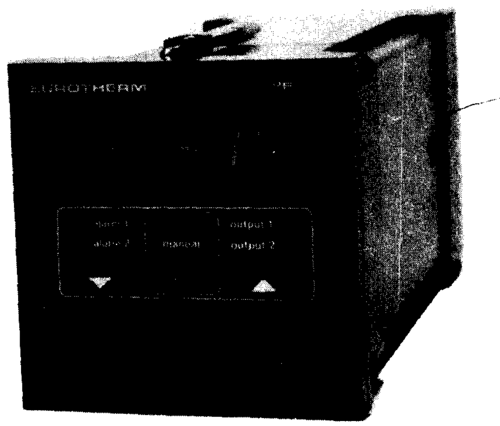
OPERATION AND MAINTENANCE MANUAL FOR



MICROPROCESSOR BASED 3 MODE CONTROLLER

MODEL 810

EUROTHERM CORPORATION
A EUROTHERM INTERNATIONAL COMPANY
11485 Sunset Hills Road □ Reston, Virginia 22090 □ Telephone: (703) 471-4870 □ Telex: 89-9449

CAUTION

Before installing, operating, or servicing equipment supplied by Eurotherm Corporation, please read the following:

INSTRUCTIONS FOR SAFE USE OF EUROTHERM EQUIPMENT

(Note: These instructions represent good engineering principles and are applicable to all control equipment of the same type, whether from Eurotherm or any other supplier.)

OVERCURRENT PROTECTION

It is recommended that A.C. power supplies to Eurotherm instruments be protected by fuses or automatic circuit breakers rated at not more than 2 amperes.

Each Output circuit should be protected by line fuses or automatic circuit breakers rated at the same current and voltage as the output device.

Note: Fuses fitted to Eurotherm Thyristor (S.C.R.) Units are for protection of the internal components only. They are not intended to replace normal line fuses. All installations using Eurotherm Thyristors or Triac units must be equipped with line fuses of appropriate ratings.

Note: The "Current Limit" feature (available as an option on some Eurotherm equipment) is not a substitute for fuses. This feature is provided to accommodate the variation in load resistance of some types of electric heating elements. It provides no protection against excess current due to insulation failure or short circuits, and suitable fuses must be provided in all cases.

VOLTAGE RATINGS

Care must be taken to ensure that maximum voltage ratings are not exceeded.

Unless otherwise stated in the specification of any particular unit, the maximum voltage which may be applied between any two isolated circuits, or between any isolated circuit and ground is limited to the highest rated supply voltage for that unit.

ENCLOSURE OF LIVE PARTS

Some metal parts of certain types of Eurotherm equipment can become electrically 'live' in some conditions of normal operation. (for example: cooling fins on some thyristor units).

Unless clearly intended to be panel mounted and accessible during normal operation, all units should be installed inside a suitable grounded metal enclosure to prevent live parts being accessible to human hands and metal tools.

It is recommended that rear terminal covers (available as an option on most Eurotherm units) be fitted wherever possible.

WIRING

It is important to connect all equipment correctly in accordance with the installation data provided for each type of unit.

Unlabelled terminals must not be used as "tie points" for other wires (unless the installation instructions mention that this is permissible). Such unlabelled terminals may be internally connected. Any questions concerning the correct wiring of a Eurotherm unit should be directed to the nearest Eurotherm Sales and Service representative.

Most connections to Eurotherm equipment require correct polarity to be maintained, and due attention must be given to ensure this.

Wiring should conform to appropriate standards of good practice and local codes and regulations. Conductors should be commensurate with voltage and current ratings of the units.

GROUNDING

All "Ground" terminals must be securely connected to ground by conductors appropriate to the current ratings of the units.

Most Eurotherm controllers have internal circuits which are isolated or "floating." This is necessary to prevent the occurrence of "ground loop" in signal circuits. To avoid possible shock hazards in the event of an internal fault causing breakdown of insulation, it is recommended that all equipment connected to any Eurotherm unit be enclosed in a grounded metal enclosure. Sheaths of thermocouples (or other sensors) should be properly grounded by a separate conductor (instead of being dependent on grounding via the machine framework).

OUT-OF-LIMITS ALARMS

In applications where excessive deviation of a controlled parameter due to equipment failure could cause damage to machinery or materials, or injury to personnel, it is recommended that an additional separate unit be used to give alarm indication or to shut down the process or both, as may be appropriate. (Note: 'Alarm boards' fitted inside controllers may not give sufficient protection in these circumstances). When 'alarm units' or 'alarm boards' are used they should be checked for correct operation and calibration at regular intervals.

SUPPLY ISOLATORS

Every electrical system should be provided with means for isolating the system from the A.C. supply to allow safe working during repair and maintenance. S.C.R.'s and Triacs are not adequate means of isolating the supply, and should always be backed by a suitable mechanical disconnect switch.

HAZARDOUS ATMOSPHERES

Unless otherwise stated in the published specification of any particular unit, Eurotherm products are not suitable for use in areas subject to hazardous atmospheres. No Eurotherm product should be connected to a circuit which passes into or through a hazardous area unless appropriate precautions are taken (even though the controller itself may be located in a safe area). Such an installation should conform to the requirements of the relevant Authority. (In USA: Factory Mutual Research Corporation and Underwriters' Laboratories Inc.)

PROCEDURE IN THE EVENT OF FAILURE

Before beginning any investigation of a fault, the electrical supplies to all equipment concerned should be switched off and isolated. Units suspected of being faulty should be disconnected and removed to a properly equipped workshop for testing. Any attempt to trouble-shoot while installed could be hazardous to personnel and equipment.

IF IN DOUBT, ASK!

If you have any questions regarding any aspect of installing, operating or servicing your Eurotherm equipment, please contact your nearest Eurotherm Sales and Service Representative.

EUROTHERM CORPORATION
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SECTION I

INTRODUCTION

1.1 Scope

This manual contains installation, operation and maintenance instructions for Eurotherm Model 810 Microprocessor Based Controller, herein referred to as the Controller (figure 1.1). Additionally, this manual includes an illustrated parts list, identifying replaceable piece parts, subassemblies and assemblies. Lastly, a product brochure, summarizing Controller specifications, ordering data and warranty information is included as an attachment at the end of this document.

1.2 Purpose and Use

The Temperature Controller is a compact high performance temperature control unit, designed for industrial and laboratory applications where precision temperature control conditions are required.

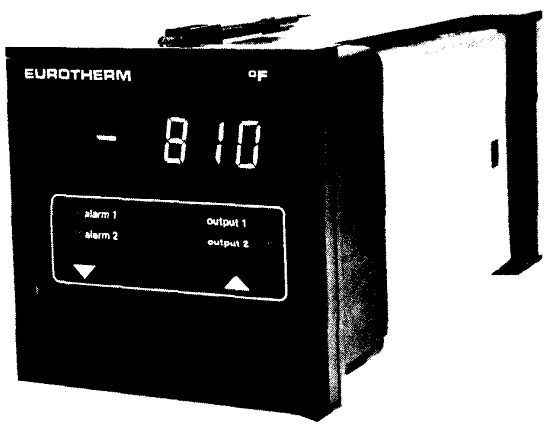


Figure 1.1: Eurotherm Model 810 Microprocessor Based Controller

SECTION II

DESCRIPTION AND DATA

2.1 General Description

The Temperature Controller is a microprocessor based, solid state, compact, three mode (proportional, integral and derivative) instrument, featuring a digital readout and a wide range of interchangeable outputs, temperature ranges and sensor types.

Controller inputs can be either thermocouple or resistance temperature detector (RTD), milliampere, or millivolt signals fed from special sensors. Thermocouple break protection and cold junction compensation are standard on all thermocouple input types.

Precise temperature settings are assured through the use of RAISE and LOWER pushbuttons and a unique digital display. The digital display is a customized fluorescent indicator panel composed of a nine segment error bargraph, to give an analog indication of proximity to setpoint, and four, seven segment indicators giving accurate indication of process variables.

The configuration of the specific controller in terms of range, input type, alarm configuration, linearization, etc. is held in electrically alterable read only memory, EAROM. In the event of power loss, this device employs charge storage characteristics to retain this specific information.

Plug-in circuit boards for input, output and optional alarm functions enable operational versatility, ease of maintenance and reconfigurability. Table 2-1 lists all of the circuit boards that may be installed in the Controller. All output boards are interchangeable, and input ranges can be changed by re-programming or by exchanging the characterizing EAROM.

The controller is ruggedly constructed and physically housed in its own panel mounting sleeve which requires a 3.62 inch square cutout. The instrument measures 7.88 inches deep.

All external connections are made on the terminal block located on the back of the instrument. A label containing connection information, model number and serial number is placed on top of the mounting sleeve.

2.2 Optional Equipment

Electrical and mechanical options available with the controller are referenced in the attached data bulletin.

2.3 Technical Characteristics

Pertinent technical characteristics for the controller are listed in Table 2-2. Refer to the product data bulletin for additional information.

2.4 Special Test Equipment

Special test equipment required to operate and maintain the controller is referenced in Table 2-3. Similar equipment may be used providing operation and maintenance performance is not degraded.

Table 2.2: Technical Characteristics

CHARACTERISTICS	SPECIFICATIONS
Ambient Temperature	0-50°C (32-122°F)
Line Voltage	105/210 VAC ± 10% 120/240 VAC ± 10% 85-264 VAC switch mode power supply
Line Frequency	48-62 Hz
Relative Humidity	0-90% Non-Condensing
Input Common Mode	300 VAC RMS maximum with respect to ground
Input Series Mode	Greater than 1000:1 (60db) giving no observable effect for up to 50mV RMS.
Power Consumption	10 VA Maximum
Setpoint Resolution	1° or 1 least significant digit
Maximum Thermocouple Resistance	100 ohms
Input Signals	Thermocouple or RTD, Milliampere, Millivolts
Deviation Indication	Vertical 9 segment bargraph display, ±0.5% to 5% of instrument span
Calibration Accuracy	±0.25% of instrument span
Proportional Band	Adjustable in steps from 0.5% to 100%
Integral (Reset)	Adjustable in steps from 15 to 1800 seconds with integral OFF
Derivative (Rate)	Adjustable in steps from 5 to 600 seconds with derivative OFF
Overall Dimensions	3.78 in. W x 3.78 in. H x 7.88 in. deep Panel cutout 3.62 in. square
Weight	2.42 lbs.
Display Size	0.500 inch high, 7 segment fluorescent display
Data Retention	Minimum 10 years with instrument unpowered. Typically 1 year with 10,000 erase/write cycles

Table 2-3: Special Test Equipment

NOMENCLATURE	MFR. AND MODEL	OPERATING RANGE
Millivolt Source	Eurotherm Model 239 Millivolt Source	0.0-59.99mV CJC compensated for R, S, K, J, E and T Thermocouples
Voltmeter		

Table 2-1: Major Subassemblies

Nomenclature
MOTHERBOARD ASSEMBLY
POWER SUPPLY/CHANNEL 1 OUTPUT BOARD
MICROPROCESSOR BOARD
CHANNEL 2 OUTPUT/ALARM BOARD (FSH, FSL, HL, LL, DL)
REMOTE ANALOG SETPOINT BOARD (RLS, RLT, MVO)
INPUT BOARD
ISOLATED D.C. SUB-BOARD A
ISOLATED D.C. SUB-BOARD B

SECTION III

PRINCIPLES OF OPERATION

3.1 Scope

This section contains the electrical principles of operation for the Temperature Controller. The discussion is keyed to an exploded view drawing, figure 3-1, illustrating the Controller in disassembled form and to a functional block diagram, figure 3-2, which shows the interrelationship of the Controller's subassemblies and components. To facilitate understanding of the Controller, a brief description of each assembly is provided.

3.2 Motherboard

The motherboard contains sets of pins for the connection of the various plug-in assemblies. With the exception of the input board and the isolated D.C. sub-boards, all other assemblies plug into the motherboard. Also, the motherboard is composed of a custom fluorescent indicator panel (FIP) containing four seven-segment indicators and a nine-segment error bargraph, a RAISE pushbutton, a LOWER pushbutton, a PARAMETER SCROLL pushbutton, a REMOTE/LOCAL pushbutton if fitted, and alarm and output LED indicators.

3.3 Power Supply/Channel 1 Output Board

The power supply/channel 1 output board contains the power supply circuitry that develops all the required voltages for the Controller, and it contains the necessary circuitry to develop the desired heat output signal. This board also contains the power feedback and mains fail detection circuitry.

The power feedback circuitry is designed to approximate a V^2 power controller. Should the microprocessor detect an A.C. power supply change, the microprocessor will adjust the output stage cycle time in order to retain the same output power level. The mains fail detection circuitry is designed to detect an A.C. power failure and alert the microprocessor. The microprocessor then ensures that all relevant circuitry is placed in a safe state.

3.4 Microprocessor Board

The microprocessor board contains the Controller microprocessor, the Dual Slope analog-to-digital converter circuitry, the watchdog circuitry, and the EAROM.

The microprocessor controls all the major functions of the Controller. The microprocessor continually updates the display, handles all operational changes via the RAISE, LOWER, and PARAMETER SCROLL pushbuttons, controls the A/D conversion, implements the 3-term control algorithm, controls the output stages, and checks for alarms.

The A/D converter circuit accepts an analog input signal and digitizes the signal for use within the microprocessor. The EAROM provides non-volatile storage of operational parameters such as control setpoints and control parameters. The watchdog circuit develops a reset signal for the microprocessor should a fault occur, and it also ensures that the microprocessor is placed in the correct state of operation on power-up or power-down. See figure 3-3 for a functional block diagram of the microprocessor.

3.5 Channel 2 Output/Alarm Board

The channel 2 output/alarm board contains the cool channel output and the alarm relays circuitry.

The controller may be fitted with two alarms, and these alarms may be full scale high, full scale low, deviation, deviation low or deviation high. Also, the alarm relays may be energized or de-energized in alarm with normally open or normally closed contacts.

3.6 Remote Analog Setpoint Board

This board contains the remote setpoint (RLS,RLT) and the measured value out (MVO) circuitry.

The remote setpoint option provides the capability to change the Controller's setpoint with an external signal. The measured value out option provides an analog retransmission of the Controller's measured value.

3.7 Input Board

The input board accepts inputs from thermocouples, 3-wire resistance thermometers and voltage or current sources. The low level transducer signals are then amplified to a nominal maximum of 10VDC and applied to the A/D converter for conversion to digital form. The input board is attached to the microprocessor board. The zero and span adjustment potentiometers are also located on this board.

3.8 Isolated D.C. Sub-Boards A and B

These two boards contain the circuitry needed to provide the desired D.C. output. These two boards can produce both D.C. voltage or D.C. current outputs. The output is isolated.

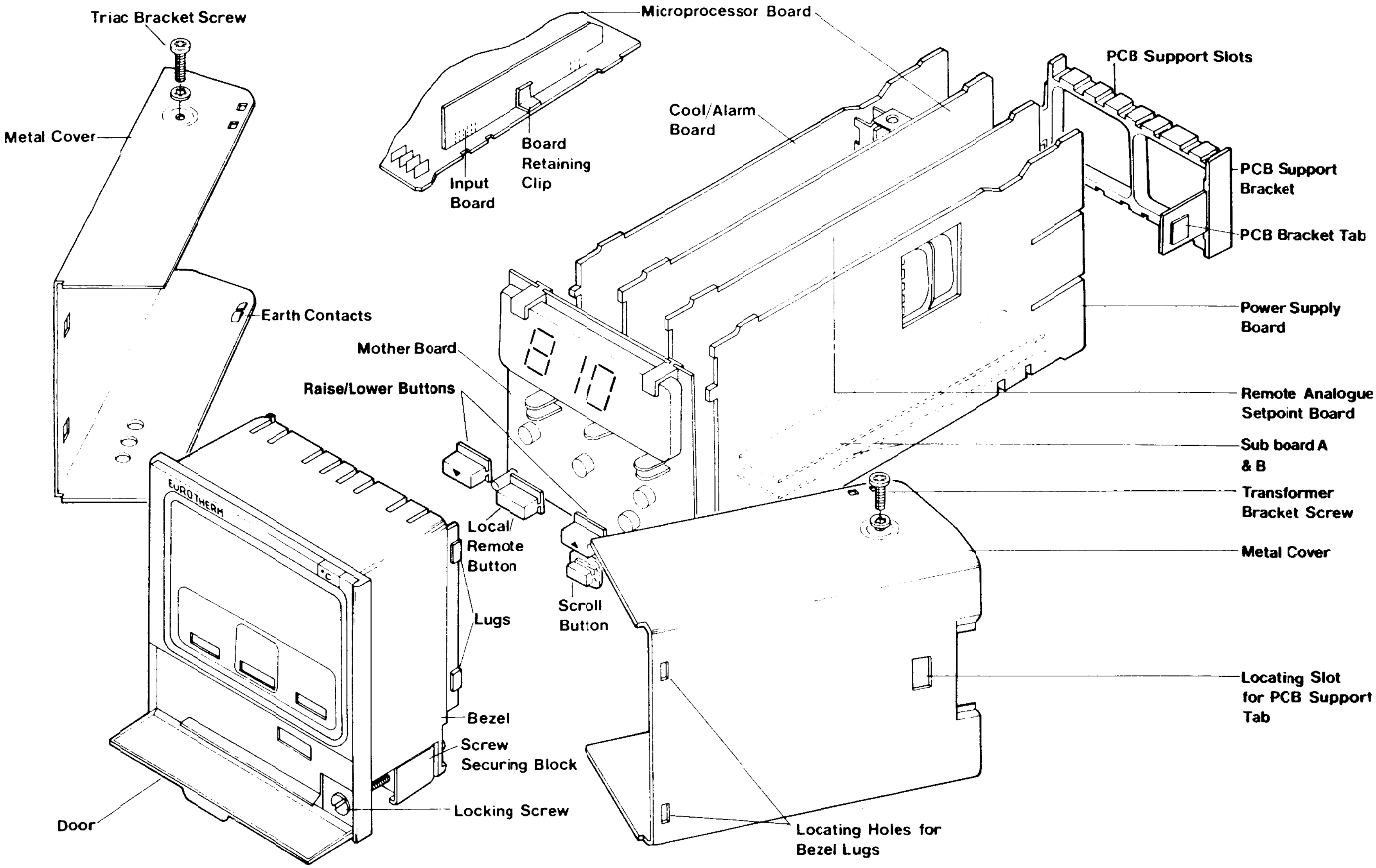


Figure 3-1: Mechanical Exploded View of 810 Controller

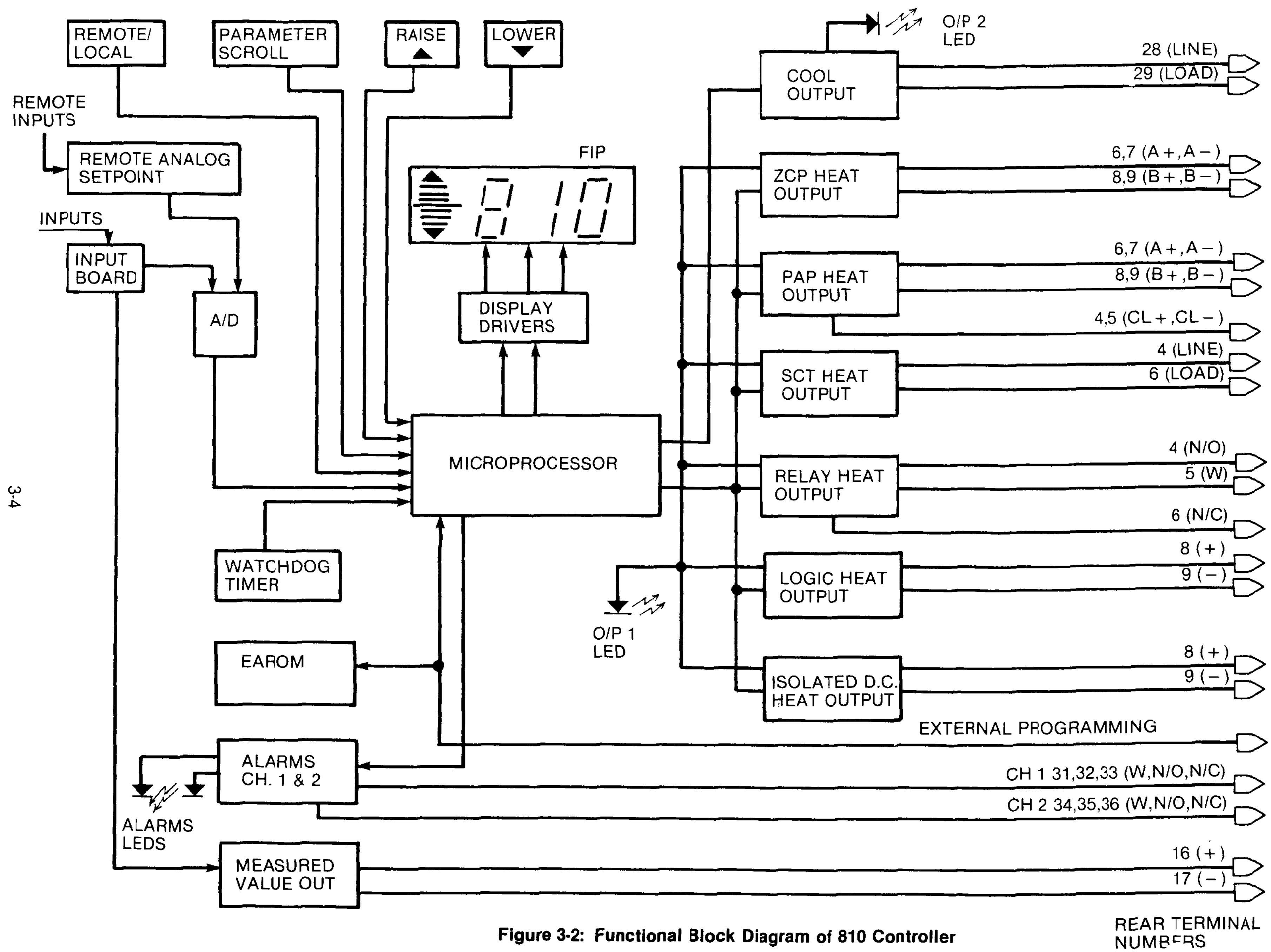


Figure 3-2: Functional Block Diagram of 810 Controller

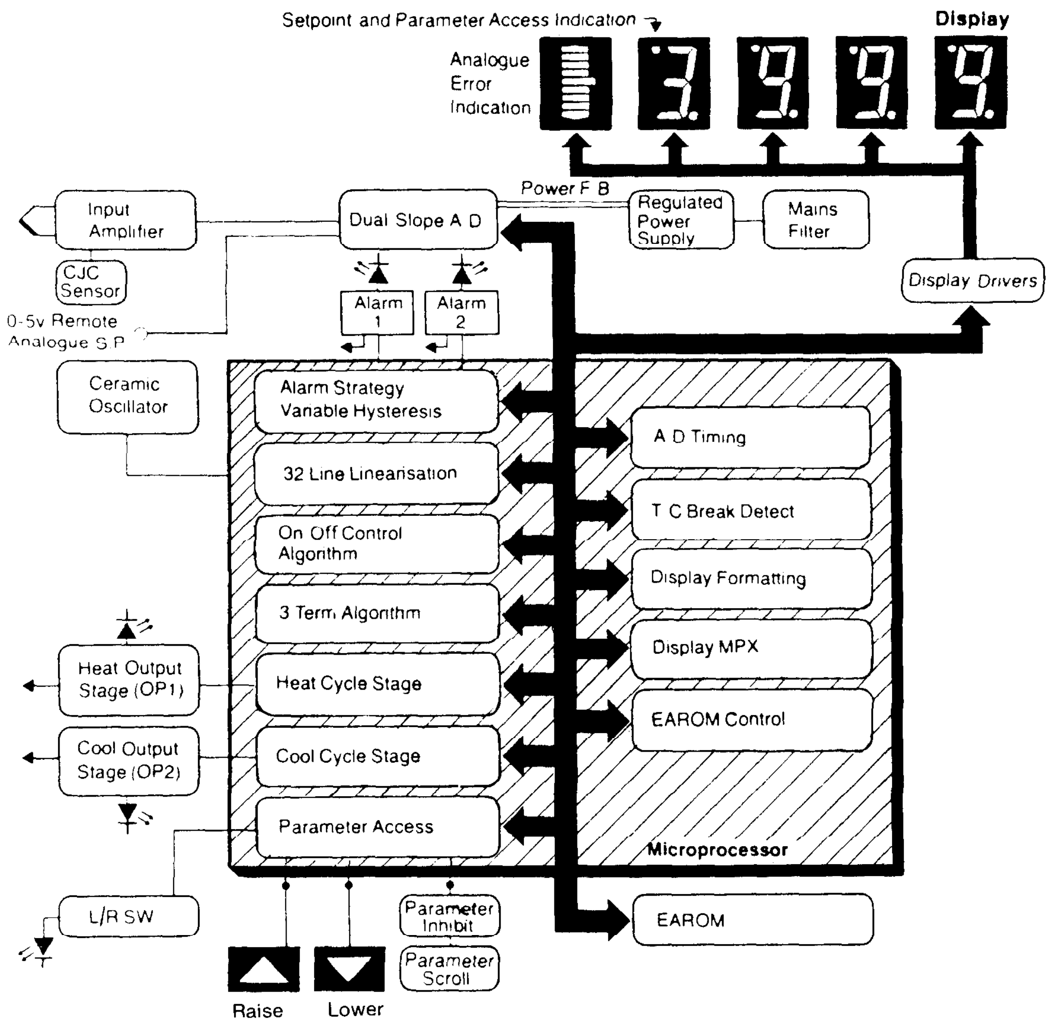


Figure 3-3: Microprocessor Block Diagram

SECTION IV

RECEIVING INSPECTION AND INSTALLATION INSTRUCTIONS

4.1 Unpacking and Unassembly Instructions

The Controller is shipped fully assembled and ready for installation. Exercise the normal precautions associated with unpacking electronic equipment. Visually check for any physical damage to the packing material. A detailed inspection should be made of the equipment surfaces that were adjacent to any damaged area.

4.2 Inspection Upon Receipt

Inspect the equipment for damage incurred during shipment as evidenced by bent or dented hardware, or cracked indicator lenses. Inventory the equipment against the packing list. If there is evidence of equipment damage, or if a part is missing, report the discrepancy.

4.3 Installation Instructions

The Temperature Controller is designed for fixed panel mounting in a 3.62 inch square (92mm) cutout. The Controller is retained by two (2) mounting clips. See figure 4.1 for instrument dimensions. A 30 position rear mounted screw terminal block allows interwiring for standard and optional instrument configurations.

a. Fixed Mounting

Fixed mounting installation procedures keyed to figure 4-2.

The instrument may be removed from its sleeve by opening the front panel access door and turning the locking screw in the bottom right-hand corner counter-clockwise with a screwdriver. The instrument will start to withdraw from its sleeve, and once the locking screw has been turned to its furthest extent, the Controller can be withdrawn by hand. *Remove the top and bottom mounting clamps from the sleeve by turning the mounting* screw counter-clockwise. Once the mounting screw has been withdrawn enough to clear the sleeve, gently ease the mounting clamp downwards inside the sleeve and remove. Insert the sleeve through the panel cut-out via the front of the panel. Fit the mounting clamps in the slots from the inside of the sleeve. From the rear of the mounting panel tighten the mounting screws with a screwdriver.

By hand ease the Controller into the sleeve to its furthest extent. DO NOT FORCE the instrument into the sleeve. The instrument will be protruding approximately ½" from the sleeve. With a screwdriver turn the locking screw in the bottom right-hand corner clockwise until tight. The Controller will be pulled completely into the sleeve, engaging the rear terminals, and be fully secure.

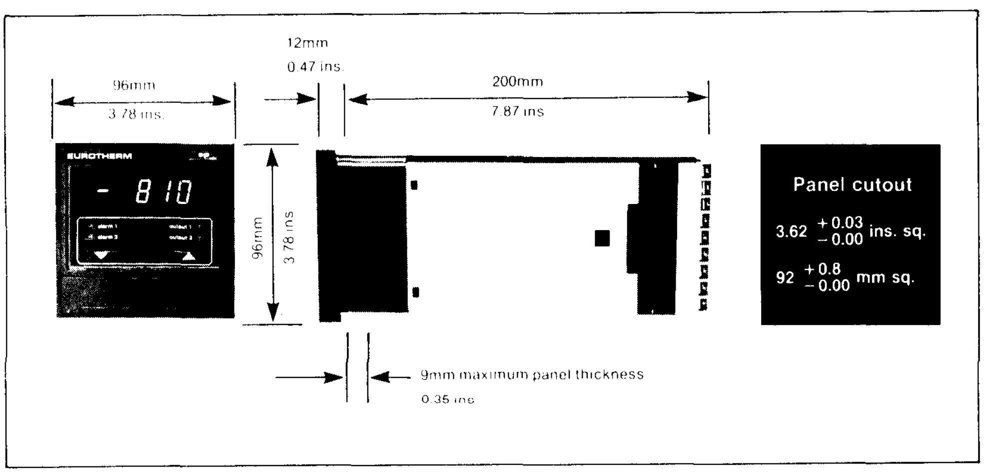


Figure 4-1: Instrument Mounting Dimensions

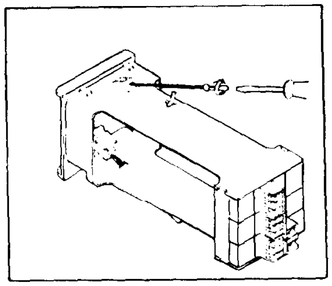


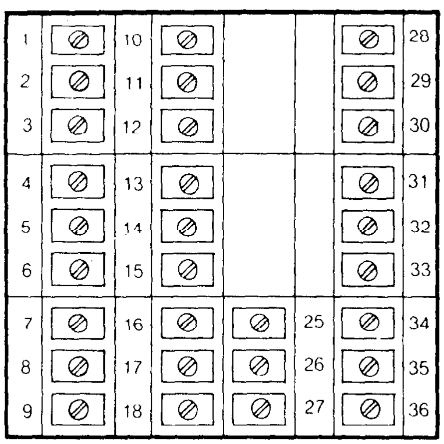
Figure 4-2: Instrument Mounting

4.4 Instrument Termination Procedures

a. General

Electrical connections to the Controller are made on the terminal block fitted with either 30 screw terminals or with 30 male faston terminals which connect with female receptacles. All connections are low current and usage of 20/AWG wire gauge size is adequate. The rear terminals can accommodate 16/AWG wire gauge size if required. A label mounted on the top of the mounting sleeve, figure 4-3, identifies all connections relevant to the instrument. When wiring sleeves, the terminal block on the sleeve is wired identically to the label on the instrument.

Note: Unlabeled Terminals should not be used as Tie-Points as they may be internally connected.



EUROTHERM

Model No: 810-073-065-101-617-24-112-405-00
Serial No: 810 OP MANUAL

2. 120 V
3. NEUTRAL
8. ISOLATED D.C. + 4-20mA
9. ISOLATED D.C. – (heat)
14. EXT. D.C. IN + 0-5V
15. EXT. D.C. IN – remote setpoint
18. EARTH
25. T/C+
27. T/C–
28. COOL TRIAC LINE.
29. COOL TRIAC LOAD.
31. ALARM RELAY COM.
32. ALARM RELAY N/O.
33. ALARM RELAY N/C.

Figure 4-3:
Instrument Terminal Block Connections and Connecting Information.

To facilitate making wire connections for the various instrument configurations, all pertinent data including connector functions, terminal block locations, wiring diagram figure references and remarks are referenced in Table 4-1.

b. Instrument Ground Connection

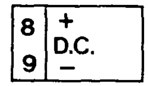
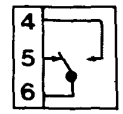
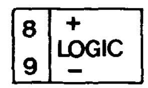
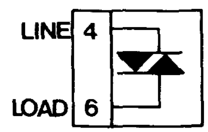
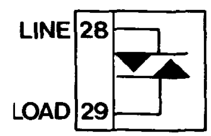
Ground connection procedures for fixed mounting instruments are provided at rear terminal 18. Refer to figure 4-3 during procedures.

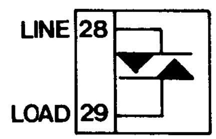
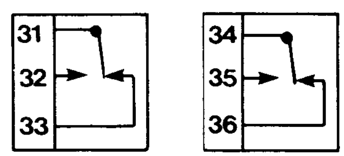
Fixed Mounting

Attach ground wire to rear terminal 18.

Table 4-4: Temperature Controller Model 810 Terminal Block Connections

FUNCTION	TERMINAL CONNECTOR NO.	TERMINAL BLOCK LOCATION	REMARKS
Instrument Power	2 - 3, 1 - 3 or 2 - 3 (switch mode)	1 2 85-264V 3 NEU 1 210V 2 105V 3 NEU 1 240V 2 120V 3 NEU	Connect the A.C. power leads between terminals 2 (105V/120VAC) and 3 (neutral) or between terminals 1 (210V/240VAC) and 3 (neutral) as required. Tolerances on the input transformer allow sufficient variation of supply voltages to accommodate standard instrument power. 105V/210V or 120V/240V 50 or 60 HZ. Use connector 18 as a ground. For the switch mode power supply, connect the A.C. power leads between terminals 2 (line) and 3 (neu.). The switch mode power supply can accommodate input supply voltages between 85 VAC and 264 VAC.
Controller Inputs a. Thermocouples	25 - 27	25 + 27 −	Thermocouple connections are made between terminals 25 (+) and 27 (−) on instruments with thermocouple sensing. Compensating lead wire of the correct type must be used between the load and the instrument, and it must be connected in the correct polarity.
b. Resistance Thermometer	25, 26, 27	25 v1 26 27 v2 i	Platinum resistance thermometer connections on instruments suitable for resistance thermometer sensing are made between terminals 25, 26 and 27. For 2 wire thermometers with short leads, connect the RTD leads between terminals 25 and 26 and jumper terminals 26 and 27.
c. D.C. Voltage or current	25 - 26	25 DCI/P+ 26 DCI/P−	D.C. Voltage or Current Input Connections are made at terminals 25 (+) and 26 (−).
Controller Outputs a. Single Output Heat Only Slow Cycle Triac (SCT)	4 - 6 (see figure 4-4 Wiring Diagram)	(minimum current 40mA) LINE 4 LOAD 6	Triac heating output connections are made between terminals 4 (Line) and 6 (Load). During the ON phase of the output cycle with the triac fired, the internal connection between terminals is made. This output is normally used to energize the coil of an external single or three phase conventional contactor or control relay. Triac rating is 1A/250V. An internal fast blow fuse (AGC1A/250V or equivalent) is used.
Single Phase SCR Pulses (ZCP/PAP)	6 - 7, 8 - 9 (see figure 4-5 Wiring Diagram)	6 A+ 7 A− 8 B+ 9 B−	Controllers with zero crossing (ZCP) or phase angle (PAP) pulse outputs have pulse pairs connected to terminals 6 (+), 7 (−), 8 (+) and 9 (−). Provision for current limit feedback is incorporated in all phase angle pulse (PAP) outputs. Pulse Outputs are fed to an external Eurotherm SCR unit employing SCR devices connected in inverse parallel. *NOTE:* When using phase angle switching with inductive loads, ensure that the load circuit is concurrently made with or before the supply to the instrument. The soft start feature of PAP will limit the inrush load current which may otherwise blow the semiconductor fuse. CONTROLLER AND SCR UNITS SHOULD BE REFERENCED TO THE SAME PHASE OF THE SUPPLY FOR PROPER PAP OPERATION.

FUNCTION	TERMINAL CONNECTOR NO.	TERMINAL BLOCK LOCATION	REMARKS
D.C. Signals (0-5V, 4-20mA, etc.)	8 - 9 (see figure 4-6 Wiring Diagram)		For controllers providing DC analog signals, the outputs are connected to terminals 8 (+) and 9 (−). Outputs are isolated and suitable for use with external Eurotherm drivers or other process controllers and power packs.
Relay	4, 5, 6 (see figure 4-8 Wiring Diagram)		Relay heating output connections are made between terminals 4 (NO), 5 (NC) and 6 (Wiper). Contact is rated for 10^6 operations. Slow cycle or ON-OFF control is available. Output is suitable for low power loads only, or for use with Eurotherm contactors.
Logic	8 - 9 (see figure 4-9 Wiring Diagram)		Logic output connections are provided at terminals 8 (+) and 9 (−). There are two types of logic outputs. One is an isolated logic output rated at 7v at 11mA; the other is an unisolated logic output rated at 13.5V at 15mA. These are the minimum specifications for a logic output. These outputs are suitable for use with Eurotherm solid state contactors. The unisolated logic output should only be used to drive a fully isolated input.
b. Dual Outputs (Heat/Cool) (1) Heat Channel (SCT)	4 - 6 (see figure 4-7 Wiring Diagram)	(min 40ma) 	Triac heating output connections are made to terminals 4 (Line) and 6 (Load) enabling heating power to be fed to the load when triac is fired. The heat channel output is normally used to energize the coil of a conventional or control relay. Triac rating is 1A, 250V. An internal fast blow fuse (AGC 1A/250V or equivalent) is used.
(2) Cool Channel (SCT)	28 - 29 (see figure 4-7 Wiring Diagram)	(min 40ma) 	Triac cooling output connections are made on terminals 28 (Line) and 29 (Load), enabling cooling power to be fed to the load when the triac is fired. The cooling channel output is normally used to energize the coil of a fan motor contactor for air cooling, or the coil of a solenoid valve for water cooling. Triac rating is 1A, 250V. An external fast blow fuse (AGC 1A/250V or equivalent) is recommended.
(a) Air Cooling (TL)	28 - 29 (see figure 4-7 Wiring Diagram)	Terminal connections same as (2) above	Order instrument with a slow cycle triac and linear cooling characteristics (TL).

FUNCTION	TERMINAL CONNECTOR NO.	TERMINAL BLOCK LOCATION	REMARKS
(b) Water Cooling (TNL)	28 · 29 (see figure 4-7 Wiring Diagram)	Terminal connections same as (2) above	Order instrument with a slow cycle triac and non-linear cooling characteristics (TNL).
(c) Air Cooling (TOO)	28 · 29 (see figure 4-7 Wiring Diagram)	Terminal connections same as (2) above	ON-OFF triac cooling. Order instrument with triac ON/OFF cooling characteristics (TOO).
(3) Heat/Cool (ZCP/SCT) (PAP/SCT)	6 - 7, 8 - 9 (see figure 4-10 Wiring Diagram)	6 A+ 7 A– 8 B+ 9 B–  (MIN 40mA)	The heat channel output is a two pulse pair either zero crossing pulses or phase angle pulses connected to terminals 6 (+), 7 (–), 8 (+) and 9 (–). These pulse pairs are in turn connected to an external Eurotherm SCR unit with SCR devices connected in inverse parallel. Since standard SCR units accept 2 pulse pairs, the SCR unit used with a heat/cool controller must be fitted with an internal pulse transformer. All Model 932 and 931 SCR units are automatically fitted with this transformer. Model 831 SCR units require only one (1) set of pulses. Models 031 and 032 require both sets of pulses. The Controller and the SCR unit should be referenced to the same phase of the supply. Triac cooling output connections, including air and water cooling characteristics, are identical to the cool channel SCT output controllers previously described.
Optional Functions a. Current Limit (CL)	4 - 5 (see figure 4-10 Wiring Diagram)	4 CL+ 5 CL–	On controllers with phase angle pulse outputs to Eurotherm SCR units, a current limit facility is available as a standard option. A current limit feedback signal is fed from the SCR unit to controller terminals 4 (+) and 5 (–). This option is available ONLY on heat outputs.
b. Low Limit Alarm (LL)	31, 32, 33, 34, 35 36 (see figure 4-11 Wiring Diagram)		Alarm output relay is deenergized with power OFF and with power ON and temperature in the "ALARM" condition (below alarm setpoint). The alarm relay is energized with power ON and temperature in the "SAFE" condition (above alarm setpoint). This is the standard configuration. It is possible to configure the alarm output relay such that it is energized with power ON and temperature in the "ALARM" condition. Normally open (NO) and normally closed (NC) contacts are available. NO and NC refer to the contact state when the alarm relay is deenergized. Relay contacts are rated at 1A, 240VAC. Wire connections are made between terminals 31 (Wiper), 32 (NO), and 33 (NC) for alarm relay 1. Wire connections for alarm relay 2 are made between terminals 34 (Wiper), 35 (NO), and 36 (NC).

FUNCTION	TERMINAL CONNECTOR NO.	TERMINAL BLOCK LOCATION	REMARKS
c. High Limit Alarm (HL)	31, 32, 33, 34, 35, 36 (see figure 4-11 Wiring Diagram)	Terminal connections same as b. above	Alarm output relay is deenergized with power OFF, and with power ON and temperature in the "ALARM" condition (above alarm setpoint). Alarm relay is energized with power ON and temperature in the "SAFE" condition (below alarm setpoint). This is the standard configuration. It is possible to configure the alarm output relay such that it is energized with power ON and temperature in the "ALARM" condition. Normally open (NO) and normally closed (NC) contact outputs are available. NO and NC refer to the contact state when the alarm relay is deenergized. Relay contacts are rated at 1A, 240VAC. Wire connections are made as stated for the low limit alarm option.
d. Deviation Limit Alarm (DL)	31, 32, 33, 34, 35, 36 (see figure 4-11 Wiring Diagram)	Terminal connections same as b. above	Alarm output relay is deenergized with power OFF, and with power ON and temperature in the "ALARM" condition (out of band about setpoint). Alarm relay is energized with power ON and temperature in the "SAFE" condition (within band). This is the standard configuration. It is possible to configure the alarm output relay such that it is energized with power ON and temperature in the "ALARM" condition. Normally open (NO) and normally closed (NC) contact outputs are available. NO and NC refer to the contact state when the alarm relay is deenergized. Relay contacts are rated at 1A, 240VAC. Wire connections are made as stated for the low limit alarm option.
e. Process Alarm (FSH)	31, 32, 33, 34, 35, 36 (see figure 4-11 Wiring Diagram)	Terminal connections same as b. above	Alarm output relay is deenergized with power OFF, and with power ON and temperature in the "ALARM" condition (above alarm setpoint). Alarm relay is energized with power ON and temperature in the "SAFE" condition (below alarm setpoint). This is the standard configuration. It is possible to configure the alarm output relay such that it is energized with power ON and temperature in the "ALARM" condition. Normally open (NO) and normally closed (NC) contact outputs are available. NO and NC refer to the contact state when the alarm relay is deenergized. Relay contacts are rated at 1A, 240VAC. Wire connections are made as stated for the low limit alarm option.
f. Process Alarm (FSL)	31, 32, 33, 34, 35, 36 (see figure 4-11 Wiring Diagram)	Terminal connections same as b. above	Output relay is deenergized with power OFF, and with power ON and temperature in the "ALARM" condition (below alarm setpoint). Alarm relay is energized with power ON and temperature in the "SAFE" condition (above alarm setpoint). This is the standard configuration. It is possible to configure the alarm output relay such that it is energized with power ON and temperature in the "ALARM" condition. Normally open (NO) and normally closed (NC) contact outputs are available. NO and NC refer to the contact state when the alarm relay is deenergized. Relay contacts are rated at 1A, 240VAC. Wire connections are made as stated for the low limit alarm option.
g. Remote/Local Setpoint (RLS,RLT)	14 - 15	14 + RLS 15 –	Remote setpoint connections are provided at rear terminals 14 (+) and 15 (–). The front panel RLS LED determines from which setpoint the controller is operating.
h. Measured Value Out (MVO)	16 - 17	16 + MVO 17 –	An unlinearized 0-10V (10mA MAX) analog retransmission of the measured value is provided on rear terminals 16 (+) and 17 (–). This output is NOT isolated from the input circuitry; therefore all connections to these terminals should be fully isolated from any source or supply.

Caution: Interconnections made to instruments other than as shown, can result in improper operation or equipment damage.

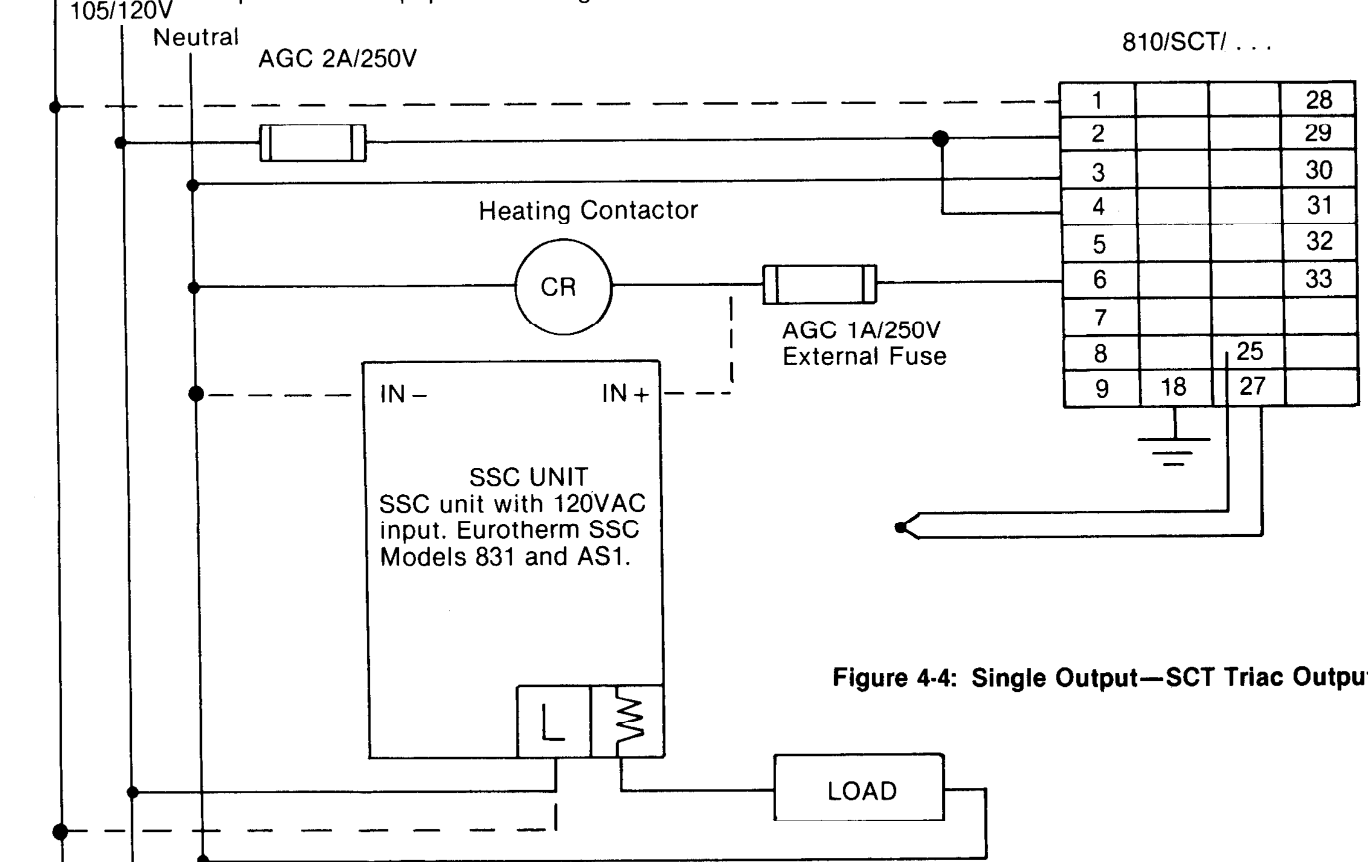


Figure 4-4: Single Output—SCT Triac Output

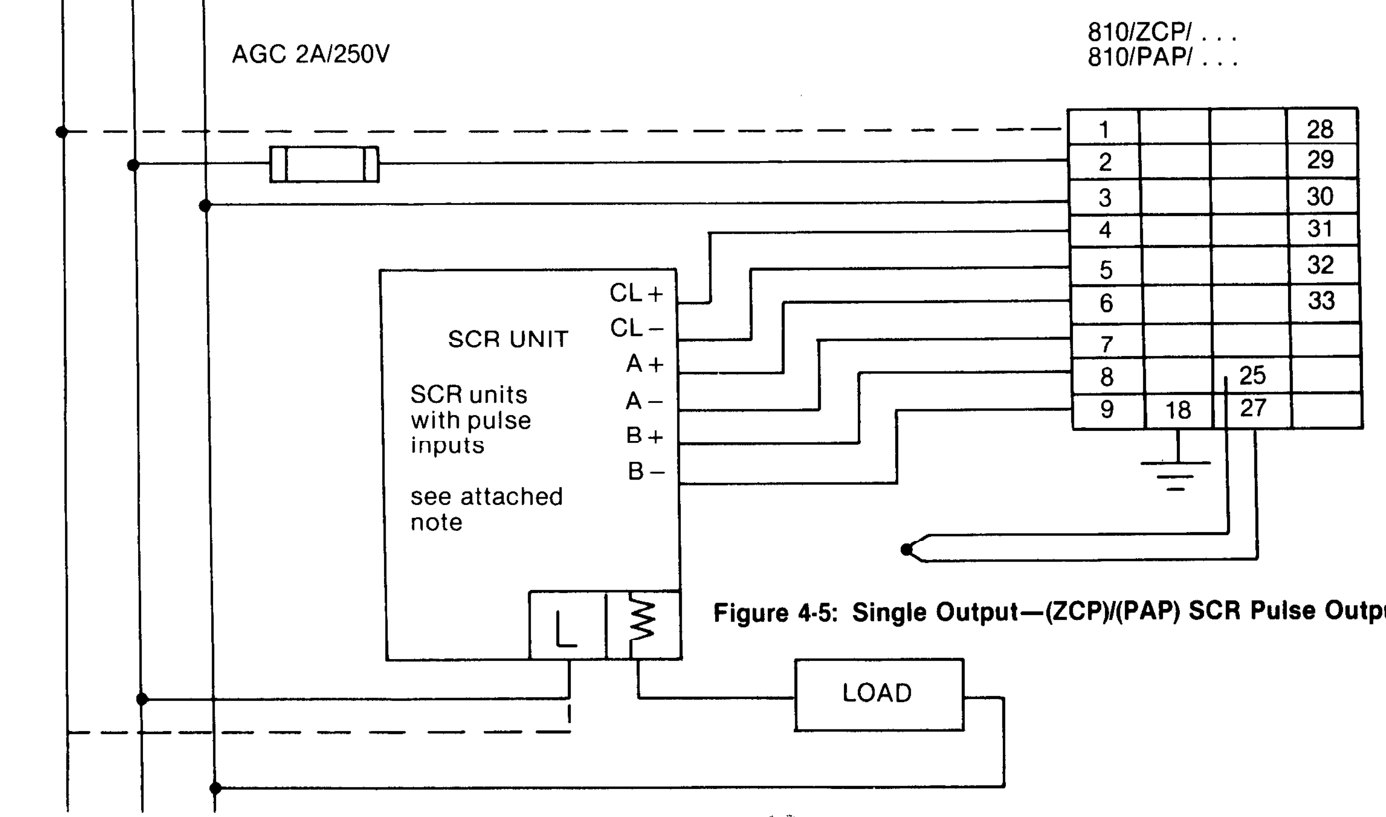


Figure 4-5: Single Output—(ZCP)/(PAP) SCR Pulse Outputs

Caution: Interconnections made to instruments other than as shown, can result in improper operation or equipment damage.

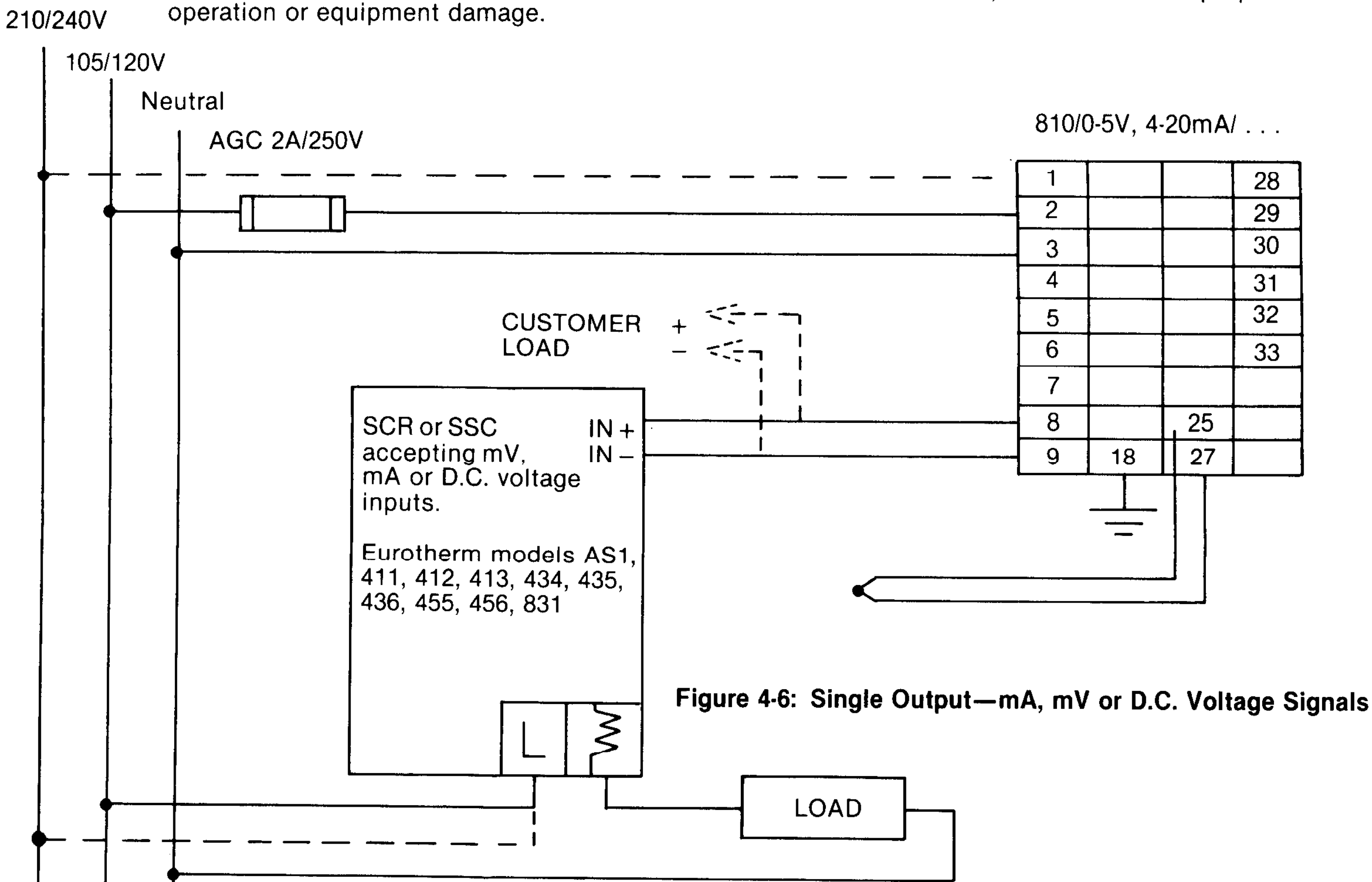


Figure 4-6: Single Output—mA, mV or D.C. Voltage Signals

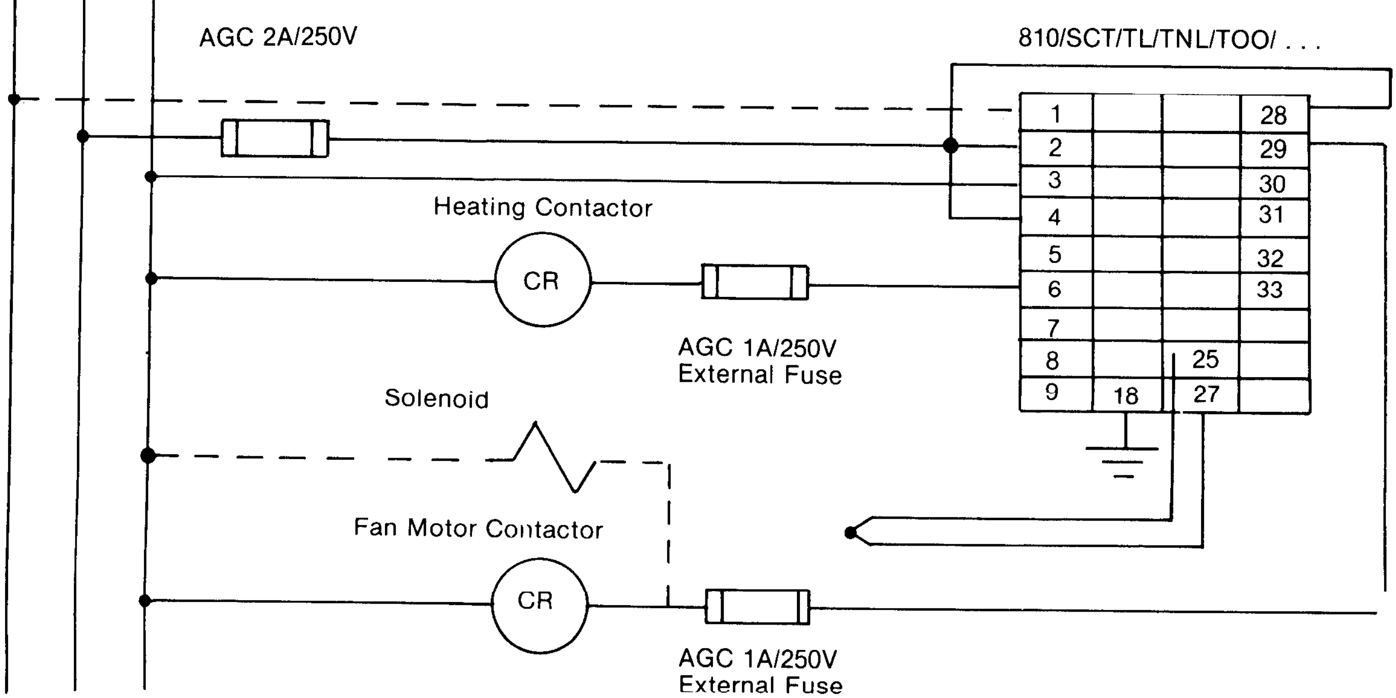


Figure 4-7: Dual Output—SCT/SCT Dual Triac Outputs

Caution: Interconnections made to instruments other than as shown, can result in improper operation or equipment damage.

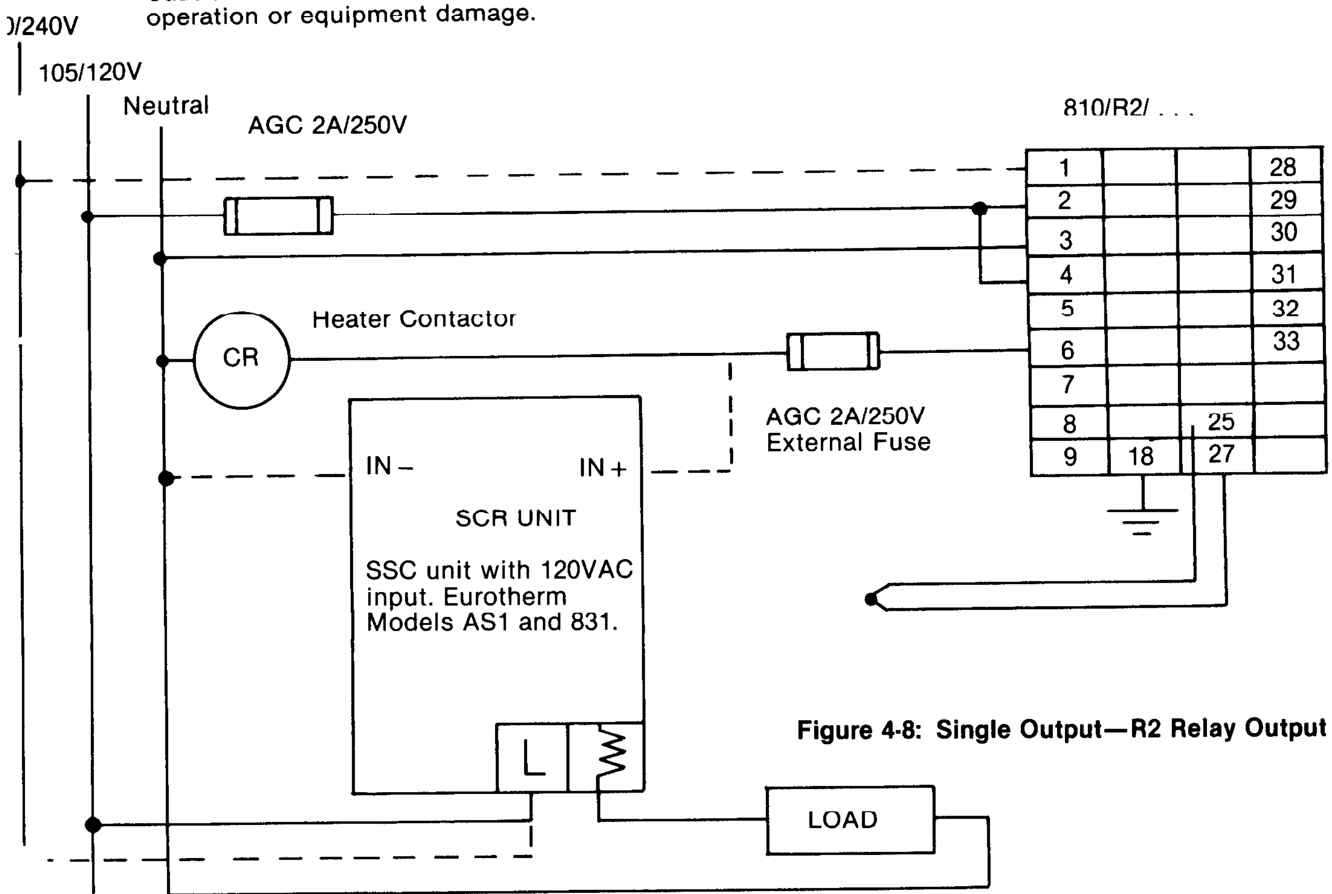


Figure 4-8: Single Output—R2 Relay Output

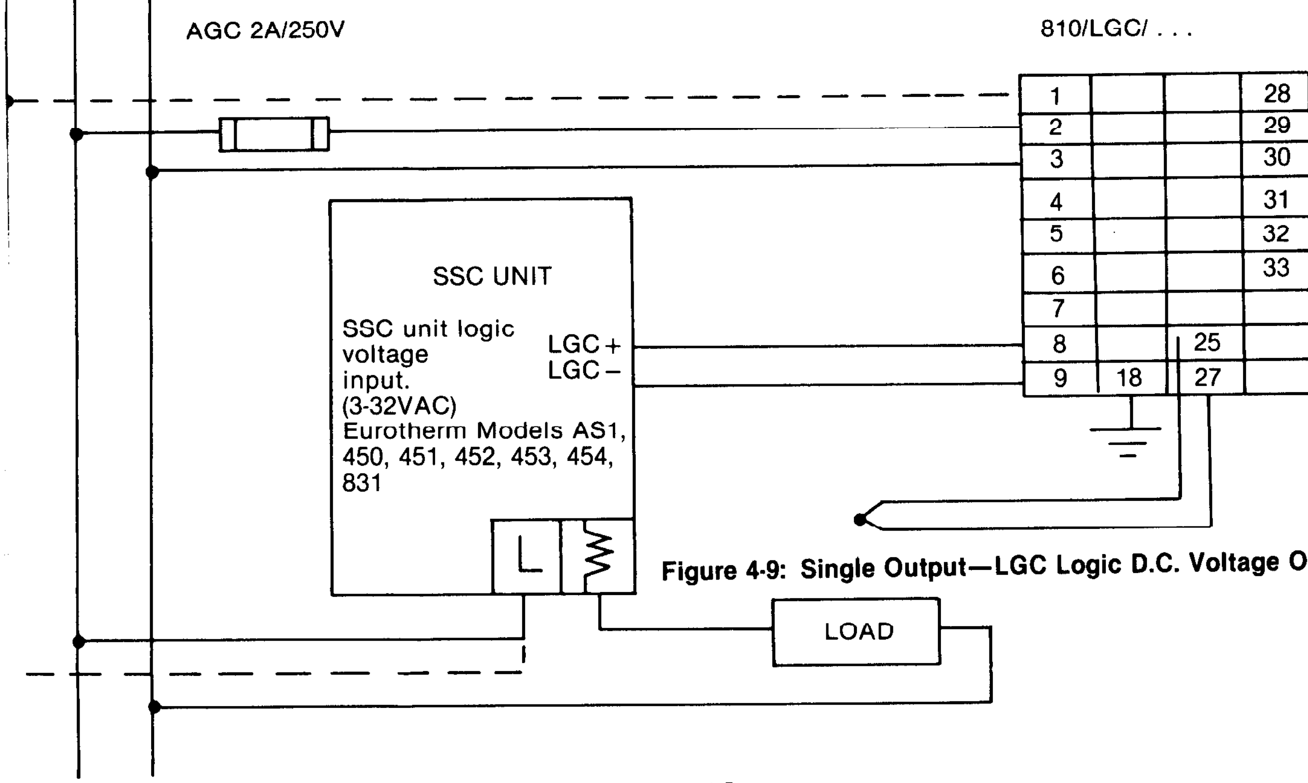


Figure 4-9: Single Output—LGC Logic D.C. Voltage Output

Caution: Interconnections made to instruments other than as shown, can result in improper operation or equipment damage.

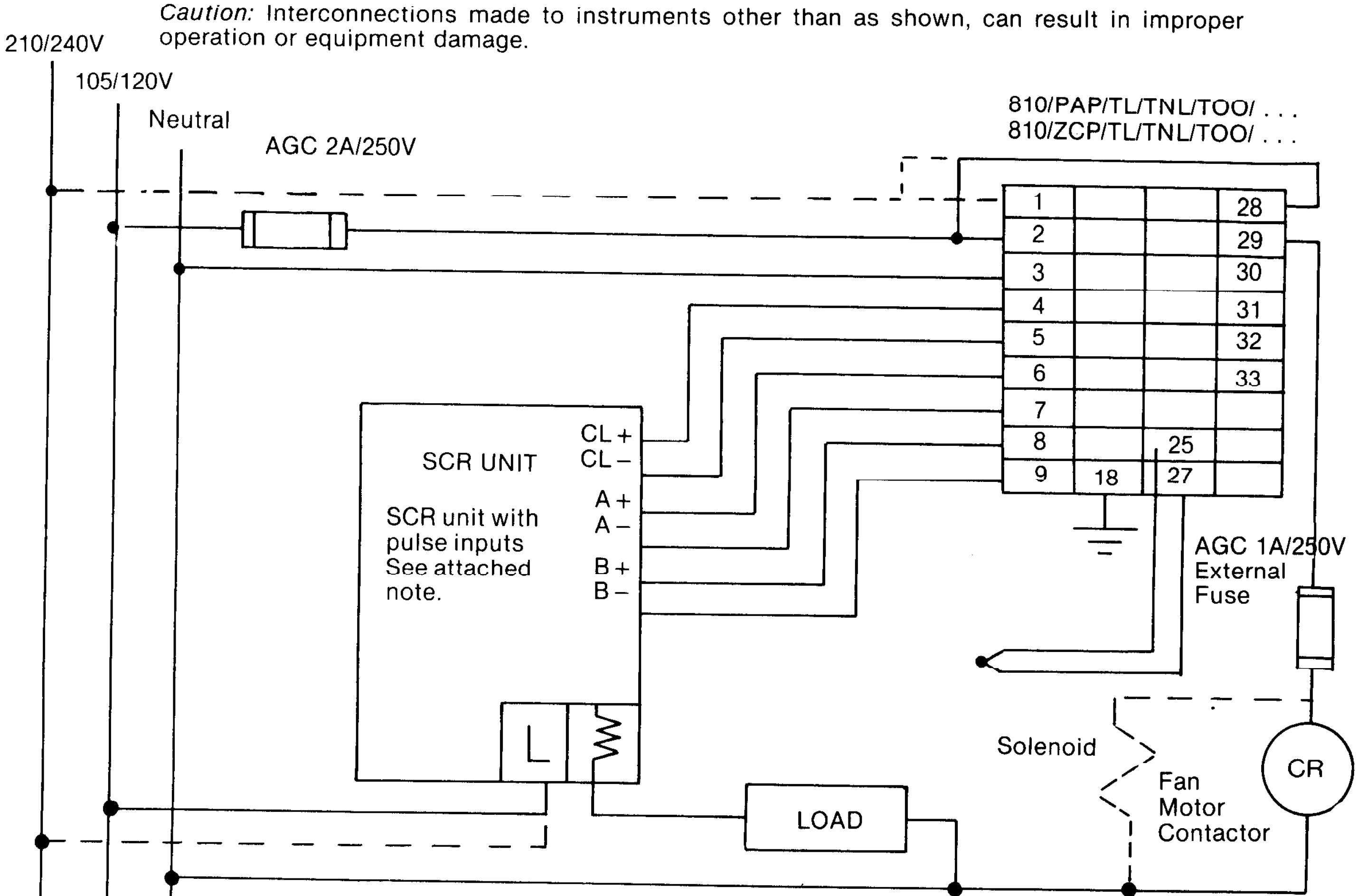


Figure 4-10: Dual Outputs—(ZCP)/(SCT) (PAP)/(SCT) SCR Pulse Heat/Triac Cool

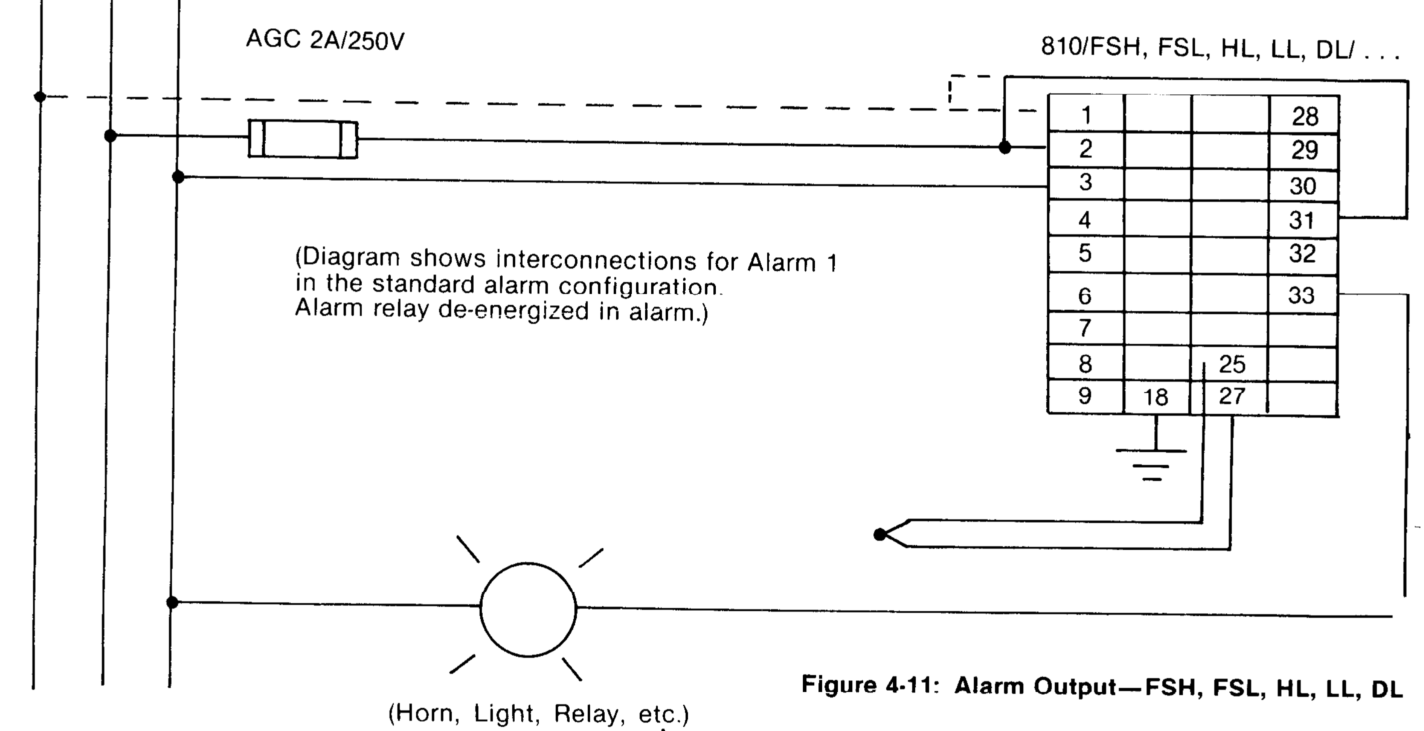


Figure 4-11: Alarm Output—FSH, FSL, HL, LL, DL

Note on Figure 4-5 Wiring Diagram

Eurotherm SCR Assemblies Model 031 and 032 require a 4-wire interface, thus both sets of pulses must be connected.

Eurotherm SCR Assemblies Model 831, 931, 932, 961, 962 require only a 2-wire interface, thus only 1 set of pulses (6 & 7 or 8 & 9) need to be connected.

For proper PAP operation, both the SCR assembly and the Controller MUST be referenced to the same phase of the power source.

The CL+ and CL− terminal connections (Current Limit Feedback) are only applicable to PAP output models.

Check with the SCR or SSC Installation Information Manual for proper SCR or SSC terminal designation.

Note on Figure 4-10 Wiring Diagram

Eurotherm SCR Assemblies Model 031 and 032 require a 4-wire interface, thus both sets of pulses must be connected.

Eurotherm SCR Assemblies Model 831, 931, 932, 961, 962 require only a 2-wire interface, thus only 1 set of pulses (6 & 7 or 8 & 9) need to be connected.

For proper PAP operation, both the SCR assembly and the Controller MUST be referenced to the same phase of the power source.

The CL+ and CL− terminal connections (Current Limit Feedback) are only applicable to PAP output models.

Check the SCR Installation Information Manual for proper SCR terminal designation.

SECTION V

OPERATING INSTRUCTIONS

5.1 General

This section contains operating instructions for the Eurotherm Model 810 Temperature Controller. Instructions consist of control and indicator descriptions and detailed operating procedures.

5.2 Controls and Indicators

Operator controls and indicators are listed and described in Table 5-1. Control/indicator locations, which numerically correspond with Table 5-1, are illustrated in figure 5-1.

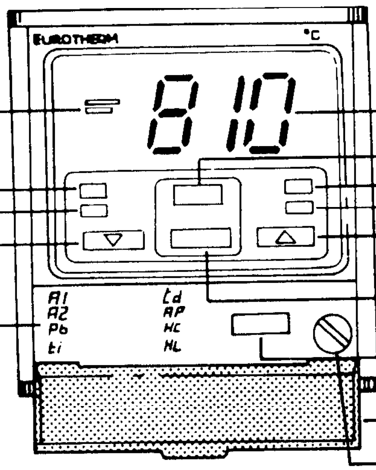


Figure 5-1: Controls and Indicators for Model 810 Temperature Controller

1. Channel 1 Output Indicator
   Output 1 LED (YELLOW)
2. Channel 2 Output Indicator
   Output 2 LED (YELLOW)
3. Display
4. RAISE Pushbutton
5. LOWER Pushbutton
6. Error Bargraph
7. Alarm 1 LED Indication (RED)
8. Alarm 2 LED Indication (RED)
9. Remote/Local Pushbutton (RLS)
10. Remote/Local LED Indication
    (RLS, RLT)
11. PARAMETER SCROLL Pushbutton
12. Front Panel Access Door
13. List of Control Parameters
14. Locking (Jacking) Screw

Table 5-1: Model 810 Temperature Controller Controls and Indicators

ITEM NO.	CONTROL/INDICATOR	FUNCTION
1.	Channel 1 Output Indicator, Output 1 LED (YELLOW) (HEAT)	Indicates power to load and is yellow for all outputs. For DC outputs, the degree of brightness intensifies as the voltage (or current) increases from minimum to maximum. In the zero crossing fired (fast cycle fired) SCR pulse output, the LED blinks brightly at each zero cross firing. In the phase angle fired SCR pulse output, brightness intensifies as firing angle increases. In the slow cycle fired triac output, the LED will display full brightness when the triac is fired and passing current. In all cases this LED indicator is HEAT to load.
2.	Channel 2 Output Indicator, Output 2 LED (YELLOW) (COOL)	Indicator is used only in heat/cool instruments for monitoring the state of the cool channel. Illumination of Output 2 LED occurs under the same conditions as that described for LED 1 (Item 1) except LED 2 applies to the cool channel output.
3.	Display	Displays all process variables including setpoint, measured value, proportional band, etc.
4.	RAISE Pushbutton	When depressed allows the value of the parameter being viewed to be raised.
5.	LOWER Pushbutton	When depressed allows the value of the parameter being viewed to be lowered.
6.	Error Bargraph	Gives an analog indication of proximity to setpoint.
7.	Alarm 1 LED Indication (RED)	Provides LED indication of ALARM 1 condition. The LED is illuminated in the alarm state.
8.	Alarm 2 LED Indication (RED)	Provides LED indication of ALARM 2 condition. The LED is illuminated in the alarm state.
9.	Remote/Local Pushbutton (RLS)	Provided on instruments fitted with the remote/local option. Depression of this pushbutton will cause the controller to operate from a remote setpoint.
10.	Remote/Local LED Indication (RLS, RLT)	Provided on instruments fitted with the remote/local option. When the controller is operating from a remote setpoint, this LED will be illuminated; otherwise it is off.
11.	PARAMETER SCROLL Pushbutton	Depression of this pushbutton allows the control parameters associated with the Controller to be viewed.
12.	Front Panel Access Door	Provides access to the PARAMETER SCROLL pushbutton and the locking (jacking) screw.
13.	List of Control Parameters	A list of all the control parameters associated with the Controller and their display mnemonic symbols (example: Hc—Heat Cycle Time).
14.	Locking (Jacking) Screw	Allows the Controller to be secured into its sleeve.

5.3 Temperature Controller Operation

Detailed instructions for operating the Controller and for the associated Controller functions are provided in the following paragraphs.

a. Indications

Measured value is displayed during normal operations. A flashing dot in the upper top left-hand corner of the display will indicate that a parameter other than measured value is being displayed. A timed interlock holds the parameter value, unless a change is made, for four to five seconds.

Behind the front panel access door on the instrument fascia and on the front panel access door itself, there is listed a series of control parameters pertinent to the Controller. Each parameter is listed in its mnemonic form. These mnemonics usually appear in the two right-hand display positions of the display. In some controllers, the mnemonics may appear in the two left-hand display positions.

Up to five (5) LEDS may be installed on the Controller's front fascia to provide a visual indication of alarms, outputs, and remote/local status.

b. Basic Operation

Four control pushbuttons on the front of the Controller cover all operation facilities of the instrument.

The setpoint is adjusted by depression of either the RAISE▲or LOWER▼pushbutton. Prolonged depression of either pushbutton gives an accelerating display, and single least significant digit changes are accomplished by individual button pushes.

Various control parameters—such as proportional band, integral and derivative time constants, approach, heat and cool cycle times, heat and cool maximum power, relative cool, and alarm setpoints—are selected by depression of the PARAMETER SCROLL pushbutton located behind the front panel access door. Continuous individual depression of the PARAMETER SCROLL pushbutton selects parameters in turn. To change a parameter value after selection by the PARAMETER SCROLL pushbutton, wait approximately two (2) seconds. The parameter mnemonic will be replaced by the present parameter value.* Depress the respective RAISE▲or LOWER▼pushbutton to make a parameter value change. Until the PARAMETER SCROLL pushbutton is released, the first letter of the parameter mnemonic will not be displayed. Also, if no action is taken by the operator within eight (8) seconds of the last action, the display will automatically revert to indicating measured value.

An optional REMOTE/LOCAL pushbutton may be installed on the instrument's front fascia.

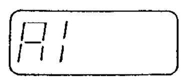
A PARAMETER SCROLL DISABLE switch is provided on all Controllers. This is an on-off slide switch located at the rear of the microprocessor board. If this switch is enabled, it will not be possible to view or change any parameters associated with the controller except for setpoint. Controllers are shipped from the factory with the PARAMETER SCROLL DISABLE SWITCH disabled. See figure 5-2.

**Note:* On controllers fitted with the self-tuning option (ST), the parameter mnemonic is NOT replaced by the present parameter value after two (2) seconds. Instead, the display will automatically revert to displaying measured value. To view the present parameter value, depress the PARAMETER SCROLL pushbutton until the desired parameter mnemonic is displayed; then depress either the RAISE or LOWER pushbutton to view the present parameter value. Continued depression of either the RAISE or LOWER pushbutton will then cause a parameter value change.

c. Parameters

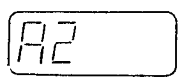
Following is a detailed discussion of all parameters associated with the Model 810 Microprocessor Based Controller. All of these parameters may be viewed by continued individual depression of the PARAMETER SCROLL pushbutton. To change the value of any of these parameters after selection by the PARAMETER SCROLL pushbutton, wait approximately two (2) seconds—except on controllers fitted with the self-tuning option. The parameter mnemonic will be replaced by the present parameter value. Depress the respective RAISE or LOWER pushbutton until the required parameter value is reached. Some parameters discussed may not be viewed because the Controller does not require their function. Shown beside each parameter is its associated mnemonic display.

A1—ALARM 1



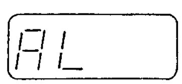
ALARM 1 temperature setpoint in instrument degrees. The value of A1 determines at what temperature alarm relay 1 will go into its alarm state. ALARM 1 may be a full scale high, a full scale low, a low, a high or a deviation alarm.

A2—ALARM 2



ALARM 2 temperature setpoint in instrument degrees. The value of A2 determines at what temperature alarm relay 2 will go into its alarm state. ALARM 2 may be a full scale high, a full scale low, a low, a high or a deviation alarm.

AL—ALARM

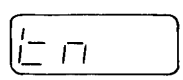


Alarm temperature setpoint in instrument degrees. For instruments with special options only one (1) alarm is available, and this is the alarm setpoint. The value of AL determines at what temperature the alarm relay will go into its alarm state. The ALARM may be a full scale low, a full scale high, a low, a high, or a deviation alarm.

Limit Alarm Note

When the controller is fitted with a high, a low, or a deviation alarm, the alarm setpoint can be adjusted between zero and a top limit, where the top limit is 20% of the instrument span. The limits for a full scale high or a full scale low alarm are zero and the span of the instrument.

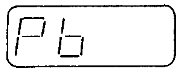
tn or tu—SELF-TUNE ENABLE/DISABLE



This is the Self-Tune Enable/Disable software switch. To enable Self-Tuning, depress the PARAMETER SCROLL pushbutton until the tn or tu mnemonic is displayed. To then enable Self-Tuning, depress the RAISE pushbutton. When the Self-Tuning Algorithm is enabled, the Controller will determine first if it is applicable to self tune based on certain restrictions. If Self-Tuning is allowed, the Controller will tune the load based on a 1/4 cycle period of oscillation. See section 5-5, Self-Tune option, for more information.

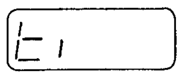
To disable Self-Tuning, depress the PARAMETER SCROLL pushbutton until the tn or tu mnemonic is displayed. To disable the Self-Tuning algorithm, depress the LOWER pushbutton. Self-Tuning will be disabled, and the Controller will operate with the control parameters it had prior to Self-Tuning being disabled.

Pb—PROPORTIONAL BANDWIDTH, ON/OFF HYSTERESIS % OF INSTRUMENT SPAN



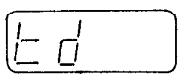
This is the Proportional Bandwidth control parameter. To obtain optimum control; the proportional bandwidth must be determined using the procedures discussed under section 5-4. For instruments with ON/OFF control, the value of Pb sets the ON/OFF hysteresis in % of instrument span. The proportional bandwidth values are adjustable in 15 steps from 0.5 to 100%.

ti—INTEGRAL TIME CONSTANT IN SECONDS (RESET)



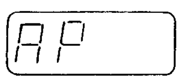
This is the Integral Time Constant control parameter in seconds. To obtain optimum control, the Integral Time Constant must be determined using the procedure discussed under section 5-4. The Integral Time Constant parameter is adjustable in 14 steps from integral OFF to 1800 seconds.

td—DERIVATIVE TIME CONSTANT IN SECONDS (RATE)



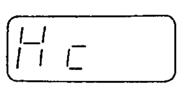
This is the Derivative Time Constant control parameter in seconds. To obtain optimum control, the Derivative Time Constant must be determined using the procedure discussed under section 5-4. The Derivative Time Constant parameter is adjustable in 13 steps from derivative OFF to 600 seconds.

AP—APPROACH CONTROL



The Approach Control parameter adjusts the start-up characteristics of the system under control by releasing the derivative action at some variable point below setpoint. The Approach Control parameter is expressed as the number of proportional bands below the setpoint, and its major function is to reduce temperature overshoot on start-up or large setpoint changes. The Approach Control parameter is adjustable in 9 steps from 0.25 to 3. See section 5.4, Control Stability, for more information on how to set the Approach Control parameter.

Hc—HEAT OUTPUT CYCLE TIME IN SECONDS



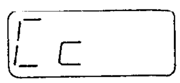
The Heat Output Cycle Time parameter adjusts the heat output cycle time. The Heat Output Cycle Time should ideally be set to the lowest time possible for the particular application.

For logic and ZCP heat outputs, the Heat Output Cycle Time is normally set to 0.3 seconds. For D.C. and PAP heat outputs, the heat output cycle time is fixed at 0.3 seconds and the Heat Output Cycle Time parameter is inoperative. For relay and SCT heat outputs, the Heat Output Cycle Time is normally set to 20 seconds. Heat Output Cycle Times less than 20 seconds for a relay output can cause increased contact wear and premature relay failure. The Heat Output Cycle Time parameter is inoperative on instruments with ON/OFF control. The Heat Output Cycle Time is adjustable in 7 steps from 0.3 to 80 seconds.

HL—HEAT MAXIMUM POWER

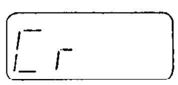
This is the Heat Maximum Power control parameter. This parameter limits the maximum heat power that may be applied to the load. This parameter may be used in place of a variac in many applications and can also be used to approximately control the rate of rise of temperature during system start-up. Two important uses for this parameter are in limiting electrical current supplied to loads which display a large negative temperature coefficient of resistance or in limiting power to over-powered heaters. The Heat Maximum Power parameter is adjustable from 0 to 100% in increments of 1%, and this parameter has a linear relationship between 0 and 100%. The Heat Maximum Power Parameter is normally set to 100%.

Cc—COOL OUTPUT CYCLE TIME IN SECONDS



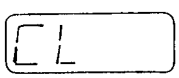
This is the Cool Output Cycle Time in seconds. The Cool Output Cycle Time should ideally be set to the lowest time possible for the particular application. On non-linear cool outputs, TNL, the Cool Output Cycle time is set to 10 seconds, and the Cc parameter is inoperative. The Cool Output Cycle Time is adjustable in 7 steps from 0.3 to 80 seconds.

Cr—RELATIVE COOL GAIN



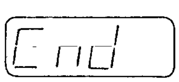
This is the Relative Cool Gain control parameter. The Relative Cool Gain is relative to the primary or heat output channel. The Relative Cool Gain is adjustable in 9 steps from 0.25 to 3.0. See section 5-4 for a procedure on how to determine the Relative Cool Gain parameter setting.

CL—COOL MAXIMUM POWER

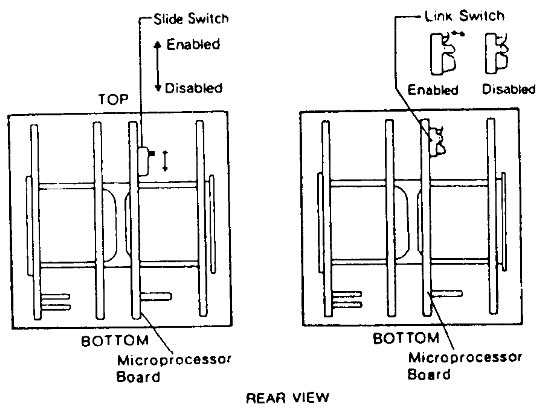


This is the Cool Maximum Power control parameter. This parameter limits the maximum cool power that may be applied to the load. The Cool Maximum Power is adjustable from 0 to 100% in increments of 1%. The Cool Maximum Power is normally set to 100%.

END



Once all control parameters have been scrolled, the word END is displayed. After eight (8) seconds, the display reverts to displaying measured value.



To enable/disable scroll button.

Figure 5.2: Parameter Scroll Disable/Enable Switch

Table 5-2: Control Parameter Steps

Prop Band (%):	0.50, 0.75, 1.00, 1.50, 2, 3, 4, 6, 8, 12, 16, 25, 35, 50, 100.
Integral (seconds):	OFF, 15, 30, 45, 60, 90, 120, 150, 200, 300, 400, 600, 900, 1200, 1800
Derivative (seconds):	OFF, 5, 10, 15, 20, 30, 40, 60, 90, 150, 200, 300, 400, 600
Approach (Relative Prop Band):	0.25, 0.50, 1.00, 1.25, 1.50, 2.00, 2.50, 3.00
Cycle Times (seconds):	0.3, 1, 5, 10, 20, 40, 80
Maximum Power (%):	0 to 100 in 1% steps
Relative Cool Gain (Relative to Heat Output):	0.25, 0.50, 0.75, 1.00, 1.25, 1.50, 2.00, 2.50, 3.00

5.4 Control Stability

The values of Proportional Bandwidth, Integral (Reset) and Derivative (Rate) time constants set in the 810 Controller before it is shipped from the factory have been found by experience to give extremely good control for the majority of systems encountered. However, sometimes it may be necessary to change one or more of these parameters to achieve stable control.

It is possible that a system will not give stable control if one or more of the following conditions exists:

a. The Proportional Bandwidth is too narrow,

b. the Integral time constant (Reset) is too short,

c. the Derivative time constant (Rate) is too long.

The 3-term control algorithm of the 810 Controller implements the PID control parameters to compensate for the system characteristics and provide system stability.

There are many ways of determining optimum control parameter values. The method suggested here is a simple, practical method of stabilization optimization. In cases where stabilization is difficult, it is of great help if a strip chart recording of the start-up response can be obtained.

Control Stability Procedure

1. Set the following control parameter values:

Proportional Band, Pb %	= 12
Integral Time, t_i	= off
Derivative Time, t_d	= off
Heat Maximum Power, HL%	= 100
Approach, AP	= 1.00
Relative Cool Gain, Cr	= 0.50 for water cooled systems
	= 2.0 for air cooled systems

2. Adjust the setpoint of the controller to the desired operating point and allow the system to stabilize. For some systems it could take as long as 30 minutes or more for the system to stabilize.

   The controller measured temperature should rise and stabilize at some point below setpoint. This sag below setpoint is called "droop error", and it will be removed by the addition of Integral Time, ti.

   If the controller measured temperature is oscillating at this point, DO NOT perform step 3.

3. Reduce the value of the Proportional Band until the measured temperature begins to oscillate.

4. Record the period of oscillation (T) for the controller as shown in figure 5-3.

5. Increase the value of the Proportional Band until the measured temperature just stops oscillating.

6. Set the values of Prop Band, Integral, and Derivative as shown below based on the response desired (reference figure 5-3.)

   a. Underdamped Response

      Prop Band—Equal to value determined in step 5.

      Integral Time—Equal to T/2 (seconds)

      Derivative Time—Equal to T/8 (seconds)

b. Normal Response (recommended)

   Prop Band—Increase by one setting from the value determined in step 5.

   Integral Time—Equal to T (seconds)

   Derivative Time—Equal to T/6 (seconds)

c. Overdamped Response

   Prop Band—Increase by two settings from the value determined in step 5.

   Integral Time—Equal to 1.5T (seconds)

   Derivative Time—Equal to T/6 (seconds)

7. For those controllers with a cooling channel the Relative Cool Gain parameter may have to be adjusted. As the controller is required to add cooling, it may cause oscillations in the measured temperature. If this occurs, the Relative Cool Gain parameter should be decreased until the measured temperature stabilizes. If the measured temperature remains above the setpoint, the Relative Cool Gain parameter should be increased. Water cooled systems typically use lower values of relative cool gain, whereas air cooled systems require higher values of relative cool gain. A good rule of thumb for the Relative Cool Gain parameter setting is 0.50 for water cooled systems and 2.0 for air cooled systems.

8. To set the Approach Control parameter, observe the rise of the measured temperature on system start-up as it warms up from cold. If the measured temperature overshoots the setpoint, increase the Approach Control parameter by one (1) setting. If, on the other hand, the measured temperature approaches the setpoint slowly with no overshoot, reduce the Approach Control parameter by one (1) setting. Figure 5.4 shows various start-up responses for a system with the same PID settings but with different Approach Control parameter settings.

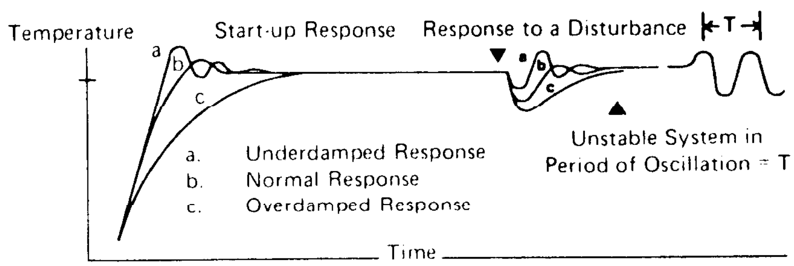


Figure 5-3

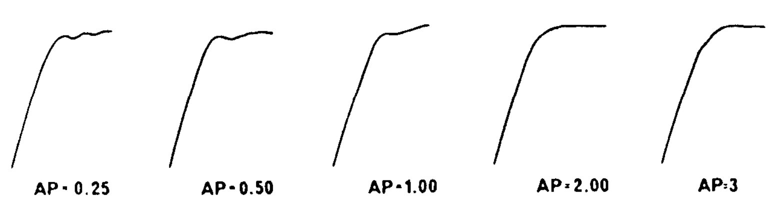


Figure 5-4

5.5 Self-Tuning Option

This section only applies to those instruments fitted with Self-Tuning.

If the Model 810 Controller is ordered with the Self-Tuning option, it will come from the factory with the Self-Tuning Algorithm ENABLED and the PARAMETER SCROLL ENABLE/DISABLE switch in the DISABLE position. With the PARAMETER SCROLL ENABLE/DISABLE switch in the disable position, it will not be possible to view or change any parameter except the setpoint; this includes the Self-Tuning Enable/Disable software switch, tn or tu. On power-up, the Controller will automatically tune the load based on a 1/4 cycle of oscillation at a point halfway between the beginning measured value and the setpoint. The PID parameters will be calculated, and the Controller will then be put into a normal PID control mode with the calculated values of PID.

At a predetermined amount of time, the Controller will start its continuously adaptive control mode. If an error of 4° or greater is detected by the Controller, the Controller will test the response of the system and adjust the proportional band based upon that response.

Self-Tuning may be manually enabled or disabled at any time. Self-Tuning may be manually enabled by depressing the PARAMETER SCROLL pushbutton until the tu or tn mnemonic is displayed. Depressing the RAISE pushbutton will then enable Self-Tuning. Once Self-Tuning is enabled, it cannot be disabled until it is disabled manually as described below. Self-Tuning may be terminated and manually disabled by depressing the PARAMETER SCROLL pushbutton until the tn or tu mnemonic is displayed. Depressing the LOWER pushbutton will then disable Self-Tuning. Once Self-Tuning is disabled, it cannot be enabled until it is enabled manually as described above.

There are three types of Self-Tuning: Start-up Self-Tune, Manual Initiation of Self-Tune (Push-to-Tune), and Continuously Adaptive Self-Tune. Each type of Self-Tune is discussed below.

a. Start-Up Self-Tune

On power-up, the Controller will demand maximum heat power, or it will demand power to the amount given by the Maximum Heat Power parameter, HL. The PID parameters of the Controller are irrelevant, but the values of the HC and AL parameters are relevant. At a point halfway between the starting measured value and the final setpoint, the controller will turn the heat output power off. The self-tuning algorithm will then watch the measured value rise and begin to fall.

The time taken for the measured value to rise to its peak and the amount of temperature rise are related to the values of PID. The Self-Tuning algorithm will calculate the PID values based upon the above stated criteria. The Controller will then be put into a normal PID control mode with these calculated values of PID.

After approximately two integral time constants, the Controller will start its continuously adaptive control mode. See Section 5.6.c for a description of Continuously Adaptive Self-Tuning. Figure 5-5 illustrates a start-up self-tune response curve for a particular load.

b. Manual Initiation of Self-Tune (Push-to-Tune)

When Self-Tuning is initiated manually, the setpoint and current measured value are first checked. If the measured value is less than half of the setpoint, the start-up case described above is assumed. If cooling power is being called for at the time that Self-Tuning is initiated, Self-Tuning will be DISALLOWED. The Controller will operate with the same PID values it had prior to the Manual Initiation of Self-Tune.

If at the time of Manual Initiation of Self-Tune the measured value is above half of the setpoint, the Controller is put into an ON/OFF control mode with a three degree deadband. Heat output power is turned off until the measured value drops three degrees. Heat output power is then applied until the measured value rises two degrees. Heat output power is again turned off, and the new PID parameters are calculated based on the time taken for the measured value to rise to its peak and the amount of temperature rise. The Controller is then put into a normal PID control mode with these new PID values. Figure 5-6 illustrates a Manually Initiated Self-Tune response curve for a particular load.

c. **Continuously Adaptive Self-Tuning**

When the Controller is operating in a normal PID control mode, the value of the error signal is continuously monitored. Whenever an error of four degrees or greater is observed, but less than the Approach Control parameter, the response of the system is tested.

If the error is corrected in an amount of time less than 1/4 of an integral time constant, the response of the system is judged to be underdamped. If the Controller is calling for heat at the time of the decision, the proportional band is increased by one table setting. If the Controller is calling for cooling at the time of the decision, the relative cool gain is decreased by one table setting.

If the error is not corrected in an amount of time equal to one integral time constant, the response of the system is judged to be overdamped. If the Controller is calling for heat at the time of the decision, the proportional band is decreased by one table setting. If the Controller is calling for cooling at the time of the decision, the relative cool gain is increased by one table setting.

Figure 5-7 illustrates the Continuously Adaptive Self-Tuning Algorithm response curve for a particular load. A perturbation was introduced in order to illustrate this type of self-tuning.

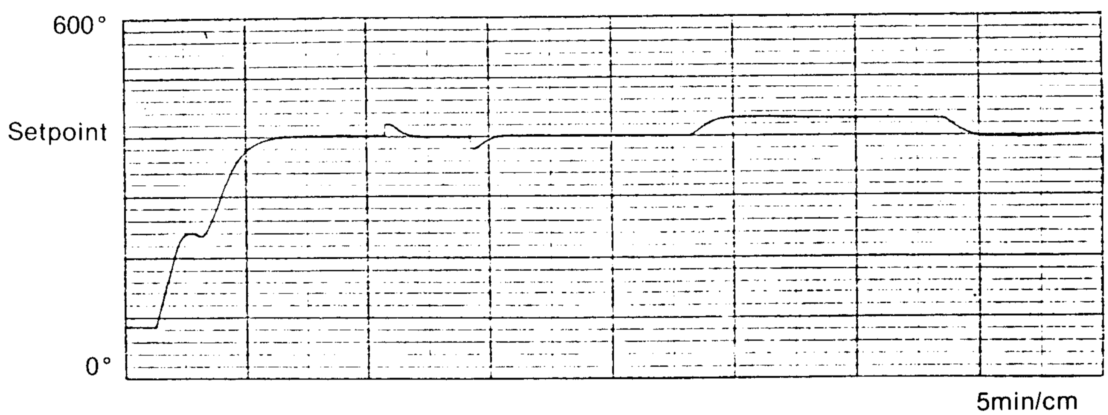


Figure 5-5: Start-Up Self-Tune Response Curve

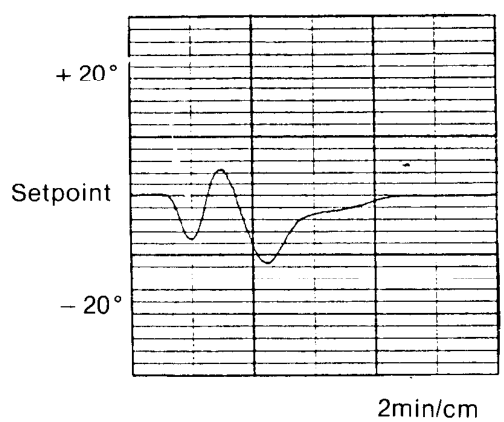


Figure 5-6: Push-to-Tune Response Curve

(Successive 20° Perturbation)

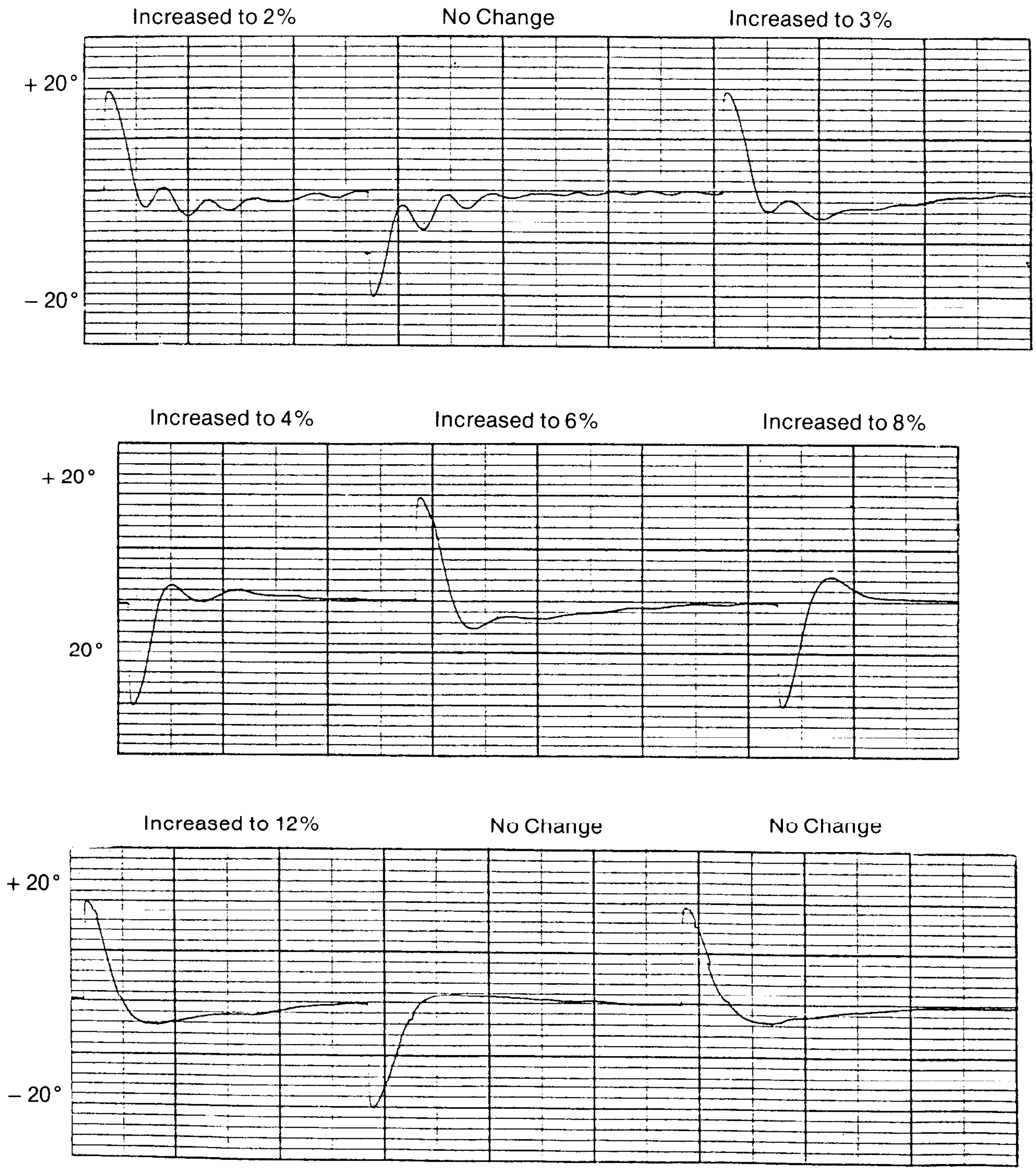


Figure 5-7: Continuously Adaptive Tuning Response Curve

SECTION VI

MAINTENANCE INSTRUCTIONS

6.1 General

This chapter provides information pertaining to the maintenance of the Temperature Controller. Maintenance instructions in this section includes preventive maintenance, cleaning, calibration, disassembly and troubleshooting.

6.2 Preventive Maintenance

Preventive maintenance, when properly performed at prescribed intervals, helps to ensure that the instrument will continue to operate properly. The controller should be inspected periodically so that defects can be corrected before they result in degradation or failure. The preventive maintenance checks and services to be performed are listed and described in Table 6-1. Defects discovered during operation of the unit should be noted and corrected as soon as operation has ceased. Stop the operation immediately if a deficiency is discovered that could result in ultimate damage to the equipment. Reasonable intervals for performing preventive maintenance checks and services should be established based on the operating environment and frequency of operation.

WARNING: Be aware of, and avoid contact with, areas of the equipment where 240 volt, 60 Hz power is normally present. Failure to observe the appropriate safety precautions may result in serious injury due to electrical shock.

6.3 Cleaning

The equipment should be kept free of dust, moisture, grease, and foreign matter. The fascia and exterior of the unit may be cleaned with a lint-free cloth dampened with a mild detergent. The unit should then be wiped with a clean damp cloth.

Table 6-1: Preventive Maintenance Checks and Services

SEQUENCE NUMBER	ITEM TO BE INSPECTED AND PROCEDURE
1	**Connectors and Cable Assemblies** Check wiring and connectors for evidence of bent pins, damaged shells, worn or frayed insulation, and oxidation. Replace damaged parts.
2	**Components** Inspect components for evidence of physical damage or overheating. If discoloration due to overheating is observed, determine the cause of the overheating. Replace the board containing the damaged components.
3	**Screws, Nuts and Bolts** Tighten all loose hardware.
4	**Controls and Indicators** Inspect front panel controls and lamp housings for loose retaining hardware; tighten as necessary. Replace if a switch or lamp housing is physically damaged.

6.4 Dismantling Instructions

The instructions outlined below are referenced to the exploded view of the Controller, figure 3-1.

Turn off all power to the instrument.

Open the front panel access door and with a screwdriver, turn the locking screw located in the bottom right-hand corner of the fascia, counter-clockwise. As the screw is turned, the instrument will start to withdraw from the sleeve. Once the locking screw has been turned to its furthest extent, the instrument can be removed from the sleeve by hand.

Place the instrument on a table. Press in the two black PCB support bracket tabs located at the rear of the instrument and gently ease the PCB support bracket out towards the rear of the instrument. Remove the transformer bracket screw and the triac screw if it is fitted.

Remove the two metal covers by gently pulling them, from the rear of the instrument, to the side of the instrument and disengaging them from their locating lugs on the instrument bezel.

All of the PCBs are now exposed. They can be removed as a unit by easing all of the PCBs out of the instrument bezel. The control pushbuttons will now fall free when the boards are removed. The various boards can now be removed from the motherboard by simply pulling the boards from their motherboard pin connectors. The Isolated D.C. Sub-Boards are soldered to the power supply board, and therefore, they cannot be removed without desoldering them.

The input board can be removed from the microprocessor board by depressing the input board clip, attached to the microprocessor board, and gently easing the input board away from the microprocessor board.

Reassembling

To reassemble the instrument, fit the control pushbuttons into their respective locations in the instrument bezel. Install the motherboard into the bezel. Install the various P.C. boards into their respective motherboard locations. The bezel is fitted with board guide slots which will be of help when re-installing the PCBs.

Refit the two metal covers to the instrument using their locating lugs on the bezel. The metal cover with three cut holes on the bottom and possibly one cut hole on the top should be installed on the right-hand side of the instrument. The other metal cover with the one cut hole on the top should be installed on the right-hand side of the instrument. Install the transformer bracket screw and the triac screw if it was removed.

Refit the PCB support bracket ensuring that the PCB support bracket tabs are positioned inside the two metal covers and that the PCBs fit into their relevant slots. Press the PCB support bracket towards the front of the instrument until the PCB support bracket tabs click in place.

Insert the instrument into the sleeve. Ease the instrument into the sleeve until firm resistance is met, but DO NOT FORCE the instrument into the sleeve. Open the front panel access door. With a screwdriver, turn the locking screw clockwise until the instrument is pulled completely into the sleeve.

6.5 Calibration

All calibration adjustments are made on the input board. A millivolt source, thermocouple compensating cable and thermocouple reference tables are required for calibration of thermocouple inputs. A source of precision resistance and a platinum resistance thermometer table for the RTD being used is required for calibration of RTD inputs.

The thermocouple calibrating source can be either a cold junction compensating source (Eurotherm Model 239) or an uncompensating source. Procedures for calibration with compensated or uncompensated sources are described below.

All calibration adjustment pots, Zero, Span, and RTD Current Balance, are located on the input board, and they can be accessed through the three holes located on the underneath left-hand side of the Controller. Refer to figure 6-1 during calibration adjustments.

a. Calibration of Thermocouple Inputs with a Compensating Source

1. Connect a calibration source (compensated or uncompensated) to Controller rear terminals 25 (T/C +) and 27 (T/C –).
2. Switch on the supply power to the Controller and to the calibration source and allow 10 minutes for warm-up. Allow a longer time for warm-up if either the Controller or the calibration source was at a radically different temperature other than ambient.
3. In order to achieve the correct thermocouple input characterization, the Controller must be calibrated at the calibration points specified in Table 6-2. Under Table 6-2, locate the Controller thermocouple input type and display range. Adjust the calibration source for the millivolt output specified under the Low Input mV column of Table 6-2.
4. Adjust the zero potentiometer, P2 on the input board, until the measured value indication is identical to the Low Temperature Value listed in Table 6-2.
5. Adjust the calibration source for the millivolt output specified under the High Input mV column of Table 6-2.
6. Adjust the span potentiometer, P3 on the input board, until the measured value indication is identical to the High Temperature Value listed in Table 6-2.
7. Recheck the Controller calibration at the Low mV Input and High mV Input. Adjust the zero and span potentiometers as required.
8. Controller accuracy can be verified at several points throughout the span of the Controller by inputting a millivolt value corresponding to the required temperature. The displayed measured value should be within ± 0.25% of span at each temperature setting.

b. Uncompensating Source

If the calibration source is uncompensating, read the temperature at rear terminals 25 and 27 by means of a thermometer. Obtain the millivolts corresponding to this temperature from the thermocouple reference tables. Reduce the calibration source millivolt output by this amount of millivolts when calibrating the controller as described in subparagraph a.

c. Calibration of Platinum Resistance Thermometer Inputs

1. In order to properly calibrate an RTD input, the Controller must be disassembled. Follow the disassembly instructions under section 6-4 of this manual only to the point of removing the two metal covers and the Channel 2 Output/Alarm Board (if installed). Be sure to reinstall the PCB support bracket before applying power to the Controller to ensure that the PCBs do not accidentally touch each other.

   Note: Be careful to avoid contact with any of the now exposed circuitry as personal injury may result.

2. Referring to figure 6-2, connect a 23K7 resistor in parallel with resistor R1 located on the input board.
3. Jumper rear terminal 25 (R.T. V1) to rear terminal 27 (R.T.I.). Connect a voltmeter between rear terminal 26 (–) (R.T. V2) and rear terminal 25 (+).

   These connections are necessary to order to adjust the RTD Current Balance potentiometer.

4. Switch on the supply power to the Controller and allow 10 minutes for warm-up. Allow a longer time for warm-up if the Controller was at a radically different temperature other than ambient.

5. Adjust the RTD Current Balance potentiometer, P1 on the input board, for a voltmeter reading of 0.00 ± 50mV.

6. Remove the supply power to the Controller. Remove the 23K7 resistor that is in parallel with resistor R1 on the input board. Remove the voltmeter from rear terminals 25 (+) and 26 (−). Remove the jumper from rear terminals 25 and 27. Reassemble the Controller following the reassembly instructions outlined in section 6-4 of this manual.

7. Connect a precision resistance source to Controller rear terminals 25 (R.T. V1) and 26 (R.T. V2). Jumper rear terminal 26 to rear terminal 27 (R.T.I.). Keep the connecting leads as short as possible.

8. Switch on the supply power to the Controller and again allow time for warm-up.

9. In order to achieve the correct RTD input characterization, the Controller must be calibrated at the calibration points specified in Table 6-3. Under Table 6-3, locate the RTD type and display range of the Controller. Adjust the resistance source for the required ohms listed under the Low Ohms Input column of Table 6-3.

10. Adjust the zero potentiometer, P2 on the input board, until the measured value indication is identical to the Low Temperature Value listed in Table 6-3.

11. Adjust the resistance source for the required ohms listed under the High Ohms Input column of Table 6-3.

12. Adjust the span potentiometer, P3 on the input board, until the measured value indication is identical to the High Temperature Value listed in Table 6-3.

13. Recheck the Controller calibration at the Low Ohms Input and the High Ohms Input. Adjust the zero and span potentiometers as required.

14. Controller accuracy may be verified at several points throughout the span of the Controller by inputting a resistance value corresponding to the required temperature. The displayed measured value should be within ±0.25% of span at each temperature setting.

d. Calibration of Linear Inputs (Voltage and Current)

1. Connect a calibration source (either a voltage or current source) to Controller rear terminals 25 (D.C. +) and 26 (D.C. −).

2. Switch on the supply power to the Controller and to the calibration source and allow 10 minutes for warm-up. Allow a longer time for warm-up if either the Controller or the calibration source was at a radically different temperature other than ambient.

3. Adjust the calibration source for the "zero" input of the Controller.

4. Adjust the zero potentiometer, P2 on the input board, until the measured value indication is identical to the "zero" display indication of the Controller.

5. Adjust the calibration source for the "span" input of the Controller.

6. Adjust the span potentiometer, P3 on the input board, until the measured value indication is identical to the "span" display indication of the Controller.

7. Recheck the Controller calibration at the zero and span inputs. Adjust the zero and span potentiometers as required.

8. Controller accuracy may be verified at several points throughout the span of the Controller by inputting a voltage or current signal corresponding to a displayed measured value. The displayed measured value indication should be within ±0.25% of Controller span at each input.

6.6 Troubleshooting Guide

If, upon completion of installation or during normal operation, the instrument fails to function properly, check all installation wiring for loose or faulty wiring connections. Particularly check that the AC power connections are wired to the correct terminals. If these items are correct, refer to Table 6-4, "Troubleshooting Guide", to assist in isolating common malfunctions. Potential problems which could be at fault and recommendations for corrective action are listed in Table 6-4.

Note: 1. Before troubleshooting the Controller, ensure that the heat maximum power parameter, HL, is set to 100%.

2. If a fault is indicated in the thermocouple or thermocouple interconnections, confirmation of this can be made as follows:

   Disconnect the compensating cable from the Controller thermocouple terminals and connect a millivolt source to these terminals. Check that the controller measured value indication moves up and down the scale as the millivolt signal corresponding to temperatures above and below the setpoint are injected. If the measured value indication fails to respond in this way, an internal fault exists in the Controller.

Table 6.4: Troubleshooting Guide

Condition	Fault	Action
With Supply Power on: Controller display does not illuminate.	a. Break in supply power connection (fuse or breaker) or b. incorrect rear terminal supply power connections or c. power supply/channel 1 output board not set up for correct supply power voltage—wrong links fitted or d. Controller transformer failure or e. Controller not seated properly in sleeve	a. Check supply power connections, fuses and breakers. Check for cause of fuse failure before replacing fuse b. Check rear terminal connections c. Fit 120V links or 240V links as required d. Replace controller transformer e. Check controller for proper installation
Error bargraph indication is upscale and display is blank.	Break in thermocouple or compensating cable	Replace thermocouple or compensating cable and check all connections
Error bargraph indication is downscale, output 1 LED is ON, but heating power is off.	Break in load connection (fuse or breaker)	Check load connections, fuses and breakers. Check for cause of fuse failure before replacing fuse
Error bargraph indication is downscale, output 1 LED is OFF, and heating power is off (for an extended period of time).	a. Channel 1 output failure b. possible tuning problem	a. Replace channel 1 output b. See section 5.4 of this manual

Table 6.4: Troubleshooting Guide

Condition	Fault	Action
Error bargraph indication is upscale, output 1 LED is OFF, but full heating power is on.	a. Short circuit in load wiring or b. external SCRs either latched on or broken down	a. Check/repair load wiring b. Check/Repair/Replace external SCR device
Error bargraph indication is downscale, output 1 LED is ON, Controller display is blank, and heating power is on.	a. Incorrect thermocouple or compensating cable connections (polarity) b. downscale break option	a. Reconnect thermocouple or compensating cable with correct polarity b. Check thermocouple or compensating cable for an open circuit
With dual output controller—error bargraph indication is upscale, output 2 LED is ON, but cooling power is off.	a. Break in cooling load connection, fuses or breakers or b. solenoid valve stuck or c. faulty pilot relay	a. Check cooling load connections, fuses and breakers. Check cause of fuse failure before replacing fuse or b. Check solenoid valve c. Check pilot relay
With dual output controller—error bargraph indication is upscale, output 2 LED is OFF, and cooling power is off (for an extended period of time).	a. Channel 2 output stage failure or b. possible tuning problem	a. Replace channel 2 output b. See section 5.4 of this manual
With system at temperature, the temperature indication swings regularly above and below setpoint and error bargraph swings with temperature.	a. Excessively narrow proportional band or b. incorrect time constants	a. Increase proportional band b. Modify time constants c. See section 5.4 of the manual
With system at temperature, the temperature indication and error bargraph indication are steady, but an error exists between actual temperature and set temperature as indicated on the display.	a. Proportional only control or b. improper tuning	a. Check proportional band and time constants (Pb, ti, td) b. See section 5.4 of this manual
With system at temperature, temperature indication hunts in a random manner.	a. Poor thermocouple connection or b. thermocouple junction deteriorating or c. improper tuning	a. Check/repair thermocouple connection b. Replace thermocouple c. See section 5.4 of this manual

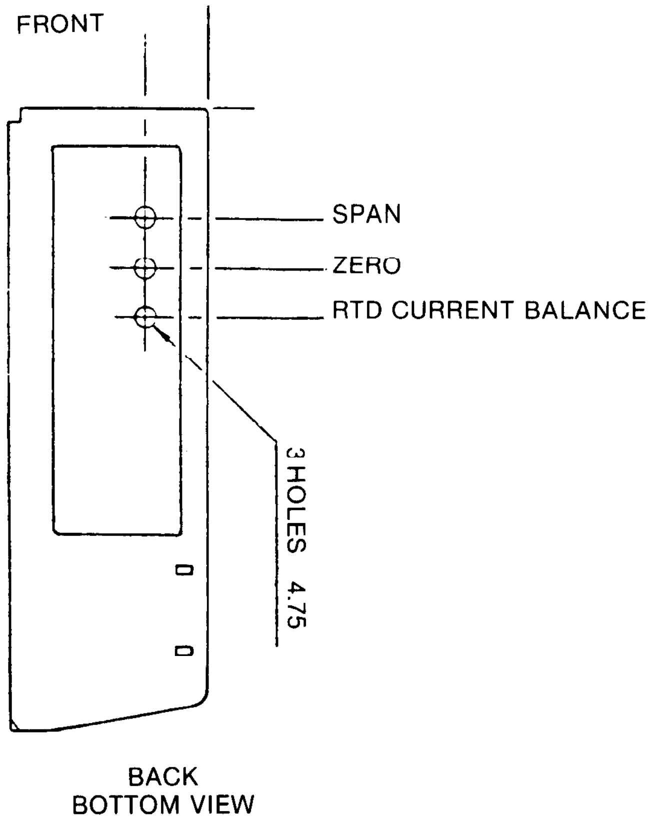


Figure 6-1: 810 Calibration Adjustments

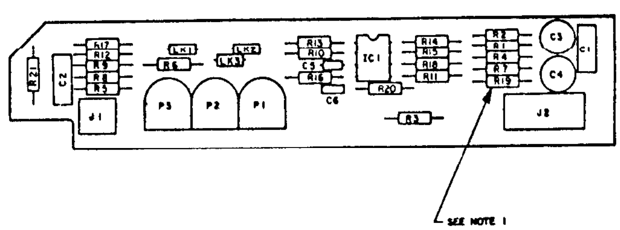


Figure 6-2: Input Board Component Layout

Table 6.2: Thermocouple Calibration Data

THERMOCOUPLE TYPE	DISPLAY RANGE	TABLE RANGE	Calibration Points			
			LOW INPUT mV (mV)	LOW TEMPERATURE VALUE	HIGH INPUT mV (mV)	HIGH TEMPERATURE VALUE
J Iron versus Constantan NBS (National Bureau of Standards)	± 250°C	± 250	− 4.632	− 100°C	+ 13.553	+ 250°C
	± 125°C	± 125	− 4.632	− 100°C	+ 6.359	+ 120°C
	0-50.0°C	0-125	+ 0.101	+ 2°C	+ 6.523	+ 123°C
	0-100.0°C	0-125	+ 0.101	+ 2°C	+ 6.523	+ 123°C
	0-200°C	0-250	0.0	0°C	+ 12.720	+ 235°C
	0-300°C	0-500	+ 0.303	+ 6°C	+ 25.994	+ 475°C
	0-400°C	0-500	+ 0.303	+ 6°C	+ 25.994	+ 475°C
	0-600°C	0-1000	+ 1.277	+ 25°C	+ 50.621	+ 880°C
	0-800°C	0-1000	+ 1.277	+ 25°C	+ 50.621	+ 880°C
	0-1000°C	0-1000	+ 1.277	+ 25°C	+ 50.621	+ 880°C
J Iron versus Constantan NBS (National Bureau of Standards)	± 500°F	± 500	− 0.748	+ 5°F	+ 11.023	+ 400°F
	± 250°F	± 250	− 6.716	− 250°F	+ 6.420	+ 250°F
	± 125°F	± 125	− 3.930	− 118°F	+ 2.673	+ 125°F
	0-50.0°F	0-125	− 0.885	0°F	+ 2.526	+ 120°F
	0-100.0°F	0-125	− 0.885	0°F	+ 2.526	+ 120°F
	0-200°F	0-250	+ 0.507	+ 50°F	+ 5.509	+ 220°F
	0-300°F	0-500	+ 0.648	+ 55°F	+ 9.790	+ 360°F
	0-400°F	0-500	+ 0.648	+ 55°F	+ 9.790	+ 360°F
	0-600°F	0-1000	− 0.611	+ 10°F	+ 24.853	+ 850°F
	0-800°F	0-1000	− 0.611	+ 10°F	+ 24.853	+ 850°F
	0-1000°F	0-1000	− 0.611	+ 10°F	+ 24.853	+ 850°F
	0-1200°F	0-2000	+ 3.115	+ 140°F	+ 39.407	+ 1300°F
	0-1600°F	0-2000	+ 3.115	+ 140°F	+ 39.407	+ 1300°F
	0-2000°F	0-2000	+ 3.115	+ 140°F	+ 39.407	+ 1300°F
B Platinum-30% Rhodium versus Platinum-Rhodium (Hoskins Manufacturing Company)	0-600°C	0-1000	+ 0.778	+ 398°C	+ 4.386	+ 950°C
	0-800°C	0-1000	+ 0.778	+ 398°C	+ 4.386	+ 950°C
	0-1000°C	0-1000	+ 0.778	+ 398°C	+ 4.386	+ 950°C
	0-1200°C	0-2000	+ 3.957	+ 900°C	+ 10.616	+ 1545°C
	0-1600°C	0-2000	+ 3.957	+ 900°C	+ 10.616	+ 1545°C
	0-2000°C	0-2000	+ 3.957	+ 900°C	+ 10.616	+ 1545°C

Table 6.2

THERMOCOUPLE TYPE	DISPLAY RANGE	TABLE RANGE	Calibration Points			
			LOW INPUT mV (mV)	LOW TEMPERATURE VALUE	HIGH INPUT mV (mV)	HIGH TEMPERATURE VALUE
B Platinum-30% Rhodium versus Platinum-6% Rhodium (Hoskins Manufacturing Company)	0-1200°F 0-1600°F 0-2000°F 0-2400°F 0-3000°F 0-4000°F	0-2000 0-2000 0-2000 0-4000 0-4000 0-4000	+0.898 +0.898 +0.898 +7.473 +7.473 +7.473	+800°F +800°F +800°F +2310°F +2310°F +2310°F	+4.873 +4.873 +4.873 +9.889 +9.889 +9.889	+1840°F +1840°F +1840°F +2700°F +2700°F +2700°F
S Platinum-10% Rhodium versus Platinum NBS (National Bureau of Standards)	0-1200°F 0-1600°F 0-2000°F 0-2400°F 0-3000°F 0-4000°F	0-2000 0-2000 0-2000 0-4000 0-4000 0-4000	+2.985 +2.985 +2.985 +4.333 +4.333 +4.333	+700°F +700°F +700°F +950°F +950°F +950°F	+8.436 +8.436 +8.436 +15.027 +15.027 +15.027	+1650°F +1650°F +1650°F +2650°F +2650°F +2650°F
S Platinum-10% Rhodium versus Platinum NBS (National Bureau of Standards)	0-600°C 0-800°C 0-1000°C 0-1200°C 0-1600°C 0-2000°C	0-1000 0-1000 0-1000 0-2000 0-2000 0-2000	+2.277 +2.277 +2.277 +3.260 +3.260 +3.260	+295°C +295°C +295°C +400°C +400°C +400°C	+9.585 +9.585 +9.585 +12.308 +12.308 +12.308	+1000°C +1000°C +1000°C +1230°C +1230°C +1230°C
E Nickel-Chromium versus Copper-Nickel NBS (National Bureau of Standards)	±250°C 0-600°C 0-800°C 0-1000°C	±250 0-1000 0-1000 0-1000	−6.231 +6.656 +6.656 +6.656	−123°C +105°C +105°C +105°C	+13.419 +75.608 +75.608 +75.608	+200°C +990°C +990°C +990°C
E Nickel-Chromium versus Copper Nickel NBS (National Bureau of Standards)	±500°F 0-1200°F 0-1600°F 0-2000°F	±500 0-2000 0-2000 0-2000	−3.650 +13.955 +13.955 +13.955	−85°F +405°F +405°F +405°F	+13.748 +57.873 +57.873 +57.873	+400°F +1400°F +1400°F +1400°F

Table 6.2

THERMOCOUPLE TYPE	DISPLAY RANGE	TABLE RANGE	Calibration Points			
			LOW INPUT mV (mV)	LOW TEMPERATURE VALUE	HIGH INPUT mV (mV)	HIGH TEMPERATURE VALUE
PL2 Platinel II (Engelhard Industries)	± 250°F 0-600°F 0-800°F 0-1000°F 0-1200°F 0-1600°F 0-2000°F	± 250 0-1000 0-1000 0-1000 0-2000 0-2000 0-2000	− 1.641 − 1.983 − 1.983 − 1.983 + 11.471 + 11.471 + 11.471	− 75°F − 100°F − 100°F − 100°F + 580°F + 580°F + 580°F	+ 3.863 + 20.606 + 20.606 + 20.606 + 41.155 + 41.155 + 41.155	+ 240°F + 950°F + 950°F + 950°F + 1815°F + 1815°F + 1815°F
G2 W/W 26% Re Tungsten versus Tungsten 26% Rhenium (Hoskins Manufacturing Company)	0-1200°C 0-1600°C 0-2000°C	0-2000 0-2000 0-2000	+ 8.076 + 8.076 + 8.076	+ 685°C + 685°C + 685°C	+ 33.367 + 33.367 + 33.367	+ 1960°C + 1960°C + 1960°C
G2 W/W 26% Re Tungsten versus Tungsten 26% Rhenium (Hoskins Manufacturing Company)	0-1200°F 0-1600°F 0-2000°F 0-2400°F 0-3000°F 0-4000°F	0-2000 0-2000 0-2000 0-4000 0-4000 0-4000	+ 4.562 + 4.562 + 4.562 + 17.174 + 17.174 + 17.174	+ 900°F + 900°F + 900°F + 2070°F + 2070°F + 2070°F	+ 15.182 + 15.182 + 15.182 + 36.312 + 36.312 + 36.312	+ 1900°F + 1900°F + 1900°F + 3900°F + 3900°F + 3900°F
C Tungsten 5% Rhenium versus Tungsten 26% Rhenium (Hoskins Manufacturing Company)	0-1200°C 0-1600°C 0-2000°C	0-2000 0-2000 0-2000	+ 6.731 + 6.731 + 6.731	+ 400°C + 400°C + 400°C	+ 29.617 + 29.617 + 29.617	+ 1695°C + 1695°C + 1695°C
C Tungsten 5% Rhenium versus Tungsten Rhenium 26% (Hoskins Manufacturing Company)	0-2400°F 0-3000°F 0-4000°F	0-4000 0-4000 0-4000	+ 10.475 + 10.475 + 10.475	+ 1100°F + 1100°F + 1100°F	+ 21.991 + 21.991 + 21.991	+ 2210°F + 2210°F + 2210°F

Table

THERMOCOUPLE TYPE	DISPLAY RANGE	TABLE RANGE	Calibration Points			
			LOW INPUT mV (mV)	LOW TEMPERATURE VALUE	HIGH INPUT mV (mV)	HIGH TEMPERATURE VALUE
D Tungsten 3% Rhenium versus Tungsten 25% Rhenium (Hoskins Manufacturing Company)	0-600°C 0-800°C 0-1000°C 0-1200°C 0-1600°C 0-2000°C	0-1000 0-1000 0-1000 0-2000 0-2000 0-2000	+ 4.771 + 4.771 + 4.771 + 6.996 + 6.996 + 6.996	+ 327°C + 327°C + 327°C + 445°C + 445°C + 445°C	+ 14.171 + 14.171 + 14.171 + 31.413 + 31.413 + 31.413	+ 800°C + 800°C + 800°C + 1720°C + 1720°C + 1720°C
R Platinum-13% Rhodium versus Platinum NBS (National Bureau of Standards)	0-600°C 0-800°C 0-1000°C 0-1200°C 0-1600°C 0-2000°C	0-1000 0-1000 0-1000 0-2000 0-2000 0-2000	+ 0.610 + 0.610 + 0.610 + 5.526 + 5.526 + 5.326	+ 95°C + 95°C + 95°C + 595°C + 595°C + 595°C	+ 8.696 + 8.696 + 8.696 + 14.624 + 14.624 + 14.624	+ 860°C + 860°C + 860°C + 1300°C + 1300°C + 1300°C
D Tungsten 3% Rhenium versus Tungsten 25% Rhenium (Hoskins Manufacturing Company)	0-1200°F 0-1600°F 0-2000°F 0-2400°F 0-3000°F 0-4000°F	0-2000 0-2000 0-2000 0-4000 0-4000 0-4000	+ 3.078 + 3.078 + 3.078 + 7.725 + 7.725 + 7.725	+ 445°F + 445°F + 445°F + 900°F + 900°F + 900°F	+ 13.579 + 13.579 + 13.579 + 22.334 + 22.334 + 22.334	+ 1420°F + 1420°F + 1420°F + 2210°F + 2210°F + 2210°F
T Copper versus Copper Nickel NBS (National Bureau of Standards)	± 500°F ± 250°F ± 125°F 0-50.0°F 0-100.0°F 0-200°F 0-300°F 0-400°F 0-600°F 0-800°F 0-1000°F	± 500 ± 250 ± 125 0-125 0-125 0-250 0-500 0-500 0-1000 0-1000 0-1000	− 2.973 − 3.039 − 3.006 − 0.571 − 0.571 − 0.674 − 0.571 − 0.571 + 0.065 + 0.065 + 0.065	− 123°F − 127°F − 125°F + 5°F + 5°F 0°F + 5°F + 5°F + 35°F + 35°F + 35°F	+ 12.572 + 4.749 + 1.105 + 1.403 + 1.403 + 3.839 + 12.572 + 12.572 + 15.118 + 15.118 + 15.118	+ 500°F + 230°F + 82°F + 95°F + 95°F + 195°F + 500°F + 500°F + 580°F + 580°F + 580°F

Table 6.2

THERMOCOUPLE TYPE	DISPLAY RANGE	TABLE RANGE	Calibration Points			
			LOW INPUT mV (mV)	LOW TEMPERATURE VALUE	HIGH INPUT mV (mV)	HIGH TEMPERATURE VALUE
K Nickel-Chromium versus Nickel-Aluminum NBS (National Bureau of Standards)	± 500°F	± 500	− 3.637	− 153°F	+ 10.151	+ 482°F
	± 250°F	± 250	− 2.699	− 100°F	+ 2.666	+ 150°F
	± 125°F	± 125	− 2.920	− 112°F	+ 2.091	+ 125°F
	0-50.0°F	0-125	0.0	0°F	+ 2.045	+ 123°F
	0-100.0°F	0-125	0.0	0°F	+ 2.045	+ 123°F
	0-200°F	0-250	+ 0.242	+ 43°F	+ 4.919	+ 248°F
	0-300°F	0-500	− 0.262	+ 20°F	+ 9.027	+ 432°F
	0-400°F	0-500	− 0.262	+ 20°F	+ 9.027	+ 432°F
	0-600°F	0-1000	+ 1.657	+ 106°F	+ 17.994	+ 820°F
	0-800°F	0-1000	+ 1.657	+ 106°F	+ 17.994	+ 820°F
	0-1000°F	0-1000	+ 1.657	+ 106°F	+ 17.994	+ 820°F
	0-1200°F	0-2000	+ 1.181	+ 85°F	+ 37.724	+ 1670°F
	0-1600°F	0-2000	+ 1.181	+ 85°F	+ 37.724	+ 1670°F
	0-2000°F	0-2000	+ 1.181	+ 85°F	+ 37.724	+ 1670°F
	0-2400°F	0-4000	+ 1.203	+ 86°F	+ 54.807	+ 2496°F
	0-2500°F	0-4000	+ 1.203	+ 86°F	+ 54.807	+ 2496°F
	0-3000°F	0-4000	+ 1.203	+ 86°F	+ 54.807	+ 2496°F
	0-4000°F	0-4000	+ 1.203	+ 86°F	+ 54.807	+ 2496°F

Table 6.2

THERMOCOUPLE TYPE	DISPLAY RANGE	TABLE RANGE	Calibration Points			
			LOW INPUT mV (mV)	LOW TEMPERATURE VALUE	HIGH INPUT mV (mV)	HIGH TEMPERATURE VALUE
R Platinum-13% Rhodium versus Platinum NBS (National Bureau of Standards)	0-1200°F	0-2000	+2.818	+648°F	+8.141	+1500°F
	0-1600°F	0-2000	+2.818	+648°F	+8.141	+1500°F
	0-2000°F	0-2000	+2.818	+648°F	+8.141	+1500°F
	0-2400°F	0-4000	+3.110	+700°F	+17.975	+2800°F
	0-3000°F	0-4000	+3.110	+700°F	+17.975	+2800°F
	0-4000°F	0-4000	+3.110	+700°F	+17.975	+2800°F
PL2 Platinel II (Engelhard Industries)	±250°C	±125	−2.594	−100°C	+3.843	+115°C
	0-300°C	0-500	+0.925	+30°C	+18.352	+460°C
	0-400°C	0-500	+0.925	+30°C	+18.352	+460°C
	0-600°C	0-1000	+8.127	+225°C	+40.743	+980°C
	0-800°C	0-1000	+8.127	+225°C	+40.743	+980°C
	0-1000°C	0-1000	+8.127	+225°C	+40.743	+980°C
	0-1200°C	0-2000	0.0	0°C	+74.204	+2000°C
	0-1600°C	0-2000	0.0	0°C	+74.204	+2000°C
	0-2000°C	0-2000	0.0	0°C	+74.204	+2000°C

Table 6.2

THERMOCOUPLE TYPE	DISPLAY RANGE	TABLE RANGE	Calibration Points			
			LOW INPUT mV (mV)	LOW TEMPERATURE VALUE	HIGH INPUT mV (mV)	HIGH TEMPERATURE VALUE
T	± 250°C	± 250	− 5.069	− 170°C	+ 9.021	+ 195°C
Copper	± 125°C	± 125	− 1.819	− 50°C	+ 5.131	+ 118°C
versus	0-50.0°C	0-125	− 0.193	− 5°C	+ 4.987	+ 115°C
Copper Nickel	0-100.0°C	0-125	− 0.193	− 5°C	+ 4.987	+ 115°C
NBS (National	0-200°C	0-250	+ 0.117	+ 3°C	+ 9.820	+ 210°C
Bureau of	0-300°C	0-500	+ 0.992	+ 25°C	+ 15.443	+ 310°C
Standards)	0-400°C	0-500	+ 0.992	+ 25°C	+ 15.443	+ 310°C
K	± 250°C	± 250	− 1.745	− 46°C	+ 9.745	+ 240°C
Nickel-	± 125°C	± 125	− 1.709	− 45°C	+ 5.124	+ 125°C
Chromium versus	0-50.0°C	0-125	0.0	0°C	+ 3.473	+ 85°C
Nickel Aluminum	0-100.0°C	0-125	0.0	0°C	+ 3.473	+ 85°C
NBS (National	0-200°C	0-250	+ 1.693	+ 42°C	+ 10.070	+ 248°C
Bureau of	0-300°C	0-500	0.0	0°C	+ 16.691	+ 407°C
Standards)	0-400°C	0-500	0.0	0°C	+ 16.691	+ 407°C
	0-600°C	0-1000	+ 2.022	+ 50°C	+ 37.325	+ 900°C
	0-800°C	0-1000	+ 2.022	+ 50°C	+ 37.325	+ 900°C
	0-1000°C	0-1000	+ 2.022	+ 50°C	+ 37.325	+ 900°C
	0-1200°C	0-2000	+ 1.203	+ 30°C	+ 54.807	+ 1370°C
	0-1600°C	0-2000	+ 1.203	+ 30°C	+ 54.807	+ 1370°C
	0-2000°C	0-2000	+ 1.203	+ 30°C	+ 54.807	+ 1370°C

Table 6.3: RTD Calibration Data

RTD TYPE	DISPLAY RANGE	TABLE RANGE	Calibration Points			
			LOW INPUT Ohms (OHMS)	LOW TEMPERATURE VALUE	HIGH INPUT Ohms (OHMS)	HIGH TEMPERATURE VALUE
100 OHM RTD	± 250°C	± 250	33.43	– 165°C	127.07	+ 70°C
	± 125°C	± 125	72.35	– 70°C	142.29	+ 110°C
	0-50.0°C	0-125	104.68	+ 12°C	138.50	+ 100°C
	0-100.0°C	0-125	104.68	+ 12°C	138.50	+ 100°C
	0-200°C	0-250	114.38	+ 37°C	161.04	+ 160°C
	0-300°C	0-500	103.90	+ 10°C	190.45	+ 240°C
	0-400°C	0-500	103.90	+ 10°C	190.45	+ 240°C
	0-600°C	0-1000	117.47	+ 45°C	304.02	+ 570°C
	0-800°C	0-1000	117.47	+ 45°C	304.02	+ 570°C
	0-1000°C	0-1000	117.47	+ 45°C	304.02	+ 570°C
100 OHM RTD	0-50.0°F	0-125	99.61	+ 8°F	118.97	+ 120°F
	0-100.0°F	0-125	99.61	+ 8°F	118.97	+ 120°F
	0-200°F	0-250	95.22	+ 10°F	132.80	+ 185°F
	0-300°F	0-500	109.35	+ 75°F	181.56	+ 420°F
	0-400°F	0-500	109.35	+ 75°F	181.56	+ 420°F
	0-600°F	0-1000	97.39	+ 20°F	167.24	+ 350°F
	0-800°F	0-1000	97.39	+ 20°F	167.24	+ 350°F
	0-1000°F	0-1000	97.39	+ 20°F	167.24	+ 350°F
	0-1200°F	0-2000	103.90	+ 50°F	293.52	+ 1000°F
	0-1600°F	0-2000	103.90	+ 50°F	293.52	+ 1000°F
	0-2000°F	0-2000	103.90	+ 50°F	293.52	+ 1000°F