

INSTRUCTION MANUAL FOR

**TCR 1 PHASE
POWER SUPPLY**

83-470-001 Revision E

MODEL _____
SERIAL NUMBER _____

LAMBDA EMI

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TCR 1 Phase OPERATION SYSTEM MANUAL
Table of Contents

I	GENERAL INFORMATION	PAGE
	1.1 Introduction	1
	1.2 Specifications	1
II	INSTALLATION	
	2.1 Initial Inspection	4
	2.2 Power Requirements	4
	2.3 Cooling	5
	2.4 Mechanical	5
III	OPERATION INSTRUCTION	
	3.1 Turn-On Check Out Procedure	6
	3.1.1 Over Voltage Output	7
	3.2 General Operation	7
	3.3 Modes of Operation	8
	3.3.1 Normal Operation	8
	3.3.2 Remote Sensing	9
	3.3.3 Remote Programming	10
	3.3.4 Remote Programming by External Resistance	10
	3.3.5 Remote Programming by External Voltage	11
	3.3.6 Remote Programming by External Current	12
	3.3.7 Parallel Operation	13
	3.3.8 Parallel Operation-Master/Slave	14
	3.3.9 Series Operation	15
	3.3.10 Remote Meters	19
IV	PRINCIPLES OF OPERATION	
	4.1 General	16
	4.2 Power Flow	16
	4.3 Signal Flow	17
	4.4 SCR Firing Circuit	18
	4.5 Metering and Auxiliary Functions	19
V	MAINTENANCE AND TROUBLESHOOTING	
	5.1 General	20
	5.2 Inspection and Cleaning	20
	5.3 Calibration	20
	5.3.1 Voltage and Current Source Adjustments	20
	5.3.2 Firing Balance	21
	5.4 Troubleshooting	21
	5.4.1 Overall Troubleshooting Procedure	22

5.4.2	Troubleshooting Chart	22
5.4.3	Overvoltage Troubleshooting	24
5.5	Diode Replacement	24

LIST OF ILLUSTRATIONS

FIGURE 1:	Front Panel Control and Indicators
FIGURE 2:	Normal Operation
FIGURE 3:	Remote Sensing
FIGURE 4:	Remote Programming by External Resistance, Voltage Mode
FIGURE 5:	Remote Programming by External Resistance, Current Mode
FIGURE 6:	Remote Programming by External Voltage, Voltage Mode
FIGURE 7:	Remote Programming by External Voltage, Current Mode
FIGURE 8:	Remote Programming by External Current, Voltage Mode
FIGURE 9:	Remote Programming by External Current, Current Mode
FIGURE 10:	Parallel Operation - Master / Slave
FIGURE 11:	Parallel Connection - Master / Slave

APPLICATIONS NOTE

MEMORANDUM TO USERS OF E/M POWER SUPPLIES IN RACK INSTALLATIONS

All E/M power supplies have been designed and tested to provide full rated current and voltage throughout the specified line voltage range at the rated ambient air temperature. To achieve this maximum rating, airflow as provided by the internal fans, proportioned and directed by chassis openings and internal partitions, must not be impeded. It is not required but is desirable to prevent blocking air openings on the top of the supply.

On 3 Phase supplies air enters the unit on the right-hand side at the location of the fans and is transferred through the supply in a horizontal direction toward the left. Airflow is reduced any time there is a negative pressure at the air inlet or positive pressure at the air outlet. Each fan is capable of providing 100 to 300 cubic feet per minute airflow (CFM) at zero static pressure. The supply itself produces some restrictions to this flow so that approximately 80% of the airflow is available. As static pressure increases, caused by additional restriction of airflow external to the power supply, the efficiency of the fans drops significantly and airflow is greatly reduced. This reduction in airflow causes a substantial increase in internal temperatures of the supply, frequent thermostat shut down and reduced power supply reliability.

On 1 Phase TCR power supplies, air enters the sides of the power supply and is exhausted out the rear. On the EMS series, air enters the unit by means of slots in the front panel and along the sides and exits primarily from the rear. The same airflow considerations as previously discussed are still applicable.

Ideally, when power supplies are mounted in a rack, the rack should have no sides or rear covers. Since this is usually not practical or safe, the installer must consider the effect of any enclosure on power supply airflow. Since the power supplies are heavy, they must be supported by some sort of rail along the sides of the supply, front to rear. This rail must be chosen for proper strength but must not be either too close to or extend up too far along the side of the supply or airflow will be blocked. To minimize vertical height use an angle iron of substantial cross section and unequal leg dimension. Do not support the power supply from the front panel only in an attempt to minimize this problem. The rail does not need to be continuous from front to back to support but for safety and ease of installing and removing the supply it usually is.

Most commercial racks are available with louvered side panels and doors. Side panels are also available with an external depth which provides an additional plenum space on each side of the rack for improved airflow.

Burn-in systems impose two additional considerations for power supply installation. The supply rack is often placed next to the oven and is sometimes integral with the oven. The thermal insulating qualities of the oven both through conduction, convection and radiation can impact substantial heat to the power supply rack and subsequently to the power supplies. If it is possible, separate the supply rack from the oven by a combination of space, insulation, reflective surfaces or moving air.

The ambient in burn-in rooms, especially in tropical climates can also be very hot. Frequently high humidity is also present. This situation, while not ideal for power supply longevity, should itself cause little difficulty. When combined with insufficient airflow, however, it can significantly affect power supply reliability and the usable output current capability of the power supply.

The rack must exchange with ambient temperature air the same number of CFM as the power supplies circulate or the power supply exhaust air will be recirculated many times resulting in a continuously rising temperature until some elevated thermal equilibrium is reached. Each 3 1/3" fan in the system transfers 40 CFM while each 4 5/8" fan moves as much as 140 CFM. Air must be exchanged from outside to inside to outside the rack at a CFM value equal to the sum of the CFM ratings of all of the fans in all of the power supplies. In addition, this transfer must be accomplished in such a way as to not impede each power supplies' internal airflow. When figuring out how to accomplish this in any given installation, consider any action which would tend to increase air pressure at air inlet points is beneficial to supply cooling.

I GENERAL INFORMATION

I.1 DESCRIPTION

This manual contains operation and maintenance instructions covering the Electronic Measurements, Inc. series of Single Phase TCR controlled power supplies. These supplies are constant voltage/constant current automatic crossover sources of regulated dc power. They are packaged in three different size rack enclosures.

I.2 SPECIFICATIONS

The following specification describes the operational characteristics of this series of power supplies. All units are shipped with AC barrier strip located on the back of the unit.

Available Rating Sizes:	600W, 1000W, 1800W, 2600W
AC Input:	600W - 115 +/- 10% 47-63 Hz
	1000W - 115 +/- 10% 47-63 Hz
	1800W - 115 +/- 10% 47-63 Hz
Note: All above units have an optional input of 208/220 +/- 10%, 47-63 Hz.	
	2800W - 208/220 +/- 10% 47-63 Hz

(See rating and additional specifications chart, on page 3, for line current at the nominal input voltages)

I.2.1 REGULATION

Constant voltage mode: Variations in output current from 5 to 100% of maximum rating cause output voltage variations of less than 0.1% of the output voltage setting when output is 50 to 100% of the maximum rating. Below 50% output voltage, output variation will not exceed 0.05% of maximum output.

Constant current Mode: Variations in output voltage from 5 to 100% of maximum rating cause output current variations of less than 0.1% of the output voltage setting when output is 50 to 100% of the maximum rating. Below 50% output current, output variation will not exceed 0.05% of maximum output.

Ripple: Measured with either positive or negative grounded, maximum output voltage and full current into a resistive load. (See Rating Chart) At 50Hz AC input ripple is 30% above 60Hz ratings.

Stability: The output voltage or current will remain within $\pm 0.05\%$ for 8 hours after warm-up, with constant line, load and temperature.

Transient Response: A 30% step increase in power demanded by the load will cause a transient in the regulated output which will typically recover to within 2% of final value within 75ms.

Temperature Coefficient: Output voltage T.C. is 0.02%/°C of maximum rating. Output current T.C. is 0.03%/°C of maximum rating.

Operating Temperature: 0 to 40°C with no derating required. Consult factory for output rating at higher temperatures.

Storage Temperature: -40 to +85°C.

I.2.2 GENERAL

Resolution: The voltage control is a ten turn potentiometer. The current control is a one turn cermet type potentiometer.

Indicators: Voltmeter, ammeter and mode of operation indicator lights. The meters are available either as analog or digital at no additional cost.

Controls: Circuit breaker on-off control voltage and current controls.

Cooling: All units are fan cooled and thermostatically protected. Air enters at sides of unit and exits at the rear. Consequently, no heat will be applied to other equipment above or below the power unit.

<u>Size:</u> 600W and 1000W	3 1/2" x 19" x 18 1/2" (89mm x 483mm x 471mm)	58 pounds 27 Kg
1800W	5 1/2" x 19" X 18 1/2" (140mm x 483mm x 471mm)	85 pounds 39 Kg
2800W	7" x 19" x 18 1/2" (178mm x 483mm x 471mm)	150 pounds 68.2 Kg

RATING AND ADDITIONAL SPECIFICATIONS					
VOLTAGE	CURRENT (AMPS)	CV-RMS RIPPLE	CC-RMS RIPPLE	% EFF (NOMINAL)	AC INPUT CUR @ @ NOM. AC INPUT
0 - 7.5	70	80mV	640mA	62	10
	115	75mV	1000mA	63	15
	200	80mV	1920mA	65	30
	300	80mV	2990mA	66	25
0 - 10	50	80mV	320mA	65	10
	90	75mV	600mA	65	15
	165	80mV	1200mA	68	30
	240	80mV	1680mA	69	25
0 - 20	30	80mV	100mA	67	10
	50	60mV	120mA	67	15
	90	80mV	320mA	70	30
	135	80mV	480mA	73	25
0 - 40	15	100mV	33mA	68	10
	25	60mV	60mA	68	15
	45	100mV	100mA	75	30
	70	100mV	150mA	80	25
0 - 60	10	120mV	18mA	70	10
	18	70mV	15mA	70	15
	30	90mV	39mA	81	30
	45	90mV	60mA	81	25
0 - 80	8	150mV	11mA	75	10
	13	80mV	10mA	77	15
	23	120mV	30mA	83	30
	34	100mV	35mA	82	25
0 - 150	4	300mV	6mA	80	10
	7	150mV	5mA	80	15
	12	200mV	13mA	84	30
	18	200mV	20mA	84	25
0 - 300	2	500mV	3mA	84	10
	3	250mV	3mA	85	15
	6	300mV	5mA	87	30
	9	300mV	8mA	85	25
0 - 600	1	1000mV	2mA	87	10
	1.6	700mV	2mA	87	15
	3	700mV	4mA	88	30
	4.5	750mV	5mA	85	25

II INSTALLATION

II.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 problems.

NOTE: If any damage is found, follow the "Claim for Damage in Shipment" instruction in the warranty section of this manual.

II.2 POWER REQUIREMENTS

A suitable source of AC power is required for this supply. The unit will operate on 50 or 60Hz line frequency. The line impedance from the power source should be fairly low since high peak currents are drawn. The service rating and connecting wire AWG size is in the table shown below. Note that this rating is not the actual specified line current, but a slightly higher service rating.

UNIT	120 VOLTS SERVICE RATING	AWG #	220 VOLTS SERVICE RATING	AWG #
600 W 800 W	20 A	12	10 A	16
1800 W	30 A	10	20 A	14
2800 W	NOT AVAILABLE	10	30 A	12

Load line power runs should be made with conductor size to match the current ratings of the supply. The following chart may be helpful in determining the proper size.

CURRENT Amps	RECOMMENDED AWG #
200	4/0
150	2/0
100	0
80	3
70	4
50	6
40	8
30	10
15	14
10	16
8	18
6	20
LESS	20

II.3 COOLING

Each power supply enclosure is cooled by a suitable sized blower fan exhausting warm air to the rear. Fresh air intake is from each side. None of the surfaces of the supply radiates heat to adjacent equipment. At least five inches of space should be allowed behind the supply and one inch along each side in the vicinity of the air inlet holes for unimpeded air flow.

II.4 MECHANICAL

The supply is capable of being rack or bench mounted. Horizontal mounting is preferred. However mounting in any position is allowed. For rack mounting, additional support other than that provided by the front panel is required, except for short term stationary mounting. Angle iron slide in mounting support or cross beam member support are required for permanent mounting. The sides of each supply are equipped with mounting holes for rack slide mounting.

The type of rack slide mountings are:

C300S18 (Chassis Trak Corporation) for:

TCR 600W 3 1/2" Power Supply

TCR 1000W 3 1/2" Power Supply

TCR 1800W 5 1/4" Power Supply

CSXX-XSM/220300 (Emcor Corporation) for:

TCR 2800W 7" Power Supply

For bench mounting, four mounting feet are provided which are adhesive mounted to the base surface of the supply.

NOTE: Do not operate the supply continuously with the covers removed since the air flow pattern within the chassis is adversely effected.

III OPERATING INSTRUCTIONS

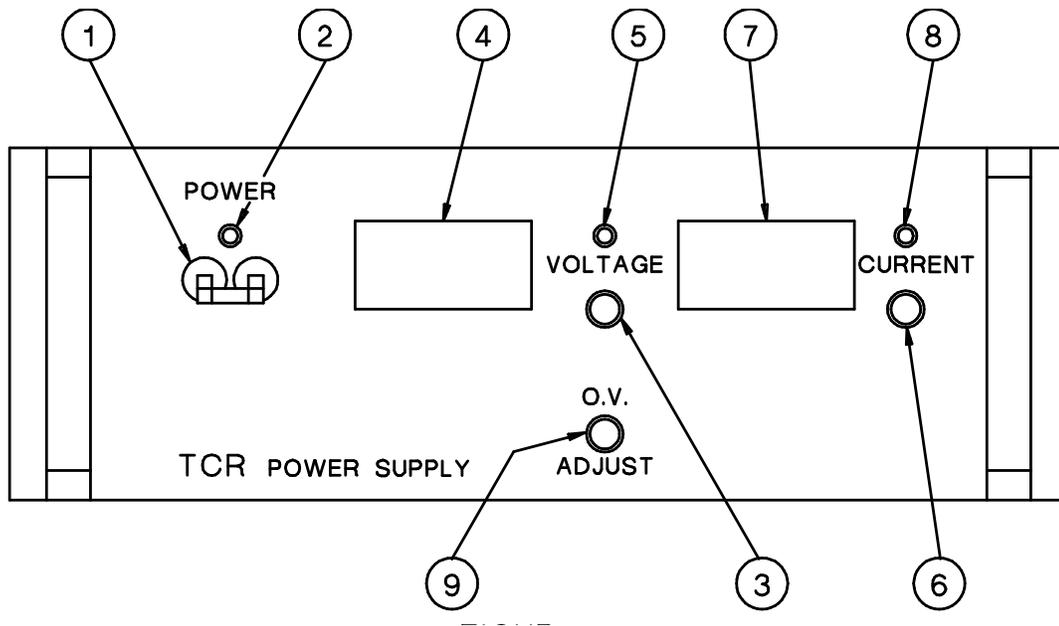


Figure 1: Front Panel Controls and Indicators

III.1 TURN-ON CHECK OUT PROCEDURE

The front panel surface 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 control and indicators (Figure 1) and ensures that the supply is operational. This preliminary check of the power supply is done without a load connected.

- A. Check the barrier jumper straps on the back of the unit, as shown in Figure 2, for normal mode.
- B. Set all controls completely counter-clockwise.
- C. Connect AC power line to back of power supply. The connecting terminals are marked to ensure proper connections.
- D. Turn the CIRCUIT BREAKER (1) on/off switch to "on". The fans will start immediately but there is a 10 to 15 seconds delay before voltage or current output will occur. This is caused by the soft start circuit.
- E. The UNIT ON INDICATOR (2) should be lit.
- F. 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.
- G. Return all controls completely counter-clockwise.

H. To check out constant current, first turn-off supply. Connect a shorting bar across the plus and minus output terminal at the back of the unit.

I. 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.

J. Return all controls completely counter-clockwise and turn unit off. Disconnect output shorting bar.

III.1.1 OVER VOLTAGE OUTPUT

If supply is equipped with an overvoltage crowbar, the front panel will contain OVERVOLTAGE ADJUSTMENT (9). This potentiometer may be adjusted through an access hole in the front panel.

NOTE: All overvoltage circuitry has been properly adjusted to their respective unit before leaving the factory.

For trip levels less than the maximum output voltage or to check the overvoltage circuitry simply, A. set the potentiometer fully clockwise, B. adjust the power supply output voltage to the desired trip level, C. slowly adjust the potentiometer counter-clockwise until overvoltage is tripped.

Once fired, the SCRs remains on until its anode voltage is removed (decreased below its "on" level) or until anode current falls below a minimum "holding" current. A power supply that has been thrown into "crowbar" must have its input power momentarily removed to extinguish the "on" SCRs. Turning the unit off and then on again will reset the OVP provided the output is not adjusted above the trip point. The overvoltage range is from 50% to 110% of the maximum output voltage of the unit.

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

III.2 GENERAL OPERATION

The voltage and current controls (local and remote) set the boundary limits for the output 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 load resistance value:

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

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

III.3 MODES OF OPERATION

This power supply is designed so that its mode of operation is selected by making strapping connections between terminals on terminal strip TB101 which is bolted to the rear panel of the power supply. The terminal designations are silk screened on the rear panel of the power supply. (Refer to the following chart).

TB101 - 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 Resistive (V PROG R)
6	Voltage Programming Resistive 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 Resistive (I PROG R)
12	- Shunt (-I)
13	Inverted Amplifier (IN AMP IN)
14	+ Shunt (+I)

III.3.1 NORMAL OPERATION

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 usually 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 supply so configured.

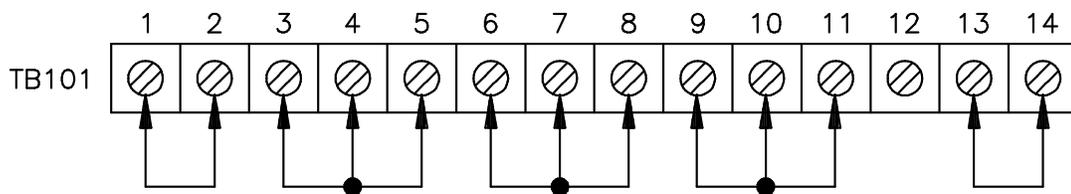


Figure 2: Normal Operation.

Connecting Load:

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.)

III.3.2 REMOTE SENSING (Figure 3)

In applications where the effect of the voltage drop (IR) of the dc load wires would adversely affect the performance of the load it is possible to sense the voltage at the load instead of 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. The max IR drop for each lead is 1.5V.

Connections for Remote Sensing

1. Remove jumpers between the following terminals:
TB101-1 and 2
TB101-7 and 8
2. Connect the positive point of load to TB101-2.
3. Connect the negative side of the load to TB101-7.
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 TB101-2 and TB101-7 within the range of .5uf 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.

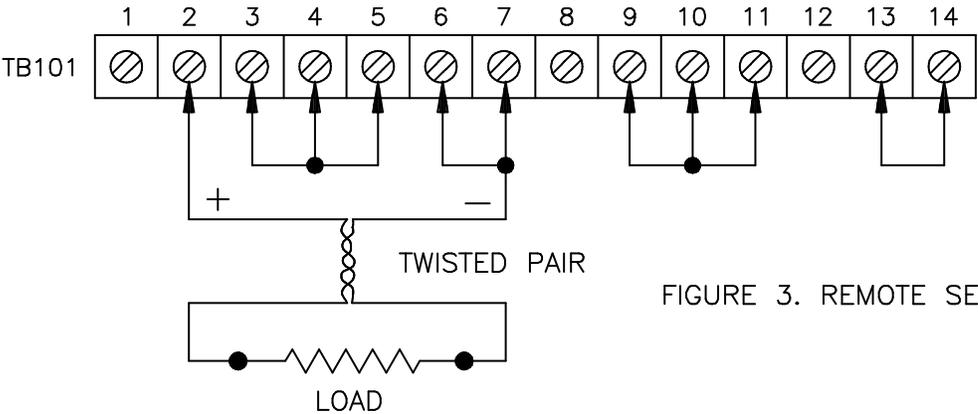


FIGURE 3. REMOTE SENSING

Figure 3: Remote Sensing

III.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 wires 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 option be used to limit the maximum voltage excursion and safely shut the power supply down.

III.3.4 REMOTE PROGRAMMING by EXTERNAL RESISTANCE (Figure 4 & 5)

Voltage Channel:

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

$$Prog (\Omega) = \frac{5000 \times \text{Desired Voltage}}{\text{Full Rated Output Voltage}}$$

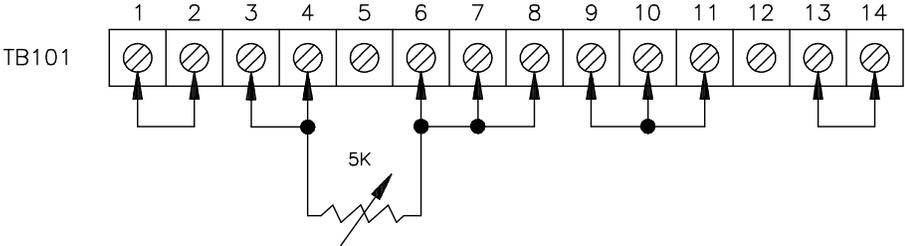


Figure 4: Remote Programming by External Resistance, Voltage Mode.

Current Channel:

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

$$Prog (\Omega) = \frac{100 \times \text{Desired Current}}{\text{Full Rated Current}}$$

1. Remove the jumper between terminals TB101-10 and 11.
2. Connect the programming resistance between terminals TB101-10 and 12.

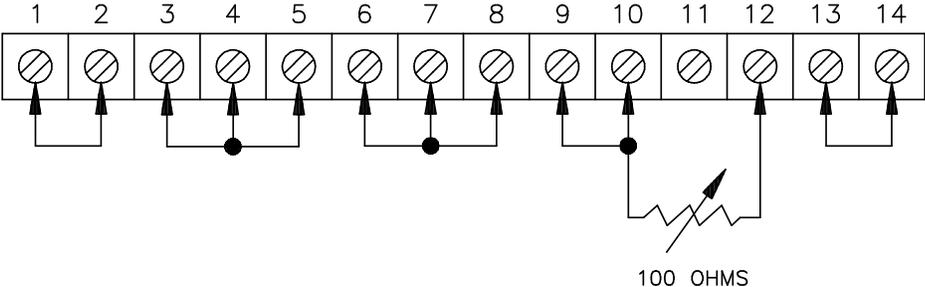


Figure 5: Remote Programming by External Resistance, Current Mode.

CAUTION: An opening in the remote programming circuit is effectively a high programming resistance and will cause 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 the load. For this reason, any programming resistor switch must have shorting contacts. This type of shorting switch connects each successive position before disconnecting the preceding one.

III.3.5 REMOTE PROGRAMMING by EXTERNAL VOLTAGE (Figures 6 & 7)

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 TB101-3,4 and 5.
2. Add a jumper between TB101-3 and TB101-7
3. Connect the programming voltage source between TB101-4 (pos) and TB101-6 (neg).

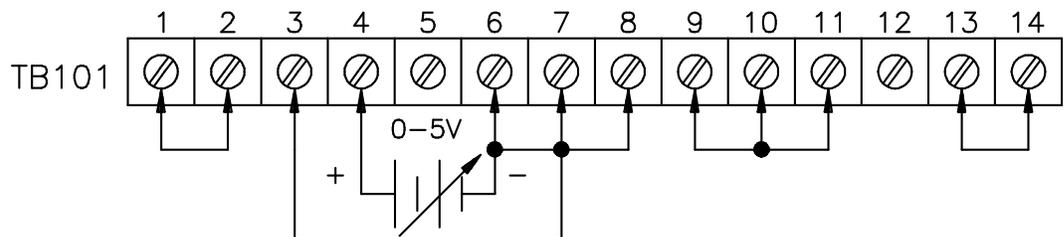


Figure 6: Remote Programming by External Voltage, Voltage Mode.

Current Channel:

A voltage of 0 to 100 Mv programs the output from zero to full rated current.

Note: A signal from a higher potential source may be attenuated to this 100mv level by a resistor divider. For best performance, the source impedance of this divider must not exceed 100 OHMS.

1. Remove the jumpers between terminals TB101-9,10 and 11.
2. Connect the programming voltage source between terminal TB101-10 (pos) and TB101-12 (neg).

CAUTION: When voltage programming of the voltage channel connect TB101-3 to TB101-7 and when voltage programming the current channel connect TB101-9 to TB101-12.

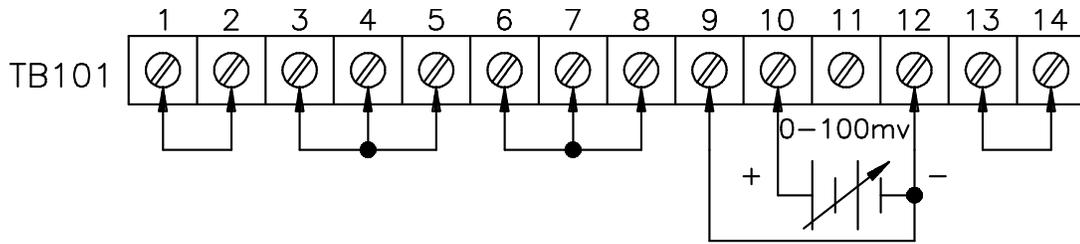


Figure 7, Remote Programming by External Voltage, Current Mode.

III.3.6 REMOTE PROGRAMMING by EXTERNAL CURRENT (Figures 8 & 9)

The front panel voltage or current control is not disabled in this programming mode. The front panel control must be left in the clockwise position to maintain the programming constant or signal to the output.

A current of 0-1Ma programs the output from zero voltage to full rated voltage or current.

Voltage Channel:

1. Remove the jumpers between terminals TB101-3 and 4.
2. Connect the programming current source between terminals TB101-4 (pos) and TB101-6 (neg).

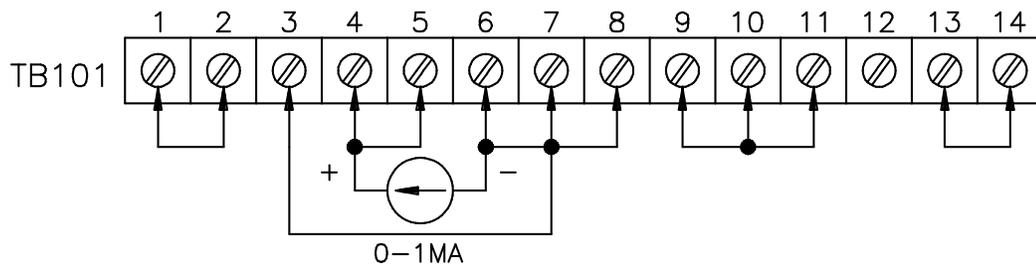


Figure 8: Remote Programming by External Current, Voltage Mode.

Current Channel:

1. Remove the jumper between terminals TB101-9 and 10.
2. Connect the programming current source between TB101-12 (neg) and TB101-10 & 11 (pos).

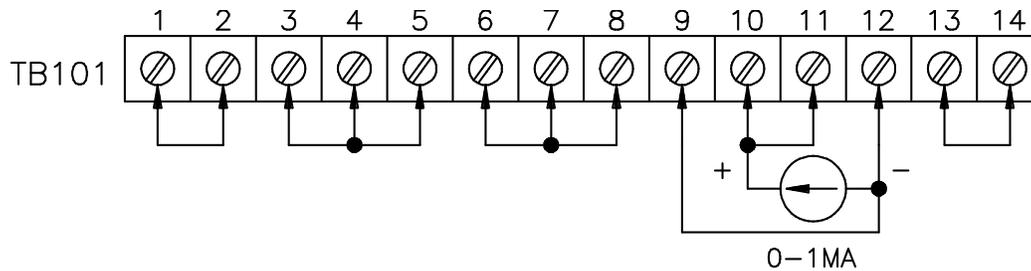


Figure 9: Remote Programming by External Current, Current Mode.

III.3.7 PARALLEL OPERATION (Figure 10)

Note: It is not recommended to operate more than three TCR 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 because of instability of the power supplies.

The simplest parallel connection is that of attaching the positive and negative terminals to their respective load points.

The procedure is as follows:

1. Turn on all units (open circuit) and adjust to appropriate output voltage.
2. Turn supplies off and connect all positive output terminals to the positive side of the load and all negative output terminals to the negative side of the load.

Note: Individual leads connecting unit to the load must be of equal lengths 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 exceed 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 a units output voltage drifts upward, it will become current limited rather than carry an excessive share of load current.

IMPORTANT: When the units contain the overvoltage option do not connect them in parallel without consulting the Engineering Staff of Electronic Measurements. Irreparable damage will occur if one of the paralleled units goes into overvoltage without proper paralleling of the OVP option.

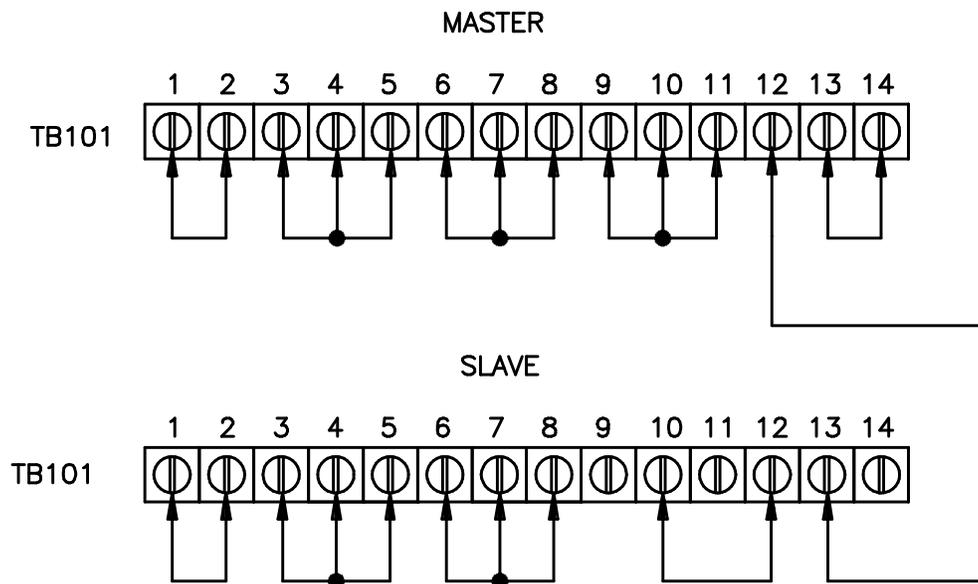


Figure 10: Parallel Operation Master/Slave.

III.3.8 PARALLEL OPERATION-MASTER /SLAVE

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:
TB101-13 and 14
TB101-9,10 and 11.
2. Connect a jumper between TB101-10 and 12 of all slaves.
3. Connect a wire between the master supply TB101-12 and TB101-13 of each slave.
4. See Figure 11 for output to load connections.
5. Set the voltage control of all slaves to full clockwise position.
6. Turn each slave on and then the master.
7. 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 assure equal sharing.

IMPORTANT: When the units contain the overvoltage option do not connect them in parallel without consulting the Engineering Staff of Electronic Measurements. Irreparable damage will occur if one of the paralleled units goes into overvoltage without proper paralleling of the OVP option.

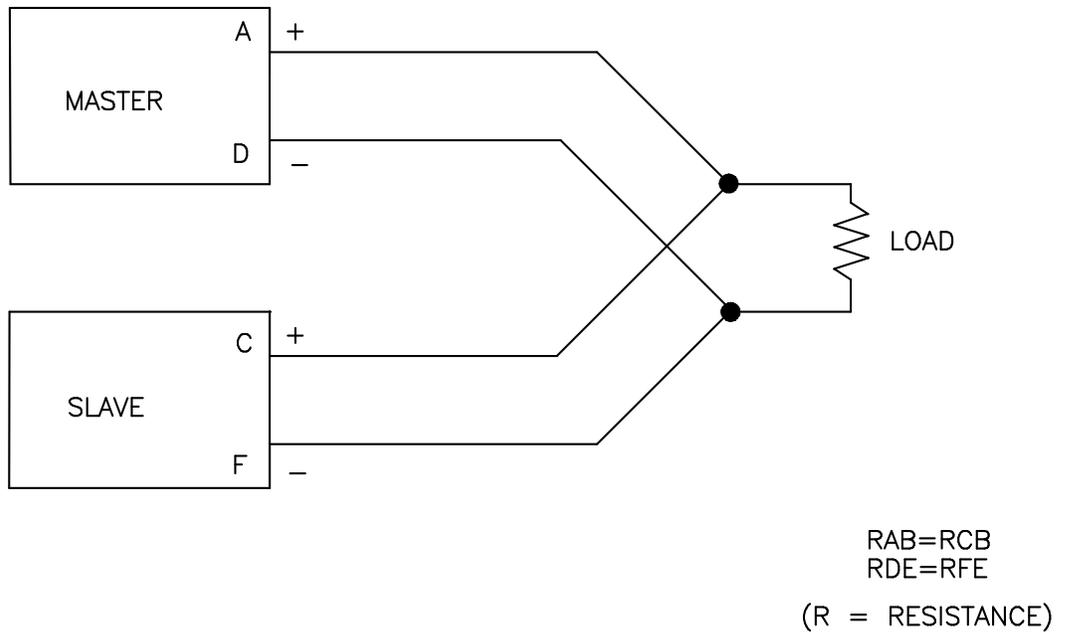


Figure 11: Parallel Connection - Master / Slave

III.3.9 SERIES OPERATION

Two TCR 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. The adjustment of each unit functions independently and the total output voltage is the sum of each unit 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 supplies.

III.3.10 REMOTE METERS

A remote voltmeter may be connected between terminals TB101-2 (pos) and TB101-7 (neg). If remote sensing is also being used, the remote voltmeter will indicate the voltage at the load. To indicate the voltage at the power supply output terminals connect the remote voltmeter between terminals TB101-1 (pos) and TB101-8 (neg).

A remote millivoltmeter, calibrated in amperes, may be connected between terminals TB101-12 (neg) and TB101-14 (pos). 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 full-scale sensitivity of the 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 leads should be shielded. One end of the shield should be grounded to chassis and the other end left floating.

IV PRINCIPLES OF OPERATION

IV.1 GENERAL

All the TCR single phase power supplies have SCR phase control which regulates the input ac voltage to the power transformer. This is accomplished by controlling the firing angle of the SCRs with a feedback loop sampling the output voltage and current. The voltage output of the power transformer is rectified and filtered to produce a stable DC power source which is user adjustable.

This section discusses the basic theory of the power and signal flow of the TCR single phase power supplies. If used as a supplement to the maintenance data provided in Section V, it will aid in isolation of unit faults. Refer to Figure 12, which is the block diagram of power and signal flow, and schematic #01-470-035 while reading this section.

IV.2 POWER FLOW

A two phase half wave controlled SCR circuit is employed to regulate the AC input voltage to the primary of transformer T1. Two pulse transformers isolate the gate signal of the two SCRs so they are not triggered at the same time. The angular position of the partial sinusoidal wave produced by the "firing" of each SCR controls the energy available to the power transformer T1. The means of determining the position and width of the sinusoidal wave corresponds closely to the commutation of the SCRs and the proportional control system. (This means, as the sine wave is delayed, the energy available in the resultant wave form is reduced and when it is advanced (toward a full sine wave) maximum energy is available.)

Transformer T1 converts the line voltage to the appropriate value. Depending on the model, the output rectification is full-wave center tapped (CR1-CR2) or full-wave bridge (CR1-CR8). The raw DC from the rectifiers is fed to output filter L1, C1, C2, C8 and C9.

At load currents that allow L1 to remain "critical" (continuous current flow) the filter averages the voltage waveform at the input of the filter. At very low load currents, the inductance is somewhat ineffective and the capacitor peak charges to provide filtering. The phase delay of the input waveform must be greater than 90 degrees and capable of approaching 180 degrees at low output voltage and current.

R4 and C4 form a snubber network across the SCRs to prevent false triggering due to dv/dt effects. R10 and C7 minimize the effects of diode commutation by absorbing high frequency energy. Resistors R5A through D act as a preload to assure stability of the loop and to improve the transient response when a load is suddenly disconnected from the supply.

IV.3 SIGNAL FLOW

Use (Figure 12) and schematic 01-470-035 as an aid in understanding the signal flow.

The bias transformer (T101) provides two voltages (50 and 20 volts AC) for operation of the control circuitry. The 50 volts from T101-4 and 6 with respect to the center tap pin 5, provide opposite polarities for line frequency referencing in SCR firing circuit.

Terminals 1 and 3 produce 20 volts RMS with respect to terminal 2. This voltage, after full wave rectification, produces plus and minus voltages on capacitors C106 and C107. The control circuitry of the supply uses the +15VDC bias level. Plus 15V load is about 150mA and minus 15V is 30mA. CR107 rectifies the 20V RMS, C106 and C107 are the filter capacitors for the plus and minus unregulated control voltage. U101 and U102 are 3 terminal regulators which output the regulated plus and minus 15 VDC.

Signals necessary for control over the SCR firing circuit are derived from amplified sampling of the output voltage and current compared to set reference point levels. These levels are from the adjustment controls which are proportional to a constant reference current multiplied by the value of the resistance of the adjustment control.

Identical constant current sources circuits are tied to the voltage and current channel controls which provided the constant current source for local programming. This current is adjustable to 1 mA by potentiometers R143 and R145. These current sources are referenced by the voltage across CR121, a 6.2 V temperature compensated Zener Diode.

The reference current level for the voltage channel flows from terminal 3 of TB101. With jumpers on terminals 3, 4 and 5 the voltage level produced when this current flows through R6 (the voltage adjustment potentiometer) is applied to pin 13 (a unity gain buffer amplifier) and then to pin 1 of IC101. The signal on the other amplifier input of IC101 pin 2 is derived from the output voltage level by the voltage division of R137 (& R138 and R139). Maximum voltage output of the supply produces 5 volts DC at pin 2 of IC101. Full clockwise rotation of R6 produces 5 volts DC at pin 1 of IC101. Through the action of the feedback loop, as resistor R6 (the voltage adjustment pot) is increased in value, the voltage at pin 1 of IC101 increases. The error signal developed at the output of IC101, pin 3 causes a proportional change in output voltage which produces a voltage on pin 2 of IC101 equal to that applied to pin 1.

The action of the current channel is identical to the voltage channel with the exception that the controlled quantity is the current that flows through shunt R11. The voltage level that this current produces flowing through R11 is applied to one input of IC101, pin 5 while the current adjustment pot R7 develops the reference potential applied to pin 6 of IC101. The level of the signal applied to pins 5 and 6 of IC101 is 0 to 100Mv.

The outputs of the voltage channel comparator/amplifier IC101 and the current channel comparator/amplifier are "ored" together in diodes CR113 and CR114. Whichever channel output is positive over rides the effect of the other and represents that channel controlling the DC output. A positive going signal at the cathode of diodes CR113 and CR114 reduces the output of the supply by retarding or delaying the conduction of the primary SCRs.

The mode indicator lights are also driven from the outputs of IC101. Whichever output (pin 3 or 4) is negative illuminates the opposite light emitting diode indicator.

Transistor Q104 amplifies the level shifts and the control signals from CR113 and CR114. The normal operating voltage at the collector of Q104 is 6.5V and a swing of 5 to 7.5 volts will range the supply from no output to full output. The lower the collector voltage on Q104 the lower the output of the supply.

There are some other functions also accomplished in the Q104 stage. R117 and C113 form a "soft start" network which reduces the turn on surge and allows bias levels to build up before output current is permitted. R117, C113, Q105, CR122, CR123 resets the soft-start circuitry. The voltage signal developed across R118 is a source of feedback through C115, R120, C114 and R119 to stabilize the current and voltage channels respectively.

CR112 functions as a peak conduction angle limiter for the SCR's by limiting the maximum positive voltage on Q104. The SCR firing pulses are developed by properly timed conduction of Q101 and Q102. This is accomplished by the combination of the phase related AC signals from terminals 4, 5 and 6 and the variable DC level from Q104.

Thermostat TS1 is placed across C113, and when an over-temperature condition exists, the output voltage is inhibited by closure of the thermostat.

IV.4 SCR FIRING CIRCUIT

The SCR firing circuit is located between the input AC source and the power transformer T1. They act as voltage controllers to vary the alternating voltage applied to the load circuit for a chosen portion of each cycle of the source voltage. A closed-loop control system in which the angle of retard at which the SCRs conduct is varied in response to an error signal.

Examining the firing circuit for one SCR only, R108 and CR105 produces a 12V square wave at line frequency with axis crossings at 0 and 180 degrees. R106 and C104 integrate the square wave into rising and falling ramp voltages with transition in voltage direction occurring at 0 and 180 degrees due to the RC networks.

When a positive DC level from Q104 is superimposed across C104, the base of Q101 will be driven into the positive travel of the ramp. The conduction causes a rapid flow of collector current in Q101 and a pulse of gate trigger current in SCR Q2. Operation of the opposite driving circuit is identical except for 180 degree pulse displacement which fires Q1 when its anode is positive. C101 and C102 store

the SCR gate pulse energy and C103 serves as an energy reservoir to prevent pulse loading of the +15V supply. Resistor R147 functions as a balance control to equalize SCR firing angles. Additional loop compensation is provided by R131 and C119 voltage channel, CR108 and R134 in current channel.

IV.5 METERING AND AUXILIARY FUNCTIONS

Voltage monitoring is achieved by connection of a self contained DC voltmeter to the sensing terminals of the supply. Output current is measured using a shunt related DC ammeter connected across the shunt R11. Calibration of this meter is made by adjustment of R8. The unit is cooled using fan B1 and is powered upon closure of the circuit breaker. On 3 1/2" units operated on 220VAC, a series resistor is inserted in series with the fan. The circuit breaker is equipped with an auxiliary trip coil that operates in conjunction with the optional over voltage protection module. It can also remotely shut the supply down whenever 5 amps of DC flows through terminals C1 and C2 of the breaker.

V MAINTENANCE AND TROUBLE SHOOTING

V.1 GENERAL

NOTE: Maintenance and / or calibration procedures contained in this section will not void the unit warranty.

A regular scheduled preventive maintenance program is recommended for the TCR single phase power supply. As a minimum, maintenance should consist of a thorough cleaning of interior and a visual inspection of components on printed circuit boards. Even a relatively clean location requires at least one inspection every six months.

V.2 INSPECTION AND CLEANING

CAUTION: Always disconnect the power supply from AC line before removing cover.

1. Remove eight 6-32 machine screws from top cover.
2. Cover can now be removed.
3. Check for loose wires, burn marks, etc.
4. A100 Control Board unplugs so it may be checked.
5. Remove dust from in and round parts with small long bristled brush or compressed air.

V.2.1 Equipment Required for Calibration and Maintenance

1. Oscilloscope - dual trace - 20KHz bandwidth - isolated from ground (Tektronix 2213 with 10x voltage probe).
2. RMS Multimeter - 100 volts DC- 1000 volts AC (Hewlett Packard HP-3465A)
3. VOM (Simpson 260)
4. Load - equal to the output capability of unit.

V.3 CALIBRATION

This procedure applies to the adjustment and calibration of a properly functioning unit only. Any malfunctions must be corrected before proceeding with calibration. It is only necessary to remove top cover to make these calibrations. (See 5.2)

V.3.1 VOLTAGE AND CURRENT SOURCE ADJUSTMENTS

The voltage calibration is done without a load connected.

1. Connect a voltmeter across TB101 pin 1 (positive) and TB101 pin 8 (negative).

2. Turn both voltage and current controls on front panel completely counter-clockwise.
3. Turn unit on.
4. Rotate R6 (voltage control) completely clockwise and R7 (current control) half a turn. Adjust R143 until the reference voltmeter indicates the full rated output voltage of the power supply, or just slightly above.

The front panel voltmeter reading should agree within 2%. To calibrate digital voltmeters adjust R111. Analog meters require no calibration. If the front panel does not zero adjust replace it.

5. Turn the power supply off and connect a reference ammeter (with an external shunt when applicable) in series with a load or short across the output terminals. Turn both voltage and current controls completely counter-clockwise.
6. Turn power supply on.
7. Calibrate the power supply ammeter by adjusting potentiometer R8 (R111 on digital meter).
8. Rotate R6 (voltage control) a full turn clockwise and turn the current control (R7) until the reference ammeter indicates the full rated output current. Adjust R145 to achieve this output.

V.3.2 FIRING BALANCE

1. Connect a load to the power supply. (A variable load would be helpful in this test.)
2. Connect oscilloscope probe (x10) on TB101 pin 1 and ground on TB101 pin 8.
3. Turn unit on. Adjust R147 to achieve the lowest ripple output. If a variable load is not available make this adjustment at highest current and voltage rating of the unit.

V.4 TROUBLESHOOTING

The power supply is divided into two basic circuit areas, power flow and signal control. The power flow circuitry consists of circuit breaker, SCR's, power transformer, rectifiers, choke and capacitors as well as the cabling interconnecting them. The signal control circuitry is contained on the removable printed circuit card. Most unit malfunctions will originate on the circuit card. Reviewing the Theory of Operation is recommended before troubleshooting the power supply.

WARNING: When servicing supply, dangerous voltage levels exist. Be especially careful of person and equipment when measuring primary circuitry since this is at line potential.

V.4.1 OVERALL TROUBLESHOOTING PROCEDURE

1. Check for obvious trouble such as input power failure, loose or incorrect strapping on rear terminals or defective meter.
2. It is common for the trouble to be caused by the DC bias or reference voltages, thus it is a good practice to check voltages on the A100 control board before proceeding to the next step. The A100 board may be disconnected from SCRs by connecting a clip lead across CR112.

Some voltages to check are: *

- *T101 pins 4 (pos) and 5 (centertap) - 50VAC RMS
- 6 (pos) and 5 (centertap) - 50VAC RMS
- 1 (pos) and 2 (centertap) - 20VAC RMS
- 3 (pos) and 2 (centertap) - 20VAC RMS

All the following positive voltage measurements are made with the negative lead of the digital meter connected to the negative output.

- Cathode of CR108 = 20 volts DC
- Emitter of Q101 = 15 volts DC
- Cathode of CR105
and CR106= 12 volts AC
- IC101 outputs 3 & 4 = 10 volts DC

*All voltages are approximations.

3. The supply should be disconnected from its load before proceeding.
4. Troubleshooting is more effective if the unit is operated in the normal mode (Normal Programming Section 3.3.1).
5. Before turning on the supply turn both current and voltage channel controls completely off (counter-clockwise).

V.4.2 TROUBLESHOOTING CHART

START	PROBLEM
TURN SUPPLY ON	OUTPUT GOES HIGH - FULL SCALE OR ABOVE. IF UNIT CONTAINS OVP OPTIONS - CIRCUIT BREAKER TRIPS

1. TURN SET OFF.
2. DISCONNECT A100 BOARD FROM POWER SECTION BY DISCONNECTING THE 4 PIN PLUG (UVXW) AND 2 PIN PLUG (S-T).
3. TURN SET ON.

PROBLEM	REMEDY
SET STILL OUT OF CONTROL	Shorted SCR
SET NO LONGER OUT OF CONTROL	CHECK R6 - Could Be Open
	<ol style="list-style-type: none"> 1. Turn power supply off. 2. Connect a clip lead between R113 and R112 and ground or negative side if C112. 3. Reconnect U-V-X-W and S-T. 4. Turn power supply on.
	CHECK R6
	<ol style="list-style-type: none"> 1. Connect digital meter between TB101-5 (pos.) and TB101-6 (neg.). 2. As R6 is rotated through its ranges, the voltage across it will vary from zero to 5V.
	CHECK R7
	<ol style="list-style-type: none"> 1. Connect digital meter positive lead to TB101-9 and negative to TB101-12. 2. As R7 is rotated through its range the voltage DC across it will vary from 0-50mV or 0-1000mV depending on the unit.
UNIT ON BUT NO OUTPUT	CHECK TRANSISTOR Q104 on the A100 C
	CHECK AC SIGNAL INPUT VOLTAGE
	CHECK AC SIGNALS at T101 Pin 7 and 12 A100 Control Board CHECK OUTPUT of BIAS TRANSFORMER T101 Between Pins: 4 & 5 - 50VAC RMS 5 & 6 - 50 VAC RMS 1 & 2 - 20 VAC RMS 2 & 3 - 20 VAC RMS * All voltage are approximately and without a load on supply
	CHECK TRANSISTOR Q104 on the A100 Control Board - Could Be Shorted
	CHECK TRANSISTOR Q105 on the A100 Control Board - Could Be Shorted

Turn Voltage and Current Channels up slowly	CIRCUIT BREAKER SNAPS OFF
	One of the high power diodes located on the heatsink could be shorted. Refer to sheet 2 of 01-470-035.
EXCESSIVE RIPPLE	CHECK OUTPUT FILTERING CAPACITORS C1, 2, 8 or 9 - Could be defective
	One of the main SCR's (Q1 or Q2) - Could be open
	INDUCTOR COIL L1 - Could be shorted
	ISOLATION CIRCUIT for the SCR's - Could have faulty component.
	Check for a 60Hz square wave of 12V peak to peak across the anode of CR105 and CR106 and ground, T101-5. Also check for a 3V peak to peak ramp voltage at junction of C104 and R104 and the junction of C105 and R105.
UNIT IS OSCILLATING	CHECK C114 and C119 - Could be defective
CURRENT OF VOLTAGE CHANNEL - DOES NOT REGULATE	CHECK IC101 and Q104 - Could be defective.

V.4.3 Overvoltage Troubleshooting

Most overvoltage faults fall into two general categories:

1. The circuit overvoltage fires at all times even when the trip point is adjusted to maximum.

Check SCR's Q201 and Q202. They could be shorted.
IC201 could be defective.

2. The overvoltage is completely inoperative at any trip point setting.

Check SCR's Q201 and Q202. They could be open.
IC201 could be defective.

V.4.4 DIODE REPLACEMENT

1. Remove 8 6-32 screws from top cover of power supply.
2. Now the top cover may be lifted off.
3. The diode heatsink is located behind the power transformer.
4. Remove the heatsink.

5. After removing diodes, wipe heatsink clean of all compound.
6. Put a fine coating of compound (low thermal contact resistance) on surface of diode that meets heatsink.
7. Mount diodes to heatsink.

If the diodes are stud mounted the following chart can be used.

DIODE THREAD SIZE	TORQUE PRESSURE
1/4 - 28 threaded device	30 inch pound - max torque
3/8 - 24 threaded device	120 inch pound - max torque
1/2 - 20 threaded device	130 inch pound - max torque
3/4 - 16 threaded device	30 foot pound - max torque

Note: Use new nut when a new diode is installed.

MODEL DICTIONARY CHART

DC VOLTAGE	TCR	XX	S	XXX	- XX	- X
DC CURRENT						

AC INPUT VOLTS		PANEL METER		FEATURES	
1	115 VAC 50-60 Hz	omit	ANALOG AM/VM	OV	OVP ADD ON
2	220VAC 50-60Hz	D	DIGITAL AM/VM	LB	LOCKBUSHING
3	100VAC 50Hz			10T	10 TURN CURRENT CONTROL
4	220VAC 50Hz			TP	TEST POINTS
5	277VAC 50/60Hz			U	UNIVERSAL PANEL MOUNTING SLOTS
6					
7					
8					

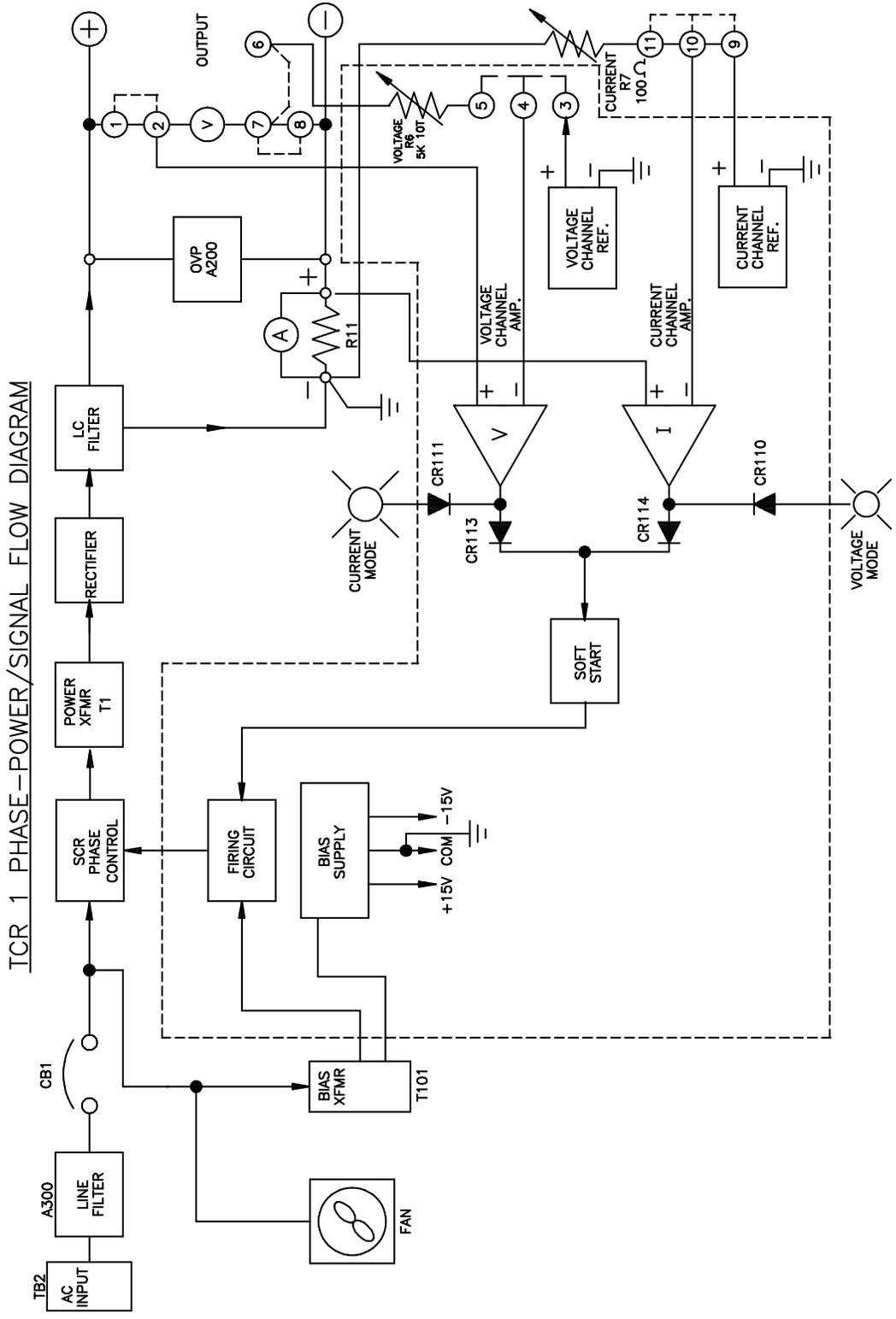


Figure 12