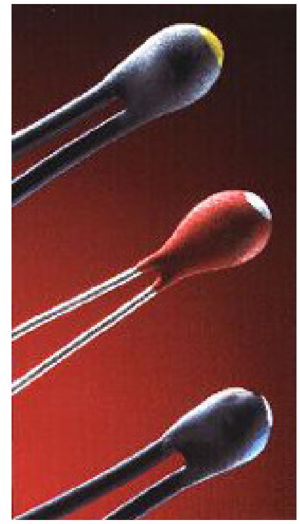
Thermistors

Introduction to Thermistors

Thermistor temperature sensors are constructed from sintered metal oxide in a ceramic matrix that changes electrical resistance with temperature. They are sensitive but highly non-linear. Their sensitivity, reliability, ruggedness and ease of use, has made them popular in research application, but they are less commonly applied to industrial applications, probably due to a lack on interchangeability between manufactures.

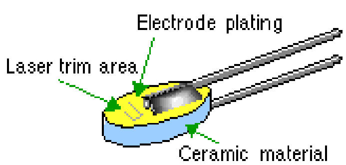
Thermistors are available in large range of sizes and base resistance values (resistance at 25°C). Interchangeability is possible to ±0.05°C although ±1°C is more common.



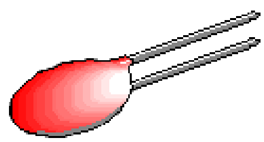
Three YSI Inc Thermistors

Thermistor construction

The most common form of the thermistor is a bead with two wires attached. The bead diameter can range from about 0.5mm (0.02") to 5mm (0.2").



Thermistor without Encapsulation



Thermistor with Encapsulation

Mechanically the thermistor is simple and strong, providing the basis for a high reliability sensor. The most likely failure mode is for the lead to separate from the body of the thermistor - an unlikely event if the sensor is mounted securely and with regard to likely vibration. The sintered metal oxide material is prone to damage by moisture, so are passivated by glass or epoxy encapsulation. If the encapsulation is compromised and moisture penetrates, silver migration under the dc bias can eventually cause shorting between the electrodes.

Like other temperature sensors, thermistors are often mounted in stainless steel tubes, to protect them from the environment in which they are to operate. Grease is typically used to improve the thermal contact between the sensor and the tube.

Thermistor characteristics

The following are typical characteristic for the popular 44004 thermistor from YSI:

Parameter	Specification
Resistance at 25°C	2252 ohms (100 to 1M available)
Measurement range	-80 to +120°C typical (250°C max.)
Interchangeability (tolerance)	±0.1 or ±0.2°C
Stability over 12 months	< 0.02°C at 25°C, < 0.25°C at 100°C
Time constant	< 1.0 seconds in oil, < 60 seconds in still air
self-heating	0.13 °C/mW in oil, 1.0 °C/mW in air
Coefficients (see Linearization below)	a = 1.4733×10^{-3}, b = 2.372×10^{-3}, c = 1.074×10^{-7}
Dimensions	ellipsoid bead 2.5mm x 4mm

To ensure the interchangeability specification, thermistors are laser trimmed in the manufacturing process.

Linearization

The thermistor's resistance to temperature relationship to temperature is given by the Steinhart & Hart equation:

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

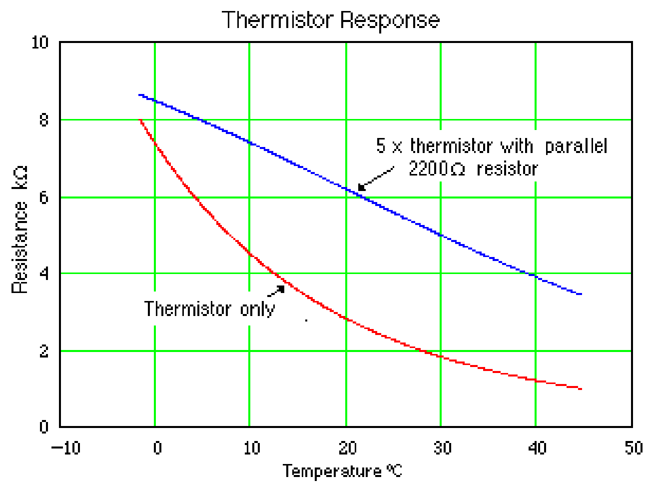
where a, b and c are constants, ln() the natural logarithm, R is the thermistors resistance in ohms and T is the absolute temperature in Kelvins. While the Steinhart & Hart equation is a close fit to practical devices, it does not always provide the precision required over the full temperature range. This can be corrected by fitting the Steinhart & Hart equation over a series of narrow temperature ranges and then 'splicing' these fits together to cover the required range.

Manufacturers will normally supply the constants as part of the specification for each part type, or alternatively will provide the resistance versus temperature tables. For precision measurement, tight tolerance parts are available, but at a premium price.

It is possible to determine the three constants by calibrating at three different temperatures and solving three simultaneous equations (based on the Steinhart & Hart equation above). This is a tedious calculation, so use the multifunctional Thermistor Calculator provided.

Hardware 'linearization'

A problem with the thermistor is the varying measured temperature resolution that is achieved over the temperature range. Usually the resolution is good at lower temperatures, but poor at higher temperatures. If the measuring device has a single scale, this can be an irritating characteristic. One way to simply fix this problem is to connect a resistor in parallel with the thermistor. The resistors value should equal the thermistor's resistance at the mid-range temperature. The result is a significant reduction in non-linearity, as the following diagram illustrates:



The plot in the above diagram shows the impact of a 2200 ohm resistor in parallel with a 2252 ohm (at 25°C) thermistor. Note the 5x scale factor difference for the 'linearized curve'. This technique is recommended whenever thermistors are used with simple measuring devices that have low ADC resolution (i.e. <12 bit).

Thermistor Manufacturers

Manufacturers of the thermistor element include: Alpha Thermistors Inc, BetaTHERM Corp, Cornerstone Sensors Inc, Murata Manufacturing Co Ltd, Pyromation Inc, Quality Thermistor Inc, Therm-O-Disc Inc, Thermometrics Inc, U.S. Sensor Corp, Victory Engineering Corp, and YSI Temperature Inc**.**

Related Devices

One form of the NTC thermistor is used in power circuits for in-rush current protection. At low temperatures they exhibit high resistance, but as current flows and self-heating warms the device, its resistance drops to allow the flow of operating current.

Related to the thermistor temperature sensor is the "Posistor" or positive temperature coefficient thermistor (PTC). These devices are useful in limiting current to safe levels. In normal operation their resistance is low, causing minimum impedance to current flow. Should the current exceed a certain level, self-heating will begin to warm the device causing higher impedance and hence more self-heating. This enters a 'thermal run away' state, with the device heating to such temperature that the current is limited to a safe level. The higher the fault current the faster the PTC thermistor will switch off.