

**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. H**



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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.

Table of Contents

| | |
|---|----|
| General Safety Warnings | 2 |
| License Agreement | 5 |
| Features | 8 |
| Setup Instructions..... | 13 |
| 1.0 Initial Setup..... | 13 |
| 2.0 Configuration Setup..... | 18 |
| 3.0 Tuning Parameter Description..... | 24 |
| 4.0 Calibration Parameter Description..... | 26 |
| 5.0 Final Setup—Controller Tuning | 27 |
| 6.0 Data Acquisition Features..... | 31 |
| 7.0 Custom Software | 32 |
| Controller Wiring Diagram: One Power Supply Setup | 33 |
| Controller Wiring Diagram: Two Power Supplies Setup | 34 |
| Safety Ground for TC-36-25-RS232-UL | 35 |
| Expansion Connector Wiring Diagram..... | 36 |
| Mechanical Package Drawing..... | 37 |
| Block Diagram..... | 38 |
| RS232 Communications Connections..... | 39 |
| Appendix A Troubleshooting Controller | 40 |
| APPENDIX B Troubleshooting Communications Port | 42 |
| APPENDIX C Serial Communications..... | 43 |
| APPENDIX D Thermistors for TC-36-25 RS232 | 56 |

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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.

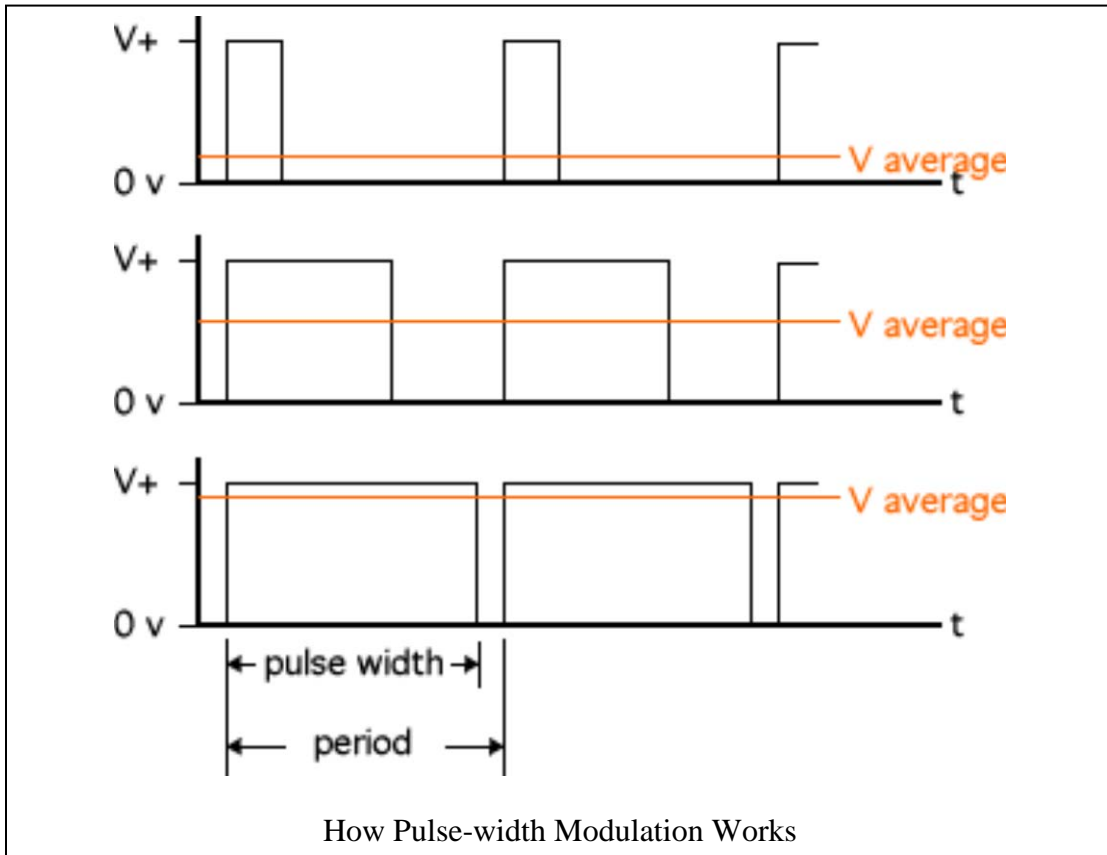


Main Features

- 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 $-20\text{ }^{\circ}\text{C}$ to $+100\text{ }^{\circ}\text{C}$ using thermistor supplied with controller
- Control temperature of $-40\text{ }^{\circ}\text{C}$ to $+250\text{ }^{\circ}\text{C}$ 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 $0.01\text{ }^{\circ}\text{C}$ or $0.01\text{ }^{\circ}\text{F}$
- Control stability of $\pm 0.01\text{ }^{\circ}\text{C}$ or $\pm 0.01\text{ }^{\circ}\text{F}$ (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 $0\text{ }^{\circ}\text{C}$ to $60\text{ }^{\circ}\text{C}$, storage temperature range of $-55\text{ }^{\circ}\text{C}$ to $+105\text{ }^{\circ}\text{C}$

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 (V_{average}) that is required by the TE device to maintain the set temperature.



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 $\pm 100\%$ 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 $-20\text{ }^{\circ}\text{C}$ to $+100\text{ }^{\circ}\text{C}$ 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 $^{\circ}\text{C}$ or $^{\circ}\text{F}$.

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

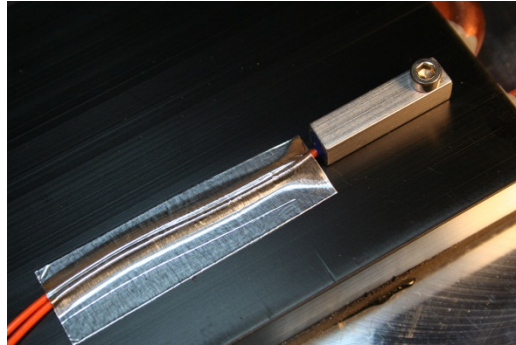
JP4-2: red wire

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 ≥ 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: 142.6185.5256). 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 V_{max} 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 V_{max} of the system will be approximately 75% of the rated V_{max} of each TE module multiplied by the number of modules in series. Applying an input voltage to the controller that is greater than the V_{max} 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 k Ω , 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://totech.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.

File Help

PC COMMUNICATIONS

SELECT COMM PORT

INITIALIZE CommCheck

TUNING

FIXED SET TEMP.

PROPORTIONAL BANDWIDTH

INTEGRAL GAIN Send Box Values

DERIVATIVE GAIN

CONTROL DEADBAND

CALIBRATE

INPUT1 OFFSET

INPUT2 OFFSET Send Box Values

HEAT SIDE MULTIPLIER

COOL SIDE MULTIPLIER

EEPROM WRITE ENABLE

CONFIGURE

SET TEMP TYPE

SET TEMP HIGH RANGE

SET TEMP LOW RANGE

DISPLAY FUNCTION ENABLE

CONTROL TYPE Send Box Values

CONTROL MODE

ALARM TYPE

POWER OUT SHUT DOWN IF ALARM

HIGH ALARM SETTING OUTPUT ON/OFF

LOW ALARM SETTING

ALARM DEADBAND

ALARM LATCH SEND LATCH CLEAR

SENSOR TYPE

CHOOSE SENSOR FOR ALARM

CHOOSE DEGC OR DEGF UNITS

OVER-CURRENT LEVEL: AMPS (APPROXIMATE)

OVER-CURRENT RESTART ATTEMPTS: CONTINUOUS

DATA ACQUISITION

SAMPLE TIME IN SECONDS

DATA LOG BOX BOX ENABLE

SAMPLE SAMPLING INDICATOR

TEMP LOG ENABLE

SET TEMP LOG ENABLE

OUTPUT LOG ENABLE

INPUT 2 AS TEMP. LOG ENABLE

OVER CURRENT

LOW VOLTAGE

SEND SET RANGE TO DISPLAY

DOWNLOAD DEFAULTS

VERIFY DEFAULTS

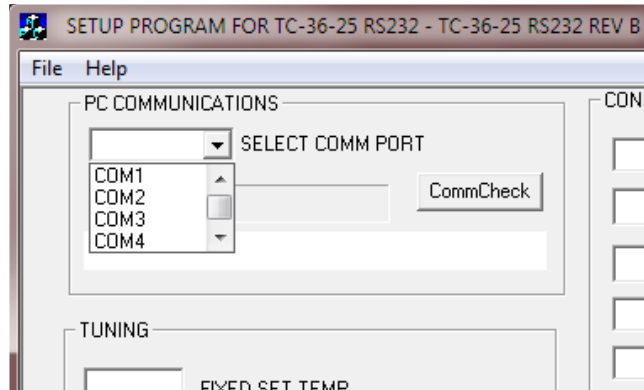
OVER CURRENT COUNT

Ready NUM

- 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.

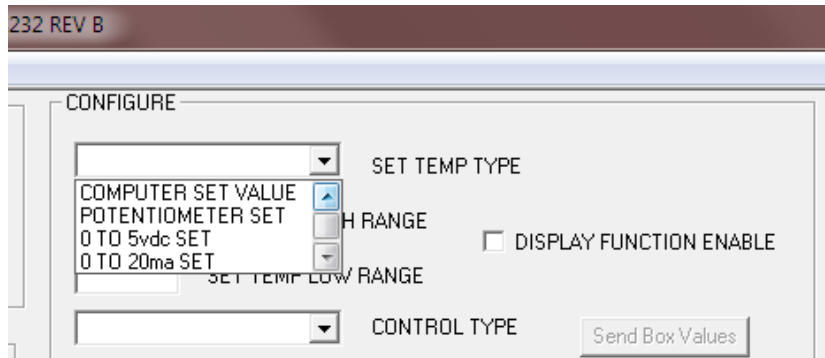
If you only have USB ports available on your computer, you can use our optional RS232 Adapter to provide USB to RS232 conversion. If you use your own USB to RS232 converter, be aware that some converters might inject noise on the transmit line from the computer and disrupt communications. The noise problem 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

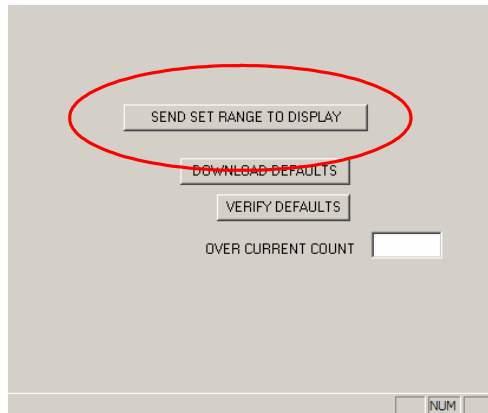
- 2.1 In the CONFIGURE section of the software, the various selections below are used to establish the custom operating criteria for the controller.



- 2.2 SET TEMP TYPE menu key:

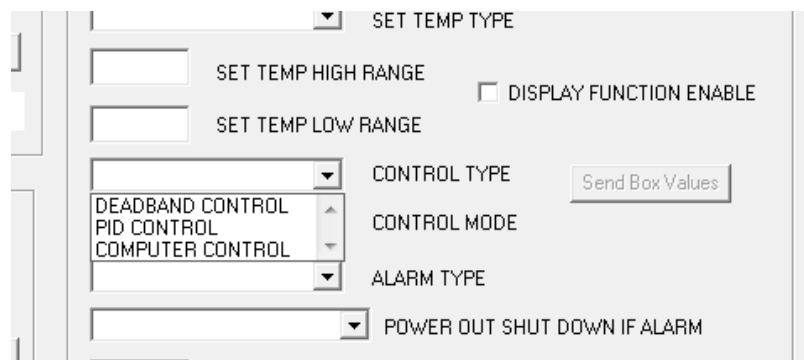
- a) COMPUTER SET VALUE: temperature set point is determined from software input
- b) POTENTIOMETER SET, 0 TO 5vdc SET, or 0 TO 20 mA SET: temperature set point is determined by remote input. Refer to the “*Controller Wiring Diagram*” and the “*Block Diagram*” for additional information. If you intend 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 indicated 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:

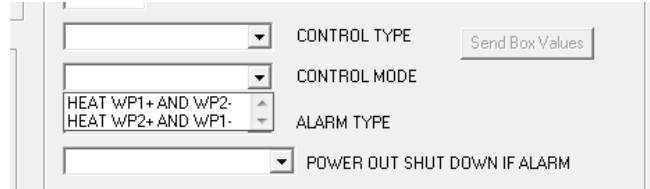
- a) DEADBAND CONTROL: selects on/off control mode. However, DEADBAND CONTROL should not be used unless care is taken to prevent the TE device from being damaged by excessive thermal cycling.
- b) PID CONTROL: selects proportional/integral/derivative control mode. When this mode is selected, the temperature 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.

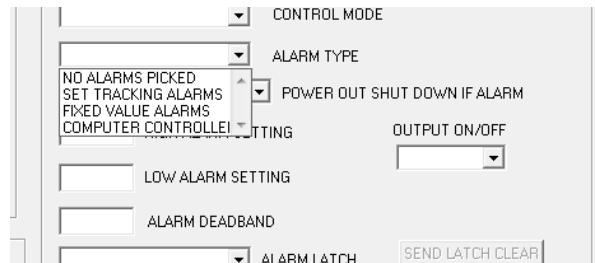
NOTE: For TE Technology’s standard products, the TE+ (red) wire should be attached to WP2 and the TE- (black) wire should be attached to WP1 as shown in the “Controller Wiring Diagram.” The CONTROL MODE should then be set to HEAT WP1+ and WP2-. Again though, do **NOT** connect the TE device at this time.



2.5 ALARM TYPE menu key:

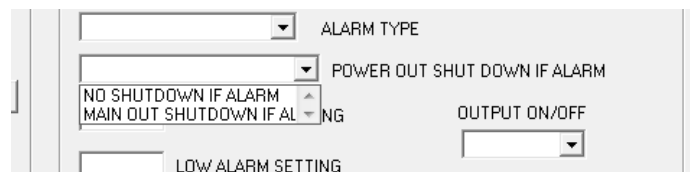
- a) NO ALARMS PICKED: no alarm condition will be monitored.
- b) SET TRACKING ALARMS: allows an alarm to be set with respect to the set temperature. It will move accordingly with a change of the temperature setting. This option can be used for a high alarm, low alarm, or both settings.
- c) FIXED VALUE 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.



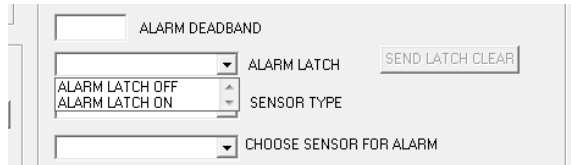
2.7 ALARM LATCH menu key:

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.

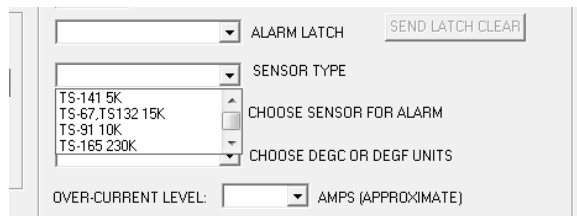


2.8 SENSOR TYPE menu key:

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.

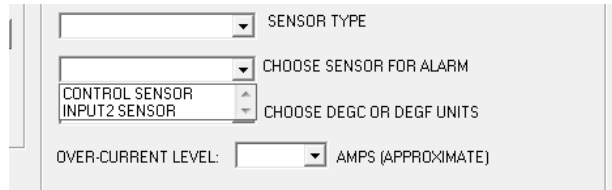
Contact TE Technology if you need a sensor that uses a temperature scale different from the “TS-67, TS132 15K”, 20 °C to +100 °C range.



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.

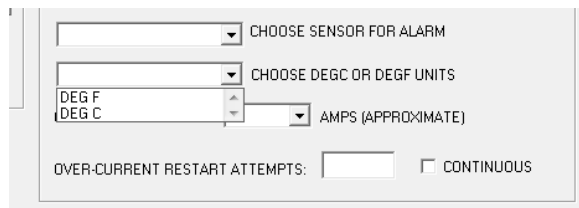
2.9 CHOOSE SENSOR FOR ALARM menu key:

- 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.)



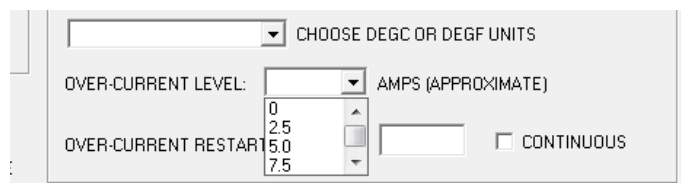
2.10 CHOOSE DEGC OR DEGF menu key:

- 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.

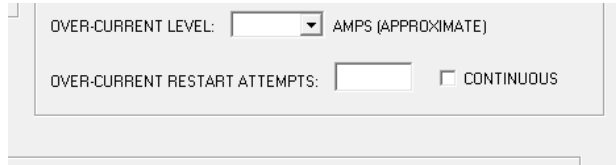


NOTE: THIS IS NOT AN ANALOG CURRENT LIMIT FEATURE!

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.

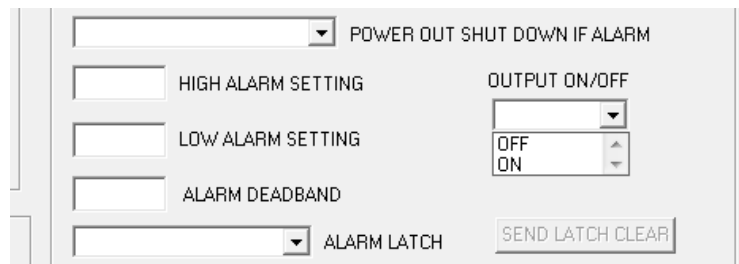
2.12 OVER-CURRENT RESTART ATTEMPTS / CONTINUOUS boxes:

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)

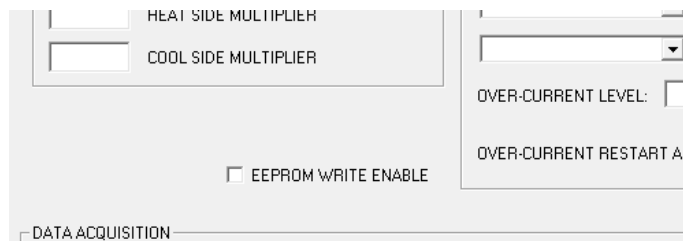


NOTE: Select OFF for the initial setup. This will ensure that the controller will not begin controlling the TE device to a temperature that might inadvertently cause damage if the controller were not yet completely set up.

2.14 EEPROM WRITE ENABLE check box:

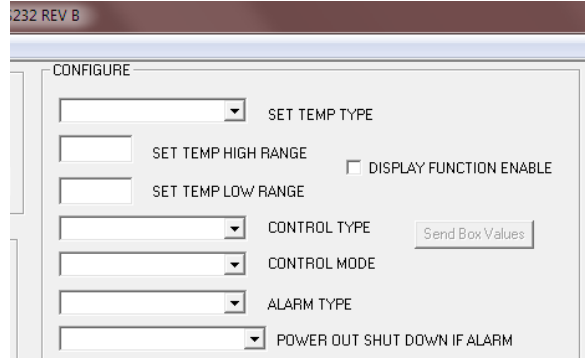
Upon a power-up or reset condition, the controller performs an initialization of all command variables that have write commands. The controller transfers the last values stored in non-volatile memory (EEPROM) to appropriately referenced static RAM locations. This action is performed so that the controller 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).



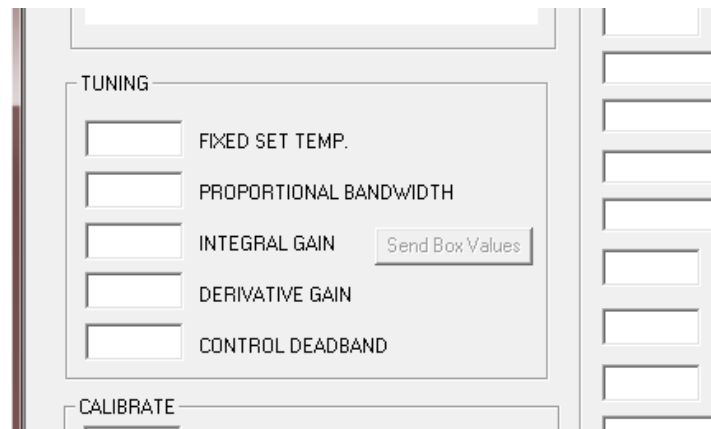
- 2.15 Review all of your controller configuration selections. If all the configuration selections are correct for your application, click the SEND BOX VALUES button in the CONFIGURE section to download these settings to the controller.

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:
- 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.
 - 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.

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

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.

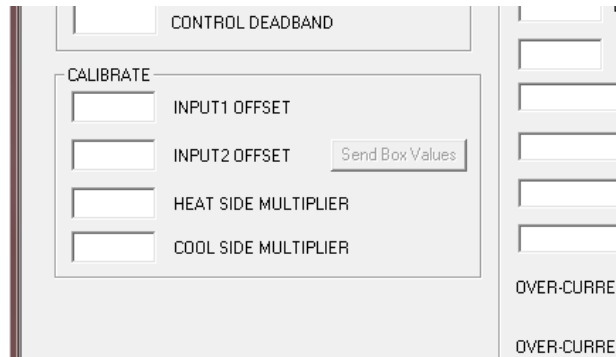
The derivative gain senses the rate of change of the temperature and allows the controller to anticipate the power needed to compensate for rapid changes in system loading. This term is generally used only on very sluggish systems or where very quick response is necessary. It works in a way similar to 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.

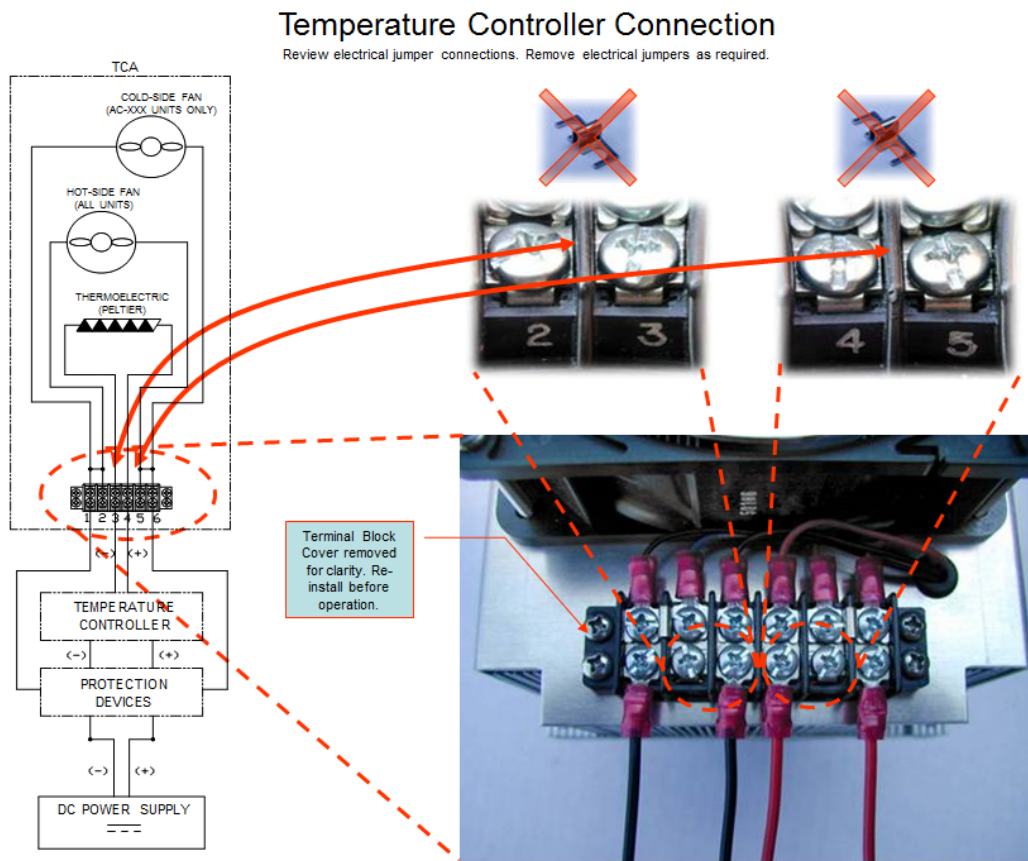
NOTE: Remember to click the SEND BOX VALUES button to update the controller anytime TUNING variables have changed.

The image shows a software interface for controller tuning. It features a 'TUNING' section with five input fields: 'FIXED SET TEMP.', 'PROPORTIONAL BANDWIDTH', 'INTEGRAL GAIN', 'DERIVATIVE GAIN', and 'CONTROL DEADBAND'. A 'Send Box Values' button is positioned to the right of the 'INTEGRAL GAIN' field. Below the 'TUNING' section is a 'CALIBRATE' section. To the right of the main interface, there is a vertical stack of several input fields, some of which are partially visible and labeled with 'H', 'L', and 'A'.

- 5.2 Connect **ONLY** the TE device to the controller:
 Positive TE device terminal to WP2
 Negative TE device terminal to WP1

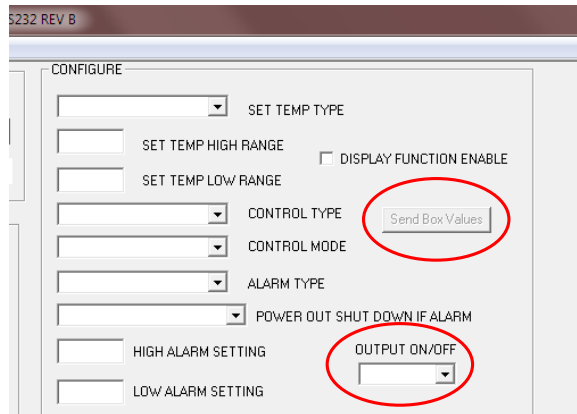


TE Technology's standard thermoelectric cooling assemblies (TCA) have at least one fan on the heat sink. The standard configuration has the thermoelectric modules and fan(s) wired to a terminal block with jumpers across the terminals so that the fans and modules are connected in parallel. However, this 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.

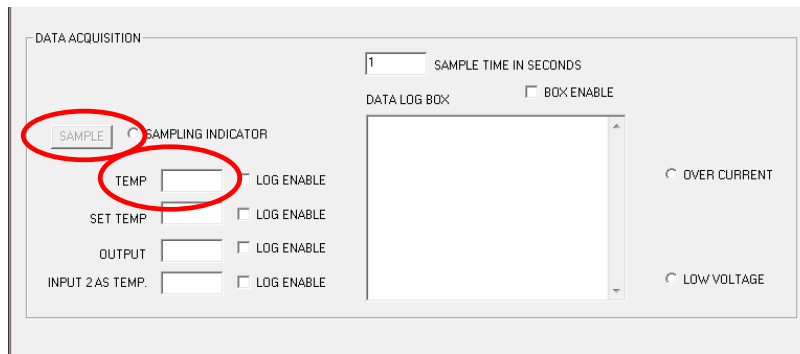
Next, select ON in the OUTPUT ON/OFF menu key in the CONFIGURE section. Then click SEND BOX VALUES in the CONFIGURE section. The controller will begin to send output power to the TE device.



- 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 PROPORTIONAL 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:

$$I = 0.54/1.25 \text{ minutes} = 0.43 \text{ repeats/minute}$$

- 5.3.5 The derivative 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: $D = 0.075 \times T$, 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

The screenshot shows a software interface titled "DATA ACQUISITION". At the top left is a "SAMPLE" button. To its right is a "SAMPLING INDICATOR" radio button. Below these are four rows of controls: "TEMP" with an input box and "LOG ENABLE" checkbox; "SET TEMP" with an input box and "LOG ENABLE" checkbox; "OUTPUT" with an input box and "LOG ENABLE" checkbox; and "INPUT 2 AS TEMP." with an input box and "LOG ENABLE" checkbox. At the top right is a "SAMPLE TIME IN SECONDS" input field containing the number "1". Below it is a "DATA LOG BOX" with a "BOX ENABLE" checkbox. To the right of the data log box are two radio buttons: "OVER CURRENT" and "LOW VOLTAGE".

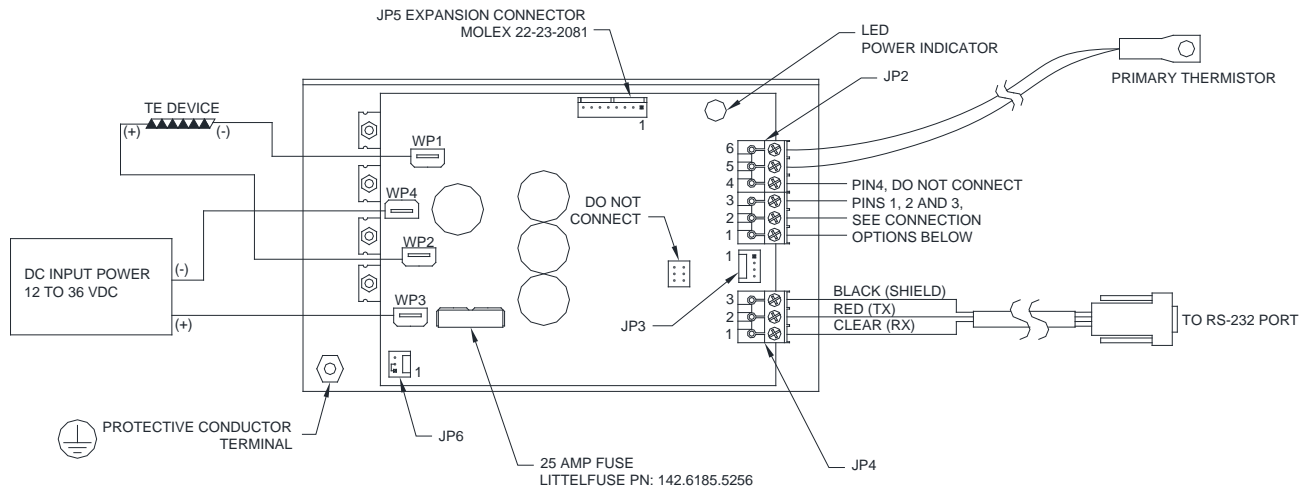
- 6.1 **SAMPLE button:**
Clicking the sample button instructs the controller to report the controller operating conditions for TEMP, SET TEMP, OUTPUT, INPUT2 AS TEMP, and OVER CURRENT COUNT.
- 6.2 **SAMPLE TIME IN SECONDS box:**
Enter the time, in seconds. This sets the controller update interval for 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.*”

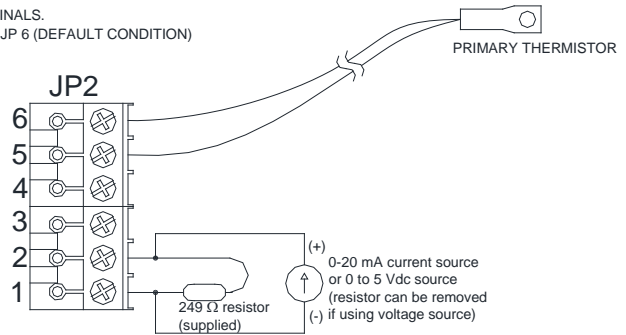
TE Technology has developed some LabVIEW programs for internal use. We would be happy to share them for use as a starting point for your custom software application. Please email the company if you are interested in this option.

Controller Wiring Diagram: One Power Supply Setup

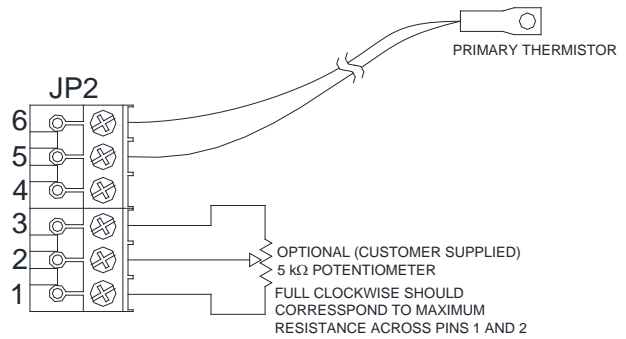


NOTE: 1. WP1, WP2, WP3, AND WP4 ARE 6.35 mm (.25 inch) QUICK CONNECT TERMINALS.
 2. SINGLE POWER SUPPLY OPTION: INSTALL JUMPER ON PINS 1 AND 2 OF JP 6 (DEFAULT CONDITION)

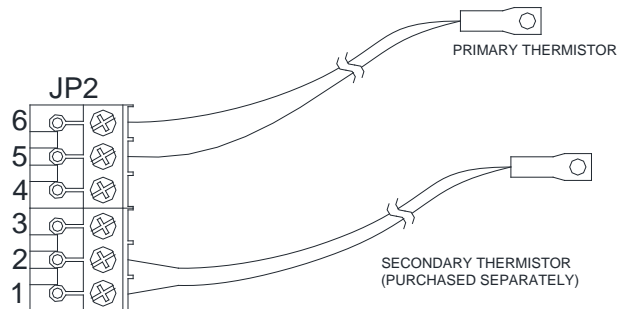
OPTION 1 Proportional Signal for Adjusting Set Point



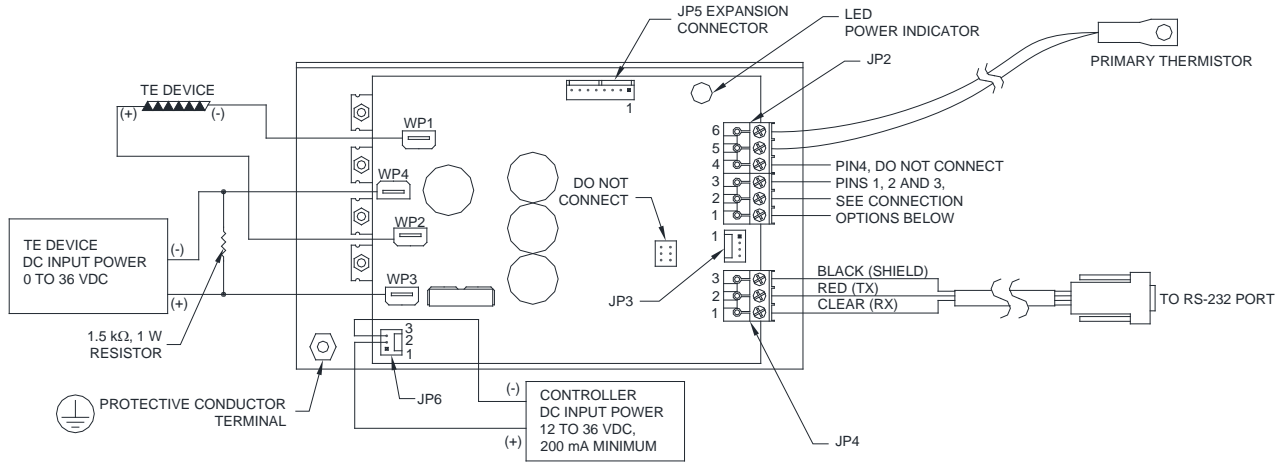
OPTION 2 Variable Resistance for Adjusting Set Point



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

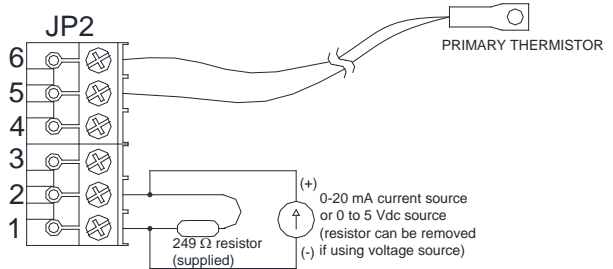


Controller Wiring Diagram: Two Power Supplies Setup

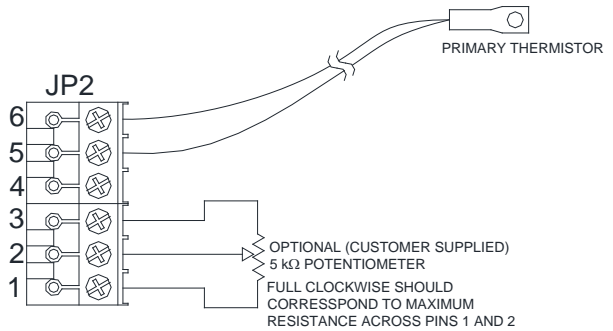


NOTE: 1. WP1, WP2, WP3, AND WP4 ARE 6.35 mm (.25 inch) QUICK CONNECT TERMINALS
 2. TWO POWER SUPPLIES SETUP: A. TE DEVICE POWER SUPPLY CONNECTS TO WP3(+) AND WP4(-)
 B. CONTROLLER POWER SUPPLY CONNECTS TO JP6-2(+) AND JP6-3(-) (REMOVE JUMPER FROM JP6)
 JP6: MOLEX PN: 22-23-2031
 3. INSTALL 1.5 kΩ, 1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

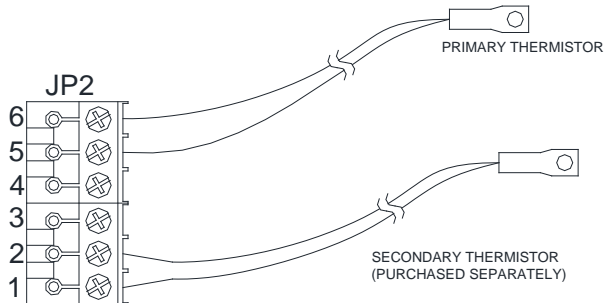
OPTION 1 Proportional Signal for Adjusting Set Point



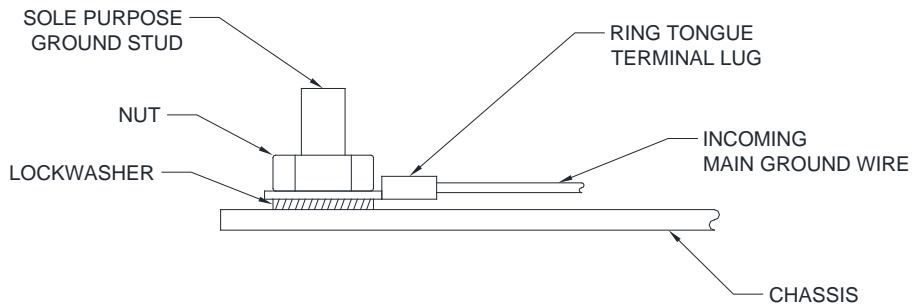
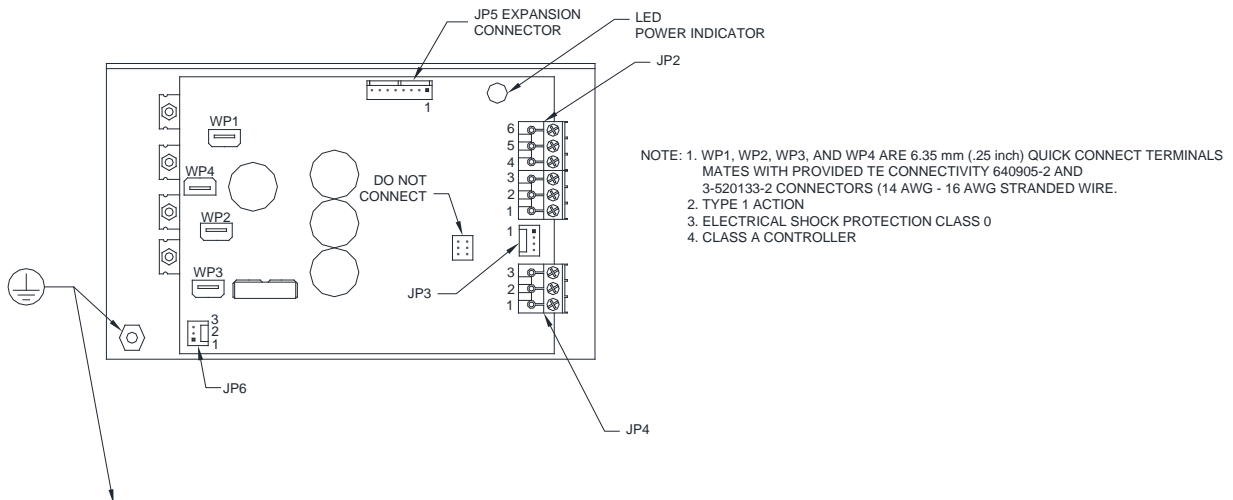
OPTION 2 Variable Resistance for Adjusting Set Point



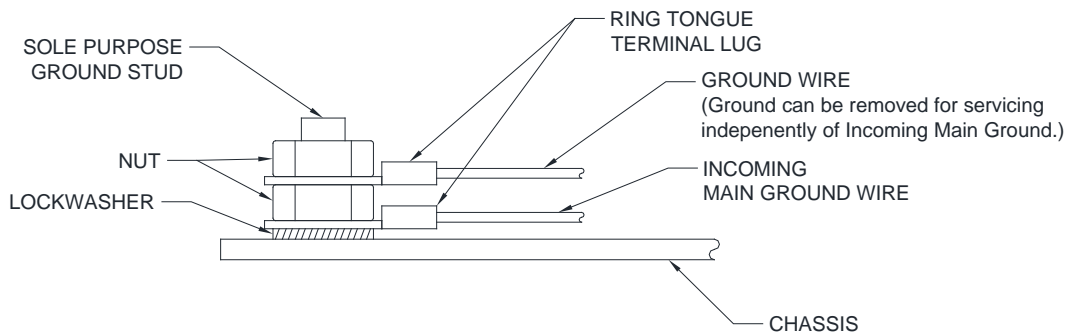
OPTION 3 Second Thermistor for Differential Control or for Sensing Over-temperature Condition



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



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

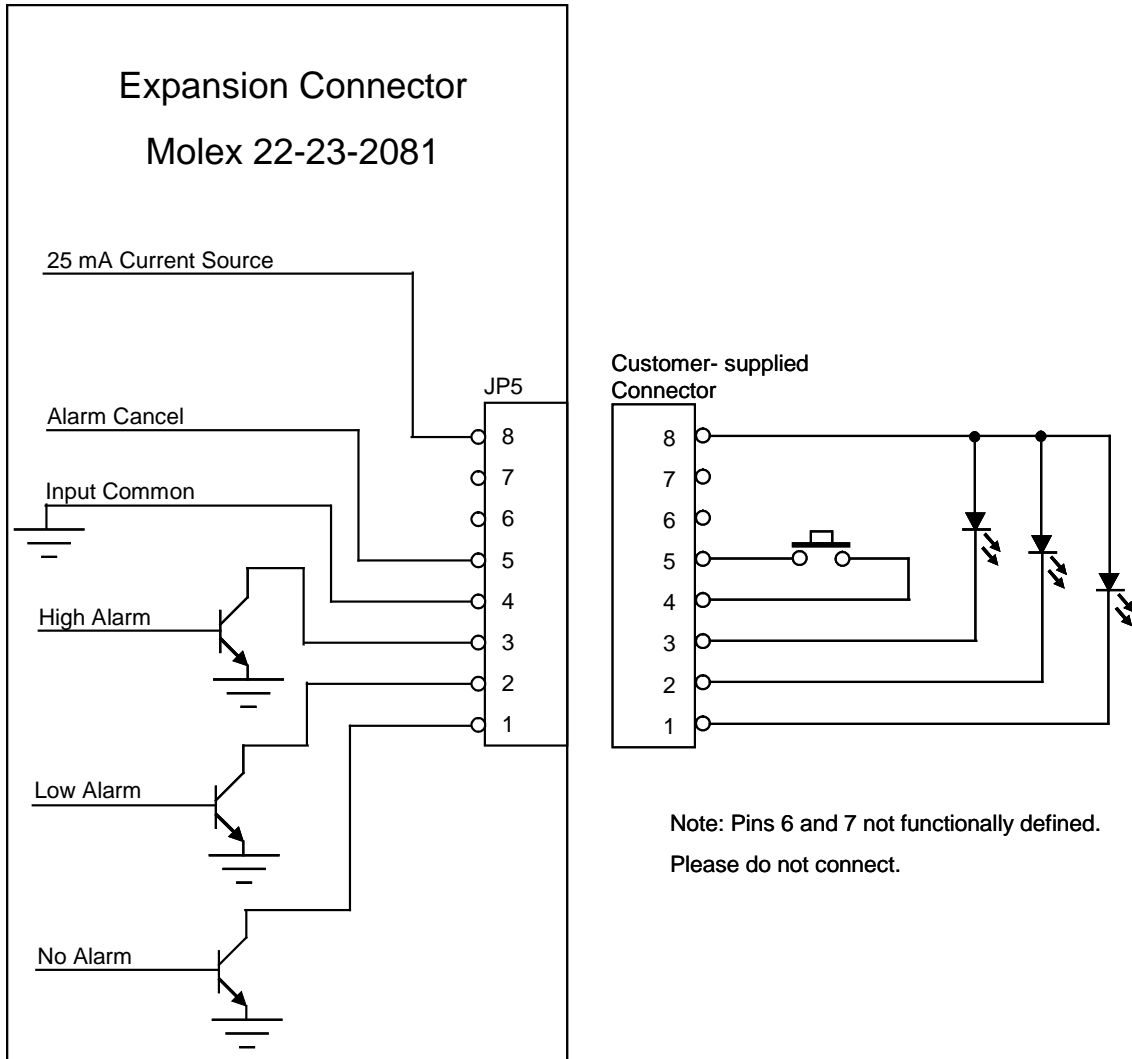


Proper Ground for TC-36-25-RS232-UL when adding Ground Wire from TE device

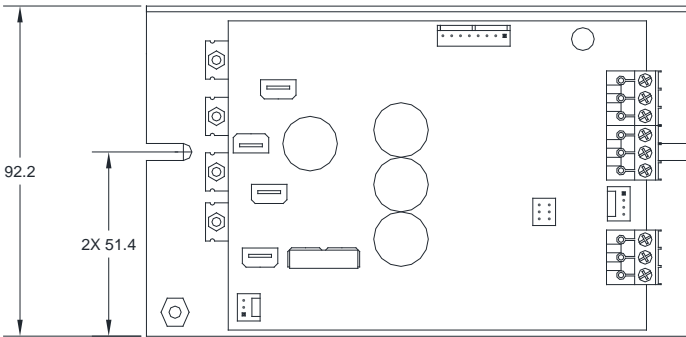
NOTE: Wire colors for Incoming Main Ground and Ground shall be green or green/yellow.

Expansion Connector Wiring Diagram

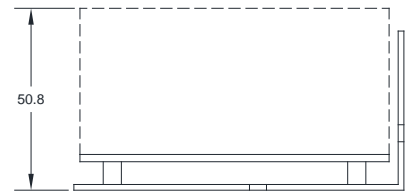
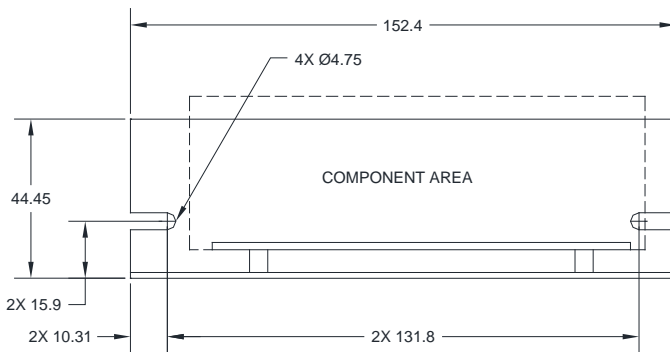
Note: The 25 mA current source is a true current source. Maximum compliance voltage is approximately $V+$, the input voltage to the temperature controller. No external current limit resistors are needed for the LED. The LED must be capable of being driven with a 25 mA continuous current.



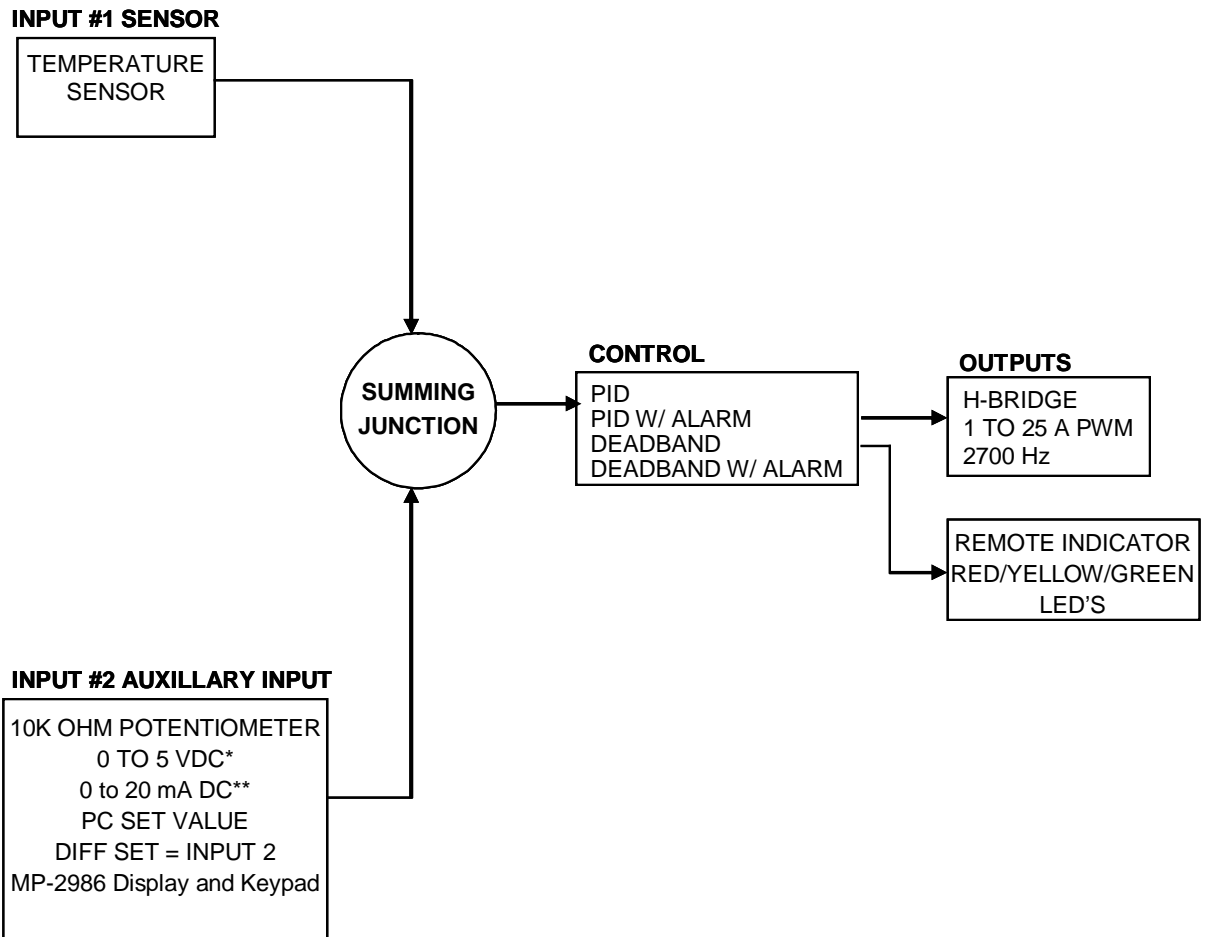
Mechanical Package Drawing



DIMENSIONS IN MILLIMETERS



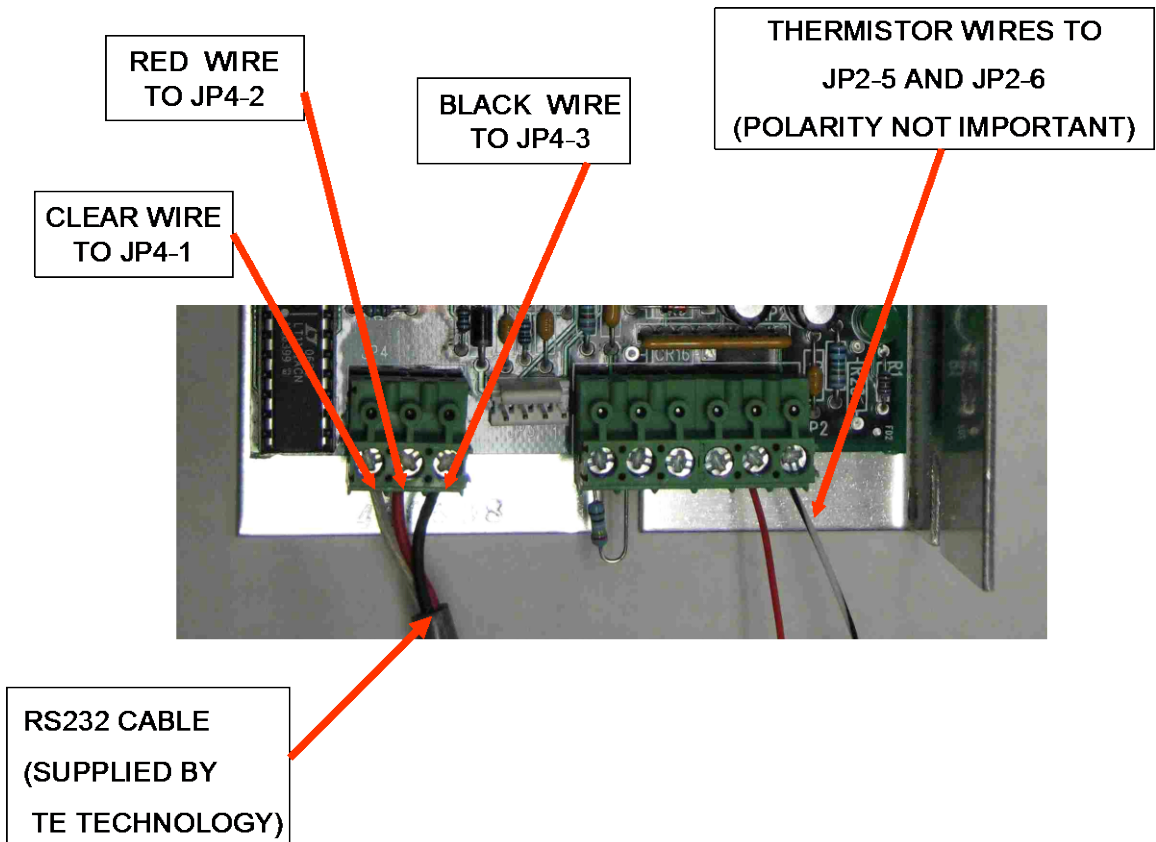
Block Diagram



*CONTROLLER INPUT IMPEDANCE 6.5K OHMS

**REQUIRES ADDITION OF EXTERNAL RESISTOR

RS232 Communications Connections



PC CONNECTION TABLE

| | <u>PC CONNECTOR</u> | | <u>PC FUNCTION*</u> | <u>CONTROLLER</u> |
|-----|---------------------|--------|---------------------|---------------------|
| | 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): $1_{10} = 00000001_{16}$ $-1_{10} = \text{ffffff}_{16}$ |
| 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). <i>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.</i> |

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

(stx)AACDDDDDDSS(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)DDDDDDSS(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) AAC0000000SS (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)DDDDDDSS(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:

| <u>ASCII Character:</u> | <u>Hexadecimal Value:</u> |
|-------------------------|---------------------------|
| 0 | 30 |
| 0 | 30 |
| 2 | 32 |
| 9 | 39 |
| 0 | 30 |
| 0 | 30 |
| 0 | 30 |
| 0 | 30 |
| 0 | 30 |
| 0 | 30 |
| 0 | 30 |
| 0 | 30 |
| 0 | 30 |
| <u>0</u> | <u>30</u> |
| Sum | 024b₁₆ |

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 100₁₀ (10.00 x 100 = 1000).
4. Convert 1000₁₀ to hexadecimal (3e8₁₆) 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, 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 |
| <u>8</u> | <u>38</u> |
| Sum | 02b4₁₆ |

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 100₁₀ (-1.50 x 100 = -150).
4. Convert -150₁₀ 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 fffff6a₁₆.
5. Compute the checksum (SS) by adding the hexadecimal ASCII values of the following characters: 0, 0, 1, c, f, 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 |
| f | 66 |
| 6 | 36 |
| <u>a</u> | <u>61</u> |
| Sum | 3ef₁₆ |

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 |
| 0 | 30 |
| <u>0</u> | <u>30</u> |
| Sum | 0241₁₆ |

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 000000fa₁₆ converts to 250₁₀. This number must then be divided by 100₁₀, 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. POWER 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 °F/°C. A value of 5 °F/°C for bandwidth and control setting of 25 °F/°C would place the proportional band from 20 °F/°C to 30 °F/°C; 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 convert 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 100₁₀ and convert to hexadecimal for the “send value.” When reading, convert the “return value” to decimal and divide by 100₁₀ 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 100₁₀ and convert to hexadecimal for the “send value.” When reading, convert the “return value” to decimal and divide by 100₁₀ to convert 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 100₁₀ and convert to hexadecimal for the “send value.” When reading, convert the “return value” to decimal and divide by 100₁₀ to convert 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 100₁₀ and convert to hexadecimal for the “send value.” When reading, convert the “return value” to decimal and divide by 100₁₀ to convert 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 100₁₀ and convert to hexadecimal for the “send value.” When reading, convert the “return value” to decimal and divide by 100₁₀ to convert 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 100₁₀ and convert to hexadecimal for the “send value.” When reading, convert the “return value” to decimal and divide by 100₁₀ to convert 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 100₁₀ and convert to hexadecimal for the “send value.” When reading, convert the “return value” to decimal and divide by 100₁₀ to convert 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 100₁₀ and convert to hexadecimal for the “send value.” When reading, convert the “return value” to decimal and divide by 100₁₀ 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 100₁₀ and convert to hexadecimal for the “send value.” When reading, convert the “return value” to decimal and divide by 100₁₀ 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 30000₁₀
 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

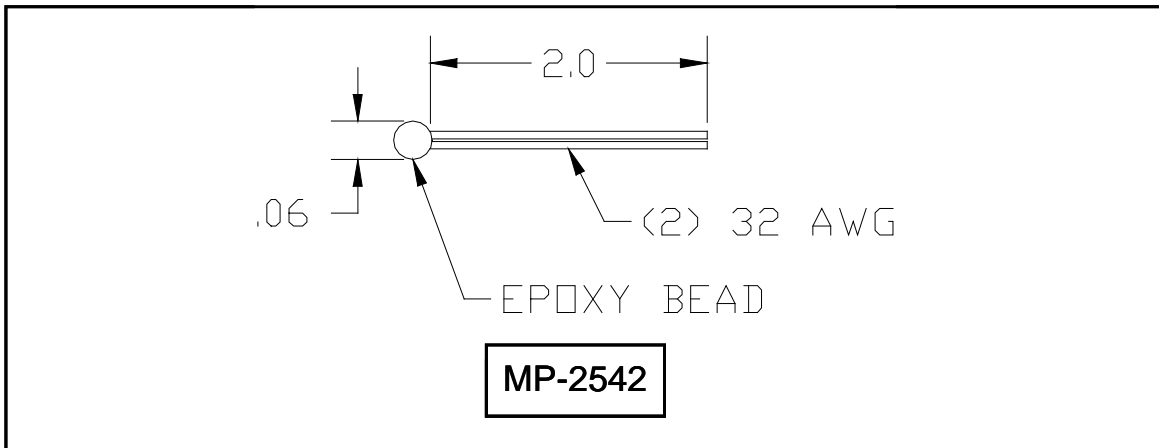
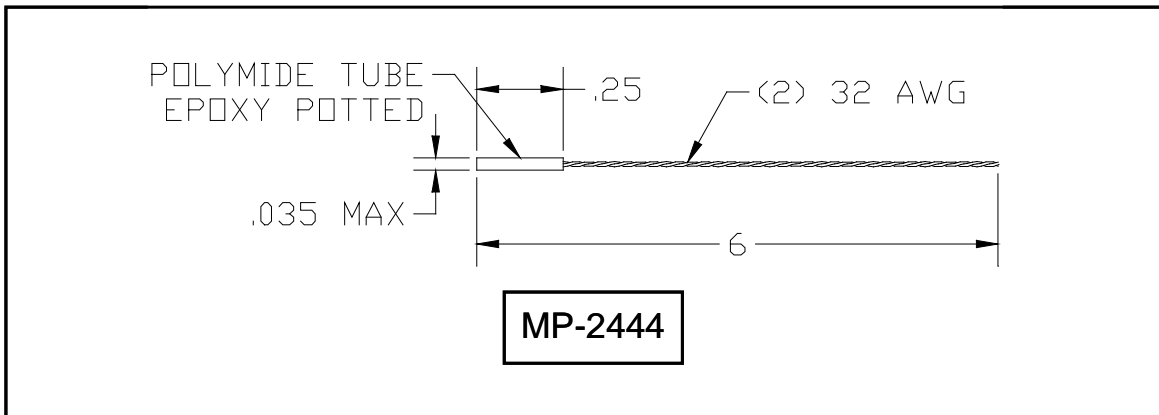
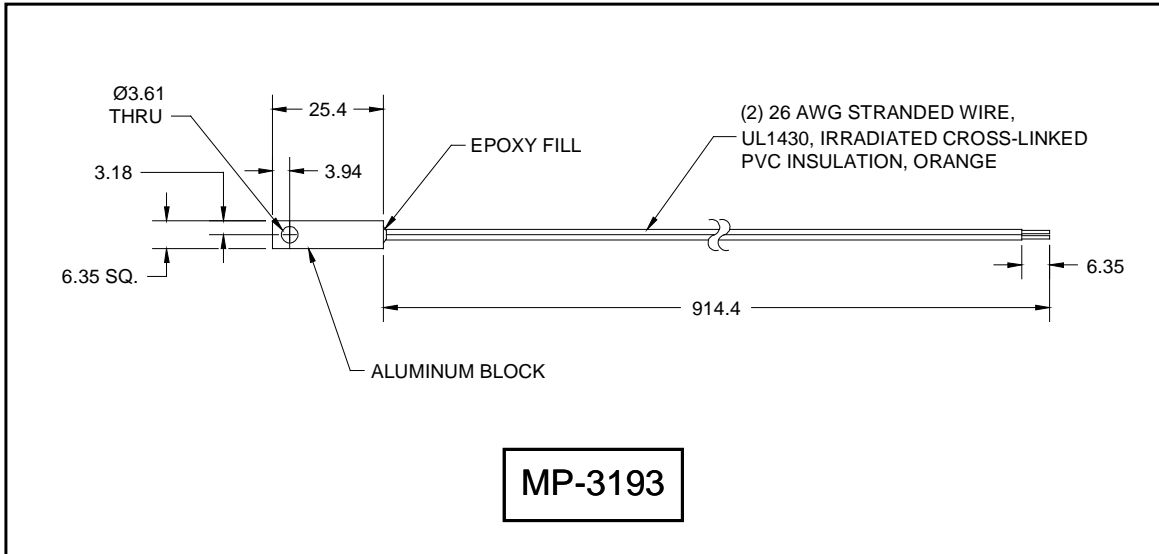
| Dec | Oct | Hex | Binary | Description |
|-----|-----|-----|----------|---|
| 000 | 000 | 00 | 00000000 | ^@ ^` NULL NUL null c-@ c-` |
| 001 | 001 | 01 | 00000001 | ^A ^a SOH GTL c-A c-a start-of-heading |
| 002 | 002 | 02 | 00000010 | ^B ^b STX c-B c-b start-of-text |
| 003 | 003 | 03 | 00000011 | ^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. Standard thermistors have TS-67 temperature-resistance curves. Additional thermistor styles are shown at www.tetech.com



**TS-67 Temperature (°C) versus Resistance (ohms, Ω) Data
for MP-3193, MP-2444, 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 $\pm 650 \Omega$, corresponding to $\pm 1^\circ \text{C}$
over a 0°C to 100°C range.

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

| | | | | | | | | | | | |
|-----|--------|-----|-------|----|-------|----|------|----|------|----|-------|
| -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

| | | | | | | | | | | | |
|----|--------|----|-------|----|-------|-----|------|-----|------|-----|------|
| 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 | | |