



Complete Guide to Smart Sensor Thermistor Measurements

There are many ways to measure temperature, including the thermistor. The thermistor has a relatively low cost (about \$.30 to \$1.30 for a single unit at the time of this writing) and exhibits a relatively large change in resistance for each degree of temperature change. It can be driven from a simple voltage divider circuit connected to a Data Acquisition system measuring on the 0 to 5 volt range. This range is high enough to eliminate some of the noise problems that may be encountered with other temperature measurement devices such as thermocouples, making them ideal for use in systems where extensive signal conditioning is not desired.

So what is a thermistor? The linguist can see that the term is composed of parts of two words – thermal and resistor – semiconductor that forms a thermally sensitive resistor. More specifically, the manufacturers tell us that the temperature can be computed from the equation:

$$1/T = a+b*x+c*x^2+d*x^3$$

$$\text{where } x = \ln(R_t/R_{25})$$

R_t is the thermistor resistance at temperature T

R_{25} is the thermistor resistance at 25 degrees C (273.15+25 K).

And T is measured in degrees Kelvin.

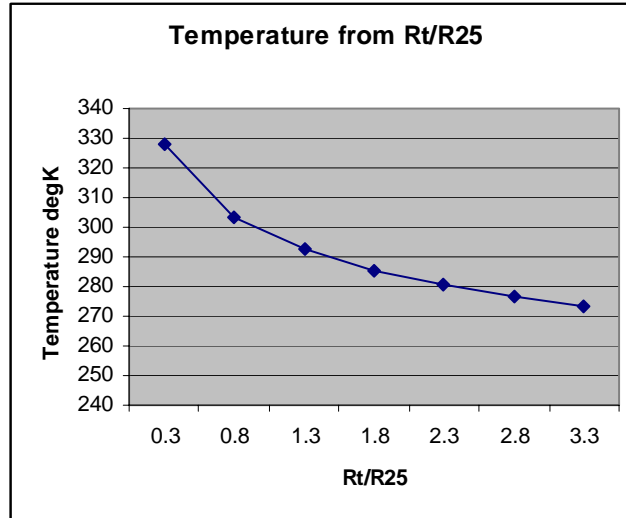
That's quite a mind boggling looking equation! And it is non-linear. In addition, some manufacturers give a, b, c, d constants in 50 degree C ranges – requiring 12 constants to cover the -50 degC to +100 degC range. Fortunately it can be simplified for all but the most precise systems:

$$1/T = a+b*\ln(R_t/R_{25})$$

Since $R_t=R_{25}$ at 298.15 degK, and $\ln(1)=0$, $a=1/298.15$

$$1/T = 1/298.15 + b*\ln(R_t/R_{25})$$

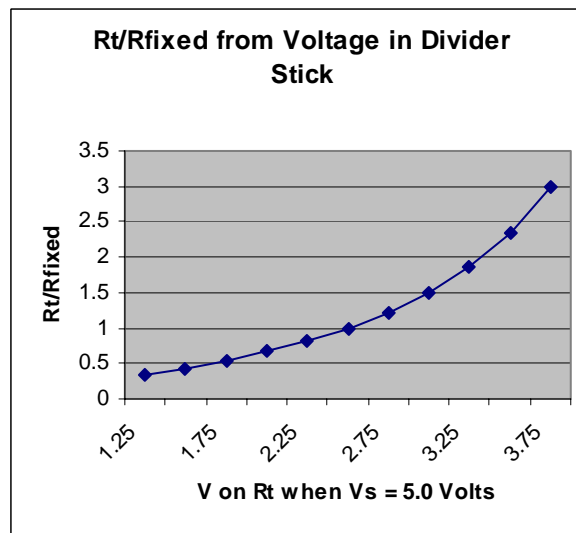
This is still non-linear, but not quite as complicated as the first equation. If we measure the resistance at 298.15 degK (R_{25}), and the resistance at another temperature, we can calibrate the thermistor. That's not too bad, but it still requires computing the ln function. It may help if we graph this:



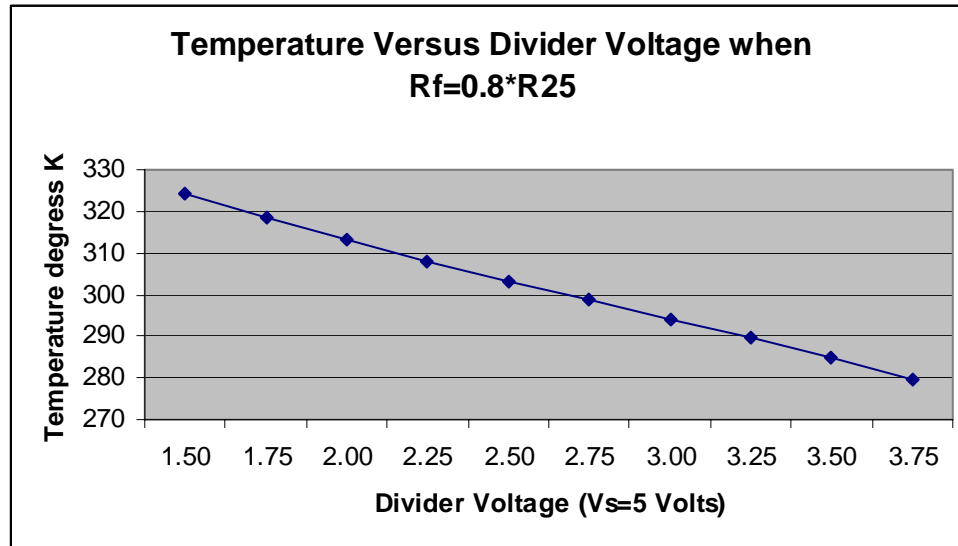
In addition, to “truly” measure the resistance would require a DMM, or at least a current source. That may be expensive or inconvenient. A cheaper way would be to use a voltage divider – place a fixed resistor in series with the thermistor, connect them to +5 volts, and measure the thermistor voltage (in addition to the +5 volt supply voltage Vs). Circuit analysis tells us that:

$$V_t = V_s \cdot R_t / (R_t + R_{\text{fixed}}), \text{ or } R_t = R_{\text{fixed}} / (V_s / V_t - 1)$$

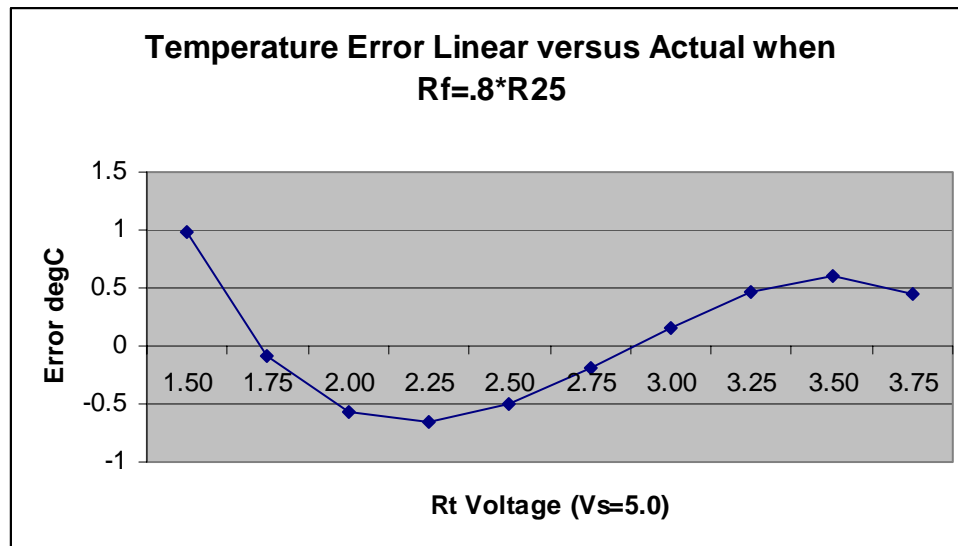
This too is a non-linear equation. Graphing, this shows:



Finally, we can put these two together – the non-linearity of the thermistor and the non-linearity of voltage versus resistance in the voltage divider actually work to our advantage. If we make the fixed resistor $0.8 \cdot R_{25}$ and plot the divider voltage versus temperature we get:



Calculating the error from the linear approximation gives:



This shows that over a 50 degC range you can have a thermistor in a voltage divider circuit and have a measurement error of less than 1 degC when you use a linear scaling of temperature to the divider voltage. If further accuracy is desired, piecewise linear segments can be used. This simplified math can speed up calibration and allow you to use a simple processor that does not have a logarithm routine, while achieving the desired accuracy of the system.