Sensing, Computing, Actuating
Lecture 8 - Thermistors

Exercise 1: Silicon resistive detector

The transfer function of a specific silicon-based temperature sensors for the range -60°C till +150°C is equal to:

$$R_T = R_{25}\left(\frac{273.15K + T}{298.15K}\right)^{2.3}$$

, with T the temperature in °C.

(a) What is the temperature coefficient of resistance (TCR) of this sensor at 25°C?

(b) The silicon-based temperature sensor has a non-linear response (in terms of the resistance R_T). A resistor is connected in parallel to the sensor to linearise the response (see Figure 1). Assume that $R_{25} = 1000\ \Omega$ holds for the sensor. What value should R_1 have to ensure that the transfer function of the circuit does not show any error at both ends of the range of the sensor?

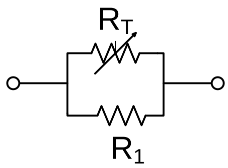

Figure 1: Linearisation of a silicon resistive detector.

(c) What is the sensitivity of the sensor circuit (dR/dT) shown in Figure 1 at a temperature of 25°C?

Exercise 2: NTC thermistor

You want to perform a number of measurement with an NTC thermistor $R_T = R_0 e^{B(1/T - 1/T_0)}$ for which it holds that $R_T = 10$ kΩ at 25°C. The dissipation constant δ of this sensor is equal to 0.14 mW/K in non-moving air at 25°C. In addition, it holds for this resistance that its ratio between the resistance at 25°C and 125°C is equal to: $R_{25}/R_{125} = 19.8$.

(a) The voltage drop V_T across the thermistor depends on the current I_T through the thermistor and the value of its resistance R_T. When the current through the sensor is limited, there exists an almost linear relation between V_T and I_T. When the current increases, the self-heating effect will result in an increasingly smaller voltage drop across the sensor. At a certain moment, the voltage drop over the sensor will even start to decrease when the current is increased even further. Show that the temperature of the sensor is equal to the following equation when the maximal voltage drop over the sensor occurs:

$$T_{max} = \frac{B - \sqrt{B^2 - 4BT_a}}{2}$$

, with T_a the environmental temperature and T_{max} the temperature of the thermistor.

(b) What is the maximal voltage drop V_T across the sensor if the sensor is placed in an environment with non-moving air with a temperature of 35°C?

(c) You want to use the thermistor for a certain application around the set-point $T_0 = 25$°C. It is therefore important that the response of the sensor is linearised around this point. To achieve this goal you will use the circuit shown below. Determine the value of the resistors R_1 and R_2 such that the equivalent resistance (transfer function) of the circuit shown an inflection point ("kantelpunt" in Dutch) at T_0 and a sensitivity of -4 Ω/°C.

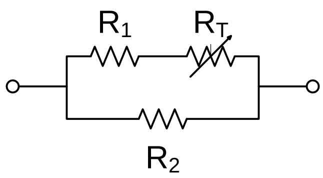

Figure 2: NTC linearisation.

(d) Many electrical circuits (e.g. op-amps, integrated circuits) have a positive temperature coefficient. An NTC thermistor is a cheap component to compensate this temperature dependency. To realize this temperature compensation, you can use the circuit shown below. The resistor $R_C = (1k\Omega)(1 + 0.004(T - 273K))$ models the circuit with a positive temperature coefficient. What value should R_1 have such that the total change in the resistance of the circuit around a temperature $T = T_0 = 25°\text{C}$ becomes independent of a small change in the temperature?

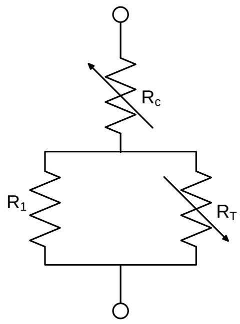

Figure 3: Temperature compensation using an NTC thermistor.