Figure 4-4 will be used for all waveform references.

4-8 E_a is an offset voltage derived by charging the ramp capacitor (C17) with a constant current, supplied through R74 and R75. This current is necessary to sustain a net negative charging current into the ramp capacitor, maintaining maximum output current at low output voltages.

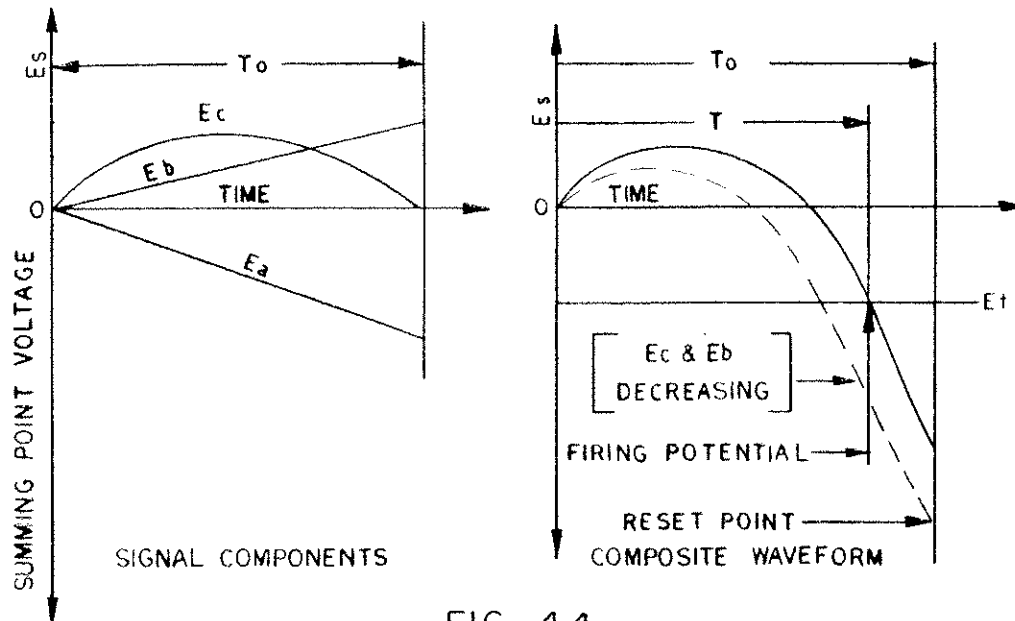


FIG. 4-4

4-9 E_b is derived by charging the ramp capacitor with a current controlled by Q24 in accordance with the signals applied to its emitter. R80 connected between the emitter of Q24 and the negative output bus, is the source of a signal which is proportional to the output voltage. R78 and R79 sense the voltage across and the current through the series transistor. This signal polarity is positive with respect to the signal injected through R80. The slope of E_b is proportional to the output voltage, the output current, and the voltage across the series transistors. For a given load current, E_b is directed such that the series regulator voltage is maintained constant for all output voltage conditions. C19 and R81 provide equalization necessary to maintain loop stability.

4-10 E_c is a negative fullwave rectified sinewave voltage, attenuated by the divider action of R68 and R69, and coupled into the summing point by means of the ramp capacitor. The amplitude of E_c is directly proportional to the input line voltage. C16 is used to smooth out any distortion which occurs in the cusp region (zero volts).

4-11 The algebraic summation of E_a , E_b , and E_c gives rise to a composite waveform E_s . The level necessary to fire the pulse generating circuit is E_t . Upon reaching the voltage, E_t , diodes CR38 and CR37 apply a turn-off signal to the base of Q22, which in turn applies a turn-on signal to the base of Q21. The output of Q21 is coupled to the gates of the silicon controlled rectifier by means of a pulse transformer T3.

4-12 The firing angle is directly proportional to the time 't' necessary for the E_s to reach E_t . Increasing line input increases E_c and time 't'. Increasing output voltage and load current decreases the slope E_b and time 't'.

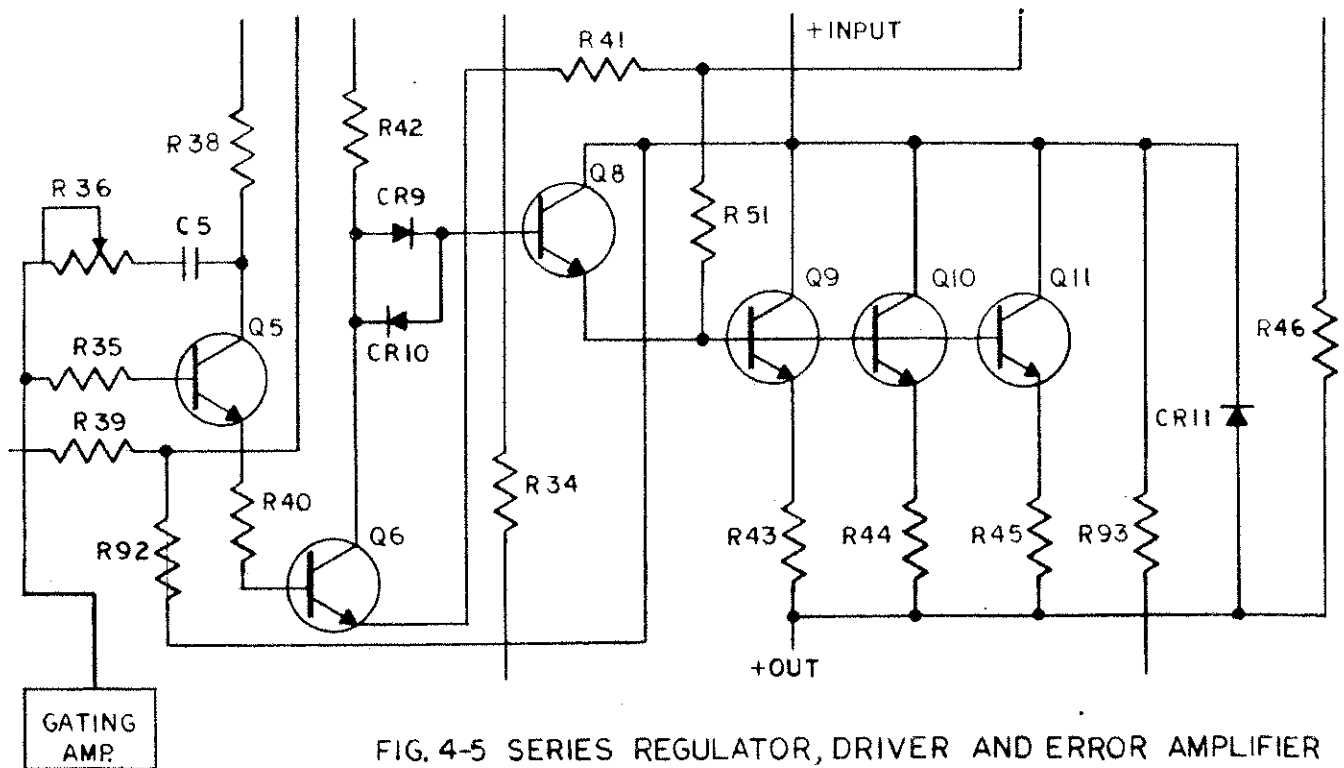


FIG. 4-5 SERIES REGULATOR, DRIVER AND ERROR AMPLIFIER

4-13 The period of E_s (T_o) is equal to twice the line input frequency (120 cycles). Reset is accomplished by application of a positive fullwave rectified sinewave to the cathode of CR36. Near the completion of the period, E_s becomes more positive than the receding reset sinewave (in the cusp region) and forward biases CR36. C17 is discharged and returned to a voltage level established by CR35 and CR36.

4-14 A circuit configuration consisting of Q24, R85, R86, and R87 forms an overvoltage detector. One end of the divider is supplied from the +15.4 volt source and the other is connected to the negative output. Fullwave rectified sinewave voltage is applied through R85 and exercises a stabilizing influence. If the output rises above a predetermined level, Q24 is acted upon and conducts, transmitting a turn-off signal to the pre-regulator control circuit. The overvoltage circuit is set for approximately 115% of maximum rated output. CR45 and R89 form a turn-on inhibitor circuit which limits the input peak currents.

4-15 SERIES REGULATOR AND ERROR AMPLIFIER (Figure 4-5)

4-16 The series regulator consists of transistors Q9 through Q16. Transistor Q7 and Q8 in a Darlington connection, is the drive for the series transistors and Q6, a common emitter, is the predriver.

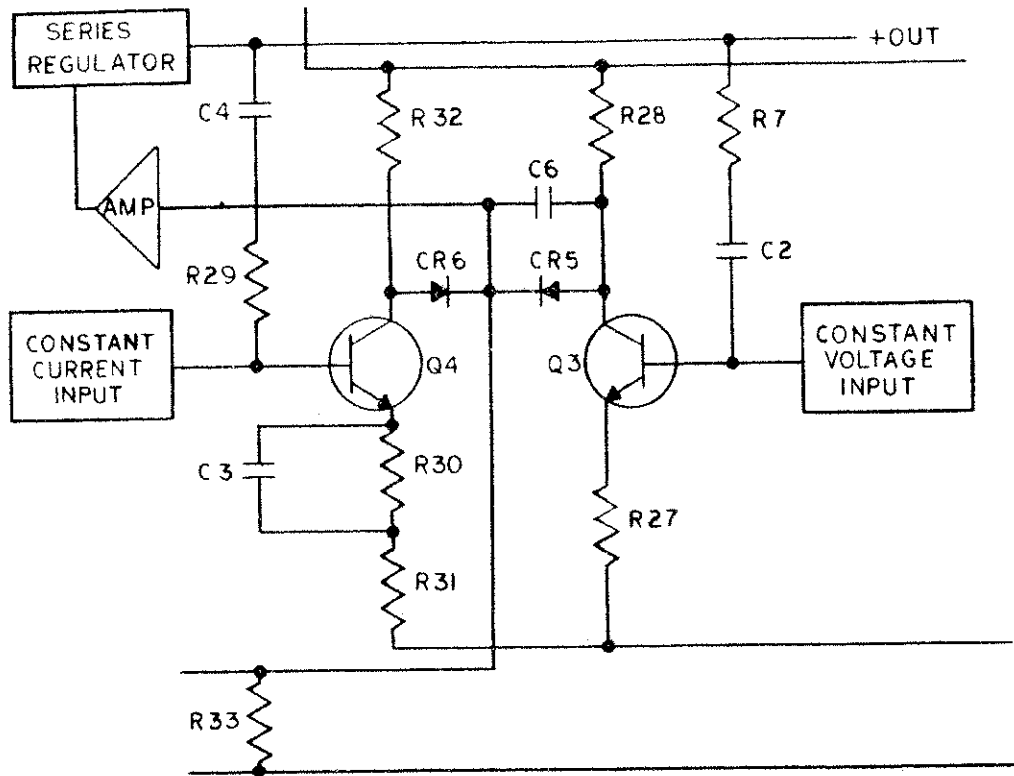


FIG 4-6 GATING AMPLIFIER

4-17 Q5 is the error amplifier transistor and signals applied to the base are amplified and applied to the base of Q6. C5 and R36 stabilize the feedback loop and CR11 is a protective diode.

4-18 AMPLIFIER GATE (Figure 4-6)

4-19 Q3, Q4, CR5, CR6, and associated components form a gated amplifier. In steady state, one transistor is saturated (collector near zero potential) and the other transistor is amplifying and passing signal current to the error amplifier. The cathodes of CR6 and CR5 are always at a greater positive potential than the saturation potential of Q3 or Q4. If we assume the system is in constant voltage operation, Q3 is operating in a linear mode while Q4 is saturated. Saturation of Q4 effectively reverse biases CR6 and only signal current through CR5 activates the error amplifier. C6 across CR5 is a commutating capacitor which improves transient response. R29, C4, R7, and C2 are low frequency loop equalizers in constant current and constant voltage respectively. C3 and R30 form a high frequency lead network in constant current.

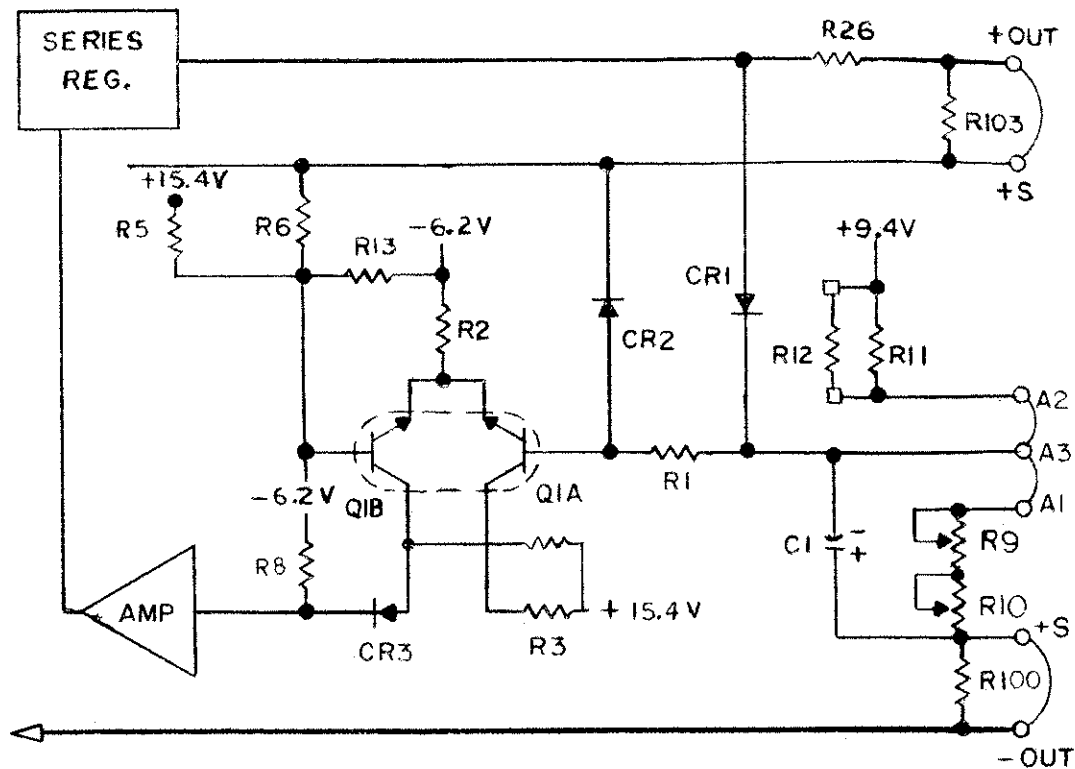


FIG. 4-7 INPUT CIRCUIT, CONSTANT VOLTAGE

4-20 CONSTANT VOLTAGE INPUT (Figure 4-7)

4-21 A differential amplifier (Q1A and Q1B) and associated circuitry are employed as a detector-amplifier in the constant voltage mode. R11 and R12 (a shunt resistor) are used to establish the programming current level. R9 and R10 are the voltage adjustment potentiometers and are shunted by C1, a low impedance AC signal path. The base of Q1B is grounded through resistor R6 in order to achieve desired thermal characteristics. The base of Q1A is connected to the junction of the programming Diode CR1 and CR2 limit voltage excursions on the base of Q1A. R1 limits the current through the programming resistor under conditions of rapid voltage turndown. CR3, R4, and R3 comprise a bias network to establish collector voltage for Q18.

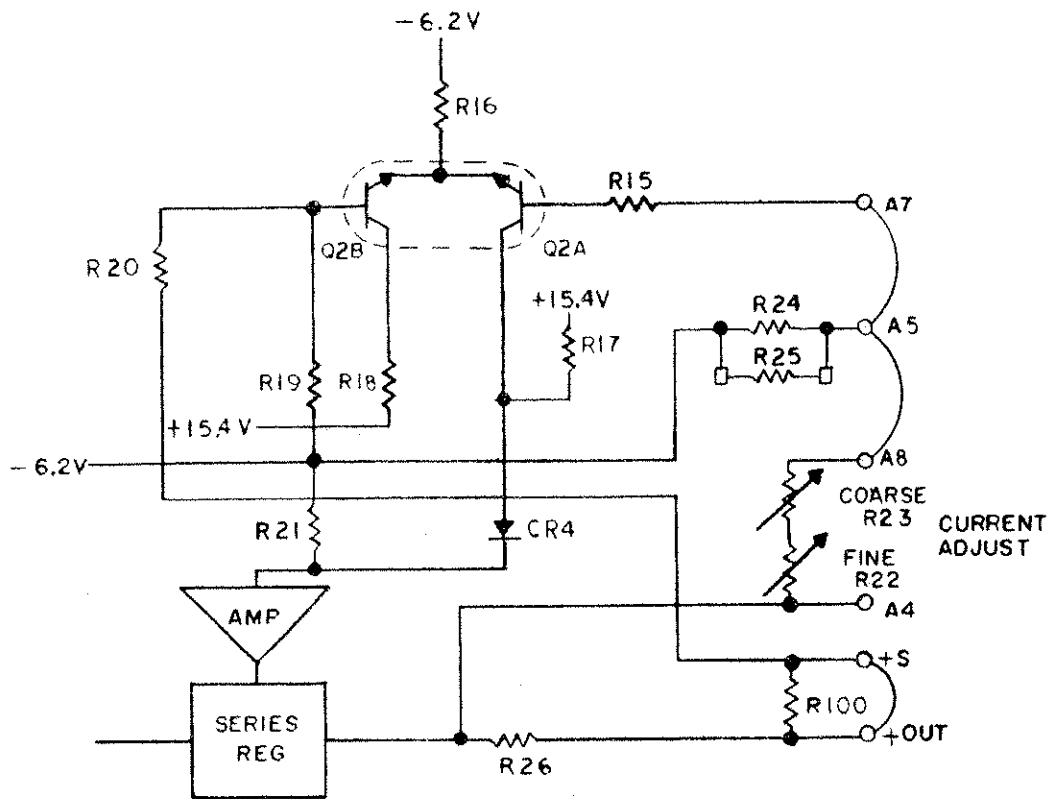


FIG. 4-8 INPUT CONSTANT CURRENT

4-22 INPUT CIRCUIT CONSTANT CURRENT (Figure 4-8)

4-23 The constant current input circuit consists of the fine current control, R22 and the coarse current control, R23, the amplifier transistors Q2A and Q2B, and associated circuit. The base of Q2B is grounded through the impedance equalizing resistor R20 in order to achieve desired thermal characteristics. The base of Q2A is connected to the junction of the programming resistors and the current pullout resistor, R24, through the impedance equalizing resistor, R15. R23 is used to adjust the programming current. CR4, R17, and R21 establish collector voltages for Q2A.

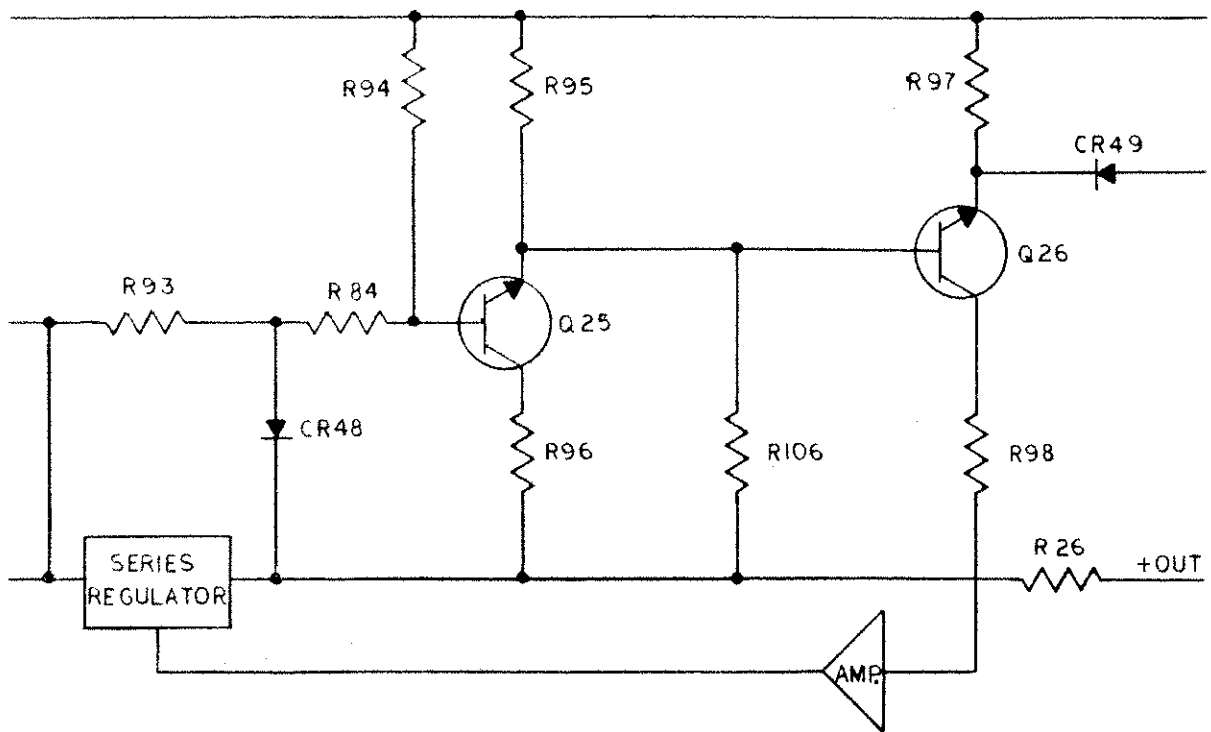


FIG. 4-9 FAULT INPUT CIRCUIT

4-24 OVERCURRENT AND SHORT CIRCUIT INPUTS (Figure 4-9)

4-25 Overcurrent protection is accomplished by means of Q26 and divider R84 and R95. Since Q26 is sensing around the current monitoring resistor (R26), it will limit the output current in accordance to the voltage established across R84 if the constant current input fails.

4-26 Short circuit protection is accomplished by means of Q25, Q26, CR48, R52, R93, R95, and R96. Divider R52, R93, and R94 is connected between the series regulator collector and the -6.2 volt supply. Q25 and Q26 are non-conducting under normal conditions; however, under short circuit conditions, the increased voltage across the series regulator drives Q25 into the saturated mode of operation. The voltage established by divider R95 and R96 at the base of Q26 forward biases Q26. The action of Q26 is to limit the current flow in the series regulator to a prescribed level. While maintaining a safe power level in the series regulator, the current discharges the input capacitors rapidly and insures quick recovery.

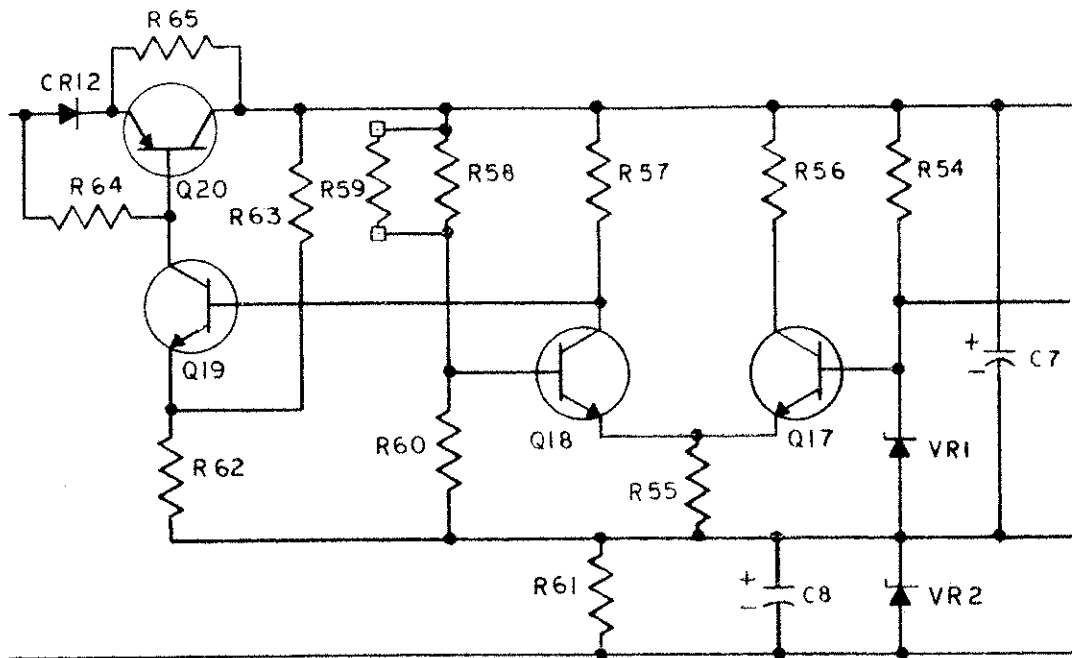


FIG 4-10 REFERENCE AND BIAS CIRCUIT

4-27 REFERENCE AND BIAS CIRCUIT (Figure 4-10)

4-28 The unregulated input voltage across C9 is finely regulated by means of Q17, Q18, Q19, Q20 and associated circuitry. The series regulator, Q20 is driven by Q19, an error amplifier, and the error amplifier is driven by the differential amplifier Q18 and Q17. The reference element for the bias regulator and the entire unit is VR1. R58 and R60 are the comparison elements and VR2 is utilized for an additional bias source. R65 minimizes power dissipation in Q20 and C7 stabilize the bias regulator loop.

4-29 REGULATOR CIRCUIT OPERATION

4-30 The circuit functions in constant voltage as follows when the output voltage changes. The change may be a slow shift in the output voltage or an AC signal. AC signals are fed to the base of Q1A through C1, and DC signals are coupled through R9 and R10. The signals are amplified, reversed in phase, and coupled to the base of Q3 through the diode CR3.

4-31 In constant voltage operation, Q3 is operating linearly and Q4 is saturated. Signals at base of Q3 are amplified, inverted in phase, and passed on to the error amplifier Q5. Depending on whether the unit is in constant voltage or constant current operation, either Q3 or Q4 is operating out of saturation.

4-32 The signal applied to Q5 is amplified and applied to the base of the driver Q6 which applies the amplified and inverted signal in phase to the bases of Q7 and Q8. This signal is amplified and applied to the base of the series transistors Q9 through Q16. The signal is applied in the phase and amplitude required to restore the original operation conditions, this maintaining the output voltage/output current of the power supply constant.

4-33 The DC output voltage is changed by varying the front panel controls. Resistor R10, in conjunction with the reference voltage, can be considered a constant current source since the voltage at the summing point (A3) is at circuit ground when the loop is in equilibrium. Potentiometer R9 and R10 are connected between the summing point and the negative sensing terminal, and since the current through it is constant, feedback action of the regulator loop will maintain the output voltage of the power supply equal to the drop across this resistor.

4-34 The DC output current is changed by varying the front panel controls. The operation of the constant current circuit is similar to the constant voltage mechanism, the input to the constant current circuit is the algebraic sum of the voltage across R22, R23, R26, R22, and R23 set the constant current level and R26 monitors the output level. Any changes are detected, amplified, and applied in proper phase to restore the original operating conditions.

SECTION V. MAINTENANCE

5-1 COVER REMOVAL AND REPLACEMENT

5-2 The cover is divided into top and bottom. Removal of the top cover provides access to a printed circuit board.

5-3 TOP COVER REMOVAL

- a. Remove the six retaining screws.
- b. Lift cover from the instrument.

5-4 TOP COVER REPLACEMENT

5-5 Replace the top cover by positioning the cover flat over the six retaining screw holes. Replace the cover retaining screws.

5-6 BOTTOM COVER REMOVAL

- a. Remove the six retaining screws.
- b. Lift cover from the instrument.

5-7 BOTTOM COVER REPLACEMENT

- a. Replace the cover by positioning the cover flat over the six retaining screw holes.
- b. Replace the cover retaining screws.

5-8 TEST EQUIPMENT REQUIRED

5-9 The test equipment for adjustment of the instrument is listed in Table 5-1. The table includes the type of equipment required, critical specifications, where the equipment is used, and recommended available commercial test equipment.

5-10 TROUBLE SHOOTING

5-11 The purpose of the trouble shooting procedure is to enable maintenance personnel to isolate troubles to a specific area, not necessarily a component. A systematic approach, such as is given later in this section, can speed up repair and minimize down time.

5-12 TROUBLE ANALYSIS

5-13 Before attempting to trouble shoot this instrument, make sure the fault is with the instrument and not with the associated circuit. The performance test will enable one to determine this without having to remove the instrument from the cabinet. The performance test will be found in paragraph 5-51.

5-14 A systematic trouble shooting procedure can be followed with this instrument. For instance, if there is no voltage throughout the instrument, check for obvious faults such as defective power cable, or power line failure, or improper strapping.

5-15 Perform a visual inspection for broken leads, overheated resistors, or cold solder joints.

5-16 The circuit consisting of series regulators and amplifiers presents a difficult problem for systematic trouble analysis. This is a feedback circuit in which a faulty component anywhere will affect the operation of the entire loop. If it is necessary to replace any component refer to Table 5-2, Replacement Guide, for adjustments or tests which may be necessary.

5-17 SEMICONDUCTOR REPLACEMENT

5-18 Before removing any transistors from the power supply, the transistors should be labeled so that in the event a defective transistor is found, its circuit location may be identified and therefore aid in isolating the source of trouble.

5-19 The semiconductors in Harrison Division power supplies generally have an H-LAB designation. Table 5-3 lists the characteristics of the semiconductors used in this power supply and suggested commercial replacements.

5-20 DETAILED TROUBLE SHOOTING PROCEDURE

5-21 Measure Power Supply Voltages. The following precautions should be taken before power supply voltages are measured. The voltage control pot and current control pot should be turned to the maximum clockwise position. The power supply should be unloaded. It is advisable to make an ohmmeter check to be certain that neither the positive or negative output terminal is grounded. The power supply may now be turned on. The following voltages which are particularly critical should then be measured first.

1. Reference Voltage

This voltage is measured between +S and 31 and should be 9.4 volts ± 0.4 volts. The 15.4 volt regulated bias voltage is out of tolerance or diode VR1 is probably defective if this voltage is out of specification.

2. 15.4 Volt Regulated Bias Voltage

This voltage is measured between +S and 32. It should be 15.4 volts ± 1.0 volts. If this voltage is out of specification, R58 may be defective. Diodes VR1, VR2, transistors Q17, Q18, or Q19 may be defective.

3. +6.2 Volts

This voltage is measured between +S and 30. It should be 6.2 volts ± 0.3 volts. Diode VR2 is probably defective if this voltage is out of specification.

(Continued on Page 5-12).

TABLE 5-1

Instrument Type	Required Characteristics	Use	Suggested Test Equipment
DC Voltmeter	Accuracy of $\pm 2\%$ Approx. ranges 0-2.5 volts 0-50 volts 0-150 volts	Measure DC	Simpson Model 269
DC Ammeter or Equivalent shunt	0-50 amps Accuracy $\pm 1\%$ 50mv/50 amp shunt	Measure DC Currents	
AC Voltmeter	Accuracy of $\pm 2\%$ Approx. voltage ranges 0-150 volts 0-300 volts	Measure AC Voltages	Simpson Model 269
AC Voltmeter	Accuracy of $\pm 3\%$ 300 volt range Expanded Scale	Measure Input Line Voltage	Weston Model 1301109
Variable Transformer	0-280 Volt ranges 28 amp current capacity	Change AC Input Voltages	Superior Type 1256C
Oscilloscope	200 μ v/cm sensitivity differential input	Measure Ripple, Trans- ient Response	ϕ Model 130C
Differential Voltmeter	1 mv Resolution	Measure Regulation	See Note 1
Load Switch	30 ampere transistor load switch or equivalent with 10 μ sec rise and fall time	Measure Tran- sient Response	

TABLE 5-1 (Cont'd)

Instrument Type	Required Characteristics	Use	Suggested Test Equipment
Load	0.8 ohms, 2500 watts 0.4 ohms, 1500 watts, and 0.08 ohms, 400 watts	Measure Loaded Characteristics at 40 volts, 20 volts, and 4 volts.	
Current Monitoring Resistor	0.02 ohm 1%, 1000 watts 20 ppm Temperature Coefficient	Measure Constant Current Operation and Adjust Ammeter	See Note 2

NOTE 1: A satisfactory substitute for a differential voltmeter is a stable reference voltage and null detector. One side of the reference voltage is connected to the power supply sensing terminal. The null detector is connected between the other power supply sensing terminal and the reference voltage. A null meter (hp Model 425A) or DC coupled scope utilizing the differential input (hp Model 130C) may be used as the null detector. A simple and satisfactory null detector is a 50 millivolt meter movement. On a 100 division scale, a two millivolt change in voltage results in a meter deflection of 4 divisions which is adequate resolution. Suitable differential voltmeters are Fluke Model 801H and Keithly Model 660.

CAUTION: Care must be exercised when using an electronic null detector in which one input terminal is grounded.

NOTE 2: Measurement techniques require the monitoring resistor used not to exceed a temperature of 80°C in free air. If forced air cooling can be employed the wattage required can be reduced to 300 watts.

CAUTION: All constant current measurements are made with the positive output terminal grounded.

TABLE 5-2
REPLACEMENT GUIDE

<u>If you change:</u>	<u>Check the following and readjust:</u>
Q1A, Q1B, Q3, CR3, CR6, CR18, CR19, CR20, VR1	Load Regulation, constant voltage
Q5, Q6, Q7, Q8	Load Regulation, transient response (R7, R36) constant voltage.
Q2A, Q2B, Q4, VR2	Line (R34) and load regulation, con- stant current.
Q19, Q20, VR1, VR2	Line Regulation at 15.4 volt source.
CR43, CR44, Q23, VR2	Series Regulator voltage R75.

TABLE 5-3

Component	Characteristics	H-LAB Designation	Suggested Replacement
Q6	NPN Si planar $50 < h_{FE} < 250$ $i_C = 1$ ma $V_{CE} = 1V$ $I_{CO} 0.25$ ma @ $V_{cbo} = 30V$	4JX11C710	2N2195A GE 2N2219 Mot.
Q23, Q24	PNP Silicon $60 < h_{FE} < 300$ $i_C = 50$ ma, $V_{CE} = 5V$ $I_{CBO} = 100$ ma @ $V_{cb} = 20V$	2N3702	2N3702 TI TIS03 TI
Q20	PNP Silicon $40 < h_{FE}$ $i_C = 1$ ma, $V_{CE} = 5V$ $P_{MAX} 600$ mw @ 25°C Ambient	S3251	S3251
Q1A, B Q2A, B	NPN Small Signal Differential amplifier $70 < h_{FE}$ $i_C = 1$ ma, $V_{CE} = 1V$ $I_{CO} = 10$ na @ 25°C $V_{cbo} = 20V$ $V_{ceo} = 15V$ $V_{bel} - V_{be2} = 2$ mv $\Delta V_{bel} - \Delta V_{be2} = 25$ $\mu V/^\circ C$	4JX12A839	2N2640 TI 2N2480A GE 12A8 GE
Q5, 21, 22, 25, 26	NPN Si planar $180 < h_{FE} < 540$ $i_C = 2$ ma $V_{CE} = 4.5V$ $I_{CBO} = .1\mu a$ @ 25°C $V_{cb} = 50V$	2N3417	2N3714 GE 4JX16B5333 2N2195A GE 2N2219 Mot.
Q7, 8, 9, 10, 11, 12, 13, 14, 15, 16	NPN Power $35 < h_{FE} <$ $i_C = 4a$ $V_{CE} = 4V$ $I_{CO} = 5$ ma 25°C $V_{cbo} = 75V$ $V_{cer} = 70V$ @ $i_C = 200$ ma $V_{ceo} = 60V$ @ $i_C = 200$ ma $1.05 > V_{BE} > .85$ $i_C = 4a$ $V_{CE} 4V$	36616	36616 RCA 2N3055 RCA

TABLE 5-3 (Cont'd)

Component	Characteristics	H-LAB Designation	Suggested Replacement
Q3, 4, 18, 17	NPN $250 < h_{FE} < 500 @ i_C = 2 \text{ ma}$ $V_{CE} = 4V$ $I_{CBO} = 100 \text{ ma} @ V_{CB} = 20V$	2N3391	2N3391 GE SM8748 TI
CR1, 2, 5, 6, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 45, 46, 47, 48	Si Diode Low Leakage	1N485B	1N485B 1N484A
CR3, 4, 10, 12, 41, 42, 43, 44, 49	Si. Rectifier .2 Amps	111S1	1N484A Sylv. 1N485B Sylv.
CR9, 13, 15, 16, 17, 18, 19, 20	Si. Rectifier	1N3253	1N3253 RCA 1N2611
CR25, 26	SCR 25 Amp rms 400 Volt PRV	C30D	C30D GE 2N3898 RCA 2N3899 RCA
CR11, 21, 22, 23, 24	Si. Rectifier 40 Amps 50 Volt PRV	1N1183A 1N1183AR (rev. pol.)	1N1183A/AR Westinghouse 1N1184A/AR Westinghouse
VR2	6.2V 400 mw zener	1N821	1N821 NA 1N821 Mot.
VR1	9.4 Temperature Compensated Reference Diode	1N2163 1N2621	1N2163 Semcor

*NOTE: These components are mounted using a mica washer and silicon grease. When replacing transistors or diodes be sure to replace the insulating washer and the silicon grease so that these components will have good heat conduction to the chassis.

TABLE 5-4
POWER SUPPLY VOLTAGES

Measured From				
-	to +			
+S	31	9.4V	±0.4V	200μv
+S	40	25.0V	±2.0V	1.0V
+S	65	1.2V	±0.2V	2 mv
+S	46	17.0V	±2.0V	1.0V
+S	19	1.0V	±0.4V	2 mv
+S	29	6.0V	±0.4V	100 mv
+S	32	15.4V	±0.5V	500μv
30	+S	6.2V	±0.3V	1 mv
+S	25	1.8V	±0.2V	2 mv
45	+S	2.4V	±0.4V	20 mv
30	32	22V	±2.0V	2 mv
30	40	32V	±2.0V	0.5V
-	29	46.0	±0.5V	100 mv
+	-	40.0V	-----	500μv

NOTE: The voltages listed above are measured at 40 volts, no load, and 208/230 volts line. These voltages will vary with line and load. The DC voltages were measured with a one hundred thousand ohms per volt voltmeter (Simpson Model 269). The ripple voltages were measured with an hp Model 130C oscilloscope using the differential mode of operation and grounded at the positive output terminal of the power supply.

TABLE 5-5
MISCELLANEOUS TROUBLES

Trouble and Description	Check:
1. Excessive Output Ripple	<ul style="list-style-type: none"> a. Check to see if output is grounded. Use 1μf capacitor if it is impossible to DC ground. b. Check voltage across series transistors. Use a scope, DC coupled to make the measurement which should be 3.8V \pm0.4V @ full load. c. Check 22 volt ripple. Should be maximum of 2 mv peak-to-peak. d. Check current control to be certain power supply is not operating in constant current mode.
2. Poor Line Regulation (Constant Voltage)	Check 15.4 volt line regulation.
3. Poor Line Regulation (Constant Current)	Check adjustment of R34.
4. Poor Load Regulation (Constant Voltage)	<ul style="list-style-type: none"> a. Measurement Technique--should measure across the sensing terminals. b. Incorrect strapping of sensing terminals. c. Q1A, Q1B, or Q3 defective. d. Current control set too close to maximum operating current.
5. Poor Load Regulation (Constant Current)	External load across output terminals (i.e., low impedance voltmeter) Q3, Q4, Q2A, Q2B, or VR2 defective. Voltage control set too close to maximum operating voltage.
6. Oscillates (Constant Voltage)	Check adjustment of R7 (equalizer), capacitor C2, and strap between A6 minus. Check adjustment of R36 and C5.
7. Oscillates (Constant Current)	Check adjustment of R36 and C5 and C3.

TABLE 5-5 (Cont'd)

Trouble and Description	Check:
8. Voltage Limited (Cannot reach maximum output voltage)	<ul style="list-style-type: none"> a. Check the voltage across series regulators for $3.8V \pm 0.4V$ @ full load. b. Check Q4, Q23, VR1, CR43, and CR44 if less than required. c. Check R10 (voltage programming) R23 (constant current programming), reference voltage (9.4V), Q3, Q26, CR18, CR19, CR20, VR2, and -17 volt unregulated bias if series regulator voltage is high.
9. Current Limited	<ul style="list-style-type: none"> a. Check the voltage across series regulators for $3.8V \pm 0.4V$ @ full load. b. Check drop across R26 which should be 0.5 volts at 50.0 amps. The resistance of R26 should be 0.01 ohms $\pm 5\%$. Check VR2, Q2A, and Q2B, and Q4 if series regulator voltage is high. c. Check R10 (voltage programming potentiometer), Q3, Q23, and -17 unregulated supply if the series regulator voltage is low.
10. Stability (Constant Voltage)	<ul style="list-style-type: none"> a. Measure stability of reference voltage (9-9.8V). Change diode VR1 if this voltage is unstable. b. Check programming resistor (use supply in Remote Programming) with a good quality, stable 20 ppm programming resistor. c. Replace R11 noting R12 should be a minimum of ten times larger is resistance than R11. d. Check Q1A, Q1B, Q3, CR1, CR2, and CR3.
11. Stability (Constant Current)	<ul style="list-style-type: none"> a. Measure stability of reference voltage 6.2 volts measured between +S and change VR2 if unstable.

TABLE 5-5 (Cont'd)

Trouble and Description	Check:
11. Stability (Cont'd) (Constant Current)	<ul style="list-style-type: none"> b. Operate power supply in constant current remote programming mode using a good quality, stable 20 ppm and TC Resistor, as programming resistor to check R26 as source of drift. Check R16, R24, and R25. c. Change Q2A and Q2B if above steps do not yield positive results.

5-22 Table 5-4 lists other voltages to measure the tolerances of these voltages, and typical peak-to-peak ripple.

5-23 Generally, malfunction of the supply is indicated by the absence of or excessive output voltage. Table 5-5 is a list of malfunctions and circuit areas to check.

5-24 POWER SUPPLY ADJUSTMENTS

5-25 The following adjustments procedure is that which is followed in the factory and is normally not required when a unit is repaired.

5-26 The front panel voltage control and current control pots should be turned to mid position. Use an ohmmeter to make certain the negative output terminal, and the collectors of Q9 through Q16, the anodes of CR21, CR22, CR23, and CR24 and cathodes of CR25 and CR26 are not grounded.

5-27 The line breaker is turned on. The output voltage should be approximately 20 volts. Vary the output voltage with the voltage control pot to be certain that the voltage control is operative. If the output voltage cannot be changed, follow the trouble shooting procedure as outlined in Section 5-20.

5-28 Regulated Bias Adjustment

- A. A differential voltmeter is used to monitor the voltage between +S and 32.
- B. R59 is adjusted so that this voltage is approximately 15.4 volts.
- C. The input line voltage is varied $\pm 10\%$ around nominal value. The voltage should not vary more than 10 mv as the input line voltage is varied.

5-29 Series Regulator Voltage Adjustments

- A. The output of the power supply is set a 4 volts and 50 amperes. The voltage across points 29 and A4 (series regulator voltage) is monitored using a Simpson 269 or equivalent. R75 is adjusted for 3.8 volts ± 0.2 volt.
- B. The output of the power supply is set at 40 volts and 50 amperes. The voltage is checked for 3.8 volts ± 0.4 volt.
- C. The value of R80 is increased to 270K and steps A and B above are repeated for 50 cycle operation.

5-30 Constant Current Adjustments. The output voltage of the power supply is set to 4 volts. The coarse current adjust is set to a maximum clockwise position. The fine current control is set to the maximum counterclockwise position. The power supply is short circuited.

- A. R25 is adjusted so that the output current is limited to 50.0 amps $\pm 1\%$ (Note: The output voltage will drop since the power supply will go into constant current operation).

- B. The coarse current control is set to maximum counterclockwise position to check for zero current.

5-31 ZERO SETTING THE METER

5-32 The meter pointer must rest on the zero calibration mark on the meter scale when the instrument is at normal operating temperature, resting in its normal operating position, and the instrument is turned off. To zero-set the meter proceed as follows:

- A. Turn on instrument and allow it to come up to normal operation temperature (about 20 minutes).
- B. Turn the instrument off. Wait 3 minutes for power supply capacitors to discharge completely.
- C. Rotate adjustment screw on top of meter clockwise until the meter pointer is to the left of zero and further clockwise rotation will move the pointer upscale towards zero.
- D. Turn the adjustment screw clockwise until the pointer is exactly over the zero mark on the scale. If the screw is turned too far, repeat steps C and D.
- E. Turn meter adjustment screw counterclockwise about 15 degrees to break contact between adjustment screw and pointer mounting yoke, but not far enough to move the pointer back downscale. If the screw is turned too far, as shown by the needle moving, repeat the procedure. The meter is now zero-set for best accuracy and mechanical stability.

5-33 Ammeter Calibration. An external ammeter accurate to 1.0% or equivalent shunt is used to measure the output current at 50.0 amperes. R101 is adjusted so that the front panel meter indicates 50.0 amperes.

5-34 Current Equalization Check. The power supply is operated at 15.0 volts out, 50.0 amperes load, and high line. The voltage between points 29 and A4 is monitored using an AC coupled scope, and the ripple unbalance should be less than 15%.

5-35 Programming Current Adjustment

- A. A differential voltmeter is connected between -S and +S. The strap between A1 and A2 is removed. An 8.0K, 0.5% programming resistor is connected between A2 and +S. A decade resistance is connected in the position of R12 and the power supply is turned on.
- B. The decade resistance is adjusted so the output voltage of the power supply as indicated by the differential voltmeter is 40 volts $\pm 2\%$.
- C. The value of the decade resistance is noted. The power supply is turned off and the decade resistance is replaced with a fixed resistor of equal value ($\pm 5\%$)

D. The value of the shunt resistor should be a minimum of 10 times the resistance of R11. If it is less than this, R11 should be replaced.

5-36 Voltmeter Adjustment (See 5-32 for meter zero adjustment). An external voltmeter (accuracy of 1.0% or better) is used to measure the output voltage of the power supply. The output voltage is set to 40 volts. R100 is adjusted so the front panel meter indicates 40 volts.

5-37 Load Regulation. The power supply is operated at 40 volts out, 208/230 line. A differential voltmeter is connected between -S and +S. The output current is varied from 0 to 50 amperes. The output voltage should not decrease more than 2 mv when the load is applied.

5-38 Line Regulation. The power supply is operated at 40 volts out and full load. A differential voltmeter is connected between -S and +S. The input line voltage is varied from $\pm 10\%$ around nominal. The output voltage should not vary more than 2 mv as the input voltage is varied. The line regulation of diode VR1 should be checked in the event the output voltage varies more than 2 mv.

5-39 Output Ripple. The power supply is operated at 40 volts out, full load and low line. An oscilloscope is connected between +S and -S. One of the output terminals of the power supply must be grounded. The maximum 120 cycle peak to peak ripple as indicated on the oscilloscope should not exceed 1 mv (exclude high frequency noise).

5-40 Low Voltage Ripple. The power supply is operated at 4 volts out, full load and high line. An oscilloscope is connected between +S and -S. One of the output terminals of the power supply must be grounded. The maximum 120 cycle peak-to-peak ripple should not exceed 1 mv (exclude high frequency noise).

5-41 Transient Response. The power supply output voltage is set at 40 volts. A switch is used to vary the power supply load from no load to 25.0 amperes. An oscilloscope is connected between +S and -S. R7 and R36 are adjusted so that the decay of the transient spike is a smooth exponential curve without undershoot, overshoot, or ringing for both the loading and unloading transients. The voltage should recover to within 20 mv of the nominal output voltage in less than 100 μ seconds. NOTE: The load should be non-inductive. The switch should have a maximum rise and fall time of 10 μ seconds.

5-42 Constant Current Checks.

5-43 The strap between A6 and minus is removed. This removes capacitor C24 from across the output terminals of the power supply. The positive output is grounded and the monitoring resistor placed in the positive leg.

5-44 A 20 milliohm resistor is connected in series with a 0.78 ohm load. The 20 milliohm resistor will be used to monitor the output current of the power supply. It should be a stable, low noise resistor having a temperature coefficient of 20 ppm or better and used at no more than 5% of its rated power. Refer to 3-42 for recommended measurement techniques. The output voltage of the power supply is changed in constant current operation by changing the load.

5-45 The power supply is turned on and the front panel voltage controls set fully clockwise and adjust load for 39 volts at 50 amperes.

5-46 Constant Current Ripple. An oscilloscope is connected across the current monitoring resistor. The maximum peak-to-peak ripple observed on the oscilloscope should not exceed 2 ma (100 ma).

5-47 Line Regulation. A differential voltmeter is connected across the current monitoring resistor. The power supply is operated at 39 volts out and 50 amperes load, and low line. The voltmeter reading is noted. The line voltage is changed to high line. The change in voltage across the current monitoring resistor, should not exceed $200\mu\text{v}$ (10 ma).

5-48 Load Regulation. A differential voltmeter is connected across the current monitoring resistor. The power supply is operated at 39 volts out and 50 amperes load, and 208/230V line. The voltmeter reading is noted. The load is shorted. The change in voltage across the current monitoring resistor should not exceed $200\mu\text{v}$ (10 ma). NOTE: The supply will go momentarily into short circuit protection.

5-49 PERFORMANCE TEST

5-51 These tests are in-cabinet specification checks and are made before disturbing any of the internal power supply adjustments. The tests may be used as an incoming inspection test, periodic maintenance, or to check the instrument after repairs. Refer to Section 3-38 before making measurements.

5-52 CONSTANT VOLTAGE

5-53 Voltmeter Check. An external voltmeter having an accuracy of 1% or better is connected across the output terminals and is used to check the front panel voltmeter at 40 volts out.

5-54 Ripple Check. The power supply is operated at 40 volts out and full load and at an input line voltage equal to low line. An oscilloscope is connected across the sensing terminals. Maximum peak-to-peak 120 cycle ripple should not exceed 1 mv (exclude high frequency noise). NOTE: One output terminal of the power supply must be grounded.

5-55 Line Regulation. The power supply is operated at 40 volts and 50 amperes load. A differential voltmeter is connected across the sensing terminals. The input line voltage is varied from low to high line value. The output voltage should not vary more than 2 millivolts.

5-56 Load Regulation. The power supply is operated at 40 volts out and 208/230 volts line. A differential voltmeter is connected across the sensing terminals. The output voltage should not decrease by more than 2 millivolts when a 50 ampere load is applied.

5-57 Transient Response. The power supply is operated at 40 volts out and 208/230 volts line. A switch having a rise and fall time of 10μ seconds or less is connected in series with a non-inductive load resistor selected so that the power supply is operated at 5.0 amperes. An oscilloscope is connected across the sensing terminals. The output voltage should recover to within 10 millivolts of the nominal output voltage within 25 μ seconds for both the loading and unloading transients. The decay of the transients should be a smooth exponential decay without ringing, overshoot, or undershoot. (See 5-41).

5-58 CONSTANT CURRENT

5-59 A 20 milliohm, 1000 watt, low temperature coefficient, wirewound resistor (see Note 2, Page 5-4) is connected in series with a 0.78 ohm load. The 20 milliohm resistor is the current sensing or monitoring resistor. The power supply voltage controls are turned to the maximum clockwise position and the load adjusted for 39 volts at 50 amperes.

5-60 Ripple Current. An oscilloscope is connected across the current monitoring resistor. The current control is adjusted so that the output current is 50.0 ampere. The maximum peak-to-peak 120 cycle ripple should be less than 2 mv (100 ma excluding high frequency noise).

5-61 Line Regulation. A differential voltmeter is connected across the current monitoring resistor. The power supply is operated at 50 amperes and 39 volts out. The line voltage is varied from long to high line. The output current should not change more than 10 ma (200μ v across 20 milliohm).

5-62 Load Regulation. A differential voltmeter is connected across the current monitoring resistor. The power supply is operated at 39 volts out and 50 amperes load. The voltage across the current monitoring resistor is noted. The external load is shortcircuited. The current magnitude as indicated by the differential voltmeter should not change more than 10 ma from that recorded at 39 volts output. NOTE: The supply will momentarily go into short circuit protection.

SECTION VI REPLACEABLE PARTS

6-1 INTRODUCTION

6-2 This section contains information for ordering replacement parts.

6-3 Table 6-4 lists parts in alpha-numerical order of the reference designators and provides the following information:

- a. Reference Designators. For abbreviations, refer to Table 6-1.
- b. Description. Refer to Table 6-2 for abbreviations.
- c. Total Quantity (TQ) used in the instrument; given only first time the part number is listed.
- d. Manufacturer's part number.
- e. Manufacturer's code number. Refer to Table 6-3 for manufacturer's name and address.
- f. $\text{\textcircled{P}}$ Part Number.
- g. Recommended spare parts quantity (RS) for complete maintenance of one instrument during one year of isolated service.
- h. Parts not identified by a reference designator are listed at the end of Table 6-4 under Miscellaneous.

6-4 ORDERING INFORMATION

6-5 To order a replacement part, address order or inquiry to your local Hewlett-Packard sales office (see lists at rear of this manual for addresses).

6-6 Specify the following information for each part:

- a. Model and complete serial number of instrument.
- b. Hewlett-Packard part number.
- c. Circuit reference designator.
- d. Description.

6-7 To order a part not listed in Table 6-4, give a complete description of the part and include its function and location.

Table 6-1. Reference Designators

A = assembly	CR = diode
B = motor	DS = device, signaling (lamp)
C = capacitor	

Table 6-1. Reference Designators (Continued)

E = misc. electronic part	RT = thermistor
F = fuse	S = switch
J = jack	T = transformer
K = relay	V = vacuum tube, neon bulb, photo cell, etc.
L = inductor	X = socket
M = meter	XF = fuseholder
P = plug	XDS = lampholder
Q = transistor	Z = network
R = resistor	

Table 6-2. Description Abbreviations

a = amperes	obd = order by description
c = carbon	p = peak
cer = ceramic	pc = printed circuit board
coef = coefficient	pf = picofarads = 10 ⁻¹² farads
com = common	pp = peak-to-peak
comp = composition	ppm = parts per million
conn = connection	pos = position(s)
crt = cathode-ray tube	poly = polystyrene
dep = deposited	pot = potentiometer
elect = electrolytic	prv = peak reverse voltage
encap = encapsulated	rect = rectifier
f = farads	rot = rotary
fxd = fixed	rms = root-mean-square
GE = germanium	s-b = slow-blow
grd = ground(ed)	sect = section(s)
h = henries	Si = silicon
Hg = mercury	sil = silver
impgr = impregnated	sl = slide
ins = insulation(ed)	td = time delay
K = kilo = 1000	TiO ₂ = titanium dioxide
lin = linear taper	tog = toggle
log = logarithmic taper	tol = tolerance
mA = milli = 10 ⁻³	trim = trimmer
M = megohms	twt = traveling wave tube
ma = milliamperes	var = variable
μ = micro = 10 ⁻⁶	w/ = with
mfr = manufacturer	W = watts
mtg = mounting	w/o = without
my = mylar	cmo = cabinet mount only
NC = normally closed	
Ne = neon	
NO = normally open	

Table 6-3. Code List of Manufacturers

CODE NO.	MANUFACTURER	ADDRESS
00629	EBY Sales Co.	New York, N. Y.
00656	Aerovox Corp.	New Bedford, Mass.
00853	Sangamo Electric Company, Ordill Division (Capacitors)	Marion, Ill.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	Beverly Hills, Calif.
01281	TRW Semiconductors, Inc.	Lawndale, Calif.
01295	Texas Instruments, Inc. Semiconductor- Components Division	
01686	RCL Electronics, Inc.	Manchester, N. H.
01930	Amerock Corp.	Rockford, Ill.
02114	Ferroxcube Corp. of America	Saugerties, N.Y.
02606	Fenwal Laboratories	Morton Grove, Ill.
02660	Amphenol-Borg Electronics Corp.	Broadview, Ill.
02735	Radio Corp. of America, Commercial Receiving Tube and Semiconductor Div.	Somerville, N.J.
03508	G. E. Semiconductor Products Dept.	Syracuse, N.Y.
03797	Eldema Corp.	Compton, Calif.
03877	Transitron Electronic Corp.	Wakefield, Mass.
03888	Pyrofilm Resistor Co.	Cedar Knolls, N.J.
04009	Arrow, Hart and Hegeman Electric Co.	Hartford, Conn.
04072	ADC Electronics, Inc.	Harbor City, Calif.
04213	Caddell-Burns Mfg. Co. Inc.	Mineola, N.Y.
04404	Dymec Division of Hewlett-Packard Co.	Palo Alto, Calif.
04713	Motorola, Inc., Semiconductor Products Division	Phoenix, Arizona
05277	Westinghouse Electric Corp. Semi-Conductor Dept.	Youngwood, Pa.
05347	Ultronix, Inc.	Grand Junction, Colo.
05820	Wakefield Engr. Inc.	Wakefield, Mass.
06004	The Bassick Co.	Bridgeport, Conn.
06486	North American Electronics, Inc.	Lynn, Mass.
06540	Amathom Electronic Hardware Co., Inc.	New Rochelle, N.Y.
06555	Beede Electrical Instrument Co., Inc.	Penacook, N.H.
06666	General Devices Co., Inc.	Indianapolis, Ind.
06751	Nuclear Corp. of America, Inc., U. S. Semcor Div.	Phoenix, Arizona

CODE NO.	MANUFACTURER	ADDRESS
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.
07137	Transistor Electronics Corp.	Minneapolis, Minn.
07138	Westinghouse Electric Corp. Electronic Tube Div.	Elmira, N. Y.
07263	Fairchild Semiconductor Div. of Fairchild Camera and Instrument Corp.	Mountain View, Calif.
07387	Birtcher Corp., The	Los Angeles, Calif.
07397	Sylvania Electric Products Inc. Mountain View Operations of Sylvania Electronic Systems	Mountain View, Calif.
07716	I. R. C. Inc.	Burlington, Iowa
07910	Continental Device Corp.	Hawthorne, Calif.
07933	Raytheon Mfg. Co., Semiconductor Div.	Mountain View, Calif.
08530	Reliance Mica Corp.	Brooklyn, N.Y.
08717	Sloan Company	Sun Valley, Calif.
08730	Vemaline Products Co.	Franklin Lakes, N.J.
08863	Nylomatic Corp.	Morrisville, Pa.
09182	Hewlett-Packard Co., Harrison Division	Berkeley Heights, N.J.
09353	C & K Components	Newton, Mass.
11236	CTS of Berne, Inc.	Berne, Ind.
11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.
11502	IRC Inc.	Boone, N.C.
11711	General Instrument Corp., Semiconductor Prod. Group, Rectifier Div.	Newark, N.J.
12136	Philadelphia Handle Co., Inc.	Camden, N.J.
12617	Hamlin Inc.	Lake Mills, Wisconsin
12697	Clarostat Mfg. Co.	Dover, N.H.
14493	Hewlett-Packard Co., Loveland Division	Loveland, Colo.
14655	Cornell-Dubilier Elec. Corp.	Newark, N.J.
14936	General Instrument Corp., Semiconductor Prod. Group, Semiconductor Div.	Hicksville, N.Y.
15909	Daven Div. of Thos. Edison Industries, Mc Graw Edison Co.	Livingston, N.J.
16299	Corning Glass Works, Electronic Components Div.	Raleigh, N.C.
16758	Delco Radio Div. of General Motors Corp.	Kokomo, Ind.
17545	Atlantic Semiconductors, Inc.	Asbury Park, N.J.

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


CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS
17803	Fairchild	Mountainview, Calif.	72699	General Instrument Corp.,	
19315	The Bendix Corp., Eclipse Pioneer Div.	Teterboro, N.J.		Capacitor Div.	Newark, N.J.
19701	Electra Mfg. Co.	Independence, Kan.	72765	Drake Mfg. Co.	Chicago, Ill.
21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.	72962	Elastic Stop Nut Corp. of America	Union, N.J.
22229	Union Carbide Corp., Linde Div.,		72982	Erie Technological Products, Inc.	Erie, Pa.
	Kemet Dept.	Mountain View, Calif.	73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Calif.
22767	ITT Semiconductors, A Division of		73168	Fenwal, Inc.	Ashland, Mass.
	International Telephone & Telegraph		73293	Hughes Components Division of Hughes	
	Corp.	Palo Alto, Calif.		Aircraft Co.	Newport Beach, Calif.
24446	General Electric Co.	Schenectady, N.Y.	73445	Amperex Electronic Co., Div. of North	
24455	General Electric Co., Lamp Division			American Phillips Co., Inc.	Hicksville, N.Y.
24655	General Radio Co.	West Concord, Mass.	73506	Bradley Semiconductor Corp.	New Haven, Conn.
26982	Dynacool Mfg. Co. Inc	Saugerties, N.Y.	73559	Carling Electric, Inc.	Hartford, Conn.
27014	National Semiconductor Corp.	Santa Clara, Calif.	73734	Federal Screw Products, Inc.	Chicago, Ill.
28480	Hewlett-Packard Co.	Palo Alto, Calif.	73978	Hardwick Hindle Co.,	
28520	Heyman Mfg. Co.	Kenilworth, N.J.		Memcor Components Div.	Huntington, Ind.
33173	G. E., Tube Dept.	Owensboro, Ky.	74193	Heinemann Electric Co.	Trenton, N.J.
35434	Lectrohm, Inc.	Chicago, Ill.	74545	Harvey Hubbel, Inc.	Bridgeport, Conn.
37942	P. R. Mallory & Co., Inc.	Indianapolis, Ind.	74868	PXR Div. of Amphenol-Borg	
42190	Muter Co.	Chicago, Ill.		Electronics Corp.	Danbury, Conn.
44655	Ohmite Manufacturing Co.	Skokie, Ill.	74970	E. F. Johnson Co.	Waseca, Minn.
46384	Penn Engr.	Doylestown, Pa.	75042	International Resistance Co.	Philadelphia, Pa.
47904	Polaroid Corp.	Cambridge, Mass.	75183	Howard B. Jones Div., of Cinch Mfg. Corp.	
49956	Raytheon Mfg. Co., Microwave and			(Use 71785)	New York, N.Y.
	Power Tube Div.	Waltham, Mass.	75382	Kulka Electric Corp.	Mt. Vernon, N.Y.
55026	Simpson Electric Co.	Chicago, Ill.	75915	Littlefuse, Inc.	Des Plaines, Ill.
56289	Sprague Electric Co.	North Adams, Mass.	76493	J. W. Miller Co.	Los Angeles, Calif.
58474	Superior Electric Co.	Bristol, Conn.	76530	Cinch	City of Industry, Calif.
61637	Union Carbide Corp.	New York, N.Y.	76854	Oak Manufacturing Co.	Crystal Lake, Ill.
63743	Ward-Leonard Electric Co.		77068	Bendix Corp., Bendix-Pacific Div.	
		Mt. Vernon, N.Y.			No. Hollywood, Calif.
70563	Amperite Co., Inc.	Union City, N.J.	77221	Phaotron Instrument and Electronic Co.	South Pasadena, Calif.
70903	Belden Mfg. Co.	Chicago, Ill.	77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
71218	Bud Radio, Inc.	Willoughby, Ohio	77342	American Machine and Foundry,	
71400	Bussmann Mfg. Div. of			Potter and Brumfield Div.	Princeton, Ind.
	Mc Graw-Edison Co.	St. Louis, Mo.	77630	TRW Electronics, Components Div.	Camden, N.J.
71450	CTS Corporation	Elkhart, Ind.	77764	Resistance Products Co.	Harrisburg, Pa.
71468	I. T. T. Cannon Electric Inc.		78189	Shakeproof Div. of Illinois Tool Works	
		Los Angeles, Calif.			Elgin, Ill.
71590	Centralab Div. of Globe Union, Inc.		78488	Stackpole Carbon Co.	St. Marys, Pa.
		Milwaukee, Wis.	78526	Stanwyck Winding Co., Inc.	Newburgh, N.Y.
71700	The Cornish Wire Co.	New York, N.Y.	78553	Tinnerman Products, Inc.	Cleveland, Ohio
71707	Coto-Coil	Providence, R.I.	79307	Whitehead Metal Products Co., Inc.	New York, N.Y.
71744	Chicago Miniature Lamp Works				
		Chicago, Ill.			
71785	Cinch Mfg. Co.	Chicago, Ill.			
71984	Dow Corning Corp.	Midland, Mich.			
72619	Dialight Corporation	Brooklyn, N.Y.			


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


CODE NO.	MANUFACTURER	ADDRESS
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
80031	Mepco Div. of Sessions Clock Co.	Morristown, N.J.
80294	Bourns, Inc.	Riverside, Calif.
81042	Howard Industries, Inc.	Racine, Wis.
81483	International Rectifier Corp.	El Segundo, Calif.
81751	Columbus Electronics Corp.	Yonkers, N.Y.
82099	Goodyear Sundries & Mechanical Co., Inc.	New York, N.Y.
82219	Sylvania Electric Products, Inc., Electronic Tube Division	Emporium, Pa.
82389	Switchcraft, Inc.	Chicago, Ill.
82647	Metals and Controls, Inc., Spencer Products	Attleboro, Mass.
82866	Research Products Corp.	Madison, Wis.
82877	Rotron Mfg. Co., Inc.	Woodstock, N.Y.
82893	Vector Electronic Co.	Glendale, Calif.
83058	Carr Fastener Co.	Cambridge, Mass.
83186	Victory Engineering Corp.	Springfield, N.J.
83298	Bendix Corp., Red Bank Div.	Eatontown, N.J.
83330	Herman H. Smith, Inc.	Brooklyn, N.Y.
83385	Central Screw Co.	Chicago, Ill.
83501	Gavitt Wire and Cable Co., Div. of Amerace Corp.	Brookfield, Mass.
83508	Grant Pulley and Hardware Co.	West Nyack, N.Y.
83594	Burroughs Corp., Electronic Components Div.	Plainfield, N.J.
83877	Yardeny Laboratories, Inc.	New York, N.Y.
84171	Arco Electronics, Inc.	Great Neck, N.Y.
84411	TRW Capacitor Div.	Ogallala, Neb.
86684	Radio Corp. of America, Electronic Components & Devices Div.	Harrison, N.J.
86838	Rummel Fibre Co.	Newark, N.J.
87034	Marco Industries Co.	Anaheim, Calif.
87216	Philco Corp. (Lansdale Div.)	Lansdale, Pa.

CODE NO.	MANUFACTURER	ADDRESS
87585	Stockwell Rubber Co., Inc.	Philadelphia, Pa.
87929	B. M. Tower Co., Inc.	Bridgeport, Conn.
88140	Cutler-Hammer, Inc.	Lincoln, Ill.
89473	General Electric Distributing Corp.	Schenectady, N.Y.
91345	Miller Dial and Nameplate Co.	El Monte, Calif.
91637	Dale Electronics, Inc.	Columbus, Neb.
91662	Elco Corp.	Willow Grove, Pa.
91929	Honeywell, Inc., Micro Switch Div.	Freeport, Ill.
93332	Sylvania Electric Prod., Inc., Semicon- ductor Prod. Div.	Woburn, Mass.
93410	Stevens Mfg. Co., Inc.	
94144	Raytheon Co., Components Div., Indus- trial Components Operation	Mansfield, Ohio
94154	Tung-Sol Electric, Inc.	Quincy, Mass.
94222	South Chester Corp.	Newark, N.J.
94310	Tru-Ohm Products, Memcor Components Div.	Chester, Pa.
95263	Leecraft Mfg. Co., Inc.	Huntington, Ind. Long Island City, N.Y.
95354	Methode Mfg. Co.	Chicago, Ill.
95712	Dage Elect.	Franklin, Ind.
96791	Amphenol Controls Div. of Amphenol- Borg Electronics Corp.	Janesville, Wis.
98291	Sealectro Corp.	Mamaroneck, N.Y.
98978	International Electronic Research Corp.	Burbank, Calif.
99934	Renbrandt, Inc.	Boston, Mass.
THE FOLLOWING H-P VENDORS HAVE NO NUMBERS ASSIGNED IN THE LATEST SUPPLEMENT TO THE FEDERAL SUPPLY CODE FOR MANUFACTURERS HANDBOOK.		
0000	Cooltron	Oakland, Calif.
00000	Plastic Ware Co.	Brooklyn, N.Y.

Table 6-4. Replaceable Parts

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	 PART NO.	RS
C1	fxd, elect 5 μ f 65Vdc	5	obd	09182	0180-1836	1
C2	fxd, film .22 μ f 80Vdc	2	192P2249R8	56289	0160-2453	1
C3	fxd, film .0047 μ f 200Vdc	2	192P47292	56289	0160-0157	1
C4	fxd, film .22 μ f 80Vdc		192P2249R8	56289	0160-2453	
C5	fxd, film .0047 μ f 200Vdc		192P47292	56289	0160-0157	
C6	fxd, film .001 μ f 200Vdc	1	192P10292	56289	0160-0153	1
C7, 8	fxd, elect 5 μ f 65Vdc		obd	09182	0180-1836	
C9	fxd, elect 325 μ f 35Vdc	1	obd	09182	0180-0332	1
C10	fxd, elect 1400 μ f 30Vdc	1	obd	09182	0180-1860	1
C11-15	fxd, elect 40,000 μ f 50Vdc	5	obd	09182	0180-1931	1
C16	fxd, elect 5 μ f 65Vdc		obd	09182	0180-1836	
C17	fxd, elect 1 μ f 35Vdc	1	150D105X9035A2	56289	0180-0291	1
C18	fxd, film .1 μ f 200Vdc	1	192P10492	56289	0160-0168	1
C19	fxd, elect 5 μ f 65Vdc		obd	09182	0180-1836	
C20	fxd, elect 20 μ f 50Vdc	1	30D206G050DC4	56289	0180-0049	1
C21, 22	NOT ASSIGNED	-	-	-	-	-
C23	fxd, elect 40 μ f 50Vdc	1	obd	09182	0180-1849	1
C24	fxd, elect 10,000 μ f 50Vdc	1	36D103G050CD6A	56289		1
C25	fxd, paper .047 μ f 600Vdc	2	160P47306	56289		1
C26	fxd, paper .47 μ f 600Vdc	2	161P47406	56289	0160-2464	1
C27	fxd, paper .047 μ f 600Vdc		160P47306	56289		
C28	fxd, paper .1 μ f 400Vdc	1	160P10494	56289	0160-0013	1
C29	fxd, paper .47 μ f 600Vdc		161P47406	56289	0160-2464	
CB1	Circuit breaker 25A@250Vac Max.	1	AM 33 Curve 5	74193	2110-0213	1
CR1, 2	Rect. si. 200mA 180prv	23	1N485B	93332	1901-0033	9
CR3, 4	Rect. si. 200mA 10prv	9	111S1	93332	1901-0461	6
CR5-7	Rect. si. 200mA 180prv		1N485B	93332	1901-0033	
CR8	NOT ASSIGNED	-	-	-	-	-
CR9	Rect. si. 500mA 200prv	9	1N3253	02735	1901-0389	6
CR10	Rect. si. 200mA 10prv		111S1	93332	1901-0461	
CR11	Rect. si. 40A 50prv	3	1N1183A	02577	1901-0315	3
CR12	Rect. si. 200mA 10prv		111S1	93332	1901-0461	
CR13-20	Rect. si. 500mA 200prv		1N3253	02735	1901-0389	
CR21	Rect. si. 40A 100prv	2	1N1183AR	02577	1901-0316	2
CR22, 23	Rect. si. 40A 50prv		1N1183A	02577	1901-0315	
CR24	Rect. si. 40A 100prv		1N1183AR	02577	1901-0316	
CR25, 26	SCR 25A 400prv	2	C30D	03508		2
CR27-40	Rect. si. 200mA 180prv		1N485B	93332	1901-0033	
CR41-44	Rect. si. 200mA 10prv		111S1	93332	1901-0461	
CR45-48	Rect. si. 200mA 180prv		1N485B	93332	1901-0033	
CR49	Rect. si. 200mA 10prv		111S1	93332	1901-0461	
CR50	Rect. si. 20A 100prv	1	A41A	03508	1901-0324	1
DS1	Indicator Light Neon	1	858-R	08717	1450-0048	1
L1	Line Choke	1	626993	09182		1
Q1, 2	SS NPN diff. amp si.	2	4JX12A839	03508	1854-0229	2
Q3, 4	SS NPN si.	5	4JX16A1014	03508	1854-0371	5
Q5	SS NPN si.	5	2N3417	03508	1854-0087	5
Q6	SS NPN si.	1	4JX11C710	03508		1
Q7-16	Power NPN si.	10	36616	09182	1854-0228	6
Q17-19	SS NPN si.		4JX16A1014	03508	1854-0371	

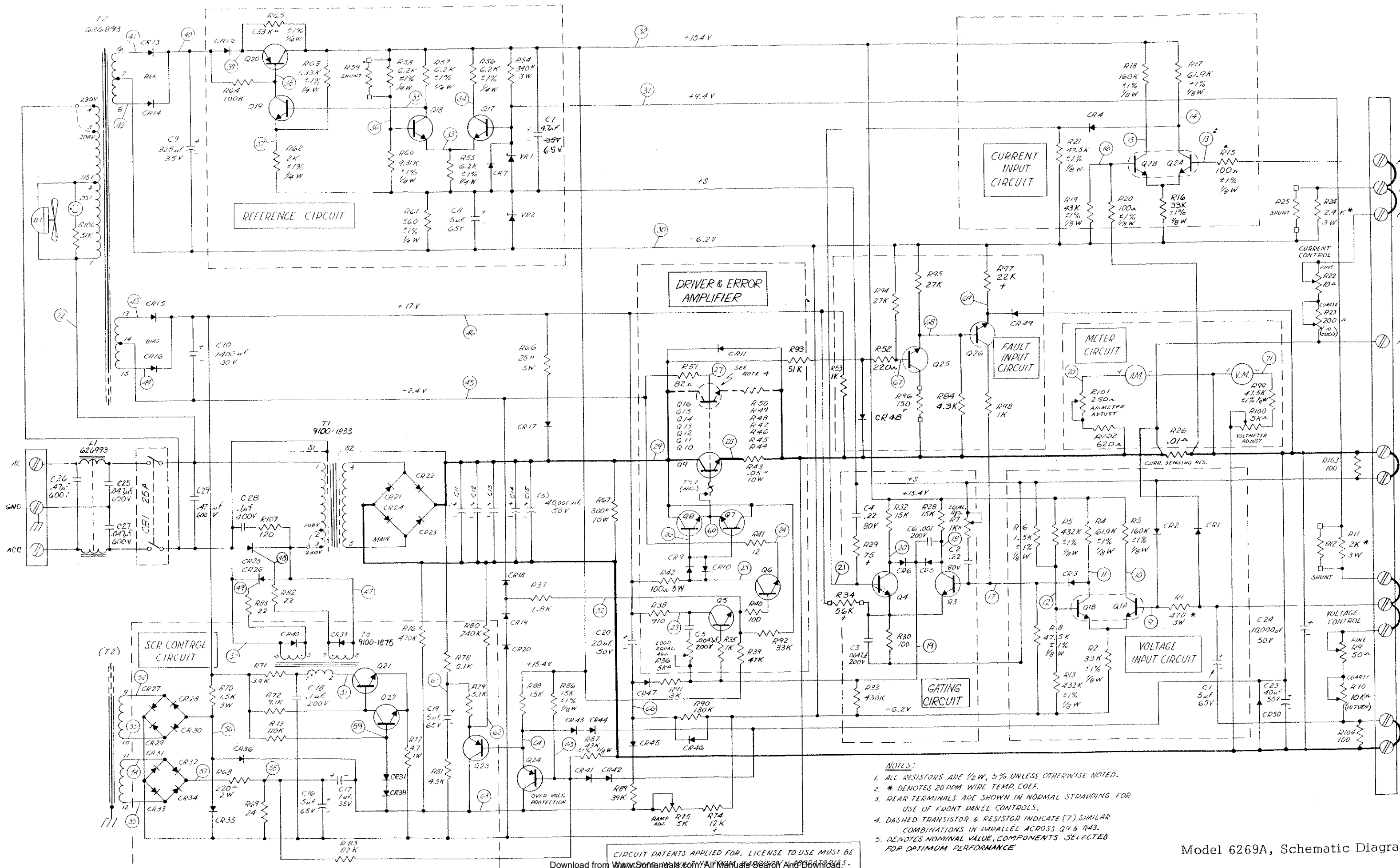
REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	 PART NO.	RS
Q20	SS PNP si.	1	S3251	07623	1853-0001	1
Q21, 22	SS NPN si.		2N3417	03508	1854-0087	
Q23, 24	SS PNP si.	2	2N2907A	56289	1853-0099	2
Q25, 26	SS NPN si.		2N3417	03508	1854-0087	
R1	fxd, ww 470 Ω \pm 5% 3W	1	242E4715	56289	0811-1555	1
R2	fxd, film 33K Ω \pm 1% 1/8W	2	obd	07716	0698-5089	1
R3	fxd, film 160K Ω \pm 1% 1/8W	2	obd	07716	0698-5092	1
R4	fxd, film 61.9K Ω \pm 1% 1/8W	2	obd	07716	0757-0460	1
R5	fxd, film 432K Ω \pm 1% 1/8W	2	obd	07716	0757-0480	1
R6	fxd, film 1.5K Ω \pm 1% 1/8W	1	obd	07716	0757-0427	1
R7	var. ww 1K Ω (Modify)	1	110-F4 obd	11236	2100-0391	1
R8	fxd, film 47.5K Ω \pm 1% 1/8W	3	obd	07716	0757-0457	1
R9	var. comp 50 Ω 2W	1	JAIN040P500UA	01121	2100-1873	1
R10	var. ww 10K Ω \pm 5%	1	100224-5	09182	2100-1866	1
R11	fxd, ww 2K Ω \pm 5% 3W	1	242E2025	56289	0811-1806	1
R12	fxd, comp (Selected) \pm 5% $\frac{1}{2}$ W	3	obd	01121		
R13	fxd, film 432K Ω \pm 1% 1/8W		obd	07716	0757-0480	
R14, 31, 105	NOT ASSIGNED	-	-	-	-	-
R15	fxd, film 100 Ω \pm 1% 1/8W	2	obd	07716	0757-0401	1
R16	fxd, film 33K Ω \pm 1% 1/8W		obd	07716	0698-5089	
R17	fxd, film 61.9K Ω \pm 1% 1/8W		obd	07716	0757-0460	
R18	fxd, film 160K Ω \pm 1% 1/8W		obd	07716	0698-5092	
R19	fxd, film 43K Ω \pm 1% 1/8W	2	obd	07716	0698-5090	1
R20	fxd, film 100 Ω \pm 1% 1/8W		obd	07716	0757-0401	
R21	fxd, film 47.5K Ω \pm 1% 1/8W		obd	07716	0757-0457	
R22	var. ww 10 Ω \pm 5%	1	100213-11	09182	2100-1857	1
R23	var. ww 200 Ω \pm 5%	1	100224-8	09182	2100-1863	1
R24	fxd, ww 2.4K Ω \pm 5% 3W	1	242E2425	56289	0811-1807	1
R25	fxd, comp (Selected) \pm 5% $\frac{1}{2}$ W		obd	01121		
R26	fxd, ww .01 Ω 20ppm	1	626990	09182	5080-7104	1
R27	fxd, comp 100 Ω \pm 5% $\frac{1}{2}$ W	5	obd	01121	0686-1015	1
R28	fxd, comp 15K Ω \pm 5% $\frac{1}{2}$ W	3	obd	01121	0686-1535	1
R29	fxd, comp 75 Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-7505	1
R30	fxd, comp 100 Ω \pm 5% $\frac{1}{2}$ W		obd	01121	0686-1015	
R32	fxd, comp 15K Ω \pm 5% $\frac{1}{2}$ W		obd	01121	0686-1535	
R33	fxd, comp 430K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-4345	1
R34	fxd, comp 56K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-5635	1
R35	fxd, comp 1K Ω \pm 5% $\frac{1}{2}$ W	3	obd	01121	0686-1025	1
R36	var. ww 5K Ω (Modify)	3	110-F4 obd	11236	2100-1824	1
R37	fxd, comp 1.8K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-1825	1
R38	fxd, comp 910 Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-9115	1
R39	fxd, comp 47K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-4735	1
R40	fxd, comp 100 Ω \pm 5% $\frac{1}{2}$ W		obd	01121	0686-1015	
R41	fxd, comp 12 Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-1205	1
R42	fxd, ww 100 Ω \pm 5% 5W	1	Type 5XM obd	63743	0812-0018	1
R43-50	fxd, ww .05 Ω \pm 5% 10W (Type HMAL -11)	8	HX-21837	73978		2
R51	fxd, comp 82 Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-8205	1
R52	fxd, comp 220 Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-2215	1
R53	fxd, comp 1K Ω \pm 5% $\frac{1}{2}$ W		obd	01121	0686-1025	
R54	fxd, ww 390 Ω \pm 5% 3W	1	242E3915	56289	0811-1799	1
R55-58	fxd, film 6.2K Ω \pm 1% $\frac{1}{4}$ W	4	obd	07716	0698-5149	1
R59	fxd, comp (Selected) \pm 5% $\frac{1}{2}$ W		obd	01121		
R60	fxd, film 9.31K Ω \pm 1% $\frac{1}{4}$ W	1	obd	07716	0698-3283	1

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	 PART NO.	RS
R61	fxd, film 560 Ω \pm 1% $\frac{1}{4}$ W	1	obd	07716	0698-5146	1
R62	fxd, film 2K Ω \pm 1% $\frac{1}{4}$ W	1	obd	07716	0757-0739	1
R63	fxd, film 1.33K Ω \pm 1% $\frac{1}{4}$ W	2	obd	07716	0698-3134	1
R64	fxd, comp 100K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-1045	1
R65	fxd, film 1.33K Ω \pm 1% $\frac{1}{4}$ W		obd	07716	0698-3134	
R66	fxd, ww 25 Ω \pm 5% 5W	1	Type 5XM obd	63743	0811-1853	1
R67	fxd, ww 300 Ω \pm 5% 10W	1	Type 10XM obd	63743	0818-0054	1
R68	fxd, film 220 Ω \pm 5% 2W	1	C42S obd	16299	0698-3628	1
R69	fxd, comp 24 Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-2405	1
R70	fxd, ww 1.5K Ω \pm 5% 3W	1	242E1525	56289	0811-1805	1
R71	fxd, comp 3.9K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-3925	1
R72	fxd, comp 9.1K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-9125	1
R73	fxd, comp 110K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-1145	1
R74	fxd, comp 12K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-1235	1
R75	var, ww 5K Ω (Modify)		110-F4 obd	11236	2100-1824	
R76	fxd, comp 470K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-4745	1
R77	fxd, comp 4.7 Ω \pm 5% 1W	1	obd	01121	0689-0475	1
R78, 79	fxd, comp 5.1K Ω \pm 5% $\frac{1}{2}$ W	2	obd	01121	0686-5125	1
R80	fxd, comp 240K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-2445	1
R81	fxd, comp 4.3K Ω \pm 5% $\frac{1}{2}$ W	2	obd	01121	0686-4325	1
R82, 83	fxd, comp 22 Ω \pm 5% $\frac{1}{2}$ W	2	obd	01121	0686-2205	1
R84	fxd, comp 4.3K Ω \pm 5% $\frac{1}{2}$ W		obd	01121	0686-4325	
R85	fxd, comp 82K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-8235	1
R86	fxd, film 15K Ω \pm 1% 1/8W	1	obd	07716	0757-0446	1
R87	fxd, film 43K Ω \pm 1% 1/8W		obd	07716	0698-5090	
R88	fxd, comp 15K Ω \pm 5% $\frac{1}{2}$ W		obd	01121	0686-1535	
R89	fxd, comp 39K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-3935	1
R90	fxd, comp 180K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-1845	1
R91	fxd, comp 3K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-3025	1
R92	fxd, comp 33K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-3335	1
R93	fxd, comp 51K Ω \pm 5% $\frac{1}{2}$ W	2	obd	01121	0686-5135	1
R94, 95	fxd, comp 27K Ω \pm 5% $\frac{1}{2}$ W	2	obd	01121	0686-2735	1
R96	fxd, comp 150 Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-1515	1
R97	fxd, comp 22K Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-2235	1
R98	fxd, comp 1K Ω \pm 5% $\frac{1}{2}$ W		obd	01121	0686-1025	
R99	fxd, film 47.5K Ω \pm 1% 1/8W		obd	07716	0757-0457	
R100	var, ww 5K Ω (Modify)		110-F4 obd	11236	2100-1824	
R101	var, ww 250 Ω (Modify)	1	110-F4 obd	11236	2100-0439	1
R102	fxd, comp 620 Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-6215	1
R103, 104	fxd, comp 100 Ω \pm 5% $\frac{1}{2}$ W		obd	01121	0686-1015	
R106	fxd, comp 51K Ω \pm 5% $\frac{1}{2}$ W		obd	01121	0686-5135	
R107	fxd, comp 120 Ω \pm 5% $\frac{1}{2}$ W	1	obd	01121	0686-1215	1
T1	Power Transformer	1	626991A	09182		1
T2	Bias Transformer	1	626893	09182		1
T3	Pulse Transformer	1	642895	09182		1
TS1	Thermal switch	1	100306-1	09182	0440-0042	1
VR1	Diode, zener 9.4V \pm 5% T.C.	1	1N2163	06751	1902-0762	1
VR2	Diode, zener 6.2V \pm 5%	1	1N821	06486	1902-0761	1

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	Ⓢ PART NO.	RS
	MISCELLANEOUS					
	Chassis Welding Assembly	1	obd	09182	5060-6101	
	Chassis, Side Left	1	obd	09182	5000-6001	
	Chassis, Side Right	1	obd	09182	5000-6002	
	Chassis, Front	1	obd	09182	5000-6003	
	Chassis, Center	1	obd	09182	5000-6004	
	Bracket, Transformer	2	obd	09182	5000-6005	
	Bracket, Heat Sink Mtg.	2	obd	09182	5000-6006	
	Chassis, Rear Assembly	1	obd	09182	06269-60001	
	Gusset	2	obd	09182	5000-6007	
	Baffle Fan	1	obd	09182	5000-6019	
	Cover	2	obd	09182	5000-6009	
	Front Panel	1	obd	09182	06269-60002	
	Plate, Heat Sink Mtg.	2	obd	09182	5000-6011	
	Bracket, P. C. Board	1	obd	09182	5000-6012	
	Bracket, P. C. Board	1	obd	09182	5000-6013	
	Bracket, P. C. Board	1	obd	09182	5000-6014	
	Buss Bar	2	obd	09182	06269-00001	
	Cover, Barrier Strip	1	obd	09182	5020-5513	
	Capacitor Clamp	1	obd	09182	5000-6017	
	Heat Sink, P. C. Board	2	obd	09182	5000-6018	
	Buss Bar - Output	2	obd	09182	5000-6144	
	Handle 7"	2	obd	09182	5020-5584	
	Heat Sink, SCR	1	obd	09182	5020-5501	
	Heat Sink, Rect.	2	obd	09182	5020-5502	
	Heat Sink, Trans.	2	obd	09182	5020-5503	
	P. C. Board Assembly Includes Components	1	obd	09182	06269-60020	
	Printed Circuit Board, Blank	1	obd	09182	5020-5504	
	P. C. Board Assembly, Includes Components	1	obd	09182	06269-60021	
	Printed Circuit Board, Blank	2	obd	09182	5020-5702	
	Barrier Strip (Modify)	1	602-3	75382	0360-1213	1
	Barrier Strip, P. C. Board	1	obd	09182	0360-1237	1
	Knob, 5/8 dia.	2	obd	09182	0370-0084	1
	Knob, 5/8 dia.	2	obd	09182	0370-0137	1
	Spacer, Insulated, heat sink	4	obd	09182	0380-0711	1
	5 Way binding post, maroon	1	DF21RC	58474	1510-0040	1
	5 Way binding post, black	2	DF21BC	58474	1510-0039	1
	Jumpers	4	601-J	75382		1
	Jumpers	2	603-J	75382		1
	Spring, Meter	8	obd	09182	1460-0256	1
	Voltmeter, $\frac{1}{4}$ mod. 1mA @ 88 Ω ±15%, 0-50V	1	obd	09182	1120-1173	1
	Ammeter, $\frac{1}{4}$ mod. 1mA @ 88 Ω ±15% 0-60A	1	obd	09182	1120-1181	1
	Bezel Meter, $\frac{1}{4}$ mod.	2	obd	09182	4040-0296	1
	Rubber bumper, Black Durom Hd. 55/60	4	3066	87575	0403-0085	1
	Insulator, heat sink mtg.	8	obd	09182	0340-0172	6
	Shoulder washer	2	100174-4	09182		1
	Wafer, mounting, SCR	1	H4021	61637	0340-0175	1
	Motor, fan	1	obd	09182	3140-0010	1
	Casting, mach.	1	obd	09182	5243A-20A	1

NEW NO.
3140-0010
519B

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	Ⓢ PART NO.	RS
	Blade, fan	1	4LHB182B	09182		1
	Heat Dissipator, Q6	1	NF207	05820	1205-0033	1
	Insulator, Transistor Pins	32	obd	09182	0340-0166	11
	Fastener, Rear chassis	6	C8032-832-4	89032	0590-0748	2
	Fastener, Input capacitor	4	C684-1024-4	89032	0590-0711	1
	Fastener	26	C8091-632-4	89032	0510-0275	6
	Fastener, Pilot Light	1	C17373 012-248	89032	0510-0123	1
	Cable Clamp Nylon Plastic	7	T4-4	79307	1400-0330	2
	Cable Clamp, C26, C29 1" I. D.	2	T6-15	79307	1400-0002	1
	Capacitor Clamp	1	obd	09182	1400-0321	1
	Capacitor Clamp 2-9/16 3 holes	1	4586-2D	56289	0180-1970	1
	Shoulder Washer #8 Output Buss	4	obd	09182	2190-0491	1
	Spacer - Insulated #8 x 5/16 LG Output Buss	4	obd	09182	0380-0710	1
	Carton	1	obd	09182	9211-0857	
	Pad - Floater	2	obd	09182	9220-1228	
	OPTION 06: Overvoltage Protection "crowbar"					
	Overvoltage Protection crowbar	1	obd	09182	Model 6917B	
	OPTION 10: Chassis Slides					
	Slides	1	SS-168NT20-21	83508	1490-0872	1
	OPTION 13: 3-Digit Decadial Voltage Control					
R10	var. ww 10K _Ω ±5% 10-Turn Knob, R10, Black	1	obd	09182	2100-1866	1
	3-Digit Decadial	1	obd	09182	0370-0137	1
		1	RD-411	07716	1140-0020	1
	OPTION 14: 3-Digit Decadial Current Control					
R23	var. ww 200 _Ω ±5% 10-Turn Knob, R23, Black	1	obd	09182	2100-1863	1
	3-Digit Decadial	1	obd	09182	0370-0137	1
		1	RD-411	07716	1140-0020	1



- NOTES:**
1. ALL RESISTORS ARE 1/2W, 5% UNLESS OTHERWISE NOTED.
 2. * DENOTES 20 PPM WIRE TEMP. COEF.
 3. REAR TERMINALS ARE SHOWN IN NORMAL STRAPPING FOR USE OF FRONT PANEL CONTROLS.
 4. DASHED TRANSISTOR & RESISTOR INDICATE (7) SIMILAR COMBINATIONS IN PARALLEL ACROSS Q9 & R43.
 5. DENOTES NOMINAL VALUE, COMPONENTS SELECTED FOR OPTIMUM PERFORMANCE

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