OMEGA's Precision Interchangeable Thermistors

What Are Thermistors?

Thermistors, derived from the term THERMally sensitive resISTORS, are a very accurate and cost-effective method for measuring temperature. Available in 2 types, NTC (negative temperature coefficient) and PTC (positive temperature coefficient), it is the NTC type thermistor that is commonly used to measure temperature.

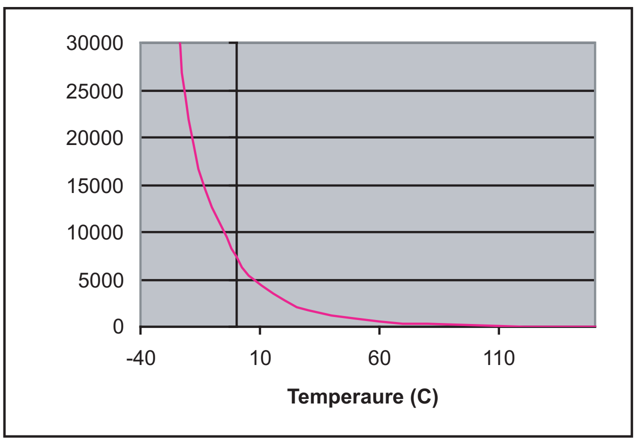
How Do They Compare to RTDs?

In contrast to RTDs that change resistance in a nearly linear way, NTC thermistors have a highly non-linear change in resistance and actually reduce their resistance with increases in temperature (See Figure 1).

The reasons that thermistors continue to be popular for measuring temperature is:

- Their higher resistance change per degree of temperature provides greater resolution
- High level of repeatability and stability (±0.1°C)
- Excellent Interchangeability
- A small size means fast response to temperature changes

Figure 1: Thermistor Curve



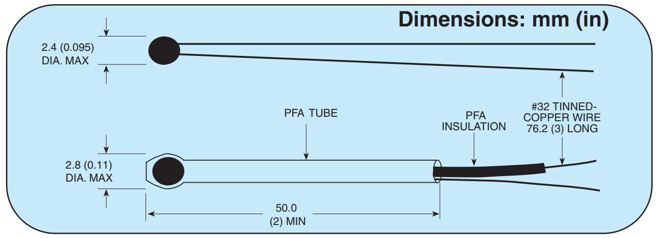
Thermistor Basics

Thermistors are made using a mixture of metals and metal oxide materials. Once mixed, the materials are formed and fired into the required shape. The thermistors can then be used "as-is" as disk-style thermistors, or further shaped and assembled with lead wires and coatings to form bead-style thermistors.

Coatings typically include:

- Epoxy coatings for lower temperature use [typically -50 to 150°C (-58 to 316°F)]
- Glass coatings for higher temperature applications [typically -50 to 300°C (-58 to 572°F)

These coatings are used to mechanically protect the thermistor bead and wire connections while providing some protection from humidity and or corrosion. It is the epoxy bead-type thermistor that is used in Omega's thermistor temperature sensor products.



Thermistors are typically supplied with very small diameter (#32AWG or 0.008" diameter) solid copper or copper alloy wires as shown above. Many times, these wires are tinned for easy soldering.

What Thermistor is Best for My Application?

Whether you are replacing an existing thermistor, or selecting one for a new application, there are 3 key pieces of information needed to obtain the desired result. These are:

1. Select the right base resistance for your new application, or correctly specify the base resistance of the thermistor needing to be replaced
2. Specify a resistance vs. temperature relationship ("curve"), or for replacement applications, make sure you know the existing thermistor information
3. Thermistor size or sensor package style

Base Resistance

NTC thermistors drop in resistance with increased temperature. This is also true of the amount of resistance change per degree the thermistor will provide. Relatively low temperature applications (-55 to approx 70°C) generally use lower resistance thermistors (2252 to 10,000 Ω). Higher temperature applications generally use the higher resistance thermistors (above 10,000 Ω) to optimize the resistance change per degree at the required temperature.

Thermistors are available in a variety of resistances and "curves". Resistances are normally specified at 25°C (77°F) , and the most common include:

- 2252 Ω
- 3000 Ω
- 5000 Ω
- 10,000 Ω
- 30,000 Ω
- 50,000 Ω
- 1 MΩ (1,000,000)

Table 1.1 shows how the resistance at 25°C (77°F) affects the amount of resistance change at a higher temperature.

Resistance vs. Temperature Curve

Unlike RTDs and thermocouples, thermistors do not have standards associated with their resistance vs. temperature characteristics or curves. Consequently, there are many different ones to choose from.

Each thermistor material provides a different resistance vs. temperature "curve". Some materials provide better stability while others have higher resistances so they can be fabricated into larger or smaller thermistors.

Table 1.1

Thermistor Model No.	Resistance @ 25°C (77°F)	Resistance Change per °C at 50°C
44004	2252 Ω	30.7 Ω
44005	3000 Ω	42 Ω
44007	5000 Ω	70 Ω
44006	10000 Ω	140 Ω
44008	30000 Ω	420 Ω

Many manufactures list a Beta (β) constant between 2 temperatures (Example: β 0/50 = 3890). This, along with the resistance at 25°C (77°F) can be used to identify a specific thermistor curve. See pages Z-254 and 255 for Omega's thermistor curves.

Size or Sensor Package Style

Once the right resistance and "curve" are established, the user should consider how the thermistor will be used. When selecting the right size or packaging for the sensor, it helps to remember that like any other sensor, a thermistor only measures its own temperature.

Thermistor beads are generally not designed for direct immersion into a process. They are small devices that change temperature very quickly since the only thing between them and the environment is a thin coating of epoxy. At Omega, offer a comprehensive line of sensors that protect the thermistor while allowing it to be used in a wide variety of applications. Below are a sampling of some of these styles.

ON-950, $43. See page D-16 for more information.

General Purpose

General purpose sensor designs are those that can be adapted to a wide variety of uses. Ranging from electronic equipment to structures, processes and design and reliability testing applications, these sensors are easy to install and monitor. The Omega ON-950 is an example of this type of construction. A small SST housing with #8-32 threaded stud can be installed into any #8-32 threaded hole, taking up a very small amount of space.

ON-403, $48.
See page D-17 for more information.

Liquid Immersion Measurement

When exposed to liquids, thermistors need to be protected from corrosion as well as positioned into the fluid so it will come to the needed temperature. This is typically achieved using closed ended tubes and specially designed housings. Care must be taken to make sure that there is a good thermal path to the thermistor, and that thermal mass is as small as possible.

ON-909-44004-40, $49.
See page D-18 for more information.

Surface Sensing

A simple but effective sensor design for monitoring surface temperature is the ON-409 attachable surface sensor. This design includes a thin, round metal stamping into which the thermistor is epoxied. The metal stamping can then be attached to a surface using an epoxy or other method to measure surface temperature.

There are many thermistor options presented in the following pages. If you don't find the right sensor for your application, or have questions concerning your application, please give our Customer Service Engineers a call. Additional information can also be found on our Website **omega.com.**

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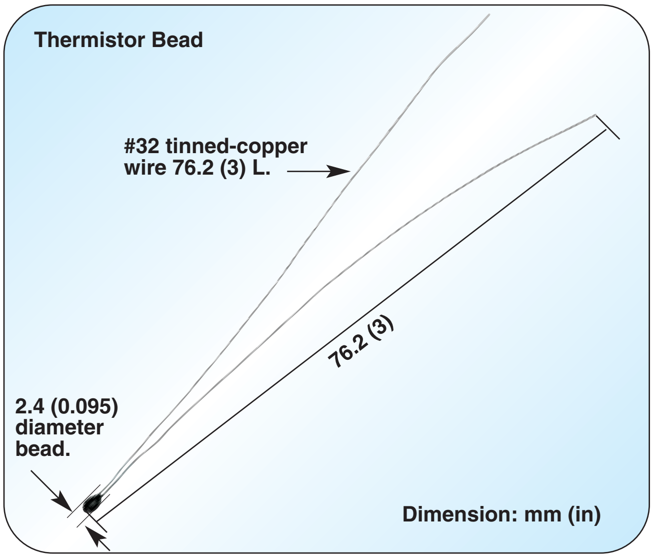
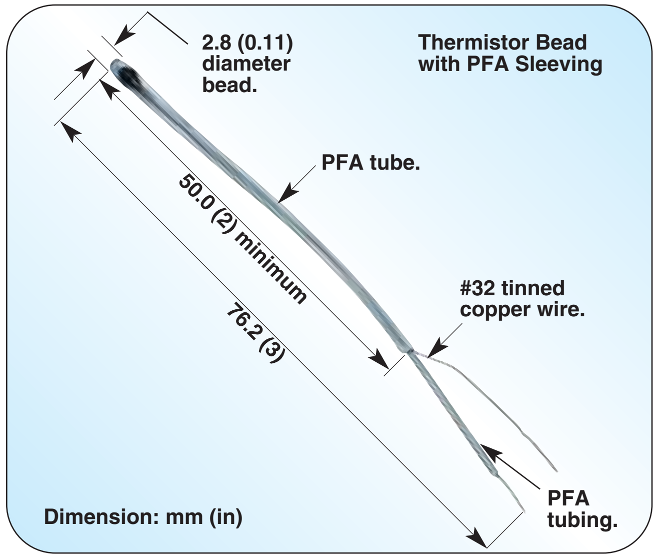
See Section I

Thermistor Elements





44000 Series
Starts at
$15

- **Epoxy Coated Thermistor Beads**
- **Precision Matched to 5 Standardized Resistance Curves**
- **Maximum Working Temperature 75°C or 150°C (See Table Below)**
- **Available in Interchangeabilities of ±0.1 or ±0.2°C (See Table Below)**

Resistance Vs. Temperature Characteristics

The Steinhart-Hart Equation has become the generally accepted method for specifying the resistance vs. temperature characteristics for thermistors. The Steinhart-Hart equation for temperature as a function of resistance is as follows:

$1/T = a + b \ln(R) + c \ln^3(R)$

where: a, b and c are constants derived from 3 temperature test points.
R = Thermistor's resistance in Ω
T = Temperature in degrees K

To determine the thermistor resistance at a specific temperature point, the following equation is used:

$R = e^{(beta-(alpha/2))1/3 - ((beta+(alpha/2))1/3}$

where:
alpha = ((a-(1/T))/c)
beta = $SQRT(((b/(3c))^3)+(alpha^2/4))$
T = Temperature in Kelvin (°C + 273.15)

The a, b and c constants for each of our thermistor selections can be found in Table 1. Using these constants with the above equations, you can determine the temperature of the thermistor based on its resistance, or determine a thermistor's resistance at a particular temperature.

Typical Thermometric Drift (±0.2°C Elements)

Operating Temp	10 Months	100 Months
0°C	<0.01°C	<0.01°C
25°C	<0.01°C	0.02°C
100°C	0.20°C	0.32°C
150°C	1.5°C	Not recommended

Table 1: Steinhart-Hart Constants

Model Number	Model Number	R25°C	A	B	C
44004	**44033**	**2252**	1.468 x 10-3	2.383 x 10-4	1.007 x10-7
44005	**44030**	**3000**	1.403 x 10-3	2.373 x 10-4	9.827 x 10-8
44007	**44034**	**5000**	1.285 x 10-3	2.362 x 10-4	9.285 x 10-8
44006	**44031**	**10000**	1.032 x 10-3	2.387 x 10-4	1.580 x 10-7
44008	**44032**	**30000**	9.376 x 10-4	2.208 x 10-4	1.276 x 10-7

Tolerance Curves

Accuracy tolerances for thermistor sensors are expressed as a percentage of temperature. This is also referred to as interchangeability. We list two basic accuracy/interchangeability specifications for our thermistors, ±0.10°C and ±0.20°C from 0 to 70°C (32 to 45°F).

Table 2: Interchangeability Tolerances

Temp (°C)	Model # 44004 ±0.20°C		Model # 44033 ±0.10°C	
	±°C	±Ω	±°C	±Ω
-80	0.42	60208	0.21	30104
-40	0.31	1516	0.16	758
0	0.20	73	0.10	37
40	0.20	10	0.10	5
80	0.22	2	0.11	1
120	0.34	0.8	0.17	0.4

Note: *Temperature values (°C) are the same for each tolerance group (±0.10 or ±0.20), resistance tolerances will change based on resistance at 25°C (77°F).*

Temperature vs. resistance tables for our thermistor products can be found on pages Z-254 and Z-255. The accuracy specification of ±0.1% or 0.2% means that each thermistor's resistance will fall within these limits between 0 and 70°C (32 and 158°F).
Table 2 illustrates the interchangeability values for the model numbers 44004 (±0.2°C) and 44033 (±0.1°C) at a number of temperatures.

Stability and Drift

While thermistors are generally very accurate and stable devices, conditions such as over-temperature exposure, humidity, mechanical damage or corrosion can cause uncontrolled changes in the resistance vs. temperature characteristics of the device. Once this characteristic has been altered, it cannot be re-established. This is one reason why most thermistors with a ±0.1°C interchangeability specifcation are rated for use at temperatures somewhat lower than those with an interchangeability of ±0.2°C.

Operating Current

The suggested operating current for bead-style thermistors is approximately 10 to 15 µA. Thermistors can experience self-heating effects if their operating currents are high enough to create more heat than can be dissipated from the thermistor under operating conditions. If higher operating currents are used, it is suggested that a self heating test be performed to insure the accuracy of the measurement.

Dissipation Constant

The dissipation constant is the power in milliwatts that will raise the resistance of a thermistor by 1°C over its surrounding temperature. Typical values include 8 mW/°C in a stirred oil bath, or 1 mW/°C in still air.

Time Constant

The time constant is the time required for a thermistor to react to a step change in temperature. For example, if exposed to a change from 0 to 100°C (32 to 212°F), the 63% time constant would be the time required for the thermistor to indicate a resistance at 63°C. Typically, bare thermistors suspended by their leads in a well stirred oil bath will have a 63% response time of 1 second maximum. PFA encased thermistors exposed to changes in air temperature will typically have a 63% response time of 25 seconds maximum.

Discount Schedule	
1 to 9	Net
10 to 24	10%
25 to 49	20%
50 to 99	30%
100 and over	40%

D

MOST POPULAR MODELS HIGHLIGHTED!

To Order *(Specify Model Number)*

Model Number	Price (Each)	Resistance @ 25°C (Ω)	Maximum Working Temp	Interchangeability @ 0 to 70°C	Storage and Working Temp for Best Stability
44004	**$15**	2252	150°C (300°F)	±0.2°C	-80 to 120°C (-110 to 250°F)
44005	**15**	3000	150°C (300°F)	±0.2°C	-80 to 120°C (-110 to 250°F)
44007	**15**	5000	150°C (300°F)	±0.2°C	-80 to 120°C (-110 to 250°F)
44006	**15**	10,000	150°C (300°F)	±0.2°C	-80 to 120°C (-110 to 250°F)
44008	**15**	30,000	150°C (300°F)	±0.2°C	-80 to 120°C (-110 to 250°F)
44033	**$22**	2252	75°C (165°F)	±0.1°C	-80 to 75°C (-110 to 165°F)
44030	**22**	3000	75°C (165°F)	±0.1°C	-80 to 75°C (-110 to 165°F)
44034	**22**	5000	75°C (165°F)	±0.1°C	-80 to 75°C (-110 to 165°F)
44031	**22**	10,000	75°C (165°F)	±0.1°C	-80 to 75°C (-110 to 165°F)
44032	**22**	30,000	75°C (165°F)	±0.1°C	-80 to 75°C (-110 to 165°F)

Note: *Thermistor elements are available with PFA sleeving over 1 lead wire and PFA overall, change middle digit model number to **"1"** and add **$18** to the base price for the ±0.2°C thermistors and add **$49** for the price of the ± 0.1°C thermistors.*

Ordering Examples: 44004, *2252 Ω thermistor bead at 25°C, ± 0.2°C interchangeability, $15. 44033, 2252 Ω thermistor bead at 25°C, , ± 0.1°C interchangeability, $22. 44104, 2252 Ω thermistor bead at 25°C, ±0.2°C interchangeability with PFA insulated lead wire and over-jacket, $15 + $18 = **$33. 44033,** 2252 Ω thermistor bead at 25°C, ±0.1°C interchangeability with PFA insulated lead wire and over-jacket, $22 + $49 = **$71.***