OPERATING AND SERVICE MANUAL

TQ SERIES

DC POWER SUPPLIES

MAGNA-POWER ELECTRONICS, INC.
81 FULTON STREET, BOONTON, NJ 07005

August 26, 2002

LIMITED WARRANTY

The following is made in lieu of all warranties expressed or implied.

Magna-Power Electronics, Inc. warranties its products to be free of manufacturing defects for a period of one (1) year from date of original shipment from its factory. Magna-Power Electronics, Inc. shall repair or replace at its discretion, any part exclusive of labor to diagnose, remove and install, which upon examination by Magna-Power Electronics, Inc., is determined to be defective in material or workmanship, providing such claimed defective material is returned upon written authorization of Magna-Power Electronics, Inc., freight prepaid. All warranty items are F.O.B. factory.

All electrical, commercial supply parts and items not manufactured by Magna-Power Electronics, Inc. shall carry the warranty of the original manufacturer and no more, but under no circumstances to exceed the "limited warranty."

Replacement parts shall be warranted for a period of 90 days.

Warranty labor shall only apply if the machine, assembly, or part is returned to the factory freight prepaid and insured.

Magna-Power Electronics, Inc. assumes no responsibility for losses of material, labor, production time, any injury, loss or damage, direct or consequential resulting from the operation of, or use, or the inability to use the product other than specifically covered in this warranty.

Damage or breakage through misuse or while in transit is not covered by this warranty.

All claims against the warranty shall be the final determination of Magna-Power Electronics, Inc.

CLAIM FOR DAMAGE IN SHIPMENT

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

RETURNING EQUIPMENT

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

1. Contact our technical service department. Give a full description of the difficulty and include the model and serial number of the unit. On receipt of this information, we will give you service information or shipping instructions.
2. Equipment returned to us must be properly packed and insured if the unit is to be returned for service. You must request a "Return Authorization Number". No returns will be accepted without a pre-authorized RA.
3. For non-warranty repairs, we will submit a cost estimate for your approval before proceeding.

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SECTION I
GENERAL INFORMATION

1.1 DESCRIPTION

This manual contains operation and maintenance instructions for Magna-Power Electronics' TQ Series medium frequency link power supplies. These power supplies are constant voltage/constant current sources suitable for a wide range of applications.

1.2 FEATURES

A crossover feature protects both power supply and load in constant voltage operation. Automatic crossover circuitry switches the power supply from constant voltage to constant current operation if the output current exceeds a preset limit. This crossover circuitry also protects the load from over voltage during constant current operation by automatically switching the power supply into constant voltage operation. The user can adjust the crossover point via the front panel controls.

TQ series power supplies are fully programmable via resistance, voltage, current, optional IEEE-488, or optional RS232. Program lines are constantly monitored for range of operation. If a line should open or if a programmable input is set beyond that anticipated, the unit safely shuts down protecting the load.

Differential amplifiers isolate the programming lines from the dc output allowing programming at any distance from the load. Additional differential amplifiers are provided for master/slave series or parallel operation.

Diagnostic functions are contained directly within the supply's control loop. Exclusive circuitry eliminates guesswork as to which function has control -- voltage, current, soft-start, or a fault condition. If the fault condition requires user attention, mains power is disconnected. All diagnostic functions are monitored with optical isolators to be paralleled for master/slave operation. In addition, control functions are also set through optical isolators to allow simultaneous control of one or more TQ series units.

Transient response is enhanced by means of feedforward compensation and optional electronic loading. Feedforward compensation detects line and load changes and offsets feedback signals before being corrected with the slower, error amplifiers. Optional electronic loading maintains output rectifiers with continuous current regardless of load conditions. This prevents peak charging of output capacitors and drooping under transient loading.

TQ series supplies have three levels of over voltage protection: shutdown of the controlling thyristors, disconnect of the main power, and optional SCR crowbar. Upon an over voltage condition, the supply must be reset forcing the user to observe the over voltage setting.

TQ series supplies have four levels of over current protection: shutdown of the medium frequency link, shutdown of the controlling thyristors, disconnect of the main power, and input fusing. Over current shutdown is detected with two time delays: a fast response for abnormal, arcing conditions and a slower response for normal, controlled current conditions. Upon an over current condition, the supply must be reset forcing the user to observe the over current setting.

1.3 COOLING

Each power supply enclosure is cooled by suitable blowers exhausting warm air to the top of the cabinet. Fresh air intake is from the bottom front and bottom rear sides of the cabinet. Blocking ventilation will cause the power supply to overheat.

1.4 INSTALLATION

The power supply is ready for operation when shipped. Electrical connections are made through the rear access panels. Power and control cables must be totally separated. Cables should be placed in independent conduits and fed through dedicated holes punched in the access panels. The unit should be operated in the upright position.

1.5 POWER REQUIREMENTS

A suitable source of ac power is required for this supply. The unit is wired for 480 V, 3φ, 50 to 60 Hz mains. For 440 V operation, internal wiring changes must be made to the unit. Information concerning conversion is covered in Section 2.14.

1.6 SPECIFICATIONS

The following specifications describe the published operational characteristics of the TQ series power supplies.

Input voltage: 440/480 Vac, 50-60 Hz, 3φ.

Regulation line and load combined: 0.1 %.

Stability: 0.1 % for 8 hours after 30 minute warm up.

Transient response: 75.0 ms to recover within 2 % of regulated output with 50 to 100 % or 100 to 50 % load change.

Ambient Temperature: 0 to 50°C.

Storage Temperature: -25 to +85°C.

Programming resistors: 1 KΩ full scale for output voltage, output current, over voltage shutdown, and over current shutdown.

Temperature coefficient: 0.04 %/°C of maximum output current.

Size: 64¼" H x 47¼" W x 24¾" D, see figures 1.1 through 1.4 for typical details.

Weight: 1600 lbs for 100 kW models and 2100 lbs for 150 kW models.

100 KW MODELS AND RATINGS - 440/480 V

MODEL	OUTPUT VOLTAGE Vdc	OUTPUT CURRENT Adc	RIPPLE VOLTAGE mVrms	% EFF.	AC INPUT CURRENT Aac
TQ16-6000	16	6000	50	82	200
TQ20-5000	20	5000	15	83	200
TQ32-3000	32	3000	30	84	195
TQ40-2500	40	2500	35	85	195
TQ50-2000	50	2000	40	85	195
TQ80-1250	80	1250	50	85	195
TQ100-1000	100	1000	55	85	195
TQ125-800	125	800	60	86	195
TQ160-620	160	620	70	86	195
TQ200-500	200	500	80	86	195
TQ250-400	250	400	90	86	195
TQ375-270	375	270	100	86	195
TQ500-200	500	200	130	87	195
TQ625-160	625	160	150	87	195
TQ800-125	800	125	175	87	195
TQ1000-100	1000	100	250	87	195

Notes:
1) Rating specified at 440 V input.
2) Specifications subject to change without notice.

150 KW MODELS AND RATINGS - 440/480 V

MODEL	OUTPUT VOLTAGE Vdc	OUTPUT CURRENT Adc	RIPPLE VOLTAGE mVrms	% EFF.	AC INPUT CURRENT Aac
TQ20-7500	20	7500	45	83	292
TQ32-4500	32	4500	30	84	285
TQ40-3750	40	3750	35	85	285
TQ50-3000	50	3000	40	85	285
TQ80-1850	80	1850	50	85	285
TQ100-1500	100	1500	55	85	285
TQ125-1200	125	1200	60	86	285
TQ160-900	160	900	70	86	285
TQ200-750	200	750	80	86	285
TQ250-600	250	600	90	86	285
TQ375-400	375	400	100	86	285
TQ500-300	500	300	130	87	285
TQ625-240	625	240	150	87	285
TQ800-180	800	180	175	87	285
TQ1000-150	1000	150	250	87	285

Notes:
1) Rating specified at 440 V input.
2) Specifications subject to change without notice.

Figure 1.1 Main 100 kW Assembly - Front View

Figure 1.2 Main 100 kW Assembly - Rear View

Figure 1.3 Main 150 kW Assembly - Front View

Figure 1.4 Main 150 kW Assembly - Rear View

SECTION II
OPERATING INSTRUCTIONS

2.1 GENERAL OPERATION

As shipped, the power supply is configured for local sensing, internal programming, and 480 V, 3φ input. The front panel voltage and current controls will set boundary limits for output voltage and current, respectively. The impedance of the load will determine whether the unit is voltage or current controlled and the illumination of the respective mode indicator light will indicate the state. If either control is set to maximum counter clockwise rotation, the other control will have little or no effect. Each control must be set to the appropriate position for proper operation.

2.2 CONTROLS AND INDICATORS

The controls and indicators are illustrated in figure 2.1.

2.3 PREPARATION FOR USE

2.3.1 UNPACKING

Carefully unpack the power supply saving all packing materials and included enclosures. Inspect for possible shipping damage. Check that there are no broken knobs or connectors, the external surface is not scratched or dented, the meter faces are not damaged, and all controls move freely. Any external damage may be an indication of internal damage.

2.3.2 ELECTRICAL CHECK

Check that the terminal jumper connections located at the rear of the supply are as shown in schematics 109201 and 109212. This depicts the normal local sense and programming configuration. It is recommended that the following brief electrical check be made shortly after unpacking the supply.

Set voltage and current controls full counterclockwise, turn the power switch off and connect a short circuit to the power output studs on the rear panel. WARNING: Never attempt to remove the power from the supply by means of the terminal strips, since the wiring is not sized to handle the current capacity of the supply. Connect the supply to a suitable source of ac voltage. For this test, only 50% of rated ac current is required.

Turn the power switch on. The power light, standby light, and soft start light should come on. Press the start switch, advance the voltage control one turn clockwise. The standby light should extinguish and the current control light should come on. Press display/reset switch and adjust over current trip to maximum current by means of screw driver adjustment. Increase the current setting to maximum and then to minimum. Dc current should increase smoothly from minimum

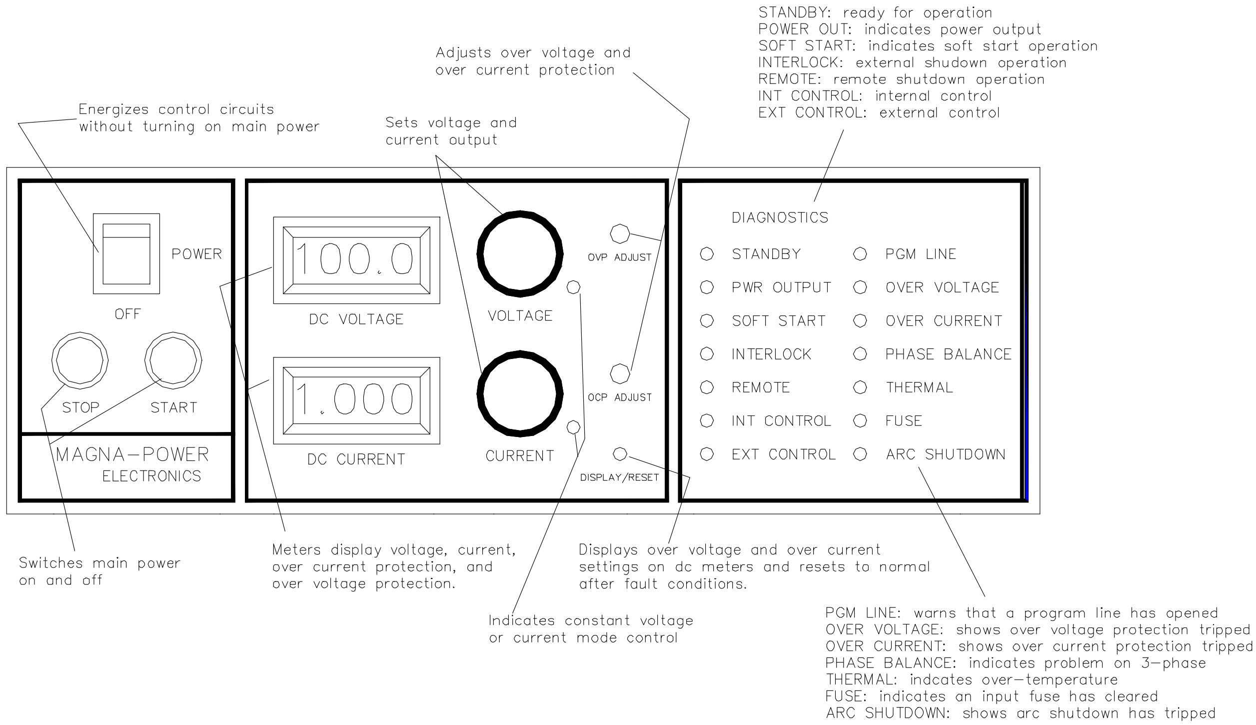


Figure 2.1 Controls and indicators

to maximum to minimum as indicated on the meter. Return all controls full counterclockwise and turn off the supply.

Press display/reset switch and adjust over current trip to half rated current. Slowly increase the current setting. Over current trip should operate at the over current trip setting, the over current light should come on, and the supply should shut down. Press display/reset switch and adjust over current trip to maximum current. Adjust the current control full counterclockwise and restart the supply. The supply should operate normally

With the power supply off, disconnect the output short circuit. Turn the power switch on. Press the start switch and advance the current control one turn clockwise. The standby light should extinguish and the voltage control light should come on. Press display/reset switch and adjust over voltage trip to maximum voltage by means of screw driver adjustment. Increase the voltage setting to maximum and then to minimum. Dc voltage should increase smoothly from minimum to maximum to minimum as indicated on the meter. Return voltage control full counterclockwise.

Press display/reset switch and adjust over voltage trip to half rated voltage. Slowly increase the voltage setting. Over voltage trip should operate at the over voltage trip setting, the over voltage light should come on, and the supply should shut down. Press display/reset switch and adjust over voltage trip to maximum voltage. Adjust the voltage control full counterclockwise and restart the supply. The supply should operate normally.

If any of these events do not occur, the supply is defective and should not be operated. Depending on the circumstances, either warranty service or trouble shooting as described in Section IV is required.

2.4 MODES OF OPERATION

2.4.1 NORMAL MODE

TQ series power supplies are normally shipped with its terminal strip jumper straps arranged for constant voltage/constant current, local sensing, local programming, single unit mode of operation. The terminal jumping pattern is shown in schematics 109201 and 109212. The operator selects either a constant voltage or a constant current output using the front panel controls (local programming, no jumper changes are necessary).

2.4.2 CONSTANT VOLTAGE

To select a constant voltage output, proceed as follows:

With the supply off, set all controls to full counterclockwise and advance current control one turn clockwise. Turn on power supply and adjust voltage trip to 110% desired output voltage. Advance voltage control for the desired output voltage with the output terminals open.

Turn off supply and short output terminals. Turn on the supply and adjust the current control for maximum output current allowable as determined by load conditions. If a load change causes the current limit to be exceeded, the power supply will automatically crossover to constant current output at the preset current limit and the output voltage will drop proportionately. In setting the current limit, allowance must be made for high peak currents which can cause unwanted crossover (see section 2.13).

Turn off the power supply, remove the short on output terminals, and connect the load. The unit is now ready for operation.

2.4.3 CONSTANT CURRENT

To select a constant current output, proceed as follows:

With the supply off, short the output terminals, set all controls to full counterclockwise, and advance the voltage control one turn clockwise. Turn on the power supply and adjust current trip to 110% desired output current. Advance current control for the desired output current with the output terminals shorted.

Turn off supply and remove short on output terminals. Turn on the supply and adjust the voltage control for maximum output voltage allowable as determined by load conditions. If a load change causes the voltage limit to be exceeded, the power supply will automatically crossover to constant voltage output at the preset voltage limit and the output current will drop proportionately.

Turn off the power supply and connect the load. The unit is now ready for operation.

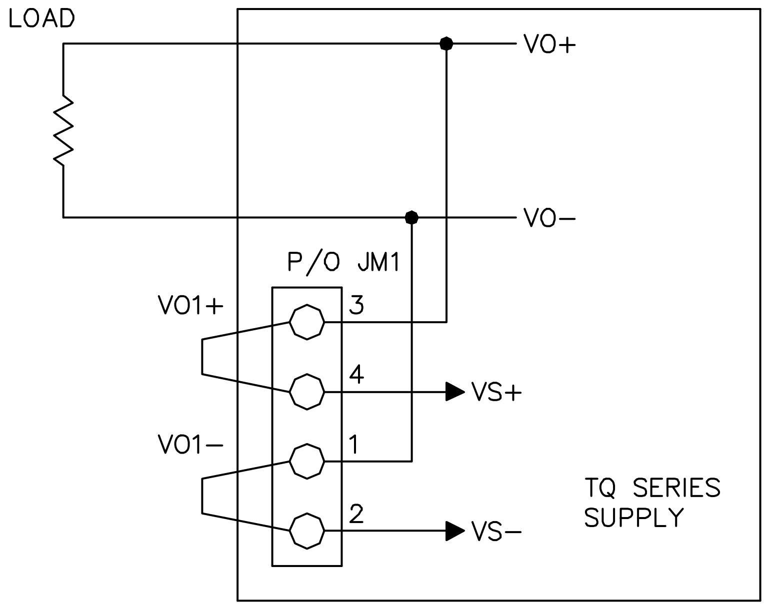
2.5 REMOTE SENSING

Remote sensing is used to improve the degradation of regulation which will occur at the load when the voltage drop in the connecting wires is appreciable. This is done by removing the jumpers between terminals 1 and 2 and terminals 3 and 4 of JO6. Using a pair of #20 AWG wires, connect terminal 4 of JO6 to the positive terminal of the load and connect terminal 2 of JO6 to the negative terminal of the load.

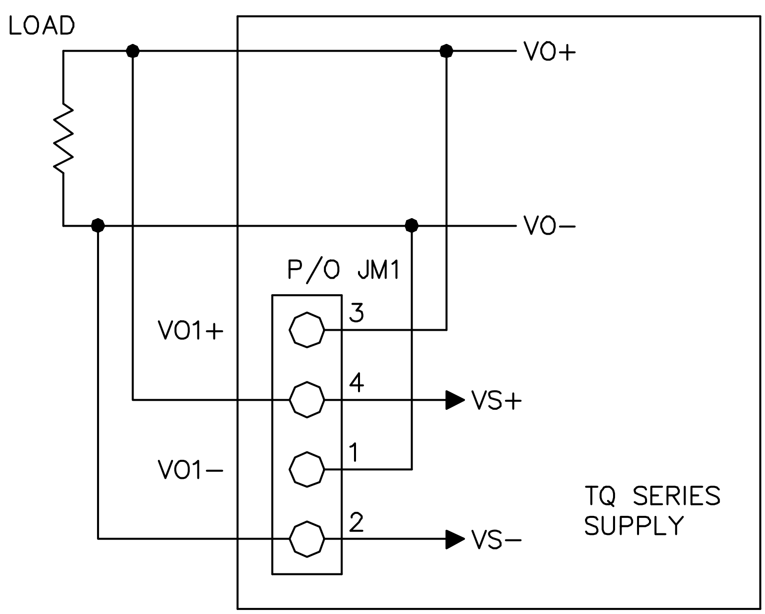
Figure 2.2 illustrates standard output sensing and remote output sensing.

2.6 STANDARD PROGRAMMING

The standard programming configuration, illustrated in figure 2.3, shows that references for voltage, current, voltage trip, and current trip are established by internal 2 mA current sources producing voltages across potentiometers RV, RI, RTV, and RTI. These potentiometers are the front panel controls for voltage, current, voltage trip, and current trip, respectively.



(a)



(b)

Figure 2.2 (a) Standard and (b) remote sensing

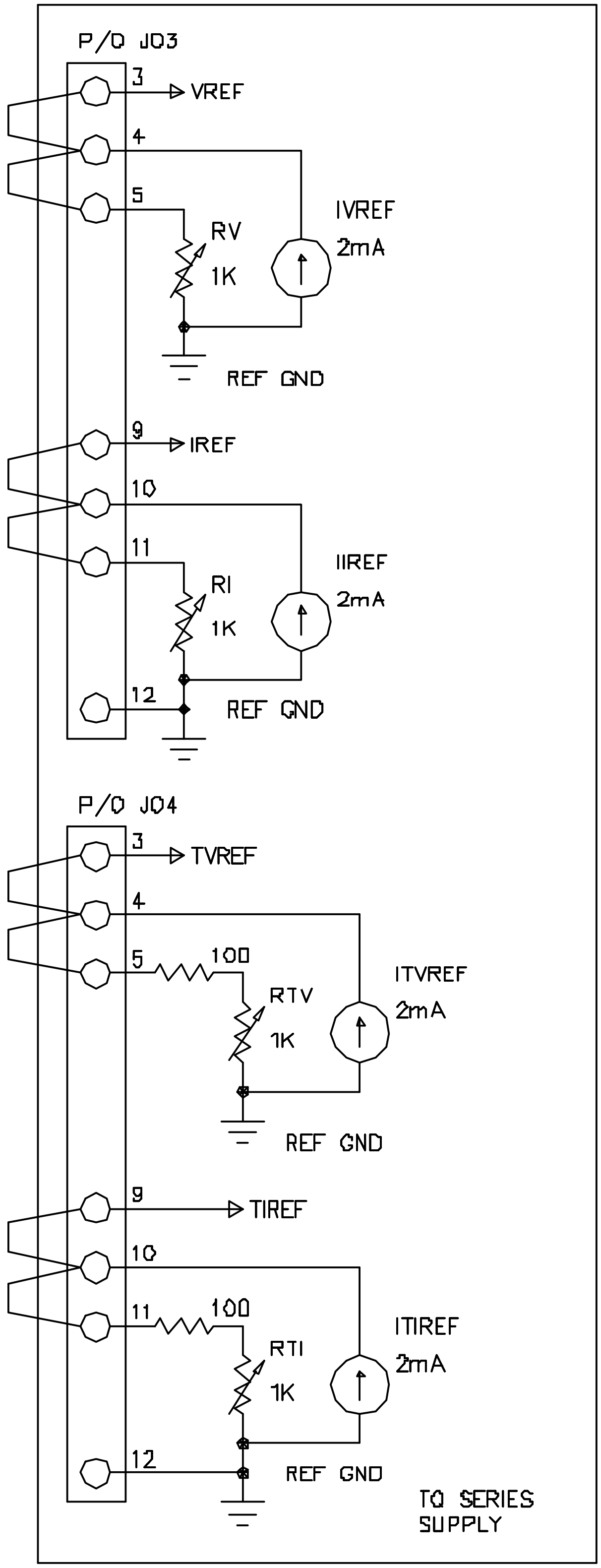


Figure 2.3 Standard programming configuration using internal potentiometers

Resistors placed in series with the voltage and current trip potentiometers allow settings above the maximum voltage and current of the supply.

2.7 REMOTE PROGRAMMING

TQ series supplies allow voltage, current, and voltage trip to be programmed from a remote location. Programming can be accomplished either by resistive, voltage, or current programming circuits.

Figure 2.4 illustrates the three alternatives for programming output voltage. The method applies equally to programming output current, voltage trip, and current trip.

2.7.1 RESISTIVE PROGRAMMING

Resistive programming requires removal of jumper between terminals 4 and 5 of JO3 and connection of an external potentiometer or resistor between terminals 4 and 12 of JO3. To minimize noise, wires should be #20 AWG twisted pair. Like the internal voltage potentiometer, the 2 mA reference produces a voltage across the potentiometer or resistor which is used to set the output voltage. A metal film resistor or wire wound potentiometer will result in the lowest temperature coefficient.

To program output current, voltage trip, or current trip, use the same method and refer to schematics 109201 and 109212 for terminal identification.

The expressions for programming output voltage, V_O, output current, I_O, voltage trip, T_V, and current trip, T_I are given as follows.

$$V_O = \frac{V_{OMAX} R_P}{1000\Omega} \quad (1)$$

$$I_O = \frac{I_{OMAX} R_P}{1000\Omega} \quad (2)$$

$$T_V = \frac{V_{OMAX} R_P}{1000\Omega} \quad (3)$$

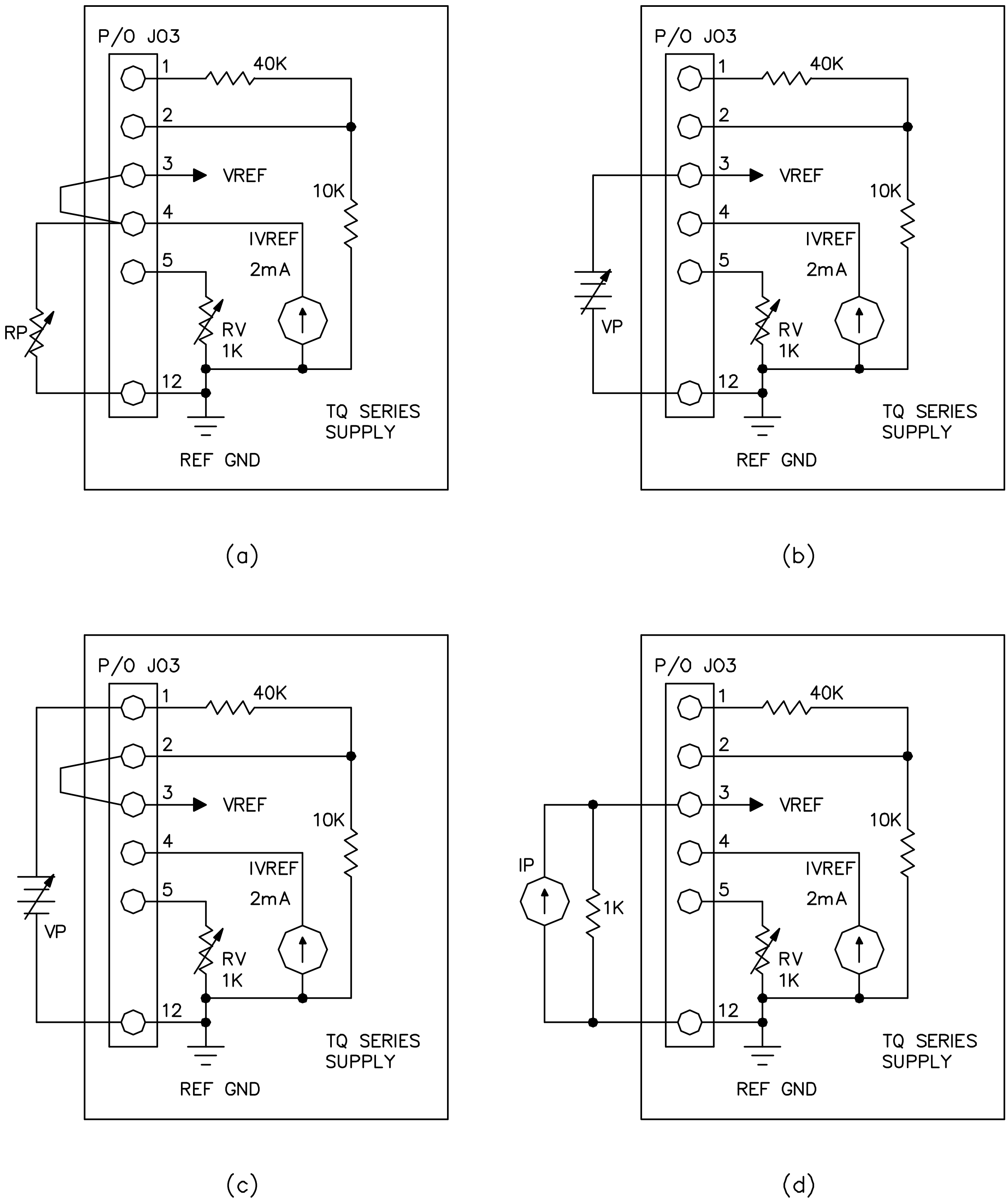


Figure 2.4 External (a) resistive, (b) 2.0 V FS voltage,
(c) 10.0 V FS voltage, or (d) current programming

$$T_I = \frac{I_{OMAX} R_P}{1000\Omega} \quad (4)$$

where:

V_{OMAX}: maximum output voltage,
I_{OMAX} : maximum output current,
R_P: programming resistor.

2.7.2 VOLTAGE PROGRAMMING AT 2.0 V INPUT

Voltage programming at 2.0 V input requires removal of jumper between terminals 3 and 4 of JO3, removal of jumper between terminals 4 and 5 of JO3, and connection of an external voltage reference between terminal 3 of JO3 (positive) and terminal 12 of JO3 (negative). To minimize noise, wires should be #20 AWG twisted pair.

To program output current, voltage trip, or current trip, use the same method and refer to schematics 109201 and 109212 for terminal identification.

The expressions for programming output voltage, V_O, output current, I_O, voltage trip, T_V, and current trip, T_I, are given as follows.

$$V_O = \frac{V_{OMAX} V_P}{2.0\,V} \quad (5)$$

$$I_O = \frac{I_{OMAX} V_P}{2.0\,V} \quad (6)$$

$$T_V = \frac{V_{OMAX} V_P}{2.0\,V} \quad (7)$$

$$T_I = \frac{I_{OMAX} V_P}{2.0\,V} \quad (8)$$

where:

V_P: programming reference voltage.

2.7.3 VOLTAGE PROGRAMMING AT 10.0 V INPUT

Voltage programming at 10.0 V input requires removal of jumper between terminals 3 and 4 of JO3, removal of jumper between terminals 4 and 5 of JO3, connection of a jumper between terminals 2 and 3 of JO3, and connection of an external voltage reference between terminal 1 of JO3 (positive) and terminal 12 of JO3 (negative). To minimize noise, wires should be #20 AWG twisted pair.

To program output current, voltage trip, or current trip, use the same method and refer to schematics 109201 and 109212 for terminal identification.

The expressions for programming output voltage, V_O, output current, I_O, voltage trip, T_V, and current trip, T_I, are given as follows.

$$V_O = \frac{V_{OMAX} V_P}{10.0\,V} \quad (9)$$

$$I_O = \frac{I_{OMAX} V_P}{10.0\,V} \quad (10)$$

$$T_V = \frac{V_{OMAX} V_P}{10.0\,V} \quad (11)$$

$$T_I = \frac{I_{OMAX} V_P}{10.0\,V} \quad (12)$$

where:

V_P: programming reference voltage.

2.7.4 CURRENT PROGRAMMING

Current programming requires removal of jumper between terminals 3 and 4 of JO3, removal of jumper between terminals 4 and 5 of JO3, connection of an external, 1K metal film resistor between terminal 3 of JO3 and terminal 12 of JO3, connection of an external current source between terminal 3 of JO3 (positive) and terminal 12 of JO3 (negative). To minimize noise, wires should be #20 AWG twisted pair.

To program output current, voltage trip, or current trip, use the same method and refer to schematics 109201 and 109212 for terminal identification.

The expressions for programming output voltage, V_O, output current, I_O, voltage trip, T_V, and current trip, T_I, are given as follows.

$$V_O = \frac{V_{OMAX} I_P}{2.0mA} \tag{13}$$

$$I_O = \frac{I_{OMAX} I_P}{2.0mA} \tag{14}$$

$$T_V = \frac{V_{OMAX} I_P}{2.0mA} \tag{15}$$

$$T_I = \frac{I_{OMAX} I_P}{2.0mA} \tag{16}$$

where:

I_P: programming current source.

2.8 ANALOG OUTPUT LINES

Two analog output lines are provided to monitor output voltage and current. Terminal 2 of JO5 monitors output voltage and terminal 4 of JO5 monitors output current. Analog output lines produce 10.0 V at full scale output voltage and current. These outputs may be used for external instrumentation or process control.

2.9 DIGITAL CONTROL LINES

All input and output control lines are connected to optical isolators for varied applications.

Input control lines are or'd with front panel controls for remote start, stop, and reset. To force any state, apply +5 V between the input control line and isolated return. As illustrated in figure 2.5, digital control lines can be paralleled with other supplies to allow simultaneous control. Input control lines or front panel controls may be disabled by removing the jumper connections between terminals 11 and 12 of JO2 or terminals 10 and 11 of JO2, respectively.

Output monitoring lines provide a means to monitor diagnostic functions as well as mode of operation (voltage or current). Figure 2.6 shows that diagnostic functions can be or'd with other supplies to simplify problem detection in large systems.

All digital lines, both control and monitoring, are referenced to a common isolated return.

2.10 DIAGNOSTIC FUNCTIONS

Diagnostic functions and mode of control are embedded in the supply's closed loop control. Voltage control, current control, and soft start indicate on the lowest of the three settings. Soft start is reset upon power-on or operation of any diagnostic function.

Diagnostic functions include thermal overload, remote shutdown, standby, phase balance, program line, internal control, external control, fuse, over voltage, over current, and arc current. All diagnostic indicators have memory retention which saves the fault condition until the power supply is reset or control power is removed and returned.

Thermal overload indicates that the SCR’s, IGBT’s, or output rectifiers have reached a critical temperature. A resetting thermal breaker will reset upon cooling. The supply must be restarted after this fault condition.

Remote shutdown forces output voltage and current to minimum, but maintains an on-state condition.

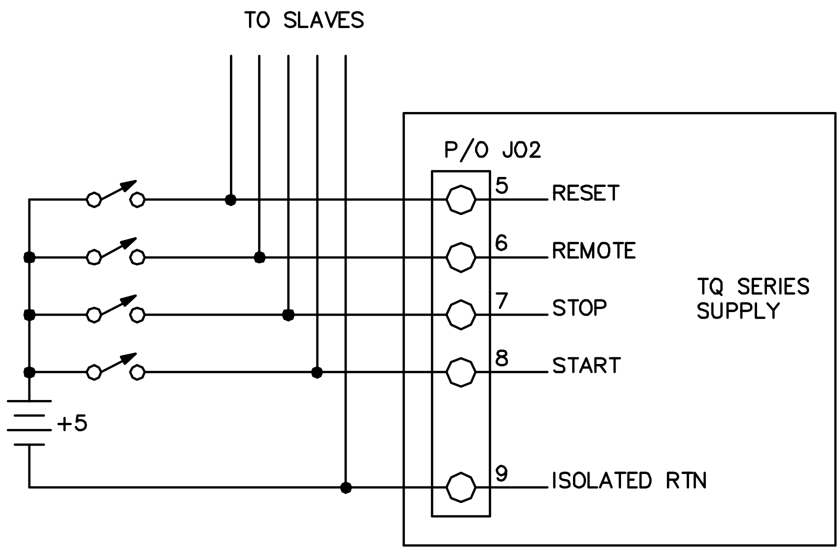


Figure 2.5 Digital control lines

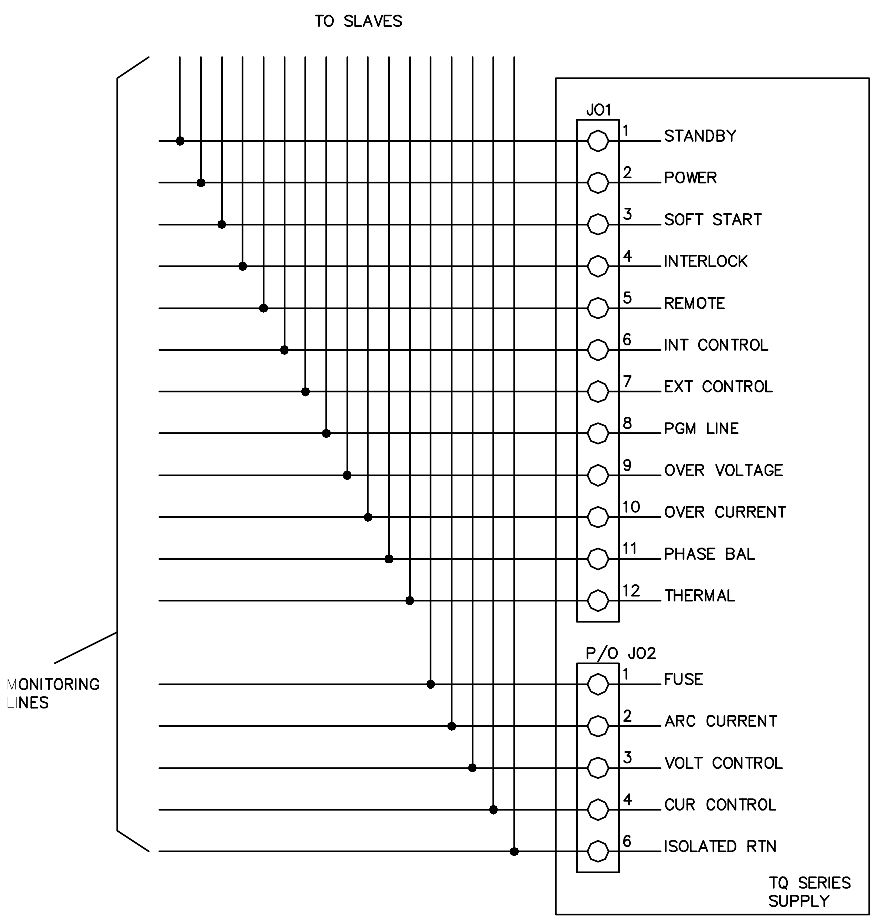


Figure 2.6 Digital output monitoring lines

Standby indicates that the control circuits are powered, but the supply is disabled through the ac contactor. This is the supply's normal off condition. To start the supply, press the start switch. To place the supply in standby, press the stop switch.

Phase balance indicates a problem with the mains supply. The supply must be restarted after this fault condition.

Opening of a program line can cause the voltage, current, over voltage, or over current trip reference to be set beyond the range of control. These lines are constantly monitored and if any of these references are set above the normal bounds, program line diagnostics will disable the supply. The supply must be restarted after this condition.

Internal and external control indicate the control mode programmed by jumper connections on JO2 (see Section 2.9). Internal control indicates that front panel start, stop, and reset switches will be functional and external control indicates that input digital lines; terminals 5, 7, and 8 of JO2; will be functional.

Fuse indicates that one of the three main fuses has cleared. Power must be removed from the supply and the fused must be replaced to correct this condition.

Over voltage indicates that the supply has exceeded the over voltage trip reference. This condition causes the supply to shutdown and optional SCR crowbar to fire. To clear this condition, the user must press the display/reset switch on the front panel. Upon pressing this switch, the over voltage trip and over current trip references are displayed and the over voltage condition is cleared. To restart the supply, simply press the start switch.

Over current indicates that the supply has exceeded the over current trip reference. To clear this condition, the user must press the display/reset switch on the front panel. Upon pressing this switch, the over voltage trip and over current trip references are displayed and the over current condition is cleared. To restart the supply, simply press the start switch.

Arc current indicates that the supply has exceeded the over current trip reference by at least a factor of two. Arc current has a quicker response than over current and is used for faster shutdown due to arcing conditions.

Opening the jumper between interlock set and interlock set return, terminals 11 and 12 of JO6, locks the power supply in an off state. The jumper may be replaced with an external safety switch for applications. Alarm and alarm return, terminals 9 and 10 of JO6, produce a contact closure for any fault condition.

2.11 PARALLEL OPERATION

Two or more power supplies can be connected in parallel to obtain a total output current greater than that available from one power supply. The total output current is the sum of the output currents of the individual power supplies. Each power supply can be turned on or off separately.

WARNING: TQ series power supplies should not be connected in parallel with optional SCR crowbar. Operation of the crowbar in such configuration can damage the power supply.

2.11.1 PARALLEL OPERATION - DIRECT

The simplest parallel connection involves attaching the positive terminals of all supplies to be paralleled to the positive point of the load and the negative terminals to the negative point of the load. The output current controls of each power supply can be separately set. The output voltage controls of one power supply (master) should be set to the desired output voltage; the other power supply (slave) should be set for a slightly higher output voltage. The master will act as a constant voltage source; the slave will act as a constant current source, dropping its output voltage to equal that of the master.

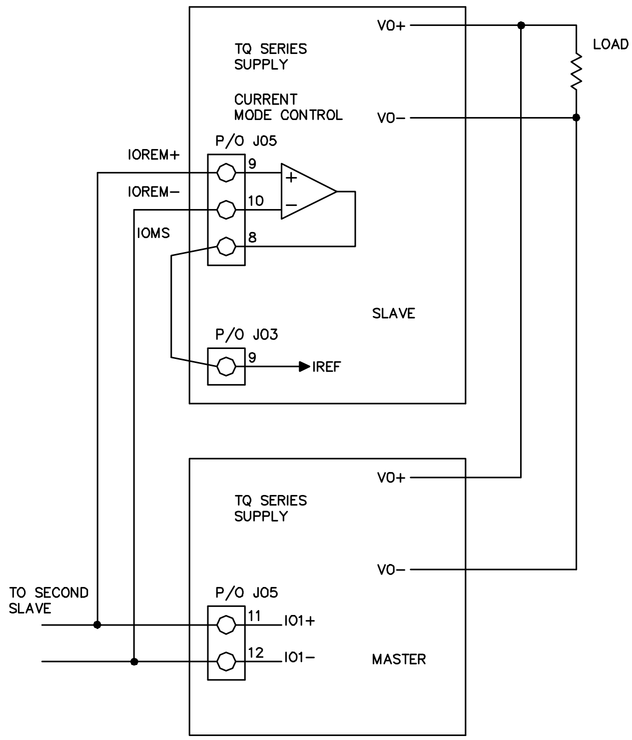
2.11.2 PARALLEL OPERATION - MASTER/SLAVE

Master/slave parallel operation permits equal current sharing under all load conditions and allows complete control of output current from one master power supply.

Figure 2.7 illustrates the terminal connection for master/slave operation and salient control circuitry. Slave operation requires removal of jumper between terminals 9 and 10 of JO3 and removal of jumper between terminals 10 and 11 of JO3. Connect jumper between terminal 8 of JO5 to terminal 9 of JO3. To interface the slave to the master, connect terminal 9 of JO5 slave to terminal 11 of JO5 master, and connect terminal 10 of JO5 slave to terminal 12 of JO5 master. To minimize noise, wires between the master and slave should be #20 AWG twisted pair.

The auxiliary differential amplifier in the slave connects to the current sensing terminals of the master. This amplifier creates a current reference signal equal to that being sensed by the master. In master/slave parallel operation, the slave output voltage should be set slightly higher than that of the master.

To add a second slave, make the same connections to the current sensing terminals of the master and connect the second slave in parallel with the other two supplies.


TQ SERIES SUPPLY
CURRENT MODE CONTROL
VO+
VO−
LOAD
P/O J05
IOREM+
IOREM−
IOMS
9
10
8
P/O J03
9
IREF
SLAVE
TQ SERIES SUPPLY
VO+
VO−
TO SECOND SLAVE
P/O J05
11
12
IO1+
IO1−
MASTER

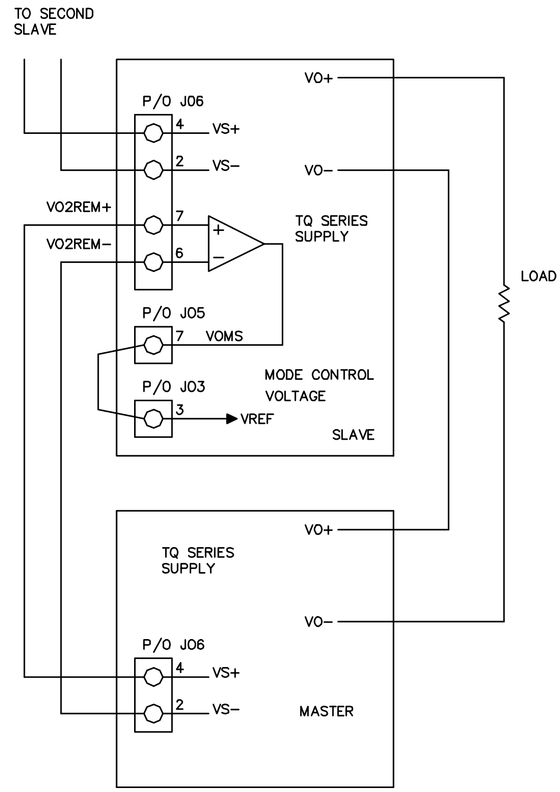

TO SECOND SLAVE
P/O J06
4
2
VS+
VS−
VO+
VO−
VO2REM+
VO2REM−
7
6
TQ SERIES SUPPLY
LOAD
P/O J05
7
VOMS
P/O J03
3
VREF
MODE CONTROL
VOLTAGE
SLAVE
TQ SERIES SUPPLY
VO+
VO−
P/O J06
4
2
VS+
VS−
MASTER

Figure 2.7 Master/slave parallel connection

Figure 2.8 Master/slave series connection

2.12 SERIES OPERATION

Two or more power supplies can be connected in series to obtain a total output voltage greater than that available from one power supply. The total output voltage is the sum of the output voltage of the individual power supplies. Each power supply can be turned on or off separately.

WARNING: No plus or minus voltage should exceed 1200 V with respect to ground.

2.12.1 SERIES OPERATION - DIRECT

The simplest series connection involves attaching the positive terminal of the first supply to the negative terminal of the second supply. The load is connected between the negative terminal of the first supply and the positive terminal of the second supply. The output current controls of each power supply are operative and the current limit is equal to the lowest control setting. If any one output current control is set too low with respect to the total output current, the series power supplies will automatically crossover to constant current operation and the output voltage will drop.

2.12.2 SERIES OPERATION - MASTER/SLAVE

Master/slave series operation permits equal voltage sharing under all load conditions and allows complete control of output voltage from one master power supply.

Figure 2.8 illustrates the terminal connection for master/slave operation and salient control circuitry. Slave operation requires the removal of jumper between terminals 3 and 4 of JO3 and the removal of jumper between terminals 4 and 5 JO3. Connect jumper between terminal 7 of JO5 to terminal 3 of JO3. To interface the slave to the master, connect terminal 7 of JO6 slave to terminal 4 of JO6 master, and connect terminal 6 of JO6 slave to terminal 2 of JO2 master. To minimize noise, wires between the master and slave should be #20 AWG twisted pair.

The auxiliary differential amplifier in the slave connects to the output of the master. This amplifier creates a voltage reference signal equal to that being sensed by the master. Master/slave series operation is intended only for power supplies with the same output voltage and current.

To add a second slave, sense the output voltage of the first slave and place the second slave at the highest potential above ground. Do not sense the output voltage of the master, for this will damage the second slave.

2.13 PULSE LOADING

The power supply will automatically crossover from constant voltage to constant current operation, or the reverse, in response to an increase (over the preset limit) in the output current or voltage, respectively. Although the preset limit may be set higher than the average current or

voltage, high peak currents or voltages, as occur in pulse loading, may exceed the preset limit and cause crossover to occur. To avoid this unwanted crossover, the preset limit must be set for the peak requirement and not the average.

There are internal capacitors across the output terminals of the power supply. These capacitors help to supply high-current pulses of short duration during constant voltage operation. Any capacitance added externally will improve the pulse current capability, but will decrease the safety provided by the constant current circuit. A high-current pulse may damage load components before the average output current is large enough to cause the constant current circuit to operate.

2.14 CONVERSION TO 440 V OPERATION

TQ series supplies are normally wired for 480 V, 3φ operation. For conversion to 440 V, 3φ, two connections have to be changed inside the supply.

Disconnect all power leads to the supply and remove the right lower front panels of the power supply.

Locate main transformer T1 and move the two wires on tap 3 to tap 2. Make sure the connection is secure. Replace the right lower front panels. The conversion is complete.

2.15 CONVERSION TO 50 HZ OPERATION

TQ series supplies are normally wired for 60 Hz operation. For operation at 50 Hz, a jumper connection on the driver board must be changed.

Disconnect all power leads to the supply and remove the left lower front panels. Locate lower printed circuit board on the side panel. Move the jumper connection on the driver board from 60 Hz to 50 Hz. Replace the left lower front panels. The conversion is complete.

2.16 NOMENCLATURE

The following defines user connections on the terminal strips and input/output power connections.

AC INPUT:

A: Phase A input.

B: Phase B input.

C: Phase C input.

GND: System ground.

DC OUTPUT:

VO+: Positive output.

VO- : Negative output.

ANALOG OUTPUTS:

V10OUT: Output voltage scaled at 10.0 V full scale.

I10OUT: Output current scaled at 10.0 V full scale.

PROGRAMMING INPUTS:

REF GND: Reference ground.

VO1+: Positive output sense.

VO1-: Negative output sense.

VS+: Non-inverting input to voltage sense amplifier.

VS- : Inverting input to voltage sense amplifier.

VO2REM+: Remote positive voltage sense of second supply.

VO2REM-: Remote negative voltage sense of second supply.

VOMS: Master/slave output of voltage sense amplifier.

IO2REM+: Remote positive current sense of second supply.

IO2REM-: Remote negative current sense of second supply.

IOMS: Master/slave output of current sense amplifier.

IVREF: Voltage control reference current.

IIREF: Current control reference current.

ITVREF: Over voltage trip reference current.

ITIREF: Over current trip reference current.

RV: Voltage control resistance.

RI: Current control resistance.

RTV: Over voltage trip control resistance.

RTI: Over current trip control resistance.

VREF: Voltage control input reference.

IREF: Current control input reference.

TVREF: Over voltage trip control input reference.

TIREF: Over current trip control input reference.

V10IN: Voltage control input at 10 V full scale.

I10IN: Current control input at 10 V full scale.

TV10IN: Over voltage trip input at 10 V full scale.

TI10IN: Over current input at 10 V full scale.

V10ATTN: V10IN attenuated to 2.0 V full scale.

I10ATTN: I10IN attenuated to 2.0 V full scale.

TV10ATTN: TV10IN attenuated to 2.0 V full scale.

TI10ATTN: TI10IN attenuated to 2.0 V full scale.

IO1+: Positive current sense.

IO1-: Negative current sense.

Int Control Set: Internal control set.

Ext Control Set: External control set.

Control RTN: Return for Int and Ext Control Set.

Interlock Set: Interlock set.

Interlock Set RTN: Interlock set return.

OPTICALLY ISOLATED CONTROL INPUTS:

ISOLATED RTN: Return path for all optically isolated inputs and outputs.

Stop: Remote stop.

Start: Remote start.

Reset: Remote reset.

Remote Set : Remote set shutdown.

OPTICALLY ISOLATED AND RELAY OUTPUTS:

Standby: Standby.

PWR: Control circuit power.

Soft Start: Soft start.

Interlock: Interlock.

Remote: Remote shutdown.

Int Control: Internal control.

Ext Control: External control.

PGM Line: Open program line shutdown.

Over Voltage: Over voltage trip shutdown.

Over Current: Over current trip shutdown.

Phase Balance: Phase balance shutdown.

Thermal: Thermal overload shutdown.

Fuse: Fuse cleared.

Arc Current: Arc current shutdown.

Volt Control: Voltage control.

Cur Control: Current control.

Alarm: Alarm relay.

Alarm RTN: Alarm relay return.

SECTION III
PRINCIPLES OF OPERATION

3.1 GENERAL

Figure 3.1 illustrates the block diagram of the TQ series supply.

Power is fed through ac fuses and is distributed to a control transformer and main 3φ contactor. The control transformer powers the contactor and power supplies in the driver board. The 3φ contactor is controlled through the control board and when excited allows power to flow through the optional EMI filter, phase control thyristors, dc link inductor, current fed inverter, and main power transformer. The optional EMI filter filters common mode and differential mode noise emanating from the supply.

Output power is controlled through a 6-pulse ac to dc converter. Thyristor timing is derived by sampling output voltage and current and comparing these signals to references established in the control board. The error signal is fed to the driver board and is used to generate isolated phase modulated signals that triggers the thyristors.

The 6-pulse ac to dc converter produces a dc bus which is connected to a dc link inductor and current fed, IGBT inverter. The inverter, which operates at 420 Hz to 780 Hz, excites the main transformer at higher than normal line frequencies. This operation produces ohmic isolation between the input and output of the power supply using a transformer of dramatically reduced size.

The output of main power transformer is converted to dc via the rectifiers. Low voltage versions of the TQ series supply use a midpoint diode configuration and higher voltage versions use a bridge configuration.

The dc output is filtered with a pie section filter. This, in combination with the dc link inductor, forms a double stage LC filter.

The electronic load dampens the response of the filter and satisfies conditions to maintain continuous current through the SCR's. This prevents peak charging of the filter capacitors and improves performance at low current loads.

The SCR and IGBT distribution boards amplify and isolate drive signals from driver board to the respective devices.

The snubber boards limit dv/dt across the thyristors and IGBT's.

The fuse detector board senses voltage across the input fuses and signals the control board upon clearing.

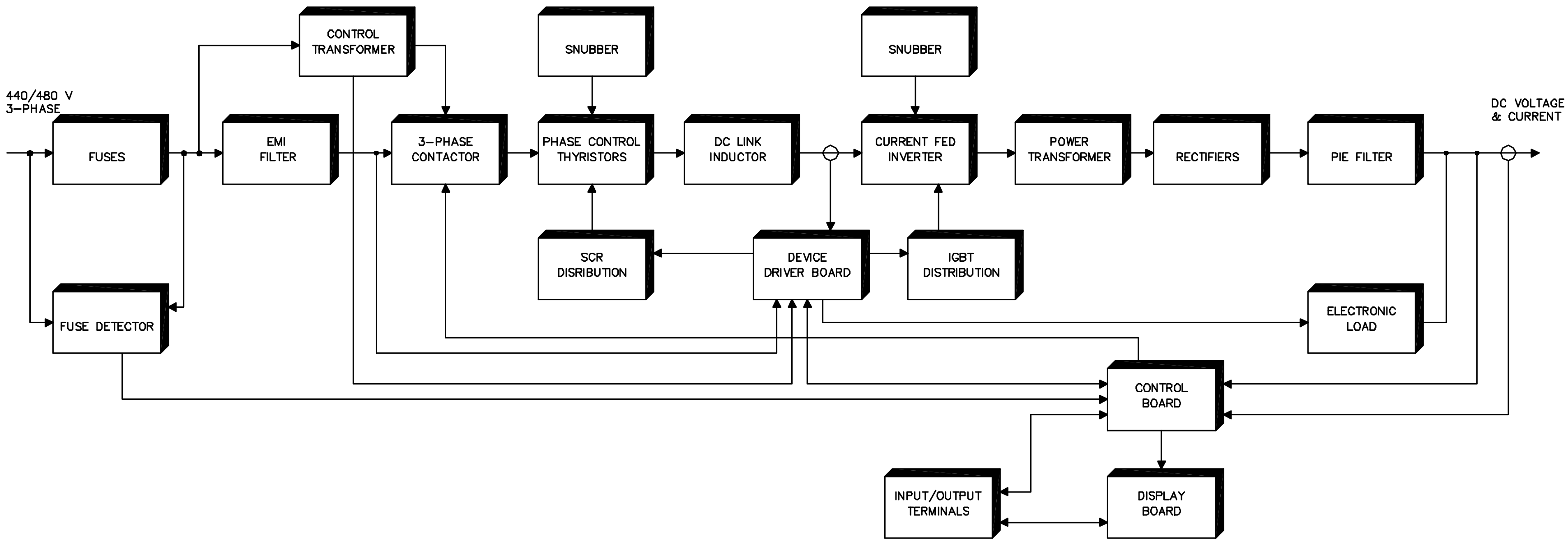


Figure 3.1 Black diagram

The display board contains light emitting diodes for displaying diagnostic conditions and provides an interface for meters and switches. It also channels control and diagnostic functions to the optical isolators.

All diagnostic functions are directly coupled to the error signal. This informs the user of precisely which function has control.

3.2 THEORY OF OPERATION

3.2.1 POWER CIRCUIT

Schematics 109201 illustrates the power circuit, connections to circuit boards, and normal mode jumper connections.

Proceeding from left to right, fuses F1 through F3 protect the ac mains from abnormal faults in the supply. Fuse F4 protects the mains from faults in control transformer T2 or any of the circuit boards.

Fans 1 through 11 are strategically arranged in the power supply to cool critical components. Capacitors C1 through C3 provide power factor correction and attenuate differential mode EMI. Varistors V1 through V3 limit incoming voltage transients.

SCR1 through SCR3 are arranged as a 6-pulse controlled rectifier which rectifies incoming ac voltage to dc. The SCR's are phase controlled as determined through timing signals derived in the driver board. Capacitors C4 through C9 provides noise immunity for the SCR's. The snubber board limits dv/dt across the thyristors.

Inductors L1 and L2 and IGBT pairs Q1 and Q2 are arranged as a current fed inverter. The IGBT’s are alternately driven at a frequency of 420 to 780 Hz. This produces a current square wave which excites transformer T1 at higher than normal line frequencies. The current fed inverter connects to a snubber board and external snubber, capacitor C19 and resistor R15, to limit dv/dt across the IGBT devices.

A dc bus filter consisting of capacitors C10, C11, C14, and C18; resistors R1, R2, R3, R4, and R10; and diode D1 limit voltage transients on the dc bus and allow transfer of inductive energy on a sudden shutdown of the inverter.

The driver board produces signals for driving the SCR’s and IGBT’s. Output are channeled to SCR and IGBT distribution boards which amplify and isolate the driving signals from the power circuit.

The secondary voltage of T1 is rectified via diodes D1 through D2. Low voltage versions of the TQ series supply use a midpoint diode configuration and higher voltage versions use a bridge configuration.

Thermal switches TB1 through TB7 are thermally connected to the SCR, IGBT, and output diode heat sinks. Upon critical temperatures the switch opens and the control board shuts down the supply.

Inductor L3 and capacitors C12 and C13 form a pie section filter providing the means to filter harmonics on the dc bus.

The optional electronic load loads the supply at near constant power. This insures continuous current through the input SCR's and prevents peak charging of output capacitors C12 and C13. Without this option resistor, resistor R5 through R7 are utilized as the means to dampen the filter.

Inductor L4, resistor R9, and SCR4 are the optional SCR crowbar circuit. Inductor L4 limits di/dt when SCR4 is fired upon an over voltage condition. The level of current in the crowbar circuit is set by resistor R9.

3.2.2 FUSE DETECTOR BOARD

Schematic 109202 illustrates the fuse detector board. The detector circuit senses clearing of the three input fuses and may be or'd with other fuse detector boards for other applications.

Operation is explained for one of the three fuse detector circuits. Clearing of a fuse produces a voltage across terminals 1 and 3 of JR1. This causes current to flow through optical isolator U1 and LED D2 to light. The outputs for the optical isolators are connected in parallel. Conduction of an optical isolator causes a fuse signal to be sent to the control board which safely shuts down the supply. Connectors JR2 and JR3 are paralleled allowing other fuse detector boards to be or'd.

3.2.3 SCR SNUBBER BOARD

The SCR snubber board is illustrated in schematic 109203.

Resistors R1 through R12 and capacitors C1 through C6 limit dv/dt across the thyristors. Varistors V1 through V6 limit voltage transients across the same.

3.2.4 IGBT SNUBBER BOARD

The IGBT snubber board is illustrated in schematic 109204.

Resistors R1 through R4, resistors R7 through R10, and capacitors C1 through C4 limit dv/dt across the IGBT's.

3.2.5 CONTROL BOARD

Schematic 109207 shows the control board.

The current reference supplies are produced by regulator U8 and quad PNP transistors U16 and U17. U8 contains a precision reference and error amplifier. Its output is connected to the base terminals of U16 and U17 which are arranged as current sources. The right transistor behaves as a pilot device. This current source sources potentiometer R2 and resistor R143. The voltage produced at pin 4 of U8 is compared with that produced by voltage divider R29 and R30. The error amplifier, internal to U8, maintains a virtual zero differential.

The five other PNP transistors are controlled in an identical manner as the pilot except these devices are used for IIREF, IVREF, ITIREF, ITVREF, and a secondary current source for the control line. Diodes D1 through D8 protect the current sources from being damaged by voltage transients.

Quad operational amplifier U1 and associated circuitry are arranged as four differential amplifiers. The amplifiers are used to sense output voltage and current and monitor a second supply for master/slave operation. Input resistors R1, R2, R3, R4, R5, R7, R9, and R11 are sized to yield 2.0 V full scale of the supply's rating when adjusted with potentiometers P7, P3, P10, and P4. Potentiometers P9 and P8 are the adjustment means for the voltmeter and ammeter, respectively. Potentiometers P15 and P14 are the adjustment means for the over voltage and over current trip meter readings, respectively.

Dual operational amplifier U4 senses over voltage and over current trip levels and connects to
terminals 37 and 38 of JC3 to display settings on the display board.

Two of the quad operational amplifiers in U2 are used as error amplifiers for output voltage and current. The positive inputs are connected to voltage and current references and the negative inputs are connected to the differential amplifiers described previously. The voltage error amplifier is compensated by resistors R52 and R141 and capacitor C36 and the current error amplifier is compensated by resistors R49 and R142 and capacitor C33. Capacitors C33 and C36 are dynamically charged through diodes D20 and D24 during inactive periods (that is, when the particular error amplifier does not have control of the feedback loop) to insure rapid crossover from voltage mode control to current mode control or visa versus.

Feedforward compensation is applied for both line and load variations. Resistor R50 and capacitor C82 offsets the voltage error amplifier for load excursions; resistors R46 and R47 and capacitors C31 and C32 offset the voltage and current error amplifiers for input line excursions.

The outputs of the error amplifiers U2, part of quad operational amplifier U3, and part of quad PNP transistors U19, produce the lowest voltage of the two error signals. Assuming pin 10 of U3 is at a lower potential than pin 12, pin 8 forces pins 9 and 13 to the same potential. This causes pin 14 to swing high rendering the second PNP transistor non-conductive. Current for the control line is produced by part of quad PNP transistors U17. This current source flows through the PNP transistor having the lowest potential and through the respective terminal of JC3.

Working in a similar manner is the soft start circuitry. Timing is produced by resistor R55 and capacitor C41. The third amplifier of U3 and third PNP transistor of U19 is connected to the same point producing the lowest potential from the error voltage amplifier, error current amplifier, or soft start circuitry.

The outputs of quad comparator of U5 are or'd to sense program lines. If any program line is greater than 2.50 V, the control line is forced low and the display board is informed of the condition.

Program line, like most of the other diagnostic conditions, are latch in state by quad flip flop U14. Quad flip flops U14 and U15 are reset during power up or by a reset pulse fed from the display board.

Thermal, fuse, phase balance, interlock, over voltage, over current, and arc current are other diagnostic functions that connect to flip flops U14 and U15. These diagnostics also drive the control line low upon a set condition.

Over voltage shutdown is produced when TP3 is greater than the reference produced at terminal 11 of JC1 (TVREF).

Over current shutdown is produced by one of two conditions: current sense, test point TP1, is greater than the reference produced at terminal 12 of JC1 (TIREF) or terminal 24 of JC6 (EXT CURRENT TRIP) is set low. Terminal 24 of JC6 connects to the over current detection circuitry in the driver board.

Arc current shutdown is similar to over current shutdown except that the trip level is multiplied by two and the response time is decreased by ten.

The soft start capacitor C41 is discharged by diode D25 and part of “and” gate U11 if the power supply is rendered to an off state for any condition.

The power supply is started by forcing terminal 12 of JC3 to a low state. This sets flip flop configuration U10, renders optical isolator U9 and TRIAC1 to an on-state, forces pin 5 of "and" gate U11 high, and relinquishes control of the control line. Resistor R137 and capacitor C69 delays turn-on of the driver board to allow time for energizing the 3φ contactor.

A start condition is allowed only if pin 10 of "and" gate U11 is high. This requires that:

1. The stop switch, sensed through terminal 11 of JC3, is not pressed.
2. Line sense is greater than the level set at pin 6 of comparator U7.
3. None of the flip flops U14 and U15 are in a set or tripped condition.

Likewise any of these conditions will cause the power supply to stop.

If any of the flip flops are tripped, then transistor Q2 is rendered conductive which energizes alarm relay K1.

Diodes D50 through D52 connect to jumper JP1 and transistor Q1. Depending on the jumper connection, over voltage, over current, or both will cause conduction of transistor Q1 and the optional SCR crowbar to fire.

3.2.6 DRIVER BOARD

Schematic 108202 illustrates the driver board.

From left to right, transformer T1, MOSFET Q1, integrated circuit U21, and associated circuitry form a flyback converter which is used for powering control circuitry, isolated phase detection circuitry, and SCR and IGBT drive circuitry. Secondary, linear regulators U22 through U24 produce +5 V and ±12 V for powering control circuitry under a wide range of load variations.

Quad operational amplifier U1 and quad comparator U2 are referenced to phase C and are used for determining zero crossings and phase balance of the 3φ mains. Phase balance is detected by the lower order harmonics produced by diode configuration D12, D13, D22, D23, D24, and D25. Zero crossings and phase balance are fed through optical isolators to quad comparator U4.

Zero crossings of phase C-A are used to synchronize the SCR and IGBT drive signals and the remaining zero crossings are used to determine phase sequence. Phase lock loop U5 and counter U6 synchronize the line to a clock operating at a multiple of the line frequency. Counter outputs are used to address EPROM U7 where desired patterns are stored. “Nand” gates U26 and U17 detect and store phase sequence during the first second of operation. The detector’s output is fed to EPROM’s U7 and U8 which selects alternate gating patterns under phase rotated conditions.

A to D converter U14 is used to convert the control signal to a 12-bit digital word. The phase instant, which is the output of counter U6, and the output of A to D converter U14 are added with full adder U9 through U11. The output of the adder is used to address EPROM U8. Data from EPROM U7 and U8 are and’d with “and” gates U12 and U13 producing phase modulated signals to drive the SCR’s.

Pin 18 of EPROM U7 produces the synchronous driving waveforms for the IGBT current fed inverter; these signals are not phase modulated. Clock and divider U29 produce asynchronous driving waveforms for the IGBT current fed inverter. Depending on the application and the jumper connection of JP1, synchronous or asynchronous operation can be selected. Resistors R57 and R58 and capacitors C43 and C44 produce time delays required for switching the current fed inverter.

Buffers U15 and U16 drive external circuitry to gate six SCR's and four IGBT's. Buffer U15 is enabled only if the ac line is above a preset reference and the SCR shutdown command at terminal 26 of JG6 is low. Buffer U16 is enabled only if the ac line is above a preset reference, the IGBT shutdown command at terminal 21 of JG6 is high, and the over current circuitry, comprised of quad comparator U8 and flip flop U17, has not tripped.

Transformer T2 and associated rectifier circuitry are used to power external isolated voltage and current detecting circuitry.

3.2.7 DISPLAY BOARD

The display board is shown in schematic 109208.

Diagnostic functions are displayed through LED's D1 through D16. Each LED is connected in series with LED's internal to quad optical isolators U1 through U4. Lighting a LED causes the output of the respective optical isolator to conduct.

In a similar but reverse manner, quad optical isolator U5 or's start, stop, reset, and remote set control lines. Applying 5 V between terminals 20 and 1, terminals 21 and 1, terminals 19 and 1, or terminals 18 and 1 of JD3 causes execution of the particular function.

"Nor" gates U6 through U8 enable control through the front panel (internal) or through connectors (external) at the rear of the power supply. The gates are enabled by setting terminals 28 and/or 29 of JD3 low.

Dual operational amplifier U9 and transistors Q1 and Q2 amplify output voltage and current signals to produce 10.0 V full scale. These amplified signals are used for user applications.

Switch S1 resets all flip flops in the control board and energizes relay K1. Relay K1 is used to switch the meter lines from output voltage and output current to over voltage trip and over current trip, respectively.

3.2.8 SCR DRIVER BOARD

Schematic 108204 illustrates the SCR driver board.

Transformer T1 connects to a flyback transformer in the driver board through terminals 1 and 2 of JR1. Diode D1 rectifies the flyback voltage producing a regulated, 10 V isolated source for powering the SCR driver board.

Optical isolator U1 drives transistors Q1 and Q2 which connects to pulse forming network resistors R3 through R5, capacitor C2, and diode D2. This network drives an SCR with a leading current pulse as determined by resistor R3 and capacitor C2 and a trailing porch as determined by resistor R4. Drive signals to optical isolator U1 feed through terminals 3 and 4 of JR1.

3.2.9 IGBT DRIVER BOARD

Schematic 108203 illustrates the IGBT driver board. Operation is similar to the SCR driver board.

Transformer T1 connects to a flyback transformer in the driver board through terminals 1 and 2 of JR1. Diodes D1 and D2 rectify the flyback voltage producing a regulated, +15 V and -7.5 V isolated sources for powering the IGBT driver board.

Optical isolator U1 drives transistors Q1 and Q2 which connects to resistor R3. Resistor R3 limits gate current to the IGBT's. Drive signals to optical isolator U1 feed through terminals 3 and 4 of JR1.

3.2.10 SCR DISTRIBUTION BOARD

The SCR distribution board is shown in schematic 109205. It is the motherboard for six SCR driver boards. The SCR distribution board connects to the driver board through terminals 1 through 20 of JS1 and connects to the SCR's through terminals 1 through 17 of JS2.

3.2.11 IGBT DISTRIBUTION BOARD

The IGBT distribution board is shown in schematic 109206. It is the motherboard for four IGBT driver boards. The IGBT distribution board connects to the driver board through terminals 1 through 16 of JS1 and connects to the SCR's through terminals 1 through 11 of JS2.

3.2.12 OUTPUT BOARD

Schematic 109209 illustrates the output board.

The output board consists primarily of connectors for interfacing all control functions to user connectors JO1 through JO6.

3.2.13 ELECTRONIC LOAD

The optional electronic load is shown in schematic 109210. The electronic load prevents peak charging of output capacitors by providing a minimum constant load which is virtually independent of output voltage.

IGBT's Q1 and Q2 connect to external resistors R5 through R7 as illustrated in schematics 109201 and 109212. With the IGBT's off, resistors R5 through R7 are connected in series and with the IGBT's on, resistors R5 through R7 are connected in parallel. IGBT Q1 and Q2 are driven with a pulse-width modulated (PWM) signal providing a controlled resistance between one-third to three times that of one resistor. Each IGBT module contains 2 devices, but only one is used here.

Inductor L1 and series capacitors C1 through C3 provide input filtering to the electronic load module. Current tranducer CT1 is used to sample current flowing through external resistor R7.

The electronic load driver is illustrated in schematic 109211. Power for the electronic load driver is supplied through terminals 7, 9, and 12 of JL2. Current mode, PWM signals are produced by integrated circuit U1. Capacitor C6 and resistor R3 determine the clock frequency which is set to approximately 10 kHz. The clock frequency determines the switching transition of the IGBT's from off to on. Current sampled by CT1 in schematic 109210 is fed to terminal 3 of JL3. The peak is used to determine the switching transition of the IGBT's from on to off. The RMS level, as determined by RMS to DC converter, integrated circuit U2, sets the magnitude of peak current which controls the duty cycle of the IGBT's and effective resistance of R5 through R7.

Transistors Q2 throught Q5 drive signal transformers T1 and T2. These transformers provide ohmic isolation for the IGBT's. The secondary windings connect to rectifier circuitry, diodes 4,5,7, and 8, which doubles the PWM clock frequency. Transistors Q6 and Q7 provide an active path to discharge the gate capacitance of the external IGBT's.

SECTION IV
MAINTENANCE AND TROUBLE SHOOTING

4.1 GENERAL

TQ series power supplies contain power and control circuitry integrated into a functioning system. Before attempting maintenance or repair, the technician should be familiar with components of the systems and the theory of operation. Some basic test equipment is also necessary: source of ac power, means of loading the supply, dc volt meter with accuracy and resolution better than the unit specifications, and an oscilloscope. The chart in section 4.2 should aid in finding operational problems.

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

4.2 TROUBLE SHOOTING GUIDE

1. Fuse blows when power supply is turned on. Power supply has a short on the primary side.
   a. Check SCR1 through SCR3.
   b. Check capacitors C1 through C3. Discharge capacitors with resistor before testing.
   b. Check varistors V1 through V3 for damage.

2. Over current trips and cannot be reset without turning off supply. An auxiliary over current detector senses dc link current. Exceeding safe levels will trip causing an over current diagnostic that cannot be reset.
   a. Check IGBT Q1 and Q2.
   b. Check diodes D2 and D5.
   c. Check SCR4

3. Unit goes to high output immediately after starting.
   a. Check SCR1 through SCR3 on primary side of power circuit.
   b. Check firing current of SCR1 through SCR3.

3. High ripple voltage.
   a. Check mains voltage for balance.
   b. Check capacitors C12 and C13 on secondary side of power circuit.
   c. Check symmetry on firing of SCR pairs SCR1 through SCR3.

4.3 CALIBRATION

4.3.1 CONTROL BOARD

Current Reference Calibration

Set power supply for remote resistive programming using two external, precision 1K resistors. Disconnect jumpers between terminals 4 and 5 of JO3 and terminals 10 and 11 of JO3. Connect 1K precision, external resistors between terminals 4 and 12 of JO3 and terminals 10 and 12 of JO4.

First adjust potentiometer R2 for 2.00 V drop across the external resistor at terminal 10 of JO3. Then adjust potentiometer R1 for 2.00 V drop across the external resistor at terminal 4 of JO3.

Remove external resistors and reconnect jumpers between terminals 4 and 5 of JO3 and terminals 10 and 11 of JO3.

Voltage Amplifiers and Voltmeter Calibration

Connect jumper between terminals 4 and 7 of JO6 and connect jumper between terminals 2 and 6 of JO6. Place first dc voltmeter across output terminals of supply and second dc voltmeter across test point TP3 (positive) and test point TP4 (negative). Using voltage mode control, increase output voltage using the front panel control until TP3 is 1.00 V. Adjust potentiometer P10 until voltage output is set to half rating.

Place second dc voltmeter across terminal 7 of JO5 and terminal 12 of JO3. Using voltage mode control, increase output voltage to half rating and adjust potentiometer P4 to 1.00 V.

Using voltage mode control, increase output voltage to half rating and adjust potentiometer P9 until voltmeter of supply equals that of the first voltmeter.

Place second dc voltmeter across terminal 3 of JO4 and terminal 12 of JO4. Using the over voltage trip potentiometer on the front panel, set second dc voltmeter to 1.00 V. Pressing the display/reset switch on the front panel, adjust potentiometer P15 until voltage reading is half rating.

Current Amplifiers and Ammeter Calibration

Place reference dc ammeter, equal to the rating of the supply, across the output terminals of the supply. Connect jumper between terminal 9 of JO5 and terminal 11 of JO5 and connect jumper between terminal 10 of JO5 and 12 of JO5. Place dc voltmeter across test point TP1 (positive) and test point TP4 (negative). With power applied to the control circuit and with the main contactor off, adjust potentiometer P12 for null at TP1. Using current mode control, increase output current using the front panel control until TP1 is 1.00 V. Adjust potentiometer P7 until current output is set to half rating.

Place dc voltmeter across terminal 8 of JO5 and terminal 12 of JO3. With power applied to the control circuit and with the main contactor off, adjust potentiometer P11 for null at terminal 8 of JO5. Using current mode control, increase output current to half rating and adjust potentiometer P3 to 1.00 V.

Using current mode control, increase output current to half rating and adjust potentiometer P8 until ammeter of supply equals that of output.

Place second dc voltmeter across terminal 10 of JO4 and terminal 12 of JO4. Using the over current trip potentiometer on the front panel, set second dc voltmeter to 1.00 V. Pressing the display/reset switch on the front panel, adjust potentiometer P14 until current reading is half rating.

4.3.2 DRIVER BOARD

Over Current Trip

Over current trip should only be calibrated after consultation with the factory. *Gross misadjustment can cause inverter failure.*

Remove jumper on between terminal 3 and 4 on connector JC2 of control board and place a 680 resistor between the same connections. This reduces the sensitivity of current amplifier allowing output currents greater than maximum allowed. Slowly and carefully increase the output current and monitor peak current sensed by the current transducer on the IGBT dc bus. Set peak current to 250 A using potentiometer P1 on the driver board.

4.3.3 DISPLAY BOARD

Output Amplifier

Place first dc voltmeter across output terminals of supply and second dc voltmeter across terminals 2 of JO5 (positive) and terminal 12 of JO4 (negative). Using voltage mode control, increase output voltage using the front panel control until output voltage is half rated. Adjust potentiometer P2 until voltage at terminal 2 of JO4 is set to 5.00 V.

Place reference dc ammeter, equal to the rating of the supply, across the output terminals of the supply. Place dc voltmeter across terminals 4 of JO5 (positive) and terminal 12 of JO4 (negative). Using current mode control, increase output current using the front panel control until output current is half rated. Adjust potentiometer P1 until voltage at terminal 4 of JO4 is set to 5.00 V.

SECTION V
SCHEMATICS

The following schematics pertain to the TQ series supply.

SECTION VI
PARTS LIST

The following parts list pertains to the TQ series supply.