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NTC THERMISTOR DESIGN GUIDE

FOR DISCRETE COMPONENTS & PROBES

www.thermistor.com

INDUSTRY'S PARTNER IN QUALITY AND PERFORMANCE™

OUR MISSION: Through teamwork, to achieve industry's confidence as the highest quality producer of temperature sensors in the world.

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NTC THERMISTOR DESIGN GUIDE FOR DISCRETE COMPONENTS & PROBES

Since 1977, Quality Thermistor, Inc. has designed and manufactured PTC and NTC thermistors of superior quality. Millions of QTI™ Brand thermistor temperature probes have been used for mission critical applications from deep below the oceans' surface to the outer reaches of space. Our state-of-the-art manufacturing facility located in Boise, Idaho combined with our high-volume assembly plant in Mexico ensure no project is to small or large for us to accommodate.

This NTC thermistor design guide has been thoughtfully prepared to address some of the most common temperature related questions facing design engineers. If you have additional questions, please feel free to contact us. We would be happy to work with you on your application.

What is a thermistor?

An NTC thermistor is a semiconductor made from metalic oxides, pressed into a small bead, disk, wafer, or other shape, sintered at high temperatures, and then coated with epoxy or glass. The resulting device exhibits an electrical resistance that has a very predictable change with temperature.

Thermistors are widely used for temperature monitoring, control and compensation. They are extremely sensitive to temperature change, very accurate and interchangeable. They have a wide temperature envelope and can be hermetically sealed for use in humid environments.

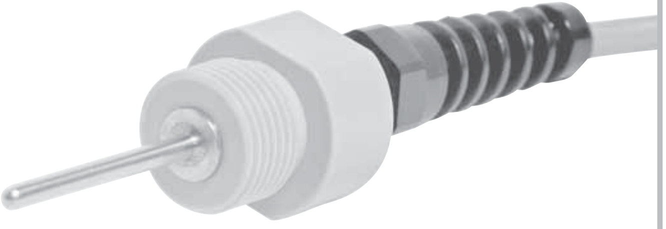
The term "thermistor" originated from the descriptor **THERM**ally sensitive Res**ISTOR**. The two basic types of thermistors are the Negative Temperature Coefficient (NTC) and Positive Temperature Coefficient (PTC).

Thermistors are available as surface mount or radial and axial leaded packages. The leaded parts can then be either over molded or housed in a variety of shapes and materials.

Although this design guide focuses on NTC (Negative Temperature Coefficient), thermistors are also available in Positive Temperature Coefficients.

therm·is·tor
Pronunciation: ther-**mis**-ter, thur-**muh**-ster
Origin: 1935–40
Function: noun
Etymology: **therm**al res**istor**

> *An electrical resistor whose resistance varies rapidly and predictably with temperature and as a result can be used to measure temperature.*



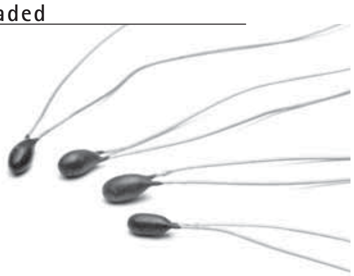
THERMISTOR STYLES

Axial Leaded (PTC)

RTH42
RTH22 PTC
QTG12 PTC
OTG10 PTC

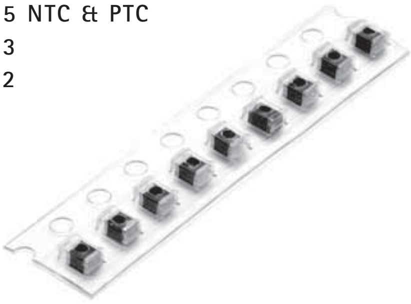
NTC Radial Leaded

QTMC
QTLC



Surface Mount

1206
0805 NTC & PTC
0603
0402



Bare Die

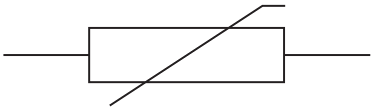
QTC11 NTC
QTC11 PTC

What is a thermistor?

Thermistor

From Wikipedia, the free encyclopedia

A thermistor is a type of resistor used to measure temperature changes, relying on the change in its resistance with changing temperature. The Thermistor was first invented by Samuel Ruben in 1930, and has U.S. Patent #2,021,491.



Thermistor Symbol

If we assume that the relationship between resistance and temperature is linear (i.e. we make a first-order approximation), then we can say that:
$\Delta R = k\Delta T$
Where
ΔR = change in resistance t
ΔT = change in temperature
k = first-order temperature coefficient of resistance

Thermistors can be classified into two types depending on the sign of k. If k is positive, the resistance increases with increasing temperature, and the device is called a positive temperature coefficient (PTC) thermistor. If k is negative, the resistance decreases with increasing temperature, and the device is called a negative temperature coefficient (NTC) thermistor. Resistors that are not thermistors are designed to have the smallest possible k, so that their resistance remains almost constant over a wide temperature range.

Steinhart Hart equation

In practice, the linear approximation (above) works only over a small temperature range. For accurate temperature measurements, the resistance/temperature curve of the device must be described in more detail. The Steinhart-Hart equation is a widely used third-order approximation:

$$\frac{1}{T} = a + b \ln(R) + c \ln^{3}(R)$$

where a, b and c are called the Steinhart-Hart parameters, and must be specified for each device. T is the temperature in Kelvin and R is the resistance in ohms. To give resistance as a function of temperature, the above can be rearranged into:

$$R = e\,(\beta - \frac{\alpha}{2})^{\frac{1}{3}} - (\beta - \frac{\alpha}{2})^{\frac{1}{3}}$$

where $\alpha = \frac{a - \frac{1}{T}}{c}$ and $\beta = \sqrt{\left(\frac{b}{3c}\right)^{3} + \frac{\alpha^{2}}{4}}$

The error in the Steinhart-Hart equation is generally less than 0.02°C in the measurement of temperature. As an example, typical values for a thermistor with a resistance of 3000 Ω at room temperature (25°C = 298.15 K) are:
$a = 1.40 \times 10^{-3}$
$b = 2.37 \times 10^{-4}$
$c = 9.90 \times 10^{-8}$

Conduction model

Many NTC thermistors are made from a pressed disc or cast chip of a semiconductor such as a sintered metal oxide. They work because raising the temperature of a semiconductor increases the number of electrons able to move about and carry charge - it promotes them into the conducting band. The more charge carriers that are available, the more current a material can conduct. This is described in the formula:

$I = n \cdot A \cdot v \cdot e$

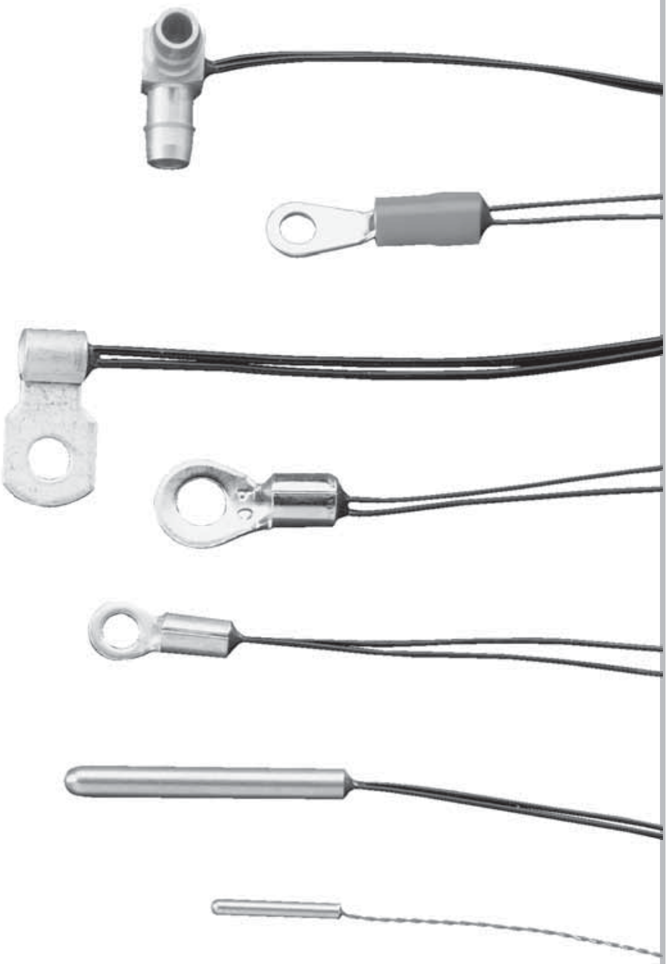
I = electric current (ampere)
n = density of charge carriers (count/m^3)
A = cross-sectional area of the material (m^2)
v = velocity of charge carriers (m/s)
e = charge of an electron

The current is measured using an ammeter. Over large changes in temperature, calibration is necessary. Over small changes in temperature, if the right semiconductor is used, the resistance of the material is linearly proportional to the temperature. There are many different semiconducting thermistors and their range goes from about 0.01 Kelvin to 2,000 Kelvins (-273.14°C to 1,700°C). QTI range -55 to 300°C.

Most PTC thermistors are of the "switching" type, which means that their resistance rises suddenly at a certain critical temperature. The devices are made of a doped polycrystalline ceramic containing barium titanate (BaTiO3) and other compounds. QTI manufactures silicon based PTC thermistors that are .7%/°C.

How To Use a Thermistor

The NTC thermistor is best suited for precision temperature measurement. The PTC is best suited for temperature compensation. The NTC thermistor is used in three different modes of operation, which services a variety of applications.



Resistance-Versus-Temperature Mode - By far the most prevalent. These circuits perform precision temperature measurement, control and compensation. Unlike the other applications this method depends on the thermistor being operated in a "zero-power" condition. This condition implies that there is no self-heating.

The resistance across the sensor is relatively high in comparison to an RTD element, which is usually in the hundreds of ohms range. Typically, the 25°C rating for thermistors is from 10Ω up to 10,000,000Ω. The housing of the thermistor varies as the requirements for a hermetic seal and ruggedness, but in most cases, there are only two wires going to the element. This is possible because of the resistance of the wire over temperature is considerably lower than the thermistor element. And typically does not require compensation because of the overall resistance.

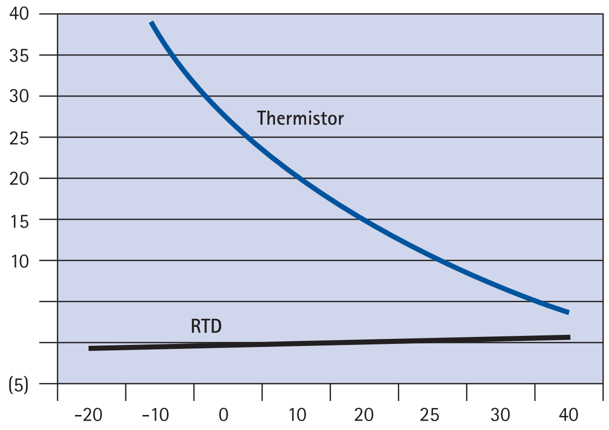
Current-Over-Time Mode – This depends on the dissipation constant of the thermistor package as well as element's heat capacity. As current is applied to a thermistor, the package will begin to self-heat. If the current is continuous, the resistance of the thermistor will start to lessen. The thermistor current-time characteristics can be used to slow down the affects of a high voltage spike, which could be for a short duration. In this manner, a time delay from the thermistor is used to prevent false triggering of relays.

This type of time response is relatively fast as compared to diodes or silicon based temperature sensors. In contrast, thermocouples and RTD's are equally as fast as the thermistor, but they don't have the equivalent high level outputs.

Voltage-Versus-Current Mode - Voltage-versus-current applications use one or more thermistors that are operated in a self-heated condition. An example of this would be a flow meter. The thermistor would be in an ambient self-heated condition. The thermistor's resistance is changed by the amount of heat generated by the power dissipated by the element. Any change in the media (gas/liquid) across the device changes the power dissipation factor of the thermistor. The small size of the thermistor allows for this type of application to be implemented with minimal interference to the system.

Why Use a Thermistor?

Resolution - Large change in resistance for a small change in temperature



Another advantage of the thermistor is its relatively high resistance. Thermistors are available with base resistances (at 25° C) ranging from tens to millions of ohms. This high resistance reduces the effect of resistance in the lead wires, which can cause significant errors with low resistance devices such as RTD's. An example of this is the traditional RTD, which typically requires 3-wire or 4-wire connections to reduce errors, caused by lead wire resistance; 2-wire connections to thermistors are usually adequate.

The thermistor has been used primarily for high-resolution measurements over limited temperature ranges (-55° to 150°C). The classic example of this would be a medical application where the user is only concerned with body temperature. However, widespread improvements in thermistor stability, accuracy, and interchangeability have prompted increased usage of thermistors in all types of industries.

Cost

Thermistors are by far the most economical choice when it comes to temperature sensors. Not only are they less expensive to purchase, but also there are no calibration costs during installation or during the service life of the sensor. In addition, if there is a failure in the field, interchangeable thermistors can be swapped out without calibration.

Speed

Due to their small size, thermistors can respond very quickly to slight changes in temperature. Caution must be taken when designing probes because materials and mass play an important role in the reaction time of the sensor. See section on "Thermal Time Constant" and "How do I design a probe?" for further details.

No Calibration Required

Properly manufactured thermistors are aged to reduce drift before leaving the factory. Therefore, thermistors can provide a stable resistance output over long periods of time.

How Do I Use a Thermistor?

What is meant by “Interchangeability” or “Curve tracking”?

A thermistor can be defined as having an interchangeability tolerance of ±0.1°C over the range from 0° to 70°C. This means that all points between 0° and 70°C, are within 0.1°C of the nominal resistance values for that particular thermistor curve. This feature results in temperature measurements accurate to ±0.1°C no matter how many different thermistors are substituted in the application.

What is meant by ‘”Point Matched”?

A standard thermistor is calibrated and tested at 25°C to a tolerance of ± 1%, 2%, 5% or ± 10%. Since these thermistors only have one controlled point of reference or ‘point matched’ temperature, the resistance at other temperatures are given by the "Resistance vs. Temperature Conversion Tables" for the appropriate material curve. The resistance value at any temperature is the ratio factor times the resistance at 25°C.

In addition to the industry standard of point matching thermistors at 25°C, Quality Thermistor can point match to a specific temperature range. Examples of this would be the freezing point of water (0°C) or human body temperature (37°C).

AVAILABLE INTERCHANGEABLE TOLERANCES

-20C° to +50°C
A2 = +/- 1°C
B2 = +/- 0.5°C
C2 = +/- 0.2°C

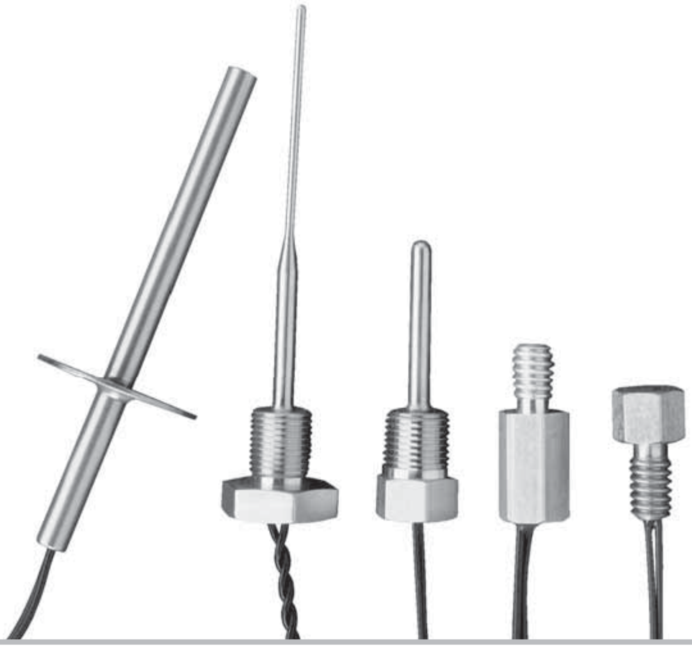
0C° to +70°C
A3 = +/- 1°C
B3 = +/- 0.5°C
C3 = +/- 0.2°C
D3 = +/- 0.1°C

0C° to 100°C
A4 = +/- 1°C
B4 = +/- 0.5°C
C4 = +/- 0.2°C

+20C° to +90°C
A5 = +/- 1°C
B5 = +/- 0.5°C
C5 = +/- 0.2°C

+20C° to +50°C
A6 = +/- 1°C
B6 = +/- 0.5°C
C6 = +/- 0.2°C
D6 = +/- 0.1°C

Closed end tube with flange, ideal for rivet mounting.



How Much Resistance Do I Need?

With an NTC thermistor, resistance decreases as the temperature rises. One main factor in determining how much resistance you need at 25°C is to calculate how much resistance you will have at your critical temperature range.

If the total wire resistance is a substantial percentage of the resistance change at your critical temperature range, you should consider increasing your base resistance at 25°C.

Determine if the resistance change at your critical temperature is large enough to compensate for any other errors in your systems design. If not, you should increase your base resistance at 25°C.

EXAMPLE –
1,000 Ω curve Z thermistor at 25°C

Between –29°C and –28° C, there is a resistance change of 990 ohms. Between 118° and 119° C, there is only a resistance change of 1.1 ohms.

Resitance @25°C	Part#	R/T Curve
500	QTMC-1	Z
2,250	-7	Z
2,500	-8	Z
3,000	-9	Z
5,000	-11	Z
10,000	-14	Z
20,000	-19	Z
1,000	-27	Y
2,000	-28	Y
100,000	-43	V

Resitance @25°C	Part#	R/T Curve
1 Meg	-65	P
9.8 Meg	-70	R
100	-78	X

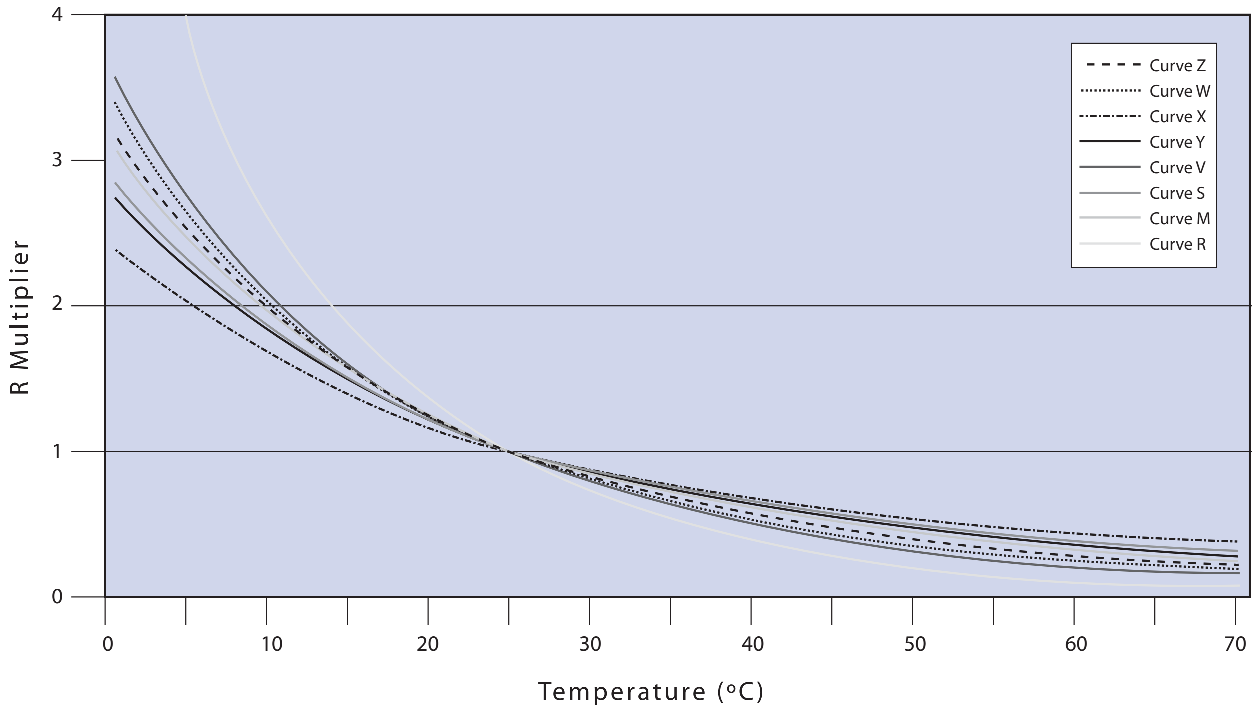
What's a Curve And Which Curve Do I Choose?

If you recall our definition of a thermistor (An electrical resistor making use of a semiconductor whose resistance varies sharply in a very predictable manner with temperature.) We can use the Stein-Hart Hart equation to predict how the thermistor reacts to temperature. If we plot these points on a graph, it forms a repeatable curve. Thermistor manufacturers can alter the chemistry of a thermistor, thereby changing the slope of a curve.

$$T_{^\circ C} = \frac{1}{A + B \cdot (1\text{n } R) + C \cdot (1\text{n } R)^3} - 273.15$$

Your curve selection should be based on how steep the curve is for your critical temperature range, size constraints and the target resistance value. Since a thermistor is based on bulk resistivity, the size of the sensor my not be feasible for your application. Unlike the RTD and Thermocouples, thermistors do not have industry standards for their curves. However, most thermistor manufacturers have curves that are similar. An example of this is Quality Thermistors ‘Z’ curve it’s by far the most common curve in the industry and most major thermistor manufacturers have a very similar curve offerings.

RESISTANCE VALUE IS ALSO A FUNCTION OF CURVE



What is Thermal Time Constant? (Mil-PRF 23648 & Mil-PRF 32192)

THERMAL TIME CONSTANT

The thermal time constant is the time required for a thermistor to change to 63.2 percent of the total difference between its initial and final body temperature when subjected to a step function change in temperature under zero power conditions.

The United States Department of Defense has a very specific method for measuring the thermal time response of a thermistor (see Mil Spec 23648)

Place thermistors in a still air controlled chamber (chamber temperature: 25°C ±1°C) with a minimum volume of 1,000 times the thermistor body and test fixture.

- ✔ Self heat the thermistor to 75°C. Allow 15 minutes (maximum) for stabilization of thermistors.
- ✔ Prepare to measure time from the instant the power is cut to the time the bridge indicator passes through the null point (43.4°C)
- ✔ Record this time: This is the time constant of the thermistor is register a 63.3% change in temperature.

That's right, the DoD Specification for thermal time response is how fast a thermistor can react to a 32° change!

Some thermistor manufacturers choose to use a 50°C change. Be sure and consult the product specifications when making a comparison.

THERMAL CONDUCTIVITY

Heat moves through a material at a specific rate. The rate it travels depends on the material itself: some materials allow heat to move quickly through them, some materials allow heat to move very slowly through them. Below is a list of different materials and how they conduct heat.

MATERIAL	THERMAL CONDUCTIVITY (W/M K)
Silver - Best	429
Copper (pure)	401
Gold	317
Aluminum (pure)	237
Brass (70Cu-30Zn)	110
Titanium	21.9
316 Stainless Steel	13.4
PEEK plastic	1.75
Thermally Conductive Epoxy	1.25
UHMW plastic	0.42

Beware of choosing a probe material based solely on conductivity. Corrosion resistance, cost, strength and machineability are all key factors.

What is Thermal Dissipation Constant?

THERMAL DISSIPATION CONSTANT

The thermal dissipation constant of a thermistor is the power required to raise the thermistors body temperature by 1°C. The dissipation constant is expressed in units of mW/°C (milliWatts per degree Centigrade).

Dissipation Constant can be affected by:

- ✔ Mass of the thermistor probe
- ✔ How the probe and sensor are mounted
- ✔ Thermal dynamics of the environment

The dissipation constant is an important factor in applications that are based on the self-heating effect of thermistors. Specifically, the change in resistance of the thermistor due to change in dissipation constant can be used to monitor levels or flow rates of liquids or gasses. As an example as the flow rate increases, the dissipation constant of the thermistor in a fluid path will increase and the resistance will change and can be correlated to the flow rate.

Stated another way, the dissipation constant is a measure of the thermal connection of the thermistor to its surroundings. It is generally given for the thermistor in still air, but sometimes in well-stirred oil.

What is Self Heating?

SELF-HEATING EFFECTS

When current flows through a thermistor, it generates heat, which raises the temperature of the thermistor above that of its environment. This of course will cause an error in measurement if not compensated for. Typically, the smaller the thermistor, the lower the amount of current needed to self-heat.

The electrical power input to the thermistor is just

$$P_E = IV$$

where I is current and V is the voltage drop across the thermistor. This power is converted to heat, and this heat energy is transferred to the surrounding environment. The rate of transfer is well described by Newton's law of cooling:

$$P_T = K(T(R) - T_0)$$

where T(R) is the temperature of the thermistor as a function of its resistance R, T_0 is the temperature of the surroundings, and K is the dissipation constant, usually expressed in units of milliwatts per °C. At equilibrium, the two rates must be equal.

$$P_E = P_T$$

The current and voltage across the thermistor will depend on the particular circuit configuration. As a simple example, if the voltage across the thermistor is held fixed, then by Ohm's Law we have I = V / R and the equilibrium equation can be solved for the ambient temperature as a function of the measured resistance of the thermistor:

$$T_0 = T(R) - \frac{V^2}{KR}$$

The dissipation constant is a measure of the thermal connection of the thermistor to its surroundings. It is generally given for the thermistor in still air, and in well-stirred oil. Typical values for a small glass bead thermistor are 1.5 mw/°C in still air and 6.0 mw/°C in stirred oil. If the temperature of the environment is known beforehand, then a thermistor may be used to measure the value of the dissipation constant. For example, the thermistor may be used as a flow rate sensor, since the dissipation constant increases with the rate of flow of a fluid past the thermistor.

How Do I Design A Probe?

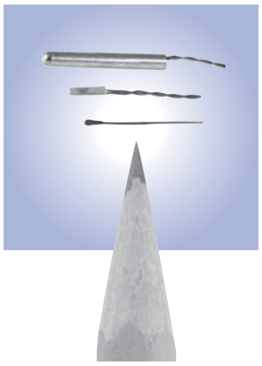
Another problem with selecting material based on thermal conductivity alone is that if the mass of highly conductive probe housing can actually act like a heat sink and pull additional heat out of the system. This can obviously create measuring inaccuracies.

To offset this, you can combine different materials while designing your probe. A low thermally conductive housing with a small highly conductive probe tip is a good solution.

In some cases, your application may require a slow thermal time response. An example of this would be an outdoor sign that displays the temperature. A large over molded probe will insulate the thermistor and even out quick fluctuations in temperature changes.

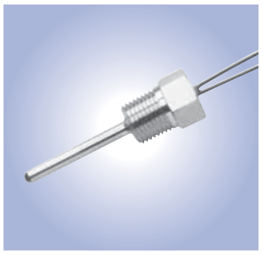
CONFINED SPACE

Due to a thermistors miniature size, they can be potted into almost any size housing. Currently, the smallest available thermistor is 0.023" max diameter. Hollow-tube rivets, set screws, hypodermic needles and direct epoxy attach are some common methods for confined space thermistor applications.



LIQUID

For liquid applications, it's best to use a threaded probe. Possibly, with some type of elastomeric seal like an o-ring. QTI also offers a complete line of NPT probe housings. Some applications require over molding the thermistor into the plastic housing of the product. Another option is to use a glass encapsulated bead. It provides a hermetic seal that is as close to 'waterproof' as Mother Nature will let us. Remember the Titanic?

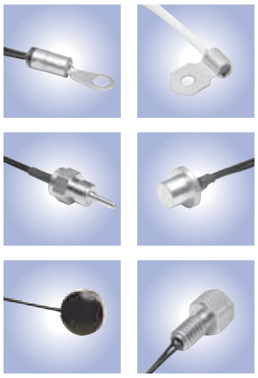


GAS/AIR

Gas and air applications have a variety of choices. Probes can be surface mounted in the flow stream or they can be projected into the air stream by means of a closed or open-end tube. When measuring gas or air under pressure, we recommend using some type of thread/o-ring combination.

SURFACE

By far the most common method for surface measurement is the ring lug. Due to the small size of the thermistor element, it can be potted into most ring lug barrels. Be careful that the wire gauge does not exceed the inside dimension of the barrel. Another option for surface measurement is direct attachment of a thermistor using a stainless steel disc.



Wire Insulation Properties

THERMAL	PVC	Halar-E-CTFE	PVC-Mylar	Kynar	Teflon-PFA	Poly-Sulfone	FEP	Kapton	TFE	Tefzel ETFE
Maximum Continous Rating (C°)	105	135	105	135	260	150	200	200	260	150
Low Temperature (C°)	-50	-100	-60	-70	-200	-100	-200	-200	-200	-100
Non-Flammability	Very Good	Excellent	Very Good	Excellent	Excellent	Good	Excellent	Excellent	Excellent	Excellent
Solder Resistant	Good	Very Good	Very Good	Very Good	Very Good	Very Good	Excellent	Excellent	Excellent	Excellent
Smoke	Moderate	Slight	Moderate	Slight	None	Moderate	None	None	None	Slight

ELECTRICAL	PVC	Halar-E-CTFE	PVC-Mylar	Kynar	Teflon-PFA	Poly-Sulfone	FEP	Kapton	TFE	Tefzel ETFE
Volume Resistivity (ohm-cm)	10^{12}	10^{13}	10^{16}	$2x10^{14}$	10^{18}	$5x10^{16}$	$2x10^{18}$	10^{18}	10^{12}	10^{16}
Dielectric Strength VPM, 1/8" thick	350	490	(1 mil film) 350	450	430	400	430	420	430	400
Dielectric Constant	5.70	2.60	3.50	7.70	2.06	3.13	2.00	2.40	2.00	2.60
Dissipation Factor (1 kHz)	.09	.002	.03	.02	.0002	.001	0.4	.001	.0002	.0008
Capacitive Frequency Stability	Fair	Excellent	Good	Poor	Excellent	Good	Excellent	Excellent	Excellent	Excellent

MECHANICAL	PVC	Halar-E-CTFE	PVC-Mylar	Kynar	Teflon-PFA	Poly-Sulfone	FEP	Kapton	TFE	Tefzel ETFE
Density (gm/cc)	1.36	1.68	1.48	1.76	2.15	1.24	2.18	1.68 (67% polyimide)	2.20	1.70
Tensile, psi	4,000	7,000	15,000	6,000	4,000	10,000	2,700	17,000	2,500	6,500
Elongation, %	250	200	50	250	300	100	250	75	225	100-400
Abrasion Resistance	Fair	Fair	Good	Excellent	Good	Excellent	Good	Excellent	Good	Excellent
Cut-through Resistance	Good	Good	Excellent	Excellent	Fair	Excellent	Fair	Excellent	Fair	Excellent
Bondability	Good	Good	Good	Good		Good		Excellent		Good

ENVIRONMENTAL	PVC	Halar-E-CTFE	PVC-Mylar	Kynar	Teflon-PFA	Poly-Sulfone	FEP	Kapton	TFE	Tefzel ETFE
Nuclear Radiation	Fair	100 megarads	Fair	Excellent	Fair	Good	Fair	200 megarads	Fair	approx.100 megarads
UV Radiation	Fair	Excellent	Fair	Excellent	Excellent	Fair	Excellent	Excellent	Excellent	Excellent

CHEMICAL	PVC	Halar-E-CTFE	PVC-Mylar	Kynar	Teflon-PFA	Poly-Sulfone	FEP	Kapton	TFE	Tefzel ETFE
Water Absorbtion	0.7%	.01%	.06%	.04%	.03%	.05%	.01%	.8%	.01%	.1%
Acids	Good	Excellent	Good	Very Good	Excellent	Good	Excellent	Fair	Excellent	Excellent
Alkali	Good	Excellent	Poor	Very Good	Excellent	Good	Excellent	Fair	Excellent	Excellent
Alcohol	Fair	Excellent	Fair	Very Good	Excellent	Fair	Excellent	Very Good	Excellent	Excellent
Cleaning Solvents (tri-chlor, carbon, tetr)	Slight Swell	Excellent	Good	Very Good	Excellent	Crazes	Excellent	Very Good	Excellent	Excellent
Aliphatic Hydrocarbons (gasoline, kersosene)	Slight Swell	Excellent	Fair	Very Good	Excellent	Good	Excellent	Very Good	Excellent	Excellent
Aromatic Hydrocarbons (benzene, toulene)	Slight Swell	Excellent	Fair	Very Good	Excellent	Crazes	Excellent	Very Good	Excellent	Excellent
Long Term Stability	Fair	Excellent	Good	Very Good	Excellent	Very Good	Excellent	Excellent	Excellent	Excellent

Conversion Tables

EQUIVALENT TABLES Decimal/inches/mm

1/64	*.0156*	0.396	17/64	*.2656*	6.746	33/64	*.5156*	13.100	49/64	*.7656*	19.446
1/32	*.0312*	0.792	9/32	*.2812*	7.143	17/32	*.5312*	13.492	25/32	*.7812*	14.842
3/64	*.0468*	1.189	19/64	*.2968*	7.541	35/64	*.5468*	13.891	51/64	*.7968*	20.241
1/16	*.0625*	1.588	5/16	*.3125*	7.938	9/16	*.5625*	14.288	13/16	*.8125*	20.637
5/64	*.0781*	1.984	21/64	*.3281*	8.337	37/64	*.5781*	14.684	53/64	*.8281*	21.034
3/32	*.0937*	2.380	11/32	*.3437*	8.730	19/32	*.5937*	15.080	27/32	*.8437*	21.480
7/64	*.1093*	2.779	23/64	*.3593*	9.129	39/64	*.6093*	15.479	55/64	*.8593*	21.828
1/8	*.125*	3.175	3/8	*.375*	9.525	5/8	*.625*	15.875	7/8	*.875*	22.225
9/64	*.1406*	3.571	25/64	*.3906*	9.921	41/64	*.6406*	16.271	57/64	*.8906*	22.620
5/32	*.1562*	3.968	13/32	*.4062*	10.317	21/32	*.6562*	16.667	29/32	*.9062*	23.017
11/64	*.1718*	4.366	27/64	*.4218*	10.716	43/64	*.6718*	17.066	59/64	*.9218*	23.416
3/16	*.1875*	4.763	7/16	*.4375*	11.113	11/16	*.6875*	17.463	15/16	*.9375*	23.810
13/64	*.2031*	5.159	29/64	*.4531*	11.509	45/64	*.7031*	17.859	61/64	*.9531*	24.208
7/32	*.2187*	5.555	15/32	*.4687*	11.905	23/32	*.7187*	18.255	31/32	*.9687*	24.605
15/64	*.2343*	5.954	31/64	*.4843*	12.304	47/64	*.7343*	18.654	63/64	*.9843*	25.001
1/4	*.25*	6.350	1/2	*.5*	12.700	3/4	*.75*	12.700	1	*1.*	25.400

Standard Stud Size U.S. (metric)	Stud Diameter In. (mm)	Terminal Hole Dia. In. (mm)
#2 M2	.0866 (2.18)	.090 (2.29)
#4 (M2,5)	.112 (2.84)	.118 (3.00)
#5 (M3)	.125 (3.18)	.127 (3.23)
#6 (M3,5)	.138 (3.51)	.146 (3.71)
#8 (M4)	.164 (4.17)	.173 (4.39)
#10 (M5)	.190 (4.83)	.198 (5.03)
1/4" (M6)	.250 (6.35)	.270 (6.86)
5/16" (M8)	.312 (7.92)	.330 (8.38)
3/8" (M10)	.375 (9.53)	.385 (9.78)
1/2" (M12)	.500 (12,7)	.520 (13.21)
5/8" (M16)	.625 (15.88)	.650 (16.51)
3/4" (M18)	.750 (19.05)	.810 (20.57)

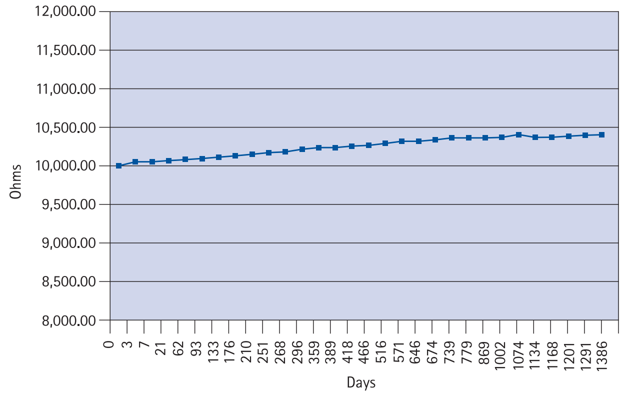
Size	Diameter Inches	Diameter mm	Ohms per 1000 ft	Ohms per km
20 AWG	0.032	0.813	10.15	33.29
21 AWG	0.029	0.724	12.80	41.98
22 AWG	0.025	0.645	16.14	52.94
23 AWG	0.023	0.574	20.36	66.78
24 AWG	0.020	0.511	25.67	84.20
25 AWG	0.018	0.455	32.37	106.17
26 AWG	0.016	0.404	40.81	133.86
27 AWG	0.014	0.361	51.47	168.82
28 AWG	0.013	0.320	64.90	212.87
29 AWG	0.011	0.287	81.83	268.40
30 AWG	0.010	0.254	103.20	338.50
31 AWG	0.009	0.226	130.10	426.73
32 AWG	0.008	0.203	164.10	538.25
33 AWG	0.007	0.180	206.90	678.63
34 AWG	0.006	0.160	260.90	855.75
35 AWG	0.006	0.142	329.00	1,079.12
36 AWG	0.005	0.127	414.80	1,360.00
37 AWG	0.005	0.114	523.10	1,715.00
38 AWG	0.004	0.102	659.60	2,163.00
2.0 mm	0.008	0.203	169.39	555.61
1.8 mm	0.007	0.178	207.50	680.55
1.6 mm	0.006	0.152	260.90	855.75
1.4 mm	0.006	0.152	339.00	1,114.00
1.25 mm	0.005	0.127	428.20	1,404.00
1.12 mm	0.004	0.102	533.80	1,750.00

Frequently Asked Questions

How does aging affect thermistor stability?

"Thermometric drift" is a specific type of drift in which the drift is the same amount of temperature at all temperatures of exposure. For example, a thermistor that exhibits a -0.02°C shift at 0°, 40° and 70°C (even though this is a different percentage change in resistance in each case) would be exhibiting thermometric drift. Thermometric drift: (1) occurs over time at varying rates, based on thermistor type and exposure temperature, and (2) as a general rule, increases as the exposure temperature increases. Most drift is thermometric.

How do thermistors fail?



The amount of drift over a period of time is dependent on the aging temperature. Please note that not all thermistor manufactures age at the same temperature so drift data may be different.

SILVER MIGRATION

This failure can occur when one or more of the following three conditions are present: constant direct current bias, high humidity, and electrolytes (disc/chip contamination). Moisture finds its way into the thermistor and reacts with the contaminant. Silver (on the thermistor electrodes) turns to solution, and the direct current bias stimulates silver crystal growth across the thermistor element. The thermistor resistance decreases, eventually reaching zero O (short) (probably the most common failure mechanism).

MICRO CRACKS

Thermistors can crack due to improper potting materials if a temperature change causes potting material to contract, crushing the thermistor. The result is a thermistor that has erratic resistance readings and is electrically "noisy."

FRACTURE OF GLASS ENVELOPE

Typically caused by mishandling of thermistor leads, this failure mechanism induces fractures in the glass coating at the lead/thermistor interface. These cracks may propagate around the thermistor bead resulting in a catastrophic upward shift in resistance. Mismatching of epoxies or other bonding materials may also cause this. Careful handling and the proper selection of potting materials can eliminate this failure.

AGING OUT OF RESISTIVE TOLERANCE

If thermistors are exposed to high temperatures over time, sometimes referred to as "aging," their resistivity can change. Generally the change is an upward change in resistivity, which results in a downward change in temperature. Selecting the proper thermistor for the temperature range being measured can minimize the occurrence of this failure. Temperature cycling may be thought of as a form of aging. It is the cumulative exposure to high temperature that has the greatest influence on a thermistor component, not the actual temperature cycling. Temperature cycling can induce shifts if the component has been built into an assembly with epoxies or adhesives, which do not match the temperature expansion characteristics of the thermistor.

What happens if my application exceeds the temperature rating?

Intermittent temperature incursions above and below the operating range will not affect long-term survivability. Encapsulate epoxy typically begins to break down at 150°C and the solder attaching leads to the thermistor body typically reflows at about 180°C. Either condition could result in failure of the thermistor.

Are thermistors ESD sensitive?

Per MIL-DTL-39032E, Table 1, thermistors by definition are not ESD sensitive.

What is the resolution of a thermistor?

There is no limit to the resolution of a thermistor. The limitations are in the electronics needed to measure to a specified resolution. Limitations also exist in determining the accuracy of the measurement at a specified resolution.

Are QTI thermistors RoHS compliant?

(What if I don't want a lead free part?)

Quality Thermistor maintains two separate manufacturing lines to meet the specific environmental needs of our customers. One line is dedicated to RoHS compliance and the other is maintained for traditional tin/lead parts for military, aerospace and medical applications.

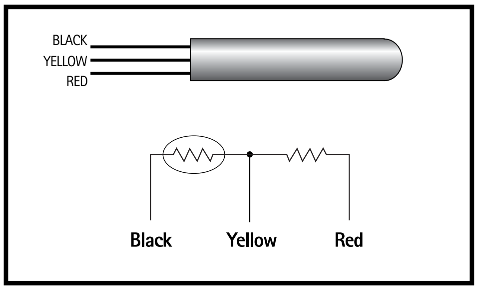
Does the length of wire impact the accuracy of a thermistor?

With a thermistor, you have the benefit of choosing a higher base resistance if the wire resistance is a substantial percentage of the total resistance. An example of this would be a 100-ohm thermistor vs a 50,000 ohm thermistor with 10' of 24 AWG wire.

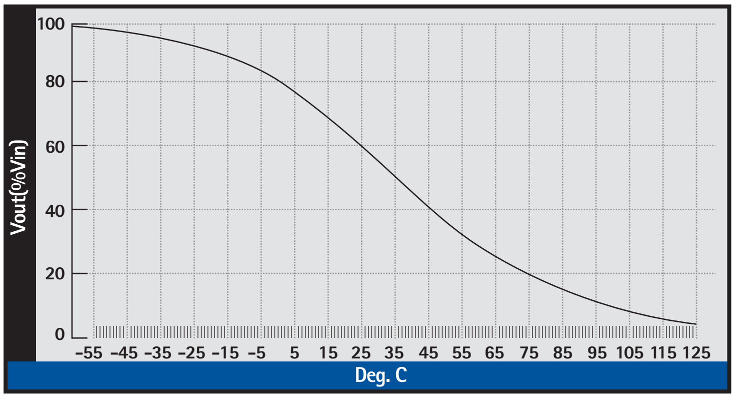
Total wire resistance = 10' x 2 wires x 0.02567 ohms per foot = 0.5134 ohms

New Products

Quality Thermistor, Inc. a leader in thermistor innovation is pleased to announce the Thermal Bridge. The Thermal Bridge incorporates a bridge resistor with the thermistor providing a more linear signal for conditioning. By incorporating a bridge resistor with a thermistor in a single precision assembly, temperature sensing is implemented without the need for calibration, potentionmeters, precision external components and with no concern for clocking and bus issues.



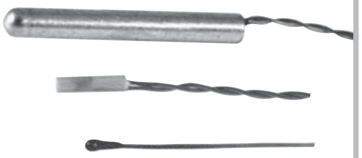
Temperature is determined by a ratio of the input versus output voltage across the sensor allowing inexpensive and precise temperature measurement capability for nearly any Microprocessor based system. With widely available embedded mixed signal processors and A-D converters, Design Engineers can easily condition the non-linear signal of NTC thermistors.



FEATURES AND BENEFITS OF USING THE THERMAL BRIDGE:

- Operating temperature range of -55 to 150°C
- Accuracy up to +/-.2°C from 0–70°C
  - Up to +/-1°C from -55 to 100°C
  - Up to +/-1.5°C from -55 to 150°C
- Available in many probe configurations or as a circuit board mounted component
- High stability with no calibration required
- Long sensor life-span
- Dynamic response for ease of measurement
- Wide operating voltage range, up to 48 VDC
- Monolithic thermistor sensor exhibits negligible capacitance and inductance
- No error introduced due to noise, and random noise self-cancels
- Low power consumption, 170uW maximum

How Small Can You Make a Thermistor?



CONFINED SPACE THERMISTORS & TEMPERATURE PROBES

- Exceptionally fast thermal response time
- Suitable for smaller temperature probe housings
- Custom and semi-custom products may be specified
- Available in point matched and interchangeable tolerances

NANO TUBE 0.023" MAX OD epoxy filled polyimide tube with insulated #38 AWG solid nickel leads, parallel bonded, 6" (76.2 mm)

Part Number	Bead Dia.	Resistance	Tolerance
QT06002-524	.023"	10,000 Ω	+/- 0.1°C (0°C to 70°)
QT06002-525	.023"	10,000 Ω	+/- 0.2°C (0°C to 70°)

MICRO TUBE 0.031" MAX OD epoxy filled polyimide tube with polyurethane nylon insulated #32 AWG solid copper leads, twisted pair, 6" (152.4mm). Tolerance +/- 0.2° (0°C to 70°)

Part Number	Bead Dia.	Resistance
QT06002-529	.031"	2,252 Ω
QT06002-530	.031"	3,000 Ω
QT06002-531	.031"	5,000 Ω
QT06002-532	.031"	10,000 Ω

MINI TUBE 0.037" MAX OD epoxy filled polyimide tube with polyurethane nylon insulated #32 AWG solid copper leads, twisted pair, 6" (152.4mm). Tolerance +/- 0.2° (0°C to 70°)

Part Number	Bead Dia.	Resistance
QT06002-526	.037"	2,252 Ω
QT06002-533	.037"	3,000 Ω
QT06002-527	.037"	5,000 Ω
QT06002-528	.037"	10,000 Ω

MINI BEAD 0.038" MAX OD epoxy coated bead with #34 AWG Poly-nylon insulated bifilar leads, twisted pair, 6" (152.4 mm). Tolerance +/- 0.2°C (0°C to 70°)

Part Number	Bead Dia.	Resistance
QTMB-14	.038"	10,000 Ω
QTMB16	.038"	15,000 Ω

	RESISTANCE			
Temp(°C)	2,252	3,000	5,000	10,000
0	7,355	9,798	16,330	32,660
5	5,720	7,620	12,700	25,400
10	4,481	5,970	9,950	19,900
15	3,538	4,713	7,855	15,710
20	2,813	3,747	6,245	12,490
25	2,252	3,000	5,000	10,000
30	1,815	2,417	4,029	8,058
35	1,471	1,960	3,266	6,532
40	1,199	1,598	2,663	5,326
45	984	1,310	2,184	4,368
50	811	1,081	1,801	3,602
55	672	896	1,493	2,986
60	560	746	1,244	2,488
65	469	625	1,041	2,082
66	453	603	1,005	2,010
67	437	582	971	1,941
68	422	563	938	1,875
69	408	544	906	1,812
70	394	525	876	1,751

Special Services

Qualified Test Lab

To ensure the quality of our QTI brand thermistors, Quality Thermistor has an extensive test lab for a wide range of testing services. In addition, this facility is available for customers for the following services:

- Power burn-in
- Temperature cycling
- Moisture testing
- Shock and vibration testing
- Temperature characterization
- Space-level screening
- QCI Military testing

Custom Design

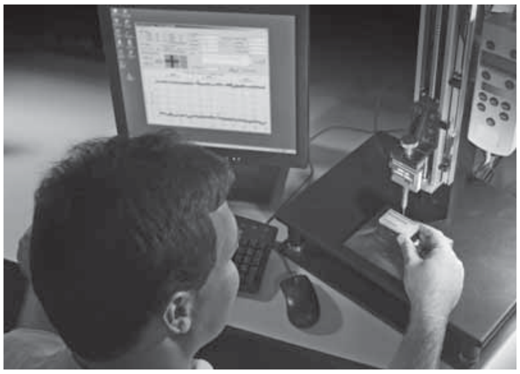
With a full staff of experienced temperature application engineers, Quality Thermistor can provide custom design services at any step along the design process. Experts in temperature measurement, compensation, and control, Quality Thermistor engineers can work with your in-house engineers or contractors, or as a full-support design team to solve your application.

- Components
- Probes
- Boards
- Systems
- Control and signal conditioning

Private Labeling

The QTI brand is recognized in many industries for high-quality manufacturing and measurement accuracy and reliability. However, in situations where private labeling is required, Quality Thermistor will provide components with no label or with your label to ensure the integrity of your branding strategy.

- Your design, your label
- Our design, your label
- Your design, the QTI label



Assembly

Quality Thermistor offers expert, timely component and board assembly services in our well-equipped Tecate, Mexico, facility. In addition, to ensure product is delivered on time, the facility's capability is mirrored at our Idaho plant.

- Highly-trained assemblers
- High-volume production
- Competitive prices
- Probe assembly
- PTC and NTC devices

CERTIFIED
ISO 9001:2000/AS9100
INTERTEK
CERTIFICATION
ANSI-RAB
QMS
ACCREDITED
National Accreditation Program

Quality Thermistor, Inc.

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For more information on Quality Thermistor, Inc., or on QTI brand thermistors, probes, and engineering services, contact Technical Support.

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