CONTROL CONCEPTS

MODEL 1037A
INSTALLATION & MAINTENANCE MANUAL

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WARNING: The Control Concepts, Inc. power controllers use power thyristors to switch voltage to the connected load. Line voltage must be assumed at the output terminals at all times, even when the control signal has been removed and the load voltage appears to be off. It has been mandated by the National Electrical Code and the Occupational Safety and Heath Act of 1970 that a physical disconnect be opened ahead of all remotely actuated controls before performing any maintenance work on the controller or its connected load.

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DESCRIPTION:

The model 1037A is a single-phase, zero-cross power controller which can be configured to linearly control either the average value of the voltage or the average value of the current applied to a resistive load by zero cross distributive operation of silicon controlled rectifiers.
See the section entitled "Zero Cross operation" (Page 2) for details.
The 1037A controller is especially suited to control the electrical power applied to single-phase resistive loads (such as silicon carbide heating elements) where the resistance changes with temperature and/or age.
With average current control the load power is linear with respect to the command signal independent of load resistance.

FEATURES:

1. Sync-guard:
This feature reduces synchronous operation of multiple controllers thereby reducing electical demand variations.

2. Trans-guard:
This feature prevents the possibility of saturation and overheating of supply transformers by eliminating the cause of DC components induced on the primary.

3. Shorted SCR detection:
A relay with form "C" contacts is energized if an SCR should fail shorted. (See Fig. 19.)

4. Current meter output:
A 0-5Vdc output signal, proportional to the *average* load current. Note: This signal, for a constant supply voltage, is also proportional to load power.

5. Duty cycle signal:
A 0 to 5Vdc signal, proportional to the *percentage of time power is applied to the load*. With average current control the resistance of the load can be determined by the ratio of this signal to the command signal. For example, assume that the power to a variable resistance load is to be controlled and that when the resistance of new elementsis one-half the value that will occur when the element resistance has increased due to usage. When voltage is applied to the new elements the current will be twice the value that will occur when the elements have aged. Since the average value of the current is being controlled and the magnitude of the current is twice the ultimate aged value the duration or duty cycle time will be one-half. The ratio of the two signals for any command will give an approximate indication of the change in the load resistance.

6. Remote Load Current Indicator:
This feature provides a means to remotely indicate the ON-OFF operation of the controller.
(See Fig. 20)

7. Run or Idle input:
Either of two commands referred to as RUN or IDLE may be selected by a remote contact.

8. Remote command limit control:
The output can be limited from 0 to 100 percent of the maximum by a remote potentiometer.
(See Fig. 17.)

9. Voltage or Current feedback:
A user selectable jumper on the printed circuit board (Page 14) determines whether the average value of the load voltage or the average value of the load current will be proportional to the command signal.

THEORY OF OPERATION:

THE SCR
The heart of the power controller is the SCR (silicon controlled rectifier).
The SCR has only two states, ON and OFF, and allows current to flow in one direction. SCR's can remain in the off state even though the applied potential may be up to 1600 volts; in the on state, they can pass several hundred amperes. When a small signal is applied between the gate and cathode terminals (Figure 1), the SCR will turn on. When the signal is removed, the SCR will turn off. See Zero-Cross operation paragraph below.

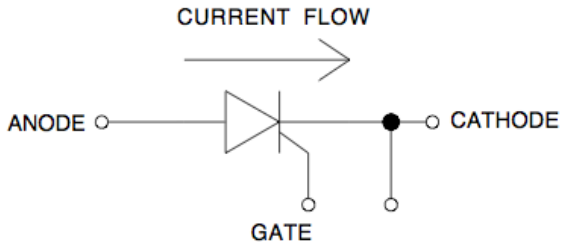


Figure 1. SCR symbol

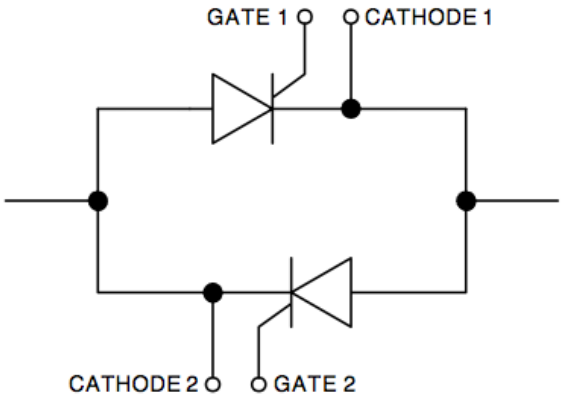


Figure 2. "Inverse parallel" configuration.

Because the SCR allows current to flow in only one direction, two SCR's are connected in an "inverse parallel" (back to back) configuration to control AC current. (Figure 2).

ZERO-CROSS OPERATION:

The term zero-cross (synchronous) operation of SCR's is derived from the fact that the SCR's are turned on only when the instantaneous value of the sinusoidal waveform is zero. Once turned on, it will remain on until the current through it is reduced below a very low value, called the holding current.

In zero-cross operation, power is applied for a number of continuous half-cycles and then removed for a number of half-cycles to achieve the desired load power in the same manner as power would be controlled with a mechanical switching device. The difference is that the SCR controllers always switch power when the instantaneous value is zero.

Various combinations of electrical half-cycles during which load power is applied or removed are combined to achieve the desired power level.
The controller will combine various ON-OFF sequences to achieve the desired output.
For example, to obtain an output equal to 66.66% of maximum output, power would be applied for three electrical half-cycles, removed for two electrical half-cycles, applied for five electrical half-cycles and removed for two electrical half-cycles. See also; Trans-Guard™ information on page 3.

SYNC-GUARD™:

The Sync-Guard™ feature reduces the possibility of synchronous operation of two or more controllers. This feature does not alter the power applied to the load, but adjusts the time when power is applied in such a manner as to reduce the possibility of two or more controllers being ON and OFF at the same time.
Figures 3 through 5 show the total current as a function of time for three controllers, with and without Sync-Guard and various load powers.

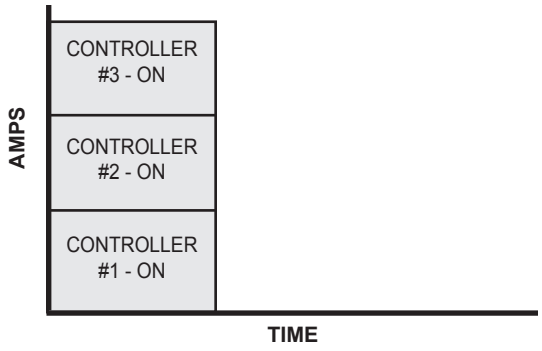


Figure 3. Three controllers providing 33.3% power operating synchronously.

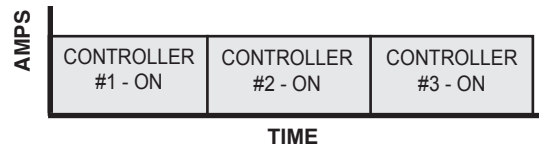


Figure 4. Three controllers providing 33.3% power each, with sync-guard™.

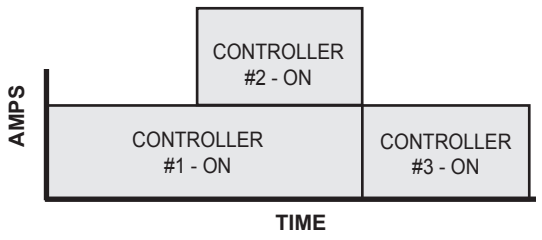


Figure 5. Three controllers with synch-guard™, two providing 33.3% power & one providing 66.6% power.

TRANS-GUARD™ OPERATION:

Transformers supplying power to zero-cross controllers can become overheated due to saturation resulting from DC components that can be induced. The half wave rectifier circuit shown in figure 6 will induce a DC voltage on the transformer primary due the the voltage drop across the source impedance during the half cycle in which the diode conducts.
The Trans-Guard™ feature eliminates this possibility by always supplying an odd number of electrical half-cycles during which power is applied and an even number of electrical half-cycles during which power is removed.

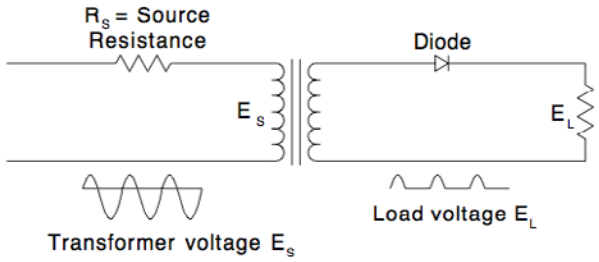


Figure 6. Transformer saturation. DC voltage is induced in the primary by DC components in the secondary.

SHORTED SCR DETECTION:

The shorted SCR relay will energize if less than 24 volts exists across the SCR switch when the SCR is intended to be off.

CURRENT FEEDBACK:

The average value of the load current is proportional to the command signal independent of variations of the load resistance or supply voltage. For a constant supply voltage the load power is also linear with respect to the command signal independent of variations of the load resistance.

For example, assume a controller is calibrated to provide 100 amps of load current when the command signal is 100% and that the supply voltage is 480 volts. The maximum power the controller would supply to the load would be 48KW. If the load resistance were 4.8 ohms, the controller would be "ON" continuously; the load voltage would be 480 volts and the load current would be 100 amps. If the load resistance were 2.4 ohms, the controller would be "ON" for 50% of the time and the load current when the controller is "ON", would be 200 amps, as shown in figure 7. If the load resistance were 1.2 ohms the controller would be "ON" for 25% of the time and the load current would be 400 amps when the controller is "ON", as shown in figure 8.

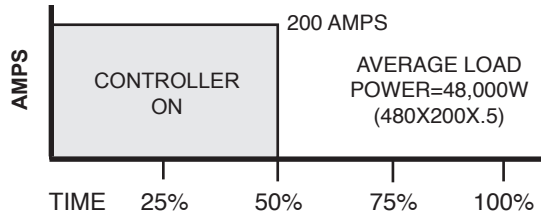


Figure 7. Load current as a function of time. 480 volts supply, load resistance 2.4 ohms, average control current 100 amps, 100% command signal.

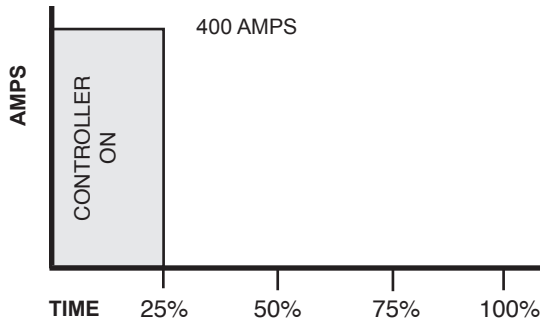


Figure 8. Load current as a function of time. 480 volts supply, load resistance 1.2 ohms, average control current 100 amps, 100% command signal.

VOLTAGE FEEDBACK:

The model 1037A controller can be configured to provide *average* voltage feedback rather than average current. In this mode the average value of the voltage applied to the load is linear with respect to the command signal.

ELECTRICAL CONNECTIONS

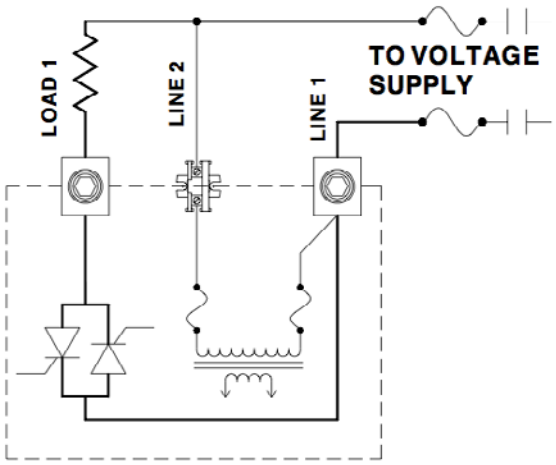


Figure 9. Electrical power path.

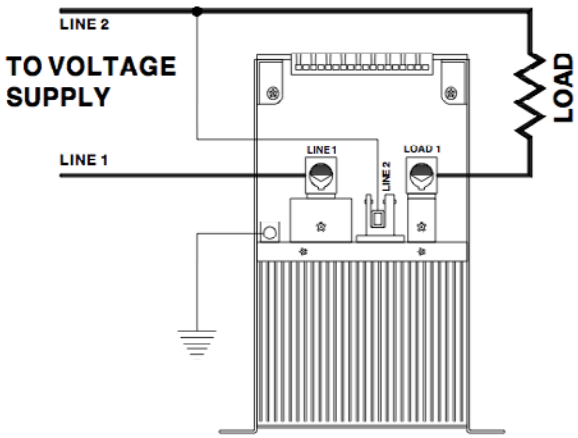


Figure 10. Power connections.

SPECIFICATIONS:

RUN COMMAND SIGNAL:	4/20mA Input Resistance: 300 ohms 0-5Vdc Input Resistance: 200K ohms Pot Input Resistance: 200K ohms (1K, 1/2 watt pot recommended, 20K permissible)
IDLE COMMAND SIGNAL:	0-5Vdc Input resistance: 200K ohms Potentiometer 200K ohms (1K, 1/2 watt pot recommended, 20K permissible)
COMMAND LIMIT CONTROL:	Maximum output power at 100% command signal can be adjusted from 0 to 100% of controller rating by a remote potentiomer. 1K potentiometer recommended for maximum linearity; up to 20K permissible.
RUN/IDLE CONTROL:	Contact closure between terminals 10 & 11 enables the run command, Open contact enables the Idle command. Open circuit 5Vdc, closed current 2mA.
COMMAND INDICATOR:	An LED indicates when the SCRs are turned on.
LOAD CURRENT INDICATOR:	The magnitude of the load current is proportional to the intensity of an LED.
SHORTED SCR INDICATOR:	An LED is on in the event that an SCR has failed in the shorted mode.
SHORTED SCR RELAY:	A relay with form C contacts rated for 120 Vac and 5 Amps change state in the event that an SCR fails in the shorted mode.
CURRENT SIGNAL:	A 0 to 5 Vdc signal proportional to the average load current . (See fig. 20)
DUTY CYCLE SIGNAL:	A 0 to 5 Vdc signal proportional to the percentage of time during which power is being applied. (See fig. 20)
REMOTE LOAD INDICATOR:	Open collector circuit 24Vdc, 25mA max. An LED (with a minimum 1K current limiting resistor) may be connected to this output. (See fig. 20).
CONTROL MODE:	Single-phase zero-cross distributive control with average current or average voltage feedback.
CONTROL RANGE:	0 to 98.5% of supply voltage.
LINEARITY:	The average value of the load voltage or load current will be within 2percent of span with respect to the command signal.
ISOLATION:	Isolation between power circuit, command signal and ground is greater than 2500 Vrms.
GATE DRIVE:	Optically coupled SCR gate drivers.
POWER CIRCUIT:	Inverse Parallel silicon controlled rectifiers (SCRs).
FRAME SIZE:	The “[XXX]A” term within the model number specifies the maximum continuous RMS current rating at the maximum operating ambient temperature of 55ºC.
OPERATING VOLTAGE:	Standard: 240, 480 or 575 Vac 50/60 Hertz +10 -15% Other voltages available - consult factory.

INSTALLATION NOTES:

TRANSFORMER TAP: Prior to mounting the controller, place the spade connector on the transformer tap that corresponds with the supply voltage to be used.

MOUNTING AND LOCATION:
The 50 and 100 amp controller must be mounted on a vertical surface such that air will flow vertically over the heat dissipating fins. All other controllers are forced air cooled and may be mounted in any direction. See pages 8, 9 & 10 for installation drawings.

COMMAND:
A potentiometer, a DC voltage or a DC current may be used as a command signal.
NOTE: Terminals 10 & 11 must be connected when the output is to be controlled by the RUN input.

Potentiometer command: A 1000 ohm to 20,000 ohm potentiometer, 1/4 watt or higher wattage, may be used as either the run or idle command signal or both. A 1000 ohm potentiometer provides the maximum linearity. See figures 14, 16, 17 & 18 for potentiometer command connections.

Voltage command: A 0 to 5 Vdc signal may be used as either the run or idle command signal or both. See figures 14, 15 & 17 for Voltage command connections.

Current loop command: A 4 to 20mA signal may be used for the run command signal. See figures 14, 15,& 17 for Current connections.
If necessary, the controller may be ordered to respond to other current command ranges; consult factory for details.

SHORTED SCR RELAY:
A relay with form C contacts rated for 120 Vac and 5 Amps change state in the event that an SCR fails in the shorted mode. See figure 19.

LOAD CURRENT INDICATOR:
A remote indicator (such as an LED & resistor) can be connected between terminal 5 and terminal 6.
Indicator current must not exceed 25mA.
24 Volts DC is applied between terminals 5 & 6 when current is applied to the load. See figure 20.

FUSING:
It is recommended that fast acting fuses such as the Bussmann type JJS and JJN be used to protect the controller and load. Control Concepts, Inc. stocks a variety of these types of fuses and fuseblocks.

RUN/IDLE:
A remote switch can be used, as shown on page 11, to cause the controller to be controlled by either a run command signal (voltage, current or potentiometer), or by an idle potentiometer. Connecting terminal 10 to terminal 11 causes the run command signal to control the output. Opening the connection between terminal 10 and terminal 11 causes the idle potentiometer to be in control.

NOTE: The two pin jumper must be connected between the center and idle pins of P2 on the circuit board, to activate the run/idle feature. See fig. 22.

REMOTE COMMAND LIMIT:
A remote potentiometer may be connected to terminals 16(CW), 15(W) and 14(CCW) as shown on page 12. The wiper position of the remote limit potentiometer determines the maxium output at 100% command signal. This allows adjustment of the range of load power from 0 to 100% of the rated current. This feature is intended as a means by which the user can conveniently change the maxium power supplied by the controller.

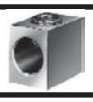
NOTE: The two pin jumper must be connected between the center and limit pins of P2 on the circuit board, to activate the remote command limit feature. See fig. 22.

CURRENT METER (I METER):
Provides a 0 to 5Vdc signal Meter impedance must be 5K or greater. See figure 20.

DUTY CYCLE METER: Provides a 0 to 5Vdc signal (with respect to common terminal 10. Load impedance must be 5K or greater. See figure 20.

POWER CONNECTIONS: The electrical connections are shown on page 4. The line and load connectors are rated for wire sizes from #6 to 500 MCM. The recommended torques as a function of wire size are:

Recommended tightening torque for the line and load connectors:



AWG or Circular Mills	Torque
4 to 6ga	100 in-lbs
1 to 2ga	125 in-lbs
1/0 to 2/0ga	150 in-lbs
3/0 to 4/0ga	200 in-lbs
250MCM	250 in-lbs
500MCM	300 in-lbs

DIMENSIONS, 50 TO 160 AMPS:

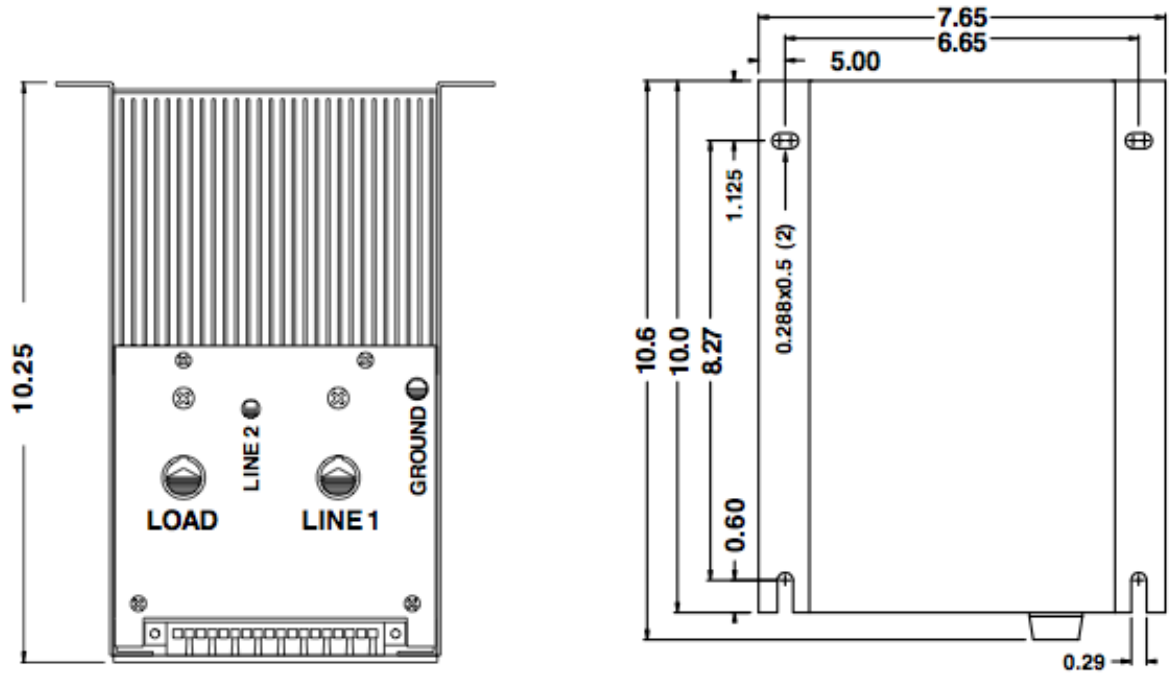


Fig. 11. Installation dimensions 50, 80, 120 & 160 Amp

NOTE: THE 50 and 80 AMP UNITS ARE NOT FAN COOLED. THEY MUST BE MOUNTED ON A VERTICAL SURFACE WITH THE FINS ORIENTED VERTICALLY SO THAT AIR MAY FLOW FREELY BETWEEN THE FINS.

120 and 160 AMP UNITS ARE FORCED AIR COOLED. THEY MAY BE MOUNTED IN ANY DIRECTION.

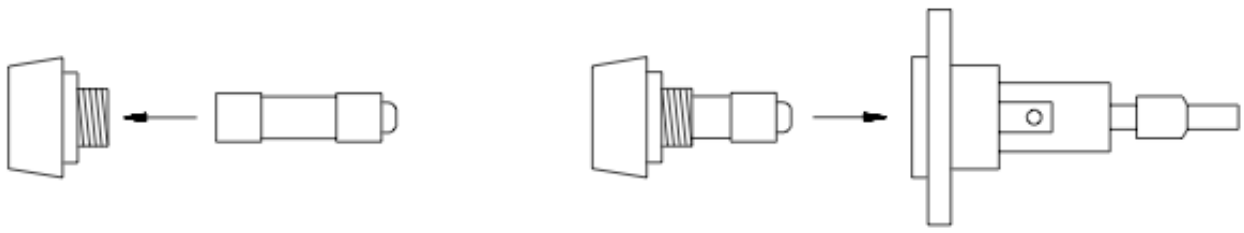


Figure 11A.

ORIENTATION OF FUSE IN HOLDER

Fuse makes contact only when correctly installed.
Place flat end of fuse in cap, then insert into holder.

DIMENSIONS, 200 to 425 AMPS:

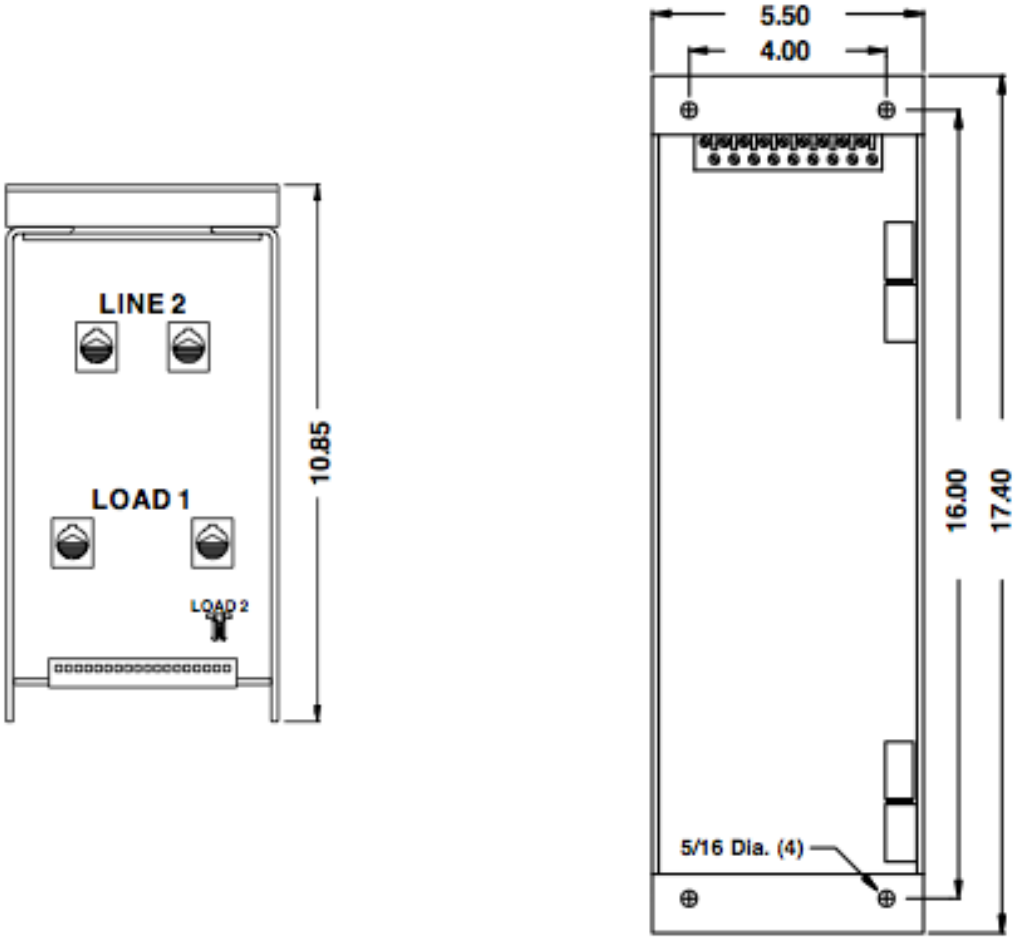


Fig. 12. - **Installation dimensions.**
200, 250, 300, 380 & 425 Amp units.
Controllers may be mounted in any direction.

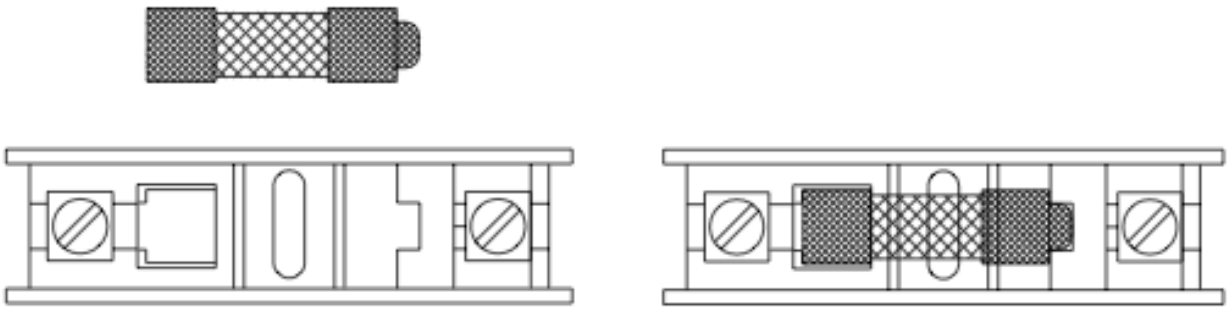
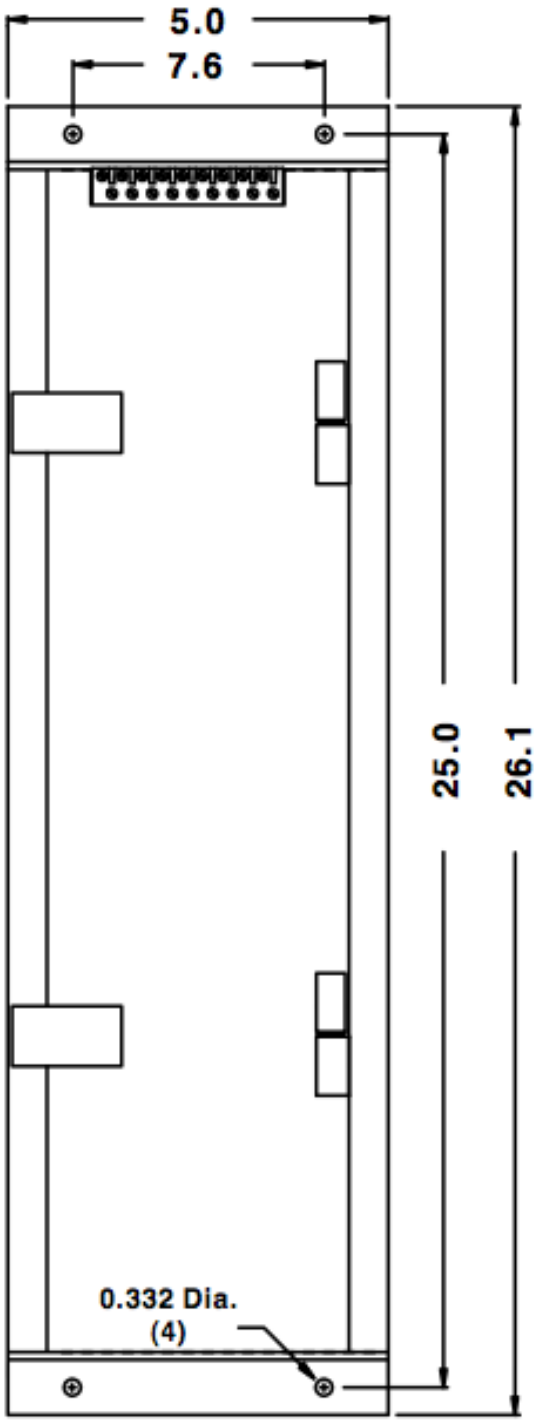


Figure 12A.
ORIENTATION OF FUSE IN HOLDER
Fuse makes contact only when correctly installed.

DIMENSIONS, 500 TO 750 AMPS:



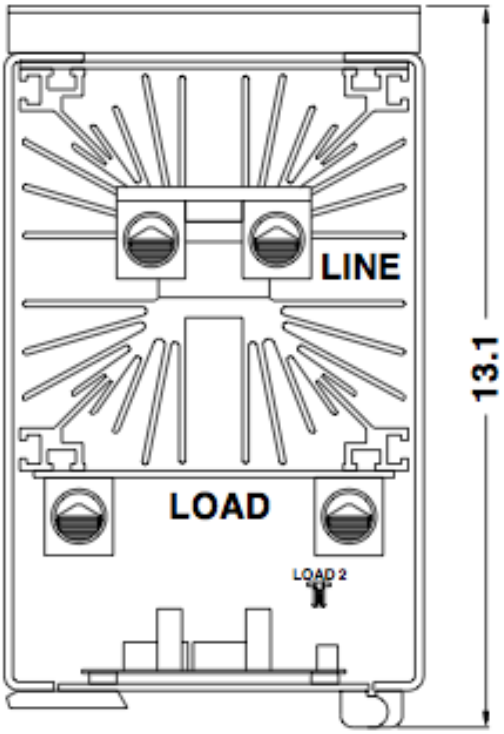


Fig. 13. - Installation dimensions.
500, 600 and 750 Amp Controllers.
Controllers may be mounted in any direction.

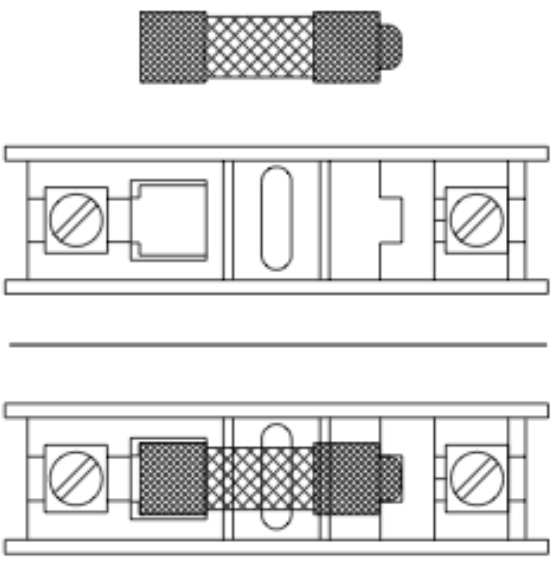


Fig. 13A. - Orientation of fuse
Fuse makes contact only when
correctly installed.

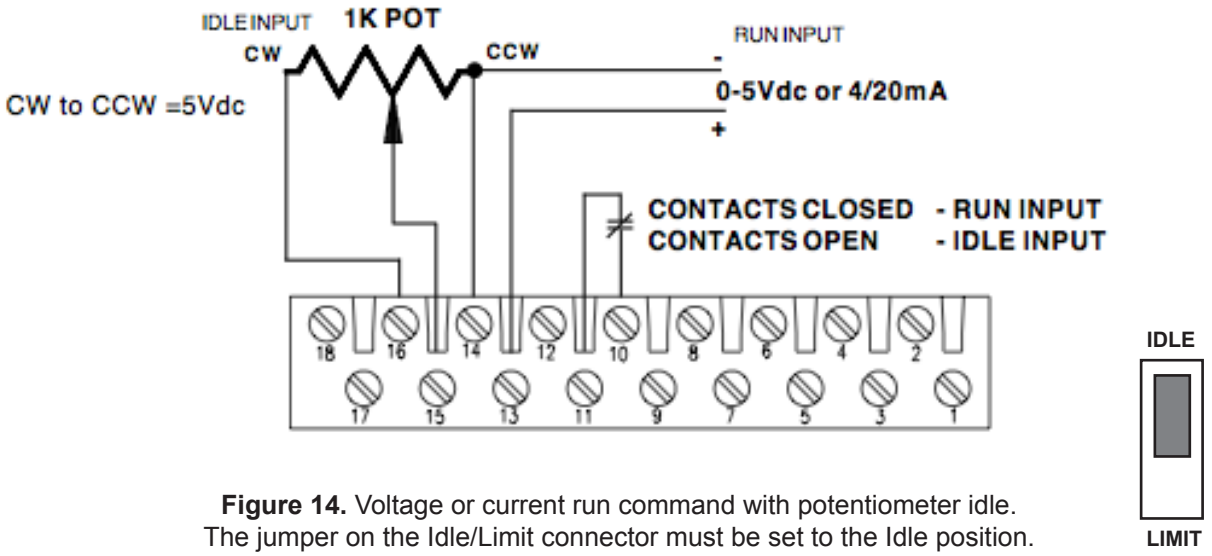


Figure 14. Voltage or current run command with potentiometer idle.
The jumper on the Idle/Limit connector must be set to the Idle position.
See fig. 22 for location of idle/limit connector.

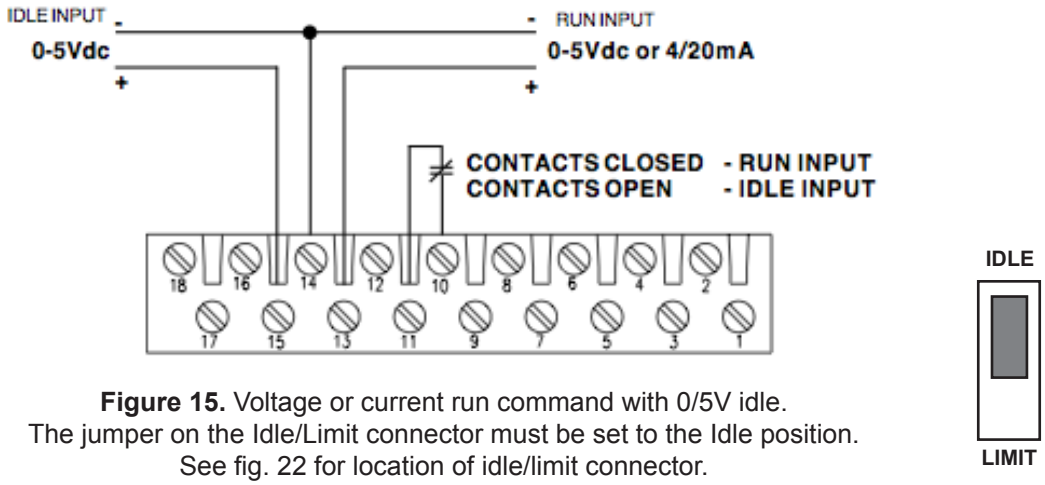


Figure 15. Voltage or current run command with 0/5V idle.
The jumper on the Idle/Limit connector must be set to the Idle position.
See fig. 22 for location of idle/limit connector.

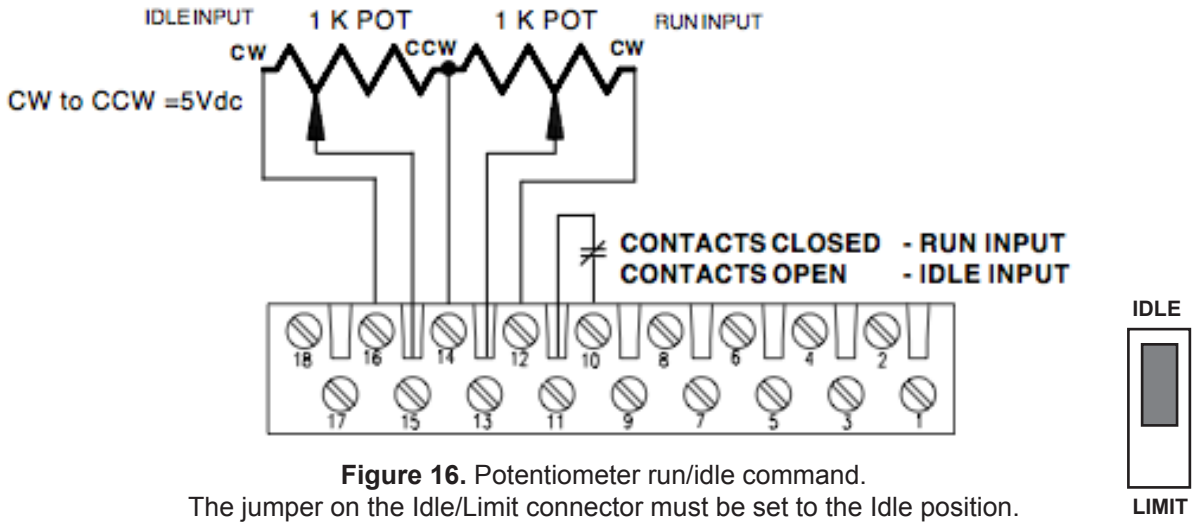


Figure 16. Potentiometer run/idle command.
The jumper on the Idle/Limit connector must be set to the Idle position.
See fig. 22 for location of idle/limit connector.

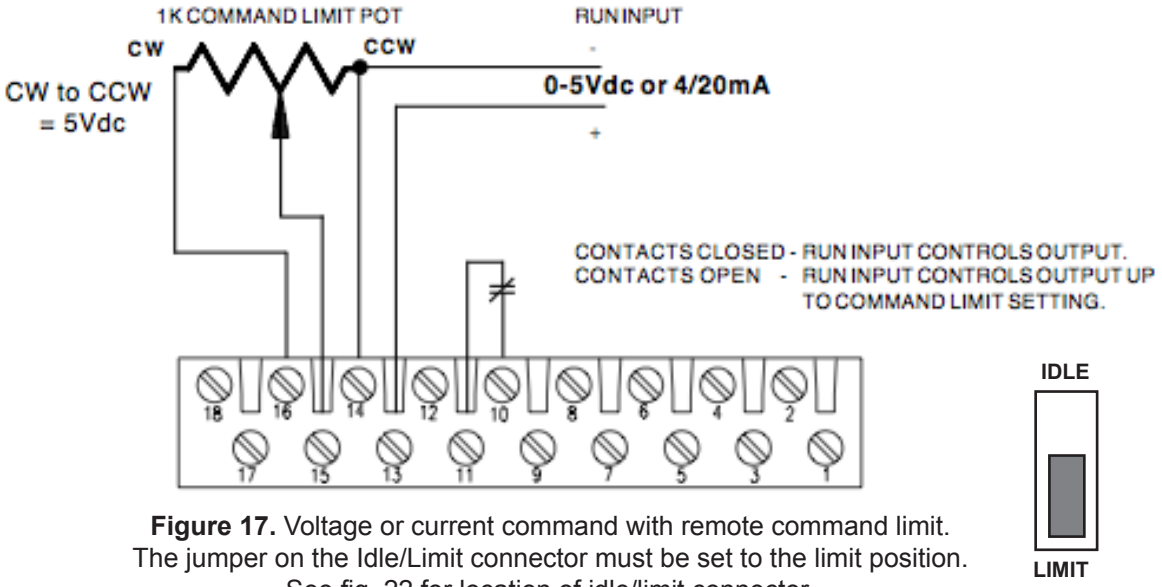


Figure 17. Voltage or current command with remote command limit. The jumper on the Idle/Limit connector must be set to the limit position. See fig. 22 for location of idle/limit connector.

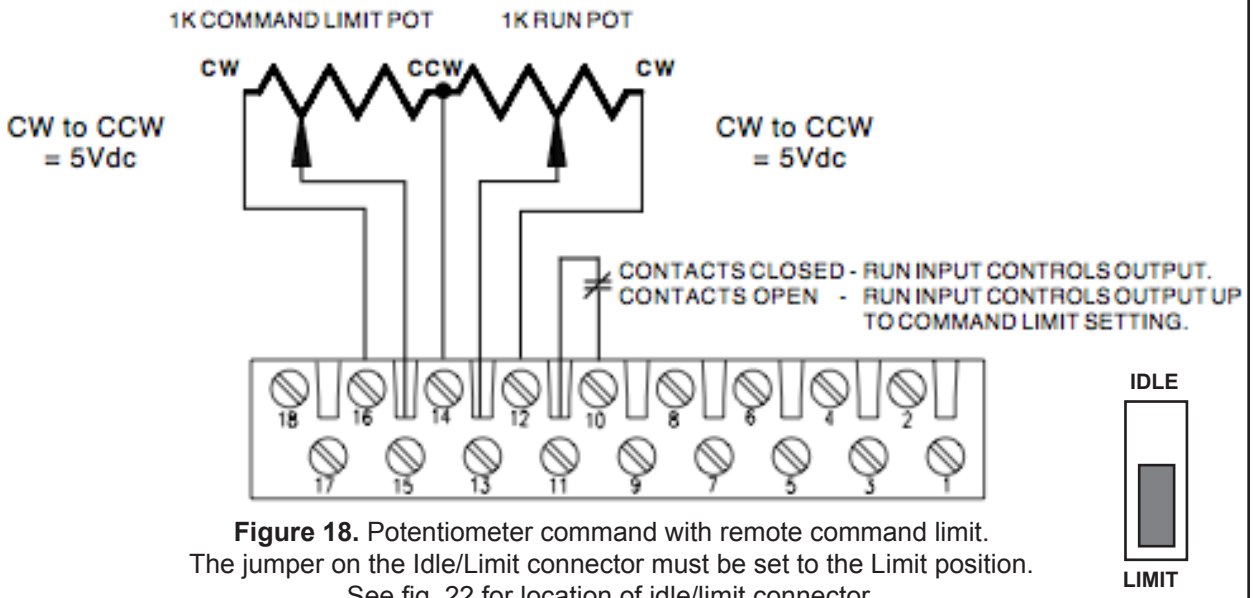


Figure 18. Potentiometer command with remote command limit. The jumper on the Idle/Limit connector must be set to the Limit position. See fig. 22 for location of idle/limit connector.

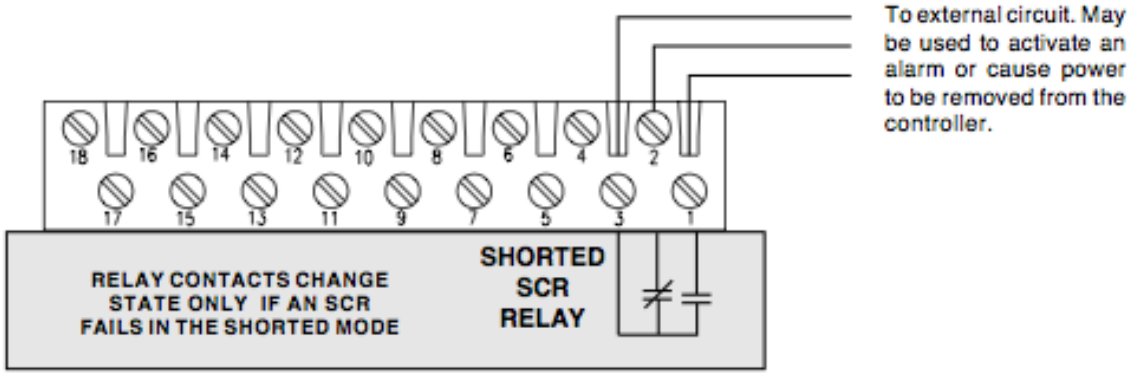


Figure 19. Shorted SCR relay.

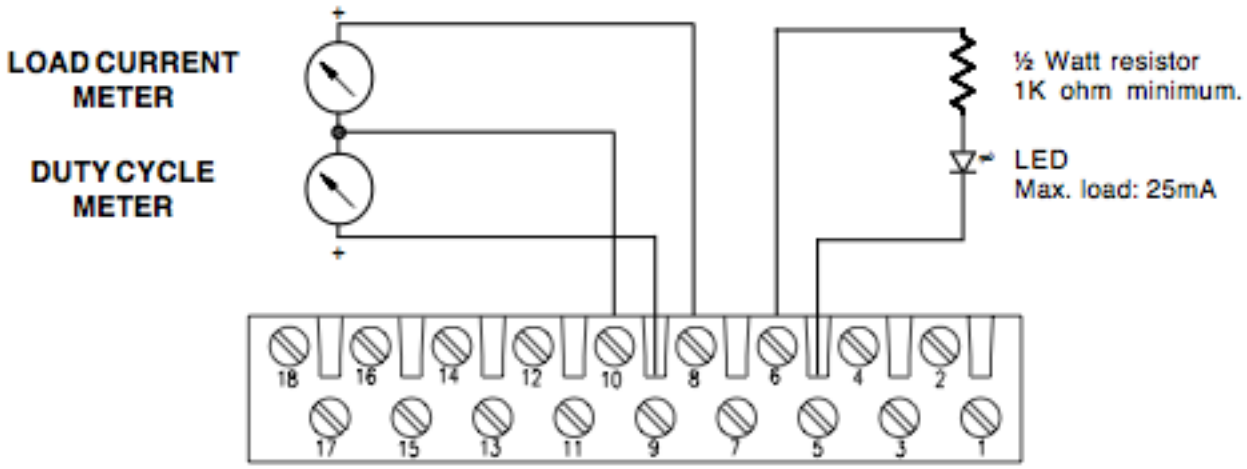


Figure 20. Remote current and duty cycle meters.
Load indicator may be connected as shown.

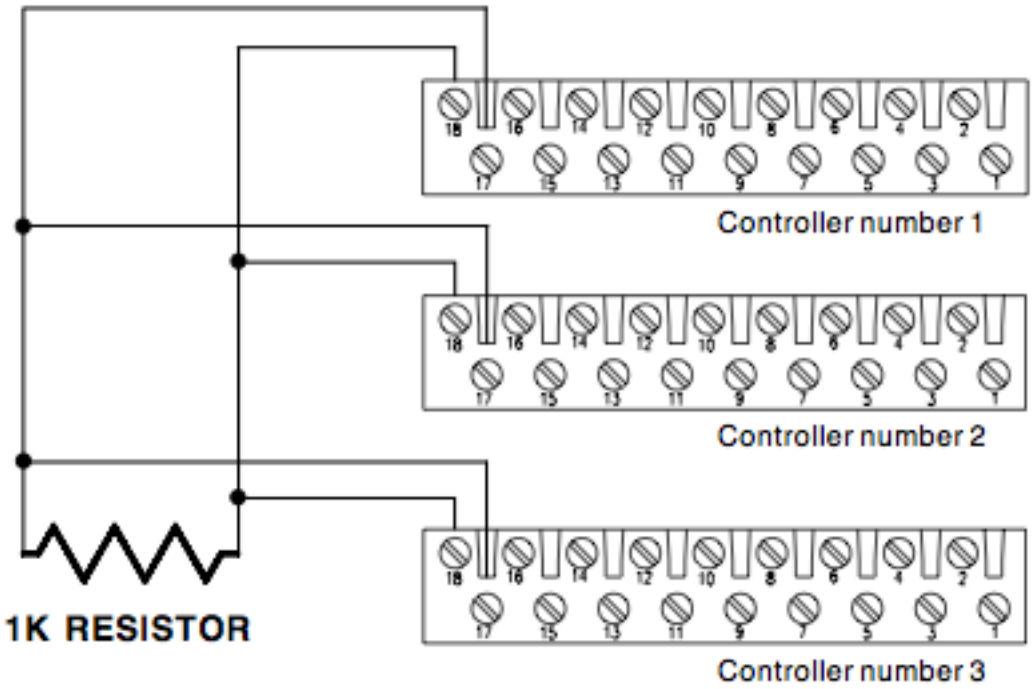


Figure 21. **Sync-Guard™ connections.**

Up to 10 controllers may be connected with the Sync-Guard™ feature.

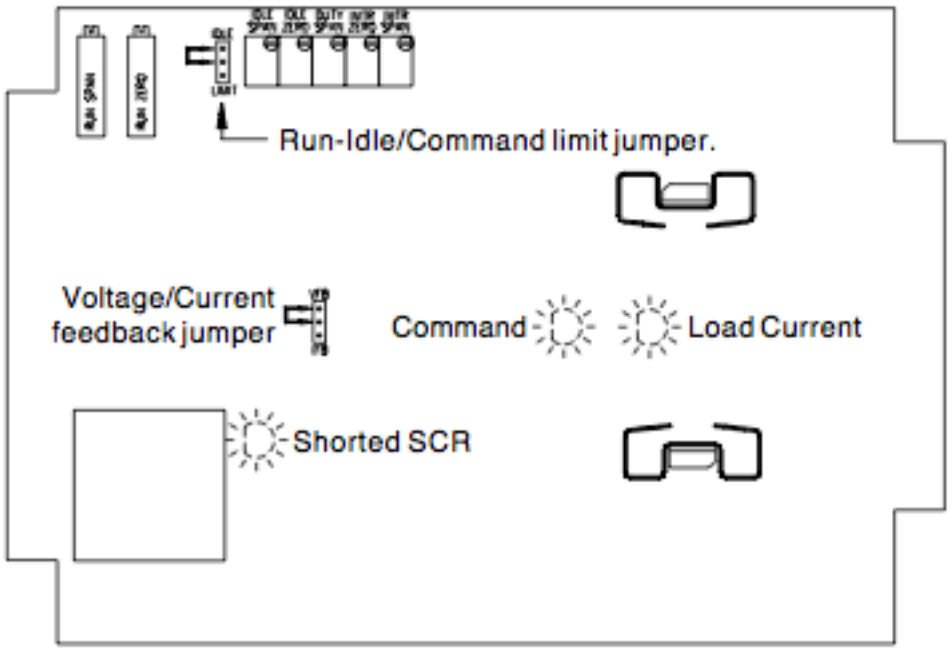


Figure 22. Circuit board layout showing potentiometers and board jumpers.

ADJUSTMENTS:

THE SPAN AND ZERO POTS ARE FACTORY ADJUSTED TO PROVIDE ZERO AND 100 PERCENT OUTPUTS WHEN THE COMMAND IS ZERO AND 100 PERCENT.

If it becomes necessary to recalibrate these adjustments, it is recommended that you follow these steps.

1. Set the command signal to minimum and adjust the zero potentiometer until the output is zero.
2. Set the command signal to maximum and adjust the span potentiometer until the output is at the desired maximum value.
3. The span and zero adjustments may interact, therefore, it may be necessary to repeat steps 1 and 2.

It is recommended that no adjustment be attempted to the Imeter Span & Zero or the duty cycle span potentiometers.

START UP:

1. Confirm that the correct voltage tap is selected on the transformer located under the lid and the desired mode (average voltage or average current) is selected.
2. Apply system power and slowly increase the command signal from zero to the desired value. If the load is not capable of the current specified by the "IFB" term in the model number full output will be obtained at less than 100 percent command.

CAUTION: PORTIONS OF THE PRINTED CIRCUIT BOARD AND OTHER PARTS OF THE CONTROLLER ARE AT LINE VOLTAGE POTENTIAL. USE EXTREME CARE TO AVOID ELECTRICAL SHOCK. IT IS RECOMMENDED THAT INSTALLATION AND SERVICE BE DONE BY A LICENSED ELECTRICIAN OR EXPERIENCED TECHNICIAN.

TROUBLE SHOOTING:

The COMMAND, SHORTED-SCR, and LOAD indicators provide a convenient method of determining the location of problems should they occur. The on/off frequency of the command indicator is proportional to the command signal. The command indicator should be off with no control signal, and the frequency should increase as the command signal is increased. Correct operation of the command indicator proves that the command signal is applied and that the majority of the circuit is operating correctly. Note that the command indicator may not be on continuously when the control signal is 100%. The command indicator is energized when a signal to turn the SCRs on is applied. The load current indicator is on when load current occurs and should be on when the command indicator is on.
The shorted SCR indicator is ON when an SCR has failed in the shorted mode.

Note: Before substituting another firing circuit for a suspected faulty circuit, check the value of the scaling resistor, R100 on each board. The value of this resistor has been selected for the current rating of the frame. If necessary, transfer the resistor from the suspected faulty circuit board to the substitute. Call the factory if help is desired.

<u>THE FOLLOWING ARE SOME SYMPTOMS AND STEPS TO HELP LOCATE PROBLEMS:</u>
NO LOAD VOLTAGE:
Note: The SCRs must have a load current of at least 1 amp to insure correct operation.
If the command light does not function, determine that the correct command signal is applied. If the command light is ON, but the load current indicator is OFF, check the fuses and system voltage.

RATED CURRENT CAN NOT BE OBTAINED:
Determine that the correct command signal is applied. It is possible that an SCR or the circuit has failed preventing one of the SCRs from turning on. This failure can be determined by checking if any DC voltage is applied to the load.

LOAD CURRENT WILL NOT GO TO ZERO:
If the command signal is zero and a small amount of load current is still being applied adjust the zero potentiometer. If the shorted SCR indicator is ON, an SCR has failed. It is, however, possible for a circuit failure to cause the same symptoms. If the shorted SCR indicator is off remove the circuit card from the controller, if the load current is now zero the circuit card has failed. If the command indicator is OFF and the current will not go to zero with the circuit card removed from the controller, an SCR has failed. If the load voltage goes to zero with the circuit card removed - replace the circuit card.

MODEL No. IDENTIFICATION:

1037A - [IFB or A] - (XX)V - (XX)A - R(cs) - I(cs) - LIM
1037A Specifies a single phase, zero-cross SCR controller.
IFB(current) Specifies current feedback.
A Specifies average voltage feedback.
(**XX**)V Specifies the rated operating voltage. **120, 208, 240, 277, 380, 415, 480** or **575** Vac
(**XX**)A Specifies the frame size of the controller. **50, 80, 120, 160, 200, 250, 300, 380, 425, 500, 600** or **750** Amps
R(**cs**) Specifies the RUN command signal. R**0/5V,** R**4/20mA** or R**pot.**
I(**cs**) Specifies the IDLE command signal. i**0/5** or i**pot.**
LIM (Optional) Uses the Idle pot as a command limiter.

NOTE: A suffix of (SC) or (SP) on the end of the model # can mean Special Control or Special Product options. Consult factory for information.

SPECIFICATIONS: (continued)

AMBIENT TEMPERATURE:	Operating 0 to 55ºC Storage -40 to 80ºC Humidity 0 to 95%, Non - Condensing		
POWER DISSIPATION:	1.5 Watts per amp of load current.		
ZERO AND SPAN:	Multi-turn potentiometers allow adjustment of ±20% of span.		
SCR PROTECTION:	DV/DT circuit consists of a .1uF capacitor in series with a non-inductive resistor connected across the SCRs. SCRs are protected from voltage transients by a Metal Oxide Varistor. DV/DT rating: 200 volts/microsecond		
SCR RATINGS:	Peak forward and reverse voltage: 1600 volts		
SCR I^2T and SURGE CURRENT RATING:	Frame rating	I^2T Rating @25°C	I_{TSM} Surge Current Rating @25°C
	50 & 80 Amps	15,000 A^2s	1,750A
	120 Amps	18,000 A^2s	1,900A
	160 Amps	80,000 A^2s	4,000A
	200 Amps	101,000 A^2s	4,500A
	250 Amps	135,000 A^2s	5,200A
	300 Amps	245,000 A^2s	7,000A
	380 Amps	500,000 A^2s	10,000A
	425 Amps	845,000 A^2s	13,000A
	500 Amps	500,000 A^2s	10,000A
	600 Amps	845,000 A^2s	13,000A
	750 Amps	1,670,000 A^2s	20,000A

MANUFACTURED BY:

CONTROL CONCEPTS

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