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**OPERATING MANUAL  
FOR A  
SINGLE PHASE FIRING CIRCUIT BOARD FCRO2100**

**ENERPRO Inc.**

5780 Thornwood Drive, Goleta, California  
Phone: 805-683-2114, Fax: 805-964-0798

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## **INTRODUCTION**

The general purpose firing board responds to a voltage or milliamp current signal to produce a delayed set of two  $180^\circ - \alpha^\circ$  high current SCR gate pulses for single phase AC/AC controller and AC/DC converters. The on board error amplifier provides a close loop feedback control for either voltage or current regulation

All of the firing circuit logic is contained in a custom 22-pin CMOS LSI gate array and along with other industry standard components mounted in a printed circuit board which is fabricated from .093 inch thick G10 epoxy-glass and its dimensions are 4.50 inch by 5.40 inch.

## **REFERENCES**

1. Drawing E211, "Single Phase 2-SCR Firing Circuit/Regulator", Part No. FCRO2100.
2. Bourbeau, F. J., "Phase Control Thyristor Firing Circuit: Theory and Applications", Power Quality '89, Oct. 17-19, Long Beach, California.

## **ELECTRICAL SPECIFICATIONS**

The electrical specifications of the General Purpose Firing Board are summarized in the table below.

Characteristic	Performance Requirement.	Supporting Information
1. Board mounted power supply for control electronics and SCR gate drive.	Connect to mains at J2-7 and J2-8 for 115/230V or 240/480V.	6 VA $1\phi$ 50/60 Hz fused board mounted transformer T1. Center-tapped primary connected for 120V, 240V or 480V.
2. SCR gate waveform.	Pulse Profile: 180 - $\alpha$ burst width and 32.6 $\mu$ s pulse width.	
3. Input control signal.	0 Vdc to 5.0 Vdc control signal. Input impedance is 10.0 K.	Option: a Shunt resistance (R23) across signal input can be selected for milliamp control signal. R23 = 249 for 4 to 20 mAdc current control signal.
4. Gate delay steady-state transfer function.	Increase in command voltage produces a proportional decrease in gate delay angle, $\alpha$ .	$\alpha_{max}$ and $\alpha_{min}$ change equally with change in $R_{bias}$ (R4). ( $\alpha_{max}-\alpha_{min}$ ) changes with $R_{span}$ (R5).
5. Gate delay dynamic transfer function bandwidth.	Attenuation = -3 dB at 67 Hz. Phase shift = $-45^\circ$ @ 57 Hz.	Frequency response can be modified by changing summing amplifier parameters.
6. Effect of frequency.	$Da/Df = 1.5^\circ/Hz$ . For 50 Hz operation, compensate by removing R24.	J3 for 50/60 switchable operation

7. Lock acquisition time.	Approximately 29 ms.	Gating is inhibited for 20 ms or longer at power-on. Inhibit period depends on Soft-Start time constant.
8. Soft-Start	Gating commences at $a_{max}$ and exponentially decays to the commanded delay when $\langle I_2 \rangle$ is ungrounded (J4-12).	Soft-Start time constant is set by C3 and R13+R14. $T = (1.5k + (R13+R14))(C3)(0.579)$ $T = \text{msec}, R = k, C = \mu F$ R13+R14 20.0k
9. Soft-Stop	Gate-delay angle ramps to $a_{max}$ before being inhibited when $\langle I_2 \rangle$ is grounded.	Soft-Stop time constant is set by C3 and R13. $T = R13(C3)(1.84)$ $T = \text{msec}, R = k, C = \mu F$ R13 1.0k
10. Power-on inhibit.	Inhibit circuit is activated at power-on.	Same delay angle response as with phase loss inhibit.
11. Low Signal Inhibit	Inhibit circuit is activated if SIG HI < 0.49 Vdc.	Eliminate this feature by removing CR3.
12. Instantaneous inhibit.	Opening the connection of $\langle I_1 \rangle$ (P1-4) to +12V instantly inhibits SCR gating. Closing the connection of $\langle I_1 \rangle$ to +12V instantly enables SCR gating.	Gating is inhibited if P1 is removed.
13. Peak gate drive open circuit voltage	15V	With a 30 Vdc supply voltage
14. Peak gate drive short circuit current.	2.0A	Measured with a 30 Vdc supply voltage and a 1.0 $\Omega$ load resistor
15. Gate drive current rise time(short circuit)	.5A in .5 $\mu$ s	Measured with a 30 Vdc supply voltage and a 1.0 $\Omega$ load resistor
16. Frequency sensitivity	2.6° el./Hz	
17. Temperature sensitivity	$\pm 2^\circ$ el. for $0^\circ C < T_a < 70^\circ C$	
18. Ambient temperature.	$0^\circ C$ to $70^\circ C$	

## **BOARD MOUNTED CONNECTORS**

The firing board uses Mate-N-Lok™ connectors and vertical headers to simplify maintenance and trouble shooting.

### **Control and Feedback Signal Connector J1**

The firing board is connected to the gate delay command and inhibit controls through a 12-position Mate-N-Lok™ connector designated as J1. This connector also accesses the outputs of the 24 Vac board mounted transformer, the 30 Vdc

rectifier and the +12 Vdc and +5 Vdc regulated outputs.

Current or voltage feedback signal is provided by positions 9 and 5 of J1. If an AC current signal is used, a rectifier U7 and a burden resistor R3 must be installed and R3 is selected for 1.0 Vdc full load feedback signal. **For a DC feedback signal, omit U7 and Jumper pads 1 and 4, 2 and 3 of U7.**

Table 1 below, illustrates pin designations.

Positions of J1	Connections	Supporting information
1, 2	24 Vac	The board AC power at the secondary of T1.
3	+30 Vdc	Rectified from 24 Vac to provide circuit board power.
4	Instant Inhibit	Instant inhibit/enable: SCR gating inhibit is controlled by disconnecting pin 4 from, or connecting pin 4 to, +12 Vdc (pin 6) respectively.
5, 9	Feedback signal input	For closed loop control, apply the voltage or current feedback signal as shown on E211.
6	+12 Vdc	Board power
7	+5 Vdc	Board Power
8	Common	Board common
10	Signal High	0 to +5.0 delay angle control signal
11	Common	Board common
12	Soft Inhibit	Soft start/stop: SCR gating inhibit is controlled by disconnecting pin 12 from, or connecting pin 12 to, COM (pin 8 or 11) respectively.

### Gate/Cathode and Power Supply Connector J2

The SCR gate/cathode and power supply interface is provided by a 8-position Mate-N-Lok™ vertical header, J2, and mating plug P2. Positions 1 and 2 of J2 and P2 access the gates and cathodes of the SCR having load connected cathode when the SCR is arranged in the in-line ac controller or bridge converter configurations. Similarly, positions 4 and 5 access the gates and cathodes of the SCR having line connected cathodes.

The board mounted 6 VA power supply transformer is normally energized by connecting the mains voltage to positions 7 and 8 of J2. The board power transformer also supplies the phase reference signal. Therefore, it is imperative that the board power be in-phase with the mains.

The transformer with a center-tapped 115/230 Vac or 240/480 Vac primary winding is standard. The transformer output is rectified and filtered and used directly for gate drive +30 V power and is also applied to a +12 regulator for operation of the control electronics circuitry.

Table 2 below, illustrates pin designations.

Positions of J2	Connections	Supporting information
1, 2	Pin 1 to gate, pin 2 to cathode	+X SCR
3, 6	No connections	
4, 5	Pin 4 to gate, pin 5 to cathode	-X SCR
7, 8	Board power supply and reference signal input	Single phase 120/240 or 240/480 Vac applied to the primary of transformer T1.

### Frequency Selection Connector J3

A 3-position header, J3, is used to select between 50 Hz and 60 Hz operation. In 60 Hz operation R24 is connected in parallel with R12. In 50 Hz operation J3 removes R24 from the circuit in order to maintain TP4 at 5.0 Vdc.

### GATE DELAY ANGLE TRANSFER FUNCTION

The gate delay angle in the open loop mode varies in negative proportion signal input voltage as shown on Fig. 1.

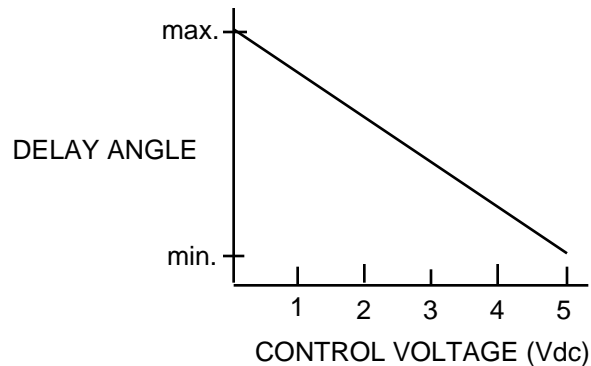


Fig. 1. Gate Delay Angle Transfer Function

The typical limits of the minimum and maximum delay angles,  $a_{min}$  and  $a_{max}$ , are  $5^\circ$  and  $175^\circ$ .

Dynamic frequency response specifications are: 3 dB attenuation at 67 Hz, and  $45^\circ$  phase shift at 57 Hz.

### GATE DELAY COMMAND

The gate delay command signal, SIG HI, may be a zero to 5.0 Vdc voltage signal or a current signal.

When the gate delay command is a current signal, R11 is selected to give a 5.0 Vdc level at the maximum delay command signal current. For typical 4-20 mAdc current signal input, R11 is select to 249 ohm.

### **BIAS AND SPAN POTENTIOMETERS**

Two 5K potentiometers, designated R4 and R5, provide for delay angle bias and span adjustment. These potentiometers allow the user to "fine tune" the board to meet their specific operational requirements.

To adjust the BIAS potentiometer, R4, increase the external command signal until the inhibit LED, PD2, extinguishes. Then adjust R4 to obtain the desired minimum SCR output.

To adjust the SPAN potentiometer, R5, increase the external command signal to maximum. Then adjust R5 to obtain the desired maximum SCR output. It may be necessary to adjust both the BIAS and SPAN potentiometers a couple of times to "fine tune" the configuration.

### **GATE INHIBITS AND INHIBITS INDICATOR PD2**

SCR gating is inhibited by making either or both of the inhibit signal points, designated as I1 and I2 and appearing at pins 4 and 12 of J4, a logic zero or by detecting a low signal input.

#### **Instantaneous Inhibit**

In the case of the instantaneous inhibit, I1, resistor RN4-7/8 on the firing board is provided to pull the I1 signal point low if the connection between I1 and +12 Vdc is opened. This ensures that SCR gating is inhibited if plug P1 is inadvertently disconnected. In applications where the instantaneous gate inhibit function is not utilized, a jumper wire is installed between pins 4 and 6 of P1 to hold I1 at +12 Vdc when P1 is installed in J1.

#### **Soft Inhibit**

The soft inhibit signal, I2, is connected to +12 Vdc through pull-up resistor RN4-3/4 on the firing board. When I2 is grounded, the gate delay angle is ramped to the maximum delay angle before gating is inhibited. This is termed the "Soft-Stop" shutdown mode. Removing the ground on I2 causes gating to be enabled with the delay angle set to the maximum limit. The delay angle then ramps down to the commanded angle. This is termed the "Soft-Start" turn-on mode. The Soft-Stop and Soft-Start periods are determined by timing resistors R14 and R13, and capacitor C3.

## **Low Signal Inhibit**

A 0.49 Vdc threshold signal and a comparator circuit provide the board inhibit function when command signal SIG HI is lower than 0.49 Vdc. To eliminate this feature, omit CR3.

## **Inhibit LED PD2**

A red LED, PD2, will be on when an inhibit signal is present.

## **POWER-ON RESET**

A power-on reset circuit (Q1, Q2 and related components) is provided to inhibit gating until the on-board power supply voltage has established. This circuit also inhibits SCR gating during line voltage dropouts.

## **GATE PULSE PROFILE**

The firing circuit uses a phase-locked loop (PLL) circuit locked to the single mains phase. The PLL oscillator output is counted down and decoded into two 0°-180° wide delayed logic signals. The 0°-180° wide delayed logic signals are modulated by the 15,360 Hz PLL Voltage Controlled Oscillator (VCO) output signal. The modulated signals output to the darlington transistor, U1, whose collectors are connected to +30 Vdc. The primaries of isolated pulse module transformers are connected to resistors and capacitors to provide pulse bursts of transformers. The transformers saturate after approximately 100µs but this is of no consequence because of the current limiting resistor in series with each of the transformer primary windings.

Fig. 2 and Fig. 3 show the waveform of pulse transformer output into 1.0 ohm resistor load and the initial pulse detail respectively.

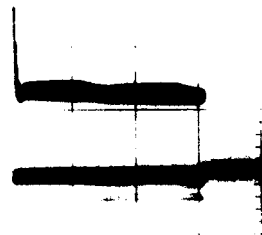


Fig. 2. 120° burst of pulse output (.5 A/div)

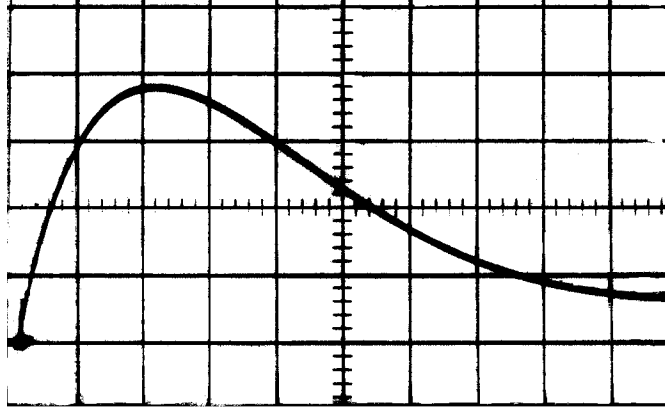


Fig. 3. Initial pulse detail (.5 A/div, 2  $\mu$ s/div)

### **GATE PULSE AMPLIFIER**

Circuitry shown in E211 consisting of transistor array U1, resistors R2 and R6, capacitor C4, and gate pulse isolation modules PM1 and PM2 amplify and shape the thyristor gate current pulses. Each pulse module consists of a 2:1 ratio pulse transformer tested for 3500 Vrms isolation, two secondary diodes, noise suppression resistors across the primary and across the gate drive output, and a fuse in series with the output.

## **INSTALLATION INSTRUCTIONS**

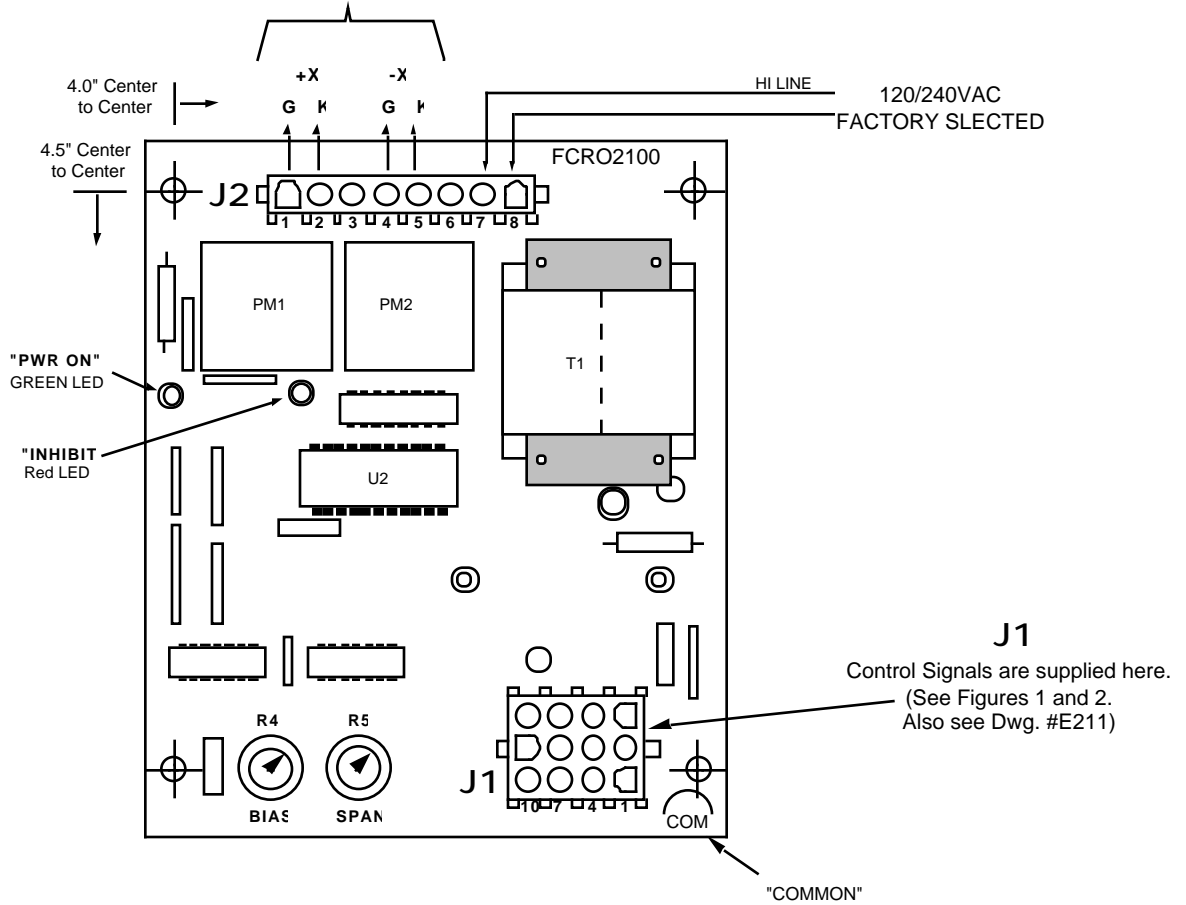
1. Remove board and connector package containing necessary interconnecting plugs and contact pins from packing.
2. The FCRO2100 is provided with AMP™ Mate-N-Lok™ connectors on the board with mating plugs and contact pins contained in the separate connector package.
3. The contact pins (AMP P# 350536-1) supplied for interconnection with customer equipment are sized to be used with wire gauges from 16 to 20 AWG. It is recommended that AMP™ Service Tool II (#29004-1) or a quality "U" Barrel crimping tool for the proper wire gauge range be used for making these connections.
4. Refer to FIG 4 at this time for a brief description showing the location of the primary control and command connectors.
  - A. **J1**, 12 pos. connector, provides for customers SCR control signals "Gate Delay Command" and "Inhibit". This connector also provides instant SCR gating by utilizing the jumper contained in the connector package (see J4 note on Figure 4). It is also possible to power the board through this connector with externally sourced 24 Vac or 30 Vdc (see DWG. E211).
  - B. **J2**, 8 pos. connector Pins 1-2 & 4-5 supply the actual gate signals to drive the customer's SCR's. Pins 7-8 of this connector provides for input power to the onboard 24 Vac power supply.
5. The FCRO2100 firing board measures 4.5"x5.3" O.A. The 4 (#8 SAE clearance) mounting holes provided measure 4.0" and 4.5" center to center. It is recommended that mounting spacers at least 1/4" long be utilized for panel mounting this device.
6. Mount the board mechanically. It is recommended that the board be physically mounted within 15" of the SCR's to be controlled to insure minimal inductive noise and positive gating of the SCR's.
7. Connection\* of the J2 Gate/Cathode control leads should be made at this time. It is recommended that the Gate and Cathode leads from the board to the SCR's be twisted pairs with at least one turn per inch to minimize inductive noise and possible false gating. Figure 5 shows a typical DC converter connection diagram. Figure 6 shows a typical AC controller connection diagram.

**\*WARNING** Check these connections very carefully before energizing the firing board. Improper or misconnections can short circuit SCR line voltage and result in product and/or customer equipment damage! If you have any questions concerning these connections, call 1-800-576-2114 (M-F, 7-4 Pacific) for assistance.

8. Connection of the J1 Command and Control signals and/or closures should be made at this time. See Figures 5 and 3 for typical Command and Control connections. J1 also provides instant SCR gating by utilizing the jumper contained in the connector package (see J1 note on Figure 4).
9. Connection of board excitation voltage at J2 (see J2 note on FIG 4) should be made after careful examination of steps 7 & 8 above. NOTE: If the mains voltage is present, applying board power will gate SCR's after a short ( 20 msec.) delay. It is important that the single phase control voltage signal applied at Pins 7-8 be "In Phase" with the voltage applied to the SCR's (see Note #1, Figs. 5 & 6).
10. Energize the board power supply. Verify that the green "PWR ON" LED indicator is on.
11. Adjust R4 "BIAS" for 0% SCR output when "SIG HI" = 0 VDC.
12. Adjust R5 "SPAN" for 100% SCR output when "SIG HI" = 5.0 VDC
13. Operate your controller as desired. Your installation was successful!

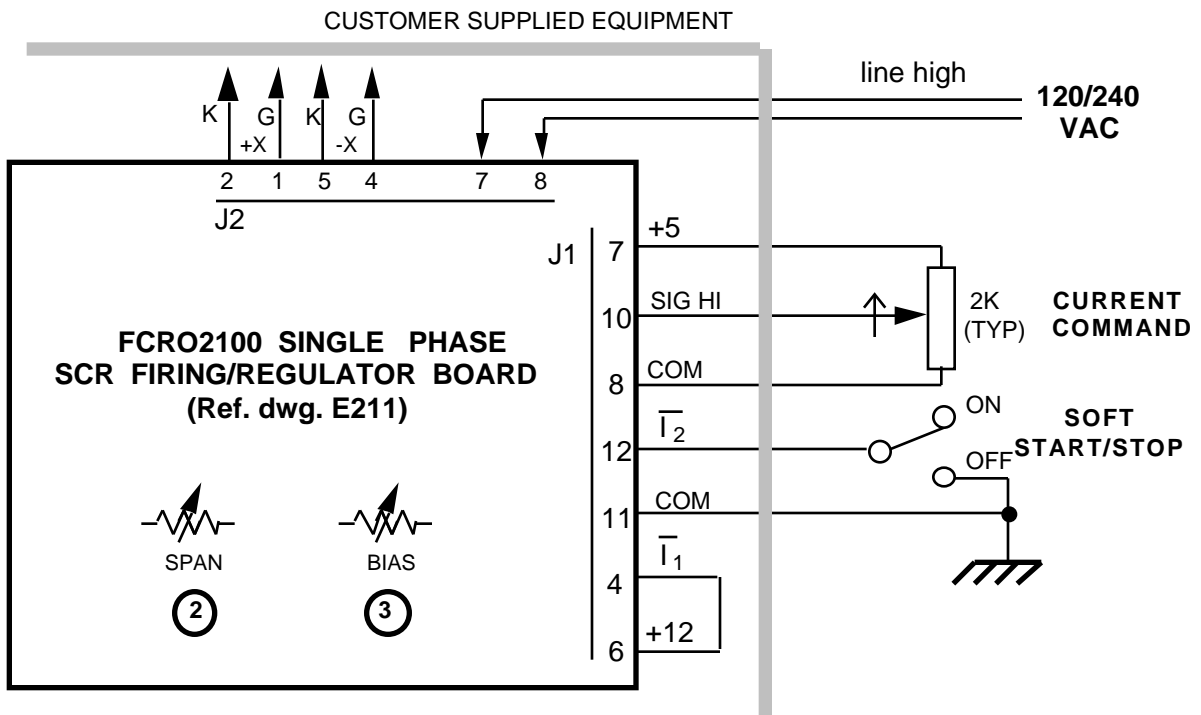
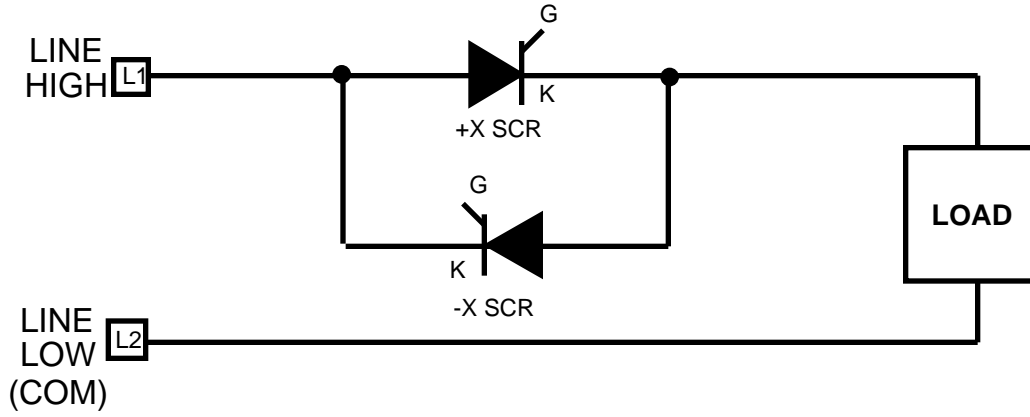
# TO SCR'S

WARNING Check these connections very carefully before energizing the firing board. Improper or misconnections will result in product and/or customer equipment damage! If you have any questions concerning these connections, call 1-800-576-2114 (M-F, 7-4 Pacific) for assistance



**FIGURE 4**

# AC CONTROLLER (TYPICAL)

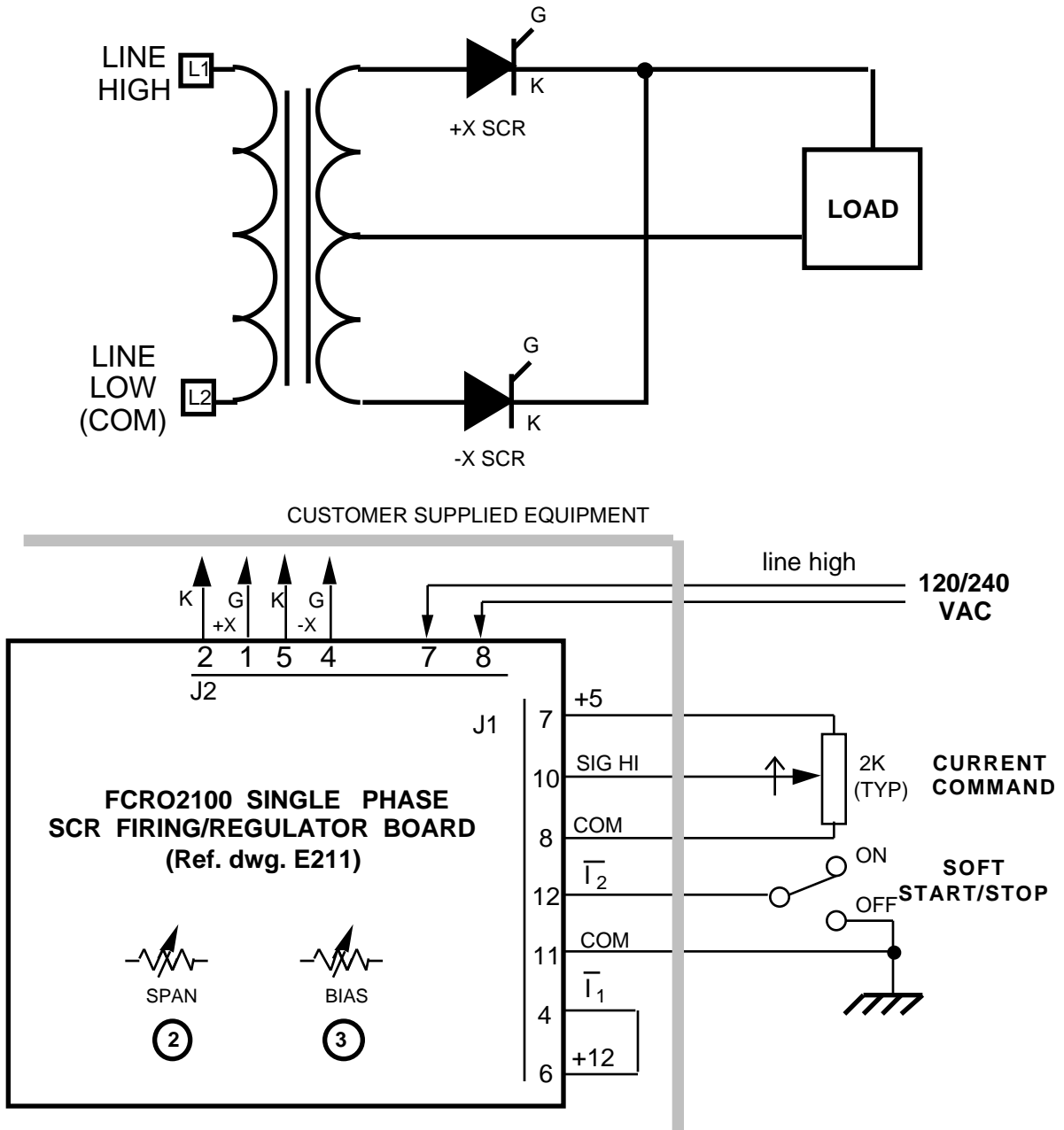


## NOTES

1. J2 #7 LINE HIGH, must be in phase with L1.
2. Adjust SPAN potentiometer R5 for 100% dc output with +5 V CURRENT COMMAND input.
3. Adjust BIAS pot. R4 for 0% dc output with 0.5 V command.

FIGURE 5

# CONVERTER (TYPICAL)



## NOTES

1. J2 #7 LINE HIGH, must be in phase with L1.
2. Adjust SPAN potentiometer R5 for 100% dc output with +5 V CURRENT COMMAND input.
3. Adjust BIAS pot. R4 for 0% dc output with 0 V command.

FIGURE 6