Calculating temperature of NTC thermistor given its resistance using the Steinhart-Hart equation

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Abstract

In this paper a general method for calculating the temperature of a NTC thermistor given its resistance is described. The Steinhart-Hart equation is explained, and how to calculate the coefficients for the equation is also described.

1 The Steinhart-Hart Equation

The Steinhart-Hart equation is used to model how the resistance of a semiconductor varies with temperature. The equation is:

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

Figure 1: Steinhart-Hart Equation

where

- T is the temperature in Kelvins.
- R is the resistance at T in Ω
- A, B, C are the **Steinhart-Hart coefficients**. These coefficients vary depending on the type of thermistor, and the temperature range that the model will be used in.

The equation was first published in 1968 by John S. Steinhart and Stanley R. Hart in Deep Sea Research and Oceanoographic Abstracts.

2 Calculating Steinhart-Hart coefficients

In some datasheets the Steinhart-Hart coefficients are given to you, but in most you must calculate them yourself. To do this you need to know at least 3 operating points. This can usually be found in the datasheet, e.g Figure 2.1. If this data is not available to you, they can be recorded using a multimeter and a device to measure the temperature of the thermistor.

Resistance-Temperature

Temperature	Type							Temperature	Type						
(°C)	102AT	202AT	502AT	103AT	203AT	503AT	104AT	(°C)	102AT	202AT	502AT	103AT	203AT	503AT	104AT
−50	24.46	55.66	154.6	329.5	1253	3168	11473	35	0.7229	1.424	3.508	6.940	13.06	32.48	60.94
−45	18.68	42.17	116.5	247.7	890.5	2257	7781	40	0.6189	1.211	2.961	5.827	10.65	26.43	48.10
−40	14.43	32.34	88.91	188.5	642.0	1632	5366	45	0.5316	1.033	2.509	4.911	8.716	21.59	38.13
−35	11.23	24.96	68.19	144.1	465.8	1186	3728	50	0.4587	0.8854	2.137	4.160	7.181	17.75	30.44
−30	8.834	19.48	52.87	111.3	342.5	872.8	2629	55	0.3967	0.7620	1.826	3.536	5.941	14.64	24.42
−25	6.998	15.29	41.21	86.43	253.6	646.3	1864	60	0.3446	0.6587	1.567	3.020	4.943	12.15	19.72
−20	5.594	12.11	32.44	67.77	190.0	484.3	1340	65	0.3000	0.5713	1.350	2.588	4.127	10.13	15.99
−15	4.501	9.655	25.66	53.41	143.2	364.6	969.0	70	0.2622	0.4975	1.168	2.228	3.464	8.482	13.05
−10	3.651	7.763	20.48	42.47	109.1	277.5	709.5	75	0.2285	0.4343	1.014	1.924	2.916	7.129	10.68
−5	2.979	6.277	16.43	33.90	83.75	212.3	523.3	80	0.1999	0.3807	0.8835	1.668	2.468	6.022	8.796
0	2.449	5.114	13.29	27.28	64.88	164.0	390.3	85	0.1751	0.3346	0.7722	1.451	2.096	5.105	7.271
5	2.024	4.188	10.80	22.05	50.53	127.5	292.5	90	0.1536	0.2949	0.6771	1.266	1.788	4.345	6.041
10	1.684	3.454	8.840	17.96	39.71	99.99	221.5	95			0.5961	1.108	1.530	3.712	5.037
15	1.408	2.862	7.267	14.69	31.36	78.77	168.6	100			0.5265	0.9731	1.315	3.185	4.220
20	1.184	2.387	6.013	12.09	24.96	62.56	129.5	105			0.4654	0.8572	1.134	2.741	3.546
25	1.000	2.000	5.000	10.00	20.00	50.00	100.0	110			0.4128	0.7576	0.9807	2.369	2.994
30	0.8486	1.684	4.179	8.313	16.12	40.20	77.81								

Unit(kΩ)

Figure 2: Example table that is found in most thermistor datasheets.

From this table we can choose 3 points that are greater than 10°C apart, and are equally spaced. For this example I will choose:

- $T_1 = 273K$, $R_1 = 27280\Omega$
- $T_2 = 298K$, $R_2 = 10000\Omega$
- $T_3 = 323K$, $R_3 = 4160\Omega$

The coefficients A, B and C can be calculated as follows:

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

Included in this project is a Python 3 script that generates the coefficients for you when you give it resistance/temperature pairs. This is found in `scripts/coefficients.py`.

3 Accuracy

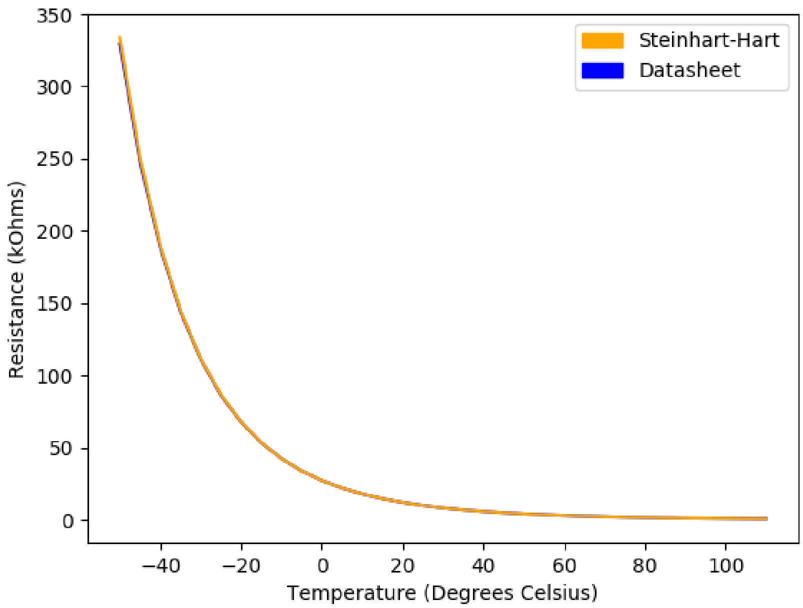

Figure 3: Graph comparing datasheet values with ones generated by Steinhart-Hart equation.

From looking at the graph there is very little difference between the two curves, showing the accuracy of the Steinhart-Hart equation.