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Steinhart–Hart equation

The **Steinhart–Hart equation** is a model of the resistance of a semiconductor at different temperatures. The equation is:

$$\frac{1}{T} = A + B\ln(R) + C[\ln(R)]^3$$

where:

- T is the temperature (in Kelvin)
- R is the resistance at T (in ohms)
- A, B, and C are the **Steinhart–Hart coefficients** which vary depending on the type and model of thermistor and the temperature range of interest. (The most general form of the applied equation contains a $[\ln(R)]^2$ term, but this is frequently neglected because it is typically much smaller than the other coefficients, and is therefore not shown above.)

Contents

Uses of the equation

The equation is often used to derive a precise temperature of a thermistor since it provides a closer approximation to actual temperature than simpler equations, and is useful over the entire working temperature range of the sensor. Steinhart–Hart coefficients are usually published by thermistor manufacturers.

Where Steinhart–Hart coefficients are not available, they can be derived. Three accurate measures of resistance are made at precise temperatures, then the coefficients are derived by solving three simultaneous equations.

Inverse of the equation

To find the resistance of a semiconductor given the temperature the inverse of the Steinhart–Hart equation must be used. See the Application Note (http://www.cornerstonesensors.com/reports/ABC%20Coefficients%20for%20Steinhart-Hart%20Equation.pdf), "A, B, C Coefficients for Steinhart–Hart Equation".

$$R = \exp\left(\sqrt[3]{y - \frac{x}{2}} - \sqrt[3]{y + \frac{x}{2}}\right)$$

where

$$x = \frac{1}{C}\left(A - \frac{1}{T}\right)$$
$$y = \sqrt{\left(\frac{B}{3C}\right)^3 + \left(\frac{x}{2}\right)^2}$$

Steinhart–Hart coefficients

To find the coefficients of Steinhart–Hart, we need to know at-least three operating points. For this, we use three values of resistance data for three known temperatures.

$$\begin{bmatrix} 1 & \ln(R_1) & \ln^3(R_1) \\ 1 & \ln(R_2) & \ln^3(R_2) \\ 1 & \ln(R_3) & \ln^3(R_3) \end{bmatrix} \begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} \frac{1}{T_1} \\ \frac{1}{T_2} \\ \frac{1}{T_3} \end{bmatrix}$$

With R_1, R_2 and R_3 values of resistance at the temperatures T_1, T_2 and T_3, one can express A, B and C (all calculations):

$$L_1 = \ln(R_1),\ L_2 = \ln(R_2),\ L_3 = \ln(R_3)$$
$$Y_1 = \frac{1}{T_1},\ Y_2 = \frac{1}{T_2},\ Y_3 = \frac{1}{T_3}$$
$$\gamma_2 = \frac{Y_2 - Y_1}{L_2 - L_1},\ \gamma_3 = \frac{Y_3 - Y_1}{L_3 - L_1}$$
$$\Rightarrow C = \left(\frac{\gamma_3 - \gamma_2}{L_3 - L_2}\right)(L_1 + L_2 + L_3)^{-1}$$
$$\Rightarrow B = \gamma_2 - C\left(L_1^2 + L_1 L_2 + L_2^2\right)$$
$$\Rightarrow A = Y_1 - \left(B + L_1^2 C\right) L_1$$

Developers of the equation

The equation is named after John S. Steinhart and Stanley R. Hart who first published the relationship in 1968.[1] Professor Steinhart (1929–2003), a fellow of the American Geophysical Union and of the American Association for the Advancement of Science, was a member of the faculty of University of Wisconsin–Madison from 1969 to 1991.[2] Dr. Hart, a Senior Scientist at Woods Hole Oceanographic Institution since 1989 and fellow of the Geological Society of America, the American Geophysical Union, the Geochemical Society and the European Association of Geochemistry,[3] was associated with Professor Steinhart at the Carnegie Institution of Washington when the equation was developed.

References

1. John S. Steinhart, Stanley R. Hart, Calibration curves for thermistors, Deep-Sea Research and Oceanographic Abstracts, Volume 15, Issue 4, August 1968, Pages 497-503, ISSN 0011-7471, doi:10.1016/0011-7471(68)90057-0 (https://doi.org/10.1016%2F0011-7471%2868%2990057-0).
2. "Memorial resolution of the faculty of the University of Wisconsin-Madison on the death of professor emeritus John S. Steinhart" (http://www.secfac.wisc.edu/senate/2004/0405/1775(mem_res).pdf) (PDF). University of Wisconsin. 5 April 2004. Retrieved 2 July 2015.
3. "Dr. Stan Hart," (http://www.whoi.edu/science/GG/people/shart/index.htm). Woods Hole Oceanographic Institution. Retrieved 2 July 2015.

External links

- Steinhart-Hart Temperature Calculator (http://www.daycounter.com/Calculators/Steinhart-Hart-Thermistor-Calculator.phtml)
