NTC Thermistor Sensor

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1 Introduction

The NTC thermistors display non-linear resistance characteristics with temperature. The resistance of an NTC will decrease at the temperature increases. This behaviour is related to it's constant value B. This phenomenon allows for use of an NTC thermistor as a temperature sensor. In the discussed experiments a Vishay NTCLE100E3 thermistor was used, with $B = 3977°K$.

2 Theory

2.1 R-T characteristics

In the following experiments measurements are compared against the linear sensor model:

$$O(I) = KI + a \tag{1}$$

where K is the sensor's sensitivity, I is the input, a is the y-intercept, and $O(I)$ is the sensor's output at a given input. The sensitivity is calculated by the following equation:

$$K = \frac{O(I_{max}) - O(I_{min})}{I_{max} - I_{min}} \tag{2}$$

where I_{max} and I_{min} are maximum and minimum input in the range of operation. Finally, the y-intercept can be found:

$$a = O(I_{min}) - KI_{min} \tag{3}$$

In the case of a NTC thermistor the input is temperature and the output is resistance. However, the relation between temperature is said to be non-linear, for the NTCLE100E3 it can be described with equation for expected intermediate temperatures, taken from the NTC's datasheet:

$$R_T(T) = R_{ref} \cdot e^{A + \frac{B}{T} + \frac{C}{T^2} + \frac{D}{T^3}} \tag{4}$$

where A, B, C, and D are constant values which are dependent on the thermistor; R_{ref} is the resistance at a reference temperature—for the thermistor used in the experiment (Brown, Black, and Orange bands) it is 10000Ω,and the constant values:

R_{ref}	10000Ω
A	-14.6337
B[1]	4791.842
C	-115334
D	$-3.730535 \cdot 10^6$

Since, the temperature T in the equation 4 is in $°K$ for measurements in $°C$ conversion is required:

$$T_K = T_C + 273.15° \tag{5}$$

When considering the equation 4 the non-linearity N should be significant. This error can be reduced. The Siemens Handout describes how the output can be linearised in a range by use of a prallel resistor. The equation for the value of such resistor is:

$$R_p = R_{T_{ctr}} \cdot \frac{B - T_{ctr}}{B + 2 \cdot T_{ctr}} \tag{6}$$

where $R_{T_{ctr}}$ and T_{ctr} are thermistor's resistance and temperature at the center of the temperature range, and B is the B (β) value of the thermistor.

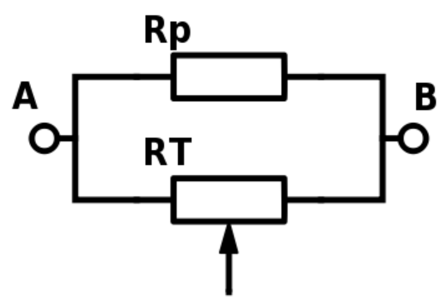

Figure 1: Parallel circuit

The expected output $R_{AB}(T)$ for a linearised thermistor setup shown in Fig.2.1 can be derived from a basic equation for resistor:

$$R_{AB}(T) = \frac{R_p \cdot R_T(T)}{R_p + R_T(T)} \tag{7}$$

3 Experiments

Two experiments were conducted. First, to determine characteristics of the non-linear response

[1]Note that this value is different to the β "B" value of a thermistor, constants from this table should only be used in combination with eqation 4

of the NTC: resistance-temperature R-T and tempera resistance T-R, maximum non-linearity $\hat{N}$ as % of $f.s.d$ (full scale deflection); response of a system linearised by a parallel resistor. Second, to find the time constant τ of the measurement system. Raw data from all measurements is presented in the Appendix.

3.1 R-T Characteristics

To measure the R-T and T-R characteristics the resistance was measured with an AMPROBE AM-510-EUR multimeter, and recorded over temperature range 90–45°C. This was achieved by measuring the temperature of water in a cup, which was cooled from 100° to 45°.

To determine the parallel resistor value $R_{T_{ctr}}$ was recorded at $T_{ctr} = 72.5°C$ and calculated using the eqation.

3.2 Time Constant

4 Results

Here, the data from each part the experiments are analysed and discussed. Important graphs, equations, and tables are shown directly in these subsections. Complete calculated data will be put into tables, graphs that can be seen in the Appendix.

4.1 R-T Characteristics

4.1.1 Non-Linear

The equation for the ideal straight line for input range 45–90° was found using the equation from the datasheet

$$K = \frac{R_T(90) - R_T(45)}{90 - 45} = \frac{0.915443 - 4.37181}{90 - 45} = -0.07681$$

aprox

$$a = R_T(45) - KI_{min} = 4.37181 + 0.07681 \cdot 45 = 7.828$$

The R-T expected output with combined data from all non-linear measurement runs is shown in the following figure:

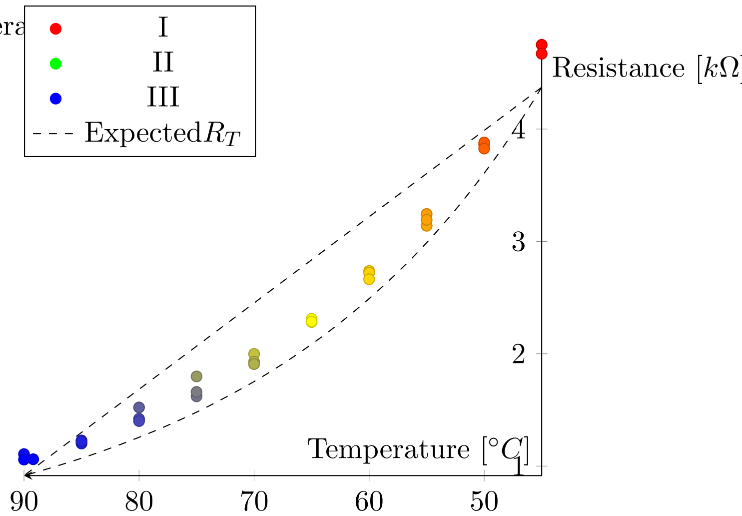

Fig.4.1.1 Non-Linear R-T

From the Fig.4.1.1 it can be seen that the thermistors output is non-linear, and the curve shape is similar to the expected response. However, a static offset can be observed, which will be discussed the Error Discussion 5.

The T-R characteristic is shown:

4.1.2 Linear

Using the eqation ?? R_p was calculated for linear range 45–90°C. B value is give in °K in the datasheet, but temperature range and measurements are in °C, therefore it must be converted to Celsius: $B_C = B_K + 273.15 = 3977 - 273.15 = 3703.85$

$$T_{ctr} = \frac{90 - 45}{2} + 45 = 72.5°C$$

$$R_p = 1807 \cdot \frac{3703.85 - 72.5}{3703.85 + 2 \cdot 72.5} = 1.705k\Omega$$

The R-T expected output with combined data from all linear measurement runs is shown in the following figure:

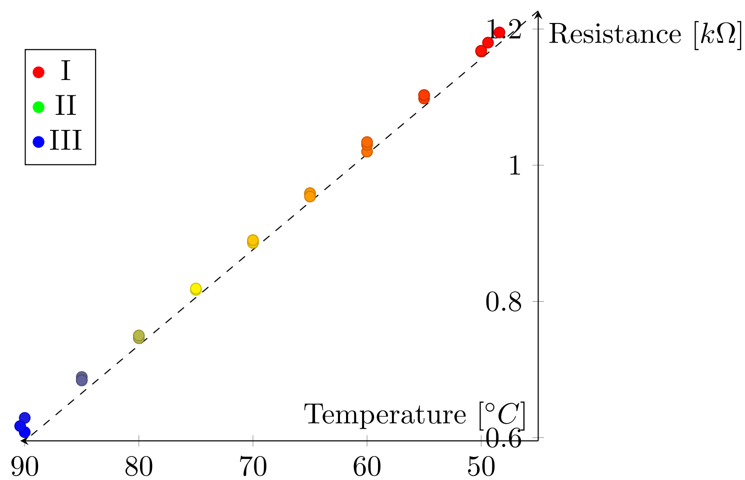

Fig.4.1.2 Linear R-T

5 Error Discussion

6 Conclusion