# OPERATING AND SERVICE MANUAL

# PX SERIES

# DC POWER SUPPLIES

MAGNA-POWER ELECTRONICS, INC.
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## 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.

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

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

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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.

## TABLE OF CONTENTS





TABLE OF CONTENTS

# SECTION I
# GENERAL INFORMATION

## 1.1 DESCRIPTION

This manual contains operation and maintenance instructions for Magna-Power Electronics' PX Series three phase, SCR power supplies. These power supplies are constant voltage/constant current sources suitable for either bench or rack mount installations.

## 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.

PX series power supplies are fully programmable via resistance, voltage, current, or optional IEEE-488/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 PX 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.

PX series supplies have three levels of over voltage protection: shutdown of controlling thyristors, disconnect of 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.

## 1.3 COOLING

Each power supply enclosure is cooled by suitable blowers exhausting warm air to the rear of the cabinet. Fresh air intake is from the top and sides. At least five inches of space should be allowed behind the supply and one inch along the top and sides. Blocking ventilation will cause the power supply to overheat.

## 1.4 INSTALLATION

The power supply is capable of being rack or bench mounted. For rack mount installations, additional support other that provided by the front panel, is required. Angle slides or cross beam supports securely fastened to the rack are recommended for supporting the weight of the power supply. The unit should be horizontally mounted.

## 1.5 POWER REQUIREMENTS

A suitable source of ac power is required for this supply. The unit is wired for 208 V, 3-phase, 50 to 60 Hz mains. For 240 V operation, four internal wiring changes must be made to the unit. Information concerning conversion is covered in Section 2.13.

PX series power supplies are optionally available for operation on 440/480 V, 3-phase, 50 to 60 Hz mains. Units are normally wired for 440 V operation and information concerning conversion is covered in Section 2.13.

## 1.6 SPECIFICATIONS

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

Input voltage: 208/240 Vac, 50-60 Hz, 3-phase (480 Vac, 50-60 Hz, 3-phase optional).

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, and over voltage shutdown.

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

Size: 12¼" H x 19" W x 24" D, see figure 1.1 for details.

Weight: 260 lbs.

**MODELS AND RATINGS - 208/240 V**

| MODEL | OUTPUT VOLTAGE Vdc | OUTPUT CURRENT Adc | RIPPLE VOLTAGE mVrms | % EFF. | AC INPUT CURRENT Aac |
|---|---|---|---|---|---|
| PX16-600 | 16 | 600 | 50 | 82 | 35 |
| PX32-300 | 32 | 300 | 30 | 83 | 35 |
| PX80-125 | 80 | 125 | 50 | 84 | 35 |
| PX125-80 | 125 | 80 | 60 | 88 | 35 |
| PX250-40 | 250 | 40 | 90 | 88 | 34 |
| PX500-20 | 500 | 20 | 130 | 88 | 34 |

Notes:
1) Rating specified at 208 V input.
2) Specifications subject to change
without notice.

**MODELS AND RATINGS - 440/480 V**

| MODEL | OUTPUT VOLTAGE Vdc | OUTPUT CURRENT Adc | RIPPLE VOLTAGE mVrms | % EFF. | AC INPUT CURRENT Aac |
|---|---|---|---|---|---|
| PX16-600 | 16 | 600 | 50 | 82 | 17 |
| PX32-300 | 32 | 300 | 30 | 83 | 17 |
| PX80-125 | 80 | 125 | 50 | 84 | 17 |
| PX125-80 | 125 | 80 | 60 | 88 | 17 |
| PX250-40 | 250 | 40 | 90 | 88 | 16 |
| PX500-20 | 500 | 20 | 130 | 88 | 16 |

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

# SECTION II
# OPERATING INSTRUCTIONS

## 2.1 GENERAL OPERATION

As shipped, the power supply is configured for local sensing, internal programming, and 208 V, 3-phase 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 schematic 105201, 105215, 105217, or 105218. 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. <u>WARNING</u>: 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 and fans should come on.

Increase the current setting to maximum and then to minimum. Dc current should increase smoothly from minimum to maximum to minimum as indicated on the meter. Return all controls full counterclockwise and turn off the supply.

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. Adjust the voltage control full counterclockwise, press display/reset, 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

PX 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 schematic 105201, 105215, 10517, or 105218. 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 supply and adjust current controls 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 2.12).

Turn off supply and remove short on output terminals. The unit is now ready to operate.

### 2.4.3 CONSTANT CURRENT

To select a constant current output, proceed as follows:

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

Turn off supply and remove short on output terminals. Turn on power supply and adjust voltage trip to 110% maximum output voltage allowable, as determined by load conditions. Advance voltage control for maximum output voltage allowable. 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.

## 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 4 and 5 of JM1. Connect new jumpers between terminals 2 and 3 and terminals 5 and 6 of JM1. Using a pair of #20 AWG wires, connect terminal 3 of JM1 to the positive terminal of the load and connect terminal 6 of JM1 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, and voltage trip are established by internal 2 mA current sources producing voltages across potentiometers RV, RI, and RT. These potentiometers are the front panel controls for voltage, current, and voltage trip, respectively.

A resistor is placed in series with the voltage trip potentiometer to allow setting above the maximum voltage of the supply.

## 2.7 REMOTE PROGRAMMING

PX 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 and voltage trip.

### 2.7.1 RESISTIVE PROGRAMMING

Resistive programming requires removal of jumper between terminals 2 and 3 of JM4 and connection of an external potentiometer or resistor between terminals 2 and 10 of JM4. 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 or voltage trip, use the same method and refer to schematic 105201, 105215, 105217, or 105218 for terminal identification.

The expressions for programming output voltage, $V_O$, output current, $I_O$, and voltage trip, $V_T$, are given below.

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

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

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

where:

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

### 2.7.2 VOLTAGE PROGRAMMING

Voltage programming requires removal of jumper between terminals 1 and 2 of JM4, removal of jumper between terminals 2 and 3 of JM4, and connection of an external voltage reference between terminal 1 of JM4 (positive) and terminal 10 of JM4 (negative). To minimize noise, wires should be #20 AWG twisted pair.

To program output current or voltage trip, use the same method and refer to schematic 105201, 105215, 105217, or 105218 for terminal identification.

The expressions for programming output voltage, $V_O$, output current, $I_O$, and voltage trip, $V_T$, are given below.

$$V_O = \frac{V_{OMAX} V_P}{2.0\ V} \tag{4}$$

$$I_O = \frac{I_{OMAX} V_P}{2.0\ V} \tag{5}$$

$$V_T = \frac{V_{OMAX} V_P}{2.0\ V} \tag{6}$$

where:

$V_P$ : programming voltage reference.

### 2.7.3 CURRENT PROGRAMMING

Current programming requires removal of jumper between terminals 1 and 2 of JM4, removal of jumper between terminals 2 and 3 of JM4, connection of an external, 1K metal film resistor between terminal 1 of JM4 and terminal 10 of JM4, connection of an external current source between terminal 1 of JM4 (positive) and terminal 10 of JM4 (negative). To minimize noise, wires should be #20 AWG twisted pair.

To program output current or voltage trip, use the same method and refer to schematic 105201, 105215, 105217, or 105218 for terminal identification.

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

$$V_O = \frac{V_{OMAX} I_P}{2.0\ \text{mA}} \tag{7}$$

$$I_O = \frac{I_{OMAX} I_P}{2.0\ \text{mA}} \tag{8}$$

$$V_T = \frac{V_{OMAX} I_P}{2.0\ \text{mA}} \tag{9}$$

where:

$I_P$ : programming current source.

## 2.8 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.

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.

## 2.9 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, and over voltage.

Thermal overload indicates that the 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.

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.

Opening of a program line can cause the voltage, current, or voltage 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.

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

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

### 2.10.1 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.

### 2.10.2 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 4 and 5 of JM4 and removal of jumper between terminals 5 and 6 of JM4. Connect jumper between terminal 8 of JM3 to terminal 4 of JM4. To interface the slave to the master, connect terminal 6 of JM3 slave to terminal 10 of JM3 master, and connect terminal 7 of JM3 slave to terminal 9 of JM3 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.

## 2.11 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.

<u>WARNING</u>: No plus or minus voltage should exceed 600 V with respect to ground.

### 2.11.1 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 output current controls are 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.

### 2.11.2 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 1 and 2 of JM4 and the removal of jumper between terminals 2 and 3 JM4. Connect jumper between terminal 9 of JM1 to terminal 1 of JM4. To interface the slave to the master, connect terminal 7 of JM1 slave to terminal 2 of JM1 master, and connect terminal 8 of JM1 slave to terminal 5 of JM1 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.

## 2.12 PULSE LOADING

The power supply will automatically cross over 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 output 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.

## 2.13 CONVERSION TO 240/480 V OPERATION

PX series supplies are normally wired for 208 V, 3-phase operation. For conversion to 240 V, 3-phase, four connections have to be changed inside the supply.

Disconnect all power leads to the supply and remove top cover.

For each of the three phases of transformer T1, move the wire from tap 2 to tap 3. On JM5, located with the taps of transformer T1, move wire from terminal 1 to terminal 2.

Secure top cover in place and connect power leads to unit. The conversion is complete.

For the 440 V, 3-phase option, PX series supplies are normally wired for 440 V. Repeated the same procedure as above for conversion to 480 V.

## 2.14 CONVERSION TO 50 HZ OPERATION

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

Disconnect all power leads to the supply and remove bottom cover. Locate two printed circuit boards. Move the jumper connection on the bottom, gate driver board from 60 Hz to 50 Hz.

Secure bottom cover in place and connect power leads to unit. The conversion is complete.

## 2.15 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:

- $V_O^+$: Positive output.
- $V_O^-$: Negative output.

PROGRAMMING INPUTS:

REF GND: Reference ground.

$V_{O1}^{+}$: Positive output sense.

$V_{O1}^{-}$: Negative output sense.

$V_{S}^{+}$: Non-inverting input to voltage sense amplifier.

$V_{S}^{-}$: Inverting input to voltage sense amplifier.

$V_{O1}^{+}$REM: Remote positive sense.

$V_{O1}^{-}$REM: Remote negative sense.

$V_{O2}^{+}$REM: Remote positive voltage sense of second supply.

$V_{O2}^{-}$REM: Remote negative voltage sense of second supply.

$V_{OM/S}$: Master/slave output of voltage sense amplifier.

$I_{O2}^{+}$REM: Remote positive current sense of second supply.

$I_{O2}^{-}$REM: Remote negative current sense of second supply.

$I_{OM/S}$: Master/slave output of current sense amplifier.

$I_{VREF}$: Voltage control reference current.

$I_{IREF}$: Current control reference current.

$I_{TREF}$: Over voltage trip reference current.

$R_V$: Voltage control resistance.

$R_I$: Current control resistance.

$R_T$: Over voltage trip control resistance.

$V_{REF}$: Voltage control input reference.

$I_{REF}$: Current control input reference.

$T_{REF}$: Over voltage trip control input reference.

$I_{O1}^{+}$: Positive current sense.

$I_{O1}^{-}$: Negative current sense.

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: Remote shutdown.

OPTICALLY ISOLATED SENSE OUTPUTS:

PWR: Control circuit power.

Cur. Control: Current control.

Volt Control: Voltage control.

Soft Start: Soft start.

Thermal: Thermal overload shutdown.

Remote Sh. Dn.: Remote shutdown.

Phase Balance: Phase balance shutdown.

PGM Line: Open program line shutdown.

Over Voltage: Over voltage trip shutdown.

Standby: Standby.

# SECTION III
# PRINCIPLES OF OPERATION

## 3.1 GENERAL

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

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

Output power is controlled through proper gating of the thyristors. 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 gate driver board and is used to generate isolated phase modulated signals that triggers the thyristors.

From the main power transformer, voltage is converted to dc via the rectifiers. Low voltage versions of the PX series supply use an interphase reactor and a midpoint diode configuration and higher voltage versions use a bridge configuration.

Dc voltage is filtered through a double LC filter.

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

The snubber board is used to limit dv/dt across the thyristors and limit incoming voltage transients from the mains.

The display board contains all light emitting diodes 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 precisely which function has control.

## 3.2 THEORY OF OPERATION

### 3.2.1 POWER CIRCUIT

Schematics 105201, 105215, 105217, 105218 illustrate 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 T3 or any of the circuit boards.

Fans 1 through 3 are strategically arranged in the power supply to cool critical components. Capacitors C1 through C3 provide power factor correction and attenuate differential mode EMI.

SCR's 1 through 6 are arranged in three reverse connected pairs. Each SCR pair is connected in series with the delta primary of transformer T1. The SCR's are phase controlled via the gate driver board providing control of power through T1 and output power circuitry. Capacitors C4 through C9 provides noise immunity for the SCR's. The snubber board limits dv/dt across the thyristors and limits incoming voltage transients from the mains.

The secondary voltage of T1 is rectified via diodes D1 through D6. Low voltage versions of the PX series supply use transformer T2, an interphase reactor, to enable 120° conduction of the power diodes and to improve input current waveform of the supply. High voltage versions, use a bridge configuration producing similar results. Resistors R1 and R2 and capacitors C10 and C11 limit voltage transients across the power diodes. Thermal switch S4 is thermally connected to the power diode heat sink. Upon critical temperatures the switch opens and the control board shuts down the supply.

Inductors L1 and L2 and capacitors C12 through C15 form a double LC 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 output rectifiers and prevents peak charging of output capacitors C12 through C15. Without this option resistor, R3 is utilized as the means to dampen the filter.

Inductor L3, resistor R6, and SCR7 is the optional SCR crowbar circuit. Inductor L3 limits di/dt when SCR7 is fired upon an over voltage condition. The level of current in the crowbar circuit is set by resistor R6.

### 3.2.2 EMI FILTER

Schematics 105208 and 105220 show the optional EMI filter. The filter is arranged to attenuate common mode and differential mode EMI. Inductor L1 is wound on a high permeability ferrite core and provides high impedance from all power lines to ground. Capacitors C4 through C6 provide a low impedance path to ground.

For differential mode attenuation, leakage inductance of inductor L1 provides high impedance between the power supply and ac mains and capacitor C1 through C3 provide low impedance path from line to line.

### 3.2.3 SNUBBER BOARD

The snubber board is illustrated in schematics 105205 and 105219.

Resistors R1 through R6 and capacitors C1 through C6 limit dv/dt across the thyristors. Varistors V1 through V6 limit voltage transients across the same.

### 3.2.4 CONTROL BOARD

Schematic 105203 shows the control board.

The control board and other connecting circuits require +5, and ±12 Volt supplies. Power from the control transformer is fed to terminal JC7, rectified via diodes D41 through D46, filtered by capacitors C22 through C24, and regulated with regulators U12 through U14.

The current reference supplies is produced by regulator U8 and quad PNP transistors U9. U8 contains a precision reference and error amplifier. Its output is connected to the base terminals of U9 which is arranged as current sources. The right transistor behaves as a pilot device. This current source sources potentiometer R3 and resistor R109. The voltage produced at test point TP2 is compared with that produced by voltage divider R75, R74. The error amplifier, internal to U8, maintains a virtual zero differential.

The three other PNP transistors are controlled in an identical manner as the pilot except these devices are use for $I_{VREF}$, $I_{IREF}$, and $I_{TREF}$. Diodes D1 through D6 and resistors R105 through R107 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 R58, R59, R60, R61, R118, R108, R115, R122 are sized to yield 2.0 Volts full scale of
supply's rating when adjusted via potentiometers R7, R9, R4, and R6. Potentiometers R8 and R5 are the adjustment means for the voltmeter and ammeter, respectively. Potentiometer R10 is the adjustment means for the voltage/current trip voltmeter reading.

Two of the quad operational amplifiers in U5 are used as error amplifiers for output voltage and current. The positive inputs are connected to the current source references and the negative inputs are connected to the differential amplifiers described previously. The voltage error amplifier is compensated by resistors R19 and R21 and capacitor C16 and the current error amplifier is compensated by resistors R18 and R20 and capacitor C17. Capacitors C16 and C17 are dynamically charged through diodes D20 and D17 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 R130 and capacitor C37 offsets the voltage error amplifier for load excursions; resistors R128 and R129 and capacitors C42 and C43 offset the voltage and current error amplifiers for line excursions.

The outputs of the error amplifiers feed circuitry, part of quad operational amplifier U2 and part of quad PNP transistors U10, to produce the lowest voltage of the two error signals. Assuming pin 3 of U2 is at a lower potential than pin 5, pin 1 forces pins 2 and 6 to the same potential. This causes pin 7 to swing high rendering the second PNP transistor non-conductive. Current for the control line is produced by transistor Q4. This current source flows through the PNP transistor having the lowest potential and through the respective terminal of JC1.

Working in a similar manner is the soft start circuitry. Timing is produced by resistor R98 and capacitor C19. The third amplifier of U2 and third PNP transistor of U10 is connected to the same point producing the lowest potential from the error voltage amplifier, error current amplifier, or soft start circuitry.

Dual comparator U7 senses the state of the thermal switch and the state of remote sense. If either comparator is forced to an output low state, the control line is set low and the diagnostic board is informed of the condition through the last PNP transistor of U10 or transistor Q5.

The outputs of three of the four comparators of U6 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.

Over voltage/current, phase balance, and standby conditions also forces the control line low and signals the display board of that condition.

Diodes D22, D23, D35, D37, D38, and D39 resets the soft start capacitor during activation of any of the respective circuitry.

The control line is level shifted through resistors R52, R86, R120, and potentiometer R12 and is fed to the gate driver board through terminal 4 of JC6.

The power supply is started by forcing terminal 10 of JC1 to a low state. This sets flip flop configuration U3, renders transistor Q7 and TRIAC1 to an on-state, forces pin 10 of "and" gate U4 low, and relinquishes control of the control line. Resistor R117 and capacitor C32 delays turn-on of the gate driver board to allow energizing of the 3-phase contactor.

A start condition is allowed only if pin 9 of "and" gate U4 is high. There are three conditions to this pin being high.

1. The stop switch, sensed through terminal 9 of JC1, is not pressed.
2. The +12 Volt supply is greater than 9.35 Volts as sensed by zener diode D48 and operational amplifier U5.
3. Pin 4 of second flip flop of U3 being high or reset. This is the over voltage/current trip flip flop.

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

In addition to the preceding stop conditions, diodes D34, D36, and D26 connect the stop line to over voltage/current trip, program line, and thermal protection circuitry causing shut down upon these fault conditions.

Pins 10 and 9 of amplifier U5 compare the output voltage to the over voltage trip reference. Upon a trip condition, the second flip flop of U3 is set and transistor Q6 is rendered conductive causing the optional SCR crowbar to fire.

Jumper JP1 sets the control board for over voltage or over current trip sense.

### 3.2.5 GATE DRIVER BOARD

Schematic 105202 illustrates the gate driver board.

Transformer T1 through T3 each contain 4 windings. Winding 7-9 is the primary and is connected through JG1 to the power mains. Winding 11-12 is a low voltage secondary and is used to sense zero crossing of the power mains. Windings 1-2 and 3-4 provide desired voltage and phase to fire the SCR's.

Resistors R1 and R2 and capacitors C1 through C3 filter the voltage sensed by transformer T1. This voltage is rectified via diodes D1 through D4 producing a full wave rectified waveform.

The full wave rectified voltage is or'd with the other phases to produce a bias voltage for quad comparator U1. Output pins 2, 1, and 14 produce 3-phase synchronization signals, phased 120° apart, for gating the SCR's.

The first gating signal, VTA, is fed to the trigger terminal of timer U3 and to diode D20. Upon zero crossing of the mains, VTA goes low, triggers U3, and resets capacitor C19. The control voltage, applied to pin 11 of U2, is initially greater than the voltage sensed across C19. This forces pin 13 of U2 high and causes C19 to rapidly charge through resistor R26. Charging is inhibited once the voltage across C19 reaches that of the control voltage. At this point pin 13 goes low and C19 continues to charge, now at a rate set by R25. The voltage across C19 appears as a ramp and pedestal with the pedestal set by the control voltage. The other phases operate in a similar manner.

When the voltage across C19 reaches the threshold of U3, the capacitor is discharged and the output, pin 3, is driven low. This triggers either optical coupler U5 or U6 depending on the phasing of the mains (U5 and U6 each contain a LED and photo SCR).

To insure phase balance of the firing angles, the threshold voltages of U3 and dual timer U4 are all interconnected. Tolerances for the ramp voltage are adjusted by potentiometers R28 and R32.

Gate firing pulses are inhibited by driving terminal 5 of JG5 low causing transistor Q1 to conduct.

Phase balance is sensed by monitoring the full wave rectified voltage of the three zero crossing detectors. Under nominal conditions, the wave form is 6-pulse and relatively smooth dc. The dc component is removed via resistor R23 and capacitor C32 and the ac component is rectified with diodes D34 and D35. Quad comparator U1 compares the rectified ac component its dc component and outputs a high signal to terminal 6 of JG3 upon limits being exceeded.

### 3.2.6 DISPLAY BOARD

The display board is shown in schematic 105204.

Diagnostic functions are displayed through LED's D5 through D13 and D15. Each LED is connected in series with LED's internal to quad optical isolators U1 through U3. Lighting a LED causes the output of the respective optical isolator to conduct.

In a similar but reverse manner, quad optical isolator U4 or's start, stop, reset, and remote control lines. Applying 5 V between terminals 2 and 1, terminals 3 and 1, terminals 4 and 1, or terminals 5 and 1 of JD3 causes execution of the particular function.

### 3.2.7 ELECTRONIC LOAD BOARD

The optional electronic load board is shown in schematic 105224. The circuit provides a constant load to the supply, a requirement needed to maintain constant rectifier current and to prevent peak charging of the output capacitors.

The electronic load circuit is a boost converter that maintains constant voltage to external power resistors. Voltage is converted by switching MOSFET Q2 at a controlled rate. Switching MOSFET Q2 on, places inductor L1 across the input and causes current to increase. Switching MOSFET Q2 off, allows current to flow through diode D6 and to the external load. The output voltage depends on the ratio of the conduction period between MOSFET Q2 and diode D6.

Integrated circuit U1, a current mode pulse-width modulation device, provides most of the control functions. Current through MOSFET Q2 is sampled with transformer T2 and is compared with the output of a voltage error amplifier internal to U1, pin 7. The voltage error amplifier compares the output voltage of the boost converter, through amplifier U2, with a reference established at pin 5 of U1. The voltage error amplifier sets the level of current flowing through MOSFET Q2 to maintain the desired output voltage. Current mode PWM is a self protective means of control which limits current to desired levels.

Integrated circuit U1 drives transformer T1 with a symmetrical PWM signal. Diodes D1 and D2 rectify this signal and drives MOSFET Q2 through diode D3. During the off period, transistor Q1 is allowed to conduct driving MOSFET Q2 off with a very low impedance.

The second amplifier of integrated circuit U2 is used to offset the voltage feedback signal. The output voltage is lowered if there is sufficient output current to maintain continuous current. Lowering the output voltage reduces losses in the external resistors.

Transistor Q4 provides slope compensation to the PWM control circuit. This maintains stability under all operating conditions.

The electronic load circuit has an EMI filter consisting of inductor L4 and capacitors C17 and C18.

## SECTION IV
## MAINTENANCE AND TROUBLE SHOOTING

### 4.1 GENERAL

PX 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. 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.
   a. Power supply has internal short. Check diodes D1 through D6 on secondary side of power circuit.
   b. Check SCR7 on secondary side of power circuit.

2. Unit goes to high output immediately after starting.
   a. Check SCR1 through SCR6 on primary side of power circuit.
   b. Check firing current of SCR1 through SCR6.
   c. Check control voltage terminal 4 of JG3 on gate driver board.
   d. Check adjustment of potentiometer R12 on control board.

3. High ripple voltage.
   a. Check mains voltage for balance.
   b. Check capacitors C12 through C14 on secondary side of power circuit.
   c. Check symmetry on firing of SCR pairs: SCR1 and SCR2, SCR3 and SCR4, and SCR5 and SCR6.
   d. Check adjustment of potentiometers R28 and R32 on gate driver board.

### 4.3 CALIBRATION

#### 4.3.1 CONTROL BOARD

Current Reference Calibration

Set power supply for remote resistive programming using three external, precision 1K resistors. Disconnect jumpers between terminals 2 and 3 of JM4, terminals 5 and 6 of JM4, and terminals 8 and 9 of JM4. Connect 1K precision, external resistors between terminals 2 and 10 of JM4, terminals 5 and 10 of JM4, and terminals 8 and 10 of JM4.

First adjust potentiometer R3 for 2.00 V drop across the current reference external resistor. Then adjust potentiometers R1 and R2 for 2.00 V drop across the voltage and voltage trip external resistors.

Reconnect jumpers between terminals 2 and 3 of JM4, terminals 5 and 6 of JM4, and terminals 8 and 9 of JM4.

Voltage Amplifiers and Voltmeter Calibration

Connect jumper between terminals 1 and 7 of JM1 and connect jumper between terminals 4 and 8 of JM1. Place first dc voltmeter across output terminals of supply and second dc voltmeter across test point TP3 to terminal 10 of JM1. Using voltage mode control, increase output voltage using the front panel control until TP3 is 1.00 V. Adjust potentiometer R7 until voltage output is set to half rating.

Place second dc voltmeter across terminal 9 of JM1 and terminal 10 of JM1. Using voltage mode control, increase output voltage to half rating and adjust potentiometer R9 to 1.00 V.

Using voltage mode control, increase output voltage to half rating and adjust potentiometer R8 until voltmeter of supply equals that of the first voltmeter.

Place second dc voltmeter across terminal 7 of JM4 and terminal 10 of JM4. Using the over voltage trip potentiometer on the front panel, set second dc voltmeter to 1.00 V. Pressing the over voltage/reset switch on the front panel, adjust potentiometer R10 until 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 10 of JM3 and terminal 6 of JM3 and connect jumper between terminal 9 of JM3 and 7 of JM3. Place dc voltmeter across test point TP1 to terminal 10 of JM4. With power applied to the control circuit and with the main contactor off, adjust potentiometer R14 for null at TP1. Using current mode control, increase output current using the front panel control until TP1 is 1.00 V. Adjust potentiometer R4 until current output is set to half rating.

Place dc voltmeter across terminal 8 of JM3 and terminal 10 of JM4. With power applied to the control circuit and with the main contactor off, adjust potentiometer R13 for null at terminal 8 of JM3. Using current mode control, increase output current to half rating and adjust potentiometer R6 to 1.00 V.

Using current mode control, increase output current to half rating and adjust potentiometer R5 until ammeter of supply equals that of output.

Zero Offset Calibration

When both voltage and current controls are fully counterclockwise, the power output is nearly inhibited. At the factory potentiometer R12 is adjusted to slightly suppress output current into a short circuit at maximum input voltage. Under open circuit voltage mode control, a slight voltage may appear at the output; this is caused by current bypassing the snubber board. Additional output preloading will minimize this effect. Gross misadjustment of this potentiometer can cause misfiring of the SCR's.

### 4.3.2 GATE DRIVER BOARD

Firing Balance

The gate driver circuit contains two potentiometers for balancing the firing angles. At the factory, potentiometers R28 and R32 are adjusted for equal ac amplitude voltage across the midpoint of the secondary diode bridge configuration (that is, the voltage from the center connection of the interphase reactor) to the negative terminal of the supply. In the higher output bridge configurations, the monitoring point is the common cathode connection of the bridge to the negative terminal of the supply.

# SECTION V
# SCHEMATICS

The following schematics pertain to the PX series supply.

# SECTION VI
# PARTS LIST

The following parts list pertains to the PX series supply.

# NOTICE

When PX series power supplies contain the overvoltage option, do not connect them in parallel without consulting the engineering staff of Magna-Power Electronics. Irreparable damage will occur if one of the paralleled units goes into overvoltage without proper paralleling of the overvoltage protection option.

# NOTICE

PX series supply is wired for 50 Hz operation.  Unit will not operate properly on 60 Hz sources. Consult factory for conversion to 60 Hz.

# NOTICE

The PX1100-9 has been modified to operate at higher than normal output voltages. To accomplish this function, the feature of remote sensing has been eliminated. Terminals 1 through 6 of JM1 have no internal connections. Jumper connections between terminals 1 and 2 of JM1 and terminals 4 and 5 of JM1 have been eliminated.

# NOTICE

This PX power supply has been manufactured with an IEEE488/RS232 interface. To implement this function, the four 10 pin terminal strips on the rear of the unit have been changed to two 12 pin terminal strips, JM1 and JM2. The external digital control lines, described in paragraph 2.8, have been channeled to the IEEE/RS232 interface and they are no longer accessible to the user. All other features are still incorporated. Please refer to the enclosed schematic for terminal identification.

To use the power supply without the IEEE488/RS232 interface set the toggle switch at the rear the power supply to internal (INT). Alternatively, to use the power supply with the IEEE/RS232 interface, set the set the switch to external (EXT) and connect the connect an IEEE488 or RS232 cable to the identified location. For RS232 operation, the switch settings on the rear of the unit must be set to 31. For IEEE operation, the switch setting must correspond to the software setting.