

**PRELIMINARY
INSTRUCTION MANUAL
FOR
REGULATED POWER SUPPLIES**

LES-EE SERIES

This manual provides instructions intended for the operation of Lambda power supplies, and is not to be reproduced without the written consent of Lambda Electronics. All information contained herein applies to all LES-EE series models unless otherwise specified.

LAMBDA ELECTRONICS

MAIN PLANT TELEPHONE: 516 MYrtle 4-4200

MELVILLE, L.I., N.Y.

IM-LES-EE

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SPECIFICATIONS AND FEATURES

Specifications apply for all models

DC OUTPUT — Voltage and Current regulated for line and load.

TABLE I

VOLTAGE AND CURRENT RATINGS

MODEL	VOLTAGE RANGE	MAXIMUM CURRENT (AMPS) AT AMBIENT TEMPERATURE			
		40°C	50°C	60°C	71°C
LES-EE-01-0V	0 to 7.5	60.0	52.0	41.0	30.0
LES-EE-02-0V	0 to 18.0	29.0	25.0	20.0	14.0
LES-EE-03-0V	0 to 36.0	14.5	12.5	10.0	7.0
LES-EE-04-0V	0 to 60.0	9.0	7.7	6.2	4.5

Current range must be chosen to suit appropriate maximum ambient temperature. Current ratings apply for entire voltage range. Derate current rating 5% for operation at 50 Hz input.

REGULATED VOLTAGE OUTPUT

Regulation (line)	0.02 per cent plus 2.0 millivolts for input variations from 105-132 or 132-105 volts AC.
Regulation (load)	0.02 percent plus 2.0 millivolts (models LES-EE-01, -02); 0.02 percent plus 4.0 millivolts (models LES-EE-03, -04) for load variations from no load to full load or full load to no load.
Ripple and Noise	10 millivolts rms, 50 millivolts peak-to-peak (model LES-EE-01); 15 millivolts rms, 100 millivolts peak-to-peak (models LES-EE-02, -03, -04) with either positive or negative terminal grounded.
Temperature Coefficient	Change in output voltage (0.02% plus 50 microvolts)/°C.
Remote Programming	
External Resistor	Nominal 200 ohms/volt output.
Programming Voltage	One-to-one voltage change.
Remote Sensing	Provision is made for remote sensing to eliminate effect of power output lead resistance on DC regulation.

REGULATED CURRENT OUTPUT: AUTOMATIC CROSSOVER

Regulation (line)	0.5 percent plus 50 mA (models LES-EE-01, -02) 0.5 percent plus 20 mA (models LES-EE-03, -04) for input variations from 105-132 or 132-105 volts AC.
Regulation (load)	0.5 percent of I _o max for load voltage changes from 5% to rated DC voltage or rated DC voltage to 5%.

REGULATED CURRENT OUTPUT: AUTOMATIC CROSSOVER (Cont'd)

- Current range 5% to full rated load current.
- Voltage range As shown in table I.

AC INPUT — 105-132, 205-265 or 187-242 (“V” option) VAC at 47-63 Hz. Input power: 750 Watts* at 0.6 Pf. Input current: 15 Amps RMS**. For operation at 50 Hz derate current rating 5% for each ambient temperature given in table I.

*With output loaded to full current rating, maximum rated output voltage, nominal input voltage.

**With output loaded to full current rating, mid-range output voltage, input voltage 132 VAC, 60 Hz.

EFFICIENCY — 60% minimum at maximum output voltage.

SOFT START CIRCUIT — Limits inrush current at turn-on to 200% of full-load peak current.

OVERLOAD PROTECTION

- Thermal Thermostat, resets automatically when over-temperature condition is eliminated.
- Electrical
 - External Adjustable, automatic, electronic current-limiting circuit, settable to 105 percent of rated current, limits output current to preset limit for protection of load and power supply when external overloads and direct shorts occur.
 - Internal 30A fuse F1 protects the AC input circuit. Overload of the supply does not cause fuse failure.

OVERVOLTAGE PROTECTION — All LES-EE models include a built-in overvoltage protection circuit which prevents damage to the load caused by excessive power supply output voltage.

INPUT CONNECTIONS — Terminal block on rear of chassis.

OUTPUT CONNECTIONS — 1/4-28 studs on rear of chassis.

OPERATING AMBIENT TEMPERATURE RANGE AND DUTY CYCLE — Continuous duty from 0° C to 71° C ambient with corresponding load current ratings for all modes of operation, and appropriate derating.

STORAGE TEMPERATURE (non-operating) — -55° C to +85° C.

COOLING — Convection cooled; no fans or blowers.

METERING — Digital panel meter monitors output voltage or load current as selected by METER SELECTION switch.

EMI — Conducted EMI conforms to MIL-I-6181D.

FUNGUS — All LES-EE power supplies are fungus inert.

CONTROLS

- Power Panel mounted switch for all units.

CONTROLS (Cont'd)

- Meter Selector Selects meter function. Either output voltage or current can be monitored; located on front panel of all models.
- DC Output Coarse and fine voltage and coarse current control permit adjustment of DC output; located on front panel of all models.
- Overvoltage Control Screwdriver adjust control located on front panel of all models.

PHYSICAL DATA

- Size 5-3/16" H x 8-3/8" W x 16" D
- Weight 27 lbs. net, 33 lbs. shipping
- Panel Finish Charcoal brown (standard); special finishes available to customer specifications at moderate surcharge.

AC INPUT OPTION

V-V1 option. Standard LES-EE power supplies can be obtained for 187-242 VAC ("V") input or 205-265 VAC ("V1") input. See nameplate for AC input rating. Derate output current rating 10% for a 187-242 VAC input. No additional derating required at 50 Hz for either V or V1 option.

MOUNTING

- Laboratory bench, table top Bumpers secured to the base of all units permit proper circulation of air through the unit. Removal of bumpers will restrict free-flow of air; avoid removing bumpers. Retractable bench rest on bottom of unit is provided as an aid in viewing output meters.
- Standard 19" Rack All units can be used with rack adapters:
LRA-1 (slide accommodation provided)
LRA-2 (conventional mount)

ACCESSORIES

- Rack Adapters Rack adapter LRA-1, with or without chassis slides is available as well as rack adapter LRA-2 which is used for simple rack installations where chassis slides are not required.

OPERATING INSTRUCTIONS

CONTROLS, INSTRUMENTS, AND FUSES

Power ON-OFF Switch. The power ON-OFF switch, located on the front panel, controls application of input power to the supply. When the switch is in the ON position, the digital panel meter will be illuminated.

OUTPUT VOLTAGE Control. The OUTPUT VOLTAGE control is a dual control consisting of a coarse adjustment potentiometer, which varies the DC voltage over a range of 0-6.5, 0-17, 0-35, 0-59 volts as applicable, and a fine adjustment potentiometer, which varies the DC voltage over a one-volt range. Clockwise rotation results in increasing voltage. The total DC voltage output for voltage regulated operation is equal to the sum of each shaft setting; for current regulated operation the maximum voltage limit is equal to the sum of each shaft setting. The control is located on the front panel of all units.

CURRENT LIMITER Control. The CURRENT LIMITER control is a single control consisting of a coarse adjustment potentiometer, which varies the DC current over 105% of the rated current range. Clockwise rotation results in increasing current. The control is located on the front panel of all units.

Digital Panel Meter. A digital meter monitors output voltage or current over the rated range. Display illuminates when the ON-OFF switch is in the "ON" position. Display flashes when meter is overloaded. Meter accuracy is 5%.

METER SELECTOR Switch. Selects meter function. Either output voltage or output current can be monitored.

Fuse. Fuse F1, internally located, is a 30 amp fuse which functions in the AC input circuit.

Connection Terminals. Make all connections to the supply at the terminal block on the rear of the supply. Apply input power to terminals 1 and 2. Always connect the ungrounded (hot) power lead to terminal 1.

The supply positive terminal is brought out to terminal 6. The supply negative terminal is brought out to terminal 4. Recommended wiring of the power supply to the load and selection of wiring is shown in figures 1 through 7. Selection of proper wiring is made on the basis of load requirements. Make all performance checks and measurements of current or voltage at the rear output terminals. Connect measuring devices directly to terminals or use the shortest leads possible.

GROUND CONNECTIONS

The Lambda power supply can be operated either with negative or positive output terminal grounded or with no terminal grounded. Both positive and negative ground connections are shown in the diagrams for all suggested output connections illustrated in this manual.

NOTE: When operating the supply with neither terminal grounded high impedance leakage resistance and capacitance paths can exist between the power supply circuitry and chassis ground.

BASIC MODES OF OPERATION

This power supply is designed to operate as a constant voltage source or as a constant current source. Automatic crossover to either mode of operation occurs when load conditions change as follows:

Constant Voltage. The power supply will function as a constant voltage source while the load current does not equal the current value, I_{LIM} , set by the CURRENT LIMITER control. When load current $I_L = V/R_L = I_{LIM}$, the supply will crossover automatically and will operate as a constant current source. Further decrease in value of load resistance R_L results in a decrease of voltage across the load while current remains regulated to I_{LIM} .

Constant Current (Automatic Crossover). The power supply will function as a constant current source while the load voltage V_L does not equal the voltage value set by the OUTPUT VOLTAGE control. When load voltage V_L equals the value set by the OUTPUT VOLTAGE control, the supply will automatically crossover and operate as a constant voltage source.

SUPPLY — LOAD CONNECTIONS

NOTE: Refer to DETAILED OPERATING PROCEDURES for step-by-step instructions for operation of power supply.

CONNECTIONS FOR OPERATION AS A CONSTANT VOLTAGE SOURCE

The output impedance and regulation of the power supply at the load may change when using the supply as a constant voltage source and connecting leads of practical length are used. To minimize the effect of the output leads on these characteristics, remote sensing is used. Recommended types of supply load connections with local or remote sensing are described in the following paragraphs.

Refer to figure 1 to determine voltage drop for particular cable length, wire size and current conditions. Lead lengths must be measured from supply terminals to load terminals as shown in figure 2.

Local Sensing Connection, Figure 3. Local sensing is the connection suitable for application with relatively constant load where extremely close load regulation over full-rated current excursion is *not* required at the load.

Remote Sensing Connection, Figure 4. Remote sensing provides complete compensation for the DC voltage drops in the connecting cables. Sensing leads should be a twisted pair to minimize AC pick-up. A 2.5 mf, elect., capacitor may be required between output terminals and sense terminals to reduce noise pick-up.

Programmed Voltage Connections, Using External Resistor, Figure 5. Discrete voltage steps can be programmed with a resistance voltage divider valued at 200 ohms/volt output and a shorting-type switch as shown in figure 5. When continuous voltage variations are required, use variable resistor with the same 200 ohms/volt ratio in place of the resistive voltage divider and shorting-type switch. Use a low temperature coefficient resistor to assure most stable operation. Turn OUTPUT VOLTAGE ADJ controls to a position slightly below minimum value of required programmed voltage.

As shown in figure 5, voltages can be programmed utilizing either local or remote sensing connections, as desired.

Programmed Voltage Connections Using Programming Voltage, Figure 6. The power supply voltage output can be programmed with an externally connected programming power supply. The output voltage of the programmed supply will maintain a one-to-one ratio with the voltage of the programming supply.

The programming supply must have a reverse current capability of 6 ma minimum.

Alternatively, when supplies with less than 6 ma reverse current capability are used, a resistor capable of drawing 6 ma at the minimum programming voltage must be connected across the output terminals of the programming supply. The programming supply must be rated to handle all excess resistor current at the maximum programming voltage.

CONNECTIONS FOR OPERATION AS A CONSTANT CURRENT SOURCE

Automatic Crossover Constant Current Connections, Figure 3. Figure 3 shows the connections which are used when operating the power supply as a constant current source with automatic crossover.

In this mode of operation, when the load voltage increases, due to changing load resistance, to the limit of the OUTPUT VOLTAGE control setting, the power supply crossover circuit will cause the unit to operate as a constant voltage supply.

CONNECTIONS FOR SERIES OPERATION

The voltage capability of LES-EE power supplies can be extended by series operation of two LES-EE power supplies of equal* voltage ratings. A maximum of 500 volts can be connected between either the +DC or -DC terminal and chassis ground.

*For applications using supplies of unequal ratings, consult factory for details of operation.

Two units are shown connected for series operation in figure 7. Figure 7 shows the series connection which would be suitable for use in all applications.

Diodes CR_A and CR_B, which protect the units against reverse voltage, must be capable of withstanding the maximum rated current.

The series connection permits operation for either constant voltage or constant current with automatic crossover to either mode of operation whenever the respective limiting operating current or voltage is reached. Figure 7 shows connection for either local or remote sensing, when the series combination is operated for constant voltage; figure 7A shows the connection required when the series combination is operated for constant current.

DETAILED OPERATING PROCEDURES

SAFETY NOTICE

DANGEROUS VOLTAGES EXIST IN THIS EQUIPMENT. OBSERVE THE USUAL SAFETY PRECAUTIONS WHEN OPERATING OR SERVICING THE EQUIPMENT TO AVOID SHOCK OR INJURY.

CONSTANT VOLTAGE OPERATION, ADJUSTABLE CURRENT LIMIT

1. Apply AC power to the supply but place power ON-OFF switch in OFF position.

NOTE: When shipped from the factory, the supply is ready for use as a constant current source with automatic crossover or as a local-sensing constant voltage source. Jumpers are connected at the factory as shown in figure 3. Take care to remove the appropriate jumpers for load requirements that need different supply-load connections. Refer to the appropriate connection diagram.

2. Determine load requirements, select wire size from figures 1 and 2, and choose desired type of supply-load connection from figures 3 and 4. Do not connect load.
3. Place power ON-OFF switch in ON position and check that digital panel meter illuminates.
4. Set CURRENT LIMITER control fully CW, place METER SELECTION switch in VOLTS position, and adjust OUTPUT VOLTAGE control knobs to obtain desired voltage indication. When the current to the load must be limited to an intermediate value within the current rating of the supply, proceed as follows:
 - (a) Place power ON-OFF switch in OFF position.
 - (b) Connect jumper between +V and -V terminals. Jumper must be capable of handling maximum output current rating of unit.
 - (c) Place power ON-OFF switch in ON position, place METER SELECTION switch in AMPS position, and adjust CURRENT LIMITER control to obtain the desired meter indication.
 - (d) Place power ON-OFF switch in OFF position and remove jumper.
5. Connect supply to load as shown on selected connection diagram.
6. Place power ON-OFF switch in ON position and check that digital panel meter illuminates.
7. Check that digital panel meter indicates desired values; as required, adjust OUTPUT VOLTAGE control knobs and CURRENT LIMITER control to obtain correct meter indications.
8. Power supply is now in proper operation.

PROGRAMMED CONSTANT VOLTAGE OPERATION, ADJUSTABLE CURRENT LIMIT

1. Apply AC power to the supply, but place power ON-OFF switch in OFF position.

NOTE: When shipped from the factory, the supply is ready for use as a constant current source with automatic crossover or as a local-sensing constant voltage source. Jumpers are connected at the factory as shown in figure 3. Take care to remove the appropriate jumpers for load requirements that need different supply-load connections. Refer to the appropriate connection diagram.

2. Determine load requirements, select wire size and length from figures 1 and 2, and choose desired type of supply-load connections from figures 5 and 6. Refer to paragraph on Programmed Voltage Connections.

3. Connect supply terminals as shown on the selected connection diagram. As shown in figure 5, take care to use a shorting-type switch for the external programming control when several voltages are desired and the programming voltage method is not used. Do not connect load.

4. When current to the load must be limited to an intermediate value within the current rating of the supply, proceed as follows:

(a) Connect jumper between +V and -V terminals. Jumper must be capable of handling maximum output current rating of unit.

(b) Place power ON-OFF switch in ON position, place METER SELECTION switch in AMPS position, and adjust CURRENT LIMITER control to obtain the desired current limit meter indication.

(c) Place power ON-OFF switch in OFF position and remove jumper between +V and -V terminals.

5. Connect supply to load as shown on the selected connection diagram.

6. Place power ON-OFF switch in ON position and check that digital panel meter illuminates.

7. Check that digital panel meter indicates desired values; as required, adjust CURRENT LIMITER knob and external programming voltage control to obtain correct meter indications.

8. Power supply is now operating properly.

CONSTANT CURRENT OPERATION WITH CROSSOVER, ADJUSTABLE VOLTAGE LIMIT

1. Apply AC power to the supply, but place power ON-OFF switch in OFF position.

NOTE: When shipped from factory, the supply is ready for use as a constant current source with automatic crossover or as a local-sensing constant voltage source. Jumpers are connected at the factory as shown in figure 3. Take care to remove the appropriate jumpers for load requirements that need different supply-load connections. Refer to the appropriate connection diagram.

2. Determine load requirements, select wire size from figures 1 and 2, and connect supply terminals as shown in figure 3. Do not connect load.

3. Adjust CURRENT LIMITER control to the desired output current as follows:

(a) Connect jumper between +V and -V terminals. Jumper must be capable of handling maximum current rating of unit.

(b) Place power ON-OFF switch in ON position, place METER SELECTION switch in AMPS position, and adjust CURRENT LIMITER control to obtain the desired load current as indicated on current meter.

(c) Place power ON-OFF switch in OFF position and remove jumper between +V and -V terminals.

4. Place power ON-OFF switch in ON position, place METER SELECTION switch in VOLTS position, and adjust OUTPUT VOLTAGE control knobs to obtain the desired voltage limit point as indicated on voltage meter.

5. Place power ON-OFF switch in OFF position and connect load to the supply as shown in figure 3.

6. Place power ON-OFF switch in ON position and check that digital panel meter illuminates.

7. Check that digital panel meter indicates desired values; adjust OUTPUT VOLTAGE control knobs and CURRENT LIMITER control as required to obtain correct indications.

8. Power supply is now in proper operation.

*SERIES CONNECTION CONSTANT VOLTAGE OPERATION, WITH CURRENT LIMIT

1. Apply AC power input to the (B) and (A) units, and place power ON-OFF switches in OFF position.

NOTE: When shipped from the factory, the supply is ready for use as a constant current source with automatic crossover or as a local-sensing constant voltage source. Jumpers are connected at the factory as shown in figure 3. Take care to remove the appropriate jumpers for load requirements that need different supply-load connections. Refer to the appropriate connection diagram.

2. Determine load requirements, select wire size from figures 1 and 2, choose correct type of series supply-load connections from figure 7. Refer to paragraph on CONNECTIONS FOR SERIES OPERATION.

3. Connect power supply terminals as shown on the selected connection diagram. Select diodes CR_A and CR_B in accordance with instructions contained in CONNECTIONS FOR SERIES OPERATION. Do not connect load.

4. Place power ON-OFF switches in ON position, place METER SELECTION switches in VOLTS position, and adjust OUTPUT VOLTAGE control knobs on the (A) and (B) units to obtain the desired total output voltage. Place power ON-OFF switch in OFF position.

5. When current to the load must be limited to an intermediate value within the current rating of each supply, proceed as follows:

(a) Connect jumpers between +V and -V terminals on the (A) and (B) units. Jumpers must be capable of handling maximum current rating of unit.

(b) Place power ON-OFF switches in the ON position, place METER SELECTION switches in AMPS position, and adjust CURRENT LIMITER control on the (A) and (B) units to the desired current limit point, as indicated on the digital panel meter.

(c) Place power ON-OFF switches in OFF position and remove jumpers between +V and -V terminals.

6. Connect supplies to load as shown on the selected connection diagram.

7. Place power ON-OFF switches in ON position and check that digital panel meters illuminate.

8. Check that digital panel meters indicate desired values; adjust OUTPUT VOLTAGE control knobs and CURRENT LIMITER control as required to obtain correct indications.

9. Power supplies are now in proper operation.

*Applies to units of equal voltage and current capacities. When units of unequal ratings are series connected, consult factory.

OPERATION AFTER PROTECTIVE DEVICE SHUTDOWN

Thermostat Shutdown. The thermostat shuts down operation of the SCR pre-regulator circuit only when the temperature of the input rectifier heat radiator exceeds a maximum safe value. The thermostat will automatically reset when the temperature of the heat sink decreases to a safe operating value.

Fuse Shutdown. Fuse will blow when the maximum rated current value for the fuse is exceeded. Fatigue failure of fuses can occur when mechanical vibrations from the installation combine with thermally induced stresses to weaken the fuse metal. Many fuse failures are caused by a temporary condition and replacing the blown fuse will make the fuse-protected circuit operative.

Overvoltage Shutdown. When the power supply output voltage increases above the overvoltage limit, the overvoltage protector sub-assembly will short circuit the output of the supply and SCR 101 will shutdown the operation of the SCR pre-regulator circuit. After eliminating the cause(s) for overvoltage, resume operation of the supply by interrupting the AC input circuit for a period of 5 seconds (refer to TROUBLE SHOOTING CHART).

MAINTENANCE

GENERAL

This section describes trouble analysis routine, replacement procedures, calibration and test procedures that are useful for servicing the Lambda power supply. A trouble chart is provided as an aid for the trouble-shooter. Refer to the section on SPECIFICATIONS AND FEATURES for the minimum performance standards.

TROUBLE ANALYSIS

Whenever trouble occurs, systematically check all fuses, primary power lines, external circuit elements, and external wiring for malfunction before trouble shooting the equipment. Failures and malfunctions often can be traced to simple causes such as improper jumper and supply-load connections or fuse failure due to metal fatigue.

Use the electrical schematic diagram and block diagram, figure 8, as an aid to locating trouble causes. The schematic diagram contains various circuit voltages that are averages for normal operation. Measure these voltages using the conditions for measurement specified on the schematic diagram. Use measuring probes carefully to avoid causing short circuits and damaging circuit components.

CHECKING TRANSISTORS AND CAPACITORS

Check transistors with an instrument that has a highly limited current capability. Observe proper polarity for PNP or NPN to avoid error in measurement. The forward transistor resistance is low but never zero; backward resistance is always higher than the forward resistance.

For good transistors, the forward resistance for any junction is always greater than zero.

Do not assume trouble is eliminated when only one part is replaced. This is especially true when one transistor fails, causing other transistors to fail. Replacing only one transistor and turning power on, before checking for additional defective components could damage the replaced component.

When soldering semi-conductor devices, wherever possible, hold the lead being soldered with a pair of pliers placed between the component and the solder joint to provide an effective heat sink.

NOTE: The leakage resistance obtained from a simple resistance check of a capacitor is not always an indication of a faulty capacitor. In all cases the capacitors are shunted with resistances, some of which have low values. Only a dead short is a true indication of a shorted capacitor.

PRINTED CIRCUIT BOARD MAINTENANCE TECHNIQUES

1. If foil is intact but not covered with solder, it is a good contact. Do not attempt to cover with solder.
2. Voltage measurements can be made from either side of the board. Use a needle-point probe to penetrate to the wiring whenever a protective coating is used on the wiring. A brass probe can be soldered to an alligator clip adapted to the measuring instrument.
3. Wherever possible, use a heat sink when soldering transistors.

4. Broken or damaged printed wiring is usually the result of an imperfection, strain, or careless soldering. To repair small breaks, tin a short piece of hook-up wire to bridge the break, and holding the wire in place, flow solder along the length of wire so that it becomes part of the circuitry.

5. When unsoldering components from the board, never pry or force loose the part; unsolder the component by using the wicking process described below:

(a) Select a 3/16 inch tinned copper braid for use as a wick; if braid is not available, select AWG No. 14 or No. 16 stranded wire with 1/2 inch insulation removed.

(b) Dip the wick in liquid rosin flux.

(c) Place the wick onto the soldered connection and apply soldering iron onto the wick.

(d) When sufficient amount of solder flows onto the wick, freeing the component, simultaneously remove iron and wick.

TROUBLE CHART

The trouble chart is intended as a guide for locating trouble causes, and is used along with the schematic diagram.

The operating conditions assumed for the trouble chart are as follows:

(a) AC power of proper voltage and frequency is present at input terminals.

(b) Either positive or negative terminal is connected to chassis ground.

(c) The power supply is connected for constant voltage with local sensing. See schematic; dotted lines indicate jumpers connected for local sensing operation.

SAFETY NOTICE

DANGEROUS VOLTAGES EXIST IN THIS EQUIPMENT EVEN IF FRONT PANEL ON-OFF SWITCH IS IN THE OFF POSITION.

TROUBLE SHOOTING CHART

<u>Symptom</u>	<u>Probable Cause</u>	<u>Remedy</u>
1. Zero volts DC output (with CURRENT LIMITER and OUTPUT VOLTAGE panel controls set for maximum)	Short circuit across output of supply F1 open	Check load and load connections; correct as necessary. Replace F1; if fuse blows immediately see Additional Symptoms A thru D, as required, and replace fuse F1 when cause is eliminated.
<u>Additional Symptoms</u>		
A. Voltage across C1 and C2 is zero and across C 104 and CR 172 is correct	OC 101, OC 102, OC 201, SUS 201, SCR 201, SCR 202, SCR 1, SCR 2, CR 5, CR 6, Q 203, Q 201 is (are) open; CR 208, Q 202 shorted	Check and replace component(s) as necessary.

TROUBLE SHOOTING CHART (Cont'd)

<u>Symptom</u>	<u>Probable Cause</u>	<u>Remedy</u>
B. Same as A above except voltage across C 104 is zero	SCR 101 fired due to overvoltage condition	Check all load and sense connections and correct as necessary. Switch unit power off. Set OUTPUT VOLTAGE control for minimum, switch unit power on and set OUTPUT VOLTAGE control for desired VOLTS indication. If overvoltage unit trips and crowbars the output, consult ADJUSTMENT OF OV ADJ CONTROL R25 procedures in manual and readjust OV ADJ control trip point for a voltage point above desired output voltage.
	Thermostat S2 closed	Refer to SPECIFICATIONS AND FEATURES in manual for current rating at ambient temperature unit is operating. If operating current exceeds specified current for the operating ambient temperature, switch unit power off and allow power supply to cool off. Resume operation at compatible output current—temperature levels.
	CR 220, CR 221, CR 222, CR 223, CR 116, Q 116 shorted; Q 107 open	Check and replace component(s) as necessary.
C. Voltage across C1 and C2 is low, but <u>not</u> zero; across CR 172 is zero and across C 104 is correct	CR 225, CR 226, CR 172, R9, R10 shorted; defective IC 171, IC 172 and IC 150	Check and replace component(s) as necessary.
D. Voltage across C1, C2, C104 and C7 is correct	Q1, Q2, Q3, Q4, Q5, Q6, R5, Q101, Q102 open; defective IC 120, IC 121, IC 122	Check and replace component(s) as necessary.
2. Output voltage too high, with no control of output	Open sense lead	Refer to appropriate connection diagram and correct as required.
	R20, R21 open; defective IC 122, IC 150, OC 101, IC 171, IC 172	Check and replace component(s) as necessary.
3. Unit cannot be adjusted to attain maximum V_0 , I_0 or minimum V_0	Unit is out of calibration	Refer to CALIBRATION PROCEDURES in manual and recalibrate unit in the proper sequence.
4. High output ripple	Low input line voltage	Refer to SPECIFICATIONS AND FEATURES for correct input voltage.

PERFORMANCE CHECKS

Checks With Constant Voltage Operation. Check the ripple and regulation of the power supply using the test connection diagram shown in figure 9. Use suggested test equipment or equivalent to obtain accurate results. Refer to SPECIFICATIONS AND FEATURES for minimum performance standards.

Set the differential meter, DC DVM (John Fluke Model 891A or equivalent) to the selected power supply operating voltage. Check the power supply load regulation accuracy while switching from the load to no-load condition. Long load leads should be a twisted pair to minimize AC pick-up.

Use a Variac to vary the line voltage from 105-132 or 132-105 volts AC and check the power-supply line regulation accuracy on the differential meter.

Use a VTVM, Ballantine 320 or equivalent, to measure rms ripple voltage of the power supply DC output. Use oscilloscope to measure peak-to-peak ripple voltage of the power supply DC output.

Checks With Constant Current Operation. Check the ripple or regulation of the power supply using the test connection diagram shown in figure 10. Refer to SPECIFICATIONS AND FEATURES for minimum performance standards.

Check the power supply load regulation accuracy while switching from the short circuit to load condition. Measure the voltage across sensing resistor R_s . Use John Fluke Model 891A or equivalent for the DVM connected across R_s . For R_s , use a 500 mv shunt rated for the same current as the unit being tested. To obtain regulation figure substitute values obtained into regulation formula:

$$\frac{\Delta E}{R_s} = \text{Regulation in milliamperes,}$$

where ΔE is the voltage change in millivolts and R_s is the resistance of the sensing resistor.

Use a Variac to vary the line voltage from 105-132 or 132-105 volts AC and check the power supply line regulation accuracy using the VTVM and the regulation formula:

$$\frac{\Delta E}{R_s}$$

COMPLETE POWER SUPPLY CALIBRATION PROCEDURE

When the power supply is to be completely calibrated, the controls listed below must be calibrated in the order listed.

Control Calibration Order

R160 Frequency Shift
R213 V_0 min
R190 V_0 max
R197 I_0 min
R189 I_0 max

Preliminary Procedure. Before proceeding with the calibration, the power supply:

- (a) must be removed from associated equipment,
- (b) must be at ambient temperature of 25-30°C,
- (c) must be disconnected from AC line input voltage,
- (d) OFF position of power ON-OFF switch must be depressed,
- (e) must be disconnected from the load.

Adjust controls in accordance with steps 1 through 8 contained in Initial Control Adjustments.

Initial Control Adjustments. To ensure predictable power supply response when input power is applied to the unit, and performing calibration procedures, adjust the following controls to the positions indicated in steps 1 through 8.

1. Turn OV ADJ on front panel to fully clockwise position.
2. Turn R160, figure A, to mid-range position.
3. Turn R213 to mid-range position.
4. Turn R190 to fully clockwise position.
5. Turn R189 to fully clockwise position.
6. Turn OUTPUT VOLTAGE VDC control on front panel to mid-range position.
7. Turn CURRENT LIMITER IDC control on front panel to mid-range position.
8. Turn R197 to fully clockwise position.

Adjustment of Frequency Shift Control R160. Whenever R5, R120, Q107, CR116 or IC150 are replaced, R160 must be recalibrated.

NOTE: When R160 alone must be recalibrated, controls R197 and R189, respectively, must also be recalibrated. At that time, R160 must be set to mid-range position, R189 must be set to fully clockwise position, and R197 must be set to fully clockwise position. Procedures for calibrating R160, R189 and R197 in this sequence, then can be selected and followed separately from the COMPLETE POWER SUPPLY CALIBRATION PROCEDURE.

1. Perform steps (a) through (e) of Preliminary Procedure.
2. Break seal on wiper of R160 from resistor housing.
3. Place power ON-OFF switch in ON position. Adjust Variac to apply 132 VAC power to the supply.
4. Place METER SELECTION switch in VOLTS position.
5. Turn OUTPUT VOLTAGE VDC control to fully clockwise position for maximum output voltage at no load, as indicated on DVM (John Fluke Model 825A or equivalent) connected to output terminals of supply.
6. Connect load to unit using local sensing connection, figure 3, and adjust load to obtain 110% of unit output current rating at 40°C ambient temperature as indicated on ammeter connected in series with load. Refer to Table 1 for maximum current ratings.
7. If output voltage drops and unit emits an audible sound, proceed to step 9.
8. If output voltage does not drop and set does not emit an audible sound, check that output current is 110% of unit output current rating. Adjust load until 110% of output current rating is obtained.
9. Adjust R160 counterclockwise until output voltage drops and unit emits an audible sound.
10. Adjust R160 clockwise to the point that audible sound stops and output voltage is at maximum rated value.

11. Check that output current is 110% of maximum rated output current. If it is not at 110% value, readjust load so 110% value is obtained and repeat steps 9, 10 and 11.

12. Seal wiper of R160 to resistor housing with Glyptol and check for 110% output current value. Repeat procedure as required to obtain correct value.

Adjustment of V_0 Min. Control R213. Whenever R221, OC201, CR213, CR214, CR215, CR216, CR217, R9, R10, CR208, Q203 or SUS201 are replaced, R213 must be recalibrated.

NOTE: When R213 alone must be recalibrated, the adjustment procedure for R213 can be selected and followed separately from the COMPLETE POWER SUPPLY CALIBRATION PROCEDURE.

1. Perform steps (a) through (e) of Preliminary Procedure.
2. Break seal on wiper of R213 from resistor housing. If only R213 alone is being calibrated, set R213 at midrange position.
3. Adjust Variac to apply 105 VAC power to the supply and place power ON-OFF switch in ON position.
4. Place METER SELECTION switch in VOLTS position.
5. Turn OUTPUT VOLTAGE VDC controls on front panel to the fully counterclockwise position.
6. Turn CURRENT LIMITER IDC controls on front panel to the fully clockwise position.
7. Connect a DVM (John Fluke Model 825A or equivalent) at supply output terminals and adjust R213 until output voltage as indicated by DVM is -0.1 volt.
8. Seal wiper of R213 to resistor housing with Glyptol and check for -0.1 volt indication. Repeat procedure as required to obtain correct value.

Adjustment of V_0 Max. Control R190. Whenever IC172, R20, R186, R188 or R194 are replaced, R190 must be recalibrated.

NOTE: When R190 alone must be recalibrated, the adjustment procedure for R190 can be selected and followed separately from the COMPLETE POWER SUPPLY CALIBRATION PROCEDURE.

1. Perform steps (a) through (e) of Preliminary Procedure.
2. Break seal on wiper of R190 from resistor housing. If only R190 alone is being calibrated, set R190 to the fully clockwise position.
3. Place power ON-OFF switch in ON position and adjust Variac to apply nominal AC power to the supply.
4. Turn CURRENT LIMITER IDC controls on front panel to the fully clockwise position.
5. Place METER SELECTION switch in VOLTS position.
6. Turn OUTPUT VOLTAGE VDC controls on front panel to the fully clockwise position; output voltage should be greater than maximum rated output voltage as indicated on DVM (John Fluke Model 825A or equivalent) connected to output terminals of unit.

7. Turn R190 counterclockwise until output voltage is 105% of rated output voltage of the unit as indicated on DVM.

8. Seal wiper of R190 to resistor housing with Glyptol and check for 105% output voltage indication. Repeat procedure as required to obtain correct value.

Adjustment of I_0 Min Control R197. Whenever IC171, R21, R185, R187, R195, R191, CS1 are replaced, both R197 and R189 respectively, must be recalibrated. R197 must be adjusted before R189.

NOTE: When R197 and R189 must be recalibrated, the adjustment procedure for each can be selected and followed separately from the COMPLETE POWER SUPPLY CALIBRATION PROCEDURE.

1. Perform steps (a) through (e) of Preliminary Procedure.
2. Break seal on wiper of R197 from resistor housing. If only R197 alone is being calibrated, set R197 to the fully clockwise position.
3. Connect DVM (John Fluke Model 825A) to output terminals of supply.
4. Place power ON-OFF switch in ON position and adjust Variac to apply nominal AC voltage to supply.
5. Turn OUTPUT VOLTAGE VDC controls on front panel clockwise until DVM indicates maximum rated output voltage for the unit.
6. Turn CURRENT LIMITER IDC control on front panel to fully counterclockwise position.
7. Turn R197 counterclockwise until output voltage just begins to drop.
8. Turn CURRENT LIMITER IDC control on front panel clockwise until output voltage begins to increase. If output voltage does not increase, turn R197 clockwise until it does increase and repeat steps 7 and 8.
9. Perform adjustment procedure for R189.
10. Seal wipers of R197 and R189 to respective resistor housings and check for appropriate indications. Repeat procedures for R197 and R189 as required to obtain correct values.

Adjustment of I_0 Max. Control R189. Whenever IC171, R21, R185, R187, R195, R191 and CS1 are replaced, both R197 and R189, respectively, must be recalibrated. R197 must be adjusted before R189.

NOTE: When R197 and R189 must be recalibrated, the adjustment procedure for each can be selected and followed separately from the COMPLETE POWER SUPPLY CALIBRATION PROCEDURE.

1. Perform steps (a) through (e) of Preliminary Procedure.
2. Break seal on wiper of R189 from resistor housing. If only R189 alone is being calibrated, set R189 to the fully clockwise position.
3. Connect load to unit, using local sensing connections, figure 3, and an ammeter in series with the load. Load must be adjustable to obtain 110% of unit output current rating at 40°C ambient temperature. Connect DVM (John Fluke Model 825A or equivalent) to output terminals of supply.
4. Place power ON-OFF switch in ON position and adjust Variac to apply nominal AC voltage to supply.

5. Turn OUTPUT VOLTAGE VDC controls on front panel clockwise until DVM indicates maximum rated output voltage for the unit.
6. Turn CURRENT LIMITER IDC control on front panel to fully clockwise position.
7. Adjust load to obtain 105% of unit output current rating at 40° C ambient temperature as indicated on ammeter connected in series with load. Refer to Table 1 for maximum current ratings.
8. Turn R189 counterclockwise until ammeter connected at load and DVM on output terminals just begin to decrease.
9. Seal wipers of R197 and R189 to respective resistor housings and check for appropriate indications. Repeat procedures for R197 and R189 as required to obtain correct values.

Adjustment of OV ADJ Control R25. The adjustment procedure requires that the power supply is removed from the associated equipment, is at an ambient temperature of 25-30° C and is operated at nominal line voltage.

Adjust the voltage-protection point of overvoltage protector circuit as follows:

1. Turn OV ADJ control on front panel fully CW.
2. The recommended voltage-protection point is 115% of normal power supply operation voltage plus one volt. Compute this value for the operating voltage being used.
3. Apply AC power to the supply and place power ON-OFF switch in ON position.
4. Place METER SELECTOR switch in VOLTS position.
5. Adjust OUTPUT VOLTAGE controls to the desired voltage-protection point; monitor the power supply output voltage to assure correct voltage. If the power supply does not have an adequate adjustment range, omit steps 6 and 7, and continue with step 8 below.
6. Slowly turn the OV ADJ control counterclockwise until the power supply output voltage drops, indicating that the voltage-protection point has been reached.
7. The voltage-protection point is now set. Place power ON-OFF switch in OFF position. Reduce power supply output voltage setting before turning power on.
8. If the power supply output voltage adjustment range does not extend to the voltage-protection point computed in step 2, proceed as follows:
 - (a) Turn on power supply and raise output voltage to the normal operating voltage; monitor the power supply output voltage.
 - (b) Slowly turn the OV ADJ control counterclockwise until the power supply output voltage drops.
 - (c) Refer to chart below, select appropriate volts/turn ratio, and turn OV ADJ control clockwise by the number of turns equivalent to 1 volt plus 15% of the operating voltage.

MODEL	VOLTS/TURN	OVERVOLTAGE ADJUSTMENT RANGE
LES-EE-01-OV	2.3	3-10 VDC
LES-EE-02-OV	2.3	6-24 VDC
LES-EE-03-OV	4.6	9-47 VDC
LES-EE-04-OV	6.9	12-70 VDC

For example:

When using power supply model LES-E-03 with output voltage setting of 20 volts, calculate as follows:

$$T = \frac{1 + .15 (OV)}{V/T}$$

where

T = turns of OV ADJ control

OV = operating voltage of power supply

V/T = volts per turn ratio from chart

$$T = \frac{1 + .15 (20)}{4.6} = 0.87$$

Rotate OV ADJ control 0.87 turn in clockwise direction to obtain a voltage setting 4.0 volts above the 20 volt power supply setting, or 24.0 volts.

Adjustment of Digital Panel Meter Calibration Controls R304 and R313. In order to ensure accuracy, the digital panel meter should be calibrated every 6 months or whenever any component part is replaced. To calibrate the meter adjust R304 and R313 as follows. The adjustment procedure requires that the power supply is removed from associated equipment, is at an ambient temperature of 25-30° C and is stabilized and not operating.

1. Connect power supply for local sensing connection as shown in figure 3, with no external load.
2. Apply AC input power to the assembly and place power ON-OFF switch in ON position.
3. Break seal on wiper of R304.
4. Connect a digital voltmeter, Data Technology Model 40 or equivalent, plus lead to terminal TP2 and minus lead to terminal TP1 on digital panel meter printed circuit board. Adjust R304 until digital voltmeter reads 100 millivolts.
5. Place METER SELECTOR switch in VOLTS position.
6. Turn OUTPUT voltage controls fully CW.
7. Break seal on wiper of R313.
8. Connect digital voltmeter being used as standard to rear terminals +S and -S. Adjust R313 until digital panel meter reading agrees with digital voltmeter reading.
9. After adjustment is completed, remove AC power input to the supply and use Glyptol sealant to seal wipers of R304 and R313 to respective resistor housing.
10. After sealing, check settings and repeat adjustment procedure if required.

SERVICE

When additional instructions are required or repair service is desired, contact the nearest Lambda office where trained personnel and complete facilities are ready to assist you.

Please include the power supply model and serial number together with complete details of the problem. On receipt of this information Lambda will supply service data or advise shipping for factory repair service.

All repairs not covered by the warranty will be billed at cost and an estimate forwarded for approval before work is started.

PARTS ORDERING

Standard components and special components used in the Lambda power supply can be obtained from the factory. In case of emergency, critical spare parts are available through any Lambda office.

The following information must be included when ordering parts:

1. Model number and serial number of power supply and purchase date.
2. Lambda part number
3. Description of part together with circuit designation.
4. If part is not an electronic part, or is not listed, provide a description, function and location of the part.

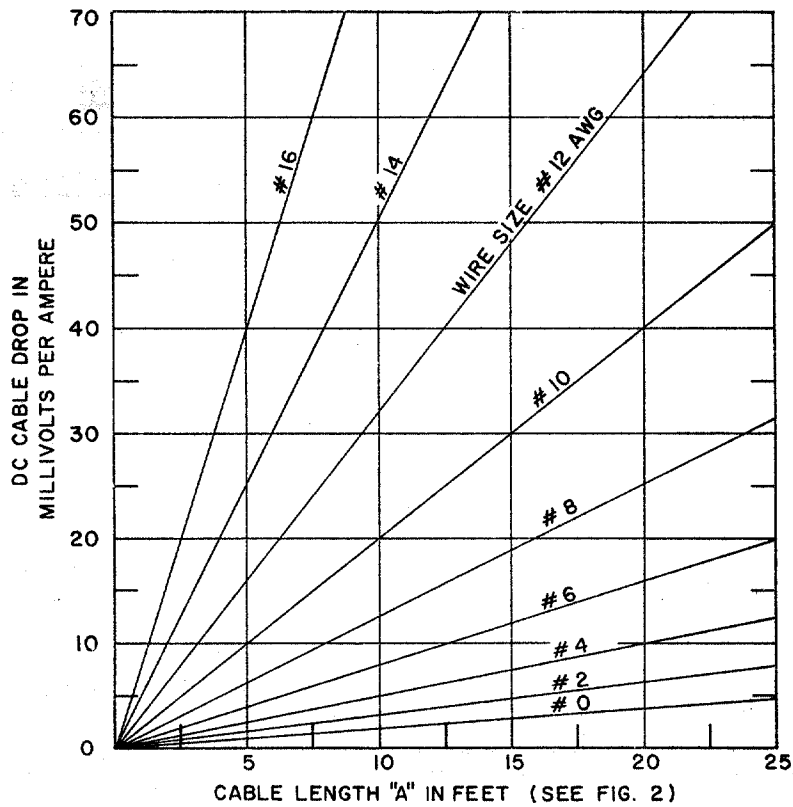


Figure 1. Cable Connection Chart.

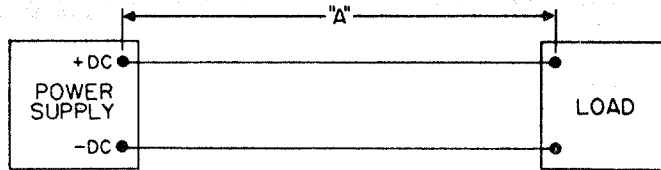
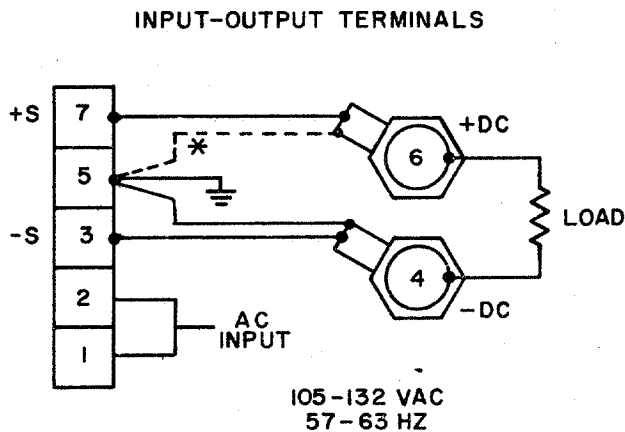


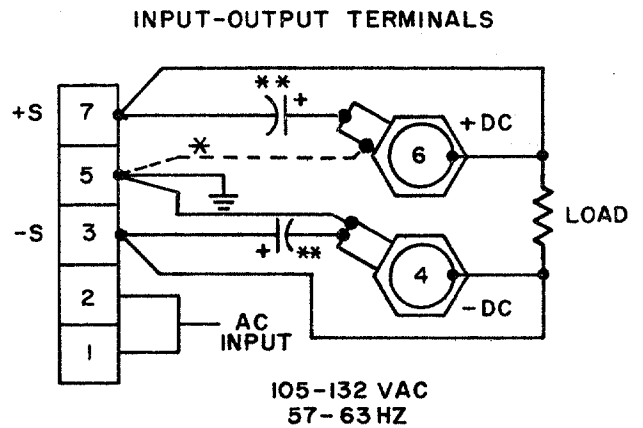
Figure 2. Cable Length "A" in Feet.



NOTE:

* FOR POSITIVE GROUND, DISCONNECT JUMPER FROM TERMINALS 4 AND 5 AND RECONNECT TO TERMINALS 5 AND 6.

FIGURE 3. LOCAL SENSING CONNECTIONS



NOTE:

* FOR POSITIVE GROUND, DISCONNECT JUMPER FROM TERMINALS 4 AND 5 AND RECONNECT TO TERMINALS 5 AND 6.
** A 2.5MF, ELECT., CAP. MAY BE REQUIRED.

FIGURE 4. REMOTE SENSING CONNECTIONS

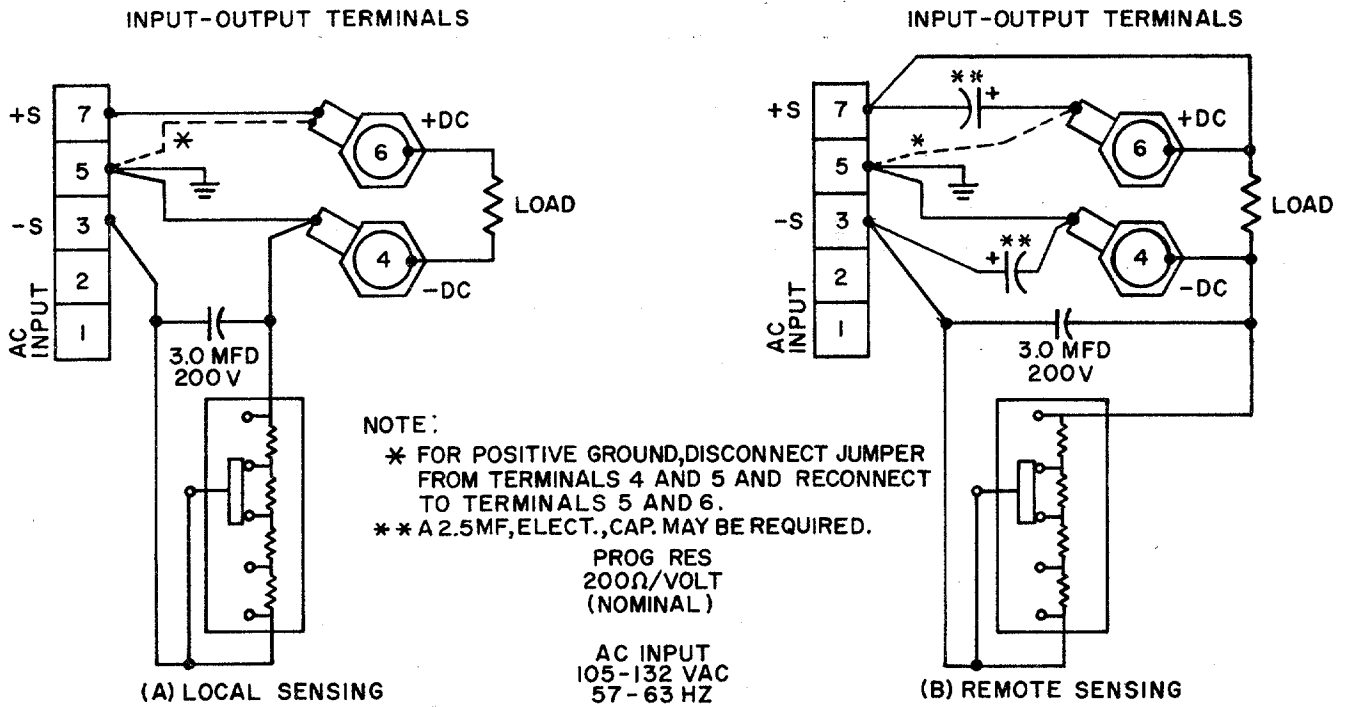


FIGURE 5. PROGRAMMED VOLTAGE WITH EXTERNAL RESISTOR

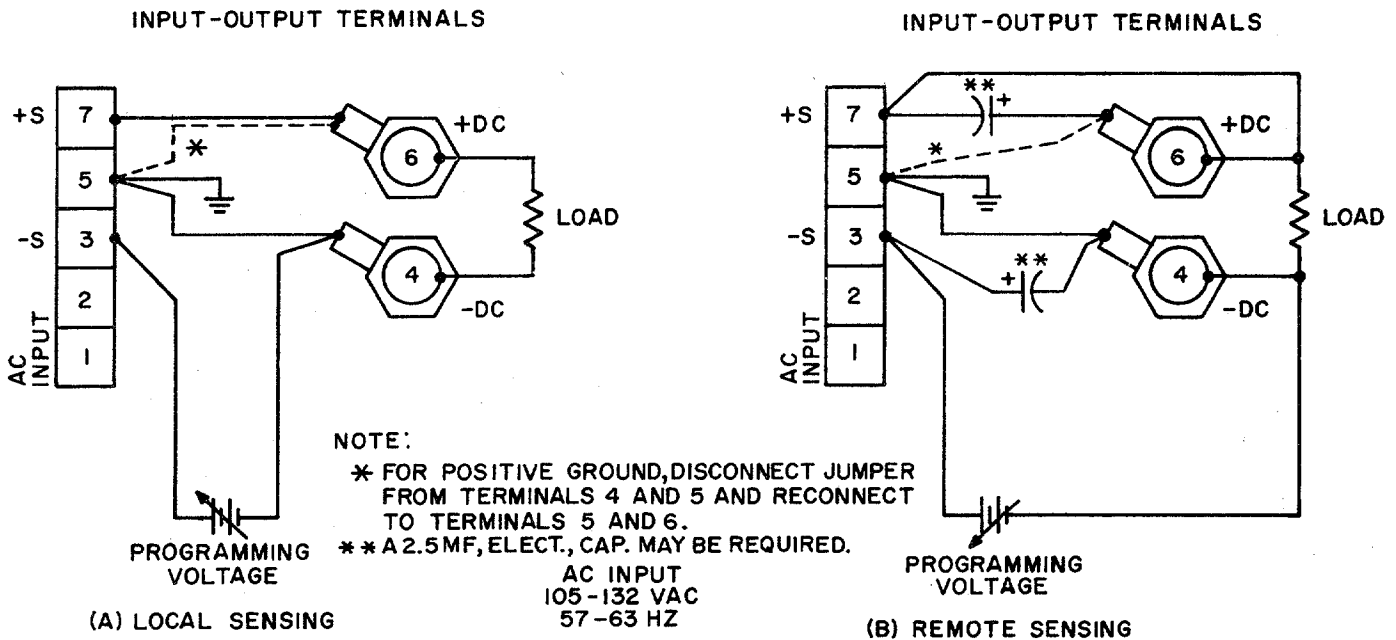
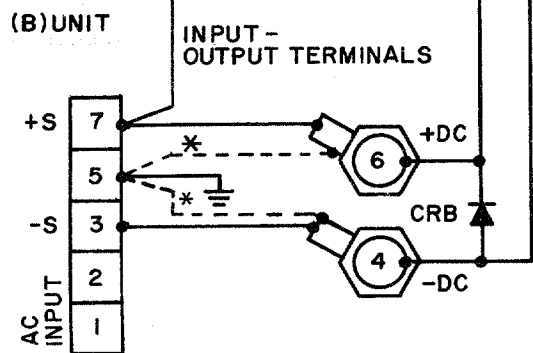
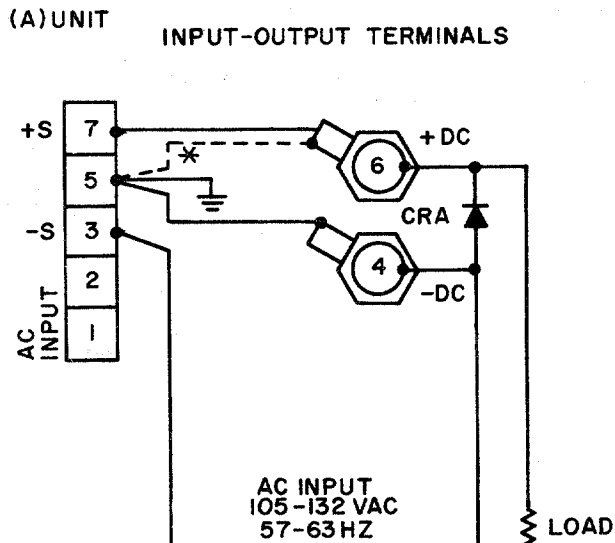
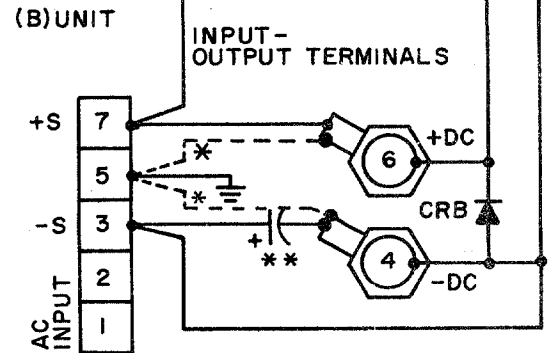
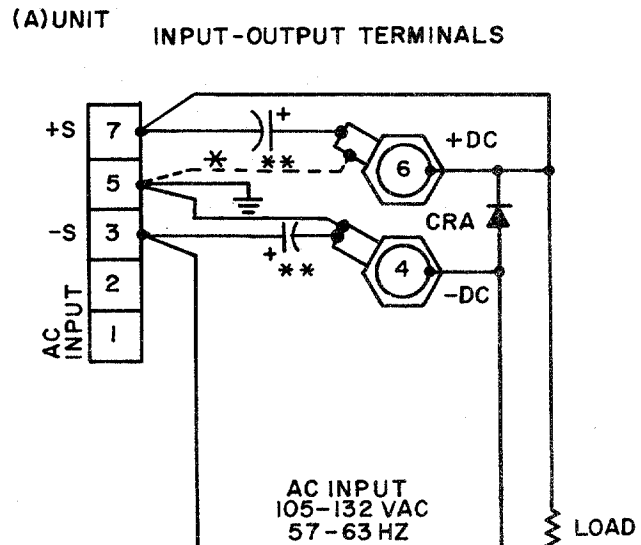


FIGURE 6. PROGRAMMED VOLTAGE WITH EXTERNAL PROGRAMMING VOLTAGE SOURCE



(A) LOCAL SENSING



(B) REMOTE SENSING

NOTE:

- * MAKE ONLY ONE GROUND CONNECTION FOR SERIES COMBINATION. TO CHANGE GROUND AS SHOWN, REMOVE JUMPER FROM TERMINALS 5 AND 4 ON (A) UNIT AND CONNECT ANY ONE OF THE OTHER JUMPERS AS SHOWN IN DOTTED LINE.
- ** A 2.5MF, ELECT., CAP. MAY BE REQUIRED.

FIGURE 7. SERIES CONNECTION

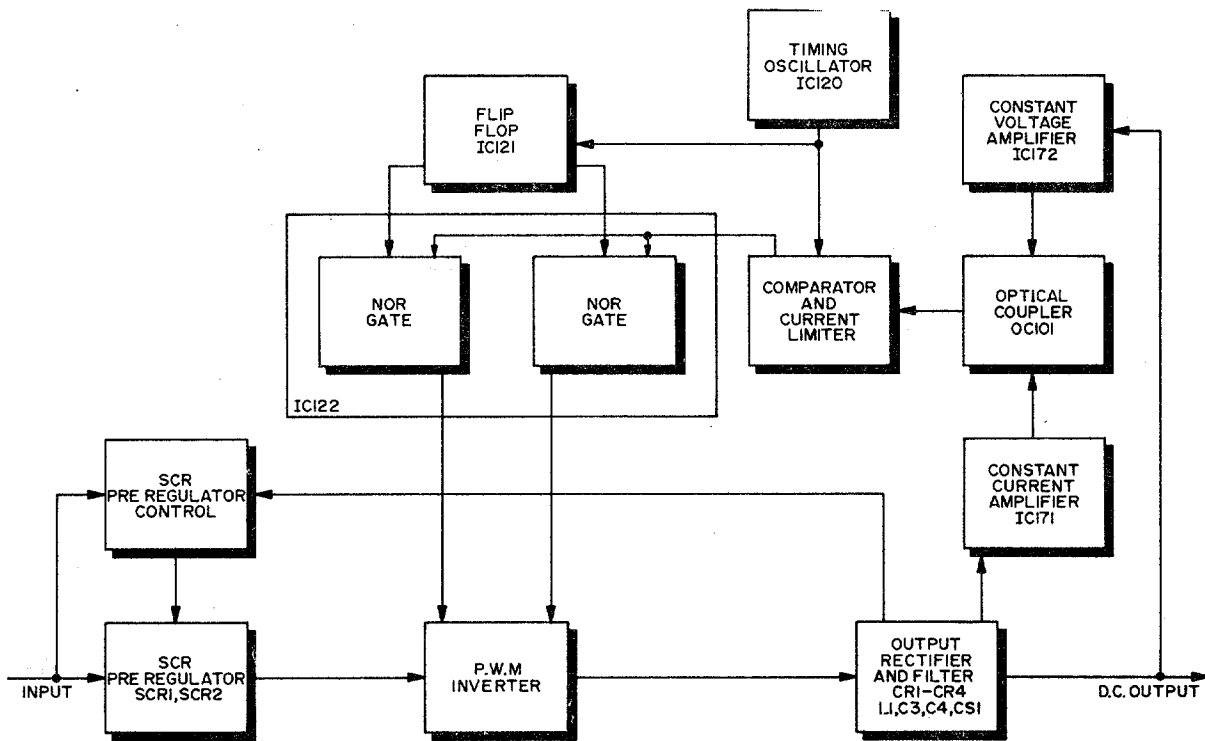
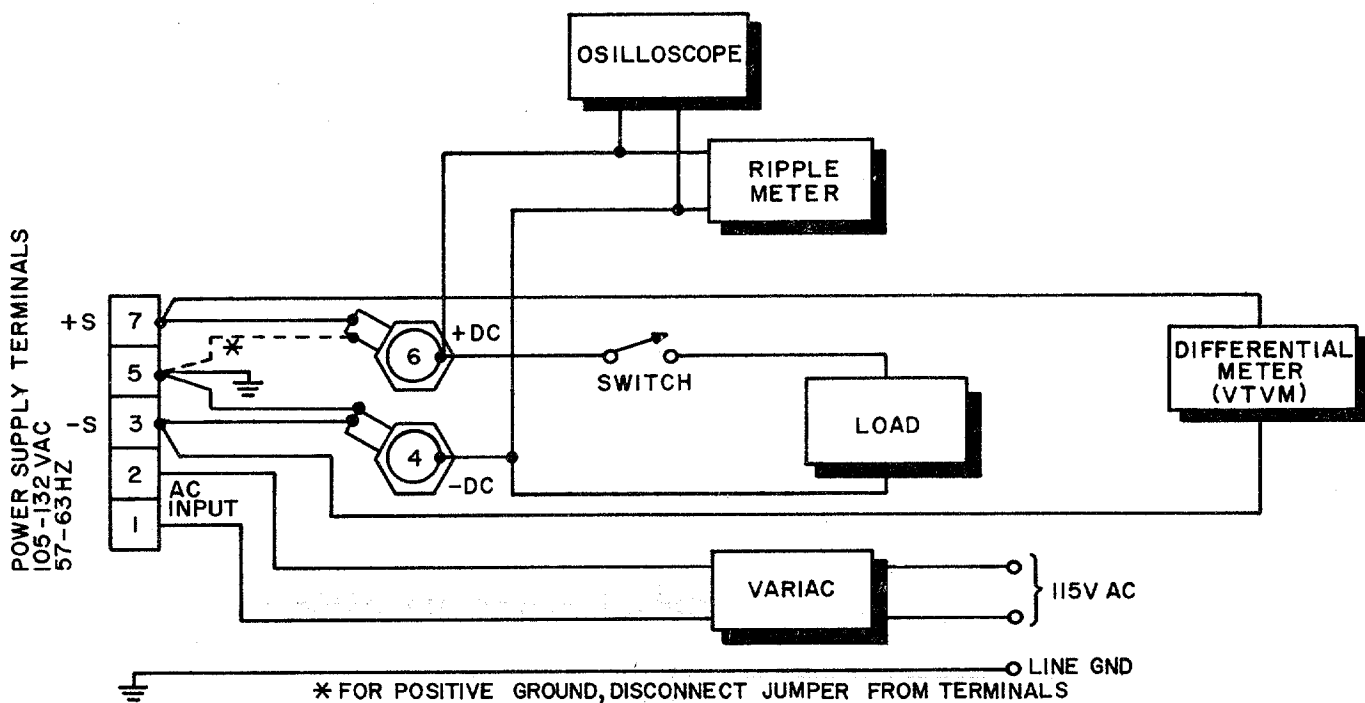


Figure 8. Typical Block Diagram.

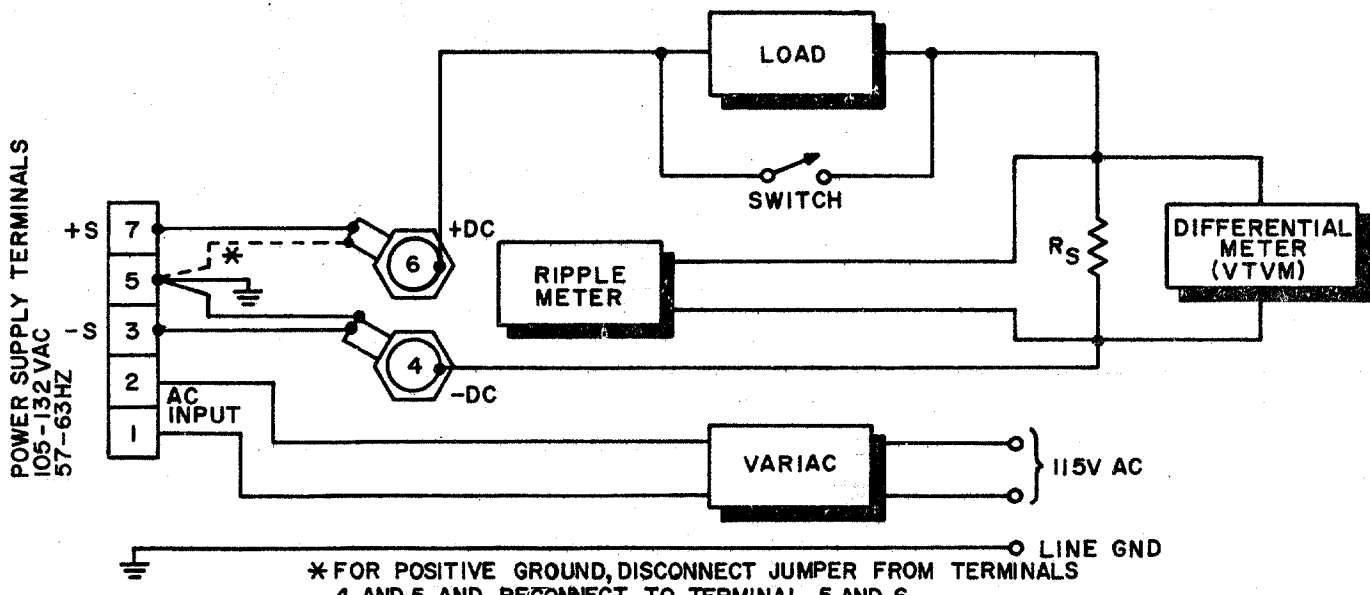


* FOR POSITIVE GROUND, DISCONNECT JUMPER FROM TERMINALS 4 AND 5 AND RECONNECT TO TERMINALS 5 AND 6.

NOTES:

1. REGULATION AND RIPPLE CHECK METERS MUST NOT BE GROUNDED THROUGH THREE-WIRE LINE CORD TO GROUND.
2. PERFORM CHECKS WITH LOCAL SENSING CONNECTIONS ONLY.

FIGURE 9 . TEST CONNECTIONS FOR CONSTANT VOLTAGE PERFORMANCE CHECKS



NOTES:

1. REGULATION AND RIPPLE CHECK METERS MUST NOT BE GROUNDED THROUGH THREE-WIRE LINE CORD TO GROUND.
2. PERFORM CHECKS WITH LOCAL SENSING CONNECTIONS ONLY.

FIGURE 10. TEST CONNECTIONS FOR CONSTANT CURRENT PERFORMANCE CHECKS

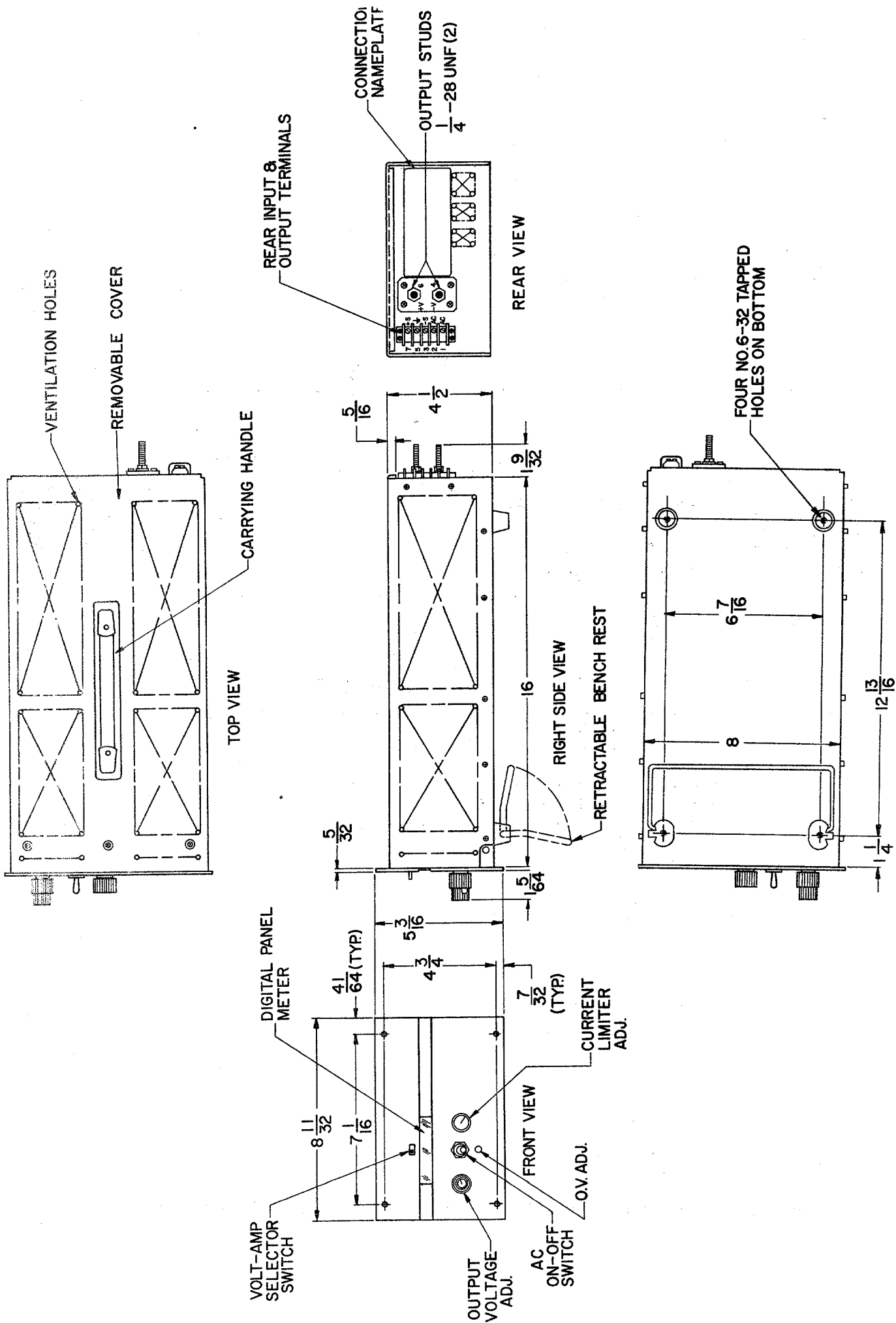


Figure 11. Outline Drawing

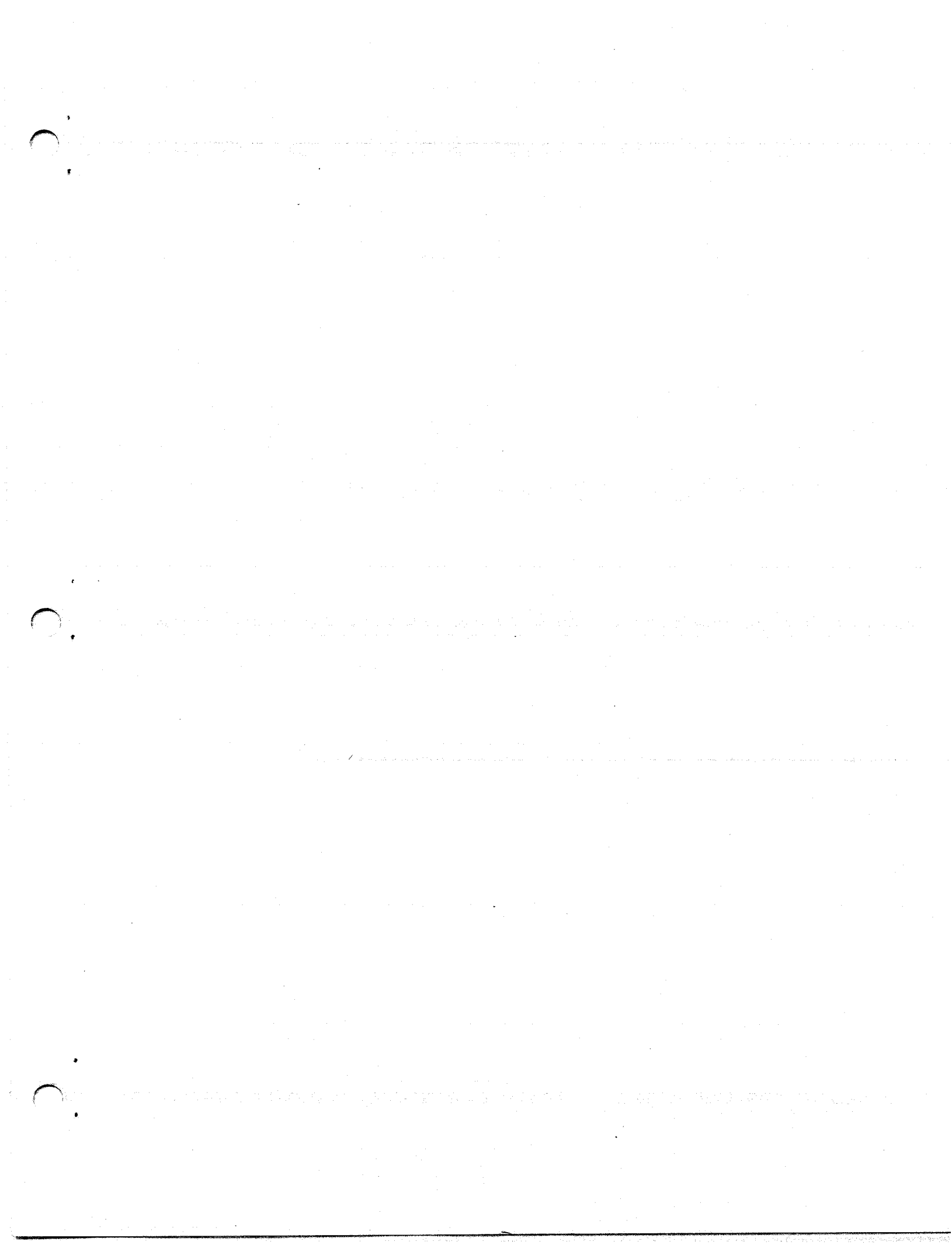


TABLE I
SCHEMATIC DATA REFERENCES
MODELS LES-EE-01-OV - LES-EE-04-OV

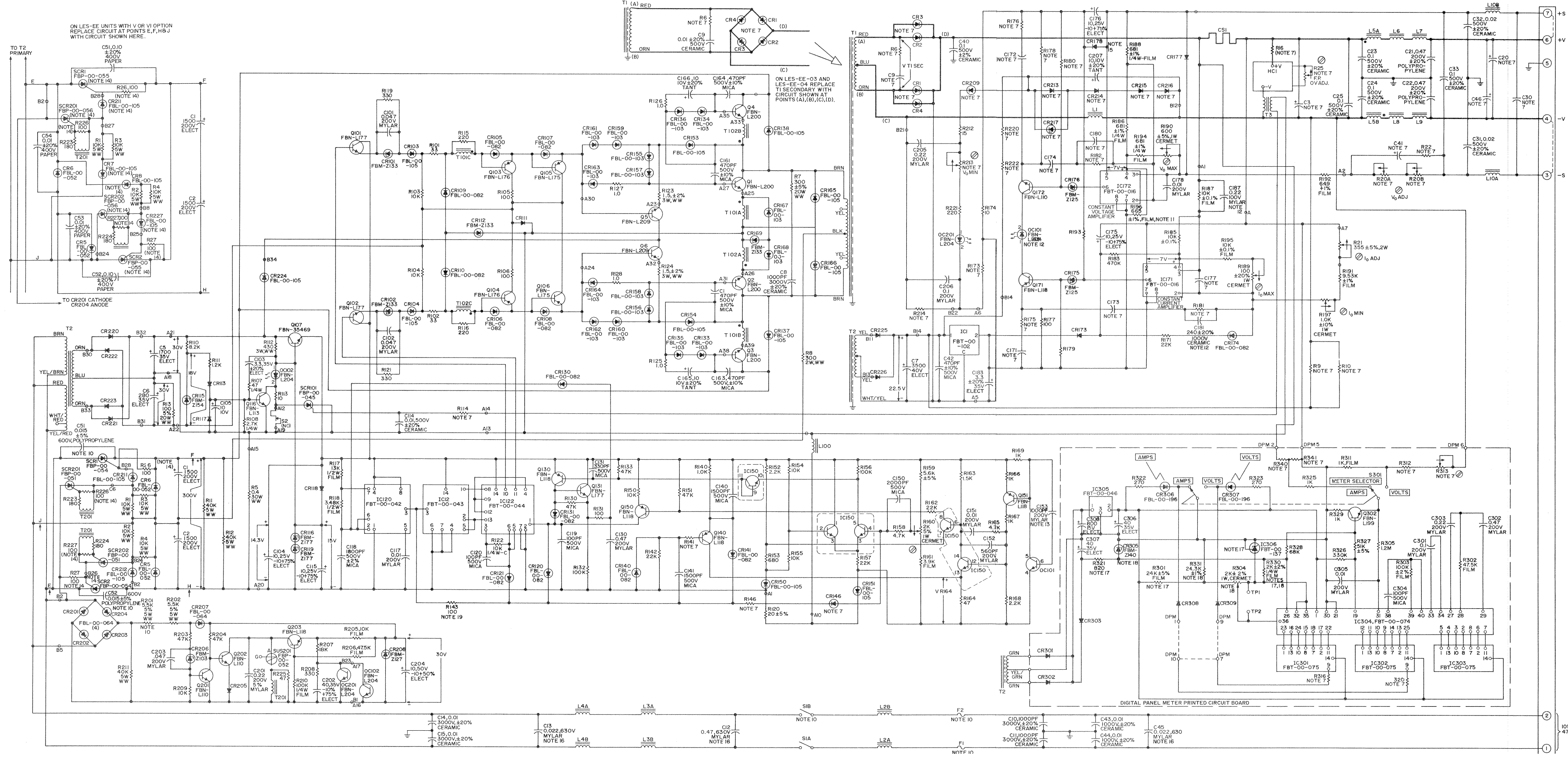
Model	Schematic Components																				
	C3	C9	C20	C30	C41	C46	C171	C172	C173	C174	C177	C180	C182	CRL4	CR209	CR213	CR215, CR216	CR217	R6	R16	
LES-EE-01-OV	-10 +50% ELECT. 10vdc	+20% 500vdc CERAMIC	+10% 50vdc ELECT.	+20% ELECT.	ELECT.	-10 +100% ELECT.	+20% ELECT.	+20% ELECT.	+10% CERAMIC	+10% 50vdc MYLAR	+10% 200vdc MYLAR	+10% 500vdc MICA	+10% ELECT.	*FBL-00- 118	*FBL-00- 103	*FBL-00- 080	*FBL-00- 080	*FBL-00- NOT USED	+5% 3W WW	+5% 20W WW	JUMPER
LES-EE-02-OV	60,000 mf 10vdc	0.02 mf	3.9 mf	3.3 mf ±20% 55vdc	NOT USED	290 mf 20vdc	3.3 mf 35vdc	2.2 mf 50vdc	0.01 mf 200vdc	.68 mf	0.01 mf	100 pf ±5%	10 pf ±20% 10vdc	118	103	080	080	NOT USED	10.0 ±10% 2W COMP.	10.0 ±10% 2W COMP.	JUMPER
LES-EE-03-OV	14,500 50 vdc	0.01 mf	3.9 mf	3.3 mf ±20% 35vdc	10 mf -10 + 75% 25vdc	100 mf 25vdc	4.7 mf ±10% 50vdc	3.3 mf 35vdc	0.022 mf 200vdc	.47 mf	0.047 mf	100 pf ±5%	1.0 mf ±20% 35vdc	**118	103	JUMPER	JUMPER	Z133	25	25	JUMPER
LES-EE-04-OV	9,000 mf 75vdc	0.01 mf	3.0 mf -10 + 75% 100vdc	3.0 mf ±10% 50vdc	10 mf -10 + 50% 50vdc	175 mf 50vdc	3.3 mf 35vdc	1 mf 35vdc	0.033 mf 200vdc	.68 mf	0.047 mf	680 pf 300vdc	3.9 50vdc	138	105	080	080	NOT USED	Z133	25	0.4

* LAMBDA PART NO.
** CR3 & CR4 NOT USED ON LES-EE-02-OV

TABLE I (Cont)

Model	Schematic Components (Cont.)																			
	R9, R10	R30A, B	R22	R25	R114	R173	R175	R176	R178	R181	R182	R213	R214	R220	R222	R312	R313	R316	R340	R341
LES-EE-01-OV	+5% 20W WW	+5% 2W WW 2-SECT.	+10% 1W COMP.	+10% 1W CERMET	+10% 1W COMP.	+5% 3W WW	+10% 1W COMP.	+10% 1W COMP.	+10% 1W COMP.	+10% 1W COMP.	+10% 1W COMP.	+10% 1W OR 0.75W	+10% 1W OR 0.75W	+5% 5W WW	+5% 5W WW	+1% 1W FILM	+10% 1W CERMET	+5% 1W COMP.	+0.5% 1W FILM	+0.5% 1W FILM
LES-EE-02-OV	100	1,800, 200	JUMPER	10,000	220	150	22	20 ±5%	270	200K 1W FILM	4,700	2,000 1W OR 0.75W	2,700	500	JUMPER	95.8K	10K	270	20	30.1
LES-EE-03-OV	160	8,500, 200	6,200	10,000	820	470	22	7.5 ±5%	330	75K	4,700	2,000 1W OR 0.75W	2,200	900	JUMPER	953K	100K	NOT USED	50	20
LES-EE-04-OV	300	7,500, 200	2,200	20,000	56	1,200	27 ±5%	33	270	47K	5,500	5,000 1W OR 0.75W	15K	900	900	958K	100K	NOT USED	113	20
LES-EE-04-OV	600	12,800, 200	3,800	30,000	100	1,200	22	22	390	47K	1,500	5,000 1W OR 0.75W	15K	1,650	1,650	958K	100K	270	20	182

† COMPONENT ON DIGITAL PANEL METER BD.



- NOTES:
1. RESISTORS ARE 1/2W COMP. W.
 2. CAPACITOR VALUES ARE IN MI.
 3. RESISTOR TOLERANCES: COM
 4. CAPACITOR TOLERANCES: EL MYLAR $\pm 20\%$, MICA $\pm 5\%$ UNLESS OTHERWISE SPECIFIED.
 5. SYMBOLS:
 - INDICATES ACTUAL UNITS
 - ⬇ INDICATES CLOCKWIS
 - * SEE INSTRUCTION M.B.
 - Λ LAMBDA PART NO. FB REPLACEMENT UNLESS OTHERWISE SPECIFIED.
 - ⊖ INDICATES TERMINAL BOARD.
 - ⊕ INDICATES ADJUSTMENT POINT.
 6. DESIGNATIONS ARE LAMBDA F
 7. SEE TABLE 1 FOR COMPONENT
 8. SEE TABLE 1 FOR VOLTAGE V
 9. THE FOLLOWING WAVEFORMS 1 AND 2 C- UNLESS OTHERWISE SPECIFIED.

- IC120, PIN 3
 IC121, PIN 2
 IC121, PIN 2
 IC122, PIN 10
 IC122, PIN 11
 IC122, PIN 11
 ACROSS R164
 (POS ON IC150 PIN 13)

10. THESE COMPONENTS USED ON V OPTIONS (187-242 VAC IN DISCONNECT T2 YEL/BRN AN CONNECT TO EACH OTHER. IN ON VI OPTIONS (205-265 VAC FROM TERMINATIONS SHOWN ON BOTH V AND VI OPTIONS: F1 UNITS)
11. NOT USED ON UNITS WITH S1
 12. ON UNITS WITH SERIAL NO. P (NOW USED ON LES-EE-04 UNITS)
 13. ON UNITS WITH SERIAL NO. PI
 14. ON UNITS WITH SERIAL NO. PI R215 & R216; R226 & R227; NO FBL-00-064; 3 ON V & VI OPT STD. CIRCUITS); CR211 WAS FB SCR1 & SCR2 EACH WAS FBP-052
 15. ON UNITS WITH SERIAL NO. PI
 16. ON UNITS WITH SERIAL NO. P 400VDC.
 17. R39 ONLY USED AND IC306 B
 18. ON UNITS WITH SERIAL NO. P FBM-2165 AND R331 WAS NO
 19. R143 NOT USED ON ALL UNITS

105-132 VAC
 47-63 Hz