Exercises: Session 7

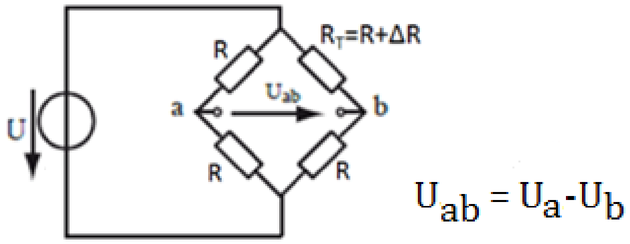
Exercise 1:

A resistive temperature sensor (platinum) is used in a Wheatstone bridge circuit as shown below in Fig. 1. Assume that the reference temperature for R_T is T_0 = 0°C, and R_T (T=0°C) = R_0 = 100 Ω.

a) What is the bridge output U_{ab} at temperature T = 10°C, given that the input voltage U = 2 V, bridge resistance R = 100 Ω at 10°C, and α = 0.00385 °C^{-1} (for this part, assume that α is constant over the temperature range 0 - 10°C)?

b) Note that the temperature coefficient, α, can depend on temperature. Assuming a starting temperature of 0°C for a measurement where $\Delta R = 3.85\ \Omega$, with the final temperature reaching 10°C, find the value of α at 10°C.

Figure 1



Exercise 2:

A temperature sensor (metal) is characterized by a temperature coefficient α = 0.1 °C^{-1} and a resistance R_T with R_0 = 10 kΩ at 0°C. You use the sensor to design a temperature measurement circuit as illustrated in Fig. 2 below. You want an output voltage U_0 = 0 V at 0°C and U_0 = 3 V at 4°C. If R_1 = 1 kΩ, choose the resistor values R_B and R_2 to implement this requirement. Assume V^+ = 10 V and V^- = -10 V.

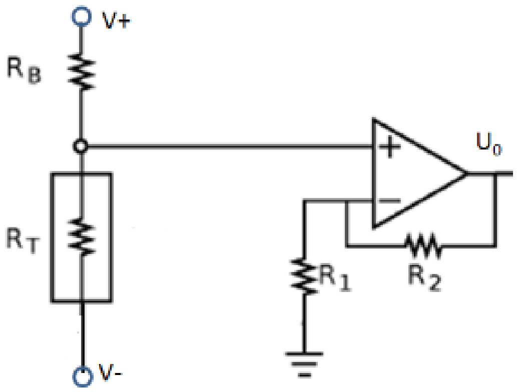


Figure 2

Exercise 3:

A metallic strain gauge with an initial resistance R_o = 240 Ω is placed on a piece of sheep bone of length $l = 10\ cm$ and cross-sectional area S = 2 cm^2, to measure its deformation as a function of applied force, and to calculate its Young's modulus, Y.

a) Assuming that the bone is in linear elastic deformation, calculate Young's modulus knowing that the resistance of the strain gauge is R = 240.013 Ω for an applied force F = 59 N.

b) Assume that the temperature increases by 1°C. Calculate the relative error of the measured elongation and Young's modulus (temperature coefficient of the gauge, $\alpha_T = 0.0039\ °C^{-1}$).

Useful formulae for a metallic strain gauge:

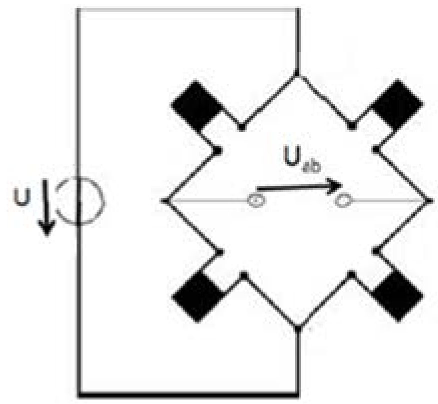
$$\frac{\Delta R}{R} = K\varepsilon_l,\ \ \varepsilon_l = \frac{\Delta l}{l},\ \ K = 1 + 2\nu + C(1 - 2\nu) \approx 2.2$$

$K = gauge\ factor;\ \nu = Poisson\ modulus;\ C = Bridgeman\ constant$

Exercise 4:

You have to design a device to directly measure the arterial blood pressure with a catheter that leads to a flexible diaphragm, which uses four identical strain gauges (R_1, R_2, R_3, R_4) mounted in a full Wheatstone bridge. Assume that each gauge has a reference resistance of R_o = 15 kΩ, gauge factor K = 50, and Young's modulus Y = 10 MPa, and that resistance varies with temperature (increases with ΔT) identically for each strain gauge.

a) Indicate how the bridge should be configured (i.e. how R_1, R_2, R_3 and R_4 should be arranged) in order to maximize the sensitivity to deformation and minimize (cancel) the effect of temperature.



b) If $U = 2\ V$, calculate the sensitivity $S = \frac{U_{ab}}{\sigma}$ (neglect the effect of temperature) in V/MPa for the configuration found in part (a).

Exercise 5 (optional):

Find an expression for the time constant τ_T of a thermal flowmeter at constant temperature.
(Hints:

- Refer to the course slides for the circuit and notation
- The transfer function in this case is defined as the ratio of the change in current Δi (required to maintain a constant temperature) to the change in fluid velocity Δv (that caused the temperature change of the sensor)
- Start by finding the following relationships: $\Delta R = f(\Delta i, \Delta v), \Delta i = f(\Delta R), \Delta i = f(\Delta v)$)