INSTRUCTION MANUAL FOR

TCR 3 PHASE

POWER SUPPLY

83-467-001 Revision B

MODEL ________________________

SERIAL NUMBER ________________

LAMBDA EMI

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TCR 3 Phase OPERATING SYSTEM MANUAL
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I GENERAL INFORMATION

I.1 INTRODUCTION

This manual contains operation and maintenance instructions covering the TCR 3 Phase Power Supply series manufactured by Electronic Measurements, Inc. of Neptune, NJ.

All models provide AC turn on/off and circuit protection by means of a UL rated input circuit breaker. Output control is provided by a 10 turn voltage control and a 1 turn current control which are monitored by front panel meters. These meters are an optional selection between either an analog or digital display.

Input AC is applied to 3 pairs of bi-directional connected SCRs placed within the delta connected primary of the main power transformer. The secondary of this transformer is rectified and double LC filtered to provide a low ripple DC output. It also has a dual-amplifier - one for voltage channel and one for current channel. In addition, it also has adjustment controls that will furnish full rated output voltage at the maximum rated output current or can be continuously adjusted throughout most of the output range.

These supplies may also be controlled locally at the front panel or remotely by external voltage, current or resistance on rear mounted programming terminals.

VOLTAGE PROGRAMMING -		
	Voltage Programming -	0 to 5Vdc Programs from 0 to full voltage output.
	Current Programming -	0 to 1mA (into 5000 ohms) Programs 0 to full voltage output.
	Resistance Programming -	0 to 5000 ohms Programs 0 to full voltage output.
CURRENT PROGRAMMING -		
	Voltage Programming -	0 to 100mV Programs 0 to full current output.
	Current Programming -	0 to 1mA (into 100 ohms) Programs 0 to full current output.
	Resistance Programming -	0 to 100 ohms Programs 0 to full current output.

Output voltage and current are continuously monitored by two front panel meters. Input power is connected to a four screw terminal at the rear of the unit. The output terminals are heavy busbars mounted on the rear of the unit. A 17 screw terminal block at the rear of the unit provides expansion of the operational capabilities of the instrument. A brief description of these capabilities are given below:

I.1.1 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.

I.1.2 remote programming

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

I.1.3 parallel operation

The power supply output 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.

I.1.4 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.

I.1.5 Remote turn on

The power supply may be remotely turned on or off by application of a combination of external voltages or interlock control. The open interlock potential is the applied external voltage level. If the interlock function is used without an external control level the open interlock potential is 24 Vdc.

I.2 SPECIFICATIONS

I.2.1 AC input

Standard AC input is 208/220/230 volts.

A three-phase, three-wire system which will operate within full specification form 190 to 253 volts or optional voltage as specified. Input AC phase rotation sequence is not critical to this supply.

The phase to phase voltage balance requirement is ± 2% to achieve ripple specification.

Current Draw Per Phase	2.5kW Units	12 Amps
at full load	5kW Units	23 Amps
	10kW Units	46 Amps

AC line current is proportional DC load current.

I.2.2 option aC

All models are available with optional AC inputs of:

INPUTS:	200V ± 10%
	380V ± 10%
	415V ± 10%
	460/480V (414-505V)
	400V ± 10%

I.2.3 line frequency: 47-63hz

I.2.4 aC inrush

All models are "soft-started" so that during initial activation or reapplication on interrupted power the input SCRs slowly "phase in" from non-conduction mode. Since the SCRs are in series with the transformer primary there is no magnetic inrush current due to core memory.

I.2.5 phase loss

Loss of a phase voltage will inhibit power supply output and illuminate the front panel phase loss light. The power supply is not damaged when the phase voltage is restored and normal operation will automatically resume.

I.2.6 regulation

Voltage Mode - For line voltage variations or load current variations within the rating of the supply, the output voltage will not vary more than 0.1% of the maximum voltage rating depending upon the unit.

Current Mode - For line voltage variations or load voltage variations within the rating of the supply, the output current will not vary more than 0.1% of the maximum current rating depending upon the unit.

On those units in which the percentage of voltage or current ripple exceeds the specified regulation, the regulation will appear to be degraded because of the effect of this ripple on the measurement.

I.2.7 stability

The output voltage or current will remain within .05% of full output for 8 hours after warm-up under fixed line load and temperature conditions.

I.2.8 transient response

A 30% step increase in power demanded by the load will cause a transient in the regulation output which will typically recover to within 2% of final value within 75 milliseconds.

I.2.9 temperature coefficient

Voltage - The temperature coefficient of the output voltage set point is 0.02% per degree centigrade of the maximum output voltage.

Current - The temperature coefficient of the output current set point is 0.03% per degree centigrade of the maximum rating of the supply.

I.2.10 ambient temperature

Operating:	0° C to +40° C
Non-Operating:	-40° C to +85° C

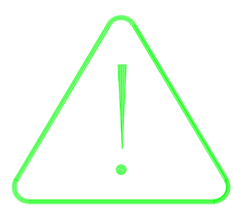
Critical circuitry is thermostat protected so that in the event of an over-temperature condition the unit is turned off until a safe temperature returns.

I.2.11 cooling

All units are air cooled and thermostatically protected. Air enters at the front right side and exits at the front left side and rear.

I.2.12 ripple

The output voltage ripple specified in the Rating Table is the worst case ripple under any resistive load condition with the power line within specification. Typically the highest ripple occurs at 50% output voltage/current and is lower at maximum output voltage and power is approached. Output ripple voltage and current is 31% higher than shown when supply is operated at 50Hz line frequency.



RATING TABLE					
OUTPUT RATINGS @50°C		**OUTPUT RIPPLE** Voltage @ Full Load	**PANEL**	**MODEL TCR**
Voltage (V)	**Current (A)**	**RMS**	**Height**	
0-7.5 0-6 0-6	0-300 0-600 0-900	35mV 30mV 30mV	7" 8.75" 12.25"	7.5T300 6T600 6T900
0-10 0-10 0-10	0-250 0-500 0-750	35mV 35mV 35mV	7" 8.75" 12.25"	10T250 10T500 10T750
0-20 0-20 0-20	0-125 0-250 0-500	20mV 20mV 20mV	7" 8.75" 12.75"	20T125 20T250 20T500
0-30 0-30	0-100 0-200	15mV 15mV	7" 8.75"	30T100 30T200
0-40 0-40 0-40 0-50	0-60 0-125 0-250 0-200	15mV 15mV 15mV 18mV	7" 8.75" 12.25" 12.25"	40T60 40T125 40T250 50T200
0-80 0-80 0-100	0-30 0-60 0-100	25mV 25mV 40mV	7" 8.75" 12.25"	80T30 80T60 100T100
0-120 0-120	0-20 0-40	40mV 40mV	7" 8.75"	120T20 120T40
0-160 0-160 0-160	0-15 0-30 0-60	60mV 60mV 60mV	7" 8.75" 12.75"	160T15 160T30 160T60
0-250 0-250 0-250	0-10 0-20 0-40	90mV 90mV 90mV	7" 8.75" 12.85"	250T10 250T20 250T40
0-500 0-500 0-500	0-5 0-10 0-20	125mV 125mV 125mV	7" 8.75" 12.25"	500T5 500T10 500T20

TABLE 1

The TCR units have a panel width of 19 inches and a depth of 22 inches.

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

This power supply requires a three-phase input, of the specified voltage and frequency, with nominal voltage line-to-line (three-wire system).

Phase rotation need not be observed when connecting power line to the input terminals of the power supply. No neutral connection is required, but for safety, the chassis ground terminal marked GRD must be connected to earth ground in accordance with electrical code requirements.

All AC input connections are made at the rear terminal block, TB2, with the insulated rectangular covering. Install the three-phase line to terminals marked ØA, ØB and ØC. Connect the ground line to terminal marked GRD. Reinstall cover plate. The user should ensure that the AC input wires are of the proper gauge. For example, the line current is 50 ampere (maximum) for a 230 VAC input, dictating that each conductor be at least number 8 gauge wire. 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 heavy enough leads to prevent substantial IR drops between the output terminals and the load. Remote sensing can be used to compensate for IR drops. Reference Section 3.3.2.

II.3 LOCATION

This instrument is fan cooled. Sufficient space must be allotted so that a free flow of cooling air can reach the sides of the instrument when it is in operation. It must be used in an area where the ambient temperature does not exceed 40° C.

III OPERATING INSTRUCTIONS

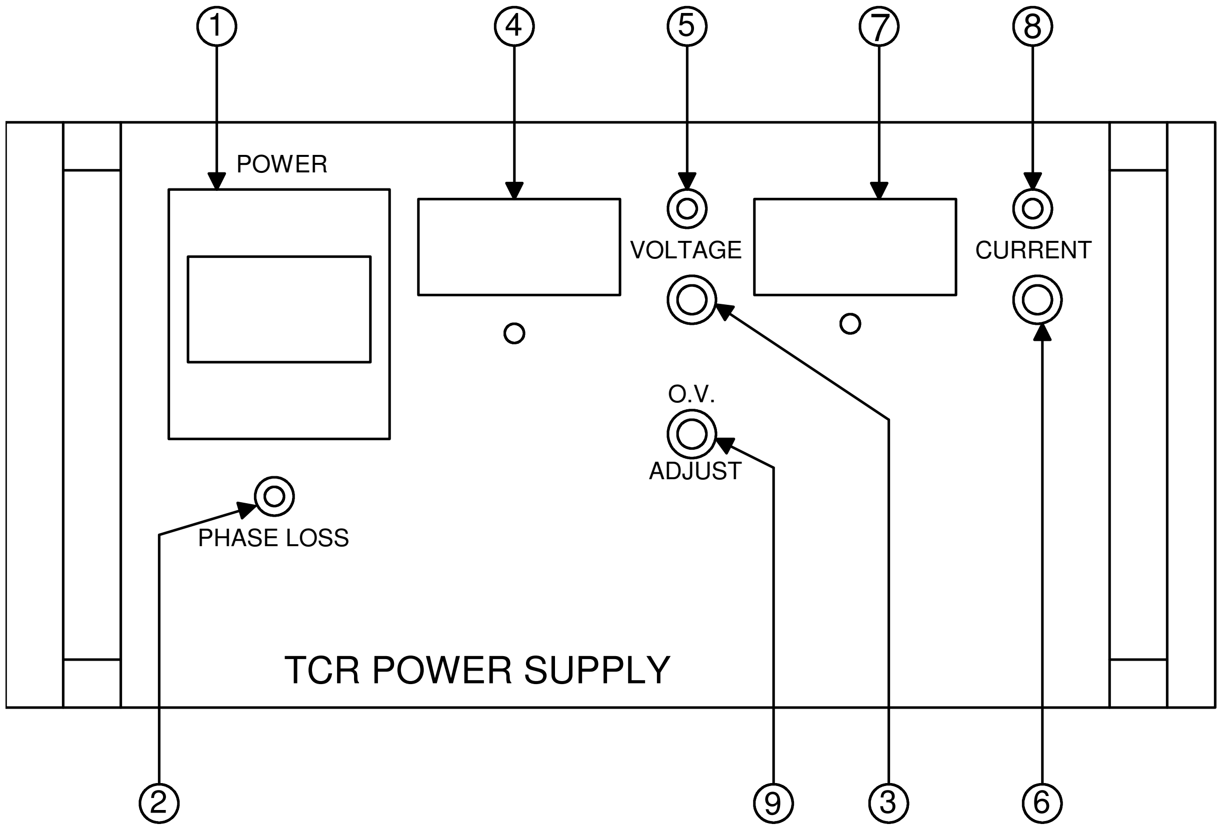


FIGURE A: FRONT PANEL CONTROLS AND INDICATORS

III.1 TURN-ON CHECK OUT PROCEDURE

1) 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 controls and indicators (Figure A) and ensures that the supply is operational. This preliminary check of the supply is done without a load connected.

2) Check the barrier jumper straps on the back of the unit, as shown in Figure 1, showing TB2 strip-normal operation.

3) Set all controls completely counterclockwise.

4) 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.

5) The PHASE LOSS INDICATOR (2) should be off.

6) 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.

7) Return all controls completely counter-clockwise.

8) 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.

9) 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.

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

III.1.1 oVP operation - figure a

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 set the potentiometer (9) fully clockwise. Now adjust the power supply output voltage to the desired trip level (3) and slowly adjust the potentiometer (9) counterclockwise until OVP trips turning off the set.

Once fired, the SCR 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 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 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, TB2, 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.

TB2 - 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 (INV AMP IN)
14	+ Shunt (+I)
15	Pins 15 and 16 Remote Voltage Turn-On
16	(Remote V IN)
16	Pins 16 and 17 Remote Dry Contact Turn-On
17	(Remote SW)

III.3.1 normal operation (Figure 1)

When shipped from the factory, each supply is configured for constant/voltage, constant/current, local programming, local sensing, and 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.

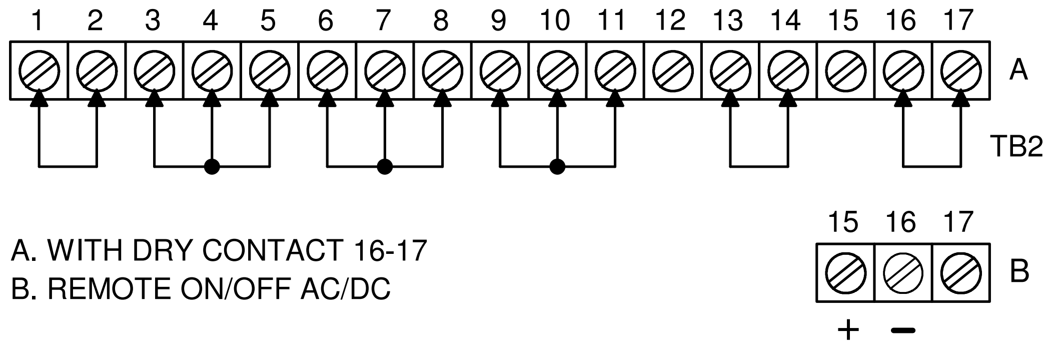


FIGURE 1: NORMAL OPERATION

<u>Connecting Load</u>

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 2)

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.

<u>Connections for Remote Sensing</u>

1) Remove jumpers between the following terminals:

   TB2-1 and 2
   TB2-7 and 8

2) Connect the positive point of load to TB2-2.

3) Connect the negative side of the load to TB2-7 and 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 TB2-2 and TB2-7 within the range of .5 to 50μf.

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.

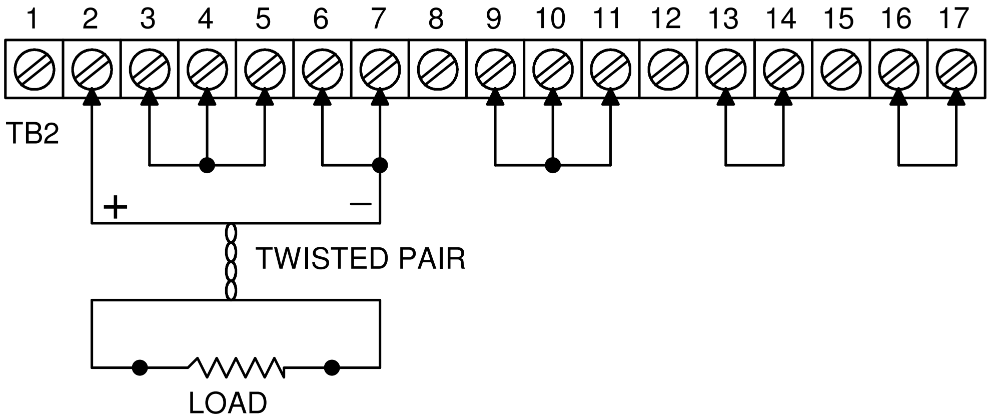


FIGURE 2: REMOTE SENSING

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 3 & 4)

Voltage Channel

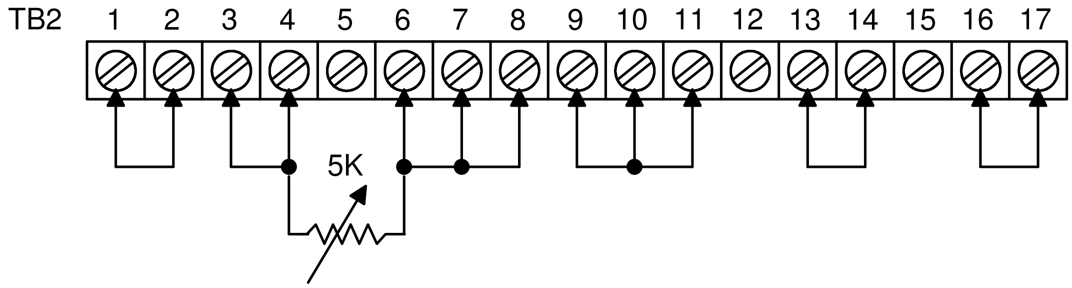


FIGURE 3: REMOTE PROGRAMMING BY EXTERNAL RESISTANCE, VOLTAGE MODE

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

Prog (Ohms) = 5000 X Desired Voltage/Full Rated Output Voltage

1) Remove the jumper between terminals TB2-4 and 5.

2) Connect the programming resistance between terminals TB2-3 & 4 and TB2-7.

Current Channel

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

Prog (Ohms) = 100 X Desired Current/Full Rated Current

1) Remove the jumper between terminals TB2-10 and 11.

2) Connect the programming resistance between terminals TB2-10 and 12.

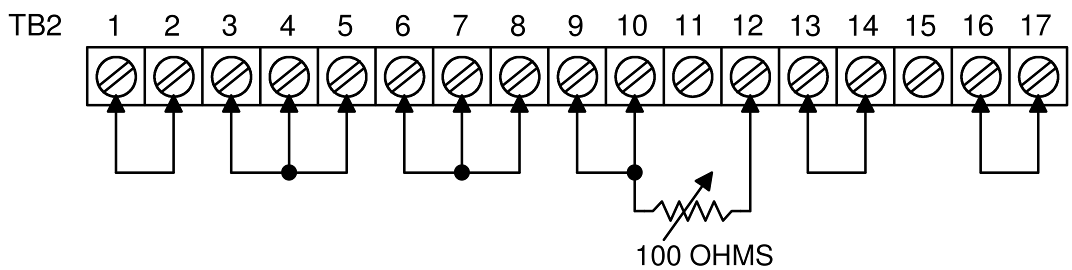


FIGURE 4: REMOTE PROGRAMMING BY EXTERNAL RESISTANCE, CURRENT MODE

CAUTION: An opening in the remote programming circuit is effectively a high programming resistance and will 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 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 TB2-3, 4 and 5.

2) Connect the programming voltage source between TB2-4 (pos) and TB2-6 (neg).

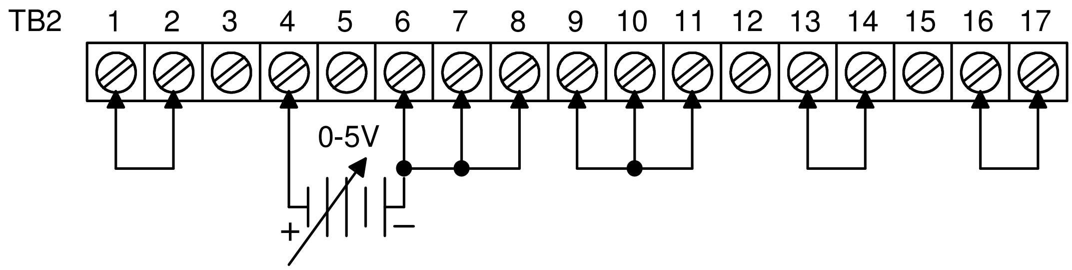


FIGURE 5: REMOTE PROGRAMMING BY EXTERNAL VOLTAGE, VOLTAGE MODE

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 TB2-9, 10 and 11.

2) Connect the programming voltage source between terminal TB2-10 (pos) and TB2-12 (neg).

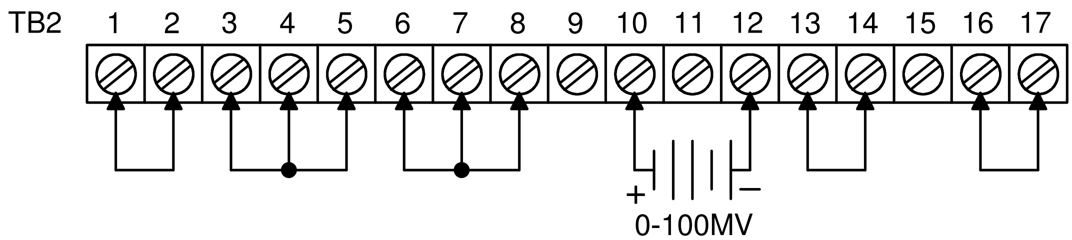


FIGURE 6: REMOTE PROGRAMMING BY EXTERNAL VOLTAGE, CURRENT MODE

III.3.6 Remote programming by external current (figures 7 & 8)

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

1) Remove the jumpers between terminals TB2-3 and 4.

2) Connect the programming current source between terminals TB2-4 (pos) and TB2-6 (neg).

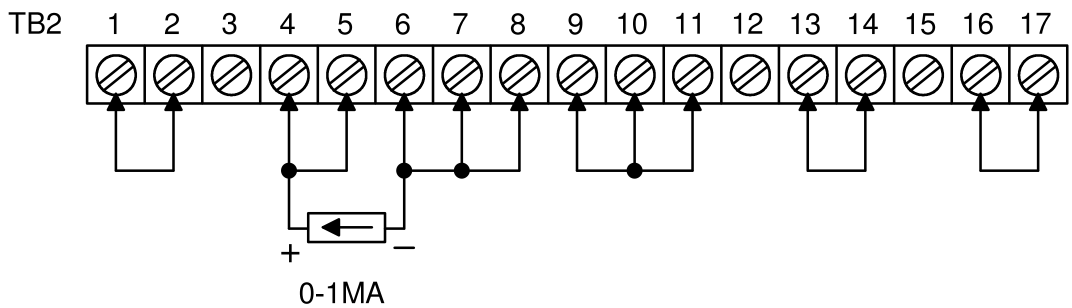


FIGURE 7: REMOTE PROGRAMMING BY EXTERNAL CURRENT, VOLTAGE MODE

Current

1) Remove the jumper between terminals TB2-9 and 10.

2) Connect the programming current source between TB2-10 (pos) and TB2-12 (neg).

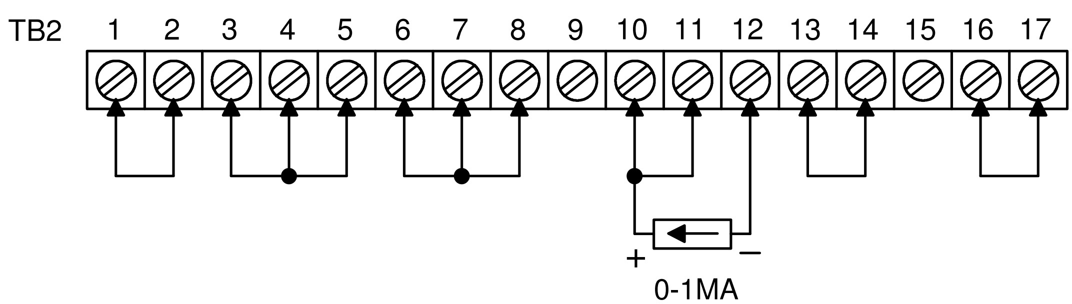


FIGURE 8: REMOTE PROGRAMMING BY EXTERNAL CURRENT, CURRENT MODE

III.3.7 parallel operation (figure 9)

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 unit's 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.

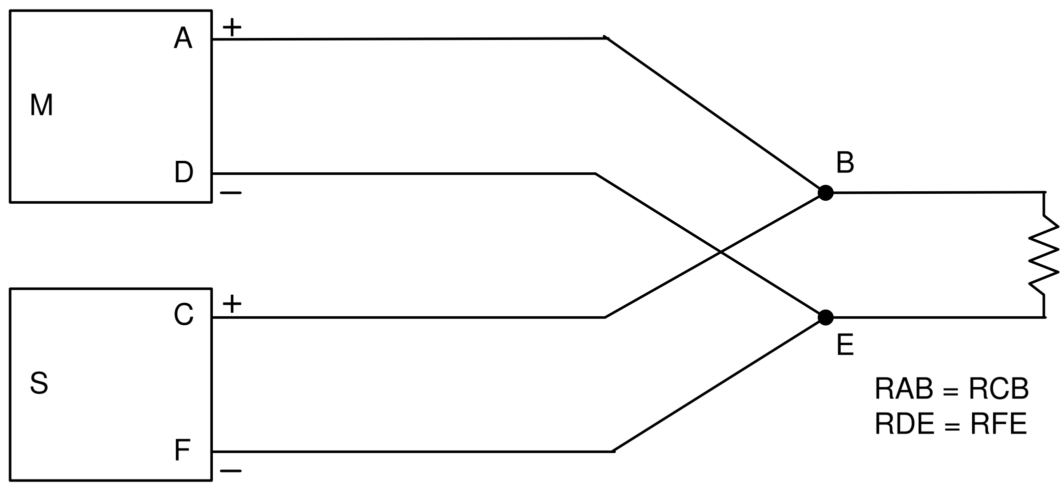


FIGURE 9: MASTER/SLAVE POWER CONNECTION

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:

   TB2-13 and 14
   TB2-9, 10 and 11

2) Connect a jumper between TB2-10 and 12 of all slaves.

3) Connect a wire between the master supply TB2-12 and TB2-13 of each slave.

4) See Figure 9 for + and - power connections.

5) Set the voltage control of each slave fully clockwise.

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.

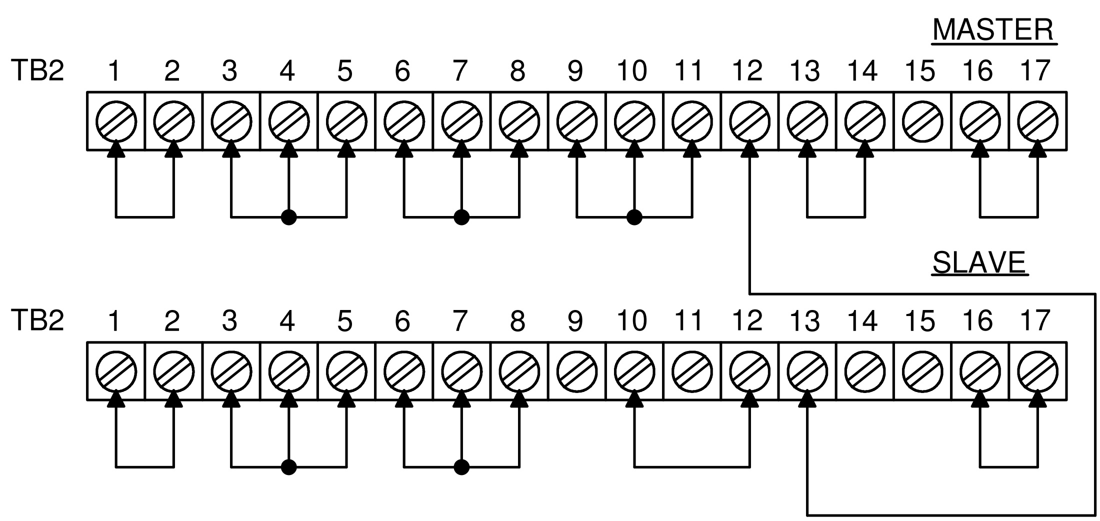


FIGURE 10: PARALLEL OPERATION MASTER/SLAVE

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.
SEE: Application note for series master/slave operation. Consult Electronic Measurements, Inc. Engineering Departments for series operation of more than two supplies.

III.3.10 remote meters

A remote voltmeter may be connected between terminals TB2-2 (pos) and TB2-7 (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 TB2-1 (pos) and TB2-8 (neg).

A remote millivoltmeter, calibrated in amperes, may be connected between terminals TB2-12 (neg) and TB2-14 (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 terminal TB2-14 and other end left floating.

III.3.11 remote turn-on

<u>External Voltage Source</u>

Remove link from TB2-16 and TB2-17. Connect a DC source of 12-24V to terminal TB2-15 positive and TB2-16 negative.

When AC is used 24-115 volts on terminals TB2-15 and TB2-16 the unit is no longer polarity sensitive.

<u>Dry Contact</u>

Connect a switch or contactor between terminals TB2-16 and TB2-17. Contact closed-unit will be on.

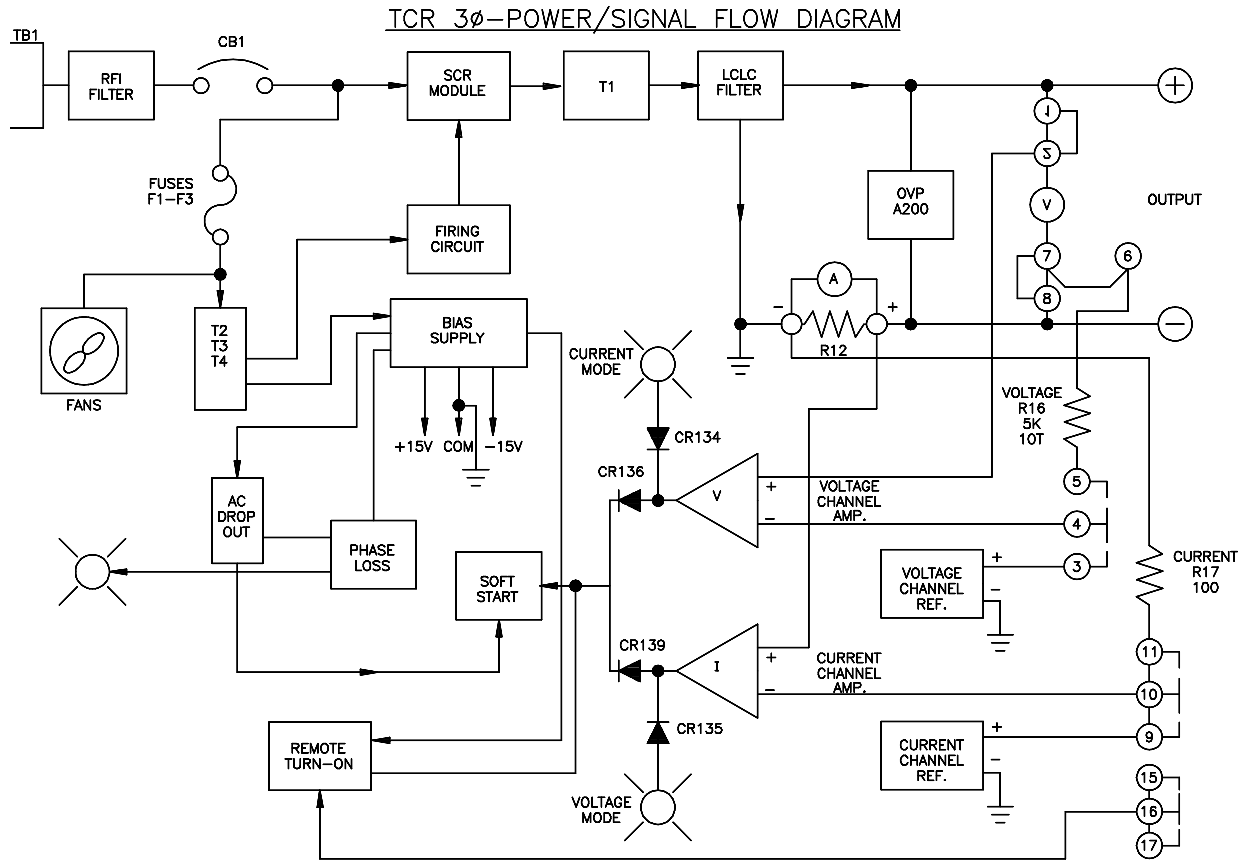

TCR 3Ø—POWER/SIGNAL FLOW DIAGRAM
TB1
RFI FILTER
CB1
SCR MODULE
T1
LCLC FILTER
FUSES F1–F3
FIRING CIRCUIT
OVP A200
OUTPUT
FANS
T2 T3 T4
BIAS SUPPLY
+15V
COM
–15V
CURRENT MODE
R12
CR134
CR136
VOLTAGE R16 5K 10T
VOLTAGE CHANNEL AMP.
AC DROP OUT
PHASE LOSS
SOFT START
VOLTAGE CHANNEL REF.
CURRENT R17 100
CR139
CURRENT CHANNEL AMP.
CR135
REMOTE TURN–ON
CURRENT CHANNEL REF.
VOLTAGE MODE

Figure 11

IV THEORY OF OPERATION

IV.1 GENERAL

The TCR 3 Phase power supply has an SCR module connected in each phase. These modules work in conjunction with the firing circuit and a feedback loop which is the constant voltage/constant current "ored" circuit. The feedback loop determines the firing angle of the SCRs ensuring a regulated AC input voltage is applied to the primary of the power transformer. This regulated AC voltage is then adjusted to the proper level by the power transformer. After being full-wave rectified and filtered a constant output voltage or current is produced.

IV.2 POWER FLOW

This section discusses the basic theory of power and signal flow of the TCR three-phase power supply. If used as a supplement to the maintenance data provided in Section V, it will aid in isolation of unit faults. Refer to Figure 11, block diagram of power and signal flow plus schematics #01-467-001, #01-119-000 and #01-120-000 when reading this section.

Explanation of power flow is as follows: At turn-on, a three-phase AC input passes through the RFI filter, circuit breaker CB1, to the SCR module networks.

The SCR modules contain two SCRs per module, which are connected in reverse parallel. Each SCR conducts upon the simultaneous application of a negative voltage to its cathode (input AC) and a positive voltage to its gate lead. During the positive half cycle Q2, Q4 and Q6 is conducting and during the negative half cycle Q1, Q3 and Q5 will conduct. The gate signal must be from 1-3 volts for the SCR to fire.

The firing angle of the SCR determines the amount of AC power applied to the input transformer. Thus the amplitude of the DC output of an SCR that is fired at an early point of the input cycle provides a higher output than one that is fired later in the input cycle.

Because of the ease with which SCRs are fired by narrow pulses, the gate-cathode terminals are paralleled by "low" impedance snubber networks (R7 and C7) to integrate out narrow noise spikes.

The SCRs operating in conjunction with the firing circuits, controls the amount of AC power applied to the primary of power transformer T1. This transformer converts the input AC voltage to the appropriate AC level for the load voltage and current. The voltage is converted to DC by center-tapped rectifiers CR1 through CR6. (Some units have bridge type rectifiers). At a high continuous load current, L1 and L2 averages the DC voltage waveform at the input of the filter. At low load current the inductance is ineffective and capacitors C16 and C17 changes to peak pulse amplitude for necessary filtering. The phase delay of the input waveform ranges from approximately 60 degrees at the full rated output to nearly 180 degrees at low output voltage and current.

Resistor R10 acts as a pre-load to assure stability when the load is disconnected from the power supply. R11 is connected to the unregulated -15V supply which insures that 50-100mA always flows through R10. Without R11 and when the output voltage is low, little or no current would be flowing through R10 so the output capacitors would never discharge to zero. CR13 bypasses the current through R10 when the current through R10 exceeds the current through R11.

The bias transformers T2 through T4 have two secondary windings. Terminals 4 and 6 on each transformer produces 50V RMS with respect to the center tap, terminal 5. This provides two sine wave signals spaced 180 degrees out of phase for referencing the SCR firing circuit to the line frequency. A voltage of 20V RMS is produced between terminals 7 and 8 of each transformer. Their voltages are full wave rectified on the A100 Control Board to provide + and - 15 VDC for control circuitry.

IV.3 SIGNAL FLOW

All the controlling circuitry for regulation of this supply is located on the A100 Control Board schematic #01-119-000. Explanation of signal flow is as follows:

The 18-20 volts AC from bias transformers T2 through T4 provides a three-phase input to the bias section of the A100 Control Board. These inputs are used for different facets of the controlling process of the power supply. Most of the circuitry uses the + and - 15 VDC regulated by IC101 and IC102. IC101 produces a +15 VDC with a 150 mA load and IC102 a - 15VDC with a 30mA load. The unregulated DC voltage is used for voltage with the remote turn-on when dry contact control is used.

When one of the input phases drops out, the conduction cycle of Q108 is reduced, allowing capacitor C129 to start charging. After three cycles of line frequency, C129 charges sufficiently to cause Q109 to conduct which turns on the front panel phase loss LED. This effectively grounds the drive circuit preventing the generation of further SCR gate pulses which shuts down the output of the unit.

The AC dropout circuit prevents the power supply from operating when the AC drops below operating range. This circuit works as follows: C128 will start discharging through R149. This will cause Q107 to start conducting grounding the firing line to the SCRs and resets the "soft start" circuit.

Once input power is at the operating level, the "soft start" circuit will reset in the following manner: Capacitor C134 slowly starts charging through the base of Q110. As C134 charges, the base current will decrease allowing the collector voltage of Q110 to slowly rise which gradually increases the conduction angle of the SCRs.

Separate constant current references are provided for the voltage and current channels. The collector current of Q111 drives the voltage channel and Q112 the current channel. These current sources are referenced by the voltage across CR133, a temperature-compensated zener diode. Since the voltage difference across the summing junction of IC104 Pin 2 is essentially zero, the voltage across CR133 also appears across the series combination of R167 and R168 (also R171 and R173) since the Vbe of Q111 and Q112 is essentially equal. A constant voltage across a fixed resistance produces a constant current. A constant emitter current produces an essentially constant collector current. The current from each of these sources is adjustable to 1mA by R167 and R171.

The reference current level for the voltage channel flows from J107-2 to TB2-3. With jumpers between terminals TB2-3, 4 and 5, the voltage level produced when this current flows through the voltage control R16 is applied through J107 Pin 10 of IC104. The signal on the other input of IC104 Pin 9 is derived from the power supply output voltage level through voltage divider R177 plus R178 and R179. Maximum rated output voltage produces +5 VDC at Pin 9 of IC104. With R16 in the fully clockwise position, +5 VDC is applied to Pin 8 of IC104. If the attenuated output voltage changes from the value set by R16 (because of load changes, for example) an error signal will be developed at the output of IC104, Pin 10. This error signal, via the SCR control circuitry, will cause a proportional change in the output voltage so as to bring the voltage on Pin 9 of IC104 equal to that applied to Pin 8.

The action of the current channel is identical to that of the voltage channel with the exception that the controlled quantity is being sampled across the shunt R12. This sampled voltage is compared to the reference voltage produced at Pin 6 of IC104, which is established from the front panel current control R17. (0 to 100 mV for all units except 600 and 900 amps, which are 0 to 50 mV).

The output of the voltage channel amplifier and the current channel amplifier are "ored" together by diodes CR136 and CR139. Whichever channel has a higher positive output signal over-rides the effect of the other and becomes the channel controlling the DC output. The output of either the voltage or current channel is fed to the base of transistor Q110 which operates as a linear amplifier whose output is fed to the phase control circuit Q101-106.

The mode indicator lights are controlled by the outputs of the voltage and current channels. For example, if the voltage channel is in control, output of the current channel is negative. This will cause current to flow through CR135 lighting the voltage LED. When the current channel is in control, current will flow through CR134 lighting the current LED.

The voltage signal developed across R164 is a source of feedback fed through R187 and C145, and R182 and C142, to stabilize the current and voltage channels respectively. Additional loop compensation is provided by R183 and C143, and R185 and C144.

A control signal that momentarily switches negative at the base of Q110 allows the collector ramp voltage to increase the firing line voltage earlier in the cycle thus increasing the SCR firing angle. A positive-going signal at the cathodes of CR136 and CR139 causes the output of the power supply to reduce by retarding the conduction of the SCRs. This shows that the amplitude of the phase angle is directly proportional to the polarity of the base signal of Q110. The collector voltage of Q110 is approximately 7 to 8 volts at full conduction angle and 5 to 6 volts for minimum conduction angle.

IV.4 SCR FIRING CIRCUIT

The SCR firing pulses are developed by properly timed conduction of Q1 thru Q6. This is accomplished by the combination of the phase related AC signals from terminals 4, 5 and 6 of T2, T3 and T4 and the variable level from Q110.

Examining the typical firing circuit for one SCR only, R101 and CR101 produce a 12V square wave at line frequency with axis crossings at 0° and 180°. R107 and C102 integrate the square wave into rising and falling ramp voltages with transition in voltage direction occurring just past 0° and 180° due to the phase shifting effect of the RC network. When a positive DC level from Q110 via J7-15 is superimposed on the ramp voltage across C102, Q101 will be driven into conduction at some time during the positive-going position of the ramp. This conduction causes a sudden current flow in the primary of T101 and a resultant pulse of trigger current from the secondary winding of T101 to the gate of SCR Q1. Operation of the opposite firing circuit is identical except for 180° displacement of the gate pulse which fires Q2 when its anode is positive.

C109 through C114 store the SCR gate pulse energy, and C108 and R128 serve as a filter to prevent pulse loading of the +15V supply. Resistors designated "*3" on the A100 schematic are selected at test to equalize SCR firing angles.

Thermal switch TS1 is connected across C134. If the diode heatsink temperature rises excessively, the thermal switch closes causing Q110 to be driven into saturation, thus shutting down the power supply output. The thermal switch will reset automatically when the heatsink temperature drops sufficiently.

IV.5 REMOTE TURN-ON

Remote Turn-On allows the user to turn the supply on from a remote location with 12-24 VDC or 24-115 VAC or a dry contact closure. IC103 isolates the remote turn-on circuitry from the power supply common.

Transistor Q110 is held in saturation by the 15 volts of the bias supply through R157 and CR130. When the internal LED of IC103 is activated by power at Pins 1 and 2, the internal darlington transistor causes most of the 15 volts to be shunted to ground. This allows Q110 to start amplifying.

When a N/O voltage switch (dry contact) for remote turn-on is used, Q113, L101, and CR129 supply the control signal for the optical isolator. Q113 is connected across the unregulated 20 DC volts of the bias supply and is used as a relaxation oscillator.

Each time Q113 conducts, it discharges C147 through L101 inducing a voltage in its secondary winding. This voltage is rectified by CR129 and filtered by C156. When a switch is connected between J12-3 and J12-2 the voltage will make a complete loop to operate the optical isolator.

IV.6 OVERVOLTAGE PROTECTION OPTION (A200 PCB #01-120-000)

The OVP option protects the power supply and the load from excessive output voltage caused by a failure in the control circuitry of the power supply, or a defect or misadjustment in the remote control circuit. IC201, Pin 2 samples the power supply output voltage level through voltage divider R202, R203 and R204. Capacitor C204 connected to Pins 3 and 4 determines the minimum duration of the overvoltage condition before the OVP trips. When the input voltage rises above the trip point set by an internal reference source, capacitor C204 begins charging. When the voltage at Pins 3 and 4 goes above the minimum duration output of IC201 Pin 8 goes positive and turns on Q201, Q202 and Q203.

SCR Q201 is connected to the collector of Q110. When Q201 conducts it shorts the firing line inhibiting the input SCRs. On low voltage power supplies, the voltage available is not high enough to trip the circuit breaker, therefore, the charged energy from a +15V capacitor, C206 is used to trip the breaker. On power supplies above 10 volts C206 and CR206 are not used. Q202 applies the DC output voltage to the circuit breaker.

Q203 and R211 serve as a low impedance high current short to crowbar the output to zero. This will prevent voltage damaging overshoot which could occur with a shorted SCR.

IV.7 DIGITAL METER A100 PCB

The major component of the Digital Meter Printed Circuit Board (A100) is a 3 1/2 digital analog to digital converter (IC17136). All necessary active devices are contained within including seven-segment decoders, display drivers, reference and clock. It also interfaces with a liquid crystal display and provides the backplane drive voltage.

V MAINTENANCE

V.1 GENERAL

A regular scheduled preventive maintenance program is recommended for the TCR 3 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 unplug power supply from AC line before removing cover.

1) Remove six 8-32 machine screws from both sides of top cover. Loosen two 8-32 machine screws at top of back of unit.

2) Cover can now be removed.

3) Check for loose wires, burn marks, etc.

4) A100 control board will snap out so it can be checked.

5) Remove dust from in and around parts with a 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 VDC - 1000 VAC (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 Section 5.2)

NOTE: If an external shunt is being used, connect it in series with the short.

1) Connect a voltmeter across the plus and minus sense leads of the shunt capable of the shunt voltage. The internal shunt of the unit is either 50 or 100 mV.

2) Turn CURRENT and VOLTAGE control completely clockwise.

3) Turn power supply ON.

4) Adjust the ICAL control R171 until the current rating of the unit is achieved.

V.3.1 ammeter calibration

1) Connect the reference ammeter (with shunt as applicable) in series with a 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 supply on.

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

6) Adjust R14 (located just behind the front panel) until the front panel ammeter reading equals that of the reference ammeter. (Analog meters)

V.3.2 firing balance

1) Connect a load to the unit.

2) Connect oscilloscope probe (x10) on TB2-1 and ground on TB2-8.

3) Adjust R120, R123, R126 for even peak voltages from cycle to cycle of the DC output.

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, SCRs, 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 starting to troubleshoot the supply.

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

V.4.1 overall troubleshooting procedure

1) Check for obvious troubles such as input power failure, loose or incorrect strapping on rear terminals of 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 the SCRs by pulling plugs J1-J6.

Some voltages to check with respect to negative terminal on standard units are:

IC101 - Pin 3	+15 volts ± .5V
IC102 - Pin 3	-15 volts ± .5V
IC103 - Pin 5	2-3 volts
IC104 - Pin 11	+15 volts ± .5V
Q110 - Collector	3-8 volts*

*This voltage is clamped at 10 volts by CR132.

3) Disconnect load and proceed to the next step.

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 (counterclockwise).

Where only one terminal is specified measurements are made with respect to I shunt common or a negative output terminal.

The chart that follows is a troubleshooting guide that should aid in discovering operational problems in the supply.

V.4.2 TROUBLESHOOTING CHART

START	PROBLEM
Turn Supply On	Output goes high - Full scale or above. If unit contains OVP option - Circuit breaker trips.

1. Turn set off. 2. Disconnect A100 board from SCRs pulling plugs J1-J6. 3. Turn set on.

PROBLEM	REMEDY
SET STILL OUT OF CONTROL	SHORTED SCR.
SET NO LONGER OUT OF CONTROL	CHECK R16 AND R17 - COULD BE OPEN.
	Check R16 1. Connect digital-meter to J7-2 and common. 2. As R16 is rotated through its ranges, the voltage across it will vary from zero to 3-5 volts. Check R17 1. Connect digital-meter to J7-9 and common. 2. As R17 is rotated through its range the voltage across it will vary from 0-50 or 0-100mV depending on the unit.
	Check transistor Q110 on the A100 control board, could be open.
UNIT ON BUT NO OUTPUT	PHASE LED LIT.
	Check AC input voltage. Check AC signal at J113-2, 3 and 4 on A100 Control Board. Check output of bias transformer T2, T3 and T4 across Pins 7 and 8. Open circuit voltage 20 volts AC. If there is not voltage at the bias transformers check, fuses F1-3.
	PHASE LED NOT LIT
	Check transistor Q110 on the A100 Control Board, could be shorted.
	Check transistors Q107 and Q109 on the A100 Control Board, could be shorted. Check transistor Q108 on the A100 Control Board, could be open.
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 Section 5.5 for diode replacement.
EXCESSIVE RIPPLE	Check output filtering capacitors C16 and C17

	could be defective.
	One of the main SCRs (Q1-Q6 could be open).
	Inductor coils L1 or L2 could be shorted.
	SCR control circuit on the A100 Control Board could be defective. 1. Check for equal ramp amplitudes across CR101-106. 2. Check that the waveform across C109-114 drops rapidly to 1.4 volts.
UNIT IS OSCILLATING	Check C142 and C145, could be defective.
CURRENT OR VOLTAGE CHANNEL DOES NOT REGULATE	Check IC104 and Q110, 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 SCRs Q201 and Q202. They could be shorted.
IC201 could be defective.

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

Check SCRs Q201 and Q202. They could be open.
IC201 could be defective.

V.5 PRIMARY DIODE REPLACEMENT

1) The bottom and side cover is all one piece and must be removed to replace diodes.

2) Remove five 8-32 screws on each side of unit cover.

3) Remove covering.

4) Turn set over to rest on top.

5) Diodes are located on bottom of unit mounted to a heatsink.

6) After removing diodes, wipe heatsink clean of all compound.

7) Put a fine coating of compound (low thermal contact resistance) on surface of diode that meets heatsink. Be careful not to get any on threads of diode.

8) Mount diodes to heatsink with sheetmetal ("PAL") nut. Torque chart follows:

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

9) Use a new nut when a new diode is installed.

V.6 FAN REPLACEMENT

After the fan is replaced the voltage across the fan motor should be measured and compared to the nameplate rating. If the voltage is not correct change the series resistor (R18, R19, R20, R21, R22, R23).

TCR THREE-PHASE 15kW ADDENDUM

This addendum covers the difference between the 2.5 - 10kW package and the 15kW.

AC INPUT:

The AC line current will be approximately 60 amps and the front panel circuit breaker is 70 amps.

COOLING:

The air flow is from right to left with some air flow out the top and back.

RATING TABLE:

OUTPUT RATINGS		OUTPUT RIPPLE VOLTAGE AT FULL LOAD	PANEL SIZE	MODEL TCR
VOLTAGE	CURRENT	RMS	HEIGHT	
4	900	35mV	17.5	4T900
6	900	35mV	17.5	6T900
30	500	20mV	17.5	30T500

The **15kW** schematic is the same as the 10kW package except for (6) fans, **TWO** connected between each of the 3 phases. The fans are the same as the ones used on the 10kW unit.

The OVP part number is listed on the schematic #01-467-001. The OVP for this unit should be bought as a complete assembly, therefore no schematic will be provided.