Calibration Equations for Thermistors

Gerald Recktenwald
Portland State University
Department of Mechanical Engineering
gerry@me.pdx.edu

May 23, 2010

Steinhart-Hart Equation

Standard calibration equation is the Steinhart-Hart Equation

$$T = \frac{1}{c_1 + c_2 \ln R + c_3 (\ln R)^3} \tag{1}$$

Least Squares Curve Fit to Steinhart-Hart Equation

Start by taking the inverse of Equation (1)

$$\frac{1}{T} = c_1 + c_2 \ln R + c_3 (\ln R)^3 \tag{2}$$

This equation is almost a polynomial of the form $T = f(\ln(R))$. Adding the missing quadratic term gives

$$\frac{1}{T} = a_1 + a_2 \ln R + a_3 (\ln R)^2 + a_4 (\ln R)^3 \tag{3}$$

Or, symbolically

$$y = a_1 + a_2 x + a_3 x^2 + a_4 x^3 \tag{4}$$

where

$$y = \frac{1}{T} \qquad\qquad x = \ln(R)$$

Calibration Summary

1. With an independent temperature reference, measure T versus R.
2. Compute transformed variables

$$y = \frac{1}{T} \qquad \text{where } T \text{ is absolute temperature, } {}^\circ\mathrm{R} \text{ or K}$$

$$x = \ln(R)$$

3. Perform a least squares curve fit to the polynomial

$$y = a_1 + a_2 x + a_3 x^2 + a_4 x^3$$

   The result of the curve fit is the set of coefficients, a_1, a_2, a_3, and a_4.
4. Whenever an R value is measured, compute T with

$$T(^\circ\mathrm{C}) = \frac{1}{a_1 + a_2 \ln R + a_3 (\ln R)^2 + a_4 (\ln R)^3} - 273.15$$

Inverse Calibration: $R = f(T)$

Experience shows that the inverse relationship can be fit with

$$\ln(R) = b_1 + b_2\left(\frac{1}{T}\right) + b_3\left(\frac{1}{T}\right)^2. \qquad (5)$$

Procedure for Obtaining $R = f(T)$

1. Convert the temperature values to $1/T$, where T an absolute temperature.
2. Convert the RCTIME output R to $\ln(R)$.
3. Use the least squares procedure to obtain b_1, b_2, and b_3 in Equation (5).

Evaluate the inverse calibration equation with

$$R = \exp\left[b_1 + b_2 \left(\frac{1}{T}\right) + b_3 \left(\frac{1}{T}\right)^2 \right]. \tag{6}$$

where T is absolute temperature.