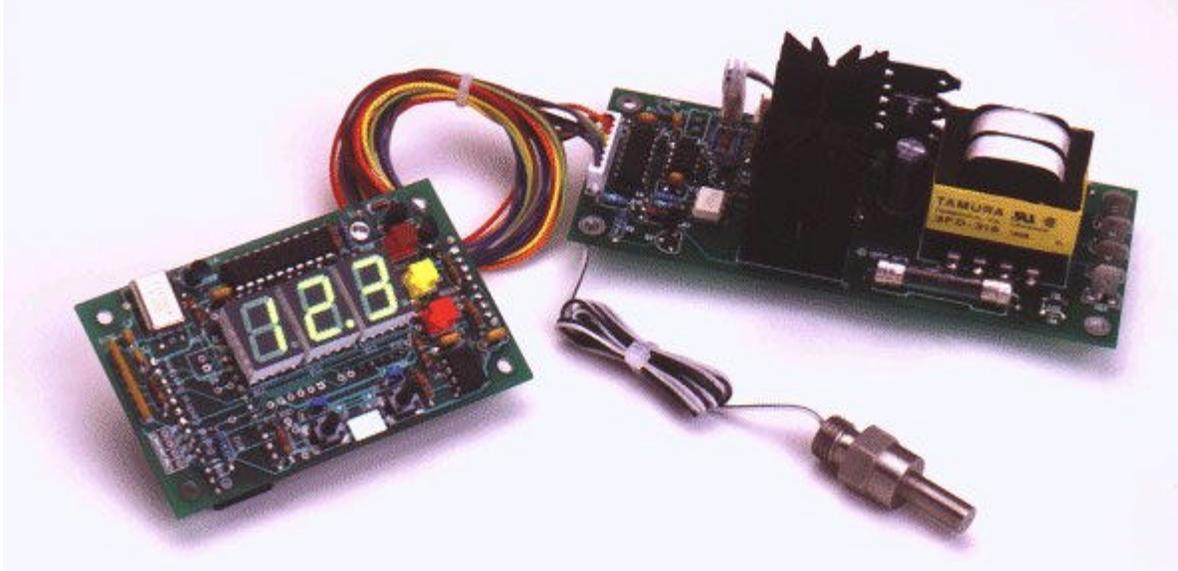


# 100 SERIES



## **MICROPROCESSOR BASED TEMPERATURE CONTROLLER REFERENCE MANUAL**

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# 100 Series Reference Manual

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## INTRODUCTION

The 100 series microprocessor based controllers are designed to be incorporated into end products that must accurately maintain constant temperatures. This manual is intended for the OEM purchaser of the control. It describes the controller's operation and covers the installation and field service procedures as well as the front panel operation of the 100 series. Purchaser's of 100 series controllers are granted a license to make copies of the Front Panel Operation section of this manual for the sole purpose of providing operating instructions to their end users.

The *Functional Description* section provides a technical overview of the 100 series and their control algorithms. It contains information useful to technical and engineering personnel who will be involved with integrating the controller into the end product.

The *Installation* section of this manual is a guide to integrating the 100 series into the end product. It contains the mechanical mounting dimensions which are common to all 100 series models. A typical installation is described in detail and the pros and cons of several variations are discussed. This section also contains data on electrical connections, both for power and the temperature sensor.

## SPECIFICATIONS

Range (Control and Display)	depends on specific model
Resolution (Control and Display )	$\pm 1$ least significant display digit
Repeatability	$\pm 1$ least significant display digit
Control Stability	$\pm 1$ least significant display digit
Maximum Load Current	10 Amps RMS
Power Requirements	120 / 240 VAC $\pm 10\%$ 50 - 60 Hz
Control Algorithm	Modified PID
Display	3 digit, .56" LED

## FRONT PANEL OPERATION

The front panel of the 100 series consists of a three digit numeric LED display, and two momentary push button switches labeled 'UP' and 'DOWN'. One of several parameters can be displayed, depending on the operating modes as described below. The parameter being displayed is always unambiguously identified by the display mode.

### **Start up**

Whenever power is applied to the controller, the software revision number is displayed for several seconds. While the software revision number is being displayed, the intensity of the display digits alternates between full and half brightness, and on some models the two outside decimal points

blink on and off. After several seconds, the display reverts to showing the controlled temperature. In this mode, at most a single decimal point is illuminated, and the display intensity is steady.

### **Normal Operation**

After approximately five seconds of no front panel button activity, the display always reverts to showing the calibrated sensor temperature. In this mode the display intensity is steady and at most a single decimal point is illuminated.

Temperatures below the display range cause the display to read 'LO'. Temperatures greater than the display range cause the display to read 'HI'.

### **Viewing the Setpoint**

The current setpoint can be displayed by momentarily pressing and releasing either the 'UP' or 'DOWN' button. Whenever the setpoint temperature is showing, the display brightness alternates between full and half intensity. The display automatically reverts to showing the controlled temperature if neither button is pressed for about five seconds.

### **Altering the Setpoint**

The current setpoint value can be altered using the 'UP' and 'DOWN' buttons while the setpoint is being displayed. To change the setpoint from normal mode, proceed as follows:

- Momentarily press then release either the 'UP' or the 'DOWN' button. The LED intensity will alternate between half and full intensity to indicate that the displayed value is the current setpoint.
- Increase or decrease the setpoint value by pressing the 'UP' or 'DOWN' buttons respectively. If either button is held down for more than several seconds, the setpoint value will increase or decrease continuously.
- When the desired setpoint is reached, wait approximately five seconds without pressing either button; the display will revert to normal mode showing the actual temperature.

The new setpoint becomes effective and is stored in the nonvolatile memory when the display reverts to normal mode.

### **Calibrating Temperature Reading**

An offset adjustment can be made to calibrate the temperature indicated by the sensor. To perform this calibration proceed as follows:

- Measure the temperature being controlled carefully with an accurate thermometer.
- Press **both** 'UP' and 'DOWN' buttons simultaneously and hold until the displayed value or the decimal points in the display flash to indicate that the controller is in calibration mode.
- The display continues to indicate the controlled temperature, which can now be increased or decreased by pressing the 'UP' and 'DOWN' buttons to match the reading from the calibration thermometer .

- The display will revert to normal mode after neither button has been pressed for approximately 5 seconds.

The new calibration factor will take effect and be stored in nonvolatile memory when the display reverts to normal mode.

## FUNCTIONAL DESCRIPTION

This section provides a technical overview of the 100 series.

### **Block Diagram Hardware Description.**

The block diagram of the 100 series is shown as Figure 1.

The 100 series is powered from either 110 or 220 VAC power. A voltage selection jumper connects the transformer primary windings in parallel or series. A conventional step-down transformer, series regulated supply provides all system power. A separate regulator supplies the 3.0 volt reference to the A/D converter.

Various drive circuits are used depending on the sensor type.

The conditioned sensor voltage applied to the A/D converter ranges from 0 to 3.0 volts.

The 68HC05 CPU acquires and averages approximately a thousand ten bit digitized samples of the conditioned sensor voltage for each reading.

The load control contact is implemented with a 15 A, 400 V triac driven by an optically isolated triac trigger.

The three, seven segment LED displays are multiplexed under the control of the MC14489 driver. The CPU periodically updates the values to be displayed, but is not directly involved in driving the individual segments.

A 32 X 8 bit EEPROM provides the nonvolatile storage for all calibration and setpoint parameters. The values are read into system RAM at power up, and updated to the EEPROM whenever they are changed by the user.

### Load Contact

The load contact is implemented with a 15 amp, 400 volt triac, triggered with an optically isolated triac trigger.

The load contact is **NOT** fused, and care must be taken to ensure that its current rating is not

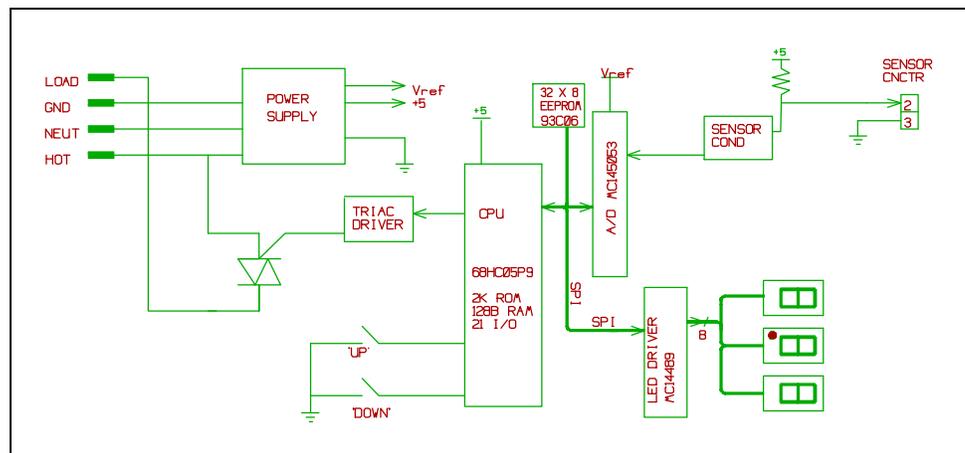


Figure 1: Model 100 Block Diagram

exceeded; even brief short circuiting of the load while it is energized will cause a triac failure.

The 100 series is intended primarily for the control of non-inductive heating loads, and is not normally fitted with a snubbing circuit. Provision exists on the power board for the user to install either an RC or varistor style snubbing network across the triac. See Switching Inductive Loads on page 8 in the *Installation* section for more detail on snubbers.

### **Control Technique**

The 100 series is a modified PID controller, using zero crossing switched, pulse width modulation to precisely control the amount of power delivered to the load. During each control cycle, the load is energized for the number of power line half cycles necessary to deliver the required power. All load switching (both on and off) is done at the power line voltage zero crossing to eliminate current transients.

In a purely proportional controller, the power applied to the load is strictly proportional to the difference between the actual and setpoint temperatures. The temperature difference corresponding to the application of full power is called the proportional bandwidth. The 100 series' proportional bandwidth is adjustable in the field for most models.

A purely proportional temperature controller suffers from the limitation that when the setpoint and actual temperatures are equal, there is no power being delivered to the load. Since all systems have some amount of heat loss, a proportional controller will always stabilize at a temperature slightly away from the setpoint, where power to the load just makes up for the steady state heat loss.

The 100 series automatically compensates for steady state control error by integrating the difference between the actual and setpoint temperatures, and using this value to adjust the load power so that the actual temperature remains exactly at the setpoint. This feature is often referred to as automatic reset in control literature.

During warm-up, while the temperature is below the proportional band, the heater would normally operate at full power. In many systems this causes overshoot because the excess heat stored in the heater and its surroundings will continue to warm the system past the setpoint temperature, even though the controller has shut off the heating element. The 100 series incorporates rate limiting (derivative) action to control the rate of temperature increase during warm up, thereby greatly reducing the build up of excessive heat. On most models the offset below threshold where this rate limiting begins is an adjustable parameter called the 'Heat Limit Threshold'.

## **INSTALLATION**

This section covers the major points to consider when incorporating the 100 series into the end product's design.

### **Sensor Connection**

The sensor is connected to J2 located near the upper left hand corner of the power board. The sensor cable should not be routed near power carrying wires to minimize noise pick-up.

## Power and Load Connections

Power and load connections are made through four 1/4 inch spade lug terminals marked HOT, NEUT, GND and LOAD, located along the right hand edge of the power board. Each pin is described in table II below. A typical connection diagram is shown in Figure 2.

Pin Name	Connect To	Comments
LOAD	Hot side of load to be controlled	Load current is supplied through this terminal.
GND	Safety (earth) ground	This terminal should be connected to the end product's chassis.
NEUT	Neutral (grounded) side of power line	
HOT	Hot side of power line	This pin is electrically connected to the LOAD pin whenever the load is energized.

**TABLE II:** Power Connections

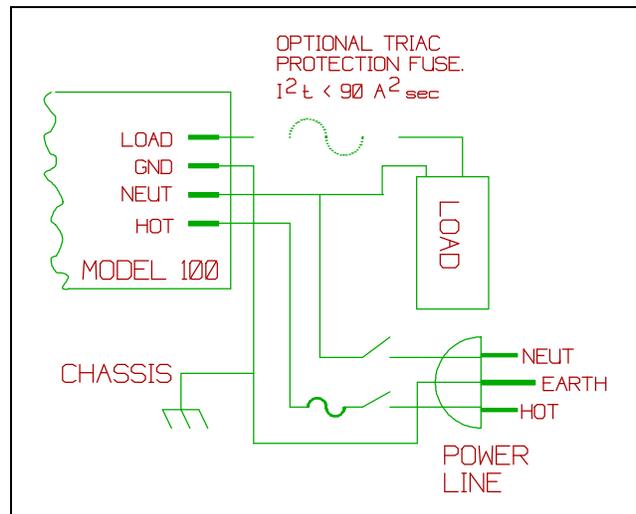
## Load Circuit Considerations

### Triac Power Dissipation

The load is switched with a 15 amp, 400 volt triac. When on, the triac dissipates up to 1.3 Watts per Ampere of load current. The specified load current is limited to 10 amps because the heat sink temperature must rise to about 60 °C above ambient to dissipate the resulting 13 Watts.

The maximum rated case temperature of the triac at 10 amps is 94 °C. Therefore the ambient temperature must be below 34 °C (93.2 °F) to avoid overheating the triac when operating at the rated load current. This rating is conservative for applications where the average load duty cycle is low to moderate.

The power board must be installed so that air can freely circulate around the triac heat sink. The maximum ambient temperature can be increased to 46 °C (114.8°F) by providing airflow of at least 200 ft/min velocity over the triac heat sink.



**Figure 2:** Typical Load Connection

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Temperature rise should be measured at the tab of the triac with the power board in its final position and all shrouds and covers in place to verify that maximum operating temperature of the triac is not exceeded.

For applications where higher power loads must be switched, an external relay can be used, eliminating all thermal considerations for the 100 series' internal triac. If a mechanical relay with significant inductance is used, a snubber may be required for proper operation.

### Triac Fault Protection

The load circuit is not fused, and will be destroyed if the load is even briefly short circuited while energized. In applications where protection against load short circuiting is required, a fuse with an  $i^2t$  rating of 90 Amps<sup>2</sup> sec or less should be installed in series with the load circuit as shown in Figure 2.

### Switching Inductive Loads

The 100 series is intended primarily for controlling resistive loads, and is supplied without the snubbing network components installed. For applications where inductive loads will be controlled, either an RC or varistor snubber should be installed across the load, as close as possible to the inductive element.

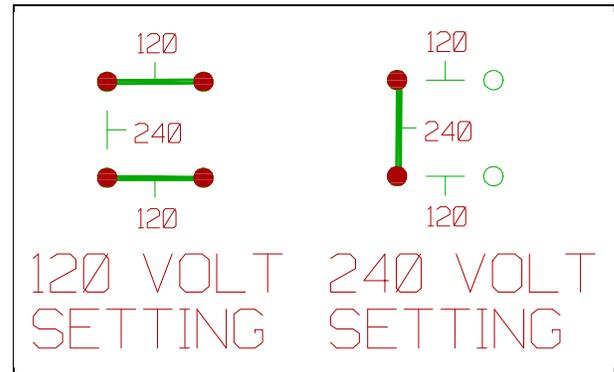
Controllers can be supplied with snubbing networks installed. Contact the factory for details.

### Voltage Selection

**CAUTION**  
**ANY JUMPER SETTINGS OTHER THAN  
THOSE SHOWN IN FIGURE 3 WILL  
RENDER THE UNIT INOPERABLE AND  
MAY CAUSE PERMANENT DAMAGE TO  
THE POWER TRANSFORMER**

The 100 series can be operated from nominal 110 or 220 volt power lines at 50 or 60 Hz.

The operating voltage is selected with the jumpers near the lower right hand corner of the power board. The only two allowable jumper settings are shown in Figure 3.



**Figure 3: Voltage Selection Jumper Settings**

### Mechanical Mounting

The 100 series is configured as two etched circuit boards connected by an 18 inch long, 8 conductor cable. The smaller board containing the LED display and two switches is referred to as the display board. The larger board containing the transformer and triac heat sink is called the power board. The mechanical mounting dimensions for both boards are shown in Figure 4. Note that the dimensions are referenced to the mounting hole pattern rather than the edges of the boards.

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The three LED digits and two buttons on the display board are the 100 series' control panel. The display board is intended to be mounted behind the end product's front panel with the LED display showing through a cutout. Two additional cutouts below it allow actuation of the switches. The display board is small and separate from the power board minimizing the front panel area required to incorporate the 100 series.

The power board contains the power and sensor connectors, and need not be accessible to the user; it can be mounted on an internal wall where space is not at a premium. The only mounting restriction is imposed by the length of the interconnect cable, and the requirement for 1.75 inches of clearance for the transformer and heat sinks.

### Display Board Mounting

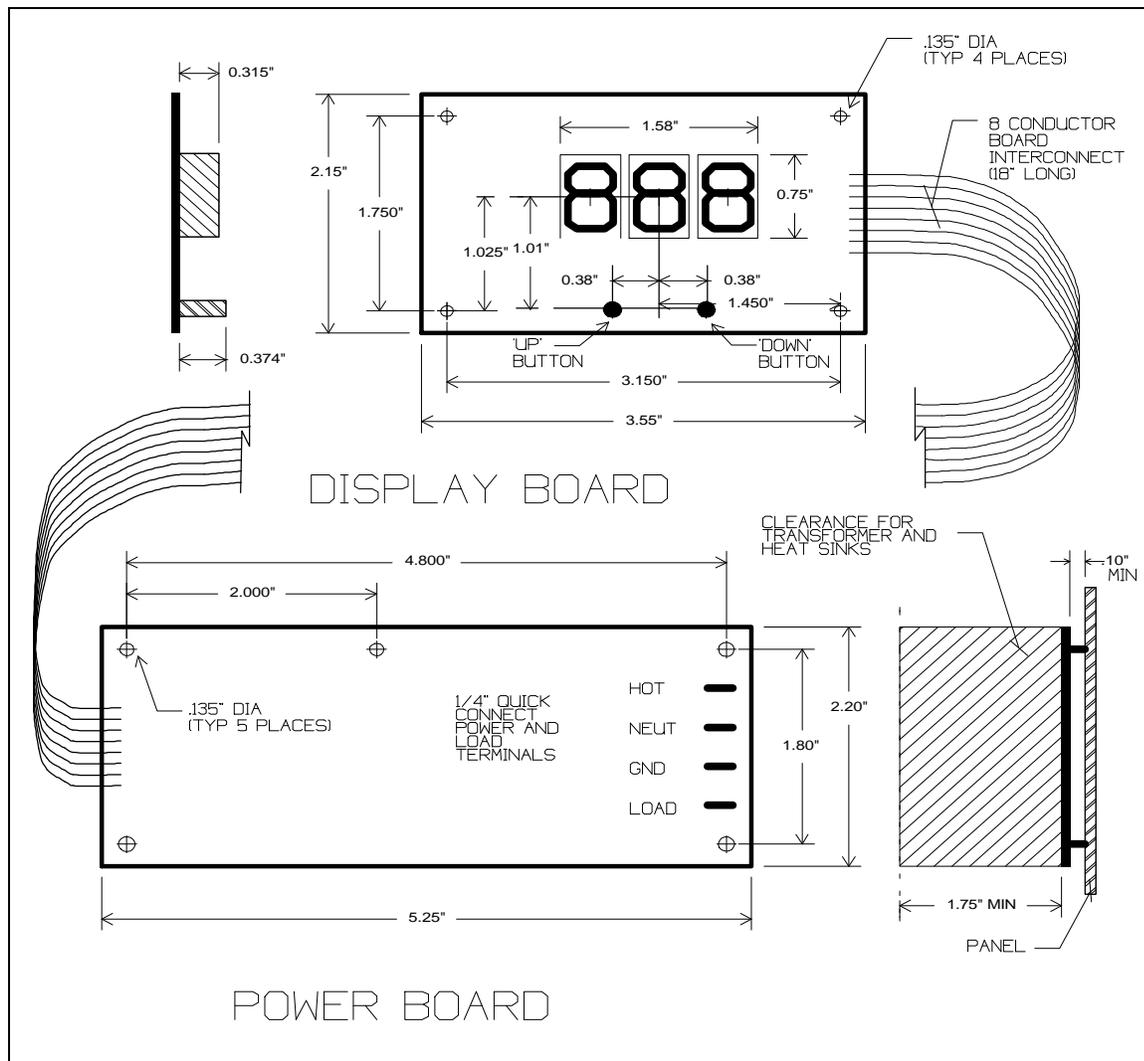
The preferred mounting for the display board is shown in . The board is mounted on standard 3/8 inch self-clinching studs (PEM SOS-12-440 or equivalent) pressed into holes drilled through the end product's front panel. Using self-clinching standoffs is preferred because the thickness of the front panel does not affect the position of the switch shaft relative to the front surface of the panel. The length tolerance of the standoffs should be  $\pm .006$ " or better.

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The pressure of the punch installing the standoffs should be set to leave a slight dimple in the front panel to ensure that the full length of the stud protrudes behind the panel. Insufficient standoff protrusion may cause the button shafts to interfere with the overlay at worst case tolerance conditions. Embossing a .030" inch 'button' into the overlay will minimize tolerancing problems.

Maximum required switch shaft travel is .015 inches. At the worst case tolerance condition of maximum stroke, shortest shaft length and longest standoff length, the front of the switch shaft must be depressed .027" below the front surface of the panel.

In applications where other mounting schemes will be used, some important tolerances to keep in mind are shown the table below.



**Figure 4:** Mechanical Mounting Dimensions

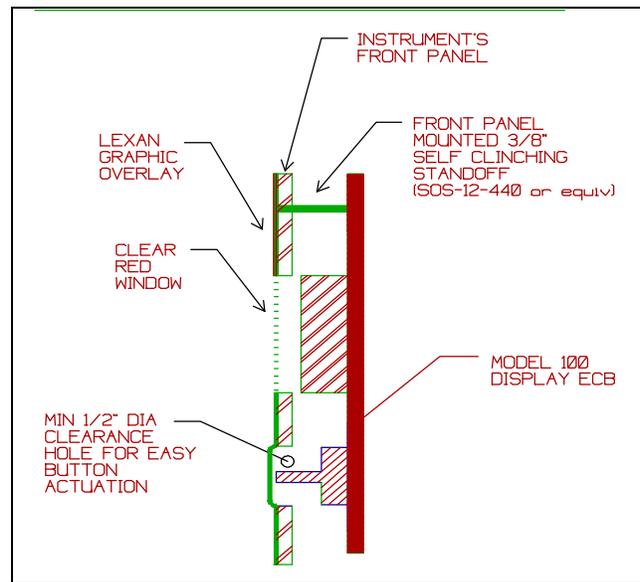
Dimension	Value in Inches
Switch shaft length (from front surface of ECB)	$.374 \pm .006$
Switch actuation travel	$.010 \pm .005$
Thickness of plating at display board mounting holes	$.004 \pm .001$

## Front Panel Trim

The preferred method of trimming the front panel is a lexan overlay with a clear red window through which the LED display can be read. A frosted window will noticeably blur the display digits, though not enough to make them unreadable.

The area on the overlay above the two switches can be marked with just a button shaped graphic to indicate where to press, or a raised button can be embossed. In any case the front panel hole through which the switch shafts protrude should be at least a half inch in diameter and burr free to allow the overlay to travel the required (up to) .027 inch into the front panel to actuate the switch without chafing the overlay material.

Be sure to specify no adhesive on the back of the overlay in the button area.



**Figure 5:** Typical Front Panel Installation

A typical front panel mounting configuration is shown in .Figure 5.

## Power Board Mounting

### CAUTION

**Potentially lethal line voltages are present on some exposed parts of the power board (such as the fuse). It must be mounted such that it is not accessible to the end user while it is energized.**

The power board is intended for mounting to an interior wall of the end product. It should be positioned so that the interconnect cable is not under mechanical tension.

Mounting dimensions are shown in Figure 4.

The back (i.e. non-component) side of the board requires a minimum 0.2 inch clearance to any conductive surface. This is usually provided by the standoffs used to mount it.

The component side of the board requires a clearance of at least 1.75 inches to allow free air circulation around the triac and power supply regulator heat sinks. Because of heat dissipated by the power supply regulator, this clearance is required even if no significant power will be controlled by the load circuit.

### **PROBE LOCATION GUIDELINES**

Keep the following points in mind when locating the temperature probe in the equipment to be controlled:

- The control will always regulate the heater to try and keep the temperature at the probe constant. It should not be located where it will be affected by outside temperature.
- Temperatures at points in the equipment far away from the probe is determined almost entirely by mechanical considerations; adjusting the tuning parameters will have very little effect on temperature uniformity
- The probe should be located so that it 'sees' the effects of changes in heater power as rapidly as possible. Large delays between a change in heater power and the time it takes for the sensor's temperature to change make it difficult to maintain stable control.
- In applications where the heat is transferred by forced air flow, the temperature probe should be directly in the flow.
- Equipment where the heat is distributed through convection or conduction, will have relatively larger temperature gradients. Placing the probe close to the heating element will provide fast, accurate control, but may result in parts of the chamber being relatively cool. Placing the probe far from the heating element will provide poorer control, but will usually result in a warmer chamber.

### **Controller Self Test**

If the offset calibration is in spec, the next thing to check is the proper performance of the controller circuitry. This is most easily done by running the built in self test program. To run the self test proceed as follows:

- Cycle the power to the controller .
- While the software revision is being displayed, press and hold both the 'UP and 'DOWN' buttons until the display shows '8.8.8.' Any segments not lit during this portion of the test are defective.
- In some software versions the individual digits will count down to 0. After all three digits have reached zero, the display will blank. On these versions simultaneously press both buttons will to start the EEPROM and A/D converter test. The majority of software versions

go immediately from lighting all segments to the EEPROM and A/D converter test without any user intervention.

- When the EEPROM and A/D converter test starts, the display is initialized to show '00'. Any faults will cause a non-zero value to be displayed as they are found. Any number other than 0 in the two right hand digits indicates a hardware problem. The middle digit indicates EEPROM errors, the right hand digit indicates A/D converter errors.
- A negative sign will be displayed in the left hand digit when the test is complete. If there have been no errors, the display will read '-00'.
- Simultaneously pressing both buttons returns to the software revision display and normal operation.

