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Instruction Manual
for
Model TC-36-25 RS232
And
Model TC-36-25-RS232-UL
Temperature Controller
For Thermoelectric Coolers

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Drawing #4637 Rev. K

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General Safety Warnings



This manual is available in English only. It must be read and followed carefully before installation and operation.

THE LATEST REVISION OF THIS MANUAL IS AVAILABLE AT www.tetech.com. Verify that you are using the latest revision available.

The temperature controller should not be used as a toy, or serious injury could result. The controller should only be used for its intended purpose of providing temperature control of TE Technology's thermoelectric devices only. The controller is intended for light industrial, laboratory, or similar use. It is not intended for household use or medical use.

Do not use in an explosive or potentially explosive environment.

Do not use the temperature controller to control capacitive or inductive loads or the controller could be damaged and/or overheat. Examples of capacitive or inductive loads include but are not limited to motors, fans, filters, and solenoids.

Do not allow the electrical connections on the printed circuit board to touch any electrically conductive surfaces.

Do not operate in an environment where the controller could come in contact with condensation, water, metal shavings, dirt or other contaminants, or electrically conductive materials. Ingress of contaminants shall be addressed when installed in the end product.

Use ESD (Electro Static Discharge) protection when installing and handling the controller.

Do not touch any of the electrical connections or components of the temperature controller while the controller is energized. Doing so can disrupt the function of the controller.

Do not use if the controller has been damaged in any way.

Only qualified technicians should install and operate this controller with the appropriate personal protective equipment.

Improper tuning of this temperature controller can lead to excessive thermal cycling and/or overheating of the thermoelectric device, either of which are known to reduce the lifetime of any thermoelectric device. Care should be taken to prevent the temperature of the thermoelectric device from going beyond the range specified by the device manufacturer. Care should also be taken so that any thermal cycling of the thermoelectric device is a result of changes in the controller's set-point temperature and not instability at a given set point due to improper selection of the tuning variables.

The temperature controller base underneath the transistor-mounting area could exceed 60 °C under normal operation. Use caution! Protect against accidental contact with hot surfaces.

Use protection devices to prevent hazardous conditions and/or damage to equipment.

Each power input that is used with the controller must be fused separately. Alternatively, a power supply with integral over-current protection may be used if it is appropriately sized for protecting the controller/TE device.

The temperature controller is intended to be used with, or incorporated into, other machinery made by TE Technology, Inc. and must not be put into service until the relevant machinery into which it is to be incorporated into has been declared in conformity with the essential requirements of the Machinery Directive 2006/42/EC.

For more information regarding protection devices read, TE Technology's Thermoelectric Cooling Assembly (TCA) Instruction manual which is available for download from TE Technology's website at www.tetech.com. The terms and provisions relating to protection devices as provided in the TCA Instruction manual are hereby incorporated by reference. A copy of the TCA Instruction manual can also be sent via regular mail upon request.

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Special Notes concerning the TC-36-25-RS232-UL

- The TC-36-25-RS232-UL temperature controller has been tested by MET Laboratories, Inc., a licensed nationally recognized testing laboratory, to UL 60730-1-Part 1-5th edition and CAN CSA E60730-1-Part 1-5th edition. It has been evaluated as follows:
  Type 1 Action
  Electrical Shock Protection Class 0
  Class A Controller
  (Please note that the TC-36-25-RS232-UL differs slightly in design and manufacture from the standard TC-36-25 RS232. If a controller meeting UL requirements is required, the TC-36-25 RS232 cannot be used a substitute; only the TC-36-25-RS232-UL may be used to meet the requirements.)
- The TC-36-25-RS232-UL is CE marked. The TC-36-25 RS232 is not CE marked and cannot be used if a CE marked product is required.
- Due to requirements for UL/CSA, the TC-36-25-RS232-UL is sold without a temperature sensor and without any connecting cables although UL recognized connectors are provided as a requisite for UL. Temperature sensors may be ordered separately; however, the temperature sensors that TE Technology offers are not UL recognized.


The controller is intended to be installed for use with an end product. Ingress of contaminants shall be addressed when installed in the end product.


If the controller is installed in an enclosure, the openings in the enclosure shall be evaluated for access to hazardous parts.


The controller shall be mounted so that it cannot rotate or be otherwise displaced and cannot be removed without the aid of a tool.


Mechanical strength of the enclosure shall be evaluated when the controller is installed in an enclosure.


Endurance testing shall be performed as required when the controller is installed in end product.


An adequate protective earthing connection shall be provided to the controller. The protective earthing connection shall be tested when installed with an end product. See "Safety Ground for TC-36-25-RS232-UL" diagram on page 35 for further details.

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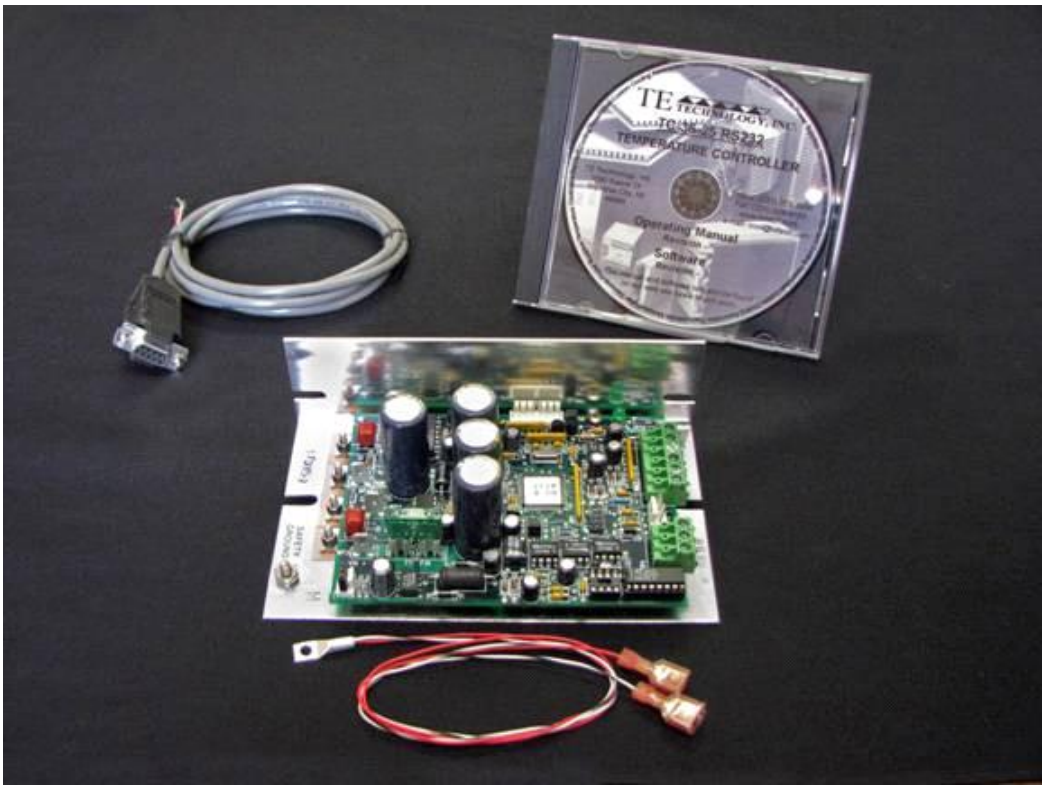
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Features

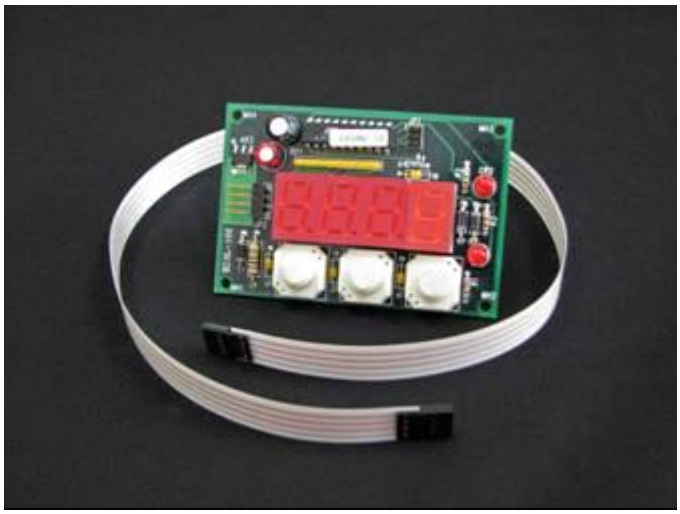


The TC-36-25 RS232 provides bi-directional (heating and cooling) temperature control for thermoelectric devices. Resistive heaters can also be controlled. An H-bridge configuration is used for the power output stage. The output stage is made from solid-state N-channel MOSFETs (no relays or mechanical components are used). These transistors are highly efficient and allow for the bi-directional flow of current through the thermoelectric coolers. Their high efficiency reduces the waste heat generated by the controller and allows for a compact design.

This controller is programmable via the RS232 communication port for direct interface with a compatible computer. Field selectable parameters or data acquisition in a half duplex mode can be performed. The supplied software is compatible with Windows 10, Windows 8, Windows 7, and Windows XP. The software provides a graphical user interface for setting control parameters and receiving feedback from the temperature sensor. However, the command set is also provided so that qualified personnel can use the controller as an embedded control, or they can create a custom program interface using LabVIEW, for example. The software can also be used to instruct the TC-36-25 RS232 to save the desired control parameters to the controller's non-volatile memory. This allows the controller to be disconnected from the computer and operated as a stand-alone controller. When operating as a stand-alone controller, the controller can be set to always control to the stored set point or it can be set up to accept a proportional signal to vary the set point as required.

Mechanically, the controller's printed circuit board is mounted to a metal bracket that is suitable for either horizontal or vertical orientation. The controller can operate in ambient temperatures from 0 °C to 60 °C without generally requiring additional heat sinking. The controller is intended to be used in locations where the controller can be protected by a secondary enclosure or other means of protection.

The MP-2986 Display and Keypad, shown below, is an optional accessory that can be purchased separately. It provides a convenient way of showing and adjusting the temperature set point or showing the actual temperature being sensed when the TC-36-25 RS232 is operating as a stand-alone controller. See the MP-2986 manual for further information.

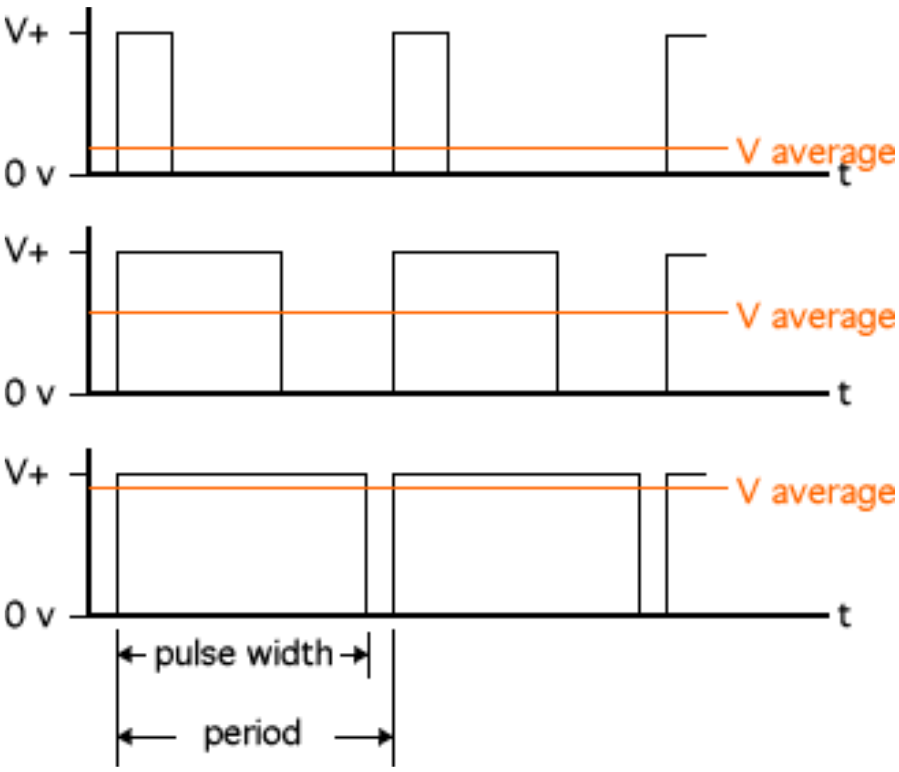


Main Features

- RoHS compliant
- Operates as a stand-alone controller or with a computer monitor
- Bi-directional, solid-state H-bridge operation for both heating and cooling
- Can be configured to control both high and low voltage thermoelectric (TE) devices:
  - ✓ Single power supply configuration for TE devices with an input voltage range from (12 to 36) VDC
  - ✓ Dual power supply configuration for TE devices with an input voltage range is less than 12 VDC:
    - Controller-circuitry input voltage range from (12 to 36) VDC
    - TE device (H-Bridge) input voltage range from (0 to 36) VDC
  - Maximum 25 A current rating, controls up to 900 W
- Soft-start features turns the output on slowly, over a one second period
- Over current shutdown that can be set in 2.5 A increments
- Open sensor and shorted sensor output shutdown with automatic restart
- Low Voltage shutdown protects the H-bridge when the control circuitry voltage is less than 12 VDC
- Pulse width modulation of output at 2700 Hz
- Computer programmable via RS232 communications port
- Control temperature of –20 °C to +100 °C using thermistor supplied with controller
- Control temperature of –40 °C to +250 °C using optional thermistors
- Proportional (P), Integral (I) and Derivative (D) control that can be selected as P, PI, PD or PID; or Deadband (on/off) with an adjustable hysteresis
- Temperature resolution of 0.01 °C or 0.01 °F
- Control stability of ±0.01 °C or ±0.01 °F (best case, when controlling a cold plate)
- Set temperature adjustable by several options:
  - Computer set via software/RS-232 communication
  - Remote potentiometer (customer supplied)
  - 0 mA to 20 mA current loop
  - 0 VDC to 5 VDC adjustable range
  - Differential temperature control (allows control to a programmable temperature difference above or below the temperature of the second thermistor, if used)
  - MP-2986 Display and Keypad (optional accessory)
- No computer programming experience required to use the communications software program (Supplied software is compatible with Windows 10/8/7/XP)
- Command set is provided so programmers can create their own software interface or embedded controller applications
- Versatile alarm system:
  - Computer configurable alarms for 25 mA, with a compliance voltage up to 11 VDC
  - Alarm cancel: selectable via computer-software communication or remote contact closure
  - The second sensor input is configurable as a heat-sink over-temperature shut-down
- Non-volatile memory retention of parameters (1,000,000 write cycles maximum; see command #34 in Appendix C for further details.)
- Operating temperature range of 0 °C to 60 °C, storage temperature range of -55 °C to +105 °C

Pulse-width modulated power output

The TC-36-25 RS232 requires a constant-voltage power supply to provide power for a thermoelectric (TE) device such as a TE cooling assembly or a Peltier (TE) module. The controller regulates the power to the TE device using a method called pulse-width modulation (PWM). With PWM, the power is rapidly switched “ON” and “OFF” at constant frequency (2700 Hz for this controller). This creates a square-wave “pulse” of power to the thermoelectric device. The “ON” time, or pulse width, can be varied to create an average output voltage (Vaverage) that is required by the TE device to maintain the set temperature.



How Pulse-width Modulation Works

The important advantage to PWM is that it does not cause the extreme temperature excursions that are experienced with a thermostatic control system. This helps to extend the life and reliability of the TE devices. Added benefits are that the controller does not generate a large amount of waste heat and it does not require a large heat sink.

Multiple Control Configurations

Depending on the input voltage required for the TE device, the TC-36-25 RS232 can be used with either one or two separate power supplies. When using one power supply, an input supply voltage ranging anywhere from (12 to 36) VDC is required to power both the controller and the TE device. The output voltage during the "ON" time is approximately equal to the input voltage.

When using two power supplies, one power supply, ranging anywhere from (12 to 36) VDC, can be used to power the controller itself; and a second power supply, ranging anywhere from (0 to 36) VDC, can be connected to the H-bridge of the controller. This second power supply allows the controller to control TE devices that must operate at a voltage less than 12 V. The self-contained H-bridge output transistors can deliver load currents from (0.1 to 25) A. (NOTE: consult appropriate installation instructions for power supply and heat sinking requirements for high current operation).

The controller tuning structure allows designation of a variety of control features:

1) The Computer Set Value provides for manual control of the output from 0% to ±100% of load power. This allows a remote device or computer to designate what output % the controller should deliver.
2) Proportional bandwidth (P) in degrees, Integral reset (I) in repeats per minute, and the Derivative rate (D) in minutes may be configured for P, PI, PD, or PID control.
3) Deadband control (on/off) with an adjustable hysteresis may also be selected. However, this control mode is not generally recommended with TE devices.
4) Differential temperature control is provided when two input sensing thermistors are used. The unit will control the differential between Input 2 (reference temperature) and Input 1 (actual system temperature).

A control temperature range of –20 °C to +100 °C is standard when using TE Technology's supplied thermistor sensor probe (MP-3193) for the primary sense temperature. Other temperature ranges are available with optional thermistors.

The set point of the controller can be changed in a variety of ways by using either a computer, a remote set-temperature potentiometer, a (0 to 5) VDC signal, a (0 to 20) mA current loop, or the MP-2986 Display and Keypad accessory. A secondary thermistor can also be used for differential control (or it could be used for alarm condition sensing). All temperatures may be consistently displayed in °C or °F.

Two types of control output modes may be selected. This determines the direction of the current flow through the thermoelectric when heating is desired. This current flow may be from Wire Point WP1+ to Wire Point WP2-. Alternatively, this current flow may be reversed from WP2+ to WP1- as selected in the configuration menu.

Several alarm settings may be selected, some of which provide an output current of 25 mA for alarm signaling. The settings can be selected for no alarm function, tracking alarm, and fixed-value alarm. Alarm temperature values can be entered in the setup menu using the supplied software. The computer-controlled selection is available for additional embedded controller input/output options. The alarm setup menu also provides for selection of an alarm latching condition. The alarm sensor may be either the control temperature sensor or a secondary thermistor sensor.

The various alarms have the ability to determine the status of the output power to the thermoelectric cooler or auxiliary heater. The main output power may be maintained during an alarm condition or shut down, depending on the user's setting.

Setup Instructions

1.0 Initial Setup



Portions of the temperature controller (the aluminum frame near the output transistors, for example) can exceed 60 °C during normal operating conditions. Temperatures greater than 60 °C can result in a hazard to the user. Use caution! Protect against accidental contact with hot surfaces.



If the temperature controller is to be used under conditions such that its surface temperatures could possibly exceed 60 °C, test the surface temperatures under the worst-case operating conditions of maximum ambient temperature and highest output current and voltage. If any portion of the temperature controller exceeds 60 °C place adequate guards around the temperature controller to prevent contact with any hot surfaces.



NOTE: the maximum allowable ambient temperature for the controller is 60 °C. Furthermore, the maximum allowable temperature of the controller base (underneath the transistor-mounting area) is 90 °C.

1.1 The TC-36-25 RS232 can run as a stand-alone controller, meaning that it can operate without the use of a computer. However, a computer is required initially to set up various operating parameters.

Make sure the computer is **OFF** and the controller is **UN-POWERED**. Connect the RS232 Communications Port from the controller (JP4) to the RS232 input (Serial Communications Port) on the computer. Pin 1 of JP4 is the controller's RX, Pin 2 of JP4 is the controller's TX, and Pin 3 of JP4 is the controller's shield.

When using the supplied RS-232 cable, connect the wires to JP4 as follows (see "*RS232 Communications Connections*" for further information):

JP4-1: clear wire

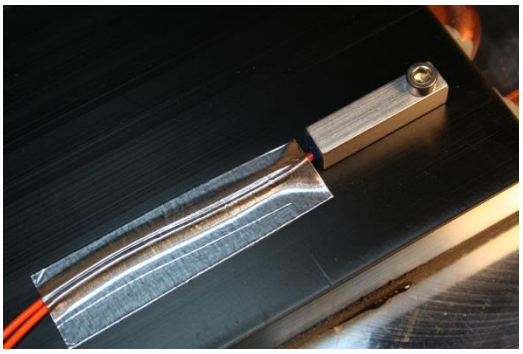
JP4-2: red wire

JP4-3: black wire

1.2 Attach the thermistor to the temperature-control location.

Generally, attaching the thermistor to the cold side of the TE device provides better control stability than locating it at the object, liquid, or air that is to be cooled/heated. However, in doing so, there will be a temperature difference between the TE device and the object, liquid, or air that is to be cooled/heated. The temperature set point can be adjusted to compensate for this temperature difference if necessary.

NOTE: When possible, it is recommended that at least 50 mm of the thermistor's wire be thermally connected to the cold side of the TE device. This can be accomplished by placing aluminum tape over the thermistor wires and adhering the wires and tape to the cold side of the cooler. If this is not done, the thermistor wires will be at a different temperature than the cold side and they will add or remove heat in the region of the thermistor, making the temperature reading **significantly less accurate** and thermal response time slower.



The standard thermistor supplied with the TC-36-25 RS232 is the MP-3193. Appendix D "*Thermistor Styles for TC-36-25 RS232*" shows dimensional data on the MP-3193 and other thermistor styles readily available as well as the corresponding temperature-resistance data. If you are using the MP-3193, it is recommended that you use thermal grease (such as TE Technology TP-1) between the thermistor and the surface to which it is mounted. See also section 2.8 for further details on using thermistors with different resistance-temperature curves than the standard thermistor.

1.3 Connect the thermistor wire leads to terminals JP2-5 and JP2-6. The thermistor is non-polarized, so it does not matter which particular lead goes to which terminal. (See "*Controller Wiring Diagram*" for reference. The thermistor is indicated in the diagram as the 'primary thermistor'.) You can lengthen the wire leads if necessary. The gauge of the wire is generally not important since the resistance of the wire is insignificant to the resistance of the thermistor.

1.4.0 The TC-36-25-RS232 can be used with either one or two separate power supplies, depending primarily on the nominal operating voltage of the TE device. If the maximum TE device input voltage is less than 12 V, then two power supplies must be used with the controller. In this case, one power supply is for the TE device, and the other power supply is for the controller itself (the microprocessor and associated electronics). Of course, just one power supply can be used for powering both the controller and the TE device provided that the TE device's nominal operating voltage is within (12 to 36) V.



When using one power supply for powering the controller and the TE device together, the power supply input voltage is passed directly through the controller to the TE device during the "ON" pulse. The user should choose an input voltage that is required for the TE device and yet is also is also ≥12 V but ≤ 36 V. The controller could be damaged if it is operated outside this range.



When using two power supplies, the controller input power supply voltage must be ≥12 V but ≤36 V and provide a minimum of 200 mA current. The TE device power supply input voltage can be ≥0 V but ≤36 V, but it should be no greater than the rated input voltage for the TE device.



The TE device current rating should be no more than 25 A at the supplied input voltage regardless of whether you are using one power supply or using two independent power supplies. *NOTE: the maximum allowable ambient temperature for the controller is 60 °C. The maximum allowable temperature of the controller base (underneath the transistor-mounting area) is 90 °C. The controller might need additional heat sinking, depending on ambient conditions and how much current is being drawn by the TE device.*

The controller does have an internal 25 A fuse to limit current (Littelfuse PN: 0997025.WXN for controllers made after 1-JAN-2021 or Littelfuse PN 142.6185.5256 for controllers made prior to 1-JAN-2021). This fuse provides a degree of protection to the controller. If the fuse needs replacing, be sure to compress the fuse holder tines to ensure the new fuse will have good electrical contact to the fuse holder. In any case, an external fuse, appropriately sized for protecting the TE device, should be connected between the controller and the TE device to prevent damage and to prevent injury to the user should an over-current condition occur with a TE device rated for less than 25 A. Alternately, a power supply with integral over current protection can be used if it is appropriately sized for protecting the controller/TE device.

When making a TE device from a single TE module, the maximum operating voltage is *usually* no more than 75% of the rated Vmax of the TE module for cooling applications. The 75% rule is based on the TE module being thermally connected to a "good" heat sink; system modeling should be done to verify this rule is applicable though. If multiple TE modules are used in an electrical series or series-parallel combination, the Vmax of the system will be approximately 75% of the rated Vmax of each TE module multiplied by the number of modules in series. Applying an input voltage to the controller that is greater than the Vmax of the system will not necessarily damage the controller (unless voltage and/or current limits are exceeded), but the TE module(s) could be damaged by overheating as a result.

Power supply and TE Device wire leads should be kept as short as possible to minimize electrical losses and reduce the likelihood of generating unwanted electromagnetic interference. Use wires of a sufficient gage appropriate to the amount of electrical energy each wire is to carry. Wire insulation and size must also be appropriate to the ambient temperature and/or temperature of objects in contact with the wire. Wire leads supplied by TE Technology are for prototyping purposes and should be reviewed for appropriateness in the final application.

Use protection devices to prevent hazardous conditions and/or damage to the load (e.g. cooling assembly, heater, etcetera) and other related equipment. Protection devices must operate independently of the temperature controller circuitry. Protection devices should be placed at all points on the load and related equipment where a hazardous condition can be detected. These protection devices should de-energize the TC-36-25 RS232, the load, and, as necessary, other related secondary equipment. It is further recommended that such devices require the user to remove and correct the root cause of a fault before allowing the TC-36-25 RS232, the load, and related equipment to be re-energized. Protection devices should include, but are not limited to:

- Fuses to prevent against electrical overloads,
- Over/under temperature thermostats to prevent against hazardous and/or damaging temperatures,
- Liquid flow meters to prevent against damage due to loss of coolant flow

The TC-36-25 RS232 controller (in conjunction with the standard and optional sensors) can detect under-temperature and over-temperature conditions as well as over-current conditions, and it can be configured to de-energize the load when such conditions are detected. However, hazards and/or risk of loss or damage to the load (e.g. cooling assembly, heater, etcetera), and/or secondary equipment could still occur if the temperature controller and/or sensors were to malfunction. Therefore, independent, redundant protection devices are recommended in addition to the safeguards provided by the temperature controller. For the purposes of this manual the temperature controller and sensors are not considered protection devices.

1.4.1 One Power Supply Operation:



Make sure the power supply is **NOT** energized while making electrical connections to the controller.



Power supply should be of voltage needed for TE device.



If voltage is not between 12 V to 36 V then a two power supply configuration is necessary.

a) Install jumper across JP6-1 and JP6-2 (default setup)

b) Connect the constant DC voltage power supply (12 to 36) V to the controller:

Positive power supply terminal to WP3

Negative power supply terminal to WP4

c) Do **NOT** connect the TE device to the controller at this time.

d) See the "*Controller Wiring Diagram (Single Power Supply Setup)*" for further details.

1.4.2 Two Power Supplies Operation:



Make sure the power supplies are **NOT** energized while making electrical connections to the controller.

a) Remove jumper across JP6-1 and JP6-2

b) Connect the constant DC voltage controller power supply (12 to 36) VDC, 150 mA minimum to the controller:

Positive power supply terminal to JP6-2

Negative power supply terminal to JP6-3

Note: JP6 is a Molex connector, part number 22-23-2031

c) Connect the constant DC voltage TE device power supply (0 to 36) VDC to the controller:

Positive power supply terminal to WP3

Negative power supply terminal to WP4

Install a 1.5 kΩ, 1 W (customer-supplied) resistor across the positive and negative power-supply terminals.

d) Do **NOT** connect the TE device to the controller at this time.

e) See the "*Controller Wiring Diagram (Two Power Supplies Setup)*" for further details.

1.5 Turn power on to both the computer and the power supply(s) (which in turn powers up the controller). The on-board green LED will flash at a steady rate to indicate that the controller is energized correctly.



Do not mount the controller to a surface which is exposed to a source of heat, such as from electronics, machinery, or solar radiation.



Do not cover the controller with any object or otherwise restrict natural convection airflow around the controller. Doing so could cause the controller to overheat.



Do not mount the controller to an insulating surface. Doing so could cause the controller to overheat.



Do not operate the controller in such a manner as to cause the surface temperature of the circuit board or its frame to reach 70 °C. Otherwise the controller might be damaged and there might be a risk of fire as a result.

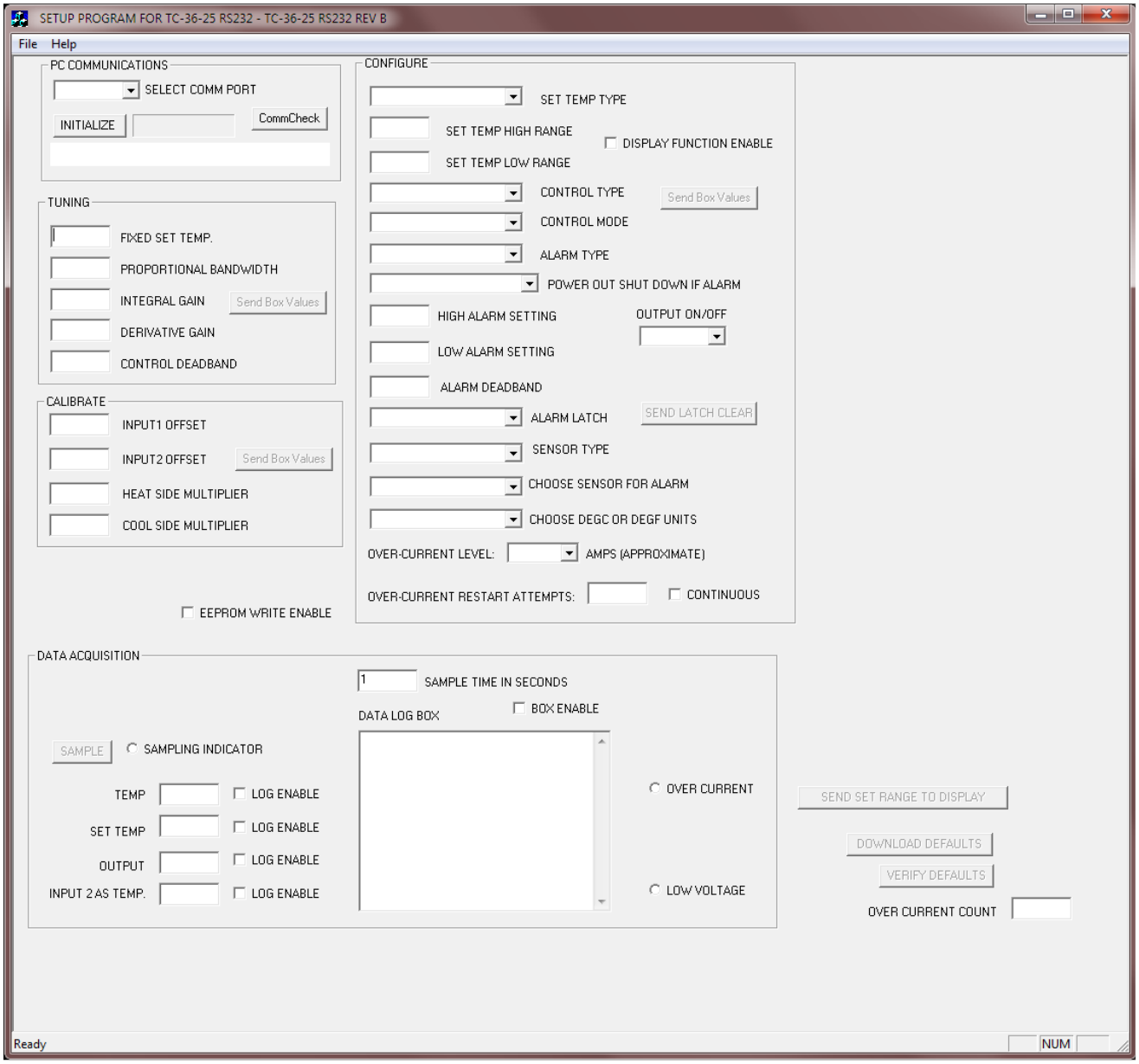


Do not allow the controller to be exposed to water (such as from dripping or leaking water lines or from water-vapor condensation if the surface temperature of the controller is below the dew point temperature).

⚠ Do not allow metallic dust/shavings to contact the controller electronics.

1.6 Insert the TC-36-25 RS232 software CD into the computer CD drive or download the software from the TE Technology website at http://tetech.com. To run the software from the CD, select START, RUN from your Windows Desktop and then enter D:\TC-36-25 RS232.exe (CD drive letter may vary). This will load the software into your computer's RAM. Alternatively, (and preferably) copy the TC-36-25 RS232.exe file to your hard-disk drive and run the program from there.

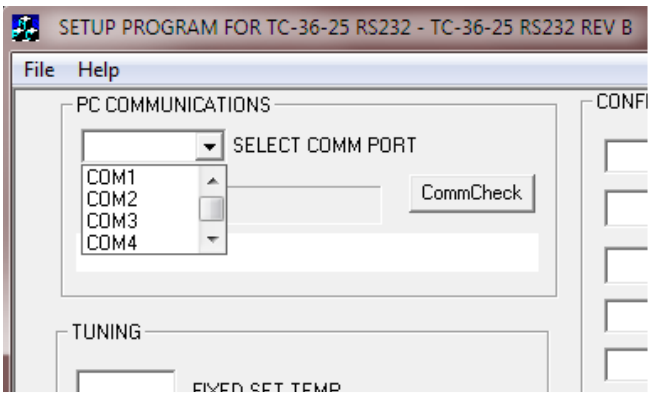
1.7 The Main Menu screen will appear on your computer monitor. All selections are made from this menu screen.



1.8 In the PC COMMUNICATIONS section, select the RS232 communications port (COM1 through COM255) to which the controller is connected by using the SELECT COMM PORT menu key. After making this selection, click on the INITIALIZE button.

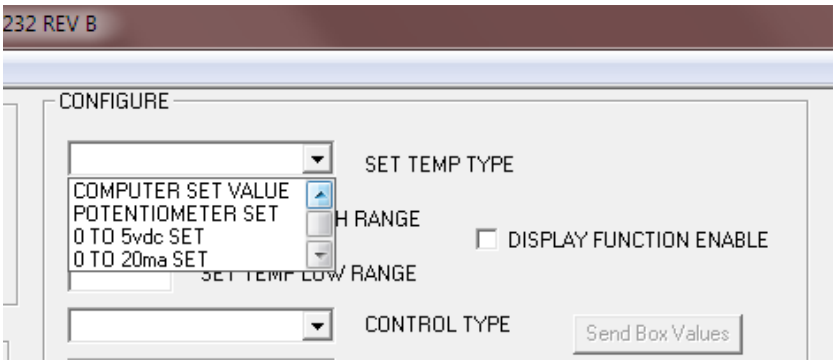
If you only have USB ports available on your computer, you can use our optional RS232 Adapter to provide USB to RS232 conversion. If you use your own USB to RS232 converter, be aware that some converters might inject noise on the transmit line from the computer and disrupt communications. The noise problem might be alleviated by installing a 0.001 microfarad, 50 V ceramic capacitor between JP4-1 and JP4-3.

NOTE: If you receive an error message, please refer to Appendix A "*Troubleshooting Communications Port*."



2.0 Configuration Setup

2.1 In the CONFIGURE section of the software, the various selections below are used to establish the custom operating criteria for the controller.



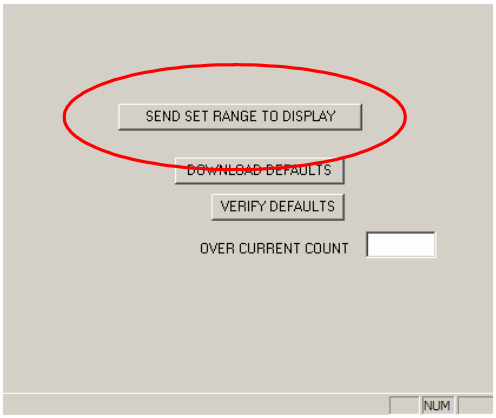
2.2 SET TEMP TYPE menu key:

a) COMPUTER SET VALUE: temperature set point is determined from software input

b) POTENTIOMETER SET, 0 TO 5vdc SET, or 0 TO 20 mA SET: temperature set point is determined by remote input. Refer to the "*Controller Wiring Diagram*" and the "*Block Diagram*" for additional information. If you intend to use one of these options, you will need to enter the SET TEMP HIGH RANGE and SET TEMP LOW RANGE values. These values are used to linearly scale the temperature range (or fixed percentage output power) that you are controlling within to the full range of the external input. The set limit values must be within the temperature range that the TC-36-25 RS232 is capable of controlling. For example, suppose you are using a (0 to 5) VDC external input to control the set point. If you then enter -20 for the SET TEMP LOW RANGE and +100 for the SET TEMP HIGH RANGE, this will create a linear scale of 5 V per 120 degrees or 0.0417 V/degree. So, to control to 10 °C, for example, you would set the external input voltage to 1.25 V.

c) DIFF.SET=INP2+FIXED SET: actual set temperature is the sum of the temperature sensed by the optional, secondary thermistor input sensor and the temperature entered as the FIXED SET TEMP value. This allows the controller to maintain a constant temperature difference between the primary thermistor temperature and the secondary thermistor.

d) JP3 DISPLAY SET VALUE: the temperature set point is determined by the set point entered with the MP-2986 Display and Keypad accessory. The DISPLAY FUNCTION ENABLE check box must be checked as well to enable the MP-2986. The allowable set temperature range for the MP-2986 can be set to the limits indicted by the values entered in the SET TEMP HIGH RANGE and the SET TEMP LOW RANGE boxes. However, to send these values to the display, the SEND SET RANGE TO DISPLAY button must be clicked. This button is located in the lower right-hand corner of the software. See the MP-2986 manual for further details.

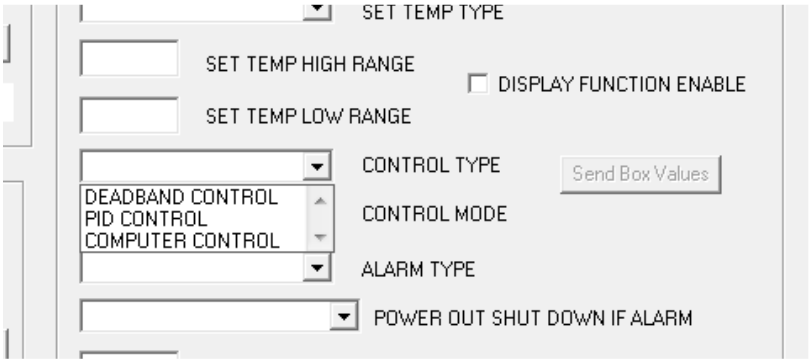


2.3 CONTROL TYPE menu key:

a) DEADBAND CONTROL: selects on/off control mode. However, DEADBAND CONTROL should not be used unless care is taken to prevent the TE device from being damaged by excessive thermal cycling.

b) PID CONTROL: selects proportional/integral/derivative control mode. When this mode is selected, the temperature controller compares the actual temperature to the set temperature and automatically adjusts the output power accordingly.

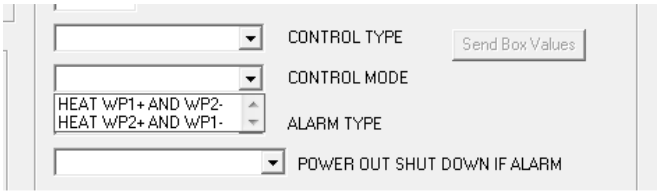
c) COMPUTER CONTROL: enables the user to select a constant, fixed-duty-cycle output (a fixed percentage output, see section 3.2 for further details.) The duty cycle is set by the value entered into the FIXED SET TEMP box. This enables the use of the externally connected computer to adjust the power output manually. There are 511 discrete output levels in the cooling mode and 511 discrete output levels in the heating mode. These are selected by entering values from -5.11 to +5.11 in the FIXED SET TEMP box. Also, see Appendix C, #14, FIXED DESIRED CONTROL SETTING.



2.4 CONTROL MODE menu key:

HEAT WP1+ AND WP2- or HEAT WP2+ AND WP1-. This selection establishes the polarity for the heating mode of the thermoelectric cooler. It allows you to reverse the current flow in the TE device without having to change the wiring.

***NOTE**: For TE Technology's standard products, the TE+ (red) wire should be attached to* WP2 *and the TE- (black) wire should be attached to* WP1 *as shown in the "Controller Wiring Diagram." The* CONTROL MODE *should then be set to* HEAT WP1+ and WP2-. *Again though, do **NOT** connect the TE device at this time.*



2.5 ALARM TYPE menu key:

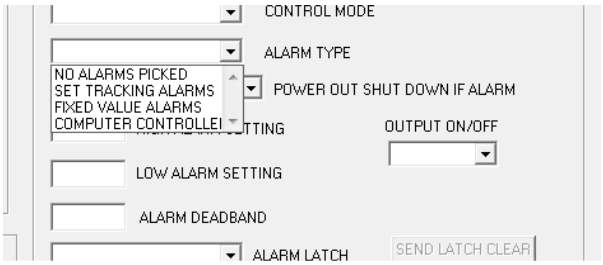
a) NO ALARMS PICKED: no alarm condition will be monitored.

b) SET TRACKING ALARMS: allows an alarm to be set with respect to the set temperature. It will move accordingly with a change of the temperature setting. This option can be used for a high alarm, low alarm, or both settings.

c) FIXED VALUE ALARMS: permits the setting of a fixed, absolute temperature either above or below the set point temperature or both.

d) COMPUTER CONTROLLED ALARM: provides for user activation of the alarm relay via the computer software. The "*Expansion Connector Wiring Diagram*" shows how customer-supplied LED's can be installed to signal various alarm conditions.

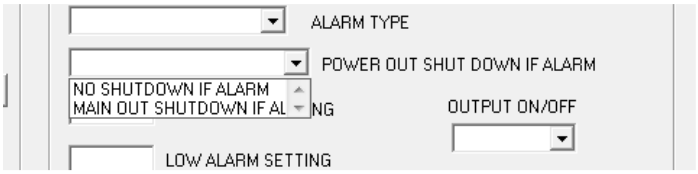
Associated with the ALARM TYPE configuration are the HIGH ALARM SETTING box, LOW ALARM SETTING box, and the ALARM DEADBAND box. If an alarm type has been selected, enter the desired high and low temperature values that will trigger an alarm condition. The ALARM DEADBAND option sets the hysteresis of the alarm values from 0.1 degrees to 100 degrees.



2.6 POWER OUT SHUT DOWN IF ALARM menu key:

a) NO SHUT DOWN IF ALARM: controller will continue to supply power to the TE device regardless of alarm condition.

b) MAIN OUT SHUTDOWN IF ALARM: shuts off power output to the TE device when an alarm condition exists.

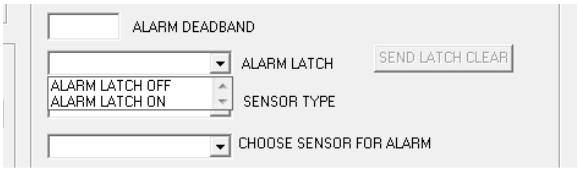


2.7 ALARM LATCH menu key:

a) ALARM LATCH OFF: controller will automatically reset to a non-alarm state if the alarm condition self-corrects.

If the alarm condition is recurring and the ALARM LATCH OFF is selected, the TE device could be damaged by thermal fatigue stress imposed by repeated long-term power cycling.

b) ALARM LATCH ON: controller will maintain the alarm condition until it is manually cleared. If an alarm condition exists, the alarm latch can be reset by clicking the SEND LATCH CLEAR button or by electrically shorting the Alarm Cancel pin, JP5-5 to the circuit ground pin, JP5-4.



2.8 SENSOR TYPE menu key:

The available options correspond to various temperature-resistance curves for thermistors as shown in "*Temperature-Resistance Curves*" in the Appendix. Select the sensor type having the same temperature-resistance curve as the thermistor you intend to use with the controller:

a) TS-141 5K, control temperature range: -40 °C to +70 °C

b) TS-67, TS132 15K, control temperature range: -20 °C to +100 °C

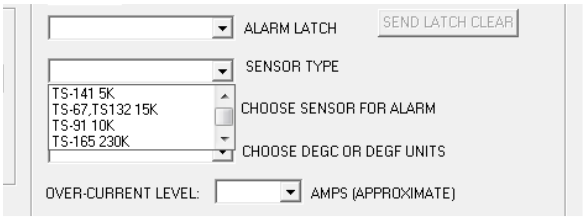
c) TS-91 10K, control temperature range: -20 °C to +85 °C

d) TS-165 230K, control temperature range: +25 °C to +250 °C

e) TS-104 50K, control temperature range: 0 °C to 150 °C

f) YSI H TP-53, control temperature range: -15 °C to +80 °C

NOTE: Select **TS-67, TS132 15K** when using the supplied **MP-3193** sensor or one of the other sensors listed in Appendix D *"Thermistor Styles for TC-36-25 RS232."* This will provide a control range of -20 °C to +100 °C. However, remember that depending on the type of cooler you have, the cooler itself might not be suitable for operation at temperatures greater than 70 °C.



If you have an existing 10 kOhm thermistor, the TS-91 10K or YSI H TP-53 might be equivalent. The TS-91 10K is equivalent to the 10 kOhm thermistor, curve "B" from YSI Temperature, Inc. The YSI H TP-53 is equivalent to the 10 kOhm thermistor curve "H" from YSI Temperature, Inc.

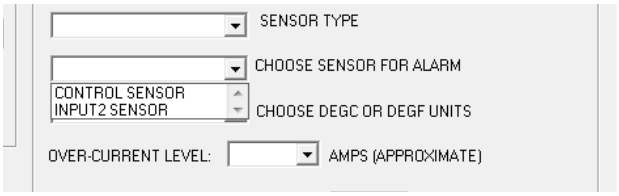
Contact TE Technology if you need a sensor that uses a temperature scale different from the "TS-67, TS132 15K", 20 °C to +100 °C range.

If you are using two thermistors with the controller, they must have the same resistance versus temperature characteristics. Also be sure that you have selected the correct sensor type. Otherwise a dangerous condition could exist because the actual temperature could be higher or lower than the temperature being interpreted by the controller.

2.9 CHOOSE SENSOR FOR ALARM menu key:

a) CONTROL SENSOR: the primary sensor temperature is monitored for alarm conditions

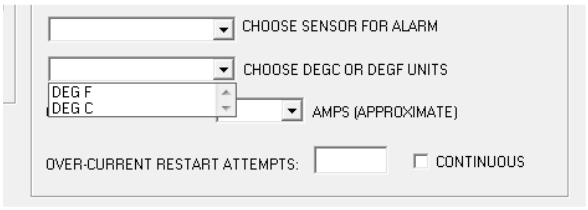
b) INPUT 2 SENSOR: a secondary thermistor (see "*Controller Wiring Diagram*") can be attached to the heat sink or other object in order to detect over-temperature conditions. (Note: the INPUT 2 SENSOR secondary thermistor cannot be used if you are using a potentiometer or voltage/current levels to control the set point.)



2.10 CHOOSE DEGC OR DEGF menu key:

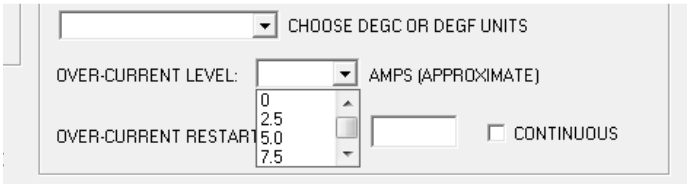
a) DEG F: all temperatures are read/interpreted in degrees Fahrenheit.

b) DEG C: all temperatures are read/interpreted in degrees Celsius.



2.11 OVER CURRENT LEVEL menu key:

This selects the level at which the over-current protection for the TE device shuts the output off. This level is adjustable in 2.5 A increments, and the allowable levels range from 0 A to 40 A. The controller will automatically attempt to restart the output (either continuously or a fixed number of times) per the conditions set as described in section 2.12. During the restart attempts, the output will still be shut down each time if the over-current level is reached again. If a fixed limit of attempts is reached the output will be disabled until a "latch clear" signal is sent (see section 2.7) or the controller is turned off and then on again.

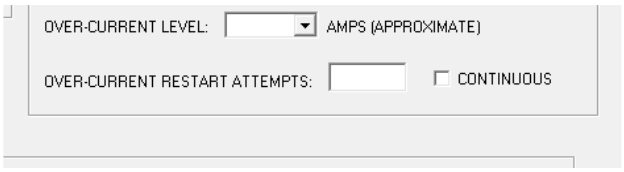


NOTE: THIS IS NOT AN ANALOG CURRENT LIMIT FEATURE!

The over-current value is approximate; the actual current value the controller shuts off at may differ by 3 A or more from the selected over-current level. Also, it is normal to have an output current surge when the direction of current flow is instantaneously reversed to a TE device that has a temperature difference established across it. When this happens, the "apparent electrical resistance" of the TE device is lower because the Seebeck back-voltage does not immediately reverse polarity. The reversal of current will eventually reverse the temperature difference across the TE device (and then its Seebeck back-voltage will likewise change polarity). As the temperature difference reverses, the current will revert back down to a steady-state level.

2.12 OVER-CURRENT RESTART ATTEMPTS / CONTINUOUS boxes:

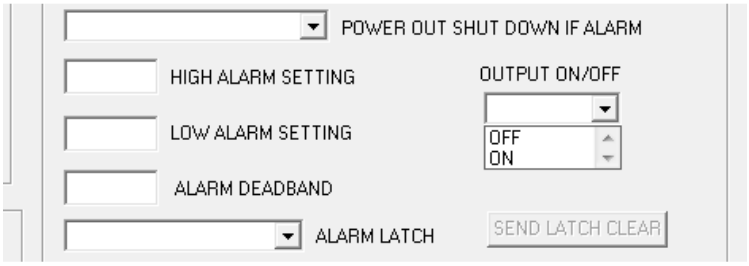
This sets the number of restarts the controller will attempt. Selecting the CONTINUOUS box provides an infinite number of restarts. If a fixed limit of attempts is reached, the output will be disabled until a "latch clear" signal is sent or the controller is turned off and then on again.



2.13 OUTPUT ON/OFF menu key:

a) OFF: output power to the TE device is shut off

b) ON: output power to the TE device is enabled and the controller will begin controlling to the set point temperature (if possible)



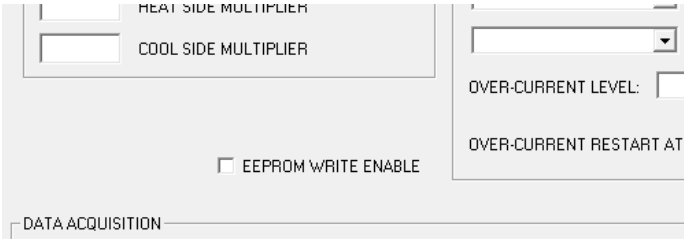
NOTE: Select OFF for the initial setup. This will ensure that the controller will not begin controlling the TE device to a temperature that might inadvertently cause damage if the controller were not yet completely set up.

2.14 EEPROM WRITE ENABLE check box:

Upon a power-up or reset condition, the controller performs an initialization of all command variables that have write commands. The controller transfers the last values stored in non-volatile memory (EEPROM) to appropriately referenced static RAM locations. This action is performed so that the controller can run faster (RAM is faster than ROM). This also allows the controller to run as a stand-alone controller, separate from the computer.

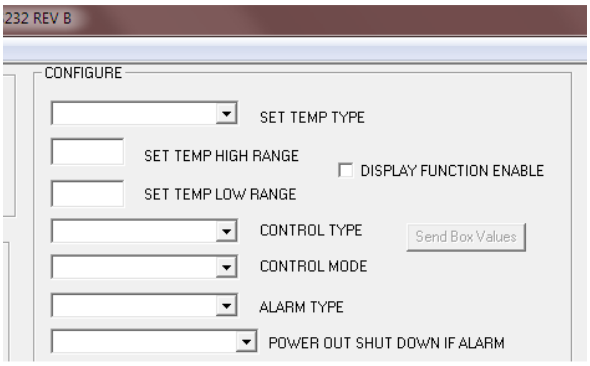
a) EEPROM WRITE ENABLE is checked: any changes in the run-time values of the command variables are stored in EEPROM as well in RAM and thus will be recalled upon a power-up or reset condition.

b) EEPROM WRITE ENABLE is un-checked: run-time values are stored only in RAM. No settings are saved to EEPROM. This setting gives you the ability to change run-time values without changing your desired power-up settings. This also allows the user to send unlimited write commands to the controller without exceeding the maximum number of writes to an EEPROM location (1,000,000).



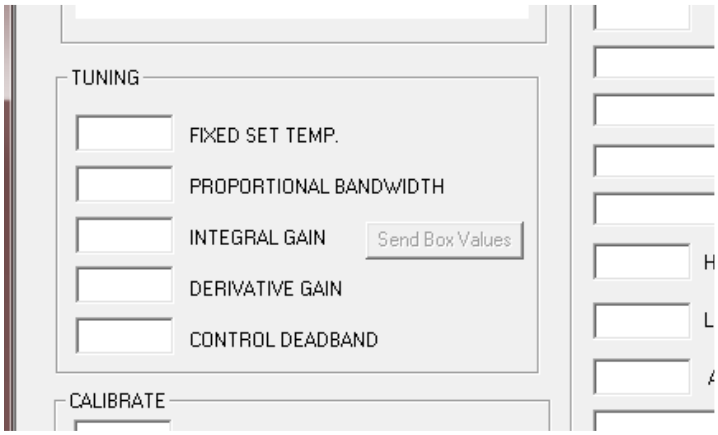
2.15 Review all of your controller configuration selections. If all the configuration selections are correct for your application, click the SEND BOX VALUES button in the CONFIGURE section to download these settings to the controller.

NOTE: Remember to click the SEND BOX VALUES button to update the controller any time CONFIGURE variables have changed.



3.0 Tuning Parameter Description

3.1 In the TUNING section of the software, the various selections below are used to establish the set point and the variables affecting set point stability.



3.2 FIXED SET TEMP. box:

a) Enter the set temperature value in degrees. This temperature must be within both the range of the selected input sensor and the limits of low and high set ranges from the controller configuration setup. Also, verify that the cooler is capable of safely operating at the entered set temperature. This is particularly important if you are heating. While you can control to +100 °C using the standard thermistor, many TE devices are only rated for at most 80 °C.

b) If you selected COMPUTER CONTROL in the CONTROL TYPE menu key under the CONFIGURE section, the values that can be entered in the FIXED SET TEMP box range from –5.11 to +5.11. This corresponds linearly to a fixed percentage of power output where –5.11 equals –100% power and +5.11 equals +100% power. If you selected HEAT WP+1 and WP2- under the CONTROL MODE menu key under the CONFIGURE section, then -5.11 corresponds to full-power cooling. The value is adjustable in 0.01 unit increments.

3.3 PROPORTIONAL BANDWIDTH:

The acceptable bandwidth values that may be entered are (1 to 100) degrees.

The proportioning bandwidth is the temperature span over which the output power is proportioned from -100% to +100%. The bandwidth is centered about the temperature set point, and once set the proportional output will vary as the actual temperature moves through the bandwidth range. That is, the controller output is +100% at the end of the bandwidth range above the set point, it decreases to 0% power as it reaches the set point, and then reverses to -100% as it reaches the end of the bandwidth range below the set point.

For example, suppose the controller is being operated in the cooling mode, the set point is 10.0 °C, and the bandwidth is set to 5 °C (with INTEGRAL GAIN and DERIVATE GAIN both set to zero). The controller will be at +100% output until the temperature cools to 12.5 °C. Power then starts to proportionally decrease as the sensor temperature is cooled below 12.5°C. The power will be reduced to 0% when the sensor is at 10.0 °C. Finally, the power will reverse polarity and proportionally increase to -100% if the sensor temperature decreases to 7.5°C.

If the bandwidth is set too narrow, the temperature will oscillate around the set point. If the bandwidth is too wide, the controller will be slow to respond or may never reach set point.

3.4 INTEGRAL GAIN:

The acceptable values that may be entered are (0.00 to 10) repeats per minute.

With just proportional control, the controller's output is, by definition, 0% when the actual temperature reaches the set temperature. Because some non-zero output power level is almost always required to reach the set point, using ***only*** proportional control will not allow the controller to maintain a desired set point. Therefore, introducing an integral gain allows for an output amount other than 0% when the actual temperature reaches the set temperature. It essentially shifts the output power to the average level required to maintain the desired set point.

For example, suppose the set temperature is 10.0 °C, the bandwidth is set to 5 °C, and the controller settled to a constant 11.2 °C (corresponding to 48% power with only the proportional bandwidth active).

- In this case the "error", or difference in temperature between the set point and actual temperature, is 1.2 °C.
- From the example in section 3.3 we know that the proportional output will change by 40% for every 1 °C change in the error (this is bandwidth gain of 40 % per °C).
- Let's assume the integral gain is activated by changing its setting from "0" to "1 per minute".

The integral function will now ramp the output at a rate determined by the error signal, the proportional bandwidth gain, and the integral gain. The rate is determined by multiplying the error, the bandwidth gain, and the integral gain. In this case, if the integral control is set to 1 repeat per minute, the controller will increase the output power at a rate of 48% per 1 minute.

$$\frac{40\%}{°C} * 1.2°C * \frac{1}{\text{minute}} = 48\% / \text{minute}$$

This output % is updated continuously. Of course, the maximum output is limited to +100% and the minimum is limited to -100%.

If the integral gain is set too high, the temperature will oscillate. If integral control is set too low, it will take a long time for the temperature to settle to steady state.

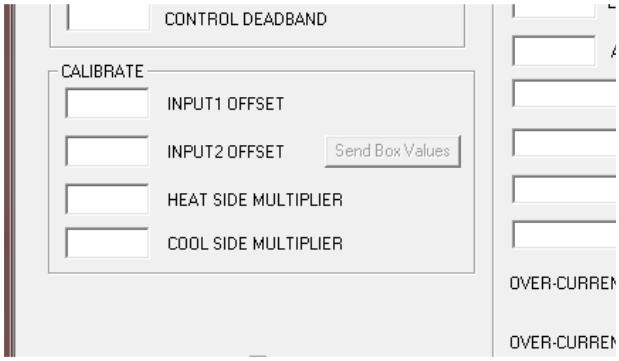
3.5 DERIVATIVE GAIN:
The acceptable values that may be entered are (0.00 to 10) cycles per minute.

The derivative gain senses the rate of change of the temperature and allows the controller to anticipate the power needed to compensate for rapid changes in system loading. This term is generally used only on very sluggish systems or where very quick response is necessary. It works in a way similar to the integral gain, but acts upon change in error signal and not the actual error signal.

3.6 CONTROL DEADBAND:
The controller can be set to turn on and off by either rising or falling temperatures where no heating or cooling takes place. This band is expressed in degrees, and the acceptable values that may be entered are 0.1 to 100. This setting is only utilized when CONTROL TYPE is set to DEADBAND CONTROL.

4.0 Calibration Parameter Description

4.1 The CALIBRATE section provides additional variables that can be used to fine tune your system's operation. You may want to try controlling with the initial settings prior to entering values in this section.



4.2 INPUT 1 OFFSET is a manual method of compensating for a temperature difference between the sensor 1 temperature and actual control temperature.

4.3 INPUT 2 OFFSET is a manual method of compensating for a temperature difference between the sensor 2 temperature and actual temperature.

4.4 HEAT SIDE MULTIPLIER is a 0.00 to 2.00 numerical multiplier that compensates for the non-symmetrical response of the thermoelectric cooler between the heat and cool modes. When the controller is in heating mode it takes the computed PID output power value and multiplies it by this multiplier to derive the actual output level. Setting the value to 0 makes the controller a "cool only" controller.

4.5 COLD SIDE MULTIPLIER is a 0.00 to 2.00 numerical multiplier that compensates for the non-symmetrical response of the thermoelectric cooler between the heat and cool modes. When the controller is in cooling mode it takes the computed PID output power value and multiplies it by this multiplier to derive the actual output level. Setting the value to 0 makes the controller a "heat only" controller.

4.6 If you have entered values in the CALIBRATE section and they are desired settings, click the SEND BOX VALUES button to download these constants to the controller.

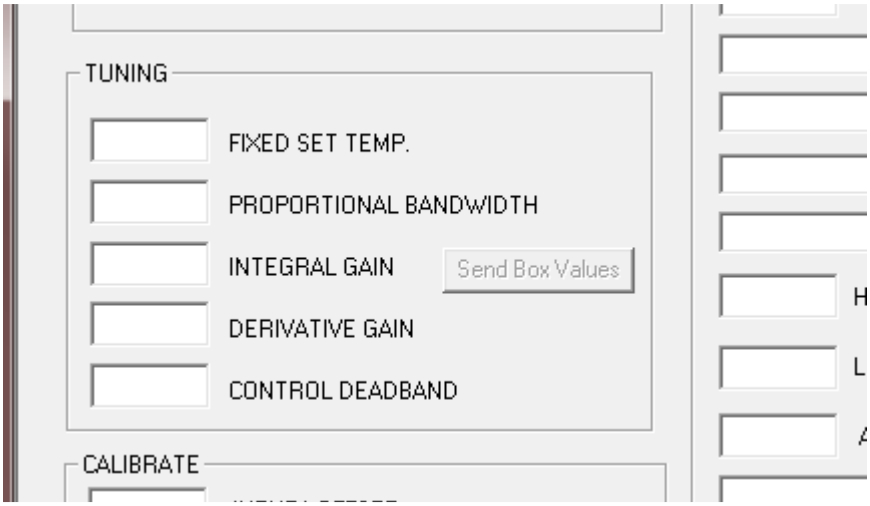
5.0 Final Setup—Controller Tuning

The tuning method follows the Ziegler-Nichols closed-loop tuning principals. The controller will first be set to a high proportional bandwidth setting with no integral or derivative function (integral gain and derivative gain = 0). Then, the bandwidth is gradually decreased until the temperature approaches set point and a small, sustained oscillation in temperature is observed. The other tuning parameters are then readjusted based on the time period of the temperature oscillation (natural period) and the proportional bandwidth needed to cause this oscillation.

⚠ Improper tuning of this temperature controller can lead to excessive thermal cycling and/or overheating of the thermoelectric device, either of which are known to reduce the lifetime of any thermoelectric device. Care should be taken to prevent the temperature of the TE device from going beyond the range specified by the device manufacturer. Care should also be taken so that any thermal cycling of the TE device is a result of changes in the controller's set-point temperature and not instability at a given set point due to improper selection of the tuning variables.

5.1 Enter the desired control set point in the FIXED SET TEMP. box of the TUNING section. Then click the SEND BOX VALUES in the TUNING section to enter the set point temperature into the controller RAM.

NOTE: Remember to click the SEND BOX VALUES button to update the controller anytime TUNING variables have changed.

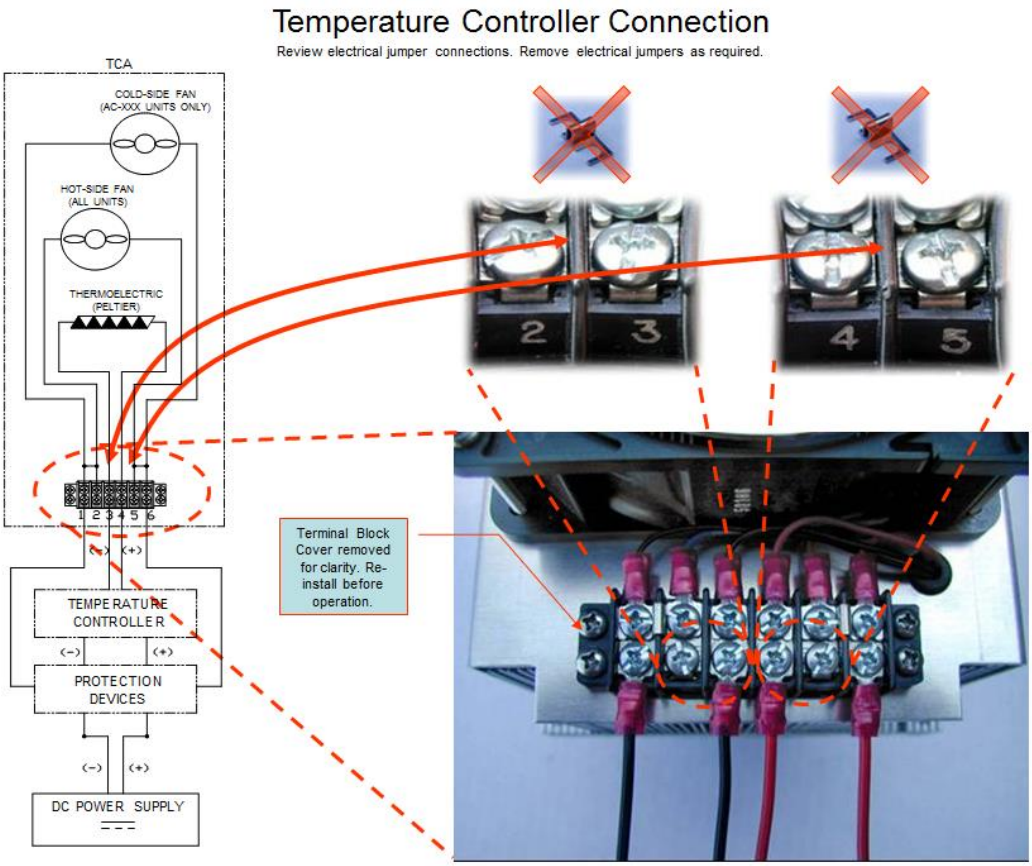


5.2 Connect **ONLY** the TE device to the controller:

Positive TE device terminal to WP2

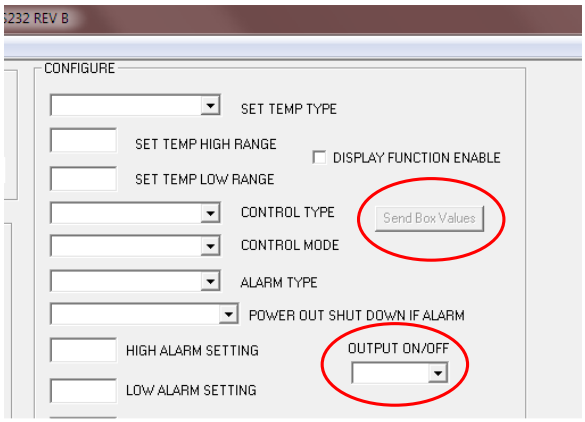
Negative TE device terminal to WP1

TE Technology's standard thermoelectric cooling assemblies (TCA) have at least one fan on the heat sink. The standard configuration has the thermoelectric modules and fan(s) wired to a terminal block with jumpers across the terminals so that the fans and modules are connected in parallel. However, this configuration is applicable only when applying power directly from the power supply. When using the TCA with the temperature controller, the jumpers **MUST** be removed so that the controller is controlling power only to the thermoelectric modules. There must be no electrical connection between the fans and the modules; fans must be connected directly to the power supply, not to the controller. *The controller will be damaged if this is not followed*. See the cooler manual for further details, but the picture below shows the basic setup.



NOTE: Generally there is approximately a 0.5 to 1.3 V drop from the power supply to the TE device. You might need to adjust the power supply accordingly to ensure full power is delivered to the TE device when needed.

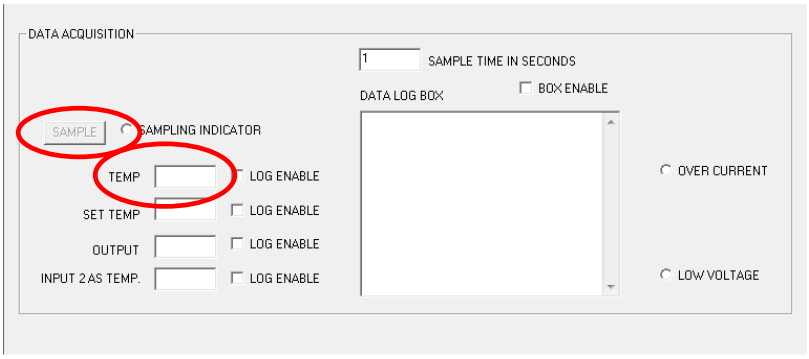
Next, select ON in the OUTPUT ON/OFF menu key in the CONFIGURE section. Then click SEND BOX VALUES in the CONFIGURE section. The controller will begin to send output power to the TE device.



5.3.0 Enter the following parameters:
PROPORTIONAL BANDWIDTH: 20
INTEGRAL GAIN: 0
DERIVATIVE GAIN: 0

NOTE: whenever a tuning parameter is entered in the box, you must click the SEND BOX VALUES button in the TUNING section in order to download the values to the controller.

5.3.1 Click the SAMPLE button to monitor the actual temperature being sensed. The sensed temperature will be shown in the TEMP box.



5.3.2 Allow the TE device to reach steady state. Incrementally reduce the bandwidth setting, allowing the controller to reach steady-state at each increment, until the system just begins to oscillate. At this point, the bandwidth is too small. Note the bandwidth setting that just caused the system to oscillate and note the time period of oscillation in minutes. The time period will be used later for determining the integral gain and derivative gain settings.

NOTE: The system temperature will likely begin to oscillate before reaching the set point temperature. This is normal.

5.3.3 Multiply the current proportional bandwidth setting by 2.2, and enter it as your new PROPOROTIONAL BANDWIDTH setting. Be sure to click “SEND BOX VALUES” after entering new parameters. The system should come into control and maintain a steady temperature near the set point.

5.3.4 The integral gain is calculated as follows: I = 0.54/T where I is the integral gain, and T is the time period, in minutes, determined in section 5.3.2. Enter this value into the INTEGRAL GAIN.

For example, suppose the system's period of oscillation with the appropriately set proportional bandwidth was 75 seconds (1.25 minutes). The suggested integral gain is therefore:

I = 0.54/1.25 minutes = 0.43 repeats/minute

5.3.5 The derivate gain is often times difficult to apply and might cause more trouble than it is worth. If you are not experienced in process control, you may be better off leaving the DERIVATIVE GAIN set to zero.

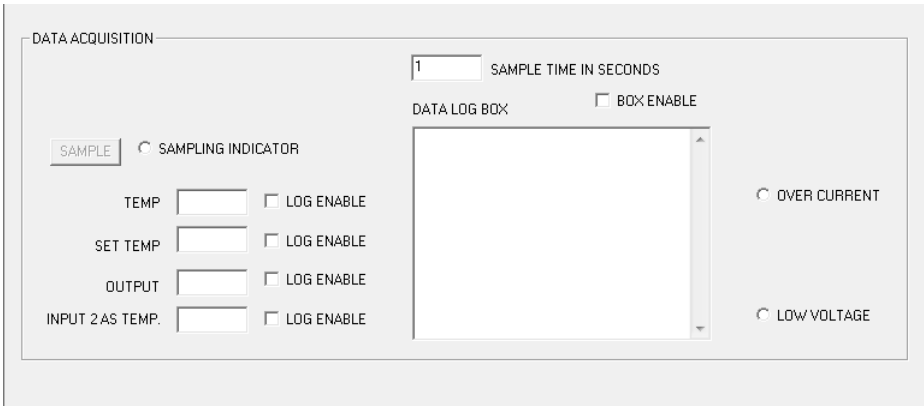
If you decide to use derivative gain, the other values should be adjusted first.

a) Instead of multiplying the initial bandwidth setting by 2.2, multiply it by 1.7, and enter this as the new PROPORTIONAL BANDWIDTH setting.
b) Calculate the integral gain as follows: I = 1.2/T, and enter this into the INTEGRAL GAIN setting.
c) Calculate the derivative gain as follows: D = 0.075 x T, and enter this into the DERIVATIVE GAIN setting.

5.4 Setup of the TC-36-25 RS232 is now complete. However, the proportional, integral, and derivative settings are approximate settings and might need further minor adjustments.

You might also want to save your settings to EEPROM for future recall (see section 2.14)

6.0 Data Acquisition Features



6.1 SAMPLE button:
Clicking the sample button instructs the controller to report the controller operating conditions for TEMP, SET TEMP, OUTPUT, INPUT2 AS TEMP, and OVER CURRENT COUNT.

6.2 SAMPLE TIME IN SECONDS box:
Enter the time, in seconds. This sets the controller update interval for the various operating conditions.

6.3 TEMP box:
This shows the temperature currently being sensed by the primary thermistor.

6.4 SET TEMP box:
This simply reports what was entered in the FIXED SET TEMP. box.

6.5 OUTPUT box:
This indicates the percentage of power (duty cycle) being applied to the TE device.

6.6 INPUT2 AS TEMP box:
This shows the temperature of the secondary thermistor if it is installed.

6.7 LOG ENABLE check box:
If the box is unchecked, the controller will not save any previous data reported to software.
If the box is checked, the controller will report the data to the DATA LOG BOX before updating at the next sample time interval.

6.8 DATA LOG BOX:
If any of the sample boxes have the LOG ENABLE box checked, the data from those boxes will be recorded to the DATA LOG BOX at each time interval. Be sure that the BOX ENABLE box is checked. The data does scroll down and off of the screen. However, you can cut and paste it into a spreadsheet if necessary.

6.9 OVER CURRENT indicator:
This indicator shows when the controller has shut the output off because of an over current condition.

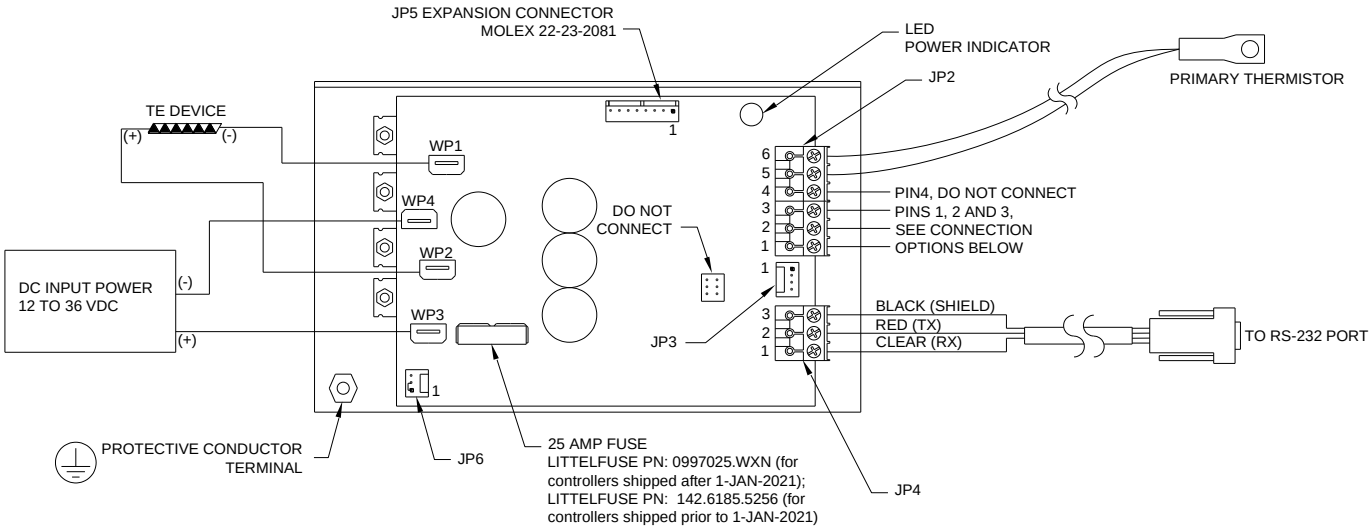
6.10 LOW VOLTAGE indicator:
This indicator shows when the output driver circuitry has turned the output MOSFETs off due to a low controller circuit voltage. The output will be turned off if the controller circuit voltage drops below approximately 11.0 to 11.2 volts. The output will automatically restart when the voltage increases to approximately 11.4 volts. This is a hardware based function safety function and cannot be overridden by software settings.

7.0 Custom Software

The controller does not specifically have to be used with the software that is provided. You can create your own control programs using commercial software such as LabVIEW from National Instruments. This might be useful if you wanted to control a specific temperature profile over a particular amount of time. This is accomplished by communicating through the RS-232 port of the computer using the command set for the controller. The command set is given in Appendix B "*Serial Communications*."

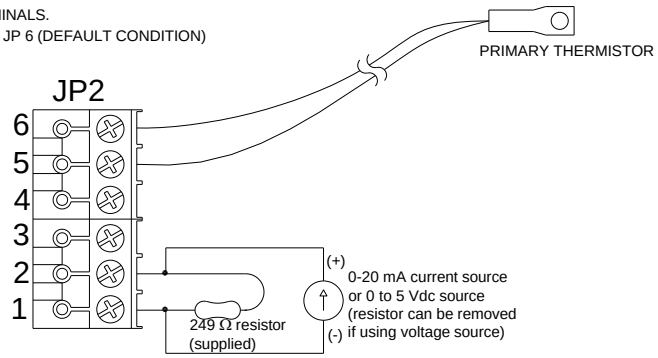
TE Technology has developed some LabVIEW programs for internal use. We would be happy to share them for use as a starting point for your custom software application. Please email the company if you are interested in this option.

Controller Wiring Diagram: One Power Supply Setup

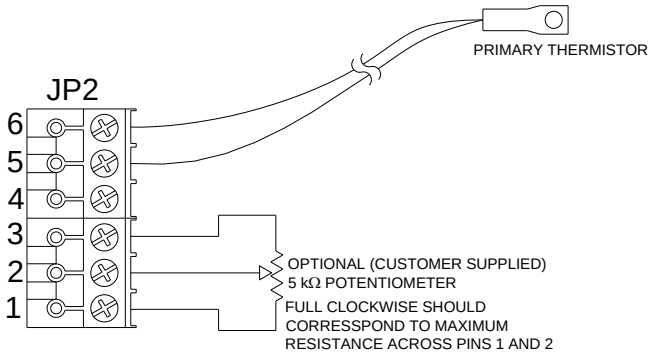


NOTE: 1. WP1, WP2, WP3, AND WP4 ARE 6.35 mm (.25 inch) QUICK CONNECT TERMINALS.
2. SINGLE POWER SUPPLY OPTION: INSTALL JUMPER ON PINS 1 AND 2 OF JP 6 (DEFAULT CONDITION)

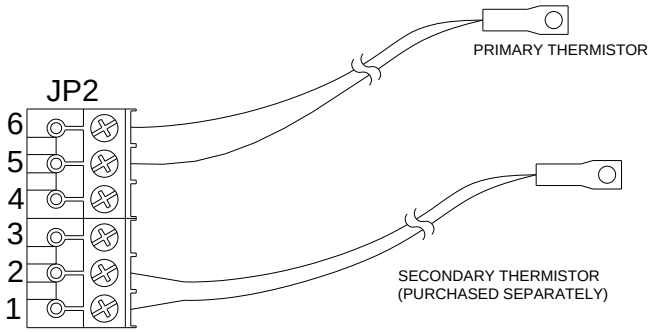
OPTION 1
Proportional Signal for Adjusting Set Point



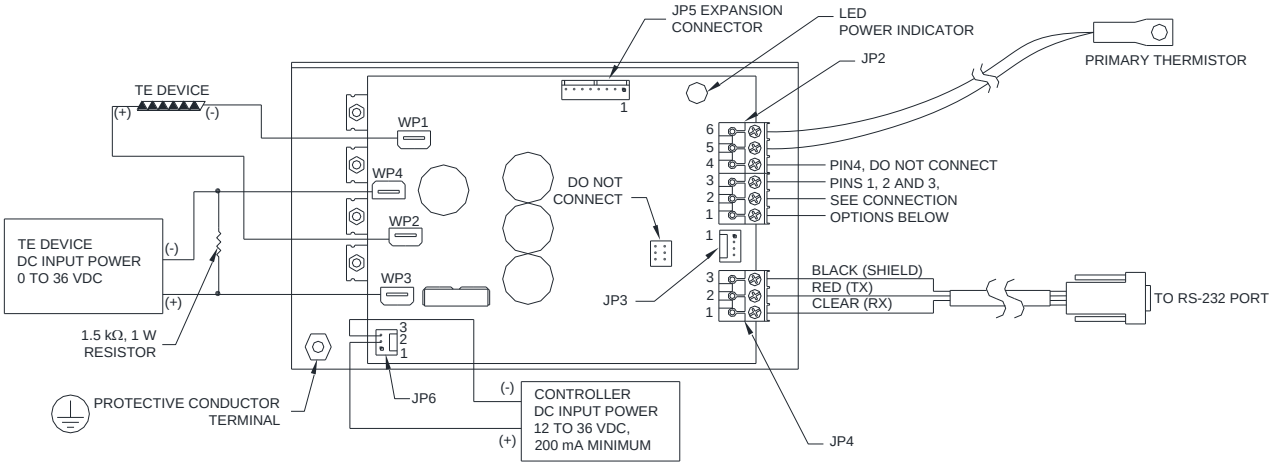
OPTION 2
Variable Resistance for Adjusting Set Point



OPTION 3
Second Thermistor for Differential Control or for Sensing Over-temperature Condition

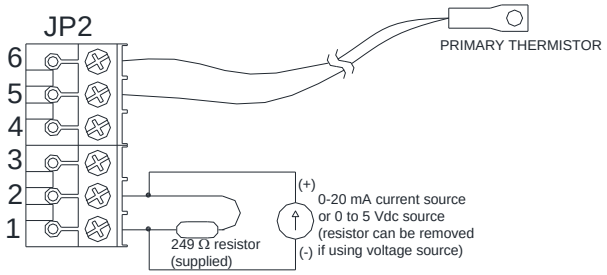


Controller Wiring Diagram: Two Power Supplies Setup

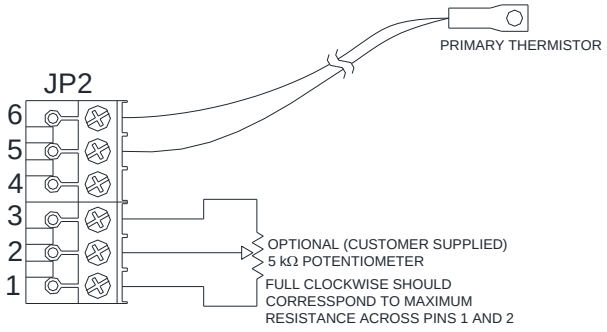


NOTE: 1. WP1, WP2, WP3, AND WP4 ARE 6.35 mm (.25 inch) QUICK CONNECT TERMINALS
2. TWO POWER SUPPLIES SETUP: A. TE DEVICE POWER SUPPLY CONNECTS TO WP3(+) AND WP4(-)
B. CONTROLLER POWER SUPPLY CONNECTS TO JP6-2(+) AND JP6-3(-) (REMOVE JUMPER FROM JP6)
JP6: MOLEX PN: 22-23-2031
3. INSTALL 1.5 kΩ, 1 W RESISTOR (customer-supplied) ACROSS WP3(+) AND WP4(-).

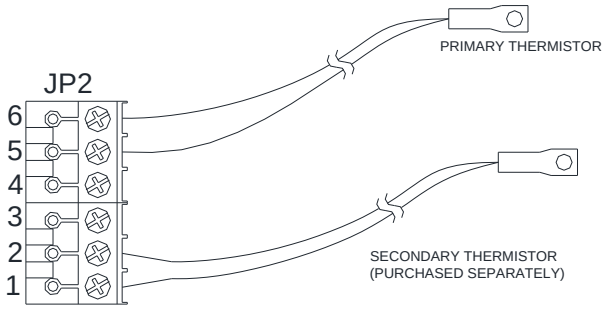
OPTION 1
Proportional Signal for Adjusting Set Point



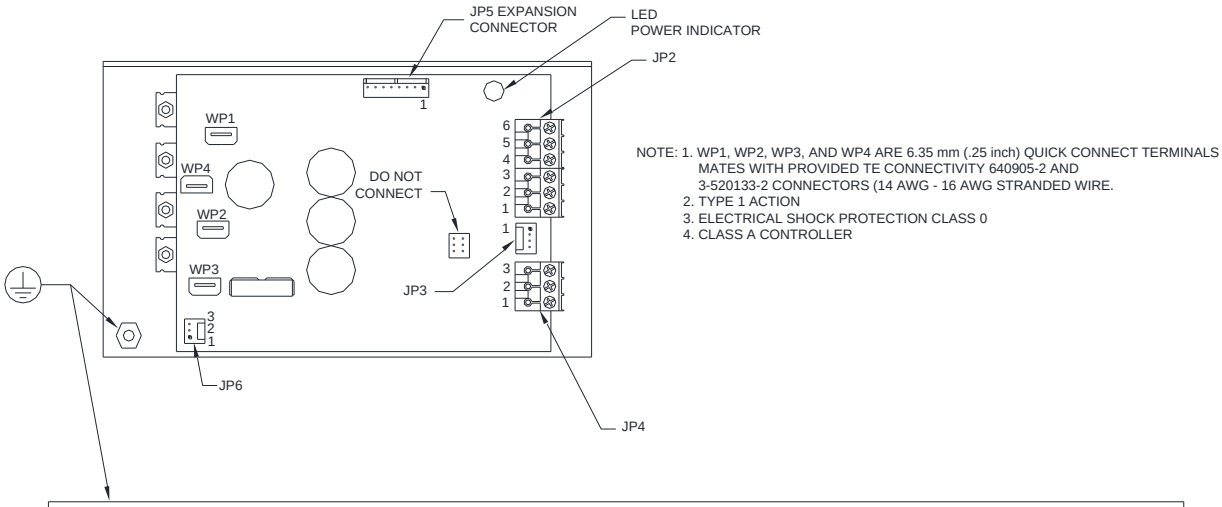
OPTION 2
Variable Resistance for Adjusting Set Point

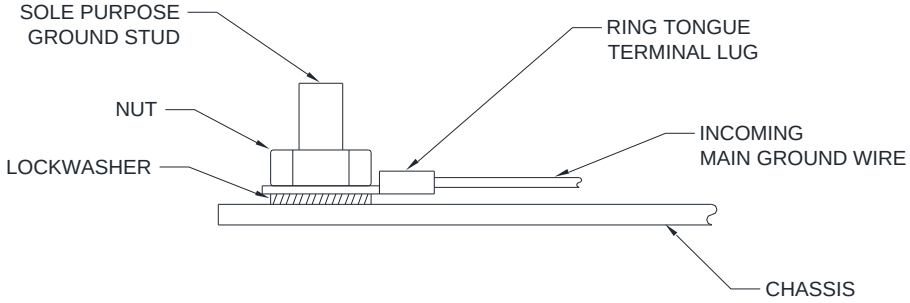


OPTION 3
Second Thermistor for Differential Control or for Sensing Over-temperature Condition

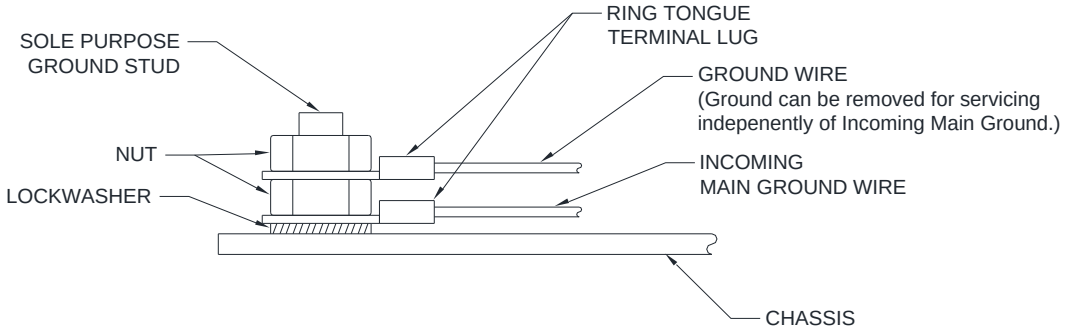


Safety Ground for TC-36-25-RS232-UL





Proper Single Ground for TC-36-25-RS232-UL

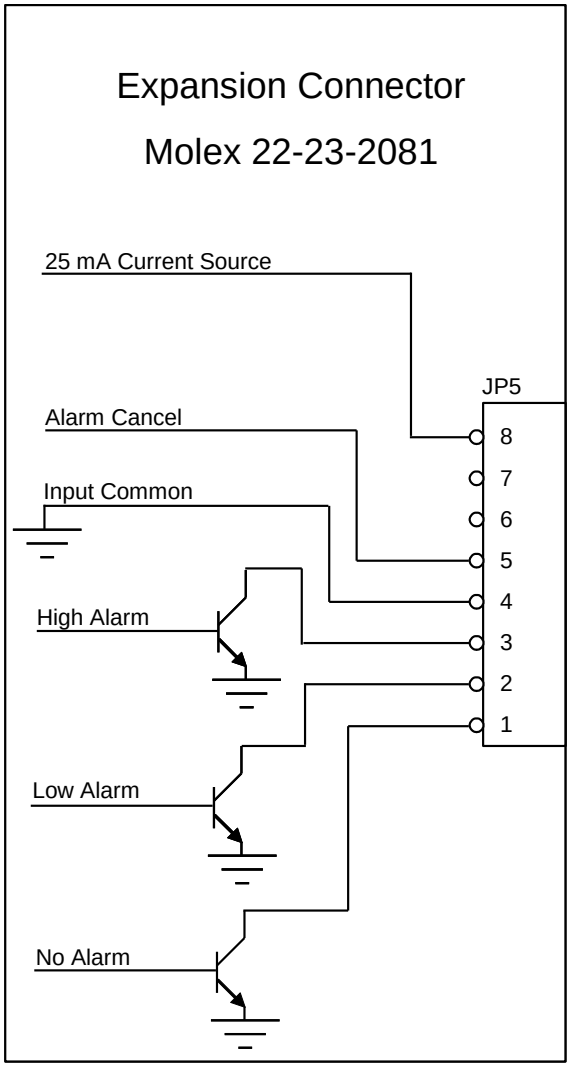


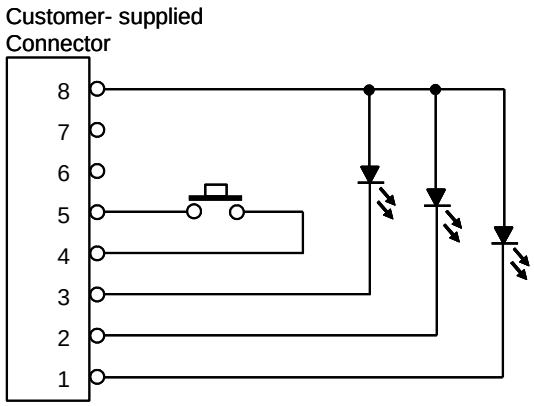
Proper Ground for TC-36-25-RS232-UL when adding Ground Wire from TE device

NOTE: Wire colors for Incoming Main Ground and Ground shall be green or green/yellow.

Expansion Connector Wiring Diagram

Note: The 25 mA current source is a true current source. Maximum compliance voltage is approximately V+, the input voltage to the temperature controller. No external current limit resistors are needed for the LED. The LED must be capable of being driven with a 25 mA continuous current.

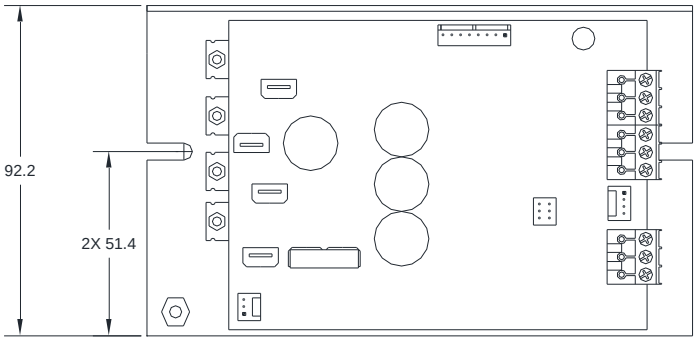




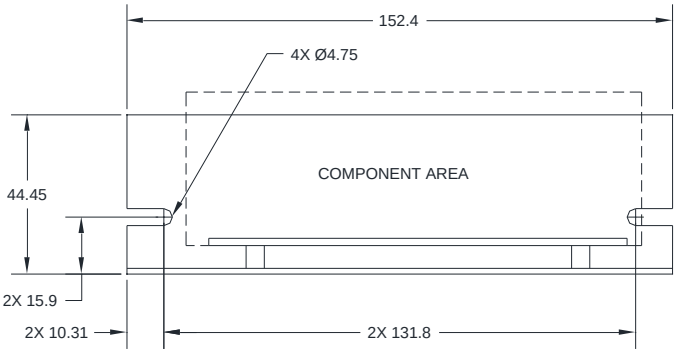
Note: Pins 6 and 7 not functionally defined.

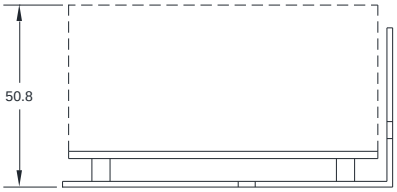
Please do not connect.

Mechanical Package Drawing

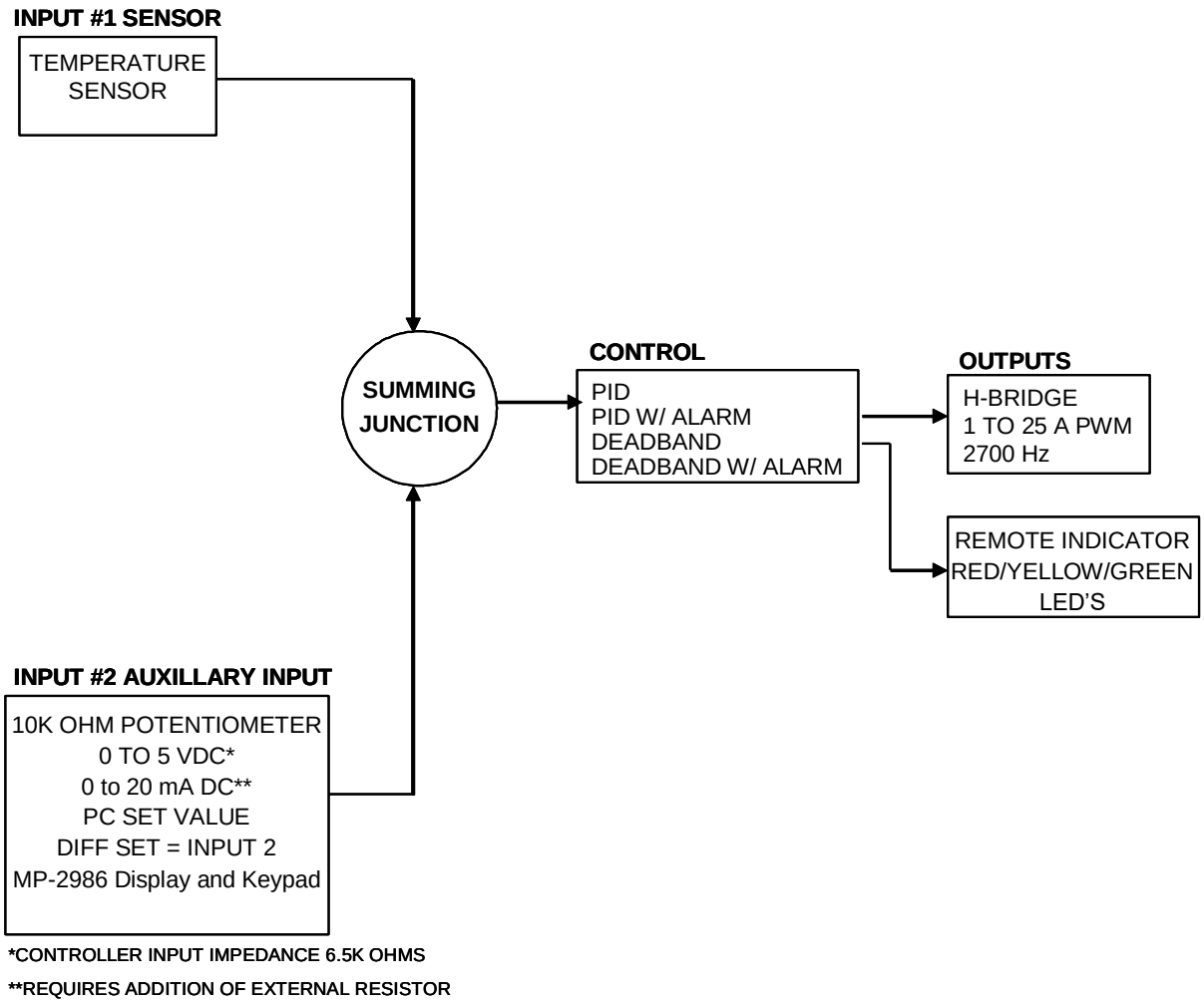


DIMENSIONS IN MILLIMETERS





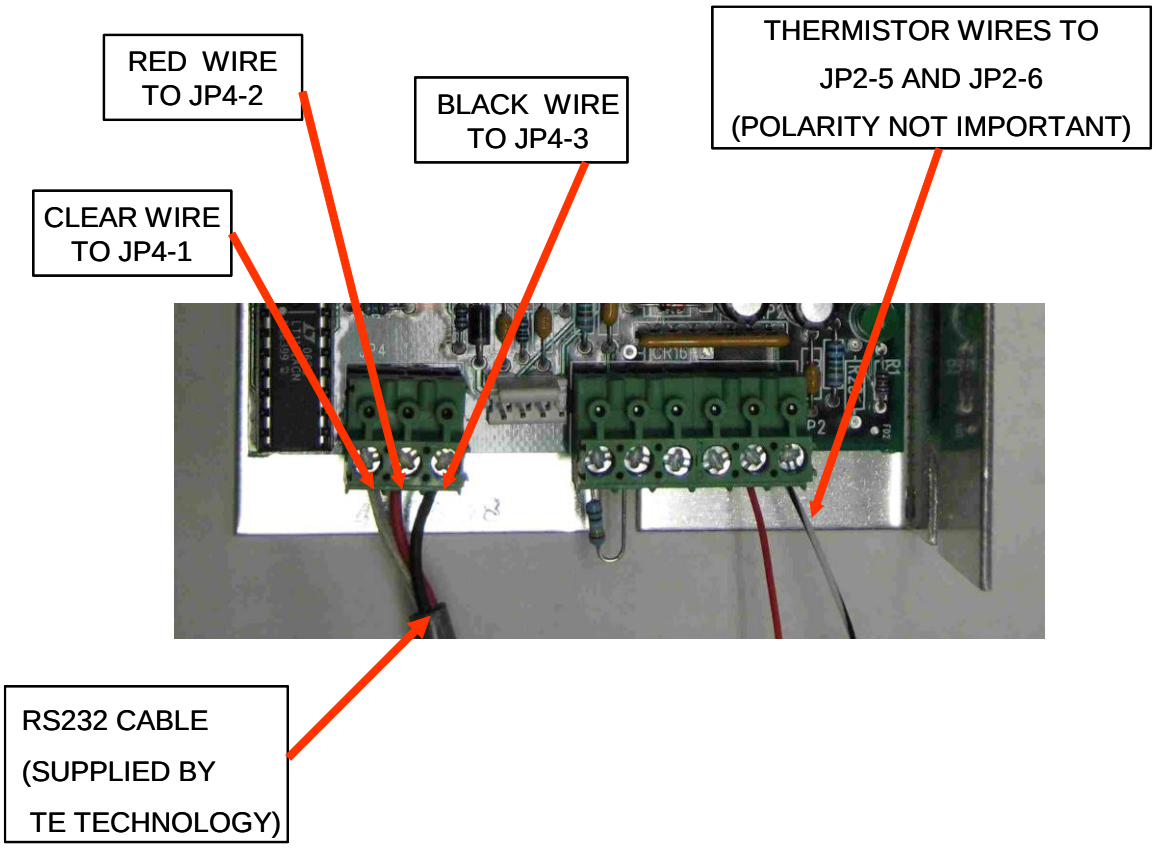
Block Diagram



*CONTROLLER INPUT IMPEDANCE 6.5K OHMS

**REQUIRES ADDITION OF EXTERNAL RESISTOR

RS232 Communications Connections



PC CONNECTION TABLE

	PC CONNECTOR		PC FUNCTION*	CONTROLLER
	9 PIN	25 PIN		
PIN	2	3	RECEIVE (RX)	TRANSMIT (TX) JP4-2
PIN	3	2	TRANSMIT (TX)	RECEIVE (RX) JP4-1
PIN	5	7	COMMON	SHIELD JP4-3

***Functions normally assigned to pins.**
Check your PC manual to confirm

Appendix A Troubleshooting Controller

CONTROLLER NOT PROVIDING THE EXPECTED OUTPUT POWER:

COMMUNICATION PROBLEM: A communication problem is not allowing software to turn the output ON, or some other parameter is not set properly due to communication problem. See Appendix B, Troubleshooting communications port.

HEAT SIDE MULTIPLIER: See Section 4.4 for reference. If this is set to 0.00, the controller will not provide any output power when the controller goes into the heating mode. Set this value to something greater than zero to restore the controller's capability of heating.

COOL SIDE MULTIPLIER: See Section 4.5 for reference. If this is set to 0.00, the controller will not provide any output power when the controller is in the cooling mode. Set this value to something greater than zero to restore the controller's capability of cooling.

LOW VOLTAGE: See Section 6.10 for reference. Verify the controller is receiving at least 12 V from the power supply. The controller will shut off output power to protect the MOSFETs from damage if the input voltage drops below 11.2 V.

OVER CURRENT: See Section 2.11, 2.12, and 6.9. Verify that the over-current level is set to an appropriate amount that is at least greater than the expected current draw of the thermoelectric device used with the controller. Check that a sufficient number of over-current restart attempts has been set.

OUTPUT ON/OFF: See Section 2.13. Verify that the controller has been set to turn on output power. You should also verify that the power supply is capable of providing the expected amount of current for the thermoelectric device at the voltage supplied by the power supply. If the power supply cannot provide sufficient current, it may be in an over-current condition.

ALARM: See Sections 2.5-2.9. Verify that there are no alarm conditions and that the temperatures which trigger an alarm condition are set correctly. If you are certain no alarm condition exists, click the SEND LATCH CLEAR button.

SYSTEM TEMPERATURE INCREASES WHEN COOLING EXPECTED:

INSUFFICIENT HEAT SINK: The thermoelectric (Peltier) elements do not have a sufficient heat sink, and input power heats entire system. In such a case, there is usually some initial reduction in temperature when power to the thermoelectric device is first turned on, but this is soon followed by a gradual heating of the system.

OUTPUT POLARITY REVERSED: Review section 2.4 and wire attachments from controller to cooler. Ensure the wire polarity is correct per schematic, and ensure proper control mode is selected. Ensure wire attachment (polarity) to the cooling device is correct. For thermoelectric (Peltier) modules, review the "*Thermoelectric Module Mounting (TEM) Mounting Procedure",* available from www.tetech.com, and verify physical orientation of the cold side module within the system. For TE Technology standard cooling assemblies, verify wires are attached to proper positions on terminal strip (see section 5.2).

SYSTEM TEMPERATURE DOES NOT RESPOND AS EXPECTED:

CONTROL TYPE IMPROPERLY SET: Set CONTROL TYPE to PID control if you want the temperature controller to adjust the output power based on the actual temperature and the set temperature. Set CONTROL TYPE to COMPUTER CONTROL if you want to use an external computer to adjust the power output manually. See Section 2.3.

IMPROPER SENSOR TYPE: Only NTC thermistors of proper type can be utilized. Verify an NTC thermistor is being used and its Resistance-versus-Temperature (R-T) curve is one that is supported by the controller. Verify the proper SENSOR TYPE has been selected, see Section 2.8.

DIGITAL DISPLAY (MP-2986) DOES NOT RESPOND AS EXPECTED:

"Serr" DISPLAYED: DISPLAY FUNCTION ENABLE check box not checked. Make selection (check box) and send values to controller.

DISPLAY DOES NOT ALTER SET TEMPERATURE: SET TEMP TYPE improperly set. Set to JP3 DISPLAY SET VALUE. This selection is at the bottom of the pull down box list, and may not be readily noticeable as a selection option. See Section 2.3.

APPENDIX B Troubleshooting Communications Port

You can perform a quick check of the communications port (without having to initialize variables) by clicking the "CommCheck" button in the PC COMMUNICATIONS section of the software screen. You should have the controller connected to a communications port and the controller powered up when performing the communications check. A "COMM ERROR!" message will show if there is no hookup. If the connection is good a "COMM OKAY" message will appear within 3-4 seconds at most.

If a USB to RS232 converter is being used, the "COMM OKAY" response should also appear within a 3-4 seconds at most if you have a good connection to the controller. However, a "COMM OKAY" might still appear but only after many seconds (15 seconds or more). In which case, the software is receiving a false indication from the USB converter, so further investigation is required. As mentioned in section 1.8, you might also need to add a 0.001 microfarad, 50 V capacitor across JP4-1 and JP4-3 to minimize noise induced by the USB converter.

When you initialize, an error message might show up if there are any additional problems. The following table offers possible solutions corresponding to a particular error:

Error Message	Cause	Solution
Comm Port Timeout	No power to TC-36-25 RS232 unit	Apply power to TC-36-25 RS232, review customer drawing for proper hookup.
Comm Port Timeout	Wrong Comm Port selected	Check computer hardware setting and set to the correct Comm Port.
Comm Port Timeout	Incorrect wiring of Comm Port to the computer.	Check for correct wiring from JP4 to the computer.
Comm Port Open Error	No Comm Port available at this port setting.	Check computer hardware setting and set to the correct Comm Port.

The controller will not communicate with the computer if the port settings are incorrect. The port settings for the RS232 controller are:
Baud Rate – 9600
Data Bits – 8
Parity – None
Start/Stop Bits – 1
Flow Control – None

Note: See Appendix C, Section III RS232 Communications Parameters regarding the insertion of a delay between sending characters if you are using your own software program.

APPENDIX C Serial Communications

I. Definitions:

Note: where applicable, the base of a number is indicated by its subscript. So, 20_{10} is the number 20 in decimal (base 10) format, and it converts to 14_{16} in hexadecimal (base 16) format.

Use lowercase ASCII characters.

(stx)	Start of text character (*) or $2a_{16}$.
(etx)	End of text character (carriage return) or $0d_{16}$.
(ack)	Acknowledge character (^) or $5e_{16}$.
AA	Address characters are ASCII characters ranging from 0 through 9 or a through f. **However, 00 is the only address that should be used for the TC-36-25 RS-232.**
CC	Command characters are ASCII characters from 0 through 9 or a through f.
DDDDDDDD	This is the ASCII representation of the hexadecimal return or send value. Negative numbers are represented by the hex 2's complement of the number (32-bit word size): $1_{10} = 00000001_{16}$ $-1_{10}=ffffffff_{16}$
SS	The 8-bit (modulo 256) hexadecimal checksum of characters sent to/from the controlling computer. This is represented as 2 ASCII characters. The checksum calculation excludes the characters (stx), SS, and (etx). *The TC-36-25 RS232 sums (in an 8-bit register) the hexadecimal values of the ASCII characters sent to/from the controlling computer. Any overflow is truncated, leaving the 8-bit (modulo 256) checksum. When the controller is receiving data, this controller calculates the checksum and compares it to the checksum sent by the controlling computer. The TC-36-25 RS232 will respond as shown below depending on whether or not the checksums match. When the controlling computer is receiving data the checksum sent by the controller can be used to make sure the data has not been received with an error. Remember, when finding the ASCII value for a hexadecimal number (a, b, c, d, e, and f) be sure to reference lower case letters.*

To write a command to the controller, the controlling computer must send the following ASCII characters:

(stx)AACCDDDDDDDDSS(etx)

If the temperature controller receives the command and the checksum is correct, the temperature controller will respond by sending back the "send value" and the checksum of those eight ASCII characters:

(stx)DDDDDDDDSS(ack)

To query a controller, there is no send value so the controlling computer only needs to send the following ASCII characters with the "D"s filled with zeros:

(stx) AACC00000000SS (etx)

If the temperature controller receives the query and the checksum is correct, the temperature controller will respond by sending back a "return value" and the checksum of those eight ASCII characters:

(stx)DDDDDDDDSS(ack)

If the checksum for a command or query is not correct the temperature controller will respond with eight upper case X's and then c0, which is the checksum of these eight X's:

(stx)XXXXXXXXc0(ack)

Remember, AA = 00 is the universal address for the TC-36-25 RS232. If the address is not correct, then the controller will not respond to any requests.

II. Examples:

A) Set the controller to control via a computer programmable set point.

1. The controller address, AA, is by definition 00.
2. The write command, CC, for "SET TYPE DEFINE" is 29.
3. A data value of "0" selects a computer communicated set value, so the eight-character send value DDDDDDDD is 00000000.
4. Compute the checksum (SS) by adding the hexadecimal ASCII values of the following characters: 0, 0, 2, 9, 0, 0, 0, 0, 0, 0, and 0:

ASCII Character:	Hexadecimal Value:
0	30
0	30
2	32
9	39
0	30
0	30
0	30
0	30
0	30
0	30
0	30
0	30
Sum	**$024b_{16}$**

   The 8-bit checksum is the 8 least significant binary bits of the sum, represented as 4b in hexadecimal.

5. Combining all of these characters into one string we send: (stx)0029000000004b(etx).
6. If the temperature controller receives the command and the checksum is correct, it will send back: (stx)0000000080(ack). If the checksum is not correct the temperature controller will send back: (stx)XXXXXXXXc0(ack).

B) Send the set temperature of 10.00 to the controller.

1. The controller address, AA, is by definition 00.
2. The control command, CC, for "FIXED DESIRED CONTROL SETTING" is 1c.
3. Multiply the desired set-point temperature by 100_{10} (10.00 x 100 = 1000).
4. Convert 1000_{10} to hexadecimal ($3e8_{16}$) and add on leading zeros to make the eight-character send value DDDDDDDD (000003e8).
5. Compute the checksum (SS) by adding the ASCII values of the following characters: 0, 0, 1, c, 0, 0, 0, 0, 0, 3, e, and 8:

ASCII Character:	Hexadecimal Value:
0	30
0	30
1	31
c	63
0	30
0	30
0	30
0	30
0	30
3	33
e	65
8	38
Sum	**$02b4_{16}$**

   The 8-bit checksum is the 8 least significant binary bits of the sum, represented as b4 in hexadecimal.
6. Combining all of these characters in one string we send: (stx)001c000003e8b4(etx).
7. If the temperature controller receives the command and the checksum is correct, it will send back: (stx)000003e8c0(ack). If the checksum is not correct the temperature controller will send back: (stx)XXXXXXXXc0(ack).

C) Send the set temperature of -1.50 °C.

1. The controller address, AA, is by definition 00.
2. The control command, CC, for "FIXED DESIRED CONTROL SETTING" is 1c.
3. Multiply the desired set-point temperature by 100_{10} (-1.50 x 100 = -150).
4. Convert -150_{10} to hexadecimal by taking the two's complement of the number. (This can be easily done by using the formula $2^n - N$, where n is the word-bit size and N is the absolute value of the number being converted.) Hence, you have $2^{32} - 150 = 4294967146_{10}$. This value then converts to $ffffff6a_{16}$.
5. Compute the checksum (SS) by adding the hexadecimal ASCII values of the following characters: 0, 0, 1, c, f, f, f, f, f, 6, and a:

ASCII Character:	Hexadecimal Value:
0	30
0	30
1	31
c	63
f	66
f	66
f	66
f	66
f	66
f	66
6	36
a	61
Sum	**$3ef_{16}$**

The 8-bit checksum is the 8 least significant binary bits of the sum, represented as ef in hexadecimal.

6. Combining all of these characters in one string we send: (stx)001cffffff6aef(etx).
7. If the temperature controller receives the command and the checksum is correct, it will send back: (stx)ffffff6afb(ack). If the checksum is not correct the temperature controller will send back: (stx)XXXXXXXXc0(ack).

D) Read the actual temperature of the control thermistor (INPUT1) from the controller at address 00.

1. Let us assume the actual temperature is 2.50 °C, and the working units have been defined as °C. This means that the controller will return a value in °C.
2. The controller address, AA, is by definition 00.
3. The control command, CC, for "INPUT1" is 01.
4. There is no send value, so we can just calculate the checksum (SS) by adding the ASCII values of the following characters: 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0:

ASCII Character:	Hexadecimal Value:
0	30
0	30
0	30
1	31
0	30
0	30
0	30
0	30
0	30
0	30
0	30
0	30
Sum	**0241_{16}**

The 8-bit checksum is the 8 least significant binary bits of the sum, represented as 41 in hex.

5. Combining all of these characters in one string we send: (stx)00010000000041(etx).
6. If the temperature controller receives the command and the checksum is correct, it will send back: (stx)000000fae7(ack). The e7 at the end of the string is the checksum of "000000fa". The value $000000fa_{16}$ converts to 250_{10}. This number must then be divided by 100_{10}, so the value would be interpreted as 2.50 °C. As in the other examples, if the checksum from the query were not correct the temperature controller would send back: (stx)XXXXXXXXc0(ack).

III. RS232 Communications Parameters (JP4 connector on controller board)

A. Baud Rate 9600
B. No Parity
C. 1 Start Bit 1 Stop Bit

NOTE if you are using communications software* different *from the one supplied with the controller: *The demands of temperature control require a relatively large portion of the processing power of the onboard microcontroller. It is possible for a host computer to send data too quickly for the controller to receive and update. TE Technology recommends adding a delay between each character sent to allow the controller sufficient time to process the information. One millisecond might be a good delay time to use initially, but the exact time will vary depending on the host computer's hardware and the particular demands on the controller at the moment.*

IV. Commands

1. INPUT1 (reads the temperature of the primary thermistor)
   Write Command: NA
   Read Command: 01
   Interpret: Convert the hexadecimal "return value" to decimal and divide by 100_{10} to interpret as the temperature in °F/°C.
   Example:
   Suppose the temperature is 10.00 °F (sensor type = 1).
   Send: *00010000000041^
   Receive *000003e8c0^
   Convert $000003e8_{16}$ to decimal = 1000_{10}
   Divide by 100 = (10.00 °F)

2. DESIRED CONTROL VALUE (set value)
   Write Command: NA
   Read Command: 03
   Interpret: This command returns the set value determined by Input2 or as a fixed value set by communications. Convert the hexadecimal "return value" to decimal and divide by 100_{10} to interpret.

3. POWER OUTPUT
   Write Command: NA
   Read Command: 02 or 04
   Interpret: -511_{10} represents –100% output.
   0 returned is 0% output.
   511_{10} represents 100% output.

4. ALARM STATUS
   Write Command: NA
   Read Command: 05
   Interpret: 0 returned means no alarms.
   Bit 0 = 1 means HIGH ALARM.
   Bit 1 = 1 means LOW ALARM.
   Bit 2 = 1 means COMPUTER CONTROLLED ALARM.
   Bit 3 = 1 means OVER CURRENT DETECTED.
   Bit 4 = 1 means OPEN INPUT1.
   Bit 5 = 1 means OPEN INPUT2.
   Bit 6 = 1 means DRIVER LOW INPUT VOLTAGE.
   Example:
   Suppose there are two alarm conditions: HIGH ALARM and OVER CURRENT DETECTED.
   Send: *00050000000045^
   Receive: *0000000989^
   Convert 00000009_{16} to binary: 0001001_2 (bit 3 and bit 0 are set)

5. INPUT 2
   Write Command: NA
   Read Command: 06
   Interpret: When a secondary thermistor temperature sensor is used, the temperature it is sensing can be read. Convert the hexadecimal "return value" to decimal and divide by 100_{10} to interpret as °F/°C.

6. OUTPUT CURRENT COUNTS
   Write Command: NA
   Read Command: 07
   Interpret: Output current detection in A/D counts.

7. ALARM TYPE
   Write Command: 28
   Read Command: 41
   Interpret: 0 sent or returned means no alarms.
   1 sent or returned means Tracking Alarm Mode.
   2 sent or returned means Fixed Alarm Mode.
   3 sent or returned means Computer Controlled Alarm Mode (see write command ALARM LATCH ENABLE).

8. SET TYPE DEFINE (the desired control temperature or "set temp" input definition)
   Write Command: 29
   Read Command: 42
   Interpret: This function tells the controller how the set-point will be communicated.
   0 sent or returned means computer communicated set value.
   1 sent or returned means Potentiometer Input.
   2 sent or returned means 0 to 5 V Input.
   3 sent or returned means 0 to 20 mA Input.
   4 sent or returned means "Differential set": Desired Control Value = Temp2 + Computer Set.
   5 sent or returned means set value is from optional MP-2986 Display and Keypad accessory.

   The range of values is settable via the commands HIGH EXTERNAL SET RANGE and LOW EXTERNAL SET RANGE.

9. SENSOR TYPE
   Write Command: 2a
   Read Command: 43
   Interpret: 0: TS141 5K
   1: TS67 OR TS136 15K
   2: TS91 10K
   3: TS165 230K
   4: TS104 50K
   5: YSI H TP53 10K

10. CONTROL TYPE
   Write Command: 2b
   Read Command: 44
   Interpret: 0 is deadband control.
   1 is PID control.
   2 is computer control.

11. CONTROL OUTPUT POLARITY
   Write Command: 2c
   Read Command: 45
   Interpret: 0 is HEAT WP1+ and WP2-.
   1 is HEAT WP2+ and WP1-.

12. OUTPUT ON/OFF
    Write Command: 2d
    Read Command: 46
    Interpret: 0 is off.
    1 is on.

13. OUTPUT SHUTDOWN IF ALARM
    Write Command: 2e
    Read Command: 47
    Interpret: 0 is no shutdown upon alarm.
    1 is to shutdown main output drive upon alarm.

14. FIXED DESIRED CONTROL SETTING
    Write Command: 1c
    Read Command: 50
    Interpret: When writing, multiply the desired control temperature by 100_{10} and convert to hexadecimal. This becomes the "send value."
    When reading, convert the "return value" to decimal and divide by 100 to convert to °F/°C.

    When CONTROL TYPE is set to "computer control", the output power sent to the cooler can be set anywhere from -511_{10} to $+511_{10}$, corresponding to -100% to +100% output power. Remember to convert to hexadecimal before sending.

15. PROPORTIONAL BANDWIDTH
    Write Command: 1d
    Read Command: 51
    Interpret: Fixed-point temperature bandwidth distributed around the control setting in ºF/ºC. A value of 5 ºF/ºC for bandwidth and control setting of 25 ºF/ºC would place the proportional band from 20 ºF/ºC to 30 ºF/ºC; that is, 5 ° above and 5 ° below set point.

    When writing, first multiply the desired bandwidth setting by 100_{10} and convert to hexadecimal for the "send value." When reading, convert the "return value" to decimal and divide by 100_{10} to covert to °F/°C.

    NOTE: when using the GUI software supplied by TE Technology, the proportional bandwidth is treated in a more conventional manner in which the bandwidth is centered about the set-point temperature. The GUI divides the bandwidth by 2 before actually writing the value to RAM/EEPROM. So, entering 5 ° through the GUI, would actually be saved as 2.5 (with appropriate conversion to hexadecimal).

16. INTEGRAL GAIN
    Write Command: 1e
    Read Command: 52
    Interpret: Fixed-point gain in repeats/min.
    Multiply desired integral gain by 100_{10} and convert to hexadecimal for the "send value." When reading, convert the "return value" to decimal and divide by 100_{10} to interpret.

17. DERIVATIVE GAIN
    Write Command: 1f
    Read Command: 53
    Interpret: Fixed-point gain in minutes.
    Multiply desired derivative gain by 100_{10} and convert to hexadecimal for the "send value." When reading, convert the "return value" to decimal and divide by 100_{10} to interpret.

18. LOW EXTERNAL SET RANGE
    Write Command: 20
    Read Command: 54
    Interpret: Value mapped to zero voltage of Input2. Only integer values are allowed. Remember to convert to hexadecimal before sending.

19. HIGH EXTERNAL SET RANGE
    Write Command: 21
    Read Command: 55
    Interpret: Value mapped to 5 volt or maximum voltage of Input2. Only integer values are allowed. Remember to convert to hexadecimal before sending.

20. ALARM DEADBAND
    Write Command: 22
    Read Command: 56
    Interpret: Temperature Input1 must move to toggle alarm output. When writing, first multiply the desired deadband setting by 100_{10} and convert to hexadecimal for the "send value." When reading, convert the "return value" to decimal and divide by 100_{10} to covert to °F/°C.

21. HIGH ALARM SETTING
    Write Command: 23
    Read Command: 57
    Interpret: Temperature reference to compare against Input1 for high alarm output. When writing, first multiply the desired setting by 100_{10} and convert to hexadecimal for the "send value." When reading, convert the "return value" to decimal and divide by 100_{10} to covert to °F/°C.

22. LOW ALARM SETTING
    Write Command: 24
    Read Command: 58
    Interpret: Temperature reference to compare against Input1 for low alarm output. When writing, first multiply the desired setting by 100_{10} and convert to hexadecimal for the "send value." When reading, convert the "return value" to decimal and divide by 100_{10} to covert to °F/°C.

23. CONTROL DEADBAND SETTING
    Write Command: 25
    Read Command: 59
    Interpret: Temperature or count span Input1 must move to toggle control output. When writing, first multiply the desired setting by 100_{10} and convert to hexadecimal for the "send value." When reading, convert the "return value" to decimal and divide by 100_{10} to covert to °F/°C.

24. INPUT1 OFFSET
    Write Command: 26
    Read Command: 5a
    Interpret: Value to offset Input1 by in order to calibrate external sensor if desired. When writing, first multiply the desired setting by 100_{10} and convert to hexadecimal for the "send value." When reading, convert the "return value" to decimal and divide by 100_{10} to covert to °F/°C.

25. INPUT2 OFFSET
    Write Command: 27
    Read Command: 5b
    Interpret: Value to offset Input2 by in order to calibrate external sensor if desired. When writing, first multiply the desired setting by 100_{10} and convert to hexadecimal for the "send value." When reading, convert the "return value" to decimal and divide by 100_{10} to covert to °F/°C.

26. HEAT MULTIPLIER
    Write Command: 0c
    Read Command: 5c
    Interpret: This multiplies the heater percentage of power to offset its effectiveness. When writing, first multiply the desired setting by 100_{10} and convert to hexadecimal for the "send value." When reading, convert the "return value" to decimal and divide by 100_{10} to interpret.

27. COOL MULTIPLIER
    Write Command: 0d
    Read Command: 5d
    Interpret: This multiplies the cooling percentage of power to offset its effectiveness. When writing, first multiply the desired setting by 100_{10} and convert to hexadecimal for the "send value." When reading, convert the "return value" to decimal and divide by 100_{10} to interpret.

28. OVER CURRENT COUNT COMPARE VALUE
    Write Command: 0e
    Read Command: 5e
    Interpret: This is the count compare value which determines an over-current condition. Current is approximately 2.5 per count. Only integer values are allowed. Remember to convert to hexadecimal before sending.

29. ALARM LATCH ENABLE
    Write Command: 2f
    Read Command: 48
    Interpret: 1 is latching enabled.
    0 is latching disabled.
    If ALARM TYPE is equal to 3 then
    1 is Computer Alarm On.
    0 is Computer Alarm Off.

30. COMMUNICATIONS ADDRESS (reserved command, do not use)

31. ALARM LATCH RESET
    Write Command: 33
    Read Command: NA
    Interpret: Send this command to reset the alarm latches.

32. CHOOSE SENSOR FOR ALARM FUNCTION
    Write Command: 31
    Read Command: 4a
    Interpret: 0 is for the Control Sensor Input.
    1 is for the Input2 Secondary Input.

33. CHOOSE °C or °F TEMPERATURE WORKING UNITS
    Write Command: 32
    Read Command: 4b
    Interpret: 0 is °F
    1 is °C

34. EEPROM WRITE ENABLE
    Write Command: 34
    Read Command: 4c
    Interpret: 0 is disable EEPROM writes
    1 is enable EEPROM writes
    Function Description: Upon a power-up or reset condition, the controller performs an initialization of all command variables that have write commands by transferring the last values stored in non-volatile memory (EEPROM) to appropriately referenced static RAM locations. This action is performed so that the controller can run faster (RAM is faster than ROM). When the "EEPROM WRITE ENABLE" is enabled, any changes in the run-time values of the command variables are also stored in EEPROM as well in RAM and thus will be recalled upon a power-up or reset condition. When the "EEPROM WRITE ENABLE" is disabled, run-time values are stored only in RAM. This setting gives you the ability to change run-time values without changing your desired power-up settings. This will also alleviate a possible problem since the maximum number of writes to an EEPROM location is 1,000,000.

35. OVER CURRENT CONTINUOUS
    Write Command: 35
    Read Command: 4d
    Interpret: 1 is continuous retry when over current detected.
    0 allows the RESTART ATTEMPTS value to be used.

36. OVER CURRENT RESTART ATTEMPS
    Write Command: 0f
    Read Command: 5f
    Interpret: Range of value 0 to 30000_{10}
    This is the amount of times the controller will attempt to restart the output after an over current condition is detected.

37. JP3 DISPLAY ENABLE
    Write Command: 36
    Read Command: 4e
    Interpret: 1 display function enabled.
    0 display function disabled.

V. ASCII Reference Table

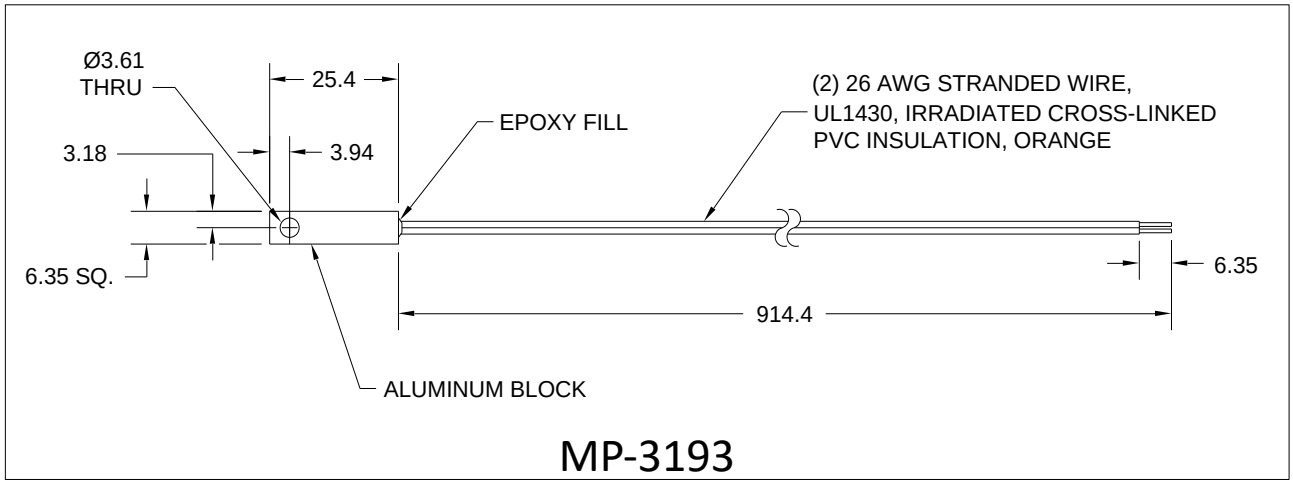
Dec	Oct	Hex	Binary	Description
000	000	00	00000000	^@ ^` NULL NUL null c-@ c-`
001	001	01	00000001	^A ^a SOH GTL c-A c-a start-of-heading
002	002	02	00000010	^B ^b STX c-B c-b start-of-text
003	003	03	00000011	^C ^c ETX c-C c-c end-of-text
004	004	04	00000100	^D ^d EOT SDC end-of-transmission c-D c-d ..._._
005	005	05	00000101	^E ^e ENQ PPC c-E c-e enquiry
006	006	06	00000110	^F ^f ACK c-F c-f acknowledge
007	007	07	00000111	^G ^g BELL BEL bell c-G c-g \a
008	010	08	00001000	^H ^h BS GET backspace c-H c-h \b
009	011	09	00001001	^I ^i TAB TCT HT tab c-I c-i \t
010	012	0A	00001010	^J ^j LF lf linefeed c-J c-j \n
011	013	0B	00001011	^K ^k VT vertical-tab c-K c-k \v
012	014	0C	00001100	^L ^l FF ff formfeed page \f c-L c-l
013	015	0D	00001101	^M ^m CR cr carriage-return c-M c-m \r
014	016	0E	00001110	^N ^n SO c-N c-n shift-out
015	017	0F	00001111	^O ^o SI c-O c-o shift-in
016	020	10	00010000	^P ^p DLE c-P c-p data-link-escape
017	021	11	00010001	^Q ^q DC1 LLO go XON xon c-Q c-Q
018	022	12	00010010	^R ^r DC2 c-R c-r
019	023	13	00010011	^S ^s DC3 stop XOFF xoff c-S c-s
020	024	14	00010100	^T ^t DC4 DCL c-T c-t
021	025	15	00010101	^U ^u NAK PPU negative-acknowledge c-U c-u
022	026	16	00010110	^V ^v SYN c-V c-v synchronous-idle
023	027	17	00010111	^W ^w ETB end-of-transmission-block c-W c-w
024	030	18	00011000	^X ^x CAN SPE c-X c-x cancel
025	031	19	00011001	^Y ^y EM SPD c-Y c-y end-of-medium
026	032	1A	00011010	^Z ^z SUB suspend c-Z c-z substitute
027	033	1B	00011011	^[^{ ESC escape c-[c-{ m-
028	034	1C	00011100	^\ ^| FS field-separator c-\ c-|
029	035	1D	00011101	^] ^} GS group-separator
030	036	1E	00011110	^^ ^~ RS record-separator c-^ c-~
031	037	1F	00011111	^_ ^DEL unit-separator US c-_ c-DEL
032	040	20	00100000	SPC space spc
033	041	21	00100001	! exclamation-point
034	042	22	00100010	" straight-double-quotation-mark
035	043	23	00100011	# number-sign
036	044	24	00100100	$ @@ dollar-sign
037	045	25	00100101	% percent-sign
038	046	26	00100110	& ampersand
039	047	27	00100111	' apostrophe
040	050	28	00101000	(left-parenthesis
041	051	29	00101001	) right-parenthesis
042	052	2A	00101010	* asterisk star
043	053	2B	00101011	+ addition-sign
044	054	2C	00101100	, comma
045	055	2D	00101101	- subtraction-sign minus hyphen negative dash

046	056	2E	00101110	. period dot decimal
047	057	2F	00101111	/ right-slash
048	060	30	00110000	0
049	061	31	00110001	1
050	062	32	00110010	2
051	063	33	00110011	3
052	064	34	00110100	4
053	065	35	00110101	5
054	066	36	00110110	6
055	067	37	00110111	7
056	070	38	00111000	8
057	071	39	00111001	9
058	072	3A	00111010	: colon
059	073	3B	00111011	; semicolon
060	074	3C	00111100	< less-than
061	075	3D	00111101	= equals
062	076	3E	00111110	> greater-than, right-chevron
063	077	3F	00111111	? question-mark, query
064	100	40	01000000	@ at-symbol, at-sign
065	101	41	01000001	A
066	102	42	01000010	B
067	103	43	01000011	C
068	104	44	01000100	D
069	105	45	01000101	E
070	106	46	01000110	F
071	107	47	01000111	G
072	110	48	01001000	H
073	111	49	01001001	I
074	112	4A	01001010	J
075	113	4B	01001011	K
076	114	4C	01001100	L
077	115	4D	01001101	M
078	116	4E	01001110	N
079	117	4F	01001111	O
080	120	50	01010000	P
081	121	51	01010001	Q
082	122	52	01010010	R
083	123	53	01010011	S
084	124	54	01010100	T
085	125	55	01010101	U
086	126	56	01010110	V
087	127	57	01010111	W
088	130	58	01011000	X
089	131	59	01011001	Y
090	132	5A	01011010	Z
091	133	5B	01011011	[left-bracket, open-square
092	134	5C	01011100	\ left-slash, backslash bash
093	135	5D	01011101	] right-bracket, close-square
094	136	5E	01011110	^ hat, circumflex, caret, up-arrow
095	137	5F	01011111	_ UNT, underscore, underbar
096	140	60	01100000	` accent-grave, backprime, backquote
097	141	61	01100001	a

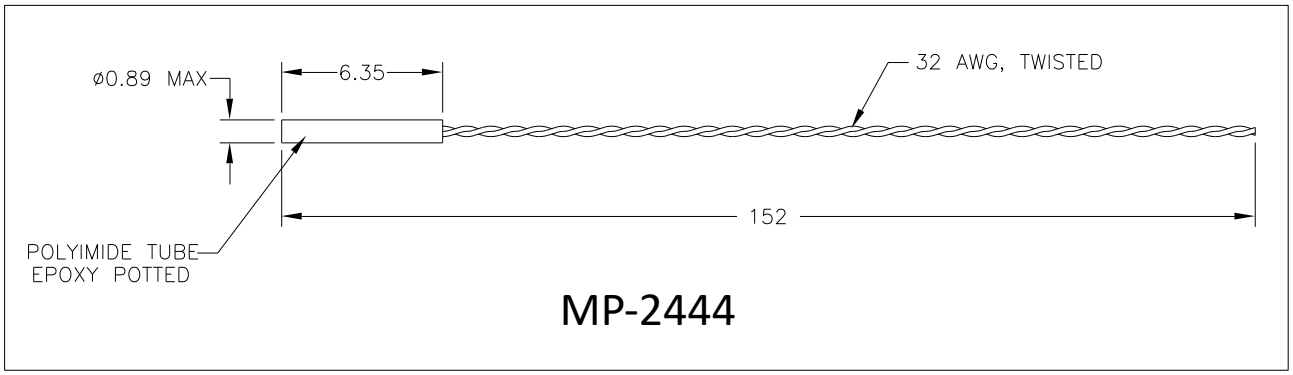
098	142	62	01100010	b
099	143	63	01100011	c
100	144	64	01100100	d
101	145	65	01100101	e
102	146	66	01100110	f
103	147	67	01100111	g
104	150	68	01101000	h
105	151	69	01101001	i
106	152	6A	01101010	j
107	153	6B	01101011	k
108	154	6C	01101100	l
109	155	6D	01101101	m
110	156	6E	01101110	n
111	157	6F	01101111	o
112	160	70	01110000	p
113	161	71	01110001	q
114	162	72	01110010	r
115	163	73	01110011	s
116	164	74	01110100	t
117	165	75	01110101	u
118	166	76	01110110	v
119	167	77	01110111	w
120	170	78	01111000	x
121	171	79	01111001	y
122	172	7A	01111010	z
123	173	7B	01111011	{ left-brace begin
124	174	7C	01111100	| logical-or vertical-bar
125	175	7D	01111101	} right-brace end
126	176	7E	01111110	~ similar
127	177	7F	01111111	^? DEL rubout delete

APPENDIX D Thermistors for TC-36-25 RS232

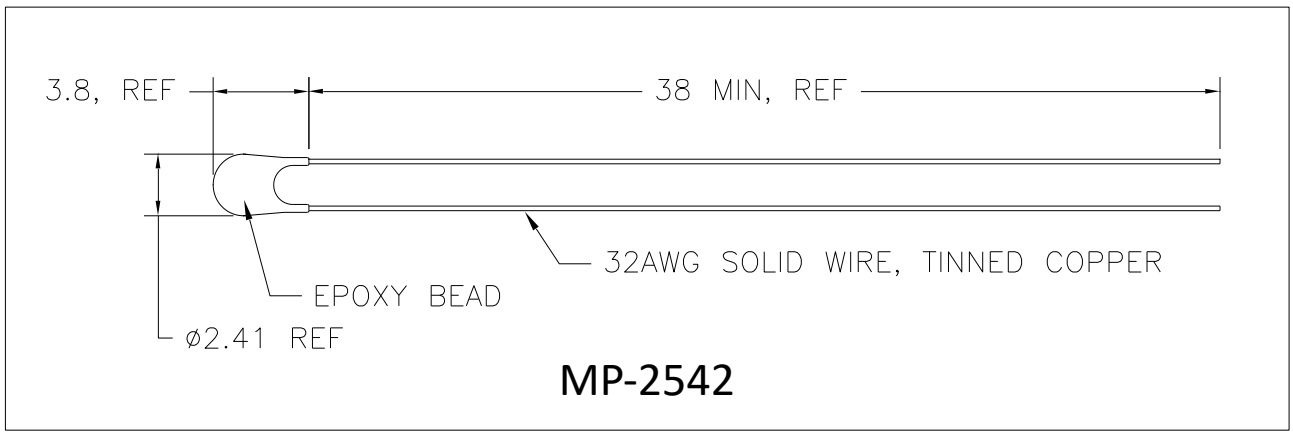
Note: All dimensions in millimeters. Most standard thermistors have TS-67 temperature-resistance curves. Additional thermistor styles are shown at www.tetech.com



MP-3193



MP-2444



MP-2542

TS-67 Temperature (°C) versus Resistance (ohms, Ω) Data

for MP-3193, MP-2444, MP-3189, MP-2996, and MP-2542 15 kΩ Thermistors

-20	146735	1	46709	22	17136	43	7075	64	3227	85	1601
-19	138447	2	44397	23	16388	44	6801	65	3115	86	1551
-18	130677	3	42213	24	15676	45	6539	66	3008	87	1503
-17	123390	4	40150	25	15000	46	6289	67	2905	88	1457
-16	116554	5	38199	26	14356	47	6049	68	2806	89	1412
-15	110138	6	36354	27	13744	48	5820	69	2711	90	1369
-14	104113	7	34608	28	13161	49	5600	70	2620	91	1328
-13	98454	8	32957	29	12606	50	5391	71	2532	92	1288
-12	93137	9	31394	30	12078	51	5190	72	2448	93	1250
-11	88138	10	29914	31	11574	52	4997	73	2367	94	1212
-10	83438	11	28512	32	11095	53	4813	74	2288	95	1176
-9	79016	12	27183	33	10637	54	4637	75	2213	96	1142
-8	74855	13	25925	34	10202	55	4467	76	2141	97	1108
-7	70938	14	24731	35	9786	56	4305	77	2072	98	1076
-6	67249	15	23600	36	9389	57	4150	78	2005	99	1045
-5	63773	16	22526	37	9011	58	4001	79	1940	100	1014
-4	60498	17	21508	38	8650	59	3858	80	1878		
-3	57410	18	20541	39	8306	60	3721	81	1818		
-2	54498	19	19623	40	7976	61	3590	82	1761		
-1	51750	20	18751	41	7662	62	3464	83	1705		
0	49157	21	17923	42	7362	63	3343	84	1652		

Note: Tolerance is ±650 Ω, corresponding to ±1 °C over a 0 °C to 100 °C range.

TS-141 Temperature (°C) versus Resistance (ohms, Ω) Data
for MP-3716

-40	168300	-19	45830	2	14750	23	5460	44	2272	65	1041
-39	157500	-18	43270	3	14030	24	5225	45	2184	66	1006
-38	147500	-17	40860	4	13340	25	5000	46	2101	67	971
-37	138200	-16	38610	5	12700	26	4787	47	2021	68	938
-36	129500	-15	36490	6	12090	27	4583	48	1944	69	906.5
-35	121400	-14	34500	7	11510	28	4389	49	1871	70	875.5
-34	113900	-13	32630	8	10960	29	4204	50	1801		
-33	106900	-12	30880	9	10440	30	4029	51	1734		
-32	100300	-11	29230	10	9950	31	3861	52	1670		
-31	94200	-10	27670	11	9485	32	3702	53	1608		
-30	88500	-9	26210	12	9045	33	3549	54	1549		
-29	83200	-8	24830	13	8630	34	3404	55	1493		
-28	78250	-7	23540	14	8230	35	3266	56	1439		
-27	73600	-6	22320	15	7855	36	3134	57	1387		
-26	69250	-5	21170	16	7500	37	3008	58	1337		
-25	65200	-4	20080	17	7160	38	2888	59	1290		
-24	61450	-3	19060	18	6840	39	2773	60	1244		
-23	57900	-2	18100	19	6535	40	2663	61	1200		
-22	54550	-1	17190	20	6245	41	2559	62	1158		
-21	51450	0	16330	21	5970	42	2459	63	1117		
-20	48560	1	15520	22	5710	43	2363	64	1079		

TS-91 Temperature (°C) versus Resistance (ohms, Ω) Data

-20	97120	1	31040	23	10920	44	4544	65	2082
-19	91660	2	29500	24	10450	45	4368	66	2012
-18	86540	3	28060	25	10000	46	4202	67	1942
-17	81720	4	26680	26	9574	47	4042	68	1876
-16	77220	5	25400	27	9166	48	3888	69	1813
-15	72980	6	24180	28	8778	49	3742	70	1751
-14	69000	7	23020	29	8408	50	3602	71	1693
-13	65260	8	21920	30	8058	51	3468	72	1637
-12	61760	9	20880	31	7722	52	3340	73	1582
-11	58460	10	19900	32	7404	53	3216	74	1530
-10	55340	11	18970	33	7098	54	3098	75	1480
-9	52420	12	18090	34	6808	55	2986	76	1432
-8	49660	13	17260	35	6532	56	2878	77	1385
-7	47080	14	16460	36	6268	57	2774	78	1341
-6	44640	15	15710	37	6016	58	2674	79	1298
-5	42340	16	15000	38	5776	59	2580	80	1256
-4	40160	17	14320	39	5546	60	2488	81	1216
-3	38120	18	13680	40	5326	61	2400	82	1178
-2	36200	19	13070	41	5118	62	2316	83	1141
-1	34380	20	12490	42	4918	63	2234	84	1105
0	32660	21	11940	43	4726	64	2158	85	1071

TS-165 Temperature (°C) versus Resistance (ohms, Ω) Data

25	231438.2	71	35099.7	117	7792.1	163	2289.3	209	830.8
26	221032.6	72	33847.4	118	7567	164	2234.8	210	814.3
27	211147.1	73	32645.5	119	7349.4	165	2181.9	211	798.1
28	201753.2	74	31491.9	120	7139	166	2130.4	212	782.4
29	192824.2	75	30384.2	121	6935.4	167	2080.3	213	767
30	184334.8	76	29320.7	122	6738.6	168	2031.6	214	752
31	176261.5	77	28299.2	123	6548.2	169	1984.3	215	737.3
32	168581.8	78	27318.1	124	6363.9	170	1938.2	216	723
33	161274.8	79	26375.3	125	6185.6	171	1893.4	217	709
34	154320.7	80	25469.4	126	6013.1	172	1849.8	218	695.3
35	147700.8	81	24598.7	127	5846.1	173	1807.3	219	681.9
36	141397.6	82	23761.8	128	5684.4	174	1766	220	668.9
37	135394.3	83	22987.1	129	5527.9	175	1725.8	221	656.1
38	129675.4	84	22183.3	130	5376.3	176	1686.7	222	643.6
39	124226.1	85	21439.1	131	5229.6	177	1648.6	223	631.4
40	119032.5	86	20723.2	132	5087.4	178	1611.5	224	619.5
41	114081.4	87	20034.4	133	4949.7	179	1575.4	225	607.9
42	109360.3	88	19371.6	134	4816.3	180	1540.3	226	596.5
43	104857.6	89	18733.7	135	4687.1	181	1506.1	227	585.3
44	100562.2	90	18119.7	136	4561.8	182	1472.7	228	574.4
45	96463.6	91	17528.5	137	4440.4	183	1440.2	229	563.8
46	92551.8	92	16959.3	138	4322.8	184	1408.6	230	553.4
47	88817.6	93	16411.1	139	4208.7	185	1377.8	231	543.2
48	85252	94	15883	140	4098.7	186	1347.8	232	533.2
49	81846.8	95	15374.3	141	3991	187	1318.5	233	523.5
50	78593.9	96	14884.1	142	3887	188	1290	234	514
51	75485.9	97	14411.7	143	3786.2	189	1262.2	235	504.7
52	72515.7	98	13956.4	144	3688.3	190	1235.1	236	495.5
53	69676.6	99	13517.5	145	3593.5	191	1208.7	237	486.6
54	66962.1	100	13094.3	146	3501.4	192	1183	238	477.9
55	64366.4	101	12686.2	147	3412.1	193	1157.9	239	469.3
56	61883.6	102	12292.7	148	3325.4	194	1133.4	240	461
57	59508.3	103	11913	149	3241.3	195	1109.6	241	452.8
58	57235.5	104	11546.8	150	3159.6	196	1086.3	242	444.8
59	55060.2	105	11193.4	151	3080.3	197	1063.6	243	437
60	52977.8	106	10852.3	152	3003.4	198	1041.5	244	429.3
61	50984.1	107	10523.1	153	2928.6	199	1019.9	245	421.8
62	49074.7	108	10205.4	154	2856.1	200	998.8	246	414.4
63	47245.8	109	9898.6	155	2785.6	201	978.3	247	407.2
64	45493.6	110	9602.3	156	2717.1	202	958.2	248	400.2
65	43814.6	111	9316.3	157	2650.6	203	938.7	249	393.5
66	42205.4	112	9039.9	158	2586	204	919.6	250	386.5
67	40662.8	113	8773	159	2523.2	205	901		
68	39183.7	114	8515	160	2462.2	206	882.8		
69	37765.4	115	8265.8	161	2402.9	207	865		
70	36404.9	116	8024.9	162	2345.3	208	847.7		

TS-104 Temperature (°C) versus Resistance (ohms, Ω) Data
for MP-3022

0	163300	26	47870	52	16700	78	6705	104	3025	130	1503
1	155200	27	45830	53	16080	79	6490	105	2940	131	1465
2	147500	28	43890	54	15490	80	6280	106	2857	132	1429
3	140300	29	42040	55	14930	81	6080	107	2778	133	1394
4	133400	30	40290	56	14390	82	5890	108	2701	134	1360
5	127000	31	38610	57	13870	83	5705	109	2626	135	1326
6	120900	32	37020	58	13370	84	5525	110	2554	136	1294
7	115100	33	35490	59	12900	85	5355	111	2484	137	1263
8	109600	34	34040	60	12400	86	5190	112	2416	138	1232
9	104400	35	32660	61	12000	87	5030	113	2351	139	1203
10	99500	36	31340	62	11580	88	4875	114	2287	140	1174
11	94850	37	30080	63	11170	89	4726	115	2226	141	1146
12	90450	38	28880	64	10790	90	4582	116	2167	142	1119
13	86300	39	27730	65	10410	91	4444	117	2109	143	1092
14	82300	40	26630	66	10060	92	4310	118	2053	144	1067
15	78550	41	25590	67	9710	93	4182	119	1999	145	1042
16	75000	42	24590	68	9380	94	4057	120	1947	146	1018
17	71600	43	23630	69	9065	95	3937	121	1896	147	994
18	68400	44	22720	70	8755	96	3821	122	1847	148	971
19	65350	45	21840	71	8465	97	3709	123	1799	149	949
20	62450	46	21010	72	8185	98	3601	124	1753	150	927
21	59700	47	20210	73	7910	99	3497	125	1708		
22	57100	48	19440	74	7650	100	3396	126	1664		
23	54600	49	18710	75	7400	101	3298	127	1622		
24	52250	50	18010	76	7160	102	3204	128	1581		
25	50000	51	17340	77	6925	103	3113	129	1541		

YSI H TP-53 Temperature (°C) versus Resistance (ohms, Ω) Data

-15	61020	6	22430	27	9227	48	4179	69	2055
-14	58010	7	21450	28	8867	49	4033	70	1990
-13	55170	8	20520	29	8523	50	3893	71	1928
-12	52480	9	19630	30	8194	51	3758	72	1868
-11	49940	10	18790	31	7880	52	3629	73	1810
-10	47540	11	17980	32	7579	53	3504	74	1754
-9	45270	12	17220	33	7291	54	3385	75	1700
-8	43110	13	16490	34	7016	55	3270	76	1648
-7	41070	14	15790	35	6752	56	3160	77	1598
-6	39140	15	15130	36	6500	57	3054	78	1549
-5	37310	16	14500	37	6258	58	2952	79	1503
-4	35570	17	13900	38	6026	59	2854	80	1458
-3	33930	18	13330	39	5805	60	2760		
-2	32370	19	12790	40	5592	61	2669		
-1	30890	20	12260	41	5389	62	2582		
0	29490	21	11770	42	5193	63	2497		
1	28150	22	11290	43	5006	64	2417		
2	26890	23	10840	44	4827	65	2339		
3	25690	24	10410	45	4655	66	2264		
4	24550	25	10000	46	4489	67	2191		
5	23460	26	9605	47	4331	68	2122		

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