GLASSMAN HIGH VOLTAGE, INC.
Route 22 East, Salem Park
Whitehouse Station, NJ 08889

INSTRUCTION MANUAL

LG SERIES

MODEL PS/LG-80P-1.5

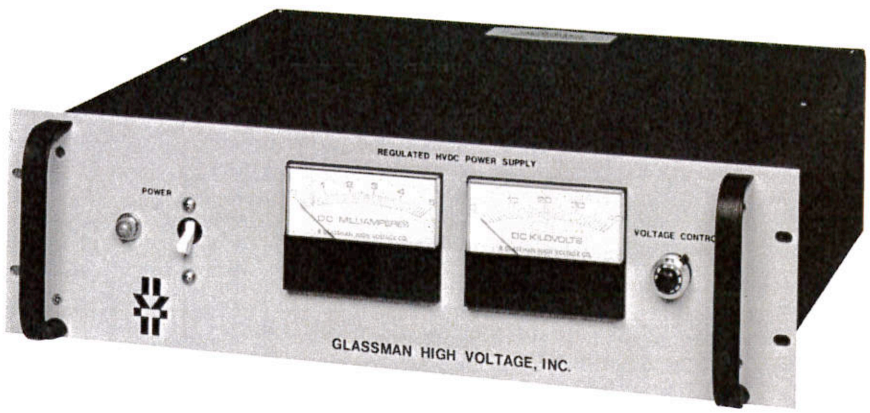
SERIAL M155820

DATE 8/21/87

TABLE OF CONTENTS

Series LG

Well Regulated Field-Proven High Voltage High Frequency 150 Watt Power Supplies



FEATURES

- Stable, high frequency, ferrite core transformer power oscillator design-minimizes power loss, eliminates many failure modes.
- Automatic protection against damage from line/load aberrations and remote-programming overvoltage.
- Remote and front panel monitoring and programming DC output voltage and current.
- Regulation better than 0.005% — line and load.
- Less than 5 msec recovery from 50% load transient.
- Full load efficiency better than 75% — low internal dissipation, very high reliability.

APPLICATIONS

- **Manufacturing Processes:** Spraying and Flocking Systems, Ion Implantation, Fault Detection, Corona Testing, Precipitation and Deposition Systems.
- **Displays:** Image Intensification, Radar Displays, Flying Spot Generators and Scanners, Waveform Generators, Large Screen CRT Display, Oscilloscopes, Projection TV.
- **R & D Instrumentation:** Mass Spectrometers, Electron Microscopes, Air Pollution Instrumentation, Capacitor Bank Charging, Nuclear Apparatus, Radiation Counters, Lasers, Voltmeter/Voltbox Calibrators, Plasma and Pinch System.
- **Powering HV Devices:** X-ray Sources, Photomultipliers, BWO/TWT/Klystron Tubes, Radiation Detectors, Accelerators, Electron Gun Devices.

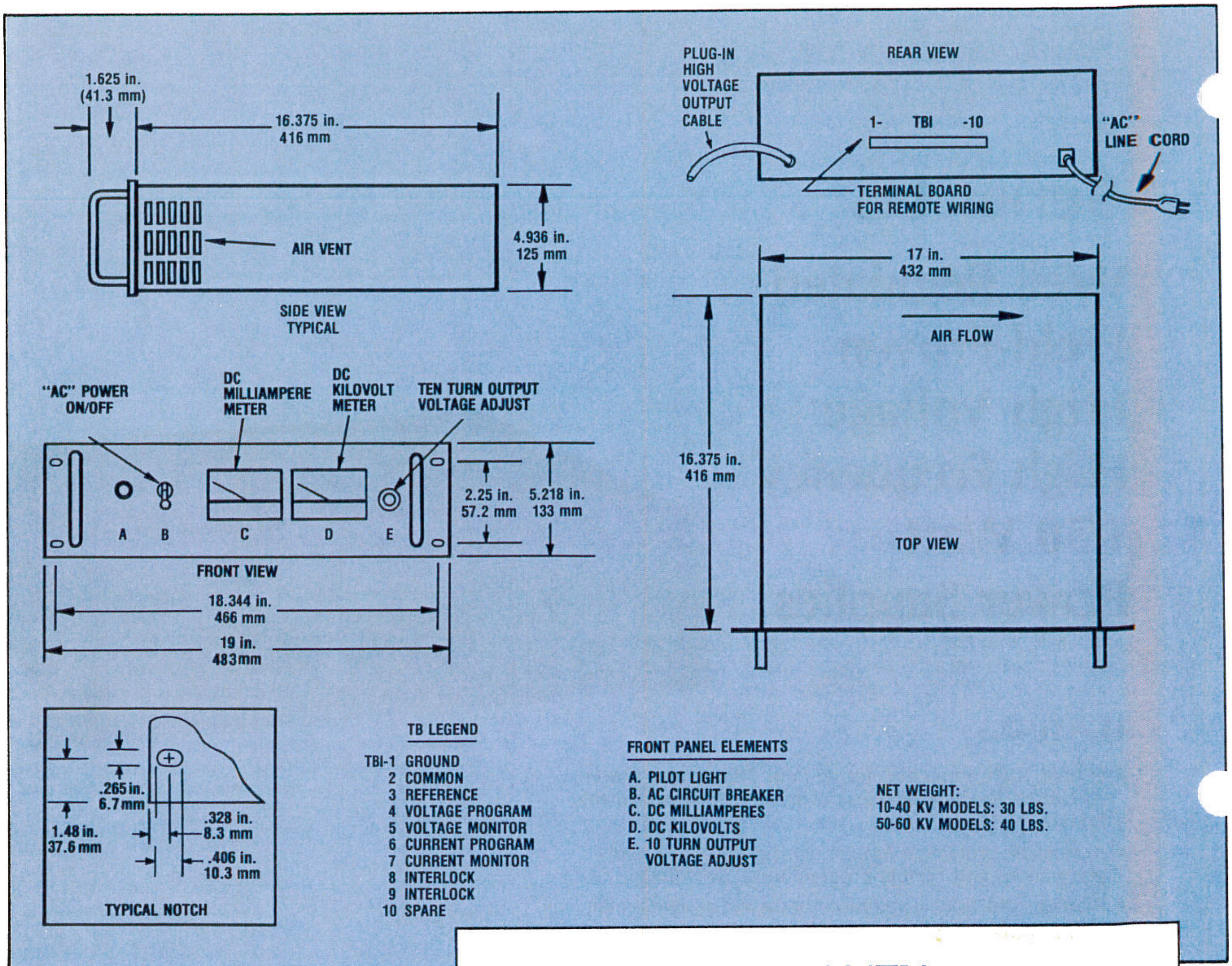
Innovations in high voltage power supply technology

GLASSMAN HIGH VOLTAGE INC.

Route #22 (East), Salem Industrial Park, P.O. Box 551, Whitehouse Station, N.J. 08889 • (201) 534-9007 TWX 710-480-2839

Catalog Series LG 10/85

MECHANICAL SPECIFICATIONS



WARRANTY

Glassman High Voltage Inc. warrants all power supplies it manufactures to be free from all defects in materials and factory workmanship, and agrees to repair or replace any power supply that fails to perform as specified within one year after date of shipment. Formal warranty available upon request.

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REPRESENTED BY:

4426 — 1080, Printed in U.S.A.

DESIGN FEATURES

Reversible Polarity: The output voltage polarity of all Series LG models is easily reversed by interchanging the entire high voltage module for the desired polarity. All polarity sensitive circuitry in the control system operates automatically for either positive or negative output polarity, so that no additional switching is required.

Voltage-Current Regulation with Automatic Cross-Over: All models feature both *voltage* and *current regulation*, with automatic crossover to voltage or current mode, as determined by the magnitude of the load.

Remote Programming and Monitoring: Remote programming capability is provided for both the voltage and current control function. Programming is accomplished by either a potentiometer (using the power supply internal reference system), or an external 0-10 volt positive programming voltage, with return to case ground.

Monitoring circuitry for both output voltage and load current is provided.

Metering: All power supplies in this series are equipped with large, accurate, directly calibrated, linear-scale panel meters that display both the output voltage and the output current. 2% full scale accuracy is provided. Both meters are protected against breakdown in the associated circuitry, so that high voltage is never brought to the front panel, and the meters are always located in the ground-return path, regardless of output polarity.

Modular Construction: All major functional circuitry, including power transistors, is mounted on a single printed circuit board, for ease of maintenance and repair. The high voltage circuitry in this entire family of power supplies is also constructed from modular subassemblies, so that replacement or repair, if required, is simple and economical.

Protection: The oscillator-rectifier circuitry provides inherent self protection against four of the most common problems encountered in earlier high voltage power supply designs: failure to re-start after overload; damage from overload; damage from shorts, transient input spikes, etc.; loss of reliability due to stress at high output after overvoltage in remote programming mode. In addition, overload, short-circuit, and arc protection is provided by automatic current regulation, and by careful surge limiting design.

High Efficiency: Efficiency is typically better than 75% at full load, which ensures low internal dissipation and thereby increases reliability.

Low Stored Energy: Like all RF oscillator power supplies, the LG Series is inherently safer to operate than line-frequency high voltage supplies, because the output capacitance is extremely low, so that the total stored energy available is quite small . . . on the order of 1 Joule.

Low Ripple: The high oscillator frequency makes it relatively easy to achieve low ripple in these supplies. Standard ripple is 0.1%, and even lower ripple is available on special order.

Excellent Transient Response: The typical recovery time from a 50% load transient is less than 5 milliseconds . . . a considerable improvement over conventional RF voltage supplies. Line transients are effectively attenuated by the filter on the low voltage regulated power supply and may generally be ignored.

Tight Static Regulation: Both line and load regulation are better than 0.005% over the entire rated range of input voltage and output current.

Radio Frequency Interference: A conducted-noise line filter is provided.

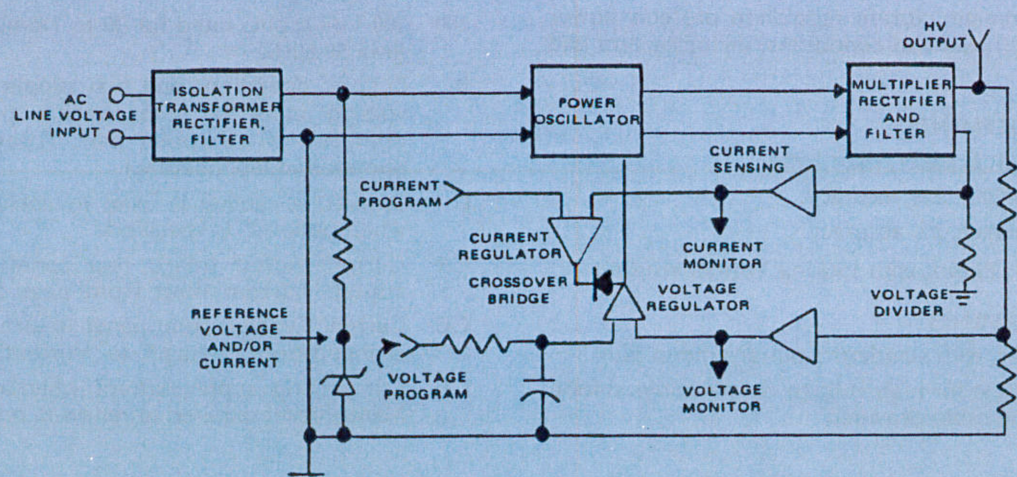
THEORY OF OPERATION

The AC power line is fed to an isolation transformer through a primary circuit breaker. The line voltage is stepped down, rectified, and filtered. The resultant unregulated DC is then fed to the power oscillator. The oscillator duty cycle is, in turn, controlled by a fast, high-gain amplifier that compares, at its input, a fixed fraction of the output voltage with a selected portion of the reference-zener voltage drop.

The oscillator controls the amplitude of the low-RF voltage supplied to the primary of a step-up transformer. The secondary of the transformer supplies the input to a set of multiplier/rectifier/filter circuits (i.e., voltage doublers, triplers, quadruplers, etc., as required by the output voltage rating) that develop the HVDC output.

The current-regulating amplifier derives its signal from a current-sensing resistance in the low-end return of the high voltage. The crossover diode functions to sink the voltage program source as required to maintain current regulation.

Energy storage is low, and the control amplifier is fast, as noted; hence, the transient response is excellent, and the regulator virtually eliminates low-frequency input ripple. High-frequency ripple is very low at no load, and increases to the rated 0.1% maximum only at full load.



MODELS

Reversible Polarity Model	Positive Polarity Model	Negative Polarity Model	Output Voltage (KV)	Output Current (mA)	Panel Height
LG 5R20	LG 5P20	LG 5N20	0-5	20.0	5-¼"
LG10R15	LG10P15	LG10N15	0-10	15.0	5-¼"
LG20R7.5	LG20P7.5	LG20N7.5	0-20	7.5	5-¼"
LG30R5	LG30P5	LG30N5	0-30	5.0	5-¼"
LG40R3.5	LG40P3.5	LG40N3.5	0-40	3.5	5-¼"
LG50R3	LG50P3	LG50N3	0-50	3.0	5-¼"
LG60R2.5	LG60P2.5	LG60N2.5	0-60	2.5	5-¼"
LG80R1.5	LG80P1.5	LG80N1.5	0-80	1.5	8-¾"
LG100R1	LG100P1	LG100N1	0-100	1.0	8-¾"

SPECIFICATIONS

Input: 105-125Vrms; 50-60 Hz, single phase. Approximately 3 amperes at rated output.

Output: 0-5KV, 20 mA to 0-100KV, 1mA (see ratings for individual models above). Continuous, stable adjustability from 0 to rated voltage and current. 10-turn front panel voltage control with resolution and readability better than 1000 ppm. Linear to 1%. Control dial can be locked.

Voltage Regulation: Load, better than 0.005% for full load variation; line, better than 0.005% over specified input range; ±1 volt.

Current Regulation: Load, better than 100 microamperes from short circuit to rated voltage at any load condition. Line, better than ±0.005% over specified input range; ±1 volt.

Ripple: 0.1% rms of rated voltage at full load. Ripple voltage is proportional to load current and decreases linearly to 0.01% rms of rated voltage at no load.

Stability: 0.01% ±1 volt per hour after ½ hour warm-up. 0.05% ±2 volts per 8 hours.

Temperature Coefficient: 0.01%/°C ±1 volt.

Ambient Temperature: −20°C to +60°C, operating; −40°C to +85°C, storage.

Polarity: Reversible or fixed. Units available with positive, negative, or reversible high voltage with respect to chassis ground.

Protection: Automatic current regulation protects power supply against all overload conditions, including arcs and short circuits.

FRONT PANEL ELEMENTS

AC Power: Circuit breaker, pilot lamp.

Output Kilovoltmeter: 2% accuracy.

Output Milliammeter: 2% accuracy.

Voltage Control: 10-turn with locking Vernier readout.

REAR PANEL ELEMENTS

Line Cord: 6-foot, with standard 3-pin grounded plug.

Output: Receptacle for high voltage coaxial cable. 8-foot, shielded, mating cable provided.

External Interlock Terminals: Output voltage is maintained at zero when external contact pair "opens". External contact pair must be "closed" for normal operation.

Remote Voltage and Current Readout Terminals: Provides 0-10VDC full scale signal with 10 kilohm impedance.

Remote Voltage and Current Control: Three terminals for either potentiometer or "remote programming" voltage with respect to ground. Supply designed for rated output with +10V input. Supply protected against remote programming overvoltage up to 50V.

OPTIONS

Symbol	Description
220	220 Volt input: rated for 210 to 250 volts. RMS 50-60HZ
100	100 Volt input: rated for 90 to 110 volts. RMS 50-60HZ
B	Bi-polar operation: any two supplies of the same voltage rating but with opposite polarity may be operated as a bi-polar pair. (They may also be operated independently.)
C	Cabinet: a cabinet is used to enclose the supply when option-C is specified.
CA	Current Adjust (rear): rear panel potentiometer adjusts current limit from near zero to rated.
CC	Current Control: front panel 10-turn potentiometer changed from "voltage" to "current" adjustment.
CT	Current Trip: supply turns off when overload occurs. Manual reset required to return to normal operation.

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LG - SERIES

INSTRUCTION MANUAL ADDENDUM

CT Option (Current Trip)
IT Option (Instant Trip)

REVISED 8/1/83

These options provide trip off and lock out of the high voltage whenever an overload condition occurs. Primary latching is accomplished by diode CR17, which is regeneratively coupled from the output to the input of the current control operational amplifier U101. See Driver Assembly Schematic CT/IT Option for full details. This diode, CR17, is added to the circuit for these options, and supplements the standard current regulator action as described in the instruction manual.

In addition to the features described above, which are common to both the CT (Current Trip) and IT (Instant Trip) Options, the IT option has a current sensing speed-up network, C30 and R54, which "anticipates" sudden load increases or arcing conditions, and, within a few microseconds, initiates the removal of drive power to the high voltage transformer. The IT option also reduces the filter capacitance by a factor of approximately 10, which significantly reduces the stored energy in the high voltage power supply.

A Zero Reset feature is included with the IT (Instant Trip) and CT (Current Trip) options. This circuit requires that the Output Adjust front panel control be reduced to its zero position every time the unit is turned on. This applies to restarting after an IT or CT trip out.

APPLICABLE SCHEMATICS:

200015
300013-020

SECTION I

GENERAL

THIS EQUIPMENT EMPLOYS VOLTAGES THAT ARE DANGEROUS. EXTREME CAUTION MUST BE EXERCISED WHEN WORKING WITH THIS EQUIPMENT.

A. Correspondence and Ordering Spare Parts

1. Each Glassman Power Supply has an identification label on the rear of the chassis that bears its model and serial number.

2. When requesting engineering or applications information, reference should be made to this model and serial number, as well as to the component symbol number(s) shown on the applicable schematic diagram, if specific components or circuit sections are involved in the inquiry.

3. When ordering spare parts, the information described in paragraph 2 should be given, in addition to the Glassman part number that appears on the parts list.

   Examples:
   1. When requesting engineering data:

      "...voltage across Capacitor C2, for serial No. 100674 of Model 30P150 power supply."

   2. When ordering that component:

      "...one (1) Glassman Part N.CFH001, Capacitor C2 for Serial No. 100674 of Model 30P150 power supply."

B. Unpacking and Inspection.

First inspect package exterior for evidence of rough handling in transit. If none, proceed to unpack... carefully. After removing the supply from its shipping container, remove the top dust cover and inspect thoroughly for evidence of damage. (In cabinet models, remove the supply from its cabinet in order to inspect it.)

IMPORTANT

In cases of damage due to rough handling in transit, notify the carrier immediately, if damage is evident from appearance of package.

Under any circumstances, do not destroy or remove any of the packing material used in a damaged shipment. Carrier companies will usually not accept claims for damaged material unless they can inspect the damaged item and its associated packing material. Claims must be made promptly -- certainly within five days of receipt of shipment.

Check out the power supply as outlined in paragraph C.

C. Installation and Operation.

The following procedure should be followed after the equipment has been placed or mounted in position, to connect and operate the equipment.

WARNING

THIS EQUIPMENT EMPLOYS VOLTAGES THAT ARE DANGEROUS. EXTREME CAUTION MUST BE EXERCISED WHEN WORKING WITH THIS EQUIPMENT.

A 3-PRONG GROUNDED PLUG IS PROVIDED FOR CONNECTION TO AC LINE. IF A GROUNDED RECEPTACLE IS NOT AVAILABLE, USE AN ADAPTER AND CONNECT THE THIRD WIRE TO A GOOD GROUND - PREFERABLY A WATER SYSTEM GROUND.

ALWAYS MAKE CERTAIN THAT THE RETURN LINE FROM THE LOAD IS CONNECTED TO THE GROUND STUD AT THE REAR OF THE UNIT. A GOOD EXTERNAL WATER SYSTEM GROUND SHOULD ALSO BE CONNECTED TO THIS STUD.

a. Check the input voltage rating on the nameplate of the supply and make certain that this is the rating of the available power source.

b. Connect the input cable to the power source.

c. Connect the high-voltage output cable and ground return lead to the load. Insert the high voltage cable into the receptacle on the rear panel. Spring action should be felt as the probe reaches the bottom of the receptacle. Hold the cable pressed down against the spring as the locking nut is screwed onto the receptacle.

d. Rotate OUTPUT VOLTAGE control to fully counter-clockwise position. (This is optional, but desireable to prevent damage to external equipment caused by inadvertent overvoltage setting. Not required if correct setting has already been determined.)

e. Apply input power to the supply by setting POWER circuit breaker to ON (up) position.

f. Rotate OUTPUT VOLTAGE control clockwise until voltmeter indicates desired output voltage. (Monitor output current, to be sure maximum rating is not exceeded.)

g. To shut down supply, set POWER circuit breaker to OFF (down) position.

WARNING: DO NOT HANDLE THE LOAD UNTIL IT HAS BEEN DISCHARGED - CHECK KILOVOLTMETER!

D. Polarity Reversal.

On reversible polarity models, the power supply has been shipped with two high voltage assemblies, one positive and one negative. The serial label on the high voltage assembly indicates its polarity. To reverse the polarity of the power supply, it is necessary to exchange the high voltage modules. This is quite easy to do and can be accomplished in just a few minutes. First, remove the power supply dust cover. Second, disconnect the "fast-on" terminals on the front of the high voltage module so that the connections from the driver assembly are free. Next, stand the power supply on its side and, while supporting the high voltage module remove the mounting screws which secure the high voltage module to the chassis.

Before attempting to lift the high voltage module out, make sure the high voltage output cable has been removed. The assembly is now free and ready to be removed.

Install the other high voltage module by reversing the above steps.

E. Remote Control Connections and Applications.

Terminal Board TB1 is mounted on the rear panel and has the following functions.

TB1-1: Ground. This is an auxiliary, instrumentation ground terminal. The main ground terminal is a "stud", E1, located near the high voltage output connector.

TB1-2: Common. This terminal is the instrumentation/measurement circuit return. It is "DC" connected to ground, internally, by a pair of back-to-back diodes. If left floating, this point will clamp at approximately 500 millivolts. The power supply is shipped from the factory with a barrier jumper across TB1-1 and TB1-2, so that normally, the common is operated at ground potential. If desired, the user may lift this jumper, and allow the common to float. This may be done for the purpose of inserting a current monitoring circuit which will measure "true" load current, with no internal drain included in the measurment. When attempting this, it should be remembered that the inserted drop must not exceed the 500 millivolt clamping voltage, or erronious readings will be obtained.

TB1-3: Reference. An ultra stable 10 volt reference voltage with respect to common, terminal TB1-2, for user programming applications is supplied. Remember that the common is normally at ground potential, so that external circuitry may be returned directly to ground. Maximum current drain from this reference should be limited to 3 milliamperes to maintain normal operation, although no damage will be done even with a severe overload at this terminal.

TB1-4: <u>Voltage Program</u>. A 0-10 volt positive signal with respect to common/ground will control the output from zero to rated voltage. The user may provide his own external programming control signal, or may use an external potentiometer across the reference to derive a programming voltage. The preferred value for an external potentiometer is 10K ohms, although values from 5K through 50K ohms will be satisfactory. When inserting an external programming signal, the negative end should be connected to the common/ground terminal TB1-1/2. The positive end should be connected to terminal TB1-4.

When connecting an external potentiometer using the power supply internal reference, connect as follows:

Clockwise terminal to TB1-3.
Counter-clockwise terminal to TB1-1/2.
Slider terminal to TB1-4.

In this mode of operation, the front panel control serves as an overvoltage limit for the remote control. As an example, if the front panel control is set to 50%, then the remote control is capable of adjustment from 0 to 50% only, which corresponds to a signal voltage of 0 to 5 volts DC. If full range control is desired, the front panel control must be set to maximum. In any case, the power supply will "clamp" the programming input at the front panel control setting, and thereby protect against inadvertent overvoltage programming signals up to 50 volts DC.

TB1-5: <u>Voltage Monitor</u>. A 0-10 volt positive signal with respect to common/ground in direct proportion to output voltage is available at this terminal. A 10K ohm limiting impedance protects the internal circuitry, so that a digital voltmeter with greater than 10 megohms input impedance would be used to monitor this terminal. It is also acceptable to use a 1 milliampere DC full scale instrument for monitor purposes.

TB1-6: <u>Current Program</u>. A 0-10 volt positive signal with respect to common/ground will control the output from zero to rated current. The user may provide his own external programming control signal, or may use an external potentiometer across the reference to derive a programming voltage. The preferred value for an external potentiometer is 10K ohms, although values from 5K through 50K ohms will be satisfactory.

When inserting an external programming signal, the negative end should be connected to the common/ground terminal TB1-1/2. The positive end should be connected to terminal TB1-6.

When connecting an external potentiometer using the power supply internal reference, connect as follows:

Clockwise terminal to TB1-3.
Counter-clockwise terminal to TB1-1/2.
Slider terminal to TB1-6.

In this mode of operation, an internal "clamp" protects the power supply against inadvertent overvoltage programming signals up to 50 volts, and limits the output current to less than 110% of rated.

TB1-7: Current Monitor. A 0-10 volt positive signal with respect to common/ground in direct proportion to output current is available at this terminal. Use an instrument with at least 1 megohm input impedance to monitor this terminal.

TB1-8 and TB1-9: External Interlock. These terminals must be connected together to enable the power supply control circuits. They have been shorted by a barrier jumper terminal at the factory to assure start-up. When desired, the jumper may be removed and replaced by an external switch device which must be closed to make the supply operable. When the external switch is open, the power supply output will drop to zero.

TB1-10: Spare Terminal.

SECTION II

THEORY OF OPERATION

Detailed schematics and parts lists for the overall, main power suppy assembly, and for major sub assemblies, are provided at the rear of this instruction manual. For the first part of the theory of operation discussion, we refer you to the overall schematic for the "main assembly" at the rear of the instruction manual. The major sub assemblies are blocked in this drawing, and the basic circuitry is straight forward and easily described. On the other hand, the schematic diagram for sub assembly A1, Drive Assembly, is more difficult to describe because of the many design details included in this drawing. Therefore, in order to make the description of this sub assembly easier to follow, we have provided some simplified drawings of various portions of this circuit. It is believed that the reader will have little difficulty in correlating these simplified schematics to the actual schematic located at the rear of the instruction manual. Our engineering department is always available to provide any additional information or details that are required.

A. Main Assembly.

Refer to Schematic, Main Assembly, LG Series at rear of book.

AC input power enters the power supply on input line cord W1. This is ordinarily 115 Volts RMS, 60HZ, with a grounded third wire connection. Optional input voltages, as described in the catalog, are available. Power enters through component FL1 which is an RF1,conductednoise filter. This component physically grounds the third wire to the chassis of the power supply. The AC power flow continues to the front panel circuit breaker, CB1. An AC POWER ON indicator lamp, DS1, is energized when the circuit breaker is closed. The flow of AC power continues to fan, B1, and to the primary of transformer, T1. The transformer primary is tapped, and is factory set for optimum operating conditions. If this supply is to be installed in a location where line variations are significantly different from the specified nominal value, then it is suggested that you consult with the factory to consider the possibility of changing the tap. The step-down power transformer secondary windings are connected across a bridge rectifier CR201, located on drive assembly A1, which in turn is connected to the capacitor input filter, C1, to develop the nominal B+ voltage for the power supply. B+ is fed to the Drive Assembly, A1, through power terminal 5 of the PC card, and the B- common is fed through terminal 7.

The front panel control elements are connected to the drive assembly via a PC card plug-in connector with the following terminal numbers.

VOLTAGE CONTROL: R1	Counterclockwise end, to terminal P1-22. Clockwise end to terminal P1-4. Slider to terminal P1-15.
KILOVOLTMETER: M1	Positive terminal to P1-17. Negative terminal to P1-22.
MILLIAMETER: M2	Positive terminal to P1-2. Negative terminal to P1-3.

The High Voltage Assembly, A2, is connected to Drive Assembly, A1, by means of removable screw connections. Five connections are provided: the voltage feedback terminal, the high voltage AC drive terminal, the ground terminal, the low end rectifier/capacitor return common terminal, and the current feedback terminal.

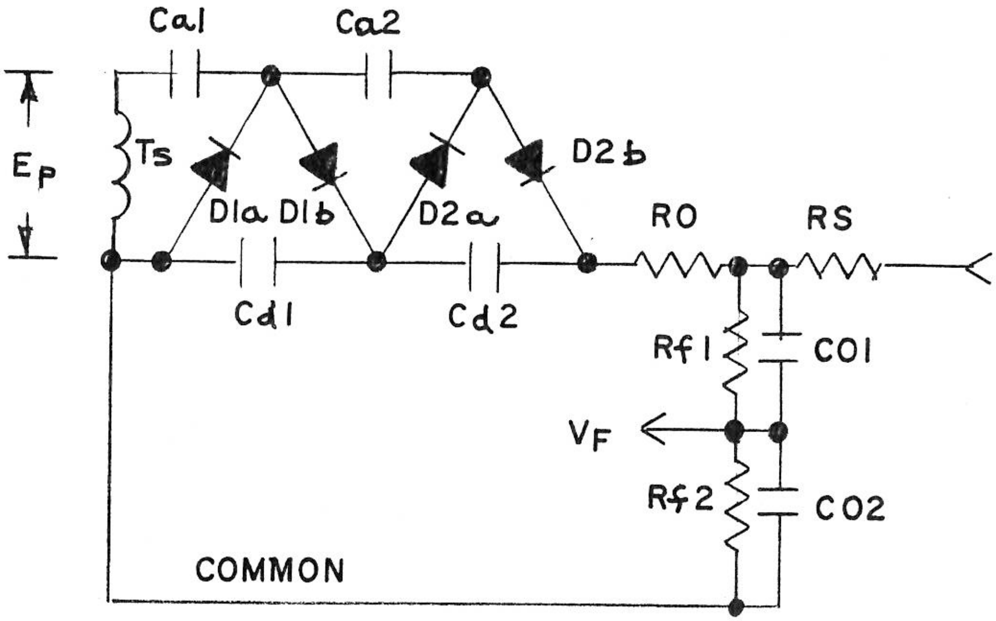
The ground stud, E1, and high voltage receptacle connection, J1, are provided at the rear of the power supply. The high voltage output cable, W2, is a removable, and pluggable co-axial assembly. The cable shield is automatically grounded to the power supply when the connector body is screwed down onto the entrance receptacle connector.

TB1 is a barrier terminal board provided on the rear of the power supply for customer functions. The functions are as follows:

TB1-1:	GROUND	TB1-6:	CURRENT PROGRAM
TB1-2:	COMMON	TB1-7:	CURRENT MONITOR
TB1-3:	REFERENCE	TB1-8:	EXTERNAL INTERLOCK
TB1-4:	VOLTAGE PROGRAM	TB1-9:	EXTERNAL INTERLOCK
TB1-5:	VOLTAGE MONITOR	TB1-10:	SPARE

See Section I, D above for complete discussion of the remote functions.

B. High Voltage Assembly.



A simplified diagram of the high voltage generating and output circuit is shown above. The circuit is a cascade voltage multiplier, frequently referred to as a Cockcroft-Walton generator. For a complete technical discussion of the circuit, numerous articles exist in the literature, of which we have listed several for reference.[1]

A brief description of the multiplier action is as follows: When Ts is at its negative peak, capacitor Ca1 charges through diode D1a to Ep, the transformer peak voltage. When the transformer polarity reverses, so that its output is positive with respect to common, the transformer voltage, Ep, is then in the same direction as the voltage on the capacitor, Ca1, and the two voltages add arithmetically. Thus, 2Ep is the driving voltage which charges capacitor Cd1 through diode D1b, and the voltage developed across the capacitor Cd1 is equal to 2Ep.

[1]"Factors Controlling the Performance of Cascade Rectifier Circuits"- R.E.Jones, R.T.Waters, Proc IEE, Vol. III, 5, May 64.

Cockcroft-Walton Voltage Multiplier Circuit, Everhart, Lorrain, Rev Sci Instrum, 1953, 24, p.221.

Continuing up the multiplier string, and considering again the negative swing of the transformer to Ep, it is easy to see that a net driving voltage of 2Ep is available to charge capacitor Ca2 to 2Ep volts, through diode D2a. Similarly, when the transformer once again drives to its positive peak, Ep, a quick calculation will show that capacitor Cd2 also will charge to a value of 2Ep through diode D2b.

Note that capacitors Cd1 and Cd2 are both charged to a voltage 2Ep. This process would continue for any additional voltage multiplier stages. Also note that capacitor Ca1 is charged to Ep, but capacitor Ca2, and all additional capacitors on this side of the voltage multiplier network charge to 2Ep. All diodes are subjected to a peak inverse voltage of 2Ep.

Thus, in the voltage multiplier network, it is seen that each stage, consisting of an AC capacitor Ca, a DC capacitor Cd, and two diodes, D1a and D1b, develops a voltage across the DC capacitor which is equal to twice the peak voltage of the transformer. It is for this reason that the stages of the voltage multiplier network are frequently referred to as voltage doubler stages. The total output voltage of the voltage multiplier is therefore seen to be 2nEp, in which n is the number of doubler stages.

In the above discussion, we have ignored the effects of regulation and component impedances. The voltage 2nEp is the output voltage in the perfect case in which all impedances are zero and the load current is zero. Inherent regulation and ripple can be calculated from the following formulas taken from the reference article by Jones and Waters on the previous page.

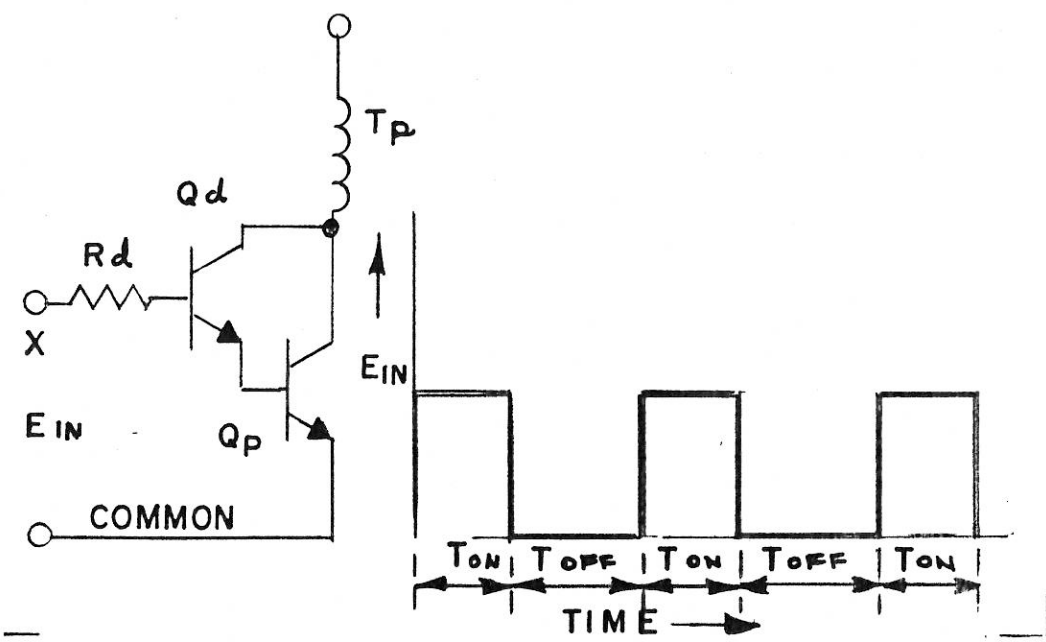
$$\text{Ripple Volts (p-p)} = In(n+1)/2fC$$
$$\text{Regulation Volts} = I\left(2n^3/3 + n^2/4 + n/12\right)/fC$$

I = DC load current (Amperes)
n = No. of doubler stages
f = Operating frequency (Hz)
C = Capacitance per stage (Farads)

The schematic shows a resistor Ro, feeding the output feedback network, consisting of resistor divider Rf1 and Rf2 across capacitor divider Co1 and Co2. The resistor divider generates feedback voltage Vf, which is used to control the regulating loop. Capacitor divider Co1 and Co2 serve as stabilizing elements for the feedback loop, as well as an output filter capacitor in conjunction with the output resistor Ro. To be specific, the ripple voltage across the voltage multiplying capacitor network consisting of Cd1 and Cd2 (Etc) is attenuated by the RC network consisting of Ro and the series combination of Co1 and Co2. Rs is a final surge limiting resistor which is a protective device in the event of sudden, severe, overload conditions on the power supply.

The high voltage transformer secondary Ts, which is shown in this schematic, is not physically within the subassembly A2. Actually, it is a part of the Drive Assembly, A1.

C. <u>Transformer Primary, and Power Transistor Collector Drive Circuit.</u>

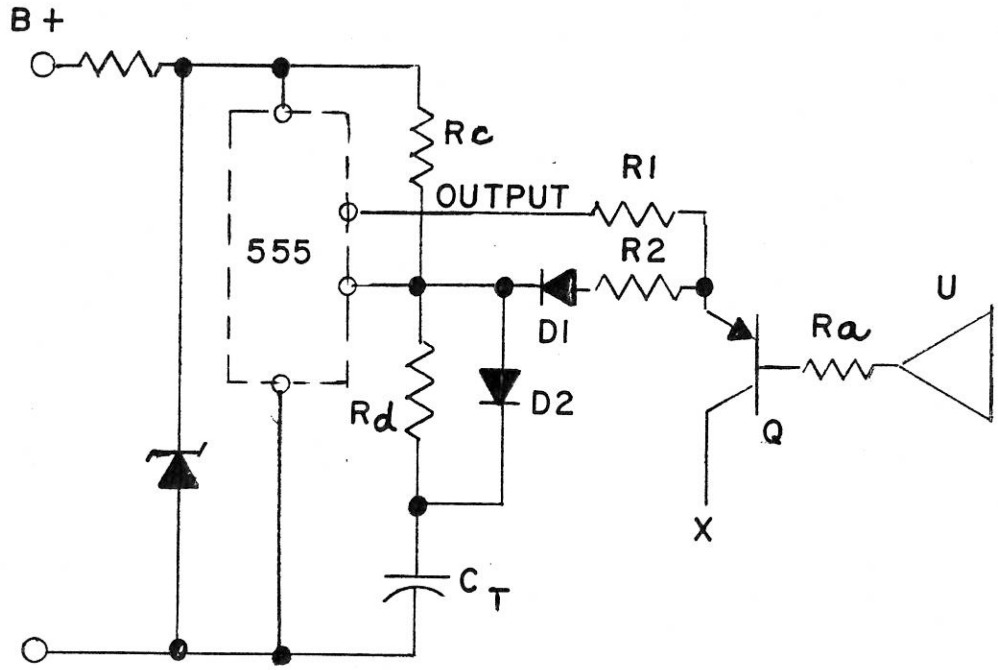


The simplified schematic shows the transformer primary, Tp, as the collector load for transistor, Qp. The drive transistor, Qd, is connected as a Darlington, and the input voltage is fed to the base through resistor Rd. A typical wave shape for Ein is also shown in the diagram. The average voltage applied to transformer primary, Tp, is a function of the ON and OFF times of the input voltage, Ein. As the ON time is reduced, the average voltage applied to the primary of Tp is reduced, and the output voltage is correspondingly and proportionally reduced. Similarly, as the

ON time is increased, the output voltage is proportionally increased.

This method of control permits the transistor to operate with extreme efficiency, since the transistor is driven towards saturation during the period when current is permitted to flow in the transformer primary winding, and the collector voltage rises when the primary current is turned off.

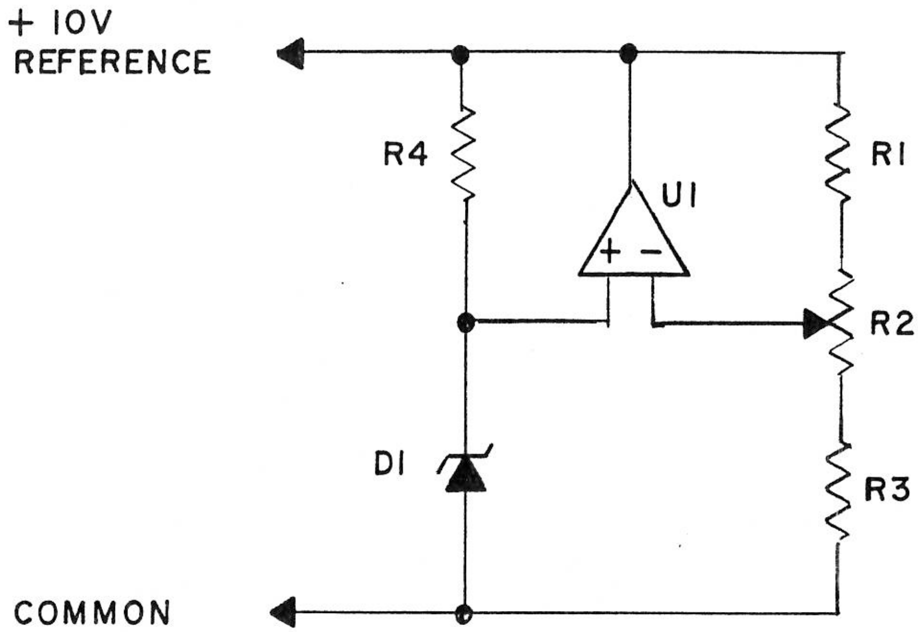
D. Base Drive Control Circuit.



The diagram above shows the circuitry used to achieve the pulse type control described in the previous paragraph. A "555" timer is used in this circuit as the basic switching element. This popular IC is produced by almost all semiconductor manufacturers including RCA, Motorola, Fairchild and National Semiconductor. Details of the circuit operation of this element may be obtained from any of these manufacturer's literature. For this power supply design, the "555" is used as shown in the diagram. A dropping resistor from B+ to a zener diode provides a stable voltage for the "555". Ct is the timing capacitor, and Rd is the discharge resistor which sets the OFF time of the drive. Specifically, the OFF time constant is RdxCt. Ct is charged through diode D2, with two components of current. One is a fixed value derived from the zener level through Rc, and determines the maximum ON time of the circuit. The other component of current used to charge Ct, is derived directly from the output of the "555" through resistors Rl, R2, and diode Dl. This second component of charging current causes Ct to charge more rapidly, and thereby decreases the ON time. The control of this latter component of Ct charging current through Rl and R2 is achieved by the amplifier, U, establishing a voltage level at the base of the transistor, Q. When the voltage level at the base of transistor Q, is increased towards the zener level, the circuit permits an increased charging current for Ct to flow through diode Dl. Similarly, when the voltage at the base of transistor Q is reduced towards the zero level, it is seen that less and less charging current is available to flow through diode Dl and D2. Thus, increasing the voltage from the amplifier to the base of the transistor Q, increases the charging rate to Ct, and reduces the ON time. Decreasing the voltage from the amplifier decreases the charging rate, thereby causing a longer ON time, with a correspondingly higher output voltage.

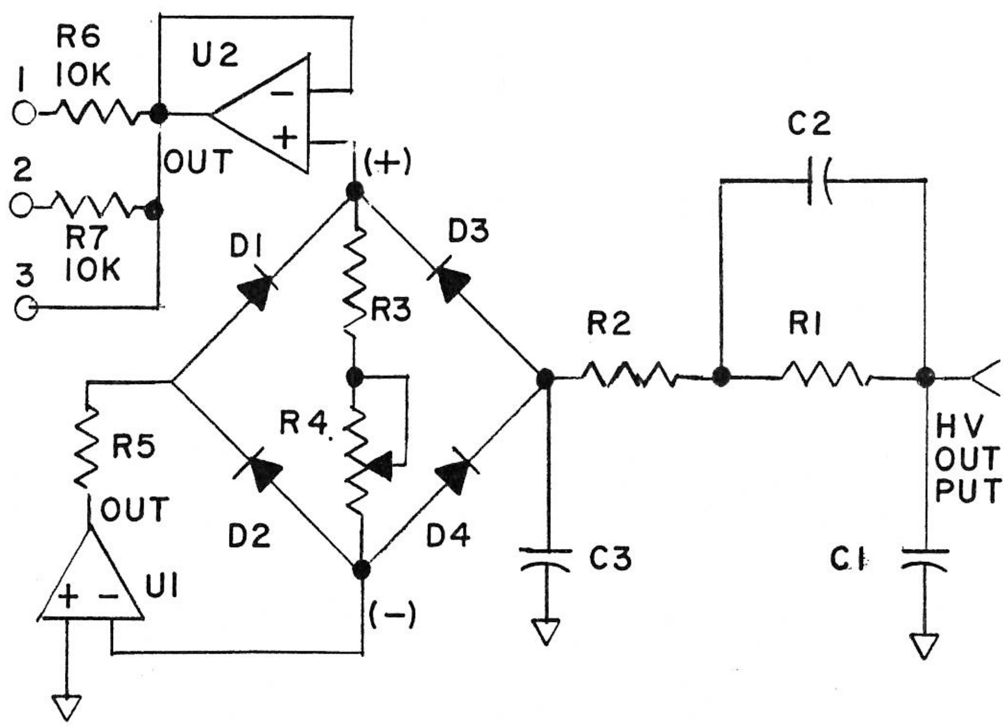
The collector of transistor Q, is connected to the drive point shown as X in the diagram of paragraph C, above. Furthermore, during the bulk of the ON time cycle, the output current of the "555", which is delivered to the emitter of transistor Q, through resistor Rl, becomes the drive current of the output stage through the collector of transistor Q. The circuit is capable of reducing the drive current to zero by raising the base of transistor Q, to a level above that of the emitter. The emitter cannot exceed the voltage set by the series charging circuit consisting of Rl, R2, Dl, and D2 to capacitor Ct. On the other hand, maximum drive and ON time is achieved by dropping the base of the transistor Q to the point corresponding to the diode Dl being held in a cut-off condition at all times.

E. Reference.



The reference supply is shown in the simplified diagram above. The circuit is a simple, but extremely effective voltage regulator, in which the ultimate reference device, zener diode D1, is self-referenced from the output of an operational amplifier, U1. In the circuit arrangement shown, the operational amplifier is used as the forward gain element of a feedback loop regulator. D1 is a reference type zener diode with a nominal voltage drop of 6.2 volts, which is applied to the non-inverting input terminal of U1. The amplifier output, +10 volts, is divided down by resistor network R1, R2, R3, and applied to the inverting input terminal of U1, thereby applying negative feedback to the amplifier. The divider ratio is adjustable by trimpot R2 to compensate for variations in the zener breakdown voltage of D1, and permitting the output of U1 to be adjusted to precisely 10 volts. The 10 volt regulated output is fed to the zener diode D1 through dropping resistor, R4, thereby establishing an essentially constant current in D1. Regulation against input line variations of ±10% is better than 5 ppm. The +10 volt output is subjected to constant resistive load, so that load regulation is negligible. Temperature and long term stability of the reference output are as good as the zener diode itself. For the LG series, the temperature coefficient is better than 20 ppm per degree C, and the long term stability is better than 25 ppm per hour.

F. Feedback Divider Input, Polarity Inverter, Follower, and Monitor Circuits.



In the above simplified schematic, C1 represents all internal elements of the high voltage generating circuit and is designated as the high voltage output terminal. Resistor R1 is the high voltage DC feedback element which consists of an appropriate series string of precision high voltage resistors. C2 is a high voltage series capacitor string which provides AC feedback for loop stability and good transient response. R2-C3 is an RF bypass filter. The DC feedback current is connected to one of the AC corners of a bridge rectifier at the junction of D3 and D4. The output of amplifier U1 is connected to the other AC corner of the bridge at the junction of D1 and D2. The non-inverting positive input of U1 is connected to common, and the inverting, negative input is connected to the DC corner of the bridge at the junction of D2 and D4.

The circuit behaves as follows. The output of amplifier U1 will establish an operating level such that the negative DC corner of the bridge is at virtual ground (common) potential, because of the "null" which must appear at the amplifier input terminal. First, consider a positive high voltage output polarity. In this case, the current may be traced from the high voltage output terminal, through the feedback resistor R1, entering the bridge through diode D3, passing down through resistors R3 and R4, leaving the bridge through diode D2, and flowing <u>into</u> the output terminal of U1, which functions as a sink for the return of the high voltage feedback current.

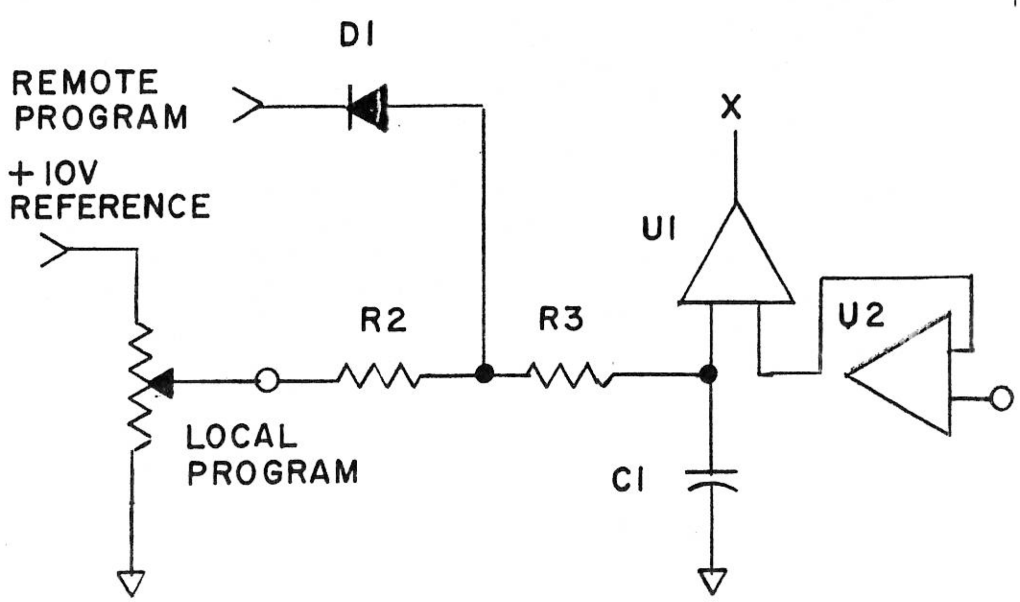
Now consider a negative high voltage output polarity. In this case, the current may be traced from the output of amplifier U1, which functions as a current source for this polarity, entering the bridge through diode D1, passing down through resistors R3 and R4, leaving the bridge through diode D4, and flowing down to the negative high voltage potential through feedback resistor R1.

Note that for either polarity, the U1 amplifier establishes a virtual zero potential at the lower end of resistor R4, and the feedback current establishes a <u>positive</u> voltage at the upper end of R3 regardless of the direction of feedback flow. Furthermore, and obviously, the positive drop across R3/R4 is directly and linearly proportional to the output voltage, and independent of the polarity.

In the actual LG series units, R1 is selected for each voltage so that the feedback current is the same for all models. This figure is nominally 50 microamperes. R3 and R4 are the same for all models, and R4 compensates for variations in R1 from unit to unit, so that the drop across the series combination of R3 and R4 can be set to 10 volts when the output is at rated voltage.

Amplifier U2 is connected as a "follower", and establishes a low impedance voltage at its output which is essentially equal to the high impedance voltage drop across the feedback divider sensing resistors R3/R4. The amplifier output is used for three functions. Terminal 1 is fed through a 10K resistor to a 1 milliampere DC full scale front panel analog meter. Thus, when the amplifier output is 10 volts (corresponding to rated high voltage output), the front panel meter indicates full scale. Terminal 2 is also fed through a 10K ohm resistor to the remote voltage monitor terminal on the rear panel. The monitor can be a 1 milliampere full scale device similar to the front panel indicator, or a high impedance voltmeter which will read 0-10 volts proportionally to 0 to rated output voltage. Terminal 3 is applied to the feedback control amplifier described in the next section.

G. Feedback Control Amplifier and Voltage Programming.

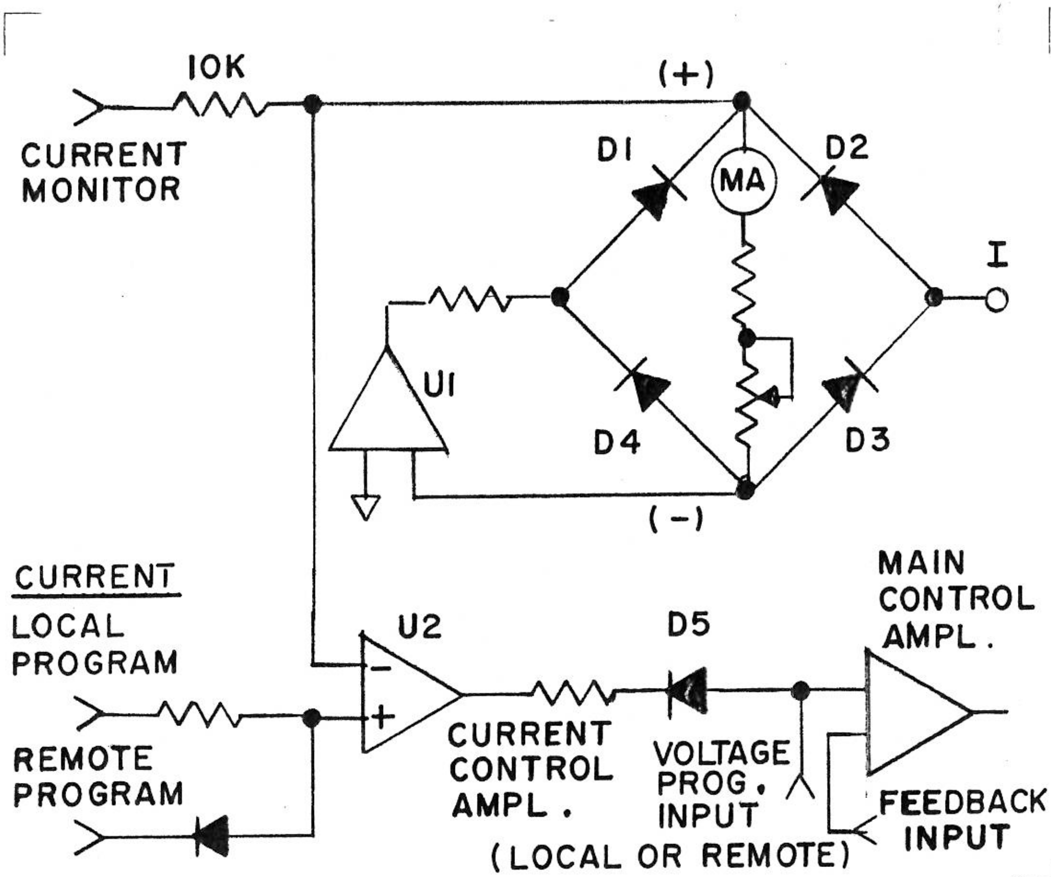


The feedback loop is closed at the input of control amplifier U1, in a conventional comparator configuration. The reference voltage, discussed in paragraph E, is applied to a ten-turn potentionmeter on the front panel. The potentiometer slider terminal can deliver any voltage between 0 and 10 volts DC depending on the potentiometer setting, to one side of the amplifier, U1, through resistors R2 and R3. The other input to amplifier U1 is taken directly from the follower amplifier whose output functions have been described in paragraph D. The reader will recall that this is the amplifier which controls the base drive of the power circuitry, and ultimately, the power supply output.

The circuit is similar to most closed loop configurations. An input signal, obtained as a portion of the reference voltage, and referred to as a "local" programming voltage, is applied to one input of the control amplifier. The loop then drives the output voltage of the power supply to a level such that the signal returned through the feedback divider and follower amplifier, U2, (described in the previous paragraph) and applied to the other input of the control amplifier, "nulls" the amplifier and balances the applied program voltage.

Diode D1 will become forward biased and will conduct when a remote program voltage signal is applied providing that it is <u>lower</u> than the voltage applied to the local program terminal. Thus, a signal at the remote program terminal is capable of reducing the signal from the internal reference. On the other hand, if the remote signal exceeds the local signal, diode D1 becomes back biased, and the remote signal decouples. Thus, the front panel control serves as an overvoltage setting for the remote programming input, and the output voltage cannot be raised above the value set by the front panel control. R2 limits the current taken by the remote program signal. R3 and C1 are noise filters for the program lines.

H. Current Regulator, Monitor, and Program.



The current control circuitry is very similar to that used for voltage control, and has been described in sections F and G above. Refer to the simplified diagram above. The power supply load current is represented by the encircled I and is constant for a particular fixed output load condition. The rectifier bridge consisting of diodes D1, D2, D3, and D4 serves the same purpose as with the feedback voltage bridge, i.e., it produces a unipolarity voltage signal across the resistors and milliameter connected between the + and - terminals of the bridge, independently of the polarity of the high voltage output or the direction of current, I. U1 performs the same functions as in the earlier arrangement; it establishes a virtual zero potential at the negative DC corner of the bridge, The major difference between this circuit and that used for voltage control is that a "follower" amplifier is not required, since the impedances associated with the input bridge circuit are sufficiently low to function without it. The positive end of the bridge is always at a positive voltage with respect to ground, proportional to the magnitude of the load current, and independent of its direction. The adjustable trim resistor within the bridge calibrates the different models in the LG series to measure +10 volts DC at the power supply rated load current.

The current monitor terminal is derived from the calibrated bridge terminal through a 10K ohm limiting resistor. Measurements should be made with an instrument having at least 1 megohm input impedance to minimize any errors.

The current sensing point is also applied to one of the input terminals of the current control amplifier, U2. The other input to the amplifier comes from the program input. In the standard LG series units, the Local Program terminal is connected to the power supply +10 volt reference, so that the amplifier enters its active operating region when the signal voltage from the current sensing point just reaches 10 volts. When the signal level is less than 10 volts, a condition which corresponds to the load current being less than its rated value, the amplifier is switched to its full "up" condition. The output of the amplifier is decoupled from its load by the blocking action of diode, D5. When the signal input to U2 reaches 10 volts, the amplifier enters its active region, its output drops so that D5 begins conducting, and the amplifier "sinks" the current from the voltage program input circuit. The extent to which the voltage program signal is reduced, is exactly that which is required to maintain the current sensing signal voltage at 10 volts, i.e., the load current is maintained constant at that value which establishes 10 volts at the diode bridge.

The current at which the circuit begins to regulate can be adjusted externally at the remote program terminal. In effect, a signal voltage at this terminal reduces the input to the current amplifier from the 10 volt level obtained from the reference voltage at the local program terminal, to any desired voltage between zero and 10 volts. Thus, the current can be made to regulate at any desired value from zero to rated current. For example, suppose a 5 volt signal is applied at the remote program terminal. This reduces the input at the amplifier terminal from 10 volts to approximately 5 volts (there is a drop in the blocking diode which sets the input slightly higher than the exact remote signal voltage). The amplifier becomes active when the input to the negative terminal of U2 just reaches 5 volts. This corresponds to a half load condition, assuming that the circuit has been calibrated to develop 10 volts across the sensing resistor at rated load.

I. External Interlock.

Refer to the complete schematic drawings at the rear of the instruction book. The power supply is shipped with a barrier jumper across TB1-8 and TB1-9 of the remote control terminal board located on the rear panel. The DRIVER ASSY schematic shows that this jumper is wired in series with the terminals designated by encircled numbers 6 and 8. It is easy to see that all control circuitry is derived from the main rectified B+ source voltage through dropping resistor R46. By opening this lead, all control functions are disabled, and no high voltage can be generated.

The user may wish to have a remote safety switch for a test cage or other control purpose. The barrier jumper may be removed and replaced by a switch located at a remote point. The switch must be rated to make and break 50 volts DC at 50 milliamperes resistive load. The switch must be in the "closed" or "shorted" position to enable the power supply.

J. High Voltage Output Polarity.

The control drive assembly circuit board operates automatically for either polarity, as has been described in sections F and H above. No changes or switching of low voltage control circuits is required to change polarity. The high voltage assembly, on the other hand, is polarity sensitive, and is manufactured for either positive or negative polarity, as specified by the user's order. Reversal of polarity is accomplished by installing the appropriate high voltage assembly. Mechanically, this is quite easy to do, and requires no soldering or unsoldering. A screw driver and pliers are sufficient tools to accomplish this work.

SECTION III

CALIBRATION PROCEDURES

This section deals with the adjustment of the various trimpots on the drive subassembly, A1. Even though all of these potentiometers are factory set and locked and should not require field adjustment, knowledge of factory adjust procedures should be helpful in fully understanding the operation of the power supply.

R38: This potentiometer compensates for tolerance in the zener diode, CR20. R38 is adjusted so that the voltage across the reference, as measured between TB1-3 and TB1-2 on the rear panel is 10.0 volts.

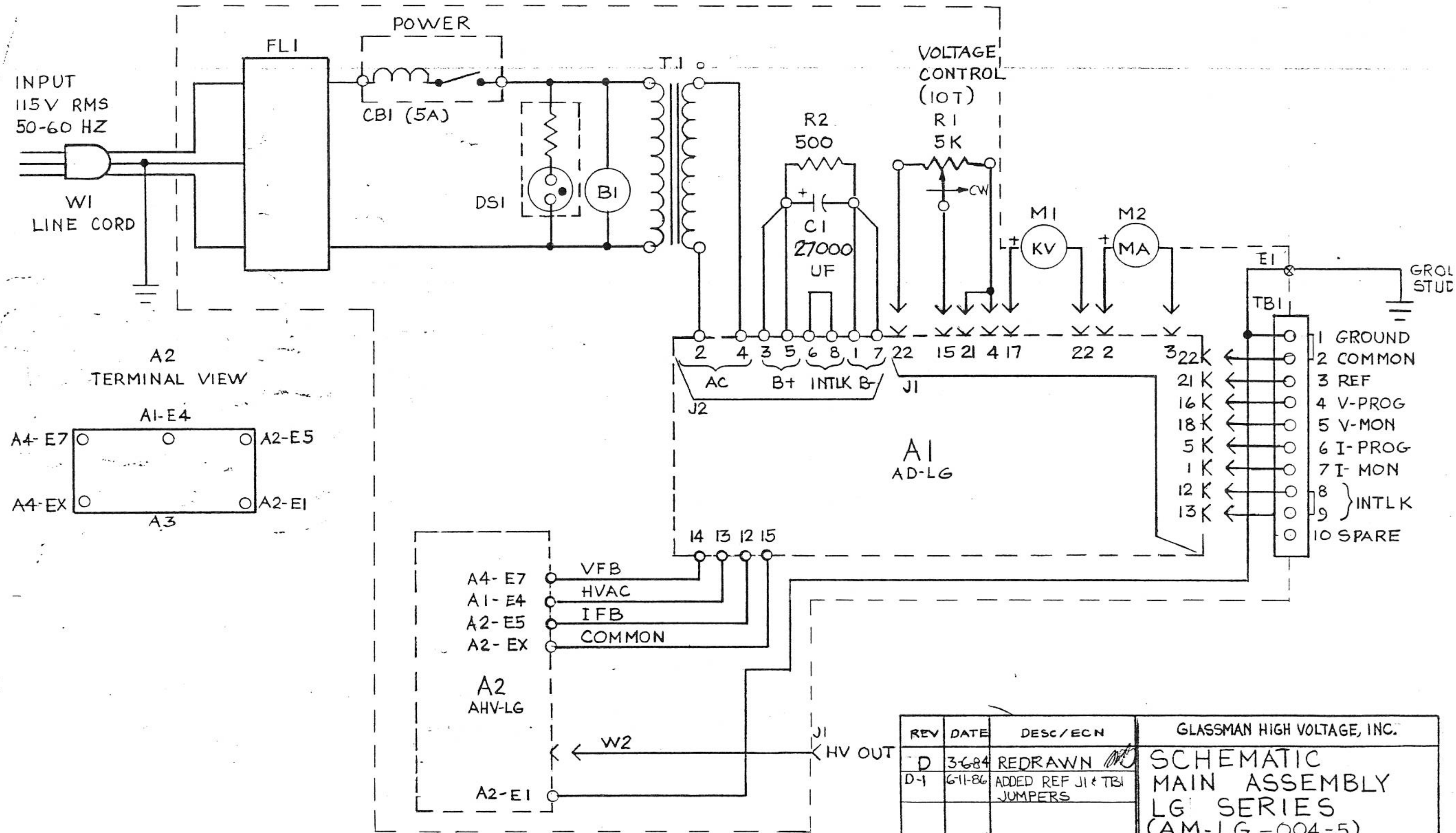
R43: This potentiometer compensates for variations in the ratio accuracy of the feedback divider network. With the front panel control potentiometer set to maximum, R43 is adjusted so that the high voltage output is at its rated value as measured on external precision voltage measuring equipment.

R26: This trimpot sets the current limit point. The adjustment is made under short circuit conditions using an external load current monitor. A second check that the current limit is functioning properly is made at some intermediate operating condition between 25% and 75% of rated output voltage.

R22: This trimpot adjusts the converter OFF time to an optimum value and compensates for gap variations in the high voltage transformer.

This adjustment is made while viewing the power transistor collector waveshape on an oscilloscope at rated output voltage and current conditions. The setting is such that the transistor turn on point occurs at approximately that point at which the collector waveshape begins to fall from the level reached during the OFF time. This is a point of maximum efficiency, and a measurement of the emitter current (by an average voltage measurement across the emitter resistors) shows a small dip occuring at this optimum point.

R15: On SCR models, this trimpot adjusts the maximum B+ DC voltage, and is normally set for approximately 40 volts at full output power.

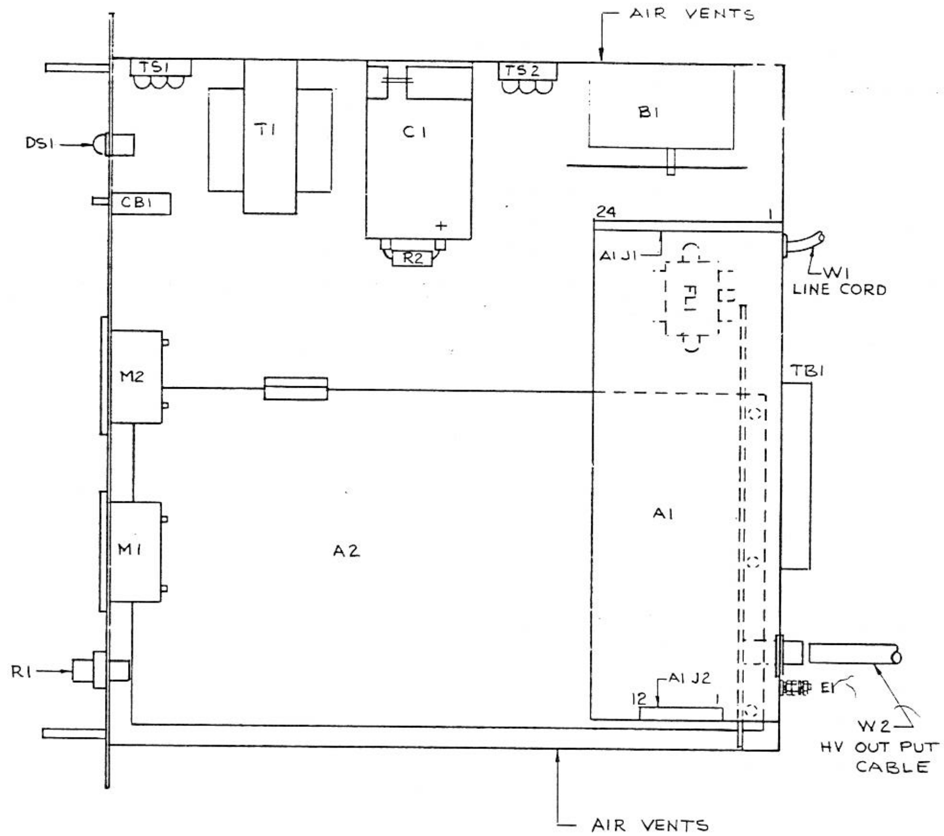


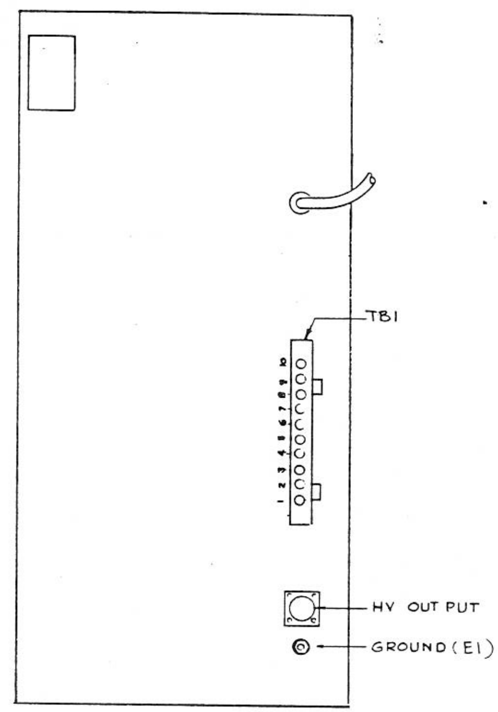
REV	DATE	DESC/ECN
D	3-6-84	REDRAWN
D-1	6-11-86	ADDED REF J1 & TB1 JUMPERS

GLASSMAN HIGH VOLTAGE, INC.

SCHEMATIC
MAIN ASSEMBLY
LG SERIES
(AM-LG-004-5)

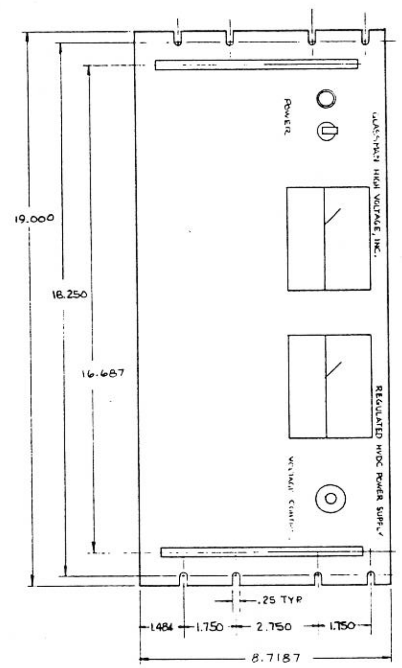
DWG NO	DWN	DATE
200015	MES	

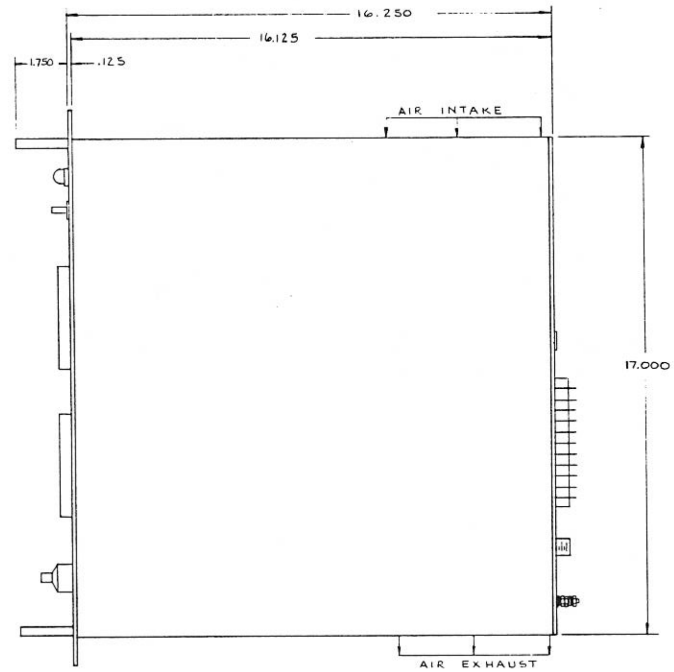


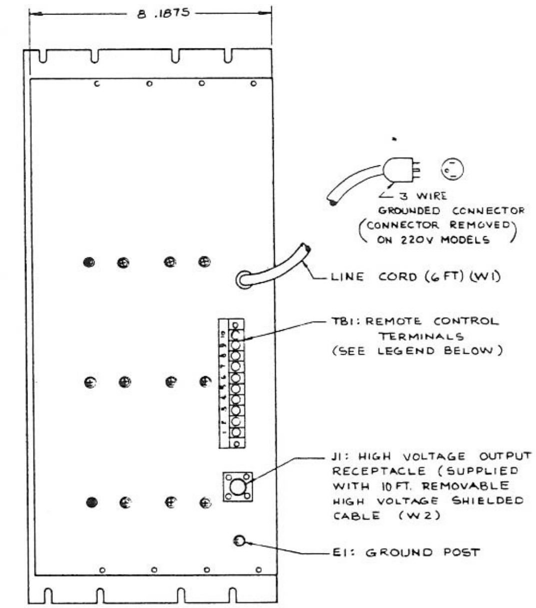


REVISIONS			
DESCRIPTION	CHK	DATE	LTR
CORRECTED E1 & B1		6-23-86	NR-1

GLASSMAN HIGH VOLTAGE, INC.			
TOLERANCES DEC ± FRAC ±		PARTS PLACEMENT MAIN ASSEMBLY LG SERIES (AM-LG-04-8)	
Drawn	Date		
MSS	9-4-85	DRAWING NO. 301018-004	REV. NR-1
Check	Date		
[illegible]	7-24-85	SCALE 1/2	Sheet 1 of 1







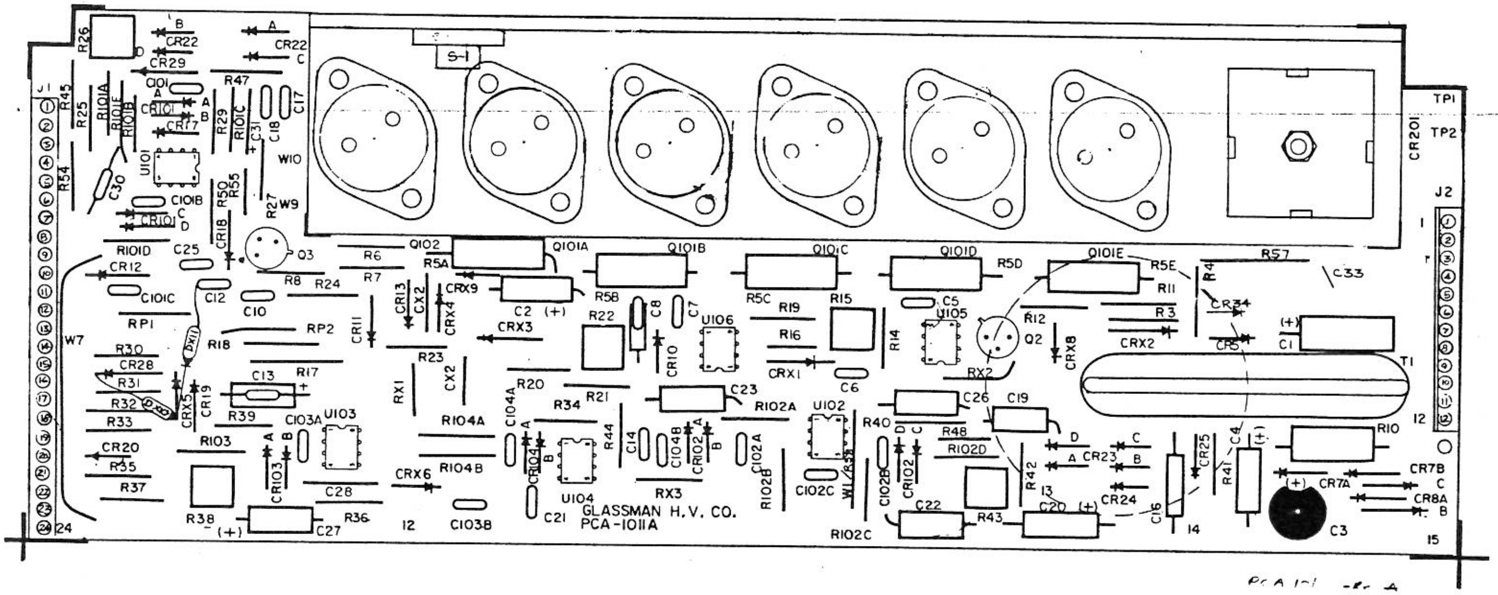
TERMINAL BOARD LEGEND

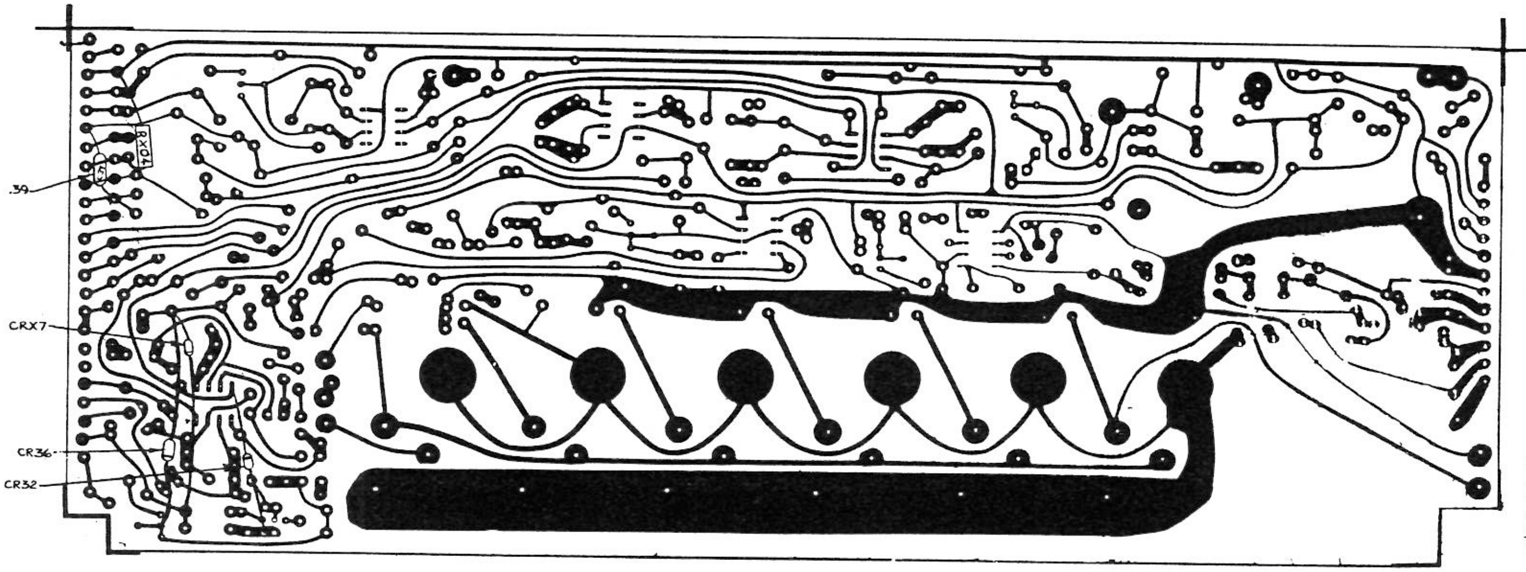
1. GROUND
2. COMMON
3. REFERENCE
4. V-PROGRAM
5. V-MONITOR
6. I-PROGRAM
7. I-MONITOR
8. INTERLOCK
9. INTERLOCK
10. SPARE

NOTE: FOR NORMAL OPERATION, JUMPER 1-2, 8-9. SEE INSTRUCTION MANUAL FOR ADDITIONAL DETAILS.

REVISIONS			
DESCRIPTION	CHK	DATE	LTR
CORRECTED HV CABLE LENGTH		2-20-86	A
CORRECTED E1		8-23-86	A1

GLASSMAN HIGH VOLTAGE, INC.	
TOLERANCES DEC ± FRAC ±	OUTLINE & INTERFACE MODEL LG 8 INCH CHASSIS (AM-LG-004-8)
Drawn M.E.S. Date 2-6-86	DRAWING NO. 401126-022 REV. A1
Check JK Date	SCALE Sheet 1 of 4

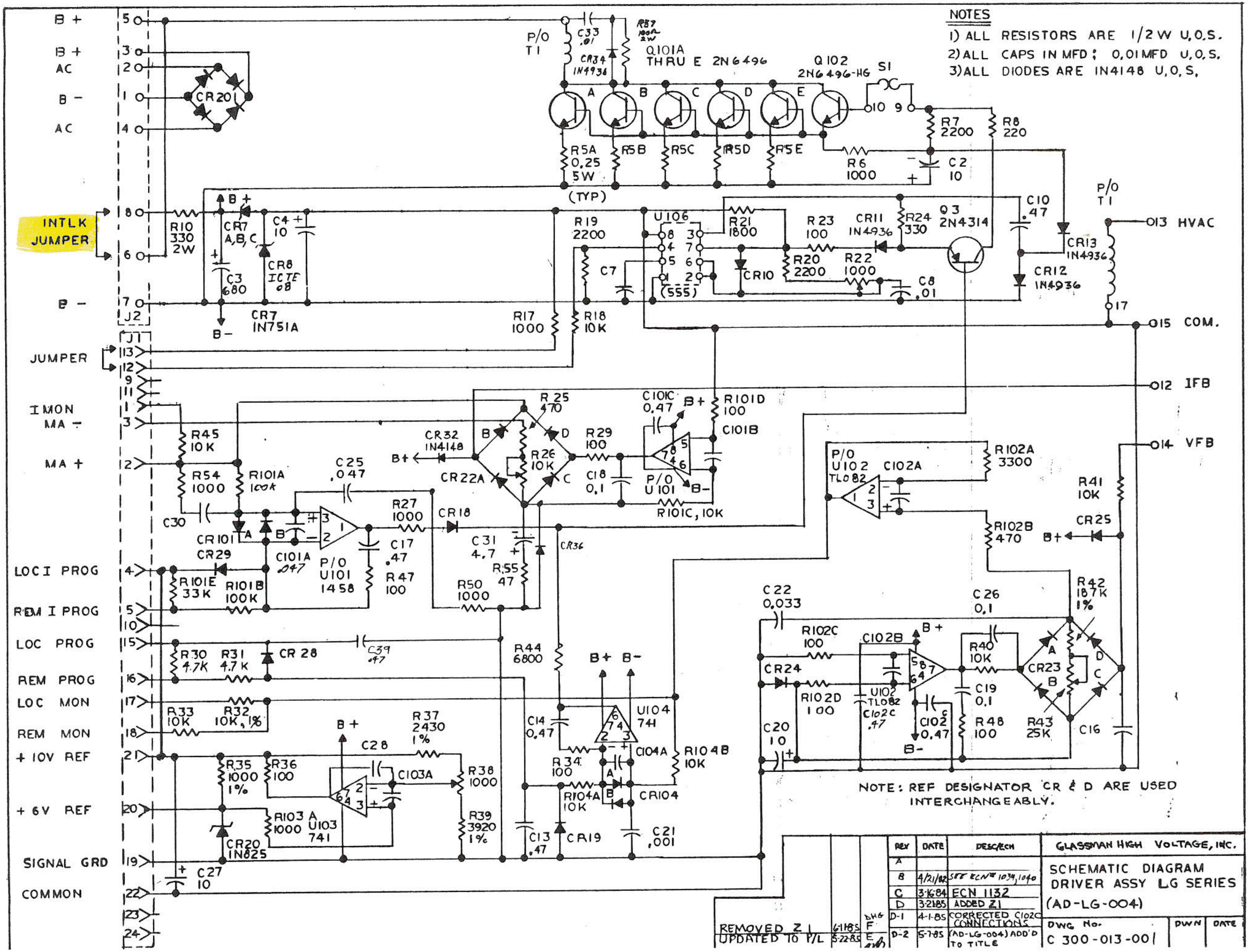


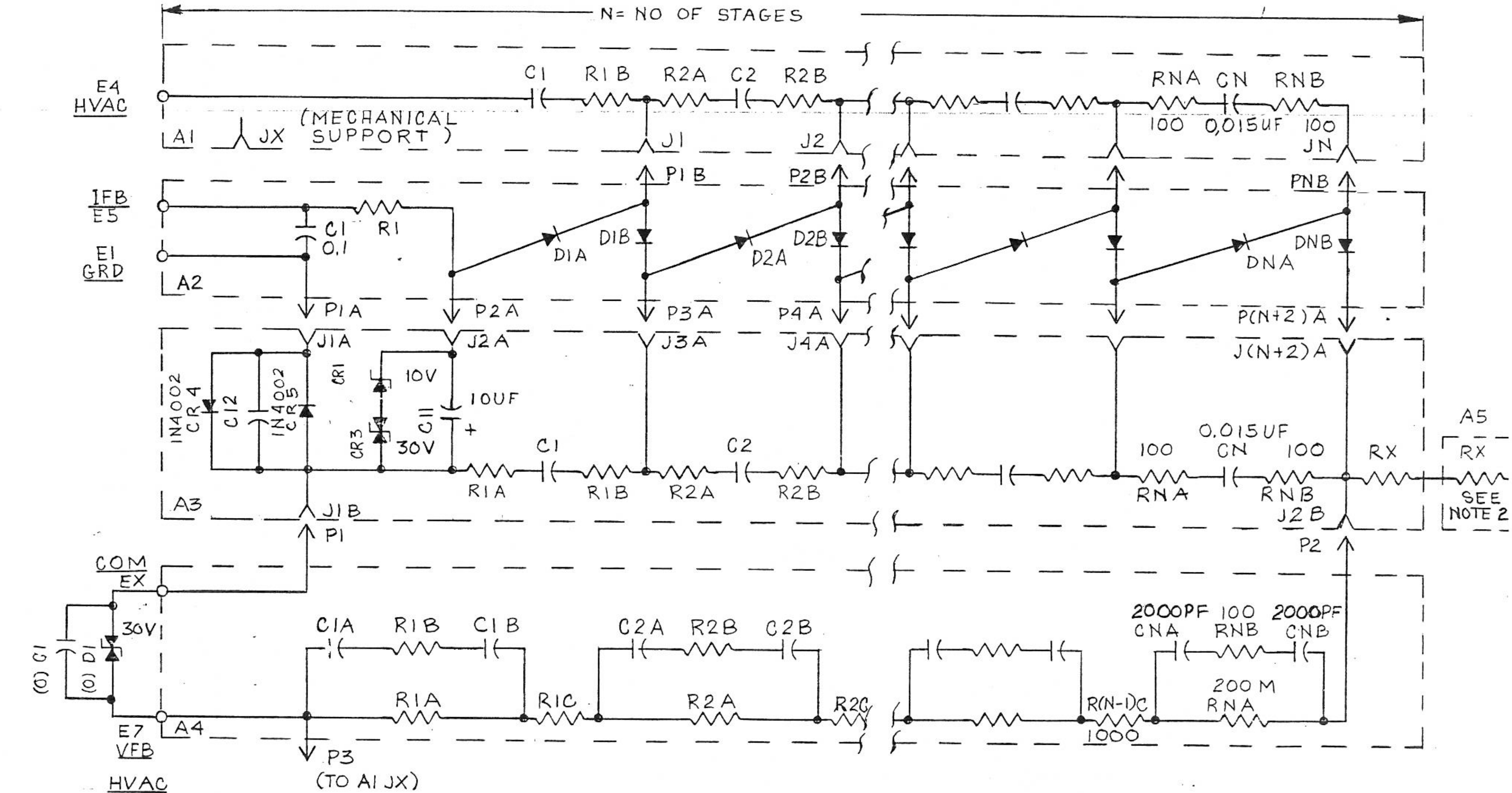


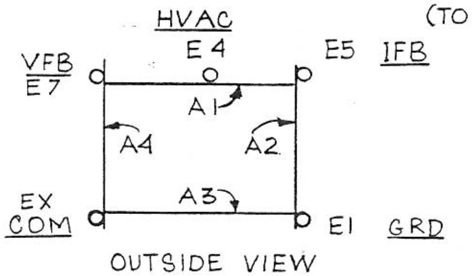
NOTE:
1, NOT ALL PARTS ARE USED IN ALL UNITS.
2, REF DESIGNATOR CR & D ARE USED INTERCHANGEABLY

REVISIONS			
DESCRIPTION	CHK	DATE	LTR
Z1 ADDED (AD-LG-004) ADDED TO TITLE		4-15-85 5-7-85	A A-1
ECN 1242, Z1 REMOVED		6-1-85	B
UPDATED POLARITY OF C13 & C31		6-12-85	C C-1

GLASSMAN HIGH VOLTAGE, INC.			
TOLERANCES DEC ± FRAC ±		PARTS PLACEMENT DRIVER ASSEMBLY LG, HG SERIES (AD-LG-004)	
Drawn	Date		
MC	7-84	DRAWING NO PCA 1011-005	REV C-1
Check	Date		
	7/21/85	SCALE	Sheet 1 of 1


NOTES
1) ALL RESISTORS ARE 1/2W U.O.S.
2) ALL CAPS IN MFD ; 0.01MFD U.O.S.
3) ALL DIODES ARE IN4148 U.O.S.
NOTE: REF DESIGNATOR CR & D ARE USED INTERCHANGEABLY.
B +
B + AC
B −
AC
INTLK JUMPER
B −
JUMPER
I MON MA −
MA +
LOC I PROG
REM I PROG
LOC PROG
REM PROG
LOC MON
REM MON
+ 10V REF
+ 6V REF
SIGNAL GRD
COMMON
J2
J1
13 HVAC
15 COM.
12 IFB
14 VFB
P/O T1
Q101A THRU E 2N6496
Q102 2N6496-HG
S1
Q3 2N4314
U106 (555)
P/O U101 1458
P/O U101
P/O U102 TL082
U102 TL082
U103 741
U104 741
CR20
CR7 A,B,C
CR7 IN751A
CR8 ICTE 08
CR11 IN4936
CR12 IN4936
CR13 IN4936
CR34 IN4936
CR32 IN4148
CR22A
CR23
CR20 IN825
R5A 0.25 5W (TYP)
R10 330 2W
RB7 100Ω 2W
GLASSMAN HIGH VOLTAGE, INC.
SCHEMATIC DIAGRAM
DRIVER ASSY LG SERIES
(AD-LG-004)
DWG No. C 300-013-001
DWN
DATE
REV
DATE
DESC/ECN
A
B 4/21/82 SEE ECN# 1039,1040
C 3-16-84 ECN 1132
D 3-21-85 ADDED Z1
D-1 4-1-85 CORRECTED C102C CONNECTIONS
D-2 5-7-85 (AD-LG-004) ADD'D TO TITLE
F 6-11-85 REMOVED Z1
E 5-22-85 UPDATED TO T/L





NOTES:
1) DIODES & C11 SHOWN FOR POS. POLARITY; REVERSE FOR NEG.
2) A5 RX VALUES
3 X 10 Ω IN SERIES, UP TO 30 KV
4 X 100 Ω IN SERIES, 40-60 KV
5 X 100 Ω IN SERIES, 80, 100 KV

REV.	DATE	DESC/ECN
A	6-6-84	CORRECTED C11
B	2-26-85	C1-B ON A4 CORRECTED
B-1	5-7-85	(AHV-LG) ADDED TO TITLE
C	6-11-85	UPDATED
D	11-8-85	NOTE 2, 3X10 @ WAS TO 40 KV
D-1	3-6-87	COR. COM. CONNECT
D-2	5-4-87	A4 CN CORR/PL

DWS
DWS

GLASSMAN HIGH VOLTAGE COMPANY

SCHEMATIC DIAGRAM
HIGH VOLTAGE ASSEMBLY
LG / HG SERIES
(AHV-LG)

DWG. NO. B200021-004 | DWN. MES | DATE 7-15-83