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 Expected Output

The output of thermistor 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:

$$R_T(T) = R_{ref} \cdot e^{A + \frac{B}{T} + \frac{C}{T^2} + \frac{D}{T^3}} \tag{1}$$

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 1 is in $°K$ for measurements in $°C$ conversion is required:

$$T_K = T_C + 273.15° \tag{2}$$

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:

$$R_p = R_{T_{ctr}} \cdot \frac{B - T_{ctr}}{B + 2 \cdot T_{ctr}} \tag{3}$$

[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 1

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. From this equation an ideal straight line equation for the linear sensor model can be found by calculating Output for I_{min} and I_{max}, then sensitivity K is

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

and y-intercept is

$$a = O(I_{min}) - KI_{min} \tag{4}$$

the following experiments all measurements are compared against the linear model

$$O(I) = KI + a \tag{5}$$

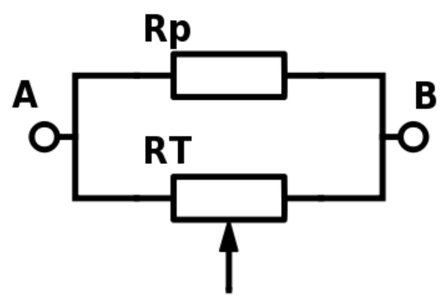

Figure 1: Parallel circuit

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:

$$R_{AB}(T) = \frac{R_p \cdot R_T(T)}{R_p + R_T(T)} \tag{6}$$

3 Experiments

For this lab assignment, two experiments were conducted. The first was to determine the following characteristics of the non-linear response of the NTC: the resistance-temperature R-T and temperature-resistance T-R, the maximum non-linearity $\hat{N}$ as % of $f.s.d$ (full scale deflection), and the response of the system linearised by a parallel resistor. The second experiment was done to find the time constant τ of the measurement system. Raw data from all measurements are presented in the Appendix.

Both of these experiments followed the same basic steps, where the thermistor was placed in an environment with a temperature significantly different from the ambient room temperature – in a cup filled with either boiling or iced water. The temperature of the environment was measured with a Fluke Thermocouple.

3.1 R-T and T-R Characteristics

To measure the R-T and T-R characteristics, the resistance of the thermistor was measured with an AMPROBE AM-510-EUR multimeter, and recorded over a temperature range of 90–45$°C$. This was achieved by measuring the temperature of boiling water in a cup, which was cooled from 100° to 45°. Having collected this data, the non-linearity of the system can be determined.

In order to establish the necessary value of the parallel resistor, $R_{T_{ctr}}$ was recorded at $T_{ctr} = 72.5°C$ (the midpoint of the temperature range in which the resistance was measured) and calculated using the equation #REFERENCE# from the NTC datasheet. Ideally, placing a parallel resistor in the system would help to linearise the change in resistance of the thermistor as a result of the change in temperature of the environment.

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:

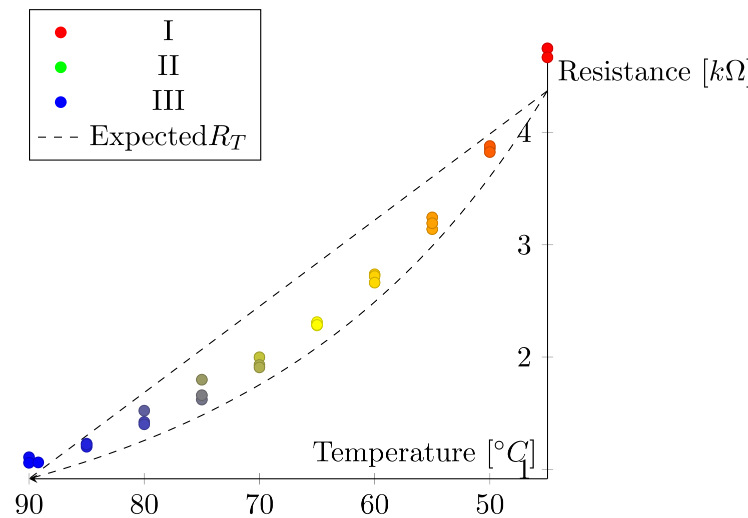

Fig.4.1.1 Non-Linear R-T

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:

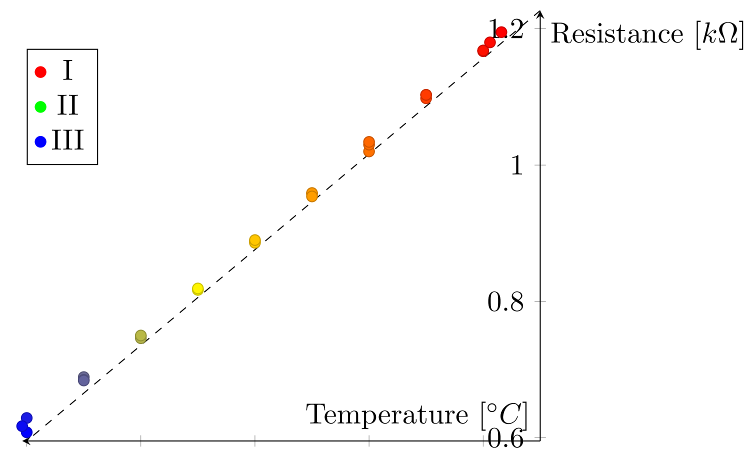

Fig.4.1.2 Linear R-T

5 Error Discussion

6 Conclusion