INSTRUCTION MANUAL
FOR

EMS
POWER SUPPLY

MODEL________________ SERIAL NO.____________

(908) 922-9300

ELECTRONIC MEASUREMENTS INC.

405 ESSEX ROAD, NEPTUNE, N.J. 07753

FIVE-YEAR WARRANTY

Electronic Measurements, Inc. warrants this equipment manufactured by us and sold by us or our authorized agents to a manufacturer or end user to be free from defects in material or workmanship. Our liability under this warranty is limited to servicing and repair or replacement of parts when equipment is returned to us with transportation charges prepaid within a period of five years after original shipment and when the equipment is shown by our inspection to be thus defective, normal wear and tear excepted.

This warranty does not apply to equipment subjected to abuse or incorrect installation or operation, nor to equipment repaired or modified outside of the Electronic Measurements, Inc. factory unless prior written approval to make such repairs or modifications has been received from the factory. The foregoing warranty is in lieu of all other express or implied warranties except of title.

CAUTION

While this supply is designed for safe operation certain precautions must be observed. The unit is intended to be operated by technically competent personnel generally familiar with the principles of electrical safety.

Whenever the AC power supply circuit is energized there are EXPOSED LETHAL VOLTAGES within the enclosure. Hence, the supply circuit must be turned off by unplugging the unit or, in the case of units hard wired to the power source, removing the line fuses or securing the breaker supplying the unit before attempting any operation requiring entry. Remember that even after the line is disconnected energy can still be stored in capacitors and such unexpected places as the interwinding capacitance of transformers.

The input, output and sensing terminals of the supply are all potentially hazardous. These risks are not always obvious. Most people are aware of the dangers inherent in high voltage equipment. However, available energy must also be considered. For example, the output terminals of a 5 volt supply are not usually thought of as dangerous. In addition to the steady state energy available, such supplies are typically terminated by very large capacitors, which can deliver huge surge currents. Consider what could happen if a ring, wrist watch, or other metallic object attached to a person were to short across the output of such a device.

High current supplies are capable of vaporizing metallic objects, such as screwdrivers. This can result in molten metal being sprayed on people.

Exercise extreme caution when using these supplies.

ELECTRICAL STANDARDS

All company primary standards are either certified directly or are traceable to certification by the National Bureau of Standards.

CLAIM FOR DAMAGE IN SHIPMENT

This instrument received comprehensive mechanical and electrical inspections before shipment. Immediately upon receipt from the carrier, and before operation, this instrument should be inspected visually for damage caused in shipment. If such inspection reveals internal or external damage in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. When referring to this equipment, always include the model and serial numbers.

RETURNING EQUIPMENT

Before returning any equipment to the factory, the following steps should be taken:

1. Notify Electronic Measurements, Inc., at 800-631-4298. Give a full description of the difficulty including the model and serial number of the unit in question. Upon receipt of this information we will assign a Return Material Authorization number (RMA) and give you shipping instructions.

2. Equipment returned to us must be packed in a manner to reach us without damage, and the shipping container must be marked with the RMA number in an area approximate to the shipping label with numbers that are easily read. All returned units that do not show the RMA number on the outside of the container will be refused.

3. For non-warranty repairs, we will submit a cost estimate for your approval prior to proceeding.

INSTRUCTION MANUAL

EMS SWITCHED-MODE POWER SUPPLY

1KW, 2KW, 2.5KW, 5KW

CONTENTS:

SECTION 1

1.1 INTRODUCTION

This manual contains instruction for operation and maintenance of the 1KW, 2KW, 2.5KW, and 5KW EMS power supply series manufactured by Electronic Measurements, Inc. of Neptune, NJ.

The EMS series has been developed specifically for laboratory test and burn-in applications. The EMS supplies produce a well regulated variable DC voltage or current source. All models provide AC turn on/off capability and circuit protection. Output control is provided by a ten turn voltage control and a one turn current control with monitoring of each by front panel meters. These meter can be optionally selected for either analog or digital display for the 2KW, 2.5KW and 5KW series. The 1KW series offers digital display only.

The input AC is rectified and filtered to provide an unregulated high voltage (265V - 350V) DC bus, which is converted to high frequency AC for transmission through a high frequency power transformer. This AC is then rectified and filtered to provide a low ripple DC output. Control is achieved by means of a dual-channel amplifier, for both voltage and current control, that furnishes full rated output voltage at the maximum rated output current or can be continuously adjusted throughout all of the output range.

All supplies can be controlled locally at the front panel or remotely by external voltage, current or resistance on the rear programming strip.

Voltage Programming:

Voltage Programming......0 to 5V DC

Current Programming......0 to 1mA (into 5000 ohms).

Resistance Programming...0 to 5000 ohms

Each range programs from zero to full output voltage.

Current Programming:

Voltage Programming......0 to 100 mV

Current Programming......0 to 1mA (into 100 ohms) /into 5K ohms.

Resistance Programming...0 to 100 ohms

Each range programs from zero to full output current.

The input power is connected to terminal block TB2 at the rear of the unit. The output terminals are heavy busbars also located at the rear. Expansion of the basic operational capabilities is achieved by utilizing the 17 screw terminal block. A brief description of these capabilities is given below.

A. Remote Sensing - Separate output sensing terminals are provided to remotely sense the power supply output at a distant load. This feature compensates for the voltage drop in the power distribution system and provides specified regulation at the point of load.

B. Remote Programming - The power supply output voltage or current can be controlled from a remote location by means of a external voltage source or resistance.

C. Parallel Operation - The power supply can be operated in parallel with another unit when greater output current capability is required. The parallel operation permits one "master" supply to control the other supplies. It is not recommended to use more than 3 power supplies in parallel unless some special scheme of parallelling is used.

D. Series Operation - Two power supplies can be used in series when a higher output voltage is required in the constant voltage mode of operation or when greater voltage compliance is required in the constant current mode of operation.

E. Remote Turn On - The power may be remotely turned on or off by application of either (1) External voltages (AC or DC) between 10V and 115V, or (2) Contact closure.

SPECIFICATIONS

1.2.1 Physical Characteristics:

POWER (W)	HEIGHT (inches)	WIDTH (inches)	DEPTH (inches)	WEIGHT (lbs)
1KW	1.75	19	17	18
2KW/ 2.5KW	3.5	19	18	35
5KW	5.25	19	21	60

1.2.2 Electrical Characteristics:

AC INPUT

POWER (W)	LINE VOLTAGE (V AC)	LINE CURRENT (A)	HERTZ	WIRE
1KW	100-132/200-264	13.8/6.9	47-63	3
2KW	200-257	13	47-63	3
2.5KW	190-250	20	47-63	3
	190-250	13.5	47-63	4
5KW	190-250	20-8	47-63	4
5KW	342-418	13.2	47-63	5

WIRE: 5 - Three Phases, neutral, protective earth.
4 - Three Phases, and protective earth.
3 - Two Phases and protective earth.

NOTE: FOR SINGLE PHASE OPERATION OF THE 2.5KW SERIES, THE DROP-OUT LINE VOLTAGE WILL BE 200VAC. HOWEVER OPERATION AT A LINE VOLTAGE OF 190VAC IS POSSIBLE BY DERATING OUTPUT VOLTAGE BY 10%.

Freq: 47 - 63 Hz.
Reduce all ratings by 10% at 47 - 53 Hz.

Inrush: Inrush current at turn on is limited to a value less than full load current.

DC OUTPUT

600W SERIES:

MODEL (V-I)	RIPPLE (RMS)
7.5-75	100mv
10-60	100mv
20-30	100mv
30-20	100mv
40-15	100mv
60-10	100mv
80-7.5	100mv

2KW SERIES:

MODEL (V-I)	RIPPLE (RMS)
7.5-265	75mv
10-200	75mv
20-100	75mv
30-65	75mv
40-50	75mv
60-33	75mv
80-25	100mv
150-13	120mv
300-6	150mv

1KW SERIES:

MODEL (V-I)	RIPPLE (RMS)
7.5-130	75mv
10-100	75mv
20-50	75mv
40-25	75mv
60-18	100mv
80-13	100mv
150-7	120mv
300-3.5	150mv
600-1.6	350mv

2.5KW SERIES:

MODEL (V-I)	RIPPLE (RMS)
7.5-300	75mv
10-250	75mv
20-125	75mv
40-60	75mv
60-40	100mv
80-30	100mv
150-16	120mv
300-8	150mv

5KW SERIES:

MODEL (V-I)	RIPPLE (RMS)
7.5-600	75mv
10-500	75mv
20-250	75mv
40-125	75mv
60-80	75mv
80-60	100mv
150-33	120mv
300-16	150mv

REGULATION

Voltage Mode: 0.1% Line and Load

Current Mode: 0.1% Line and Load

TRANSIENT RESPONSE

A 30% step load will cause a transient deviation from regulation, recovering to within 2% of final value within 1mS. Maximum deviation is 300mV for Model EMS 10-250.

STABILITY

The output voltage or current will remain within 0.05% of set point for 8 hours after warm-up under fixed load and temperature conditions.

TEMPERATURE

Voltage: 0.02% per degree centigrade
Current: 0.03% per degree centigrade

AMBIENT TEMPERATURE

Operating:	0 to 50 deg. C:	1KW and 2.5KW
	0 to 40 deg. C:	5KW
	0 to 70 deg. C:	with 1% derating for each degree above rated.

Non Operating: -55 deg. C to 85 deg. C

COOLING

All units are forced air cooled with air entering through the front and sides and exiting through the rear. Reference paragraph 2.4 for discussion regarding location.

PROTECTION

Thermal: Thermostat protects unit from excessive ambient temperature as well as inadequate forced air cooling. Restart is automatic upon removal of thermal overload.

Overvoltage: Overvoltage protection is front panel adjustable. When the pre-set voltage is exceeded, the inverter drive is removed and the output crowbar is activated. Input power must be momentarily removed in order to restore normal operation.

ISOLATION

Input/Ground 2500VDC
Input/Output 2500VDC
Output/Ground 1500VDC

NOTE: The input line terminals must be shorted together when Hi-Pot potentials are applied. This will eliminate the possibility of internal damage to the power supply under these extreme conditions. Similar precautions must be taken while doing the high pot from output to Chassis.

SECTION 2

INSTALLATION

2.1 INITIAL INSPECTION

Before shipment, this instrument was inspected and found to be free of mechanical and electrical defects. As soon as the unit is unpacked, inspect for any damage that may have occurred in transit. Check for broken knobs or connectors, that the external surface is not scratched or dented, meter faces are not damaged and that all controls move freely. Any external damage may be an indication of internal probelems.

2.2 MECHANICAL CHECK

1. Remove 6-32 machine screws from both sides of top cover.

2. Cover can now be removed.

3. Inspect for loose hardware, damaged components or broken wires.

4. Check operation of controls.

2.3 POWER REQUIREMENTS

The user should ensure that the AC input wires are of the proper gauge. The safety ground wire must be the same gauge as the AC input wires to ensure that it does not open and create a safety hazard. Load wires to be connected to the POS. and NEG. output terminals must be of sufficient size to prevent substantial IR voltage drops between the output terminals and the load. Remote sensing can be used to compensate for degraded regulation.
Reference paragraph 3.3.2.

1. The 1KW unit will be factory set for 115 or 230V AC input. This will be decided by customer upon ordering and will be indicated on unit upon delivery. Look for AC input rating on each unit received and operate accordingly.

   Install single phase line to terminals marked AC. Connect GND line to terminal marked GND. Replace cover plate.

See the note for change over between 115V/230V input for 1KW.

WARNING: Do not operate a 115V AC unit at 230V AC; Unit will be permanently damaged.

2. The 2.5KW series of power supplies can operate from either a three-phase or a single-phase input of the specified voltage and frequency, with nominal voltage line-to-line. Phase rotation need not be observed when connecting the power line to the input terminal of the power supply.

   Install the three phase line to terminals marked Phase A, Phase B, and Phase C. Connect the GND line to terminal marked GND.
   Reinstall cover plate.

NOTE: It is important that single phase power should be applied between terminals Phase A and Phase B.

3. The 5KW unit is designed to operate on 208/220/230V AC 3 Phase input and 380V input AC.

   Install three phase line to terminals marked Phase A, Phase B, Phase C. Connect GND lead to terminal marked GND. Replace cover plate. In case of 5KW 380VAC unit, connect both neutral and protective earth as shown.

2.4 LOCATION

This instrument is fan cooled. sufficient space must be allocated so that a free flow of cooling air can reach the sides of the instrument when it is in operation. It is also desirable, although not mandatory, that the unit should be located so as to allow cooling air to enter through the top cover. the power supply is to be used in an area where the ambient temperature does not exceed 50 degrees centigrade. A higher ambient temperature is permissible where appropriate reduced rating is use. Reference paragraph 1.2.3.

the voltage across CR5, a temperature compensated zener diode. The current from each of the sources is adjustable to 1 mA by R3 and R5.

Modulator:

U8 performs all of the PWM functions. The industry standard UC1524A was chosen in this application. Extensive documentation is available along with numerous application notes. However, in this discussion, it is sufficient to recognize that its primary function is to convert the differential analog signal on pins 1 and 2 to CLK1 and CLK2. The reference input pin 2 is derived from the reference output pin 16, and the voltage divider R72 and R73. The transconductance amplifier consisting of pins 1,2 and 9 (output)is configured as an inverting amplifier with a gain of 0.5. Pin 9 is clamped by CR15 and CR35, corresponding to soft- start and overcurrent protection, respectively. The oscillator frequency of 100KHz is set by R75 and C50.

Voltage Control Channel:

Voltage control and error amplification are implemented by U6 and associated components. The non-inverting input is routed from the (+) sensing terminal TB1-2 (+V Rem) through R49, R50 and R52. The inverting input is routed from TB1-4 (V Amp In) through R51, C36 and R53. The signal at TB1-4 is the voltage reference set by a 1mA current that flows through the programming resistance R4 (in the normal mode of operation).

The voltage amplifier compares the reference and sense voltages and amplifies the error with appropriate compensation for loop gain shaping. The R54, C40 feedback combination provides a pole-zero combination, with the pole at DC for best DC regulation. The R51, C36, R53 combination provides phase lead as required for overall loop stability. R55 is an offset adjustment for zero nulling, and is set during calibration.

Current Control Channel:

Current control and error amplification are implemented by U5/2 and associated components. The non-inverting input is routed from the current shunt (+) sense terminal TB1-13 (Inv Amp In) through R45. The inverting input is routed from TB1-12 (I Amp In) through R44. The signal at TB1-12 is the current reference set by a 1mA current that flows through the programming resistance R5 (in the normal mode of operation). The error amplifier U5/2 compares the reference and sense currents and amplifies the error, with appropriate compensation provided by R48 and C31. Offset adjustment is provided by R47 and is set during calibration.

The outputs of the voltage and current channels are "ORed" via diodes CR31 and CR27, and thus provide automatic crossover from current to voltage control, and vice versa. The U5/1 and Q10 combination ensures that the current channel output may never fall too far below the voltage output, thus reducing the transition time at crossover.

Additional attenuation of the analog channels' output is provided by R64, R65 and R66 (factory set) before the signal is fed to the input amplifier of the modulator.

Transistor Drive: Reference 01-000187 Sheet 2

The outputs of U8 are ORed to provide a PWM signal @ 100KHz. This is used as a clock for the power mosfet driver IC (U1) located on the A200 board. The totem pole outputs of the UC3706 drive T2. With The internal flip-flop active the outputs at U1/6 and U1/11 are alternating providing balance transformer drive.

4.4 EMS 2.5KW POWER SUPPLY SERIES:

4.4.1 POWER FLOW

Reference: 01-473-001 Main Schematic
01-000-250 A200 Inverter Board
01-168-000 A300 Line Filter

The AC input enters through TB2 on the rear of the unit. It passes through the line filter which is located on the A300 board. The purpose of the EMI Line filter is to attenuate high frequency conducted emissions generated inside the unit, and thus reduce the high frequency current drawn from the power source. In addition, and for enhanced performance, design practice which attacks the source of the emissions has been followed. Such practice includes: Snubbing to reduce dV/dT; Faraday shields; Minimizing capacitance from circuits to ground; Minimizing the area of high frequency current loops.

The load side of the line filter connects to a 25 Amp circuit breaker CB1 which allows power to pass through the rectifier bridges CR1 and CR2 to supply the DC bus capacitance C1. At turn on, the contact of K1 is in the open position, thereby limiting the inrush current that would otherwise flow through the rectifiers. After a short delay of about five seconds, the contact closes allowing normal power transfer.

The DC bus voltage (265V - 350V) is fed to the A200 Inverter Board, which consists of a set of switching transistors configured as a full bridge inverter. The DC bus is locally bypassed by capacitors C15 and C16 minimizing the area of high frequency current loops. Each transistor is protected by a fast recovery inverse parallel diode. Also, each transistor is protected by a turn-off snubbing network, reducing the switching stress and associated power loss. The drive circuitry ensures fast switching and is phased so that Q1 and Q4 are turned on together, as are Q2 and Q3. The result of this switching is to produce a PWM quasi-square waveform that is impressed on the power transformer T1. (Series coupling capacitors are a necessary addition to ensure steady-state volt-second balance and thus prevent transformer saturation.) Snubbing of leakage inductance induced voltage spikes is implemented by R9, C6 and C11. The output of the A200 Inverter boards are available at terminals HF1 and HF2. The output current is sensed by current transformers T3 and T6 and the measured signal returned via J3 to the A100 Control Board.

The power transformer T1 provides the necessary voltage stepdown or stepup.

Fast recovery rectifiers (or Schottky diodes for low voltage units) convert the secondary output into a unipolar variable pulse width waveform. Filtering is achieved with the L1, L2, C5, C6 combination. Normal LC filtering action would be implemented if L1 had no additional winding. However, improved performance is possible with the additionl winding combined with C5 and L2. The effect of this combination is to considerable reduce the voltage ripple flowing through the output capacitor C6, and thus reduce the voltage ripple due to capacitor ESR. Higher frequency noise spikes are attenuated by C7, a metallized polycarbonate film capacitor with very low ESR and high resonant frequency.

4.4.2 SIGNAL FLOW Reference: 01-000-172 A100 Control Board

All of the control circuitry is located on the A100 Control Board. The board receives its power from the Bias transformer T2 through connector J1. The input AC (18-20 Volts) is full-wave rectified and filtered by CR1 and C1, C2. The fixed regulator U1 gives a regulated +15 volts at 0.5 amp. The fixed regulator U2 provides -15 volts at 0.5 amps. The +/- 15V supply thus formed is used to power all the integrated circuits on the board.

Supervisory Functions:

Most supervisory functions are performed by U4 and associated circuitry. These functions include: Undervoltage lockout and Soft start, Overvoltage protection, Mode detect and Remote Turn-on.

(1) Undervoltage Lockout and Soft Start

The unregulated side of U1 (an indirect measure of the AC input voltage) is sensed through R17. When this voltage is below approx. 13V, the output of amplifier U4/1 is high, which keeps Q5 fully on. Pin 5,8 of U8 (the Digital Shut down Port) is thus clamped low by CR15. When the voltage at R17 rises above 13V, the output of U4/1 latches low, and thus Q6 and the LOW LINE LED turn off. Q5 will also turn off if permitted by the diodes CR12, CR14, CR16 and CR17, controlled respectively by the remote Turn-on, Thermostat protection, Overvoltage protection and Turn-on delay circuits.

(2) Overvoltage Protection

The overvoltage trip setpoint is set by potentiometer R8 through J3/20. The actual output voltage is sensed by R26 from J2/7. The amplifier U4/2 has latching positive feedback, which requires removal of AC power for resetting after the O.V.P. has been activated. U4/2 also has also has negative feedback with C23 which prevents noise tripping of the latch. Once u4/2 latches high, Q5 is turned on, and thus the control pin is pulled low, causing shutdown of the modulator. Also, the SCR Q8 is fired and the output of the power supply is crowbarred. The OV LED is lighted through J3/12.

(3) Turn-on Delay

U4/3 provides a five second delay by comparing the 5 Volt reference with the voltage on C26. When power is applied, C26 charges through R34 with the necessary time constant to provide the desired delay. After the delay, the output of U4/3 rises, turning on Q9, thereby activating the relay K2 which causes the bus charging resistor R1 to be shorted. At the same time, the CR16 clamp on Q5 is released, allowing the soft start circuit to commence its operation.

(4) Mode Detect

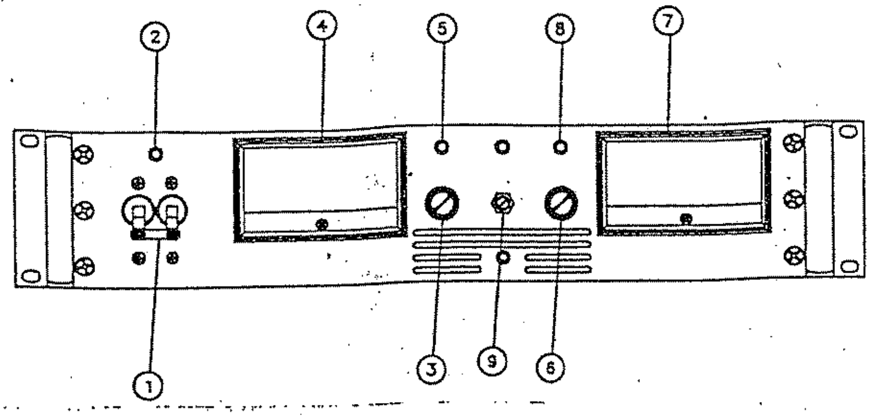
R38 samples the voltage at the output of U6. This is the voltage channel output and this point will be above +3V if the voltage channel is in control. If the current channel is in control, this point will integrate down to approximately -0.7V. U4/4 compares this level with zero and thus lights either the VOLTAGE MODE LED through R41 and J3/16 or the CURRENT MODE LED through R40 and J3/17.

(5) Remote Turn-on

This feature allows the user to control the power supply from a remote location with either 12-24V DC or 24-115V AC or a dry contact closure. U3 provides isolation from the power supply ground.

SECTION 3

OPERATING INSTRUCTIONS



3.1 INITIAL TURN-ON

The front panel contains all the controls and indicators necessary to operate the supply in its normal mode. The following checkout procedure describes the use of the front panel controls and indicators (Fig 3.1) and insures that the supply is operational. This preliminary check of the power supply should be performed under the no load condition.

1. Check the barrier jumper straps in the back of the unit, as shown in Fig. 3.2, for normal mode.

2. Set all controls completely counterclockwise.

3. Turn the CIRCUIT BREAKER (1) on/off switch to ON. The fans will start immediately, but there is a five second delay before power output occurs. This delay allows for gradual charging of the main bus capacitors and thus limits the AC inrush current.

4. The POWER ON indicator should be lit.

5. Advance CURRENT CONTROL (6) one-half turn and slowly advance VOLTAGE CONTROL (3). The DC VOLTMETER (4) will deflect from zero to maximum rating of the supply as this control is advanced completely clockwise. The VOLTAGE INDICATOR (5) will be lit.

6. Return all controls completely counterclockwise.

7. To verify constant current operation, first turn off the supply. Connect a shorting bar across the POS and NEG output terminals at the rear of the unit.

8. Turn the circuit breaker on/off switch to ON. Advance the VOLTAGE CONTROL (3) one turn clockwise and slowly advance the CURRENT CONTROL (6). The DC AMMETER (7) will deflect smoothly from zero to the rated current of the supply as this control is advanced clockwise. The CURRENT INDICATOR (8) will be lit.

9. Return all controls completely counterclockwise and turn unit off. Disconnect output shorting bar.

3.1.1 OVERVOLTAGE PROTECTION

The front panel contains the OVERVOLTAGE ADJUSTMENT (9). This potentiometer may be adjusted through an access hole in the front panel.

To set overvoltage trip levels less than the maximum output voltage, or to check the operation of the overvoltage circuitry, this sequence should be followed: (a) Set the potentiometer fully clockwise. (b) Adjust the power supply output voltage to the desired trip level. (c) Slowly adjust the potentiometer counterclockwise until overvoltage is tripped.

Recovery from activation of the O.V.P. circuitry requires that the input power be momentarily removed. Turning the unit off and then on again will reset the O.V.P., provided that the output is not adjusted above the trip point. The overvoltage range is from 0% to 100% of the maximum output voltage of the unit.

If any of the above events do not occur, the supply is defective and must not be operated. Depending on circumstances, either warranty service or troubleshooting as elsewhere in this manual is required.

3.2 GENERAL OPERATION

The voltage and current controls (local and remote) set the boundary limits for the voltage and current respectively. The relationship of load resistance to control settings determines whether the power supply is operating in constant voltage or constant current mode. Automatic crossover between modes occurs at the following resistance value.

$$\text{Load Resistance (OHMS)} = \frac{\text{Voltage Control Setting (volts)}}{\text{Current Control Setting (amperes)}}$$

At higher load resistance, the power supply operates in the constant voltage mode and at lower resistance in the constant current mode.

3.3 MODES OF OPERATION

The mode of operation is determined by selecting strapping connections on terminal strip TB1, located on the rear panel. The terminal designations are silk screened on the rear panel of the power supply. (Refer to the following chart).

TB1 Pin #	PIN DESCRIPTION
1	+ Voltage (+V)
2	+ Voltage Remote (+V REM)
3	Voltage Programming Current (V PROG I)
4	Voltage Amplifier (V AMP IN)
5	Voltage Programming Resistance (V PROG R)
6	Voltage Programming Resistance Common (V PROG R COM)
7	- Voltage Remote (-V REM)
8	- Voltage (-V)
9	Current Programming Current (I PROG I)
10	Current Amplifier (I AMP IN)
11	Current Programming Resistance (I PROG R)
12	- Shunt (-I)
13	Inverted I Amplifier In
14	+ Shunt (+I)
15&16	Remote Voltage Turn On (Remote V IN)
16&17	Remote Dry Contact Turn On (Remote SW)

3.3.1 NORMAL OPERATION (Figure 1)

When shipped from the factory, each supply is configured for constant voltage, constant current, local programming, local sensing, single unit mode of operation. This normal mode of operation is used in most applications. All performance specifications, unless otherwise stated, are defined in this configuration. Ripple, programming speed, transient response and stability are optimized with the power supply so configured.

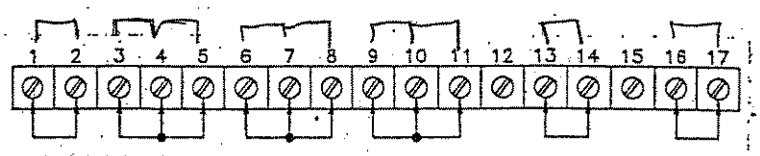


Figure 1. Normal Operation

Load Connection:

Each load must be connected to the power supply output terminals using separate pairs of connecting wires. This will minimize mutual coupling effects between loads and will retain full advantage of the low output impedance of the power supply. Each pair of connecting wires must be as short as possible and twisted or shielded if strong AC or RF fields are present to reduce noise pickup. (If a shielded pair is used, connect one end of the shield to ground at the power supply and leave the other end disconnected.)

3.3.2 REMOTE SENSING (Figure 2)

In applications where the effect of the voltage drop (IR drop) of the load wires would adversely affect the performance of the load, it is possible to sense the voltage at the load rather than at the output terminals of the power supply. Remote sensing will therefore remove the effect of changes in load current through the power distribution system. The maximum available load voltage then equals the rated power supply output voltage less the total of the IR drop.

Instructions for Remote Sensing:

1. Remove jumpers between the following terminals: TB1-1 and TB1-2
   TB1-7 and TB1-8
2. Connect the positive point of load to TB1-2.
3. Connect the negative side of the load to TB1-7 and TB1-6.
4. If the sense points are separated from each other by some distance, it is sometimes necessary to connect a capacitor across the load, or between TB1-2 and TB1-7, within the range of 5 to 50uF.

NOTE: Since the voltmeter is internally connected to the sensing terminals, it will automatically indicate the voltage at the load, not the power supply output terminal voltage.

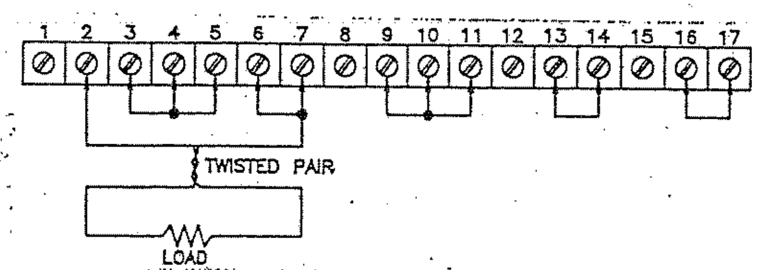


Figure 2. Remote Sensing

3.3.3 REMOTE PROGRAMMING

This power supply may be operated in a remotely programmed mode (externally controlled) by the use of an external resistance. The wire connecting the programming terminals of the supply to the remote programming device should be twisted or, if strong AC or RF fields are present, shielded.

Caution: If the remote programming function fails or is inadvertently adjusted so that the output voltage is programmed to levels of greater than 15% above ratings, damage to the output filter capacitors may occur. To protect against this, it is suggested that the overvoltage protection be used to limit the maximum voltage excursion and safely shut the power supply down.

3.3.4 REMOTE PROGRAMMING by EXTERNAL CURRENT (Figures 3 & 4)

Voltage Channel:

A resistance of 0 to 5000 ohms programs the output from zero to full rated voltage.

Programming Resistance = Desired Voltage/Full Rated Output x 5000

1. Remove the jumper between terminals TB1-4 and TB1-5.
2. Connect the programming resistance between terminals TB1-4 and TB1-7.

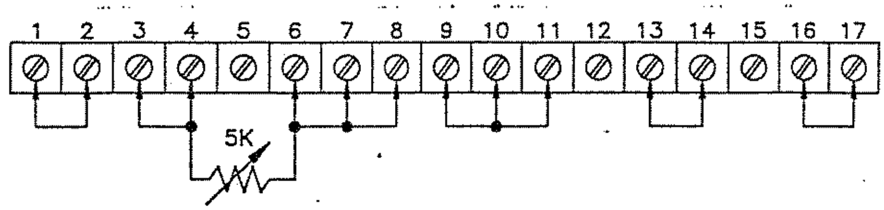


Figure 3. Remote programming by External Resistance, Voltage Mode

Current Channel:

A resistance of 0 to 100 ohms programs the output from zero to full rated current.

Programming Resistance = Desired Voltage x 100/Full Rated Output

1. Remove the jumper between terminals TB1-10 and TB1-11.

2. Connect the programming resistance between terminals TB1-10 and TB1-12.

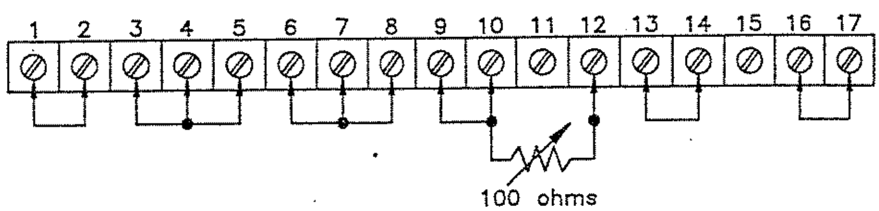


Figure 4. Remote programming by External Resistance, Current Mode

Caution: An opening in the remote programming circuit is effectively a high programming resistance and will allow an uncontrolled voltage or current rise to the maximum output of the power supply. This may cause possible damage to the power supply and/or load. For this reason, any programming resistor switcher must have shorting contacts. This type of shorting switch connects each successive position before disconnecting the preceding one.

3.3.5 REMOTE PROGRAMMING by EXTERNAL VOLTAGE (FIGURE 5 & 6)

The front panel voltage or current control is disabled in this operating mode.

VOLTAGE CHANNEL:

A voltage of 0 to 5V programs the output from zero to full rated voltage.

1. Remove the jumpers between terminals TB1-3, TB1-4 and TB1-5.

2. Connect the programming voltage source between TB1-4 (positive) and TB1-6 (negative).

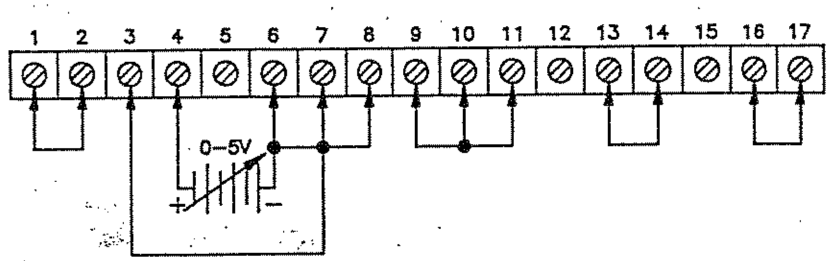


Figure 5. Remote Programming be External Voltage, Voltage Mode

CURRENT CHANNEL:

A voltage of 0 to 100mV programs the output from zero to full rated current. 0 to 5V programming in current channel is and option.

NOTE: A signal from a higher potential source may be attenuated to this 100mV level by a resistor divider. For best performance, this source impedance of this divider should not exceed 1000 ohms.

1. Remove the jumpers between terminals TB1-9, TB1-10 and TB1-11.

2. Connect the programming voltage source between terminals TB1-10 (positive) and TB1-12 (negative).

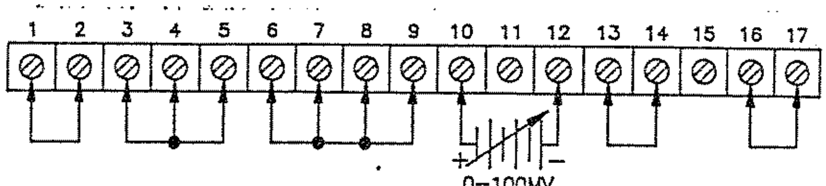


Figure 6. Remote Programming by External Voltage, Current Mode.

3.3.6 REMOTE PROGRAMING by EXTERNAL CURRENT (figures 7 & 8)

The front panel voltage or current control is disabled in this programming mode.
A current of 0 to 1mA programs the output from zero voltage to full rated voltage or current.

VOLTAGE CHANNEL:

1. Remove the jumpers between terminals TB1-3, TB1-4 and TB1-5.

2. Connect a 5K ohm, 1% 0.5W resistor between TB1-4 and TB1-6.

3. Connect the programming current source between terminals TB1-4 (positive) and TB1-6 (negative).

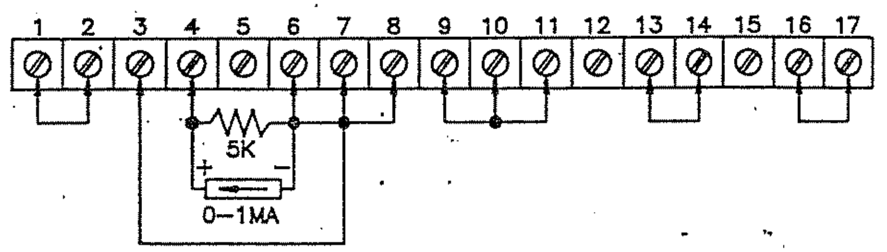


Figure 7. Remote Programming by External Current, Voltage Mode.

CURRENT CHANNEL:

1. Remove the jumper between terminals TB1-9, TB1-10 and TB1-11.

2. Connect a 100 ohm, 1% 0.5W resistor between TB1-10 and TB1-12.

3. Connect the programming current source between terminals TB1-12 (negative) and TB1-10 (positive).

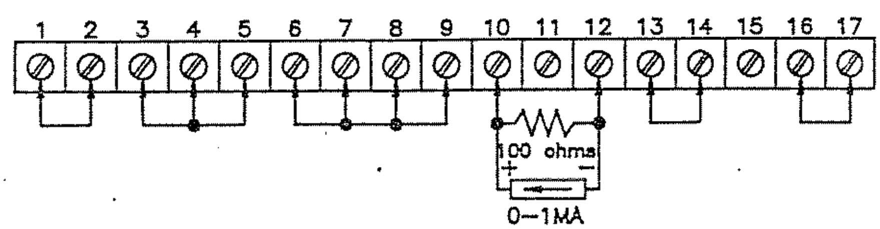


Figure 8. Remote Programming by External Current, Current Mode.

3.3.7 PARALLEL OPERATION (Figure 9)

NOTE: It is not recommended to operate more than three EMS power supplies in parallel without thorough evaluation by the user, with counseling from the Engineering Department of Electronic Measurements, Inc.. This will help avoid any failures in the application due to instability of the power supplies.

The simplest parallel connection is that of attaching that of positive and negative terminals to their respective load points. The procedure is as follows:

1. Turn on all units (open circuit) and adjust to the appropriate output voltage, as in figure 9.

2. Turn supplies off and connect all positive output terminals to the positive side of the load and all negative supplies to the negative side of the load.

NOTE: Individual leads connecting the units to the load must be of equal length and oversized to provide as low an impedance as practical for the high peak currents.

3. Set the current controls clockwise.

4. Turn units on one at a time, until the sum of the power supply current capabilities exceeds the load current drawn.

5. Using the voltage controls, balance each unit voltage for equal output current. Balance the current of each unit for equality.

6. Set the current controls to limit just above running current so that if the output voltage of any unit drifts upward, it will become current limited rather than carry an excessive share of load current.

IMPORTANT: The OVP set-point potentiometers should be set fully clockwise to ensure that neither power supply will be crowbarred. Disconnect the crowbar resistor R31 and switch Q8 from A100 board. In order to get OVP option with paralleled units please contact the Engineering Dept of Electronic Measurements, Inc..

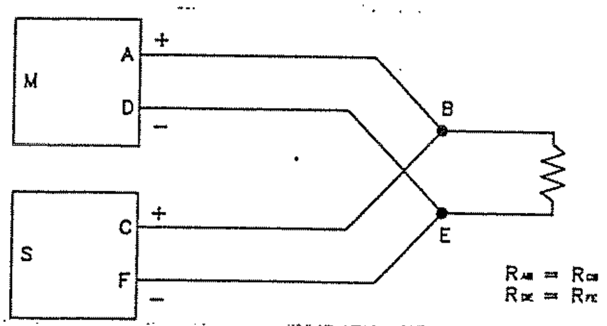


Figure 9. Parallel Operation

3.3.8 PARALLEL OPERATION - MASTER/SLAVE (Figure 10)

In this configuration, the power supply designated the master is used to control the voltage and current operation of all other supplies, referred to as slaves.

1. Disconnect the following jumpers of all slaves:
   TB1-13,TB1-14
   TB1-9, TB1-10
   & TB1-11
2. Connect a jumper between TB1-10 and TB1-12 of all slaves.

3. Connect a wire between the master supply TB1-12 and TB1-13 of each slave.

4. See Figure 9 for + and - voltage connection.

5. Turn each slave on and then the master.

6. Adjust the master for required output voltage or current. The output leads from each power supply must be of equal resistance to a point of load near the supply to ensure equal sharing.

7. In case of noise or problems contact Engineering Dept. Electronic Measurements, Inc..

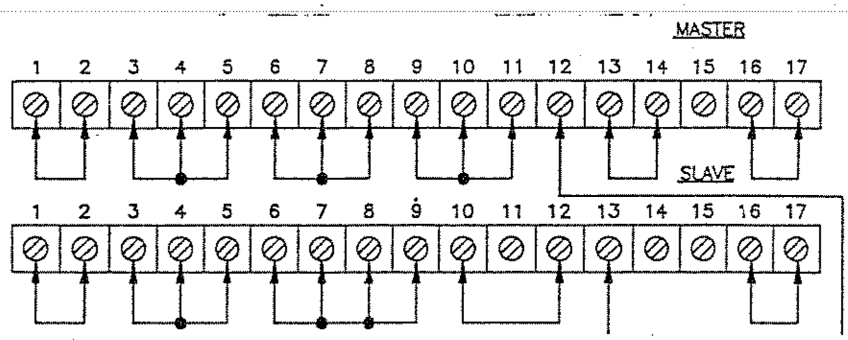


Figure 10. Parallel Operation, Master/Slave

3.3.9 SERIES OPERATION

Two EMS power supplies can be operated in series simply by connecting the negative output terminal of one unit to the positive output terminal of the other. In this configuration each unit is adjusted independently, and the total output voltage is the sum of each unit's output voltage. NOTE: The voltage at any output terminal must never exceed 600V with respect to chassis ground. Consult Electronic Measurements, Inc. Engineering Department for series operation of more than two power supplies.

3.3.10 REMOTE METERS

A remote voltmeter may be connected between TB1-2 (positive) and TB1-7 (negative). If remote sensing is also being used, the remote voltmeter will indicated the voltage at the load. To indicate the voltage at the power supply output terminals connect the remote voltmeter between terminals TB1-1 (positive) and TB1-8 (negative).

A remote millivoltmeter, calibrated in amperes, may be connected between terminals TB1-12 (negative) and TB1-13 (positive). A voltage of 0 to 100mV across these terminals indicates output current from zero to full rating, unless otherwise specified (see main schematic). To compensate for voltage drops in long remote ammeter leads, a meter movement having a fullscale sensitivity of less than 100mV is used in series with a calibrating resistor.

The leads to the remote meters should be twisted, and if strong AC or RF fields are present, the lead should be shielded. One end of the shield should be grounded to terminal TB1-14 and the other end left floating.

3.3.11 REMOTE TURN ON

EXTERNAL VOLTAGE SOURCE: Connect either an external 12-24V DC voltage supply or a 24-115V AC voltage supply to pins 15 & 16 TB1. The link between Terminals 16 & 17 must be removed. NOTE: Terminals are polarity sensitive DC. Terminal 15 is positive and terminal 16 is negative.

DRY CONTACT: Connect a N/O voltage switch or contactor between terminal 15 & 16 of J1. Open contact implies Power supply is disabled and close contact enable the power supply.

SECTION 4

THEORY OF OPERATION

4.1 This section details the principles of operation of the EMS series of switched-mode power supplies. The following schematics are referenced:

1KW:	01-473-001 (Main)	01-000-188 (A100)
	01-000-187 (A200)	01-000-208 (A200)
	01-000-207 (600W units)	01-178-000 (A300) for special
2KW/2.5KW:	01-473-001 (Sht 2 of 4 for 2KW)	
	01-473-001 (Sht 3 of 4 for 5KW)	
	01-000-273 (A100) for both	
	01-000-250 (A200)	01-168-000 (A300) for 2.5KW unit
5KW: 220VAC	01-473-001 (Main)	01-000-275 (A100)
	01-168-000 (A300)	01-000-250 (A200)
5KW: 380VAC	01-473-001 (Main)	01-000-303 (A100)
	01-000-302 (A300)	01-000-260 (A200)

4.2 General:

The EMS 1KW, 2KW, 2.5KW and 5KW series of power supplies operate from 115/230V single phase, 208/220V single or three phase , and 208/220 three phase power sources, respectively. These supplies have been developed specifically for laboratory test and burn-in applications. Features include low ripple, fast transient response, automatic crossover between voltage and current channels, low cost and low weight.

The basic principle of operation is outlined below. The input AC power is rectified and filtered to produce an unregulated DC voltage bus. The high frequency inverter then converts this to an AC waveform for transmission through a ferrite-based transformer. The secondary output is rectified and filtered to produce the low ripple DC voltage required. Regulation is achieved through modulation of the pulse width generated by control stage.

For the purposes of explaining the operation of this power supply series, the power flow and the control functions of each power series will be considered separately in the following sections.

4.3 EMS 1KW POWER SUPPLY SERIES:

4.3.1 POWER FLOW

Reference: 01-473-001 Main Schematic
01-000-187 A200 Inverter Board
01-178-000 A300 Line Filter

The AC input enters through TB2 on the rear of the unit. It passes through the line filter which is located on the A300 board. The purpose of the EMI Line filter is to attenuate high frequency conducted emissions generated inside the unit, and thus reduce the high frequency current drawn from the power source. In addition, and for enhanced performance, design practice, which attacks the source of the emissions, has been followed. Such practice includes:

Snubbing to reduce dV/dT; Faraday shields; Minimizing capacitance from circuits to ground; Minimizing the area of high frequency current loops.

The load side of the line filter connects to a DPDT Switch which allows power to pass through the rectifier bridge to supply the DC bus capacitances C1 and C2. At turn on, the contact of K1 is in the open position, thereby limiting the inrush current that would otherwise flow through the rectifiers. After a delay of about five seconds, the contact closes allowing normal power transfer.

The DC bus voltage (265V - 350V) is fed to the A200 Inverter board, which consists of a set of power MOSFET'S configured as a half bridge inverter. The DC bus is locally bypassed by capacitors C1 and C2 minimizing the area of high frequency current loops. The drive circuitry ensures fast switching and is phased so that Q1 is ON while Q2 is OFF. The result of this switching is to produce a PWM quasi-square waveform that is impressed on the power transformer T1. (Series coupling capacitors are a necessary addition to ensure steady-state volt-second balance and thus prevent transformer saturation.) Snubbing of leakage inductance induced voltage spikes is implemented by R3 and C3. The output of the A200 inverter board is available at terminals HF1 and HF2.

The power transformer T1 provides the necessary voltage stepdown. The construction incorporates a grounded faraday shield both for safety and for reduction of capacitive noise transfer to the output.

Fast recovery rectifiers (or Schottky diodes for low voltage units) convert the secondary output into a unipolar variable pulse width waveform. Filtering is achieved with an LC combination.

4.3.2 SIGNAL FLOW Reference: 01-000-158 A100 Control Board

All of the control circuitry is located on the A100 Control Board. The board receives its power from the bias transformer T2 on the A100 board. The input AC (14-15 volts) is full-wave rectified and filtered by CR1 and C1, C2. The adjustable regulator (U1) is set to give a regulated +12Volts at 1 amp. The fixed regulator (U2) provides -12Volts at 0.5 amps. The +/- 12V supply thus formed is used to power all the integrated circuits on the board.

Supervisory Functions:

Most supervisory functions are performed by U4 and associated circuitry. These functions include: Undervoltage lockout and Soft start; Overvoltage protection; Turn-on delay; Mode detect; Remote Turn-on.

(1) Undervoltage Lockout and Soft Start

The unregulated side of U1 (an indirect measure of the AC input voltage) is sensed through R17. When this voltage is below approx. 13V, the output of amplifier U4/1 is high, which keeps Q5 fully on. Pin 9 of U8 (the control pin) is thus clamped low by CR15. Also, C21 is fully discharged. When the voltage at R17 rises above 13V, the output of U4/1 latches low, and thus Q5 will turn off if permitted by the diodes CR12, CR14 CR16 and CR17, controlled respectively by the Remote Turn-on, Thermostat protection, Overvoltage protection and Turn-on delay circuits. With Q5 off, the slow start is activated and controlled by the charging rate of C21.

(2) Overvoltage Protection

The overvoltage trip setpoint is set by potentiometer R8 through J3/6. The actual output voltage is sensed by R26 from J2/1. The amplifier U4/2 has latching positive feedback, which requires removal of AC power for resetting after the O.V.P. has been activated. U4/2 also has negative feedback with C23 which prevents noise tripping of the latch. Once U4/2 latches high, Q5 is turned on. and thus the control pin is pulled low, causing shutdown of the modulator. Also, the SCR (Q8) is fired and the output of the power supply is crowbarred. The OV LED is lighted through J3/8.

(3) Turn-on Delay

U4/3 provides a five second delay by comparing the 5 Volt reference with the voltage on C26. When power is applied, C26 charges through R34 with the necessary time constant to provide the desired delay. After the delay, the output of U4/3 rises, turning on Q9, thereby activating the relay (K1) which causes the bus charging resistor R1 to be shorted. At the same time, the CR16 clamp on Q5 is released, allowing the soft start circuit to commence its operation.

(4) Mode Detect

R38 Samples the voltage at the output of U6. This is the voltage channel output and this point will be above +3V if the voltage channel is in control. If the current channel is in control, this point will integrate down to approximately -0.7V. U4/4 compares this level with zero and thus lights either the VOLTAGE MODE LED through R41 and J3/12 or the CURRENT MODE LED through R40 and J3/13.

(5) Remote Turn-on

This feature allows the user to control the power supply from a remote location with either 12-24V DC or 24-115V AC or a dry contact closure. U3 provides isolation from the power supply ground.

The on-board jumper determines whether the remote turn-on circuitry is active. If the jumper is connected so that CR11 is pulled to ground, then the remote turn-on circuitry is not active. Alternatively, if the jumper connects pin 4 of U3 to ground, then this circuitry is active. With the internal LED of U3 not activated, Q4 is turned on, which shuts down the modulator through CR12 and Q5. Any event that activates the internal LED, allows the modulator to function and thus let power pass to the power supply output. The internal LED of U3 can be activated in two ways: (1) Application of external voltage (AC or DC) across TB1-15 and TB1-16; (2) Dry contact closure across TB1-16 and TB1-17.

With dry contact closure, the power is supplied by the relaxation oscillator consisting of T1, Q3 and associated components. Each time that Q3 conducts, it discharges C147 through the primary of T1, inducing a voltage in its secondary winding. This voltage is rectified by CR8 and filtered by C15.

Set-Point Reference:

Separate constant current references are provided for the voltage and current channels. The collector current of Q1 drives the voltage channel and the collector of Q2 drives the current channel. The +12V supply for circuitry under consideration is RC filtered with R8 and C10 to minimize noise feedthrough. The current sources are referenced by

The on-board jumper determines whether the remote turn-on circuitry is active. If the jumper is connected so that CR11 is pulled to ground, then the remote turn-on circuitry is not active. Alternatively, if the jumper connects pin 4 of U3 to ground, then this circuitry is active. With the internal LED of U3 not activated, Q4 is turned on, which shuts down the modulator through CR12 and Q5. Any event that activates the internal LED, allows the modulator to function and thus let power pass to the power supply output. The internal LED of U3 can be activated in two ways: (1) Application of external voltage (AC or DC) across TB1-15 and TB1-16; (2) Dry contact closure across TB1-16 and TB1-17.

With dry contact closure, the power is supplied by the relaxation oscillator consisting of T1,Q3 and associated components. Each time that Q3 conducts, it discharges C147 through the primary of T1, inducing a voltage in its secondary winding. This voltage is rectified by CR8 and filtered by C15.

Set-point Reference:

Separate constant current references are provided for the voltage and current channels. The collector current of Q1 drives the voltage channel and the collector of Q2 drives the current channel. The +15 supply for circuitry under consideration is RC filtered with R8 and C10 to minimize noise feedthrough. The current sources are referenced by the voltage across CR5, a temperature compensated zener diode. The current from each of the sources is adjustable to 1 mA by R3 and R5.

Modulator:

U8 perfroms all of the PWM functions. The industry standard UC1526A was chosen in this application. Extensive documentation is available along with numerous application notes. However, in this discussion, it is sufficient to recognize that its primary function is to convert the differential analog signal on pins 1 and 2 to a PWM signal on pins 13-15 and 16-15, designated CLK2 and CLK1. The reference input pin 1 is derived from the reference output pin, 18 and the voltage divider R72 and R73. The transconductance amplifier consisting of pins 1,2 and 3 (output) is configured as an inverting amplifier with a gain of 0.5. Soft Start capacitor C52 connected between pin4 and gnd. Oscillator frequency is set by C50, R66 and R75. R78 gives the required dead time between two consequent pulses. The digital control ports pin 5 and 8 are pulled low for shutting the PWM down. The oscillator frequency is set to 66KHz. The ref at pin 1 is pulled down low by average current limiting circuitry through CR35.

Voltage Control Channel:

Voltage control and error amplification are implemented by U6 and associated components. The non-inverting input is routed from the (+) sensing terminal TB1-2 (+V Rem) through R49, R50 and R52. The inverting input is routed from TB1-4 (V Amp In) through R51, C36 and R53. The signal at TB1-4 is the voltage reference set by a 1mA current that flows through the programming resistance R4 (in the normal mode of operation). The voltage amplifier compares the reference and sense voltages and amplifies the error with appropriate compensation for loop gain shaping. The R54, C40 feedback combination provides a pole-zero combination, with the pole at DC for best DC regulation. The R51, C36, R53 combination provides phase lead as required for overall loop stability.

R55 is an offset adjustment for zero nulling, and is set during calibration. 10 volts output implies the shutdown condition and -0.7V implies maximum pulse width at the PWM.

Current Control Channel:

Current control and error amplification are implemented by U5/2 and associated components. The non-inverting input is routed from the current shunt (+) sense terminal TB1-13 (Inv Amp In) through R45. The inverting input is routed from TB1-12 (I Amp In) through R44. The signal TB1-12 is the current reference set by a 1mA current that flows through the programming resistance R5 (in the normal mode of operation). The error amplifier U5/2 compares the reference and sense currents and amplifies the error, with appropriate compensation provided by R48 and C31. Offset adjustment is provided by R47 and is set during calibration.

The outputs of the voltage and current channels are "ORed" via diodes CR31 and CR27, and thus provide automatic crossover from current to voltage control, and vice versa. The U5/1 and Q10 combination ensures that the current channel output may never fall too far below the voltage output, thus reducing the transistion time at crossover.

Additional attenuation of the analog channels' output is provided by R64 and R65. Before the signal is fed to the input amplifier of the modulator.

Over Current Protection:

A measure of transformer primary current and switch current is available at J4-1 and J4-2. This signal is used at two places:

A: Average current limiting circuit
B: Peak current limiting circuit

Average Current Limiting Circuit:

This circuit is implemented using U7 and the associated components. If the average current from the switch exceed the threshold set by R63 and R62 U7 pin 7 integrates down to -0.7V. This limits the pulse width out of the PWM U8. In this operation Pin 1 of U8 is pulled low through CR35. CR36 prevents the pin 7 of U7 from going negative. This circuit activates when the switch current in the inverter exceeds 15 amps.

Peak Current Limiting:

This circuit activates when the switch current in the inverter exceeds 22 amps. The comparator U10 and associated components are used to implement this circuit. In the normal operation pin 1 of U10 should be 5V. If E2 jumper in installed the shut-down is permanent. In other words in order to reactivate the power supply the AC power has to be disconnected. In this mode of operation pin 5 and 8 are pulled low in order to achieve shut-down. If RC network is installed in place of E2 jumper the power supply goes in repetitive mode of operation. Bang control principal is used. The output current of the power supply will look triangular in this mode of operations. This circuit activates only in the fault condition like saturation of output-transformer or short circuit on the H-bridge etc...

Transistor Drive:

IXLD 4429, an industry standard for FET drives, is used to drive the H-Bridge. This buffer IC is chosen for its high peak current capability and high speed of operation. Extensive documentation is available for this part.

4.5 EMS 5.0 KW POWER SUPPLY SERIES

4.5.1 REFERENCE:

01-473-001	Main schematic 220 VAC input.
01-473-022	Main schematic 380 VAC input.
01-000-260	A200 Inverter Board.
01-000-275	A100 Board Schematic.
01-168-000	A300 Board line filter 220 VAC.
01-000-302	A300 board line filter 380VAC.

Input Power distribution - 220VAC Models: The input 3 phase 220VAC and ground enters the power supply at TB2, located on the rear of the power supply. The ground is connected to the chassis at the input. The 3 phases are connected to the bridge rectifier CR1, CR2, and CR3 via the line filter and circuit the breaker. The rectified DC is connected to C1 through the inrush current limiter circuit K1 and R1.

The raw DC bus is connected to the A200 Inverter boards, which consists of a set of switching transistors (IGBT's) configured as full bridge inverter.

Input Power distribution - 380 VAC models: This power supply requires a 3phase 5 wire system. The input is connected to TB2 located on the rear. The three phases are connected to CR1 via the circuit breaker and line filter. The rectified DC voltage is connected to the capacitive voltage divider of C1 and C2 through the inrush current limiter circuit K1 and R1.

Two full bridge inverters are connected to C1 and C2 (one across each capacitor) such that they see one half of DC bus voltage. R11 connects the junction of C1 and C2 to neutral for safe operation of the circuit.

The Inverter Board Circuit (01-000-260): The full bridge inverter uses IGBT's as switching elements. It is locally bypassed by C15 and C16. These capacitors deliver the pulse current of the inverter and help reduce the size of high frequency current loop. The leakage inductance induced spike is snubbed by C7, R7A and R7B. Every device has an antiparallel diode and RCD snubber to reduce the dV/dT across the device. T3 and T4 are used for sensing the current through the device and provide input to the current limit section of the control circuit.

C17 and C18 are used to ensure steady state Volt-second balance across the primary of the power transformer, this in turn prevents transformer saturation.

Output from the inverter boards is fed to the primary of the T1 transformer. The secondary of T1 is connected to a full wave high frequency Rectifier bridge. The rectified pulse width modulated DC is averaged by LC filter. The LC filter consists of L1, L2, C7, C8, C9 and C15. The combination of L2, C7, and R11 form a series resonant trap for the carrier frequency. C8 is a large electrolytic capacitor which provides very low transient impedance to the output of the power supply. C9 is a very low ESR metallized polycarbonate film capacitor with a very high resonant frequency. The film capacitor reduces the Voltage ripple in the output due to the ESR of electrolytic.

4.5.2 SIGNAL FLOW REFERENCE: 01-000-275 A100 Control Board.

All the control circuitry is located on the A100 control card. This board is powered by the secondary side of the T2 bias transformer, ±15 volts and ground for the control circuits is created on the board itself.

Function of the Control Card:

1) Reference Generation
2) CC/CV Control
3) Pulse width modulation circuit.
4) Remote Turn On circuit.
5) Supervisory Function.
6) Over current protection.
7) IGBT Drive Circuit.

4.5.2.1 SET POINT REFERENCE

Separate constant current references are provided for voltage and current channels. The collector current of Q1 drives the voltage channel and the collector current of Q2 drives the current channel. The +15 volts is RC filtered by R8 and C10 to minimize noise feedthrough. The current sources are referenced by the voltage across CR5, a temp. compensated zener diode. The current from each of the sources is adjustable to 1 ma by R3 and R5. These ref. current sources are terminated at TB1-3 and TB1-9 on the rear of the power supply.

4.5.2.2 CC/CV CONTROL

Voltage control and error amplification is implemented by U6 and its associated components. The reference is applied to the inverting terminal. R49 and R50 attenuate the output voltage to a 0-5 volts level for 0-100% of the output voltage. R51, R53, R54, C39, and C40 forms the compensation network for the Voltage Channel. The output of the V-channel amp. can be measured at TP1. It is 15 volts for shutdown condition and -0.7 volts for maximum pulse width.

Current control and error amplification are implemented by U8 and its associated components. The current is sensed using the shunt in the secondary side of high frequency power transformer. The reference is connected to the inverting terminal of U8. C29, C30, C31, R48, and R44 give the compensation for the current channel. The output of current channel amplifier can be measured at TP2 on A100 board.

The output is 15 volts for shutdown condition and -2.7 volts for maximum pulsewidth.

The output of voltage and current channels are "ORed" via diodes CR31 and CR27, and thus provide automatic crossover from current to voltage control and vice versa.

Additional attenuation of the analog channels output is provided by R67 and R68.

4.5.2.3 PULSE WIDTH MODULATION CIRCUIT

U15 performs all the PWM functions. The industry standard UC3526 was chosen in this application. Its primary function is to convert the differential analog signal on pins #1 and #2 to PWM signals on pin #16 and pin #13. The 5 Volts ref. is used on the A100 board for supervisory functions and for driving the input of the gate drive buffers U9, U10, U11 and U12. Digital control ports pin #5 and pin #8 are pulled low for any fault condition.

Pin #5 and Pin #8 can be pulled low by either Q5 in the supervisory circuit or by pin #1 of U13. U13 pin #1 is pulled low by the Average current limiting circuit.

4.5.2.4 REMOTE TURN ON CIRCUIT

As indicated on sheet 1 of the A100 schematic, Q3, T1, and C18 form a relaxation oscillator. The secondary of T1 is rectified to generate an isolated source for remote turn on applications. This rectified DC is connected to optocoupler U2 (LED side) through TB1 pins #16 and 17. The use of this circuit is explained on page 17 of this manual.

4.5.2.5 SUPERVISORY FUNCTIONS

Most supervisory functions are performed by U4 and its associated components. These functions include Under-voltage lockout, Over-voltage protection, Turn on delay, Mode detect, Remote turn on, and Over temperature shutdown.

In every fault condition Q5 is pulled low, pulling the digital shutdown ports low on U15.

1. UNDERVOLTAGE LOCK OUT

The unregulated side of "Housekeeping" power supply is an indirect measure of the AC input. This is sensed through R17 and R18. The voltage across R18 is compared against the 5 volt ref. from U15. When Input AC goes below 180VAC (for a 220VAC input supply) pin 7 of U4 goes high. That in turn switches Q5 on, creating a shutdown condition. The fault condition automatically clears when the input AC goes above 185VAC.

2. OVERVOLTAGE PROTECTION

The overvoltage trip set point is set by potentiometer R8 on the front panel. The actual output voltage is sensed by R26 and R27. U4-C has latching positive feedback, which requires removal of AC power for resetting after OVP has been activated. C23 provides the negative feedback which prevent the noise tripping of the latch. On activation of the OVP, Q5 and Q7 are turned on and , Q8 if present is fired, crowbaring the output.

3. INRUSH CURRENT LIMITING

K1 (relay coil), is controlled by Q9. R34, R35, R36, R37, C26 and U4-A control the base of Q9. When the main circuit breaker is turned on, Q9 is off and Q5 is on because the collector of Q9 is high. After the elapsed time, determined by C26 and R34, the output at pin #1 of U4-A goes high. This energizes K1 and releases Q5 simultaneously.

4. MODE DETECT

R38 and R39 sample the output voltage of U6 and U8. Depending upon the relative magnitude there outputs, U4-D integrates up or down (±15 Volts)
controlling the mode indicator LED's on the front panel.

5. REMOTE TURN ON

This feature allows the user to control the power supply from a remote location with either 12-24VDC or 24-115 VAC or dry contact closure. U2 provides the isolation form the power supply ground. When U2 is not activated Q4 is turned on which turn's on the Q5 and thus creating the shutdown of the power supply. The internal LED of U2 can be activated by A)Application of above mentioned voltages(AC or DC) across TB1-15 and TB1-16. B)Dry contact closure across TB1-16 and TB1-17.

With dry contact closure, the power is supplied by the relaxation oscillator consisting of T1, Q3 and associated components. Each time Q3 conducts it discharges C18 through the primary of T1, inducing voltage on the Secondary winding. This voltage is rectified by CR8 and filtered by C15.

4.5.2.6 OVER CURRENT PROTECTION

A measure of transformer primary current is available at J4-5 and 6 , and on J5-5 and 6. The filtered current signal is applied to two sections of the A100 board. The first one is Average Current Limit Circuit (AVCL), implemented using U7 and associated component. The second one is called Peak Current Shutdown Circuit (PCSC). The AVCL has a lower threshold, created by R87 and R63. When this threshold is exceeded the output of U7-C integrates down towards -0.7. This pulls down Pin #1 of U15 thereby reducing the pulse width such that the average current is not beyond the threshold value of 20 Amps.

When the output current from the inverter is higher than 24 Amps. U13 pulls pin #5 and pin #8 of U15 low, forcing a soft start of the whole circuit. This prevents all the catastrophic failure and reduces the downtime of the end user.

4.5.2.7 DRIVE CIRCUIT

IXLD4429, an industry standard FET drive DIP, is used to drive both bridges. This buffer IC is chosen for its peak current capability (6 amps.). In This application the buffer works like a level shifter.

SECTION 5

MAINTENANCE AND CALIBRATION

5.1 General:

A regularly scheduled preventative and corrective maintenance program isrecommended for the EMS series of power supplies. As a minimum, maintenance should consist of a thorough cleaning of the interior, and a visual inspection of components on the printed circuit boards, Even a relatively clean location requires at least one inspection every six months.

5.2 Inspection and Cleaning

Caution: Always unplug power supply from AC line before removing cover.

1. Remove ten 6-32 screws from both sides of side cover.
2. Cover can now be removed.
3. Check for loose wires, burn marks, etc.
4. A100 board can be withdrawn by removing the screw form each corner.
5. Remove dust from parts with a small, long bristled brush or use a air blower to remove the dust.

5.3 Calibration

Equipment required for calibration:

1. RMS Multimeter - 100V dc, 1000V ac e.g. Hewlett Packard HP 3465A)
2. VOM - (Simpson 260)
3. Load - equal to the output capability of the unit.

The calibration procedure that follows applies to a properly functioning unit. Any malfunction must be corrected before proceeding with calibration. It is necessary only to remove top cover to make these calibrations (see 5.2).

Caution: Hazardous voltages (up to 360V dc) are present during normal operation. Before removing the cover, the power source should be disconnected, and a period of 20 minutes allowed for the 34 discharge of storage capacitance.

5.3.1 Meter Zero Calibration

The zero set for both voltage and current front panel meters is located on the panel meters and is accessible at the front panel. Zero adjust should be performed with power removed.

5.3.2 Null Adjustments

A. The voltage control channel (U6) is nulled by adjusting R55 in the following manner:

1. Turn the VOLTAGE control completely counter clockwise and the CURRENT control completely clockwise.

2. Connect a load and a digital voltmeter across the output terminals.

3. Turn the power on.

4. Adjust R55 until the power supply output voltage starts to increase in the normal polarity. Reverse adjustment direction of R55 until the output voltage decreases to zero. Do not continue adjustment past this point.

5. Remove power.

B. The current control channel (U8) is nulled by adjusting R77 the following manner.

1. Turn the VOLTAGE control completely clockwise and the CURRENT control completely couter clockwise.

2. Connect a load or short circuit across the output terminals.

3. Connect a millivoltmeter across the current shunt sense terminals observing correct polarity.

4. Turn the power on.

5. Adjust R77 until the power supply output current startsto increase in the normal polarity. Reverse adjustment direction of R77 until the output current decreases to zero. Do not continue adjustment past this point.
6. Remove power.

5.3.2 Voltage and Current Source Adjustments

A. Voltage:

NOTE: This calibration is performed without a load.

1. Connect a voltmeter across the output terminals.

2. Turn the VOLTAGE and CURRENT controls completely counter-clockwise.

3. Turn the power on.

4. First turn the current, then the voltage channel completely clockwise.

5. Adjust the VCAL control R3 until the rated output voltage is reached. The front panel voltmeter should agree within 2%. If does not, check its zero adjustment or replace the meter.

6. Remove power.

B. Current:

NOTE: This calibration is performed with the output shorted.

1. Connect a millivoltmeter across the current shunt sense terminals, observing correct polarity.

2. Turn VOLTAGE and CURRENT control completely clockwise.

3. Turn the power on.

4. Adjust the ICAL control R5 until the current rating of the unit is achieved.

5. Remove power.

5.3.4 Ammeter Calibration

1. Connect the reference ammeter (with shunt as applicable) in series with the load or short circuit across the output terminals.

2. Turn the VOLTAGE control fully clockwise.

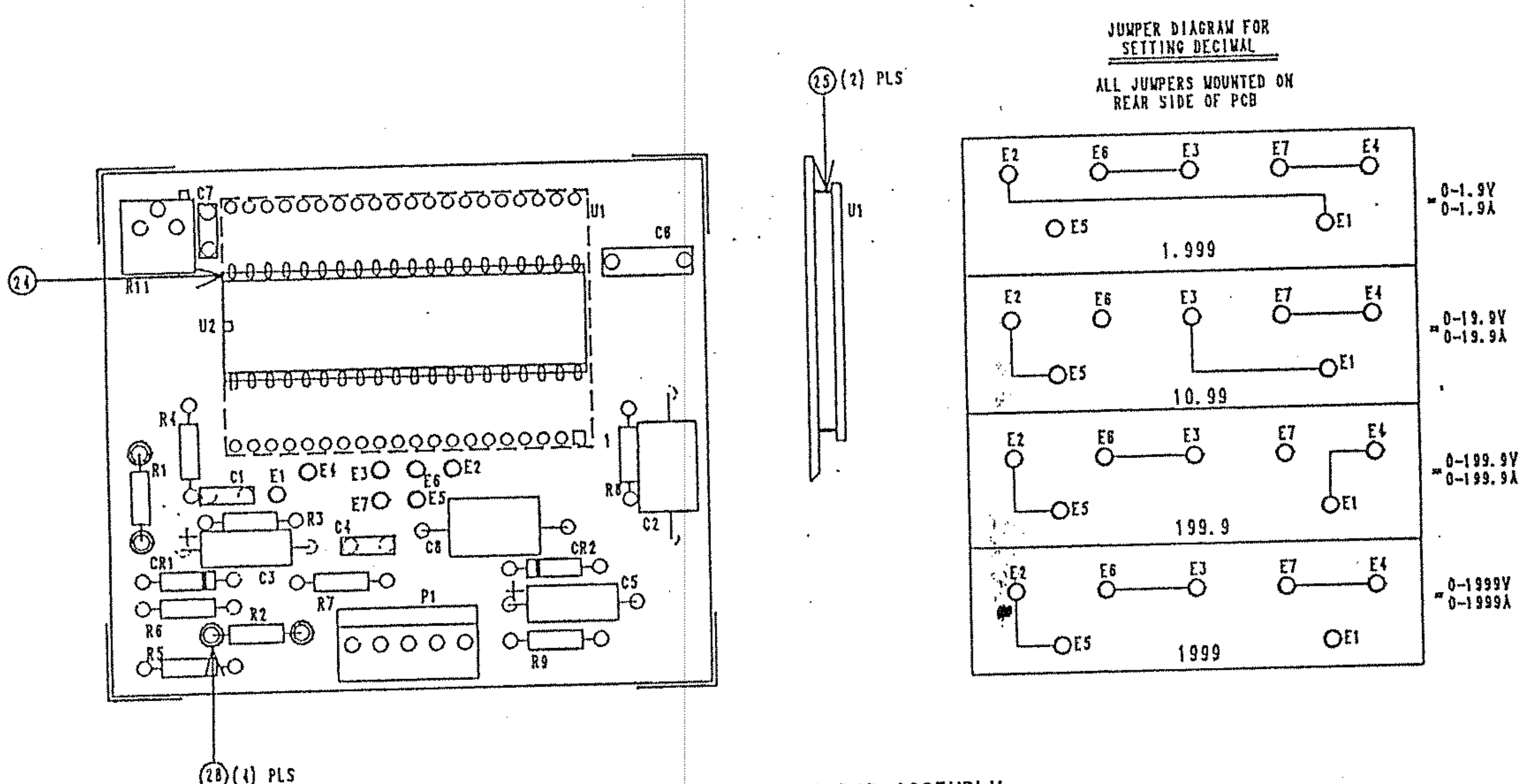
3. Check the zero adjustment of the front panel ammeter.

4. Turn the power on.

5. Adjust the CURRENT control so that the reference ammeter indicates full rated output current of the supply.

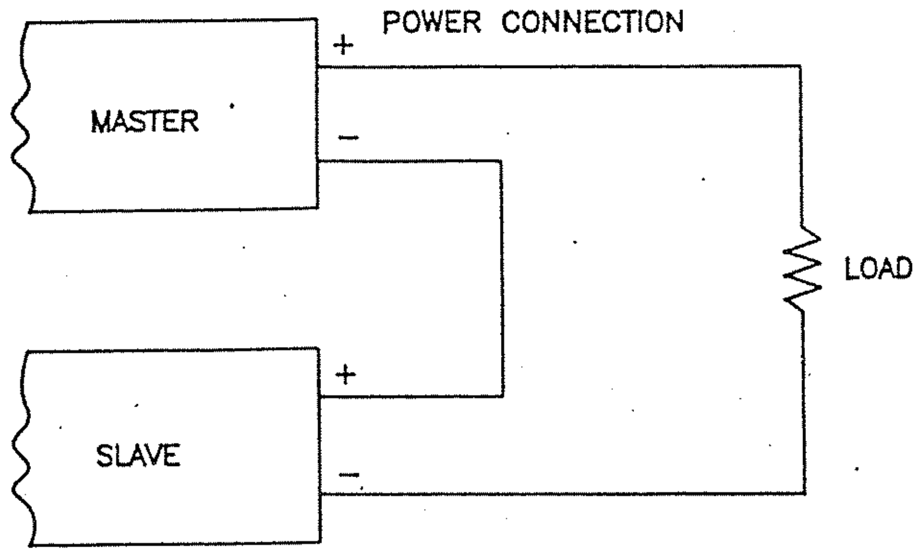
6. Adjust R7 (located just behind the front panel) until the front panel ammeter reading equals that of the reference ammeter.

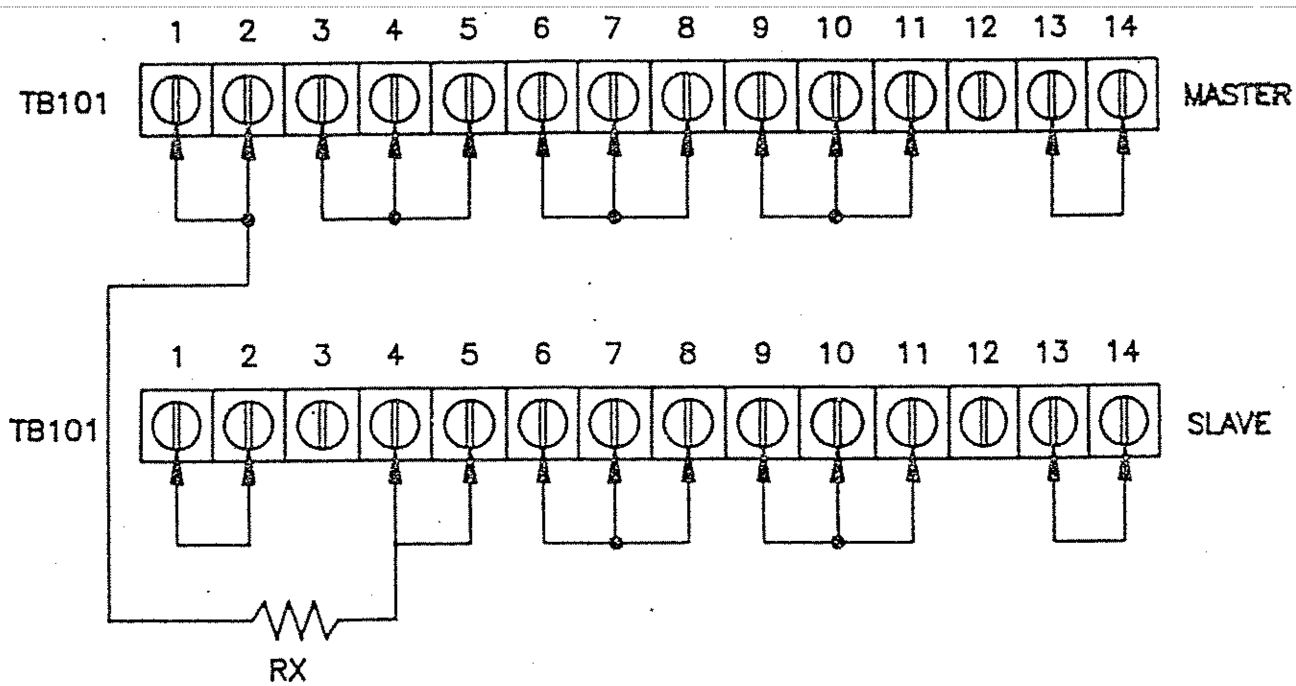
7. Remove power.



A100 PCB ASSEMBLY
E/M DIGITAL METER
SCALE: 2x1
20-160-000 REV.N

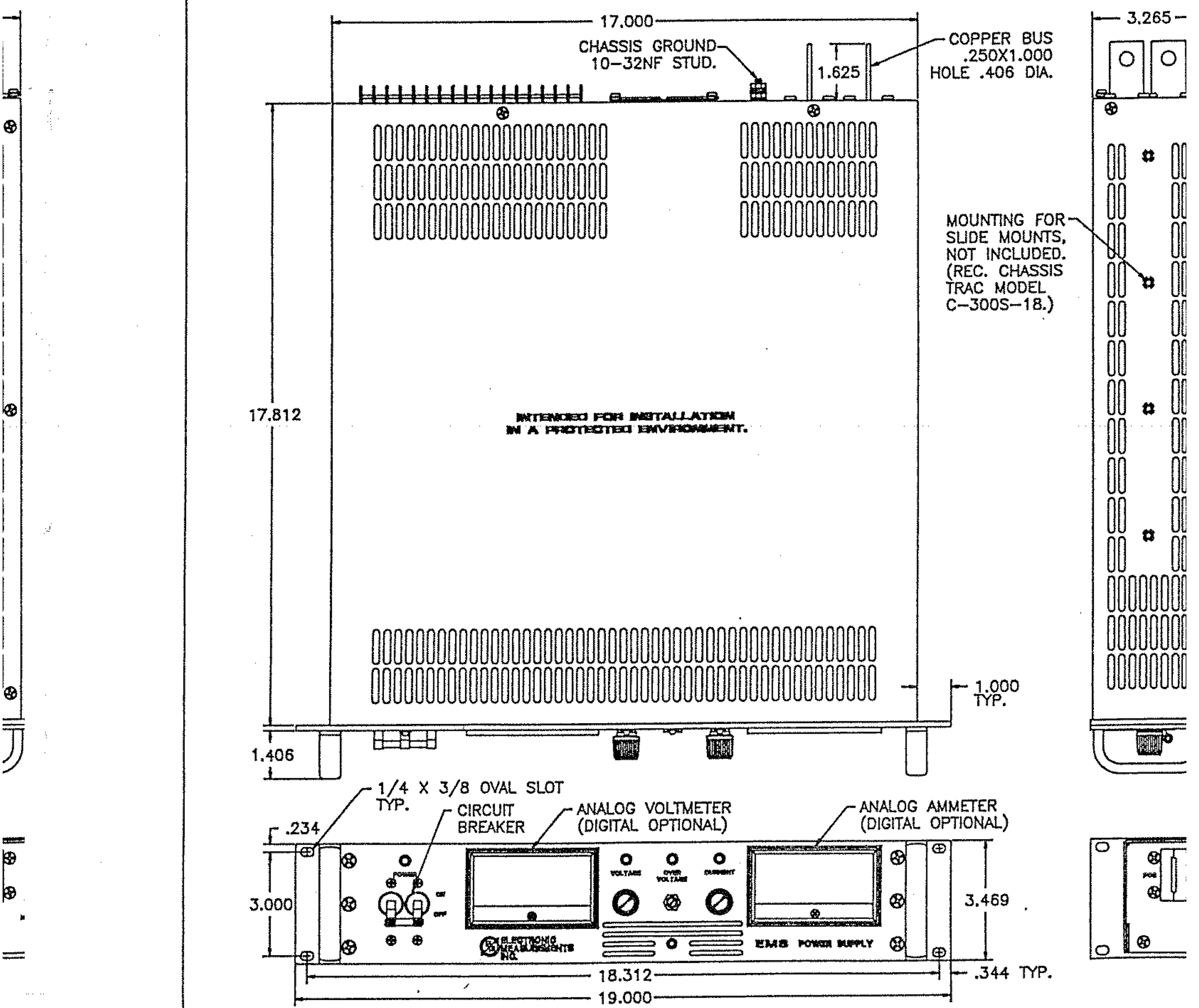
SERIES MASTER / SLAVE OPERATION
OF
EMI POWER SUPPLY



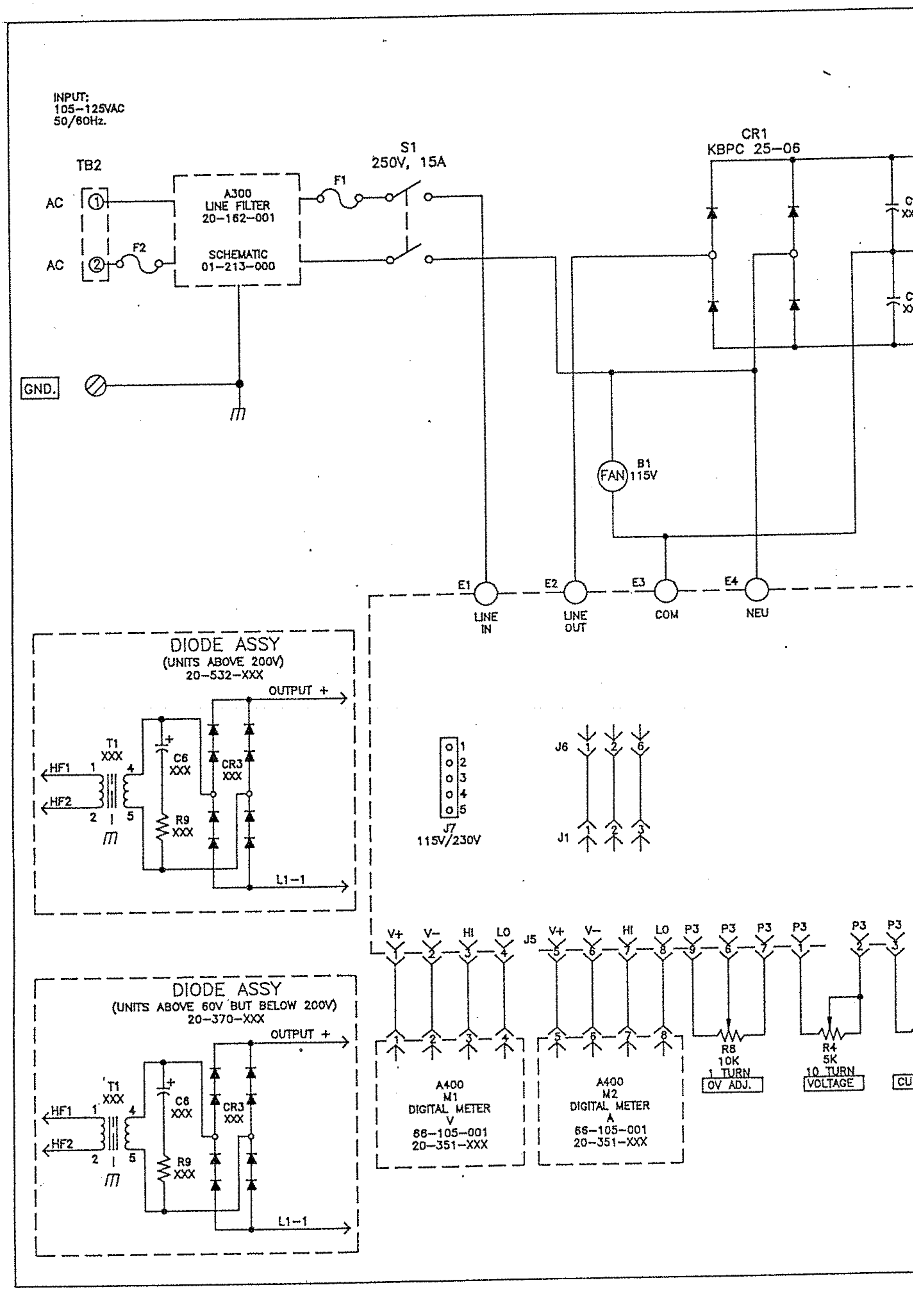


CONTROL TERMINAL CONNECTION.

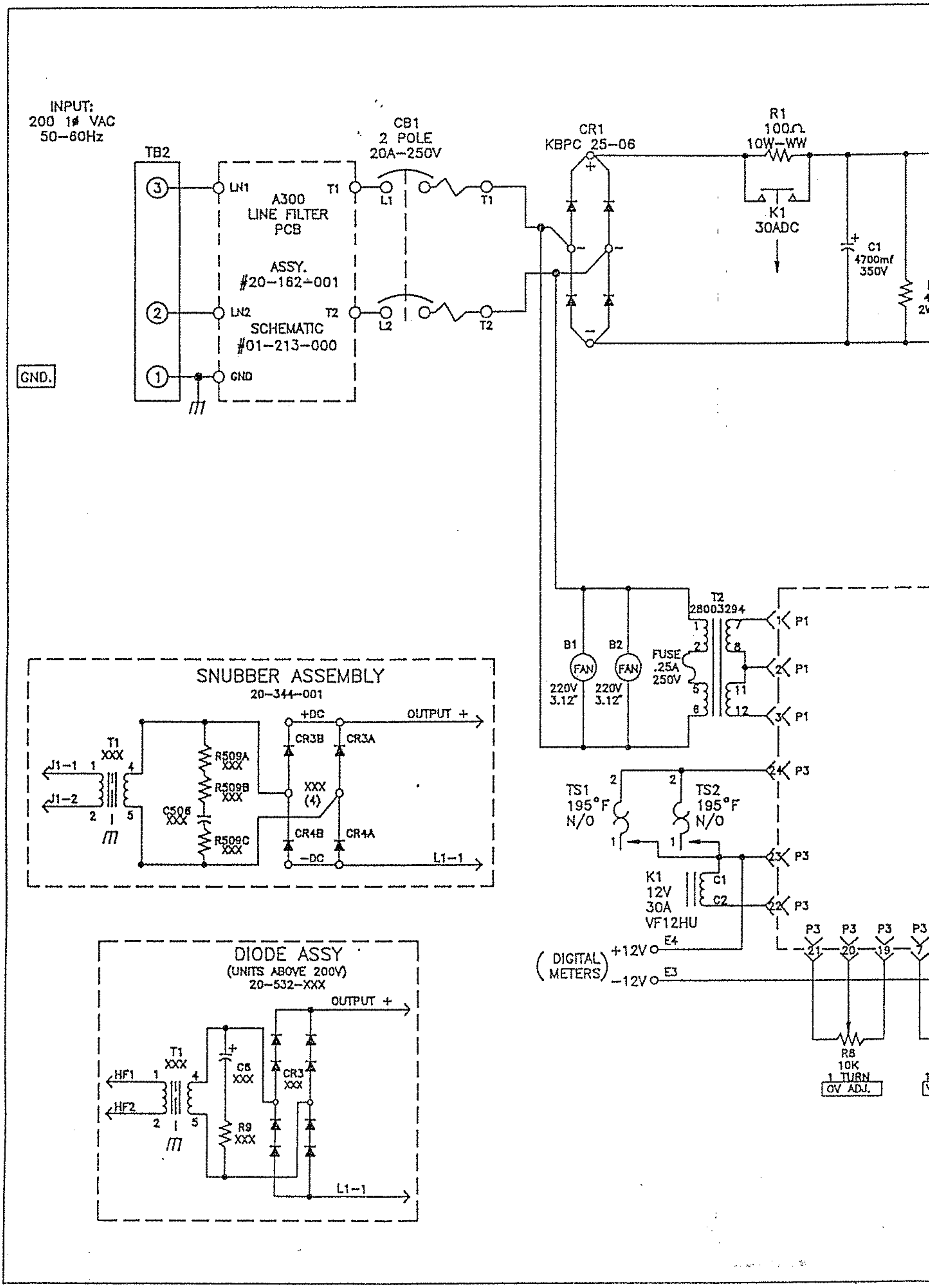
TO DETERMINE RX = [(SUM OF SUPPLY VOLTAGE OUTPUTS) (1000 OHMS)
SUBTRACT 5000 OHMS.
(SLAVE) VOLTAGE & CURRENT CONTROL FULL – CLOCKWISE

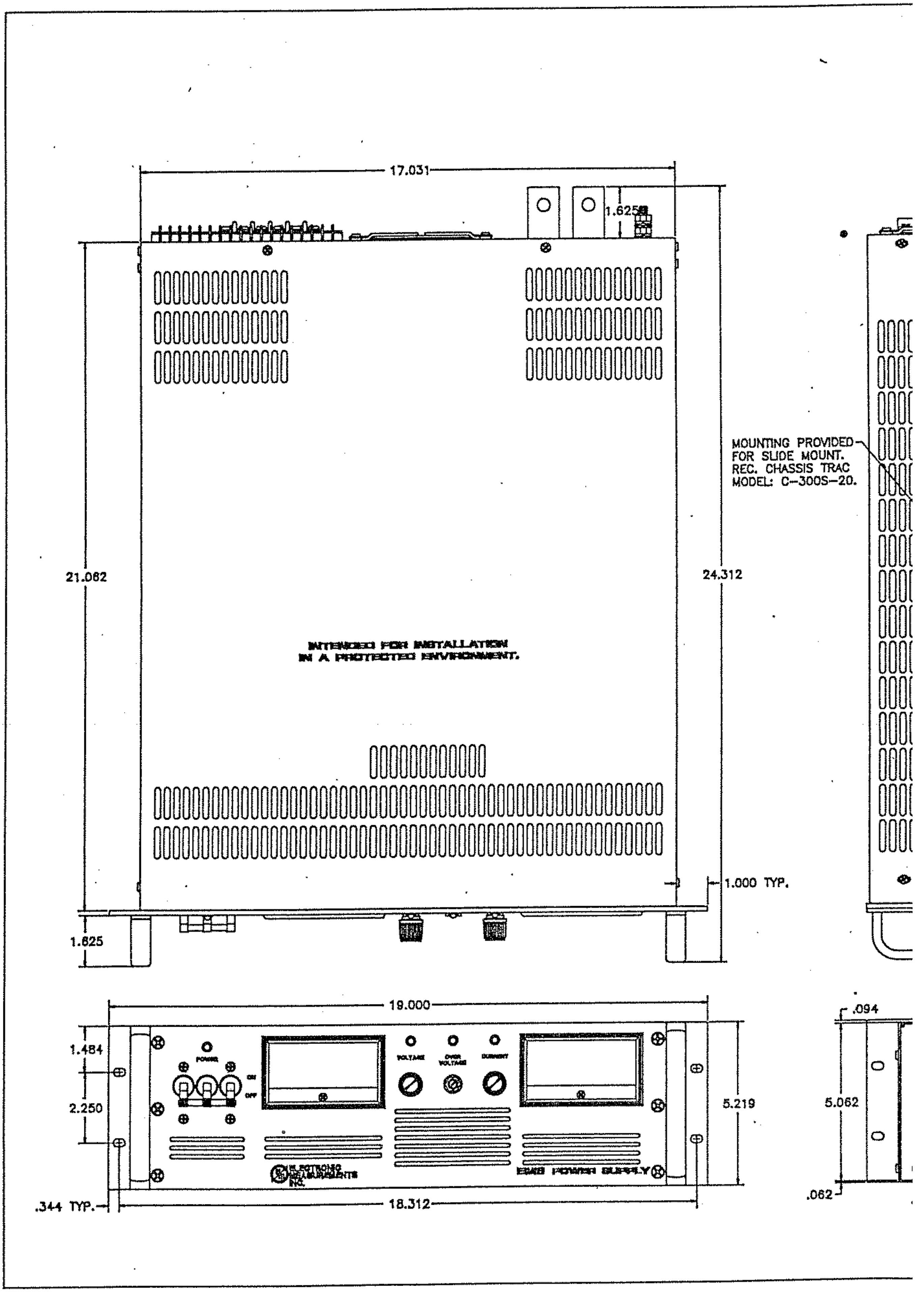


17.000
CHASSIS GROUND 10-32NF STUD.
1.625
COPPER BUS .250X1.000 HOLE .406 DIA.
3.265
MOUNTING FOR SLIDE MOUNTS, NOT INCLUDED. (REC. CHASSIS TRAC MODEL C-300S-18.)
17.812
INTENDED FOR INSTALLATION IN A PROTECTED ENVIRONMENT.
1.000 TYP.
1.406
1/4 X 3/8 OVAL SLOT TYP.
CIRCUIT BREAKER
ANALOG VOLTMETER (DIGITAL OPTIONAL)
ANALOG AMMETER (DIGITAL OPTIONAL)
.234
3.000
3.469
ELECTRONIC MEASUREMENTS INC.
EMS POWER SUPPLY
18.312
.344 TYP.
19.000

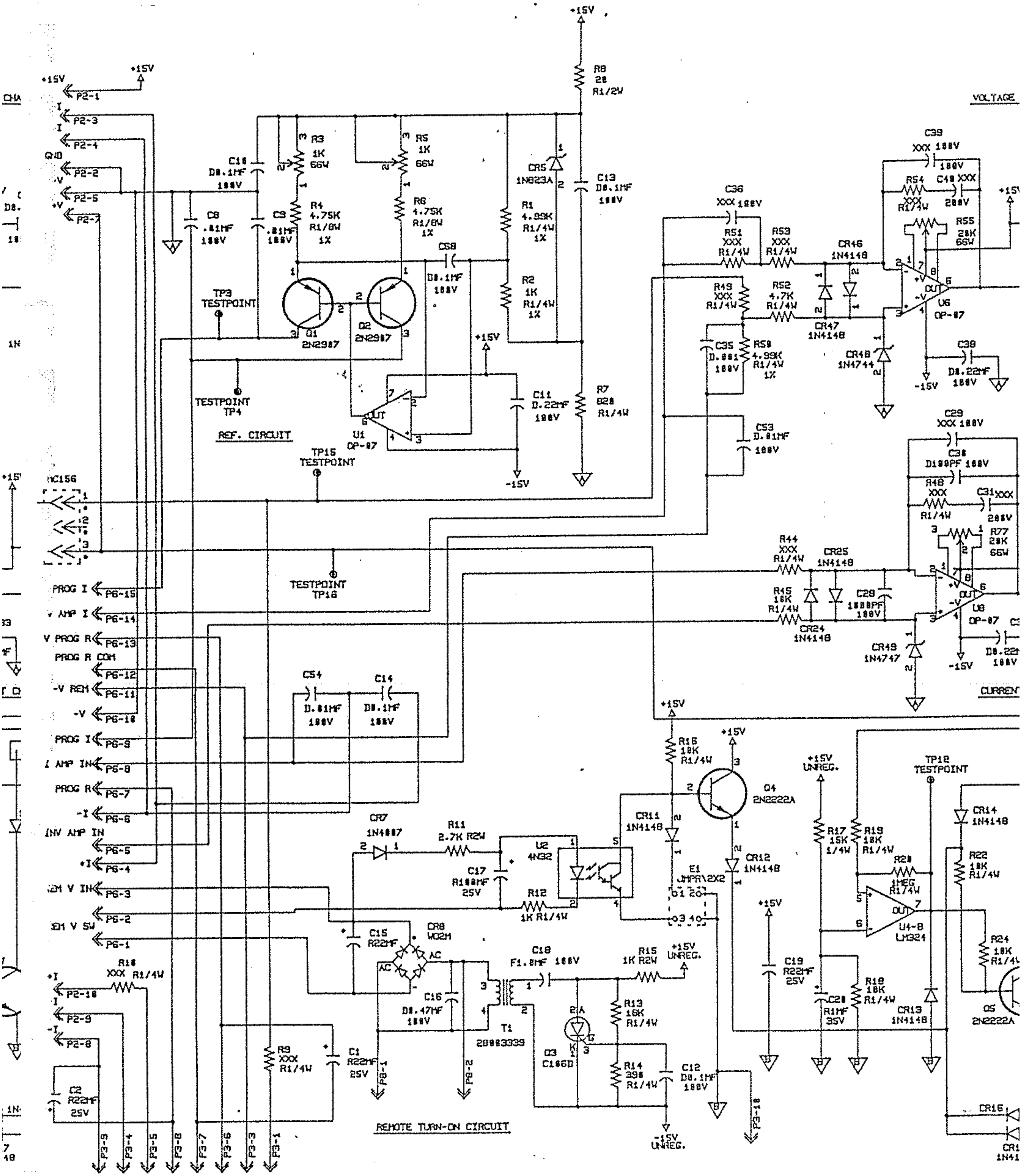


INPUT:
105-125VAC
50/60Hz.
TB2
AC
AC
F2
A300
LINE FILTER
20-162-001
SCHEMATIC
01-213-000
F1
S1
250V, 15A
CR1
KBPC 25-06
GND.
B1
115V
FAN
E1
LINE IN
E2
LINE OUT
E3
COM
E4
NEU
DIODE ASSY
(UNITS ABOVE 200V)
20-532-XXX
OUTPUT +
T1
XXX
HF1
HF2
C6
XXX
CR3
XXX
R9
XXX
L1-1
J7
115V/230V
J6
J1
DIODE ASSY
(UNITS ABOVE 60V BUT BELOW 200V)
20-370-XXX
OUTPUT +
T1
XXX
HF1
HF2
C6
XXX
CR3
XXX
R9
XXX
L1-1
V+
V-
HI
LO
J5
P3
A400
M1
DIGITAL METER
V
66-105-001
20-351-XXX
A400
M2
DIGITAL METER
A
66-105-001
20-351-XXX
R8
10K
1 TURN
OV ADJ.
R4
5K
10 TURN
VOLTAGE
R5
10Ω

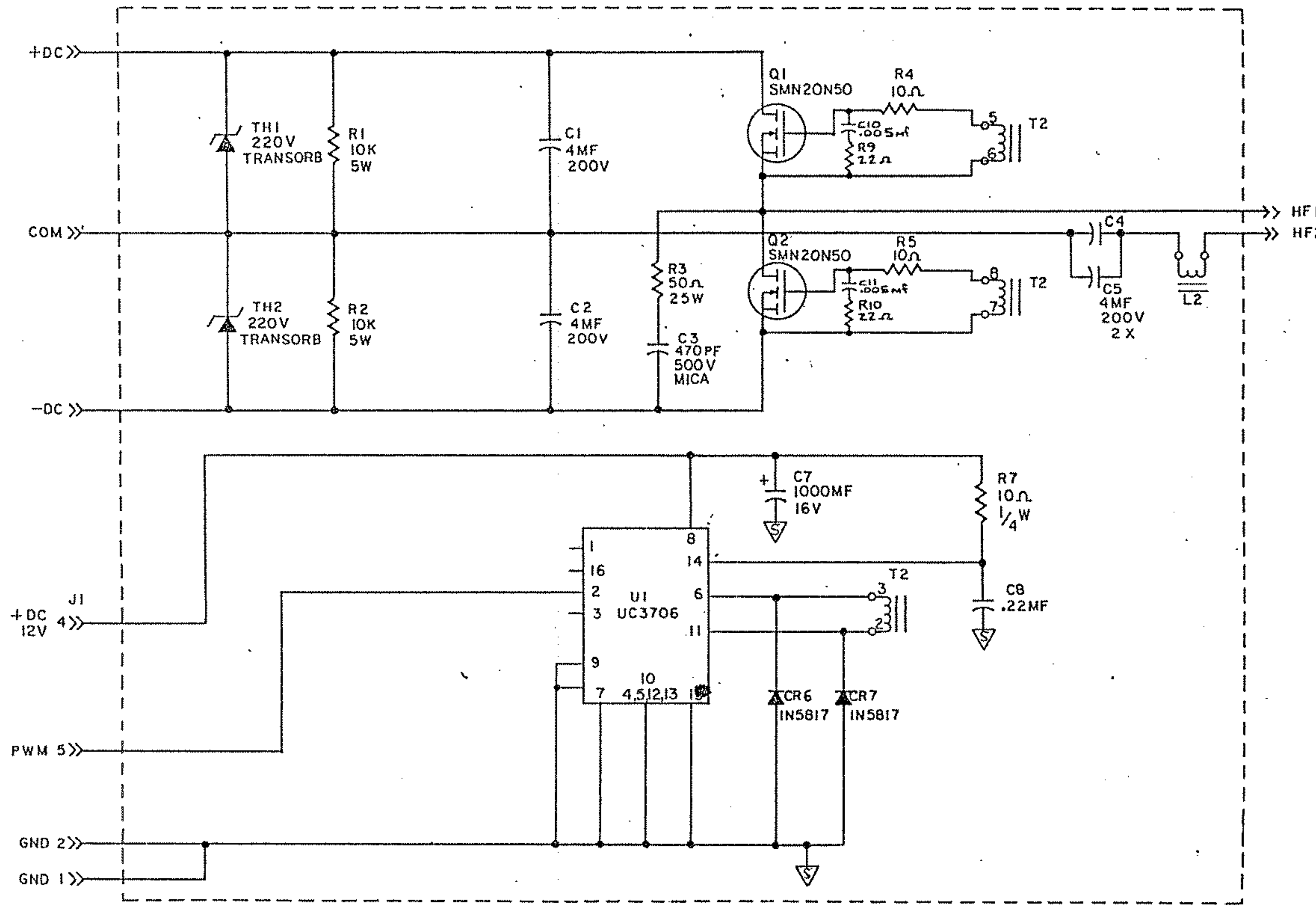

INPUT:
200 1ø VAC
50-60Hz
TB2
GND.
A300
LINE FILTER
PCB
ASSY.
#20-162-001
SCHEMATIC
#01-213-000
CB1
2 POLE
20A-250V
CR1
KBPC 25-06
R1
100Ω
10W-WW
K1
30ADC
C1
4700mf
350V
T2
28003294
B1
B2
FAN
220V
3.12"
FUSE
.25A
250V
P1
P3
TS1
195°F
N/O
TS2
195°F
N/O
K1
12V
30A
VF12HU
DIGITAL
METERS
+12V
E4
-12V
E3
R8
10K
1 TURN
OV ADJ.
SNUBBER ASSEMBLY
20-344-001
T1
XXX
J1-1
J1-2
R509A
R509B
R509C
C508
+DC
-DC
CR3B
CR3A
CR4B
CR4A
XXX
(4)
OUTPUT +
L1-1
DIODE ASSY
(UNITS ABOVE 200V)
20-532-XXX
HF1
HF2
C6
XXX
CR3
R9
OUTPUT +
L1-1



17.031
1.625
MOUNTING PROVIDED FOR SLIDE MOUNT. REC. CHASSIS TRAC MODEL: C-300S-20.
21.062
24.312
INTENDED FOR INSTALLATION IN A PROTECTED ENVIRONMENT.
1.000 TYP.
1.625
19.000
.094
1.484
2.250
5.219
5.062
EMS POWER SUPPLY
.344 TYP.
18.312
.062


REF. CIRCUIT
REMOTE TURN-ON CIRCUIT
VOLTAGE
CURRENT
+15V
-15V
R8 20 R1/2W
R3 1K 66W
R5 1K 66W
R4 4.75K R1/8W 1%
R6 4.75K R1/8W 1%
C10 D0.1MF 100V
C8 .01MF 100V
C9 .01MF 100V
CR5 1N823A
C13 D0.1MF 100V
R1 4.99K R1/4W 1%
R2 1K R1/4W 1%
C60 D0.1MF 100V
Q1 2N2907
Q2 2N2907
TP3 TESTPOINT
TESTPOINT TP4
U1 OP-07
C11 D.22MF 100V
R7 820 R1/4W
TP15 TESTPOINT
TESTPOINT TP16
C36 XXX 100V
R51 XXX R1/4W
R53 XXX R1/4W
CR46 1N4148
R49 XXX R1/4W
R52 4.7K R1/4W
CR47 1N4148
C35 D.001 100V
R50 4.99K R1/4W 1%
CR48 1N4744
C53 D.01MF 100V
C39 XXX 100V
R54 XXX R1/4W
C40 XXX 200V
R55 20K 66W
U6 OP-07
C38 D0.22MF 100V
C29 XXX 100V
C30 D100PF 100V
R48 XXX R1/4W
C31 XXX 200V
R77 20K 66W
R44 XXX R1/4W
CR25 1N4148
R45 10K R1/4W
CR24 1N4148
C28 1000PF 100V
U8 OP-07
CR49 1N4747
P2-1 P2-3 P2-4 P2-2 P2-5 P2-7
GND
PROG I P6-15
V AMP I P6-14
V PROG R P6-13
PROG R COM P6-12
-V REM P6-11
-V P6-10
PROG I P6-9
I AMP IN P6-8
PROG R P6-7
-I P6-6
INV AMP IN P6-5
+I P6-4
REM V IN P6-3
P6-2
REM V SW P6-1
C54 D.01MF 100V
C14 D0.1MF 100V
R16 10K R1/4W
Q4 2N2222A
CR11 1N4148
CR12 1N4148
E1 JMPR\2X2
CR7 1N4007
R11 2.7K R2W
U2 4N32
C17 R100MF 25V
R12 1K R1/4W
C15 R22MF
CR8 W02M
AC
C18 F1.0MF 100V
R15 1K R2W
+15V UNREG.
C16 D0.47MF 100V
T1 20003339
R13 10K R1/4W
Q3 C106B
R14 390 R1/4W
C12 D0.1MF 100V
-15V UNREG.
P8-1 P8-2
P3-10
R10 XXX R1/4W
P2-10 P2-9 P2-8
R9 XXX R1/4W
C1 R22MF 25V
C2 R22MF 25V
P3-9 P3-4 P3-5 P3-8 P3-7 P3-6 P3-3 P3-1
C19 R22MF 25V
R17 15K 1/4W
R19 10K R1/4W
R20 1MEG R1/4W
U4-B LM324
C20 R1MF 35V
R18 10K R1/4W
TP12 TESTPOINT
CR14 1N4148
R22 10K R1/4W
R24 10K R1/4W
CR13 1N4148
Q5 2N2222A
CR15

APPLICATION				LTR.	E.C.O. NO.	BY	APP.
DASH	USED ON	NEXT ASSY.	QTY.				



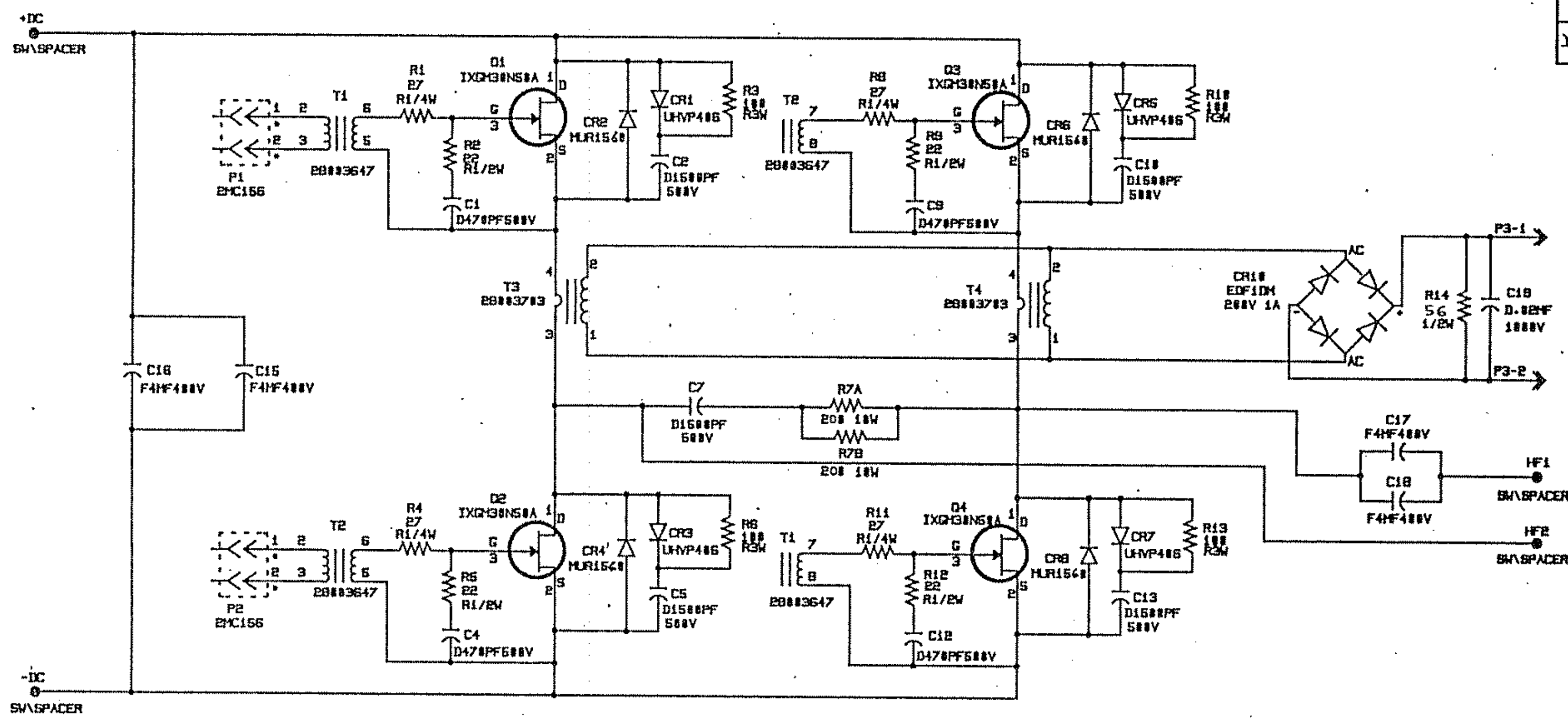
MTL:		DWN: REW	DATE: 1-17-89	ELECTRONIC MEASUREMENTS INCORPORATED
		CHK:	DATE:	TITLE: A200 INVERTER P/S 600W
FIN:	P/L: 473	ENG:	DATE: 1/21/89	
	SCALE:	APP:	DATE: 1/25/89	DWG. NO. 01-000-207 REV.

SHEET 1 OF 1

APPLICATION			
DASH	USED ON	NEXT ASSY.	QTY.
	EMS 2KW, 2.5KW	HEATSINK	1

LTR.	E.C.O. NO.	BY	APP.
A	ECO#10539 3/25/91	BM	

DWG. NO. 01-000-250 REV. A



NOTES:

1) UNLESS SPECIFIED, ALL RESISTORS ARE IN OHMS AND ARE 5%, CARBON FILM; ALL CAPACITORS ARE IN MICROFARADS. K=1,000 AND M=1,000,000.
2) REFERENCE ASSEMBLY DWG NO 20-442-000.
3) Q1 THRU Q4 MOUNT AT HEATSINK ASS'Y LEVEL.

EMS 2KW EMS 2.5KW

ELECTRONIC MEASUREMENTS INCORPORATED

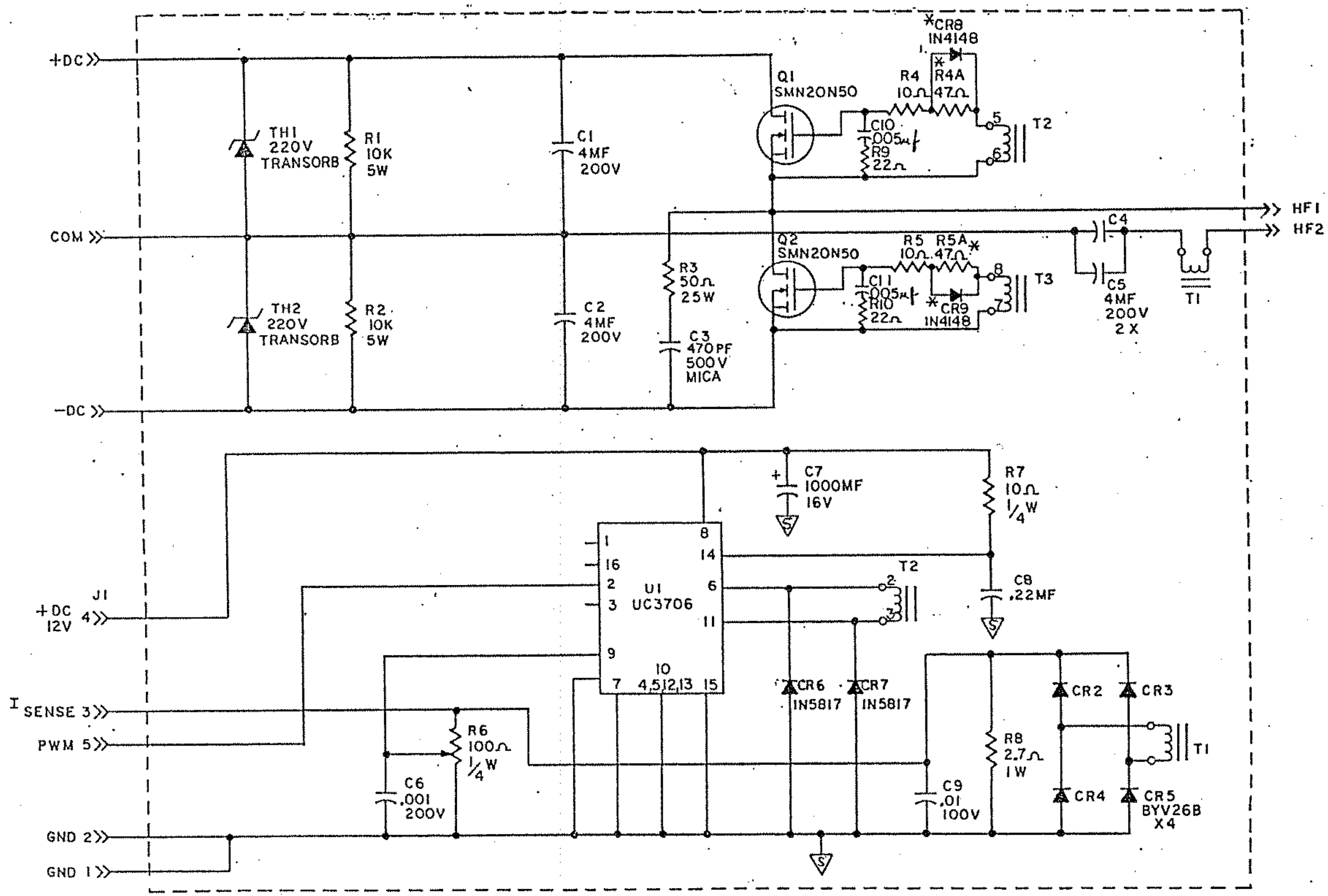
NTL:		DWN: GFS	DATE: 1-11-90
		CHK: KRW	DATE: 2-27-93
FIN:	P/L: 473	ENG:	DATE: 2-2-93
	SCALE: ~	APP:	DATE:

TITLE: AZON PCB SCHEMATIC INVERTER/FET EMS

DWG. NO. 01-000-250 REV. A

SHEET 1 OF 1

APPLICATION				LTR.	E.C.O. NO.	BY	APP.
DASH	USED ON	NEXT ASSY.	QTY.				



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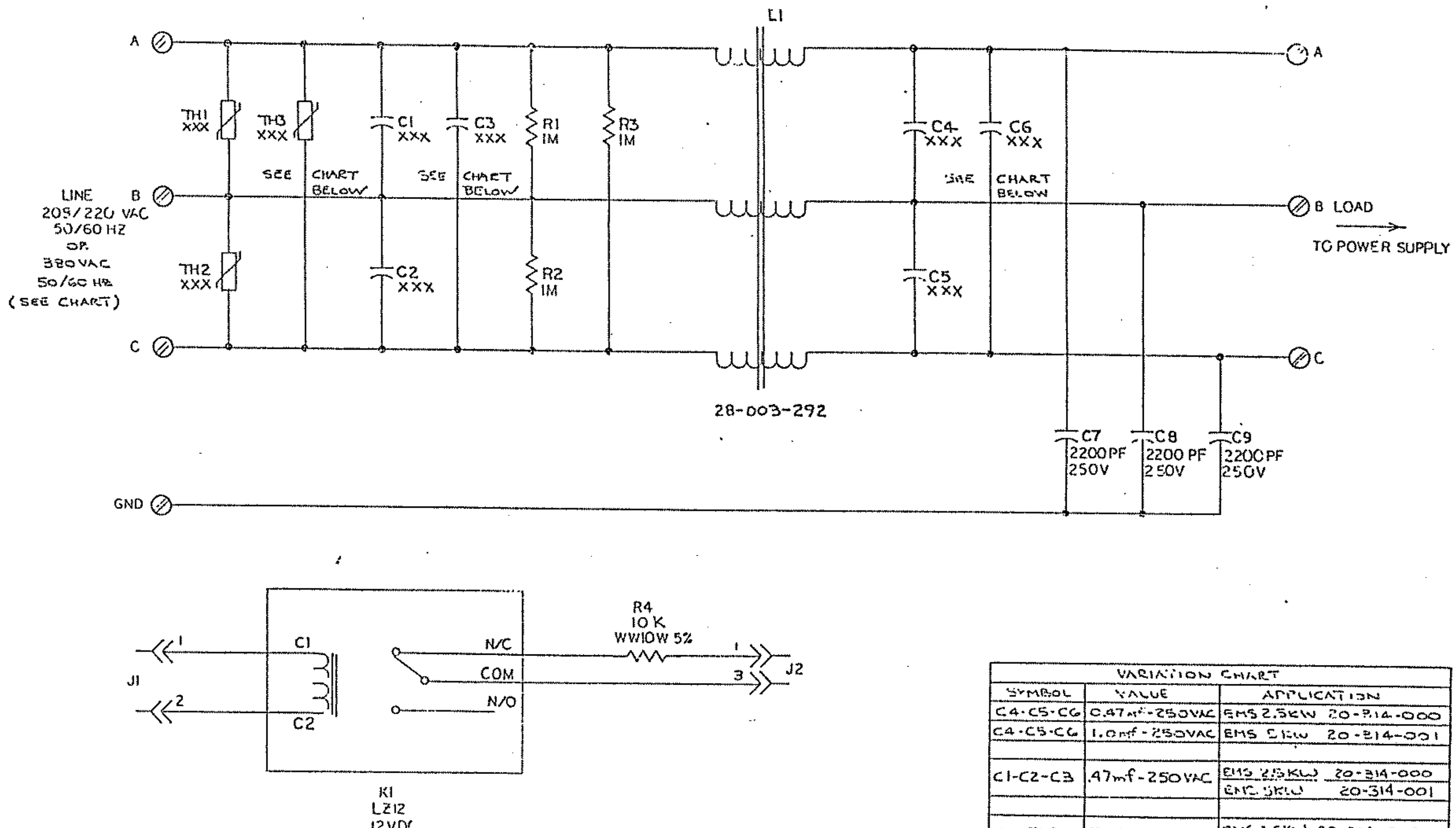
FIN:	P/L: 473	CHK:	DATE:	TITLE: A200 INVERTER EMS 300-3.5 1KW P/S
	SCALE:	ENG:	DATE: 1/25/89	DWG. NO. 01-000-208 REV.
		APP:	DATE: 1/25/89	SHEET 1 OF 1

APPLICATION		
USED ON	NEXT ASSY.	QTY.
EMS 2.5 KW	20-314-000	~
EMS 5 KW	20-314-001	~

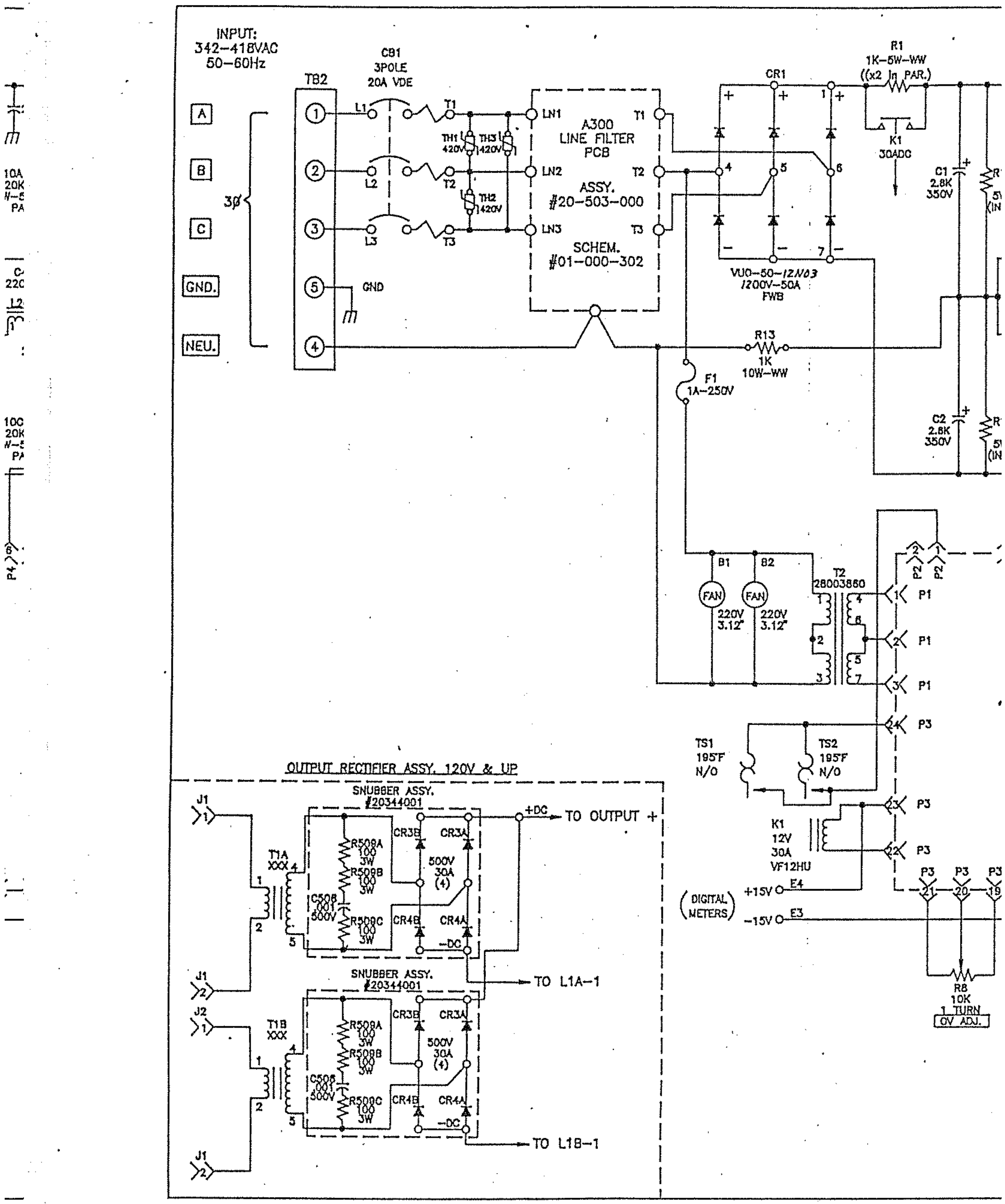
LTR	E.C.O. NO.	BY	APP.
A	TABUL FOR 380V LINE	REW	[illegible]
B	[illegible] 12-17-[illegible]	EM	[illegible]
C	ADD NOTES	GFS	[illegible]



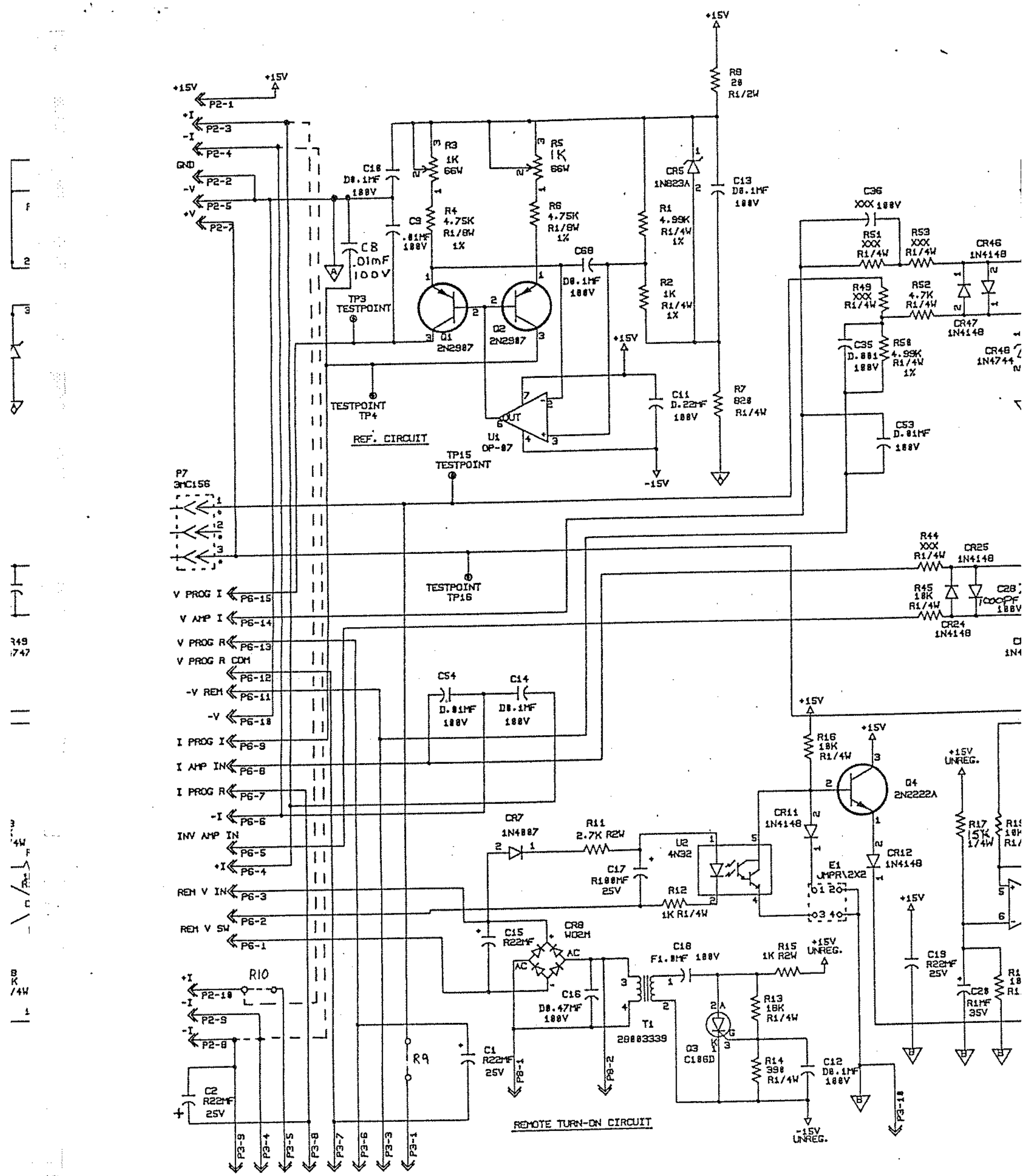
VARIATION CHART		
SYMBOL	VALUE	APPLICATION
C4-C5-C6	0.47mf-250VAC	EMS 2.5KW 20-314-000
C4-C5-C6	1.0mf-250VAC	EMS 5KW 20-314-001
C1-C2-C3	.47mf-250VAC	EMS 2.5KW 20-314-000 EMS 5KW 20-314-001
TH1-TH3	275V-2500A	EMS 2.5KW 20-314-000 EMS 5KW 20-314-001
TH1-TH3	420V-2750A	EMS 5KW 380V 20-314-002

EMSII 2.5KW & EMSII 5KW
EMS 2.5KW & EMS 5KW

MTL:	TOL: .XX = ± .02" .XXX = ± .005" ANGLES ± 1/2°	DWN: LC DATE: 9-23-86 CHK: GFS DATE: 8-24-87	ELECTRONIC MEASUREMENTS INCORPORATED
FIN:	P/L 473/485	ENG: [illegible] DATE: [illegible]	TITLE: SCHEMATIC EMS 3Ø A300 PCB ASSY SWITCHER



INPUT:
342-418VAC
50-60Hz
A
B
C
GND.
NEU.
3Ø
TB2
CB1
3POLE
20A VDE
L1
L2
L3
T1
T2
T3
TH1 420V
TH3 420V
TH2 420V
GND
LN1
LN2
LN3
A300
LINE FILTER
PCB
ASSY.
#20-503-000
SCHEM.
#01-000-302
CR1
VUO-50-12N03
1200V-50A
FWB
R1
1K-5W-WW
((x2 In PAR.)
K1
30ADC
C1
2.8K
350V
C2
2.8K
350V
R13
1K
10W-WW
F1
1A-250V
B1
B2
FAN
FAN
220V
3.12"
220V
3.12"
T2
28003860
P1
P2
P3
TS1
195°F
N/O
TS2
195°F
N/O
K1
12V
30A
VF12HU
DIGITAL
METERS
+15V
E4
-15V
E3
R8
10K
1 TURN
OV ADJ.
OUTPUT RECTIFIER ASSY. 120V & UP
SNUBBER ASSY.
#20344001
J1
J2
T1A
XXX
T1B
XXX
R509A
100
3W
R509B
100
3W
R509C
100
3W
C508
.001
500V
CR3B
CR3A
CR4B
CR4A
500V
30A
(4)
+DC
-DC
TO OUTPUT +
TO L1A-1
TO L1B-1



+15V
P2-1
+I
P2-3
-I
P2-4
GND
P2-2
-V
P2-5
+V
P2-7
R8
20
R1/2W
R3
1K
66W
R5
1K
66W
C10
D0.1MF
100V
C9
.01MF
100V
R4
4.75K
R1/8W
1%
R6
4.75K
R1/8W
1%
CR5
1N823A
C13
D0.1MF
100V
R1
4.99K
R1/4W
1%
R2
1K
R1/4W
1%
C8
.01mF
100V
C60
D0.1MF
100V
TP3
TESTPOINT
Q1
2N2907
Q2
2N2907
TESTPOINT
TP4
REF. CIRCUIT
U1
OP-07
OUT
C11
D.22MF
100V
R7
820
R1/4W
-15V
TP15
TESTPOINT
P7
3MC156
C36
XXX 100V
R51
XXX
R1/4W
R53
XXX
R1/4W
CR46
1N4148
R49
XXX
R1/4W
R52
4.7K
R1/4W
CR47
1N4148
C35
D.001
100V
R50
4.99K
R1/4W
1%
CR48
1N4744
C53
D.01MF
100V
TESTPOINT
TP16
R44
XXX
R1/4W
CR25
1N4148
R45
10K
R1/4W
CR24
1N4148
V PROG I
P6-15
V AMP I
P6-14
V PROG R
P6-13
V PROG R COM
P6-12
-V REM
P6-11
-V
P6-10
I PROG I
P6-9
I AMP IN
P6-8
I PROG R
P6-7
-I
P6-6
INV AMP IN
P6-5
+I
P6-4
REM V IN
P6-3
P6-2
REM V SW
P6-1
C54
D.01MF
100V
C14
D0.1MF
100V
R16
10K
R1/4W
Q4
2N2222A
CR7
1N4007
R11
2.7K R2W
C17
R100MF
25V
R12
1K R1/4W
U2
4N32
CR11
1N4148
CR12
1N4148
E1
JMPR\2X2
R17
15K
1/4W
+15V UNREG.
C15
R22MF
CR8
W02M
AC
C16
D0.47MF
100V
C18
F1.0MF 100V
R15
1K R2W
+15V UNREG.
T1
20003339
R13
10K
R1/4W
Q3
C106D
R14
390
R1/4W
C12
D0.1MF
100V
C19
R22MF
25V
C20
R1MF
35V
-15V UNREG.
R10
P2-10
P2-9
P2-8
C2
R22MF
25V
R9
C1
R22MF
25V
P8-1
P8-2
P3-10
REMOTE TURN-ON CIRCUIT
P3-9
P3-4
P3-5
P3-8
P3-7
P3-6
P3-3
P3-1