Application Sheet

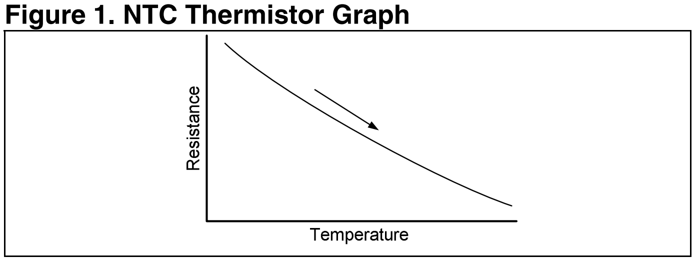
NTC Thermistor Slope and Resistance Deviation

General Information

Reference: R-T Curve information is available in the "Resistance – Temperature Conversion Tables" application sheet.

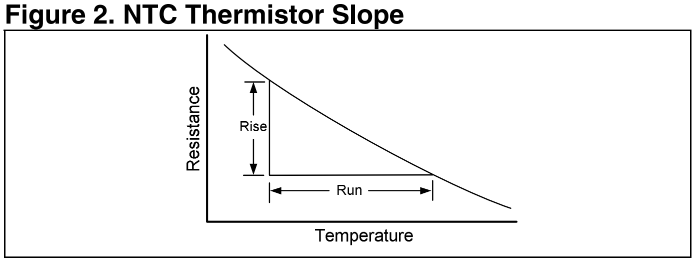
NTC Thermistor Resistance
NTC (Negative Temperature Coefficient) thermistors are the most sensitive temperature sensing devices in general use. An NTC thermistor decreases in resistance with an increase in temperature (see Fig. 1). There are several methods for quantifying and defining behavior. All pertain to the steepness of the resistance-temperature curve when plotted.

Figure 1. NTC Thermistor Graph



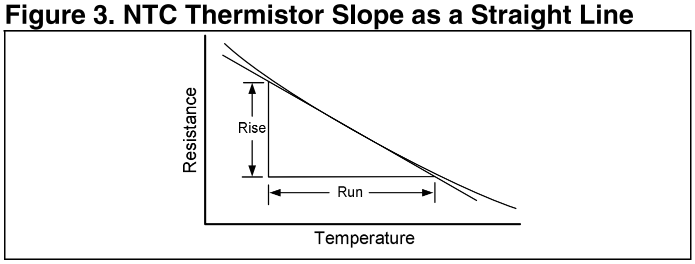
The steepness of the curve is usually referred to as its "slope" which is the relationship of "rise over run" (see Fig. 2).

Figure 2. NTC Thermistor Slope



If the graph is quite curved, a straight line is drawn tangent to the curve at the point of interest (see Fig. 3). Also notice that the line slopes "down hill" indicating a negative slope.

Figure 3. NTC Thermistor Slope as a Straight Line



In actual practice, very little data is graphed and analyzed geometrically in this way because it is too time consuming to first obtain sufficient data on a particular thermistor and then to graph the results. It is easier to take resistance data at two widely-separated temperatures and find the ratio of their resistances.

Nearly all thermistors have a normal resistance stated at the reference temperature of 25 °C [77 °F]. To determine the slope at this point, the resistance could be found at 24.5 °C [76.1 °F] and 25.5 °C [77.9 °F] and compared; however, a temperature measurement inaccuracy of 0.1 °C at each point may result in an error up to 20%.

Standard practice is to compare the value at 0 °C [32 °F] and 50 °C [122 °F]. For a 10,000 Ohm thermistor curve 16L, the resistance values are shown in Table 1.

Table 1. 10,000 Ohm Curve 16L Thermistor Values

Temperature	Resistance
0 °C [32 °F]	32,650 Ohm
50 °C [122 °F]	3603 Ohm

$$\text{Ratio} = \frac{32{,}650 \text{ Ohm}}{3603 \text{ Ohm}} = 9.06 \text{ Ohm}$$

Ratios for other thermistor materials range from approximately 5 to 15. The "0 to 50" ratio as well as the "25 to 125" ratio, which is used for the higher temperature rated devices, is available in the reference. The higher resistance materials tend to have steeper slopes and therefore higher ratios.

Although the ratio is useful concept, application engineers often need the actual slope at a particular temperature or even every degree over a wide temperature range. Analytic geometry suggests that the units of slope would be "the change in Ohms per degrees Celsius".

This sounds correct; however, it ignores the actual resistance point. The actual resistance change is related to the resistance. A 10K R-T Curve 16L thermistor has a slope of 440 Ohm per degree at 25 °C [77 °F]; however, a 1k device has only a 44 Ohm change per degree at the same point.

A more rigorous concept would be "Ohms per Ohm per degrees Celsius". In this notation, a typical slope would be 0.44 Ohm/Ohm/C° but even this is a little awkward. Changing "Ohms per Ohm" to a percentage results in "Ohms change per degrees Celsius" and is usually referred to as α (alpha).

$$\text{Slope} = \alpha = \%\ \Delta C°$$

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Example 1:

How fast will a 10k thermistor change at 25 °C [77 °F] where the slope is -4.4%/°C?

4.4% of 10,000 Ohm = 440 Ohm

Therefore, a thermistor heating up and just passing through 25 °C [77 °F] will lose 440 Ohm for each degree. At 26 °C [78.8 °F] the resistance will be 560 Ohm. Note that for the next degree, the drop will be only 420 Ohm (4.4% of 956 Ohm).

Example 2:

Using the same curve 16L what is the change in temperature if at one time the resistance was 9854 Ohm and is now 10,152 Ohm?

Change in Ohms:
10,152 Ohm – 9854 Ohm = 298 Ohm

α – 4.4%/C°
4.4% of 10K = 440 Ohm/C°

If 440 Ohm represents one degree, what part of a degree does 298 Ohm represent?

298 Ohm/440 Ohm = 0.68 °C change

Example 3:

If a thermistor is specified as a 10k curve 16L with tolerance of 5%, what is the equivalent tolerance in degrees?

A simple ratio can be used:

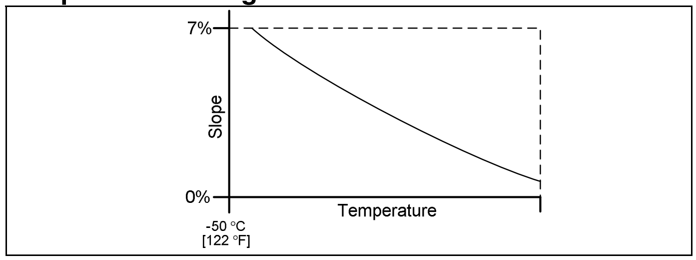
α of 4.4% is to one degree as 5% is to what degrees?

5/4.4 = 1.14 °C, therefore, a 5% tolerance on the resistance is the same as a 1.14 °C temperature tolerance.

It would be convenient if the slope were constant over the complete temperature range but the slopes are steeper on the cold end and a little flatter on the hot end of the temperature span (see Fig. 4).

As an example, the slope at -40 °C [-40 °F] is typically 6%/°C while at 100 °C [212 °F] the slopes come down to approximately 3%/°C.

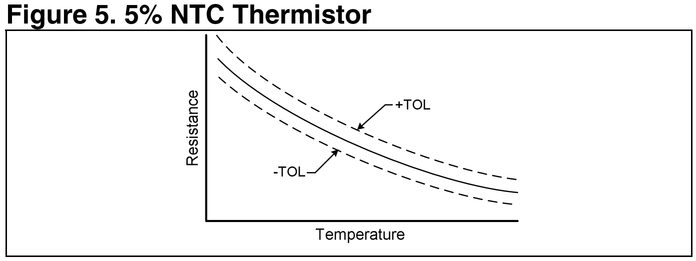
Figure 4. NTC Thermistor Slope Change with Temperature Change



A practical way to find the slope at 75 °C [167 °F] is to use the Steinhart-Hart equation to find the resistance at 74 °C [165.2 °F] and at 76 °C [168.8 °F]. Take the difference in resistance and divided by two. If the slope is required for each degree over a temperature range, then it is most easily done on a computer spreadsheet.

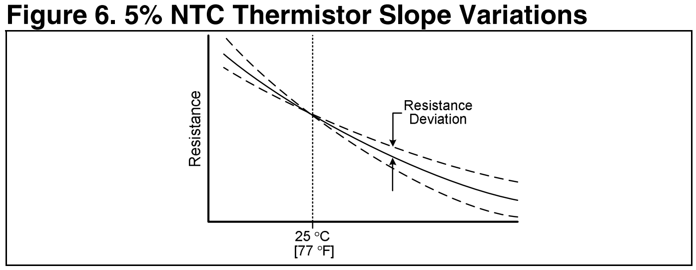
Slopes have their own tolerance and influence the resistance tolerance over the specified temperature range. A few examples will illustrate. A thermistor specified as a 5% device may be graphed showing the limits as two curves parallel to the normal (see Fig. 5).

Figure 5. 5% NTC Thermistor



Thermistors that are exactly on nominal (0% at 25 °C [77 °F]) but exhibit slope variations are graphed showing divergent lines, as if the normal curve were rated about the 25 °C [77 °F] point (see Fig. 6).

Figure 6. 5% NTC Thermistor Slope Variations



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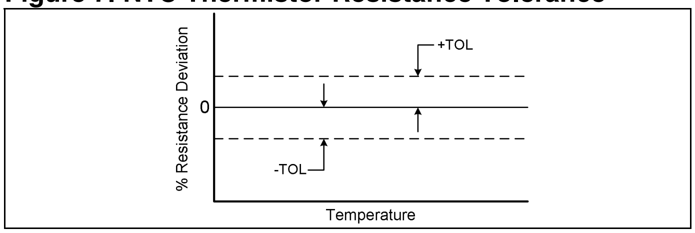
The further away from the nominal temperature of 25 °C [77 °F], the wider is the line divergence. The actual amount is referred to as “Resistance Deviation” and is given as a percent.

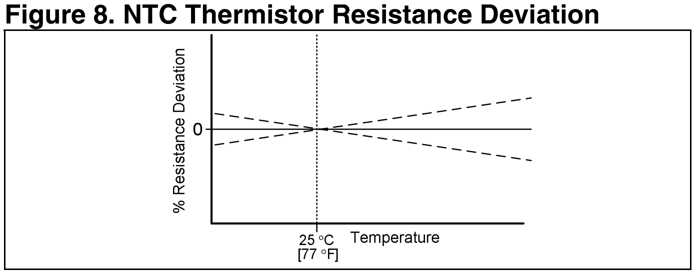
Only the percentages of the resistance tolerance and the resistance deviation tolerance need be plotted. The resistance tolerance would be a straight line as a function of temperature (see Fig. 7).

Figure 7. NTC Thermistor Resistance Tolerance



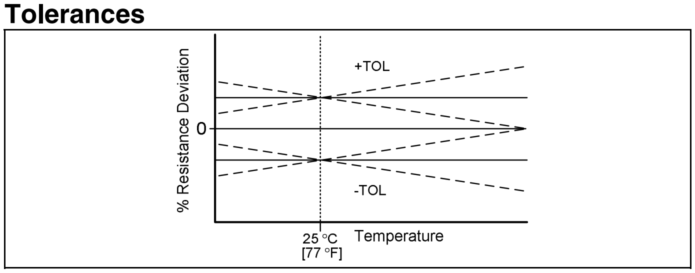
The resistance deviation percentages may also be plotted (see Fig. 8). The result is a horizontal “V” with the point at 25 °C [77 °F]. The V becomes wider with higher temperatures and a mirror image with colder temperatures. A thermistor with a steeper curve that is nominal produces the line going down to the right. The upward pointing line results from a thermistor with a less steep curve.

Figure 8. NTC Thermistor Resistance Deviation



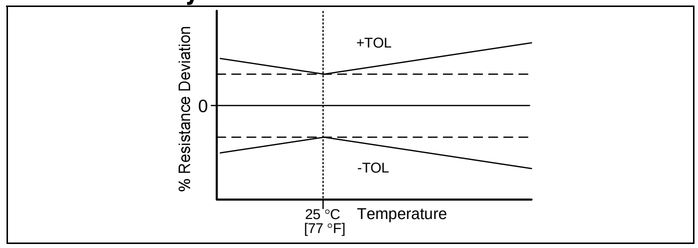
Superimposing the resistance deviation on the plus resistance tolerance and again on the minus resistance tolerance result in the graph shown in Fig. 9:

Figure 9. NTC Thermistor Resistance Deviations and Tolerances



The two tolerances can help or hinder each other; however, the worst case is shown in Fig. 10.

Figure 10. NTC Thermistor Nominal Resistance Tolerance Only



This type of representation resembles a bow tie with the knot at the nominal specification temperature, usually but not necessary, at 25° C [77 °F]. The tolerance at this point is just the nominal resistance tolerance. To find the tolerance at any other temperature point, the resistance deviation tolerance must be added.

Example 1:

For an R-T Curve 16L device with a nominal tolerance of 5% at 25° C [77 °F], what is the worst case tolerance at 70° C [158 °F]?

Using the reference, the resistance deviation is found to be 2.5% at 70 °C. This 2.5% is added to the 5% resulting in a total tolerance of 7.5% at 70 °C [158 °F].

What is the 7.5% resistance tolerance as an equivalent temperature tolerance?

The alpha for this device is 3.4%/C° at 70 °C [158 °F].

$$\frac{7.5\%}{3.4\%/°C} = 2.2\ °C$$

Total tolerance = ±2.2 °C

Example 2:

If a ±1 °C temperature accuracy is required at 50 °C [122 °F], what resistance tolerance is needed at 25 °C [77 °F].?

For R-T Curve 16L, the alpha at 50° C [122 °F] is 3.8%/°C.

$$1°\ C \times 3.8\%/°C = 3.8\%$$

According to the “Resistance-Temperature Conversion Tables Application Sheet”, deviation is 1.5% at 50 °C [122 °F]:

$$3.8\% - 1.5\% = 2.3\%$$

A 2.3% resistance tolerance is required at 25 °C [77 °F].

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