

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 $B = 3977^\circ K$.

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 it's datasheet, here modified for temperature T in $^\circ C$

$$R(T) = R_{ref} \cdot e^{A + \frac{B}{T+273.15} + \frac{C}{(T+273.15)^2} + \frac{D}{(T+273.15)^3}}$$

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 . The constant values:

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

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

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

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 senso 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

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

the following experiments all measurements are expected to follow the linear model

$$O(I) = KI + a$$

3 Experiments

Two experiments were conducted. First, to determine characteristics of the non-linear response of the NTC: resistance-temperature R-T and temperature-resistance T-R, maximum non-linearity \hat{N} as % of full scale deflection *f.s.d*; 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 $90-45^\circ C$. 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 $T_{ctr} = 72.5^\circ C$ and calculated using the equation.

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:

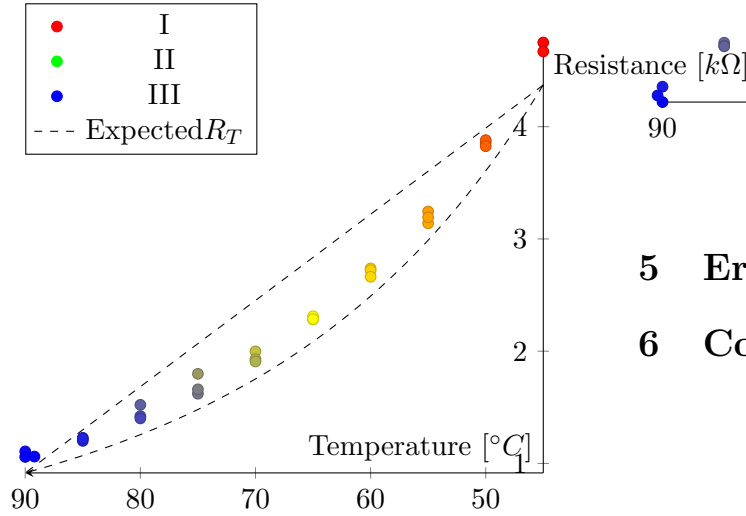


Fig.4.1.1 Non-Linear R-T

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 in the Error Discussion 5.

The T-R characteristic is shown:

4.1.2 Linear

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

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

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

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

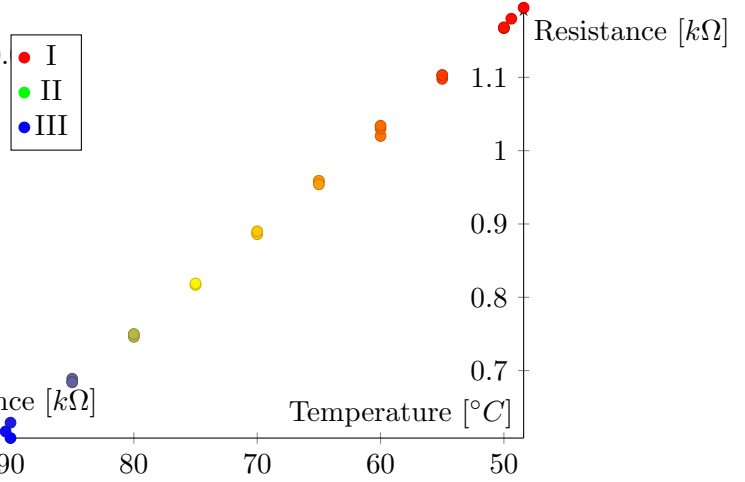


Fig.??? Linear R-T

5 Error Discussion

6 Conclusion