

**Operation Manual
for
Model TC-24-12
Thermoelectric Cooler
Temperature Controller**

**July 1, 2004
Drawing #4093 Revision B**

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Notice: Improper tuning of this temperature controller (or any 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.

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Features

- Input voltage from (10.8 to 26.4) volts DC
- Maximum 11.9 amps output current
- Proportional-Integral (PI) control
- Bi-directional, solid-state H-bridge operation, for heating and cooling applications
- Pulse-width modulation of output at 1000 Hz
- Control temperature of $-20\text{ }^{\circ}\text{C}$ to $+100\text{ }^{\circ}\text{C}$ using MP-2379 thermistor (supplied with the controller)
- Control stability of up to $\pm 0.3\text{ }^{\circ}\text{C}$ (when controlling a cold plate)
- Proportional (P) bandwidth adjustment of $1.0\text{ }^{\circ}\text{C}$ to $15.0\text{ }^{\circ}\text{C}$ and Integral (I) rate adjustment of 0 to 2.55 repeats per minute
- Removable terminal strip for easy connection of power, cooler, and thermistors
- Test points for reading Set Temperature, P, I, and thermistor voltages
- Temperature status LEDs
- Two inputs for optional, over-temperature thermistors or thermostats
- Over-temperature alarm (with alarm output transistor) configurable for continuous shutdown or automatic resetting of output power
- Fault detection indications through the LEDs
- Operating temperature range: 0 to $60\text{ }^{\circ}\text{C}$
- Storage temperature range: -55 to $105\text{ }^{\circ}\text{C}$

Overview

1.0 General Description

The TC-24-12 Temperature Controller is a pulse-width-modulated (PWM), bi-polar output device capable of controlling a thermoelectric cooler in both the cooling and heating modes. The controller uses a proportional and integral control mode, and consists of a microprocessor, thermistor inputs, a power output stage, and set-temperature/tuning potentiometers. Temperature status indicator LEDs, an alarm output transistor, and voltage test points are also included. The potentiometers can be removed and set-point/tuning parameters can be preprogrammed from the factory for high-volume applications if desired.

The TC-24-12 will operate with input voltages ranging from (10.8 to 26.4) volts DC (a minimum of 10.8 V input is needed to operate the on-board microprocessor). It will control output currents of up to 11.9 amps maximum (with no load on the alarm circuit). The H-bridge output stage uses highly efficient N-channel MOSFET output devices, so no additional heat sinking is needed. The TC-24-12 offers a low-cost means of temperature control, yet because of its PWM methodology, when used properly, it will not reduce the cooler's reliability as might otherwise happen with on-off types of controllers. (Additional information on cooler reliability and the affects of PWM control can be found at <http://www.tetech.com/publications/pubs/ICT99MJN.pdf>).

2.0 PWM Control Description

The TC-24-12 uses PWM at 1000 Hz, meaning that the power is switched between fully "ON" and fully "OFF" one thousand times per second. Varying the ratio of "ON" time to "OFF" time regulates the amount of cooling. The output of the controller is a square wave with the duty cycle (the ratio of the "ON" portion of the cycle versus the total cycle) being varied as necessary to achieve the desired cooling or heating. Essentially, the input voltage to the controller is switched ON or OFF to the thermoelectric module(s). Thus, the input voltage to the temperature controller will define the output voltage to the cooler when the power is switched "ON"—there is not a linear output voltage to the thermoelectric module(s) that increases as more cooling is required. One should therefore choose an input voltage that is no greater than the V_{max} of the cooling assembly or thermoelectric module(s). When making a cooling system from thermoelectric modules, the maximum operating voltage (the controller's input voltage) is typically no more than 75% of module's V_{max} . Of course, multiple modules can be used in a series or series-parallel combination, and the V_{max} of the module system will be the total V_{max} of the modules in series. In this case, the input voltage is generally no more that 75% of the V_{max} of the module system.

3.0 Control Thermistor Input

The TC-24-12 uses a negative temperature coefficient thermistor to give feedback to the control circuitry. The sensor's nominal resistance is 15,000 ohms at 25 °C. The same type of thermistors can also be used for sensing over-temperature conditions. (See section 4.0 below.) The standard thermistor-head styles and resistance-verses-temperature curves are shown in “*Thermistor Styles for TC-24-12*” (The MP-2379 thermistor is provided with the controller).

If you want to use thermistors that have different resistance-versus-temperature curves than the standard thermistor, it can be done as long as the operating resistance range is within that of the

standard thermistor. The thermistor should be a negative temperature coefficient device. Because the temperature controller is really measuring the thermistor's resistance and converting this to a temperature, the temperature controller will be "fooled" into thinking that the thermistor is at a different temperature than it really is, and the Set-Temperature will be skewed accordingly. A loss of resolution, control range, and control stability may occur as a result. The user assumes all risks associated with making any substitutions and TE Technology assumes no liability whatsoever for the operation of the controller when a non-standard thermistor is used.

The controller is pre-programmed to enter into a "Fault Mode" if the controller senses the resistance of control thermistor as either a short circuit or an open circuit. When a fault is sensed, the controller will perform the following tasks:

1. Turn off the output to the thermoelectric module(s)
2. Flash LEDs to indicate a control thermistor fault has been sensed (see *Fault Detection Indications*)
3. Electrically short Pins JP2-3 and JP2-4 to the circuit ground through the drain of the alarm output transistor

The controller will return to normal operating mode as soon as the resistance of control thermistor is no longer sensed as an open or short circuit.

4.0 Over-Temperature Thermistor / Thermostat Inputs

Two additional thermistors may be used as over-temperature sensors. Generally, these would be attached to the hot and cold sides of the cooling assembly. The controller is pre-programmed to enter into a "Fault Mode" if the resistance of either over-temperature thermistor drops below approximately 2620 ohms, which corresponds to a fault temperature of 70 °C with the standard series thermistors. When a fault is sensed, the controller will perform the following tasks:

1. Turn off the output to the thermoelectric module(s)
2. Flash LEDs to indicate a fault temperature has been sensed (see *Fault Detection Indications*)
3. Pins JP2-3 and JP2-4 are shorted to the circuit ground through the drain of the alarm output transistor

The return to normal operating conditions depends on the placement of the two-pin jumper at JP4. If the jumper is installed (pins are shorted together) then the output to the TE load will latch off if a fault temperature is detected. With this jumper setting the controller will need to have its power removed in order to unlatch and reset the controller. This mode allows the user to correct the problem that caused the fault condition, and it prevents the thermoelectric cooling system from being destroyed by over-temperature conditions and/or thermal cycling. This is the recommended operating mode.

If the jumper is removed then the controller will return to normal operating conditions when the fault sensor's resistance increases beyond approximately 5390 ohms, which corresponds to a temperature of 50 °C with the standard thermistors. NOTE: If the cause of the fault condition continues to exist, this mode would thermally cycle the cooler because power is being removed and then reapplied. Thermal cycling could eventually destroy the thermoelectric cooling system. Therefore, this mode should only be used if the thermoelectric cooler is protecting expensive or critical equipment and failure of the thermoelectric cooling system, while undesirable, is preferable to having absolutely no cooling in the system.

The TC-24-12 also allows the use of thermostatic control devices to be used in place of over-temperature thermistors. These devices essentially are electrical contacts that are either electrically open or closed. When a thermostatic device is used in place of the thermistor, an over-temperature fault is signaled when the contacts of the thermostat electrically close (that is, use a thermostat that is normally open and closes on temperature rise). If the jumper on JP4 is out then the power is restored when the contacts open. This allows the user to select thermostats that close and open at temperatures that are different from the pre-programmed 50 °C and 70 °C thermistor temperatures.

NOTE: If you are using an over-temperature thermostat in place of a thermistor, make sure that both wire leads from the thermostat are electrically isolated from all other points in the system. This can be accomplished by simply purchasing a thermostat with electrically isolated leads or by ordering the thermistors with an optional plastic sheath.

5.0 Test Points

One ground test-point and four signal test-points are provided to aid in setup and for monitoring the sensor voltage and the potentiometer voltages. Test points allow the user to read the Set Temperature, P, I, and thermistor voltages. See “*Component Identification*” and “*Controller Wiring Diagram*” for additional reference.

6.0 Temperature status LEDs

Three LEDs are provided to indicate the status of the temperature of the control sensor relative to the set temperature. If the control sensor is more than 1 °C colder than the set temperature the blue LED is illuminated, if it is within 1 °C of set temperature the green led is illuminated, and if it is more than 1 °C warmer than set temperature the red is illuminated.

7.0 Fault Detection Indications

All LEDs will flash simultaneously at approximately if fault sensors are used and a fault condition is detected. The LEDs will illuminate sequentially (red, green, blue, etc.) when the control sensor is detected as open or short circuit.

8.0 Fuse

The TC-24-12 uses one 15-amp automotive-type fuse. Should the fuse blow open, the cause of failure should be remedied, and the fuse should be replaced with Littlefuse part number 257015 or equivalent.

9.0 Alarm Output Connector

The input and output connections are made through the connector JP2, (TYCO/AMP part number 640452-4). This is a 4-pin male header; there are a number of possible female mating connectors, but an example for an insulation displacement type is TYCO/AMP 640441-4.

Pins 1 and 2 of the connector are used as a voltage source and are connected to the controller’s input voltage (JP3-1). Pins 3 and 4 are the open drain of a field-effect transistor. The drain is closed, effectively shorting pins 2 and 3 to ground, when a control sensor or over-temperature

fault condition occurs. Thus, a load circuit may be placed between pins 1&2 and pins 3&4, and the load will be energized when a fault condition is detected. The drain re-opens and the load circuit will be de-energized when the fault condition is cleared. The maximum current for the alarm circuit is 2.5 amps. Because the power to the alarm circuit is supplied by the input power to the controller and the maximum input current to the controller is limited to 12 amps, any current supplied to the alarm circuit will cause a likewise reduction in the total output power available to the thermoelectric load. See section titled “*Input/Output Connector*” for additional reference.

NOTES:

When actuating an inductive load such as a mechanical relay or solenoid an external clamping diode must be used in parallel with the inductive load to prevent a reverse inductive-voltage spike from destroying the output transistor.

The condition of jumper JP4 determines how over-temperature faults are cleared.

10.0 Input/Output Connector

The input and output connections are made through JP3, a detachable connector (Phoenix Contact part number 1779916). Wires are inserted into each wire opening (located on top of the connector as shown in the “*Component Identification*” photo and “*Controller Wiring Diagram*”). The wires are then clamped in place by tightening the respective screw on the side of the terminal.

NOTE:

The connector can be removed by pulling the detachable portion away from the circuit board. The wire acts as a heat sink for the connector, and the maximum current of 12 A for any pin in the connector at a 50 °C circuit board temperature can be achieved only when stranded wire with a conductor cross section of 2.5 square millimeters is used. The wire that is supplied with the connector is approximately 2 square millimeters in cross sectional area (for ease of handling purposes). If you plan to operate the controller so the required input current is 12 A, be sure to replace the standard wire with wire of the appropriate size for this current draw. The controller’s electronics take less than 100 mA of current, so the combined output current to the TE load and alarm circuit should not exceed 11.9 A.

Setup

11.0 Controller Set-Up

Setup Note: See “*Component Identification, Controller Wiring Diagram, and Mechanical Drawing Package*” for additional reference.

- 11.1 Attach the thermistor to the control location. Generally, this is the cold side of the cooler rather than the part itself that is to be cooled/heated. This provides better control stability although there may be a temperature difference between the cooler and the part. Attach the thermistor wire leads to JP3-9 and JP3-10 (polarity is not important).

NOTES:

As much wire length of the thermistor should be thermally connected to the cold side as possible. This will help eliminate errors resulting from heat conducting along the wire leads and affecting the sensor reading. 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 less accurate. By “pre-cooling” the thermistor’s wire leads, the thermistor’s temperature will be allowed to assume the temperature of the cold side as closely as possible. “Pre-cooling” can be accomplished by placing aluminum tape over the wire leads and adhering it to the cold side of the cooler.

Different thermistor heads are available. See “*Thermistor Styles for TC-24-12*” for information on standard ones available. One MP-2379 thermistor is normally supplied with the TC-24-12.

For over-temperature protection, additional thermistors or thermostats can be wired up to JP3-5/JP3-6 and JP3-6/JP3-7.

- 11.2 Connect the appropriate DC power supply [(10.8 to 26.4) volts] to the controller by connecting the positive lead (+) to JP3-1 and the negative lead (-) to JP3-2. Turn the power supply on. **DO NOT CONNECT THE CONTROLLER TO THE TE MODULE AT THIS TIME.**
- 11.3 Adjust the Set Temperature using potentiometer R13. The voltage across TP3 and TP2 (common) can be used to interpret the Set Temperature. The potentiometer range corresponds to -20 °C at full counter-clockwise (0 Volts at TP3) to +100 °C at full clockwise (5 V at TP3). This is a 25-turn potentiometer, so each full turn corresponds to a 4.8 °C change in the Set Temperature. The “*Temperature vs. Sensor/Potentiometer Voltage*” graphs and tables show the relationship between voltage and Set Temperature. This step allows the user to set the Set Temperature at a desired level before applying power to the thermoelectric module(s).
- 11.4 Turn the power supply off. Then connect the thermoelectric module positive lead (+) to JP3-3 and the negative lead (-) to JP3-4. Turn the power supply back on to begin controlling the temperature.

12.0 Control Function Description

12.1 Proportional control: This eliminates much of the temperature cycling inherent in on/off control. Proportional control increases or decreases the output of the controller depending on the difference between the set temperature and the actual temperature. The proportioning bandwidth is the temperature span over which the power is proportioned from -100% to +100% power, centered about the set temperature. That is, the controller output decreases to 0% power as it reaches the set temperature and to $\pm 100\%$ power (depending on whether the controller is in the heating or cooling mode) as it reaches either end of the bandwidth.

For example, suppose the controller is being operated in the cooling mode, the set point is $10\text{ }^{\circ}\text{C}$, and the bandwidth is set to $5\text{ }^{\circ}\text{C}$. The controller power is at +100% and starts to proportionally decrease as the sensor temperature cools below $12.5\text{ }^{\circ}\text{C}$. The power will be reduced to 0% when the sensor is at $10\text{ }^{\circ}\text{C}$. The power will then proportionally increase at negative power up to -100% when the sensor is at $7.5\text{ }^{\circ}\text{C}$. (Of course, this example presumes that the cooler would have enough capacity to cool to $7.5\text{ }^{\circ}\text{C}$.)

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 it may never reach the set temperature.

12.2 Integral Control: This corrects for any offset between the set temperature and the sense temperature by averaging the offset with respect to time. This essentially shifts the proportioning bandwidth.

For example, suppose the set temperature is $10\text{ }^{\circ}\text{C}$, the bandwidth is set to $5\text{ }^{\circ}\text{C}$, and the controller settled to a constant $11\text{ }^{\circ}\text{C}$ (corresponding to 40% power). If the integral control is set to 1 repeat per minute, the controller will increase the power to 80% in 1 minute. In this example, after one minute of operation the controller calculated that the error from the desired temperature to actual temperature was $1\text{ }^{\circ}\text{C}$ above set temperature. With a bandwidth of $5\text{ }^{\circ}\text{C}$, the controller then calculated that it needed an additional 40% output (100% change in output per $2.5\text{ }^{\circ}\text{C}$ of error * $1\text{ }^{\circ}\text{C}$ error = 40%). This additional 40% output was added to the existing 40% output to yield 80% output. The integral portion of the output is recalculated at the frequency specified by the integral potentiometer. Thus, at the next update period for the integral the controller will add or subtract as necessary from the 80% output. Of course, the maximum output is limited to +100%, and the minimum is limited to -100%.

If the integral control 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.

13.0 Controller Tuning

Tuning of PI control requires knowing the time period of the natural temperature cycle of the system and the bandwidth used to achieve this cycle. The following steps will tune the controller:

13.1 Verify that the power supply on.

- 13.2 Set the Integral Rate Potentiometer (R16) to zero by adjusting it to its maximum counter-clockwise position (voltage at TP5 = 0.0V). This turns off the integral function.
- 13.3 Set the Proportional Bandwidth Potentiometer (R14) to its maximum clockwise position (voltage at TP4 = 5.0 V).
- 13.4 Adjust the Set-Temperature Potentiometer (R13) to the desired temperature using TP3 and the voltage versus Set-Temperature graph/data as a guide.
- 13.5 Adjust the Proportional Bandwidth Potentiometer counter-clockwise until a small, sustained temperature oscillation is observed. (You can adjust in initial increments of 1 V, or 5 turns. Then, once an initial oscillation is observed, adjust the potentiometer clockwise until the oscillations are barely detectable).
- 13.6 Record the voltage at the Proportional Bandwidth Potentiometer (at TP4) to sustain the temperature oscillation.

_____ Volts

- 13.7 The time that it takes to go from one peak temperature to the next peak temperature is the natural period. Record the time of the natural period in minutes.

_____ Minutes

- 13.8 Measuring the voltage at TP4, turn the Proportional Bandwidth Potentiometer clockwise until the voltage recorded in section 12.6 is doubled (this now doubles the bandwidth.) If the voltage recorded in section 12.6 is greater than 2.5 V, then adjust the Proportional Bandwidth Potentiometer until the voltage is 5.0 V.
- 13.9 Set the controller Integral Rate variable (the number of repeats per minute) to the inverse, or reciprocal, of the natural period recorded in section 12.7 by adjusting R16. There are 0.102 repeats per minute per turn of R16. Using the voltage at TP5 as a guide, the Integral Rate can be set as follows: voltage at TP5 = $5/2.55 * (\text{reciprocal of natural period recorded in section 12.7})$. See the “Integral Rate as a Function of Voltage” graph for further reference.
- 13.10 These Proportional and Integral settings are approximate settings and may need further minor adjustments. Record the final voltages used on the Proportional Bandwidth Potentiometer and Integral Rate Potentiometer.

Final voltage on the Proportional Bandwidth Potentiometer (TP4)
= _____ Volts.

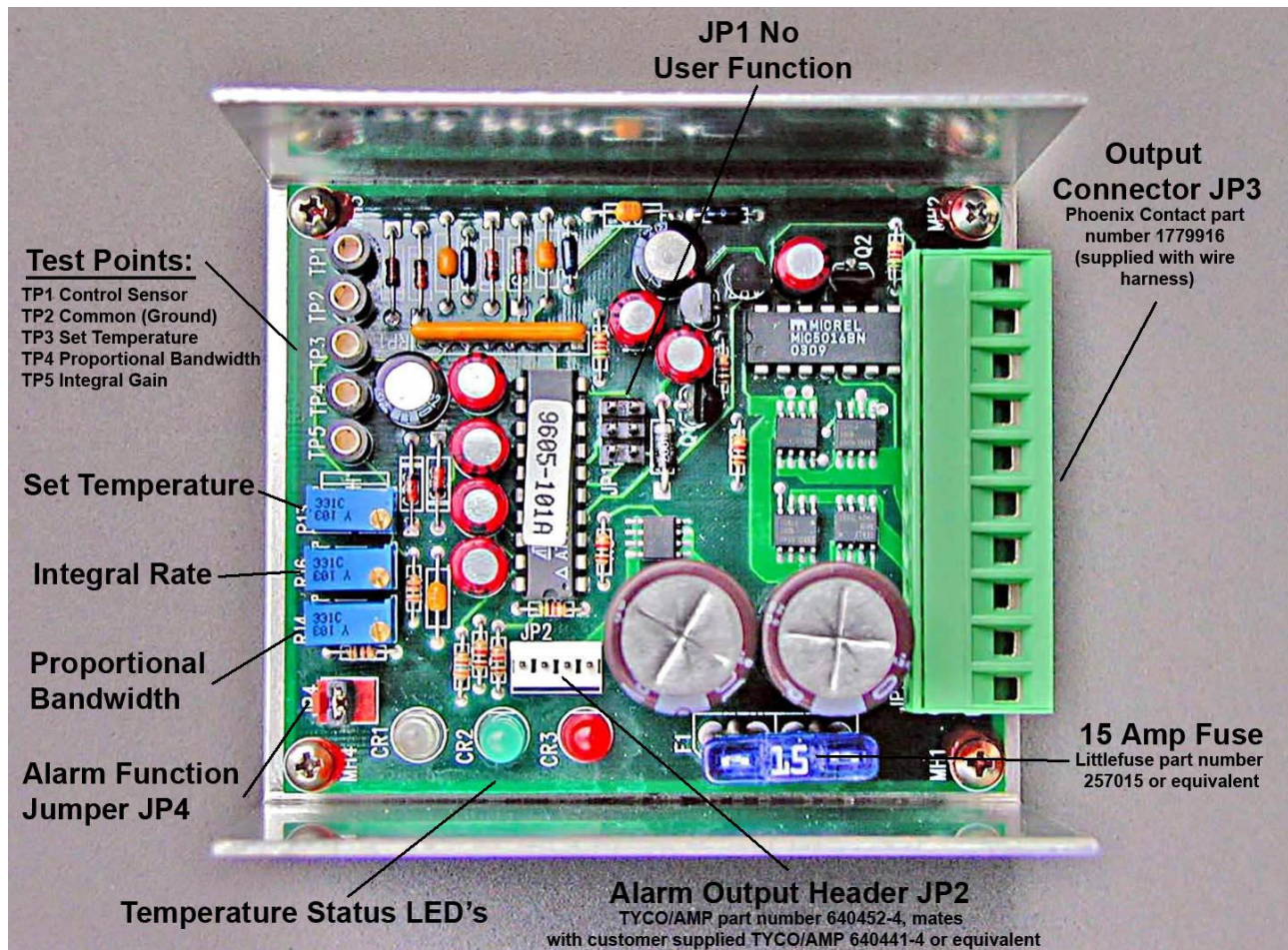
Final voltage on the Integral Rate Potentiometer (TP5) = _____ Volts.

Additional systems with the same thermodynamic properties will operate using the Potentiometer settings listed above.

Tuning Example:

- A. Suppose that the Proportional Bandwidth Potentiometer (R14) was set to 0.6 volts to just sustain a temperature oscillation. (Reference sections 12.5 and 12.6).
- B. It was then observed that the natural period of this oscillation was 2 minutes. (Reference section 12.7)
- C. The Proportional Bandwidth Potentiometer (R14) should be adjusted so the voltage at TP4 is equal to 1.2 volts. (Reference section 12.8 and the “*Proportional Bandwidth as a Function of Voltage*” graph.)
- D. The Integral Rate Potentiometer (R16) should be set to the inverse of the natural period. This is $1/(2 \text{ min}) = 0.5$ repeats per minute. The potentiometer should be adjusted until TP5 is at 0.98 volts. (Reference section 12.9 and the “*Integral Rate as a Function of Voltage*” graph.)

Component Identification



Notes:

Test Points (TPs):

- TP1 is the control sensor voltage
- TP2 is the common (signal ground) for all test points
- TP3 is the set potentiometer voltage
- TP4 is the proportional potentiometer voltage
- TP5 is the integral gain potentiometer voltage

Potentiometers:

- R13 = Set Temperature adjustment (-20 to 100 °C), clockwise to increase
- R14 = Proportional Bandwidth adjustment (1.0 to 15 °C), clockwise to increase
- R16 = Integral Rate adjustment (0 to 2.55 repeats per minute), clockwise to increase

All potentiometers have a 25-turn adjustment range. When the end of the adjustment range is reached continued rotation of the adjustment screw will result in a faint clicking sound.

Temperature status LED's:

- BLUE LED (CR1) on when the control sensor is more than 1 °C below Set Temperature.
- GREEN LED (CR2) is on when the control sensor is within +/- 1 °C of Set Temperature.
- RED LED (CR3) is on when the control sensor is more than 1 °C above Set Temperature.

Alarm Output connector JP2:

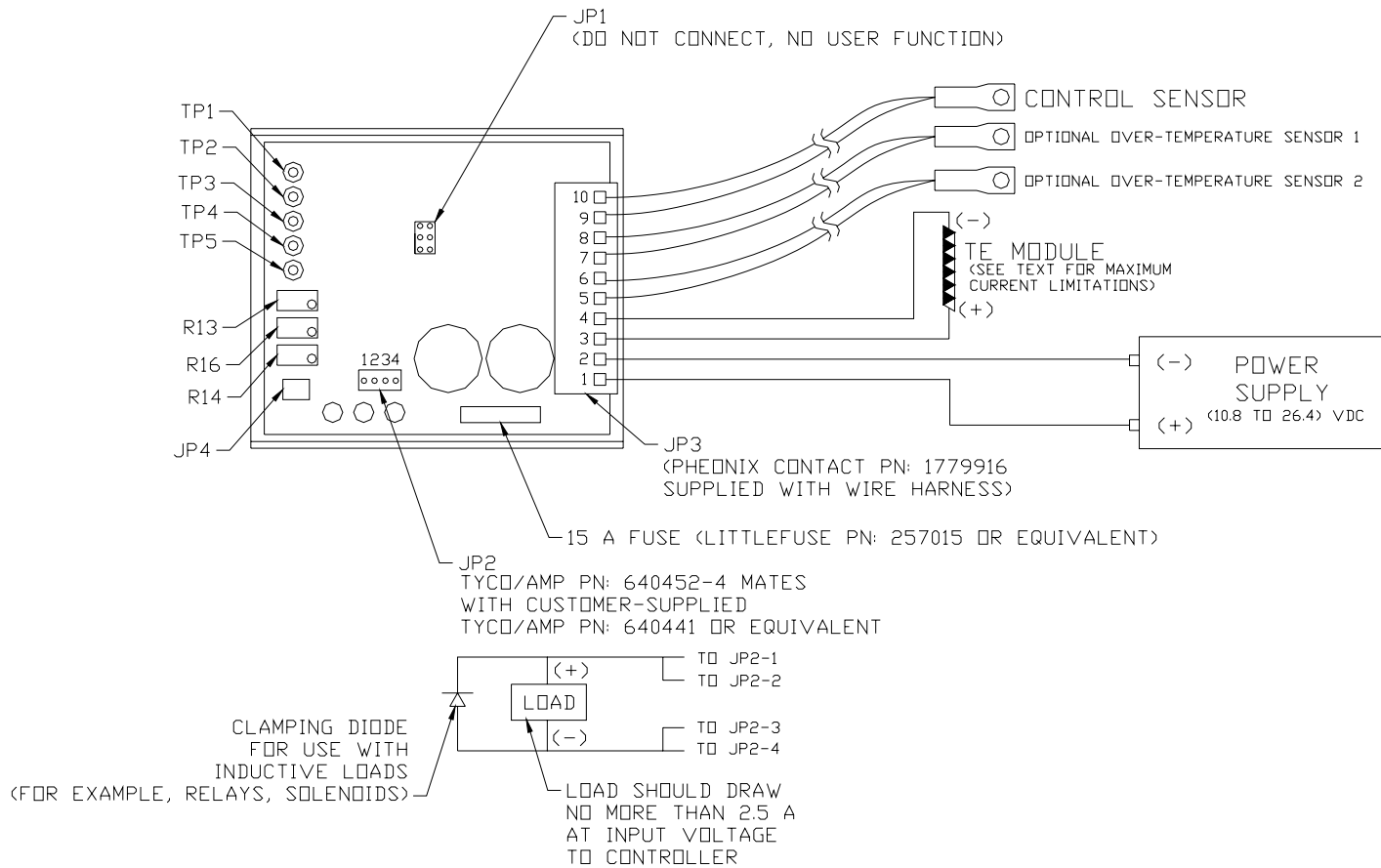
- JP2-1 DC input + (same voltage potential as JP3-1)
- JP2-2 DC input + (same voltage potential as JP3-1)
- JP2-3 OPEN DRAIN (on during control sensor or over-temperature fault condition).
- JP2-4 OPEN DRAIN (on during control sensor or over-temperature fault condition).

Input/Output connector JP3:

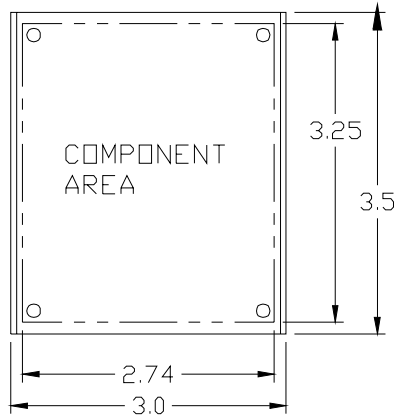
- JP3-1 DC input + (10.8 volts DC to 26.4 volts DC, 12 amps maximum)
- JP3-2 DC input –
- JP3-3 + TE power output (+ when cooling required)
- JP3-4 - TE power output (- when cooling required)
- JP3-5 fault sensor 1 common
- JP3-6 fault sensor 1 input
- JP3-7 fault sensor 2 input
- JP3-8 fault sensor 2 common
- JP3-9 control sensor common
- JP3-10 control sensor input

When one or more external fans are used on the thermoelectric assembly, these should be wired directly to a fixed voltage power supply for constant operation. If the controller is being used with one of our standard cooling assemblies that contains a terminal strip, the jumpers connecting the fan terminals to the thermoelectric module wires should be removed.

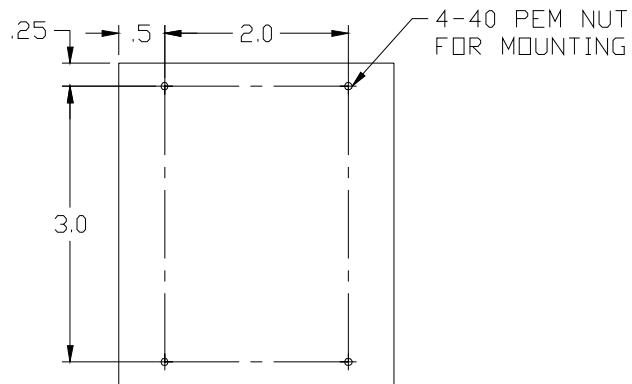
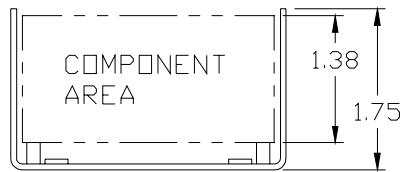
Controller Wiring Diagram



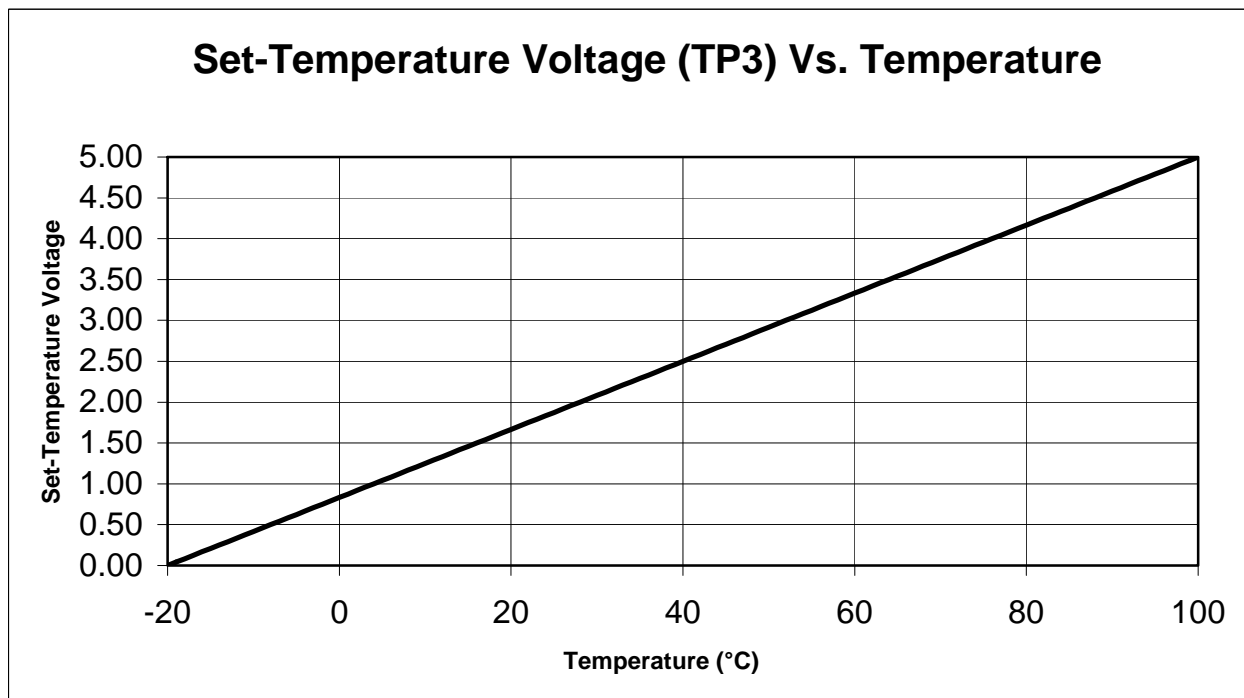
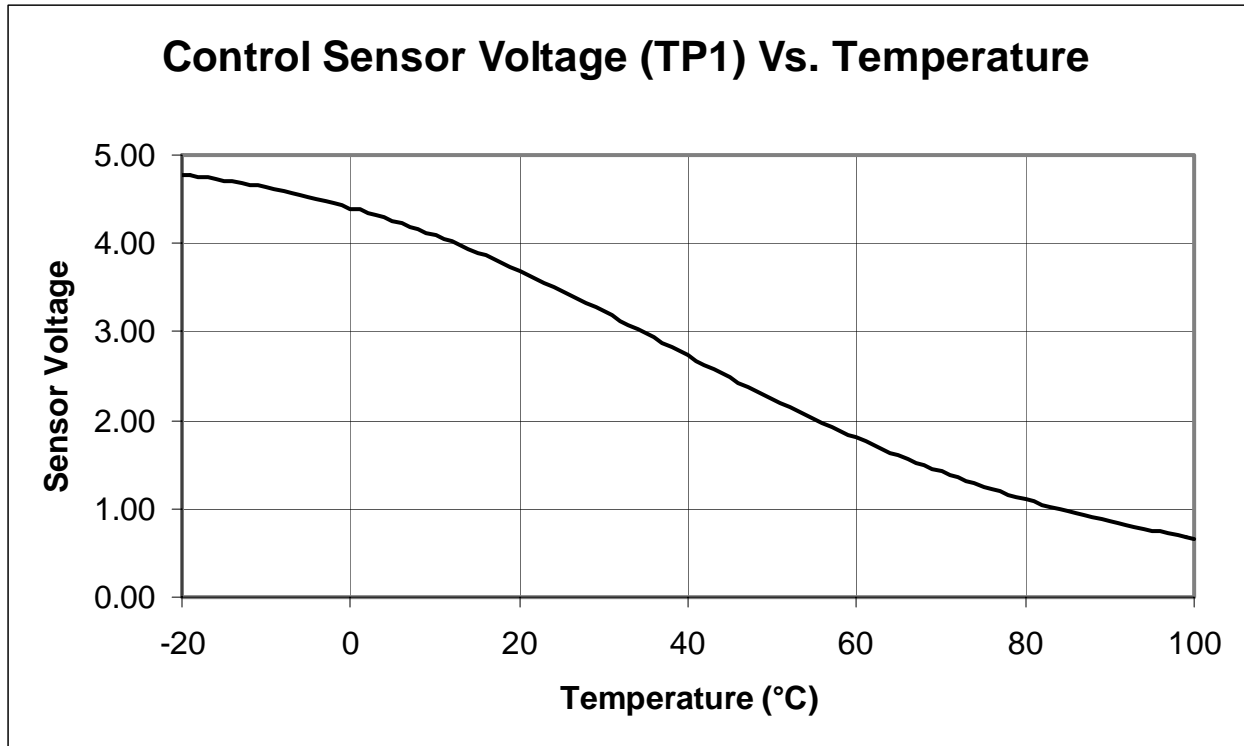
Mechanical Package Drawing



DIMENSIONS IN INCHES



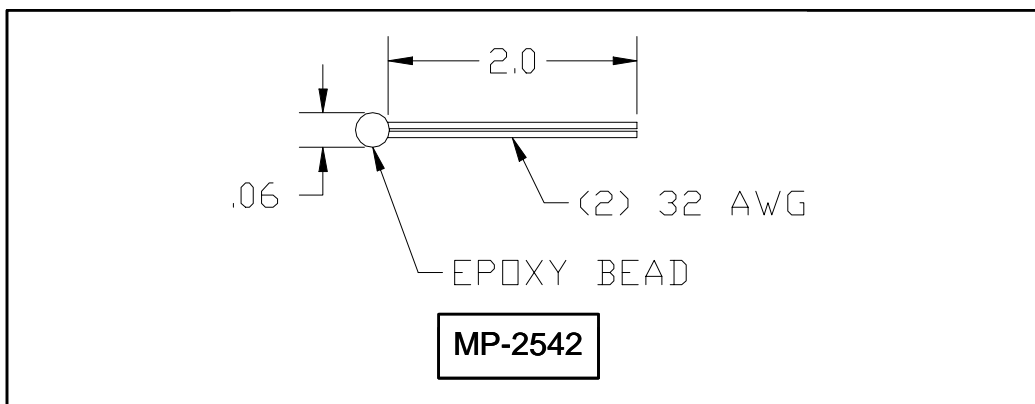
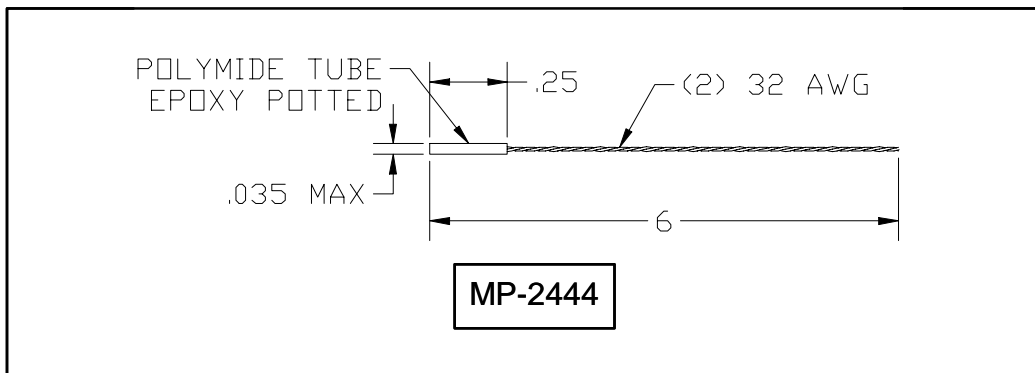
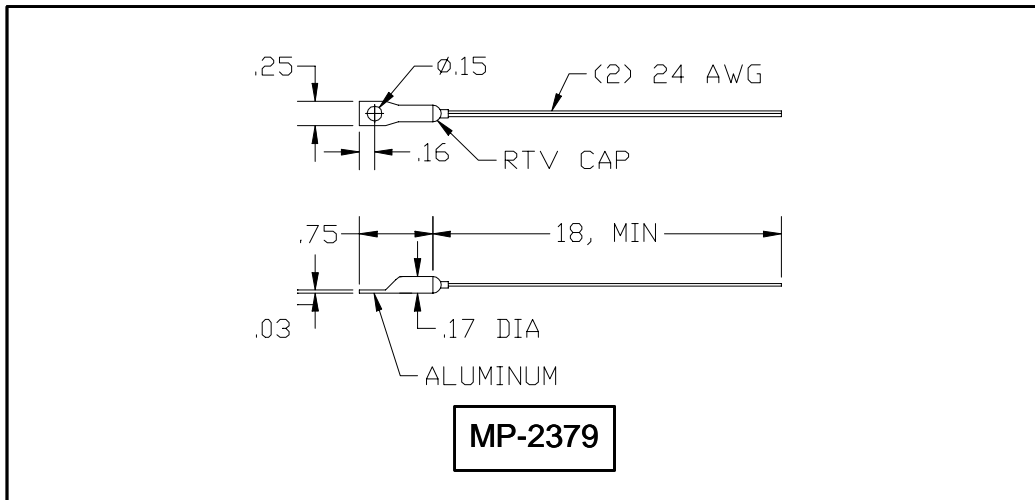
Temperature vs. Sensor/Potentiometer Voltage (graphs)



Temperature vs. Sensor/Potentiometer Voltage (table)

Sensor Temp. (°C)	Sensor Voltage (TP1)	Sensor Resistance	Set Temperature (TP3) Voltage	Sensor Temp. (°C)	Sensor Voltage (TP1)	Sensor Resistance	Set Temperature (TP3) Voltage
-20	4.78	145692	0.00	41	2.68	7675	2.54
-19	4.77	137492	0.04	42	2.63	7375	2.58
-18	4.76	129803	0.08	43	2.58	7088	2.63
-17	4.74	122591	0.13	44	2.53	6814	2.67
-16	4.73	115823	0.17	45	2.48	6552	2.71
-15	4.71	109469	0.21	46	2.43	6302	2.75
-14	4.70	103501	0.25	47	2.38	6062	2.79
-13	4.68	97895	0.29	48	2.34	5833	2.83
-12	4.67	92626	0.33	49	2.29	5613	2.88
-11	4.65	87671	0.38	50	2.24	5403	2.92
-10	4.63	83012	0.42	51	2.19	5202	2.96
-9	4.61	78627	0.46	52	2.15	5010	3.00
-8	4.59	74500	0.50	53	2.10	4826	3.04
-7	4.57	70614	0.54	54	2.06	4649	3.08
-6	4.55	66954	0.58	55	2.01	4480	3.13
-5	4.53	63504	0.63	56	1.97	4318	3.17
-4	4.50	60253	0.67	57	1.92	4162	3.21
-3	4.48	57187	0.71	58	1.88	4013	3.25
-2	4.45	54295	0.75	59	1.84	3870	3.29
-1	4.43	51567	0.79	60	1.80	3733	3.33
0	4.40	48991	0.83	61	1.76	3601	3.38
1	4.38	46559	0.88	62	1.72	3475	3.42
2	4.35	44261	0.92	63	1.68	3354	3.46
3	4.32	42091	0.96	64	1.64	3237	3.50
4	4.29	40039	1.00	65	1.60	3126	3.54
5	4.26	38099	1.04	66	1.56	3018	3.58
6	4.23	36264	1.08	67	1.52	2915	3.63
7	4.19	34528	1.13	68	1.49	2816	3.67
8	4.16	32885	1.17	69	1.45	2721	3.71
9	4.12	31330	1.21	70	1.42	2630	3.75
10	4.09	29857	1.25	71	1.38	2542	3.79
11	4.05	28462	1.29	72	1.35	2457	3.83
12	4.02	27140	1.33	73	1.32	2376	3.88
13	3.98	25886	1.38	74	1.28	2298	3.92
14	3.94	24698	1.42	75	1.25	2222	3.96
15	3.90	23571	1.46	76	1.22	2150	4.00
16	3.86	22502	1.50	77	1.19	2080	4.04
17	3.82	21487	1.54	78	1.16	2013	4.08
18	3.78	20524	1.58	79	1.13	1949	4.13
19	3.73	19609	1.63	80	1.10	1886	4.17
20	3.69	18740	1.67	81	1.08	1826	4.21
21	3.65	17914	1.71	82	1.05	1769	4.25
22	3.60	17130	1.75	83	1.02	1713	4.29
23	3.56	16384	1.79	84	1.00	1660	4.33
24	3.51	15675	1.83	85	0.97	1608	4.38
25	3.46	15000	1.88	86	0.95	1558	4.42
26	3.42	14358	1.92	87	0.93	1510	4.46
27	3.37	13747	1.96	88	0.90	1464	4.50
28	3.32	13166	2.00	89	0.88	1419	4.54
29	3.27	12612	2.04	90	0.86	1376	4.58
30	3.23	12084	2.08	91	0.84	1335	4.63
31	3.18	11582	2.13	92	0.81	1294	4.67
32	3.13	11103	2.17	93	0.79	1256	4.71
33	3.08	10647	2.21	94	0.77	1218	4.75
34	3.03	10211	2.25	95	0.75	1182	4.79
35	2.98	9796	2.29	96	0.74	1147	4.83
36	2.93	9400	2.33	97	0.72	1114	4.88
37	2.88	9022	2.38	98	0.70	1081	4.92
38	2.83	8662	2.42	99	0.68	1050	4.96
39	2.78	8317	2.46	100	0.66	1020	5.00
40	2.73	7989	2.50				

Thermistor Styles for TC-24-12



**Temperature versus Resistance
for MP-2379, MP-2444, and MP2542 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 $\pm 1 \text{ }^\circ\text{C}$
over a $0 \text{ }^\circ\text{C}$ to $100 \text{ }^\circ\text{C}$ range.

Proportional Bandwidth/Integral Rate Voltage (graphs)

