

The Steinhart-Hart Thermistor Equation:

The Steinhart-Hart thermistor equation is named for two oceanographers associated with Woods Hole Oceanographic Institute on Cape Cod, Massachusetts.

The first publication of the equation was by **I.S. Steinhart & S.R. Hart** in "**Deep Sea Research**" vol. **15 p. 497 (1968)**.

The equation is derived from mathematical curve-fitting techniques and examination of the Resistance versus Temperature characteristic of thermistor devices.

In particular, using the plot of the natural log of resistance value, **ln(R)** versus **(1/T)** for a thermistor component to consider **(1/T)** to be a polynomial in **ln(R)**, an equation of the following form is developed:

$$\frac{1}{T} = A_0 + A_1(\ln(R)) + \dots + A_N(\ln(R))^N$$

(where T is the temperature in Kelvin, and A₀A_N are polynomial coefficients that are mathematical constants.)

The order of the polynomial to be used to model the relationship between R and T depends on the accuracy of the model that is required and on the non-linearity of the relationship for a particular thermistor.

It is generally accepted that use of a third order polynomial gives a very good correlation with measured data, and that the "squared" term is not significant.

The equation then is reduced to a simpler form, and it is generally written as:

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

Equation # 8

where: A, B, and C are constant factors for the thermistor that is being modelled.

This is the Steinhart-Hart equation, with Temperature as the main variable.

The equation is presented explicitly in resistance, on the summary page of information on the Steinhart-Hart equation. Before summarizing the situation, some general points of relevance in understanding the practical issues associated with it are discussed:

The equation is relevant for the complete useful temperature range of a thermistor.

The coefficients A, B, and C are constants for the **individual** thermistors. Unlike Alpha and Beta they should **not be regarded as material constants**.

The A, B, and C constants are established for individual thermistors in a particular temperature range as follows:

The equation is considered for three temperature points in the range – usually at the low end, the middle and the high end of the range. This ensures best fit along the full range. (The smaller the temperature range, the better the calculations will match measured data.) The temperature values are usually taken to be 0°C, 25 °C and 70 °C therefore these values are used to illustrate the principle.

Precisely controlled measurements of temperature and associated resistance value of the thermistor are made in a temperature controlled medium at these three calibration points.

These accurately measured values of Resistance and Temperature are inserted into the equation to form three simultaneous equations as follows: **(note: 0°C = 273.15K)**

$$\frac{1}{T_0} = \frac{1}{273.15} = A + B(\ln(R_0)) + C(\ln(R_0))^3$$

$$\frac{1}{T_{25}} = \frac{1}{298.15} = A + B(\ln(R_{25})) + C(\ln(R_{25}))^3$$

$$\frac{1}{T_{70}} = \frac{1}{343.15} = A + B(\ln(R_{70})) + C(\ln(R_{70}))^3$$

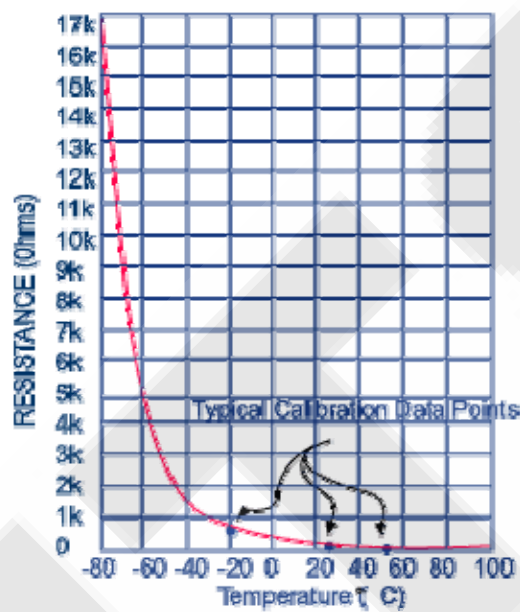
Since the resistance values are measured numerical quantities, the equations are a system of three

simultaneous equations in three unknowns namely A, B and C. The values for A, B and C can be found by standard mathematical techniques for solving simultaneous equations, or by use of analytical software tools.

This is a brief summary of the origins and techniques used to derive the A, B and C coefficients for thermistor components. These values are sometimes referred to as the "Steinhart Coefficients" for a thermistor.

It should be noted that the Steinhart-Hart equation produces a good approximation to the relationship between T and R for the complete range of a thermistor based on data from just three calibration points.

R-T Graph for BetaTHERM part # 0.1K1A Thermistors. Full Temperature range from -80 °C to +100 °C Maximum.



Graph # 7

Because the Steinhart-Hart equation is a mathematical approximation, it is instructive to do some calculations using the equation for a thermistor and to compare the resulting temperature or resistance values with the published R/T data. The published R/T tables are based on actual measurements, but the difference between values calculated from the Steinhart-Hart equation and the published data should typically be less than +/- 0.01 °C.

This is illustrated for a 10K3 device over a limited range in the table on this page. The table was generated by using the published Resistance versus Temperature data for this device, and inserting the Resistance values into the Steinhart-Hart equation to calculate the Temperature. This calculated Temperature can then be compared with the reference Temperatures at which the resistance was measured.

Relevant information for the practical use of the Steinhart-Hart equation to model thermistors. This includes a statement of the equation explicitly in resistance form and a listing of the Steinhart coefficients for a range of BetaTHERM components.

It should be noted that Steinhart-Hart coefficients that are in the summary table were not all derived from measurements at 0 °C, 25 °C and 70 °C. For devices with higher resistance values (for example 1M9A1), which are generally used at higher temperatures, the Steinhart-Hart coefficients were derived from measurements at 25 °C, 100 °C and 150 °C. These temperature values are more representative of the temperature range where these thermistors are used. The values of the calibration temperatures are included in the table.

The Steinhart-Hart equation is a very useful means of modelling the Resistance versus Temperature characteristics of a Thermistor but it should be remembered that it provides good correlation with actual

measurements for a thermistor in ideal measurement conditions. This concept of "ideal" measurement conditions and factors that affect the measured value of resistance of a thermistor is explained in the sections that follow the summary page relating to the Steinhart-Hart equation.

Comparison of actual (measured) data and calculated temperature values using measured resistances in Steinhart-Hart equation for BetaTHERM 10K3 device:

Measured Resistance (Ohms)	Actual Temperature (°C)	Temperature Calculated (°C)
49633.00	-8	-7.999
47047.00	-7	-6.999
44610.00	-6	-5.999
42314.60	-5	-5.000
40149.50	-4	-4.000
38108.50	-3	-3.000
36182.80	-2	-2.000
34366.10	-1	-1.000
32650.80	0	-0.001
31030.40	1	1.000
29500.10	2	2.000
28054.20	3	3.000
26687.60	4	3.999
25395.50	5	4.999
24172.70	6	5.999
23016.00	7	7.000
21921.70	8	7.999
20885.20	9	8.999
19903.50	10	9.999
18973.60	11	10.999
18092.60	12	11.999
17257.40	13	12.999
16465.10	14	13.999
15714.00	15	14.999
15001.20	16	15.999
14324.60	17	17.000
13682.60	18	17.999
13052.80	19	19.033
12493.70	20	19.999
11943.30	21	20.999
11420.00	22	22.000
10922.70	23	23.000
10449.90	24	24.000
10000.00	25	25.000