DC POWER SUPPLY

LVR SERIES, MODEL 6265A

SERIAL NUMBER PREFIX 6L

Printed: November, 1966
hp Stock Number: 06265-90001

SPECIFICATIONS

Input: 105-125/210-250 VAC, single phase, 50-60 cps.

Output: 0-36 volts @ 0-3 amperes.

Load Regulation: Constant Voltage -- Less than 0.01% plus 500μv for a full load change.
Constant Current -- Less than 0.02% plus 500μa for a full load change.

Line Regulation: Constant Voltage -- Less than 0.01% plus 500μv for a change in line voltage from 105 to 125 volts (or 125 to 105 volts).
Constant Current -- Less than .02% plus 500μa for a change in line voltage from 105 to 125 volts (or 125 to 105 volts).

Ripple and Noise: Constant Voltage -- Less than 500μv rms.
Constant Current -- Less than 3 ma rms.

Maximum Operating Temperature: 50°C.

Temperature Coefficient: Output voltage change per degree Centigrade is less than 0.01% plus 500μv. Output current change per degree Centigrade is less than .01% plus 1 ma.

Stability: As a constant voltage source, the total drift for 8 hours (after 30 minutes warm-up) at a constant ambient is less than 0.03% plus 2 mv. As a constant current source, the total drift for 8 hours (after 30 minutes warm-up) at a constant ambient is less than .03% plus 2 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 50 microseconds is required for output voltage recovery (in constant voltage operation) to within 10 millivolts of the nominal output voltage following a full 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 3.4 amps.

MANUAL CHANGES

DC POWER SUPPLY
Model 6255A
Manual Serial Number Prefix 7F

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

SERIAL		MAKE CHANGES
Prefix	Number	
7F	0851 - 0950	1
ALL		Errata
7L	0951 - 1275	1, 2
7L	1276 - 1500	1, 2, 3
7L	1501 - 1560	1, 2, 3, 4
8L	1561 - up	1 thru 5

CHANGE 1: In the replaceable parts table, make the following changes:

R15: Change to 240KΩ, 1/2W, hp Part No. 0686-2445.
R35: Change to 120Ω, 1/2W, hp Part No. 0686-1215.
R40: Delete resistor R40.
R62: Change to 750Ω, 1/8W, hp Part No. 0757-0420.
R63: Change to 5KΩ potentiometer, hp Part No. 2100-1824.
R64, 65: Change to 12KΩ, 1/8W, hp Part No. 0698-5088.
VR6: Add new Zener diode, VR6, (4.22V) hp Part No. 1902-3070.

On the schematic, delete resistor R40 in the meter circuit and connect VR6 in its place. Anode of VR6 to base of Q15 and cathode to +12.4V.

ERRATA: Change F1 to 4 Amperes, 250V, 3AG, hp Part No. 2100-0055, on parts list and schematic.

CHANGE 2: On the Title Page, change Serial Number Prefix from "7F" to "7L".

In the replaceable parts table, delete switch/indicator S1/DS1 and add new "toggle" type switch and separate indicator, as follows:

S1: Switch, SPST, ON/OFF, hp Part No. 3101-1055.
DS1: Indicator lamp, neon, hp Part No. 1450-0048.

CHANGE 3: In the replaceable parts table and on the schematic, add new resistor R78, 100Ω, 5%, $\frac{1}{2}$W, hp Part No. 0686-1015. Connect R78 between base of Q4 and emitter of Q5.

ERRATA: Q3, 5, 8, 10, 12, 14, 15: Change to 2N2907A, Sprague, 56289, 1853-0099.

On page 3-5, Figure 3-11, remove straps between A10 and +S and +S and + terminals on all "slave" supplies. Connect A10 to + terminal on all "slaves".

CHANGE 4: In the replaceable parts table, change Q11 to 2N4045, hp Part No. 1854-0221.

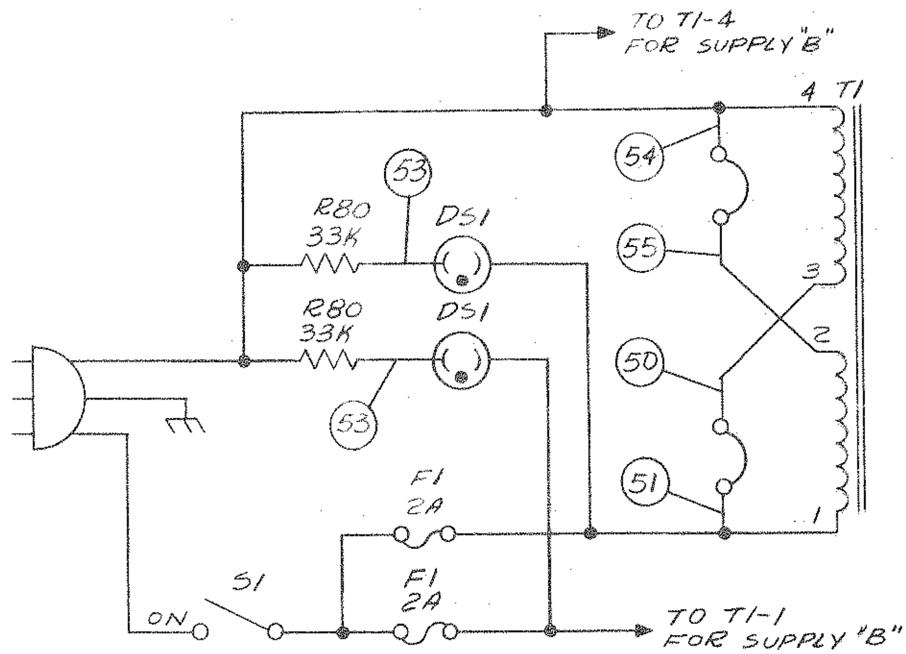
▶CHANGE 5: On the Title Page, change Serial Number Prefix to "8L".

In the replaceable parts table, make the following changes:

CHANGE 5 CONTINUED:

Add DS1, Qty 1 (total Qty 2), Pilot Light, Neon, Sloan, ⓗ Part No. 1450-0048.
Add F1, Qty 1 (total Qty 2), fuse cartridge, 2 Amp, ⓗ Part No. 2110-0002.
Add R80, 33K, $\frac{1}{2}$W, 5% Qty 1 (total Qty 2), ⓗ Part No. 0686-3335.

On the schematic, input power area, show separate fuse, pilot light, and resistor (R80) for the power transformer for each supply (A and B). Only the power-on switch (S1) and the line cord are now common to both supplies. Input power circuit now appears as shown below:



12-10-68

Controls: A single control makes possible continuous adjustment of the output voltage over the entire range from 0 to 36 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 40V voltmeter and a 0-3 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 300 ohms/amp.

Cooling: Convection cooling is employed. The supply has no moving parts.

Size: 3-1/2" H x 16-3/4" D x 19"W (Standard Relay Rack Mounting).

Weight: 36 pounds net; shipping weight 47 pounds.

Finish: Light gray front panel with dark gray case.

Power Cord: A 3-wire 5 foot power cord is provided with each unit.

SECTION I.

1-1 GENERAL INFORMATION

1-2 The Harrison Laboratories 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 Laboratories 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 is convection cooled 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.

1-10 POWER CABLE

1-11 A 5 foot three conductor power cable is supplied with the instrument terminated in a polarized three-prong male connector recommended by the National Electrical Manufacturers' Association (NEMA). NEMA recommends that the instrument panel and cabinet be grounded. All Harrison Laboratories instruments are equipped with a power cable which when plugged into an appropriate receptacle grounds the instrument. The offset pin on the power cable three-prong connector is the ground pin.

1-12 To preserve the protection feature when operating the instrument from a two contact outlet, use a three-prong to two-prong adaptor and connect the green pigtail on the adaptor to ground.

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 only necessary to connect the power cable supplied with the instrument to the POWER input and the instrument is ready for operation.

2-5 This instrument is air cooled. Sufficient space to permit free 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^{o}C. (122^{o}F).

2-6 POWER REQUIREMENTS

2-7 The LVR series can be operated from either 115 or 230 volts AC, 48 to 63 cps source. The instrument as shipped from the factory is normally wired for 115 volt operation. If the instrument is to be used on a 230 volt line, the following changes must be made.

a. Unplug the line cord and remove top cover.

b. Remove the strap between 1 and 3 and 2 and 4 on the power transformer (T1).

c. Add strap between 2 and 3.

d. Replace fuse F1 with a 230 volt fuse having one half the previous current rating.

e. Replace top cover. Turn on instrument and operate normally.

2-8 Instruments with an output capacity exceeding 5 amperes 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 is equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cable three-prong connector is the ground pin.

2-11 To preserve the protection feature when operating this instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green pigtail on the adapter to ground.

2-12 REPACKAGING FOR SHIPMENT

2-13 The following list is a general guide for repackaging an instrument for shipment. If you have any questions, contact your authorized Harrison Laboratories sales representative.

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 Laboratories. 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 Harrison Laboratories 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.

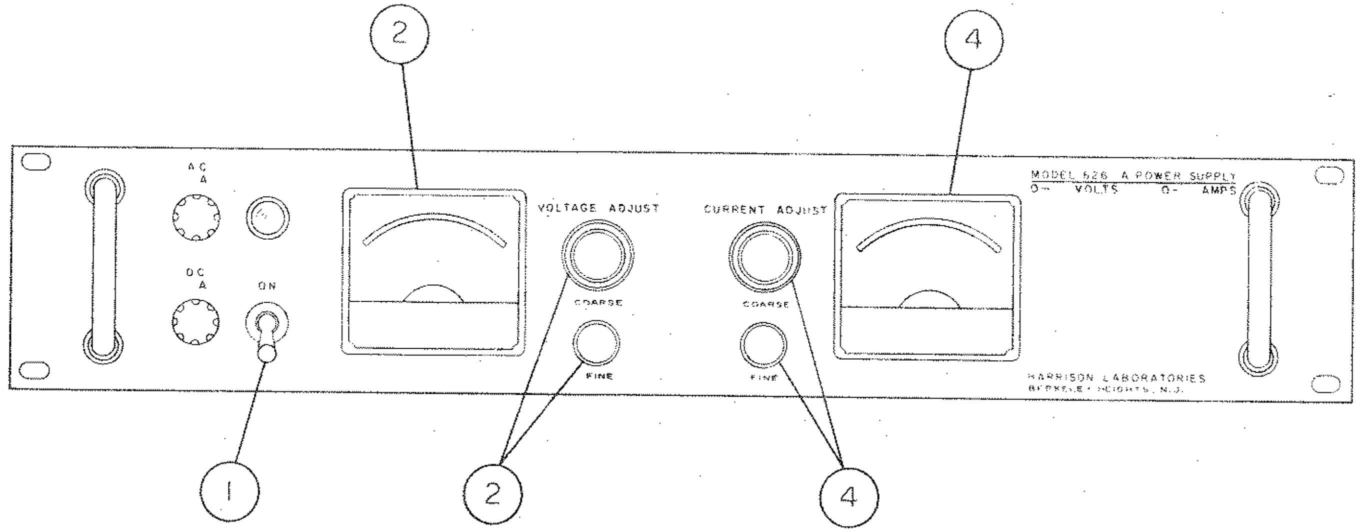
3-7 Sensing is automatically accomplished at the rear terminals of the power supply as shipped from the factory. The user should realize that the specifications describing the electrical characteristics of the power supply are written for measurements made on the sensing terminals of the power supply. 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.

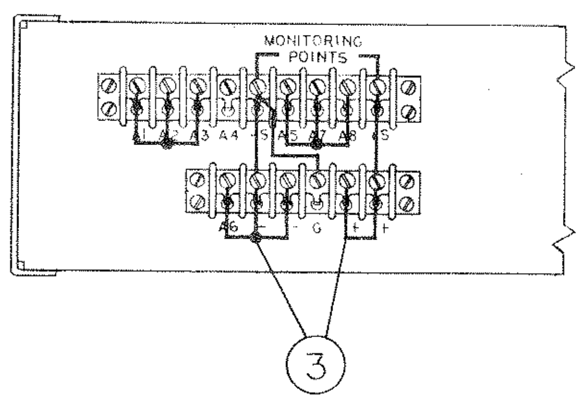
3-8 OPERATING PROCEDURE

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 pot is disabled when the following remote programming procedures are followed.





1. TURN A.C. 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

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.

(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.

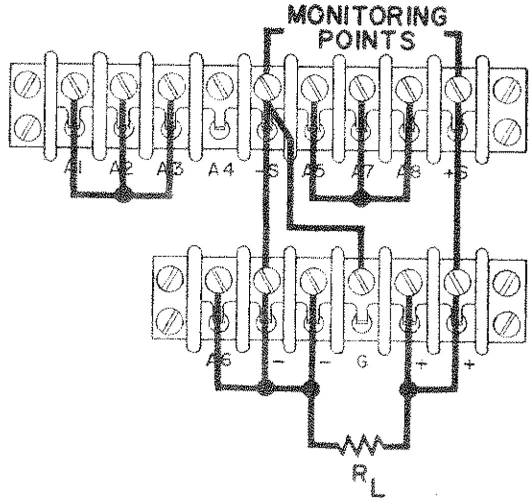
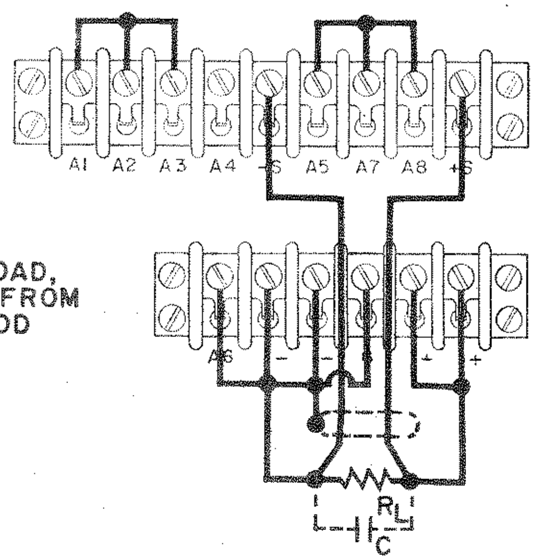
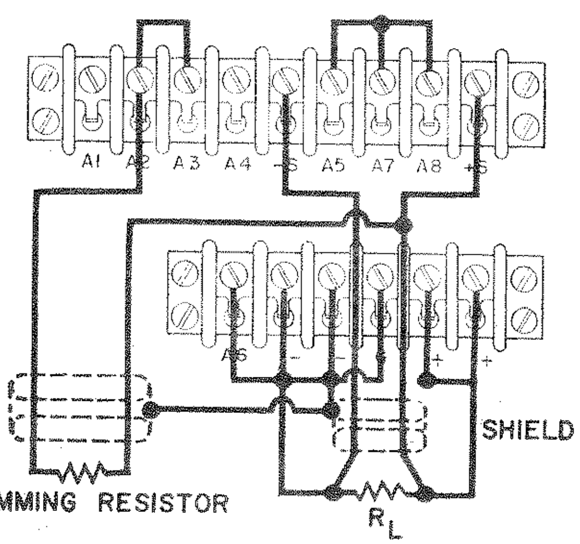


FIG. 3-2 NORMAL.



NOTE: FOR LOW AC IMPEDANCE AT LOAD, REMOVE STRAP FROM – TO A6 AND ADD CAPACITOR C.

FIG. 3-3 REMOTE SENSING.



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

FIG. 3-4 REMOTE SENSING 8 REMOTE PROGRAMMING.

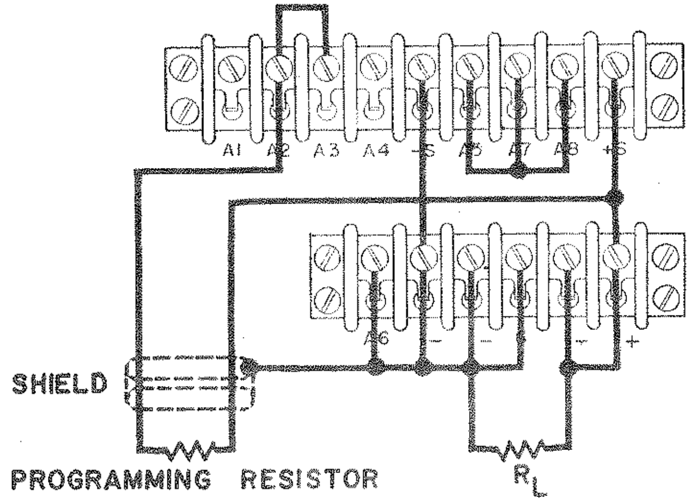


FIG. 3-5 A (RESISTANCE PROGRAMMING) REMOTE PROGRAMMING CONSTANT VOLTAGE

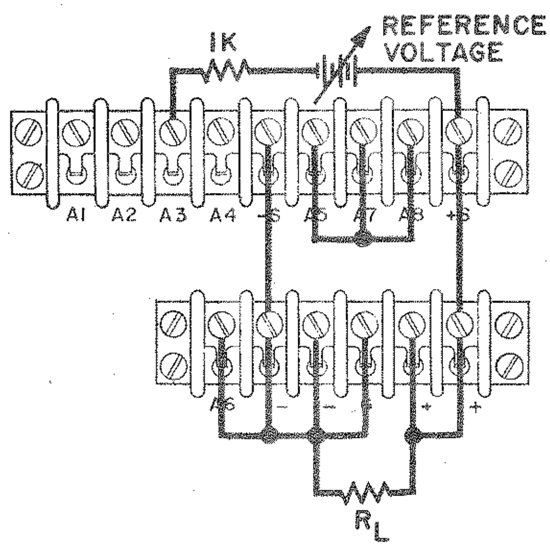


FIG. 3-5 B (VOLTAGE PROGRAMMING) REMOTE PROGRAMMING CONSTANT VOLTAGE

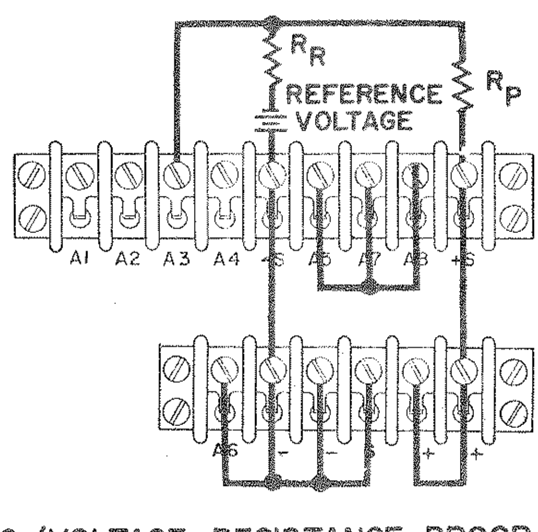


FIG. 3-5 C (VOLTAGE-RESISTANCE PROGRAMMING) REMOTE PROGRAMMING CONSTANT VOLTAGE

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:

$$I_o = \frac{V_R}{R_M} \text{ Amps} \qquad V_R = \text{Reference Voltage} \qquad R_M = \text{Internal Monitoring Resistor}$$

(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:

$$I_o = \frac{V_{REF}}{R_M} \quad \frac{R_A}{R_B}$$

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.

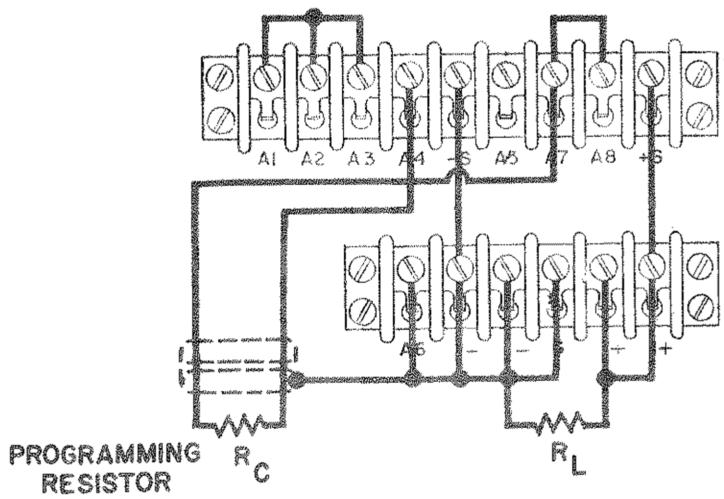


FIG. 3-6A REMOTE RESISTANCE PROGRAMMING CONSTANT CURRENT

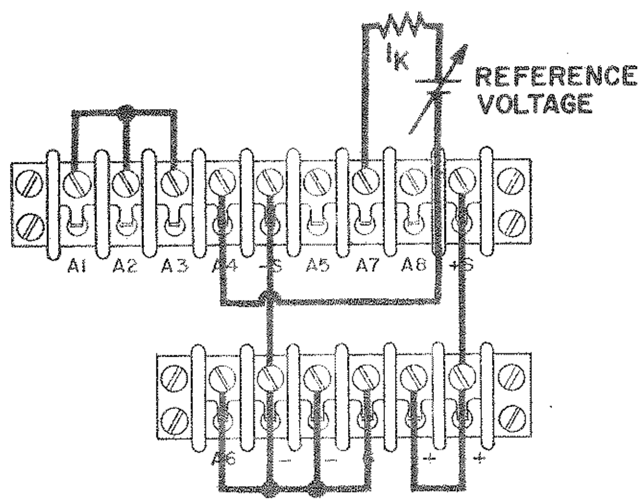


FIG. 3-6B (VOLTAGE PROGRAMMING) REMOTE PROGRAMMING CONSTANT CURRENT

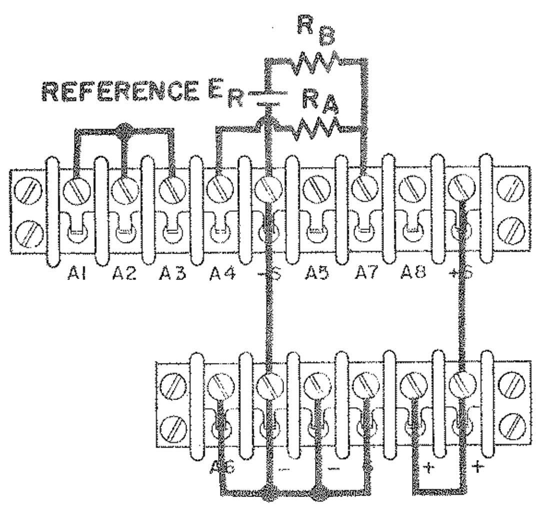


FIG. 3-6C (VOLTAGE & RESISTANCE PROGRAMMING)
REMOTE PROGRAMMING CONSTANT CURRENT

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.

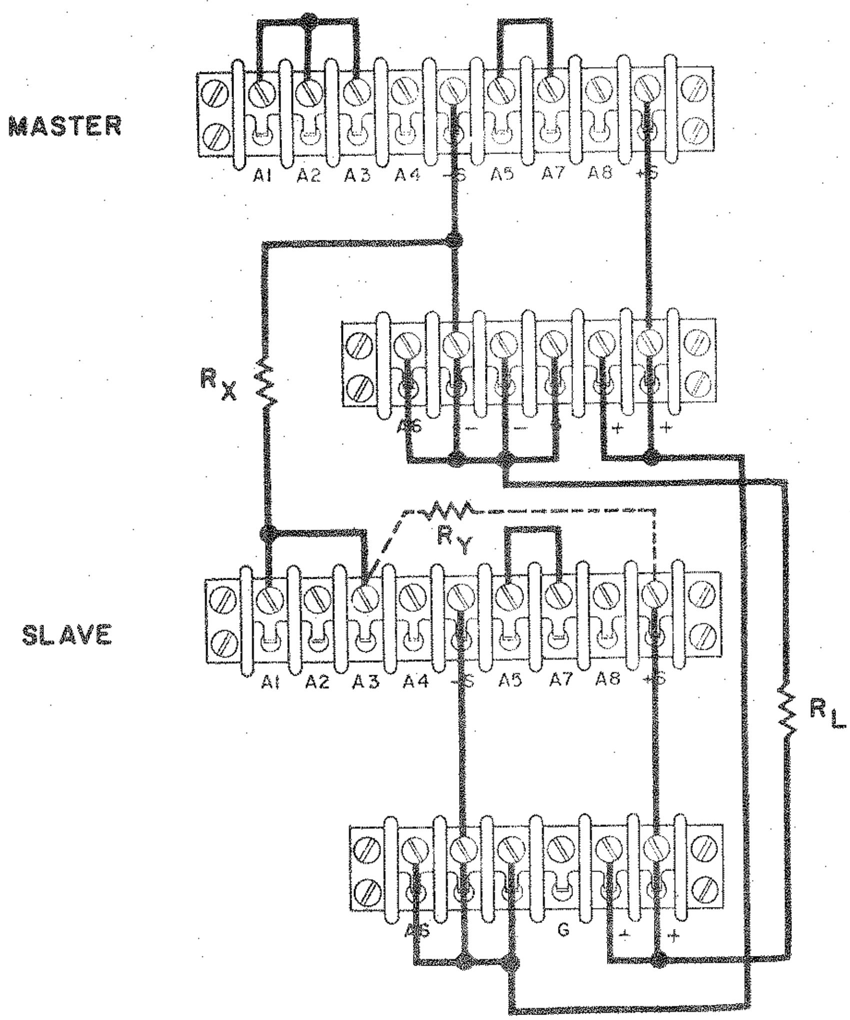
b. R_x and R_y should be selected so that a current equal to the programming current flows at maximum output voltage. The voltage across R_x will be equal to the output voltage of the master unit. The voltage across R_y will equal the output voltage of slave unit one.

c. The most negative 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.

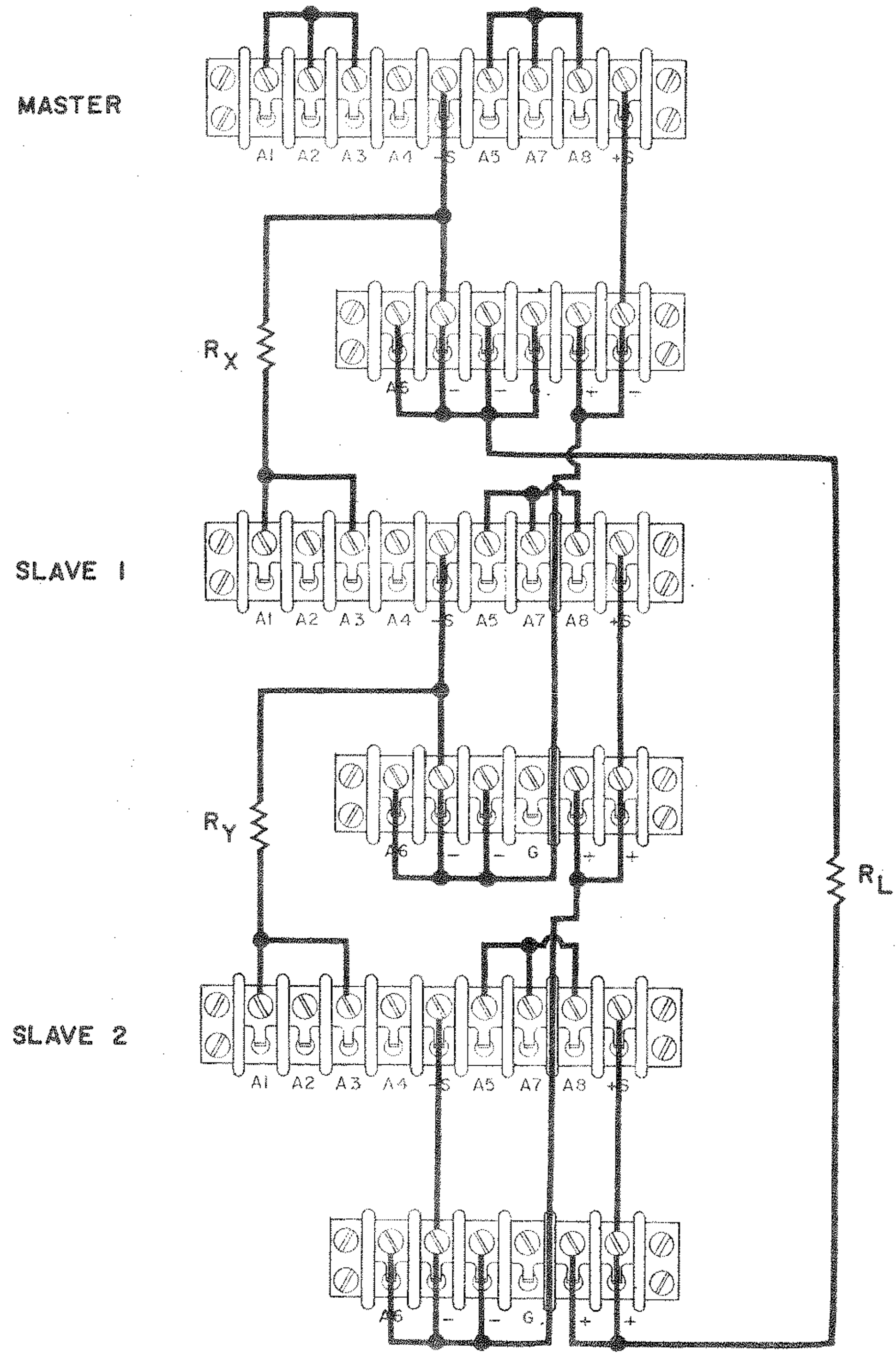
a. The most negative power supply must be selected as the master or control unit.



NOTE: FOR EXTERNAL PROGRAMMING OF SLAVE SUPPLY, ADD R_Y, REMOVE STRAP FROM A6 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

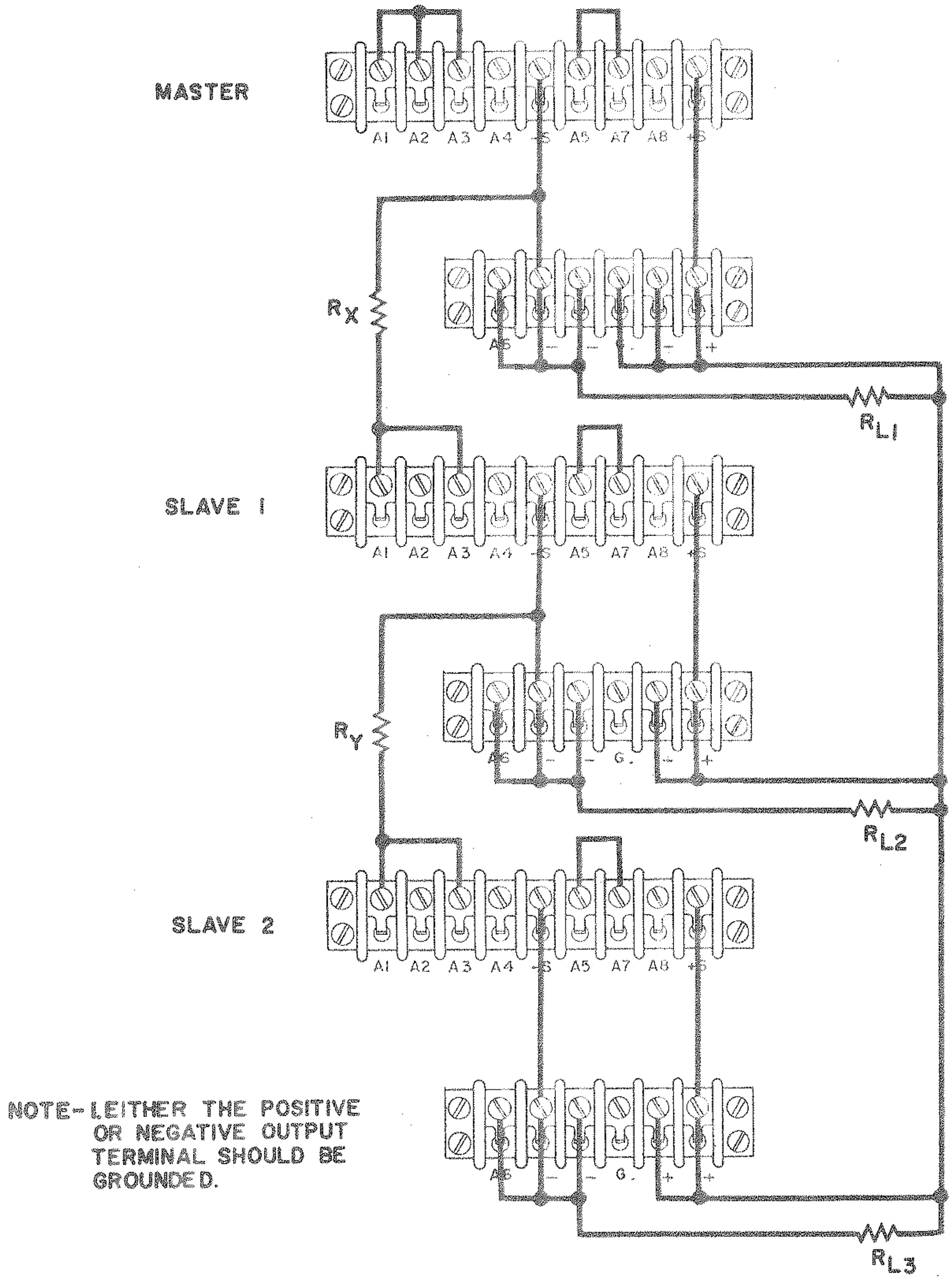


FIG. 3-9 AUTO TRACKING

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 ^{o}C) and selected such that the individual slave output currents equal (±10%) the master output current.

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 R82 and R83. The resistor should be selected so that at maximum operating current, the voltage drop across the resistor will be 1.0 volts. The line and load regulation of the power supply will now be 0.05 percent of maximum operating current rather than 0.05 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/^{o}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.

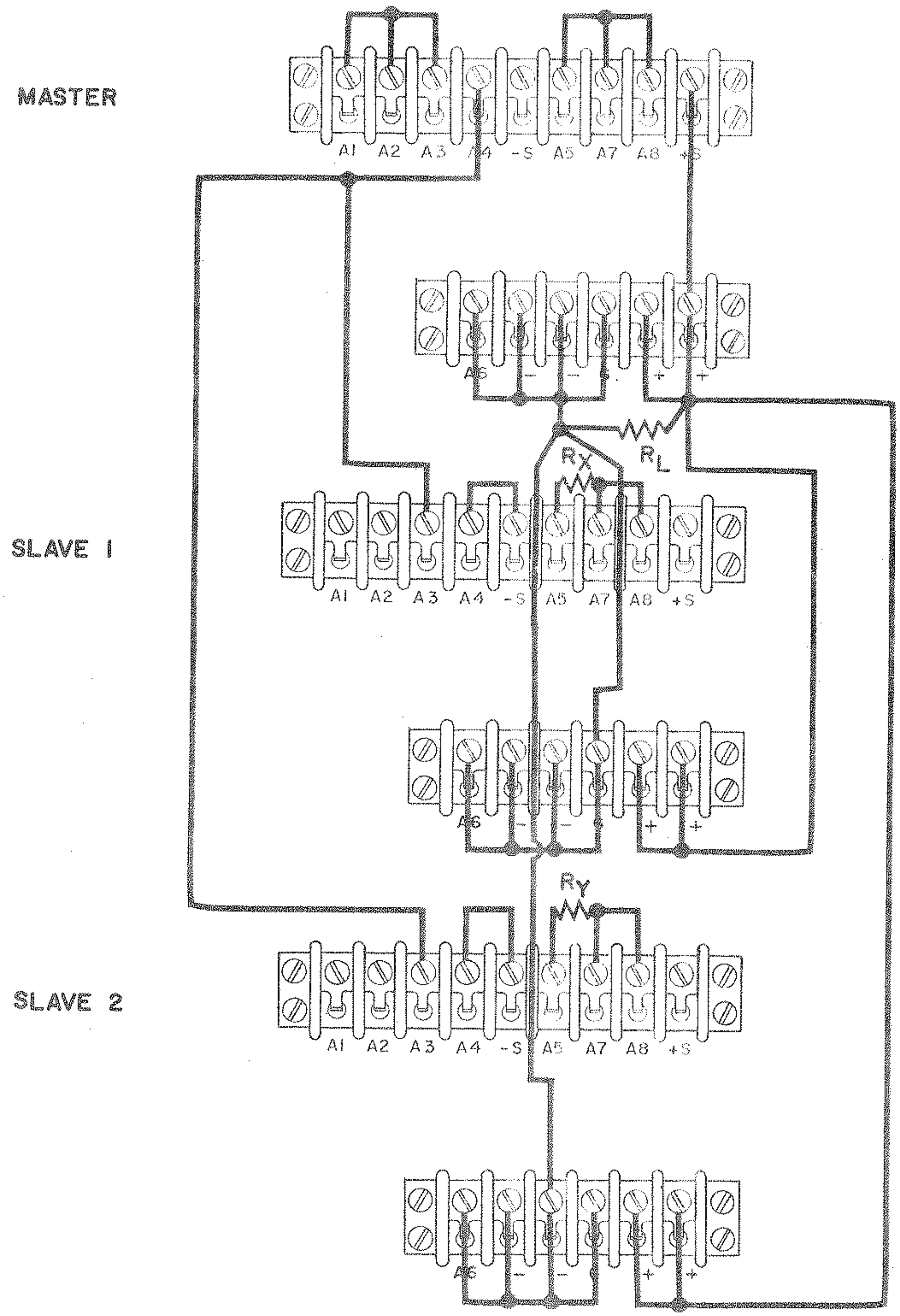


FIG. 3-9 AUTO PARALLEL

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 100 ma 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/^{o}C) resistor and should be used at no more than 5% of its rating power.

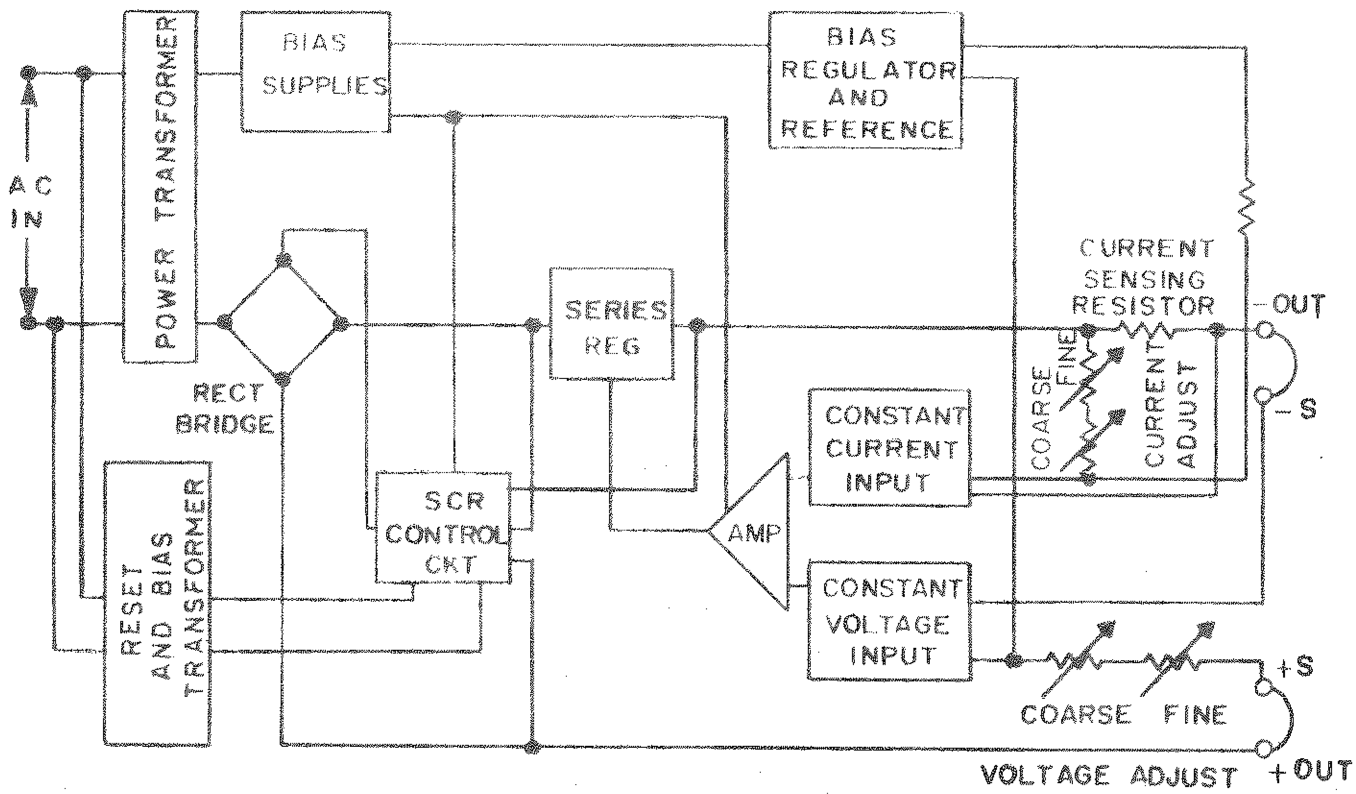


FIG. 4-1 BLOCK DIAGRAM

4-1 OVERALL BLOCK DIAGRAM (Figure 4-1)

4-2 The main power transformer supplies AC voltage to the main and auxiliary supplies. The main rectifier is a bridge configuration employing two silicon controlled rectifiers as control elements. The function of the preregulator is to minimize the power dissipated in the series control element for all output and input conditions. The output current is monitored by a current sensing resistor. The voltage across the current sensing resistor is directly proportional to the output current and provides signal voltage to the current limit input circuit. The output voltage of the power supply is monitored by a constant voltage input circuit through the sensing terminals. Any changes in the output voltage/output current are detected in the constant voltage/constant current input circuit, amplified in the error amplifier, and applied to the series regulator in a manner which tends to counteract the changes in the output voltage/current. The bias supplies furnish voltages which are used throughout the instrument for reference and supply purposes.

4-3 BIAS AND RESET SUPPLIES

4-4 The auxiliary windings of T1 supply AC voltage to the bias rectifiers and all pertinent voltages are shown in Figure 4-2. Alternating preregulating control voltages (reset and AC compensation) are also supplied by transformer T1.

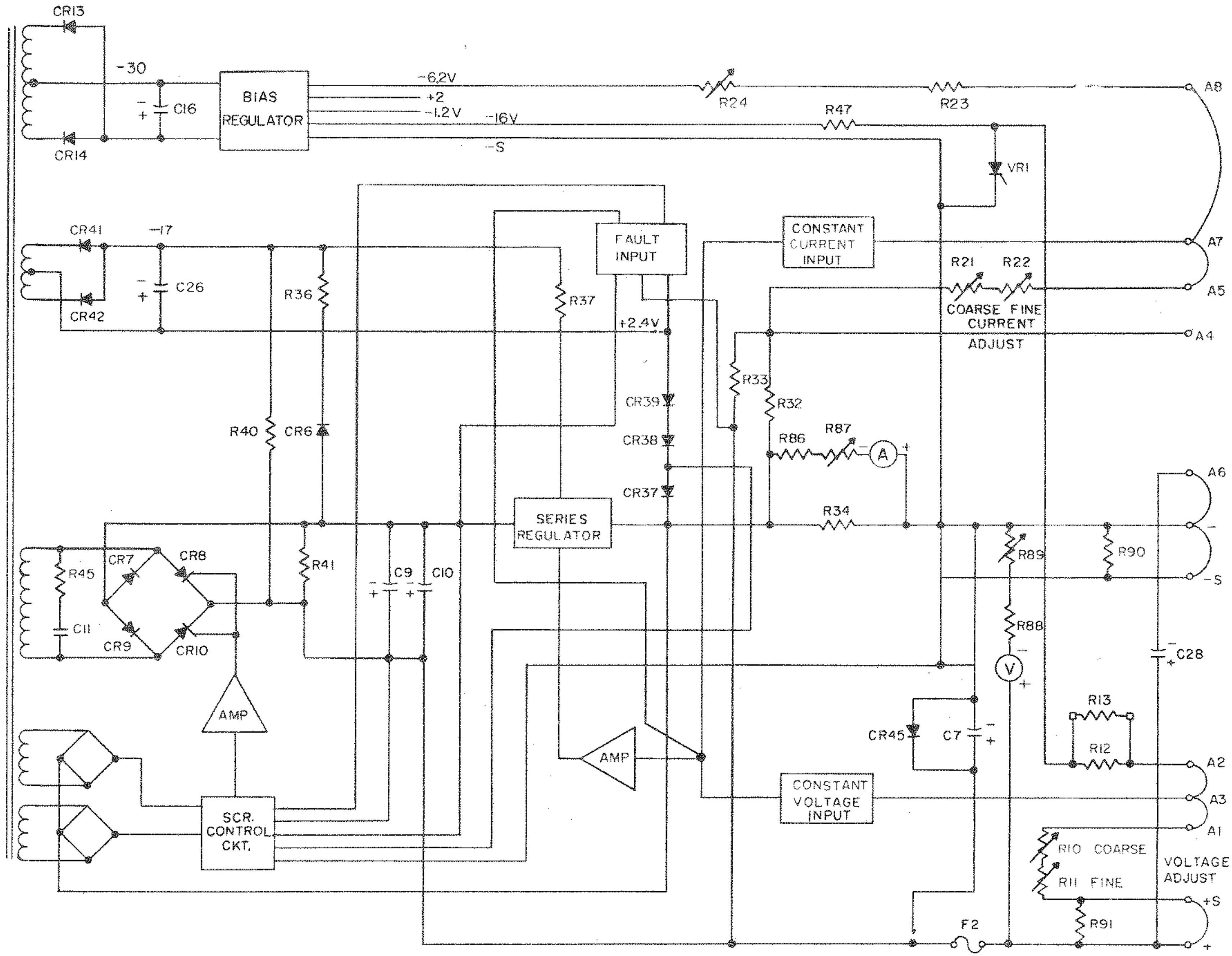


FIG. 4-2 SIMPLIFIED SCHEMATIC

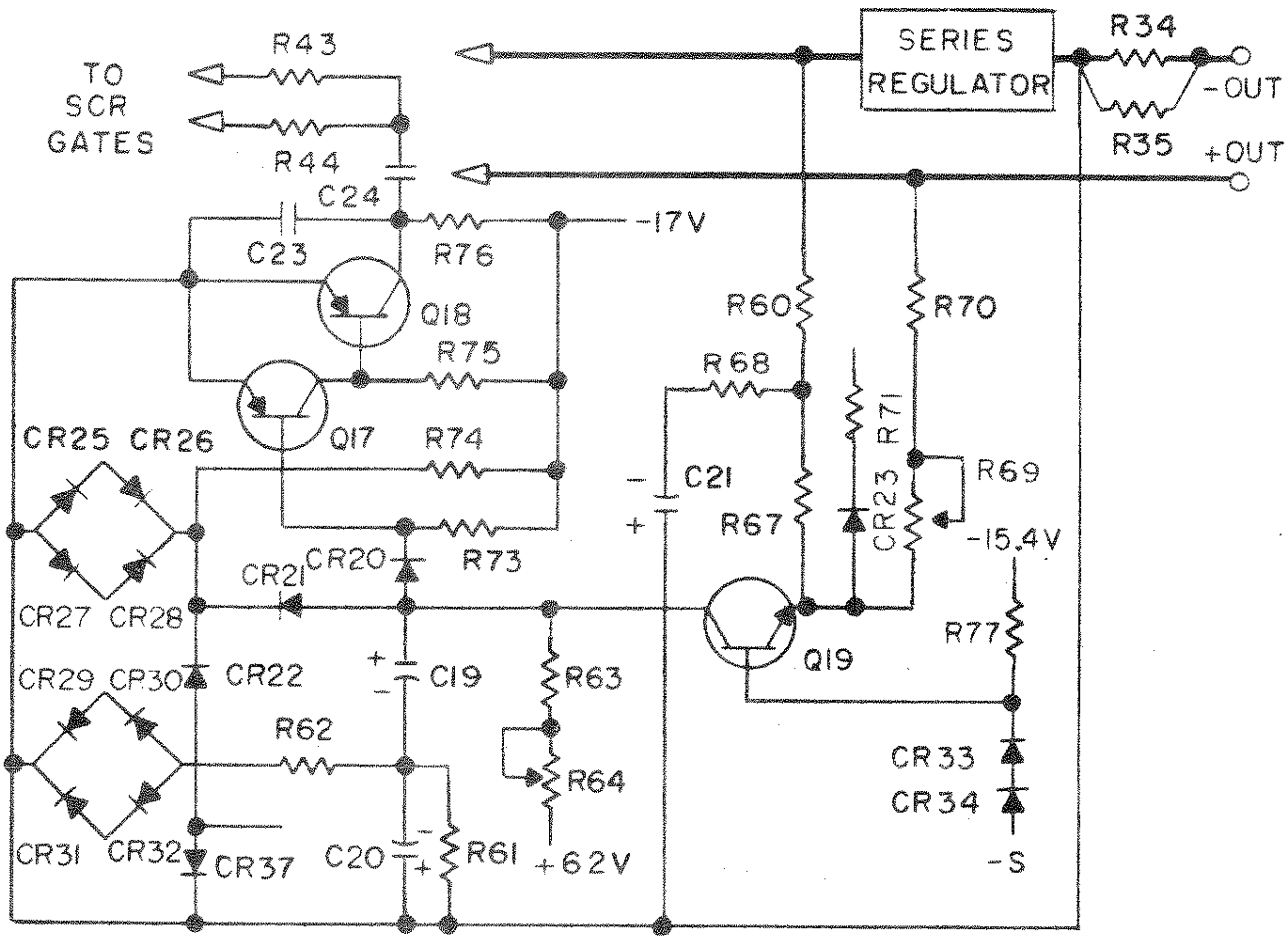


FIG. 4-3 PREREGULATOR

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 Q19 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 siganl 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 (C19) with a constant current, supplied through R63 and R64. This current is necessary to sustain a net positive charging current into the ramp capacitor, maintaining maximum output current at low output voltages.

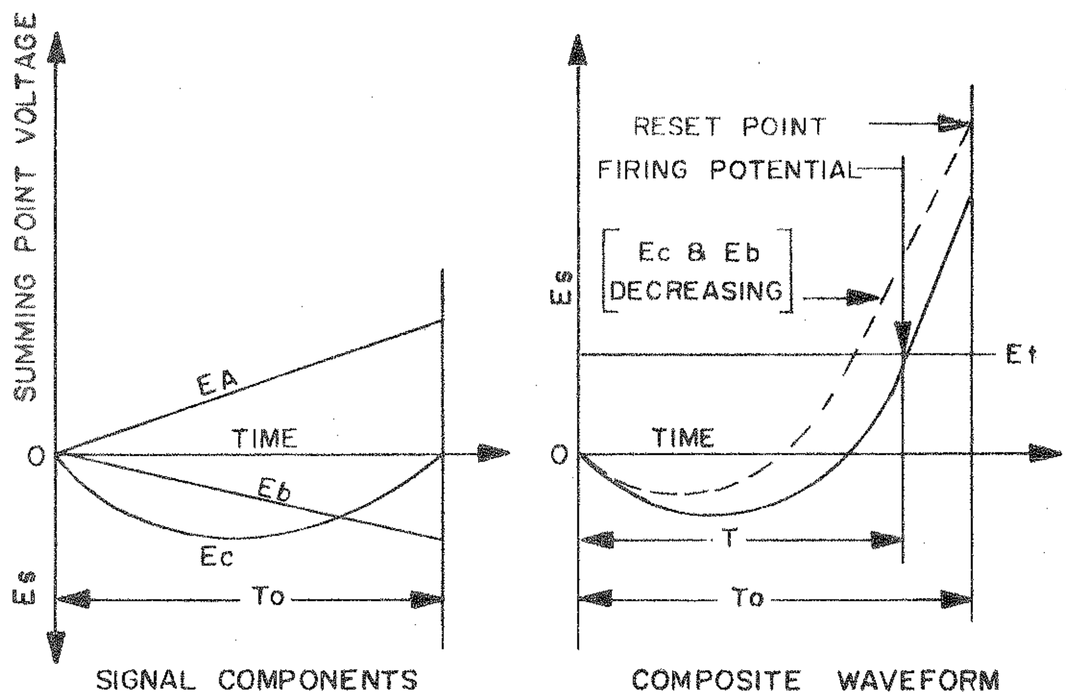


FIG. 4-4

4-9 E_b is derived by charging the ramp capacitor with a current controlled by Q19 in accordance with the signals applied to its emitter. R69 and R70 connected between the emitter of Q19 and the positive output bus, are the source of a signal which is proportional to the output voltage. R66 and R67 sense the voltage across and the current through the series transistor. This signal polarity is negative with respect to the signal injected through R69 and R70. 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, Eb is directed such that the series regulator voltages is maintained constant for all output voltage conditions. C21 and R68 provide equalization necessary to maintain loop stability.

4-10 E_c is a negative fullwave rectified sinewave voltage, attenuated by the divider action of R61 and R62, 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. C20 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, diode CR20 closes,applying a turn-off signal to the base of Q17, which in turn applies a turn-on signal to the base of Q18. Due to the saturation of Q18, the charge stored in C24 is discharged through the gates of the silicon controlled rectifiers. C23 is high frequency shunt and R43 and R44 are gate current limiting resistors. R71 and CR23 form a turn-on inhibitor circuit which limits the input peak currents.

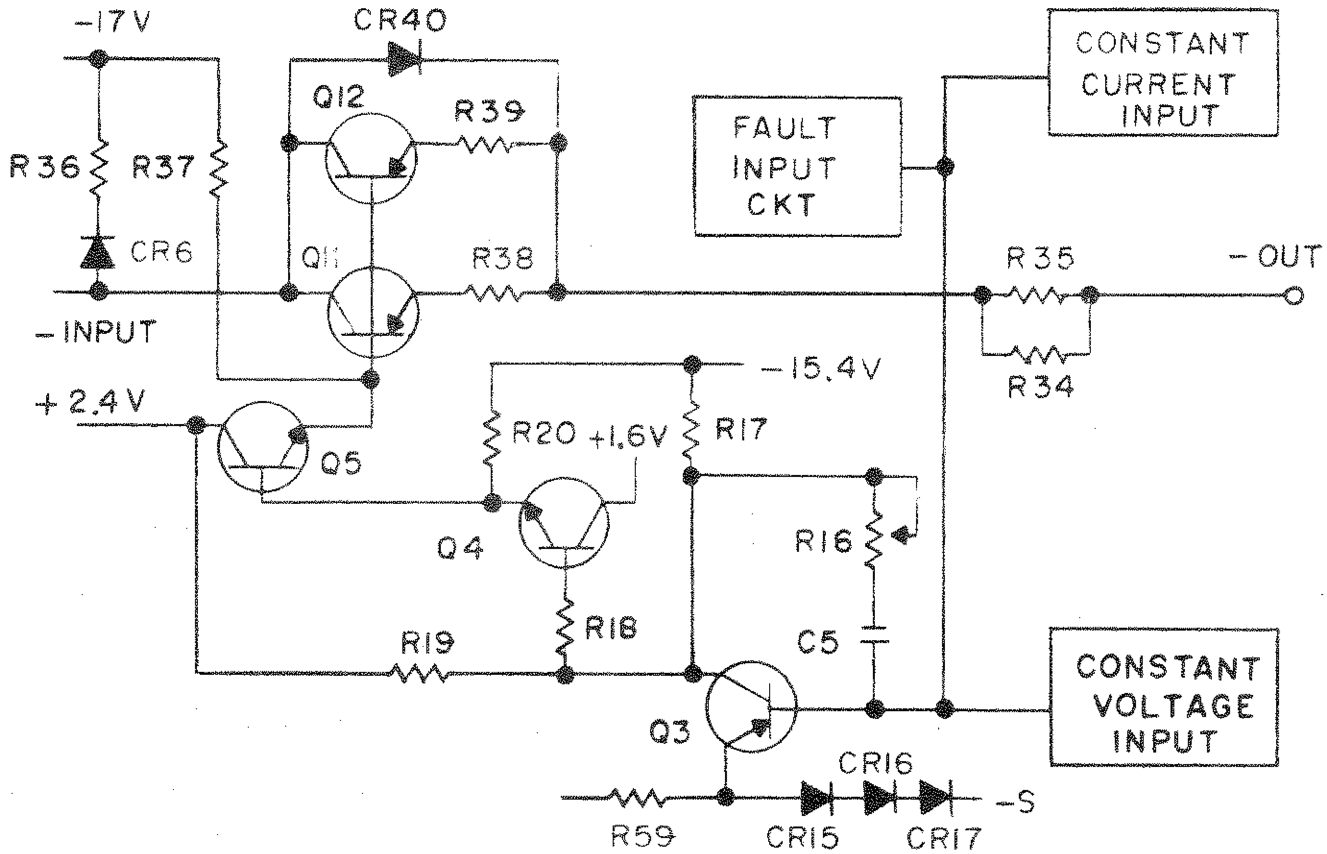


FIG. 4-5 ERROR AMPLIFIER AND SERIES REGULATOR

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'.

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 CR21. Near the completion of the period, E_s becomes more positive than the receding reset sinewave (in the cusp region) and forward biases CR21. C19 is discharged and returned to a voltage level established by CR21, CR22, and CR37.

<u>4-14 SERIES REGULATOR AND ERROR AMPLIFIER (Figure 4-5)</u>

4-15 The series regulator consists of transistors Q11 and Q12. Transistor Q5, an emitter follower, is the drive for the series transistors and Q4, also an emitter follower, is the predriver.

4-16 Q3 is the error amplifier transistor and signals applied to the base are amplified and applied to the base of Q4. C5 and R16 stabilize the feedback loop and CR40 is a protective diode.

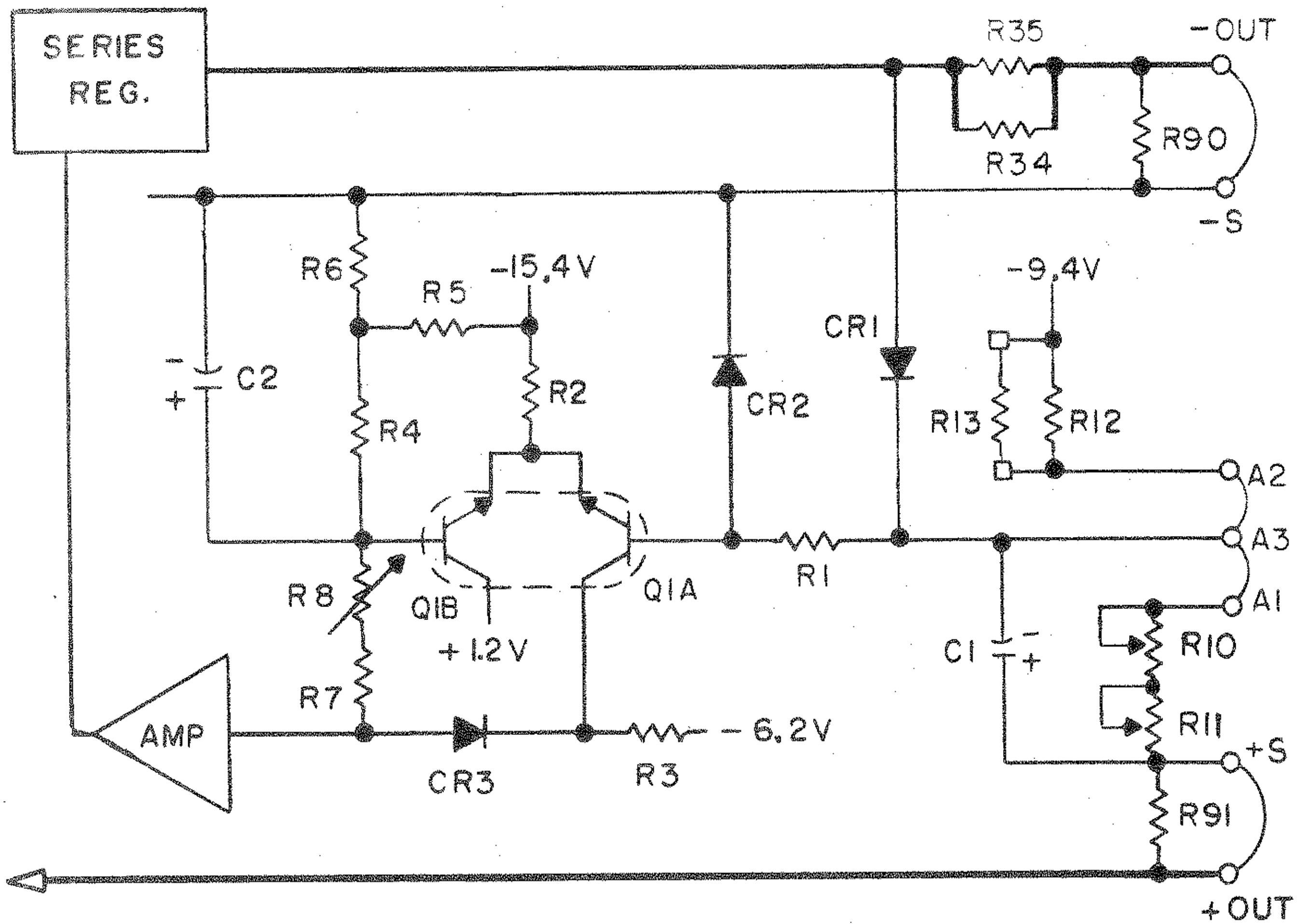


FIG. 4-6 INPUT CIRCUIT, CONSTANT VOLTAGE

4-17 CONSTANT VOLTAGE INPUT (Figure 4-6)

4-18 A differential amplifier (Q1A and Q1B) and associated circuitry are employed as a detector-amplifier in the constant voltage mode. R12 and R13 (a shunt resistor) are used to establish the programming current level. R10 and R11 are the voltage adjustment potentiometers and are shunted by C1, a low impedance AC signal path. The base of Q1B is grounded through resistors R4 and R6 in order to achieve desired thermal characteristics. The base of Q1A is connected to the junction of the programming resistor and the current pullout resistor R12 through a current limiting resistor (R1). 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. R7 and R8 are a positive feedback loop to increase the DC circuit gain, and C2 stabilizes this local feedback loop. CR3 and R3 comprise a decoupling network isolating the constant voltage input when in other modes of operation.

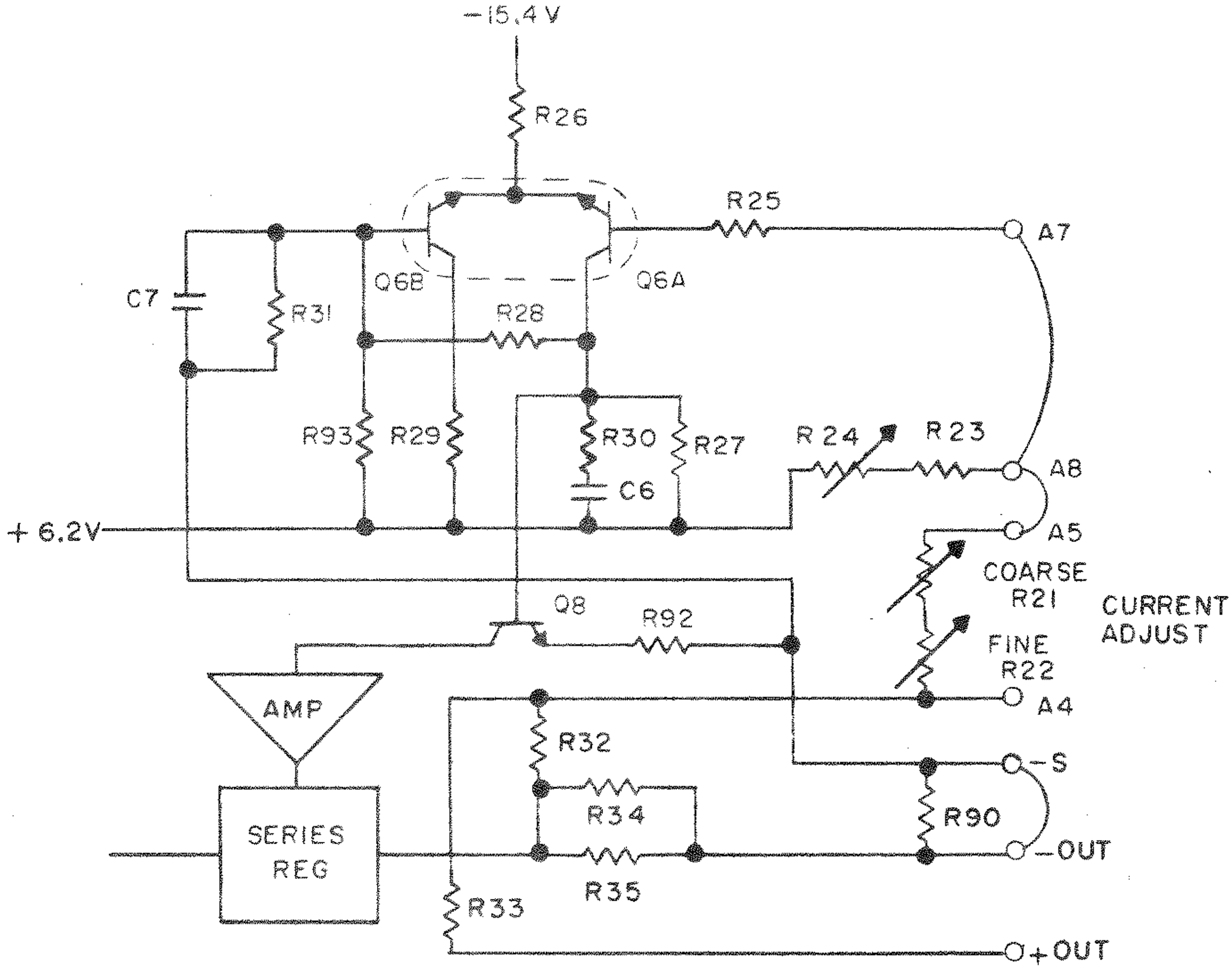


FIG. 4-7 INPUT CONSTANT CURRENT

4-19 INPUT CIRCUIT CONSTANT CURRENT (Figure 4-7)

4-20 The constant current input circuit consists of the fine current control, R22 and the coarse current control, R21, the amplifier transistors Q6A and Q6B, and associated circuit. The base of Q6B is grounded through the impedance equalizing resistor R31 in order to achieve desired thermal characteristics. The base of Q6A is connected to the junction of the programming resistors and the current pullout resistor, R23, through the impedance equalizing resistor, R25. R24 is used to adjust the programming current. R28 is used to increase DC circuit gain. C7 stabilizes the local feedback loop. R32 and R33 are arranged in a network which changes the bias voltage of Q6A as the output voltage changes. This network is required to compensate for an error current generated by the voltmeter shunting the output terminals. R30 and C6 provide required loop stability in constant current operation. Q8, a common emitter amplifier, increases loop gain, decreasing the current change necessary to traverse the crossover region.

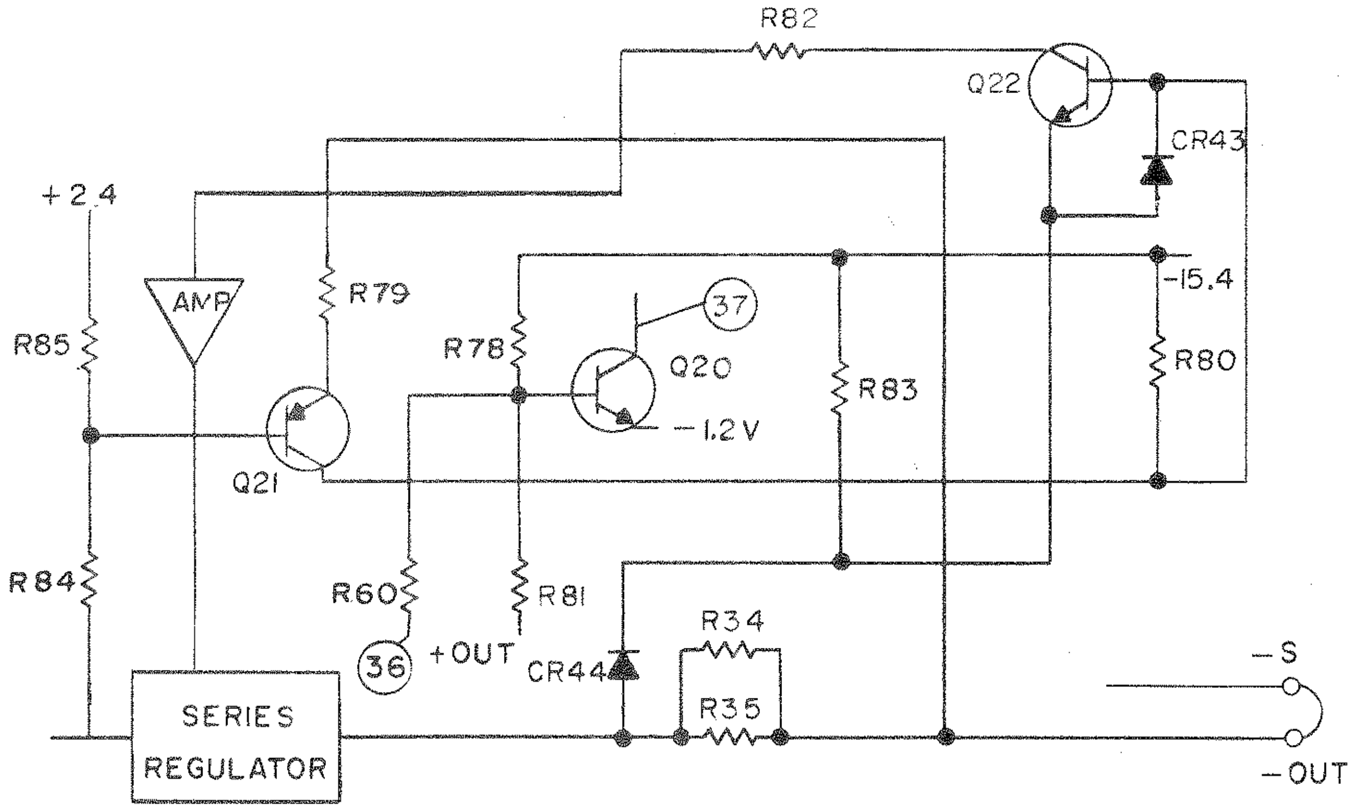


FIG. 4-8 FAULT INPUT CIRCUIT

4-21 OVERVOLTAGE AND SHORT CIRCUIT INPUTS (Figure 4-8)

4-22 A circuit configuration consisting of Q20, R60, R78, and R81 forms an overvoltage detector. One end of the divider R78 and R81 is supplied from the -15.4 volt source and the other is connected to the positive output. Fullwave rectified sinewave voltage is applied through R60 and exercises a stabilizing influence. If the output rises above a predetermined level, Q20 is acted upon and conducts, transmitting a turn-off signal to the preregulator control circuit. The overvoltage circuit is set for approximately 115% of maximum rated output.

4-23 Short circuit protection is accomplished by means of Q21, Q22, R79, R80, R84, and R85. Divider R84 and R85 is connected between the series regulator collector and the +2.4 volt supply. Q21 and Q22 are non-conducting under normal conditions; however, under short circuit conditions, the increased voltage across the series regulator drives Q21 into the saturated mode of operation. The voltage established by divider R79 and R80 at the base of Q22 forward biases Q22. The action of Q22 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.

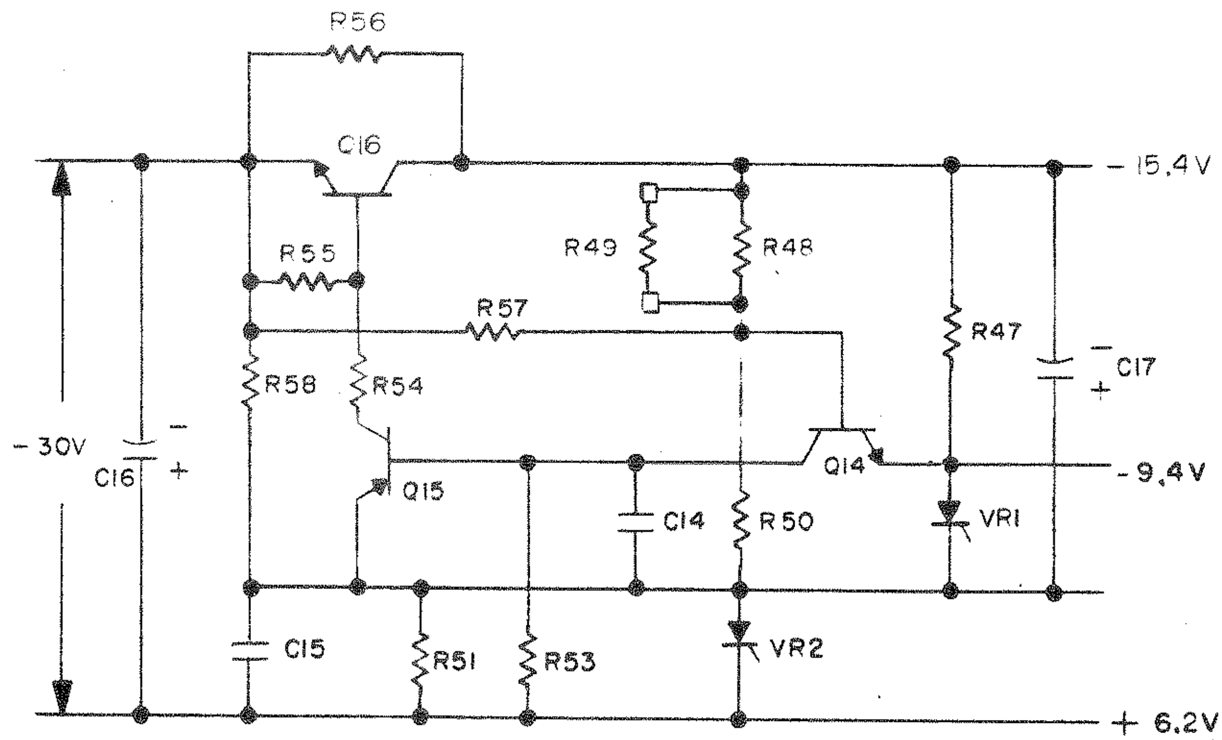


FIG. 4-9 BIAS REGULATORS AND REFERENCE CIRCUIT

4-24 REFERENCE AND BIAS CIRCUIT (Figure 4-9)

4-25 The unregulated input voltage across C16 is finely regulated by means of Q14, Q15, Q16 and associated circuitry. The series regulator, Q16, is driven by Q15, an error amplifier, and the error amplifier is driven by the detector, Q14. The reference element for the bias regulator and the entire unit is VR1. R48 and R50 are the comparison elements and VR2 is utilized for an additional bias source. R57 attains output immunity to line variations. R56 minimizes power dissipation in Q16 and C17 and C14 stabilize the bias regulator loop.

4-26 REGULATOR CIRCUIT OPERATION

4-27 The circuit functions 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 R10 and R11. The signals are amplified,reversed in phase, and coupled to the base of Q3 through the gating diode CR3.

4-28 The voltage on the anode of the CR3 and the collector of Q8 is established by the base voltage of Q3. The cathode voltage of CR3 is established by the collector voltage of Q1A. The base voltage of Q8 is established by the collector voltage of Q6A. Transistor Q1A will be conducting when the supply is in the constant voltage mode of operation and CR3 is forward biased.

4-29 Transistor Q6A, begins to conduct when the supply goes into the constant current mode of operation. At this time, the voltage across the output terminals decreases. The signal applied to the base of Q1A will result in its collector voltage going positive and reverse biasing CR3. Q8 is forward biased due to the conduction of Q6A. There is a transistion region during which both inputs will be active and is referred to as the cross-over region.

4-30 The signal applied to Q3 is amplified, inverted and applied to the base of the predriver Q4 which applies the amplified signal in phase to the base of Q5 the driver. This signal is amplified by Q5 and applied to the base of the series transistors Q11 and Q12. The signal is applied in the phase and amplitude required to restore the original operating conditions, thus maintaining the output voltage/output current of the power supply constant.

4-31 The DC output voltage is changed by varying the front panel controls. Resistor R12, in conjunction with the reference voltage, can be considered a constant current source since the voltage at the summing point (11) is at circuit ground when the loop is in equilibrium. Potentiometer R10 and R11 are connected between the summing point and the positive sensing terminal, and since the current through it is constant, feed-back action of the regulator loop will maintain the output voltage of the power supply equal to the drop across this resistor.

4-32 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 R21, R22, R34. R21 and R22 set the constant current level and R34 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 required 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 5-50.

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 burned out fuses (AC and DC), 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 Laboratories 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 27 and should be 9.4

(continued on Page 5-12)

TABLE 5-1

Instrument Type	Required Characteristics	Use	Suggested Test Equipment
DC Voltmeter	Accuracy of ±2% Approx. ranges 0-2.5 volts 0-50 volts 0-150 volts	Measure DC	Simpson Model 269
DC Ammeter	0-10 amps Accuracy ±1%	Measure DC Currents	
AC Voltmeter	Accuracy of ±2% Approx. voltage ranges 0-150 volts	Measure AC Voltages	Simpson Model 269
AC Voltmeter	Accuracy of ±1% 90-130 Volts Expanded scale	Measure Input Line Voltage	Triplett Model 420M
Variable Transformer	100-130 volt ranges 5 amp current capacity	Change AC Input Voltage	Superior Type Q116U
Oscilloscope	200μv/cm sensitivity differential input	Measure Ripple, transient Response	HP Model 130C
Differential Voltmeter	1mv resolution	Measure Regulation	See note
Load Switch	2 μ sec rise and fall time	Measure Transient Response	Mercury Relay, Clare Type HGP1002

Instrument Type	Required Characteristics	Use	Suggested Test Equipment
Load	12 ohms, 200 watts 6 ohms, 100 watts, and 3 ohms, 20 watts	Measure Loaded Characteristics at 36 volts, 18 volts and 9 volts.	
Current Monitoring Resistor	0.3 ohm 1%, 200 watts 20 ppm temperature coefficient	Measure Constant Current Operation and Adjust ammeter	

NOTE: 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 differ-erential 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.

TABLE 5-2

REPLACEMENT GUIDE

If you change:	Check the following and readjust:
Q1A, Q1B, CR3, CR15, CR16, CR17 CR37, CR38, CR39, VR2	Load regulation, constant voltage--R8
Q3, Q4, Q11	Load regulation, transient response, constant voltage, R8, R16
Q6A, Q6B, Q8, VR2	Line and load regulation, constant current.
Q14, Q15, Q16, VR1, VR2, CR8	Line regulation at 15.4 volt source
CR33, CR34, Q19, VR2	Series Regulator Voltage R64

TABLE 5-3

Component	Characteristics	H-Lab Designation	Suggested Replacement
Q4,16	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.
Q3,17,18,21	PNP Alloy $70 < h_{FE} < 200$ $i_c = 1$ ma, $V_{CE} = 1V$ I_{co} 2μa @ $V_{cbo} = 5V$	GT2555	2N520A GI 2N404A GE RCA
Q15	PNP Alloy $75 < h_{FE}$ $i_c = 50$ ma, $V_{CE} = 1V$ P_{MAX} 90 mx @ 70° C Ambient	2N1377	2N1377 TI
Q1A, B Q6A, B	PNP Power Drift Field $70 < h_{FE}$ $i_c = 1$ ma, $V_{CE} = 1V$ $I_{co} = 10$ na @ 25°C $V_{cbo} = 20V$ $V_{ceo} = 15V$ $V_{be1} - V_{be2} = 2$ mv $\Delta V_{be1} - \Delta V_{be2} = 25$ μv/°C	4JX12A839	2N2640TI 2N2480A GE 12A8 GE
Q8,14,19,20, 22	NPN $75 < h_{FE} < 225$ $i_c = 2$ ma $V_{CE} = 4.5V$ $I_{co} = .5$μa @ 25°C $V_{cbo} = 18V$	16B2	2N2195A GE 2N2219 Mot.
Q11	PNP Power $75 < h_{FE} < 150$ $i_c = 3A$ $V_{CE} = 1V$ $I_{co} = 2$ ma 25°C $V_{cbo} = 60V$ $V_{ces} = 75V$	B1203	2N1137A Bendix

TABLE 5-3 (Cont'd)

Component	Characteristics	H-Lab Designation	Suggested Replacement
CR1,2,3,6,11,20, 21,22,23,24, 25,26,27,28,29, 30,31,32	Si Diode Low Leakage	1N485B	1N485B 1N484A
CR15,16,17,33, 34,37,38,39	Si Rectifier .2 Amps	111S1	1N484A Syl. 1N485B Syl.
CR13,14,41,42	Si Rectifier	1N3253	1N3253 RCA 1N2611
CR8,10	SCR 20 Amp rms 100 volt PRV	C20A	C20A GE C11A GE
CR7,9	Si Rectifier 12 Amps	1N1200A	1N1200A RCA 1N1342 RCA
CR40,45	Si Rectifier 3A, 200 PRV	MR1032B	MR1032B Mot 1N1200 RCA
VR2	6.2V 400 mw zener	1N821	1N821 NA
VR1	9.4 Temperature compensated reference diode	1N2163	1N2163 Semcor 1N2621

*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	27	9.4V	±0.4V	200µv
-S	32	25.0V	±2.0V	1.0V
-S	50	1.2V	±0.2V	2 mv
-S	58	17.0V	±2.0V	1.0V
-S	56	1.2V	±0.4V	1mv
-S	25	5.8V	±0.2V	30 mv
-S	28	15.4V	±1.0V	500µv
33	-S	6.2V	±0.4V	1 mv
15	-S	1.8V	±0.2V	2 mv
59	-S	2.4V	±0.4V	20 mv
33	28	22V	±2.0V	2 mv
33	32	30V	±2.0V	0.5V
+	39	41.0	±0.5V	30 mv
+	-	36.0V	----	500 µv

NOTE: The voltages listed above are measured at 36 volts, no load, and 115 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 negative output terminal of the power supply.

TABLE 5-5

MISCELLANEOUS TROUBLES

Trouble and Description	Check:
1. Excessive Output Ripple	a. Check to see if output is grounded. Use 1μf capacitor if it is impossible to DC ground. b. Check voltage across series transistor Q1. Use a scope, DC coupled to make the measurement which should be 3.5V $\pm$0.4V. 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	Check 15.4 volt line regulation.
3. Poor Load Regulation (Constant Voltage)	a. Measurement Technique -- should measure across the sensing terminals. b. Check adjustment of R8. c. Incorrect strapping of sensing terminals. d. Q1A, Q1B, or Q3 defective. e. Current control set too close to maximum operating current.
4. Poor Load Regulation (Constant Current)	C27 leaky -- External load across output terminals (i.e. low impedance voltmeter) Q8, Q3, Q6A, Q6B, or VR2 defective. Voltage control set too close to maximum operating voltage.
5. Oscillates	Check adjustment of R16 (equalizer), capacitor C5, and strap between A6 minus.

TABLE 5-5 (Cont'd)

Trouble and Description	Check:
6. Voltage Limited (Cannot reach maximum output voltage)	a. Check the voltage across series regulator Q11 for 3.5V ± 0.4V. b. Check Q4, Q19, VR1, CR33 and CR34 if less than required. c. Check R10 (voltage programming) R21 (constant current programming), reference voltage (9.4V), Q3, Q22, CR15, CR16, CR17, CR37, CR38, CR39, VR1 and -17 volt unregulated bias if series regulator voltage is high.
7. Current Limited	a. Check the voltage across series regulator Q11 for 3.5V ± 0.4V. b. Check drop across R34 which should be 0.9 volts at 3.0 amps. The resistance of R67 should be 0.30 ohms ± 5%. Check VR2, Q6A, Q6B and Q8 if series regulator voltage is high. c. Check R10 (voltage programming potentiometer), Q3, Q4, and -17 unregulated supply if the series regulator voltage is low.
8. Stability (Constant Voltage)	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 R12 noting R13 should be a minimum of ten times larger in resistance than R12. d. Check Q1A, Q1B, Q3, CR1, CR2 and CR3.
9. Stability (Constant Current)	a. Measure stability of reference voltage 6.2 volts measured between -S and change VR2 if unstable. 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 R34 as source of drift. Check R23, R24, and R26.

TABLE 5-5 (Cont'd)

Trouble and Description	Check:
9. Stability (Constant Current)	c. Change Q6A and Q6B if above steps do not yield positive results.

volts ±0.4 volts. The 15.4volt regulated bias voltage is out of tolerance or diode VR1is probably defective if this voltage is out of specification.

2. 15.4 Volt Regulated Bias Voltage

   This voltage is measured between -S and 28. It should be 15.4 volts ±1.0 volts. If this voltage is out of specification, R48 may be defective. Diodes VR1, VR2, transistors Q14, Q15 or Q16 may be defective.

3. +6.2 Volts

   This voltage is measured between -S and 26. It should be 6.2 volts ±0.4 volts. Diode VR2 is probably defective if this voltage is out of specification.

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 Make sure that both the AC and DC fuses are inserted in the fuseholders. The front panel voltage control and current control pots should be turned to the maximum clockwise position. Use an ohmmeter to make certain the negative output terminal, and the collector of Q11 the anodes of CR25 and CR27 and the cathodes CR8 and CR10 are not grounded.

5-27 The line switch is turned on. The output voltage should exceed 36 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 28.

B. R49 is adjusted so that this voltage is approximately 15.4 volts.

C. The input line voltage is varied from 102 to 127 volts. 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 at 36 volts and 3 amperes. The voltage across points 25 and 22 (series regulator voltage) is monitored using a Simpson 269 or equivalent. R64 is adjusted for 3.5 volts ± 0.1 volt.

B. The output of the power supply is set at 3 volts and 3 amperes. The voltage is checked for 3.5 volts ± 0.4 volts.

5-30 Constant Current Adjustments. The output voltage of the power supply is set to 3 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. R24 is adjusted so that the output current is limited to 3.4 amps ±0.1 amp. (Note: The output voltage will drop since the power suppl 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 better is used to measure the output current at 3.0 amperes. R87 is adjusted so that the front panel meter indicates 3.0 amperes.

5-34 Current Equalization Check. The power supply is operated at 12.0 volts out, 3.0 amperes load, and 125 volts line. The voltage between points 25 and 52 is monitored using an AC coupled scope, and the ripple unbalance should be less than 25%.

5-35 Programming Current Adjustment

A. A differential voltmeter is connected between -S and +S. The strap between A1 and A2 is removed. A 7.2K, 0.5% programming resistor is connected between A2 and +S. A decade resistance is connected in the position of R13 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 36 volts ±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 (±5%).

D. The value of the shunt resistor should be a minimum of 10 times the resistance of R12. If it is less than this, R12 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 36 volts. R89 is adjusted so the front panel meter indicates 36 volts.

5-37 Load Regulation. The power supply is operated at 36 volts out, 115 volts line. A differential voltmeter is connected between -S and +S. The output load is varied from 0 to 3 amperes. R11 is adjusted so that the output voltage does not decrease more than 3 mv when the load is applied.

5-38 Line Regulation. The power supply is operated at 36 volts out and full load. A differential voltmeter is connected between -S and +S. The input line voltage is varied from 105 to 125 volts. The output voltage should not vary more than 3 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 3 mv.

5-39 Output Ripple. The power supply is operated at 36 volts out, full load and 102 volts 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.

5-40 Low Voltage Ripple. The power supply is operated at 3 volts out, no load and 125 volts 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.

5-41 Transient Response. The power supply output voltage is set at 36 volts. A switch is used to vary the power supply load from no load to 3.0 amperes. An oscilloscope is connected between +S and -S. R16 is 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 10 mv of the nominal output voltage in less than 50μseconds. NOTE: The load should be non-inductive. The switch should have a maximum rise and fall time of 2μseconds. A mercury relay such as the Clare relay type HGP 1002, manufactured by the C.P. Clare & Company, Chicago, Illinois, operated at line frequency is a satisfactory switch.

5-42 Constant Current Checks.

5-43 The strap between A6 and minus is removed. This removes capacitor C28 from across the output terminals of the power supply.

5-44 A one ohm resistor is connected in series with an 11.0 ohm load. The one ohm 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 techniqures. 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 36 volts at 3 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 3 mv (3ma).

5-47 Line Regulation. A differential voltmeter is connected across the current monitoring resistor. The power supply is operated at 36 volts out and 3 amperes load, and 105 volts line. The voltmeter reading is noted. The line voltage is changed to 125 volts. The change in voltage across the current monitoring resistor, should not exceed 1 mv (1 ma).

5-48 Load Regulation. A differential voltmeter is connected across the current monitoring resistor. The power supply is operated at 36 volts out, 3 amperes load, and 115 volts line. The voltmeter reading is noted. The 12.0 ohm load is shorted. The change in voltage across the current monitoring resistor should not exceed 1 mv (1ma). NOTE: The supply will go momentarily into short circuit protection.

5-49 The power supply is turned off, the strap between A6 and minus is replaced.

5-50 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 36 volts out.

5-54 Ripple Check. The power supply is operated at 36 volts out and full load and at an input line voltage equal to 105 volts. An oscilloscope is connected across the sensing terminals. Maximum peak-to-peak 120 cycle ripple should not exceed 1 mv. NOTE: One output terminal of the power supply must be grounded.

5-55 Line Regulation. The power supply is operated at 36 volts and 3 amperes load. A differential voltmeter is connected across the sensing terminals. The input line voltage is varied from 105 to 125 volts. The output voltage should not vary more than 3 millivolts.

5-56 Load Regulation. The power supply is operated at 36 volts out and 115 volts line. A differential voltmeter is connected across the sensing terminals. The output voltage should not decrease by more than 3 millivolt when a 3 ampere load is applied.

5-57 Transient Response. The power supply is operated at 36 volts out and 115 volts line. A switch having a rise and fall time of 2μseconds or less is connected in series with a non-inductive load resistor selected so that the power supply is operated at 3.0 amperes. An oscilloscope is connected across the sensing terminals. The output voltage should recover to within 10 millivolts of the nominal output voltage within 50μseconds 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 one ohm, 200 watt, low temperature coefficient, wirewound resistor is connected in series with a 12.0 ohm load. The one ohm resistor is the current sensing or monitoring resistor. The power supply voltage controls are turned to the maximum clockwise position.

5-60 Ripple Current. An oscilloscope is connected across the current monitoring resistor. The current control is adjusted so that the output current is 10.0 ampere. The maximum peak-to-peak 120 cycle ripple should be less than 3 ma (3 mv across 1 ohm).

5-61 Line Regulation. A differential voltmeter is connected across the current monitoring resistor. The power supply is operated at 3 amperes and 36 volts out. The line voltage is varied from 105 to 125 volts. The output current should not change more than 1 ma (1 mv across 1 ohm).

5-62 Load Regulation. A differential voltmeter is connected across the current monitoring resistor. The power supply is operated at 36 volts out and 3 ampere load. The voltage across the current monitoring resistor is noted. The external 12.0 ohm load is shortcircuited. The current magnitude as indicated by the differential voltmeter should not change more than 1 ma from that recorded at 36 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. ⓗ 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, photocell, etc.
L = inductor	
M = meter	X = socket
P = plug	XF = fuseholder
Q = transistor	XDS = lampholder
R = resistor	Z = network

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
impg	= 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	Dallas, Texas
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.
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	International Resistance Co.	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.
11711	General Instrument Corp., Semiconductor Prod. Group, Rectifier Div.	Newark, N.J.
12136	Philadelphia Handle Co., Inc.	Camden, N.J.
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, McGraw 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
19315	The Bendix Corp., Eclipse Pioneer Div.	Teterboro, N.J.
19701	Electra Mfg. Co.	Independence, Kan.
21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.
22229	Union Carbide Corp., Linde Div., Kemet Dept.	Mountain View, Calif.
22767	ITT Semiconductors, A Division of International Telephone & Telegraph Corp.	Palo Alto, Calif.
24446	General Electric Co.	Schenectady, N.Y.
24455	General Electric Co., Lamp Division	Nela Park, Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
28480	Hewlett-Packard Co.	Palo Alto, Calif.
28520	Heyman Mfg. Co.	Kenilworth, N.J.
33173	G. E., Tube Dept.	Owensboro, Ky.
35434	Lectrohm, Inc.	Chicago, Ill.
37942	P.R. Mallory & Co., Inc.	Indianapolis, Ind.
42190	Muter Co.	Chicago, Ill.
44655	Ohmite Manufacturing Co.	Skokie, Ill.
47904	Polaroid Corporation	Cambridge, Mass.
49956	Raytheon Mfg. Co., Microwave and Power Tube Div.	Waltham, Mass.
55026	Simpson Electric Co.	Chicago, Ill.
56289	Sprague Electric Co.	North Adams, Mass.
58474	Superior Electric Co.	Bristol, Conn.
61637	Union Carbide Corp.	New York, N.Y.
63743	Ward-Leonard Electric Co.	Mt. Vernon, N.Y.
70563	Amperite Co., Inc.	Union City, N.J.
70903	Belden Mfg. Co.	Chicago, Ill.
71218	Bud Radio, Inc.	Willoughby, Ohio
71400	Bussmann Mfg. Div. of McGraw-Edison Co.	St. Louis, Mo.
71450	CTS Corporation	Elkhart, Ind.
71468	I. T. T. Cannon Electric Inc.	Los Angeles, Calif.
71590	Centralab Div. of Globe Union, Inc.	Milwaukee, Wis.
71700	The Cornish Wire Co.	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.
72699	General Instrument Corp., Capacitor Div.	Newark, N.J.
72765	Drake Mfg. Co.	Chicago, Ill.
72982	Erie Technological Products, Inc.	Erie, Pa.
73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Calif.
73293	Hughes Components Division of Hughes Aircraft Co.	Newport Beach, Calif.
73445	Amperex Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
73506	Bradley Semiconductor Corp.	New Haven, Conn.
73559	Carling Electric, Inc.	Hartford, Conn.
73734	Federal Screw Products, Inc.	Chicago, Ill.
73978	Hardwick Hindle Co., Memcor Components Div.	Huntington, Ind.
74193	Heinemann Electric Co.	Trenton, N.J.
74545	Harvey Hubbel, Inc.	Bridgeport, Conn.
74868	FXR Div. of Amphenol-Borg Electronics Corp.	Danbury, Conn.
75042	International Resistance Co.	Philadelphia, Pa.
75183	Howard B. Jones Div., of Cinch Mfg. Corp. (Use 71785)	New York, N.Y.
75382	Kulka Electric Corp.	Mt. Vernon, N.Y.
75915	Littlefuse, Inc.	Des Plaines, Ill.
76493	J. W. Miller Co.	Los Angeles, Calif.
76854	Oak Manufacturing Co.	Crystal Lake, Ill.
77068	Bendix Corp., Bendix-Pacific Div.	No. Hollywood, Calif.
77221	Phaostron Instrument and Electronic Co.	South Pasadena, Calif.
77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
77342	American Machine and Foundry, Potter and Brumfield Div.	Princeton, Ind.
77630	TRW Electronics, Components Div.	Camden, N.J.
77764	Resistance Products Co.	Harrisburg, Pa.
78189	Shakeproof Div. of Illinois Tool Works	Elgin, Ill.
78488	Stackpole Carbon Co.	St. Marys, Pa.
78526	Stanwyck Winding Co., Inc.	Newburgh, N.Y.
78553	Tinnerman Products, Inc.	Cleveland, Ohio
79307	Whitehead Metal Products Co., Inc.	New York, N.Y.
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
80031	Mepco Div. of Sessions Clock Co.	Morristown, N.J.
80294	Bourns, Inc.	Riverside, Calif.

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

CODE NO.	MANUFACTURER	ADDRESS
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 Corporation of America, Electronic Components & Devices Div.	Harrison, N.J.
87034	Marco Industries Co.	Anaheim, Calif.
87216	Philco Corp. (Lansdale Div.)	Lansdale, Pa.
87585	Stockwell Rubber Co., Inc.	Philadelphia, Pa.
87929	B. M. Tower Co., Inc.	Bridgeport, Conn.

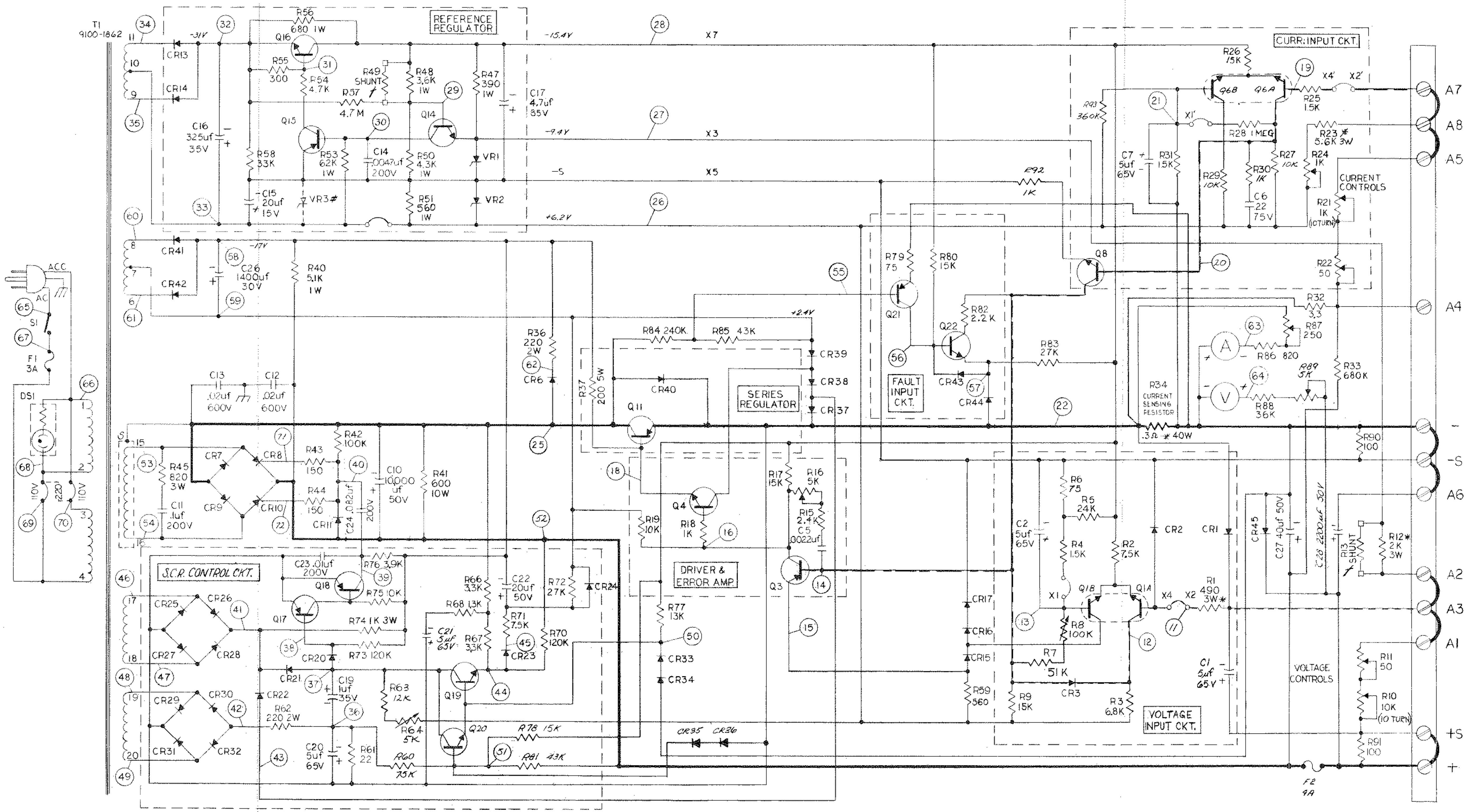
CODE NO.	MANUFACTURER	ADDRESS
88140	Cutler-Hammer, Inc.	Lincoln, Ill.
89473	General Electric Distributing Corp.	Schenectady, N.Y.
91345	Miller Dial and Nameplate Co.	El Monte, Calif.
91637	Dale Electronics, Inc.	Columbus, Neb.
91662	Elco Corp.	Willow Grove, Pa.
91929	Honeywell, Inc., Micro Switch Div.	Freeport, Ill.
93332	Sylvania Electric Prod., Inc., Semiconductor Prod. Div.	Woburn, Mass.
93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio
94144	Raytheon Co., Components Div., Industrial Components Operation	Quincy, Mass.
94154	Tung-Sol Electric, Inc.	Newark, N.J.
94310	Tru-Ohm Products, Memcor Components Div.	Huntington, Ind.
95263	Leecraft Mfg. Co., Inc.	Long Island City, N.Y.
95354	Methode Mfg. Co.	Chicago, Ill.
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	QTY	MFR. PART NO.	MFR. CODE	hp PART NO.	RS
C1, 2, 7, 17, 20, 21	fxd, elect 5µf 65Vdc	6	D33689	56289	0180-1836	2
C3, 4, 8, 9, 18, 25	NOT ASSIGNED	–	–	–	–	–
C5	fxd, film .0022µf 200Vdc	1	192P22292	56289	0160-0154	1
C6	fxd, film .22µf 80Vdc	1	192P2249R8	56289	0160-2453	1
C10	fxd, elect 10,000µf 50Vdc	1	36D103G050CD6A	56289		1
C11	fxd, film .1µf 200Vdc	1	192P10492	56289	0160-0168	1
C12, 13	fxd, ceramic .02µf 600Vdc	2	ED-02	72982		1
C14	fxd, film .0047µf 200Vdc	1	192P47292	56289	0160-0157	1
C15	fxd, elect 20µf 15Vdc	1	30D206G015BB4	56289	0180-0300	1
C16	fxd, elect 325µf 35Vdc	1	D34656	56289	0180-0332	1
C19	fxd, elect 1µf 35Vdc	1	150D105X9035A2	56289	0180-0291	1
C22	fxd, elect 20µf 50Vdc	1	30D206G050DC4	56289	0180-0049	1
C23	fxd, film .01µf 200Vdc	1	192P10392	56289	0160-0161	1
C24	fxd, film .082µf 200Vdc	1	192P82392	56289	0160-0167	1
C26	fxd, elect 1400µf 30Vdc	1	D38303	56289	0180-1860	1
C27	fxd, elect 40µf 50Vdc	1	D27906	56289	0180-1849	1
C28	fxd, elect 2200µf 50Vdc	1	36D222G050AC6A	56289	0180-1898	1
CR1-3, 6, 11, 20-32	Diode, si.	18	1N485B	93332	1901-0033	8
CR4	NOT USED	–	–	–	–	–
CR5, 12, 18, 19, 35, 36	NOT ASSIGNED	–	–	–	–	–
CR7, 9	Rect. si. 12A 100prv	2	1N1200A	02735	1901-0002	2
CR8, 10	SCR 7A 100prv	2	C20A	03508	1884-0031	2
CR13, 14, 41, 42	Rect. si. 500mA 200prv	4	1N3253	02735	1901-0026	4
CR15-17, 33, 34, 37-39, 43, 44	Rect. si. 200mA 10prv	10	111S1	93332		6
CR40, 45	Rect. si. 3A 200prv	2	MR1032B	04713	1901-0416	2
DS1	Indicator Light Neon	1	32RL2211T	95263	1450-0303	1
F1 110V oper.	Fuse Cartridge 3A@125V 3AG S.B.	1	313003	75915	2110-0029	5
F1 220V oper.	Fuse Cartridge 2A@250V 3AB	1	314002	75915	2110-0100	5
F2 DC	Fuse Cartridge 4A @ 250V 3AG	1	312004	75915	2110-0055	5
Q1, 6	SS NPN diff. amp	2	4JX12A839	03508	1854-0229	2
Q2, 5, 7, 9, 10, 12, 13, 20	NOT ASSIGNED	–	–	–	–	–
Q3, 17, 18, 21	SS PNP Ger.	4	GT2555	11711		4
Q4, 16	SS NPN si.	2	4JX11C710	03508		2
Q8, 14, 19, 22	SS PNP si.	4	4JX6B533	03508		4
Q11	Power PNP Ger.	1	B1203	83298		1
Q15	SS PNP Ger.	1	2N1377	01295	1850-0170	1
R1	fxd, ww 490Ω ±5% 3W 20ppm	1	242E4915	56289	0811-1801	1
R2, 71	fxd, comp 7.5KΩ ±5% 1/2W	2	EB-7525	01121	0686-7525	1
R3	fxd, comp 6.8KΩ ±5% 1/2W	1	EB-6825	01121	0686-6825	1
R4, 25, 31	fxd, comp 1.5KΩ ±5% 1/2W	3	EB-1525	01121	0686-1525	1

REF. DESIG.	DESCRIPTION	QTY	MFR. PART NO.	MFR. CODE	hp PART NO.	RS
R5	fxd, comp 24KΩ ±5% 1/2W	1	EB-2435	01121	0686-2435	1
R6, 79	fxd, comp 75Ω ±5% 1/2W	2	EB-7505	01121	0686-7505	1
R7	fxd, comp 51KΩ ±5% 1/2W	1	EB-5135	01121	0686-5135	1
R8	var, comp 100KΩ Ser. 70	1	HQ-3427	71450		1
R9, 17, 26, 30, 80	fxd, comp 15KΩ ±5% 1/2W	5	EB-1535	01121	0686-1535	1
R10	var. ww 10KΩ	1	971N	24655		1
R11, 22	var, comp 50Ω 2W	2	JAIN040P500UA	01121	2100-1873	1
R12	fxd, ww 2KΩ ±5% 3W 20ppm	1	242E2025	56289	0811-1806	1
R13, 49	fxd, comp Selective ±5% 1/2W	3		01121		1
R14, 52	STRAP	–	–	–	–	–
R15	fxd, comp 2.4KΩ ±5% 1/2W	1	EB-2425	01121	0686-2425	1
R16, 64, 89	var. ww 5KΩ (Modify)	3	Type 110-F4 obd	11236	2100-1824	1
R18, 92	fxd, comp 1KΩ ±5% 1/2W	2	EB-1025	01121	0686-1025	1
R19, 27, 29, 75	fxd, comp 10KΩ ±5% 1/2W	4	EB-1035	01121	0686-1035	1
R20, 35, 38, 39, 46, 60, 65, 69, 78	NOT ASSIGNED	–	–	–	–	–
R21	var. ww 1KΩ	1	971K	24655		1
R23	fxd, ww 5.6KΩ ±5% 3W 20ppm	1	242E5625	56289	0812-0091	1
R24	var. ww 1KΩ (Modify)	1	Type 110-F4 obd	11236	2100-0391	1
R28	fxd, comp 1 Meg ±5% 1/2W	1	EB-1055	01121	0686-1055	1
R32	fxd, comp 3.3Ω ±5% 1/2W	1	EB-0335	01121	0686-0335	1
R33	fxd, comp 680KΩ ±5% 1/2W	1	EB-6845	01121	0686-6845	1
R34	fxd, ww .3Ω ±5% 40W 20ppm	1	2BR-37 Offset Mtg	73978		1
R36, 62	fxd, met. ox 220Ω ±5% 2W	2	Type C42S obd	16299	0698-3628	1
R37	fxd, ww 200Ω ±5% 5W	1	Type 5XM obd	63743	0811-1204	1
R40	fxd, comp 5.1KΩ ±5% 1W	1	GB-5125	01121	0689-5125	1
R41	fxd, ww 600Ω ±5% 10W	1	Type 10XM obd	63743	0811-1910	1
R42	fxd, comp 100KΩ ±5% 1/2W	1	EB-1045	01121	0686-1045	1
R43, 44	fxd, comp 150Ω ±5% 1/2W	2	EB-1515	01121	0686-1515	1
R45	fxd, ww 820Ω ±5% 3W	1	242E8215	56289	0813-0010	1
R47	fxd, comp 390Ω ±5% 1W	1	GB-3915	01121	0689-3915	1
R48	fxd, comp 3.6KΩ ±5% 1W	1	GB-3625	01121	0689-3625	1
R50	fxd, comp 4.3KΩ ±5% 1W	1	GB-4325	01121	0689-4325	1
R51	fxd, comp 560Ω ±5% 1W	1	GB-5615	01121	0689-5615	1
R53	fxd, comp 62KΩ ±5% 1W	1	GB-6235	01121	0689-6235	1
R54	fxd, comp 4.7KΩ ±5% 1/2W	1	EB-4725	01121	0686-4725	1
R55	fxd, comp 300Ω ±5% 1/2W	1	EB-3015	01121	0686-3015	1
R56	fxd, comp 680Ω ±5% 1W	1	GB-6815	01121	0689-6815	1
R57	fxd, comp 4.7MΩ ±5% 1/2W	1	EB-4755	01121	0686-4755	1
R58	fxd, comp 33KΩ ±5% 1/2W	1	EB-3335	01121	0686-3335	1
R59	fxd, comp 560Ω ±5% 1/2W	1	EB-5615	01121	0686-5615	1
R61	fxd, comp 22Ω ±5% 1/2W	1	EB-2205	01121	0686-2205	1
R63	fxd, comp 12KΩ ±5% 1/2W	1	EB-1235	01121	0686-1235	1
R66, 67	fxd, comp 3.3KΩ ±5% 1/2W	2	EB-3325	01121	0686-3325	1
R68	fxd, comp 1.3KΩ ±5% 1/2W	1	EB-1325	01121	0686-1325	1
R70, 73	fxd, comp 120KΩ ±5% 1/2W	2	EB-1245	01121	0686-1245	1
R72, 83	fxd, comp 27KΩ ±5% 1/2W	2	EB-2735	01121	0686-2735	1
R74	fxd, film 2KΩ ±5% 2W	1	Type C42S obd	16299		1
R76	fxd, comp 3.9KΩ ±5% 1/2W	1	EB-3925	01121	0686-3925	1
R77	fxd, comp 13KΩ ±5% 1/2W	1	EB-1335	01121	0686-1335	1
R81	fxd, comp 39KΩ ±5% 1/2W	1	EB-3935	01121	0686-3935	1
R82	fxd, comp 2.2KΩ ±5% 1/2W	1	EB-2225	01121	0686-2225	1
R84	fxd, comp 240KΩ ±5% 1/2W	1	EB-2445	01121	0686-2445	1

REF. DESIG.	DESCRIPTION	QTY	MFR. PART NO.	MFR. CODE	hp PART NO.	RS
R85	fxd, comp 43KΩ ±5% 1/2W	1	EB-4335	01121	0686-4335	1
R86	fxd, comp 820Ω ±5% 1/2W	1	EB-8215	01121	0686-8215	1
R87	var. ww 250Ω (Modify)	1	Type 110-F4 obd	11236		1
R88	fxd, comp 36KΩ ±5% 1/2W	1	EB-3635	01121	0686-3635	1
R90, 91	fxd, comp 100Ω ±5% 1/2W	2	EB-1015	01121	0686-1015	1
R93	fxd, comp 360K ±5% 1/2W	1	EB-3645	01121	0686-3645	1
S1	Switch ON/OFF	1	T110	73559		1
T1	Power Transformer	1	636591	09182		1
VR1	Diode zener 9.4V T.C.	1	1N2163	06751	1902-0762	1
VR2	Diode zener 6.2V	1	1N821	06486	1902-0761	1
VR3	NOT USED	-	-	-	-	-
	Barrier Strip	1	601-YSY-6	75382	0360-1224	1
	Barrier Strip 1/16 wire term	1	obd	09182	0360-1235	1
	Jumper	7	601J	75382	0360-1280	2
	Handle 2-1/4"	2	obd	09182	1440-0059	1
	Ferrule	4	900-12	75915	1440-0053	1
	Fuse Holder	2	342014	75915	1400-0084	1
	Lockwasher	1	1224-08	78189	2190-0037	1
	Nut	1	903-12	75915	2950-0038	1
	Washer-Neoprene	1	901-2	75915	1400-0090	1
	Knob 5/8 Dia. Blk.	4	obd	09182	0370-0137	1
	Meter 0-40 Volts 58Ω 1mA movement	1	obd	09182	1120-1328	1
	Meter 0-3 Amps 58Ω 1mA movement	1	obd	09182	1120-1333	1
	Nut Captive	12	C8091 632-24B	89032	0510-0275	3
	Line Cord 6' 18-3 (16-30) Slate Grey Stranded Plug PH151	1	KH-4629	70903	8120-0852	1
	Strain Relief Bushing	1	SR-6P3-4	28520	0400-0098	1
	Capacitor Clamp 2-9/16 3 Hole	1	4586-2D	56289	0180-1970	1
	Capacitor Clamp 1-3/8 2 Hole	1	4586-97A	56289	0160-2149	1
	Capacitor Clamp	1	obd	09182	1400-0321	1
	Eyelet-Tubular	8	obd	09182	0361-0327	2
	Transistor Socket	7	3305	91662	1200-0708	2
	Mica Insulator	1	734	08530	0340-0174	1
	Rubber Bumper Black Durom Hard 55/60	4	3066	87585	0403-0085	1
	Cable Clamp Nylon Plastic	1	T4-4	79307	1400-0330	1
	Snap Button Hole Plug 3/8	1	652	83330	6960-0001	1
	Insulator Transistor Pin	2	obd	09182	0340-0166	1
	Insulator	2	obd	09182	0340-0168	1
	Insulator	2	obd	09182	0340-0170	1
	Insulator	2	obd	09182	0340-0169	1



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NOTES:

1. ALL RESISTORS ARE 1/2 WATT 5% UNLESS OTHERWISE NOTED.
2. * DENOTES 20 PPM WIRE TEMP. COFF.
3. REAR TERMINAL STRIP IS SHOWN IN NORMAL STRAPPING.
4. # DENOTES THAT COMPONENT IS OMITTED EXCEPT IN CHOPPER UNITS.
5. INPUT VOLTAGES MEASURED AT 115VAC LINE, NO LOAD.
6. - - - - - DENOTES VOLTAGE SIGNAL.
7. — — — DENOTES CURRENT SIGNAL.
8. ⨍ COMPONENT SELECTED FOR OPTIMUM PERFORMANCE.

DWG NO. 626500

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